# Assessing Mechanisms Driving Relative Reproductive Success

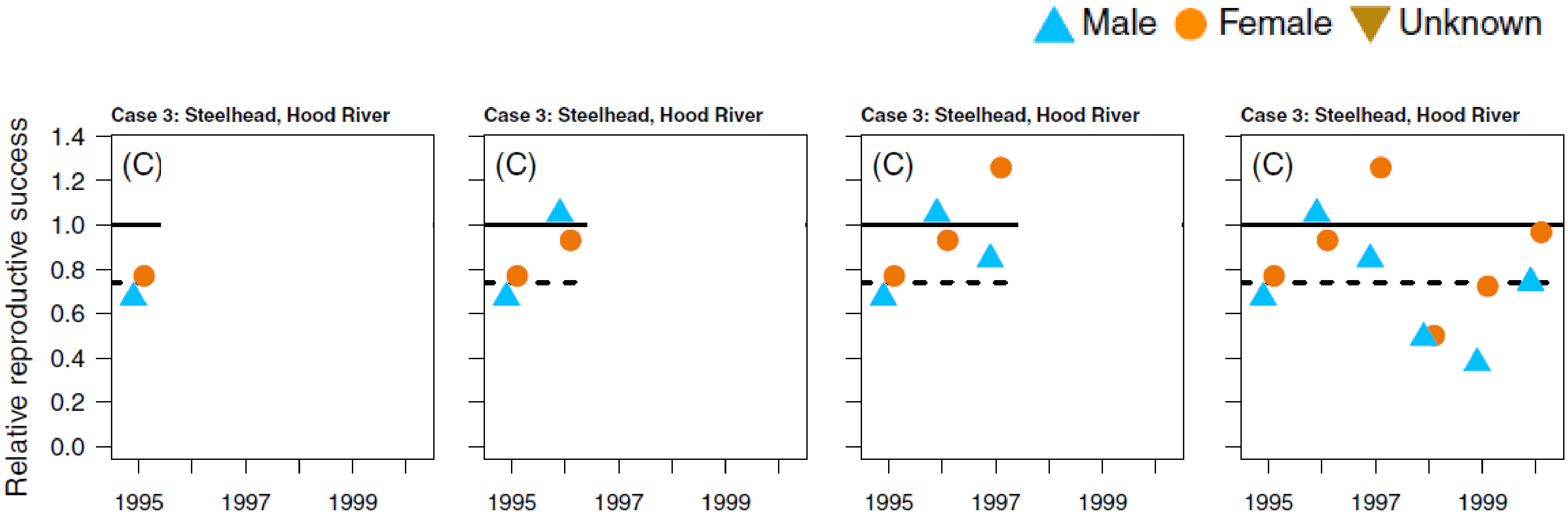
Chris Habicht and Bill Templin
Gene Conservation Laboratory
Alaska Department of Fish and Game
Alaska Board of Fisheries Hatchery Committee
March 7, 2020

Tab 7

# RRS Estimates: 20% Complete
# RRS Interpretation: 0% Complete

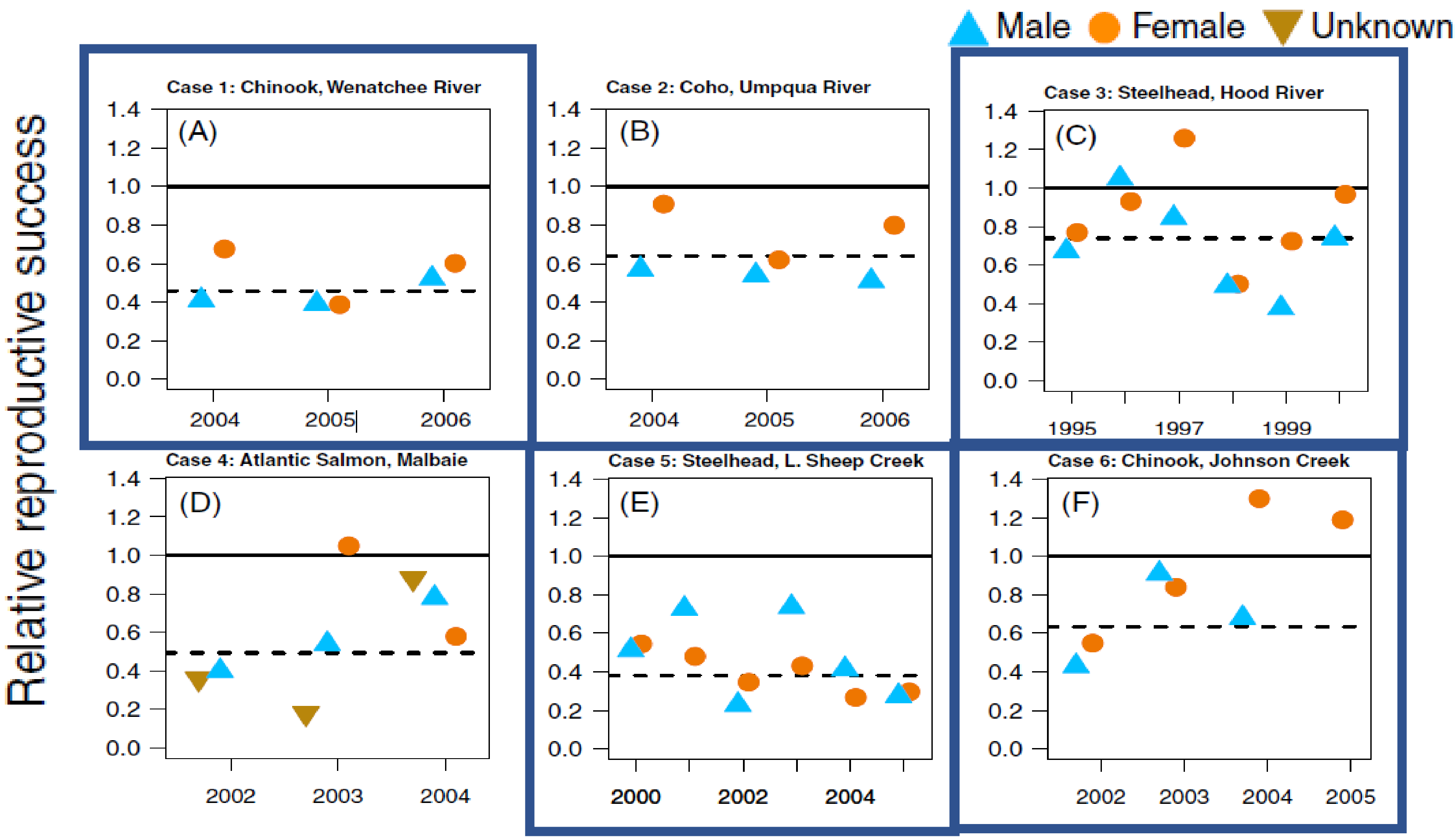
- Inappropriate to interpret beyond:
  - 2 streams; 3 more
  - 3 years, 5 more
- Does not represent variation:
  - Across years, within stream
  - Across steams
  - Across generations (grandoffspring)
  - Across species (chum salmon)

# Example of RRS Across Years Within Species and Location: Steelhead, Hood River




From Christie et al. 2014;
original data Araki et al. 2007

# Examples of RRS Across Years Within Species and Locations




From Christie et al. 2014;
original data various sources

# RRS Estimates: 20% Complete
# RRS Interpretation: 0% Complete

- Inappropriate to interpret beyond:
  - 1 stream (Hogan Bay)
  - 1 generation for even- and odd-years
- Does not represent variation:
  - Across species (chum salmon)
  - Within stream, across years
  - Across steams
  - Across generations (grandparents)
- We do not know what is driving RRS
  - Once we have results, we can investigate mechanisms

# Many Mechanisms May Drive Measured RRS: Here Are a Few

Many generations
(e.g. genetic)

One generation
(e.g. non-genetic)

