Alaska Salmon Hatchery Reports:

Research and related issues

Bill Templin

Board of Fisheries Work Session
October 2018
Anchorage

RC 39

Outline

I. Definitions
II. Alaska's Precautionary Approach
III. Update on the Alaska Hatchery Research Program
IV. Studies germane to PWS hatchery/wild interactions
V. Genetic effects
VI. Carrying capacity
VII. Review of literature
VIII. Identified research needs

Working definitions

Precautionary Principle — Rule or Standard

When human activities may lead to morally unacceptable harm that is scientifically plausible but uncertain, actions shall be taken to avoid or diminish that harm.

- COMEST/UNESCO

Precautionary Approach — Method

A set of agreed cost-effective measures and actions, including future courses of action, which ensures prudent foresight, reduces or avoids risk to the resources, the environment, and the people, to the extent possible, taking explicitly into account existing uncertainties and the potential consequences of being wrong.

- S. Garcia, FAO Fisheries Dept

COMEST, UNESCO. "The precautionary principle." *World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris* (2005).

Definition in SSFP 5 AAC 39.222(c)(5)

(5) in the face of uncertainty, salmon stocks, fisheries, artificial propagation, and essential habitats shall be managed conservatively as follows:

(A) a precautionary approach, involving the application of prudent foresight that takes into account the uncertainties in salmon fisheries and habitat management, the biological, social, cultural, and economic risks, and the need to take action with incomplete knowledge, should be applied to the regulation and control of harvest and other human-induced sources of salmon mortality; a precautionary approach requires

(i) consideration of the needs of future generations and avoidance of potentially irreversible changes;

(ii) prior identification of undesirable outcomes and of measures that will avoid undesirable outcomes or correct them promptly;

(iii) initiation of any necessary corrective measure without delay and prompt achievement of the measure's purpose, on a time scale not exceeding five years, which is approximately the generation time of most salmon species;

(iv) that where the impact of resource use is uncertain, but likely presents a measurable risk to sustained yield, priority should be given to conserving the productive capacity of the resource;

(v) appropriate placement of the burden of proof, of adherence to the requirements of this subparagraph, on those plans or ongoing activities that pose a risk or hazard to salmon habitat or production;

(B) a precautionary approach should be applied to the regulation of activities that affect essential salmon habitat.

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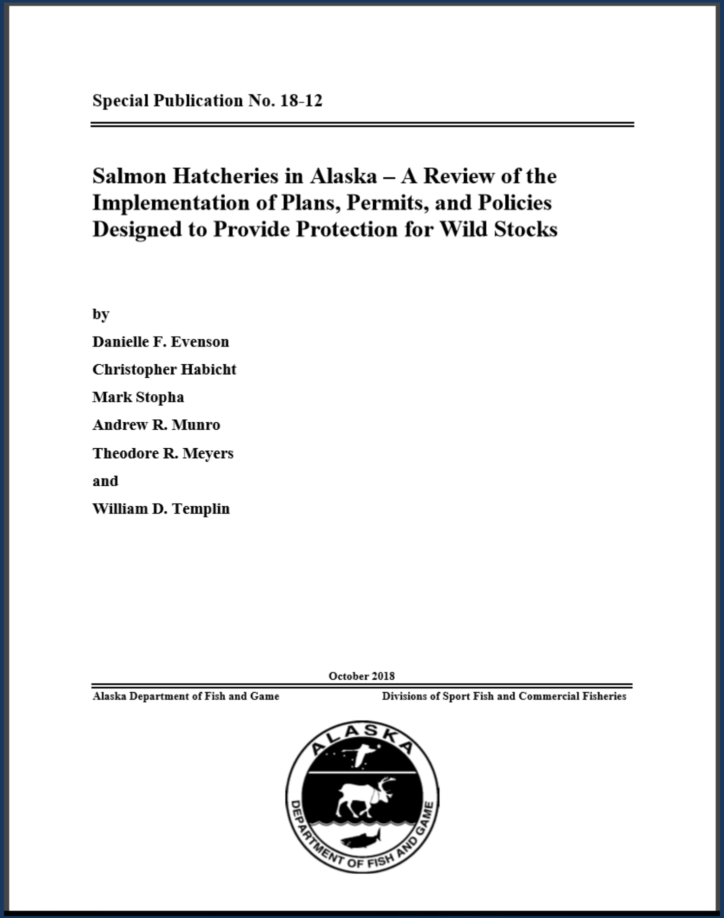
Policy and Implementation

1. Overview of the structure of Alaska’s approach – Policies, Plans, Permits
2. Elements used for implementation of policies
   - Management
   - Fish health
   - Genetics
3. Case studies
   - Southeast Alaska king salmon
   - Prince William Sound pink salmon
4. Recommendations


Special Publication No. 18-12

Salmon Hatcheries in Alaska – A Review of the Implementation of Plans, Permits, and Policies Designed to Provide Protection for Wild Stocks

by
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Theodore R. Meyers
and
William D. Templin

October 2018

Alaska Department of Fish and Game — Divisions of Sport Fish and Commercial Fisheries

Alaska's Precautionary Approach

Relevant policy elements

1. Management
   – Wild stock conservation priority
   – Management for sustained yield
   – Assessment of stock interaction: fisheries and escapement
2. Fish Health
   – Hatchery inspections
   – Disease reporting and history
3. Genetics
   – Use appropriate local stocks
   – Identify significant or unique wild stocks, and wild stock sanctuaries
   – Assessment of hatchery/wild stock interaction and impacts

Hatchery Reform In the Pacific Northwest

Hatchery Scientific Research Group

- US Congress established in 2000 to evaluate hatchery and wild salmon interactions
- Charged with reviewing all hatchery programs in the Pacific Northwest
- Intent to use science to direct reform
- Continual process

Definitions

Precaution is taking protective measures in advance to avoid harm

Policies constitute the framework for the precautionary approach to hatchery production of salmon in Alaska

Implementation is the application of precautionary policies to specific species at a given time and location

Alaska's Precautionary Approach

Policy and Implementation

Case studies

- Southeast Alaska king salmon
  - Smaller releases for diverse fisheries
  - Longer hatchery residency
  - Larger life history variation

