Marine Environmental Variation and Hatchery Rearing Strategies: Match or Mis-match?

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NOAA FISHERIES

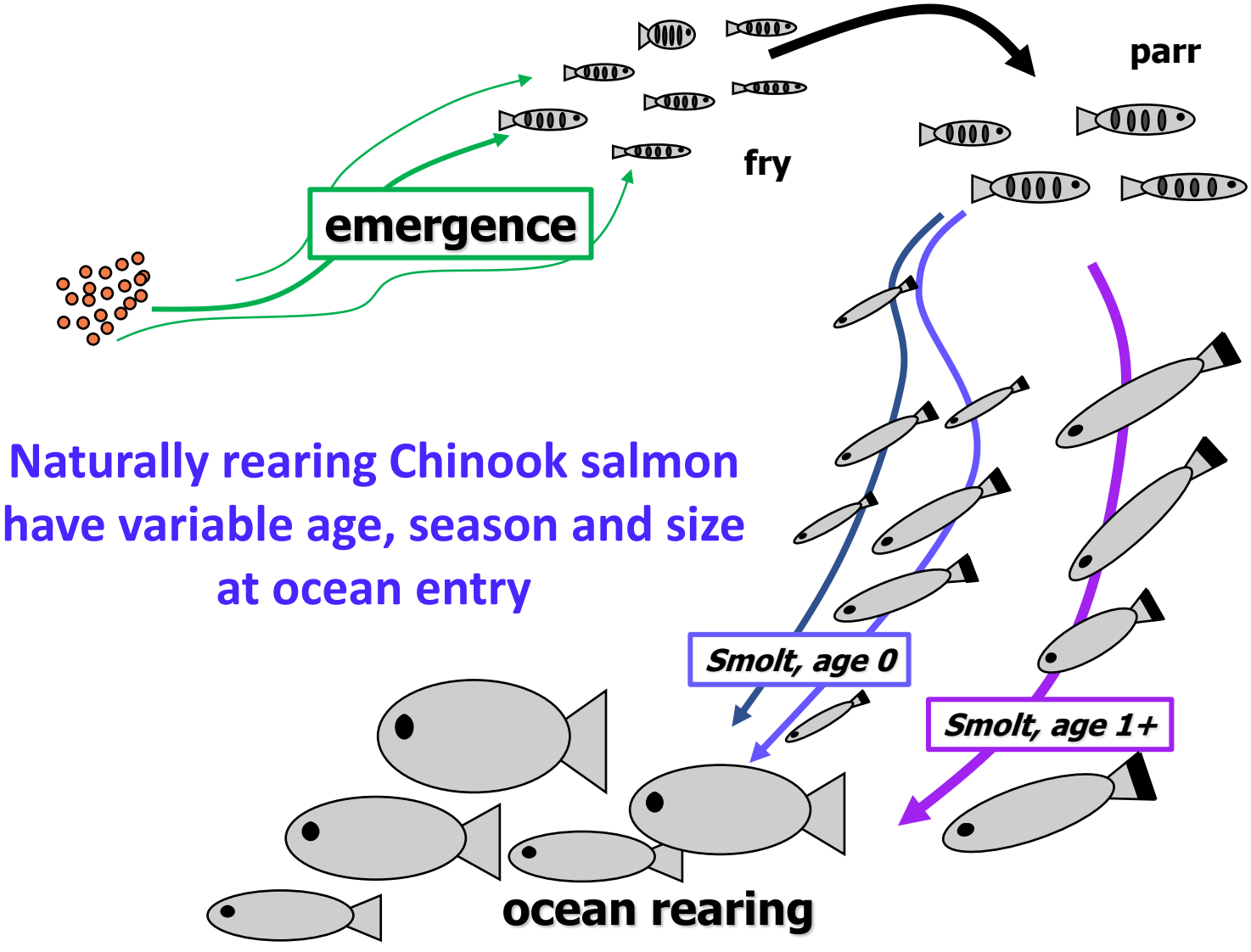
Questions

How does variation in age, season or size at release affect hatchery recoveries?

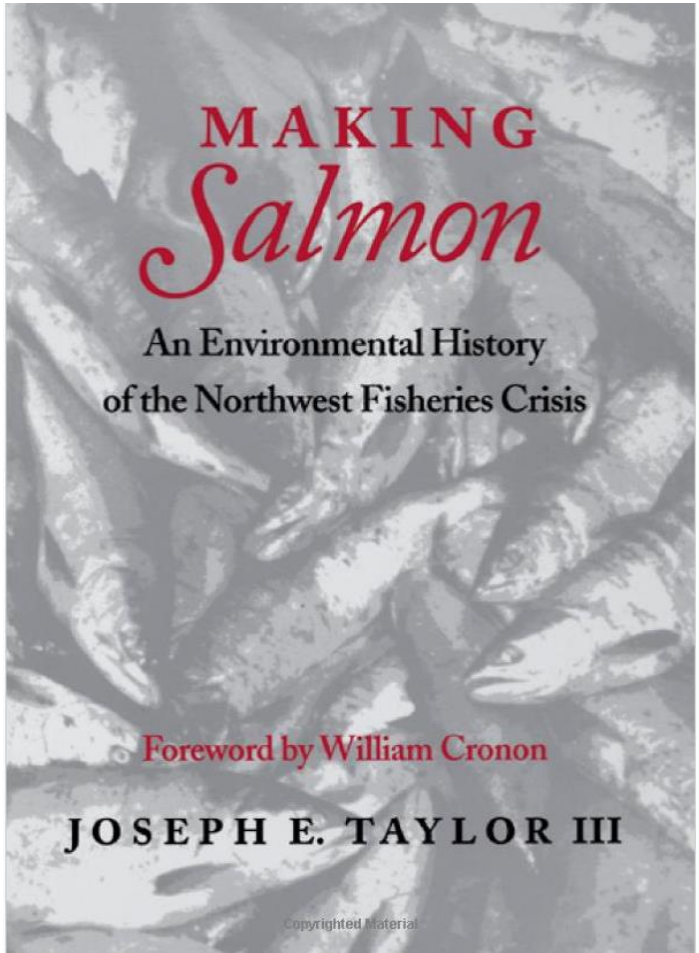
How does a varying ocean environment affect salmon survival?

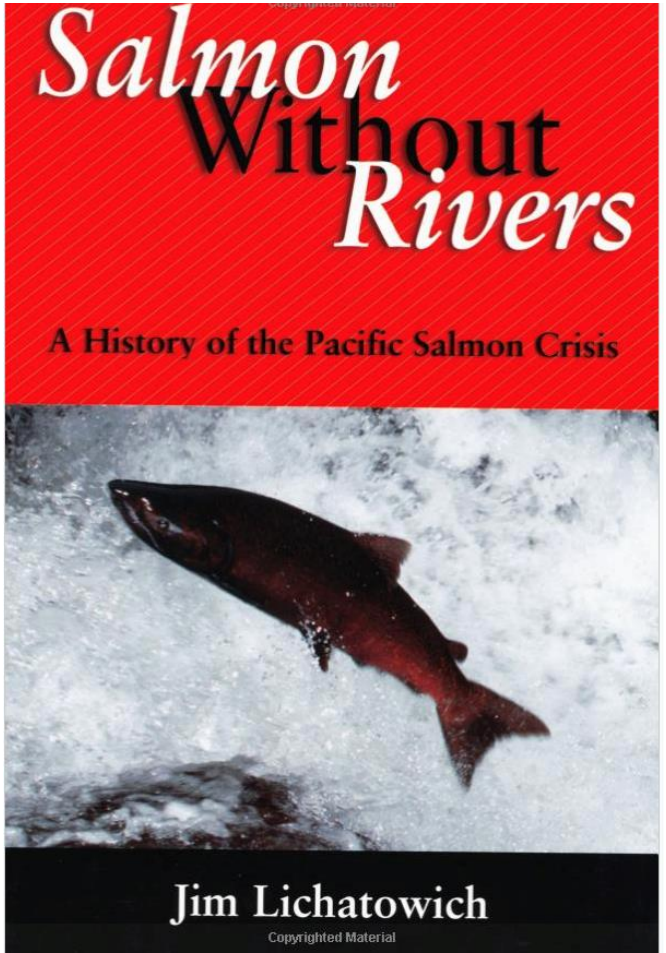
=> Should current hatchery strategies be reconsidered given a changing and more variable ocean?

1. **Hatcheries (opinionated)**
2. **The Pacific Ocean**
3. **Hatcheries meet the Pacific Ocean**


parr
fry
emergence
Naturally rearing Chinook salmon have variable age, season and size at ocean entry
Smolt, age 0
Smolt, age 1+
ocean rearing

Production hatchery strategies are based on industrial agriculture





Industrial Agriculture

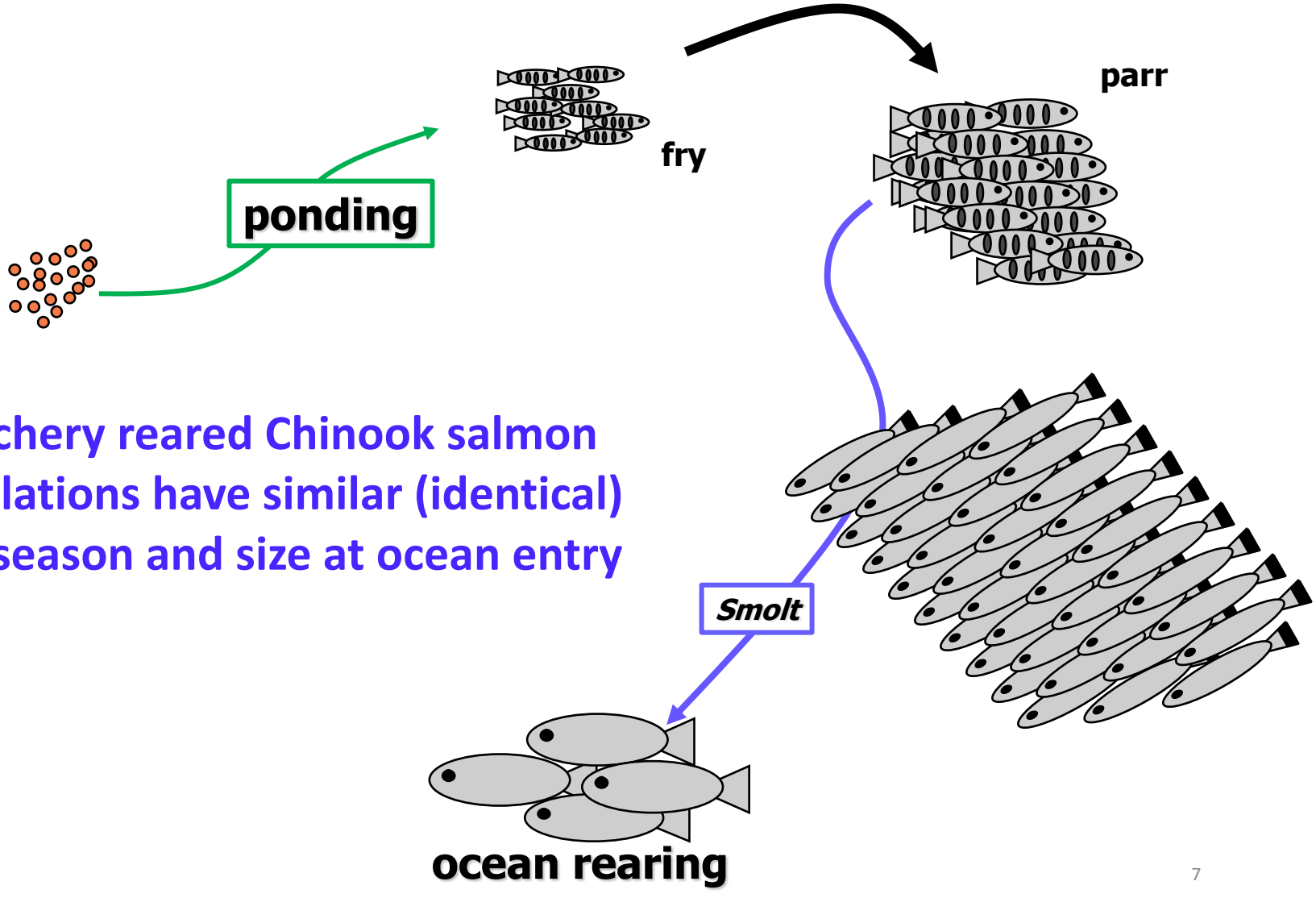
High Production (1,000,000s)

Efficiency (smolt/$)

Standardization

Variation is eliminated
fish are same size and age
released at the same time

=> Goal is most smolts for fewest $$



Hatchery reared Chinook salmon populations have similar (identical) age, season and size at ocean entry

