Some trends in hatchery effects science

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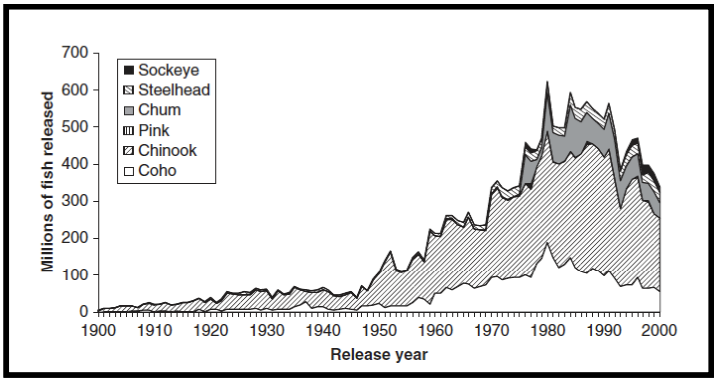
Context

- Hatcheries in PNW first appear late 1800's
- Major production increases in 1960's, levels off in the '80's, declines more recently

Source: UW Image Library



Source: Naish et al. 2007

Purposes

- Mitigation for habitat loss
- Fishery enhancement
- Supplementation

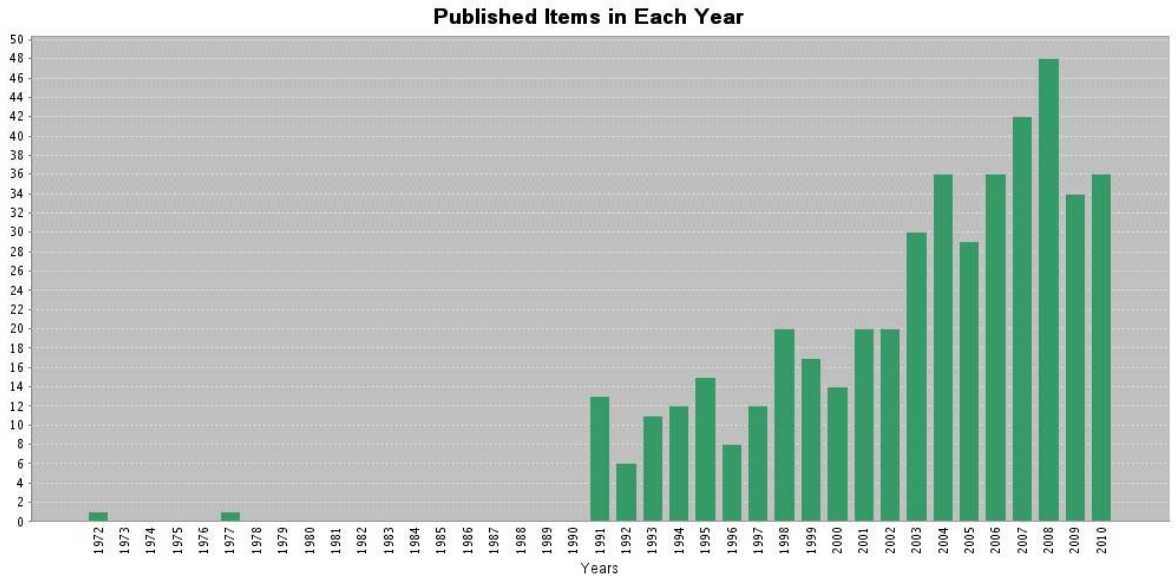
Benefits of hatcheries

- Fishery benefits
  - Numerous fisheries target hatchery stocks and depend on hatchery production
- Conservation benefits
  - Supplementation
  - Safety nets
  - Gene banks
- Ecosystem benefits
  - Killer whale food
  - Source of marine nutrients for terrestrial ecosystems

Risks (to wild populations) from hatcheries

- Biological risks to wild salmon
  - Genetic
    - Domestication, loss of diversity
  - Ecological
    - Competition, Predation, Disease
- Societal interactions
  - Take money and effort away from habitat problems
  - Overharvest of wild stocks
  - May not be sustainable in the long-term

Trends in hatchery science:

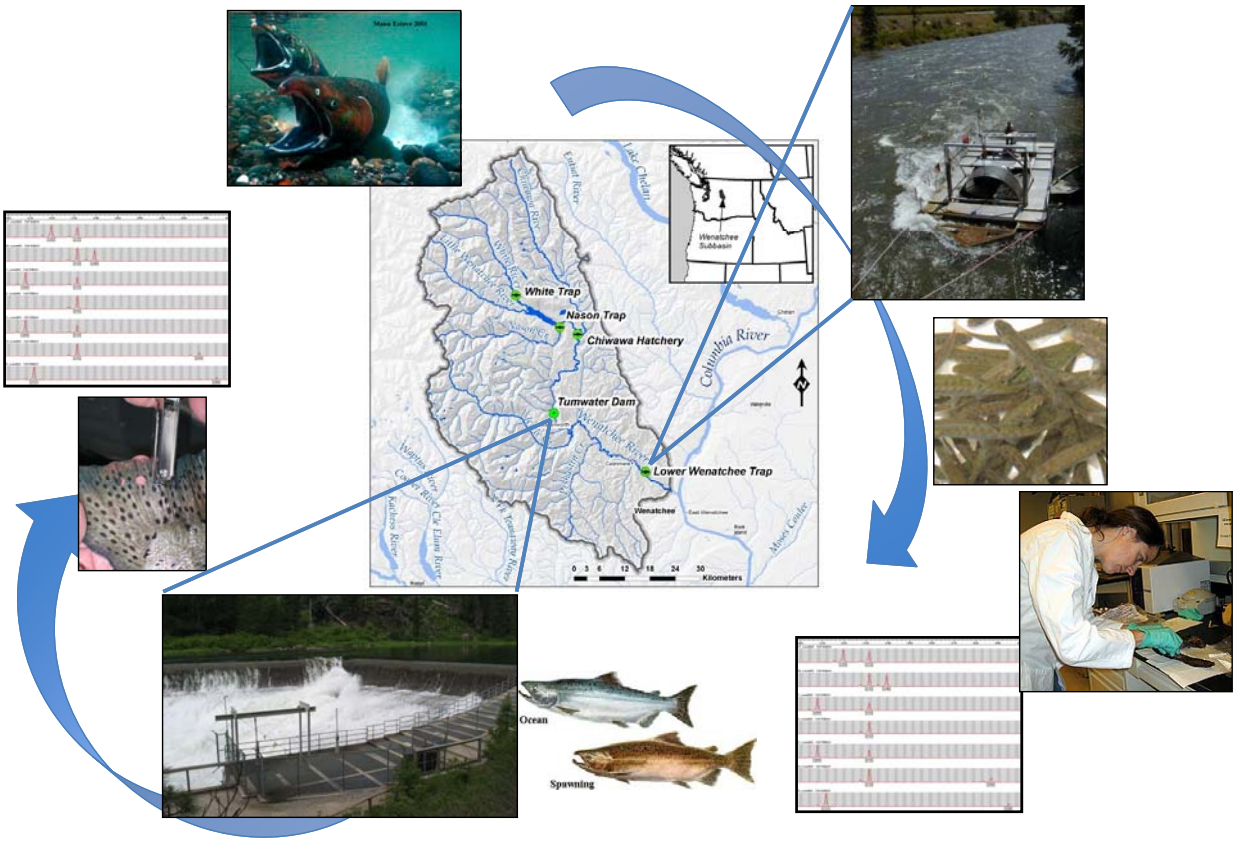


Topic=(hatchery AND (wild OR natural) AND (salmon OR trout) AND (fitness OR reproductive success OR survival))

2 emerging trends, and 2 nagging questions

- Trends
  - Poor reproductive success of hatchery fish
  - Large scale negative correlations between the presence of hatchery fish and wild population performance
- Nagging questions
  - What causes the trends?
  - Are there large scale, cumulative effects?

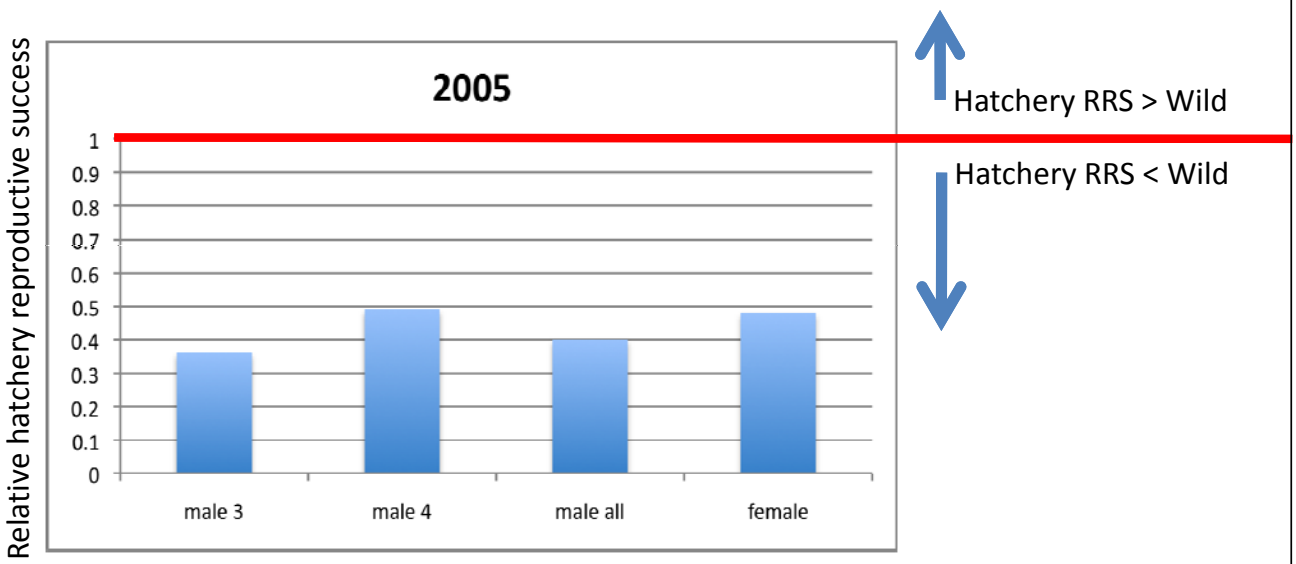
Measuring reproductive success wild



Basic reproductive success data

Fish #	Weight	Date	Age	Origin	Sex	# offspring
34200-0719	7.4	6/30/08	1.3	W	F	20
34200-3110	5.34	7/23/08	1.2	W	F	17
34200-0059	10.22	6/16/08	1.3	W	F	14
34200-1201	10.78	7/5/08	1.3	W	F	12
34200-0093	6.4	6/19/08	1.2	H	F	10
34200-0749	5.6	6/30/08	1.2	H	F	10
34200-0236	4.64	6/22/08	1.2	W	F	8
34200-0268	7.8	6/22/08	1.3	H	F	8
34200-0710	5.9	6/30/08	1.2	H	F	8
34200-1055	6.86	7/5/08	1.3	H	F	8