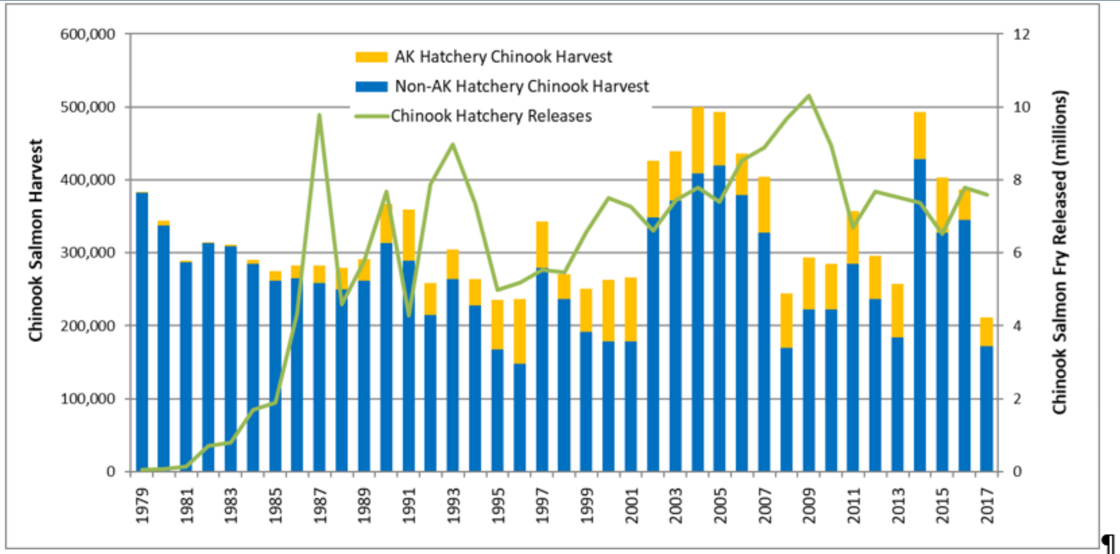

Figure 6.–Southeast Alaska Chinook salmon harvests and hatchery releases in millions, 1979–2016

- Prince William Sound pink salmon
  - Larger releases for commercial fisheries
  - Shorter hatchery residency
  - Smaller life history variation
  - Higher wild stream hatchery proportions

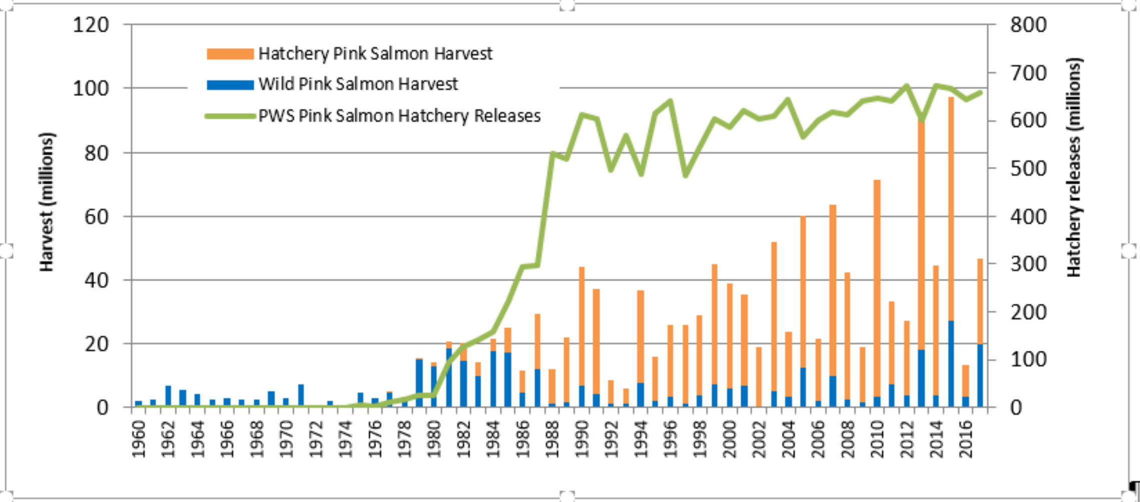

Figure 8.–Prince William Sound pink salmon hatchery releases and harvests in millions, 1960–2017.

Policy and Implementation

Recommendations:

1. Clarify the *Genetic Policy* and technical terms:
   - Define significant and unique stocks and sanctuaries
   - Revisit criteria intended to ensure stock diversity among hatcheries
   - Provide guidance for protection of donor stocks
2. Improve communication of policies, plans, and processes to regulatory bodies and stakeholders
3. Continue basic research:
   - To understand population structure
   - To understand homing and the effects of straying
   - To increase hatchery diversity

Two issues emerged that need to be addressed.

Neither has a simple answer.

What does the presence of hatchery strays in wild streams mean:

1. When assessing genetic risk?

2. When assessing escapement?

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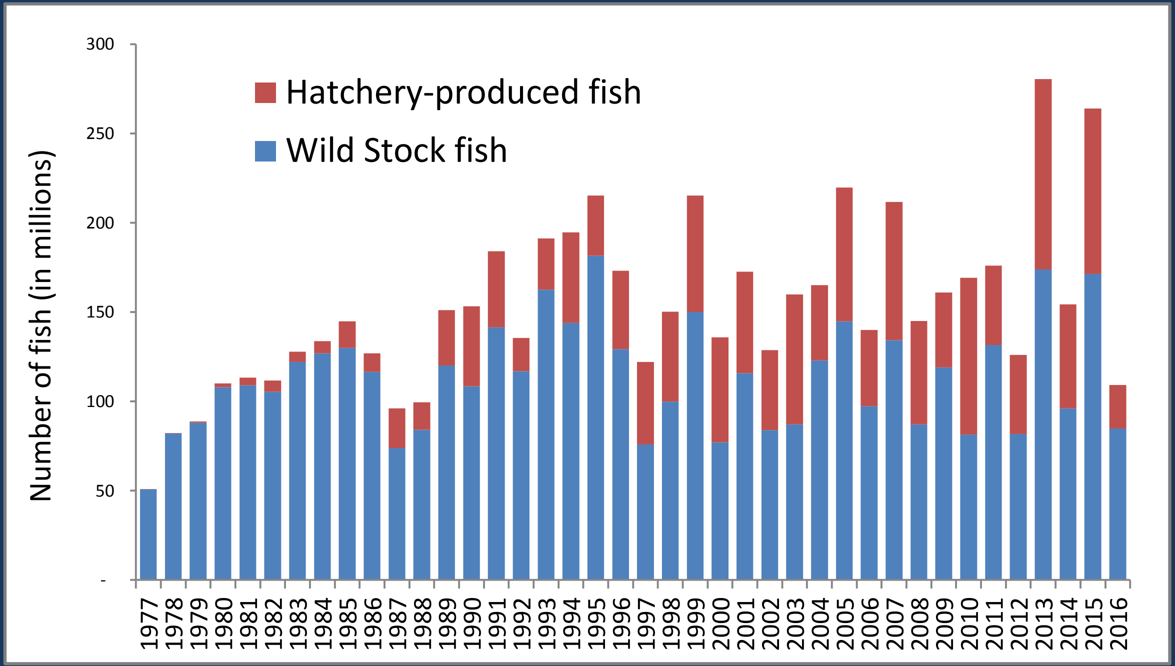
Alaska Hatchery Research Program
Background & Overview

- Why the program was initiated
- Program structure
- Key questions addressed
- Results

Background

- Private non-profit (PNP) hatcheries account for ⅓ of the commercial harvest
- Alaska hatchery releases:
  - 39% are pink salmon in PWS
  - 28% are chum salmon in SEAK
- Hatchery straying documented in both regions
- Unknown if these hatchery strays affect fitness of wild salmon
- Previous research found fitness impacts to wild stocks, but in other species and using other practices



Alaska commercial harvest of wild and hatchery salmon, 1977-2016.

