A Simple Spreadsheet Model For Evaluating Recovery Strategies For Snake River Fall Chinook Salmon

James G. Norris

Fisheries Research Institute, University of Washington, Seattle, WA 98195

Introduction

Management controls for Snake River fall chinook salmon can be grouped into four broad categories: (1) improving production; (2) improving downstream passage of smolts; (3) reducing harvest; and (4) improving upstream passage of returning adults. Current modeling efforts to analyze recovery strategies utilize downstream passage and life-cycle models to predict the effects of a relatively narrow range of management options that often include several specific actions within each of the four categories mentioned above. This approach often makes it difficult to see the bigger picture. Clearly, improvements in any one of the four categories reduces the need for improvements in the other three. Before selecting options within each category, it would seem prudent to first decide how much each category should, and can, contribute to the overall solution. I suggest that the decision-making process should proceed in two steps: (1) set improvement goals for each category; and (2) determine specific tactics for reaching each goal. This approach will help stakeholders understand their relative contribution to the overall recovery effort and will focus modeling efforts on more specific problems within categories.

This report has two goals: (1) describe a simple spreadsheet model that encompasses all of the major life history stages of chinook salmon; and (2) use the model to define an overall solution space in terms of three of the four control variables (downstream survival, harvest, and upstream passage). The results are presented in a single graph that illustrates all possible solutions to reaching a specific escapement goal, in this case set at 3,000 spawners in year 2017. For example, the model indicates that improving downstream survival 36%, reducing harvest by 60%, and improving upstream survival to 90% is equivalent to improving downstream survival by 360%, reducing harvest by 30%, and making no improvements in upstream survival.

Methods

The model incorporates the production and downstream passage features of the Stochastic Life Cycle Model (SLCM; Lee and Hyman 1992) and the adult life history and harvesting features of the Pacific Salmon Commission (PSC) Chinook Model. It was written as a spreadsheet in Microsoft Excel. The computational sequence is given in Fig. 1 and the equations and parameters are given below:

Population ageing:

$$N_{a+1} = OcnRun_a$$

where N_a = abundance of age a fish and $OcnRun_a$ is the number of age a fish remaining in the ocean at the end of the year. Initial abundances at the start of year 1994 were taken from output from the PSC Chinook Model ($N_1 = 15{,}868$; $N_2 = 6{,}839$; $N_3 = 1{,}330$; $N_4 = 3{,}705$; $N_5 = 100$).

Natural ocean mortality:

$$N_a = N_a \cdot s_a$$

where s_a = ocean survival rate for age a ($s_1 = 0.5$, $s_2 = 0.6$, $s_3 = 0.7$, $s_4 = 0.8$, $s_5 = 0.9$; from PSC Chinook Model).

Ocean Harvesting:

$$OcnCatch_a = N_a \cdot HR \cdot OcnHR_a$$

where HR is the overall harvest rate control variable and ranges from 0 to 1 (0 = no harvest; 1 = status quo harvest) and $OcnHR_a$ is the status quo ocean harvest rate for age a ($OcnHR_3 = .215$, $OcnHR_4 = .422$, $OcnHR_5 = .368$; from Schaller and Cooney 1992, Table 4).

Maturation:

$$TermRun_a = (N_a - OcnCatch_a) \cdot MatRate_a$$

$$OcnRun_a = (N_a - OcnCatch_a) \cdot (1 - MatRate_a)$$

where $TermRun_a$ is the number of age a fish returning to the river, $OcnRun_a$ is the number of age a fish remaining in the ocean at the end of the year, and $MatRate_a$ is the maturation rate for age a ($MatRate_2 = .07$, $MatRate_3 = .21$, $MatRate_4 = .65$, $MatRate_5 = 1.0$; from PSC Chinook Model).

River Harvesting:

$$RiverCatch_a = TermRun_a \cdot HR \cdot RivHR_a$$

where HR is the overall harvest rate control variable and ranges from 0 to 1 (0 = no harvest; 1 = status quo harvest) and $RivHR_a$ is the status quo river harvest rate for age a ($RivHR_3 = .278$, $RivHR_4 = .588$, $RivHR_5 = .678$; from Schaller and Cooney 1992, Table 4).

Adult Escapement (ages 3, 4, and 5):

$$AdltEsc = \sum_{a=3}^{5} (TermRun_a - RiverCatch_a)$$

Pre-spawning mortality:

$$Spawners = AdltEsc \cdot PreSpawnSurv$$

where *PreSpawnSurv* is the prespawning survival control variable (= 0.603 for base case conditions; PSC Chinook Model).

