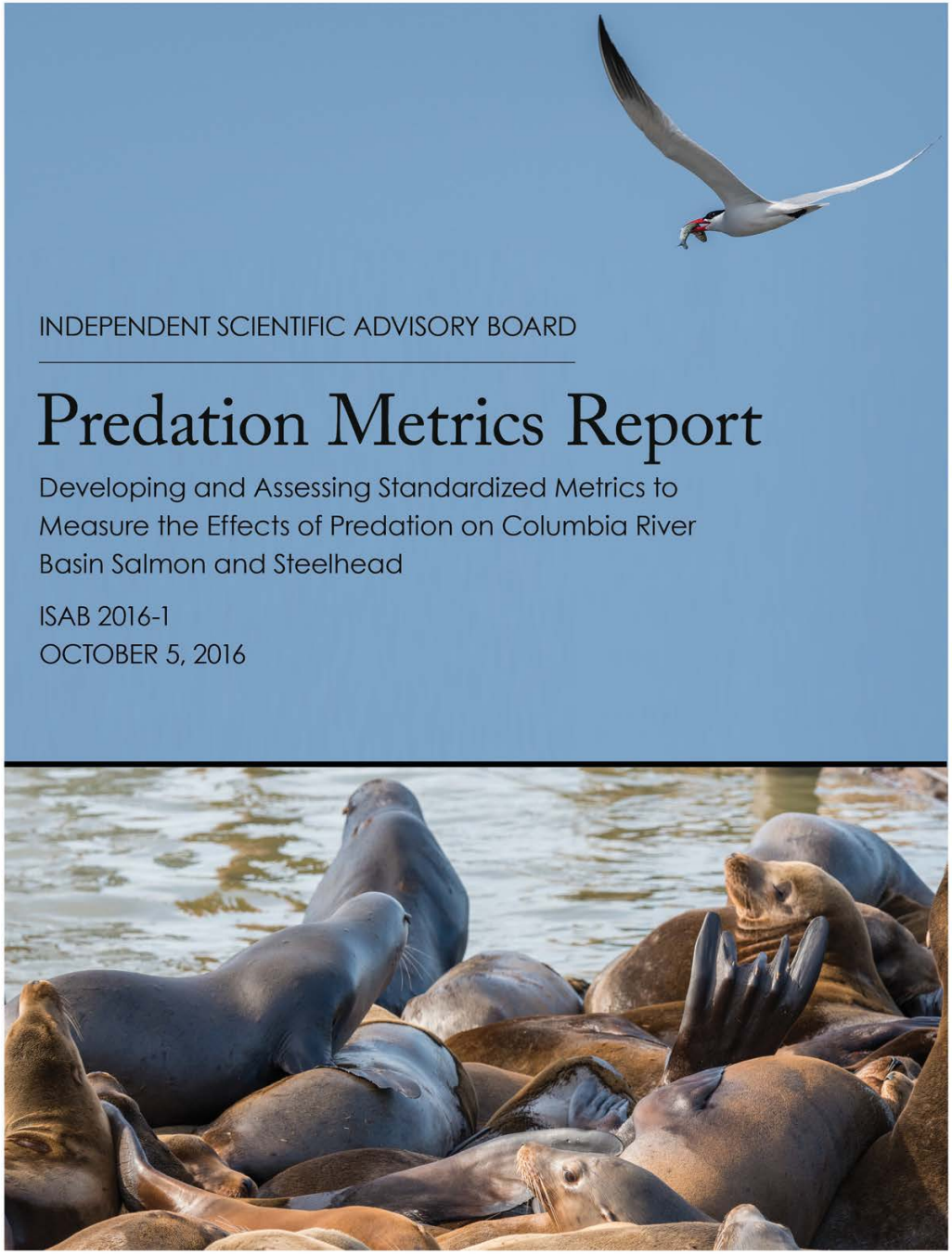

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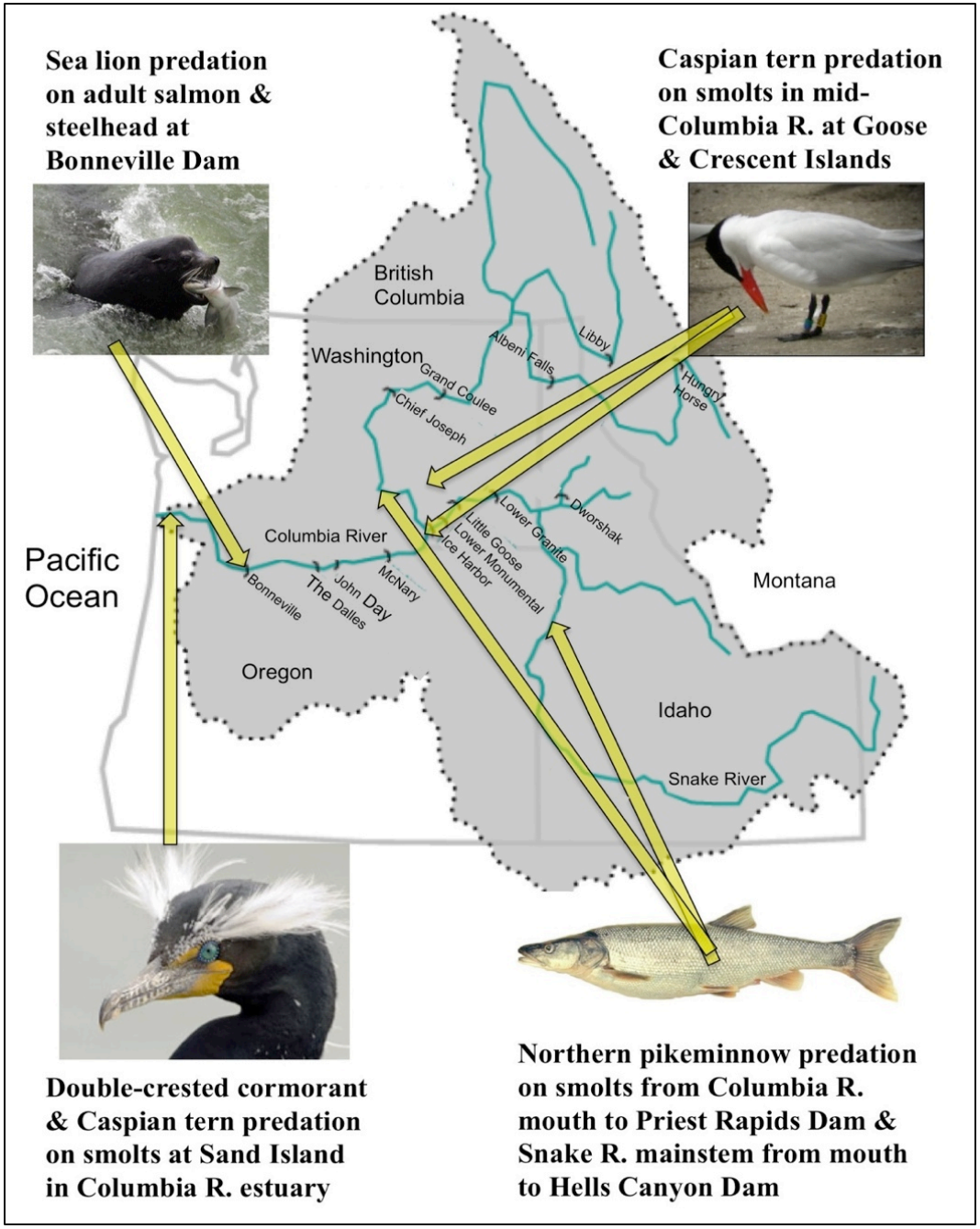
Photos by Tony Grover



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

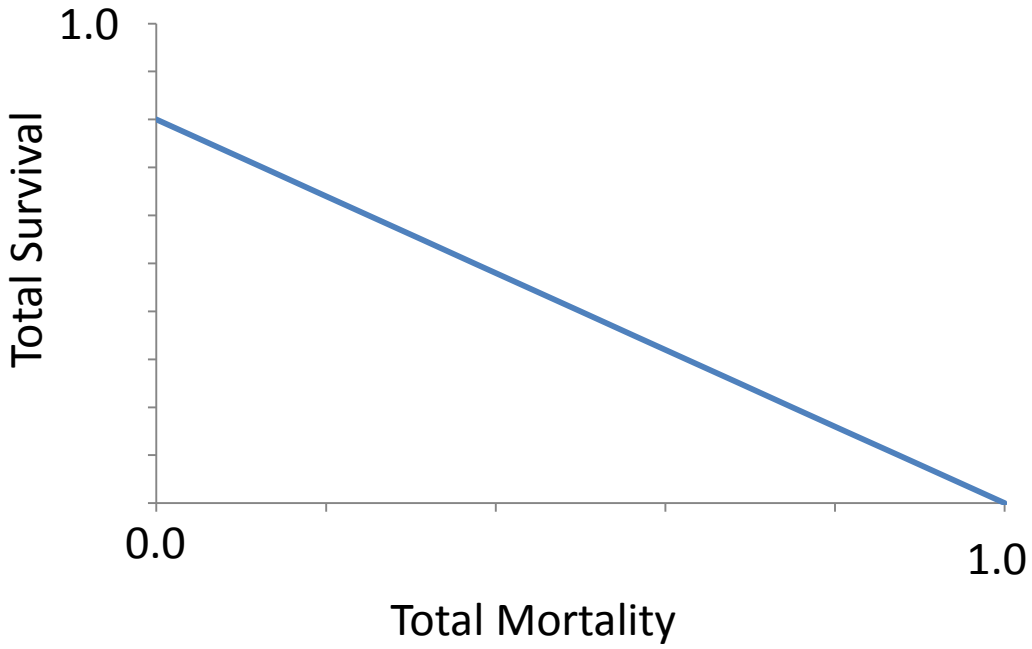
- Predators impact salmon survival at all life stages
  - Pristine & developed watersheds
- Predation-related mortality rate is often higher when salmon abundance is low
- Predators help maintain community structure & diversity: removal may have unintended effects

