#### Chilkat Lake Sockeye Salmon

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Chilkat Lake, located approximately 44 river km upstream from the city of Haines, supports one of the largest runs of sockeye salmon in Southeast Alaska. Chilkat Lake sockeye salmon are primarily harvested in the District 15 commercial drift gillnet fishery in northern Lynn Canal. Smaller but unknown portions of the Chilkat sockeye salmon run are harvested in the commercial purse seine fisheries that target pink salmon in Icy and northern Chatham straits (Ingledue 1989; Gilk-Baumer et al. 2015) and in subsistence fisheries in Chilkat Inlet and in the Chilkat River. A small portion of the Chilkat sockeye salmon run is also harvest by sport fisheries on the Chilkat River. Stock composition of sockeye salmon harvested in the mixed stock District 15 commercial drift gillnet fishery was estimated using scale pattern analysis from 1980 through 2016 (McPherson 1990) and, more recently, solely through genetic stock identification since 2017 (Bednarski et al. 2017; Ransbury et al. 2021). Chilkat Lake sockeye salmon escapements have been estimated through weir counts (1967–1993), weir counts with concurrent mark–recapture estimates (1994 and 1995, 1999–2007), mark–recapture estimates only (1996–1998), Dual-frequency Identification Sonar (DIDSON) counts with concurrent mark–recapture estimates (2008–2016), and DIDSON counts only from 2017 on (Eggers et al. 2010; Sogge and Bachman 2014; Bednarski et al. 2017; Zeiser et al. 2020; Ransbury et al. 2021). Visual weir counts provided minimum estimates of escapement due to flow reversals, turbid water, and frequent lowering of a boat gate in the middle of the weir, all of which potentially allowed fish to pass undetected. Conversely, mark–recapture estimates may be greatly inflated, but may provide an index of escapement (Bednarski et al. 2017). DIDSON counts are also considered minimum estimates of escapement due to undetected passage of small numbers of fish at night during flow reversals; however, confidence in DIDSON counts is much greater than in the visual weir counts (Bednarski et al. 2017).

The current biological escapement goal range of 70,000–150,000 sockeye salmon was established in 2009, based on a stock-recruit analysis by Eggers et al. (2008, 2010). Following a comprehensive review of historical stock assessment data (Bednarski et al. 2017), Miller and Heinl (2018) updated the escapement goal analysis using age-structured state-space stock-recruit models to better account for multiple overlapping methods of escapement enumeration and missing data (brood years 1976−2012; calendar years 1976–2016). Model results were similar to those of Eggers et al. (2010), and the escapement goal review committee recommended maintaining the biological escapement goal range of 70,000–150,000 sockeye salmon (Heinl et al. 2017).

For this review, methods used by Miller and Heinl (2018) were updated to include brood years 2013−2018. An age-structured state-space spawner-recruit model was fit to data on abundance, harvest, age composition, and coefficients of variation to examine the effect of autocorrelation on recruits, to account for multiple overlapping methods of escapement enumeration and missing data (age composition was considered unknown in the model for years 1996–1998 when the weir was not operated; Figures 1 and 2). DIDSON escapement counts were treated as the “true” counts and the weir counts and mark–recapture estimates of escapement were treated as indices of escapement in the state-space model. Despite the addition of sixyears of data (Figure 3), the resulting parameter estimates were very similar to those estimated by Miller and Heinl (2018). The posterior median escapement leading to maximum sustained yield from the model output is estimated to be 96,300 spawners (95% credible interval 65,600–260,900 spawners; Table 1). The probability of achieving 90% of maximum sustained yield (MSY) at the upper and lower bounds of the current escapement goal is estimated to be 65% and 31%, respectively (Figure 4), and an average 64% over the entire escapement goal range. Yield would be maximized at escapements near *S*MSY (near 84% probability of achieving 90% of MSY; Figure 4). These probabilities improve substantially with respect to achieving 80% of MSY. Uncertainty regarding the effects that unknown subsistence and commercial purse seine harvests might have on the spawner-recruit analysis, uncertainty regarding the true spawner-recruit relationship and estimated production parameters, and higher estimated probabilities of reducing yield to less than 90% of MSY at escapements below 70,000 fish suggests that a precautionary approach to the lower bound of the escapement goal is warranted. The escapement goal review committee recommended maintaining the current biological escapement goal of 70,000–150,000 sockeye salmon counted with the DIDSON system at the Chilkat Lake weir site (Figure 5).

