Northwest **Power** and
Conservation Council

October 4, 2016

MEMORANDUM

TO: **Council members**

FROM: **Erik Merrill and Nancy Leonard**

SUBJECT: **ISAB Predation Metrics Report Presentation**

BACKGROUND:

Presenters: Greg Ruggerone, ISAB Chair, Steve Schroder, ISAB Vice-Chair, and other ISAB members on the phone

Summary: At the request of the Northwest Power and Conservation Council, the Independent Scientific Advisory Board (ISAB) reviewed and recommended potential alternative metrics for evaluating and comparing the effects of predation at different stages in the life cycle of anadromous salmon and steelhead in the Columbia River Basin. This ISAB review is intended to inform a future technical workgroup charged with developing standardized predation metrics to help determine the effectiveness of predator management actions. Current predator control efforts in the Columbia River Basin intended to benefit salmon and steelhead include lethal removal of northern pikeminnow and northern pike and non-lethal and lethal methods to control avian predators (primarily ringed-bill and California gulls, Caspian terns, and double-crested cormorants) and pinnipeds (primarily California sea lions).

The ISAB's conclusions and recommendations are based on a targeted but not exhaustive literature review and a series of scientific and technical briefings by experts working in the Basin. The ISAB considered three types of alternative metrics: two are used to evaluate short-term effects of

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predation on salmon, and a third is used to examine long-term effects. The ISAB developed criteria that can be used to informally compare alternative metrics and a hierarchical approach for evaluating their usefulness.

At first glance, developing a metric to evaluate the consequences of predation on salmonid populations might seem straightforward. Predators take individuals from a population and cause a corresponding decline in salmonid abundance. However, it can be misleading to assume that mortality at each life stage accumulates additively over the salmonid life cycle if other factors *compensate* for this mortality.

The ISAB considers compensatory mortality the most important uncertainty to address when developing a predation metric. Compensatory mortality occurs when predation mortality at one life stage is offset to some degree by decreased mortality at the same or subsequent life stages. For example, a predator might eat an injured or weak fish that would have died before reaching adulthood; therefore, controlling this predator would not result in more adult fish. The ISAB reviewed evidence for mechanisms of compensation, including (1) density dependent survival due to factors other than predation, (2) selective predation based on fish size and condition, (3) and switching behavior of predators, which may be caused by a change in abundances of alternative prey species or when secondary predators increase predation on salmon following control of the primary predator. Considerable compensation in predation-related mortality may occur between juvenile and adult life stages, but additional compensation may also occur during the subsequent spawner-to-smolt stage, indicating the need to consider predation within the context of the entire life cycle. Much of this compensation may stem directly from density dependence. For example, loss of 50% of a juvenile salmon population in response to predation or other factors would likely reduce intraspecific competition for resources, potentially leading to increased growth and survival among the survivors.

A review and comparison of three alternative metrics using a standard set of evaluation criteria revealed that a single metric would not be adequate for evaluating all goals.

The ISAB recommends:

1. Using and further refining two types of metrics currently in use in the Basin:

    a. *Equivalence-factor metrics* (for example, adult equivalents), which can be used to compare the effects of predation on salmon and steelhead at different points in their life cycle.

    b. *Change in population growth rate metric* (also called *delta lambda,* $\Delta\lambda$), which can be used to compare how different predation scenarios affect rates of population recovery or decline.

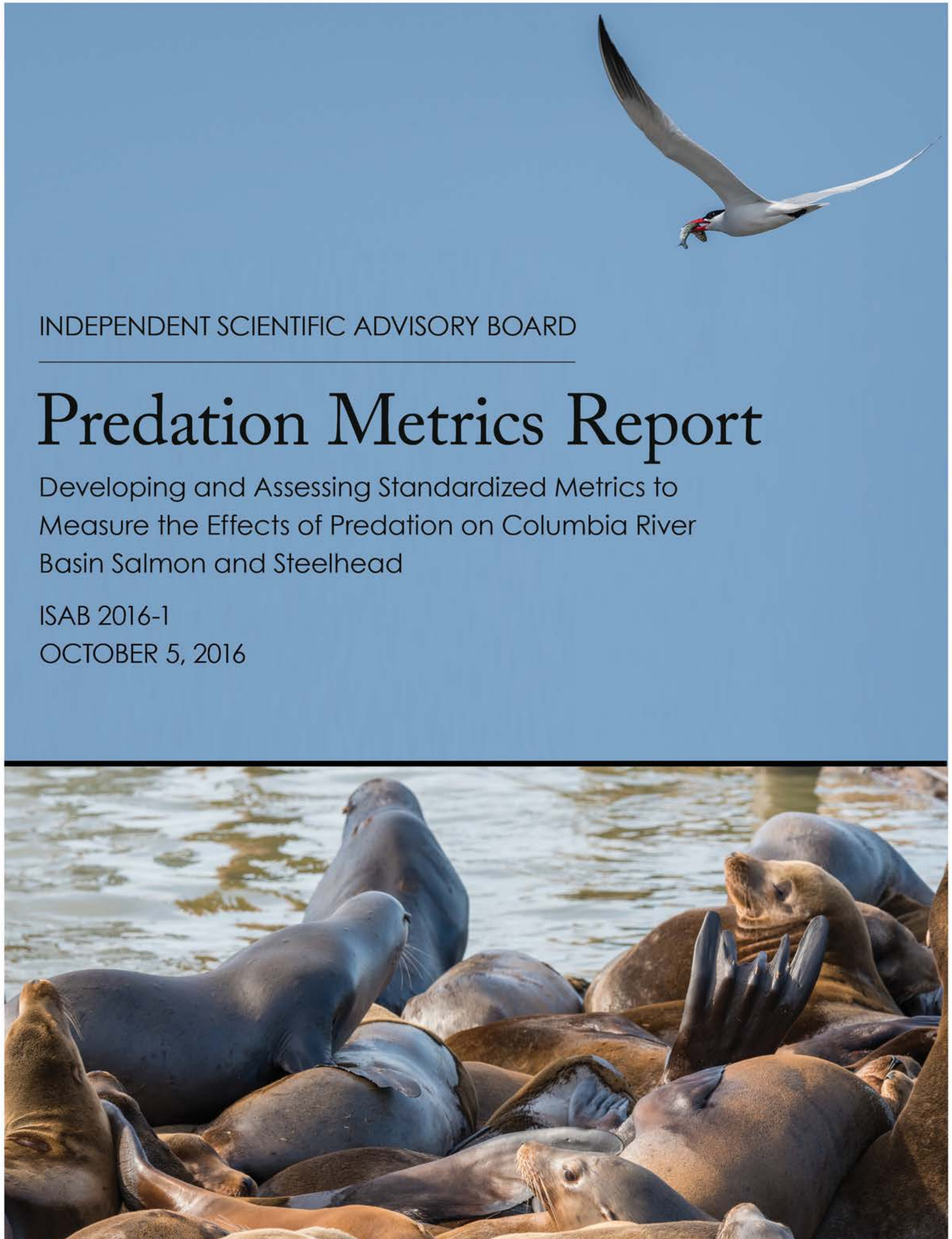
2. Adjusting the *equivalence-factor metrics* and the *population growth rate metric* ($\Delta\lambda$) to account for assumed or estimated compensation in mortality.

