Review of Evidence of Genetic Interaction Between Hatchery and Wild Pink Salmon in Prince William Sound

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Gene Conservation Laboratory

Alaska Department of Fish and Game

AHRP Informational Meeting

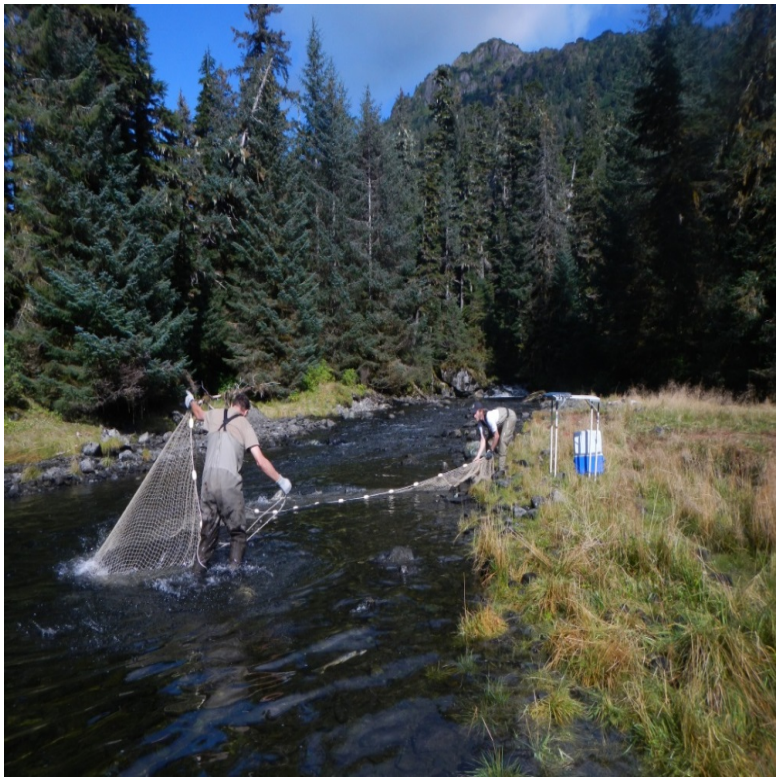
March 9, 2022

Why Do We Care About Genetic Interactions?

- Wild stock priority aims to protect wild production
  - Genetic Policy : "*First priority will be given to the protection of wild stocks from possible **harmful** interactions with introduced stocks*"
  - SSFP: "*…wild salmon stocks and fisheries on those stocks should be protected from **adverse** impacts from artificial propagation and enhancement efforts*"
- Harmful/adverse genetic interactions:
  - Loss of diversity among populations
  - Introduction of poorly adapted traits
- It is also possible to have hatchery/wild interactions that are not harmful/adverse

Outline

- Population structure
- Hatchery fish in streams
- Run timing differences
- Relative reproductive success
- Productivity of wild fish



Population Structure

- Observations that indicate potential genetic interaction
  - Previous studies indicated that pink salmon in PWS are not one population

Genetic Characterization of Prince William Sound Pink Salmon Populations

Report
to
Alaska Department of Fish and Game
Feb. 15, 1977
by
Jim Seeb
and
Lisa Wishard

INFORMATIONAL LEAFLET NO. 181

SEPARATION OF SOME PINK SALMON (Oncorhynchus gorbuscha Walbaum) SUB-POPULATIONS IN PRINCE WILLIAM SOUND, ALASKA BY LENGTH-WEIGHT RELATIONSHIPS AND HORIZONTAL STARCH GEL ELECTROPHORESIS

By
Richard B. Nickerson

Ecology of Freshwater Fish 1999: 8: 122–140
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ECOLOGY OF FRESHWATER FISH
ISSN 0906-6691

Allozyme and mitochondrial DNA variation describe ecologically important genetic structure of even-year pink salmon inhabiting Prince William Sound, Alaska

Seeb JE, Habicht C, Templin WD, Seeb LW, Shaklee JB, Utter FM. Allozyme and mitochondrial DNA variation describe ecologically important genetic structure of even-year pink salmon inhabiting Prince William Sound, Alaska.
Ecology of Freshwater Fish 1999: 8: 122–140. © Munksgaard, 1999

Abstract – Allozyme and mitochondrial DNA (mtDNA) data were obtained from pink salmon throughout Prince William Sound, Alaska, from two hatchery, five upstream, and 20 tidal locations distributed among five management regions collected during 1994. Screening for allozymes included 66 loci for 92 to 100 fish per sample. Thirty-four loci had variant allele frequencies >0.01 in one or more collections and were used for population analyses. Eight haplotypes were detected after screening 40 fish per collection for variation at the ND5/ND6 region of mtDNA using six restriction enzymes. Significant and apparently stable differences detected by both data sets permit rejecting a null hypothesis of panmixia and support managing native populations in Prince William Sound at the regional level. Distinctions between upstream and tidal collections were detected within Lagoon Creek (allozymes) and Koppen Creek (mtDNA). Significant regional heterogeneity was detected within upstream (allozymes and mtDNA) and tidal (allozymes) collections; however, upstream collections were more divergent from each other than were tidal collections. The absence of distinction of Armin F. Koernig Hatchery from almost all regions was consistent with multiple origins of this stock. Conversely, Solomon Gulch Hatchery in the East Region was distinct from all regions but East, consistent with a more restricted origin and influence.

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[1]Alaska Department of Fish & Game, Commercial Fisheries Division, Anchorage, Alaska, [2]Washington Department of Fish & Wildlife, Olympia, [3]School of Fisheries, University of Washington, Seattle, Washington, USA

Key words: allozyme; mtDNA; genetics; pink salmon

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Accepted for publication April 9, 1999

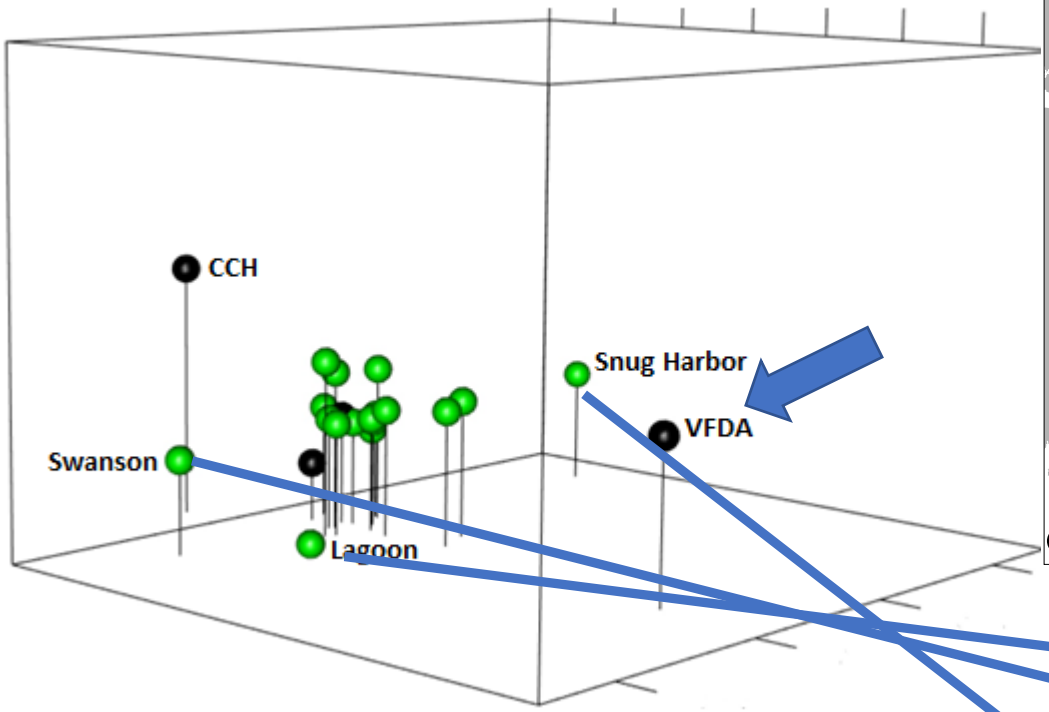
Un resumen en español se incluye detrás del texto principal de este artículo.