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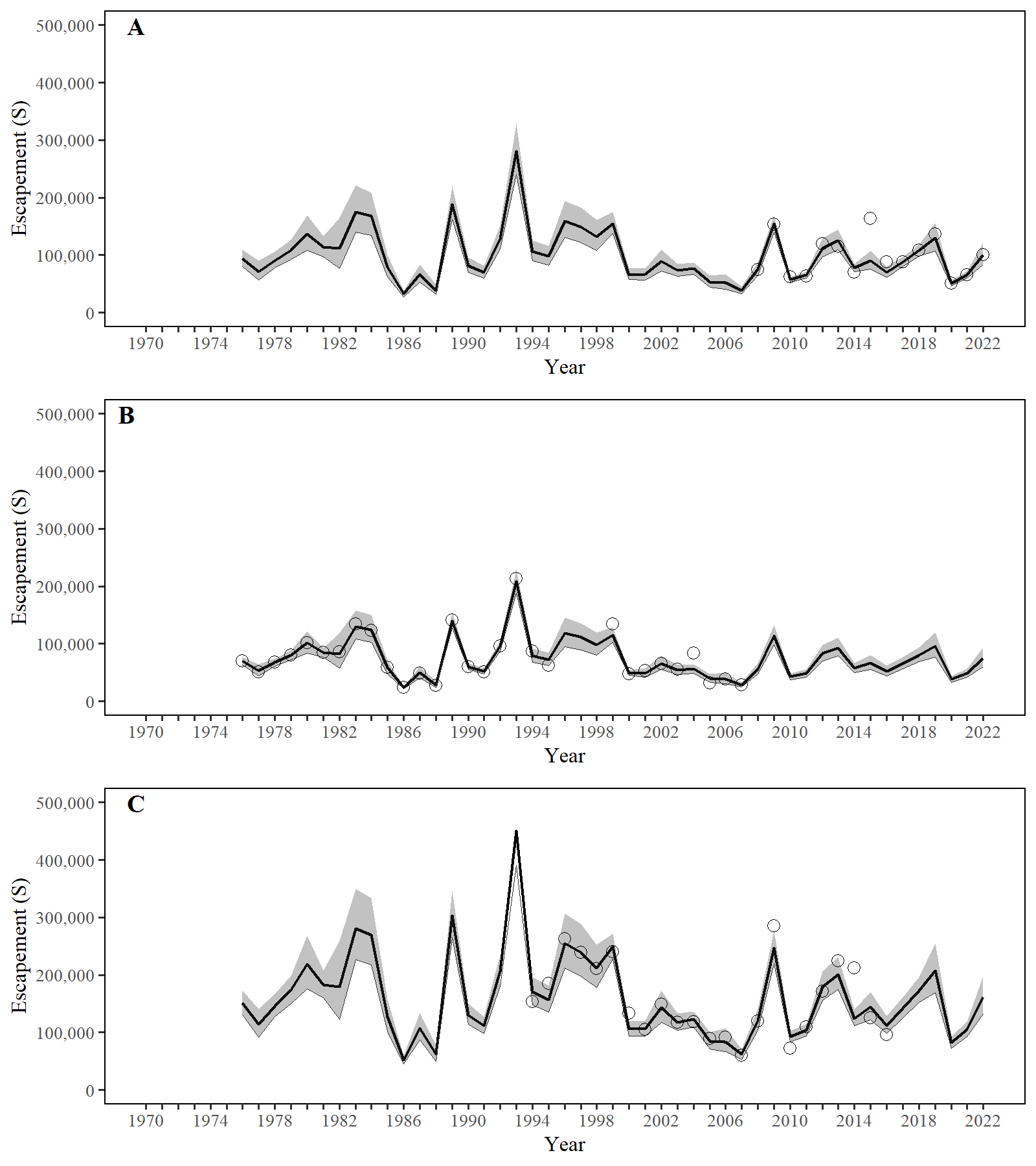
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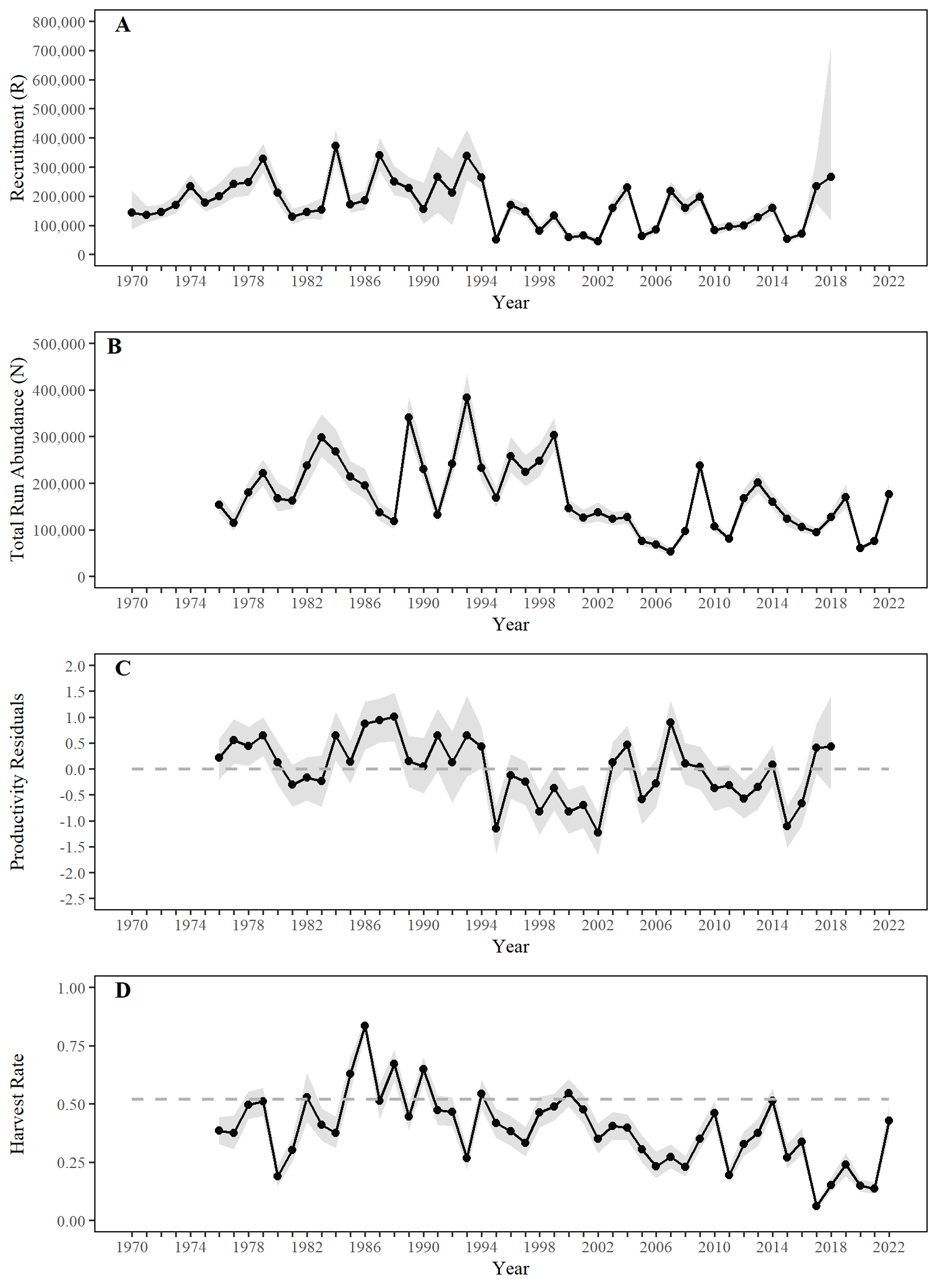
**Table 1.**–Parameter estimates from the state-space model fitted to the Chilkat Lake sockeye salmon data for calendar years 1976–2022 (brood years 1976–2018). Posterior medians are point estimates; the 2.5th and 97.5th percentiles define 95% credible intervals for the parameters. The parameter ln(*a'*)is the log-normal bias-corrected alpha parameter. Biological benchmarks are based on the log-normal bias-corrected alpha parameter. Refer to Miller and Heinl 2018 for parameter definitions.

