Shiny Escapement Goal Analyses

**Methodology**

Spawner-Recruit Model

The model fits two set of Ricker Spawner-Recruit models: Standard and AR1. Both takes that same linearized form.

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| or  where | (1) |

In standard model, error c is iid (independent and identically distributed), whereas in AR1model error is first order autocorrelation.

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| Standard Ricker:  AR 1 Ricker: | (2) |

Both models are fitted with R nmle package of gls function with maximum likelihood estimation method.

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| model.s <- gls(log(R/S)~s,method='ML')  model.ar1 <-gls(log(R/S)~s,correlation=corAR1(0.5,~1),method='ML') | (3) |

The program automatically selects (Auto option) AR 1 Ricker model when p-value of likelihood ratio tests between the two models. User can also choose either standard or AR 1.

Following derived parameters were estimated using a simple linear regression analysis (Hilborn and Walters 1992). Fishery management parameters MSY, Smsy, and Umsy were estimated

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|  | (4) |

S x = ∑ x i = 24.76 , S y = ∑ y i = 931.17 S x x = ∑ x i 2 = 41.0532 , S x y = ∑ x i y i = 1548.2453 , S y y = ∑ y i 2 = 58498.5439 {\displaystyle {\begin{aligned}&S\_{x}=\sum x\_{i}=24.76,\quad S\_{y}=\sum y\_{i}=931.17\\[5pt]&S\_{xx}=\sum x\_{i}^{2}=41.0532,\quad S\_{xy}=\sum x\_{i}y\_{i}=1548.2453,\quad S\_{yy}=\sum y\_{i}^{2}=58498.5439\end{aligned}}} **Bootstrap Analyses and Expected Yield and Smsy and Smax Probability Profiles**

Residual bootstrap technique was employed to examine distribution of the above parameters.

In standard Ricker model, residuals are assumed *iid*. Thus, bootstrap residuals () were generated by random selection (with replacements) from the residuals, and bootstrap observations () were generated by adding the bootstrap residuals to expected value.

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|  | (5) |

In AR1 Ricker model, residuals have AR1 structure, , where *νi* is *iid*. Thus, AR1 residuals (*νi*) were derived  (i = 2,….,n) and , where is model estimated AR1 autocorrelation parameter. From this, bootstrap AR1 residuals were generated by random selection (with replacement) from the AR1 residuals. Then, bootstrap residuals  were generated by AR1 process ( (i = 2,….,n) and  ). Finally, bootstrap observations () were generated by adding the bootstrap residuals to expected value.

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| ,  (*i* = 2, 3,…, n)  (i = 2,….,n) | (6) |

From the bootstrap observations, bootstrap Ricker and management parameters were estimated with the same analyses process (eq1,3,4). This procedure were repeated 10000 times.

***Smsy* and *Smax* Probability profile**

*Smsy* probability profile is a probability that an expected mean yield (Y) is exceeding X% of mean maximum sustained yield (Ymax) at given escapement) (*s*). Similarly, *Smax* profile is a probability that expected mean recruit (R) is exceeding X% of mean maximum recruit (Rmax) at given escapement) (*s*).

Those two probability profiles were generated as follows. First, given range of escapement incremental ranges of escapement (***s*** = {*s1*,*s2,*,…. *sn*}), bootstrap expected recruit (*Rbs*) and yield (*Ybs* ) were calculated using the bootstrap Ricker model parameters. Each expected value was evaluated with corresponding criterion values and given 1 (above) or 0 (below).

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|  | (7) |

Smsy and Smax probability profile are simply mean of the above function at given escapement.

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|  | (8) |

By intersecting cut-off probability, a range of escapement (s) that exceed Smsy or Smax profile probability are derived.

**Fishery Management Strategy Evaluation Simulation Model**

Let *Sy* be the number of spawners in *y-*th brood year. The number of brood year recruits produced from the spawner (*Ry*) would follows Ricker (1954) spawner-recruit function with autoregressive lognormal errors (Noakes et al. 1987)

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|  | (1) |

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| , where | (2) |

*Maturity Schedule*

Individuals of *y*-th brood year recruits (*Ry*) spend *a-th* years to mature and rerun in *y+a-th* calendar year.

Let *Pa,y* be a probability of *y*-th brood year recruits spend *a-th* year and return as *a-th age* in calendar year *yc*, then the number of a-th year salmon returning in calendar year yc (*Nyc,a*) is

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| where *yc = y+a* | (3) |

Annual maturation probabilities of y-th brood year are random variable of Dirichlet distribution.

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|  | (4) |

where *Pi,k,m* are mean maturity proportion

*Annual Run*

The number of Chinook salmon retuning in *yc*-th calendar year (*Nyc*) consists of recruits of *a*-th age of spawners of *yc – a*-th year.

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|  | (5) |

During the season, the returning Chinook salmon (*Nyc,p*) will be forecasted with normal distribution error (*Nyc,p*)

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|  | (6) |

*Annual Harvest and Escapement*

Based on the projected forecast return (*Nyc,p*) and escapement goal range, preojected fishery harvest (*Hyc,p*) is determined as follows.

Case 1: when projected return is lower than target escapement goal, close fishery and harvest is 0.

Case 2: when projected return is above the target escapement goal, the projected harvest is minimum of (1) yields above target escapement goal with maximum harvest rate( *fmax*(*Nyc,p* - *Hyc,p* )) or (2) the maximum harvest (*Hmax*).

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|  | (6) |

Actual harvest *Hyc* is model as normal distribution with implementation error

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|  | (7) |

The number of Chinook salmon reaching spawning grounds (i.e., escapement) in calendar year yc (*Syc*) is subtraction of harvest from run.

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|  | (8) |

Then *Syc* was looped back to the equation (1)

*Escapement goal assessment*

Escapement goal was set by (1) assessing age composition of Run and creating brood table, (3) statistically fitting spawner-recruit data to Ricker Spawner-Recruit model and find management parameters (e.g., Smsy, Smax), and (4) determine escapement goal range, and management target goal.

Run assessment

Observed run size is a sum of observed escapement and harvest with observation error

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| *Where* | (9) |

In a given *yc*-th year observed recruit of *yc-A* th brood year (A= maximum observed age) is calculated by summing observed *a-th* age run of *yc-A+a -th* year.

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| where *a = i+k* | (10) |

Spawner-Recruit Analyses

Spawner-Recruit analysis was conducted by fitting the observed Spawner and Recruit data to liner Ricker Spawner-Recuit model.

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|  | (11) |

By fitting the model, two management parameters (Smsy: the escapement that produces maximum sustained yield and Smax: the escapement that produces maximum recruit were estimated as

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|  | (12) |

Based in the above management criterion, lower and upper bound of escapement goal range was determined as 80% and 160% of the

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| EGl = 0.8(*Smsy* or *Smax*)  EGu = 1.6(*Smsy* or *Smax*)  EGt = (EGl+EGu)/2 | (13) |