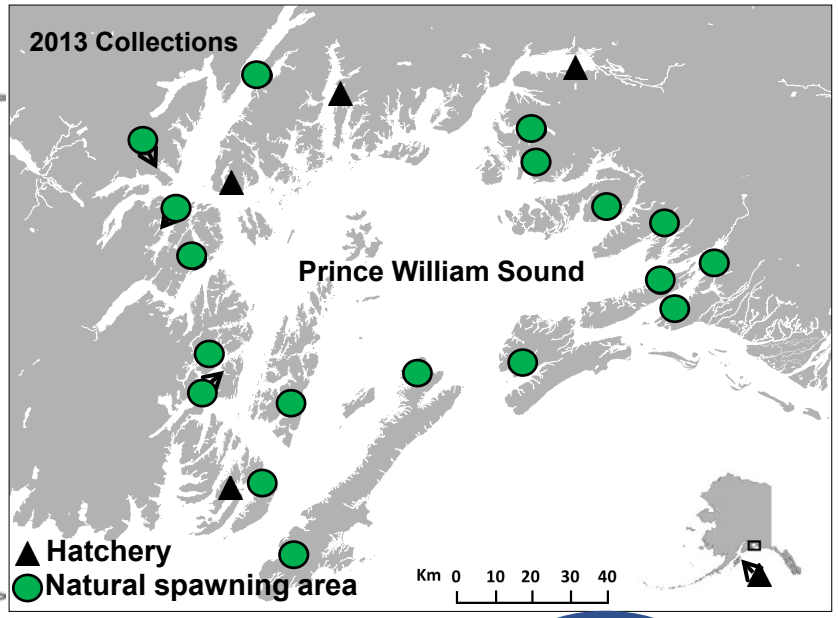
Population Structure

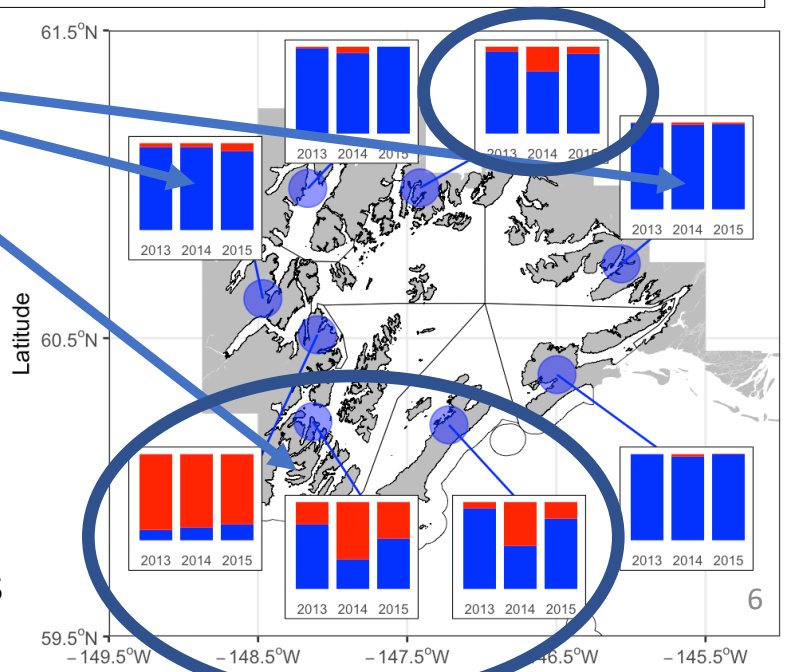
- Observations that indicate potential genetic interaction
  - Previous studies indicated that pink salmon in PWS are not one population

- But…
  - Current study also found significant structure
  - Outliers found in both districts with high and low hatchery proportions

