Northwest **Power** and **Conservation** Council

March 3, 2015

MEMORANDUM

TO: **Council members**

FROM: **Erik Merrill and Jim Ruff**

SUBJECT: **ISAB Report - Density Dependence and its Implications for Fish Management and Restoration Programs in the Columbia River Basin**

BACKGROUND:

Presenters: Greg Ruggerone, ISAB Vice-Chair, and Kurt Fausch, ISAB member

Summary: In response to a March 2014 assignment from the Council, NOAA Fisheries, and Columbia River Indian tribes, the Independent Scientific Advisory Board (ISAB) reviewed the implications of density dependence in fish populations in the Columbia River Basin.

The ISAB's key findings include:

- Many salmon populations throughout the interior of the Columbia River Basin are experiencing reduced productivity associated with recent increases in natural spawning abundance, even though current abundance remains far below historical levels. Density dependence is now evident in most of the ESA-listed populations examined and appears strong enough to constrain their recovery. This fact raises the question: *Why is density dependence more evident than expected at low abundances?*
- The ISAB reanalyzed the admittedly limited historical data to better evaluate the potential capacity for salmon and steelhead in the Columbia Basin before hydrosystem development. The ISAB

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concludes that historical all-species capacity was likely in the range of 5 to 9 million adult fish per year, which is less than previously published estimates (e.g., 7.5 to 16 million adults per year) but still much higher than current abundance levels (~2.3 million fish per year during 2000-2012).

- Evidence for strong density dependence at current abundance suggests that habitat capacity has been greatly diminished. Roughly one-third of the Basin is no longer accessible to anadromous salmon, and continuing changes to environmental conditions stemming from climate change, chemicals, and intensified land use appear to have further diminished the capacity of habitat that remains accessible. Density dependence was also observed in some less altered watersheds.
- Hatchery releases account for a large proportion of current salmon abundance. Total smolt densities may be higher now than historically. By creating unintended density effects on natural populations, supplementation may fail to boost natural origin returns despite its effectiveness at increasing total spawning abundance.
- Identifying mechanisms that contribute to density dependence in particular habitats and life stages—such as limitations in spawning habitat, rearing habitat or food supply, or predator-prey interactions—can help to guide habitat restoration and population recovery actions.
- Understanding density dependence (e.g., stock-recruitment relationships) in salmon populations is central to evaluating responses to recovery actions and for setting spawning escapement goals that will sustain fisheries and a resilient ecosystem.

The ISAB's key recommendations include:

Anadromous salmonids

- Account for density effects when planning and evaluating habitat restoration actions.
- Establish biological spawning escapement objectives that account for density dependence.
- Balance hatchery supplementation with the Basin's capacity to support existing natural populations by considering density effects on the abundance and productivity of natural origin salmon.
- Improve capabilities to evaluate density dependent growth, dispersal, and survival by addressing primary data gaps.

Non-anadromous salmonids

- Recognize that carrying capacity for non-anadromous salmonids can be increased by restoring in-stream structure and riparian vegetation.
- Recognize that carrying capacity for non-anadromous salmonids can be reduced through competitive interactions with stocked hatchery trout or invasive non-native trout.

- Consider the probable effects of density on survival, emigration, growth, and size/age at maturity when developing angling regulations to achieve conservation and recreational goals.

Sturgeon

- Consider habitat capacity and the probable effects of density on growth and survival when developing stocking programs to conserve white sturgeon.

Lamprey

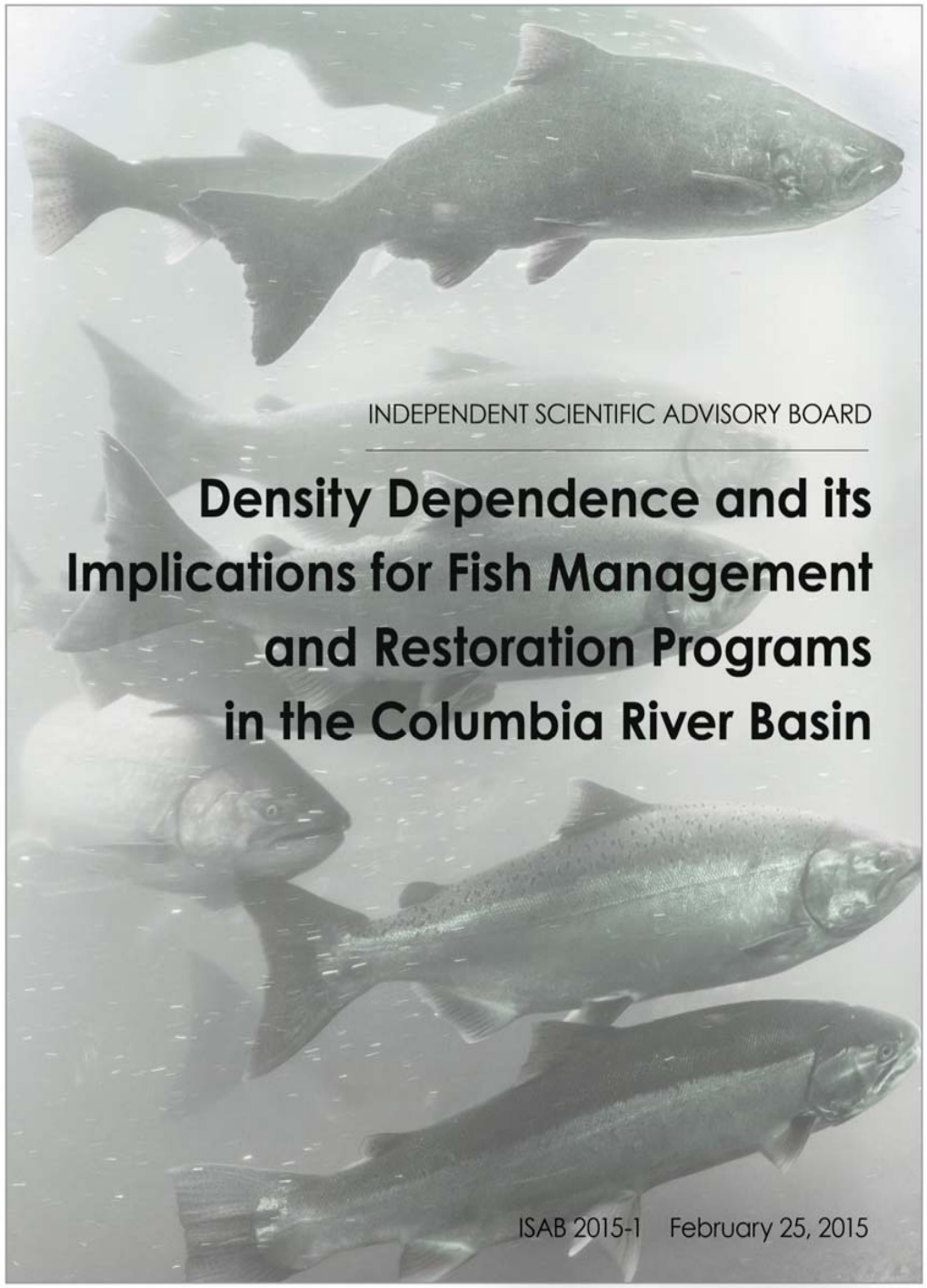
- Initiate studies to gather information about current densities of Pacific lamprey in the Basin and to learn about density dependent processes that might thwart efforts to promote their recovery.