Relaxation of natural selection

# Relaxation of Selection: A Genetic Example

- Hatcheries increase survival – that's the whole point
- Most mortality in the wild is due to unsurvivable events, e.g.:
  - Too much rain – scouring
  - Too little rain – dewatering
  - Too cold – freezing
  - Disturbance
- Some mortality in the wild is caused by genetic issues:
  - Most of these would die in a hatchery anyway
  - Some might survive in a hatchery, e.g.:
    - Lack of disease resistance
    - Inability to avoid predators
    - Tolerance of temperature or oxygen fluctuations
- The conditions in the hatchery do not select out the same fish as the conditions in the wild

# Many Mechanisms May Drive Measured RRS: Here Are a Few

Many generations
(e.g. genetic)

One generation
(e.g. non-genetic)

Relaxation of natural selection

Spawning ground familiarity

# Spawning Ground Familiarity: A Non-Genetic Example

- Homing fish have the potential to find the location where they were incubated
- These incubation locations were suitable (otherwise the fish would not have survived)
- Staying fish (regardless of origin), need to identify a suitable location
- Straying fish that find suitable locations, produce progeny that, if they home, will have the homing fish advantage
- Straying fish that do not find a suitable location, will produce fewer (if any) progeny.
- Therefore, most of this effect is wiped out the next generation

# Many Mechanisms May Drive Measured RRS: Here Are a Few

Many generations (e.g. genetic)

One generation (e.g. non-genetic)

Relaxation of natural selection

Spawning ground familiarity

Domestication selection

Epigenetics

Genetic drift

Run timing-associated variables

- Fishery prosecution
- Spawning ground competition
- Straying fish delays

Broodstock incompatibility

Sexual selection

# Data Available to Investigate Mechanisms Driving RRS

- Genetic mechanisms
  - Modeling
  - Grandparent RRS
  - Historical and contemporary genetic structure (PWS)

- Non-genetic mechanisms
  - Timing of spawning
  - Location within stream
  - Fishery prosecution

# Questions?

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

Chris Habicht and Bill Templin
Gene Conservation Laboratory
Alaska Department of Fish and Game

Alaska Board of Fisheries Hatchery Committee
March 7, 2020

Tab 7

# 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
- Relative reproductive success
- Productivity of wild fish

# Population Structure

- Observations that indicate higher risk
  - 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.

**J. E. Seeb[1], C. Habicht[1], W. D. Templin[1], L. W. Seeb[1], J. B. Shaklee[2], F. M. Utter[3]**
[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

J. E. Seeb, Alaska Department of Fish & Game, Commercial Fisheries Division, Anchorage, AK 99518, USA

Accepted for publication April 9, 1999

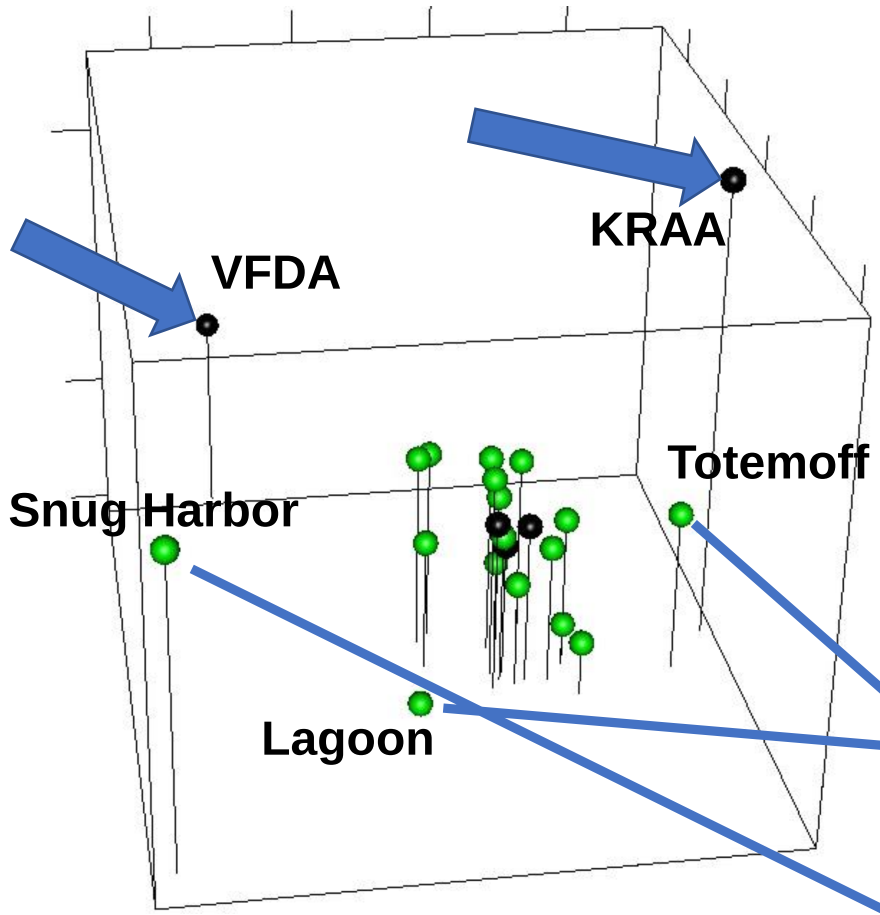
**Un resumen en español se incluye detrás del texto principal de este artículo.**

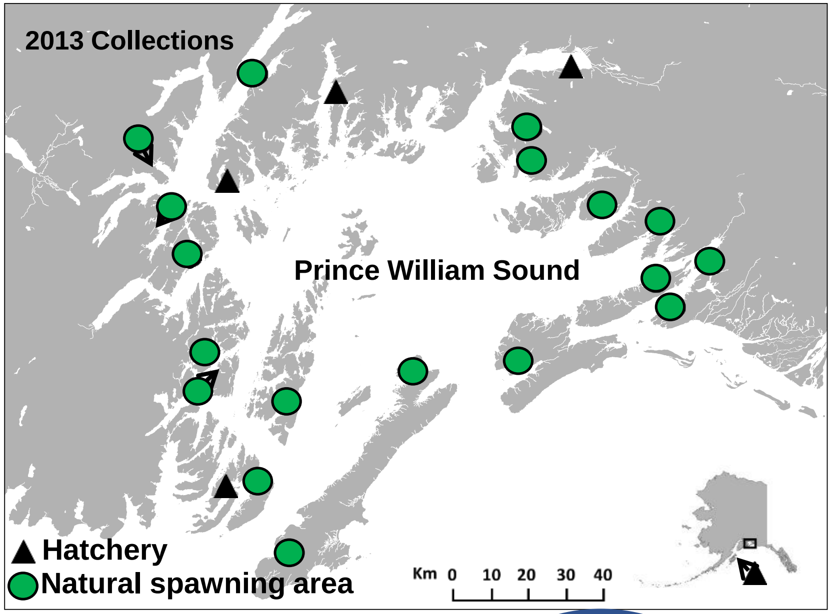
# Population Structure

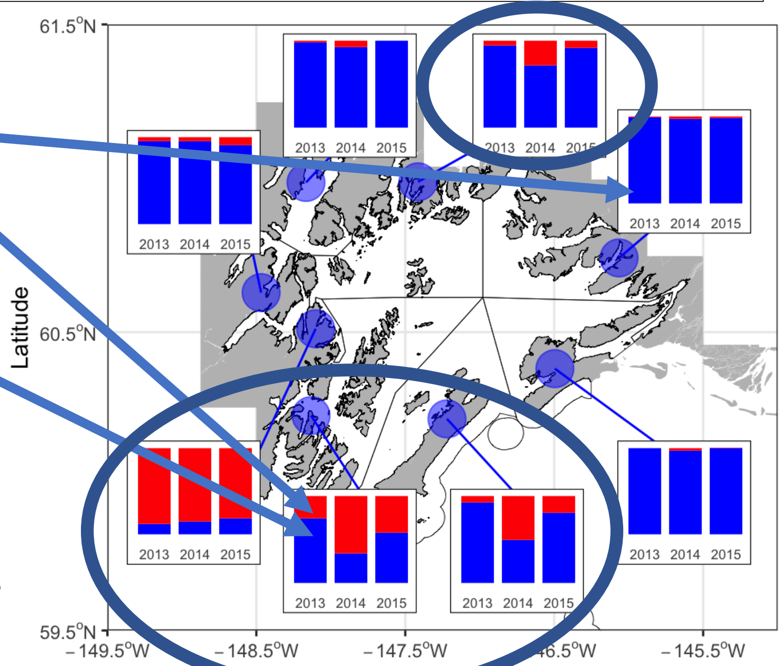
- Observations that indicate higher risk
  - Previous studies indicated that pink salmon in PWS are not one population