Production of progeny in the next year:

$$N_1 = Spawners \cdot \frac{females}{Spawner} \cdot \frac{eggs}{female} \cdot \frac{presmolts}{egg} \cdot \frac{smolts}{presmolt} \cdot DownSurvRate \cdot s_1$$

where

females/spawner = 0.583 (Fisher et al 1992);

eggs/female = 4,300 (Fisher et al 1992);

presmolts/egg = 0.20 (Fisher et al 1992);

smolts/presmolt = 0.25 (Fisher et al 1992);

DownSurvRate = downstream survival control variable (= 0.16 for base case conditions);

s_1 = ocean survival rate of age 1 fish (0.5).

For base case conditions, the *DownSurvRate* parameter was set to 0.16 because that value gave an escapement trajectory very similar to that of the PSC Chinook Model (see Fig. 2) and seemed reasonable based on other studies (Hilborn 1993; Anderson 1994).

The analysis was conducted by systematically fixing the *HR* and *PreSpawnSurv* control variables over a range of values (0 to 1 for *HR*; 0.6 to 0.9 for *PreSpawnSurv*) and using the "solver" tool in Excel to find the value of the third control variable—*DownSurvRate*— such that the number of spawners in year 2017 was equal to 3,000.

Results

The results are given in Fig. 3 and Tables 1 and 2. Any point on one of the four lines in Fig. 3 defines a combination of downstream survival rate, harvest rate reduction, and upstream survival rate that gives 3,000 spawners in year 2017. For example, if harvest rates are reduced by 30%, downstream survival would have to be increased from 16% to between 36% (if upstream survival is improved to 90% survival) and 58% (if upstream survival remains at 60%). Note that in the absence of fishing, some improvement in downstream or upstream survival is still necessary for the stock to rebuild.

Discussion

The analysis described in this report does not answer specific questions regarding alternative methods of improving downstream survival, reducing harvest rates, or improving upstream survival. Other models and analysis methods can be used to decide among those alternatives. For example, the CRiSP.2 model can be used to define equivalent methods of reducing harvesting rates (Norris, in prep). Instead, this analysis provides a broader perspective of the recovery problem in terms of the trade-offs required to meet the recovery goal. The important results are presented in Table 2 and Fig. 3.

The results from this model are consistent with those from the PSC Chinook Model, which also indicated that a 30% reduction in harvest rates would require a 3.4-fold improvement in downstream survival (Norris 1995).

References

Anderson, J. J. 1995. Comparison of mainstem recovery options Recover-1 and DFOP. (unpublished manuscript).

Fisher, T. R., D. C. Lee, and J. B. Hyman. 1992. Input parameters for the modeling of upper Snake River wild chinook salmon with the stochastic life-cycle model (SLCM). (unpublished manuscript).

Hilborn, R. (in prep).

Lee, D., and J. B. Hyman. 1992. The stochastic life-cycle model (SLCM): simulating the population dynamics of anadromous salmonids. US Dept. of Ag., Forest Service, Intermountain Research Station, Research Paper INT-459. 30 p.

Norris, J. G. 1995. Memorandum to Charles Paulsen dated Feb. 15, 1995.

Norris, J.G. (in prep). Defining equivalent harvest reduction policies for endangered Snake River fall chinook salmon. Can. J. Fish. Aquat. Sci. xx: xxxx-xxxx.

Schaller, H., and T. Cooney. 1992. Draft Snake River fall chinook life-cycle simulation model for recovery and rebuilding plan evaluation. (Unpublished document).

Table 1. Downstream survival multipliers (i.e., amount the base case rate of 0.16 must be multiplied by) for values of harvest rate reductions and prespawning survival rates required to achieve 3,000 spawners in year 2017.

Harvest Reduction (%)	PreSpawnSurv = 0.6	PreSpawnSurv = 0.7	PreSpawnSurv = 0.8	PreSpawnSurv = 0.9
0	6.451	5.426	4.647	4.053
10	5.281	4.44	3.801	3.314
20	4.361	3.665	3.136	2.733
30	3.63	3.049	2.608	2.272
40	3.043	2.555	2.185	1.903
50	2.569	2.156	1.843	1.605
60	2.183	1.831	1.565	1.362
70	1.865	1.565	1.337	1.163
80	1.603	1.344	1.148	0.999
90	1.385	1.161	0.991	0.862
100	1.202	1.007	0.86	0.748

Table 2. Downstream survival rates for values of harvest rate reductions and prespawning survival rates required to achieve 3,000 spawners in year 2017. For example, if harvest rates are reduced by 30%, downstream survival rates would have to equal 0.582 (if prespawning survival is 0.6) or 0.364 (ifprespawning survival is 0.9).