- Consider lessons learned about supplementation and density dependence in anadromous salmonids when planning future actions to propagate and translocate (i.e., supplement) lamprey within the Basin.

Relevance: Understanding density dependence—the relationship between population density and population growth rate—is important for effective implementation of the Columbia River Basin Fish and Wildlife Program, biological opinions, recovery plans, and tribal programs. Information on how density dependence limits fish population growth and habitat carrying capacity is vital for setting appropriate biological goals to aid in population recovery, sustain fisheries, and maintain a resilient ecosystem. Habitat restoration and population recovery actions can be planned and implemented more effectively by understanding mechanisms that cause density dependence in particular cases, such as limited food supply, limited rearing or spawning habitat, or altered predator-prey interactions.

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/isab2015-1



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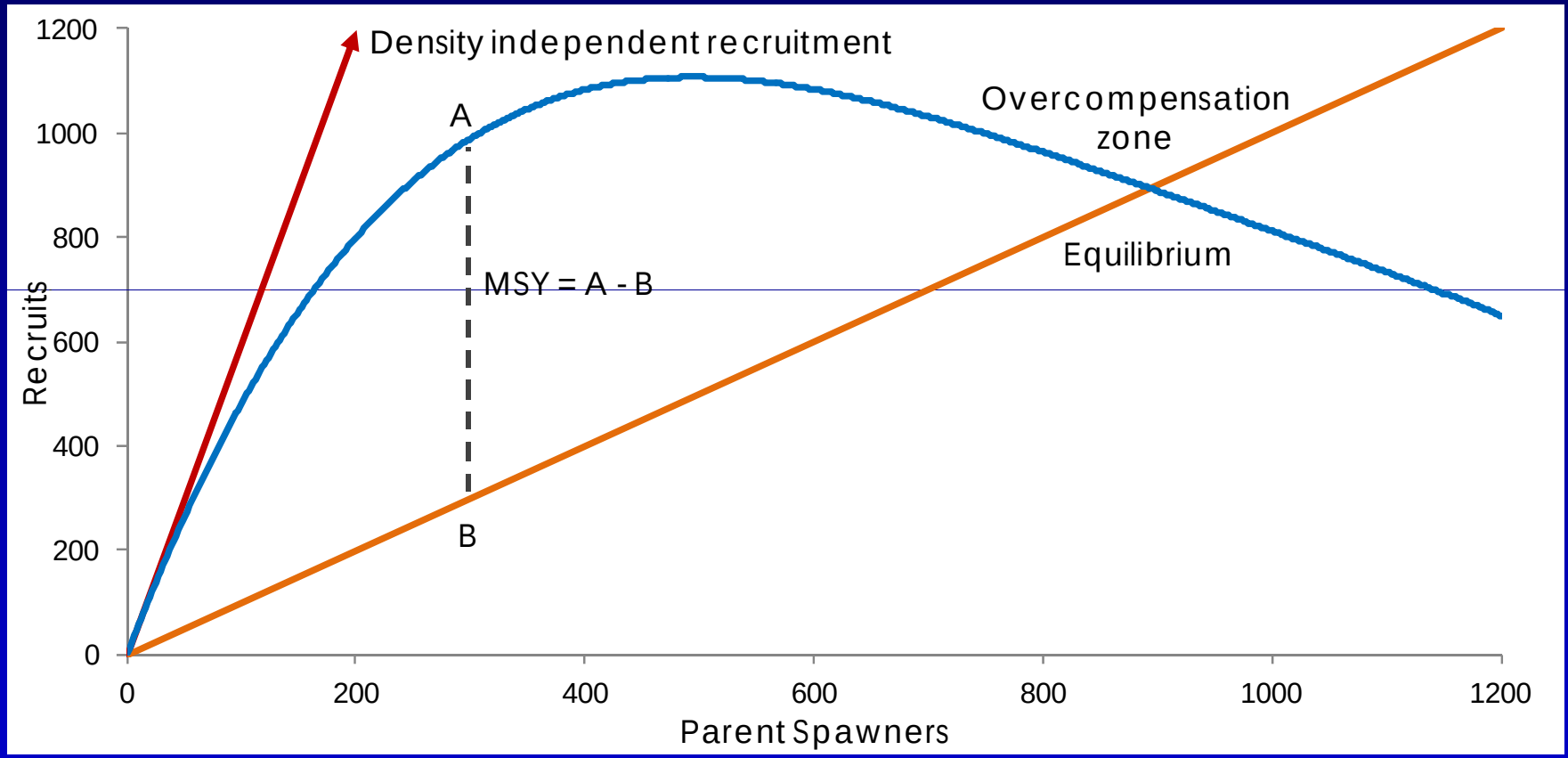
Presentation to Council
March 11, 2015

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.