Types Of Predation Mortality

- Additive
- Compensatory
- Depensatory

Additive Mortality

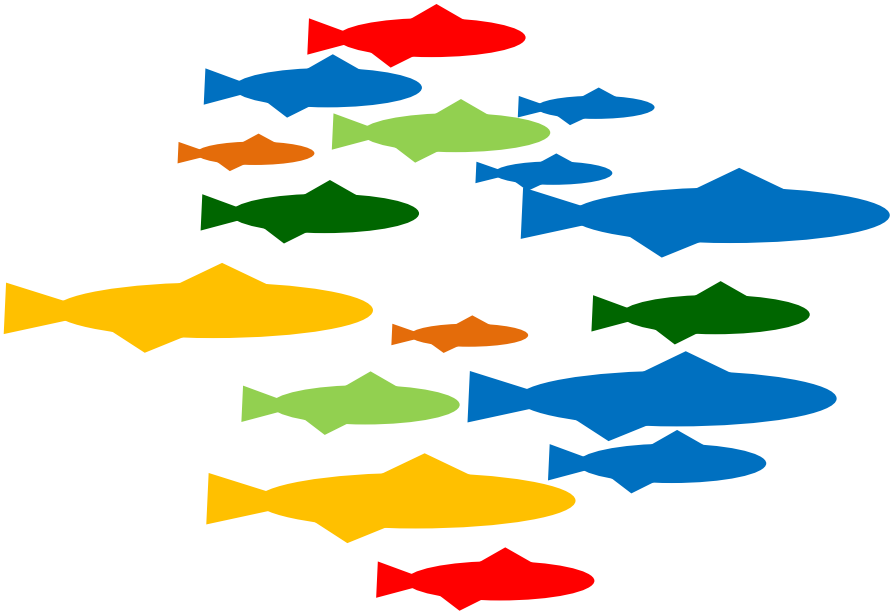
- Causes an immediate reduction in total survival across the entire life of salmon



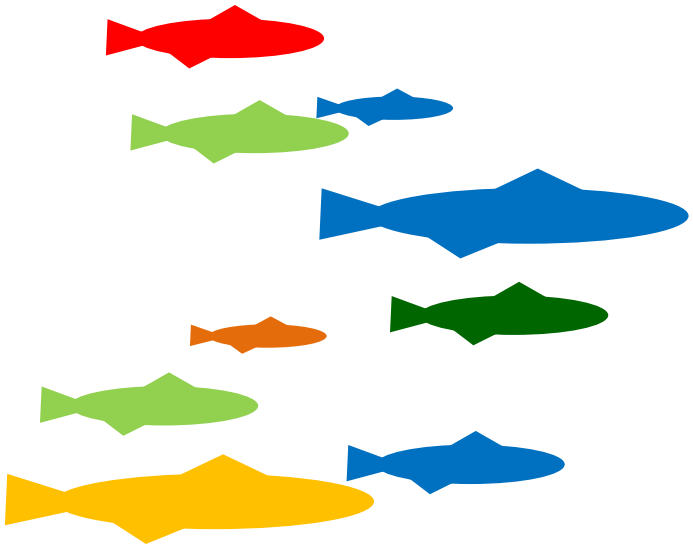
Additive Mortality

Random or Non-Selective Predation

Before Predation



After Predation



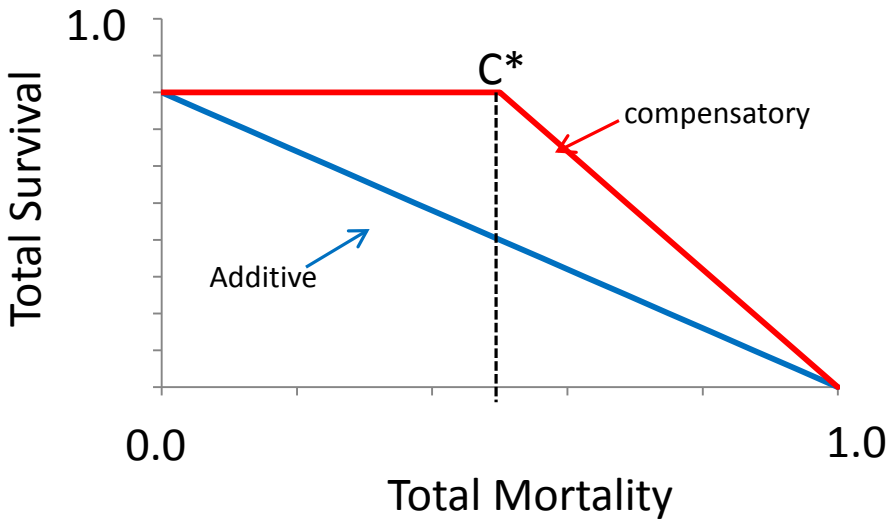
If density dependence is not present and predation is non-selective, predation is ADDITIVE

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

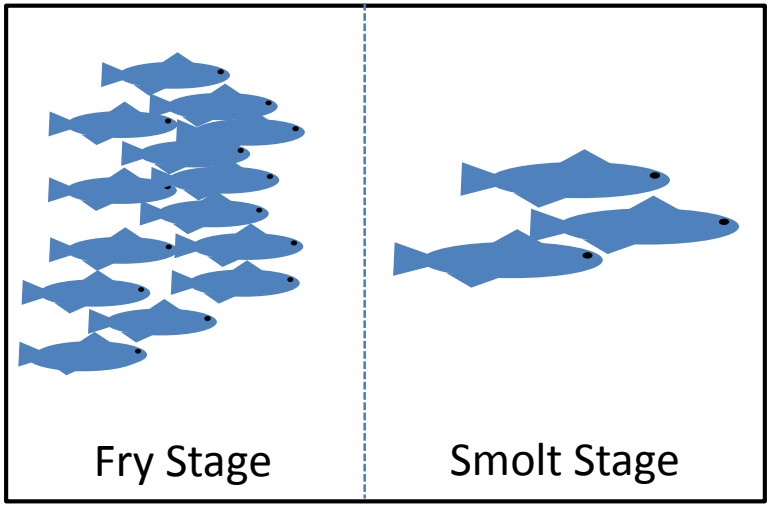
- Most important uncertainty when developing a predation metric