3. Placing predation mortality in the context of a life-cycle model.

The ISAB concludes that individual metrics are useful, but metrics can be more informative when incorporated in a life-cycle model that can help disentangle multiple factors affecting salmon survival and interactions among those factors. Furthermore, such processes and interactions can be evaluated in modeled scenarios and verified with data. This approach could help guide research, monitoring, and evaluation of predation throughout the salmonid life cycle, both to provide the data necessary to parameterize and verify models, and to refine metrics. A significant challenge will be to estimate the degree of compensation associated with predation and predator control actions at different life stages. If estimates of compensation are not available, then assumptions about potential compensation should be considered when evaluating predator effects on salmon and steelhead populations and the benefits of predator control programs. Finally, the ISAB encourages the future workgroup charged with developing a standardized predation metric(s) to fully consider our recommended metrics and also explore additional alternative methods and metrics.

Workplan: ISAB reviews are called for in the Council's work plan and the Fish and Wildlife Program.

More Info: www.nwcouncil.org/fw/isab/isab2016-1


INDEPENDENT SCIENTIFIC ADVISORY BOARD

Predation Metrics Report

Developing and Assessing Standardized Metrics to Measure the Effects of Predation on Columbia River Basin Salmon and Steelhead

ISAB 2016-1
OCTOBER 5, 2016

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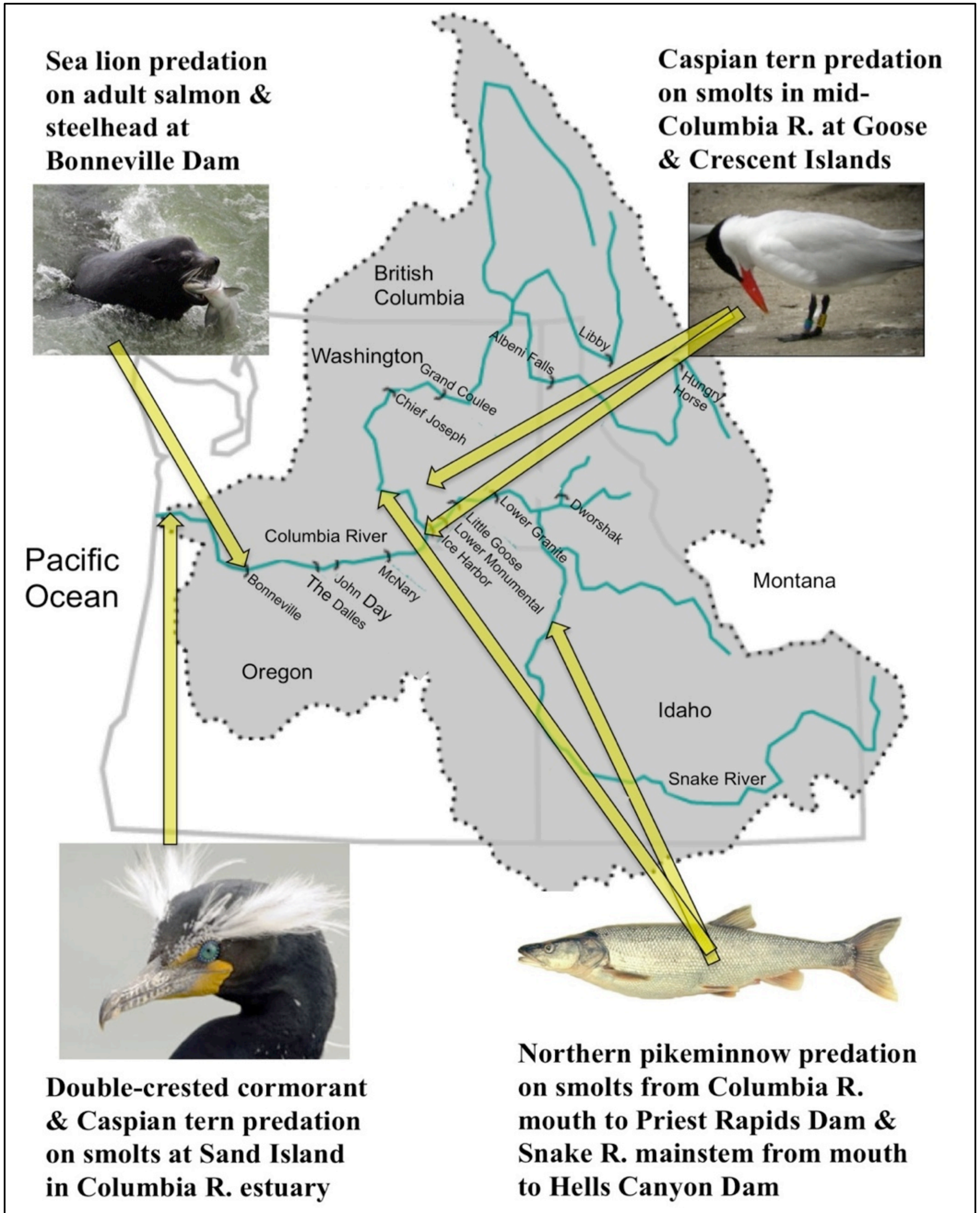
Oct 12, 2016

Photos by Tony Grover

Predator Control Programs in the Columbia Basin



- Sea Lion predation on adults
- Tern, cormorant, and gull predation on smolts
- Pikeminnow predation on smolts
- Northern pike in upper Columbia