Assumptions of industrial smolt production

Unlimited ocean carrying capacity

Positive relationship between smolt release and adult return

Uniform marine environment across years

All smolts have same performance

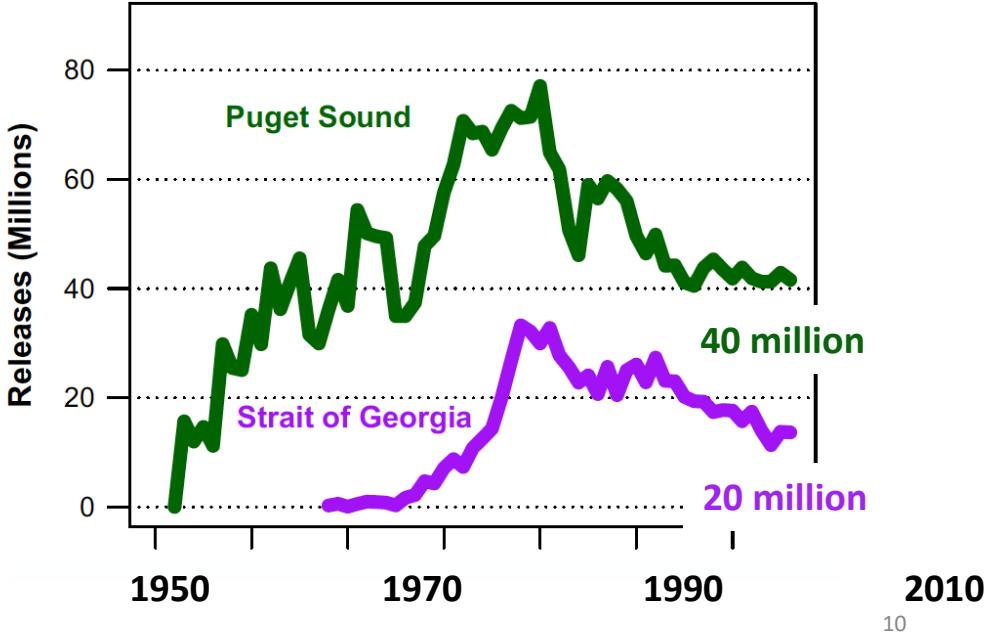
Trajectory of hatchery production strategies in the Puget Sound

esa ECOSPHERE

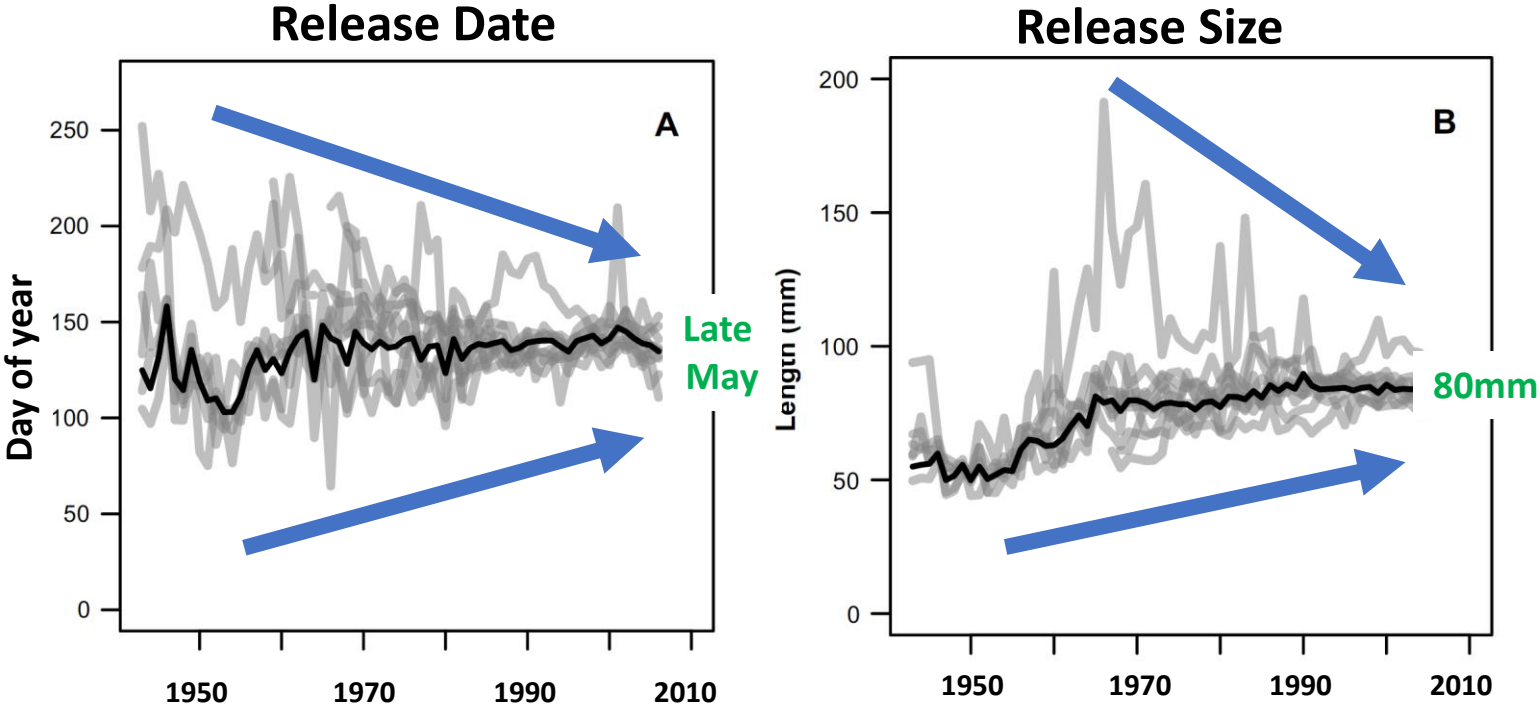
Ecological implications of changing hatchery practices for Chinook salmon in the Salish Sea

Benjamin W. Nelson,[1,2,†] Andrew O. Shelton,[3] Joseph H. Anderson,[4] Michael J. Ford,[3] and Eric J. Ward[3]

Chinook Salmon Hatchery Releases (millions)

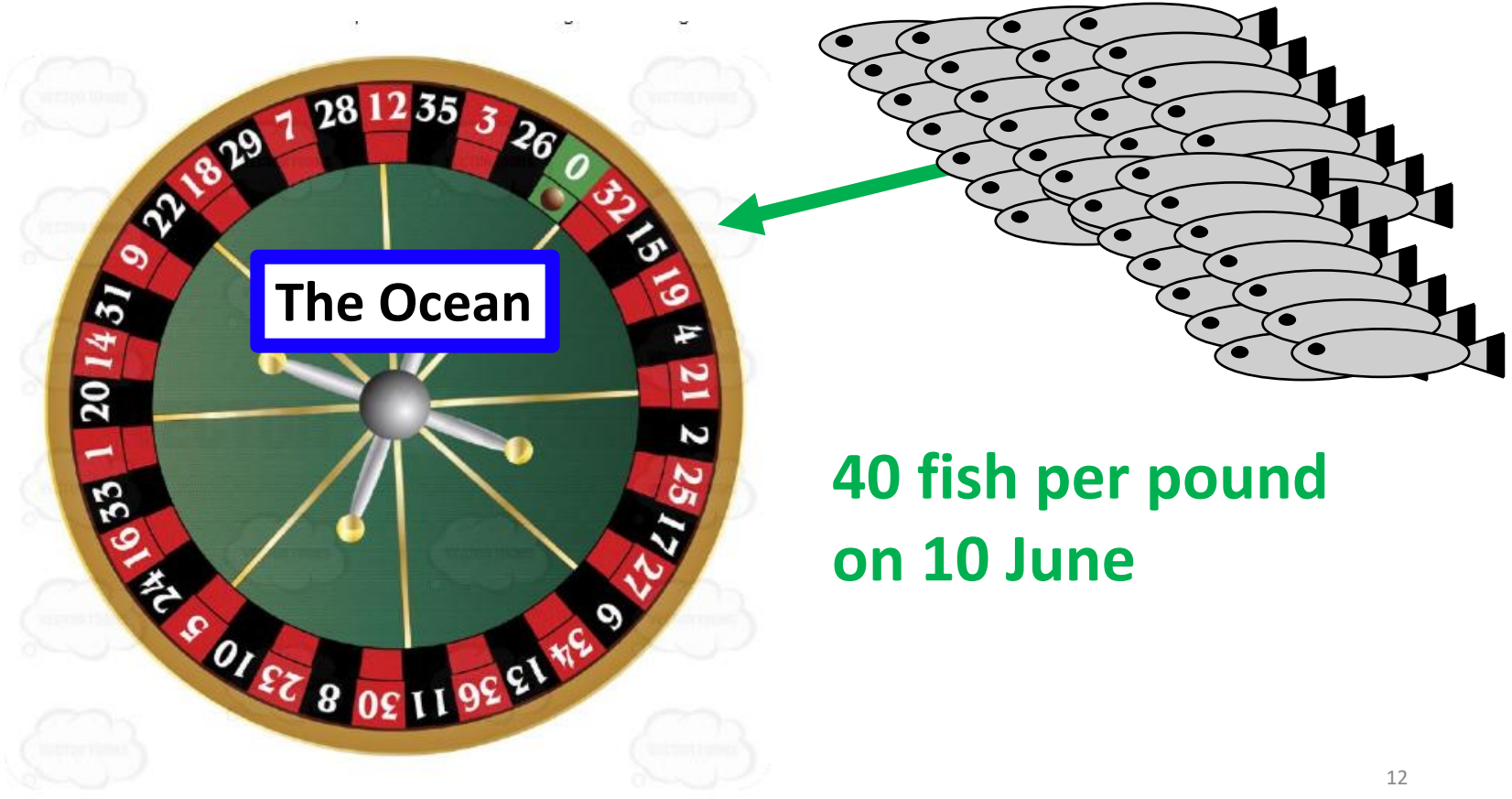


Variation in hatchery release time and release size of Chinook salmon in Salish Sea has decreased and become unimodal



Nelson et al. 2019

Hatchery release strategy = The Big Bet: release of a uniform group of smolts in the early summer

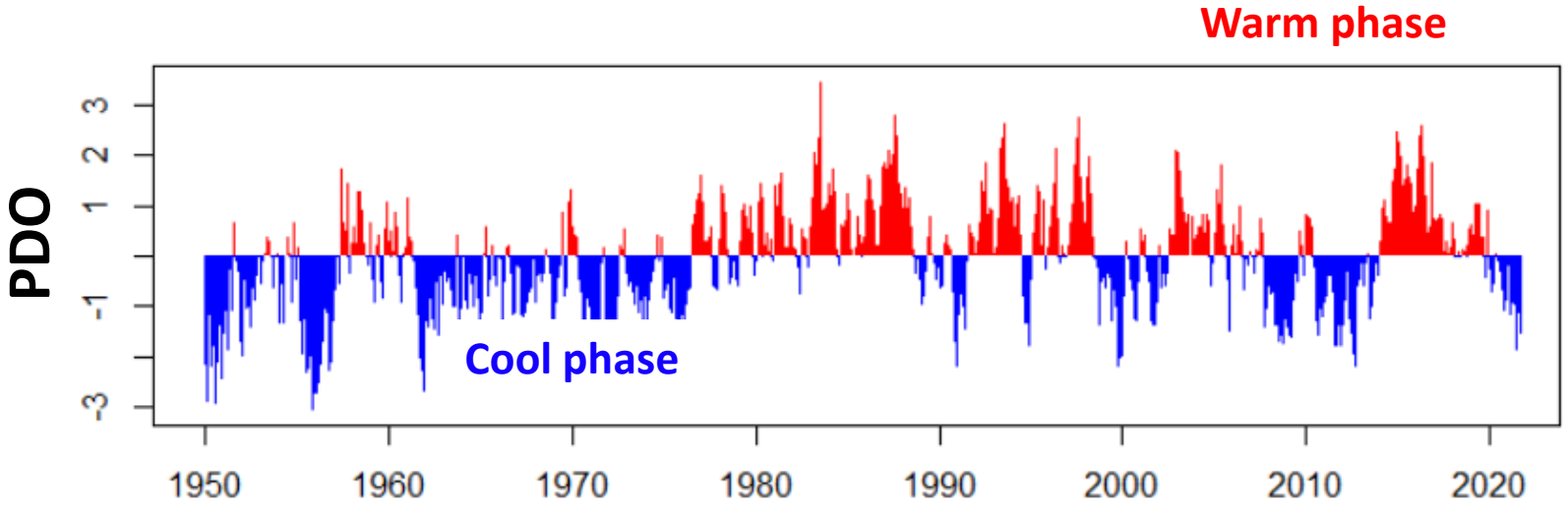


1. Hatcheries (opinionated)
   The “Big Bet”

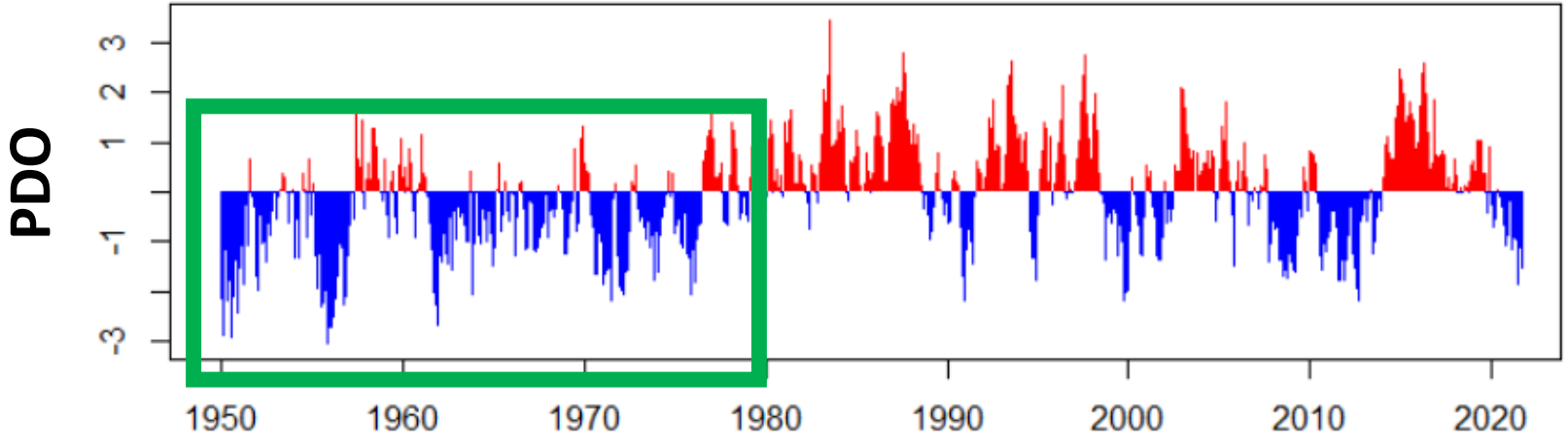
2. **The Pacific Ocean**

3. Hatcheries meet the Pacific Ocean

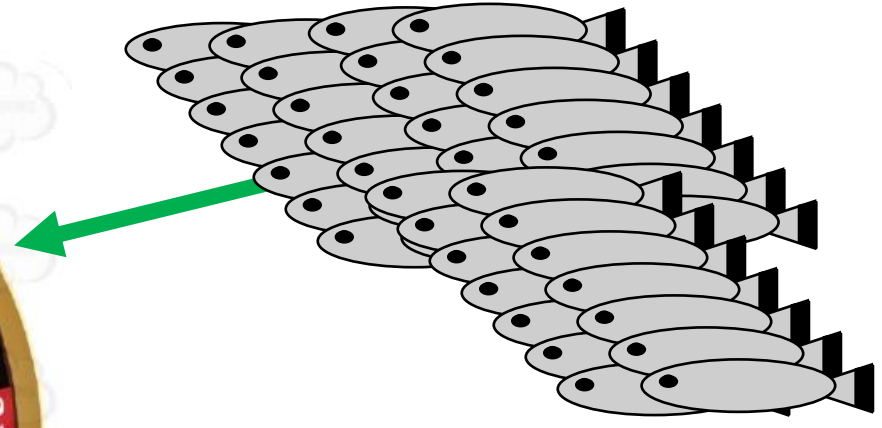
The Pacific Decadal Oscillation (PDO) is an index of spatial ocean temperature pattern that correlates with many biological processes, including salmon productivity



Hatchery production strategies were developed during a period of predictably ”good” ocean conditions (50’s to 70’s)