Stopha, M. 2017. Alaska fisheries enhancement annual report 2016. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J17-04, Anchorage.

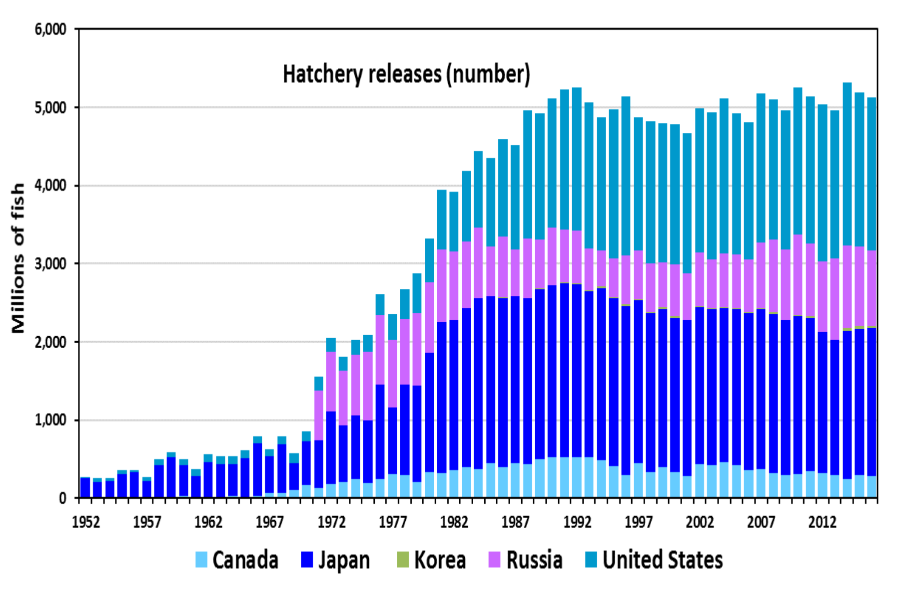
- Alaska policy mandates sustainable productivity of wild stocks
- PNP operators proposed that ADF&G organize a science panel of experts to design and implement a long term research project to inform future resource management decisions

AHRP

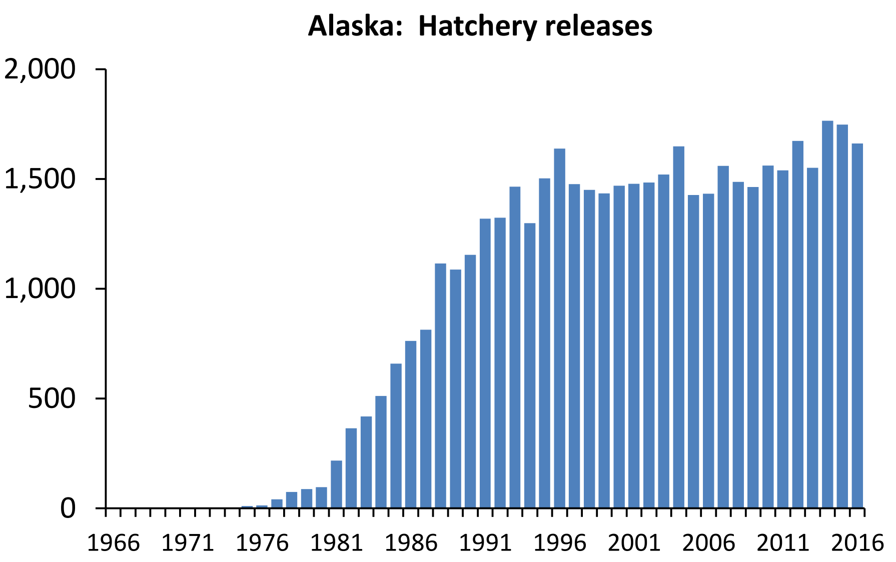
Why pursue this research?

Large-scale salmon releases raise concerns for wild stock impacts

- Do hatchery fish detrimentally affect productivity and sustainability of wild stocks?



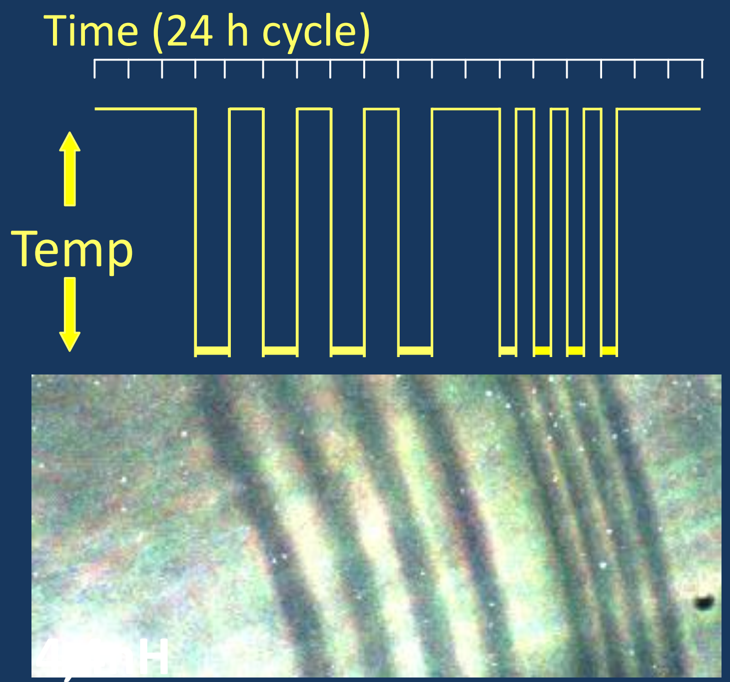
Data Source: North Pacific Anadromous Fish Commission (NPAFC). 2017. NPAFC Pacific salmonid hatchery release statistics (updated 31 July 2017). North Pacific Anadromous Fish Commission, Vancouver. Accessed July, 2017. Available: www.npafc.org