Odd Year Genetic Relationships; Pink Salmon In PWS



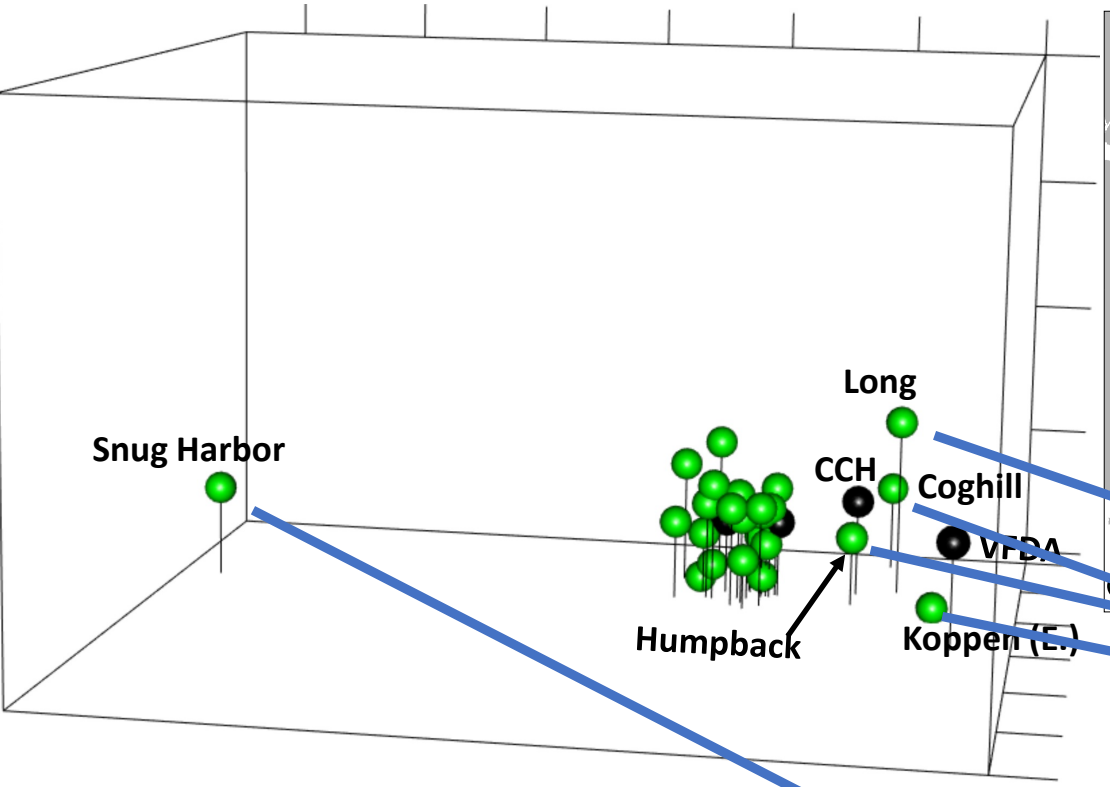


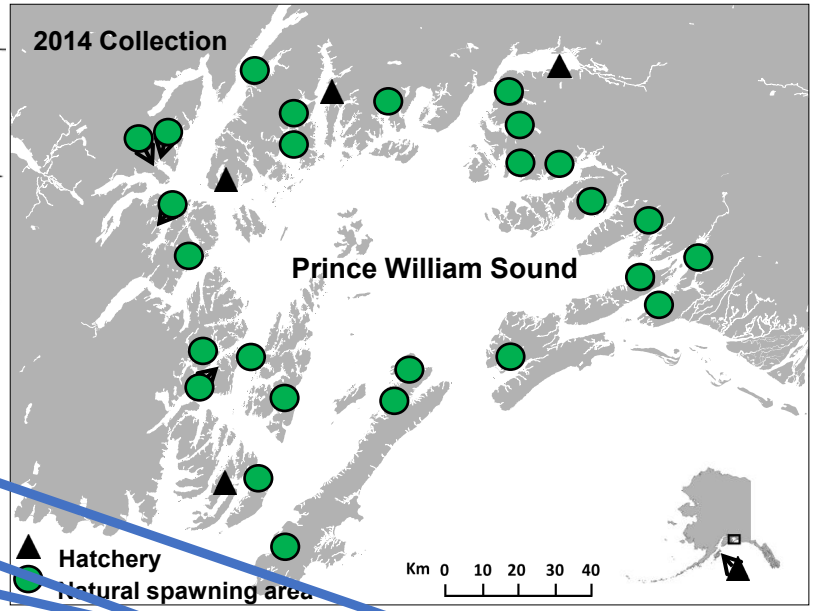


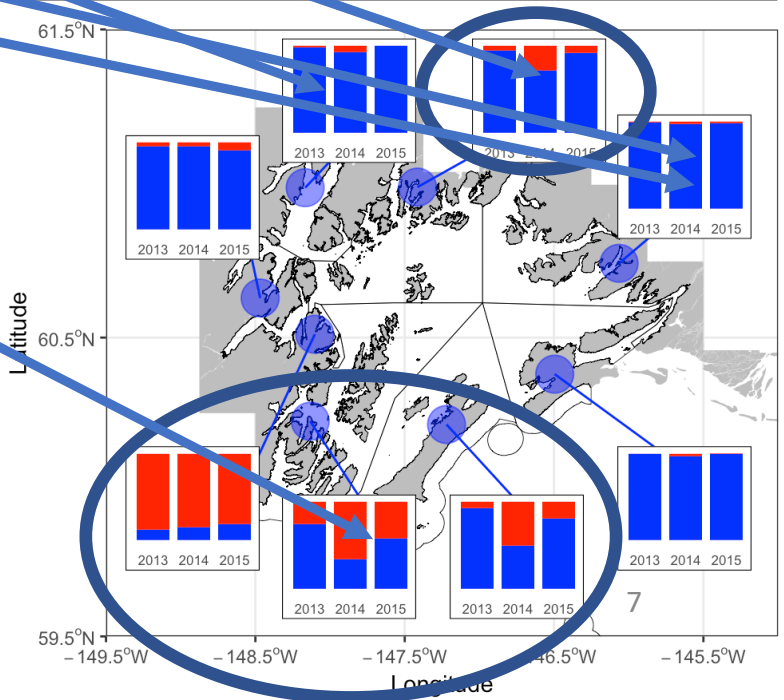
Distribution of outlier samples:

- 1 of 6 in districts with higher hatchery proportions
- 2 of 12 in districts with lower hatchery proportions

Even Year Genetic Relationships; Pink Salmon in PWS







Distribution of outlier samples:

- 2 of 11 in districts with higher hatchery proportions
- 3 of 15 in districts with lower hatchery proportions

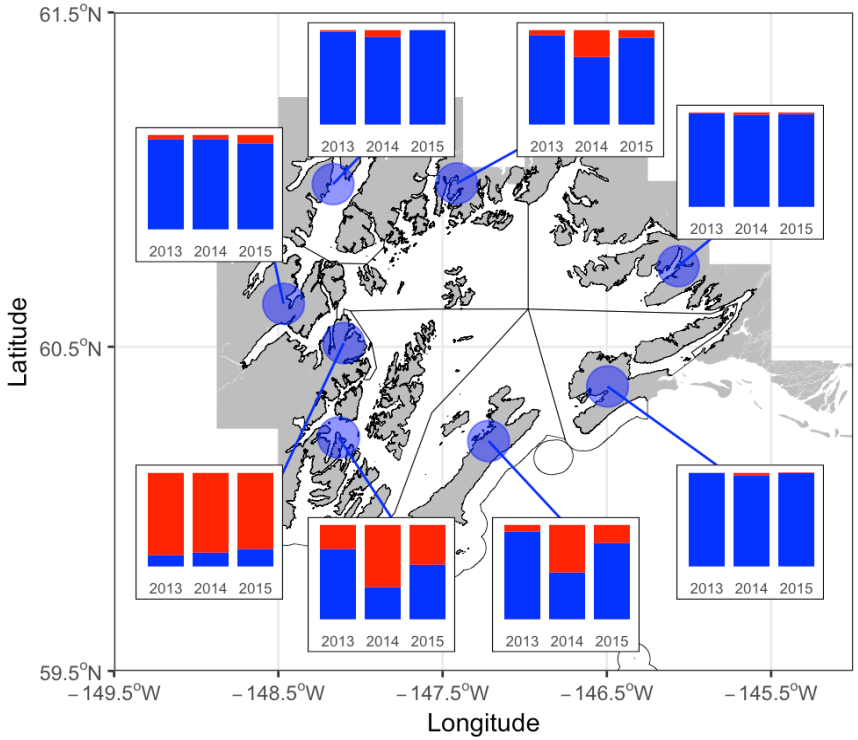
Population Structure

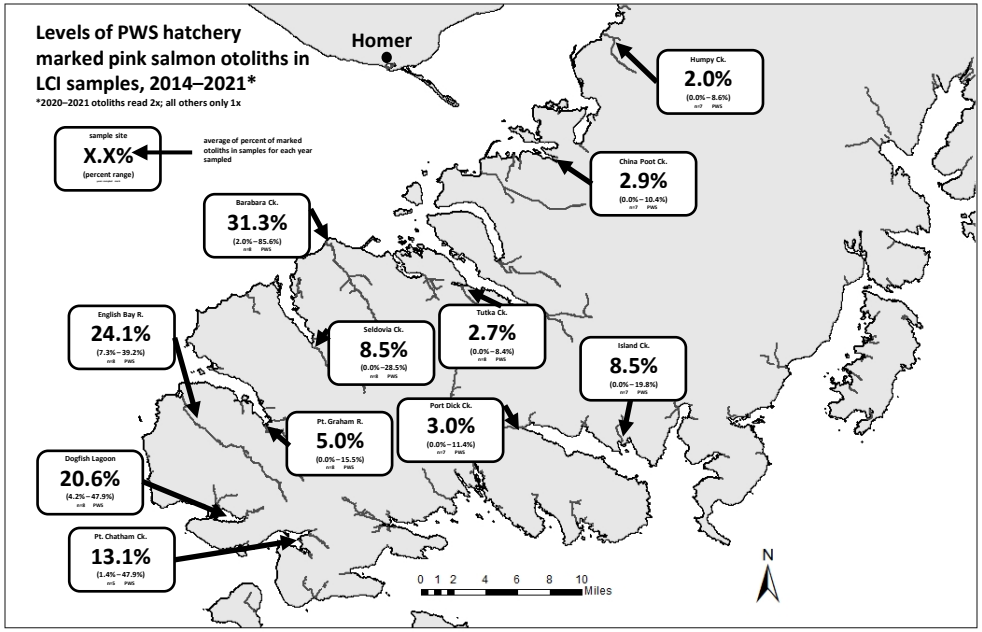
- Observations that indicate potential genetic mechanism
  - Previous studies indicated that pink salmon in PWS are not one population
- But…
  - Current study also found significant structure
  - Outliers found in both districts with high and low hatchery proportions
- Next steps
  - Examine historical vs contemporary population structure
  - Expand the scope westward

Hatchery Fish in Streams

- Observations that indicate potential genetic mechanism
  - Found PWS hatchery fish in streams
  - Some streams had high proportions
  - Found PWS hatchery fish in Lower Cook Inlet

