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
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)

Relaxation of natural selection

One generation (e.g. non-genetic)

Spawnung 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)

- Relaxation of natural selection
- Domestication selection
- Genetic drift
- Broodstock incompatibility
- Sexual selection

One generation (e.g. non-genetic)

- Spawning ground familiarity
- Epigenetics
- Run timing-associated variables
  - Fishery prosecution
  - Spawning ground competition
  - Straying fish delays
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 (Onchorhynchus gorbuscha Walbaum)
SUB-POPULATIONS IN PRINCE WILLIAM SOUND, ALASKA BY LENGTH-WEIGHT RELATIONSHIPS AND HORIZONTAL STARCH GEL ELECTROPHORESIS

By
Richard B. Nickerson

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


Abstract — Allozyme and mitochondrial DNA (mtDNA) data were obtained from pink salmon throughout Prince William Sound, Alaska, from two hatcheries, live 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.

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

Levels of PWS hatchery marked pink salmon otoliths in samples (excluding SHAs) 2014 - 2018

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

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

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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

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

“...we estimate that the PWS hatchery program has increased the total catch by an average of 17 million fish...”

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

“...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...”

“...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 0-4.6M wild, net gain of 21-25M
- 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)

Pre-hatchery period

Hatchery period

Total return of wild fish

Years
PWS Pink Salmon Total Wild Run: 1960-2019

- Hatchery fish in escapement (only for 2013-15)
- Wild fish in escapement (includes hatchery-origin, except 2013-15)
- Wild fish in hatchery cost recovery
- Wild fish in commercial harvest (common property catch)

Number of fish (millions)

Year


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

- **Hatchery fish in escapement (only for 2013-15)**
- **Wild fish in escapement (includes hatchery-origin, except 2013-15)**
- **Wild fish in hatchery cost recovery**
- **Wild fish in commercial harvest (common property catch)**

### Number of fish (millions)

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PWS Pink Salmon Total **Wild Run (Even Year):**

High hatchery production period (1986-2018)

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

- Hatchery fish in escapement (only for 2013-15)
- Wild fish in escapement (includes hatchery-origin, except 2013-15)
- Wild fish in hatchery cost recovery
- Wild fish in commercial harvest (common property catch)
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?
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
“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 one 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
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.
Questions for Prudential Judgment

1. Does an event occur?
2. How often and to what extent?
3. Does the event have an effect?
4. Is the effect harmful?
5. Would addressing the harm cost more than it would benefit?
**Issue: Hatchery fish spawning in streams**

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

**Implementation Needs:**
1. Define scope
2. Identify facilitator group
3. Seek funding
Thank you

Any Questions?