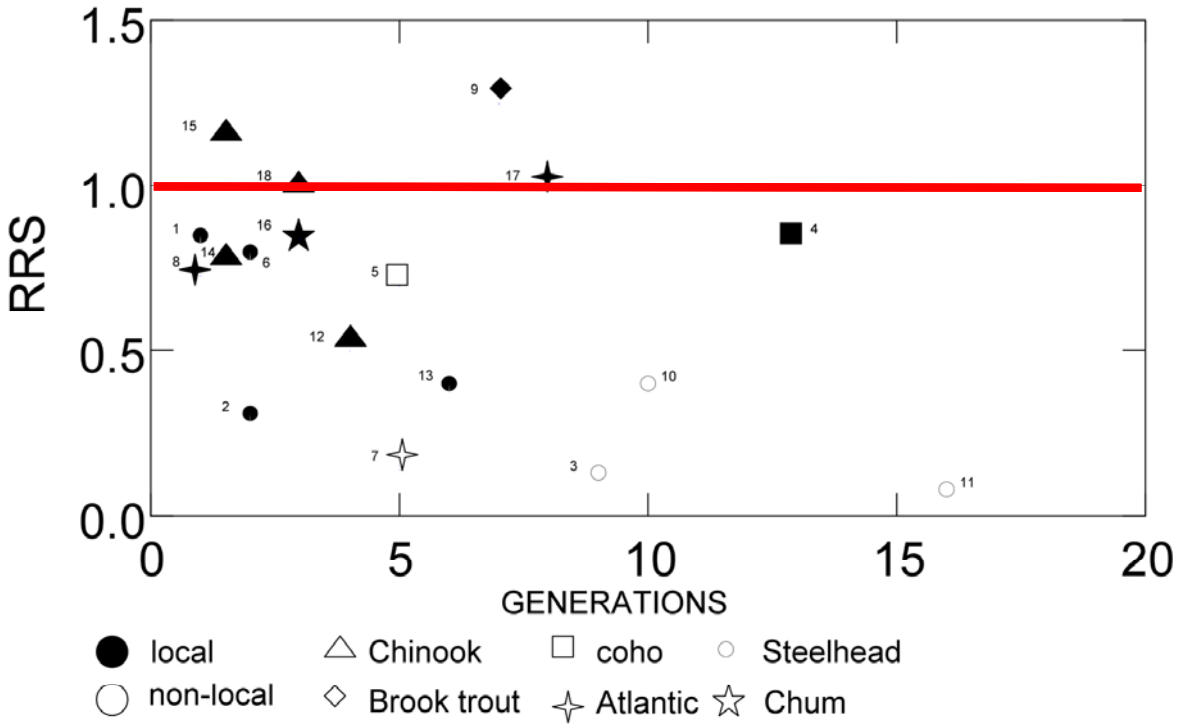
Example results – Wenatchee Chinook



Average number of offspring per naturally spawning hatchery fish

Average number of offspring per naturally spawning wild fish

How general is low hatchery fitness?

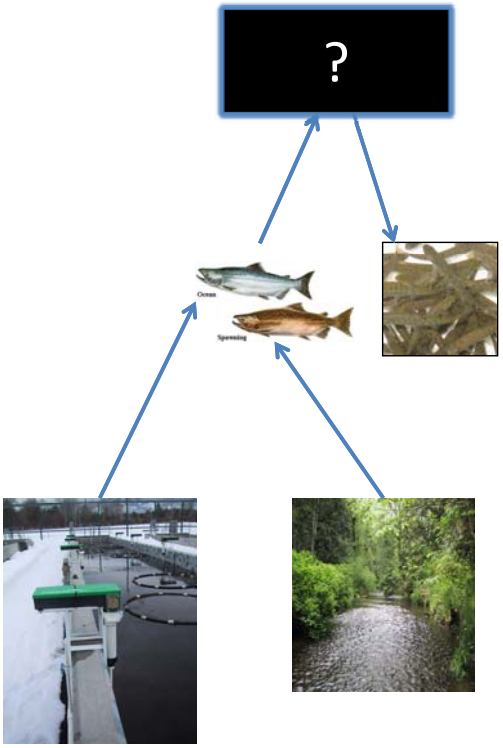


Summary: Emerging trend 1

- Hatchery fish RRS generally is lower than wild fish RRS
  - True for both “supplementation” and “production” programs
  - Hatchery steelhead may have particularly low RRS
  - Lots of variation
  - Limited information on sub-yearling release strategies – fall Chinook, chum, pink

Key question – why do hatchery fish have low reproductive success?

- Most RRS studies are “black boxes”
- Most RRS studies confound genetic and environmental effects

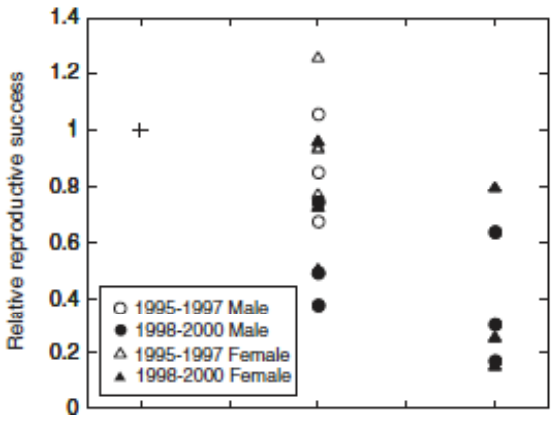


Some answers are emerging

Genetic Effects of Captive Breedi Cause a Rapid, Cumulative Fitnes Decline in the Wild

Hitoshi Araki,* Becky Cooper, Michael S. Blouin

Science 318:100(2007)