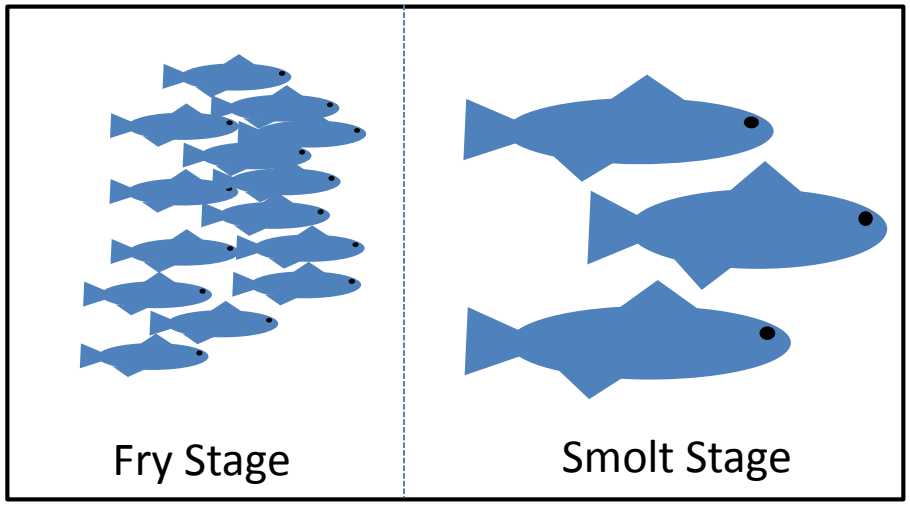
Compensatory Mortality

Density Dependence: fry to smolt stage

No Predation



With Predation



Mortality Factors

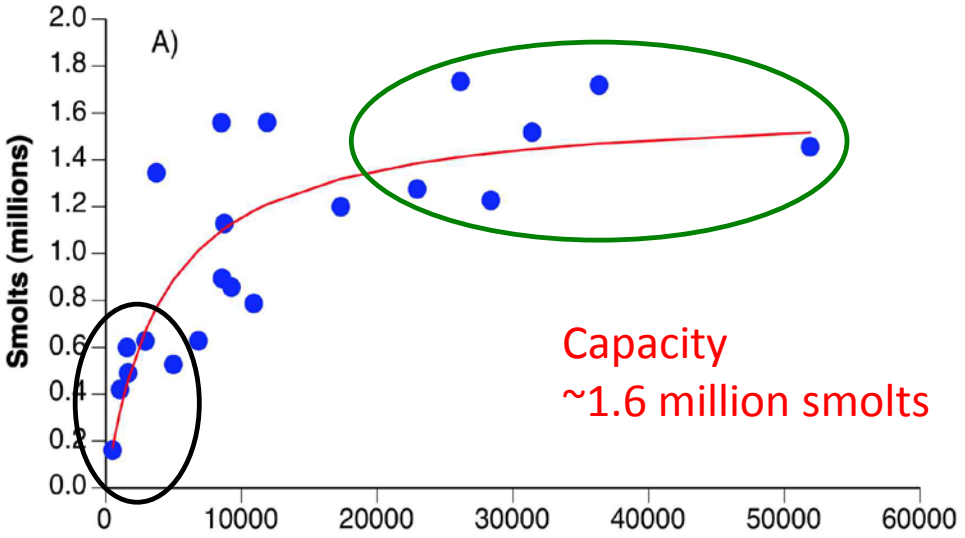
- Disease Transmission
- Competition for:
  - Food
  - Cover
  - Territories

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.