Harvest Reduction (%)	PreSpawnSurv = 0.6	PreSpawnSurv = 0.7	PreSpawnSurv = 0.8	PreSpawnSurv = 0.9
0	1.034	0.870	0.745	0.650
10	0.847	0.712	0.609	0.531
20	0.699	0.587	0.503	0.438
30	0.582	0.489	0.418	0.364
40	0.488	0.410	0.350	0.305
50	0.412	0.346	0.295	0.257
60	0.350	0.294	0.251	0.218
70	0.299	0.251	0.214	0.186
80	0.257	0.215	0.184	0.160
90	0.222	0.186	0.159	0.138
100	0.193	0.161	0.138	0.120

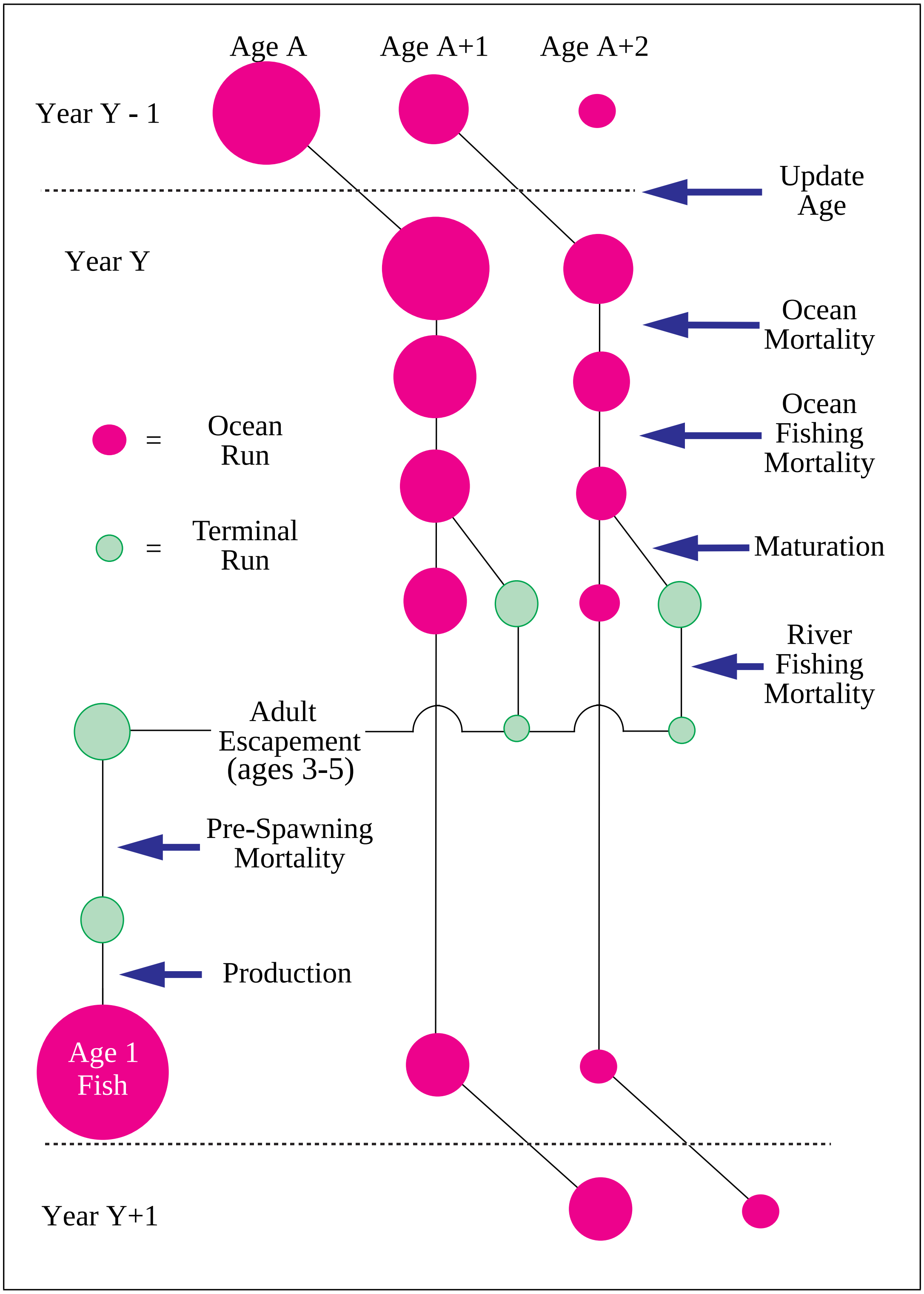

Fig. 1. Illustration of the annual computation cycle in CRiSP.2 and spreadsheet model described in this report.

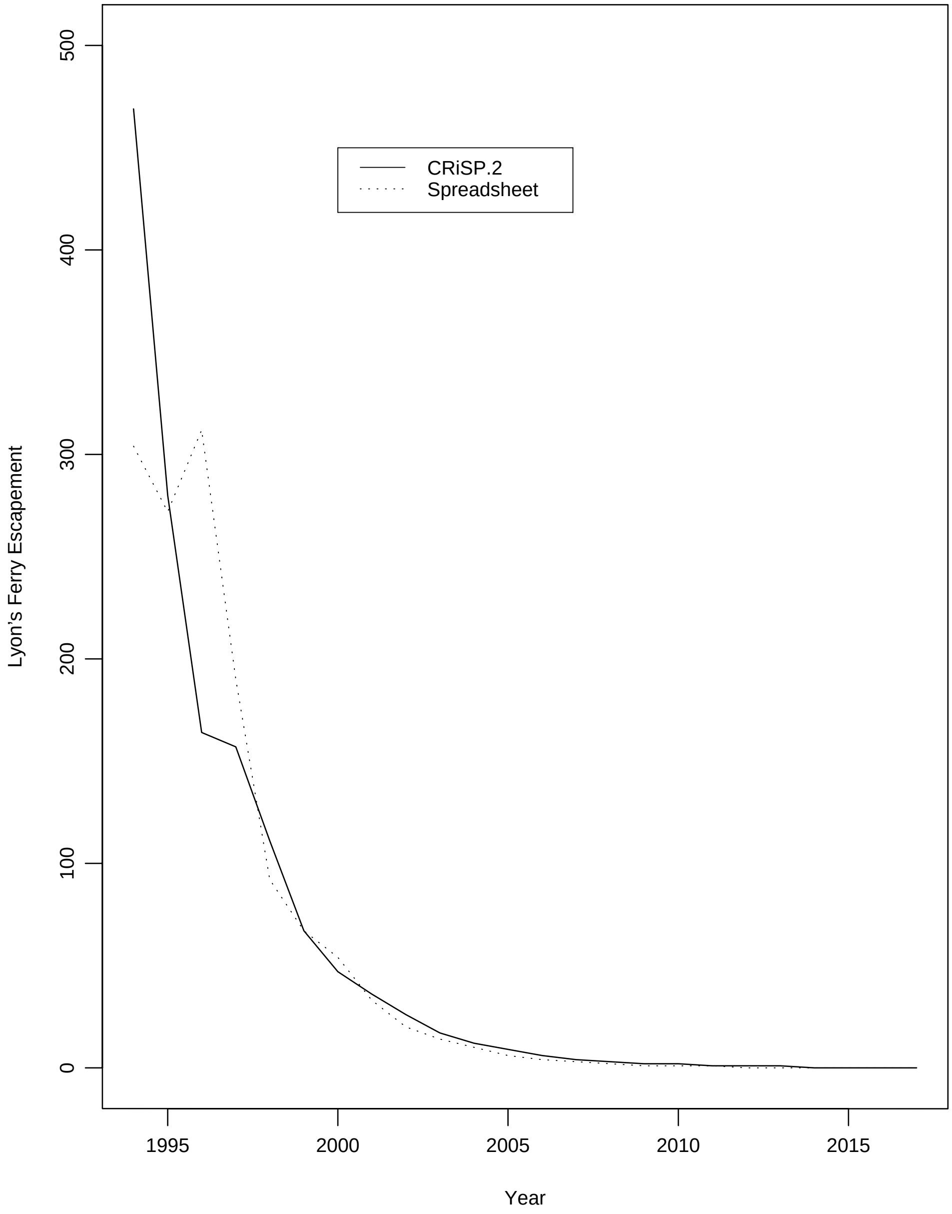

Fig. 2. Spawning trajectories for the Lyon's Ferry indicator stock from the CRiSP.2 model (10/94 calibration) and from the spreadsheet model described in this report (under base case conditions).

