Excerpts from:

KLAMATH RIVER FALL CHINOOK

(JULY 2019)

SALMON REBUILDING PLAN

https://www.pcouncil.org/documents/2019/07/klamath-river-fall-chinook-salmon-rebuilding-plan-regulatory-identifier-number-0648-bi04-july-2019.pdf/

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4.5 Recommendation 5: Habitat Committee (page 48)

This report has identified that habitat conditions appear to have contributed to escapement shortfalls and thus the overfished status determination. It is recommended that the Council direct the Habitat Committee to work with tribal, federal, state, and local habitat experts to review the status of the essential fish habitat affecting KRFC and, as appropriate, provide recommendations to the Council for restoration and enhancement measures within a suitable time frame, as described in the FMP. We also recommend that the Council direct the Habitat Committee to evaluate the topics provided in Section 4.7 *Further recommendations.* The habitat-related topics in that section lie outside the expertise of the STT and thus the Habitat Committee is better suited to conduct such a review.

4.7 Further recommendations (page 51)

1. Support management of flow in the Klamath River that can help ameliorate *C. shasta* infection rates and associated fish mortality. Such flow management includes providing high winter substrate mobilization flows and emergency "dilution" flows during the spring. In general, it appears that bed mobility in high winter flow events is a key river function that keeps the polychaete worm host of the disease from proliferating.

2. Support dam removal efforts in the Klamath Basin to provide increased cold water refugia. Although there is little that can be done to lower mainstem Klamath River water temperatures on a large scale, dam removal will provide access to cold water tributaries that are currently located out of reach above the dams, as well as access to large Cascade spring complexes such as exist near J.C. Boyle Dam. These refugia will provide relief from high water temperatures, and access to these cold water areas may lower prevalence of infection. Dam removal will also reconnect the sediment budget downstream of the dams, thereby increasing bed mobility and reducing the abundance of polychaete worms that are host to juvenile disease in the Klamath River.

3.0 Review of Potential Factors Leading to Overfished StatusFreshwater survival (page 7)

3.1.1 Review of freshwater conditions

River flows and temperatures during spawning

Fall Chinook salmon in the Klamath River Basin typically spawn during October and November. Flows on the mainstem Klamath River during the spawning period were low for brood years 2012, 2013, and portions of 2014 compared to brood years 2000-2010 (Figure 3.1.1.a). On the Trinity River, flows during the spawning period for brood years 2011-2014 were qualitatively similar to flows for brood years 2000-2010 (Figure 3.1.1.b).

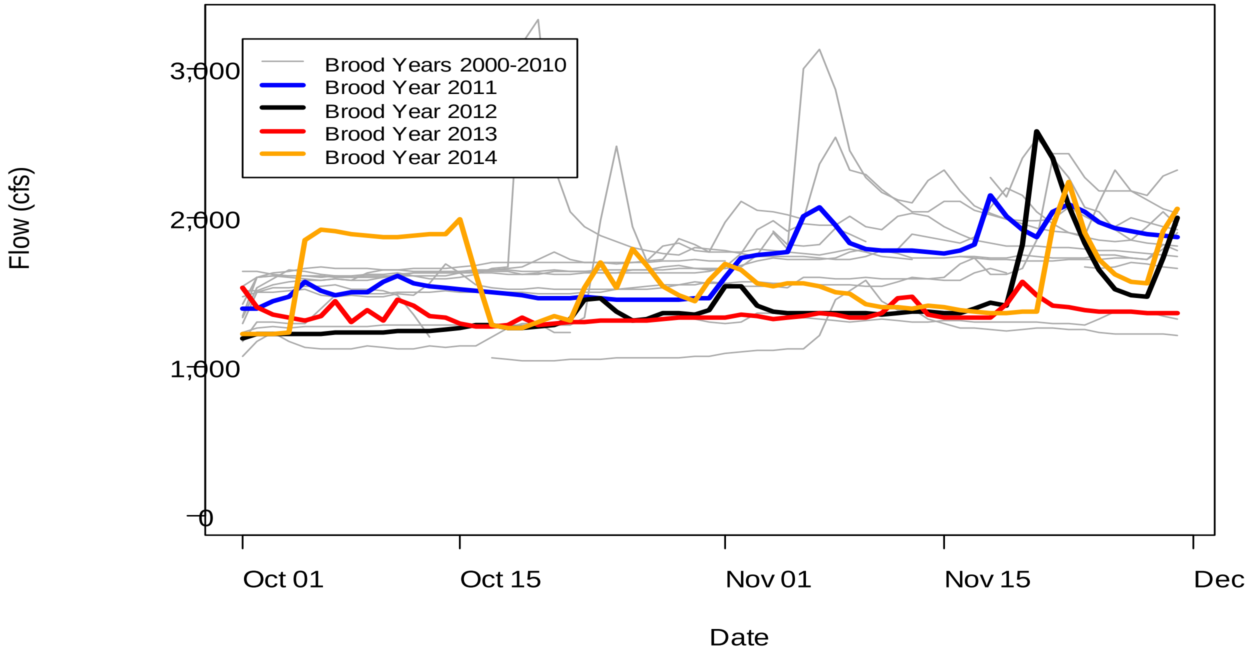

Figure 3.1.1.a. Flows during the spawning period on the Klamath River at the Seiad Valley USGS gauge (Gauge 11520500, at rkm 209) for brood years 2000-2014.

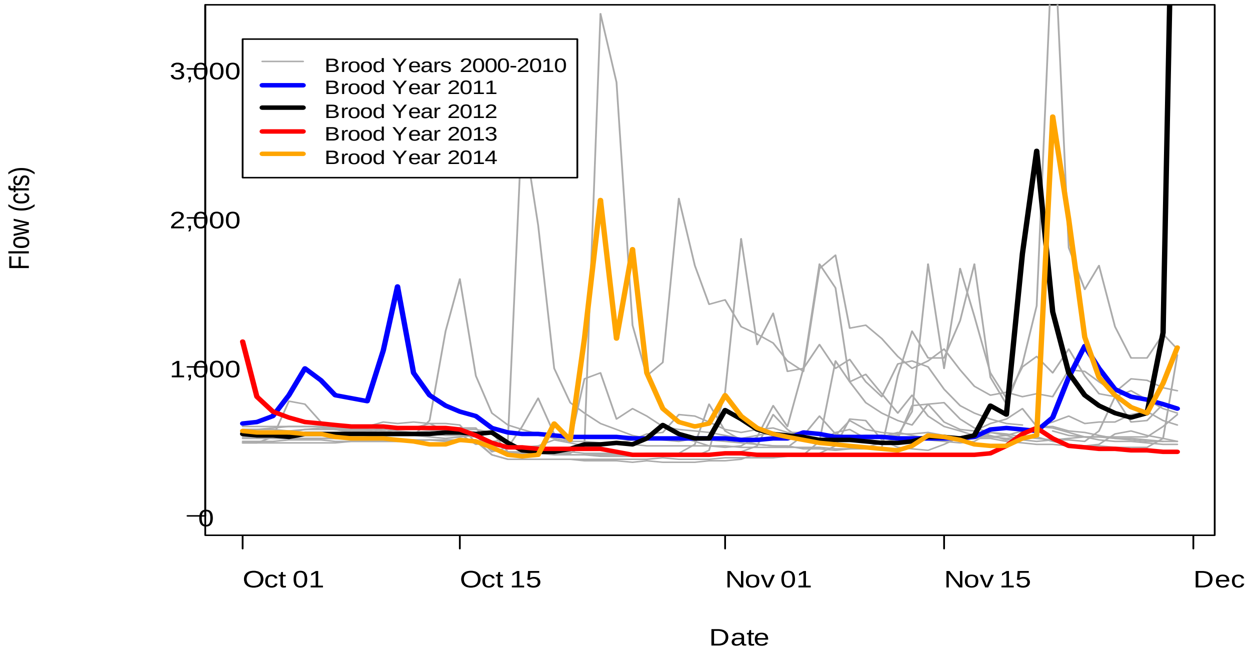

Figure 3.1.1.b. Flows during the spawning period on the Trinity River at the Burnt Ranch USGS gauge (rkm 79) for brood years 2000-2014.

The U.S. Environmental Protection Agency (EPA) has identified criteria for Pacific Northwest water temperatures to protect Pacific salmon (USEPA 2003). David and Goodman (2017) summarized river temperatures at index sites within the Klamath River and compared temperatures to the EPA 13˚C seven-day average daily maximum (7DADM) criterion for spawning, incubation, and emergence during October 1 – April 30 each year. For brood years 2011-2013, the 13˚C criterion was exceeded for 30-37 days at the site on the Klamath River above the Scott River (Figure 3.1.1.c). For brood year 2014 the criterion was exceeded for 52 days.

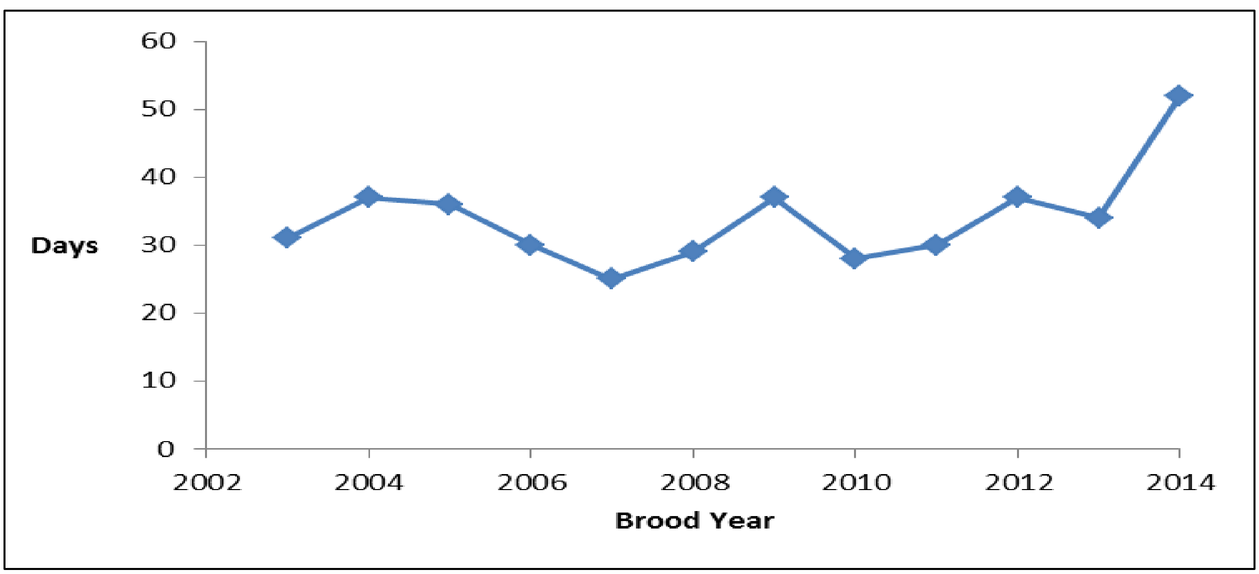

Figure 3.1.1.c. Number of days exceeding the 13˚C seven-day average daily maximum (7DADM) EPA criterion for spawning, incubation, and emergence at the Klamath River above the Scott River (David and Goodman 2017).