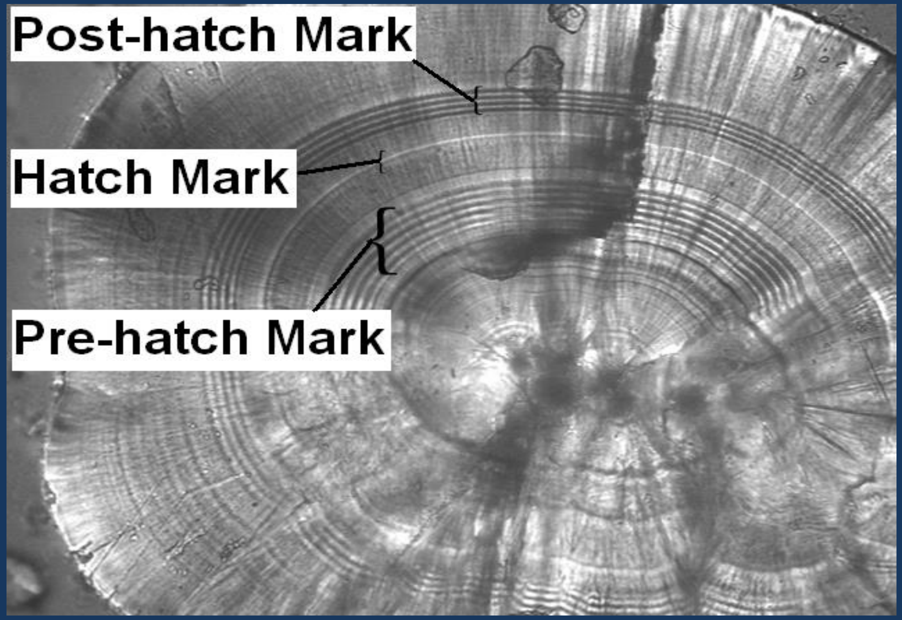


Stopha, M. 2017. Alaska fisheries enhancement annual report 2016. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J17-04, Anchorage.

Tool for detecting hatchery fish

Otolith Thermal Marking





Alaska marks > 80% of hatchery fish ~ 1.2 Billion
(100% for PWS and SEAK pink and chum)

- NPAFC Voucher DB (Images & Data): http://npafc.taglab.org/MarkSummary.asp

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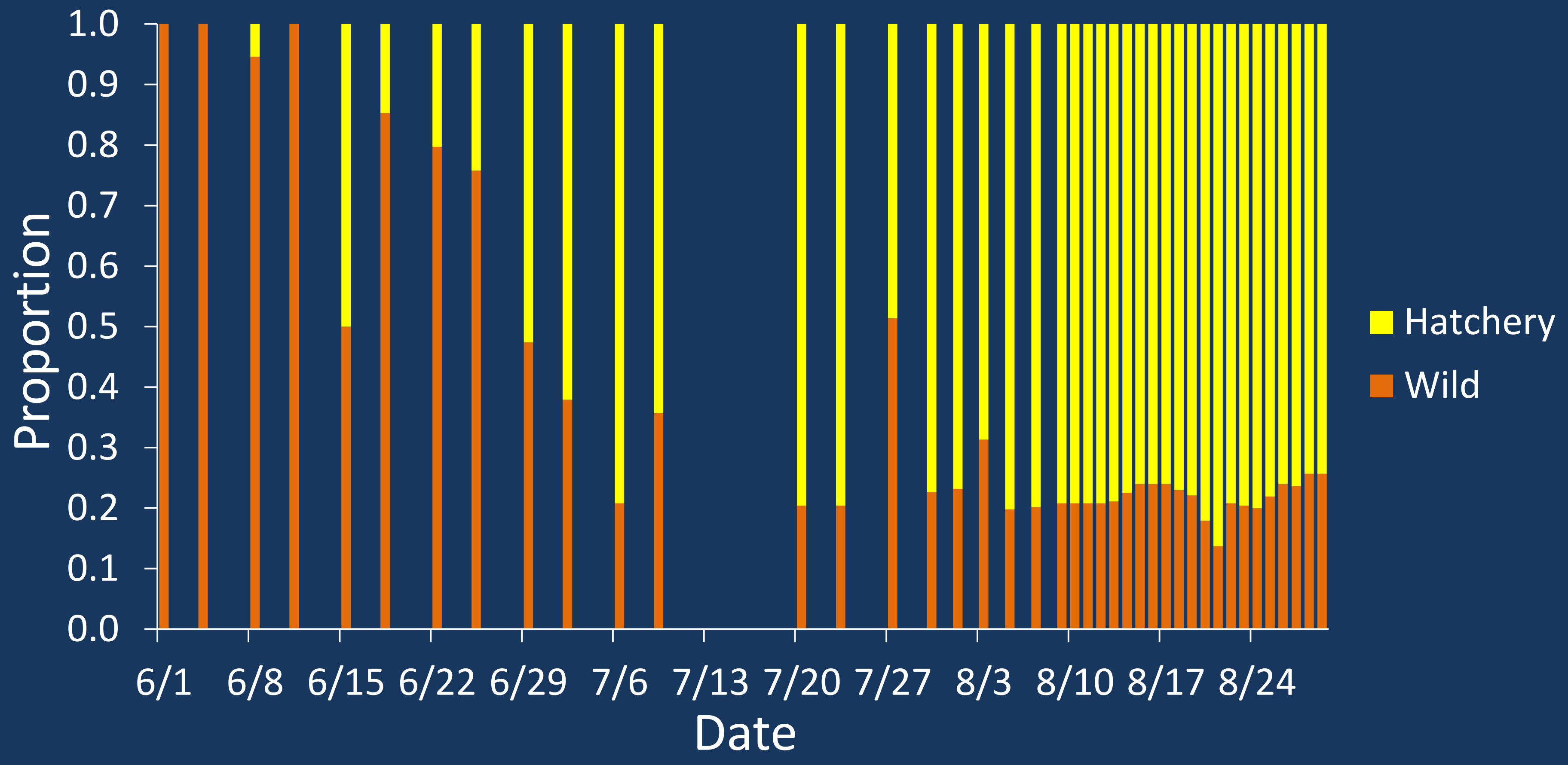
Otolith Mark Use 1
In-Season Harvest Monitoring

Example: Pink salmon, PWS SW District, 2015



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.

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Otolith Mark Use 2

Measure Straying

Are hatchery fish straying? If so, how many fish are straying?