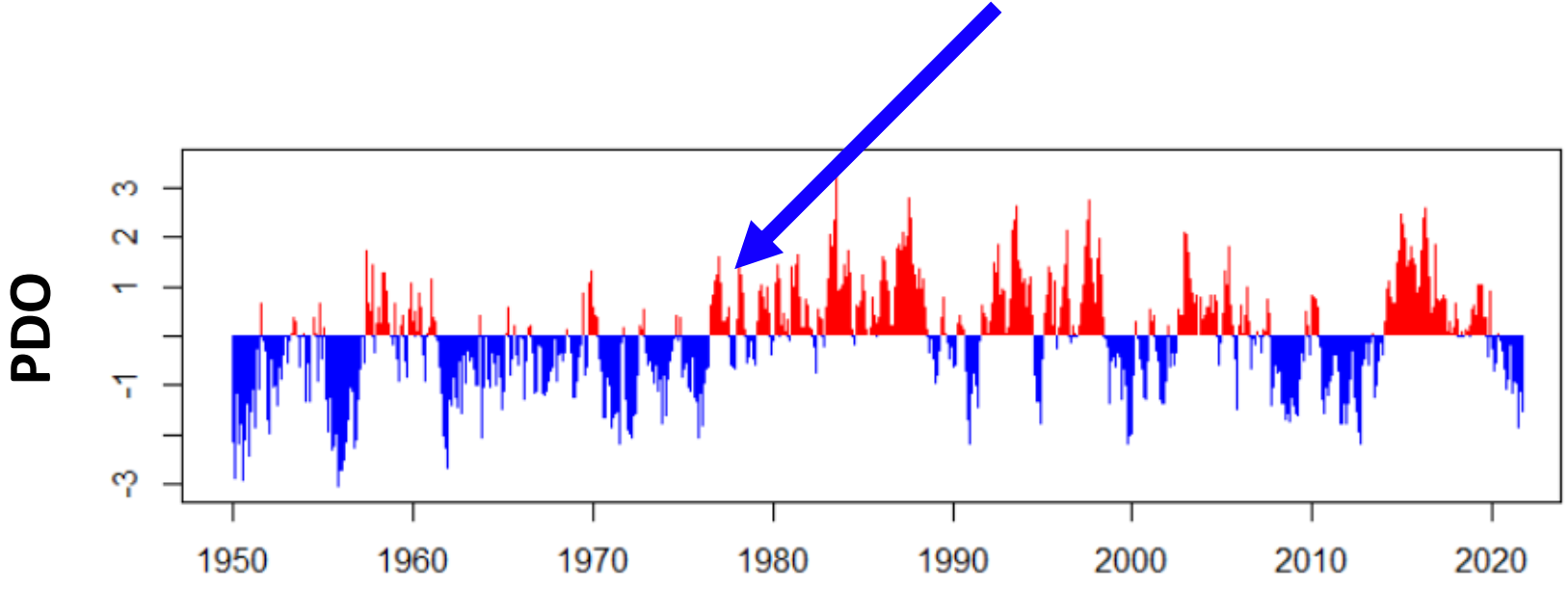


The “Big Bet” worked well during the period of hatchery development (1950s – 1970’s) as ocean conditions were favorable and stable across years

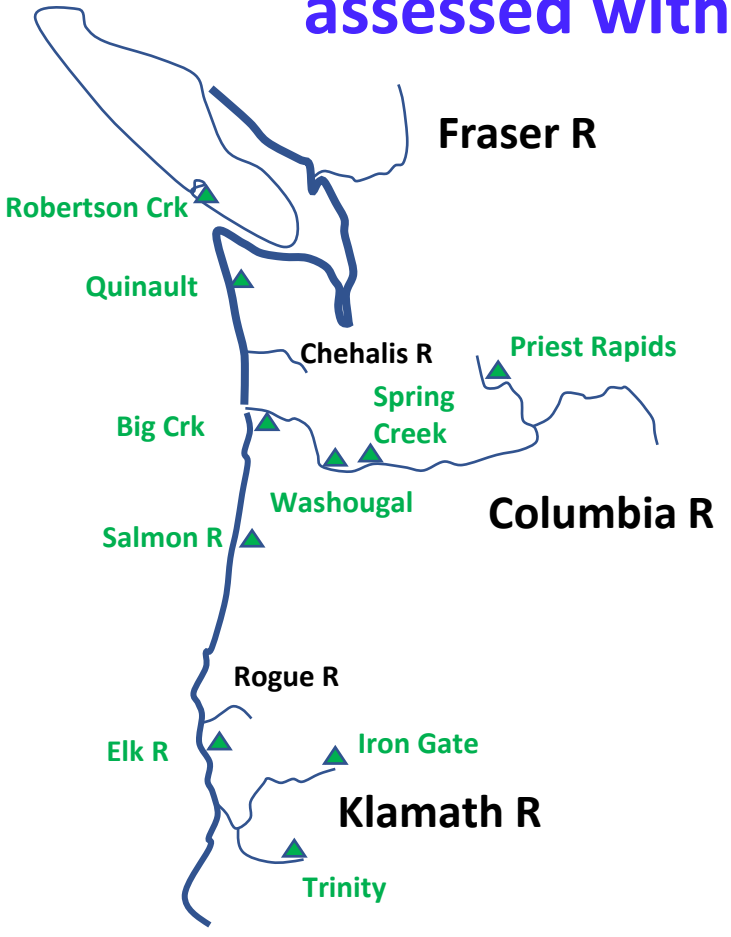


40 fish per pound on 10 June

Large-scale application, recovery and reporting of CWTs starts in late 1970's as ocean becomes more variable

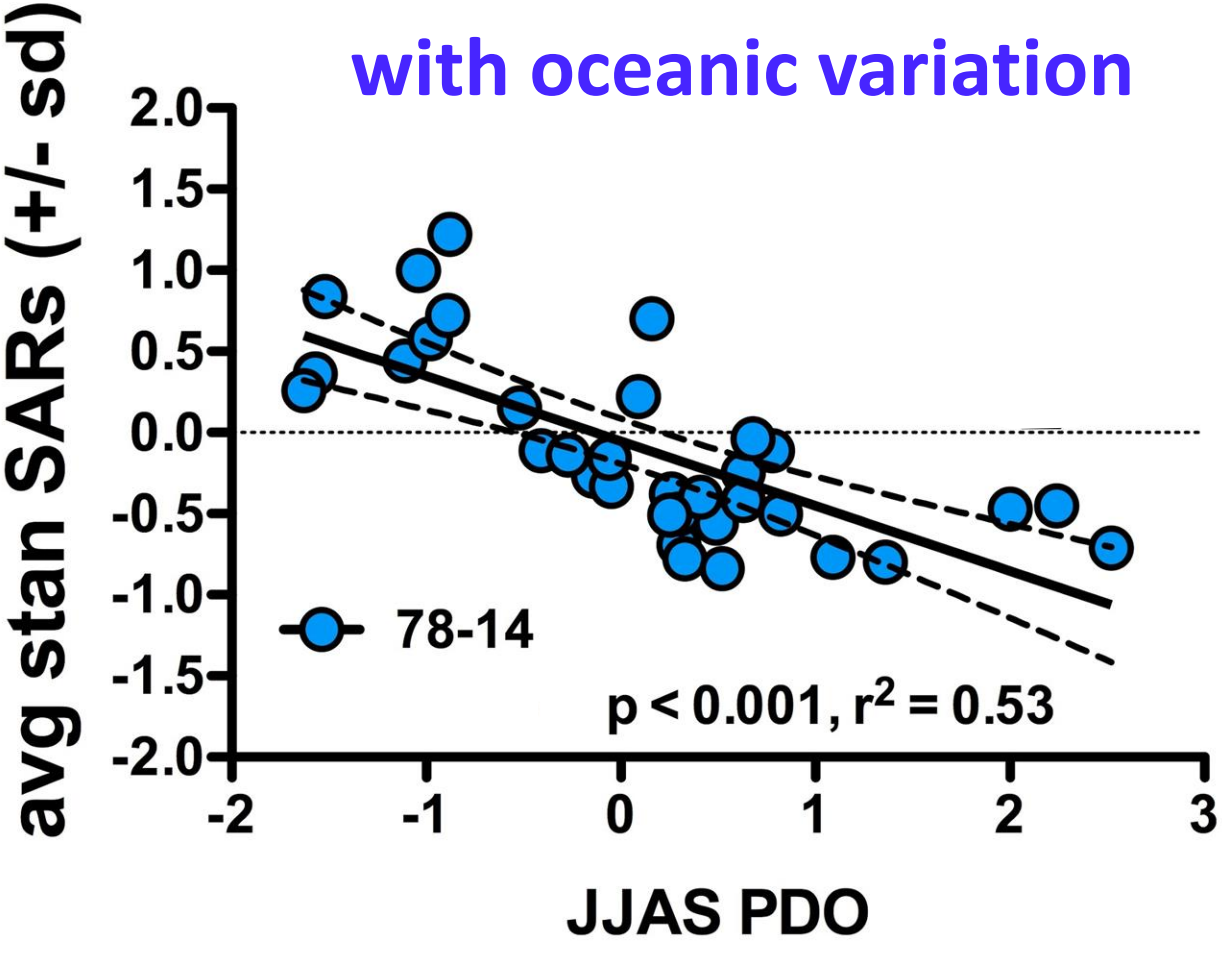


Fall chinook salmon hatchery recoveries assessed with CWTs



1977 - 2014

Salmon recoveries are correlated with oceanic variation



Assumptions of industrial smolt production

X **Unlimited ocean carrying capacity**

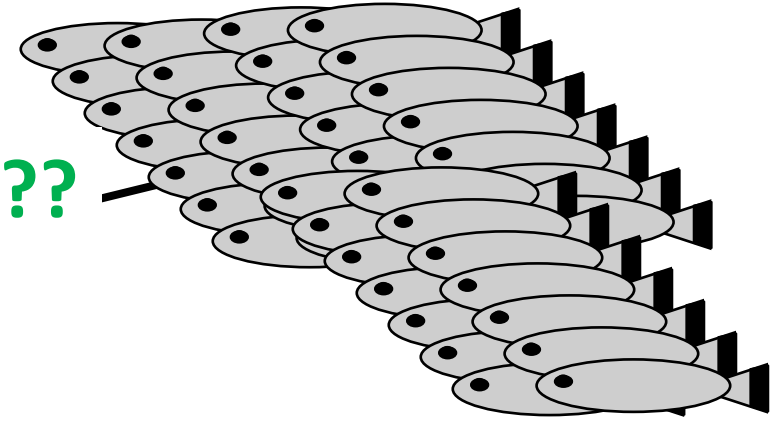
X **Positive relationship between smolt release and adult return**

X **Uniform marine environment across years**

All smolts have same performance

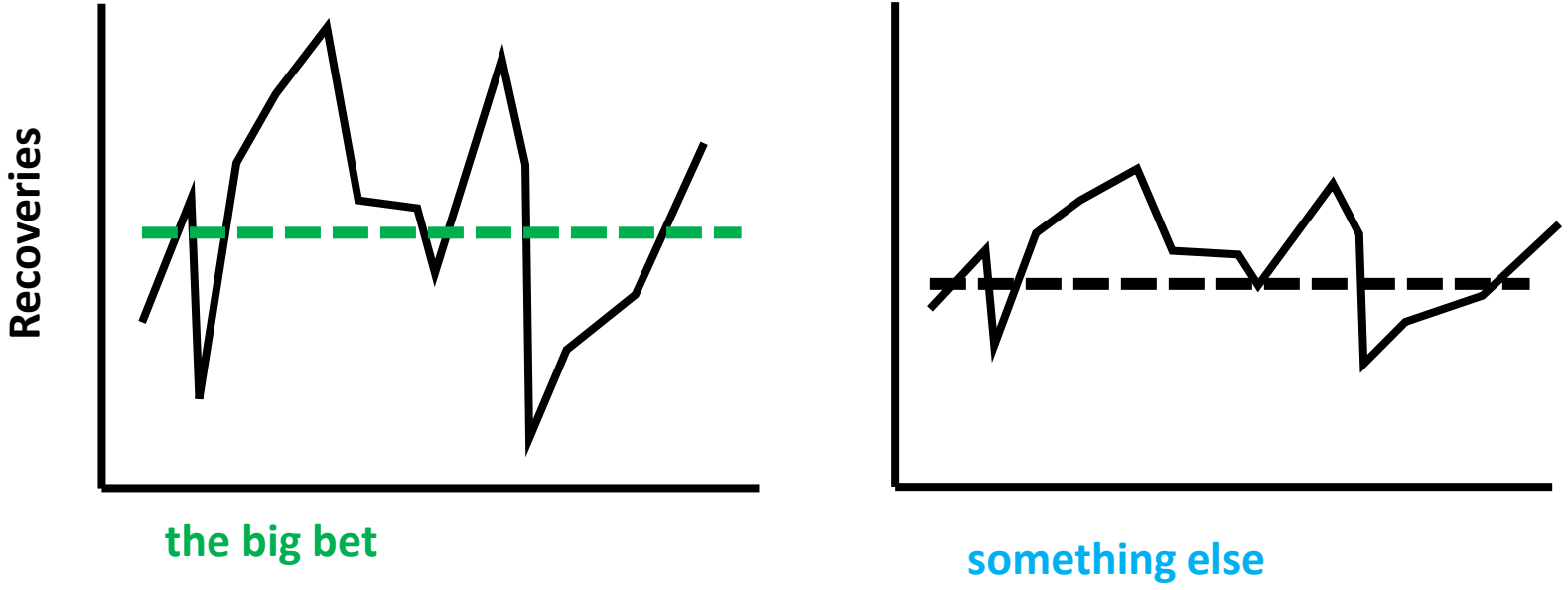
Is the “Big Bet” the only smolt production strategy?

?????????



40 fish per pound on 10 June

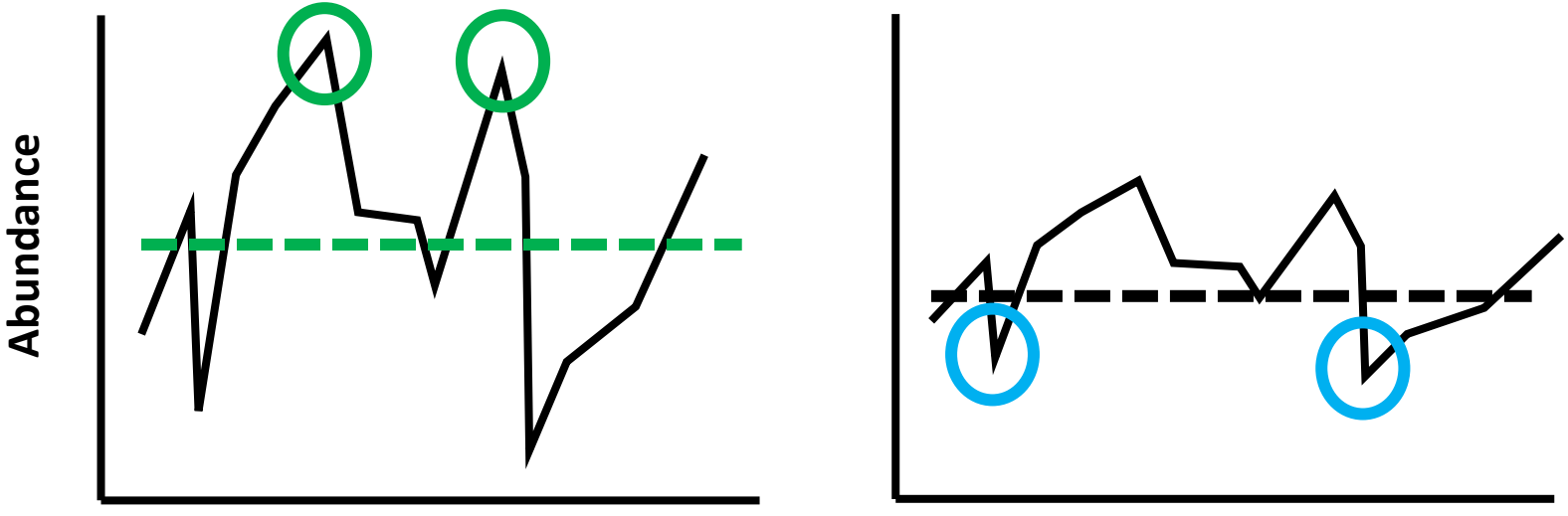
Thought experiment:
Are there alternative production strategies that might produce different magnitudes of variance?