High water temperatures during the spawning period were frequently observed on the Trinity River based on observations at the USGS gauge near Hoopa, California (Figure 3.1.1.d). During the month of October, water temperatures were mostly above the EPA 13˚C criterion for spawning, incubation, and emergence, and were occasionally near the 16.7˚C level associated with 100% egg mortality. In 2013, water temperatures were generally below the 13˚C criterion for most of the spawning period, except during the first half of October when temperature measured above the 13˚C criterion. Water temperatures in 2011, 2012, and 2014 were well above the 13˚C criterion for most of October.

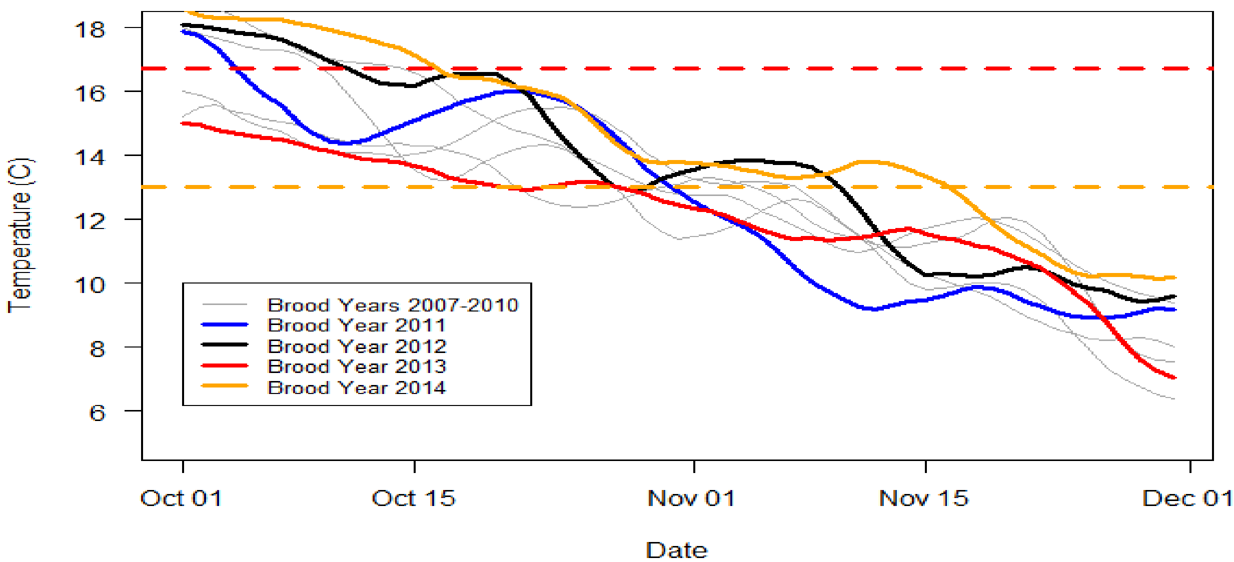

Figure 3.1.1.d. Seven-day average water temperatures in the Trinity River near Hoopa, California (rkm 20) during the spawning period for fall Chinook salmon across brood years 2007-2014. The dashed orange line represents the EPA 13˚C criterion for spawning, incubation, and emergence and the dashed red line represents the temperatures associated with 100% egg mortality (16.7˚C).

<u>Flows and temperatures during rearing and outmigration</u>

Flows in the Klamath Basin during the emergence, rearing, and outmigration period were low for brood years 2012-2014 compared to flows experienced by juveniles from brood years 2000-2011 (Figure 3.1.1.e). These flow levels were some of the lowest observed during this time period.

The EPA has identified criteria for Pacific Northwest water temperatures to protect Pacific salmon (USEPA 2003). These include a 15˚C temperature criterion for juvenile rearing. Water temperatures in the Klamath River, measured at the USGS gauge at Klamath, California indicated that the EPA 15˚C rearing criterion was exceeded beginning in late April or May for brood years 2012-2014 and in June for brood year 2011 (Figure 3.1.1.f). Brood years 2012-2014 experienced comparatively warmer temperatures throughout the January 1 – June 30 period.

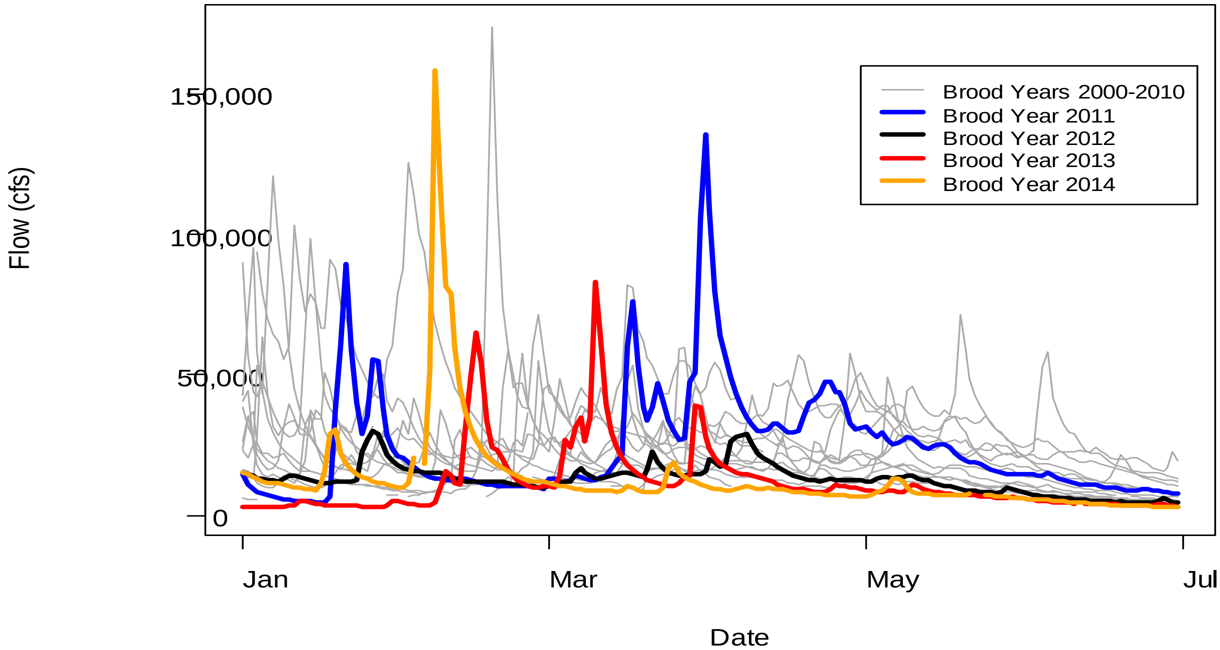

Figure 3.1.1.e. Flows during the emergence, rearing, and juvenile outmigration period on the Klamath River measured at Klamath, California (USGS gauge 11530500) for brood years 2000-2014.

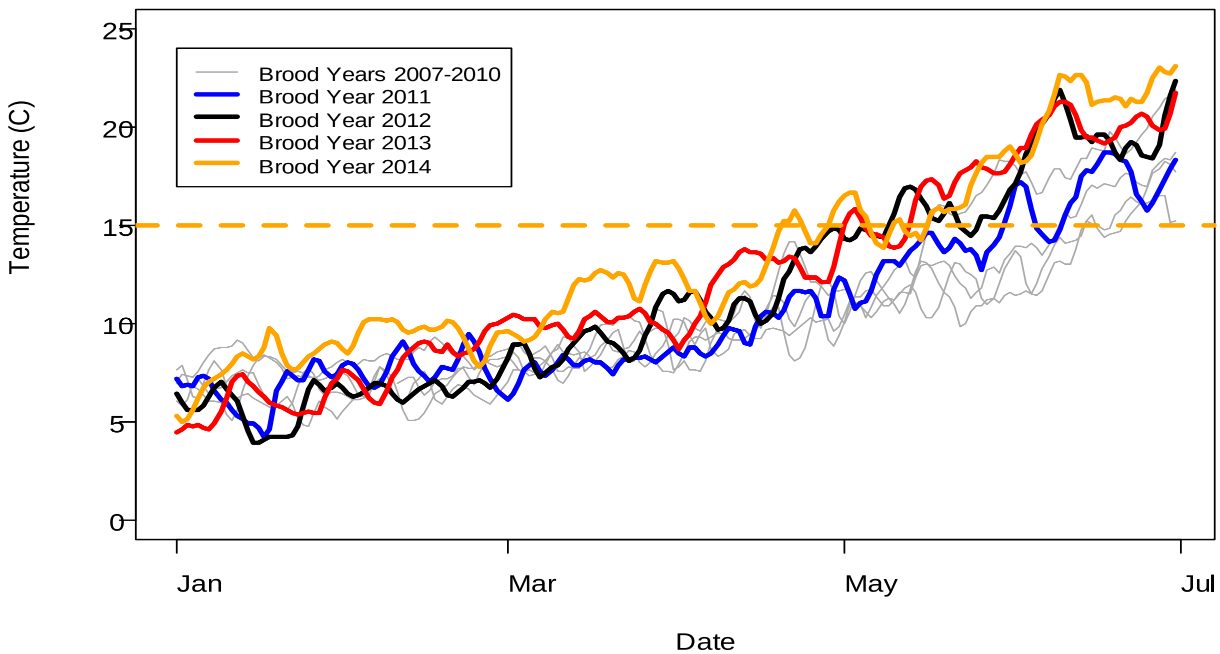

Figure 3.1.1.f. Klamath River water temperatures measured at the USGS gauge at Klamath, California (USGS gauge 11530500) during January 1 through June 30 experienced by juveniles from brood years 2007-2014. The EPA 15˚C rearing criterion is represented by the dashed line.