District-level hatchery proportions





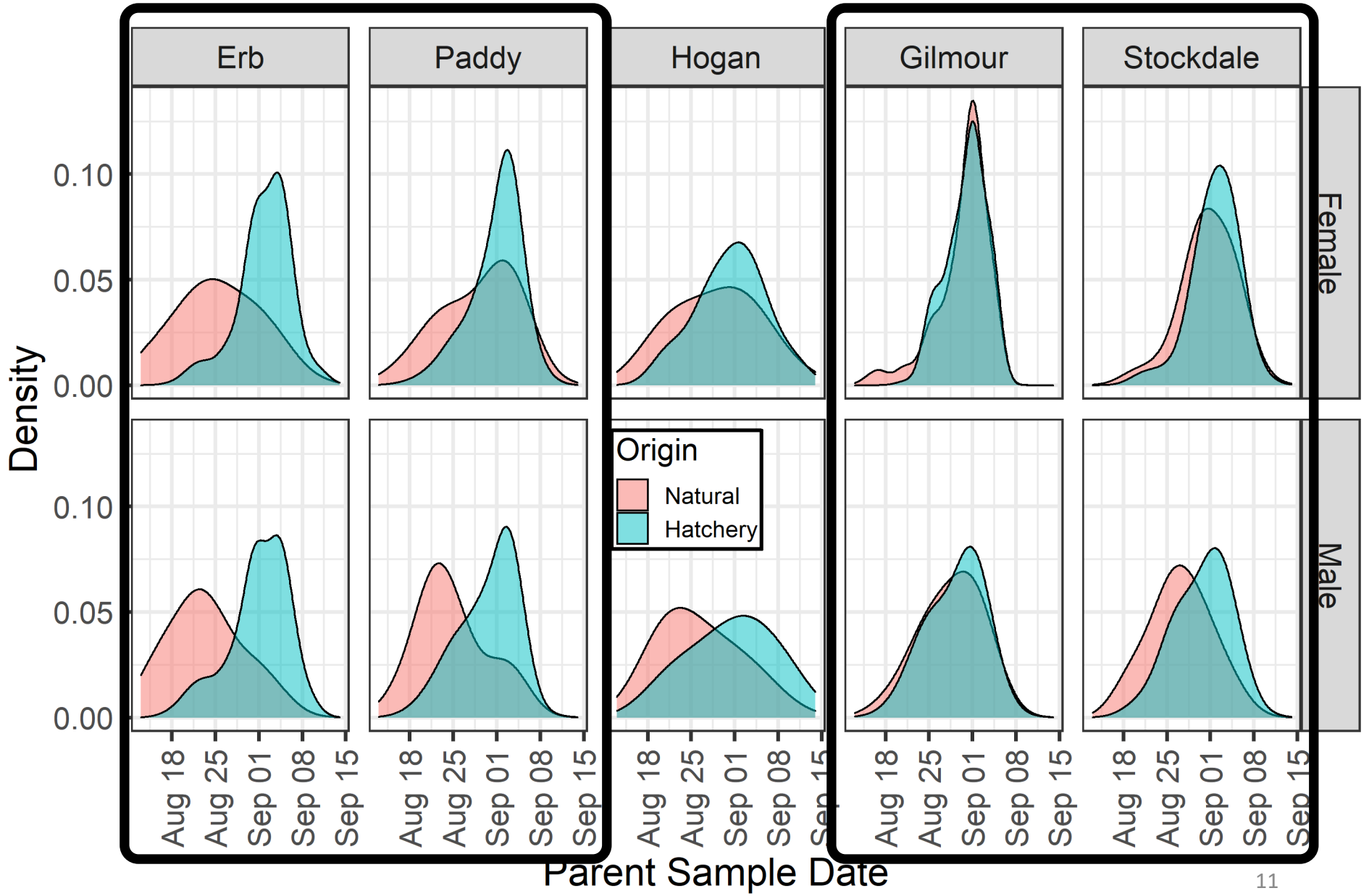
0.1% - 89.9%; Sound-wide annual average 4-14%

2.0% - 31.3%

Hatchery Fish in Streams

- Observations that indicate potential genetic mechanism
  - Found PWS hatchery fish in streams
  - Some streams had high proportions
  - Found PWS hatchery fish in Lower Cook Inlet
- But…
  - Population structure
  - Run timing differences between hatchery fish and wild fish persist in some streams

Results: Phenotypic Differences 2014



Hatchery Fish in Streams

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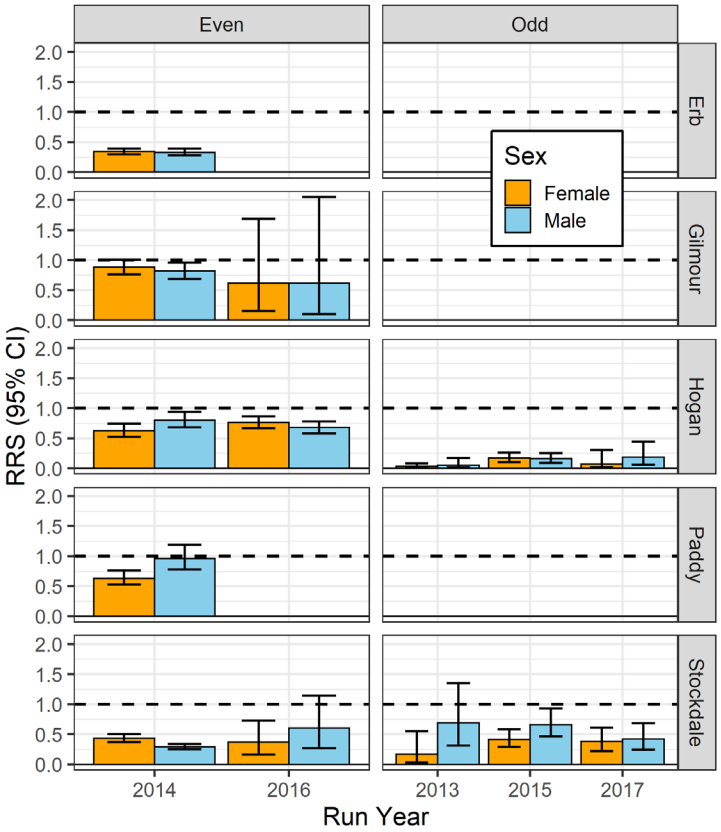
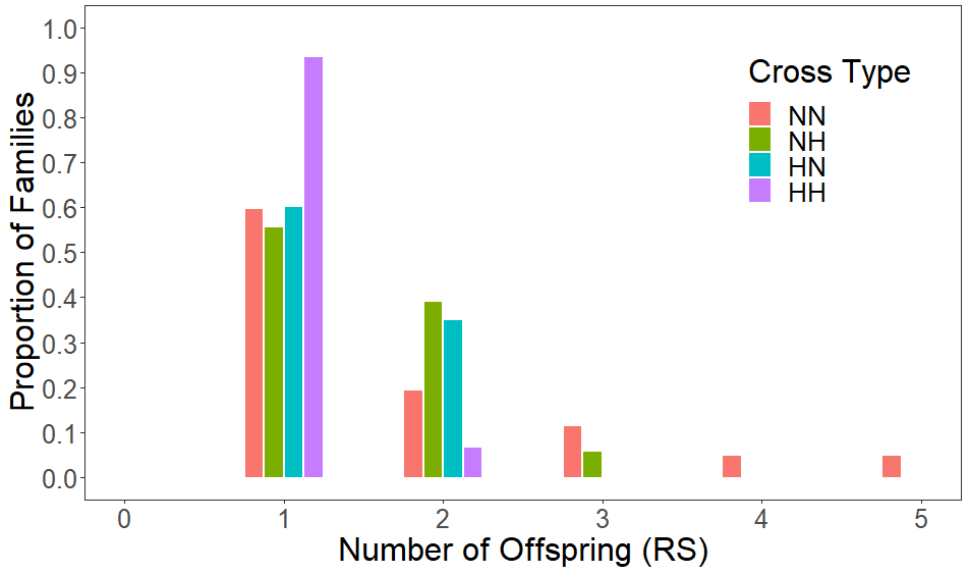
- But…
  - Population structure
  - Run timing differences between hatchery fish and wild fish persist
- Next steps
  - Examine run timing in more detail
  - Assess patterns of hatchery proportions among Cook Inlet streams

Relative Reproductive Success of Hatchery Vs Wild Fish

- Observations that indicate potential genetic interaction
  - Hatchery fish are reproducing in the wild
  - Hatchery fish have generally lower reproductive success in first generation
  - Hatchery fish are interbreeding with wild fish





Relative Reproductive Success of Hatchery Vs Wild Fish

- Observations that indicate potential genetic mechanism
  - Hatchery fish are reproducing in the wild
  - Hatchery fish have lower reproductive success
  - Hatchery fish are interbreeding with wild fish
- But…
  - Persistence of run timing among wild and hatchery fish
  - Population structure
  - Mechanisms may be ecological
- Next steps
  - Determine if RRS patterns are repeatable
    - All streams for even years, still need 3 streams for odd
    - Still need replicate years for 2 even year streams
  - Determine if RRS patterns are persistent or ephemeral
    - Grandparentage
  - Model genetic mechanisms

Productivity of Wild Fish

- Observations that indicate potential genetic mechanism
  - Published studies assert hatchery fish replace rather than augment wild fish
  - Genetic and ecological mechanisms proposed

Transactions of the American Fisheries Society 129:333–350, 2000

A Review of the Hatchery Programs for Pink Salmon in Prince William Sound and Kodiak Island, Alaska

RAY HILBORN*
University of Washington, School of Fisheries, Box 357980, Seattle, Washington 98195-7980, USA
DOUG EGGERS
Division of Commercial Fisheries, Alaska Department of Fish and Game, Post Office Box 25526, Juneau, Alaska 99801-5526, USA

"The evidence suggests that the hatchery program in Prince William Sound replaced rather than augmented wild production."