Thought experiment:
Are there alternative production strategies that might produce different magnitudes of variance?

Annual mean is higher
Max annual catch is higher

<u>Minimum</u> annual catch is higher
Variance is lower



the big bet

something else

Are hatchery goals:

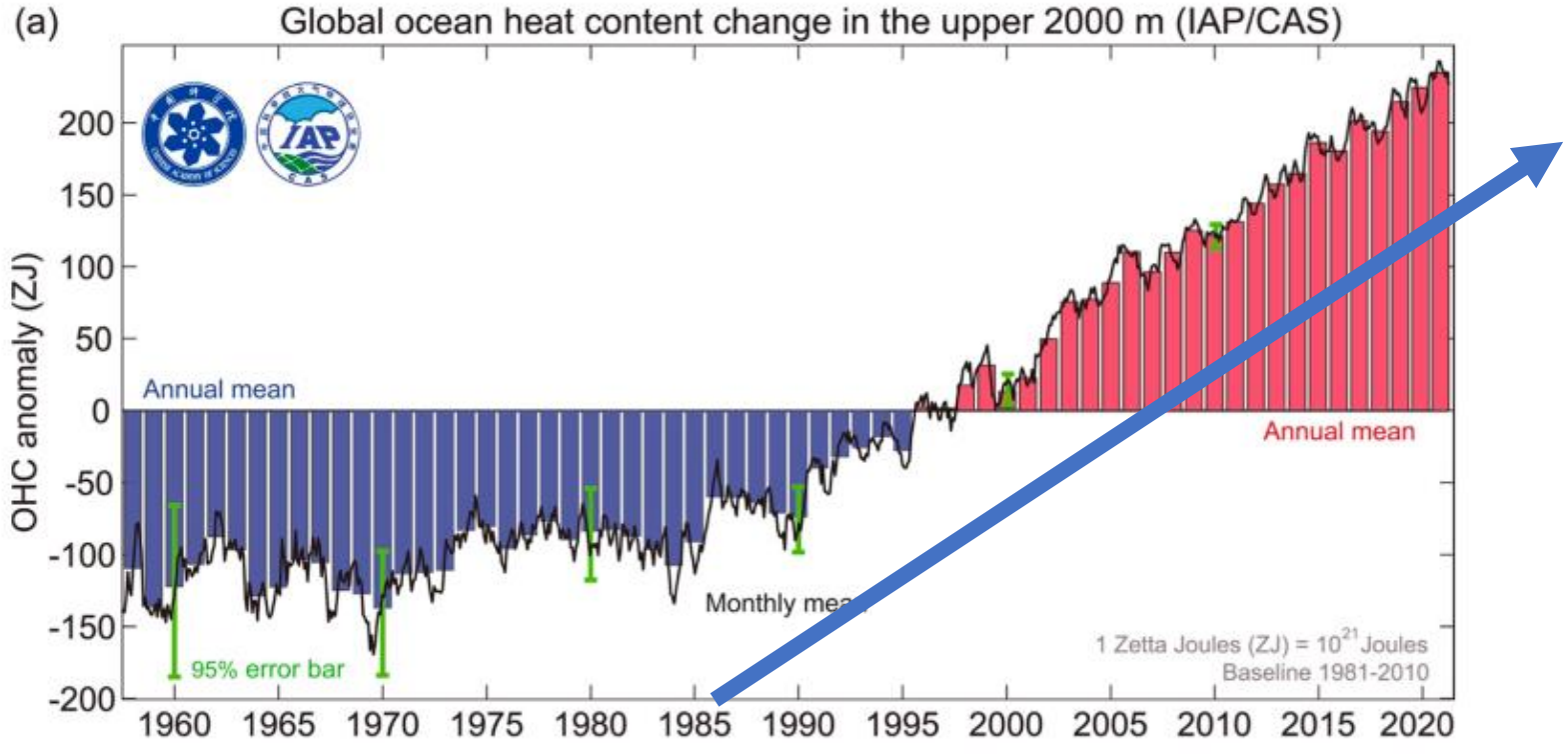
1) maximizing return every year?

or

2) minimizing variance in return between years?

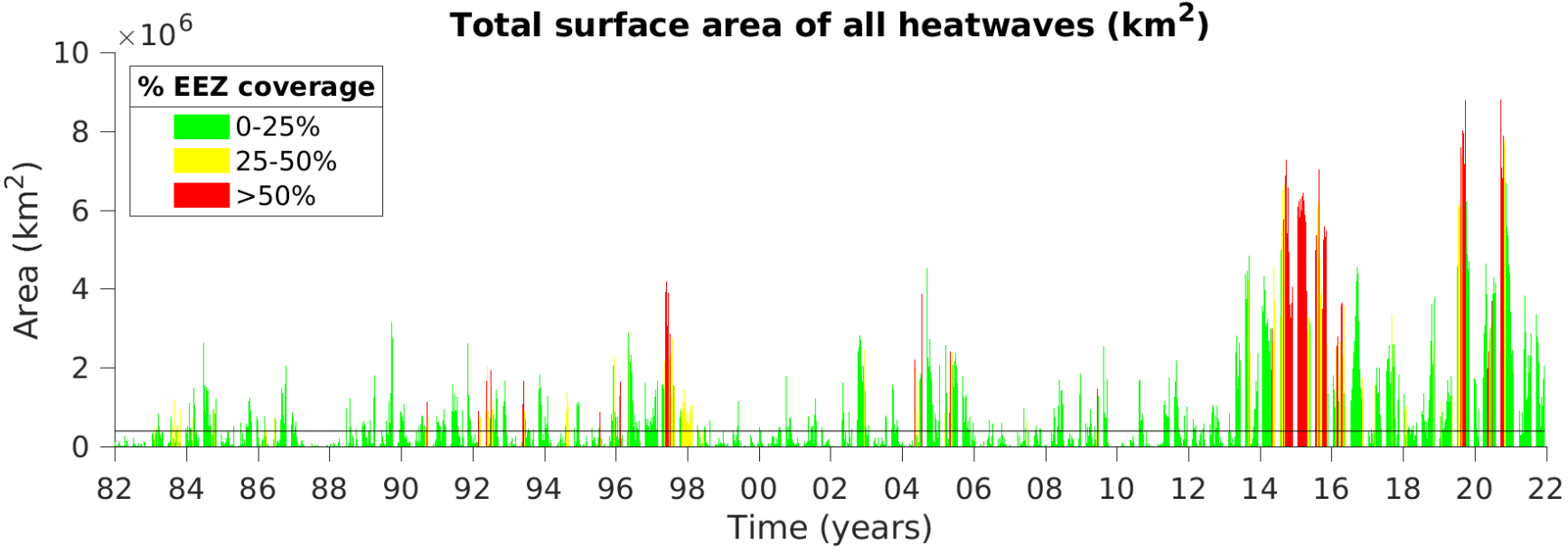
And now – climate change

The ocean environment is changing
1). Increasing trend



Cheng et al. 2022

The ocean environment is changing
2). Increasing variation, both frequency and magnitude



2020-21 California Current Ecosystem Status Report
NOAA California Current IEA Team

Long-term changes in environment will be masked by increased short-term variability (N. Bond) (both frequency and magnitude)

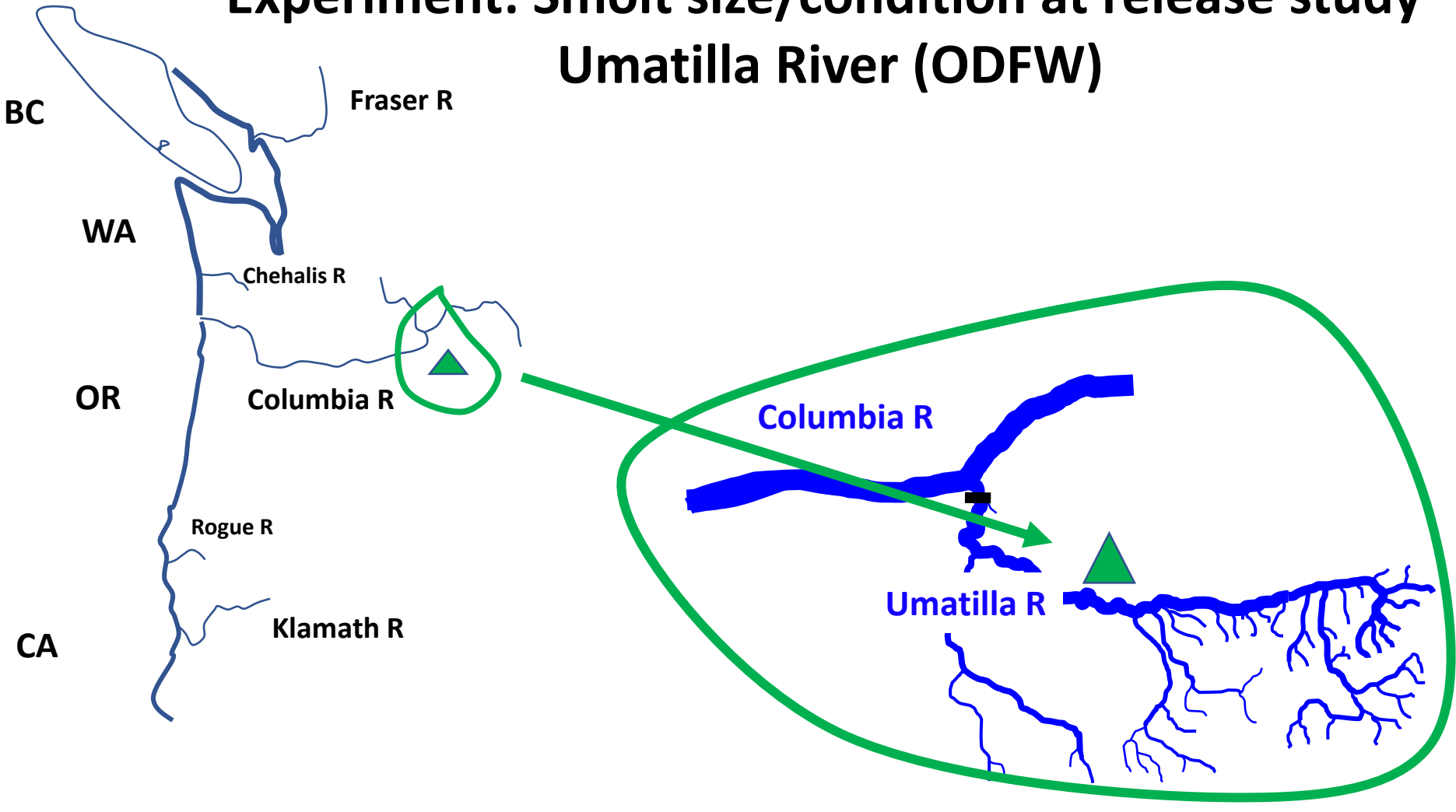
$\Rightarrow$ Average will become more conceptual than real

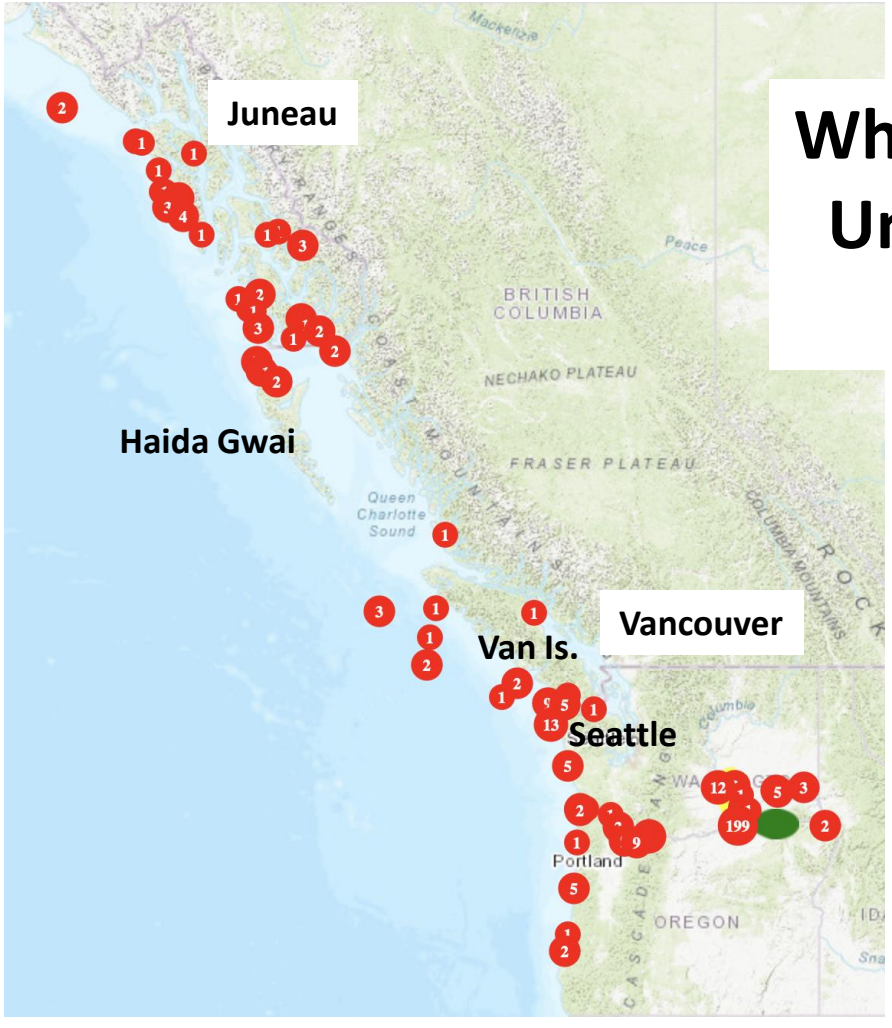
1. Hatcheries (opinionated)
   The “Big Bet”

