

## APPENDIX A

### Evaluation of Alternative Size Limits for Klamath River Fall Chinook Salmon Harvest

The analyses presented herein were prepared to evaluate the potential impacts to Chinook Salmon from increasing the size limit distinguishing age-two from age-three for in-river recreational harvest of fall Chinook Salmon. Data used in this analysis was collected by staff at the California Department of Fish and Wildlife (Department) and the Hoopa Valley Tribe.

Klamath River fall Chinook (KRFC) Salmon are managed based on adult quotas, meaning that once the quota has been attained, the fishery for adult-sized KRFC is closed. The Klamath basin is divided into four “sub-quota” zones – two each in the Klamath and Trinity Rivers – to provide equitable harvest opportunities to recreational anglers throughout the basin. Each sub-quota area has its own adult allocation and can be closed independently based on near real-time adult KRFC harvest estimates. In most years, regulations allow for a grilse fishery to continue if or when adult closures have occurred, which affords extended recreational harvest opportunity when adult quotas are attained. Department data has demonstrated that the size of grilse (age-two) and adults (age-three and older) overlap in all years to some degree. Consequently, the fishery in general, and the grilse fishery in particular, need to be structured to minimize impacts to adult KRFC conservation goals and to minimize the potential for exceeding harvest quotas.

Current management in the Klamath River assumes an adult size limit of greater than 22 in (55.9 cm) total length (TL) for recreational harvest, whereas the preliminary adult size cutoff for research and monitoring is typically 55 cm (21.7 in) fork length (FL). Total length is used for recreational harvest because it is consistent with fishing regulations for all species state-wide. Fork length is used for research and monitoring of salmon and steelhead because it provides a more consistent measurement across the range of conditions encountered in a scientific context, e.g., fin erosion due to spawning, especially postmortem. These size limits are used to separate grilse from adults during the season because the true age of individual fish cannot be determined until well after the time of harvest. Some grilse are larger, and some adults are smaller than the size limit (Figures 1 and 2). Also, the size that minimizes these overlaps varies from year to year and can only be determined through retrospective analyses. Figures 3 and 4 show the interannual variability in the median and range of lengths for known or estimated age-two and age-three KRFC. The in-season size limits for recreational harvest and for research and monitoring typically do not change from year to year. Recreational anglers have expressed concern that differences in the types of measurement (i.e., TL vs. FL) and/or the size limit of 22” TL reduces their access to grilse Chinook Salmon, particularly in years when adult quotas have been attained and recreational harvest is restricted to the take of grilse.