- Loss of 19M wild, net gain of 1M

NRC Research Press
ARTICLE

Measuring the net biological impact of fisheries enhancement: pink salmon hatcheries can increase yield, but with apparent costs to wild populations

Ricardo O. Amoroso, Michael D. Tillotson, and Ray Hilborn

"…we estimate that the PWS hatchery program has increased the total catch by an average of 17 million fish…"

- Loss of 13M wild, net gain of 17M

Productivity of Wild Fish

- Observations that indicate potential genetic interaction
  - Published studies assert hatchery fish replace rather than augment wild fish
  - Genetic and ecological mechanisms proposed

Received: 18 August 2021 | Revised: 2 December 2021 | Accepted: 12 December 2021

DOI: 10.1111/gcb.16049

RESEARCH ARTICLE

Non-stationary and interactive effects of climate and competition on pink salmon productivity

Jan Ohlberger[1] | Eric J. Ward[2] | Richard E. Brenner[3] | Mary E. Hunsicker[4] | Stormy B. Haught[3] | David Finnoff[5] | Michael A. Litzow[6] | Tobias Schwoerer[7] | Gregory T. Ruggerone[8] | Claudine Hauri[9]

"… we find evidence that hatchery pink salmon releases negatively affect wild pink salmon productivity, likely through competition between wild and hatchery juveniles in nearshore marine habitats."

- Wild productivity decreased by 55%, but worth the net benefit?

Productivity of Wild Fish

- Observations that indicate potential genetic mechanism
  - Published studies assert hatchery fish replace rather than augment wild fish
  - Genetic and ecological mechanisms proposed
- But…
  - Other published studies assert that the replacements were much lower
  - Ecological mechanisms proposed

Chapter 23
Effects of Hatchery Releases and Environmental Variation on Wild-stock Productivity: Consequences for Sea Ranching of Pink Salmon in Prince William Sound, Alaska

ALEX C. WERTHEIMER[1], WILLIAM R. HEARD[1] and WILLIAM W. SMOKER[2]
[1] *National Marine Fisheries Service Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801 USA,* [2] *University Alaska Fairbanks Juneau Center Fisheries Ocean Sciences, 11120 Glacier Highway, Juneau, Alaska 99801 USA*

"…we estimated for return years 1990-2000 that the annual loss in wild production due to displacement by hatchery fish was 0-4.6 million pink salmon…"

- Loss of 0-4.6M wild, net gain of 21-25M

Reviews in Fish Biology and Fisheries (2004) 14: 321–334
DOI 10.1007/s11160-004-2942-4

Relationship of size at return with environmental variation, hatchery production, and productivity of wild pink salmon in Prince William Sound, Alaska: does size matter?

Alex C. Wertheimer[1], William R. Heard[1], J. M. Maselko[1] & William W. Smoker[2]
[1]*National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, AK 99801, USA (Phone: +1-907-789-6040; Fax: +1-907-789-6094; E-mail: Alex.Wertheimer@noaa.gov);* [2]*University of Alaska, Fairbanks, Juneau Center for Fisheries and Ocean Sciences, 11120 Glacier Highway, Juneau, AK 99801, USA*

"We estimated an annual wild-stock yield loss of 1.03 million pink salmon, less than 5% of the annual hatchery return of 24.2 million adult pink salmon for brood years 1990–1999."

- Loss of 1M wild, net gain of 23M

Productivity of Wild Fish

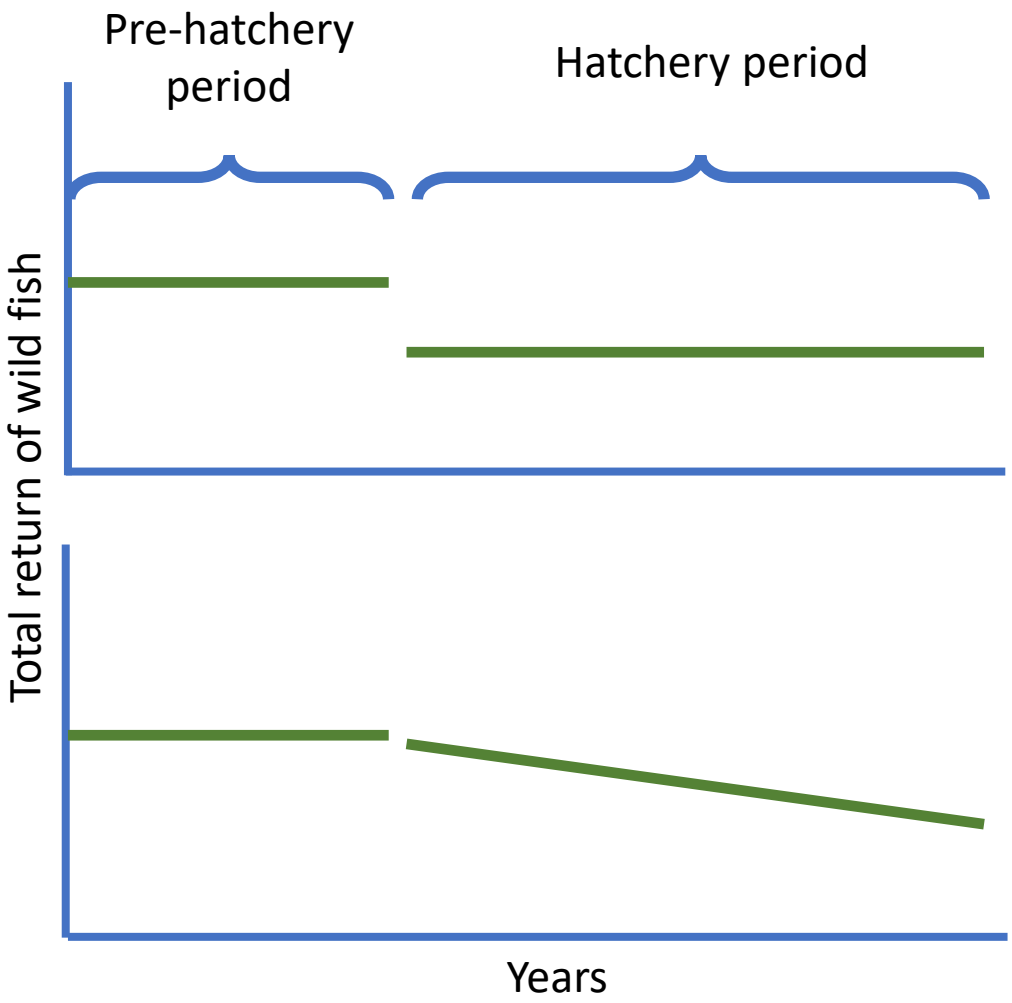
- Observations that indicate potential genetic mechanism
  - Published studies assert some displacement
  - Genetic and ecological mechanisms proposed
- But…
  - Other published studies assert that the replacements were much lower
  - Ecological mechanisms proposed
  - Wild productivity trends appear stable during high hatchery production period