- Observations that indicate lower risk
  - Current study found significant structure
  - Outliers found in both districts with high and low hatchery proportions

# Odd Year Genetic Relationships; Pink Salmon In PWS



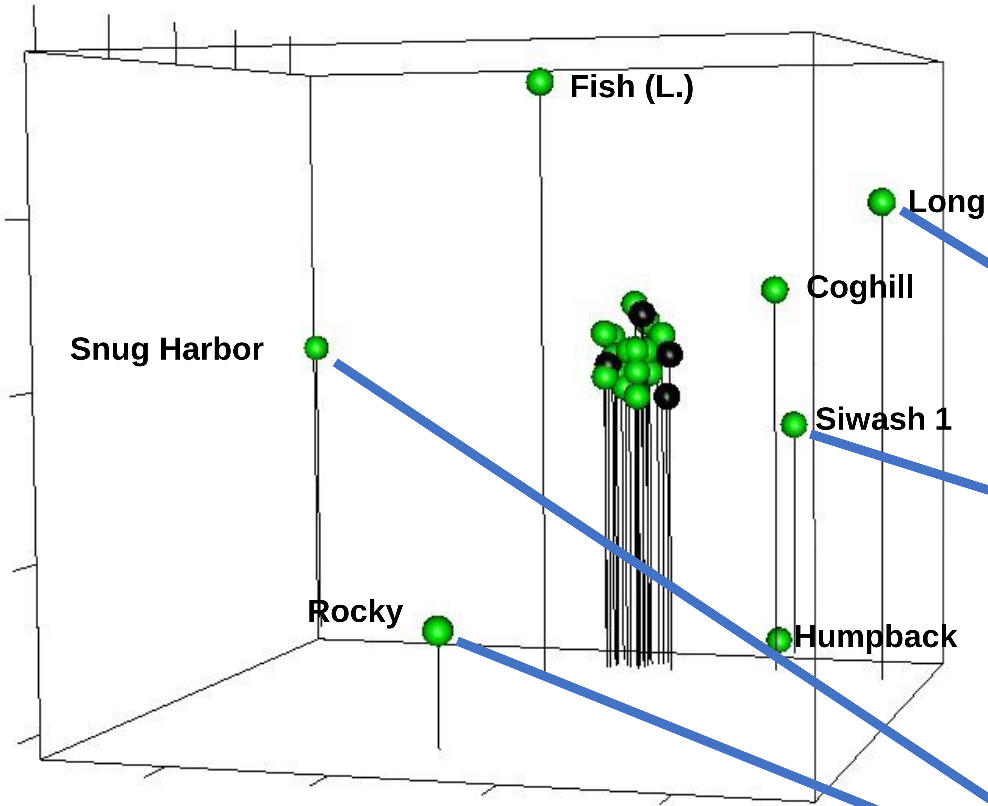



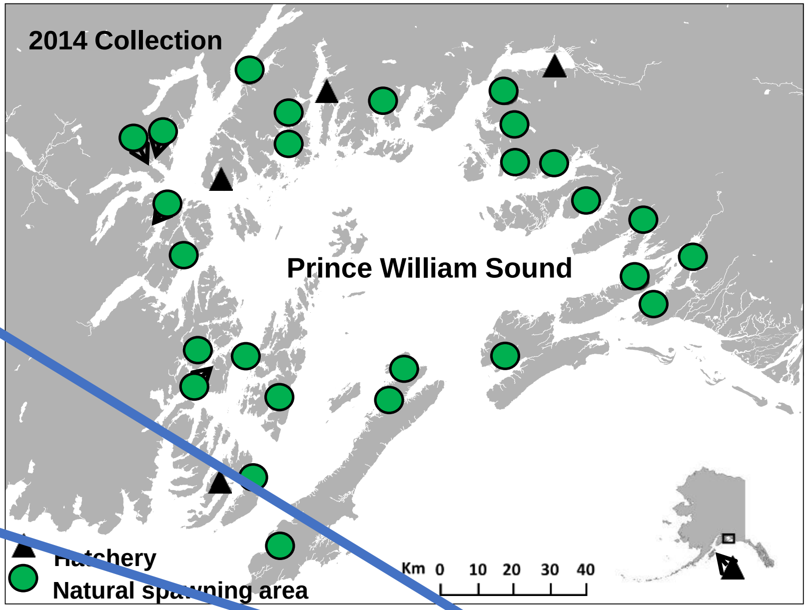



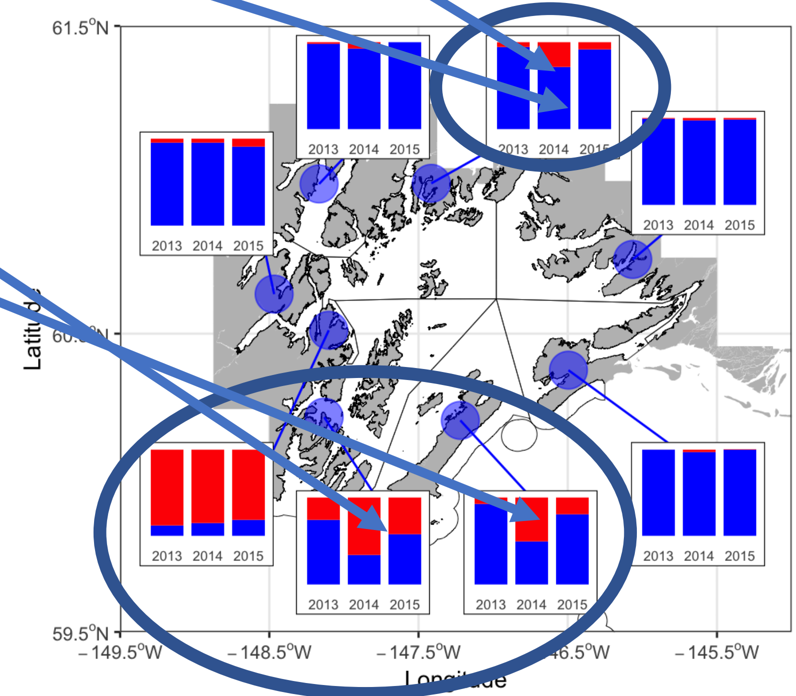

Distribution of outlier samples:

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

# Even Year Genetic Relationships; Pink Salmon in PWS




Distribution of outlier samples:

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

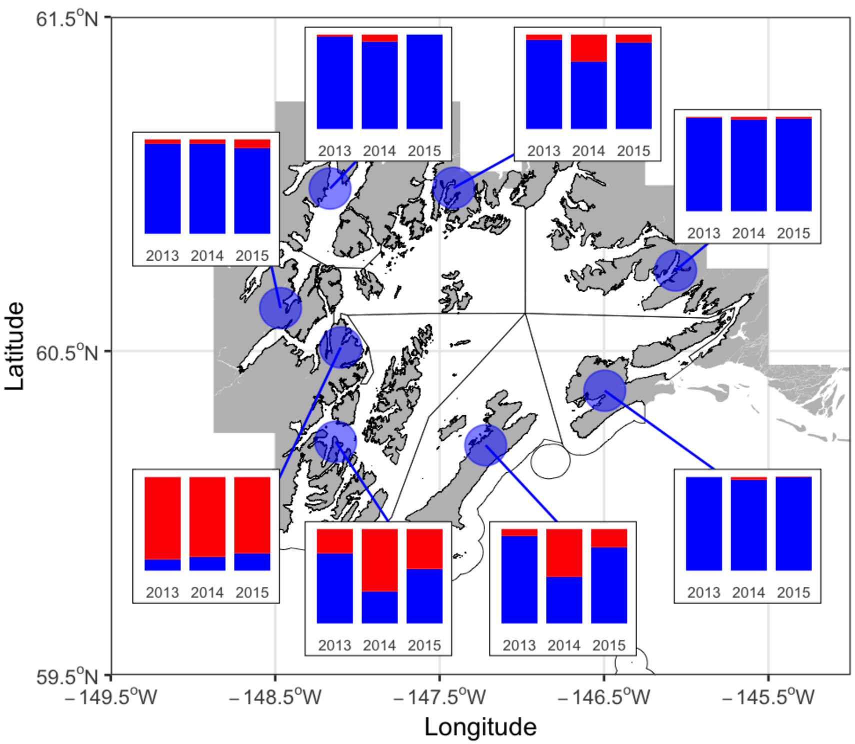
# Population Structure

- Observations that indicate higher risk
  - Previous studies indicated that pink salmon in PWS are not one population
- Observations that indicate lower risk
  - Current study 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