ISAB Task

- Recommend common metric(s) to measure the effects of predation on salmon and steelhead:
  - Inform future technical workgroup efforts
  - Allow comparisons of predation across the salmon life cycle
  - Enable evaluation of predation as a factor limiting recovery
  - Facilitate evaluation of predator control programs

ISAB Assumptions/Background

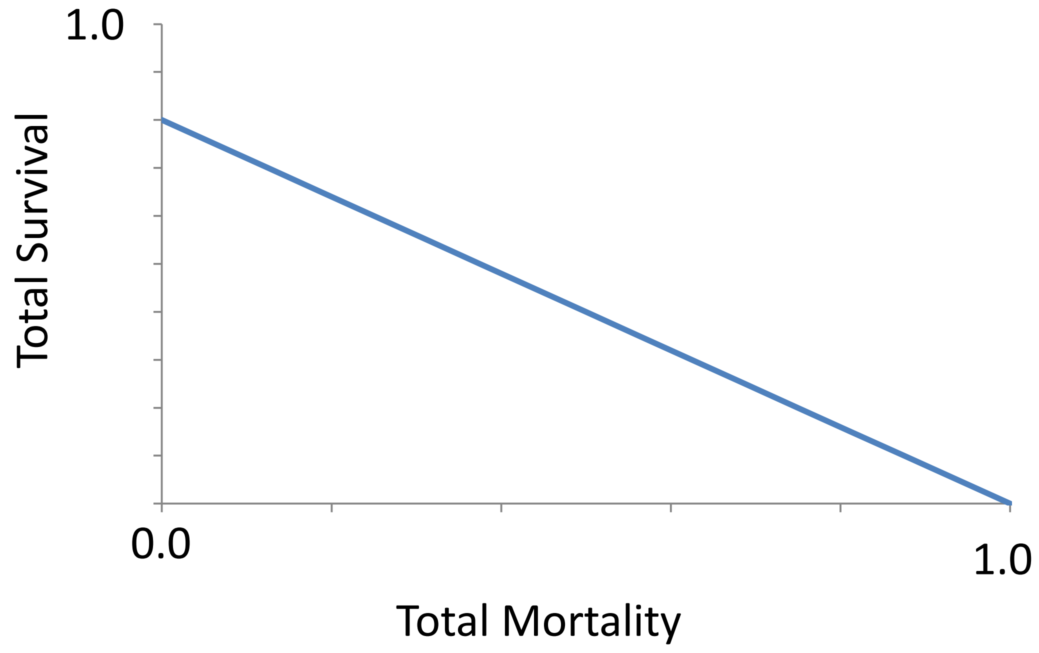
- Predators impact salmon survival at all life stages
  - Pristine & developed watersheds
- Predation-related mortality rate is often higher when salmon abundance is low
- Predators help maintain community structure & diversity: removal may have unintended effects

Types Of Predation Mortality

- Additive
- Compensatory
- Depensatory

Additive Mortality

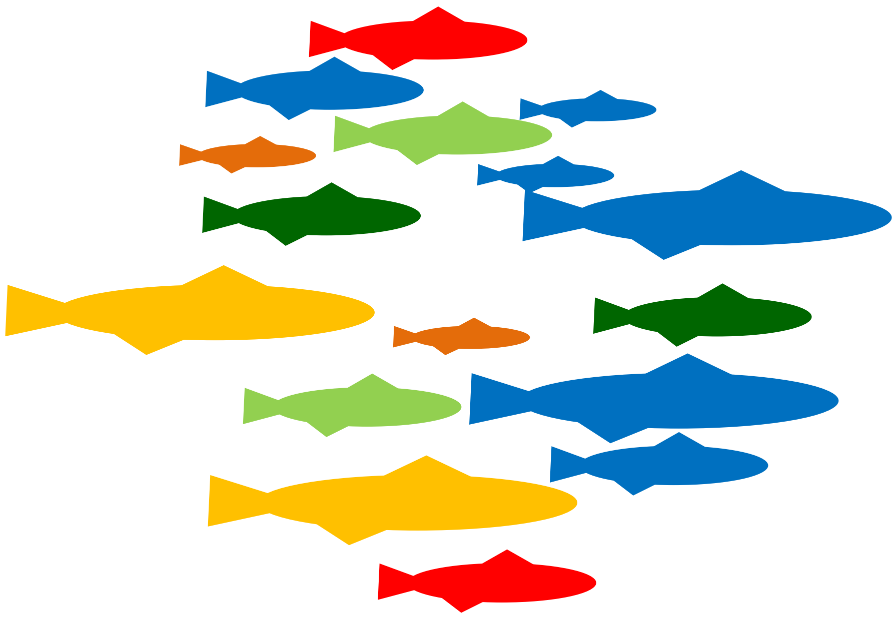
- Causes an immediate reduction in total survival across the entire life of salmon