2. The Pacific Ocean
   Increasing variability

3. Hatcheries meet the Pacific Ocean

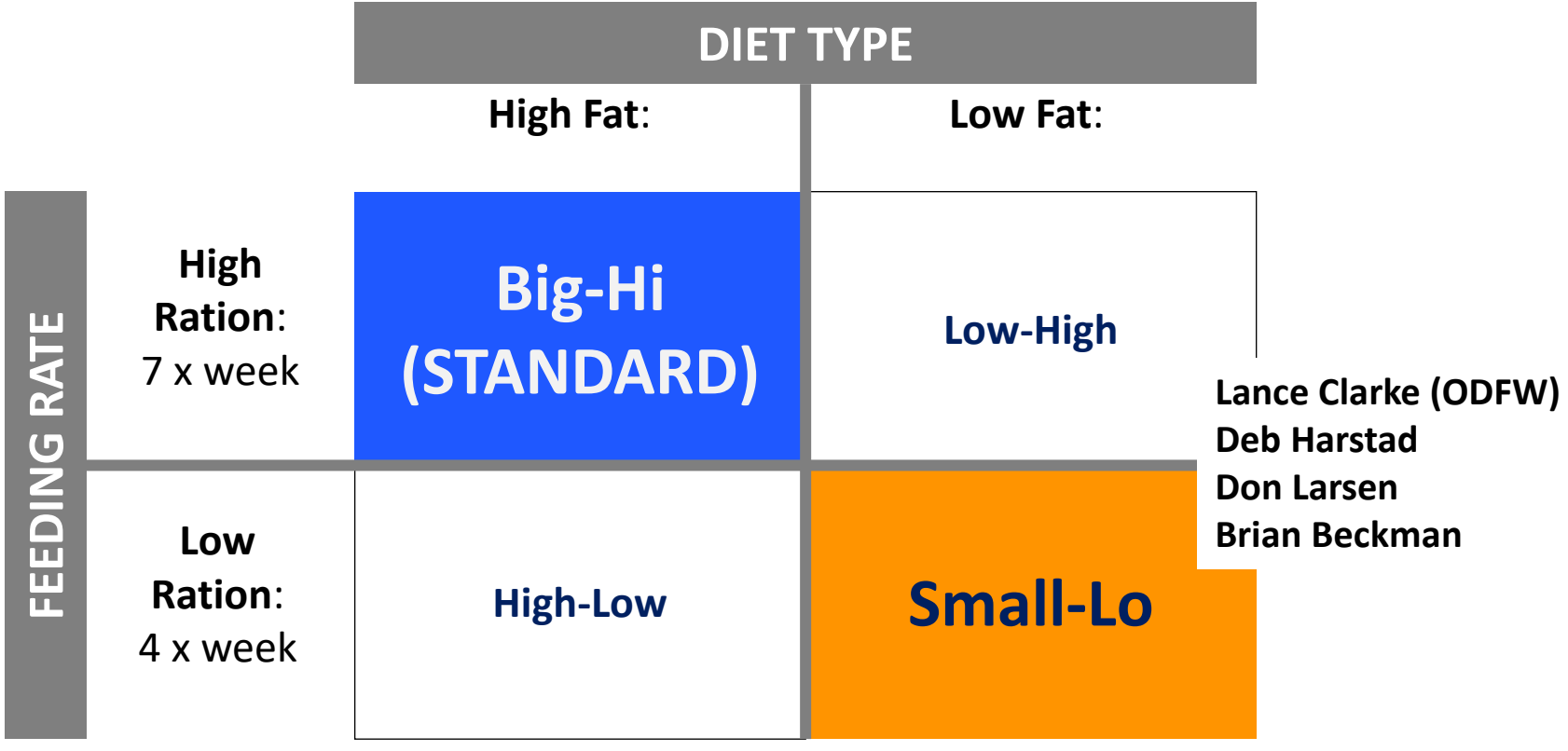
Experiment: Smolt size/condition at release study
Umatilla River (ODFW)



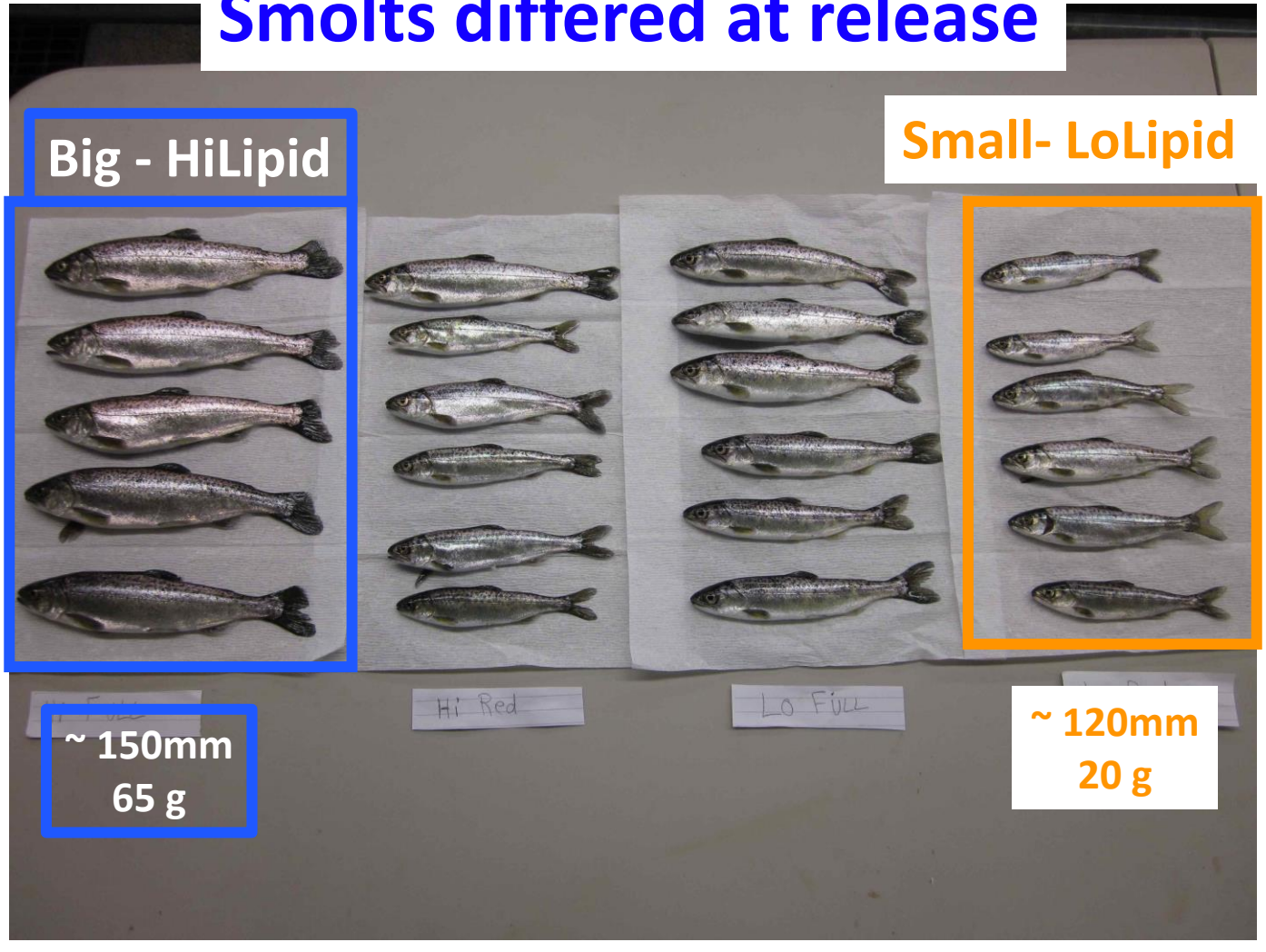


Why does a PSC audience care? Umatilla Hat. CWT recoveries 2012 release (RMIS)

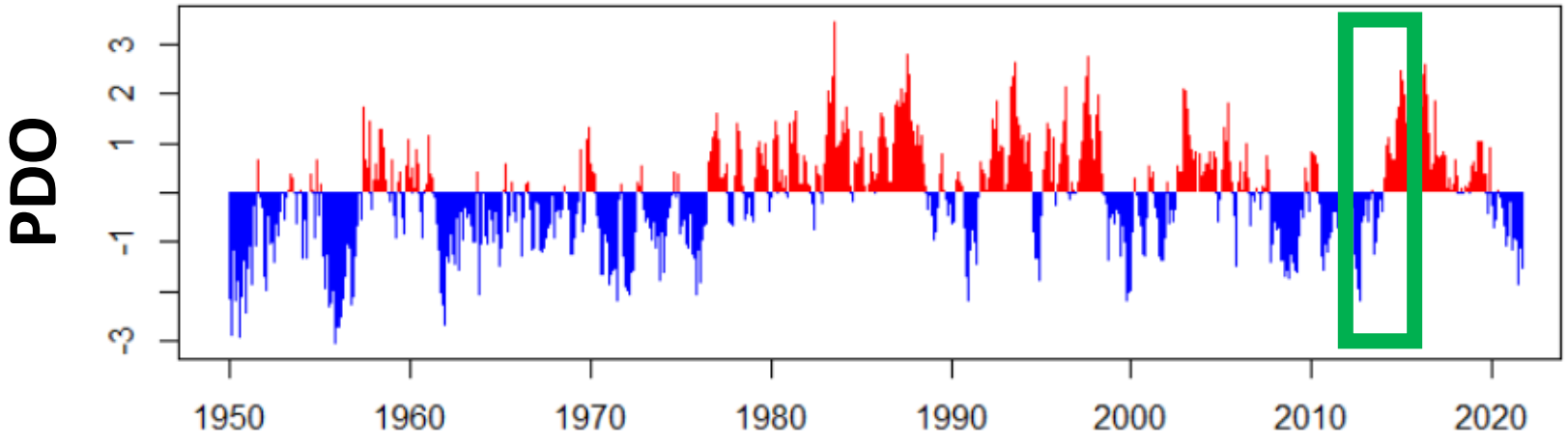
Experiment: Ration x Lipid for juvenile rearing, determine “best” rearing strategy, replicated over 4 release years



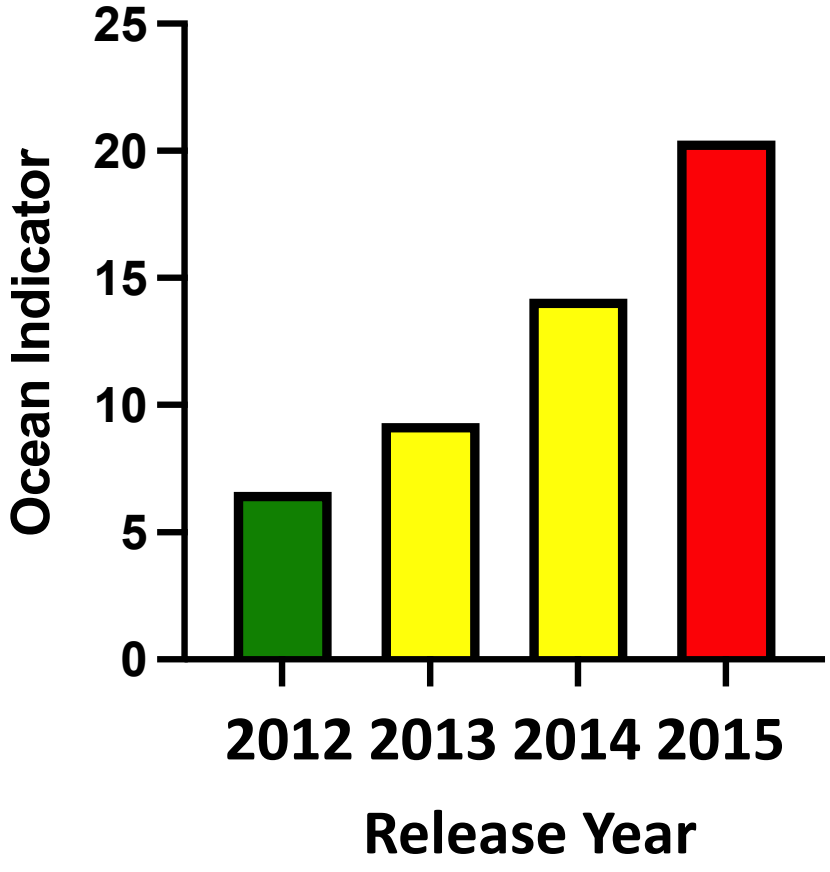
Smolts differed at release



Experiment occurred during a period of extreme ocean variation (the Blob)



Ocean conditions varied strongly over 4 release years

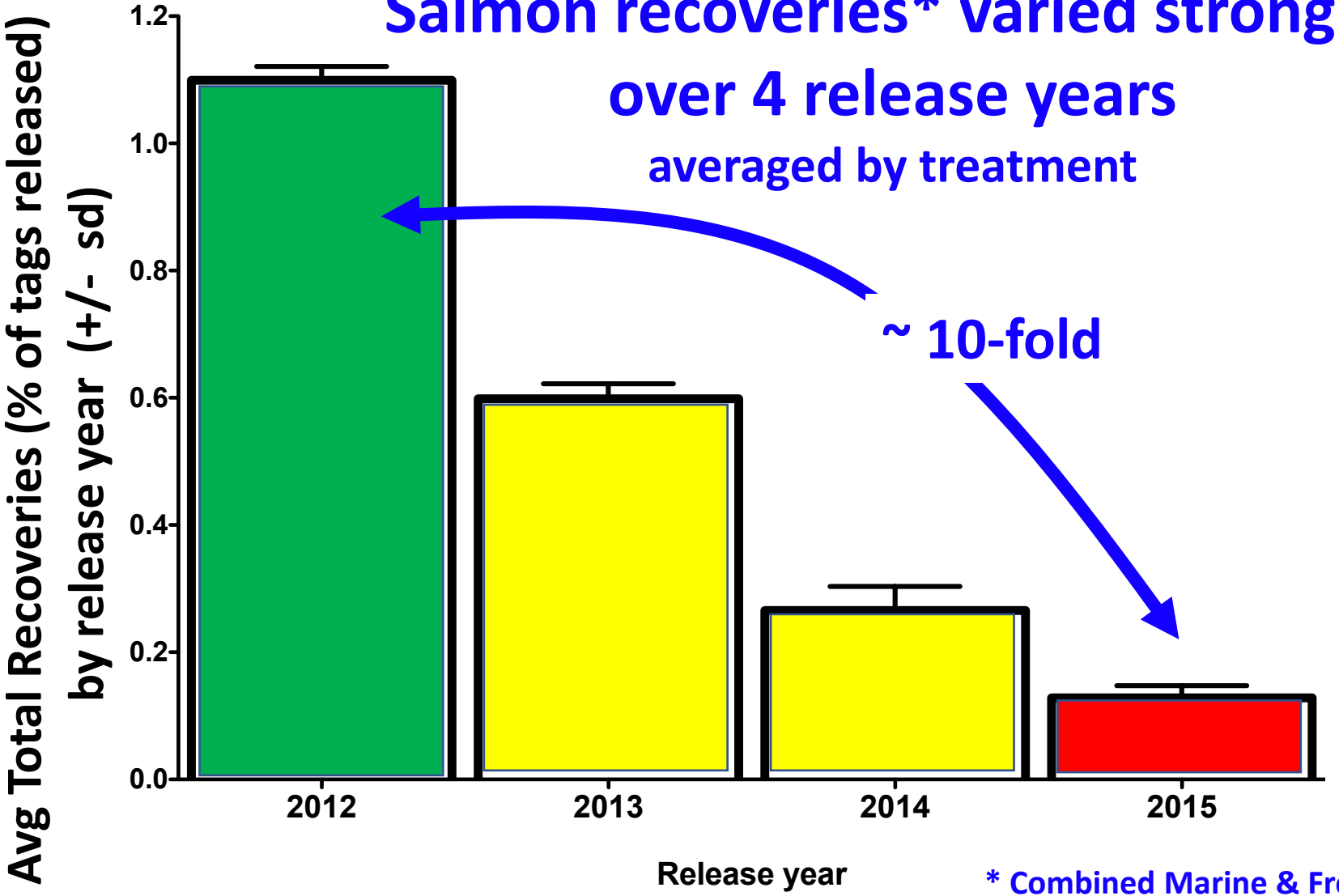


NWFSC, NMFS

https://www.fisheries.noaa.gov/west-coast/science-data/ocean-ecosystem-indicators-pacific-salmon-marine-survival-northern

