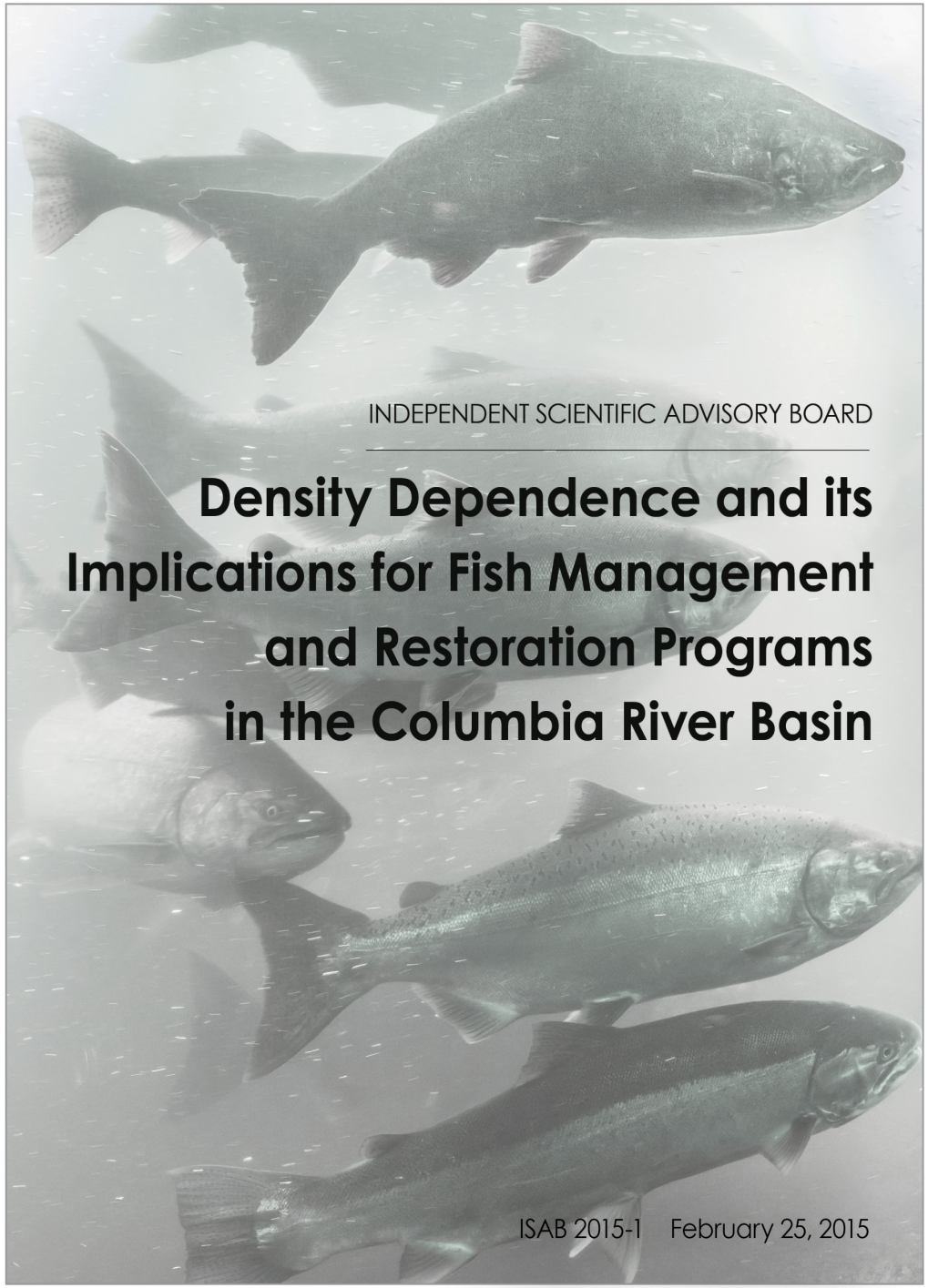

Presentation to Willamette Fisheries Science Review

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Why is Density Dependence Important?

"If only density-independent causes of mortality exist, the stock can vary without limit, and must eventually by chance decrease to zero"

W.E. Ricker 1954

"Compensatory density dependence must exist for naturally stable populations to persist under harvesting"