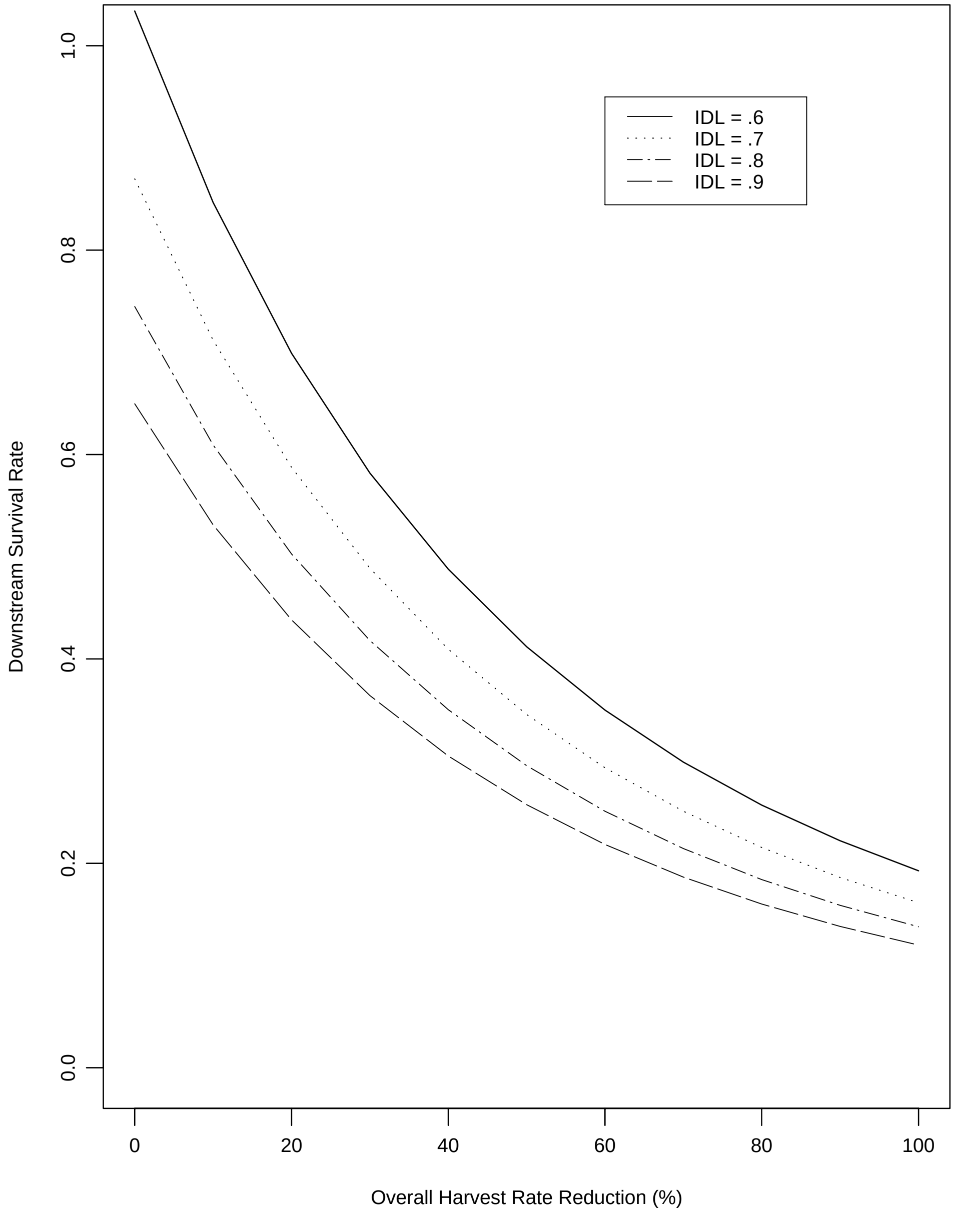

Fig. 3. Combinations of downstream survival rate, harvest reduction, and prespawning survival rate (labeled IDL in the legend for Inter-Dam Loss rate) that give 3,000 spawners in year 2017. See Table 2 for exact values.