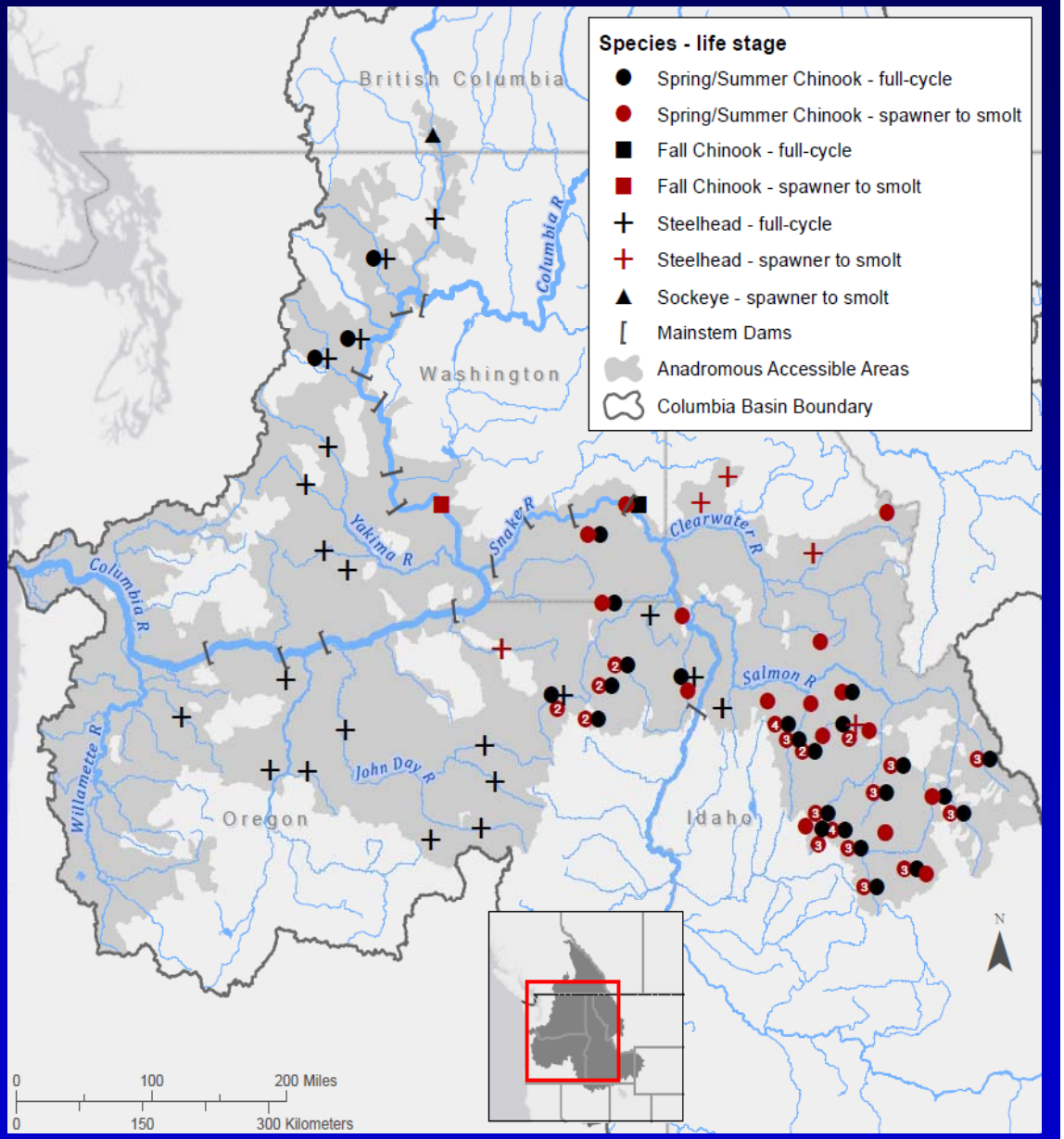
Key Recommendation

Account for density effects when planning and evaluating:

- habitat restoration actions
- hatchery supplementation
- spawning escapement goals

Compensatory Density Dependent Studies: Where?

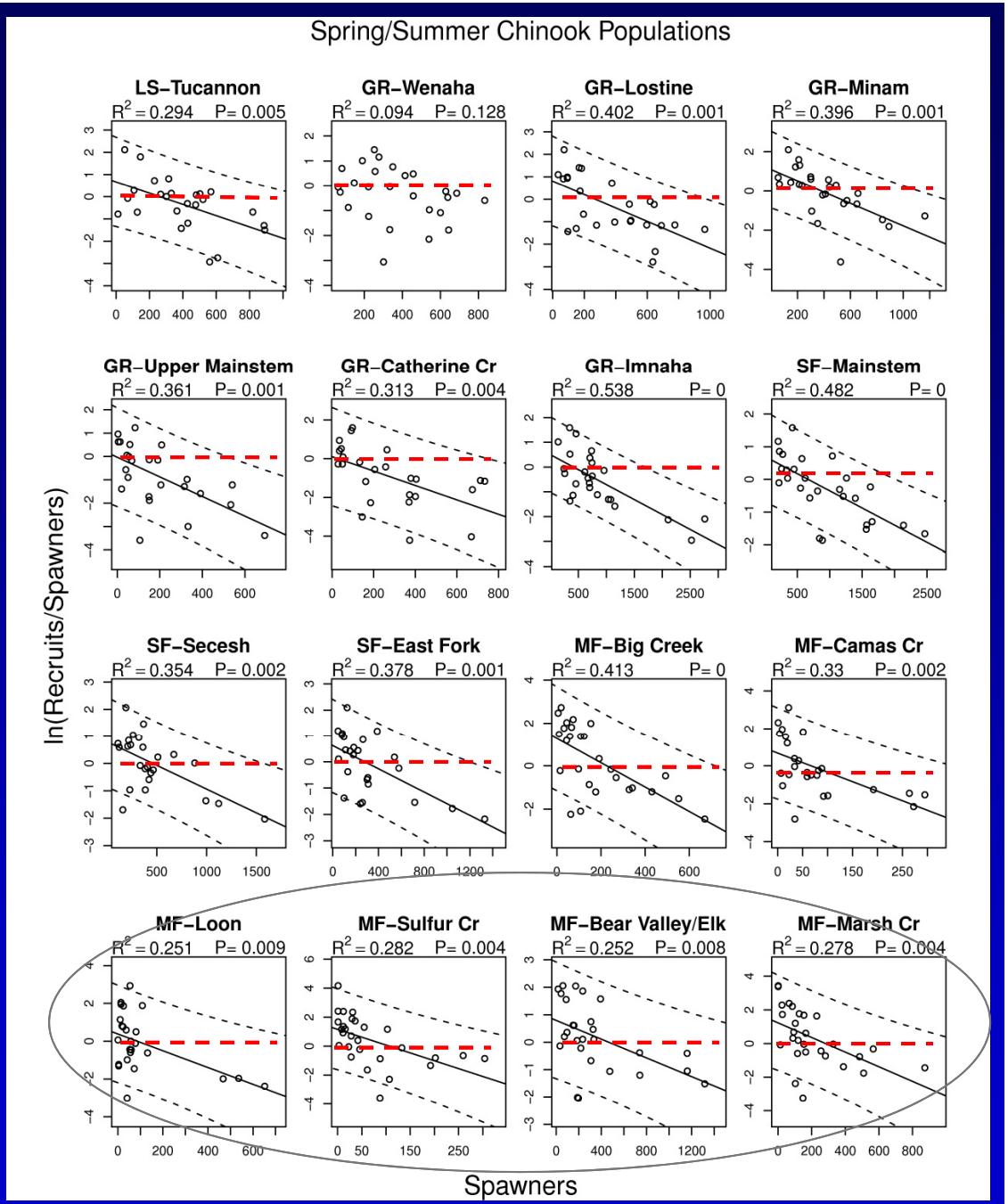
- Primarily spring/summer Chinook & steelhead in the interior.
- Few studies below Bonneville & during juvenile emigration.
- Few coho studies.



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: DD
- All 20 Interior Columbia River steelhead populations: Strong DD.
- R/S often < 1 (must improve conditions to achieve recovery)
- What life stage?