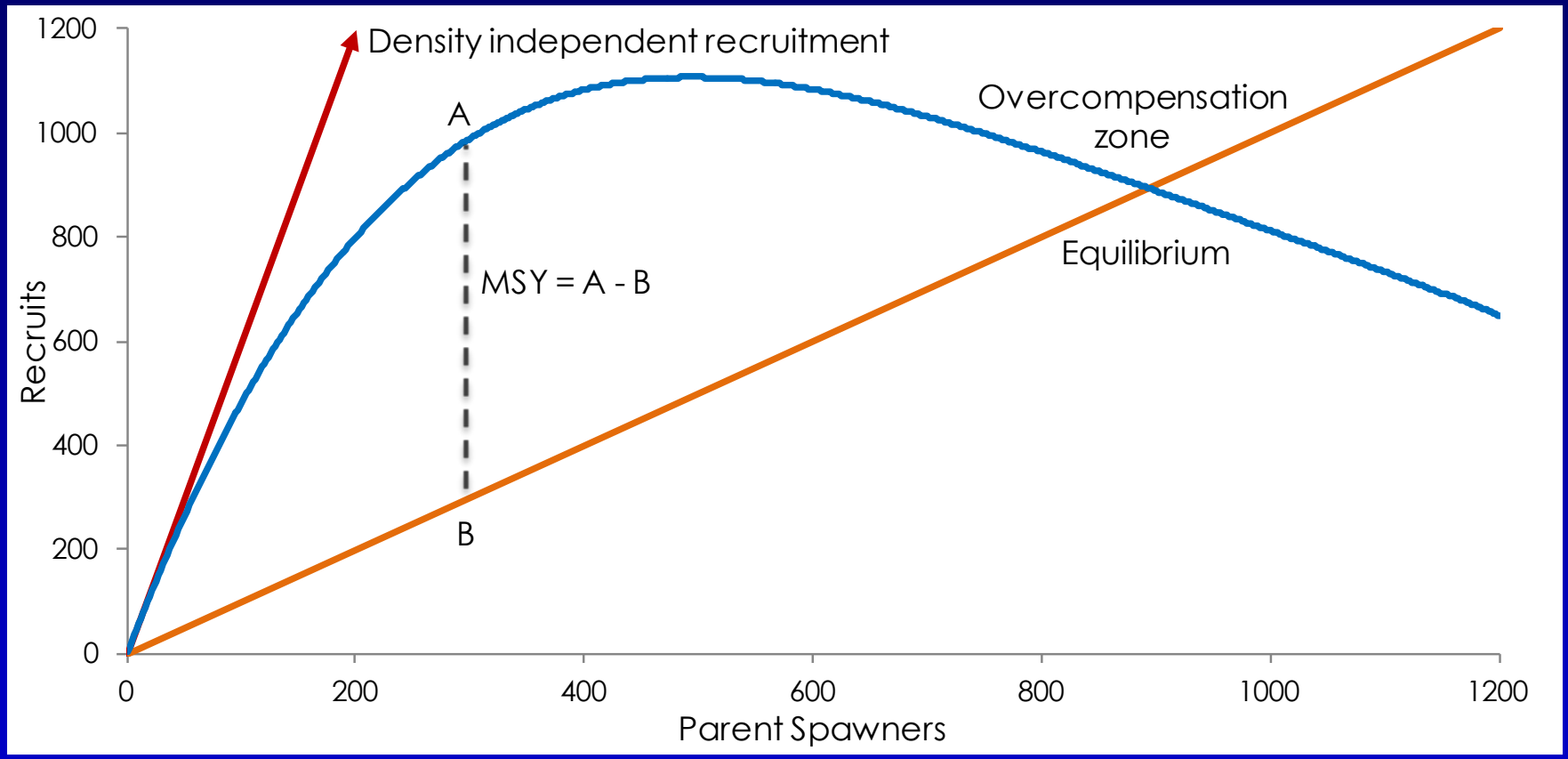
Rose et al. 2001

Key Finding

Density dependence is now evident in most of the ESA-listed populations examined and appears strong enough to constrain their recovery.

What is density dependence and why is it important?

Example: Ricker Curve



1) More resources per individual at lower densities: better growth & survival.
2) Compensatory density dependence provides resilience for populations to rebound from low abundance and enables stability.

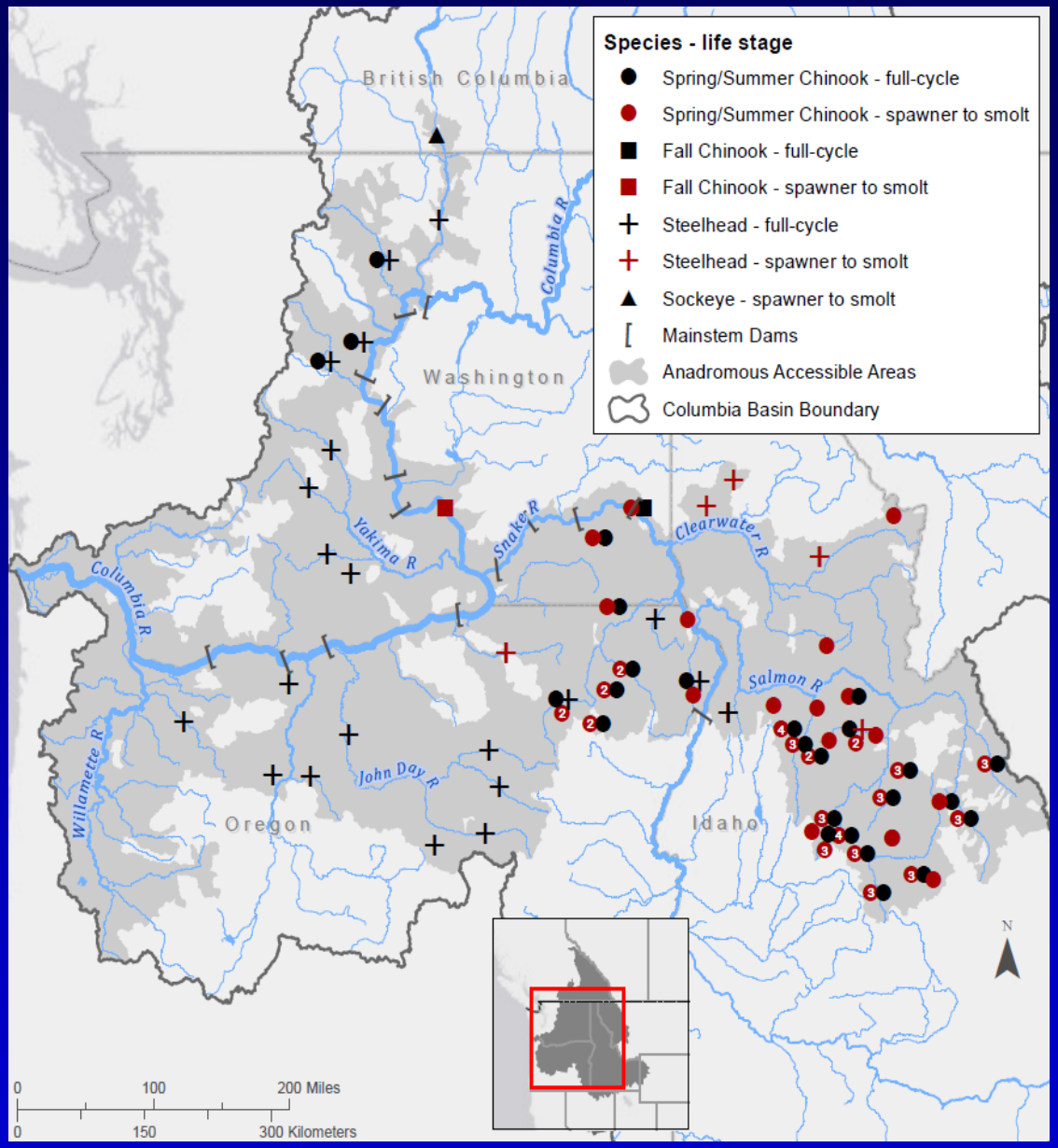
Key Recommendation

Account for density effects when planning and evaluating:

- Habitat restoration actions
  -- Improve action efficiency
- Hatchery supplementation
  -- Improve stock rebuilding & sustainability
- Spawning escapement goals
  -- Increase harvest of surplus hatchery fish
  -- Plan for additional nutrients via carcasses

Compensatory Density Dependent Studies: Where?

