Searching for a Life History Approach to Salmon Escapement Management

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Introduction

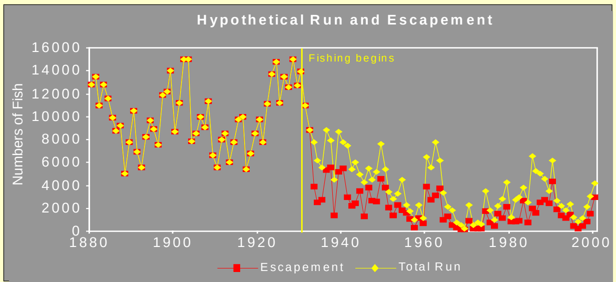
The role of interactions between Pacific salmon ocean biomass production, harvest, and resultant carcass-derived nutrient supply to the freshwater salmon ecosystem have not yet been quantified. Previous spawner-recruit methods for assessing the effects of harvest on long-term salmon population health have in many cases been inadequate (see our example below). We therefore developed a heuristic, life-history based, spreadsheet survival model to analyze the effects of various harvest scenarios on population sustainability.

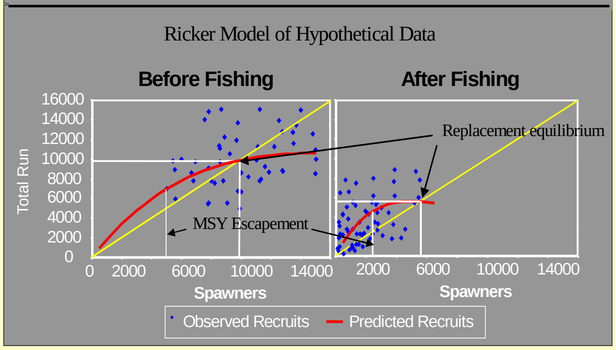
Objectives

- Show a hypothetical example of how Ricker models have inadvertently been misused
- Describe the importance of biological equilibrium
- Suggest a hypothetical, heuristic modeling approach for evaluating harvest effects.
- Make recommendations for future escapement management

The Fallacy of Spawner-recruit Models for Salmon

Ricker spawner-recruit models can underestimate the true population equilibrium replacement and therefore overestimate the equilibrium harvest level. Hypothetical, but realistic data from before and after fishing illustrate this phenomenon. Although pre-exploitation run size data is almost never available, we emulated data based on historic core analysis of marine-derived nutrients from Alaskan lakes which have been validated as a surrogate for run size.

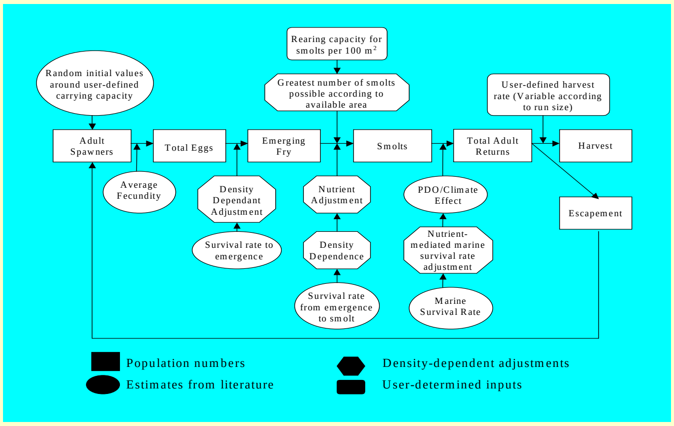




Notice that the equilibrium population replacement point and the so-called MSY escapement level shifts dramatically to lower levels when the population is under exploitation for the SAME HABITAT. This suggests that harvest CAN influence the total production in the absence of habitat alteration.

A Life-History-Based Approach

We wanted to investigate whether the pattern found in the hypothetical data might be real so we developed a life-history based simulation as illustrated below.



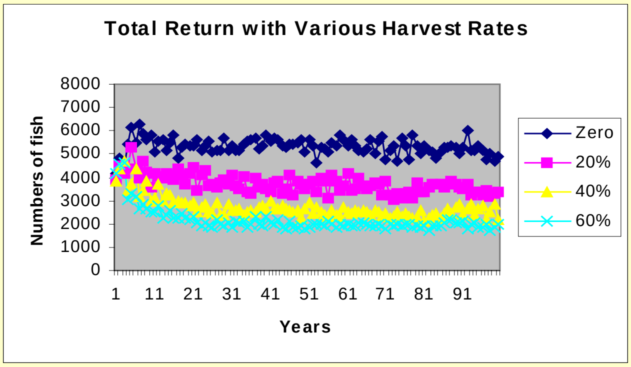
■Model Assumptions

- True equilibrium carrying capacity is known
- Carrying capacity constant over model life
- Density dependence occurs in freshwater only
- Nutrient feedback rate is known
- No interspecific nutrient relationship
- No straying or genetic effects
- Assume no overload of nutrients – ecological balance
- Start with zero harvest – model in equilibrium

Model Runs

We simulated the life history survival steps for a hypothetical coho salmon population. The model also incorporates salmon carcass-driven nutrient feedback from the marine to the freshwater ecosystems. We used survival rates from the literature and individual, stochastically varied, terms for spawner to egg, egg to fry, fry to smolt, and smolt to adult survival. The effects of climate variation and nutrient feedback on survival were simulated, as were density-dependent effects of the numbers of spawners and fry on freshwater survival of eggs and juveniles. The model calculated expected run size, escapement, and harvest over 100 years. Each model run was iterated 100 times and the results were averaged.

We first brought the model into equilibrium, with no harvest. Then we subjected the unexploited equilibrium population to 100 years of 20, 40, and 60% harvest and found each of these harvest rates gradually reduced the population to a steady state of respective reduction, regardless of generous compensatory survival at low population sizes (see Figure below).



Our preliminary model indicates that the concept of a “harvestable surplus” may not occur in every population and that managers should be more conservative in estimating harvest levels. Most importantly, managers should strive to determine what the true equilibrium population capacity is for the habitat, and then decide whether there are excess fish to harvest.

Future Directions for Escapement Management

- **Next steps for this modeling approach**
  - Increase survival rates to see where populations recover
  - Add environmental catastrophes
  - Formalize mathematically
  - Apply to specific test streams
  - Test variety of harvest strategies, e.g., only harvest production peaks
- **Field Research to support escapement management**
  - Study ideal carrying capacities and bottlenecks in some experimental streams
    - Study salmon ecosystems as escapement is allowed to increase
    - Intentionally under-harvest some experimental streams
  - Continue experimental nutrient replenishment
  - Research on ocean survival, growth, competition, and driving factors
  - Data feeds into new models
- **Escapement Management**
  - Continue to explore new management models
  - When in doubt, harvest conservatively
  - Consider all uses of salmon when estimating escapement needs, e.g., eggs into gravel, nutrients, food for predators

Conclusions

We encourage salmon researchers to continue exploring this approach and recommend that managers consider this or similar modeling for helping to establish escapement goals and evaluating escapement decisions. Until this and other management techniques are refined, managers should strive for generous escapements to support nutrient rebuilding as well as egg deposition, both necessary for strong future salmon production.