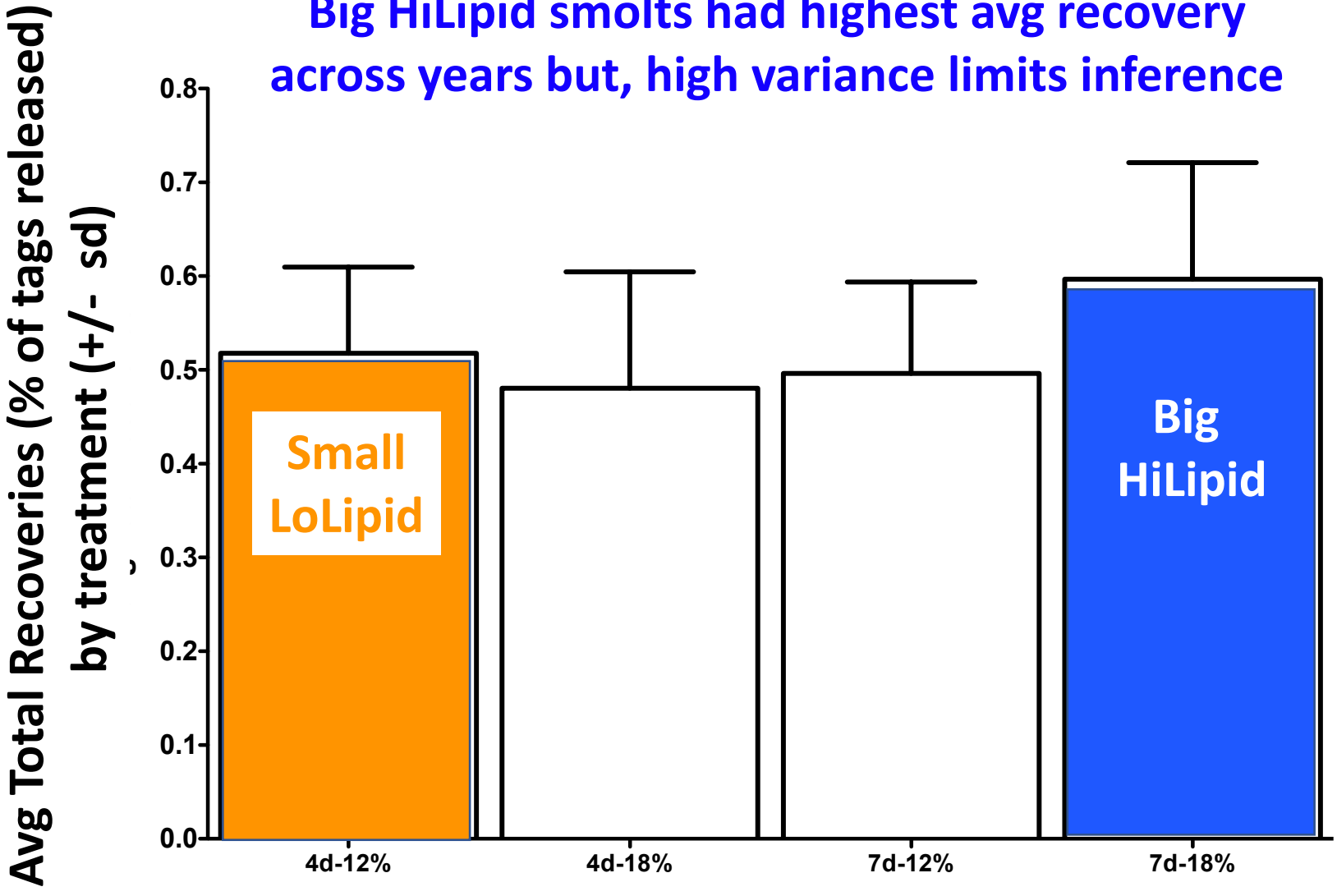
Salmon recoveries* varied strongly over 4 release years

averaged by treatment

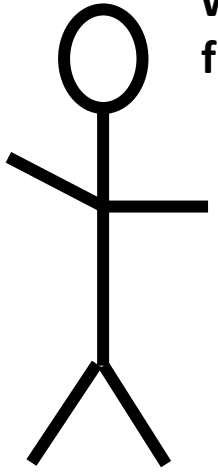


* Combined Marine & Freshwater

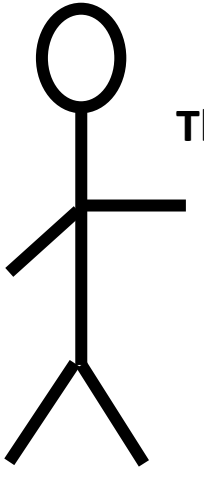
Big HiLipid smolts had highest avg recovery across years but, high variance limits inference



There was strong resistance to Umatilla study as many people ”knew” that smaller smolts would have lower survival



Won’t get any fish back from those puny smolts

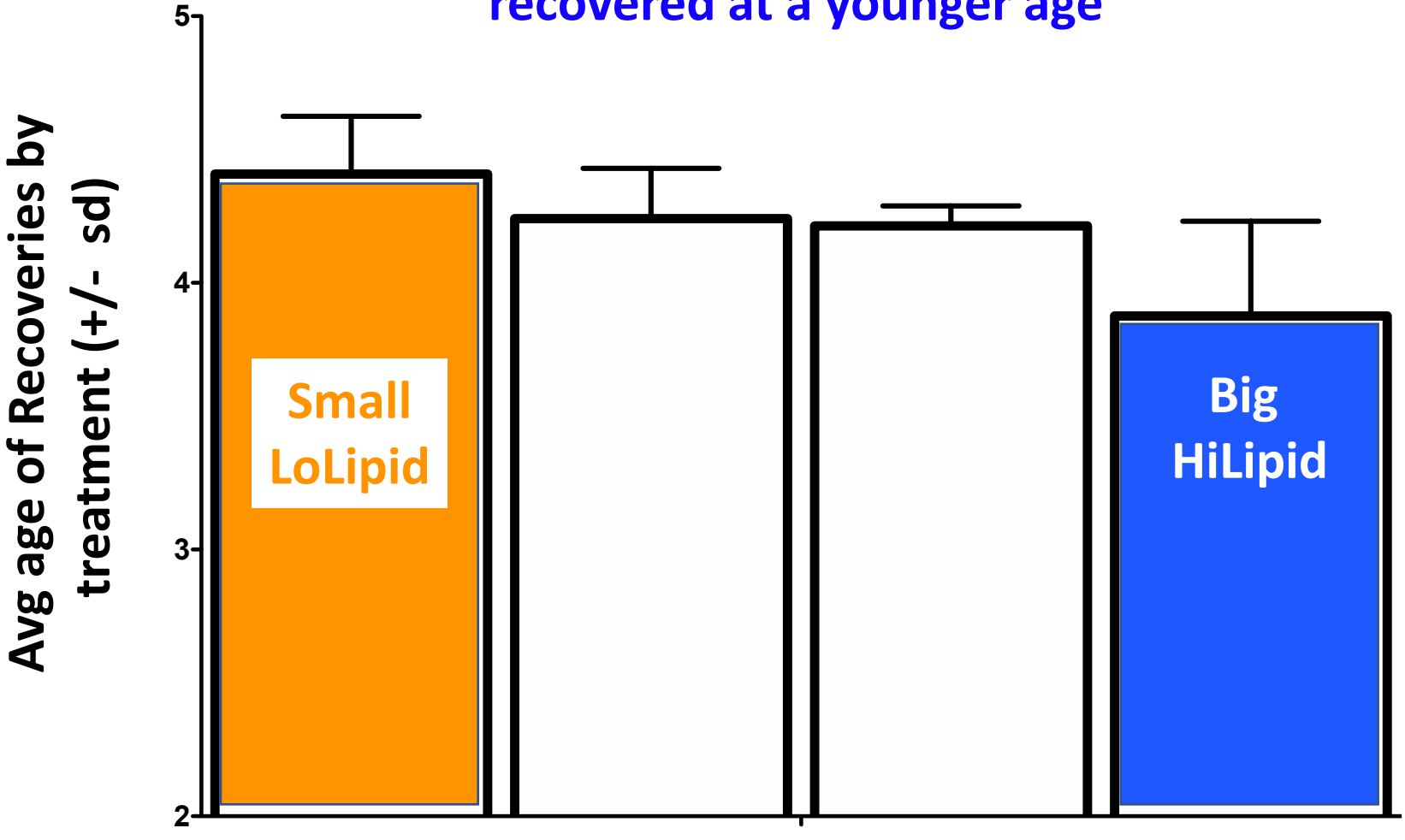


That’s been done before, it won’t work.

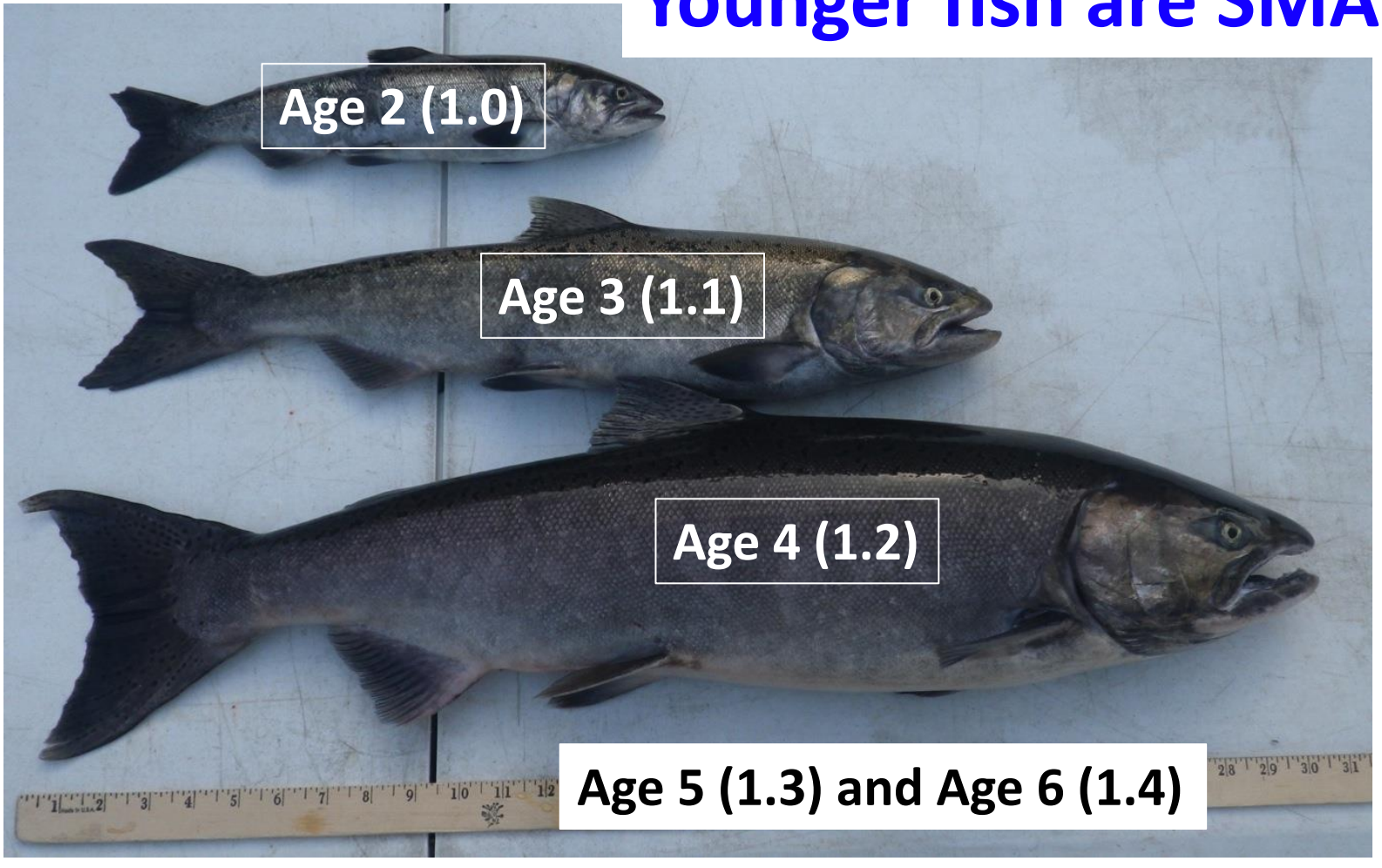
But – recoveries were roughly equivalent