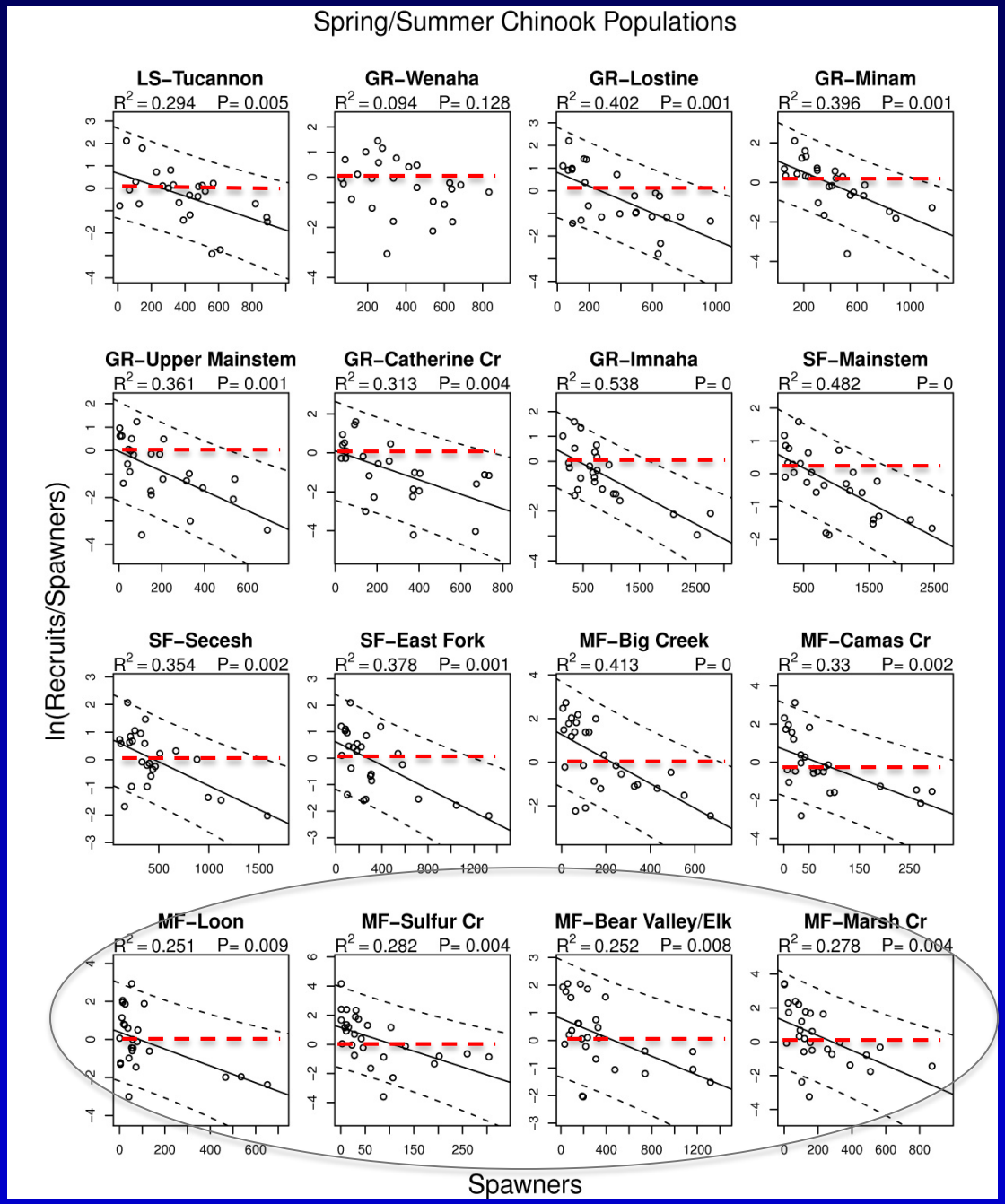
- Primarily spring/summer Chinook & steelhead in the interior.
- Few studies below Bonneville (Willamette) & during juvenile emigration.
- Few coho studies.



Map produced for ISAB by Brett Holycross and Van C. Hare, PSMFC.

Life Cycle Density Dependence

- 25 of 27 Columbia R spring/summer Chinook populations: strong DD.
- Snake R fall Chinook: strong DD
- All 20 Interior Columbia River steelhead populations: Strong DD.
- R/S often < 1 (must improve conditions to achieve recovery)
- What life stage?