3.1.2 Parental stock size and distribution

Parental abundance of natural-area spawners for the critical broods[1] of 2011-2014 was generally near or above average compared to the previous 33-year averages (Figure 3.1.2.a). The Scott and Shasta Rivers, and Bogus Creek, did experience below average escapement in 2011, however, adult escapement the following year was above average, particularly in the Shasta River. Adult escapement to natural areas in the Klamath Basin in 2011 was the lowest (46,763) for the critical broods, however the number of adult natural-area spawners that year still exceeded the S_{MSY} escapement objective of 40,700. The subsequent broods (2012-2014) all surpassed the S_{MSY}. Two of the broods, 2012 and 2014, were two (2014) to three (2012) times the KRFC S_{MSY} value. Parental escapement for the critical broods did not limit recruitment due to low numbers, though the large escapements for the 2012 and 2014 broods may have potentially reduced future recruitment due to density dependent factors. See Figure 3.1.2.a and Table 3.1.2.a for details.

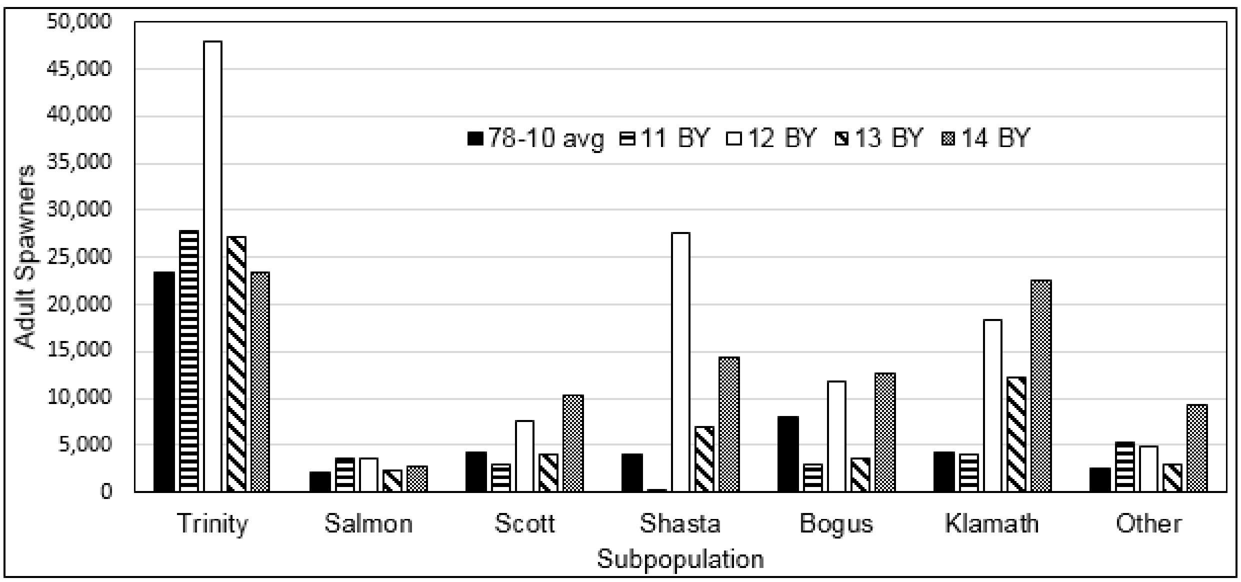

Figure 3.1.2.a. Adult spawning escapement to natural areas for 2011-2014 brood years (BY) compared to 1978-2010 averages.

[1] We define "critical broods" as the brood years that primarily contributed to escapement in 2015-2017.

Table 3.1.2.a. Klamath River Fall Chinook natural-area and hatchery adult spawner escapement.

Return Year	Upper Trinity[a/]	Salmon River	Scott River	Shasta River	Bogus Creek	Mainstem Klamath[b/]	Other Tributaries[c/]	Total Natural	Hatchery Iron Gate	Hatchery Trinity	Total Hatchery	Grand Total
1978	31,052	2,600	3,423	12,024	4,928	1,700	2,765	58,492	6,945	6,034	12,979	71,471
1979	8,028	1,000	3,396	7,111	5,444	4,190	1,468	30,637	2,301	1,335	3,636	34,273
1980	7,700	800	2,032	3,762	3,321	2,468	1,400	21,483	2,412	4,099	6,511	27,994
1981	15,340	750	3,147	7,890	2,730	3,000	1,000	33,857	2,055	2,370	4,425	38,282
1982	9,274	1,000	5,826	6,533	4,818	3,000	1,500	31,951	8,353	2,058	10,411	42,362
1983	17,284	1,200	3,398	3,119	2,713	1,800	1,270	30,784	8,371	5,494	13,865	44,649
1984	5,654	1,226	1,443	2,362	3,039	1,350	990	16,064	5,330	2,166	7,496	23,560
1985	9,217	2,259	3,051	2,897	3,491	468	4,294	25,677	19,951	2,583	22,534	48,211
1986	92,548	2,716	3,176	3,274	6,124	603	4,919	113,360	17,096	15,795	32,891	146,251
1987	71,920	3,832	7,769	4,299	9,748	863	3,286	101,717	15,189	13,934	29,123	130,840
1988	44,616	3,273	4,727	2,586	16,215	2,982	4,987	79,386	16,106	17,352	33,458	112,844
1989	29,445	2,915	3,000	1,440	2,218	1,011	3,839	43,868	10,859	11,132	21,991	65,859
1990	7,682	4,071	1,379	415	732	505	812	15,596	6,719	1,348	8,067	23,663
1991	4,867	1,337	2,019	716	1,261	572	877	11,649	4,002	2,482	6,484	18,133
1992	7,139	778	1,873	520	598	366	754	12,028	3,581	3,779	7,360	19,388
1993	5,905	3,077	5,035	1,341	3,285	647	2,568	21,858	20,828	815	21,643	43,501
1994	10,906	3,216	2,358	3,363	7,817	3,249	1,424	32,333	13,808	3,264	17,072	49,405
1995	77,876	4,140	11,198	12,816	45,225	6,472	4,067	161,794	22,681	15,178	37,859	199,653
1996	42,646	5,189	11,952	1,404	10,420	2,790	6,925	81,326	13,622	6,411	20,033	101,359
1997	11,507	5,783	8,284	1,667	9,809	3,472	5,622	46,144	13,275	5,387	18,662	64,806
1998	24,460	1,337	3,061	2,466	6,630	2,913	1,621	42,488	14,923	14,296	29,219	71,707
1999	6,753	670	3,021	1,296	3,537	1,978	1,202	18,457	9,290	5,037	14,327	32,784
2000	23,468	1,544	5,729	11,025	34,678	3,271	3,013	82,728	71,635	25,976	97,611	180,339
2001	35,991	2,607	5,398	8,452	11,927	9,832	3,627	77,834	37,204	17,908	55,112	132,946
2002	10,880	2,669	4,261	6,432	17,530	21,650	2,213	65,635	23,667	3,516	27,183	92,818
2003	31,173	3,302	11,988	4,134	15,422	17,722	3,901	87,642	31,970	29,812	61,782	149,424
2004	12,718	282	445	833	3,493	5,037	1,023	23,831	10,582	12,399	22,981	46,812
2005	12,987	401	698	2,018	5,341	4,622	722	26,789	13,955	13,744	27,699	54,488
2006	15,375	1,278	3,007	789	3,368	4,538	1,808	30,163	11,604	7,918	19,522	49,685
2007	39,038	1,377	4,494	2,009	4,677	6,914	2,161	60,670	16,969	18,081	35,050	95,720
2008	11,006	1,749	3,445	2,741	3,001	5,830	3,078	30,850	9,101	4,451	13,552	44,402
2009	16,168	2,204	2,167	6,145	5,455	7,945	4,325	44,409	12,263	7,351	19,614	64,023
2010	21,579	2,478	2,114	1,261	3,180	3,684	2,929	37,225	10,278	7,774	18,052	55,277
2011[d/]	**27,718**	**3,674**	**3,019**	**213**	**2,919**	**3,933**	**5,287**	**46,763**	**8,490**	**13,847**	**22,337**	**69,100**
2012[d/]	**47,921**	**3,561**	**7,569**	**27,600**	**11,792**	**18,249**	**4,851**	**121,543**	**38,478**	**17,461**	**55,939**	**177,482**
2013[d/]	**27,127**	**2,240**	**4,036**	**6,925**	**3,682**	**12,192**	**2,954**	**59,156**	**13,431**	**3,717**	**17,148**	**76,304**
2014[d/]	**23,312**	**2,706**	**10,419**	**14,412**	**12,607**	**22,443**	**9,205**	**95,104**	**24,300**	**6,975**	**31,275**	**126,379**
2015[e/]	**4,727**	**1,978**	**2,092**	**6,612**	**2,308**	**7,407**	**2,988**	**28,112**	**7,956**	**3,129**	**11,085**	**39,197**
2016[e/]	**3,444**	**1,032**	**1,376**	**2,754**	**830**	**2,902**	**1,599**	**13,937**	**2,436**	**1,142**	**3,578**	**17,515**
2017[e/f/]	**4,534**	**1,338**	**2,269**	**3,287**	**1,874**	**3,922**	**1,290**	**18,514**	**7,443**	**3,770**	**11,213**	**29,727**
78-14 avg.	24,278	2,304	4,415	4,819	7,924	5,250	2,937	51,927	15,449	9,008	24,457	76,384
11-14 avg.	**31,520**	**3,045**	**6,261**	**12,288**	**7,750**	**14,204**	**5,574**	**80,642**	**21,175**	**10,500**	**31,675**	**112,316**
15-17 avg.	**4,235**	**1,449**	**1,912**	**4,218**	**1,671**	**4,744**	**1,959**	**20,188**	**5,945**	**2,680**	**8,625**	**28,813**
78-17 avg.	22,775	2,240	4,227	4,774	7,455	5,212	2,864	49,546	14,736	8,533	23,269	72,816

a/ Trinity River basin upstream of Willow Creek weir, excluding Trinity River Hatchery.

b/ Mainstem Klamath River excluding all tributaries and Iron Gate Hatchery.

c/ All tributaries to the Klamath River excluding Salmon, Scott, Shasta, and Bogus, and tributaries to the Trinity River downstream of Willow Creek weir.

d/ Parent broods associated with adult returns during the overfished period.

e/ Return years comprising the overfished period.

f/ Estimates are preliminary.