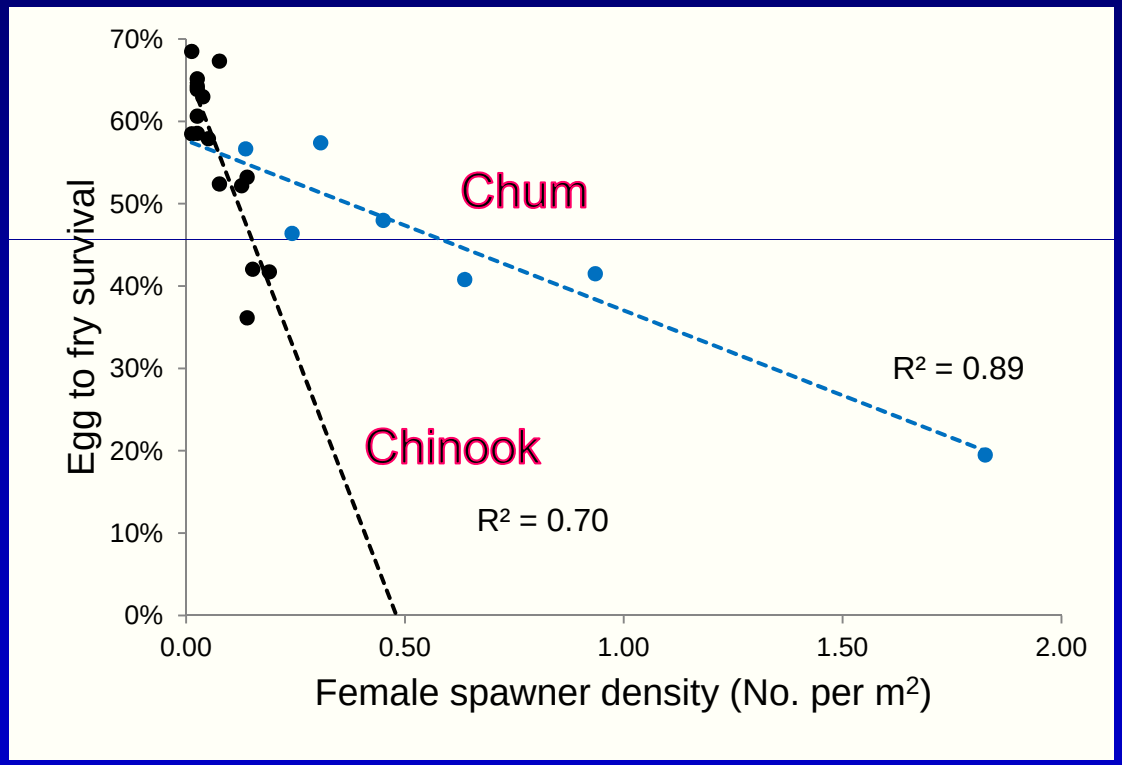


Source: Zabel & Cooney 2013

Spawning Stage: Chinook v. Chum

Experimental Spawning Channel

- 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

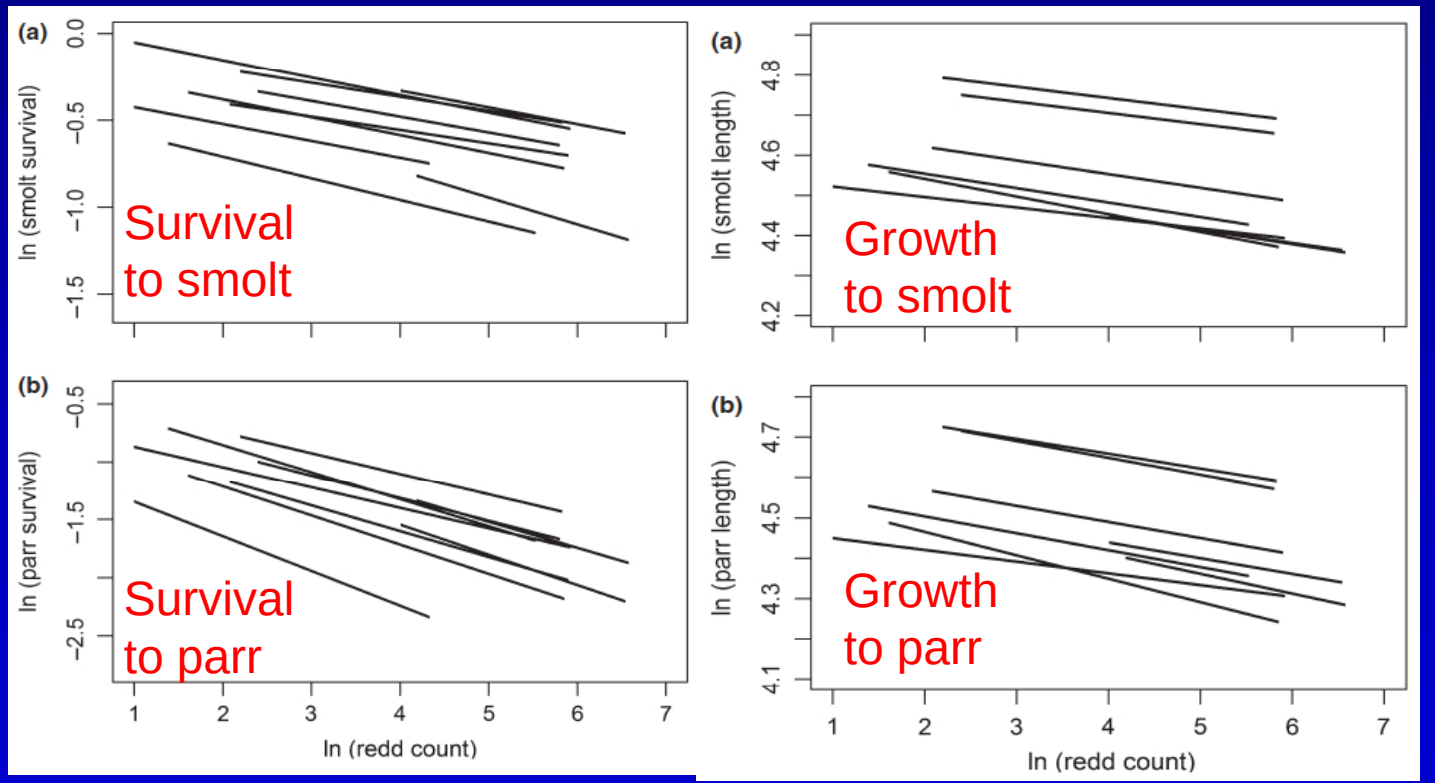


Source: Schroder 1974, Schroder et al. 2008

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.

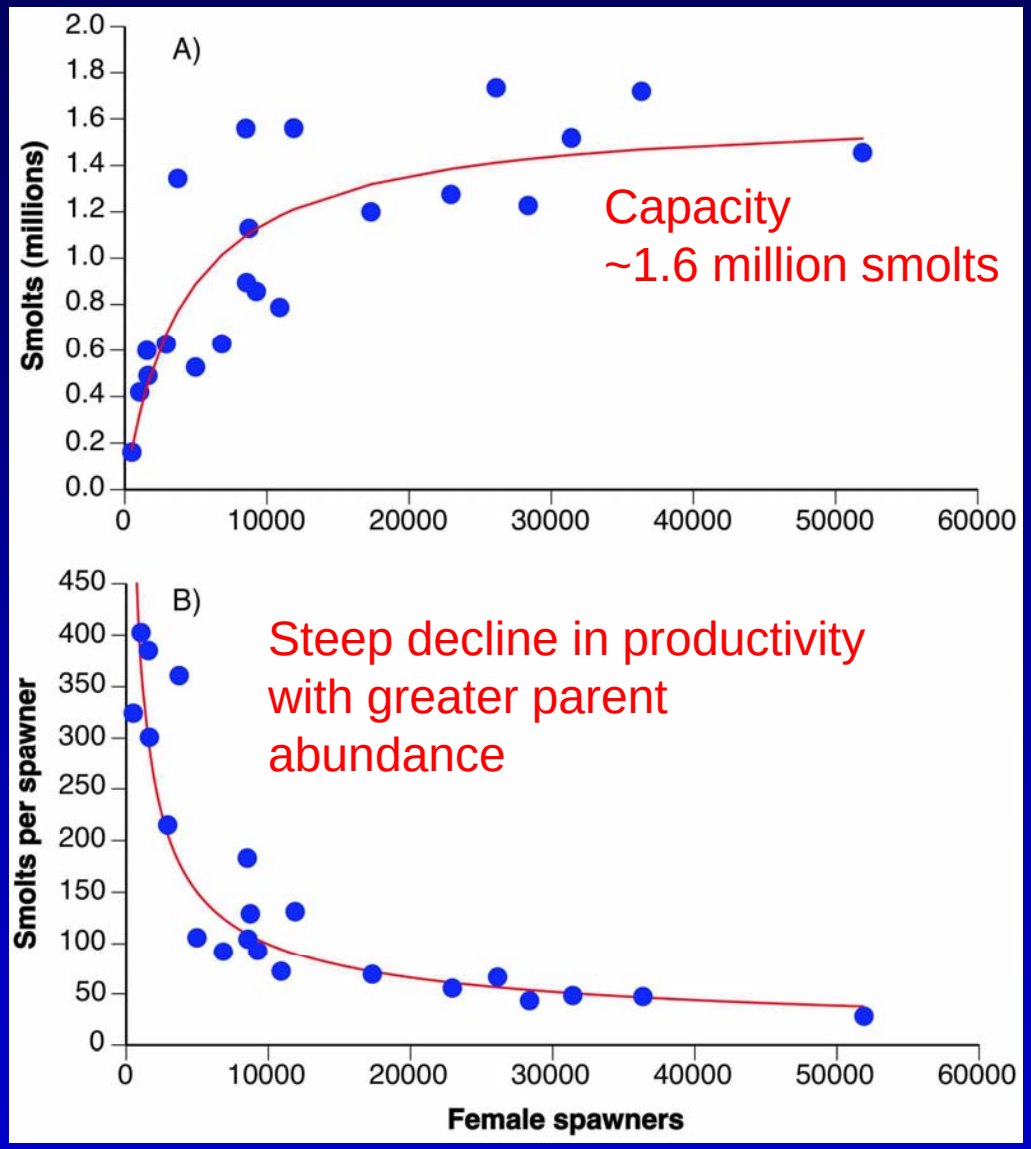
Density effects such as this can guide restoration actions