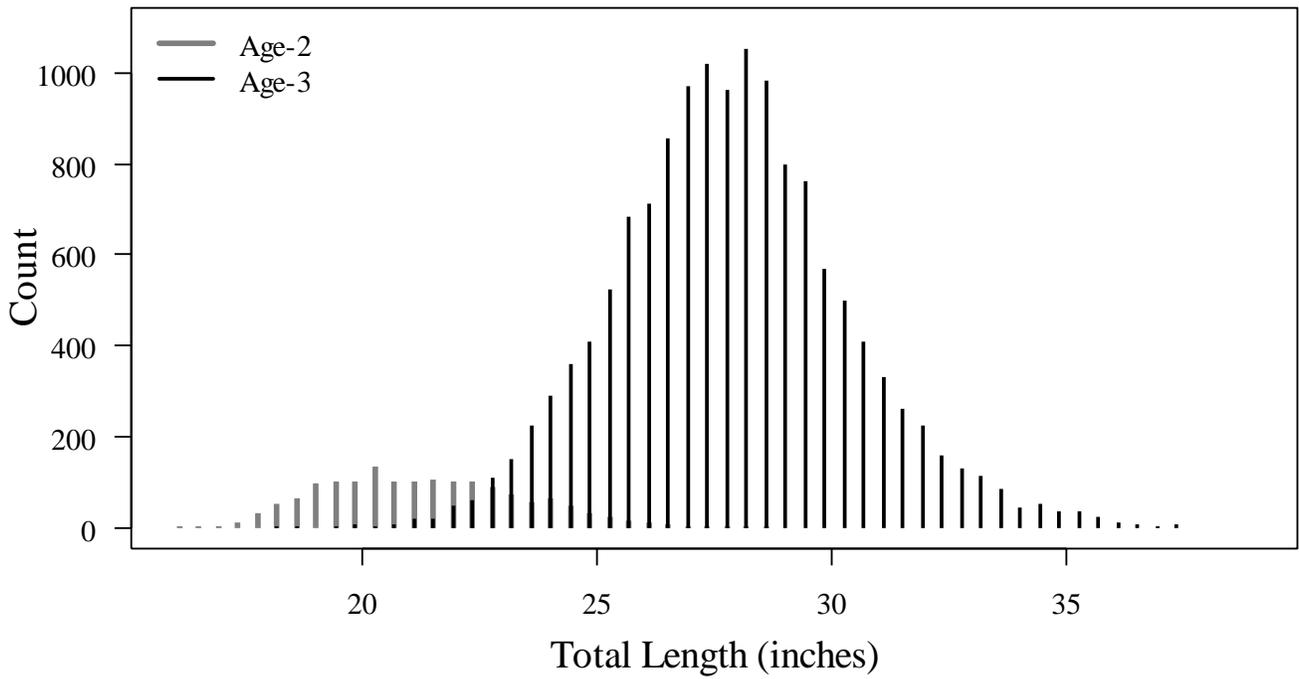


Figure 1. Length frequency histograms of known age-two and known age-three fall Chinook Salmon collected at Trinity River hatchery, 1998 and 2008-2018.

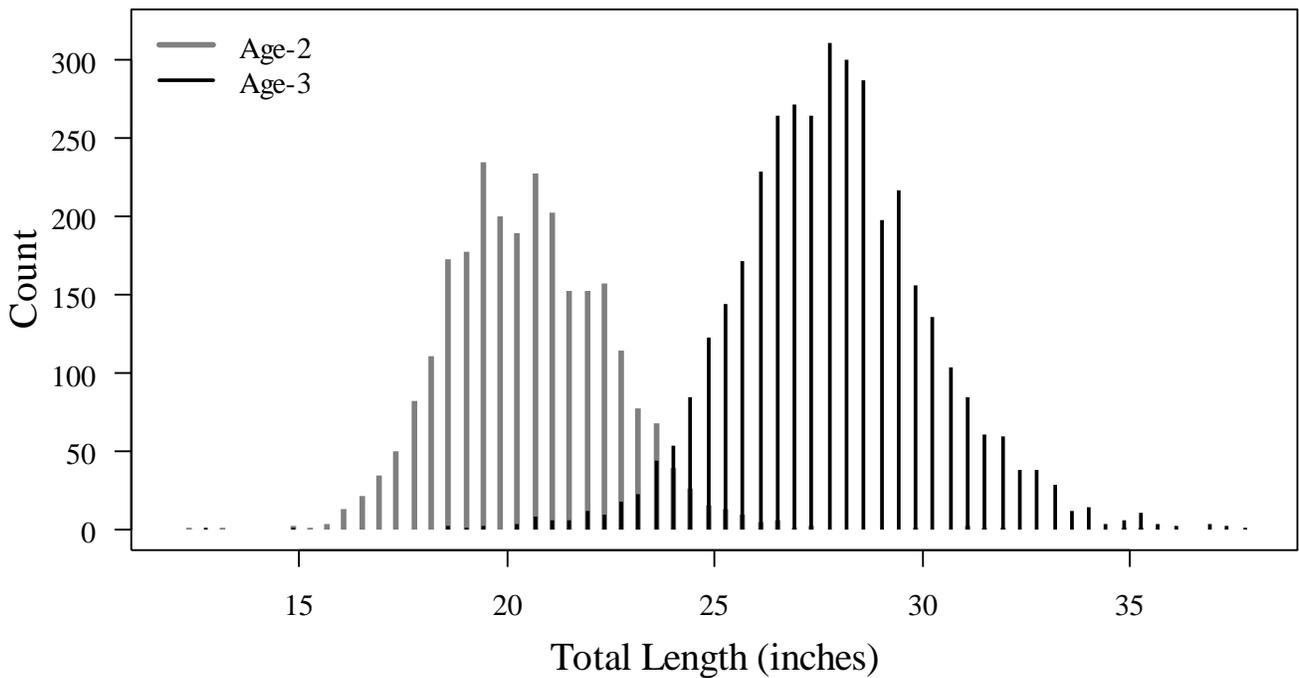


Figure 2. Length frequency histograms of estimated age-two and estimated age-three fall Chinook Salmon collected at Willow Creek weir, Trinity River, 2008-2018.