Production of wild fish

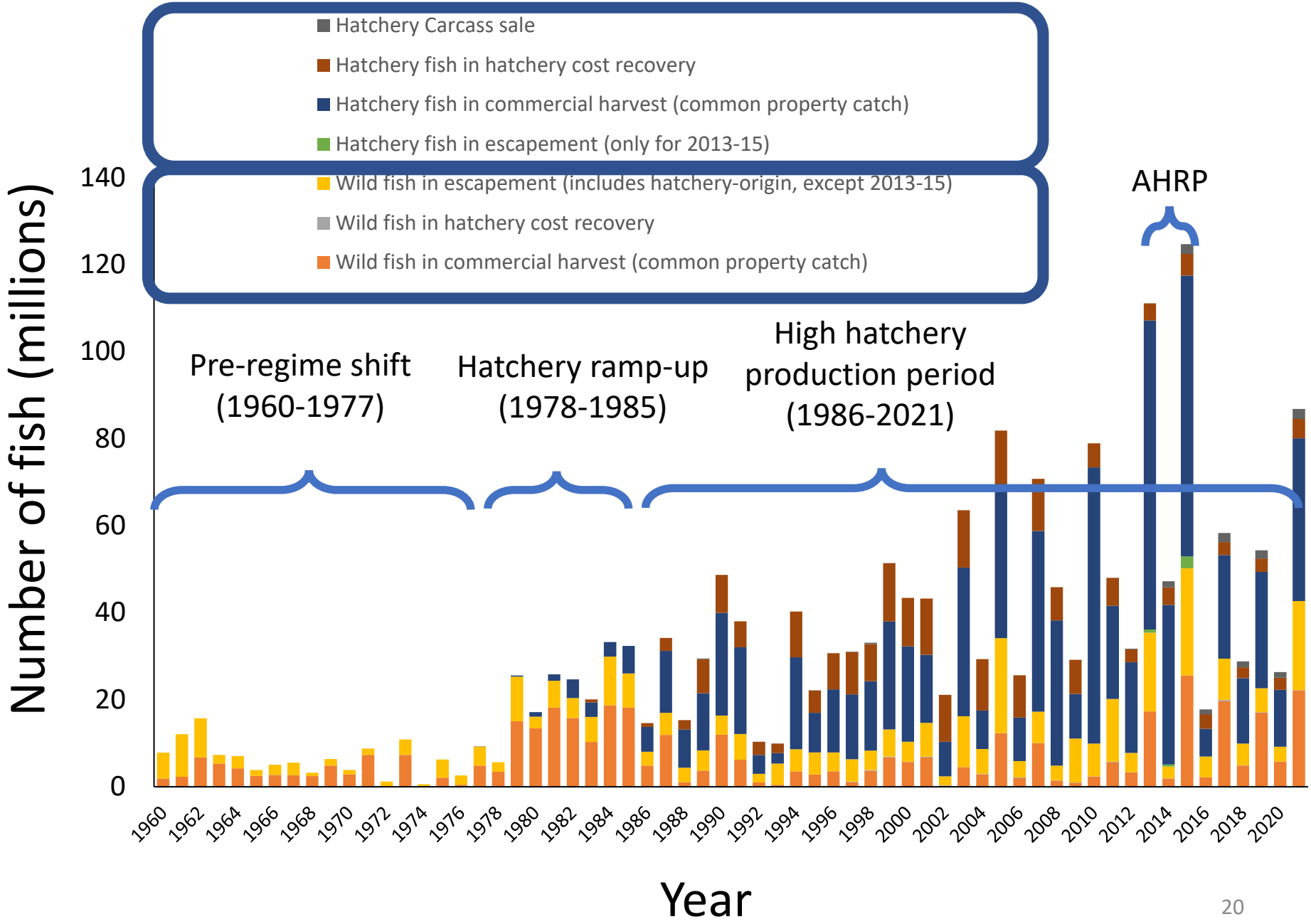
Cartoon of production response from ecological and genetic mechanisms

Partial Replacement
Ecological mechanism
(e.g. competition)

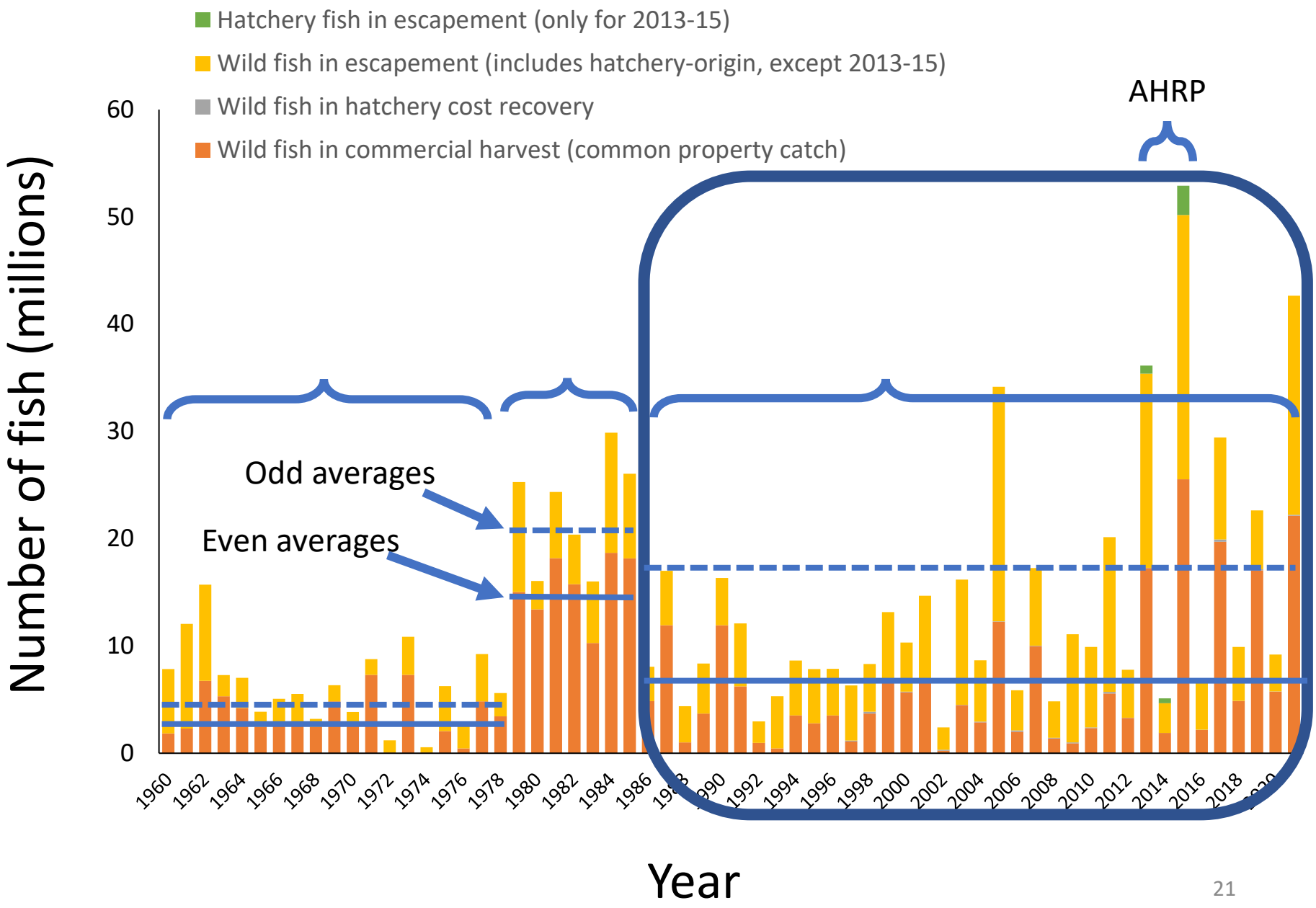
Partial Replacement
Genetic mechanism
(e.g. ill adapted traits)