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.
- <u>Population resilience at low abundance</u>



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

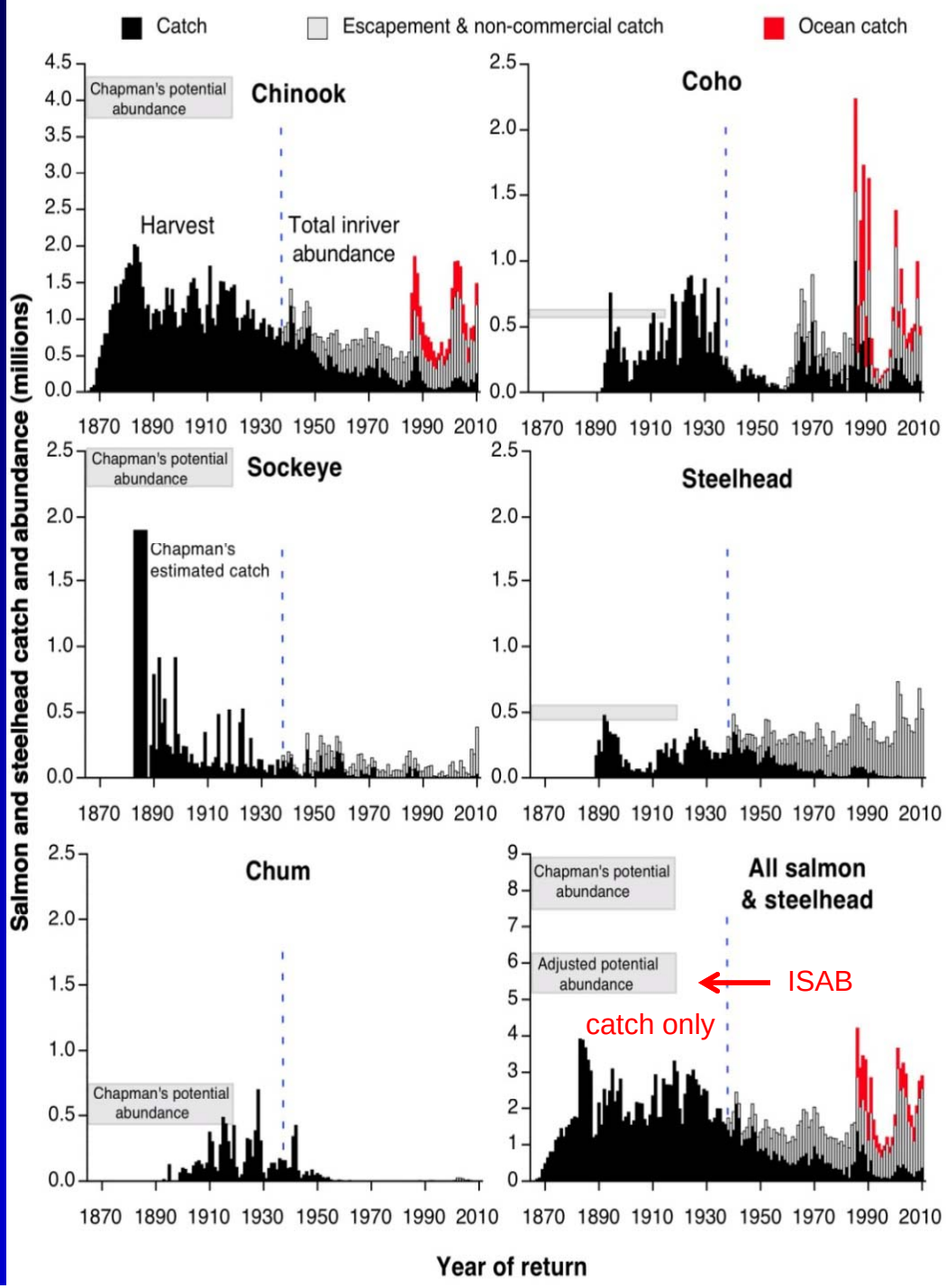
All Salmon & Steelhead

- Chapman (1986):