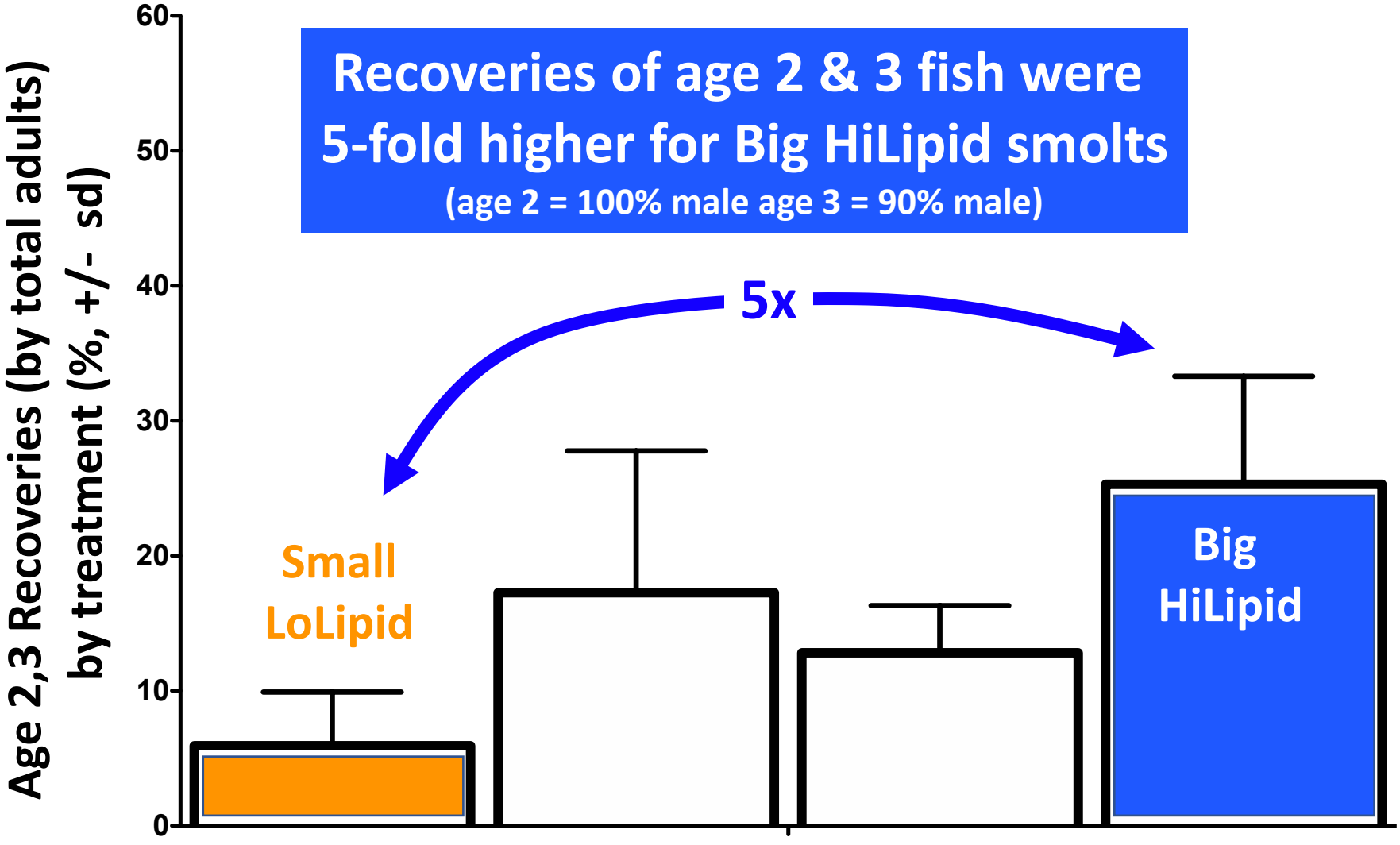
Fish were recovered over 5 year classes

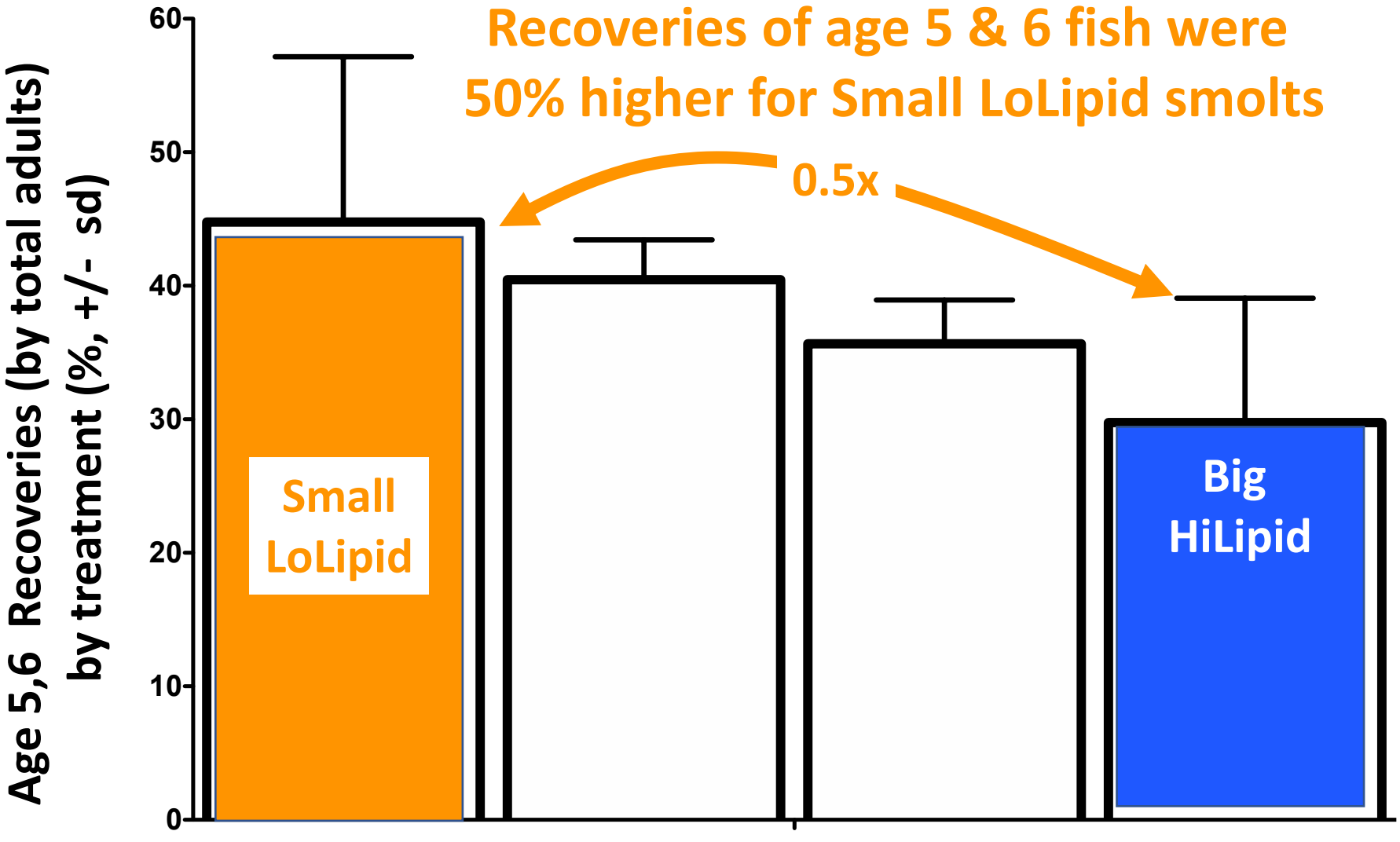
Age at recovery varies, with Big-HiLipid smolts recovered at a younger age



Younger fish are SMALL

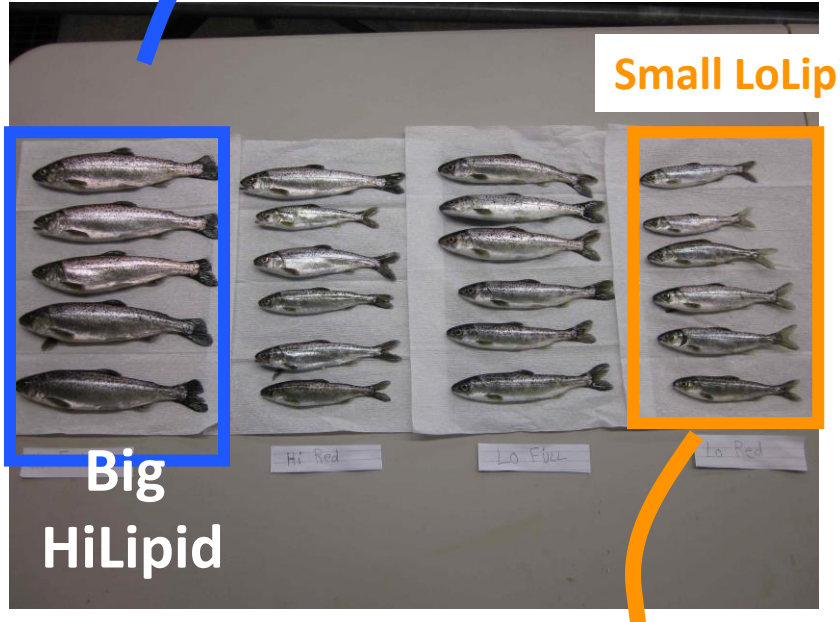



Recoveries of age 2 & 3 fish were
5-fold higher for Big HiLipid smolts
(age 2 = 100% male age 3 = 90% male)
Age 2,3 Recoveries (by total adults)
by treatment (%, +/- sd)
60
50
40
30
20
10
0
5x
Small
LoLipid
Big
HiLipid


Recoveries of age 5 & 6 fish were
50% higher for Small LoLipid smolts
0.5x
Age 5,6 Recoveries (by total adults)
by treatment (%, +/- sd)
60
50
40
30
20
10
0
Small
LoLipid
Big
HiLipid

Release character of smolts alters age at maturity

Younger and Smaller



Older and Larger

Assumptions of industrial smolt production

X Unlimited ocean carrying capacity

X Positive relationship between smolt release and adult return

X Uniform marine environment across years

X **All smolts have same performance**

What's certain about these results?

Huge difference between years

Average treatment recoveries not different across years
=> Interesting implications for hatchery production

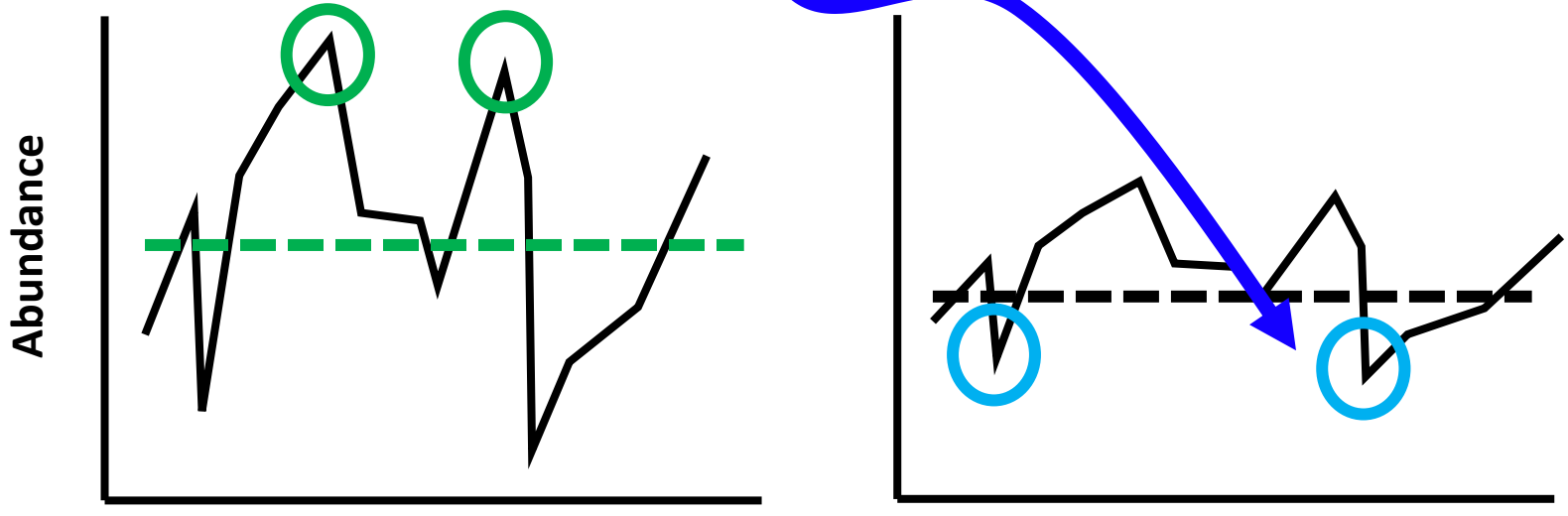
Differences in age at maturation

Remember this? **Thought experiment:**

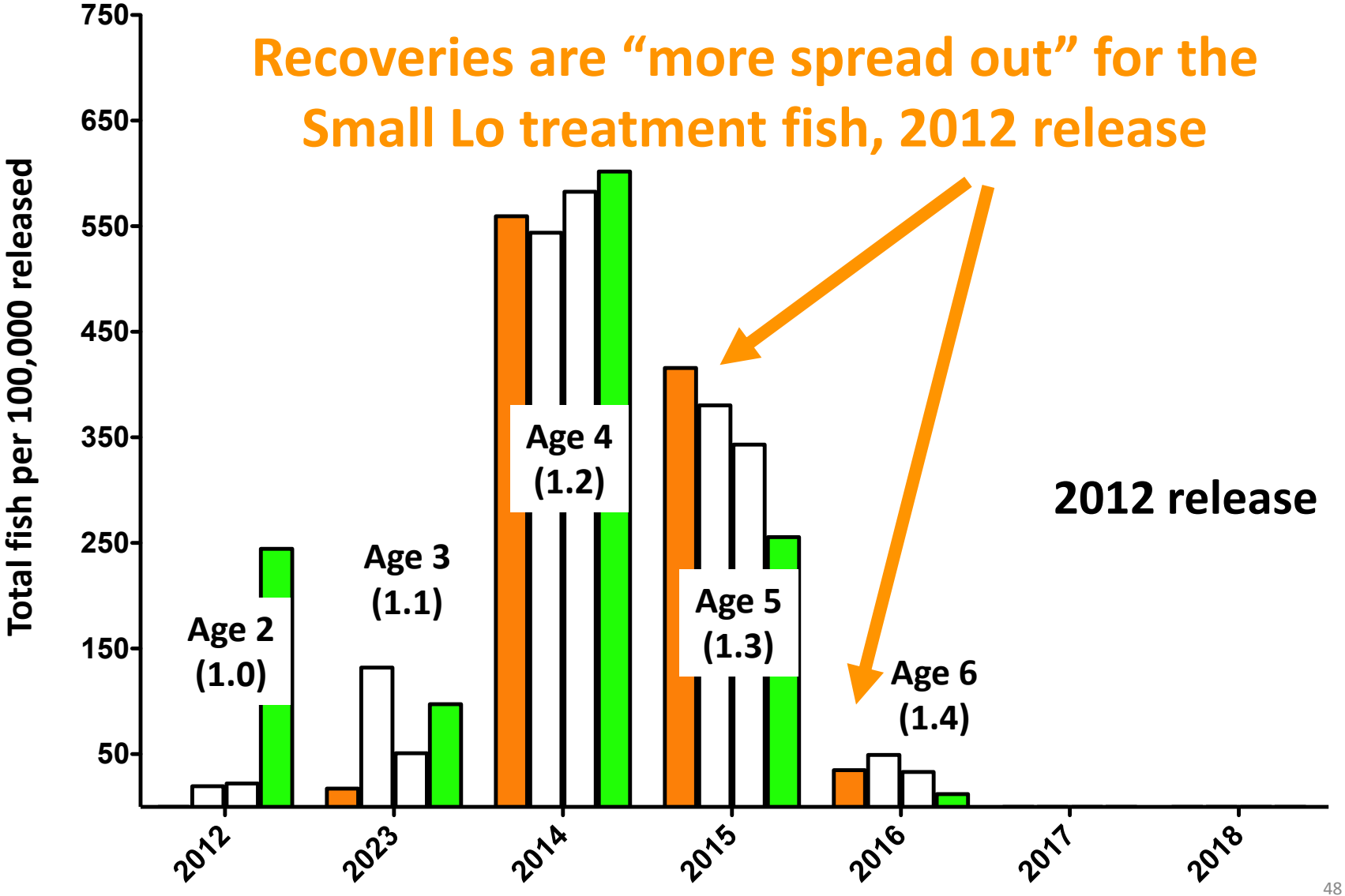
Are there alternative production strategies that might produce different magnitudes of variance?