- Prince William Sound and SE Alaska- pink & chum
  Alaska Hatchery Research Program (2013-2023)
- Lower Cook Inlet - pink
  Otis and Hollowell (2014-2017)
- SE Alaska - chum
  Heinl and Piston (2008-2010)
- Prince William Sound - pink, chum & sockeye
  Joyce and Evans (1997-1999)
  Brenner and Moffitt (2004-2010)

Otolith Mark Use 3

Detect Effect of Straying

Are there effects of straying on productivity?

Numerous studies, but may not be directly applicable to pink and chum in Alaska

- Different life histories (king, coho, steelhead)
  - ✓ Freshwater residence time
  - ✓ Life span and age structure

- Different hatchery practices
  - ✓ Local broodstock
  - ✓ 10,000 + parents spawned
  - ✓ Limited holding or feeding

How do we obtain the information needed to answer questions?

- Funding partnership: State, Operators & Industry
- Fundamental questions aimed at examining impacts of hatchery straying on fitness of wild stocks

✓ Pink and chum salmon PWS
✓ Chum salmon SEAK

AHRP Science Panel

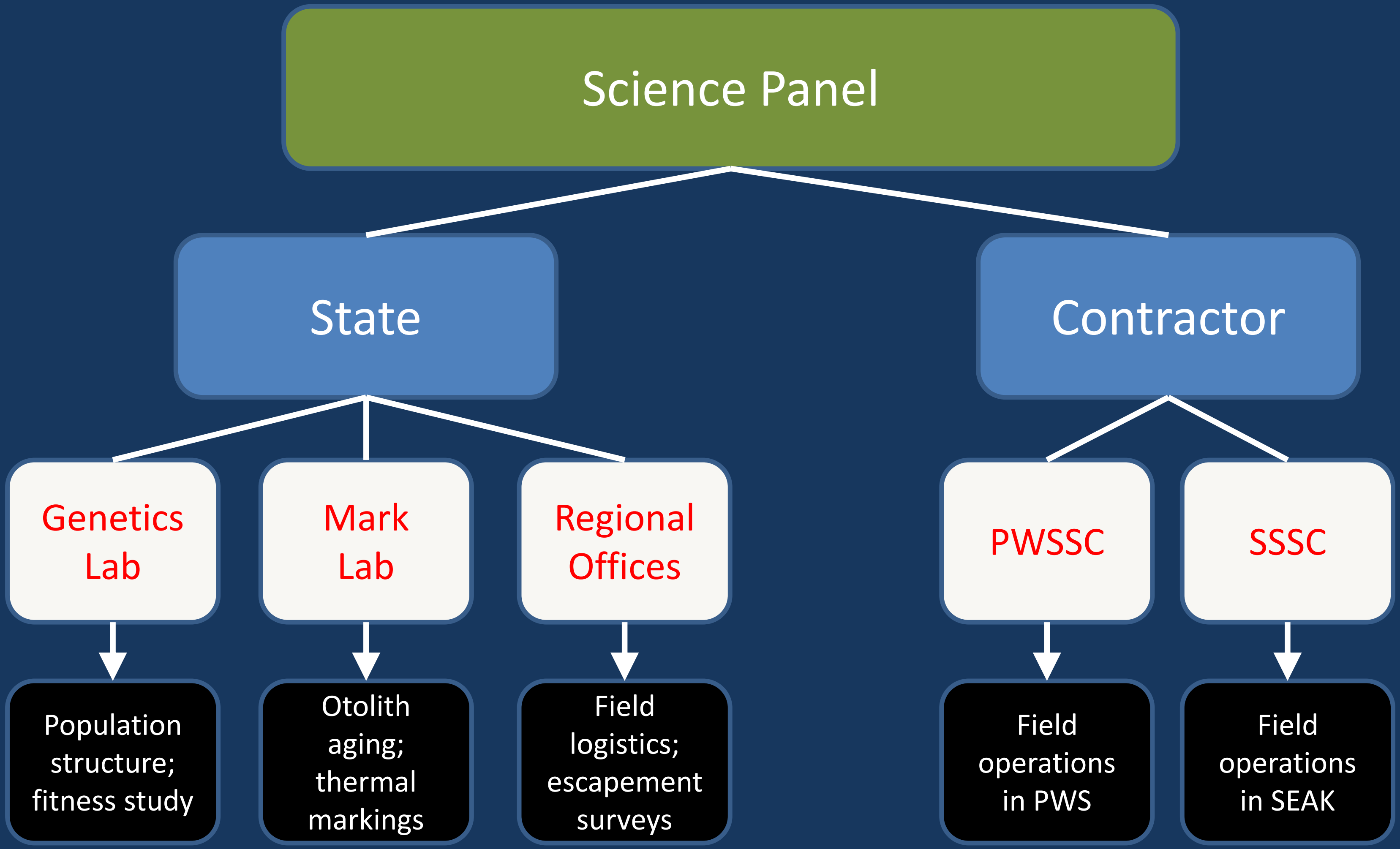
Panel Charge –

Translate questions into specific research projects. Develop a framework for research that could be used to address these questions.

Panel Makeup – 13 members:

- Alaska Department of Fish and Game
- National Marine Fisheries Service
- University of Alaska
- Aquaculture associations

AHRP Structure



AHRP Research Questions

1) What is the genetic stock structure of pink and chum in PWS and SEAK?

2) What is the extent and annual variability of straying?

3) What is the impact on fitness (*productivity*) of natural pink and chum stocks?

AHRP Research Questions

1) What is the genetic stock structure of pink and chum in PWS and SEAK?

Pink salmon in PWS

Ecologically important, but shallow, structure observed in even and odd years (1990s)

Re-examine structure with new samples and new markers (2013-2015)

Compare 1990s structure to present structure

Chum salmon in PWS and SEAK

Temporal and regional structuring observed within SEAK and PWS (1990s & 2013).

Examine fine-scale structure using updated methods

Field and laboratory work completed

Report on odd-year pink salmon available

AHRP Research Questions

1) What is the genetic stock structure of pink and chum in PWS and SEAK?

Among pink salmon populations

https://www.americanangler.com/wp-content/uploads/2017/03/pink-salmon-range.jpg

AHRP Research Questions

1) What is the genetic stock structure of pink and chum in PWS and SEAK?

Across the range of Pink Salmon populations

https://www.americanangler.com/wp-content/uploads/2017/03/pink-salmon-range.jpg

AHRP Research Questions

2) What is the extent and annual variability of straying?