The U.S. Fish and Wildlife Service (USFWS) has conducted mark-recapture studies using salmon carcasses to quantify the total number of spawners in the Klamath River from IGD to the confluence with the Shasta River (Gough and Som 2017). The USFWS has also quantified the number of redds within standardized index reaches of the mainstem Klamath River (Gough et al.

2018). In addition to the spawning that occurs in the mainstem Klamath River, spawning escapement estimates have been generated for Bogus Creek and the Shasta River (CDFW 2018), as well as many other tributaries.

For later comparisons with juvenile production estimates in Section 3.1.5 *Stock and recruitment*, we estimated the combined number of spawners in the Bogus Creek Basin, the Shasta River Basin, and the mainstem Klamath River from IGD downstream to the confluence with the Scott River. This combined estimate consisted of the California Department of Fish and Wildlife (CDFW) estimates of the number of spawners from the Bogus Creek Basin and the Shasta River Basin (CDFW 2018), the USFWS estimates of the number of spawners in the Klamath River from IGD to the confluence with the Shasta River (Gough and Som 2017), and the USFWS estimates of the number of redds in the Klamath River from the confluence with the Shasta River downstream to the Scott River. The number of redds in this reach was multiplied by two to estimate the number of spawners in this reach.

The combined number of spawners upstream of the confluence with the Scott River ranged from a low of 4,900 in 2016 to a high of 53,588 in 2012, with an average of 20,509 across brood years 2001 through 2016 (Figure 3.1.2.b). The estimated number of spawners in brood years 2012 and 2014 were well above average, the number of spawners in 2013 was average, and the number of spawners in 2011 was below average.

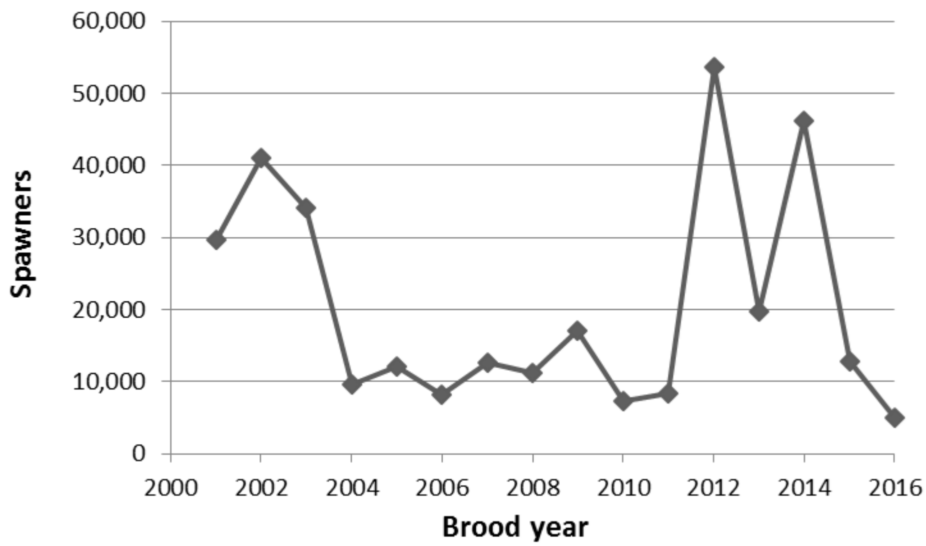

Figure 3.1.2.b. Estimated total number of spawners in the Shasta River Basin, the Bogus Creek Basin, and the mainstem Klamath River upstream of the confluence with the Scott River during 2001-2016.

Gough and Som (2017) provide estimates of the percentage of females that were pre-spawn mortalities and females that were partially spawned in the mainstem Klamath River between IGD and the confluence with the Shasta River over brood years 2001 through 2016 (Figure 3.1.2.c). Across those brood years, the average levels of pre-spawn mortality and partial spawning has been 8.3 percent and 4.4 percent, respectively. Estimates for brood years 2011-2014 were qualitatively similar to estimates from the previous years.

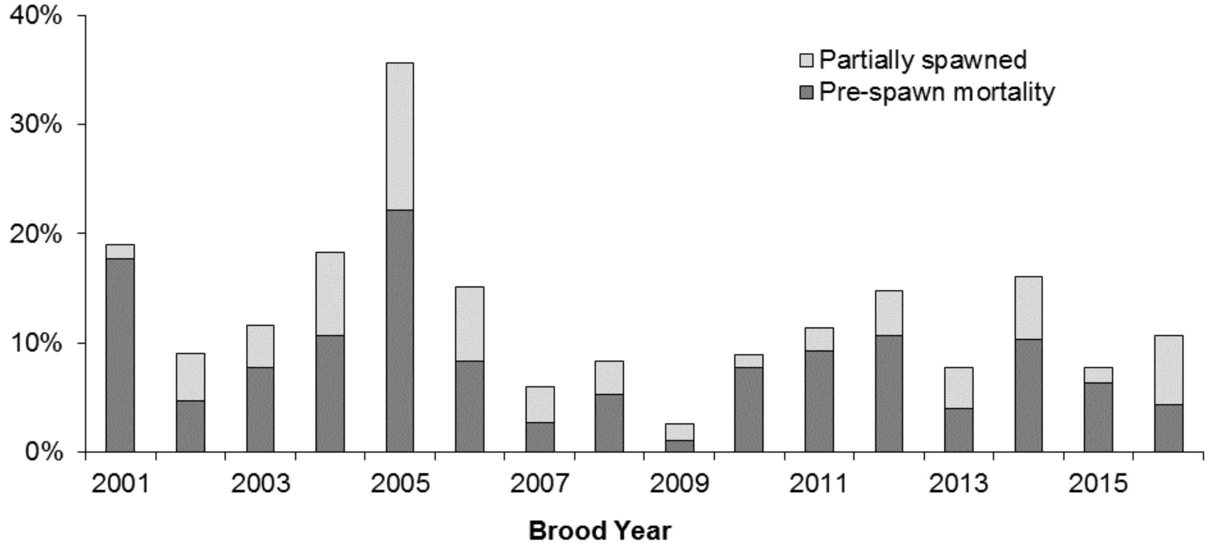

Figure 3.1.2.c. Estimates of the percentage of females that were partially spawned or were pre-spawn mortalities in the mainstem Klamath River between Iron Gate Dam and the confluence with the Shasta River.

Redd dewatering can occur when there is a reduction in flow following redd construction. Data collected on the Trinity River during 2013-2016 found evidence of redd dewatering following the termination of flow augmentation releases, but the number of dewatered redds was estimated to be less than 1% of the total number of redds in the mainstem Trinity River (Stephen Gough, USFWS, personal communication). Based on these data, redd dewatering does not appear to have been a substantial factor influencing the 2013 and 2014 brood years.

Hatchery escapement trends of adult KRFC were similar to natural areas. IGH and TRH received an average of 31,675 adult KRFC during the critical brood years, which is above the 1978 through 2014 average of 24,457. However, when their progeny returned as adults during 2015-2017, they averaged 8,625 spawners annually, approximately 27 percent of the 2011-2014 average. See Table 3.1.2.a for details.

3.1.3 Juvenile production estimates

CDFW has used rotary screw traps annually since 2000 on the Scott River and 2001 on the Shasta River (brood years 1999 and 2000, respectively) to estimate the number of out-migrating juvenile KRFC (emigrants). CDFW also monitors KRFC in the Scott and Shasta Rivers to enumerate adult returns using video weirs and mark-recapture methods. The Scott River averaged 112 emigrants produced per adult and the Shasta River averaged 405 emigrants produced per adult over the entire time series (Tables 3.1.3.a, 3.1.3.b). Both rivers show a positive correlation between number of adults and number of emigrants produced (correlation coefficients estimated to be 0.52 and 0.80 for the Scott and Shasta Rivers, respectively). For the critical broods of 2011-2014, the mean number of emigrants per adult spawner on the Scott River was 61 percent of the mean across broods 1999-2015 (Table 3.1.3.a). Each of the critical broods had emigrants per spawner values lower than the mean value computed across all broods. For the Shasta River, the mean number of emigrants per spawner for the critical broods exceeded the mean value computed across all broods, but individual years varied widely (Table 3.1.3.b).

Brood years 2011 and 2013 had among the highest estimates of emigrants per spawner for the entire time series while the 2012 and 2014 broods were lower than the long-term average.

The number of total emigrants from the Scott River, averaged over the critical broods, was very similar to the average over all broods (Table 3.1.3.a). For the Shasta River, the average number of emigrants for the critical broods exceeded the average over all broods by a factor of 1.7. The two largest estimates of emigrating juveniles across all years with data were from broods 2012 and 2013 (Table 3.1.3.b).

Table 3.1.3.a. Scott River adult spawner and emigrant Chinook salmon estimates. Bolded values indicate the critical brood years.