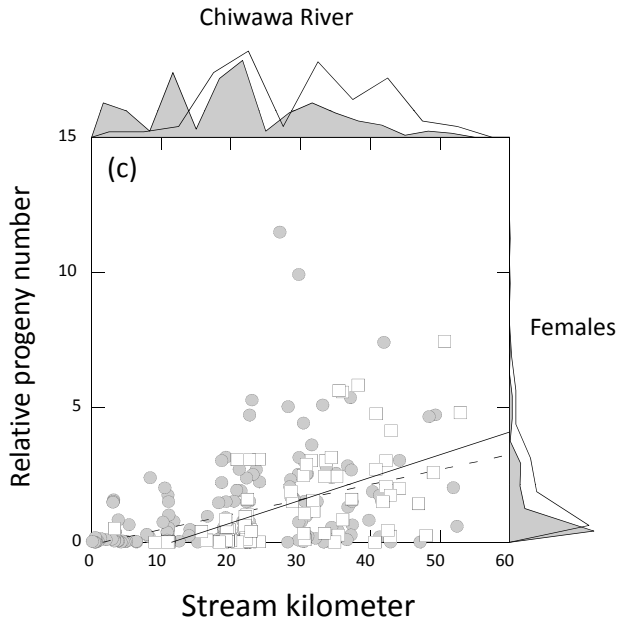


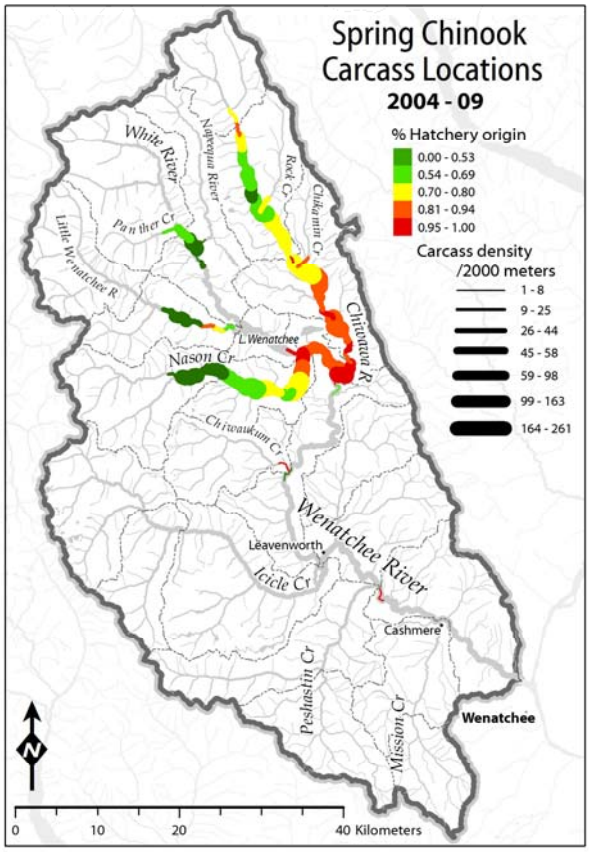
Number of wild parents 2 1 0

Rearing environment N H H

Evidence for heritable effects

Spawning location





Williamson, Murdoch, Pearsons, Ward and Ford, in press

Evidence for genetic (domestication) effects based on 'common garden' experiments

	Number of published studies			
Trait	Local brood	Trait difference	Non-local brood	Trait difference
Anti-predator response	5	5	4	4
Aggression	4	2	1	0
Growth	2	2	2	2
Other	3	3	--	--

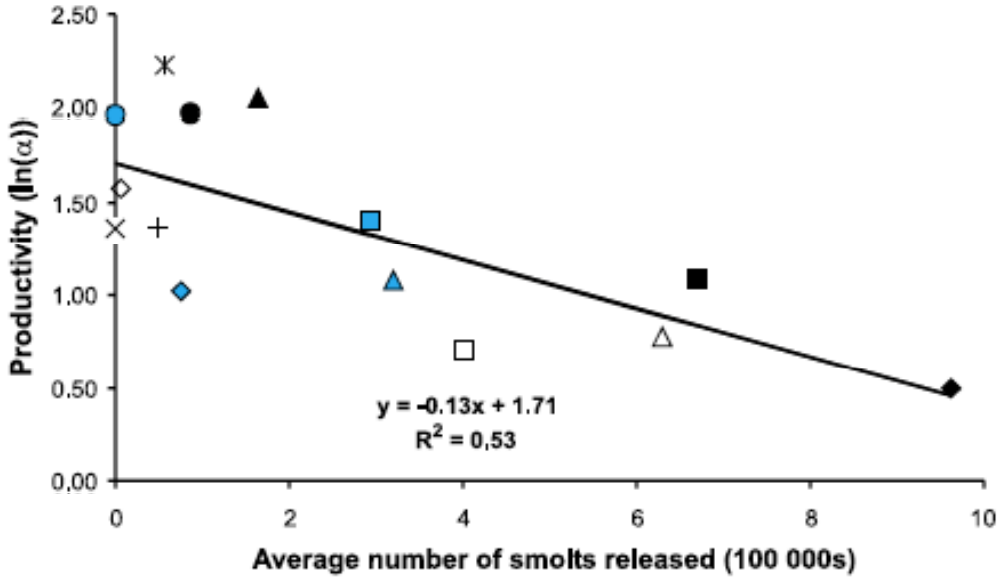
Caveats: i) maternal effects; ii) small differences; iii) negative results?, iv) does not include farmed Atlantic salmon

See review by Fraser (2008) *Evolutionary Applications*

Summary of causes

- Evidence of both environmental and heritable effects
- Genetic architecture of differences unknown
- No general trend at this point in the relative importance of genetic versus environmental effects

Trend 2: measuring effects on wild productivity

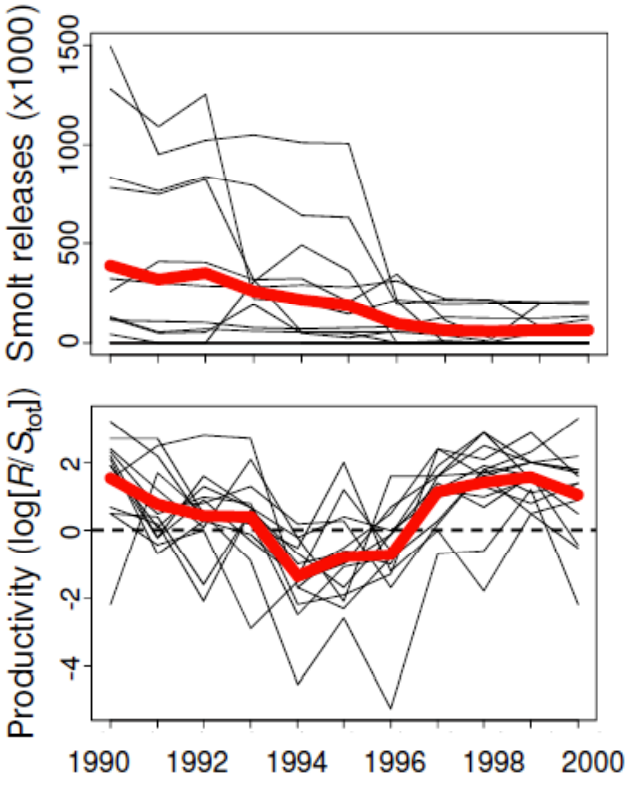


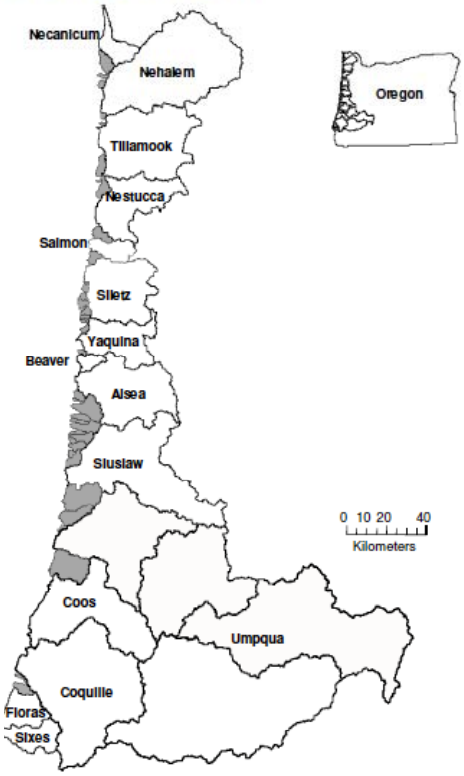
Chilcote et al. 2003

Review of 7 published studies (RIST 2009)