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| --- | --- | --- | --- | --- | --- |
| Parameter | 2.5% | Median | 97.5% | Mean | Posterior CV |
| *a* | 1.76 | 2.86 | 4.86 | 2.98 | 0.27 |
| ln(a) | 0.56 | 1.05 | 1.58 | 1.06 | 0.25 |
| ln(a') | 0.78 | 1.26 | 1.90 | 1.28 | 0.22 |
| *b* | 1.60E-06 | 5.42E-06 | 9.33E-06 | 5.41E-06 | 0.36 |
| *f* | 0.09 | 0.41 | 0.73 | 0.41 | 0.39 |
| *sR* | 0.46 | 0.57 | 0.73 | 0.58 | 0.12 |
| *S*EQ | 162,084 | 234,223 | 611,713 | 275,634 | 0.49a |
| *S*MAX | 107,233 | 184,519 | 623,391 | 235,121 | 0.71a |
| *S*MSY | 65,566 | 96,257 | 260,869 | 114,361 | 0.52a |
| *U*MSY | 0.35 | 0.52 | 0.70 | 0.52 | 0.17 |
| D | 16.64 | 24.52 | 36.03 | 24.96 | 0.20 |
| *p*4 | 0.04 | 0.05 | 0.07 | 0.05 | 0.14 |
| *p*5 | 0.53 | 0.56 | 0.59 | 0.56 | 0.03 |
| *p*6 | 0.35 | 0.38 | 0.42 | 0.38 | 0.04 |
| *q*m-r | 1.48 | 1.60 | 1.73 | 1.60 | 0.04 |
| *q*weir | 0.65 | 0.74 | 0.84 | 0.74 | 0.06 |

