Framework to Estimate Snake Basin Steelhead and Chinook Population Abundance and Productivity

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Background

PIT-tagging and biological sampling at Lower Granite Dam provide the simplest approach to estimating and understanding status and trends of fish populations returning to key spawning locations. Previously developed PIT-tag based models adhere to the principal of parsimony (i.e., use the simplest approach that requires the fewest assumptions for meeting the objective), which, is generally recognized as the best approach (Coelho et al. 2018) for ecological modeling applications with a specific and known target (i.e., estimating population indicators). The developed PIT-tag based abundance model, DABOM, informs fisheries managers of total population abundance from direct observations of tagged fish returning to known spawnings locations without making unnessary assumptions; examples include migration corridor conditions or fish straying behavior (See et al. 2016). The DABOM model only requires basic mark-recapture assumptions (See et al. 2016) that are common place in animal marking studies and two other main assumptions; 1) all fish returning to the same population have similar run-timing past Lower Granite Dam, and 2) the last tag detection location represents the location of spawning. These same PIT-tag observations used in the DABOM model, combined with biological sampling information, also provide fisheries managers with life history metrics for each population (Powell et al. 2018). Thus, eliminating the need for additional data collection, QA/QC processing and further assumptions regarding migration cooridor differences between life history groups. Then, by simply combining the two metrics estimated from the same dataset (i.e., abundance and life history proportions) biologists can develop run-reconstruction brood tables and estimate productivity using only Lower Granite Dam PIT-tagging and subsequent tag observations.

In addition to being the simplest approach for estimating population status and trends, the previously developed PIT-tag based approaches yield unbiased estimates of uncertainty. The level of uncertainty surrounding status and trend metrics is absolutely necessary for fisheries managers and provide a guage to the true state of the population in question. Without uncertainty surrounding status and trend estimates an unknown amount of risk is tied to each management decision regarding the population. The DABOM approach estimates uncertainty in population indicators by including all available sources of error in Lower Granite abundance estimates and tag observations using a state-space modeling approach (See et al. 2016). Kinzer et al. (2017) showed the estimated uncertainty around population abundance was unbiased with coverage probabilities matching desired alpha levels. And although Powell et al. (2018) did not report uncertainty around estimated life history metrics, variance calculations for proportion are well known (Agresti 2002; Casella and Berger 2002) and have reliable statistical properties. Once, variances are calculated for life history metrics we can use common variance properties to produce uncertainty around brood table components and adult-to-adult productivity values. Thus, giving fisheries managers the tools necessary for creating an informed decision process.

This document serves as a draft outline of the methods and next steps required to estimate Snake River basin steelhead and Chinook salmon population abundance and productivity with uncertainty using a comprehensive and integrated approach. To date, the currently available PIT-tag observation models lacked a defined link across outputs. Model integration is explicitly defined in this document and provide fisheries managers with a framework for estimating the abundance of various life history groups (e.g., females, age classes), and for developing population productivity estimates with uncertainty.

Methodology

Population Abundance

Weekly main tributary branch abundance is estimated by combining the postierior distributions of wild escapement (w) past Lower Granite Dam for each weekly (t) time period, ($X_{w,t}$), from STADEM with weekly movement probabilities, ($\psi_{j,t}$), into each main tributary branch (j) from DABOM. Total tributary branch abundance is then estimated by summing across the product for all n weeks.

$$\hat{N}_j = \sum_{t=1}^{n} X_{w,t}\psi_{j,t}$$

Population abundance is obtained by summing across all main branch estimates that belong to population Pop.

$$\hat{N}_{Pop} = \sum_{j \in P} \hat{N}_j$$

Life History Proportions

Female proportions (f_{Pop}) for each population can be estimated using a logistic regression model and the sex of all unique PIT-tagged fish ($x_{i,Pop}$) observed in the population.

$$logit(\frac{f_{Pop}}{1 - f_{Pop}}) = \alpha_{Pop} + \beta_{Pop} x_{i,Pop}$$

Where α_{Pop} and β_{Pop} parameters come from normal distributions that have a common mean (μ) and standard deviation (σ) for all populations.

$$\alpha_{Pop} \sim Normal(\mu_\alpha, \sigma_\alpha)$$
$$\beta_{Pop} \sim Normal(\mu_\beta, \sigma_\beta)$$

Proportions of each age group, or brood years, within populations can be estimated using a multinomial distribution, and the age determined from Lower Granite scale analaysis of all unique PIT-tagged fish observed in the population ($x_{i,BY,Pop}$).

$$x_{i,BY,Pop} \sim MultiNom(A_{BY,Pop})$$

Where ($A_{BY,Pop}$) is a vector of all brood year classes returning to the population, and each proportion is derived from a uniform dirichlet hyper-distribution.