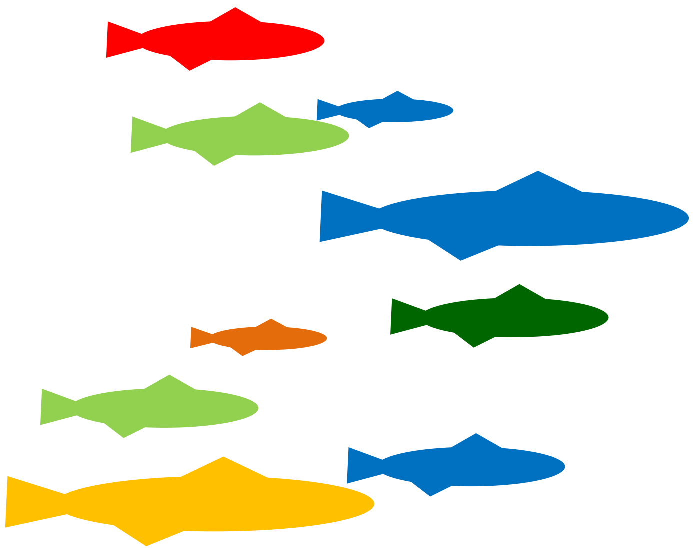
Additive Mortality

Random or Non-Selective Predation

Before Predation



After Predation



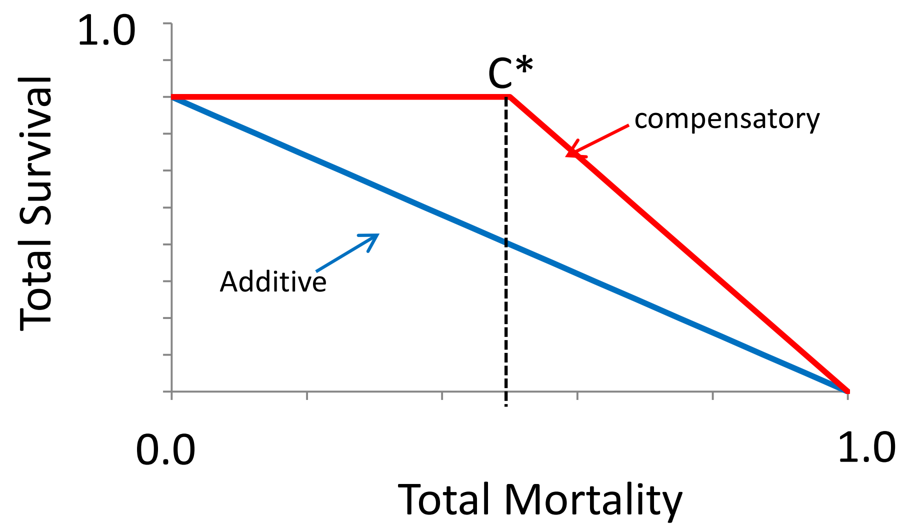
If density dependence is not present and predation is non-selective, predation is ADDITIVE

If predators kill 10% of juvenile salmon, then adult salmon are reduced by 10%.

Compensatory Mortality

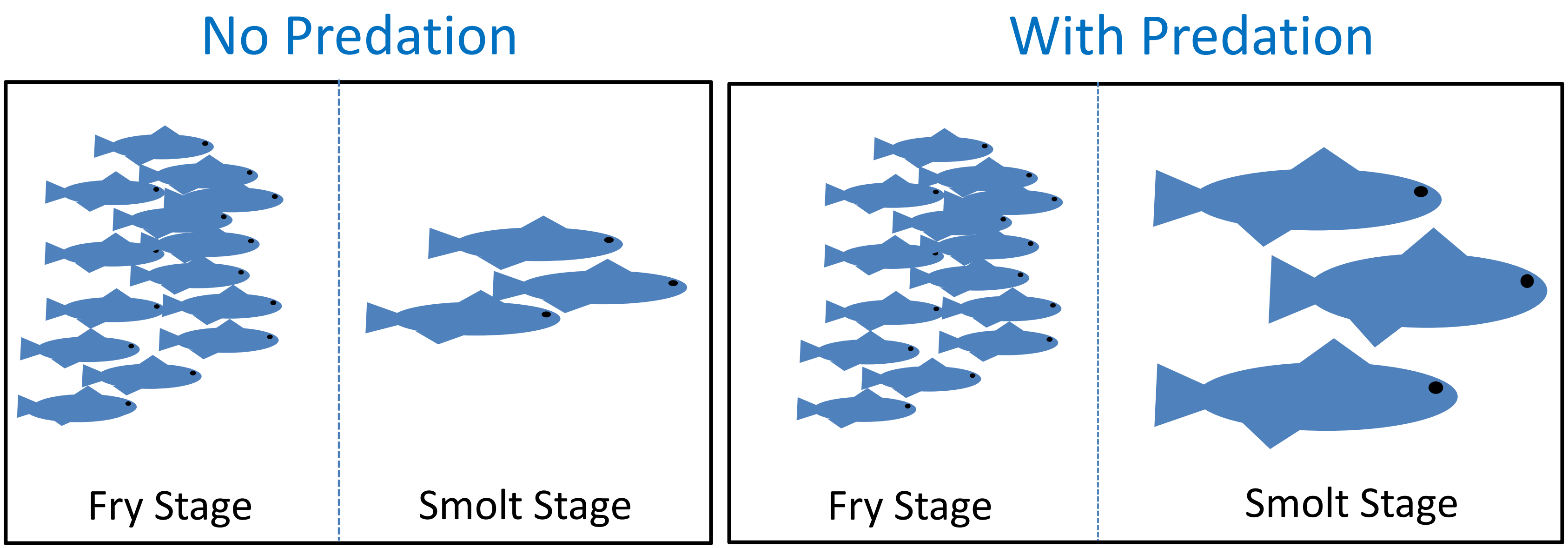
- Occurs when predation at one life stage is offset by decreased mortality at the same or subsequent life stages
  - density dependence
  - predator selectivity
  - predator switching

- Most important uncertainty when developing a predation metric



Compensatory Mortality

Density Dependence: fry to smolt stage



Mortality Factors

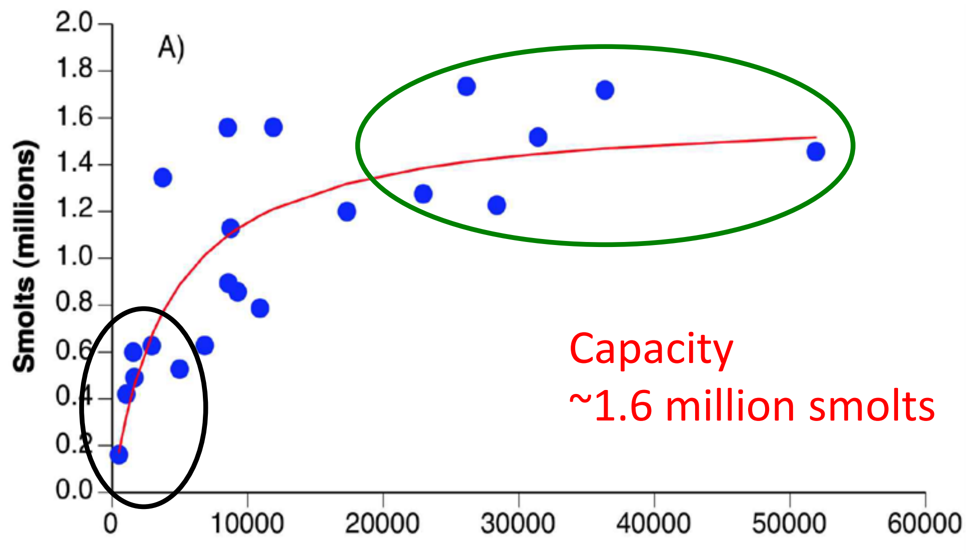
- Disease Transmission
- Competition for:
    - Food
    - Cover
    - Territories

Predation

- Reduced Competition
- Increased growth & size
- Reduced disease transmission
- In some instances may increase recruit numbers

Compensatory Mortality
Density Dependence: spawner to smolt stage

- If 50,000 female spawners, predators could eat 10,000 spawners and have little effect on smolt production.
- If only 5,000 spawners, then predation on 1,000 spawners would have a large effect on smolt production.