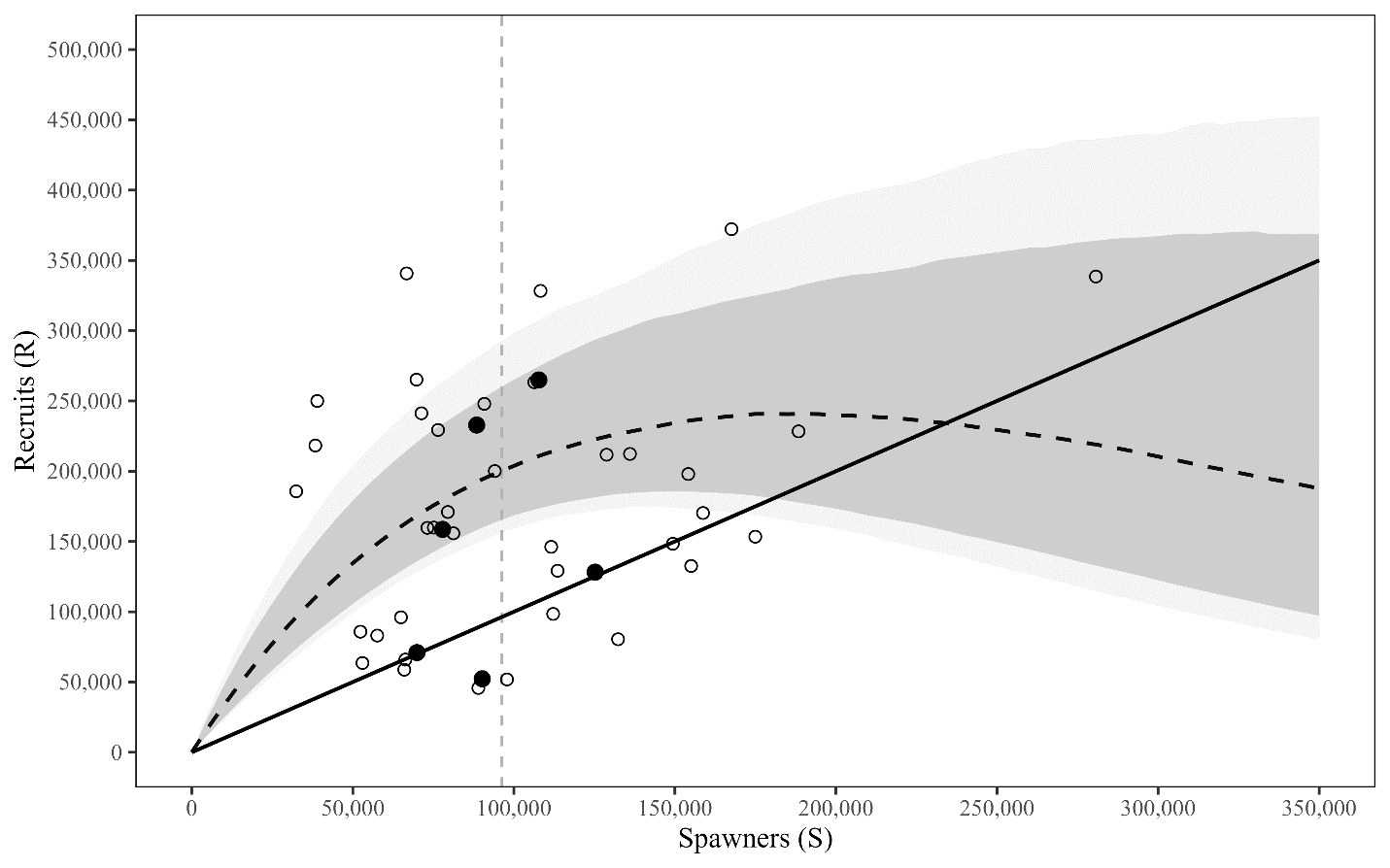
aThe coefficients of variation for the reference points *S*EQ, *S*MAX, and *S*MSYwere calculated as (97.5th–2.5th percentile)/3.92/posterior median point estimate. If the posterior median is approximately normal, then the lower and upper bounds of the 95% credibility are both ~1.96 × standard errors from the median point estimate.