$$A_{BY,Pop} \sim Dir(1, ..., 1)$$

Population Demographic Abundance

Demographic group abundance can be estimated by multipling posterior distributions of population abundance ($\hat{N}_{Pop}$) with the desired life history proportions, $\hat{f}_{Pop}$ or ($A_{BY,Pop}$), as follows.

$$\hat{N}_{f,Pop} = \hat{N}_{Pop}\hat{f}_{Pop}$$
$$\hat{N}_{BY,Pop} = \hat{N}_{Pop}\hat{A}_{BY,Pop}$$

Proportion of Hatchery Origin Spawners

The proportion of hatchery origin abundance contributing to natural spawning is often needed for status assessments. Assuming a consistent PIT-tagged to un-tagged ratio of hatchery stocks observed at Lower Grante Dam and those observed at tag detection location within populations, the proportion of hatchery origin spawners ($pHOS_s$) can be estimated as the following. Total hatchery returns to a population is the sum of all hatchery stocks estimated within the population ($\hat{N}^{Pop}_{Stock,Pop}$), where ^{Pop} indicates fish in the population and LGD indicates fish at Lower Granite Dam, . Then, the a

$$\hat{N}^{Trib}_{POP,Hat} = \frac{n^{Trib}_{POP,Hat}\hat{N}^{LGD}_{Hat}}{n^{LGD}_{Hat}}$$

$$p\hat{HOS}_s = \frac{\hat{N}^{Trib}_{POP,Hat}}{\hat{N}^{Trib}_{POP,Hat} + \hat{N}^{Trib}_{POP,Nat}}$$

$$\hat{S}_{Hat} = \frac{n^{PIT}_{GSI,OtherArray}}{(n^{PIT}_{GSI,OtherArray} + n^{PIT}_{GSI,CorrectArray})}$$

Population Productivity TBD

Talking Points for Jason V. with Lance H.

(1) Above outline is merely a proof of concept; we anticipate a more detailed and complete product on July 24th for full group discussion.

(2) Our goal before the July 24th meeting is to further develop the modeling framework and statistical equations for review, produce a draft sensitivity analysis to test statistical properties (e.g., expected uncertainty around productivity estimates), and produce actual results for review.

(3) Participants include Biomark ABS staff (Chris Beasley, Kevin See, Mike Ackerman), NPT staff (Rick Orme, Ryan Kinzer) and IDFG staff (if interested, potential folks could include; Tim Copeland, Matt Campbell, Eric Stark, Brian Knoth, or new John Powell).

- We want to be cautious of participant's time, yet, remain focused on producing results for the July 24th discussion. Participation is contingent on being available to spend considerable time during the next few weeks to meet the goal.

(4) Estimating abundance and productivity indicators for status assessment needs was an original goal of this PIT-tag based modeling effort from the beginning under the ISEMP contract. NPT was sub-contracted to assist in the development of abundance models and to report abundance estimates (Rick Orme). IDFG was sub-contracted to provide life-history metrics of PIT-tagged fish through genetic sex determination and scale analysis (Matt Campbell's group). Abundance and life-history metrics were then going to be combined to create productivity estimates for status assessment needs, and reported in a collaborative multi-entity report. The full integrated approach has never been completed, and the collaborative report has never been implemented. Instead, IDFG began producing Chinook and steelhead population monitoring reports, using data collected from multiple entities, without co-manager collaboration for the purpose of providing status assessment information (examples include: Knoth et al. 2018, Felts et al. 2018). Another IDFG driven process, Stark et al. (2018), produces a collaborative report in authorship only to recognize data sources. However, the methods were developed by IDFG without much outside collaboration, yet, authorship suggests co-managers support the reported methods and resulting estimates.

> "The purpose of this report is to develop and summarize population level information to evaluate the status of wild adult steelhead populations in Idaho. Population abundance, productivity and life history information are key data to information DSP viability and management. This is the third year in which we assembled all wild adult steelhead information collected state-wide under one cover".
>
> —Knoth et al. 2018

(5) Co-managers need to decide if we should provide a single estimate for population status assessment needs or produces multiple estimates using different methodology. If a single estimate is chosen, method development and reporting should be a multi-entity collaborative process. And further, to best protect the resources method selection should be based on the best available science and not previous reporting responsibilities, data collecting agencies, cost, or from concerns over future funding. Alternatively co-managers may decide different methods are necessary to meet different purposes, and choose to provide multiple estimates for each population which would allow data consumers and users to select methods that are best matched for their needs.

- Current Independent Approaches to Population Status Assessment Metrics
  - Tributary/Population Abundance from DABOM: Rick Orme (NPT)
  - Idaho Adult Steelhead Monitoring: Brain Knoth (IDFG)
  - Idaho Adult Chinook Salmon Monitoring: Eli Felts (IDFG)
  - Snake River Basin Steelhead Run-Reconstruction: Eric Stark (IDFG)
  - Natural Origin Chinook Salmon and Steelhead Life History and Genetic Diversity: John Powell (IDFG)