Brood year[a/]	Emigrants	Lower Confidence Limit	Upper Confidence Limit	Adult Parents	Emigrant/ Parent
1999	160,906	52,719	269,093	3,021	53
2000	457,800	398,422	517,177	5,729	80
2001	239,483	140,620	338,346	5,398	44
2002	125,909	78,709	173,109	4,261	30
2003	1,029,696	870,359	1,189,033	11,988	86
2004	178,885	154,929	202,840	445	402
2005[b/]	10,890	6,982	14,797	698	16
2006	435,279	401,400	469,158	3,007	145
2007	552,472	500,947	603,997	4,494	123
2008	930,731	876,028	985,433	3,445	270
2009	655,467	571,177	739,757	2,167	302
2010	126,104	111,480	140,727	2,114	60
2011	**173,602**	**149,325**	**197,879**	**3,019**	**58**
2012	**656,031**	**606,468**	**705,594**	**7,569**	**87**
2013	**423,085**	**364,462**	**481,709**	**4,036**	**105**
2014	**243,431**	**210,816**	**276,047**	**10,419**	**23**
2015	56,634	16,799	63,880	2,092	27
1999-2015 avg.	379,789	324,214	433,446	4,347	112
2011-2014 avg.	374,037	332,768	415,307	6,261	68

a/ Brood year is the return year of adult parents, emigrants are estimated the following spring/summer.

b/ Redd scour in December 2005 appeared to reduce emigrant production in 2006.

Table 3.1.3.b. Shasta River adult spawner and emigrant Chinook salmon estimates. Bolded values indicate the critical brood years.

Brood year[a/]	Emigrants	Lower Confidence Limit	Upper Confidence Limit	Adult Parents	Emigrant/ Parent
2000	4,203,764			11,025	381
2001	3,509,388			8,452	415
2002	1,020,905			6,432	159
2003	2,486,076	2,194,650	2,777,503	4,134	601
2004	297,208	282,945	311,472	833	357
2005[b/]	83,387	76,439	90,335	2,018	41
2006	579,735	556,443	603,026	789	735
2007	938,503	872,905	1,004,102	2,009	467
2008	718,949	687,412	750,486	2,741	262
2009	2,347,783	2,265,226	2,430,341	6,145	382
2010	654,625	631,256	677,994	1,261	519
2011	**166,500**	**159,571**	**173,429**	**213**	**782**
2012	**5,218,270**	**4,916,768**	**5,519,771**	**27,600**	**189**
2013	**4,744,838**	**4,591,469**	**4,898,206**	**6,925**	**685**
2014	**2,901,966**	**2,772,054**	**3,031,878**	**14,412**	**201**
2015	2,757,850	2,661,219	2,854,481	6,612	417
2016	776,697	725,794	827,601	2,754	282
2000-2016 avg.	1,965,085	1,671,011	1,853,616	6,139	405
2011-2014 avg.	3,257,894	3,109,966	3,405,821	12,288	464

a/ Brood year is the return year of adult parents, emigrants are estimated the following spring/summer.

b/ Redd scour in December 2005 appeared to reduce emigrant production in 2006.

The USFWS, in collaboration with the Karuk Tribe and the U.S. Geological Survey (USGS), has used rotary screw traps and frame nets to estimate juvenile production of age-0 KRFC at three index sites in the Klamath River (Gough and Som 2017). The downstream-most Kinsman site (rkm 237.55) samples juveniles from the Bogus Creek Basin, the Shasta River Basin, and the mainstem Klamath River upstream of the confluence with the Scott River. The Kinsman site is also located downstream of a known infectious zone for *Ceratonova shasta* (see Section 3.1.4 *Disease*). Because this site effectively samples all production upstream of the confluence with the Scott River, and it is located downstream of the *C. shasta* infectious zone, it provides a useful indicator of juvenile production in the Klamath River Basin.

Across brood years 2001-2014, the number of age-0 KRFC at the Kinsman site has averaged 2.4 million fish, ranging from a low of 0.3 million fish produced from brood year 2011 to a high of 7.7 million fish produced from brood year 2012 (Figure 3.1.3.a). The estimates of juvenile production were the lowest for brood year 2011, but were above-average for brood years 2012-2014.

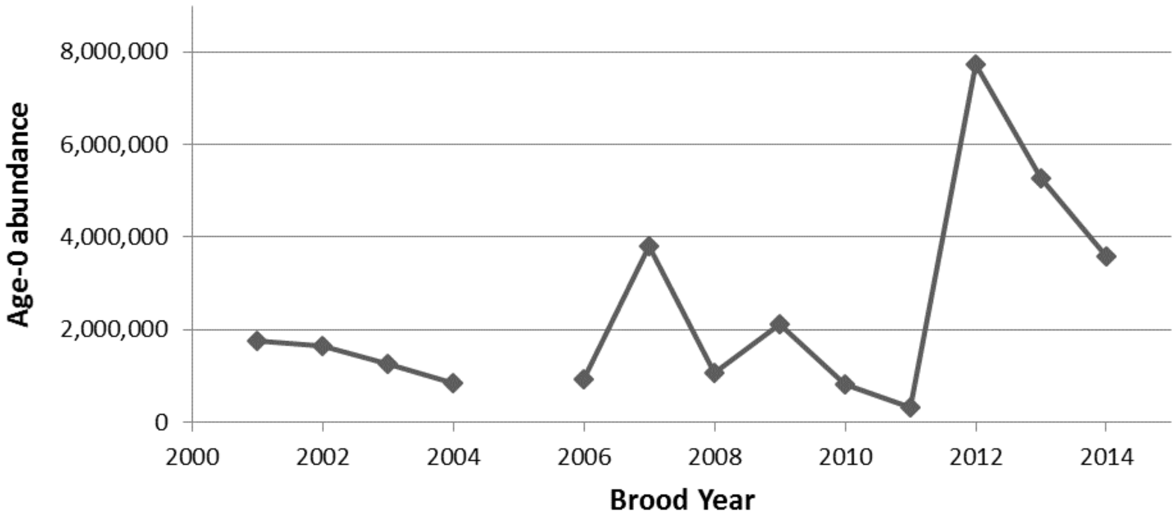

Figure 3.1.3.a. Estimates of age-0 KRFC abundance at the Kinsman site on the Klamath River from brood years 2001-2014 (Gough and Som 2017). Estimates for brood year 2005 could not be generated due to high flow conditions in 2006.

The Yurok Tribe, in collaboration with the USFWS, has used rotary screw traps and mark-recapture efforts to estimate population size of Chinook salmon emigrants (fall and spring run combined) on the Trinity River near Willow Creek, CA since 2002. The USFWS operated this trapping location from 1989-2001, using slightly different methods to estimate population (data not presented) (Petros et al. 2016). The screw traps encounter both hatchery and naturally produced emigrants. However, the data presented are only the estimates of naturally produced emigrants. CDFW monitors adult returns of fall and spring Chinook using weirs and mark-recapture methods near Willow Creek (for fall run) and Junction City (for spring run). The Trinity River averaged 90 emigrants per adult for the 2001-2016 broods (Table 3.1.3.c), with a weak positive correlation between the number of adults and the number of emigrants produced (correlation coefficient of 0.23). For the critical broods of 2011-2014, the mean number of emigrants per adult spawner on the Trinity River was 92 percent of the mean across broods 2001-2016. Brood years 2011 and 2012 had the two highest estimated number of total emigrants across the time series, 2013 was near the average, and 2014 was below average.

Table 3.1.3.c. Trinity River adult spawner and emigrant Chinook salmon estimates for the area upstream of Willow Creek (fall and spring run combined). Bolded values indicate the critical brood years.

Brood year[a/]	Emigrants	Lower Confidence Limit	Upper Confidence Limit	Adult Parents	Emigrant/ Parent
2001	1,225,557	698,882	2,079,775	46,275	26
2002	572,740	201,691	1,282,301	34,625	17
2003	739,138	315,402	1,573,826	64,474	11
2004	2,681,621	1,403,019	5,648,278	18,417	146
2005[b/]	223,767	118,293	430,031	20,071	11
2006	1,864,654	1,361,552	2,566,689	18,330	102
2007	2,112,760	1,637,110	2,765,686	47,192	45
2008	2,950,452	2,191,155	3,954,788	15,476	191
2009	3,578,162	2,229,153	5,538,099	19,892	180
2010	2,802,970	1,924,965	4,413,722	28,196	99
2011	**5,345,168**	**2,220,686**	**14,548,896**	**35,027**	**153**
2012	**4,728,170**	**3,411,455**	**7,852,721**	**64,038**	**74**
2013	**2,409,657**	**1,784,133**	**3,293,980**	**33,083**	**73**
2014	**880,976**	**592,851**	**1,414,138**	**26,145**	**34**
2015	791,407	612,261	1,027,141	6,782	117
2016	741,581	640,038	856,552	4,775	155
2001-2016 avg.	2,103,049	1,333,915	3,702,914	30,175	90
2011-2014 avg.	3,340,993	2,002,281	6,777,434	39,573	83

a/ Brood year is the return year of adult parents, emigrants are estimated the following spring/summer.

b/ Redd scour in December 2005 appeared to reduce emigrant production in 2006.

3.1.4 Disease

Low river flows caused in part by drought, and in part by water management practices upriver, above average temperatures, and decades of low winter flows and sediment flow interruption from water management and the presence of the dams, have all combined to send fish disease rates to very high levels.

Infection of juvenile salmonids from the parasite *Ceratonova shasta* (*C. shasta)* in the Klamath River has been substantial in many recent years, but especially in 2014 and 2015. *C. shasta* is a myxozoan parasite with a complex life cycle, and it infects both salmonids and the freshwater polychaete worm *Manayunkia speciosa* (*M. speciosa*). Infected *M. speciosa* produce actinospores which infect salmonids. Infected salmonids produce myxospores which in turn infect *M. speciosa*. Clinical signs of the disease that are exhibited by infected salmonids include necrosis of intestinal tissue that can be accompanied by a severe inflammatory reaction (enteronecrosis) and subsequent death (Bartholomew et al. 1989). In the wild, heavily infected fish show lethargy and appear bloated.

Concerns regarding high disease levels in the Klamath River during the early 2000s led to a collaborative research and monitoring effort that was initiated in 2005 by the USFWS, Oregon State University, the Yurok and Karuk Tribes, and others. These research and monitoring efforts have resulted in a robust knowledge of the basic lifecycle of *C. shasta*, the factors that exacerbate its infection of salmonids, the genetic factors of different strains of the parasite, as well as information on spore infectivity, mortality rates of fish related to spore concentrations, effects of temperature, and so forth.