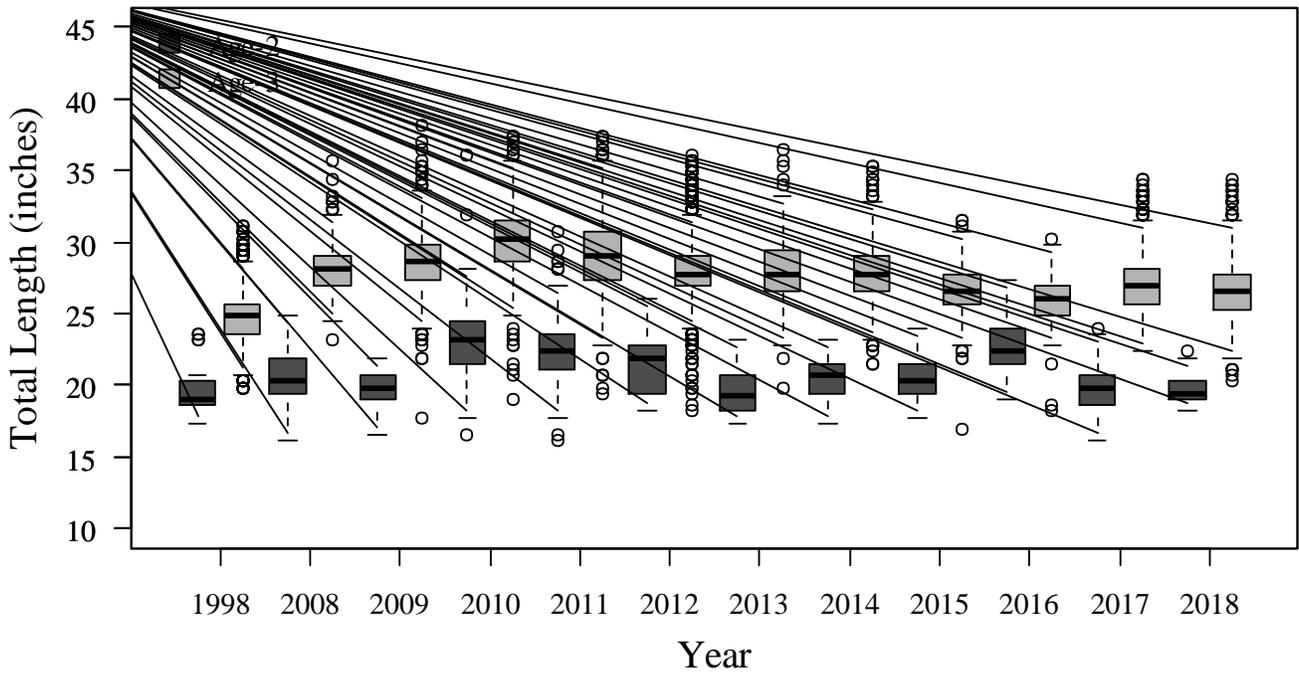


Figure 3. Timeseries of box and whisker plots of total lengths from known age-two and age-three fall Chinook Salmon collected at Trinity River hatchery, 1998 and 2008-2018. Horizontal bars indicate medians, boxes encompass the 25<sup>th</sup> to 75<sup>th</sup> percentiles, whiskers extend to 1.5 times the height of each box, and outliers are presented as open circles.