Stream sampling – Pink salmon (2013-2015)

– Proportions of hatchery fish in **streams**

– 28 study streams; 488 site visits; 105,500 samples

District	Estimated hatchery fraction (2013)	Estimated hatchery fraction (2014)	Estimated hatchery fraction (2015)
Eastern (221)	0.013	0.045	0.021
Northern (222)	0.045	0.273	0.173
Coghill (223)	0.018	0.099	0.000
Northwestern (224)	0.034	0.067	0.157
Eshamy (225)	0.868	0.899	0.807
Southwestern (226)	0.290	0.490	0.336
Montague (227)	0.110	0.394	0.159
Southeastern (228)	0.001	0.036	0.010
Overall	0.044	0.148	0.095

Range by district
0 - 90%

Annual weighted average
4-15%

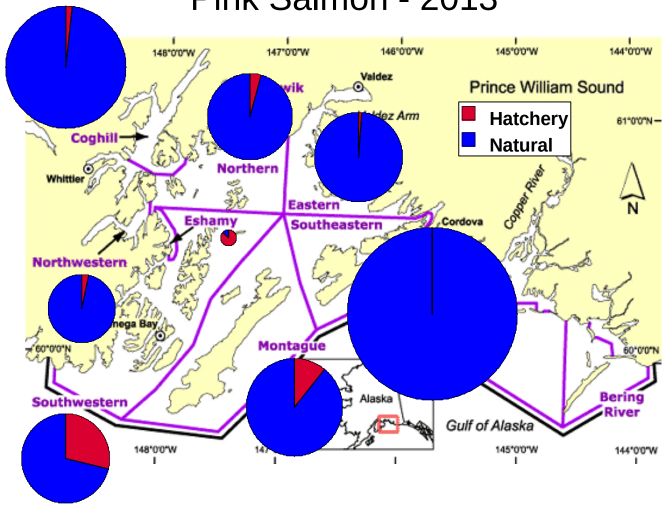
Knudsen et al. (2016). Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska.

AHRP Research Questions

2) What is the extent and annual variability of straying?

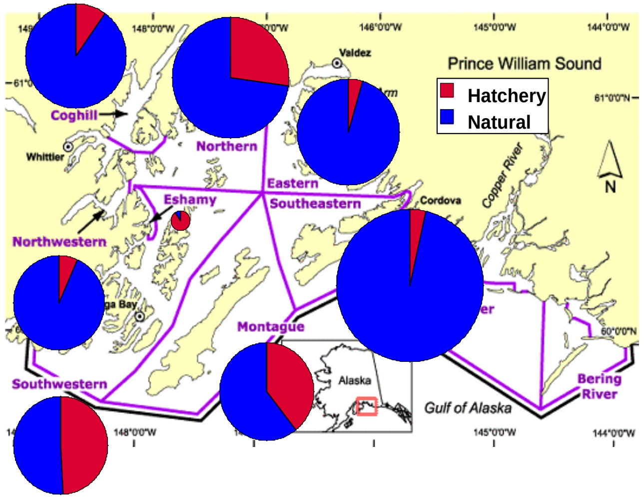
Stream sampling – Pink salmon

Pink Salmon - 2013



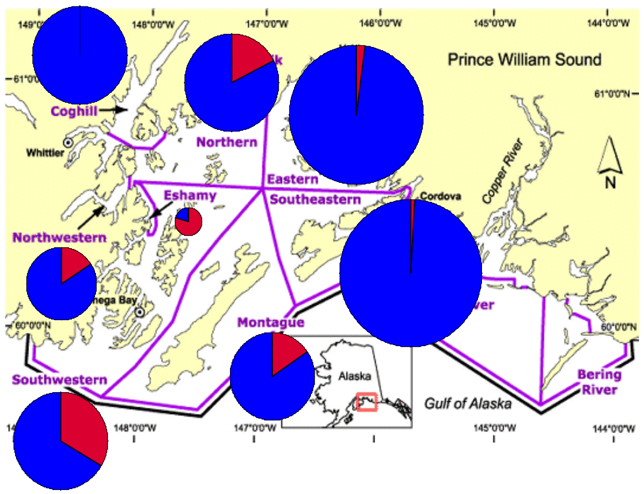
Overall an estimated 4.4% of an estimated 16.4 million spawners were of hatchery-origin.

Pink Salmon - 2014



Overall an estimated 14.8% of an estimated 5.9 million spawners were of hatchery-origin.

Pink Salmon - 2015



Overall an estimated 9.5% of an estimated 42.0 million spawners were of hatchery-origin.

Knudsen et al. (2016). Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska.

AHRP Research Questions

2) What is the extent and annual variability of straying?

Stream sampling – Chum salmon (2013-2015)

- Proportions of hatchery fish in **<u>streams</u>**
- PWS: 17 study streams; 222 site visits; 17,000 samples
- SEAK: 32 study streams; 352 site visits; 29,400 samples

PWS

Average in District 0-85%
Annual Average 3%

District	Estimated hatchery fraction (2013)	Estimated hatchery fraction (2014)	Estimated hatchery fraction (2015)
Eastern (221)	0.004	0.041	0.013
Northern (222)	0.080	0.054	0.097
Coghill (223)	0.049	0.000	0.008
Northwestern (224)	0.052	0.015	0.038
Montague (227)	0.783	0.803	0.846
Southeastern (228)	0.022	0.000	0.031
Overall	0.028	0.032	0.031

SEAK

Average in District 2-13%
Annual Average 5-9%

District	Estimated hatchery fraction (2013)	Estimated hatchery fraction (2014)	Estimated hatchery fraction (2015)
Northern Southeast Outside	0.019	0.015	0.021
Northern Southeast Inside	0.074	0.065	0.127
Southern Southeast	0.081	0.051	0.050
Overall	0.073	0.054	0.092

Knudsen et al. (2016). Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska.

AHRP Research Questions

2) What is the extent and annual variability of straying?

Ocean sampling 2013–2015 (PWS only)

- Proportions of hatchery fish in **run**
- Results (7,800 samples):
  - Pink salmon: 55-86%
  - Chum salmon: 51-73%

Species Common Name	Year	Hatchery Proportion	SE
Pink Salmon	2013	0.679	.016
	2014	0.864	.03
	2015	0.549	.004
Chum Salmon	2013	0.725	.019
	2014	0.511	.029
	2015	0.688	.015

Knudsen et al. (2016). Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska.

AHRP Research Questions

2) What is the extent and annual variability of straying?

Wild and Hatchery run size estimates

– Preliminary PWS run size estimates; 2013-2015 (Thousands)

Species Year	Natural spawners	Hatchery strays	Total spawners	Natural run	Hatchery run	Total run
Pink salmon						
2013	15,698	701	16,399	33,096	69,888	102,985
2014	5,130	741	5,872	6,960	42,757	49,718
2015	37,972	4,009	41,981	63,531	77,335	140,866
Chum salmon						
2013	894	50	944	1,141	3,007	4,148
2014	925	49	975	1,175	1,228	2,404
2015	890	28	919	1,128	2,484	3,612

Knudsen et al. (2016). Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska.