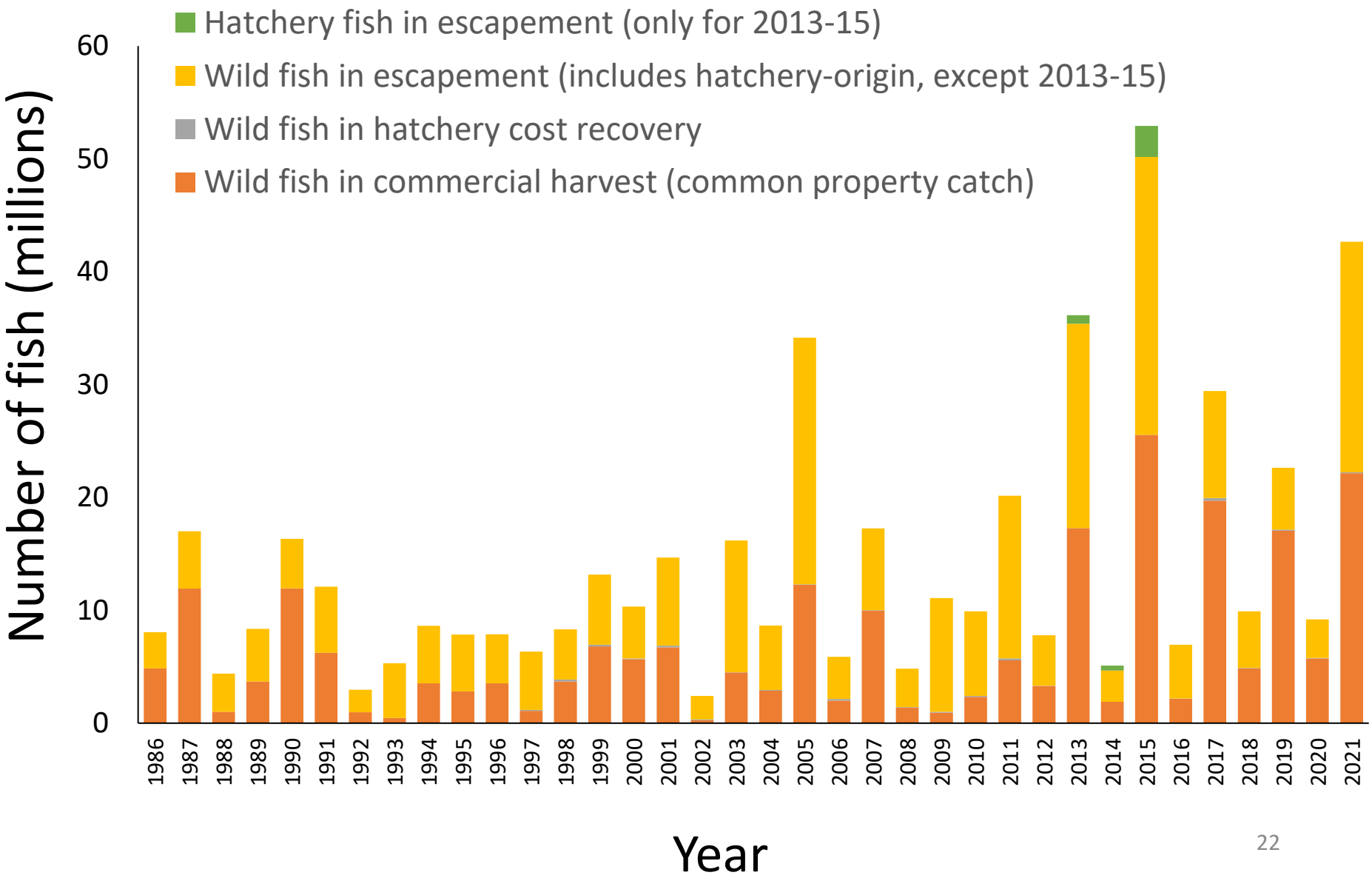
PWS Pink Salmon Total Run: 1960-2021



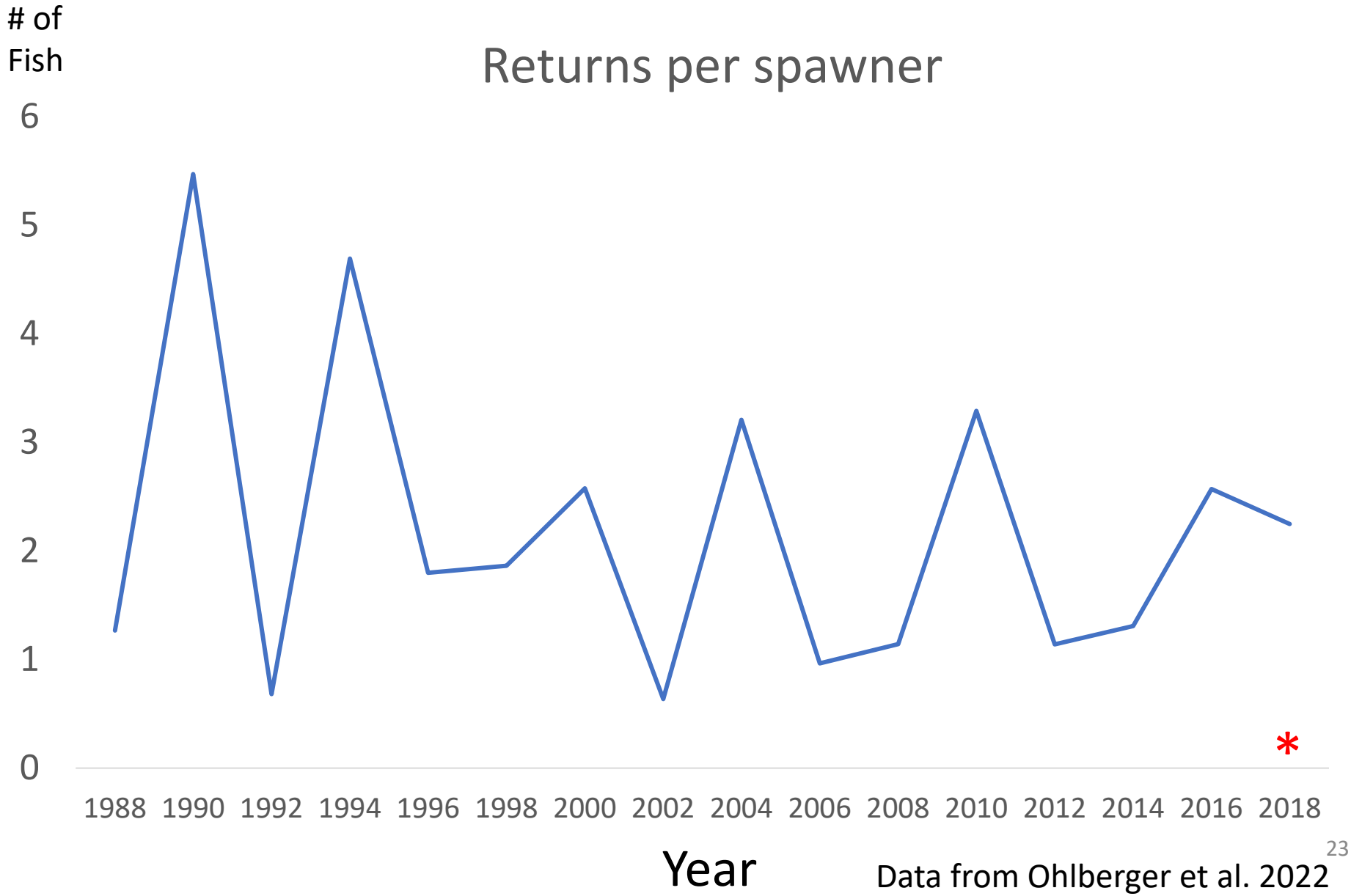
PWS Pink Salmon Total **Wild Run:** 1960-2021



PWS Pink Salmon Total **Wild Run: High hatchery production period** (1986-2019)

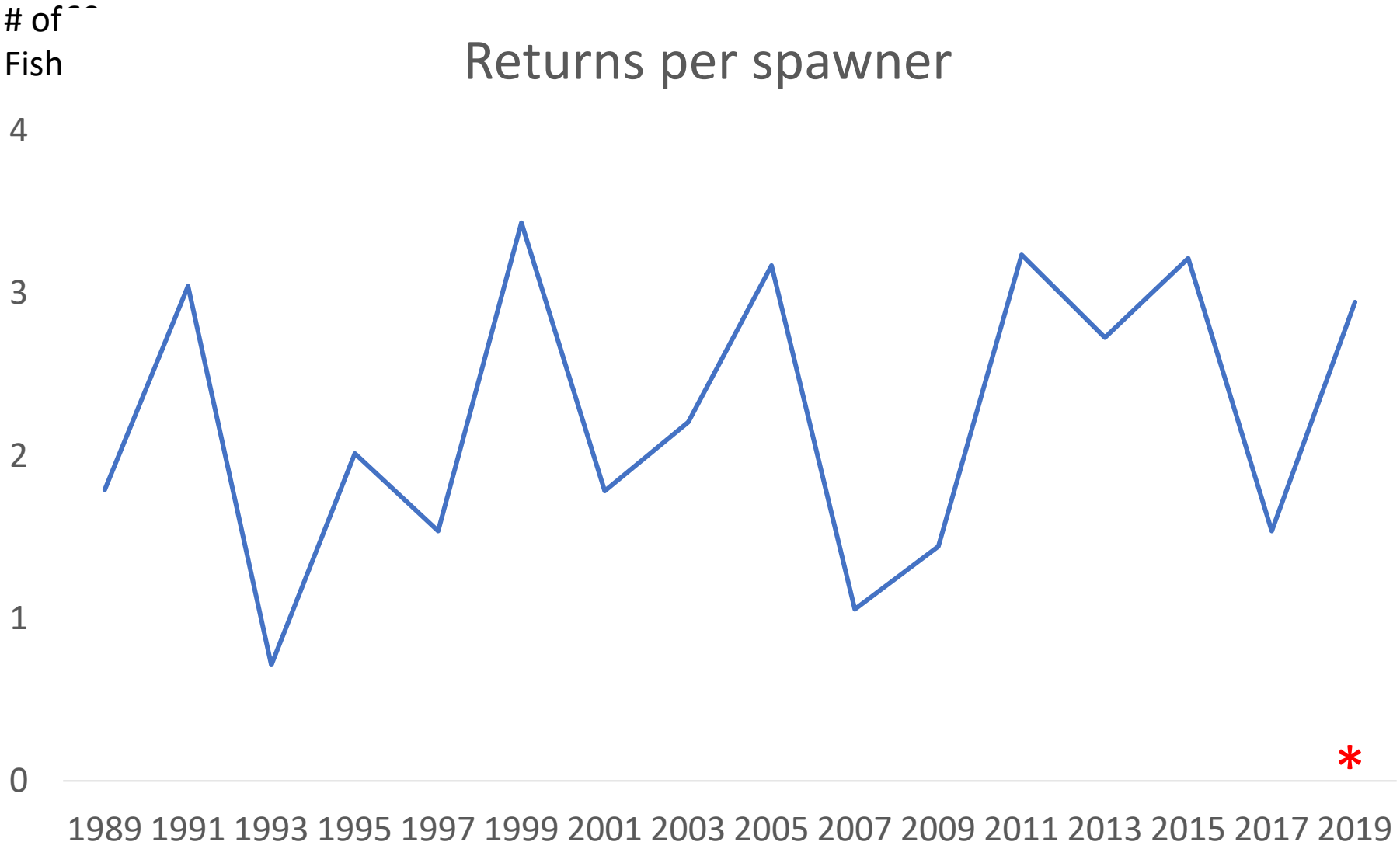


PWS Pink Salmon Total **Wild Run (Even Year):** **High hatchery production period** (1986-2018)