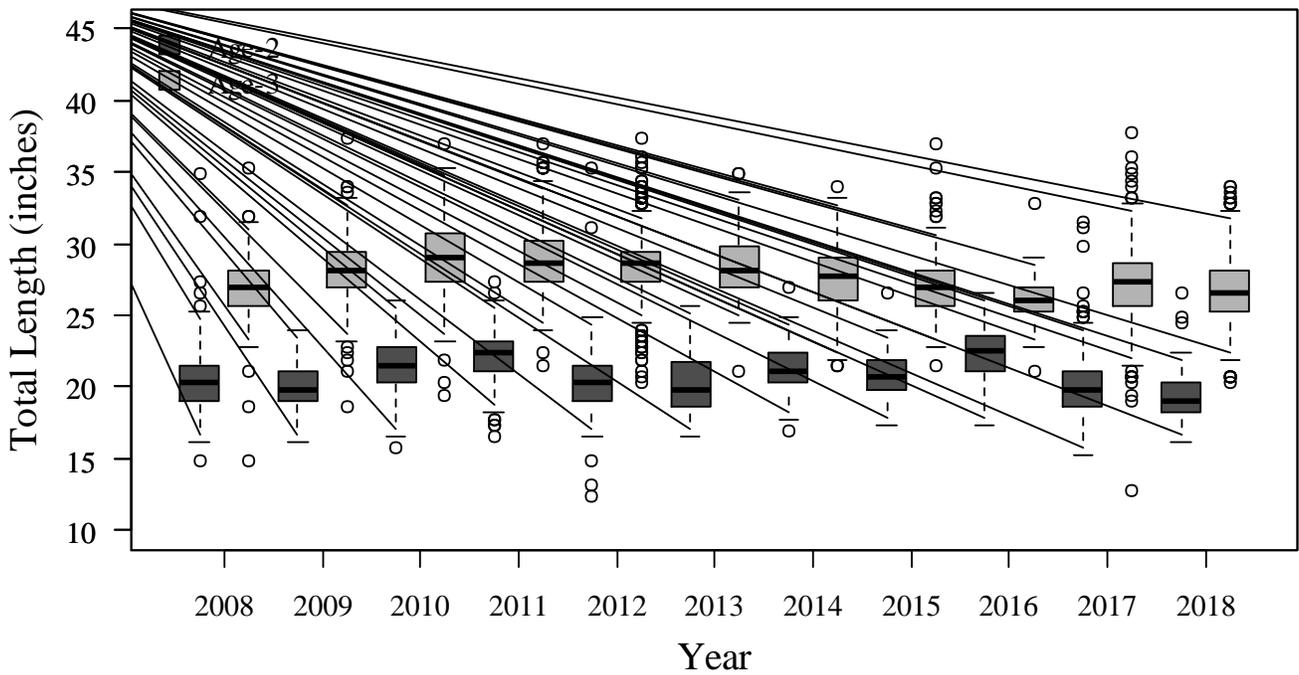


Figure 4. Timeseries of box and whisker plots of total lengths from estimated age-two and age-three fall Chinook Salmon collected at Willow Creek weir, 2008-2018. Horizontal bars indicate medians, boxes encompass the 25<sup>th</sup> to 75<sup>th</sup> percentiles, whiskers extend to 1.5 times the height of each box, and outliers are presented as open circles.

## Conversion of FL to TL

Fish are measured to the nearest centimeter FL for research and monitoring, whereas recreational angling regulations are defined by the nearest inch TL. Nearly all data available on the length of known-age or estimated-age fish (from coded wire tags [CWT] or scale aging) is from research and monitoring (i.e., centimeter fork length). Because this analysis is intended to inform recreational angling regulations, we converted centimeters FL to inches TL.

In August 2019, 115 adult Salmon captured at Junction City weir were measured to the nearest centimeter FL and TL. A linear regression model was fit to these data (Figure 5), which yielded an  $R^2$  value of 0.9934. Model residuals were examined and did not indicate any violations of model assumptions, and there were no outliers with high leverage. The fitted model was then used to estimate total length for known-age fish measured to FL at Trinity River hatchery, Iron Gate hatchery, and Willow Creek weir. Estimates of TL for known-age or estimated-age fish were then converted to inches. All Salmon used for the FL to TL regression were presumed to be spring run, but we believe it is reasonable to assume that the same relationship applies to fall run Chinook Salmon.