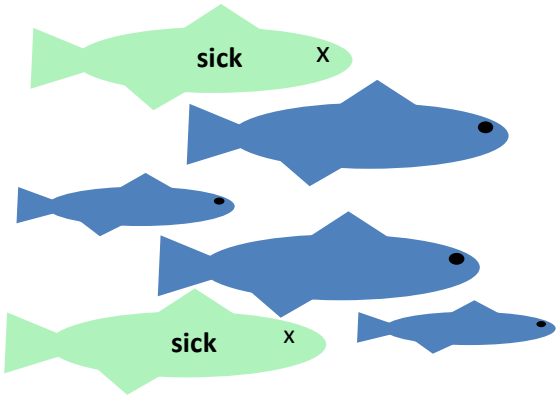
Female spring/summer Chinook spawners

ISAB 2015-1

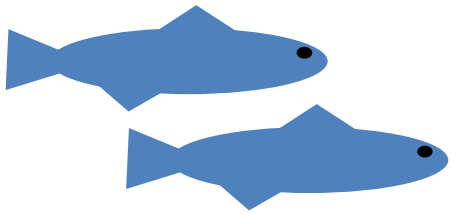
Compensatory Mortality

Selective Predation

Before Predation



After Predation

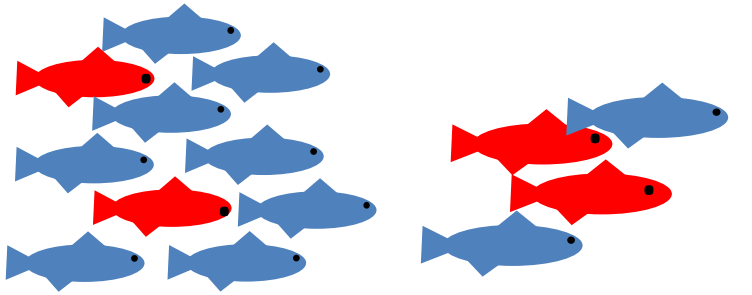


- If predation occurs on less fit individuals (small, diseased, etc.) then predation is COMPENSATORY
- Survival probabilities to subsequent life stages will increase among fish that survive predation

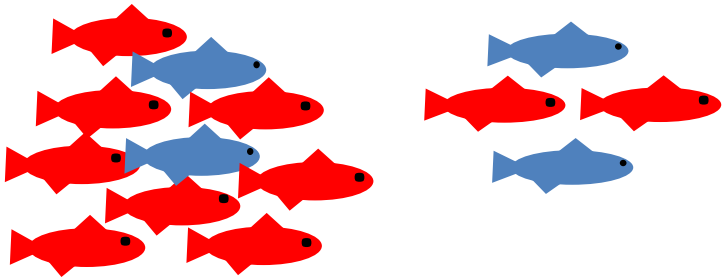
Compensatory Mortality

Prey Switching

Before and After Predation



Before and After Predation



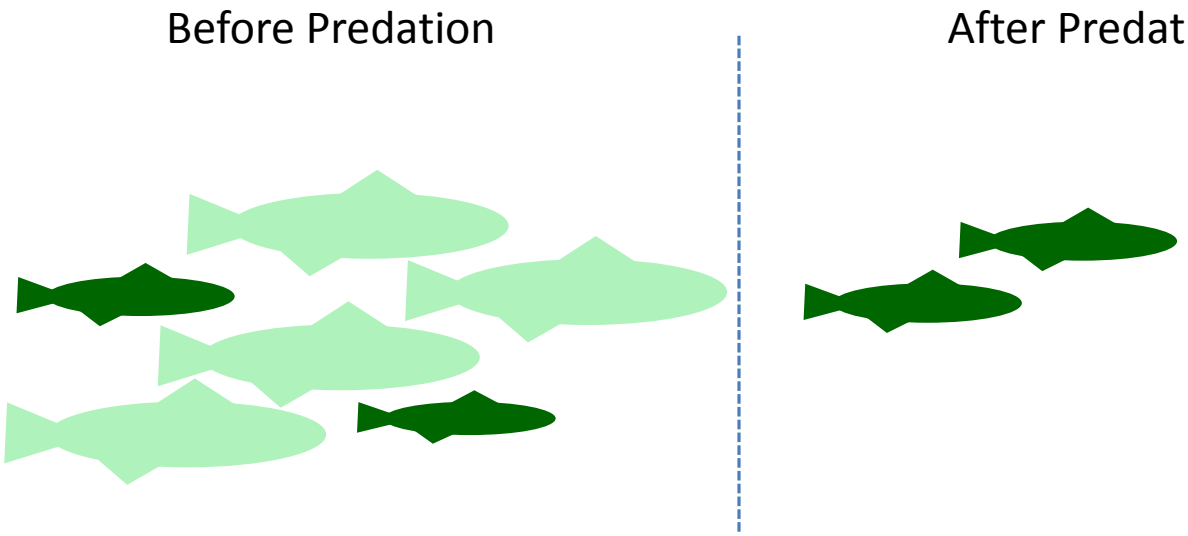
"Red fish" mortality is very low until they become more abundant