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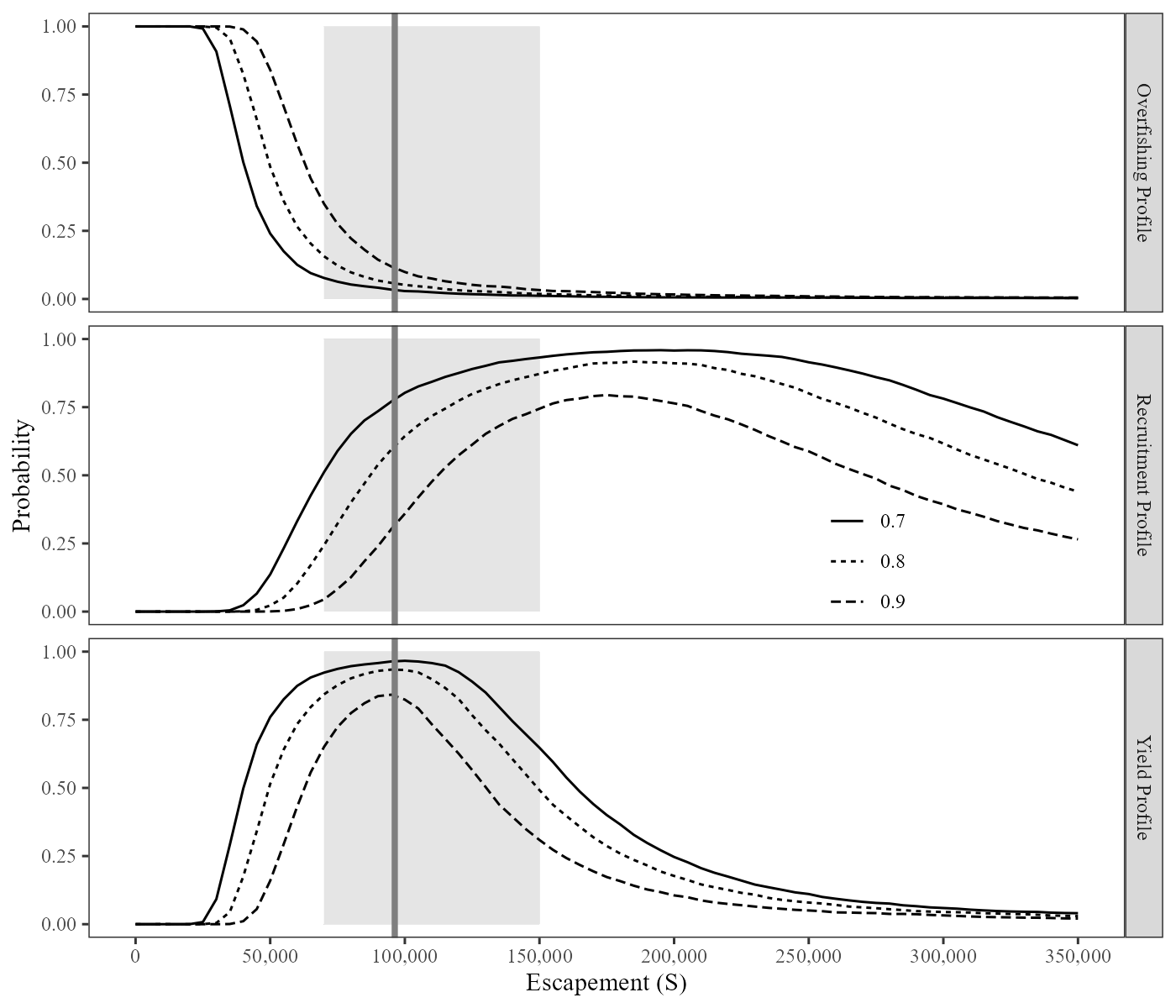
**Figure 1.**–Observed counts and estimates (open circles), modeled estimates (posterior median; solid line), and 95% credible intervals (shaded areas) of escapement (DIDSON counts; Panel A) and indices of escapement (weir counts, Panel B; mark–recapture estimates, Panel C) from the state-space model of Chilkat Lake sockeye salmon, calendar years 1976–2022.