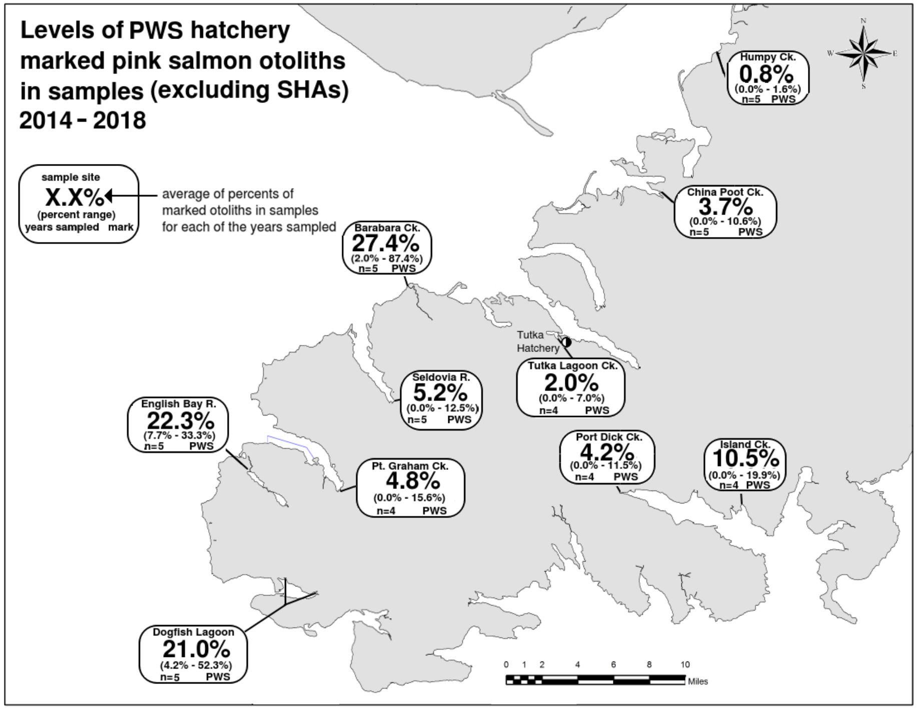
# Hatchery Fish in Streams

- Observations that indicate higher risk
  - Found PWS hatchery fish in streams
  - Some streams had high proportions
  - Found PWS hatchery fish in Lower Cook Inlet

District-level hatchery proportions




Stream-level hatchery proportions



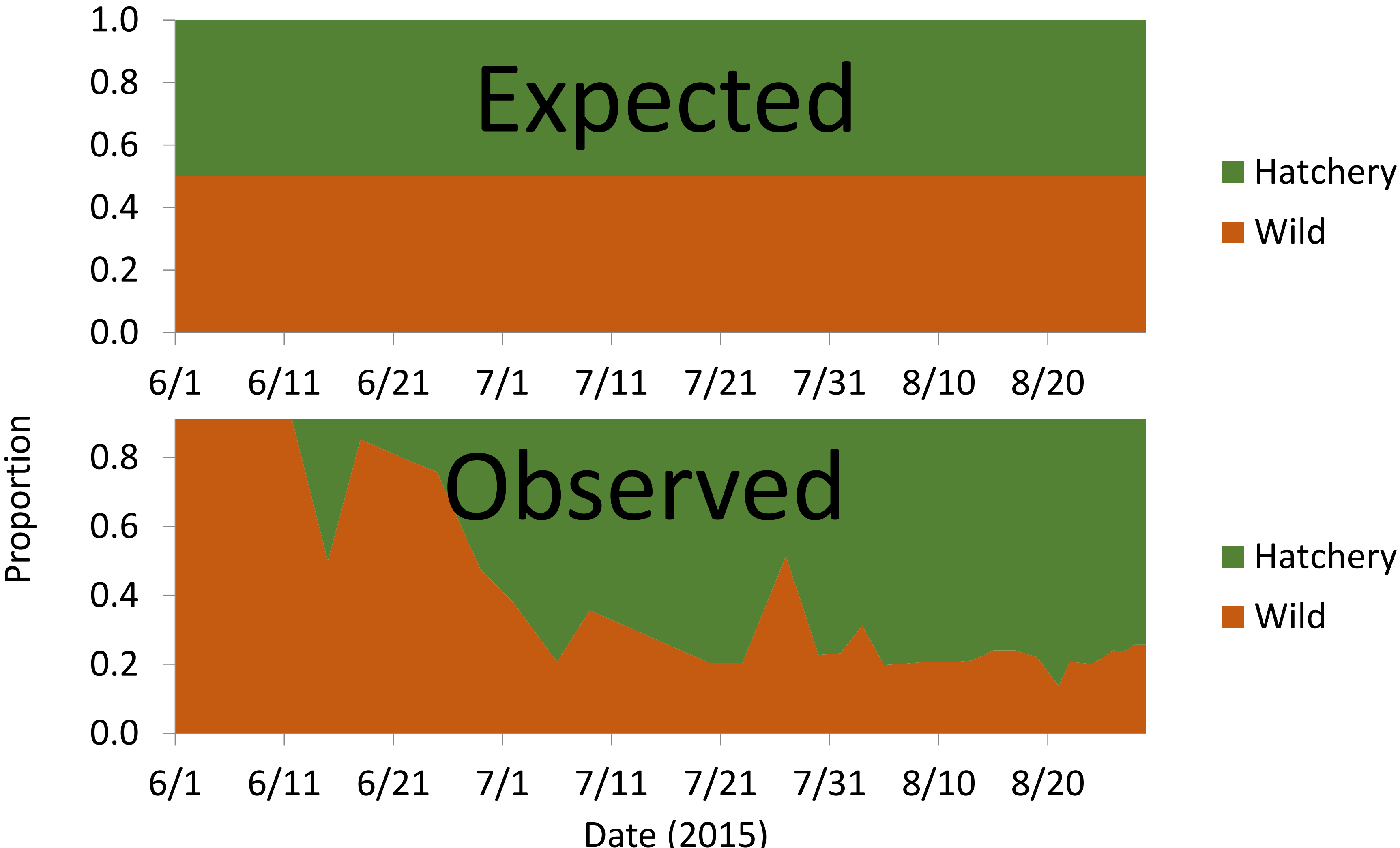

0.1% - 89.9%; Sound-wide annual average 4-14%

0.8% - 27.4%

# Hatchery Fish in Streams

- Observations that indicate higher risk
  - Found PWS hatchery fish in streams
  - Some streams had high proportions
  - Found PWS hatchery fish in Lower Cook Inlet
- Observations that indicate lower risk
  - Population structure
  - Run timing differences between hatchery fish and wild fish persist

# Wild Fish Appear To Be Maintaining Earlier Run Timing




Haught, S., J. Botz, S. Moffitt, and B. Lewis. 2017. 2015 Prince William Sound Area Finfish Management Report. Alaska Department of Fish and Game, Fishery Management Report No. 17-17, Anchorage.