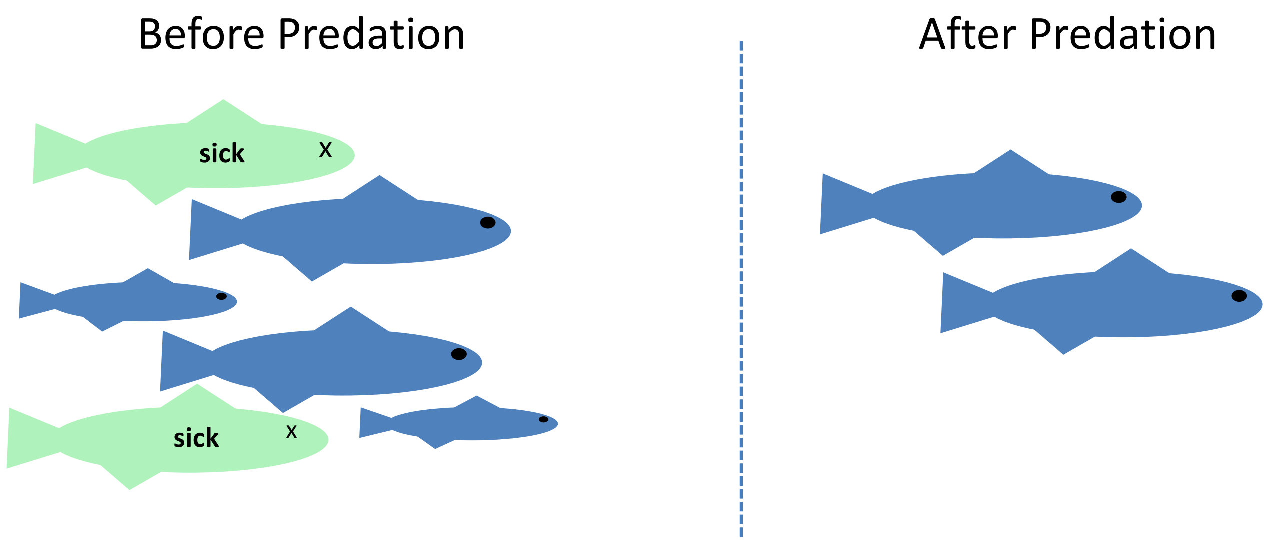


Female spring/summer Chinook spawners

ISAB 2015-1

Compensatory Mortality

Selective Predation

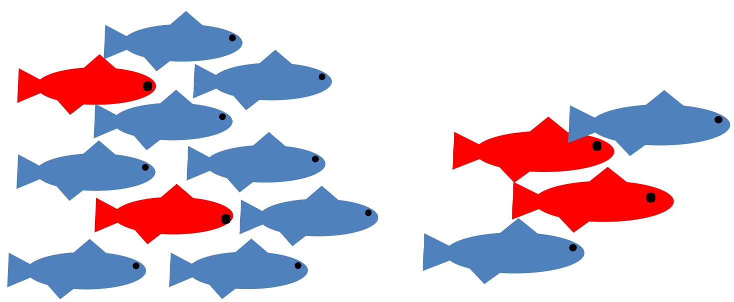


- If predation occurs on less fit individuals (small, diseased, etc.) then predation is COMPENSATORY
- Survival probabilities to subsequent life stages will increase among fish that survive predation

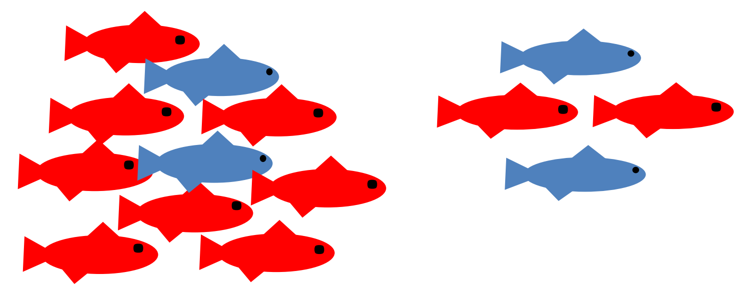
Compensatory Mortality

Prey Switching

Before and After Predation



Before and After Predation



“Red fish” mortality is very low until they become more abundant

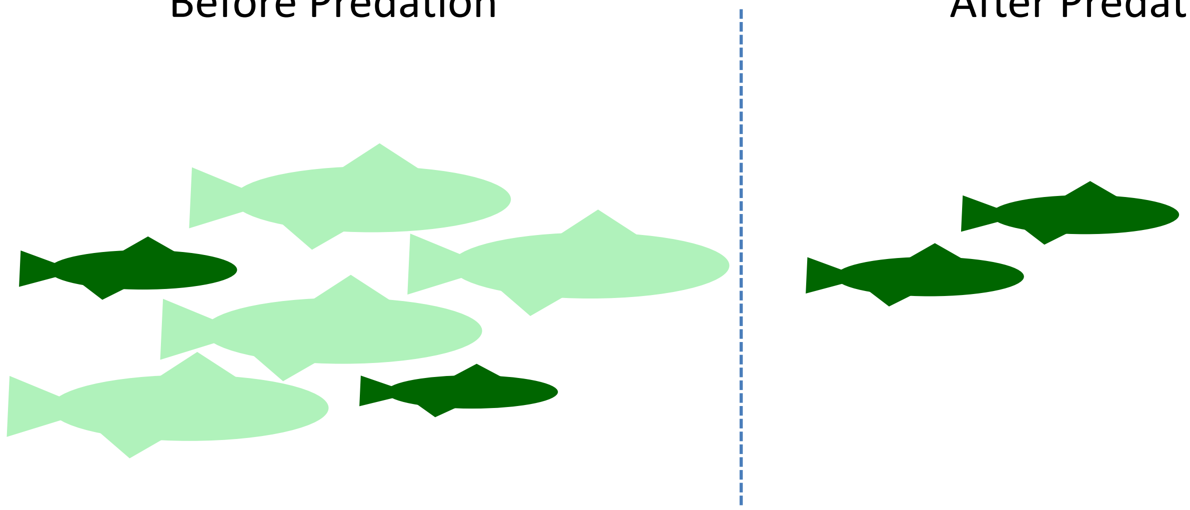
Why?
Predators must “learn” to recognize prey
Predators must “learn” to capture prey