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

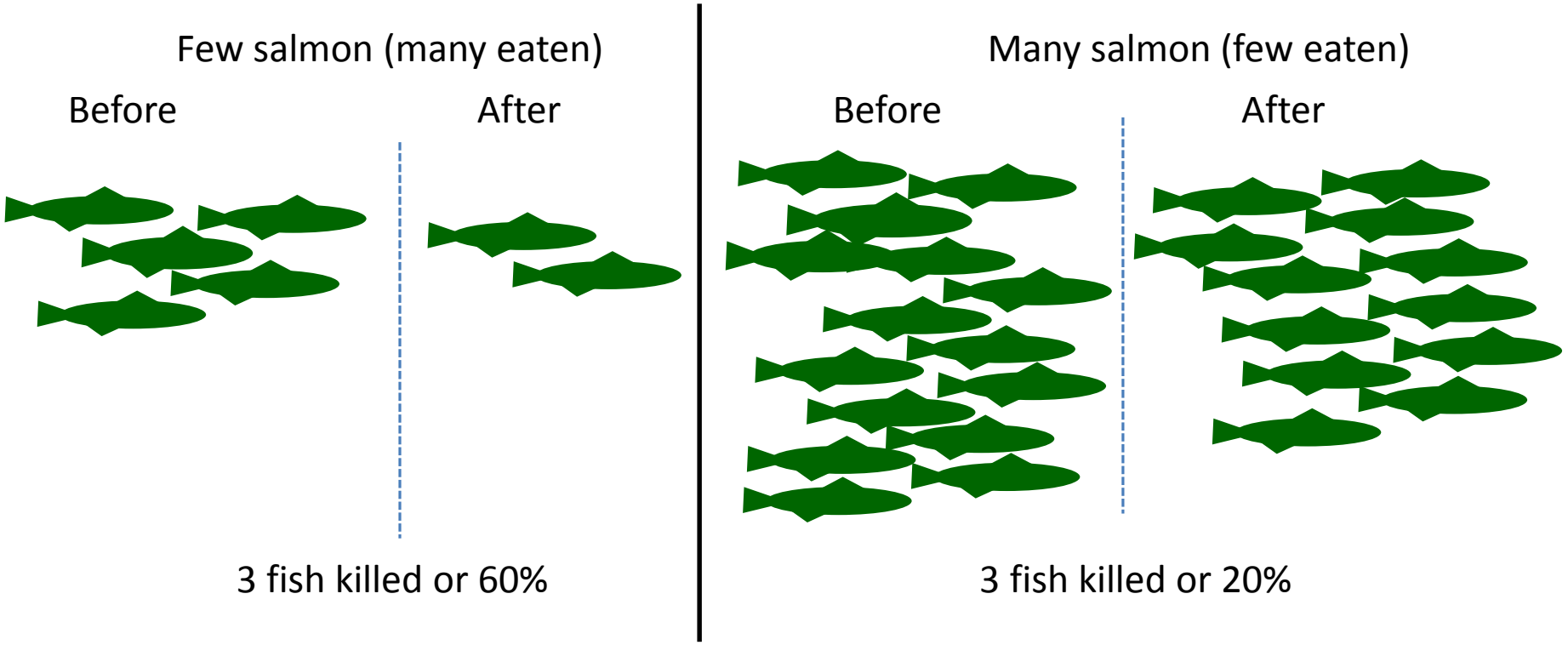


If predation occurs on individuals that would otherwise be more likely to survive (e.g., large smolts) then predation is DEPENSATORY

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

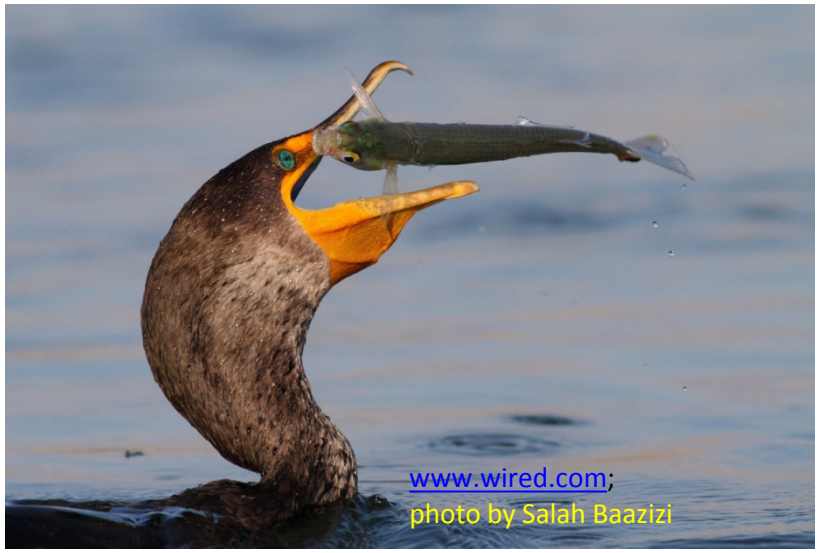
Conclusion

- 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

Fineartamerica.com

Double Crested Cormorants

- Salmonid body size not as important

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

www.audubon.org

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

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

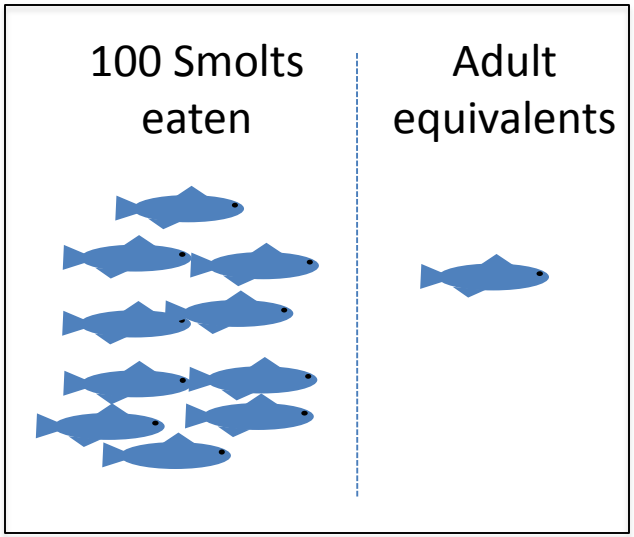
$$\frac{\mathrm{cov}(n,h)}{\sqrt{\mathrm{Var}(n)\mathrm{Var}(h)}} = -\frac{\mathrm{Var}(h)}{\sqrt{\mathrm{Var}(n)\mathrm{Var}(h)}} - \frac{\mathrm{cov}(S,h)}{\sqrt{\mathrm{Var}(n)\mathrm{Var}(h)}}$$