# Hatchery Fish in Streams

- Observations that indicate higher risk
  - Found PWS hatchery fish in streams
  - Some streams had high proportions
  - Found PWS hatchery fish in Lower Cook Inlet
- Observations that indicate lower risk
  - Population structure
  - Run timing differences between hatchery fish and wild fish persist
- Next steps
  - Estimate wild straying rates
  - Examine run timing in more detail
  - Assess patterns of hatchery proportions among Cook Inlet streams

# Relative Reproductive Success of Hatchery Vs Wild Fish

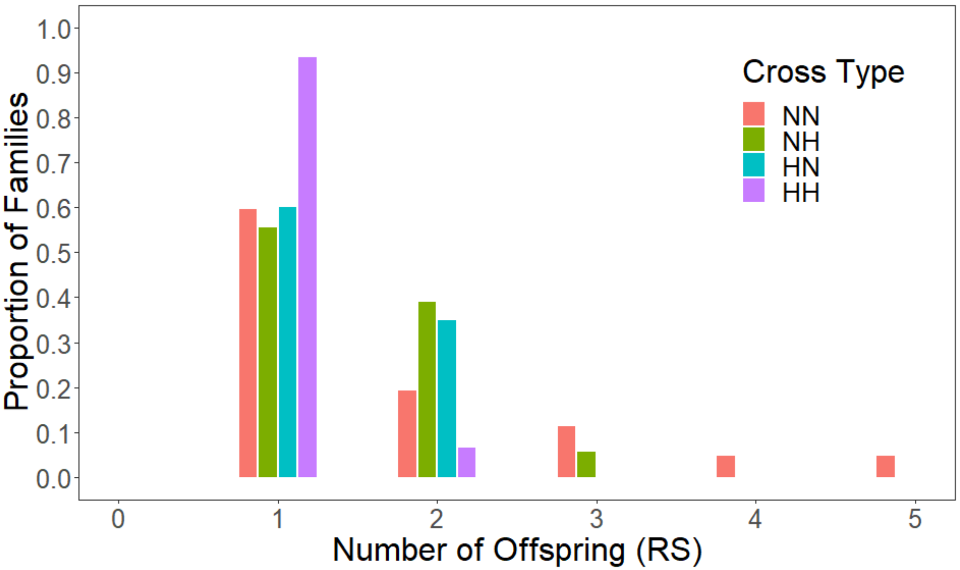
- Observations that indicate higher risk
  - Hatchery fish are reproducing in the wild
  - Hatchery fish have generally lower reproductive success
  - Hatchery fish are interbreeding with wild fish

**Hogan** — RRS (95% CI) Hatchery / Natural

| Year | Male | Female |
|---|---|---|
| 13/15 | **0.05** (0.01-0.17) | **0.03** (0.01-0.08) |
| 14/16 | **0.86** (0.67-1.12) | **0.47** (0.37-0.62) |
| 15/17 | **0.16** (0.09-0.25) | **0.17** (0.10-0.26) |

**Stockdale** — RRS (95% CI) Hatchery / Natural

| Year | Male | Female |
|---|---|---|
| 13/15 | **0.69** (0.31-1.35) | **0.17** (0.03-0.55) |
| 14/16 | **0.28** (0.24-0.34) | **0.42** (0.35-0.50) |
| 15/17 | **0.66** (0.46-0.93) | **0.41** (0.29-0.58) |



# Relative Reproductive Success of Hatchery Vs Wild Fish

- Observations that indicate higher risk
  - Hatchery fish are reproducing in the wild
  - Hatchery fish have lower reproductive success
  - Hatchery fish are interbreeding with wild fish
- Observations that indicate lower risk
  - Persistence of run timing among wild and hatchery fish
  - Population structure
  - Mechanisms may be ecological
- Next steps
  - Determine if RRS patterns are repeatable
    - Only investigated 2 of 5 streams so far
    - Only investigated 3 of 8 years sampled so far
  - Determine if RRS patterns are persistent or ephemeral
    - Grandparentage

# Productivity of Wild Fish

- Observations that indicate higher risk
  - 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
© Copyright by the American Fisheries Society 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

1233

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 higher risk
  - Published studies assert hatchery fish replace rather than augment wild fish
  - Genetic and ecological mechanisms proposed
- Observations that indicate lower risk
  - 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

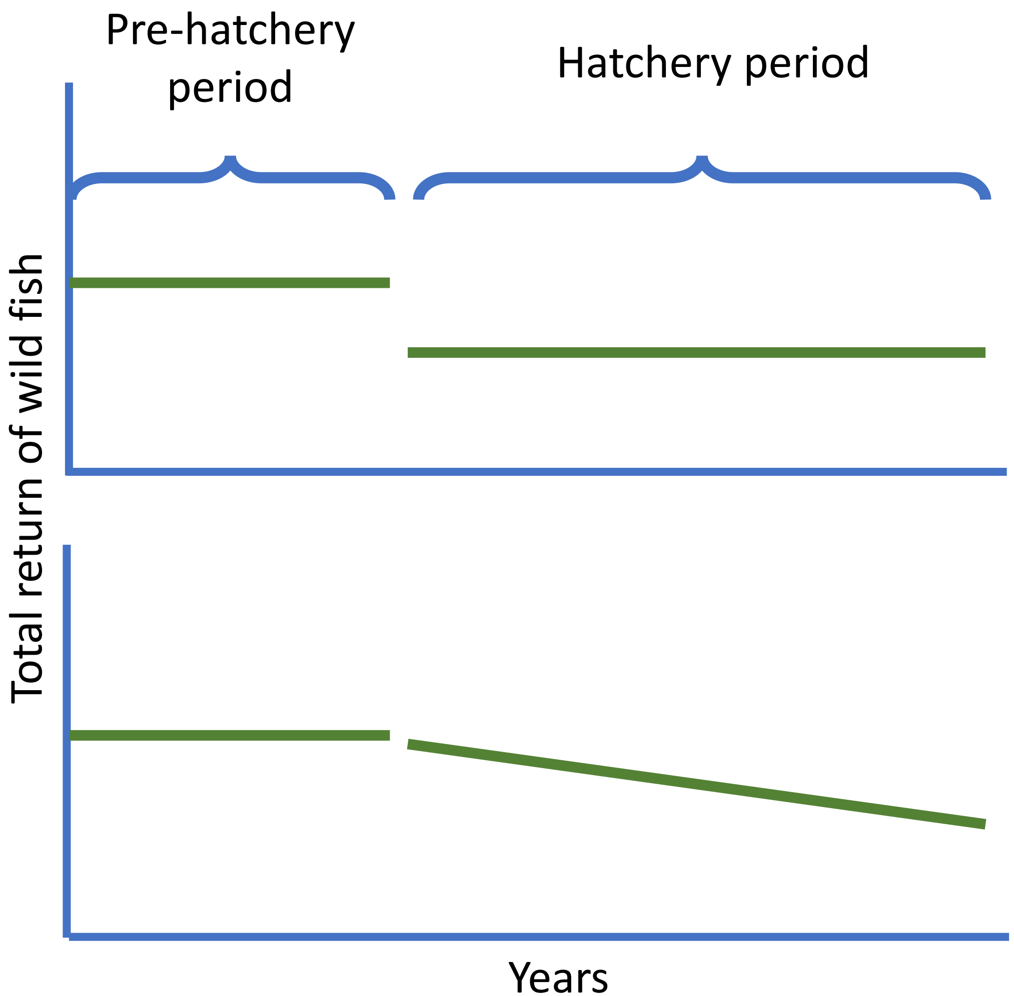
- Observations that indicate higher risk
  - Published studies assert some displacement
  - Genetic and ecological mechanisms proposed
- Observations that indicate lower risk
  - Other published studies assert that the replacements were much lower
  - Ecological mechanisms proposed
  - Wild productivity trends appear stable