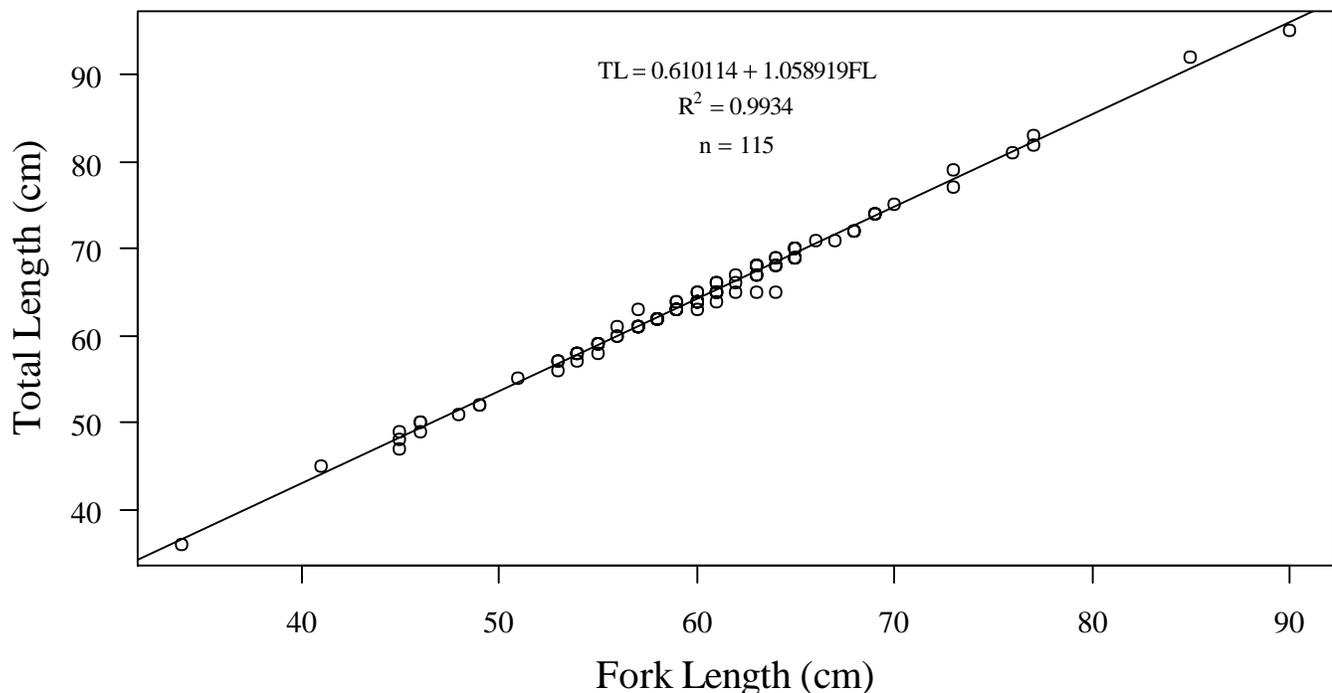


Figure 5. Scatterplot of total length vs. fork length of spring Chinook Salmon captured at Junction City weir in August 2019. The sample size (n), fitted regression line, equation, and coefficient of determination ( $R^2$ ) are presented.

## Effects on age-three Chinook Salmon from size limits of 21 to 24 inches total length

Chinook Salmon returning to hatcheries in the Klamath and Trinity Rivers are measured to the nearest centimeter FL, and heads from fish with adipose fin clips are taken for later recovery and decoding of CWTs. Coded wire tag numbers indicate the hatchery of origin, release type (fingerling or yearling), run type (spring or fall), and brood year from which a fish originated, which in turn provides a known age. Length and known age data from all fall Chinook Salmon fingerlings and yearlings returning to Iron Gate and Trinity River hatcheries with CWTs from 1998 and 2008-2018 were obtained from Department staff. Fall Chinook Salmon were selected because in-river recreational fisheries only receive an adult quota for fall Chinook Salmon, so presumably any change

to size limits would only affect fall Chinook Salmon. Fingerlings and yearlings were selected because both are vulnerable to harvest and are indistinguishable to anglers, thus the combination of release types is more representative of fish that would be affected by a regulation change than either release type on its own. Using data from 2008-2018 is somewhat arbitrary, but we believe this period provides sufficient data to evaluate the effects of any regulation change. The size limit was increased from 22" TL to 24" TL for one year in 1998, which coincided with below average size three-year-old fish returning to the Klamath basin. We include this year as a case study.