AHRP Research Questions

Wild and Hatchery harvest rate estimates; PWS Pink

	Estimated Harvest Rates	
Year	Hatchery	Natural
2013	0.99	0.53
2014	0.98	0.26
2015	0.95	0.40

Knudsen et al. (2016). Interactions of Wild and Hatchery Pink Salmon and Chum Salmon in Prince William Sound and Southeast Alaska.

AHRP Research Questions

3) What is the impact on fitness (productivity) of natural pink and chum stocks?

Fitness – the ability to survive and reproduce
[average contribution by average individual to next generation]

If hatchery fish are less fit in wild streams, then

1. Hatchery fish will produce fewer offspring

AND

2. Wild fish will produce fewer offspring due to interbreeding.

AHRP Research Questions

3) What is the impact on fitness (productivity) of wild pink and chum stocks?

Relative reproductive success (2013-2023)

- Identify number of offspring produced by hatchery- and wild-origin parents
- Follow 2 broodyears for 2 generations
- PWS pink salmon: 6 streams; 689 site visits; 168,800 samples (2013-2017)
- SEAK chum salmon: 4 streams; 146 site visits; 11,800 samples (2013-2017)

Sampling Year

Species		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Chum	BY 1	F_0			F_1	F_1/F_2	F_1/F_2	F_1/F_2	F_2	F_2	F_2	
	BY 2		F_0			F_1	F_1/F_2	F_1/F_2	F_1/F_2	F_2	F_2	F_2
Pink	Odd BY 1	F_0		F_1		F_2						
	Even BY 2		F_0		F_1		F_2					

AHRP Summary

Information was needed to assess impact of hatcheries on wild stocks

AHRP designed to address three specific research questions

1. Genetic population structure
   - Odd and even year completed; reports in process
   - Historical analysis; in process
2. Patterns of straying (2013-2015)
   - Hatchery proportions in escapement; completed and reported
   - Estimate of hatchery and wild returns; completed and reported
   - Estimate of hatchery and wild harvest rates; completed and reported
3. Effect of strays on fitness
   - Sampling in PWS; completed
   - Processing and analysis in PWS; in process
   - Sampling, processing and analysis in SEAK; in process

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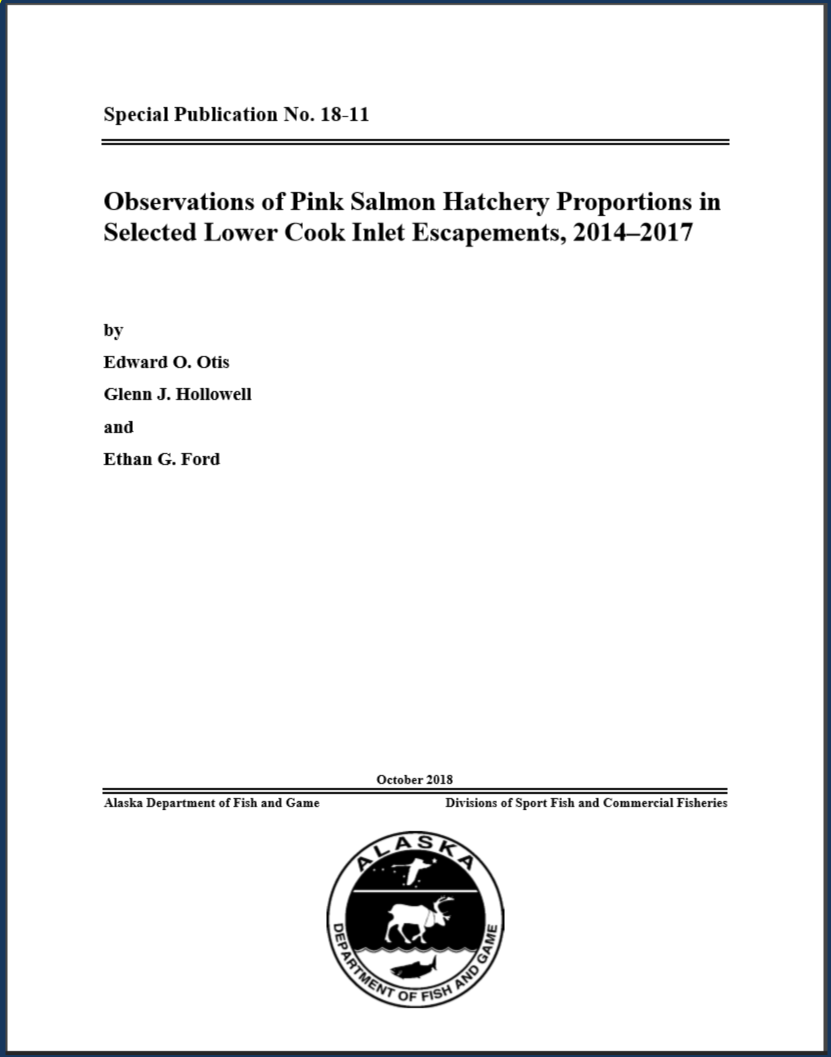
Lower Cook Inlet stray study
2014-2017 (2018)

Purpose

Intended to collect baseline data associated with 2 recently reopened hatcheries.

Methods

- 8-16 streams surveyed each year
- Core streams visited at least twice per year
- Collected otoliths from spawned-out carcasses (fresh and old)



Special Publication No. 18-11

Observations of Pink Salmon Hatchery Proportions in Selected Lower Cook Inlet Escapements, 2014–2017