# Productivity of wild fish

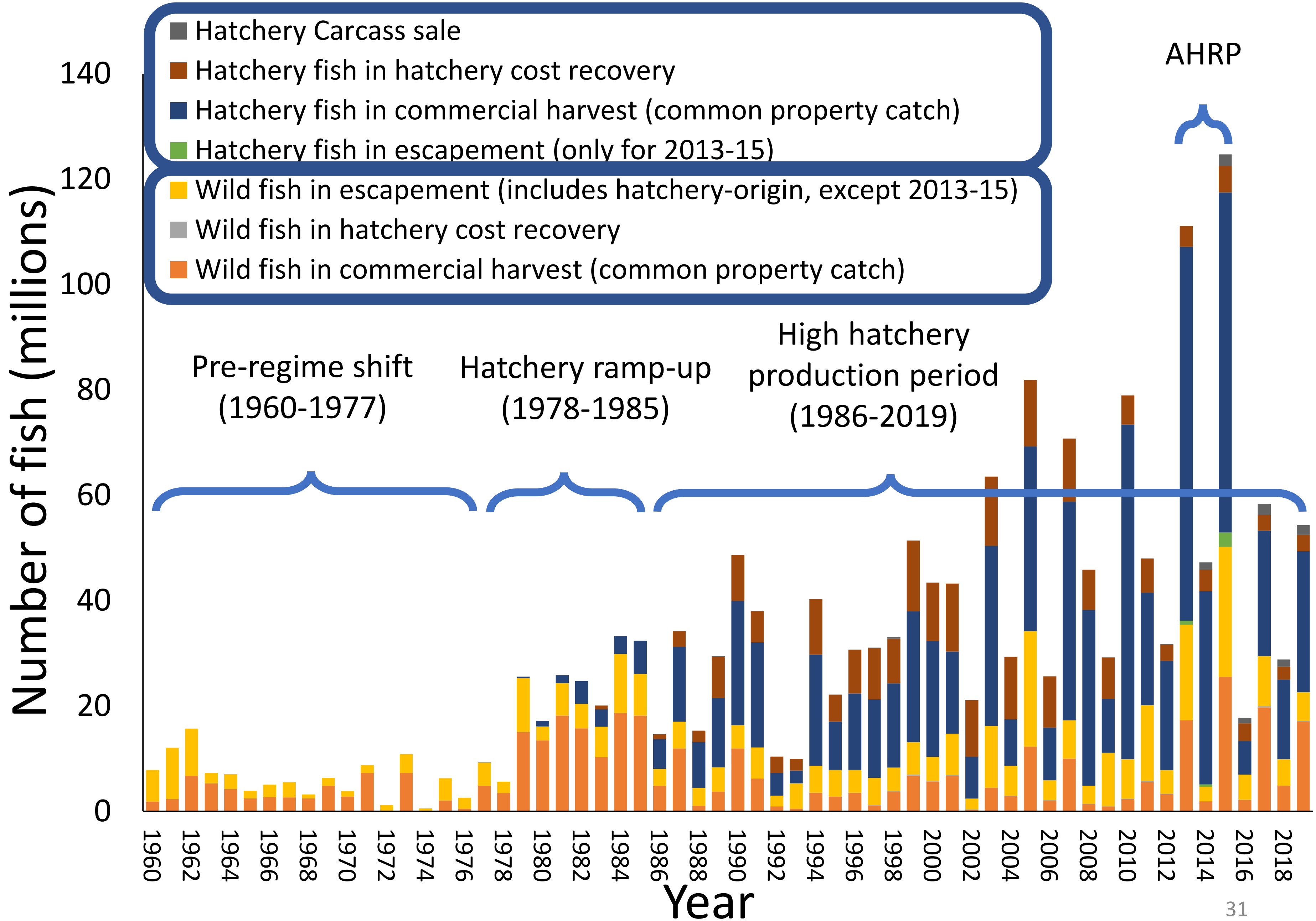
Cartoon of production response from ecological and genetic mechanisms

Partial Replacement
Ecological mechanism
(e.g. competition)

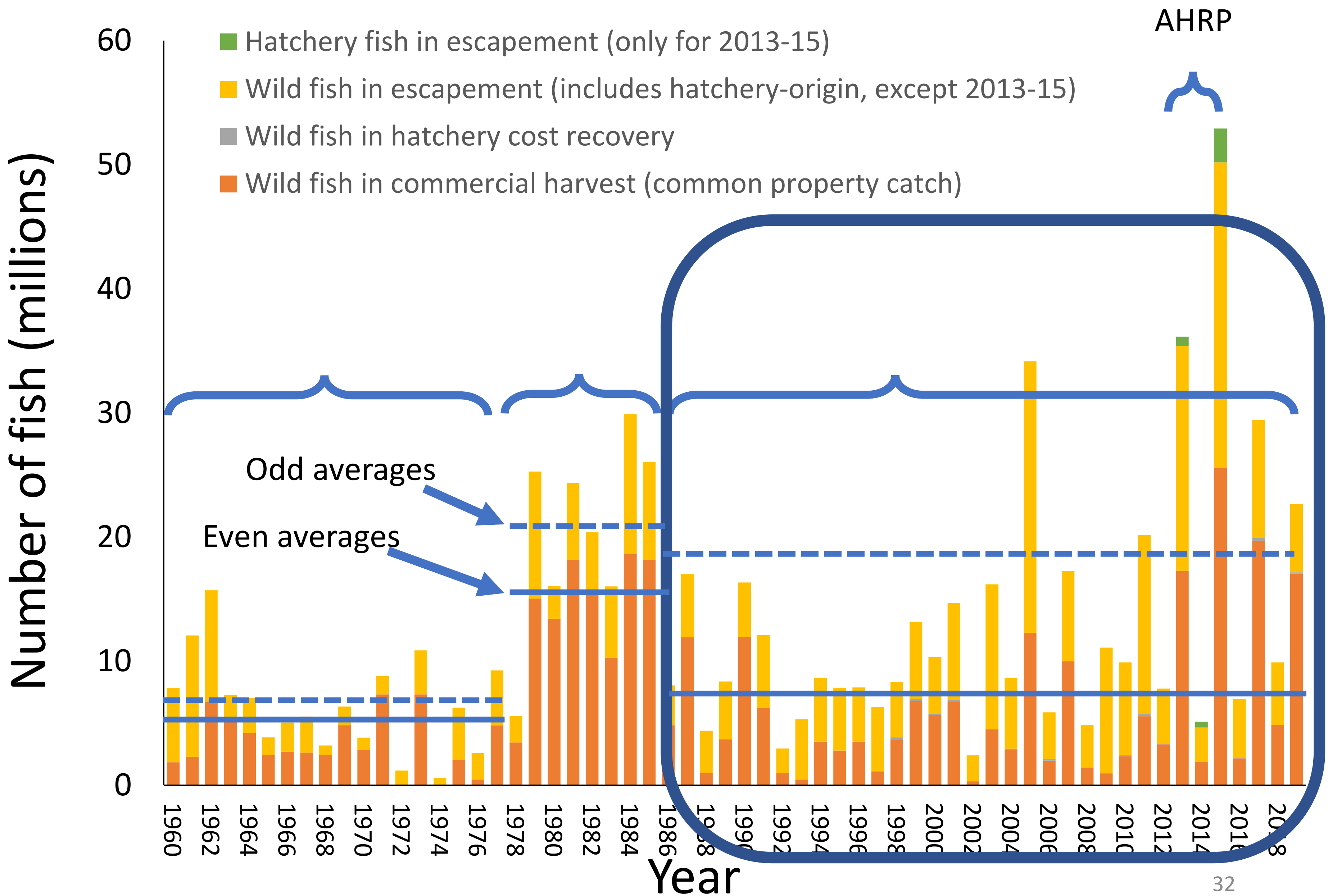
Partial Replacement
Genetic mechanism
(e.g. ill adapted traits)