A fish weir has been operated on the Trinity River near the town of Willow Creek annually since 1978, where salmon and steelhead are captured and tagged to estimate run sizes. Each trapped fish is measured to the nearest centimeter FL, and scales are collected from a systematic random sample of Chinook Salmon. Scales are aged by the Hoopa Valley tribe to estimate proportions of each age class in the run. Length and scale-estimated age data from fall Chinook Salmon sampled at Willow Creek weir from 2009 to 2018 were obtained from Hoopa Valley Tribe Fisheries Department staff. These data are intended to be used at the population scale, as opposed to using ages of individual fish, by estimating proportions at age that are corrected for reader bias. However, it is not possible to correct for such errors for individual fish, and we have not attempted to do so here. Accuracy of scale aging from 2009-2018 has ranged from 92.3% to 100% and averaged 98.3% for age-two fish, and ranged from 87.0% to 99.2% and averaged 96.8% for age-three fish. Consequently, we expect these data to accurately represent the population.

For each year, hatchery or weir, and proposed length cutoff (21" to 24" TL) we calculated the proportion of known (or estimated) age-two fish larger than the cutoff and the proportion of known (or estimated) age-three fish smaller than the cutoff. Age-four and age-five fish were not considered because they are rarely small enough to be affected by a 24" TL size limit in any meaningful way. The proportion of age-three fish smaller than the cutoff provides an estimate of the magnitude of potential unintended recreational harvest of age-three fish from a given minimum adult size limit (i.e., age-three fish presumed to be age-two because they are less than the cutoff), which we will refer to as impacts to age-three fish for simplicity. Age-three fish comprise the vast majority of the quota-managed fishery in most years. Results are presented separately for known-age fish returning to Iron Gate and Trinity River hatcheries and estimated-age fish captured at Willow Creek weir. It is important to note that none of these samples fully represent the combined Klamath-Trinity stock of fall Chinook Salmon for several reasons. Hatchery recoveries are skewed heavily toward hatchery-origin fish and thus underrepresent natural-origin fish if there is a systematic difference in sizes at age for these two groups. In addition, samples from all locations used in this analysis are collected from the population after in-river tribal and recreational fisheries have selectively removed certain size classes of fish due to fishing regulations (e.g., adult size limits) and/or size-selection bias of fishing methods (e.g., gill nets). Lastly, all samples are taken after Klamath and Trinity sub-stocks have segregated themselves by migrating upstream of Weitchpec into the Klamath or Trinity rivers, respectively, thus the samples may not represent the combined Klamath-Trinity stock encountered by anglers in the lower Klamath River downstream of Weitchpec.

A size limit of 21" TL would protect nearly all age-three fall Chinook Salmon in all years and shows a highly variable percent of age-two fish that would be unavailable during a grilse-only fishery (e.g., after an adult quota is met). Potential unintended impacts to age-three fish were less than 2% at all locations in all years (Tables 1-3) and were generally well below 1%. The percent of age-two fish greater than 21" ranged from 11.76% at Trinity River hatchery in 1998 to 96.41% in 2014 at Iron Gate hatchery.

The current size limit of 22" TL has protected the vast majority of age-three fall Chinook Salmon for the past 10 years. Impacts to age-three fish from a 22" TL size limit exceeded 2% at Trinity River

hatchery and Willow Creek weir in one year each and were generally less than 1% at all locations in most of the past 10 years (Tables 1-3). Impacts have increased in recent years, particularly at Willow Creek weir and Iron Gate hatchery, which reflect the small size at age we have observed in the Klamath River in recent years resulting from inland drought conditions and poor ocean conditions. The percent of age-two fish greater than 22" TL has been highly variable, ranging from 0% at Trinity River hatchery in 2009 to 88.51% at Iron Gate hatchery in 2011.