Effect
Proportion of a prey population lost is low when it is relatively rare

Depensatory Mortality

Selective Predation on Robust Salmon

Before Predation | After Predation

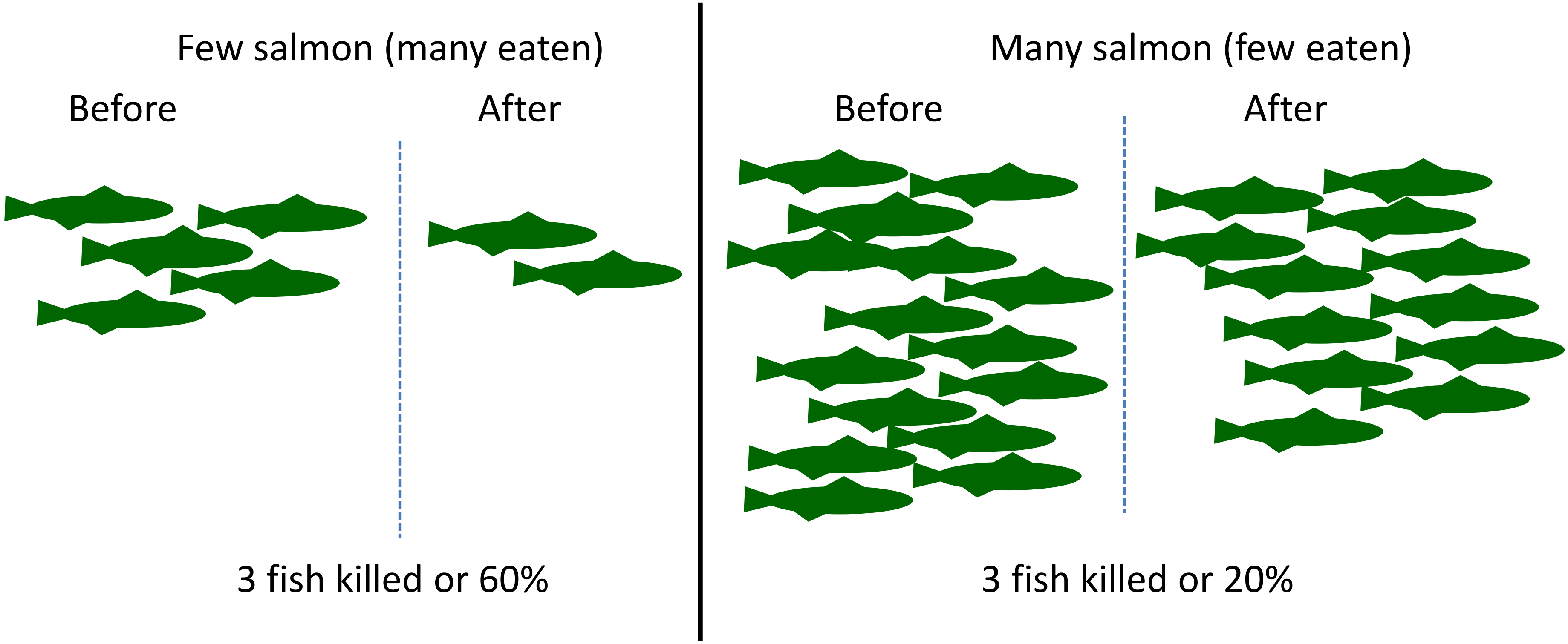


If predation occurs on individuals that would otherwise be more likely to survive (e.g., large smolts) then predation is DEPENSATORY

Survival after predation is lower than if no predation

Depensatory Mortality

Prey Swamp Predators



Abundance affects percentage of salmon population eaten by predators

Evidence of Selectivity
Fishes

Fish predators generally choose:

- Smaller fish
- Less healthy
- Hatchery over wild

Conclusion

- Most predation is compensatory rather than additive

walleye image (chartomcharters.com; small mouth bass image (usbr.gov); northern pike image (landbigfish.com); northern pikeminnow image (peteheley.com)

Evidence of Selectivity

Birds

Factors Affecting Prey Vulnerability To Bird Predation

- Surface orientation (e.g., steelhead)
- Body Size
- Condition
- Migration Timing (time of day/time of year)
- Abundances of salmon versus alternative prey

Evidence of Selectivity
Birds

Caspian Terns

- Consume larger than average salmonids

Double Crested Cormorants

- Salmonid body size not as important

Fineartamerica.com

General Conclusions

- Juvenile salmonids in poor condition are consumed by birds

- Depending on species may select large, small, or be non-size selective

- Bird predation is complex: may be ADDITIVE, COMPENSATORY, or DEPENSATORY depending upon species

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Evidence of Selectivity
Mammals

Pinnipeds

- May select smaller fish (jacks)?
- Prey on early portions of the spring Chinook run
- Increasing numbers of Steller sea lions at Bonneville Dam in the fall (impact?)

Orcas

- Prefer large salmon (Chinook, chum)

General Conclusions

- More information is needed to Determine if predation is ADDITIVE or COMPENSATORY

Quantifying Compensatory Mortality

- Testing compensatory versus additive mortality is complicated
- ISAB report identifies statistical issues that could bias the analysis