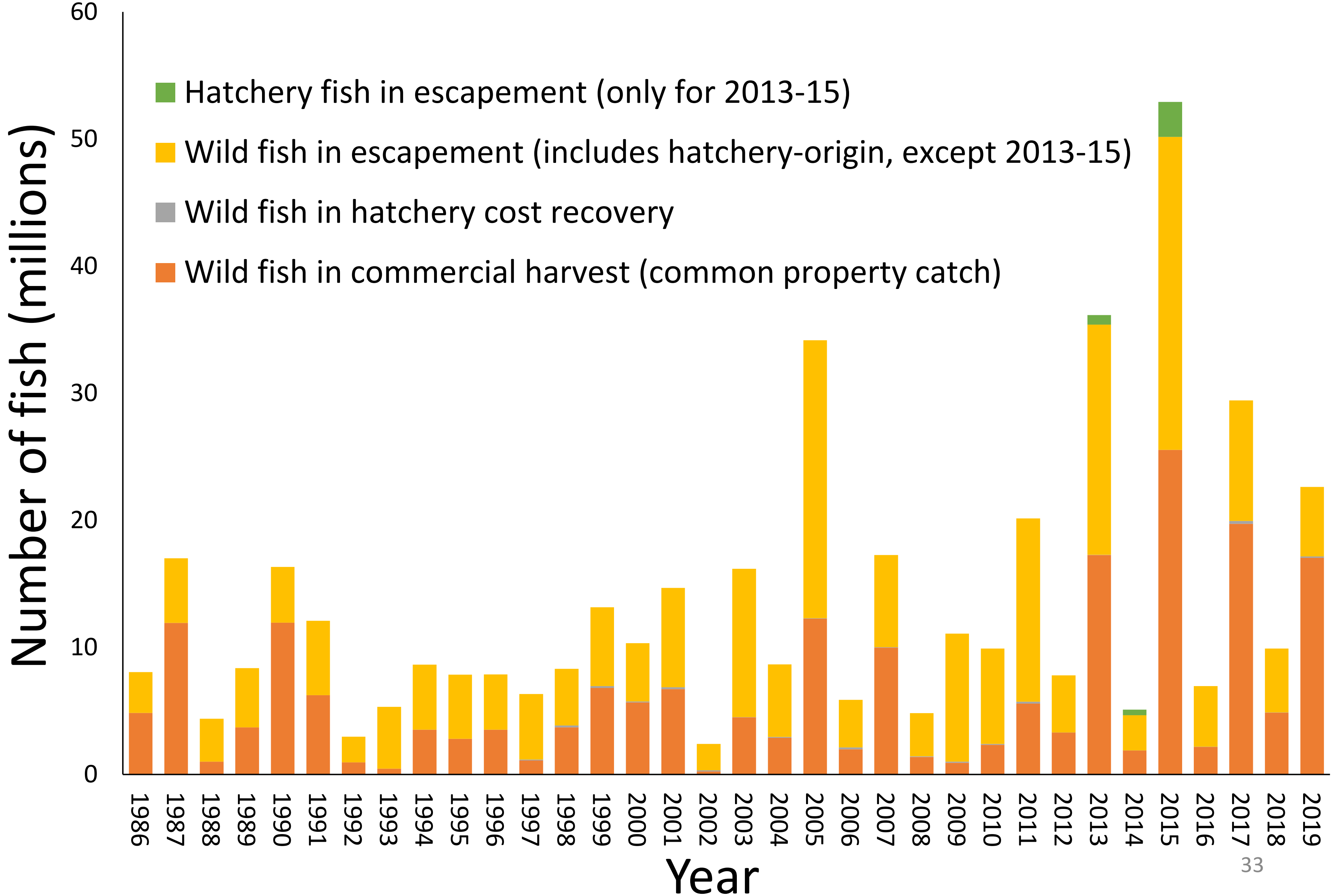
# PWS Pink Salmon Total Run: 1960-2019



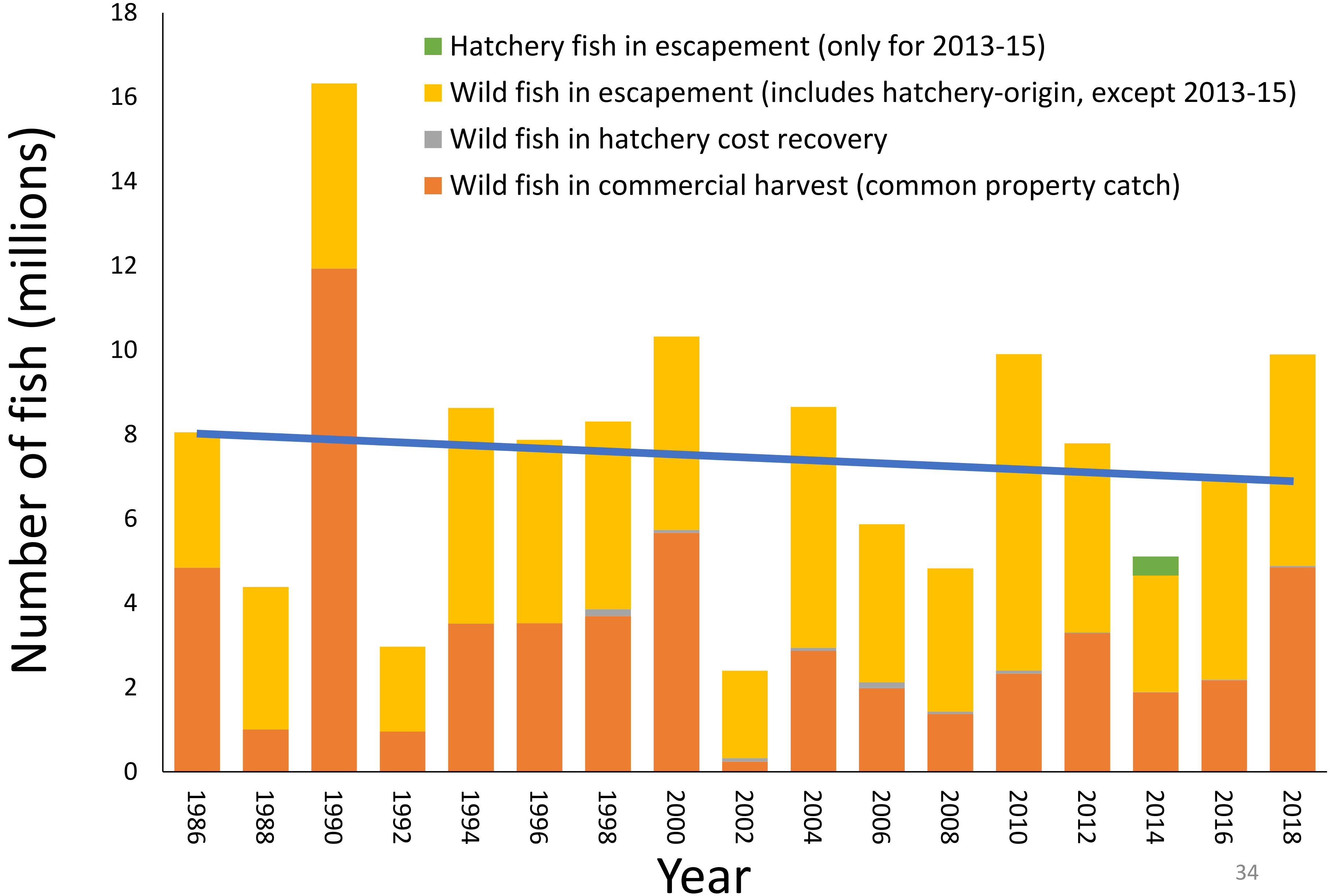
# PWS Pink Salmon Total **Wild Run:** 1960-2019