Source: Zabel & Cooney 2013

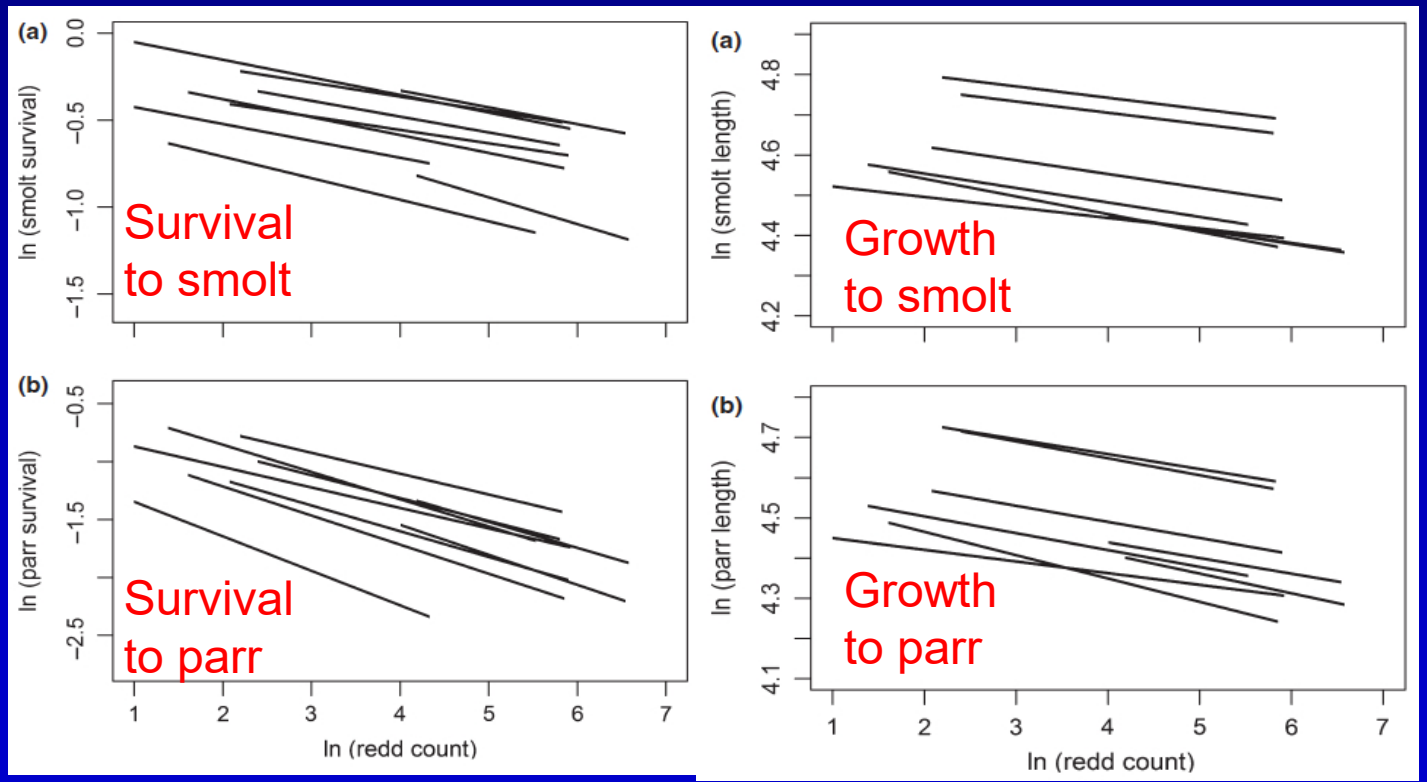
Spawning Stage:
Few Data in Columbia Basin

- Egg to fry survival is density dependent
- Density dependence "stronger" in Chinook
- Chum do better than Chinook when high spawning density
- Little information for spawning stage in Columbia

Spawner to Smolt Stage: Growth & Survival is Density Dependent

- Example: Snake R spring/summer Chinook
- 8 populations; other examples in report
- Density dependent dispersal observed & is key to recovery.

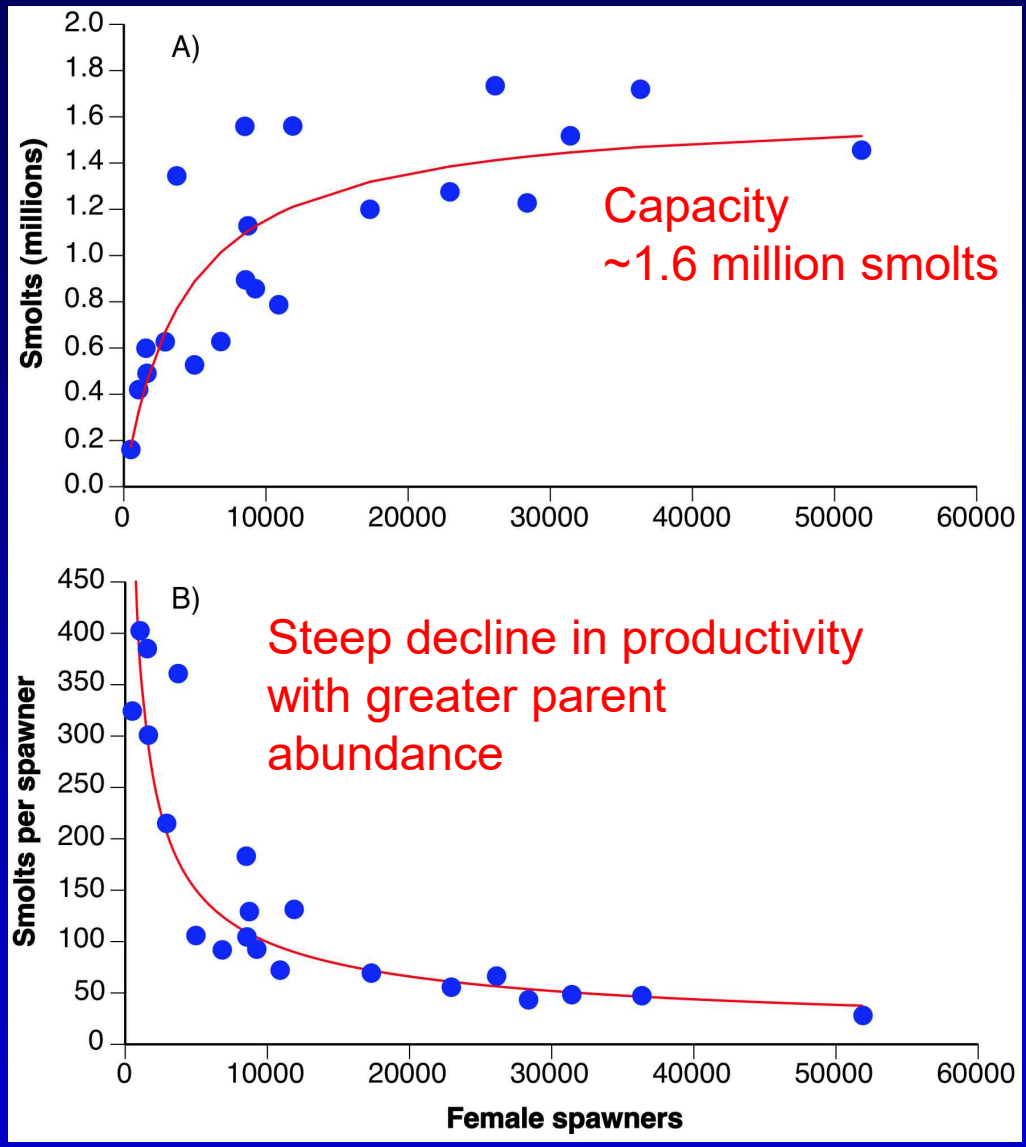
Density effects such as this can guide restoration actions