- All reported slopes were negative
- Effects detected for both releases and proportion hatchery spawners (pHOS)
- Intra-specific and inter-specific effects

Oregon Coast Coho Salmon





Buhle, E.R., et al. Biol. Conserv. (2009)

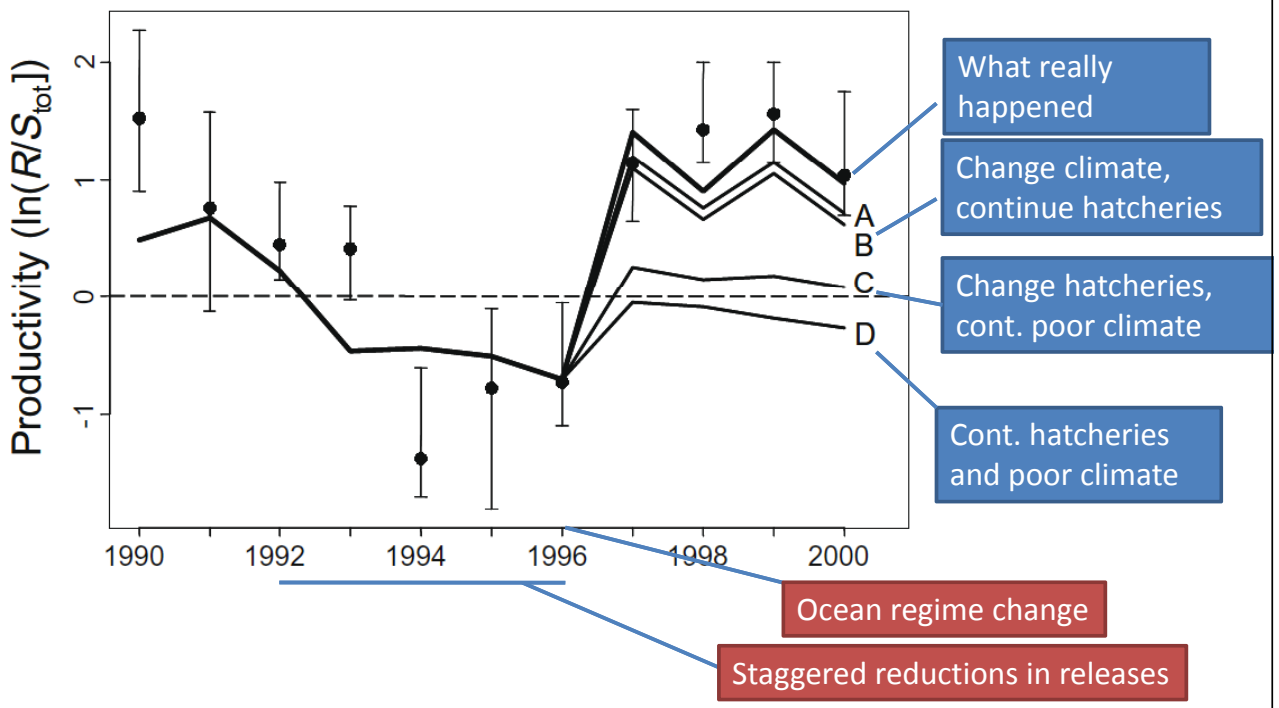
Extended Ricker Models

$$\log\left(\frac{R_{jt}}{S_{jt}}\right) = a_j + b_w S_{w,jt} + b_h S_{h,jt} + b_1 F_{j,t+1} + b_2 M_{j,t+2} + b_3 K_j + b_4 T_{t+2} + b_5 T_{t+3} + b_6 M_{j,t+2} T_{t+3}$$

- a_j: intrinsic productivity (pop-specific)
- $b_w S_{w,jt}$: spawner density (W, H)
- $b_h S_{h,jt}$: fry releases (fish/km)
- $b_1 F_{j,t+1}$: smolt releases (# of fish)
- $b_2 M_{j,t+2}$: freshwater habitat capacity (Nickelson 1998)
- $b_3 K_j$: ocean conditions (SST, Logerwell et al. 2003)
- $b_4 T_{t+2}$, $b_5 T_{t+3}$: ocean conditions (SST, Logerwell et al. 2003)
- $b_6 M_{j,t+2} T_{t+3}$: smolt releases x ocean

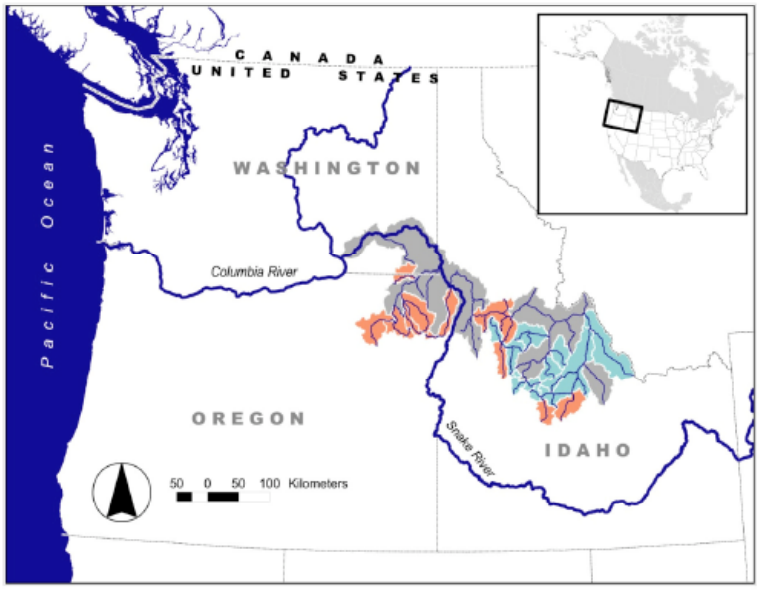
- Each model assumes either (1) only wild spawners produce recruits, or (2) all spawners contribute equally to recruits
- Fit set of 82 candidate models by maximum likelihood
- Rank models based on AIC_c

Was there a benefit?