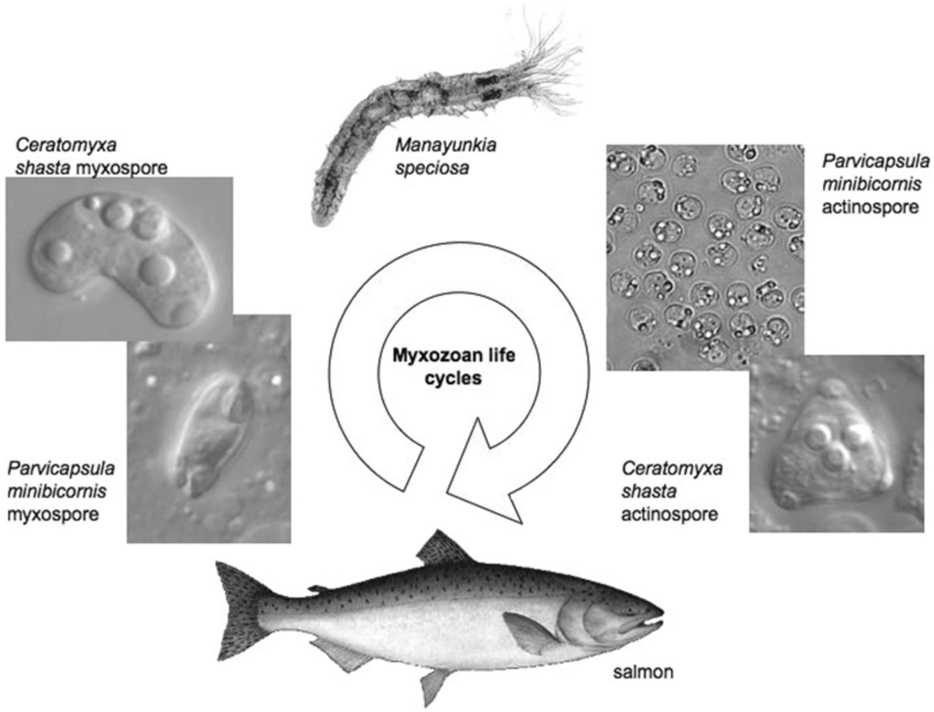

Figure 3.1.4.a. The life cycle of *Ceratonova shasta* (formerly *Ceratomyxa shasta*) and *Parvicapsula minibicornis*. *Manayunkia speciosa* is a small freshwater polychaete worm (3-5 mm in length) and intermediate host of both parasites. (Graphic provided with permission from J. Bartholomew and Steve Atkinson, Oregon State University).

Observed prevalence of infection (POI) of juvenile KRFC sampled between the Shasta River confluence and the Trinity River confluence in May through July of 2014 and 2015 were 81 percent and 91 percent, respectively (True et al. 2016). This considerably exceeds the take limit of 49 percent infection in Chinook salmon as a surrogate for infection in coho salmon in the Biological Opinion (BiOp) for Southern Oregon Northern California Coast (SONCC) coho salmon for the federally operated Klamath Irrigation Project (NMFS and USFWS 2013).

Violation of the take threshold identified in the BiOp led to litigation (*Hoopa Valley Tribe, Yurok Tribe, PCFFA v. U.S. Bureau of Reclamation*, 2017) resulting in efforts to address the disease issue. First, the Arcata USFWS office summarized the known information on the parasite and the factors causing it to induce mortality in juvenile salmon in the Klamath River and summarized this information in four technical memoranda [Shea et al. 2016 (aka Geomorphology Memo), Som and Hetrick 2016 (aka Spore Memo), Som et al. 2016a (aka Fish Infection Memo), and Som et al. 2016b (aka Polychaete Memo)]. This information was used in a Guidance Document (Hillemeier et al. 2017) that made six management recommendations. Several of the recommendations were implemented in 2017 and 2018, including higher winter flow releases to cause river bed movement below IGD and an emergency flow release in response to rising prevalence of *C. shasta* infection in 2018.

Estimated *C. shasta* infection rates in natural KRFC populations at the Kinsman trap location (rkm 237.55) were lower than observed sample POI in 2014 and 2015, although still substantial (Table 3.1.4.a, 3.1.4.b). Infection rates of sampled fish are typically higher than estimated natural

Chinook salmon population infection rates because: 1) weekly sample sizes are not weighted by abundance, but remain constant even as the natural juvenile emigration wanes and infection rates increase, and 2) weekly samples include hatchery fish that are typically released after natural fish emigrate past the Kinsman trap location, at a time when disease infection rates are elevated. Furthermore, the Kinsman trap, where the natural population abundance is estimated, is located 237.55 kilometers upriver from the Pacific Ocean. It is likely that POI rises as fish move downriver, because the exposure of these fish to the pathogen continues during their emigration to the ocean, at a time when water temperatures are typically increasing (see Figure 3.1.1.f). Increased water temperature is known to exacerbate POI by *C. shasta* (Som et al. 2016a, Figure 3).

Table 3.1.4.a. Historic annual prevalence of *Ceratonova shasta* infection (% positive by assay) in all juvenile Chinook salmon collected from the main stem Klamath River between Iron Gate Dam and Trinity River confluence during May through July, 2006-2017 (True et al. 2017).

Year	Histology (% Positive)	QPCR (% Positive)
2006	21	34
2007	21	31
2008	37	49
2009	54	45
2010	15	17
2011	2[a/]	17
2012	9[a/]	30
2013	16[a/]	46
2014	42[a/]	81
2015	62[a/]	91
2016	14[a/]	48
2017	8[a/]	26
Mean	**25**	**43**

a/ Histology limited to two reaches in 2011 (K4 and K1) and two reaches in 2012-2017 (K4 and K3).

Table 3.1.4.b. Estimate of proportion of population of natural fish infected with *Ceratonova shasta* at the Kinsman trap (rkm 237.55) for 2005-2015. Pop. LCL is lower confidence limit, Pop. Est is estimated proportion of natural fish infected with *C. shasta*, Pop. UCL is upper confidence limit. POI is percent of sampled fish infected with *C. shasta*. QPCR was used to detect *C. shasta* (Som et al. 2016a).

Year	Origin	POI	Pop. LCL	Pop. Est	Pop. UCL
2005	All	0.41	0.26	0.38	0.47
2007	All	0.28	0.07	0.1	0.15
2008	All	0.6	0.43	0.51	0.58
2009	All	0.5	0.5	0.58	0.66
2010	Wild/ Unknown	0.12/ 0.15	0.02	0.04	0.07
2011	Wild	0.2	0.07	0.11	0.17
2012	Wild/ Unknown	0.06/ 0.00	0.04	0.08	0.14
2013	Wild	0.18	0.03	0.06	0.09
2014	Wild	0.67	0.12	0.18	0.26
2015	Wild/ Unknown	0.66/ 0.96	0.2	0.29	0.39

Disease rates from *C. shasta* infection are largely a function of flow regimes, water temperature, adult salmonid carcass densities, sediment regimes, and are potentially exacerbated by hatchery production goals and fish release strategies. The operation of the U.S. Bureau of Reclamation Klamath Irrigation Project affects the total volume of flow in the Klamath River, the hydrograph, and generally alters the geomorphological features of the Klamath River (NMFS and USFWS 2013, Shea et al. 2016). A consequence of the impaired natural flow is the elevated rate of *C. shasta* infection in SONCC (NMFS and USFWS 2013, p. 341) and KRFC populations.

As stated in a USFWS technical memorandum (Shea et. al 2016) regarding the geomorphic aspects of the *C. shasta* disease and its obligate parasite in the Klamath River:

> *Development of flow releases from Iron Gate Dam that are intended to adversely impact the* C. shasta *life cycle by targeting the disruption of the obligate invertebrate host as suggested by Alexander et al. (2016) should identify specific physical objectives. The specification should identify the desired form of bed modifications (e.g., sand mobilization or gravel mobilization) and the extent of the mobilization (e.g., from riffles, from channel margins, from pools, etc.). The frequency and seasonal timing of environmental flows should also be specified. Seasonal timing should be based on biological objectives and constraints. Seasonal timing might also be based on physical objectives such as sequencing flows to occur simultaneously or following unregulated tributary peak flows.*

Since the year 2000, peak flows during the winter period have decreased significantly (Figure 3.1.4.b). At the same time, the presence of the dams has interrupted the transport of sediment in the area below IGD. This stable flow and lack of sediment supply substantially increased the concentration of the polychaete worm that is an obligate alternate host for *C. shasta,* thereby increasing the infection and subsequent mortality of juvenile salmonids from *C. shasta.*