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

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

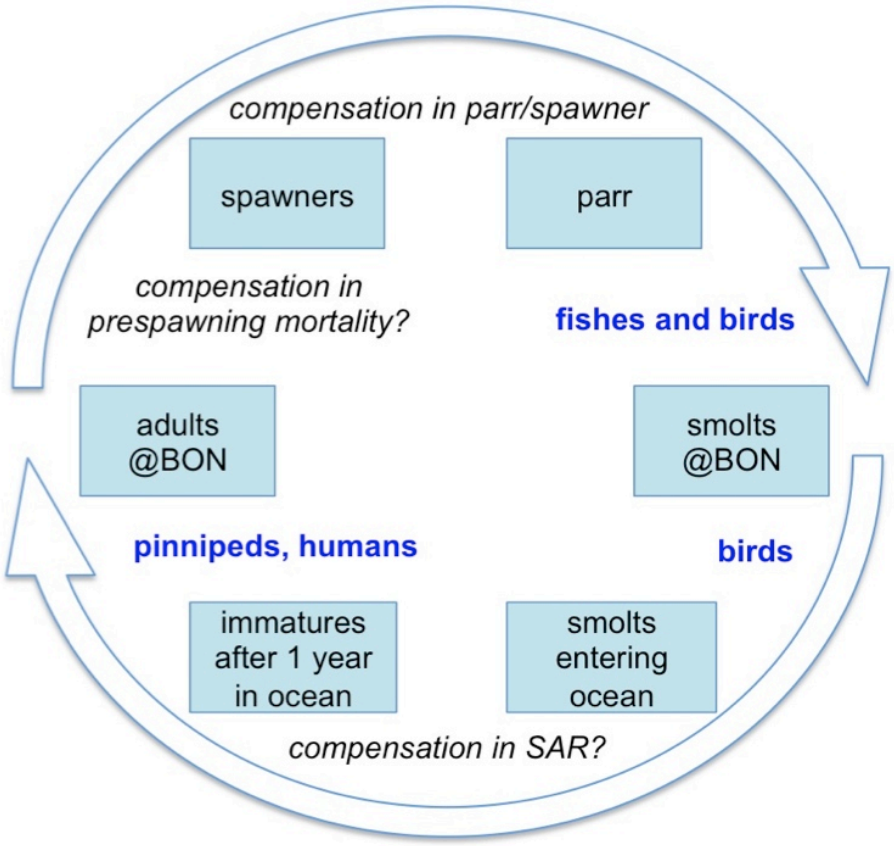


Change in growth rate metric

- Population growth rate (Lambda, λ)
  - Values > 1: growing population
  - Values < 1: declining population
  - Values = 1: stable
- Change in growth rate (Delta Lambda, Δλ)
  - 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

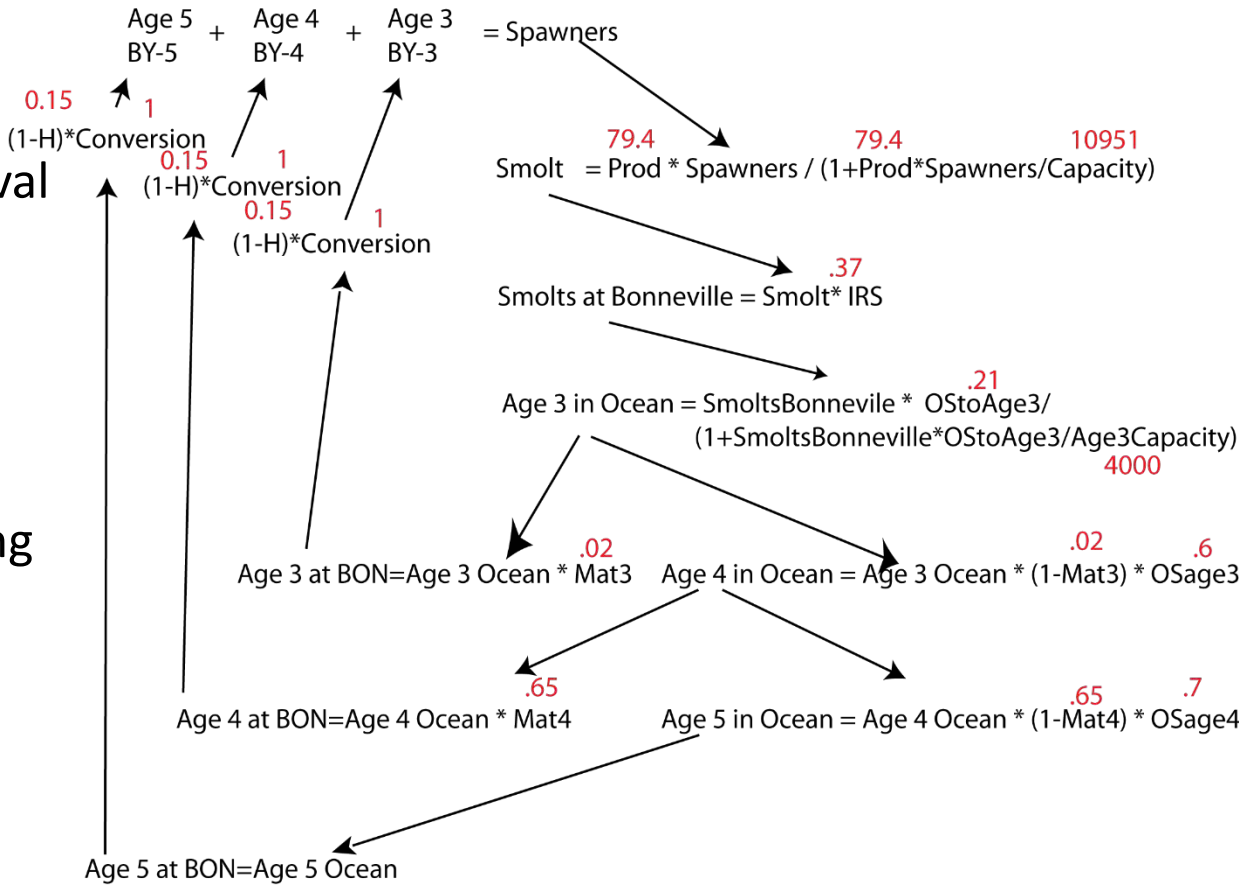
- Framework for incorporating key mortality sources and management actions
  - predator control
  - compensatory mortality
    - density dependence
  - hydrosystem factors
  - habitat restoration
  - ocean survival, climate
- NOAA & CSS life cycle models
  - need to incorporate predation