Walters et al. (2013a)

Snake R Spring/Summer Chinook: spawner to smolt

- Strong density dependence
- > ~20,000 females may not produce more smolts
- Smolt production in 1960s: ~2-4 million.
- Population resilience at low abundance



Source: Raymond (1979), Petrosky et al. (2001), Zabel et al. (2006), Kennedy et al. (2013), T. Copeland, IDFG.

Key Finding

Density dependence is now evident in most of the ESA-listed populations examined and appears strong enough to constrain their recovery.

Why? Aren't current abundances relatively low?

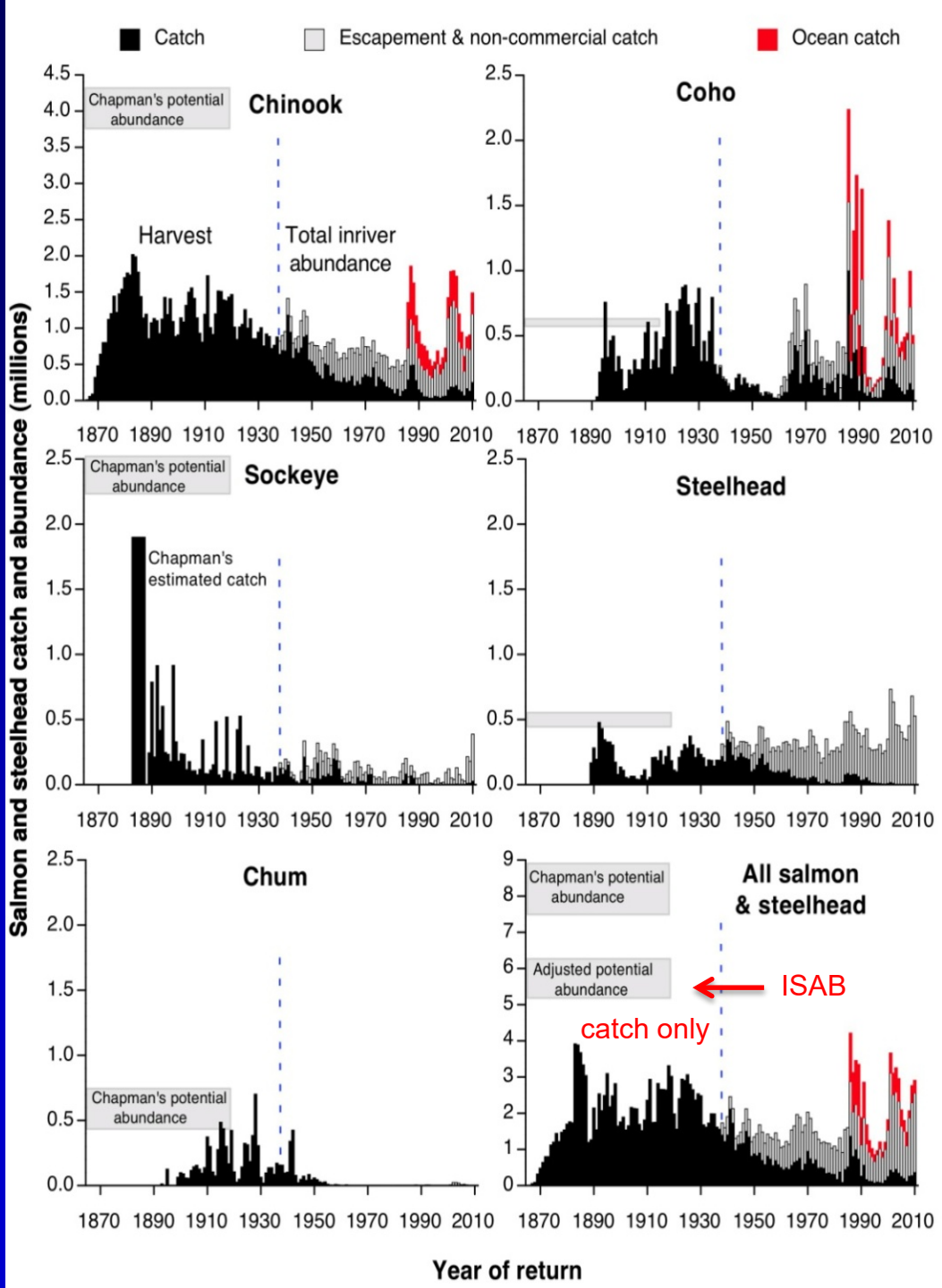
Pre-development Capacity of the Columbia River Basin

All Salmon & Steelhead

- Chapman (1986):