  7.5-8.9 million

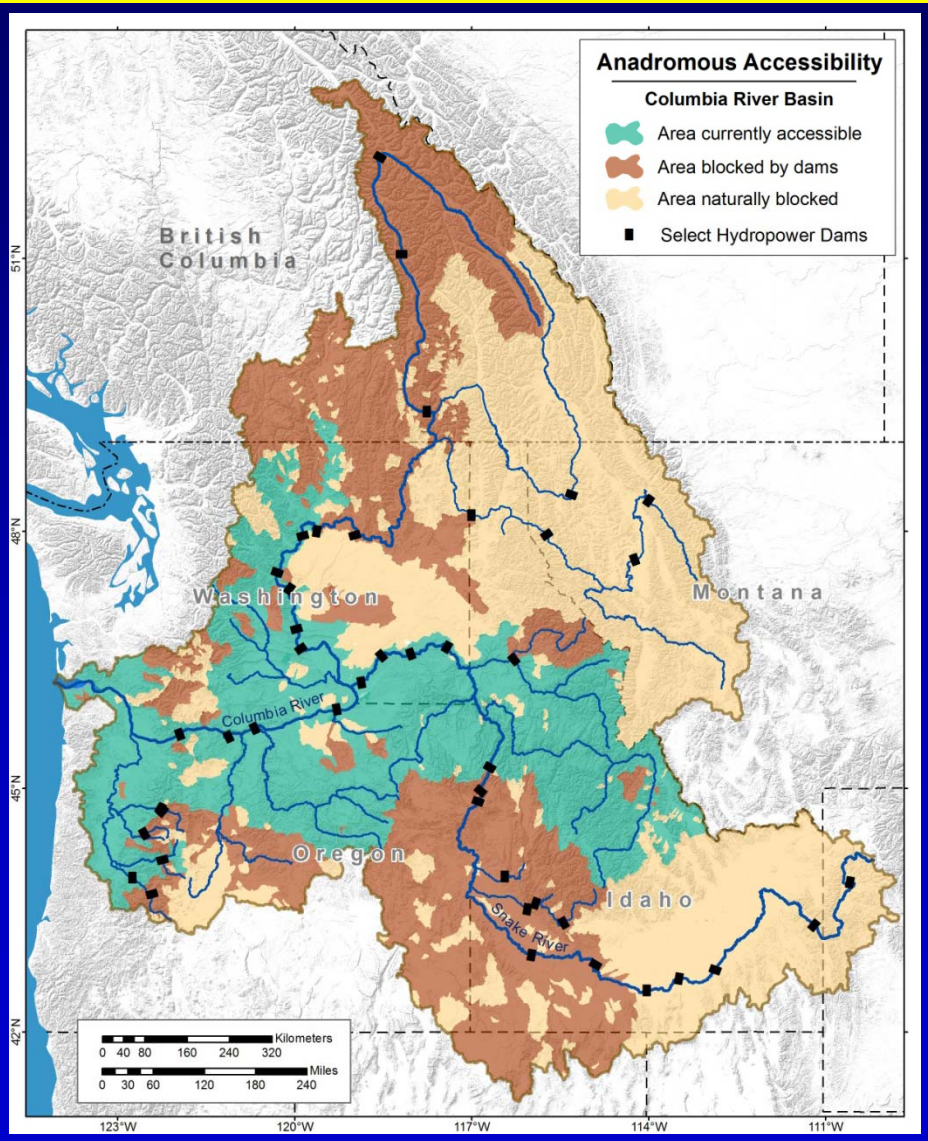
- NPPC (1986): 9-16 million

- ISAB: ~~5-9 million



Area Blocked to Anadromous Salmon

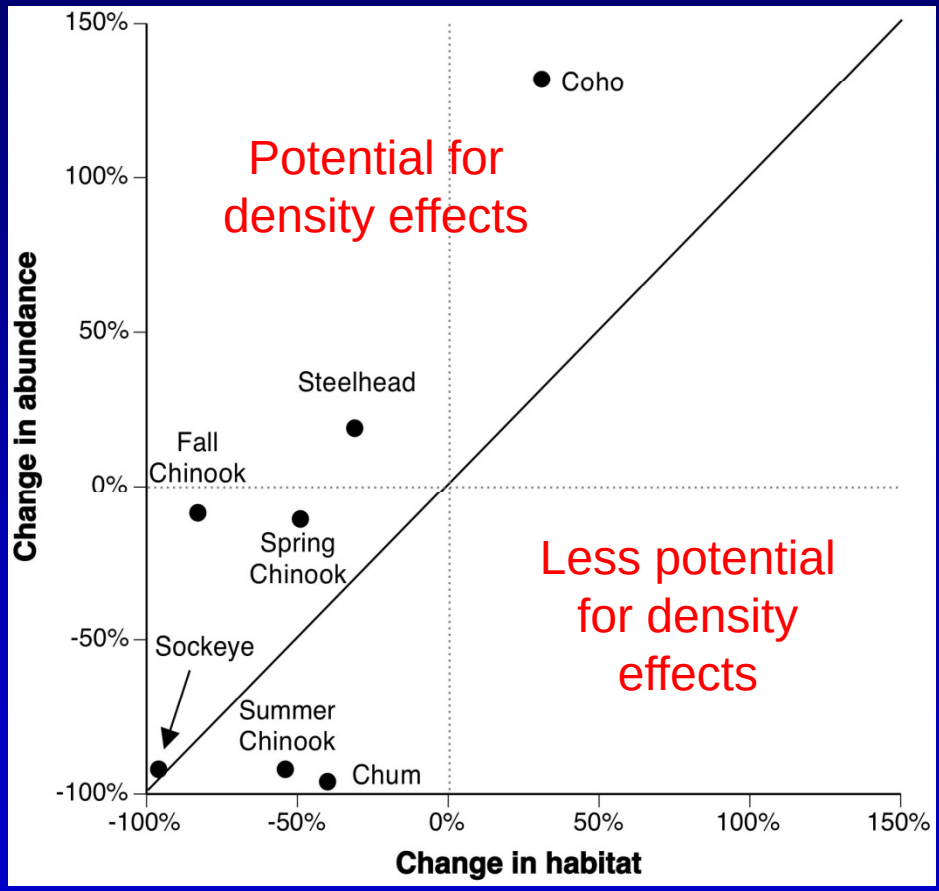
- 31% of previously accessible habitat now blocked.
- Impact varies by species.



Map produced for ISAB by Van C. Hare, PSMFC

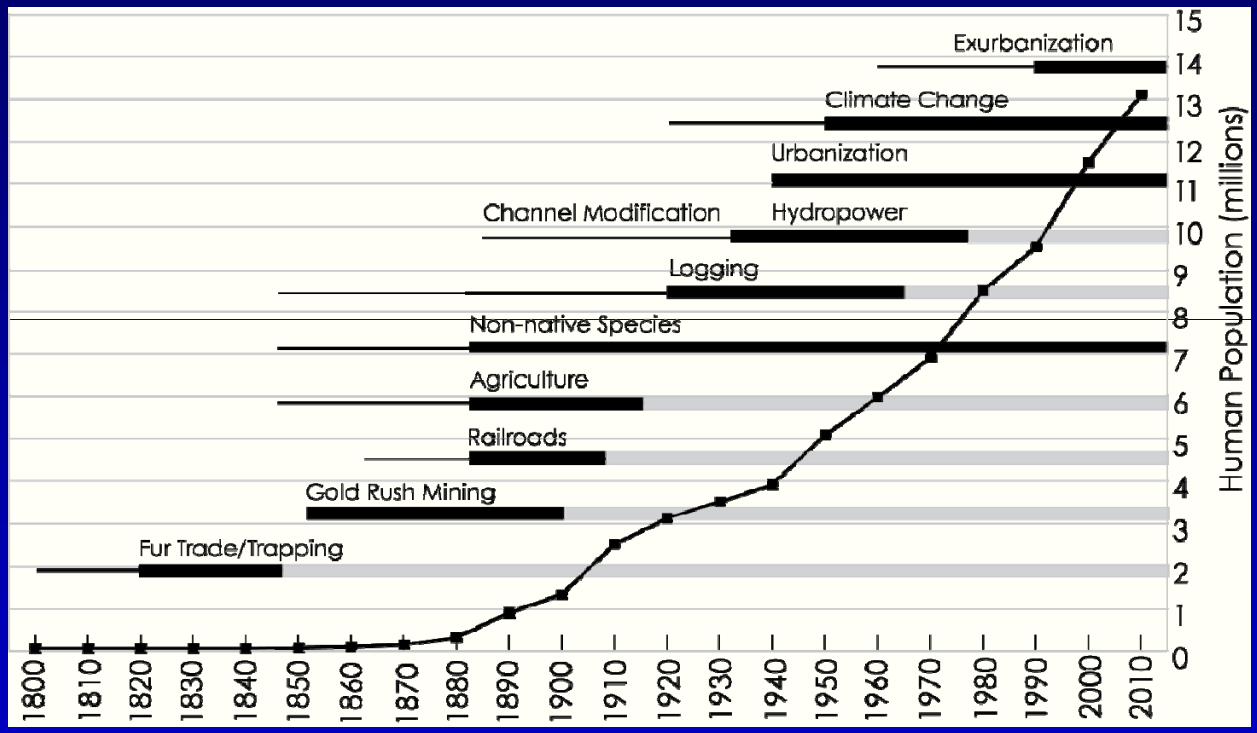
Could “density” (wild & hatchery salmon) be greater today?