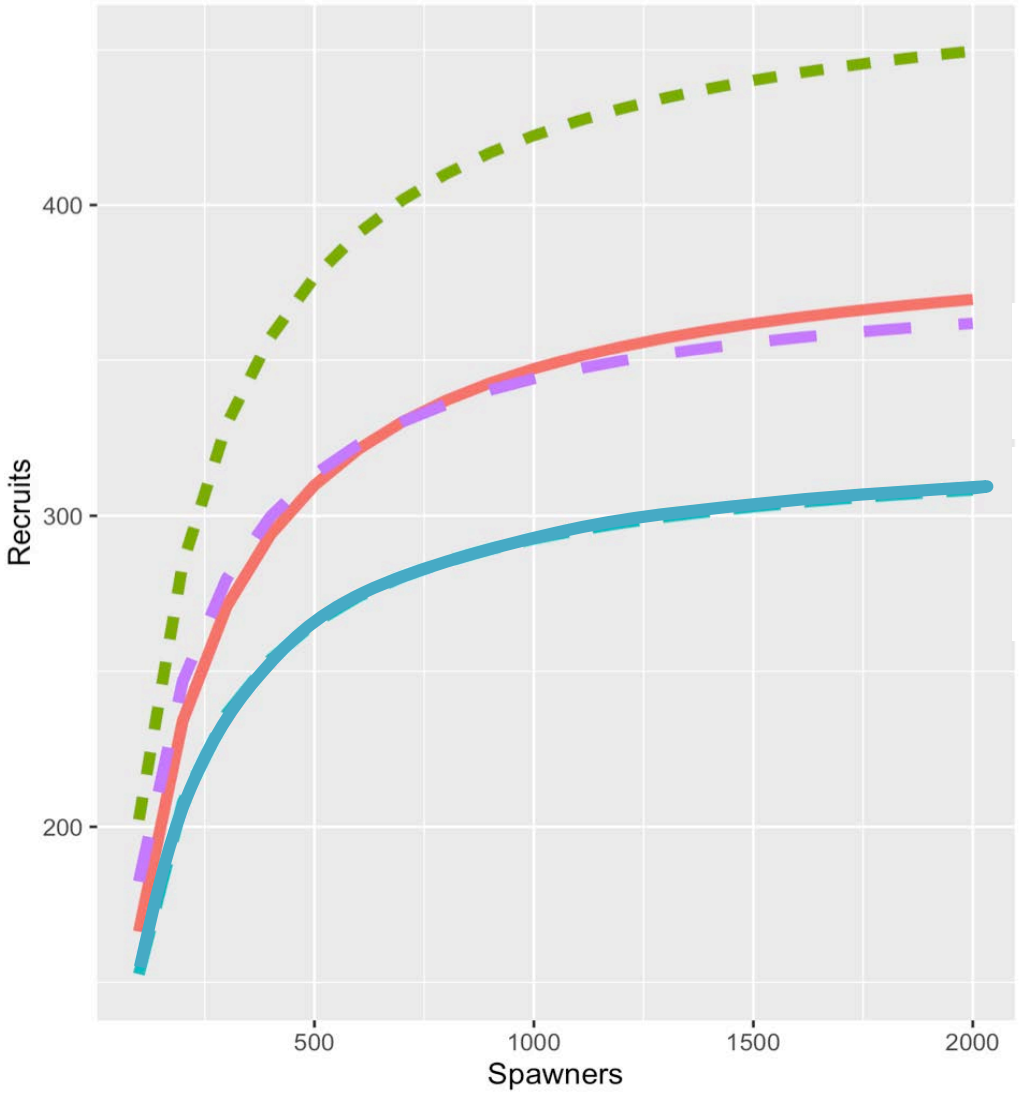
Simple Life-cycle Model

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