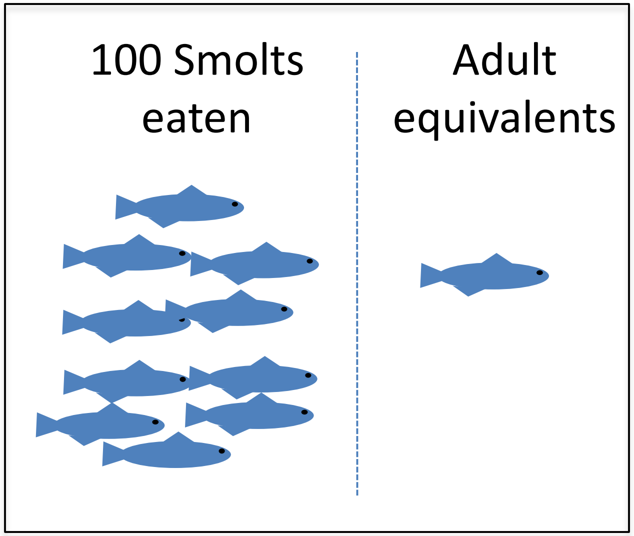
$$\mathrm{cov}(n,h) = -\mathrm{Var}(h) - \mathrm{cov}(S,h)$$

$$\frac{\mathrm{cov}(n,h)}{\sqrt{\mathrm{Var}(n)\mathrm{Var}(h)}} = -\frac{\mathrm{Var}(h)}{\sqrt{\mathrm{Var}(n)\mathrm{Var}(h)}} - \frac{\mathrm{cov}(S,h)}{\sqrt{\mathrm{Var}(n)\mathrm{Var}(h)}}$$

$$\mathrm{cor}(n,h) = -\sqrt{\frac{\mathrm{Var}(h)}{\mathrm{Var}(n)}} - \frac{\mathrm{cov}(S,h)}{\sqrt{\mathrm{Var}(n)\mathrm{Var}(h)}}$$

Equivalence Metrics

- Standardize and compare predation effect at one life stage to another life stage
- Adult equivalents:
  - if predators kill 100 smolts, and 1% of smolts typically survive to adults at Bonneville, then:
  - 1 adult equivalent salmon killed, assuming no compensation between smolts and adults

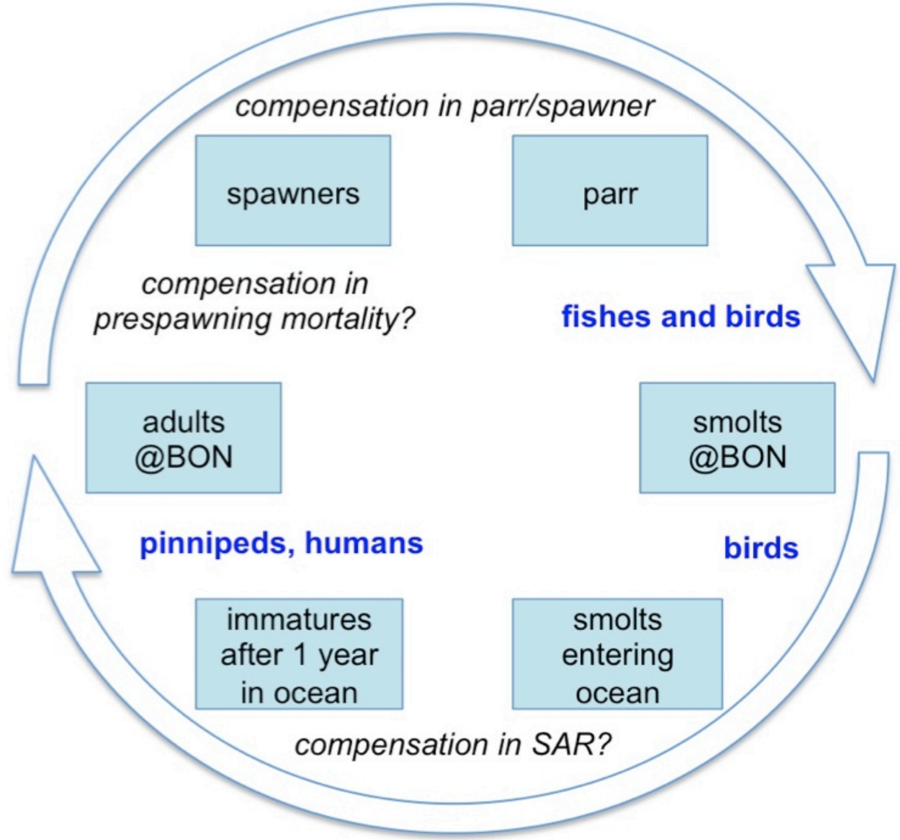


Change in growth rate metric

- Population growth rate (Lambda, λ)
  - Values > 1: growing population
  - Values < 1: declining population
  - Values = 1: stable
- Change in growth rate (Delta Lambda, $\Delta\lambda$)
  - Proportional change in population growth rate
- Compare relative benefit of various management actions
  - typically assumes no compensatory mortality
- Best used in conjunction with other metrics
  - Metrics must be evaluated with proper context