Buhle, E.R., et al. Biol. Conserv. (2009)

Similar analysis now completed for Snake River sp/su Chinook

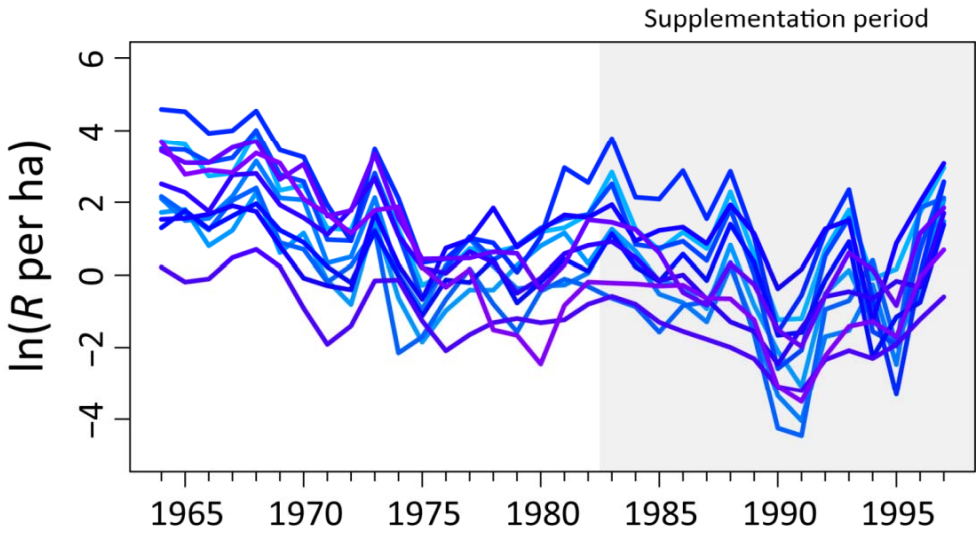


Data

- 23 populations: 11 supplemented, 12 "reference"
- Adult (spawner) density, 1973-2006
- Adult age composition
- Wild- vs. hatchery-origin proportions

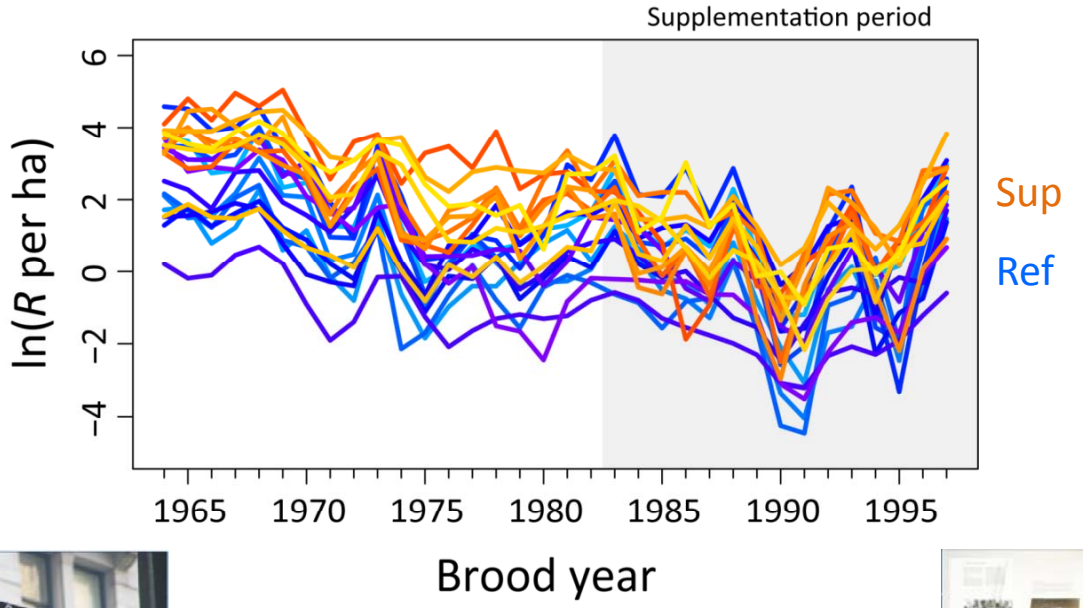
Mark Scheuerell, Eric Buhle, Scheuerell, Buhle , Brice Semmens, Mike Ford, Tom Cooney, Rich Carmichael, in prep

Time series of wild spawner density



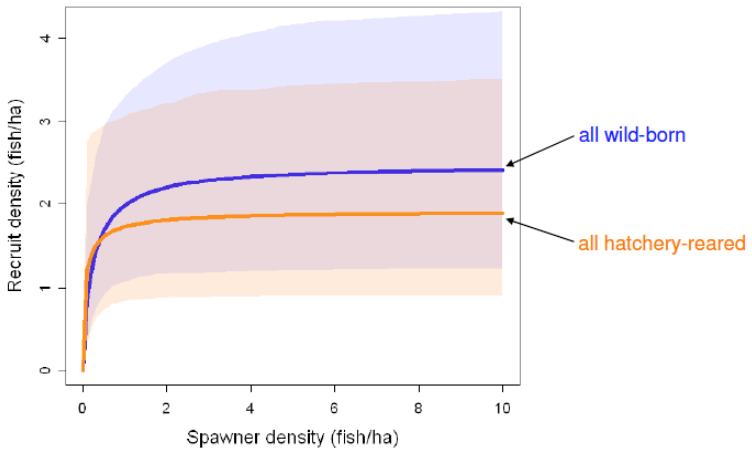
Ref

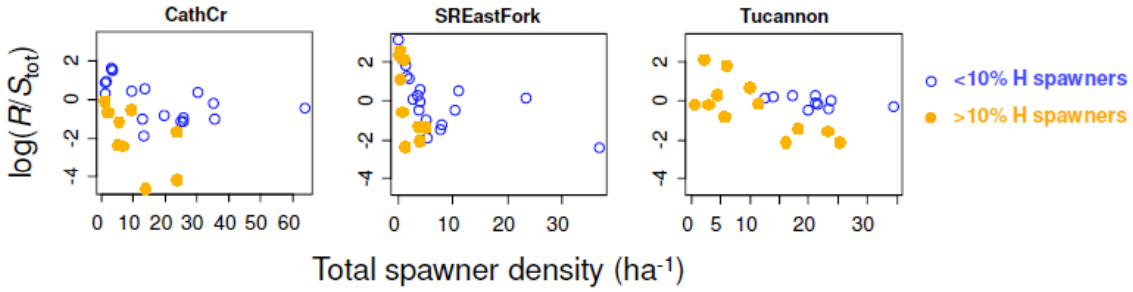
Time series of wild spawner density



Effects on productivity

- No effect on natural abundance
- No effect on productivity at very low abundance
- Negative effect on productivity higher abundance