**Figure 2.**–Point estimates (posterior medians; circles) and 95% credible intervals (shaded areas) of escapement, recruitment by brood year, total run abundance, Ricker productivity residuals by brood year, and harvest rates from the state-space model of Chilkat Lake sockeye salmon, 1976–2022. The dotted line in Panel C is a reference line. The posterior median of *U*MSY is plotted as a dashed horizontal reference line in Panel D.



**Figure 3.**–Plausible spawner-recruit relationships for Chilkat Lake sockeye salmon as derived from the age-structured state-space model fitted to abundance, harvest, and age data for brood years 1976–2018. Posterior medians of recruits and spawners are plotted as open circles for brood years 1976–2012 and posterior medians of recruits and spawners are plotted as solid black circles for the six most recent years of data (brood years 2013–2018). The heavy dashed line is the Ricker relationship constructed from ln(*α*’) and *β* posterior medians with 90% and 95% credible intervals (darker and lighter shaded areas, respectively). Recruits replace spawners on the solid diagonal line. The vertical dotted (grey) line is the posterior median of *S*MSY.



**Figure 4.**–Overfishing profiles (OFPs), optimal recruitment profiles (ORPs), and optimal yield profiles (OYPs) for Chilkat Lake sockeye salmon. OYPs and ORPs show probability that a specified spawning abundance will result in specified fractions (70%, 80%, and 90% line) of maximum sustained yield or maximum recruitment. OFPs show the probability that reducing escapement to a specified spawning abundance will result in less than specified fractions of maximum sustained yield. The shaded region shows the current biological escapement goal range of 70,000 to 150,000 spawners and the solid vertical line is the posterior median of spawning abundance at maximum sustained yield (*S*MSY) obtained from the state-space model.



**Figure 5.**–Estimated Chilkat Lake sockeye salmon escapements, 1976–2022, and biological escapement goal range of 70,000–150,000 fish. Expanded DIDSON counts are shown as columns, 2008–2022; escapements estimated from model outputs (posterior medians and 95% credible intervals) are shown as data points, 1976–2022.