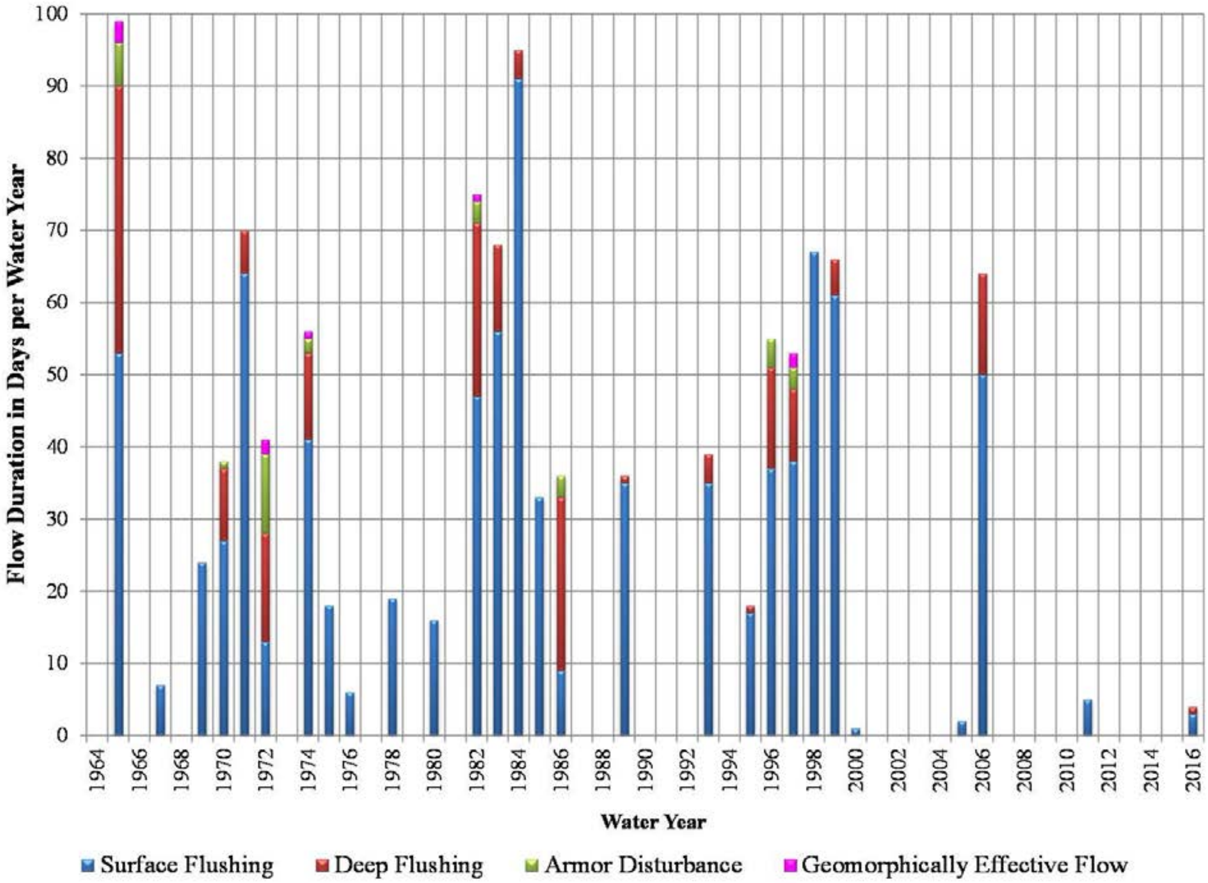

Figure 3.1.4.b. Duration of sediment mobilization flows in days per water year in the Klamath River below Iron Gate Dam water for water years 1964-2016 (taken from Shea et. al 2016).

Water flows were lower than average during 2013 – 2015 (Figures 3.1.1.a, 3.1.1.b, 3.1.1.e). In the years 2013 and 2014, the Klamath River experienced severe droughts. In 2015 precipitation was about average during the winter, but low snow pack and depleted groundwater from the previous drought contributed to low spring/summer inflow to Upper Klamath Lake and associated Klamath River flows (Figure 3.1.1.e). Water temperatures were above average (Figure 3.1.1.f) during the spring of these three years, and high temperatures are thought to be a contributing factor to high POI rates observed in Klamath River fish (Som et al. 2016a, Figure 3).

A critical stage of the life history of *C. shasta* includes high densities of myxospores being released from a small portion of decomposing salmon carcasses and subsequently floating downstream to be ingested by, and infect, polychaete worms (*M. speciosa*). Such infection of polychaete worms can be exacerbated by the relatively large number of adult salmon carcasses that are often concentrated downstream of IGD (upper limit of anadromy due to no fish passage). It is hypothesized that stable and low flows in the late fall/early winter, such as those experienced since 2000, minimize the distribution of these carcasses and the myxospores they release, thereby exacerbating the infection of polychaete worms by *C. shasta*.

IGH has a production goal to release 6,000,000 juvenile KRFC salmon annually. This production goal includes the release of 5.1 million fingerlings at 90 fish per pound (fpp) in early June and the release of 900,000 yearlings at 10 fpp between October 15 and November 20 (CA HSRG 2012). The release period for fingerlings from IGH is later than when the majority of natural-origin KRFC fingerlings have emigrated from the upper river, and generally aligns with the highest weekly POI estimates for each year (Som et al. 2016a, Figure 5; Hillemeier et al. 2017, Table 1). Summaries of the weekly POI samples over the hatchery outmigration period suggest that a high proportion of the IGH stock may become infected with *C. shasta* during some years.

IGH fingerlings that die from *C. shasta* may perpetuate the life cycle of *C. shasta* in the Klamath River. Just as adult carcasses infected with *C. shasta* release myxospores that infect polychaetes, juvenile carcasses also release myxospores that can infect polychaetes. These infected polychaetes may then release actinospores that infect adult KRFC while migrating up the Klamath River en-route to spawning grounds. The actinospores within the adult salmon may then develop into myxospores, thereby increasing the magnitude of myxospores released by rotting adult salmon carcasses on the spawning grounds. An unknown in regard to this cycle is the effect that warm Klamath River water temperatures have upon this cycle, as warm water can affect the viability of *C. shasta*.

3.1.5 Stock and recruitment

Stock-recruitment relationships are used to characterize the relationship between the number of parental spawners and their progeny. The number of progeny produced per spawner is typically highest at low spawner abundance and declines with increasing spawner abundance due to density dependent effects (e.g., redd superimposition at high spawner densities). In addition to quantifying density-dependent effects, stock-recruitment relationships are also useful for quantifying density-independent effects (e.g., water temperature during egg incubation). Density-independent effects can be indexed by examining the residuals[2] from a stock-recruitment relationship, with negative residuals representing lower than expected recruitment given the number of parental spawners, and positive residuals representing higher than expected recruitment given the number of parental spawners. For these reasons, stock-recruitment relationships provide a useful framework for characterizing the levels of density-dependence alongside density-independent effects in a population.

The estimated number of spawners upstream of the Scott River and the juvenile production estimates at the Kinsman site provide the necessary components for examining the stock-recruitment relationship for this portion of the Klamath River Basin (Figure 3.1.5.a). The Ricker stock-recruitment function that was fit to these data indicated that mean age-0 abundance increases with increased spawner abundance, there was a relatively low amount of density-dependence, and there was a large amount of density-independent variation.

[2] Residuals are the difference between the observed $\log_e$ (recruits / spawners) and the predicted $\log_e$ (recruits / spawners) from the stock-recruitment relationship.

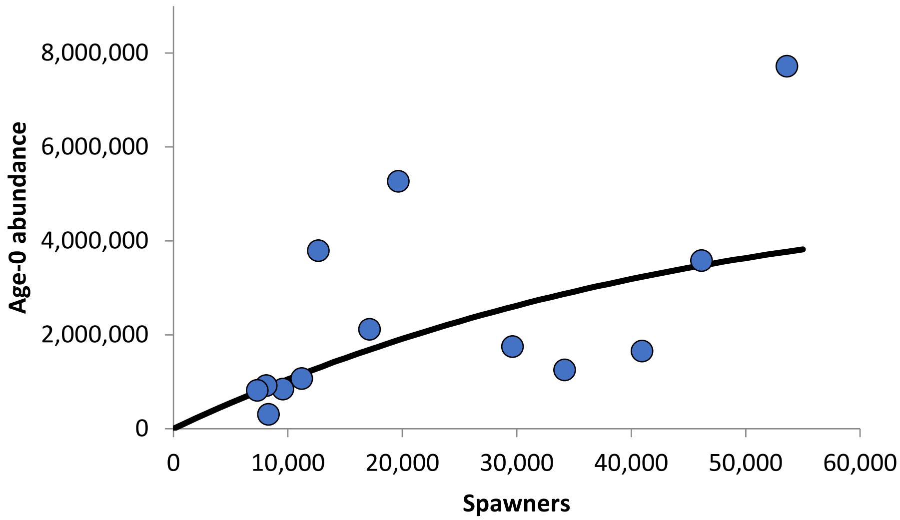

Figure 3.1.5.a. Estimates of the number of the total number of spawners in the Bogus Creek Basin, the Shasta River Basin, and the mainstem Klamath River upstream of the Scott River confluence and the age-0 abundance estimates at the Kinsman site for brood years 2001-2014. The black line represents the Ricker stock-recruitment function that was fit to the data.

As mentioned above, the residuals from the fitted stock-recruitment relationship characterize the density-independent factors influencing productivity, with negative residuals indicating lower-than-expected recruitment given spawner abundance and positive residuals indicating higher-than-expected recruitment given spawner abundance. Examining the residuals for the fitted stock-recruitment function for the Klamath River data indicated that brood years 2007, 2012, and 2013 had higher-than-expected recruitment given spawner abundance in those years (Figure 3.1.5.b). Brood years 2001-2004 and 2011 indicated lower-than-expected recruitment given spawner abundance in those years.

Figure 3.1.5.b**.** Residuals from the fitted stock-recruitment relationship by brood year for the Klamath River.

3.1.6 Hatchery production

KRFC are propagated at two hatcheries: Iron Gate Hatchery (IGH) at the base of IGD and Trinity River Hatchery (TRH) at the base of Lewiston Dam, the upper limits of anadromy for the Klamath and Trinity rivers, respectively. Both facilities were constructed to mitigate for habitat loss above the dams. Salmon from both hatcheries spawn in natural areas throughout the basin, especially in the vicinities of the hatcheries themselves, and thus contribute to the FMP-defined stock status which is solely based on natural area escapement. In recent years, both hatcheries have begun to incorporate recommendations from CA HSRG (2012) with respect to minimum levels of natural-origin inclusion in their broodstock. These new protocols are intended to transition Chinook production at these facilities to programs that are more integrated with their natural counterparts, lessening the genetic impacts to the natural population from interbreeding with hatchery-origin fish. However, these recommendations were not yet being implemented when the broods that contributed to the current overfished status were produced.

The two hatcheries have specific KRFC production goals, totaling 6 million fish at IGH and 2.9 million at TRH. The majority of these salmon (5.1 million at IGH and 2 million at TRH) are released directly into the river as smolts at or near their respective facilities when they reach an average length of about three inches and average weight of about 90 fpp. The target release time is during the first half of June, although release timing can be advanced if river water temperatures are projected to be suboptimal during the downstream migration period. The remaining 900,000 juveniles at each hatchery are retained until they reach an average weight of 10 fpp, and released as yearlings in October and November. In the past, an additional 180,000 yearlings were reared at Fall Creek Hatchery (FCH), an upstream facility built before construction of IGD, and released from IGH. This shifted the 6 million fish target at IGH to 4.92 million smolts and 1.08 million yearlings, however the additional rearing at FCH ceased after 2003 so the smolt target has reverted to 5.10 million. Table 3.1.6.a displays historical smolt and yearling release numbers for the 1981-2014 broods.