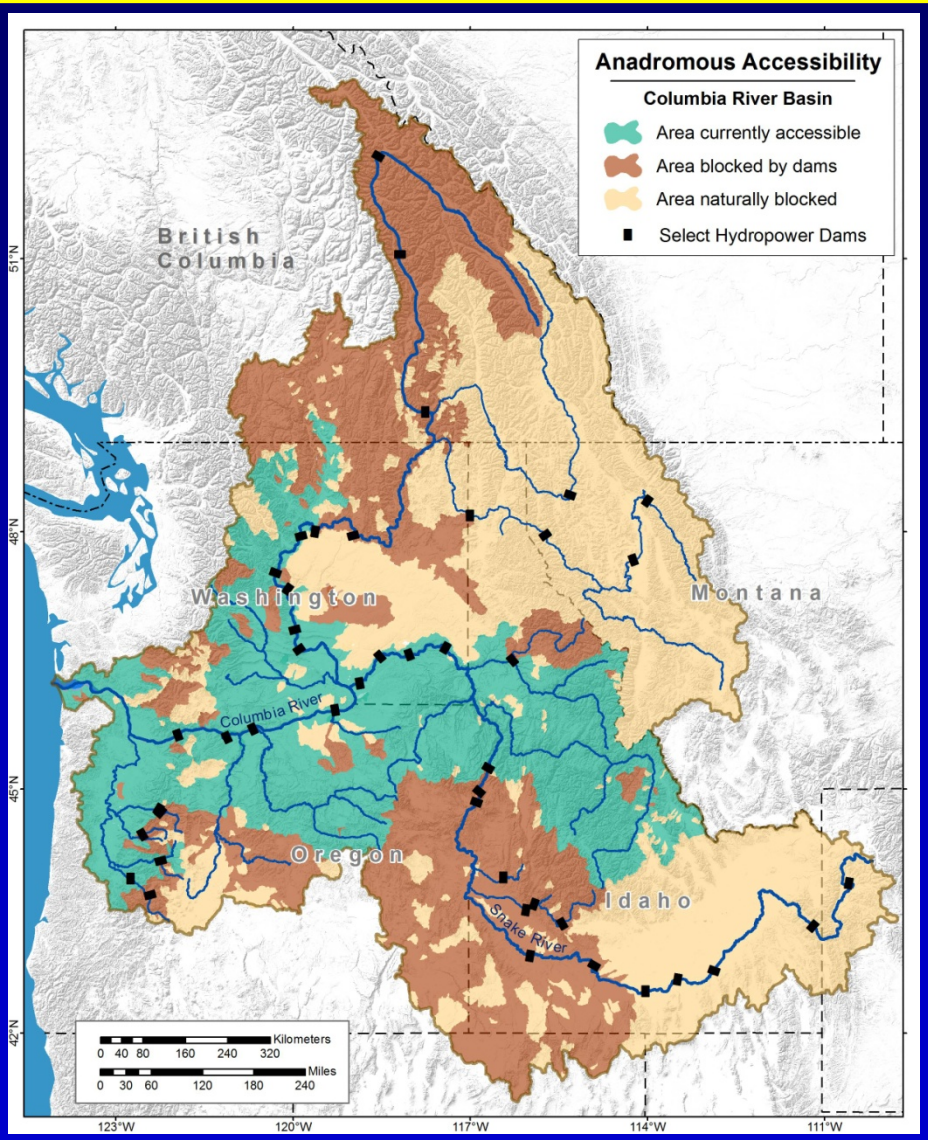
  7.5-8.9 million
- NPPC (1986): 9-16 million
- ISAB: ~~5-9 million
- Current abundance:

  2.3 million (2000-2012)



Area Blocked to Anadromous Salmon

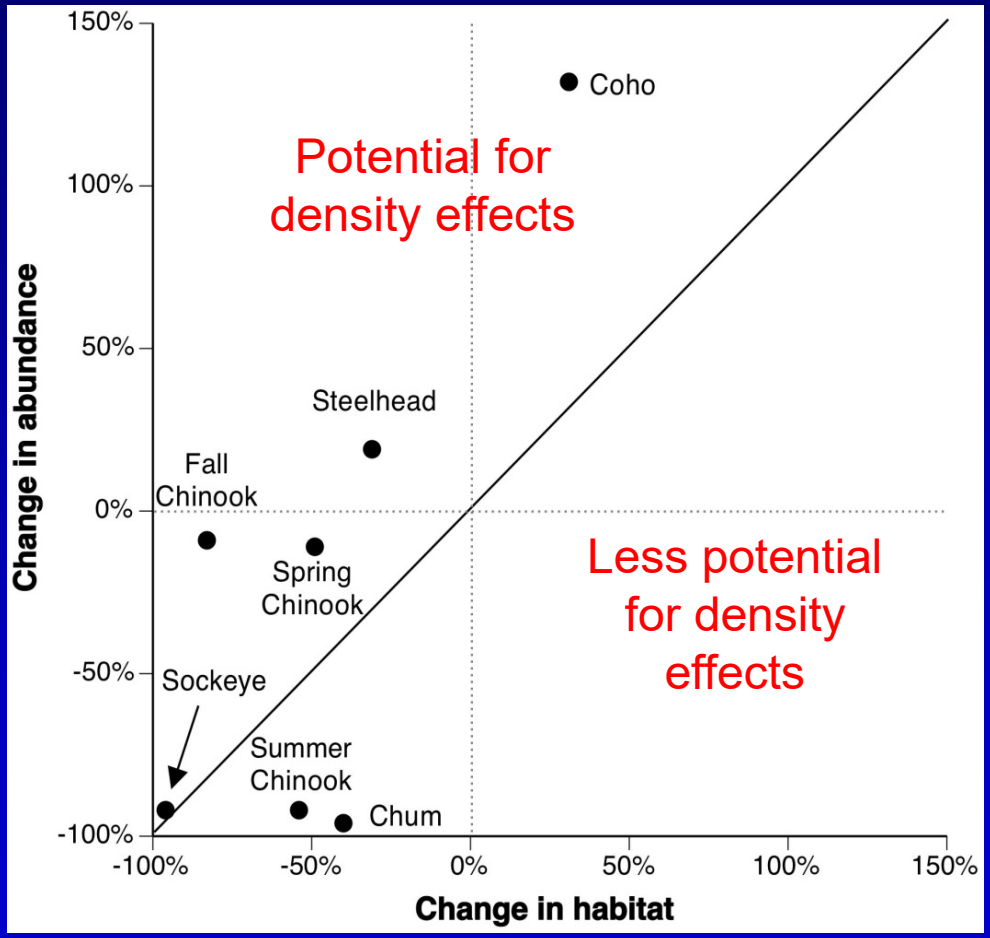
- 31% of previously accessible habitat now blocked.
- Impact varies by species.