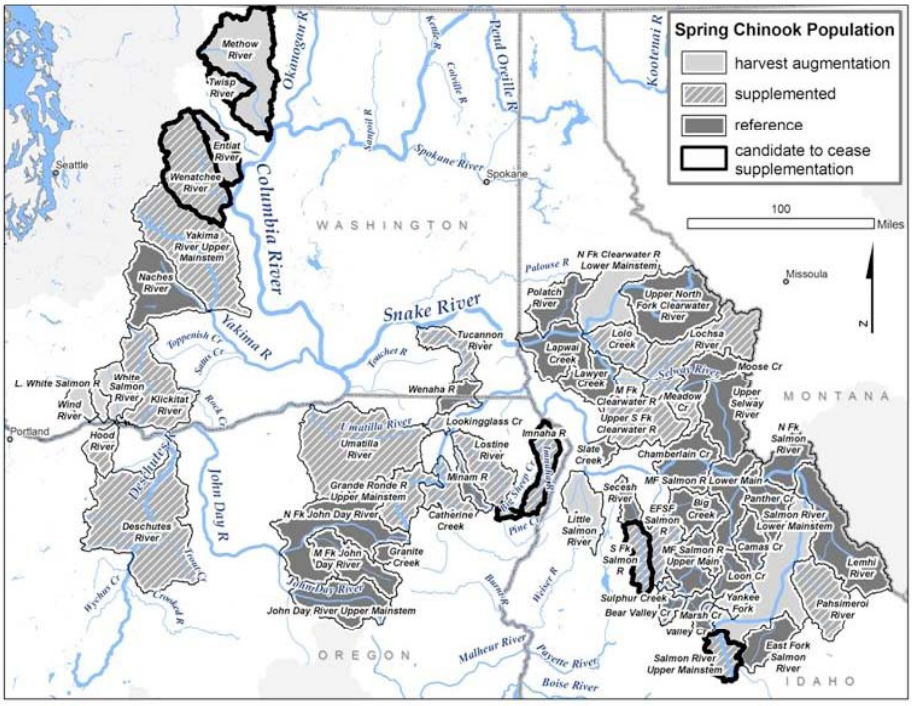




Summary: emerging trend 2

- Negative correlations between hatchery influence and wild productivity are widespread
  - But… causation not always clear
- Habitat or ocean conditions do not appear to explain pattern
- Some evidence of 'reversibility' – reducing hatchery releases can increase natural productivity (Oregon Coast)

Opportunities to "test" trend 2



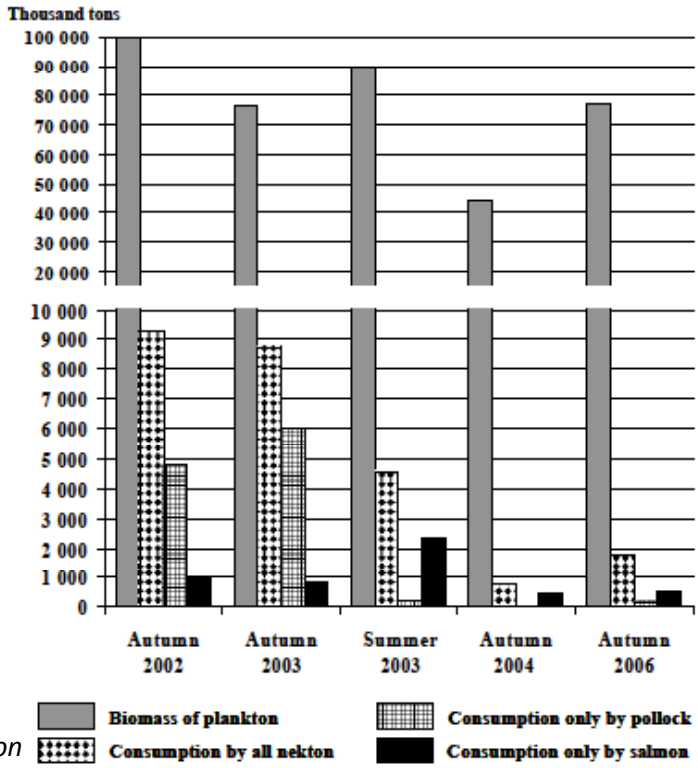
Ad Hoc Supplementation Monitoring and Evaluation Workgroup (AHSWG) 2008

Columbia River Hatchery Effects Evaluation Team

A final nagging question – cumulative effects in mainstem, estuary, ocean?

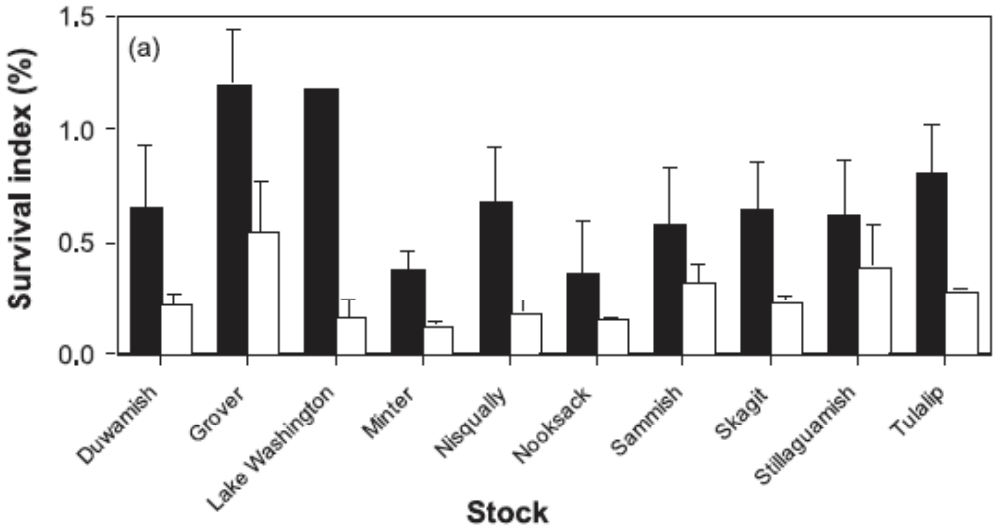
Photo credit: Walter Siegmund, wikicommons