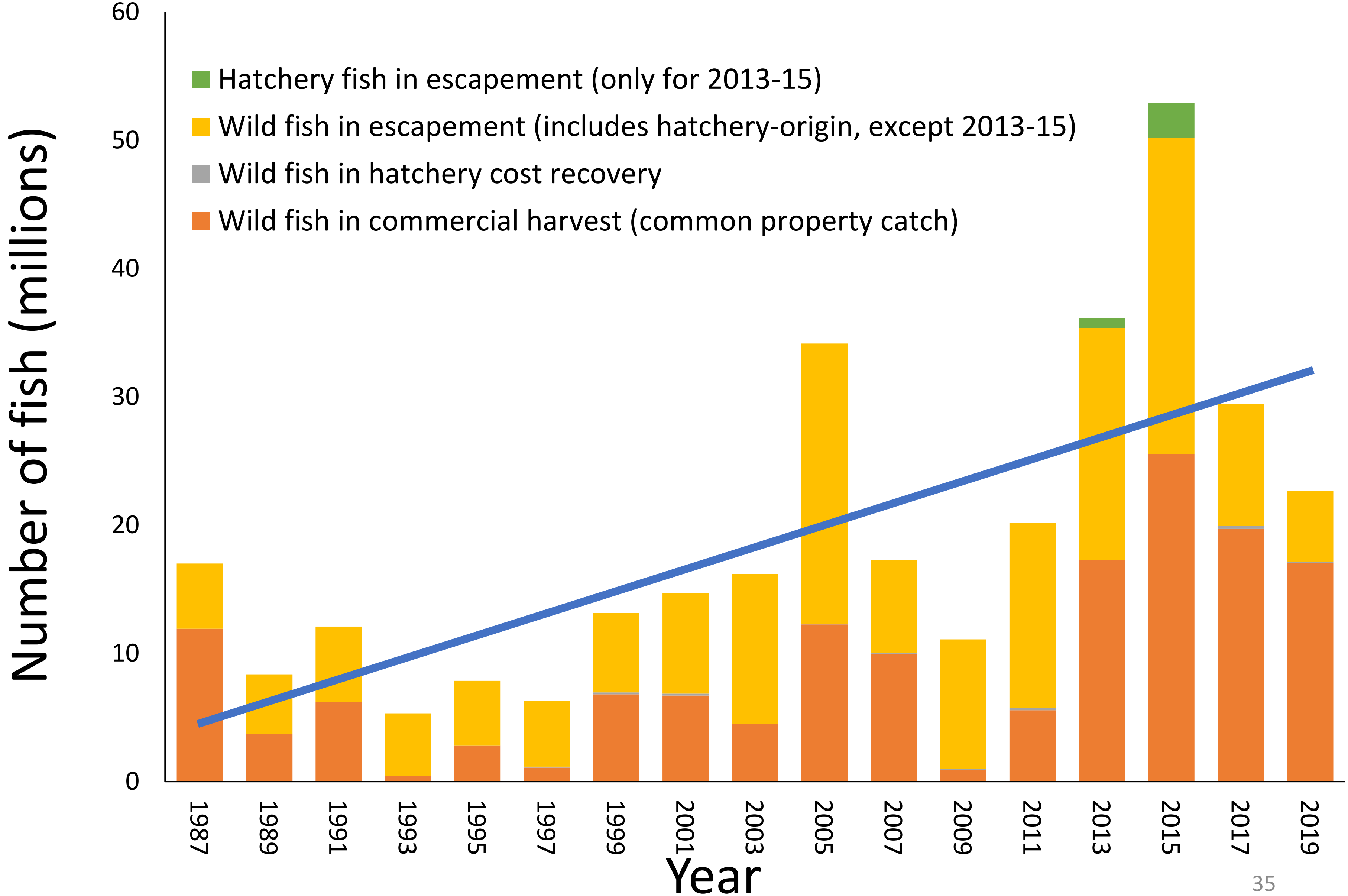
# PWS Pink Salmon Total **Wild Run:**
# **High hatchery production period** (1986-2019)



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



# PWS Pink Salmon Total **Wild Run (Odd Year):**
# **High hatchery production period:** 1987-2019



# 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 higher risk
  - Published studies assert some displacement
  - Genetic and ecological mechanisms proposed
- Observations that indicate lower risk
  - Other published studies assert that the replacements were much lower
  - Ecological mechanisms proposed
  - Wild productivity trends appear stable
- Next steps
  - Conduct additional analyses of wild productivity
    - Include recent years
    - Account for environmental variables
    - Examine productivity trends among Districts with:
      - High hatchery proportions
      - Low hatchery proportions

# 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 obvious
  - Population structure exists
  - Outlier populations may have high hatchery proportions
  - Run timing has not converged
  - 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 patterns are persistent or ephemeral; grandparentage

- Potential future actions by ADF&G:
  - Estimate wild straying rates; AHRP may provide some insights/data
  - Examine run timing in more detail
  - Conduct additional analyses of wild productivity
  - Expand the scope of population structure westward
  - Assess patterns of hatchery proportions among Cook Inlet streams


Questions?
07.30.2014

# Application of Science to Policy

Bill Templin and Andrew Munro
Division of Commercial Fisheries
Alaska Department of Fish and Game

Alaska Board of Fisheries Hatchery Committee

March 7, 2020

Tab 7

# Application of Science to Policy

"The relationship between science and policy is, and always will be, complicated."

*Adapted from* Chris Tyler
Centre for Science and Policy
Cambridge University

Making good policy decisions is a difficult task:

- There is never <u>one</u> right answer
- Even when you make a good decision there will be serious downsides
- No decision is made with complete information
- Often what you know is somewhat uncertain

# Application of Science to Policy

The AHRP is providing valuable biological information for understanding the interaction between hatchery and wild pink and chum salmon.

- Scientifically answerable questions
- Appropriate study design

However, more than biology must be considered when making decisions about salmon resources:

1) Biological, 2) Social, 3) Economic, and 4) Cultural

The interface of science and policy is where scientific knowledge is incorporated into belief/value systems to provide a bridge for decision making.

# Application of Science to Policy

# One Model for Science – Policy Dialogue

**Questions for Prudential Judgment**

**Science**

1. Does an event occur? — Observe

2. How often and to what extent?

3. Does the event have an effect?

— Measure/ Experiment

4. Is the effect harmful? — Compare to standard

5. Would addressing the harm cost more than it would benefit? — Collate/ Evaluate

**Policy or Human valuation**

# Application of Science to Policy

## Example Application

Science

Policy or Human valuation

**<u>Issue:  Hatchery fish spawning in streams</u>**

1. Are hatchery pink salmon spawning in streams in Prince William Sound?

2. Which streams have spawning hatchery pink salmon and how many are present?

3. Does the presence of spawning hatchery pink salmon have an effect on wild pink salmon populations?

4. Is the effect of hatchery-origin pink salmon spawning with wild pink salmon harmful?

5. Would the cost to restrain hatchery-origin pink salmon from spawning in streams outweigh the benefit from reducing the interaction?

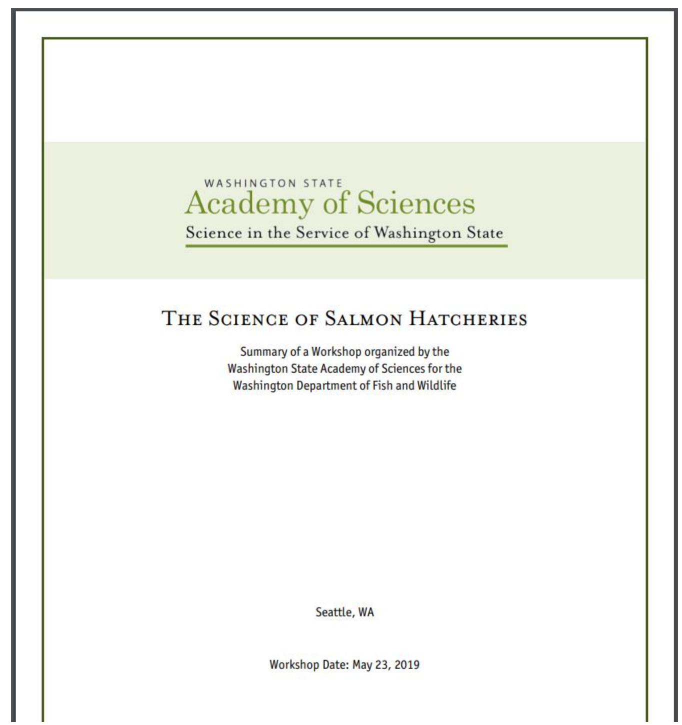
# Path Forward

**Need**:

1. Questions 4 & 5 require definitions of harm, cost and benefit and the means to weigh them
2. Pink salmon field work completed in 2020
3. Pink salmon fitness results expected in next couple of years

**Proposal**: Request a third party to convene a working group of agency staff, stakeholders and subject matter experts to:

1. Review current state of knowledge
2. Identify issues, concerns, and data needs
3. Provide ADF&G with recommendations


WASHINGTON STATE
Academy of Sciences
Science in the Service of Washington State

THE SCIENCE OF SALMON HATCHERIES

Summary of a Workshop organized by the Washington State Academy of Sciences for the Washington Department of Fish and Wildlife

Seattle, WA

Workshop Date: May 23, 2019

**Implementation Needs**:

1. Define scope
2. Identify facilitator group
3. Seek funding


Thank you
Any Questions?