Map produced for ISAB by Van C. Hare, PSMFC

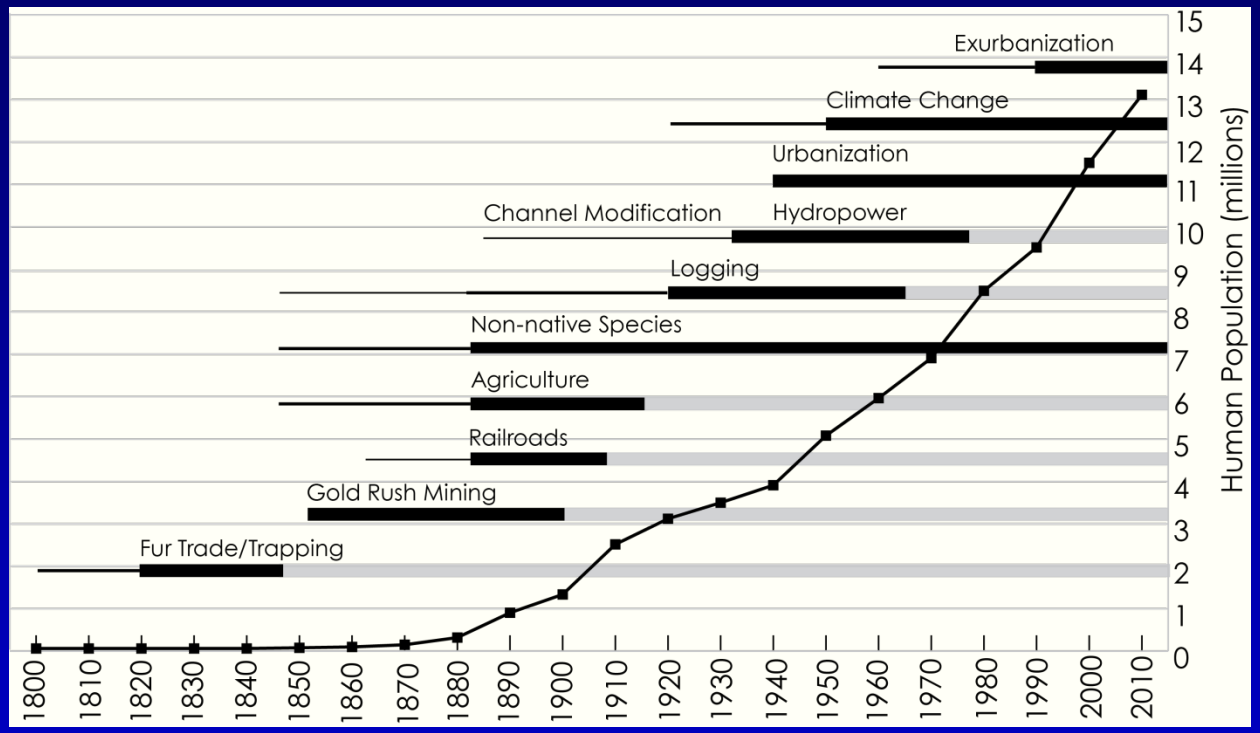
Could “density” (wild & hatchery salmon) be greater today?

- Initial evaluation of potential density effects.
- Change (%) in abundance versus accessible habitat: ~1850 to 1986-2010
- Spring & fall Chinook, coho, steelhead
- Caution (hatchery fish in hatcheries)



Columbia is Novel Ecosystem

- Habitat change impacts *intrinsic* productivity & capacity
- **Salmon capacity reduced by loss of diverse habitats that support diversity of life histories.**
- Invasion by non-native species



More Key Findings

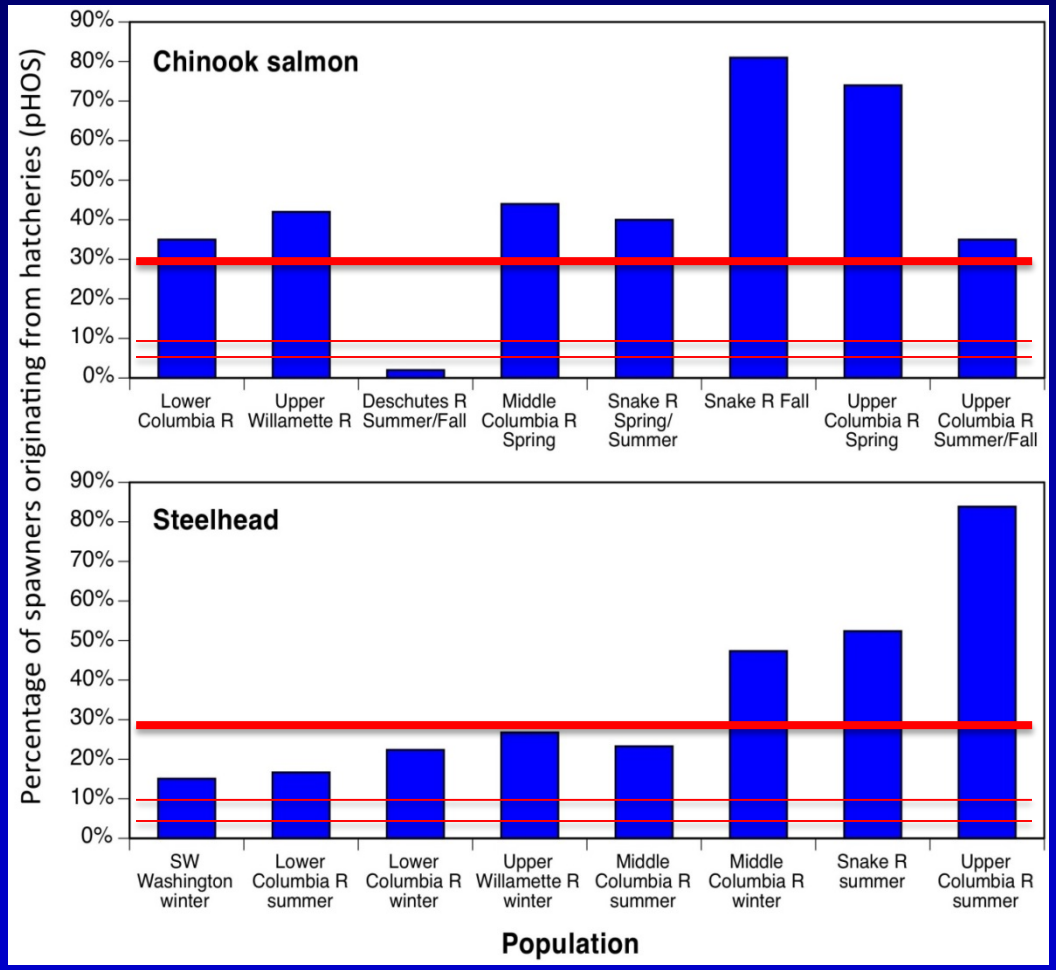
Hatchery salmon account for a large proportion of current salmon abundance & contribute to density effects:

- Total smolt densities may be higher now than historically
- Many hatchery adults spawn in rivers & capacity is often exceeded

- But primary cause of strong density dependence at low abundance is altered habitat, including the hydrosystem

Hatchery Contribution to Natural Spawners: Supplementation & Straying

- Many spring/summer Chinook & steelhead not sustainable at higher densities
- Integrated hatchery approach not possible without sustainable natural population
- *"At what level of supplementation do genetic and ecological risks outweigh demographic benefits, such that hatchery supplementation should be scaled back?"* T. Cooney

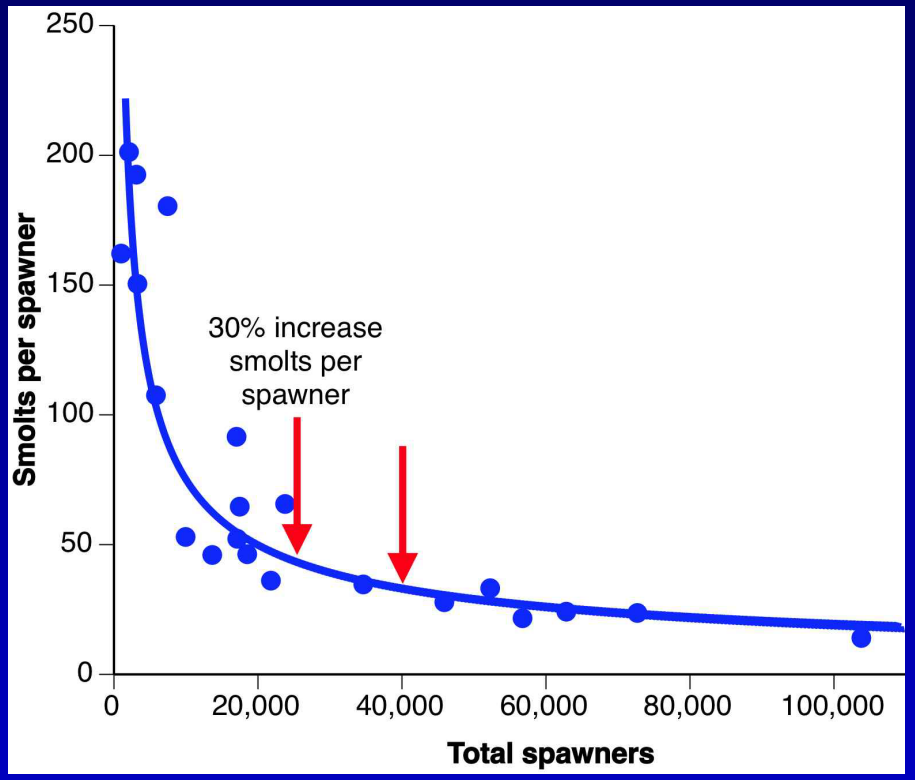


Modeled data, L. Mobrand, HSRG, February 2013.

Benefits from Considering Density Dependence

Example:

- 40,000 potential spawners
- 16,000 hatchery fish (pHOS = 40%)
- 14,400 harvest 90% hatchery fish
- 25,600 actual spawners
- 6% revised pHOS
- 30% increase smolts per spawner
- 17% loss in smolt production offset by higher smolt quality



Benefits:

- 1) reduce pHOS & promote adaptation
- 2) harvest more fish (terminal area)
- 3) increase salmon productivity (smolts per spawner)

Habitat restoration, including water transactions, could cause this curve to rise and become less steep, resulting from increased productivity and capacity.

Recommendations Recap

- Understand why density dependence occurs in particular habitats and life stages of fish (e.g., limitations in spawning habitat, rearing habitat or food supply, or predator-prey interactions). This can help guide habitat restoration and population-recovery actions.
- Set biologically-based spawning escapement goals or harvest rates that sustain fisheries and a resilient ecosystem. Use goals as a reference points.

Recommendations Recap, cont'd

- Account for density effects when evaluating habitat restoration actions. Otherwise findings may be misleading.
- Balance hatchery production with the Basin's capacity to support existing natural populations. Harvest surplus hatchery fish.

Reservoir Rearing by Chinook in Alaska

Chignik Lake, Alaska Peninsula

- Chinook spawn in outlet river (spawn habitat likely key limiting factor)
- Most Chinook fry rear in outlet river during spring and summer (potential limitation)
  - Avoid abundance coho predators in lake
- Chinook fingerlings enter the lake in late summer/fall & over-winter in lake
- Yearling Chinook rear in lake along with highly abundant coho and sockeye salmon (feeding interaction w/ other species may be limitation??)
- Yearling Chinook tend to be deeper than surface-oriented coho; both eat sockeye fry & insects.
- Lake rearing appears to support rapid growth

Questions?

"Nobody goes there anymore. It's too crowded."

Y. Berra 1998

Report available:

www.nwcouncil.org

End