Life Cycle Models

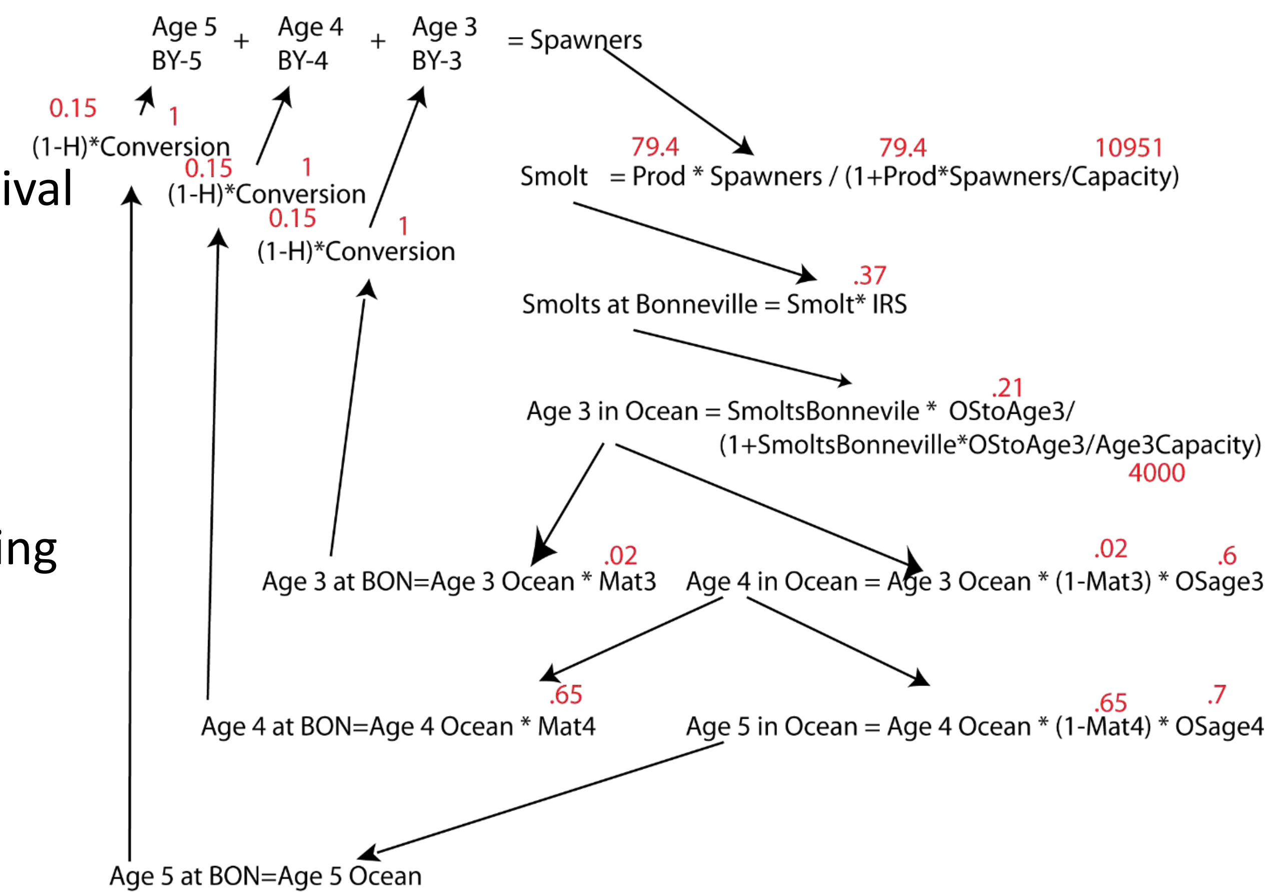
- Framework for incorporating key mortality sources and management actions
  - predator control
  - compensatory mortality
    - density dependence
  - hydrosystem factors
  - habitat restoration
  - ocean survival, climate
- NOAA & CSS life cycle models
  - need to incorporate predation



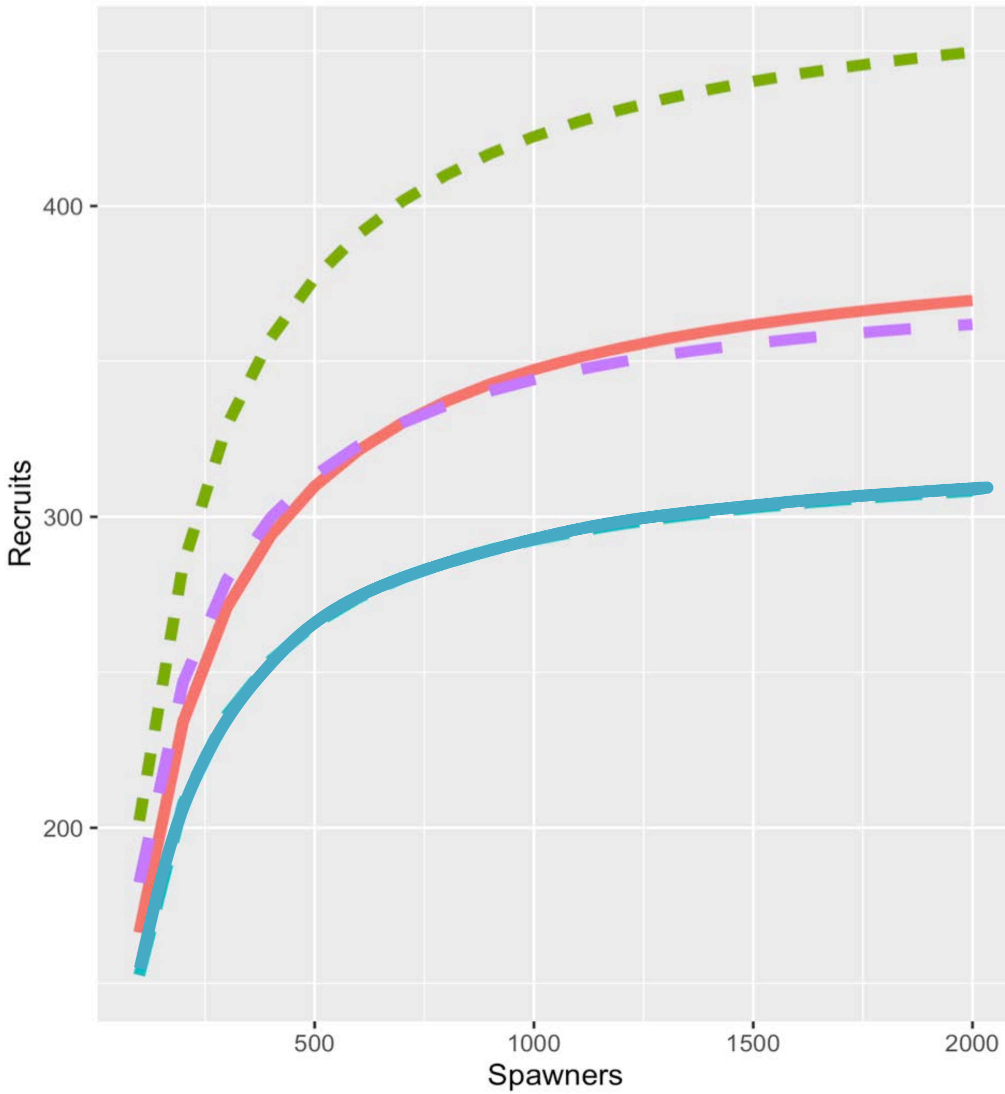
Simple Life-cycle Model

Grande Ronde Chinook

- Appendix D
- Change in in-river survival
- Change in density dependence (DD) in estuary
- Includes DD on spawning grounds
- Based on existing CSS model



Grande Ronde Life-cycle Model



Predator control
Estuary: no DD

No predator control
Estuary: no DD

Predator control
Estuary: DD

No predator control
Estuary: DD

ISAB Recommendations

- Use and refine two types of metrics used in the Basin:
  - Equivalence-factor metrics (e.g., adult equivalents)
  - Change in population growth rate metric ($\Delta\lambda$)
- Adjust metrics to account for compensation
  - if no data, adjust using plausible compensation
- Use life-cycle models to estimate compensation-adjusted values
  - assess predation impacts on salmon viability