Argument against density dependence in the ocean



Svetlana V. Naydenko
North Pacific Anadromous Fish Commission Bulletin No. 5: 231-241, 2009

Evidence for density dependence: Effects of pink salmon on Puget Sound Chinook survival

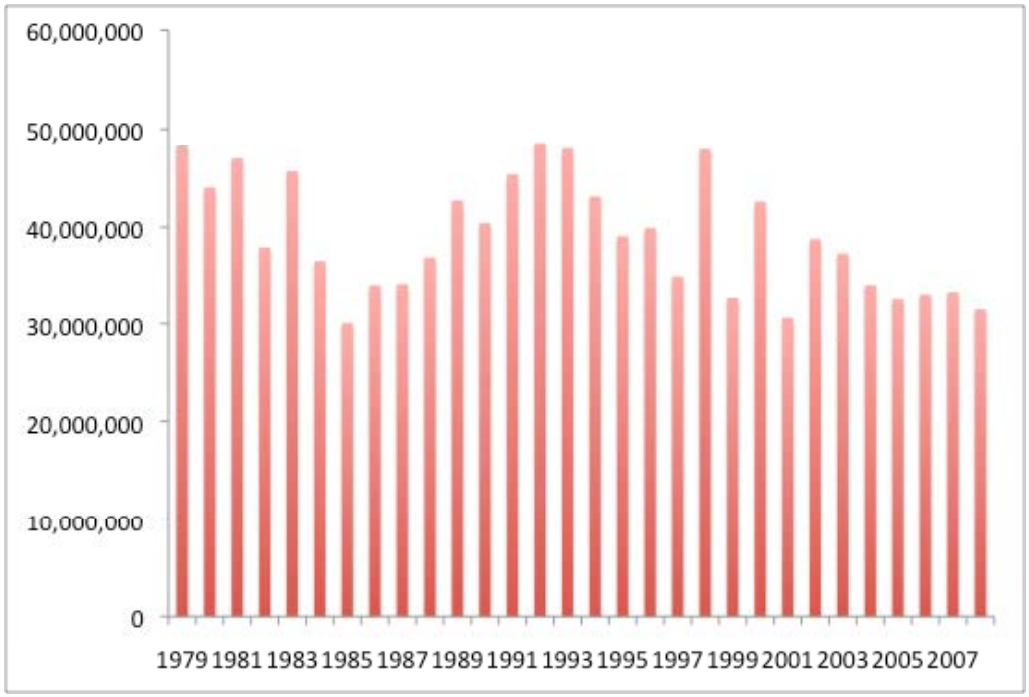


Odd years – no pink salmon juveniles

Even years - 43M pink salmon juveniles

Ruggerone and Goetz (2004)

Vary Columbia River hatchery releases to test for effects on growth and survival?



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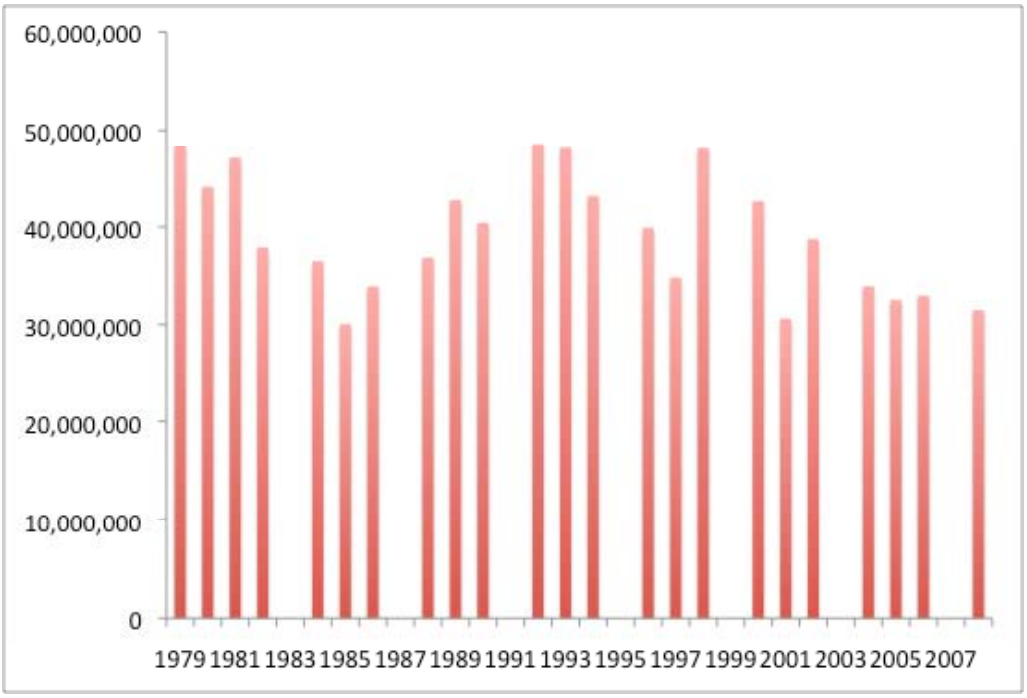

Implications for recovery strategies

- Current science indicates that limiting natural spawning of hatchery fish is generally beneficial to wild populations
  - But… some safety nets are important
- There is evidence that reducing hatchery production leads to increased wild production
- Quantifying the cumulative effects of hatchery releases is very important – could be a factor limiting recovery of some ESUs

Further reading

RIST hatchery report:
http://www.nwfsc.noaa.gov/trt/puget_docs/hatchery_report_april92009.pdf

State of the Salmon Ecological Interactions Conference:
http://www.stateofthesalmon.org/conference2010/presentations.html