**SK Chinook scale age study paper 2 outline**

**Influence of age error on management of Chinook salmon in Alaska**

**INTRODUCTION**

* Part of sustainable management of salmon is developing population models to set escapement goals,
* Population models use abundance and age data
* Bias in age data could lead to incorrect escapement goals
* Bias is calculated from median ages and the age estimates from 10 experienced readers
* We can examine the impact of bias in age estimates on mangemet: impact on escapement goal and harvest recomendation

*The overarching goal* of this project is to improve scale-based methods for estimating age of Chinook salmon so that population production estimates can be refined and stock assessments and forecasts can be improved in Alaska.

*Objective 1:* Quantify the variability in Chinook salmon ages for Alaska stocks. (Addressed in paper 1)

*Objective 2:* Quantify the impact of variability in age estimations on management of Chinook salmon populations. (addressed in paper 2)

**METHODS**

Short description of scale age data collection

Short description of reader error/bias collection

* Assume median age is true age
* Error (bias) rates are the percent of scales were the original age is different from median age

Methods to achieve Objective 2: Quantify the impact of variability in age estimations on management of Chinook salmon populations

* Description of methods used in simulation model:

Hamachan’s simulation is a full management strategy evaluation (MSE) model.

In a nutshell.

1. Population model dynamics is created as Ricker AR1 with pre-specified RS parameter (including stochasticity)
2. Model incorporates: harvest, escapement, aging, forecast, management implementation errors
3. Model starts with average recruit (prespecified), grow x years without harvest
   1. Then y years with Umsy
   2. Then start managing fishery for z years based on escapement goal estimated by previous y years
      1. Smsy goal. Smax goal
      2. Prespecified harvest strategy and fishing capacity
      3. Update escapement goal  every 6 years based on all data (y + up to current years)

The simulation results above is based on no observation (escapement, harvest, implementation) errors, so that only aging error is considered.

To assess impact of age error on Smsy, we would summarize:

1. Average percent of time harvest is higher than the upper bound of the escapement goal in years 75-100 for 1000 simulations
2. Percent of time the escapement goal is higher at year 100 than at year 75 for 1000 simulations

Without age bias and with age bias. Then compare to these two values.

**RESULTS**

Effect of reader error on estimates of SMSY and escapement goals

* Simulation model conclusion is that aging error CAN affect estimates of SR curve and Smsy (from Hamachan).
* This occurs when harvest and run size is often left side (i.e. escapement is LOWER than Smsy) (from Hamachan).

**DISCUSSION**

* When you have high harvest rate, you don’t have enough information about Smsy or you could say about slope and intercept estimates of Ricker SR parameters.  Consequently, slight changes in R (due to aging error) will affect Smsy (from Hamachan).
  + Similar to other Chinook salmon st studies (Kope 2006; Zabel et al. 2002)

References

Kope, R. (2006). Cumulative effects of multiple sources of bias in estimating spawner–recruit parameters with application to harvested stocks of Chinook salmon (Oncorhynchus tshawytscha). *Fisheries research*, *82*(1-3), 101-110.

Zabel, R. W., & Levin, P. S. (2002). Simple assumptions on age composition lead to erroneous conclusions on the nature of density dependence in age-structured populations. *Oecologia*, *133*(3), 349-355.

**Aging Error Simulation model**

Aging Error

Let *efi,j* be the probability of *i-th* freshwater age (*i* : 0,1,2) read as *j-th* age (*j* : 0,1,2), and *esk,l* be the probability of *k-th* saltwater age (*k* : 0,1,2,3,4,5) read as *l-th* saltwater age (*l* : 0,1,2,3,4,5), and assume that the probability is independent.

Let *Pi,k* and *P̂i,l* be the TRUE and observed proportion of *i-th* freshwater and *k-th* saltwater age scales (i.e., Age i.k). Then, observed proportion of *i-th* freshwater and *k-th* saltwater ages is a proportion of the sum of *i-th* freshwater and *k-th* saltwater scales read correctly, and other freshwater and saltwater age scales read incorrectly as *i-th* freshwater and *k-th* saltwater scale.