A size limit of 23" TL shows more variable impacts to age-three fish at all locations sampled, but potential impacts were still relatively low. Over the past 10 years, potential impacts have not exceeded 3.45% (Tables 1-3). Potential impacts have increased in recent years, which is particularly evident at Iron Gate hatchery. From 2009 to 2015, potential impacts to age-three fish from a 23" TL size limit averaged 0.25% and did not exceed 0.44%, but the average from 2016-2018 was 2.49% and was not less than 1.51%. The percent of age-two fish greater than 23" TL was also highly variable, ranging from 0% at Trinity River hatchery in 2009 and 2018 to 65.47% at Iron Gate hatchery in 2014.

Potential impacts to KRFC from a size limit of 24" TL is much more variable and has also increased in recent years. Potential impacts are seen at all locations in all years (i.e., none are 0%). In the past 10 years, potential impacts to age-three fish have exceeded 5% several times at each location and exceeded 10% at Willow Creek weir in 2016.

The 1998 run year presents an illustrative case study because the size limit was changed to 24" TL that year, and, coincidentally, fish were particularly small that year (Figure 1). The same methods for real-time quota management that are employed today were also used in 1998, and post-season analysis revealed that the quota had been exceeded by 5,910 fish. Even at the current size limit of 22" TL, potential impacts to age-three fish exceeded 5% (Tables 1, 3). Assuming a 24" TL size limit, potential unintended impacts to age-three KRFC may have exceeded 37% (Table 3). Reducing the minimum adult size limit from 24" to 23" TL reduced potential impacts by more than half as measured at the two hatcheries. Potential impacts were still alarmingly high for a 23" TL size limit – 14.17% at Trinity River hatchery and 17.73% at Iron Gate hatchery. While 1998 is an outlier compared to the past 10 years, recent increases in the potential unintended impacts to age-three fish suggest that caution should be exercised when considering an increased size limit.

Anecdotal observations from the 2019 run indicate that fish are small this year. Numerous Chinook Salmon less than 16.9" TL have been trapped at Willow Creek weir, and a 19.8" TL age-three fish (based on CWT) was recovered at Iron Gate hatchery.

Table 1. Proportions of known age-two falling above and known age-three falling below proposed minimum adult size limits of 21" to 24" total length collected at Trinity River hatchery, 1998 and 2008-2018 return years.

year	21" TL cutoff		22" TL cutoff		23" TL cutoff		24" TL cutoff	
	age2 > 21"	age3 < 21"	age2 > 22"	age3 < 22"	age2 > 23"	age3 < 23"	age2 > 24"	age3 < 24"
1998	11.76%	0.58%	11.76%	5.62%	11.76%	14.17%	0.00%	29.44%
2008	39.60%	0.00%	18.79%	0.00%	8.05%	0.00%	4.03%	0.29%
2009	8.11%	0.07%	0.00%	0.20%	0.00%	0.27%	0.00%	0.75%
2010	84.56%	0.22%	67.45%	0.43%	50.34%	0.65%	34.56%	0.86%
2011	76.89%	0.15%	52.80%	0.23%	34.06%	0.46%	20.19%	0.88%
2012	65.62%	0.26%	43.75%	0.40%	21.88%	0.58%	15.62%	1.21%
2013	20.00%	0.43%	6.67%	0.87%	3.33%	1.30%	0.00%	3.03%
2014	41.51%	0.00%	13.21%	0.23%	5.66%	0.81%	0.00%	2.08%
2015	36.36%	0.25%	4.55%	0.76%	2.27%	2.53%	2.27%	5.06%
2016	87.21%	1.38%	61.63%	2.07%	37.21%	3.45%	25.58%	6.90%
2017	21.00%	0.00%	4.20%	0.00%	1.31%	0.95%	0.26%	4.86%
2018	13.89%	0.13%	2.78%	0.47%	0.00%	1.73%	0.00%	5.93%