Data from Ohlberger et al. 2022

PWS Pink Salmon Total **Wild Run (Odd Year):**
High hatchery production period: 1987-2021



Data from Ohlberger et al. 2022

AHRP Measured High Returns Per Spawner for One Generation

- 2013 wild escapement:
  - Wild origin = 15.7M
  - Hatchery origin = 0.7M
  - Total = 16.4M
- 2015 wild return:
  - Wild origin = 63.5M

- Returns per spawner (2013/2015) = 3.9 fish

- Note: 2015 was the largest wild return since 1960; may not be representative of other years

Productivity of Wild Fish

- Observations that indicate potential genetic mechanism
  - Published studies assert some displacement
  - Genetic and ecological mechanisms proposed
- But…
  - Other published studies assert that the replacements were much lower
  - Ecological mechanisms proposed
  - Wild productivity trends appear stable
- Potential next steps
  - Model demographic and genetic effects of hatchery/wild interactions on population recruitment and resilience

So Where Are We Now?

- Most direct way to reduce potential for harmful genetic interactions is to keep hatchery-origin fish out of wild streams
- There is potential for harmful genetic interactions
  - Hatchery fish are in streams
  - Hatchery fish are interbreeding with wild fish
  - Hatchery fish in streams are producing progeny
  - Hatchery fish in streams have lower estimated reproductive success
- Effects of negative genetic interactions are not conclusive
  - Population structure patterns not consistent
  - Run timing has not converged in some high pHOS streams
  - Wild fish productivity trends appear stable
- Lack of evidence does not prove lack of harmful genetic interactions; some effects are difficult to measure:
  - Reduced potential for adaptation
  - Reduced ability to buffer (“Portfolio Effect”)

Where Do We Go From Here?

Fill in information gaps

- Planned activities by AHRP:
  - Examine historical vs contemporary population structure
  - Determine if RRS patterns are repeatable
  - Determine if RRS are persistent or ephemeral; grandparentage

- Planned activities outside of AHRP
  - Examine heritability of traits
  - Test for genetic signals of hatchery domestication (inadvertent)
  - Assess patterns of hatchery proportions among Cook Inlet streams

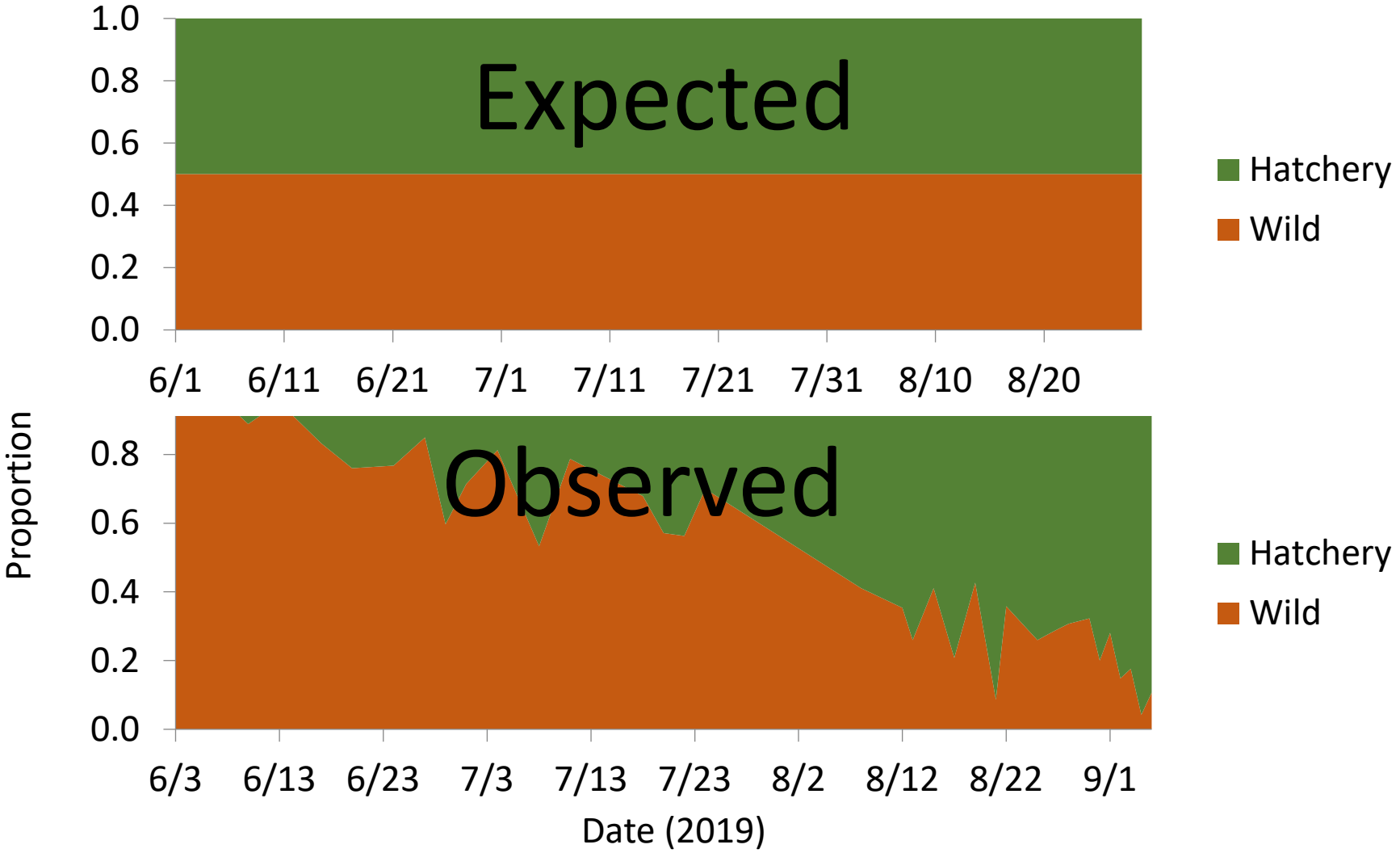
- Potential future actions by ADF&G:
  - Expand the scope of population structure westward
  - Examine run timing in more detail

Next analyses using non-AHRP funding

- Pacific States Marine Fisheries Commission
  - Population structure of pink salmon in Lower Cook Inlet
    - Genetic relationships between PWS and LCI populations
    - Genetic relationships among LCI populations
  - Genome sequencing
    - Search for genetic basis for reduction in reproductive success
      - Original brood source vs contemporary hatchery
      - 1990's hatchery vs contemporary hatchery
    - If so, investigate introgression into the wild
      - Natural stocks in high hatchery proportion streams (Southwest)
      - Natural stocks in low hatchery proportion streams (East)
- Cooperative Institute for Climate, Ocean, and Ecosystem Studies
  - Quantifying the effects of hatchery production on wild salmon productivity and viability to support sustainable aquaculture in Alaska and the Pacific Northwest


Questions?
07.30.2014

Wild Fish Appear To Be Maintaining Earlier Run Timing



Morella, J., C. W. Russell, J. Botz, and S. Haught. 2021. 2019 Prince William Sound area finfish management report. Alaska Department of Fish and Game, Fishery Management Report No. 21-19, Anchorage.