For an example, the proportion of Age 1.3 scales read observed Age 1.3 is a sum of

1. True Age 1.3 proportion (*P1,3*) with probability of not reading freshwater age 1 as ages 0 and 2 (1 - *ef1,0* - *ef1,2* ) and saltwater age 3 as ages 0,1,2,4, and 5 (1 – *es3,0* – *es3,1* – *es3,2* – *es3,4* – *es3,5*)

*= P1,3*(1 - *ef1,0* - *ef1,2* )(1 – *es3,0* – *es3,1* – *es3,2* – *es3,4* – *es3,5*)

1. Ages 0.3, 2.3, 1.0, 1.2, 1,4, and 1.5 scales read as 1.3

= *ef0,1P0,3* + *ef2,1P2,3* + *es0,3P1,0* + *es1,3P1,1* + *es2,3P1,2* + *es4,3P1,4* + *es5,3P1,5*

This formulated as follows

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|  |  |

Aging error rate (%) for freshwater and saltwater ages. +/- 1 indicates reading age 1 year older/younger than true age.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Aging Error | Freshwater Age | | | Saltwater Age | | | | |
| 0 | 1 | 2 | 1 | 2 | 3 | 4 | 5 |
| -1 | NA | 1 | 25 | 5 | 5 | 4 | 8 | 25 |
| +1 | 25 | 1 | NA | 8 | 5 | 3 | 2 | NA |

Fishery 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) |

Where ln(*α*)and *β* are the productivity and density dependent parameters of the Ricker stock-recruit relationship, *ϕ* is the autoregressive lag-1 (AR1) coefficient, *at* is independent, identically distributed normal random variables, each with mean zero and variance , , and *ωt-1* is a residual starting from *ω0.* In this model, *ϕ* was set to 0.6

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|  | (2) |

*Maturity Schedule*

Individuals of *y*-th brood year recruits (*Ry*) mature spend *i-th* (0, 1, or 2) year at freshwater and *k-th* (1,2,3,4, or 5) years in saltwater before maturation and return to natal river. This results in *a-th* (a = freshwater + saltwater + 1) age returning in *y+a-th* calendar year (Table ).

Table x: Freshwater-saltwater age combinations

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | Saltwater | | | | |
| Freshwater | 0 | 1 | 2 | 3 | 4 | 5 |
| 0 | 0.0 (Age 1) | 0.1 (Age 2) | 0.2 (Age 3) | 0.3 (Age 4) | 0.4 (Age 5) | 0.5 (Age 6) |
| 1 | 1.0 (Age 2) | 1.1 (Age 3) | 1.2 (Age 4) | 1.3 (Age 5) | 1.4 (Age 6) | 1.6 (Age 7) |
| 2 | 2.0 (Age 3) | 2.1 (Age 4) | 2.2 (Age 5) | 2.3 (Age 6) | 2.4 (Age 7) | 2.6 (Age 8) |

Let probability of *y*-th brood year recruits spend *i-th* freshwater and *k-th* saltwater as *Pi,k, y*, then the number of *a-th age* Chinook salmon returning to spawn in calendar year *yc* (*Ny,a*) is

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| where *a = i + k +1, 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) |

Model Simulation

We chose 3 stocks

|  |  |  |  |
| --- | --- | --- | --- |
| Stock | Kuskokwim | Karluk | Copper |
| ln(alpha) | 1.77 | 0.30 | 1.70 |
| beta | 9.71 x 10-6 | 3.83 x 10-5 | 3.32 x 10-5 |
| Sigma () | 0.21 | 0.38 | 0.21 |
| Age 1.1 | 0.003 | 0.033 | 0.006 |
| Age 1.2 | 0.197 | 0.120 | 0.081 |
| Age 1.3 | 0.384 | 0.310 | 0.583 |
| Age 1.4 | 0.389 | 0.451 | 0.327 |
| Age 1.5 | 0.028 | 0.087 | 0.004 |
| R0 | 213000 | 8000 | 58000 |

The simulation model was run for 100 years, in which fishery with the maximum sustainable harvest rate (Umsy) and spawner-recruit data collection stated in year 50. Fishery management based on escapement goal range started in year 76 using spawner-recruit data collected from years 50 to 75. Simulating board of fishery process, escapement goal was updated every 6 years using all data from year 50.