Table 2. Proportions of estimated age-two falling above and known age-three falling below proposed minimum adult size limits of 21" to 24" total length sampled at Willow Creek weir, 2008-2018 return years.

year	21" TL cutoff		22" TL cutoff		23" TL cutoff		24" TL cutoff	
	age2 > 21"	age3 < 21"	age2 > 22"	age3 < 22"	age2 > 23"	age3 < 23"	age2 > 24"	age3 < 24"
2008	32.94%	1.56%	13.41%	2.34%	6.71%	3.12%	2.96%	4.69%
2009	25.69%	0.26%	11.01%	0.78%	3.67%	1.30%	1.83%	1.81%
2010	62.35%	0.86%	38.24%	1.29%	21.76%	1.29%	12.35%	2.58%
2011	75.66%	0.00%	52.12%	0.32%	27.25%	0.63%	12.70%	0.63%
2012	36.75%	0.23%	14.53%	0.58%	3.42%	1.05%	2.56%	1.86%
2013	27.78%	0.00%	20.83%	1.52%	8.33%	1.52%	2.78%	1.52%
2014	60.82%	0.00%	34.02%	1.46%	16.49%	2.44%	4.12%	4.39%
2015	45.22%	0.00%	15.65%	0.56%	6.09%	1.69%	2.61%	3.39%
2016	87.50%	0.00%	55.00%	1.69%	35.00%	3.39%	15.00%	10.17%
2017	27.39%	0.86%	10.37%	1.60%	4.78%	2.21%	1.98%	5.40%
2018	15.74%	0.87%	3.70%	1.57%	2.78%	3.30%	2.78%	6.09%

Table 3. Proportions of known age-two falling above and known age-three falling below proposed minimum adult size limits of 21" to 24" total length collected at Iron Gate hatchery, 1998 and 2009-2018 return years.

year	21" TL cutoff		22" TL cutoff		23" TL cutoff		24" TL cutoff	
	age2 > 21"	age3 < 21"	age2 > 22"	age3 < 22"	age2 > 23"	age3 < 23"	age2 > 24"	age3 < 24"
1998	13.33%	0.85%	0.00%	8.37%	0.00%	17.73%	0.00%	37.45%
2009	57.78%	0.00%	28.89%	0.00%	13.33%	0.19%	4.44%	0.38%
2010	93.78%	0.00%	77.20%	0.00%	56.48%	0.26%	28.50%	0.26%
2011	96.39%	0.07%	88.51%	0.14%	75.46%	0.29%	51.35%	0.79%
2012	84.39%	0.08%	57.56%	0.12%	32.68%	0.26%	11.71%	0.36%
2013	61.96%	0.10%	36.08%	0.10%	20.39%	0.19%	10.59%	0.48%
2014	96.41%	0.12%	81.17%	0.24%	65.47%	0.44%	41.26%	0.61%
2015	64.52%	0.00%	25.81%	0.00%	12.90%	0.13%	3.23%	0.66%
2016	64.71%	0.30%	29.41%	0.60%	23.53%	1.51%	23.53%	6.33%
2017	71.55%	0.27%	36.64%	1.70%	14.44%	3.30%	5.17%	7.59%
2018	63.24%	0.36%	25.00%	1.08%	14.71%	2.67%	4.41%	6.26%

### Key points

- The range and average size of age-two and age-three KRFC changes annually.
- No pre-season data exists to make annual changes to the size limit for grilse KRFC.
- The KRFC fishery is managed using an adult quota designed to meet escapement objectives, and grilse are not quota managed.
- In some years (e.g., 1998) a significant proportion of age-three KRFC are less than the current 22" TL size limit, making them vulnerable to grilse-directed fisheries. These fish are later reclassified as adults, which can result in escapement shortfalls and/or exceeding adult quotas.
- The current size limit of 22" TL protects most adult KRFC in most years
- A size limit of 24" TL increases the inter-annual variability in potential unintended impacts to age-three KRFC.
- Increasing the size limit increases conservation risk due to the potential for harvest of adults less than the grilse size during grilse fisheries.