Table 3.1.6.a. Numbers of juvenile fish released from Iron Gate Hatchery (on the Klamath River) and Trinity River Hatchery for the 1981-2014 broods.

	Iron Gate Hatchery			Trinity River Hatchery			Hatchery
Brood Year	Smolts	Yearlings	IGH Total	Smolts	Yearlings	TRH Total	Releases
1981	852,092	165,820	1,017,912	939,300	1,093,613	2,032,913	3,050,825
1982	1,418,610	901,880	2,320,490	430,930	860,813	1,291,743	3,612,233
1983	2,993,372	1,323,738	4,317,110	2,575,335	967,781	3,543,116	7,860,226
1984	2,900,044	928,000	3,828,044	510,000	1,149,598	1,659,598	5,487,642
1985	12,204,669	1,952,688	14,157,357	1,556,569	1,017,849	2,574,418	16,731,775
1986	9,320,000	900,153	10,220,153	7,705,007	982,784	8,687,791	18,907,944
1987	6,260,000	1,898,000	8,158,000	2,350,205	93,223	2,443,428	10,601,428
1988	10,186,000	807,070	10,993,070	2,822,022	1,112,987	3,935,009	14,928,079
1989	5,100,000	0	5,100,000	2,749,774	524,688	3,274,462	8,374,462
1990	5,182,309	990,000	6,172,309	0	643,910	643,910	6,816,219
1991	6,757,600	1,755,694	8,513,294	581,539	933,796	1,515,335	10,028,629
1992	3,300,312	947,024	4,247,336	2,342,037	971,588	3,313,625	7,560,961
1993	4,962,344	824,589	5,786,933	202,275	213,101	415,376	6,202,309
1994	4,777,556	904,096	5,681,652	2,153,982	950,015	3,103,997	8,785,649
1995	5,618,804	404,172	6,022,976	2,037,759	909,622	2,947,381	8,970,357
1996	5,280,648	1,085,526	6,366,174	2,099,346	916,971	3,016,317	9,382,491
1997	5,097,161	0	5,097,161	2,397,657	907,354	3,305,011	8,402,172
1998	4,949,084	0	4,949,084	2,045,197	1,013,543	3,058,740	8,007,824
1999	5,007,431	1,045,306	6,052,737	1,967,853	859,486	2,827,339	8,880,076
2000	4,939,997	911,147	5,851,144	2,149,891	872,665	3,022,556	8,873,700
2001	4,967,089	1,087,081	6,054,170	2,065,049	925,162	2,990,211	9,044,381
2002	5,116,165	1,083,902	6,200,067	2,083,157	953,197	3,036,354	9,236,421
2003	5,182,092	685,819	5,867,911	2,149,880	906,234	3,056,114	8,924,025
2004	5,369,792	842,848	6,212,640	2,047,269	940,547	2,987,816	9,200,456
2005	6,171,838	874,917	7,046,755	2,070,713	950,932	3,021,645	10,068,400
2006	5,364,332	984,271	6,348,603	2,021,056	965,516	2,986,572	9,335,175
2007	5,290,005	1,104,870	6,394,875	1,804,492	995,750	2,800,242	9,195,117
2008	3,983,360	773,583	4,756,943	2,045,097	1,043,517	3,088,614	7,845,557
2009	4,528,056	855,000	5,383,056	2,041,026	928,142	2,969,168	8,352,224
2010	3,953,247	1,053,482	5,006,729	1,975,984	954,381	2,930,365	7,937,094
2011	**4,665,888**	**1,148,850**	**5,814,738**	**1,895,326**	**867,882**	**2,763,208**	**8,577,946**
2012	**4,136,672**	**979,668**	**5,116,340**	**1,757,825**	**982,968**	**2,740,793**	**7,857,133**
2013	**4,481,905**	**993,717**	**5,475,622**	**2,166,642**	**988,251**	**3,154,893**	**8,630,515**
2014	**3,794,691**	**943,489**	**4,738,180**	**1,404,634**	**987,101**	**2,391,735**	**7,129,915**
1981-2010 avg	5,234,467	903,023	6,137,490	1,997,347	885,292	2,882,639	9,020,128
2011-2014 avg	4,269,789	1,016,431	5,286,220	1,806,107	956,551	2,762,657	8,048,877

The production goals at IGH may change if removal of the four most downstream dams on the Klamath River, including IGD, occurs as planned beginning in 2021. The existing fish collection facility will be demolished in the process, and the water supply will be lost once reservoir drawdown commences. Solutions to these problems are currently being assessed.

Hatchery spawning techniques promote exceptionally high egg fertilization rates, and due to their confinement, the resulting fry are able to avoid most of the perils that naturally produced fish encounter during their juvenile freshwater residency. Diseases and parasites are treated promptly, steps are taken to minimize bird predation, and fish are fed special high protein diets that increase growth rates and result in smolts that are probably larger than their naturally produced counterparts. Yearlings however, while released at a larger size than smolts, are likely smaller at that date than the surviving natural-origin and smolt-released hatchery fish that have already resided in the ocean for several months. The policy to delay smolt releases until June when the fish are ready to migrate to sea is intended to minimize competition (interaction) with naturally produced KRFC rearing in-river. To the extent possible, river conditions are closely monitored at the hatcheries to ensure the fish are released when environmental conditions are suitable.

The maturation schedule for smolt releases is believed to be similar to that of naturally produced fish. While survival of yearling releases is higher than smolts, maturation is delayed because of their smaller size at age from extended hatchery rearing time (Hankin 1990), and the importance of size at age to the onset of sexual maturity in Pacific salmon (Hankin et al. 1993).

3.1.7 Other relevant factors

Interactions between hatchery- and natural-origin adults on the spawning grounds

Straying of hatchery-origin Chinook onto natural spawning grounds leads to interactions with natural-origin Chinook, potentially reducing spawning success and productivity of natural populations. In the Klamath Basin, these interactions are especially prevalent in the vicinities of the two hatcheries, most notably in Bogus Creek, a small Klamath tributary adjacent to IGH, and the Trinity River near TRH. This can lead to competition with natural-origin KRFC over spawning areas and redd superimposition (CDFG and NMFS 2001). In the Trinity River, a large percentage of the carcasses are typically recovered in the first several miles downstream of TRH, and it is believed that pre-spawn mortality is density-dependent in this portion of the basin (Hill 2014). Additional concerns for natural populations include disease transmission, and reduced fitness caused by genetic alterations from interbreeding with hatchery-origin Chinook (CDFG and NMFS 2001). In the Trinity River, there is also the potential for hatchery-origin fall-run Chinook to hybridize with spring-run Chinook, and vice versa. These concerns and potential long-term consequences of hatchery- and natural-origin Chinook interactions are discussed in more detail in CDFG and NMFS (2001).

Table 3.1.7.a displays the basin-wide natural area adult escapement since 1996, broken down into the estimated hatchery- and natural-origin components. Prior to 1996, IGH would sometimes close their fish ladder early if they received large numbers of spawners, forcing any remaining hatchery-bound KRFC to spawn in-river. Due to this practice, hatchery-origin contributions through 1995 are not directly comparable to the values reported here. If hatchery-origin Chinook compose a large percentage of the natural area escapement in consecutive years, it may be indicative of a downward trend in natural production, likely exacerbated by the processes outlined above. During 1996-2014, hatchery-origin KRFC constituted on average 24 percent of the total natural area adult escapement in the basin. However, during 2015-2017, hatchery-origin KRFC only composed an average of 9 percent of the natural area adult escapement. Thus, hatchery-origin Chinook did not appear to have an elevated influence on the

broods that made up the 2015-2017 escapements. Also, it is not uncommon for hatchery-origin fish to compose smaller proportions of the natural area escapement during years of low hatchery returns. Since hatchery-origin Chinook that spawn in natural areas tend to do so in the vicinities of the hatcheries, it is believed that a greater portion of them enter the hatchery when it is not as crowded, rather than resorting to spawning in-river. The IGH returns during 2015-2017 were the lowest since 1992. While TRH has experienced low escapement numbers in more recent years (e.g., 2013, 2008, and 2002), the returns during 2015-2017 were still much lower than average, and the 2016 return was the lowest on record (PFMC 2018b).

Table 3.1.7.a. Estimates of natural- and hatchery-origin adult spawners in Klamath Basin natural areas.

	Natural Area Adult Spawners			Percent
Year	Natural-Origin	Hatchery-Origin	Total	Hatchery-Origin
1996	67,458	13,868	81,326	17%
1997	42,230	3,914	46,144	8%
1998	31,074	11,414	42,488	27%
1999	12,600	5,856	18,456	32%
2000	58,753	23,976	82,729	29%
2001	56,187	21,648	77,835	28%
2002	60,399	5,236	65,635	8%
2003	64,245	23,399	87,644	27%
2004	10,957	12,874	23,831	54%
2005	17,472	9,318	26,790	35%
2006	21,066	9,095	30,161	30%
2007	51,416	9,254	60,670	15%
2008	25,503	5,346	30,849	17%
2009	38,608	5,803	44,411	13%
2010	33,602	3,623	37,225	10%
2011	27,666	19,099	46,765	41%
2012	96,576	24,969	121,545	21%
2013	46,137	13,018	59,155	22%
2014	74,451	20,653	95,104	22%
2015	**25,619**	**2,493**	**28,112**	**9%**
2016	**12,875**	**1,062**	**13,937**	**8%**
2017	**16,649**	**1,865**	**18,514**	**10%**
1996-2014 avg.	44,021	12,756	56,777	24%
2015-2017 avg.	18,381	1,807	20,188	9%

If the number of hatchery-origin KRFC spawning in natural areas were increased during 2015-2017 to reflect the 24 percent long-term average, escapements would have been 33,687, 16,929, and 21,892 adults, respectively. All of these values still fall below the S_{MSY} of 40,700 natural area adults, and two of the three years would still be below the MSST of 30,525. The three-year geometric mean would be 23,198 natural area adult spawners, which is below the MSST and thus KRFC would still be overfished.