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



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



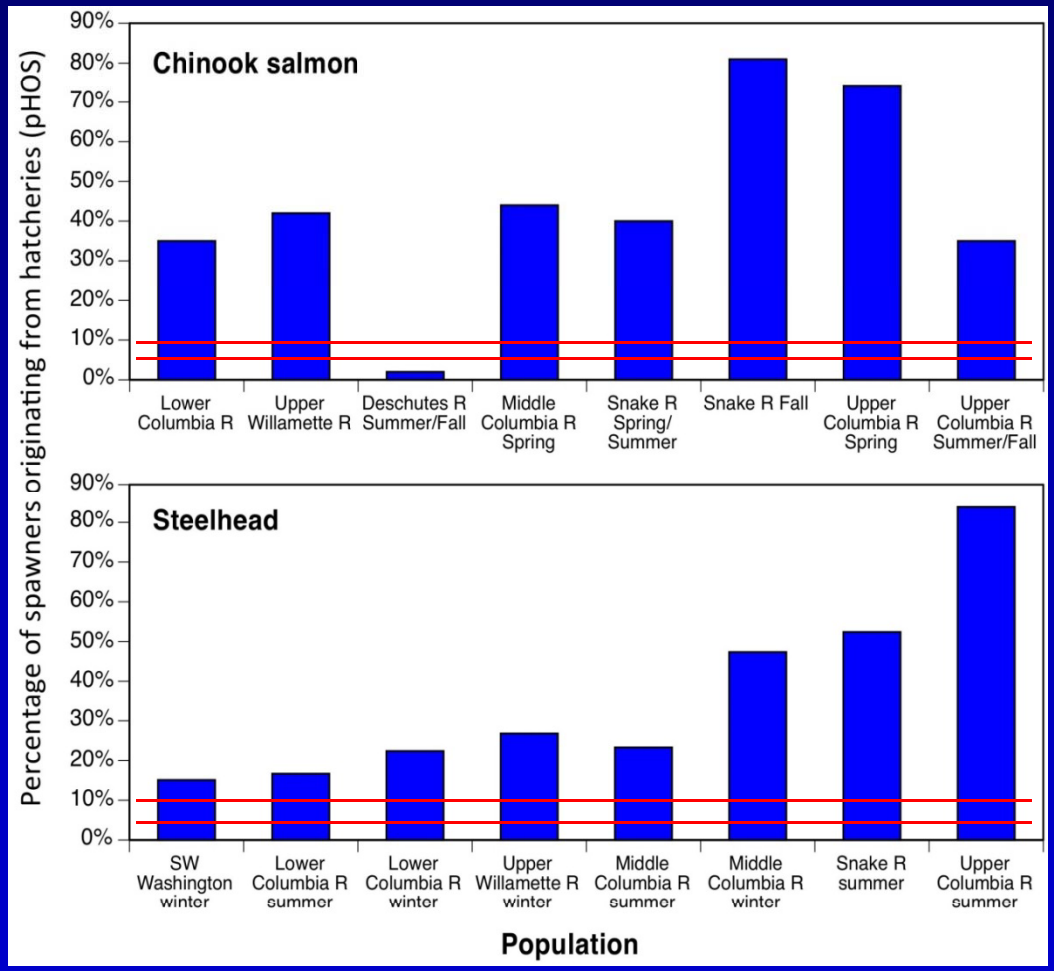
Key Findings (Anadromous) cont'd

Hatchery releases account for a large proportion of current salmon abundance

- Total smolt densities may be higher now than historically.
- By creating unintended density effects on natural populations, supplementation may fail to boost natural origin returns despite its effectiveness at increasing total spawning abundance.

Hatchery Contribution to Natural Spawners: Supplementation & Straying

- Supplementation & straying contribute to density effects
- Many spring/summer Chinook & steelhead not sustainable at higher densities
- Integrated hatchery approach not possible without sustainable natural population
- pHOS guidelines for segregated hatchery shown (red lines)

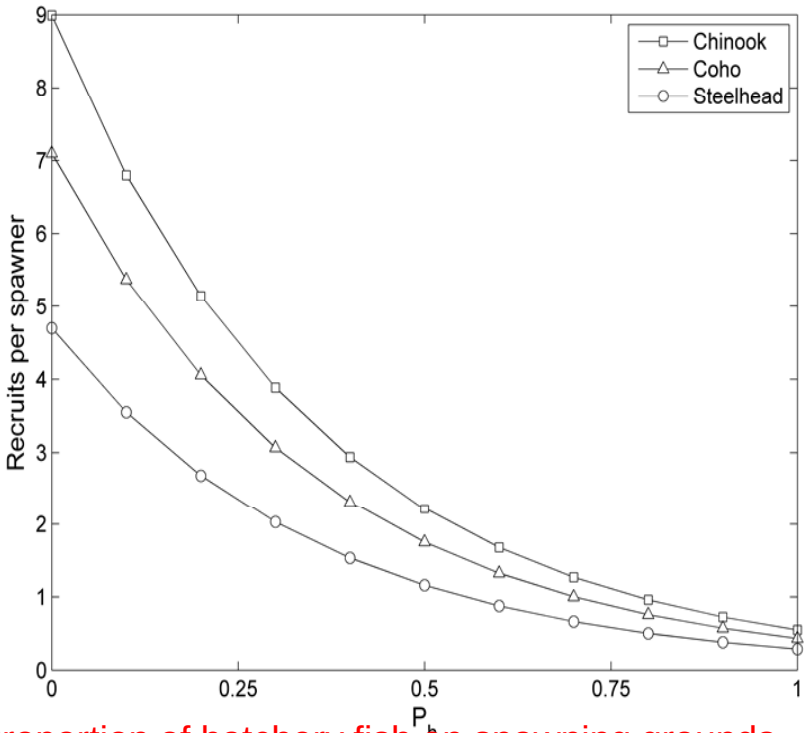


Modeled data provided by L. Mobrand, HSRG, February 2013.

“Supplementation” Effects on Recruitment

“Supplementation” lowers *intrinsic* productivity & resilience of Chinook, coho, steelhead (20 yrs of data, 71 populations).

Supplementation may not provide population boost even with increased spawner abundance (Spring/Summer Chinook).

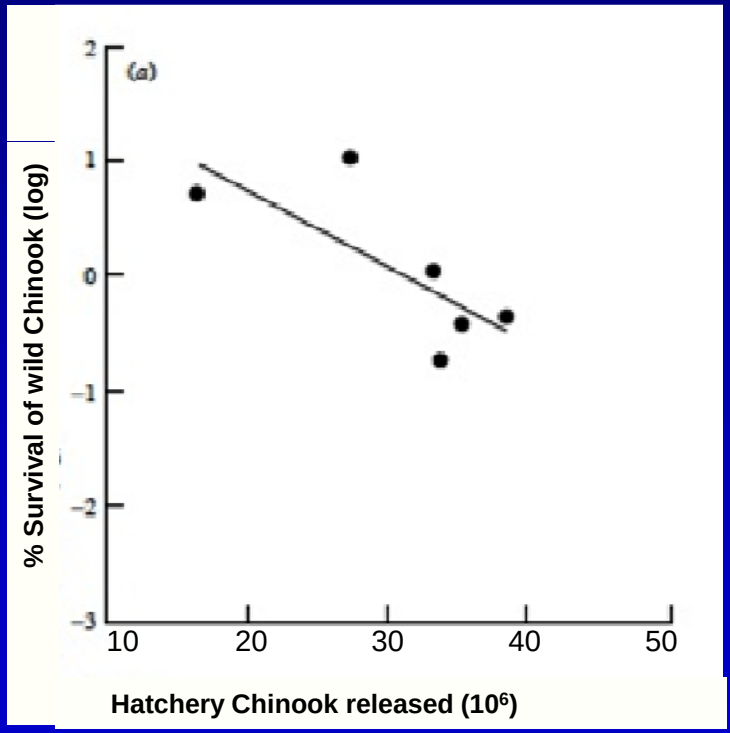


Proportion of hatchery fish on spawning grounds

Chilcote et al. (2013)
Buhle et al. (2013, 2014)