Annual mean is higher
Max annual catch is higher

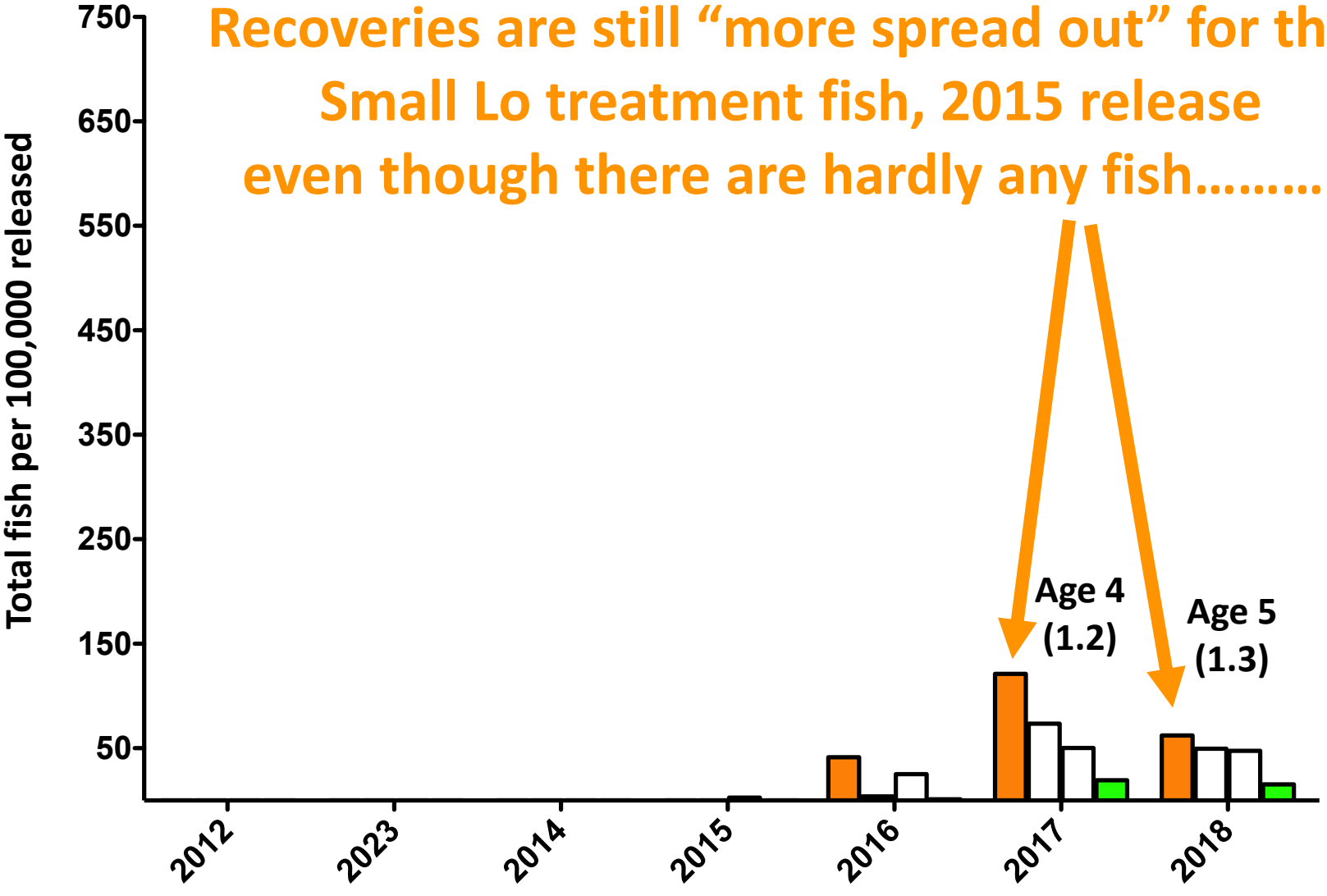
Minimum annual catch is higher
Variance is lower



Recoveries are “more spread out” for the Small Lo treatment fish, 2012 release

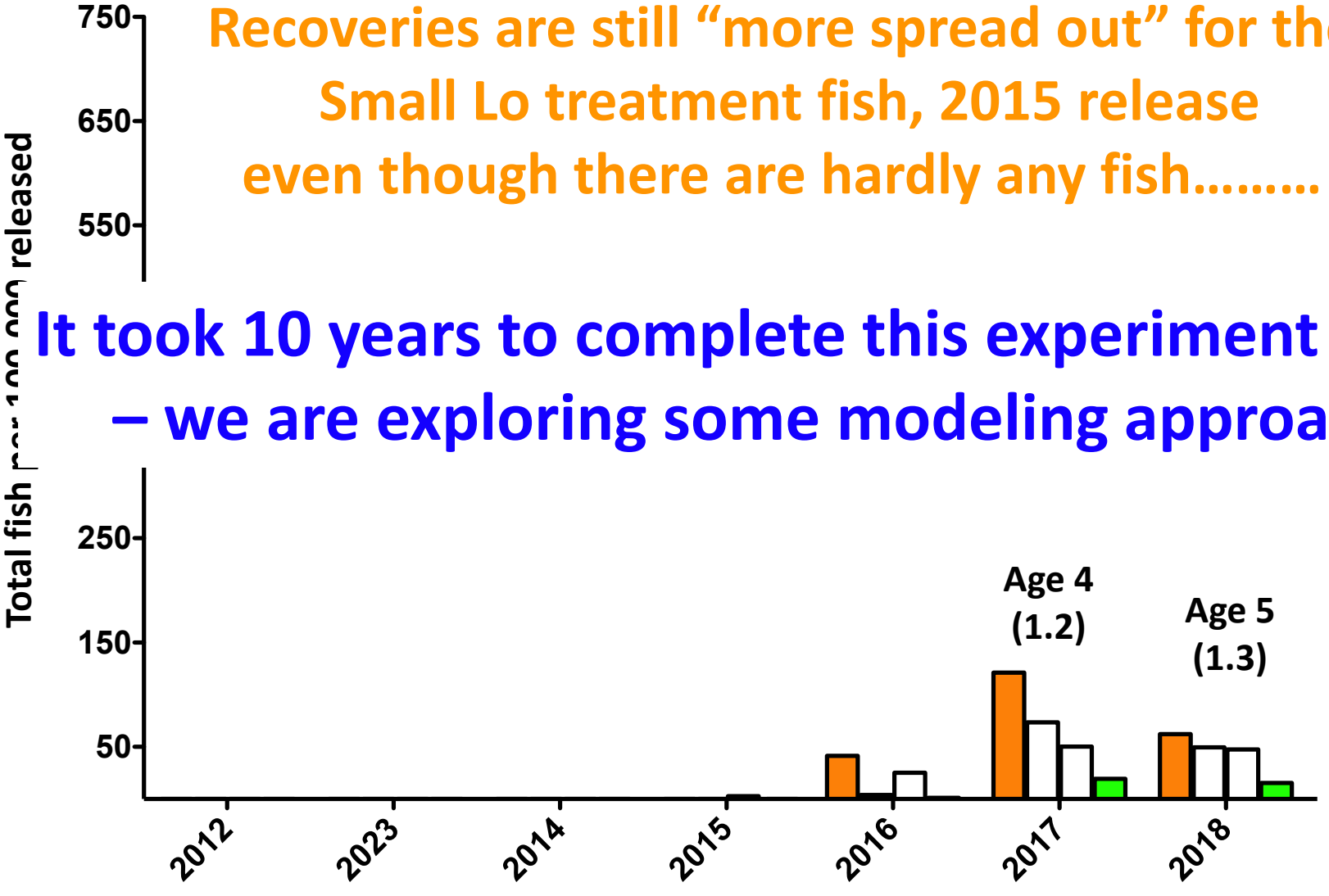


Recoveries are still “more spread out” for the Small Lo treatment fish, 2015 release even though there are hardly any fish……



Recoveries are still “more spread out” for the Small Lo treatment fish, 2015 release even though there are hardly any fish……

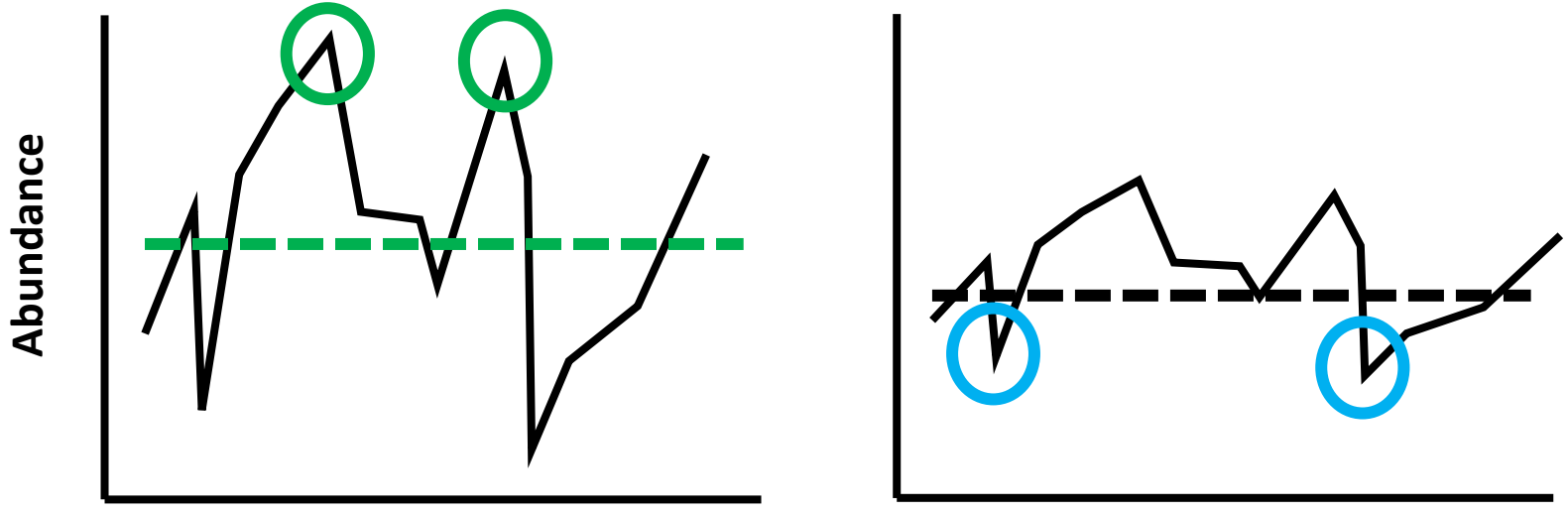
It took 10 years to complete this experiment – we are exploring some modeling approaches



Thought experiment:
Are there alternative production strategies that might produce different patterns of variance? Maybe?

Annual mean is higher
Max annual catch is higher

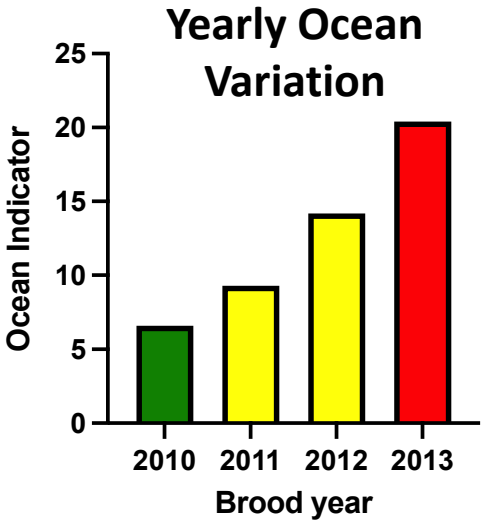
Minimum annual catch is higher
Variance is lower

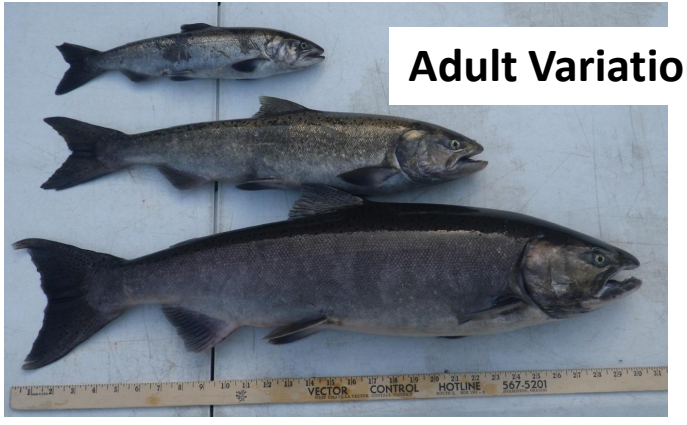


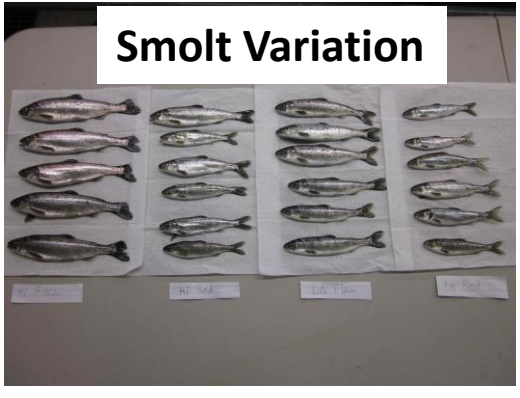
the big bet

something else

Summary







X Assumptions of industrial smolt production

Ask questions

What are hatchery goals?

What strategies are used to meet goals?