Estuary and Ocean Rearing

- Density dependence in estuary & ocean is a data gap for Columbia R species
- Evidence for density dependence in estuary and ocean found in other regions
- Estuarine habitat restoration in Columbia Basin focuses on habitat diversity and habitat capacity to support subyearling salmonids
- Spring Chinook survival at sea declined with hatchery Chinook releases but only with poor ocean conditions



Source: Levin et al. 2001

Part II: "Resident" trout, kokanee, sturgeon, and lamprey

- Different animals, different questions
- Trout: Four questions re: DD and carrying capacity (CC)
  - Habitat restoration ***Complicated***
  - Hatchery stocking ***Clear***
  - Nonnative trout invasions ***Relatively clear***
  - Angling regulations/closures ***Relatively clear***

- Does habitat restoration increase CC, and trout density?
  - Trout move in and stay
  - Survive better first year
- Does stocking reduce CC for wild trout?
  - Modest effects on growth and none on survival
  - Comprehensive study in ID detected no effects
  - Hybridization and disease are common

- Do nonnative trout ruin the neighborhood for natives?
  - Removal increased native trout 10 times
  - Brook trout pack in more tightly
    - Greater load on ecosystem; can reduce spiders and birds
- Can native trout populations rebound when fishing is reduced?
  - Slow-growing bull trout can
  - Reach new limits

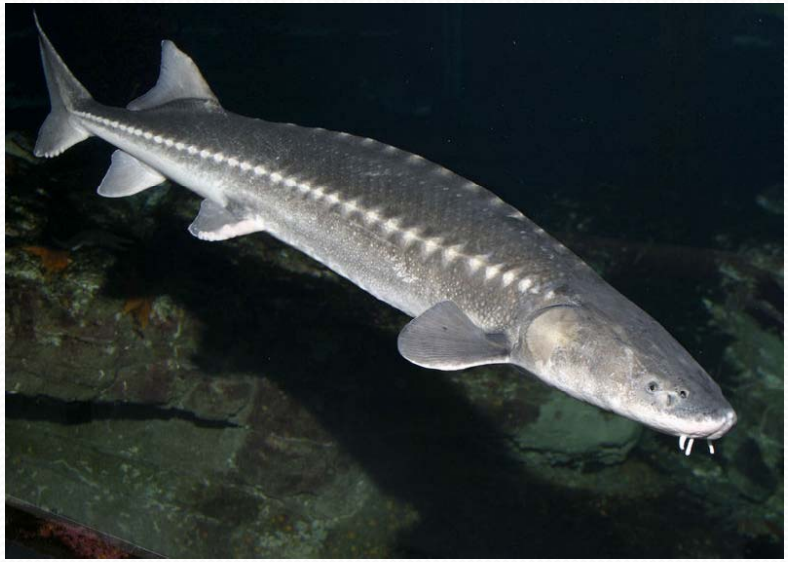
Kokanee

- Kokanee widely stocked, with widely fluctuating populations
  - Limited plankton food in unproductive reservoirs
  - Fluctuating flows kill eggs/fry, but increase growth
  - Manage for the middle (Goldilocks)

www.fishwithjd.com

Sturgeon

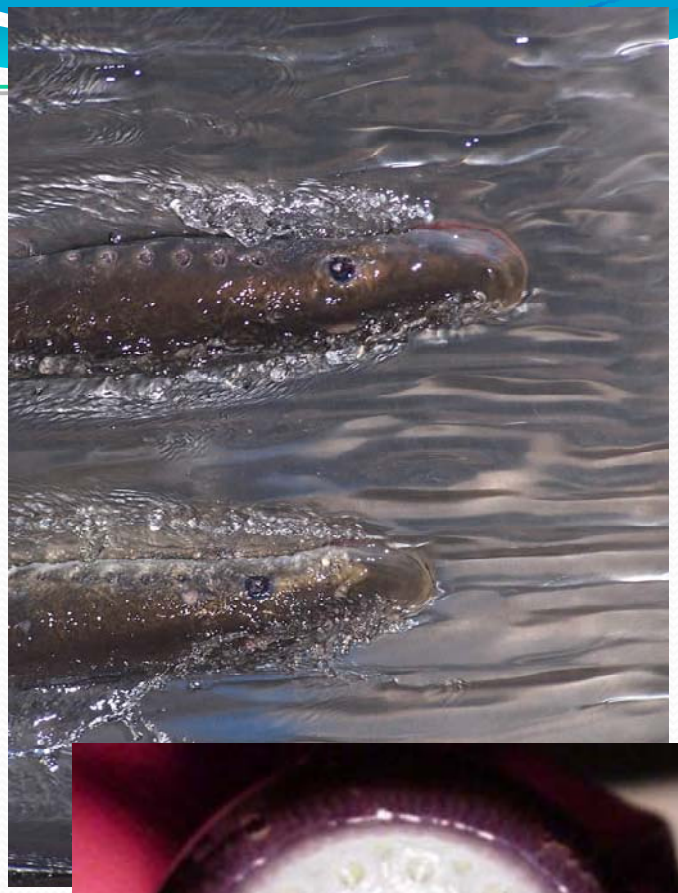
- Declined basin-wide, esp. above Bonneville
  - Low reproduction and juvenile survival
- Endangered Kootenai River population
  - Stocking for conservation
  - Lower growth and survival with more stocking
  - Lower temperature and fewer nutrients with Libby Dam
  - Realistic goals in “novel ecosystems”

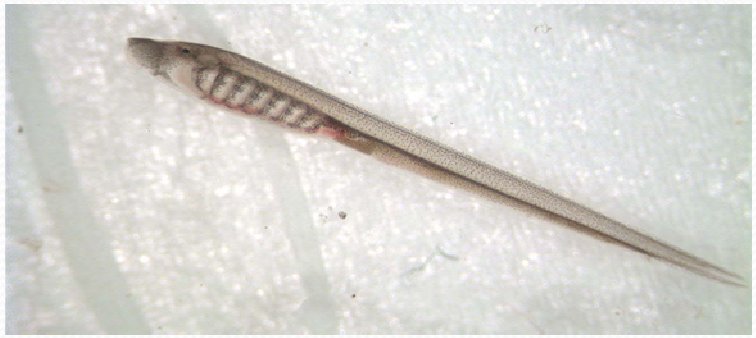


www.montereybayaquarium.com;
www.buffalopost.net

Lamprey

- Density has declined sharply in last 40 years
- Some hints that crowding affects repro/growth/survival
- Numbers rise/fall with host fish in ocean





Images courtesy A. Maule, L. Weiland

Recommendations Recap (All species)

- Understand why density dependence occurs in particular habitats and life stages of fish, such as 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 also a resilient ecosystem & use goals as a reference points.

Recommendations Recap, cont'd (All species)

- Account for density effects when evaluating habitat restoration actions.
- Balance hatchery production with the Basin's capacity to support existing natural populations.
  - Anadromous salmonids
  - Trout
  - Sturgeon
  - Lamprey
- Consider density dependence findings & recommendations when implementing the Fish & Wildlife Program.

Questions?

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

Y. Berra 1998