by

Edward O. Otis

Glenn J. Hollowell

and

Ethan G. Ford

October 2018

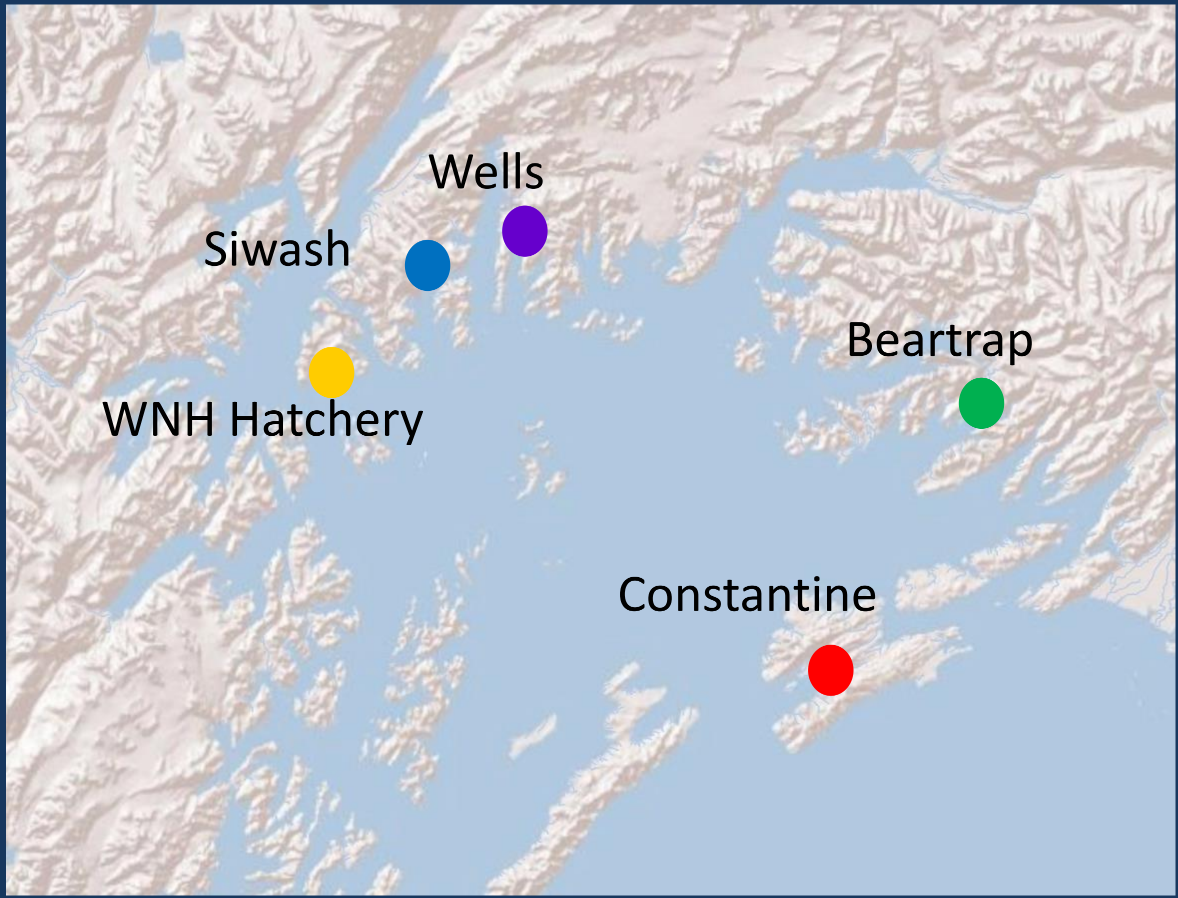
Alaska Department of Fish and Game | Divisions of Sport Fish and Commercial Fisheries

Results

- Hatchery % varied widely among streams and across years within streams
- LCI hatchery % were highest in samples collected from streams closest to hatchery release sites (<6 mi)
- PWS hatchery % in LCI streams was highly variable, unexpectedly high (up to 87%) in some streams
- Across years more PWS marks were found than LCI marks in samples from streams outside hatchery SHAs.
- Observing PWS hatchery pink salmon in LCI streams 150-300 miles away demonstrates a broader scope of interaction than expected.

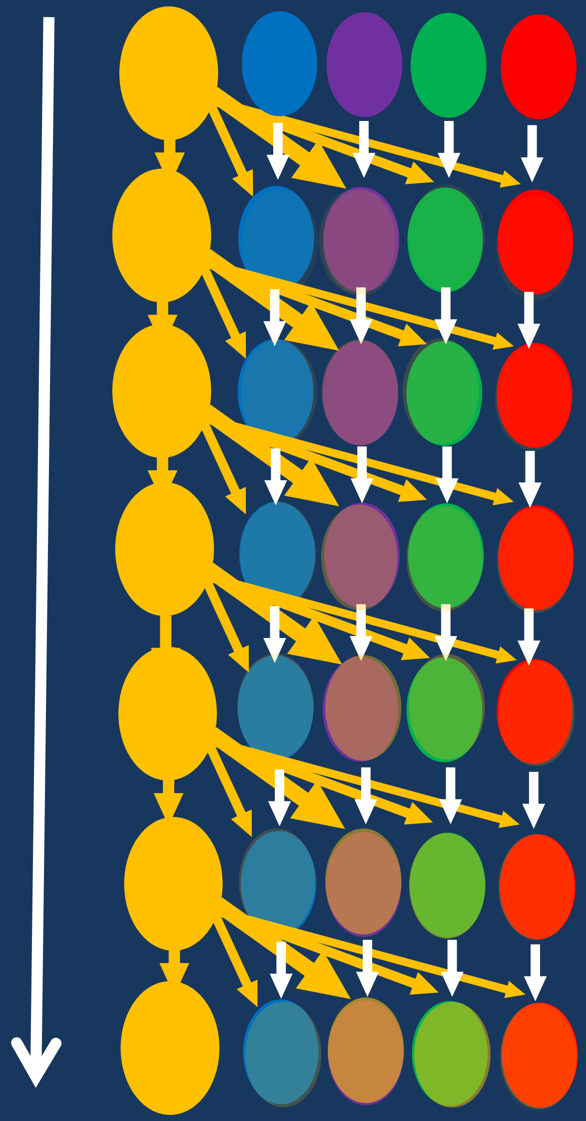
Prince William Sound chum study

- Straying observed
- Collections:
  - Pre-hatchery: 1964 - 1984
  - Recent: 2008 - 2010
- Questions:
  - Are old and new collections similar?
  - Do new collections look more like the hatchery than old collections?

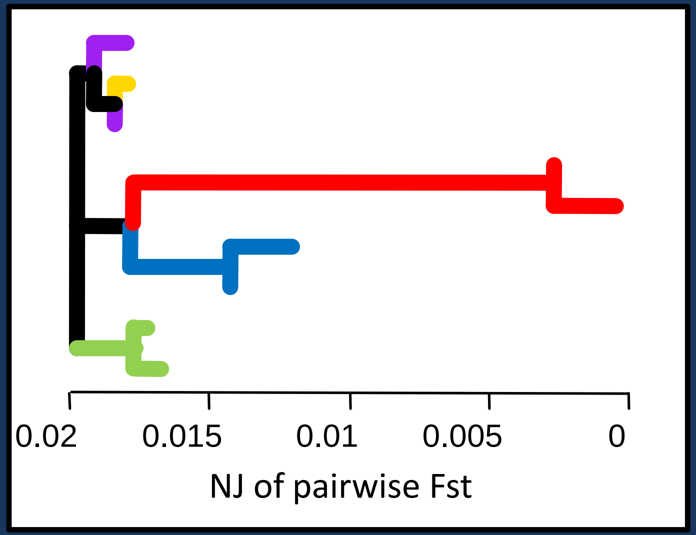


Results

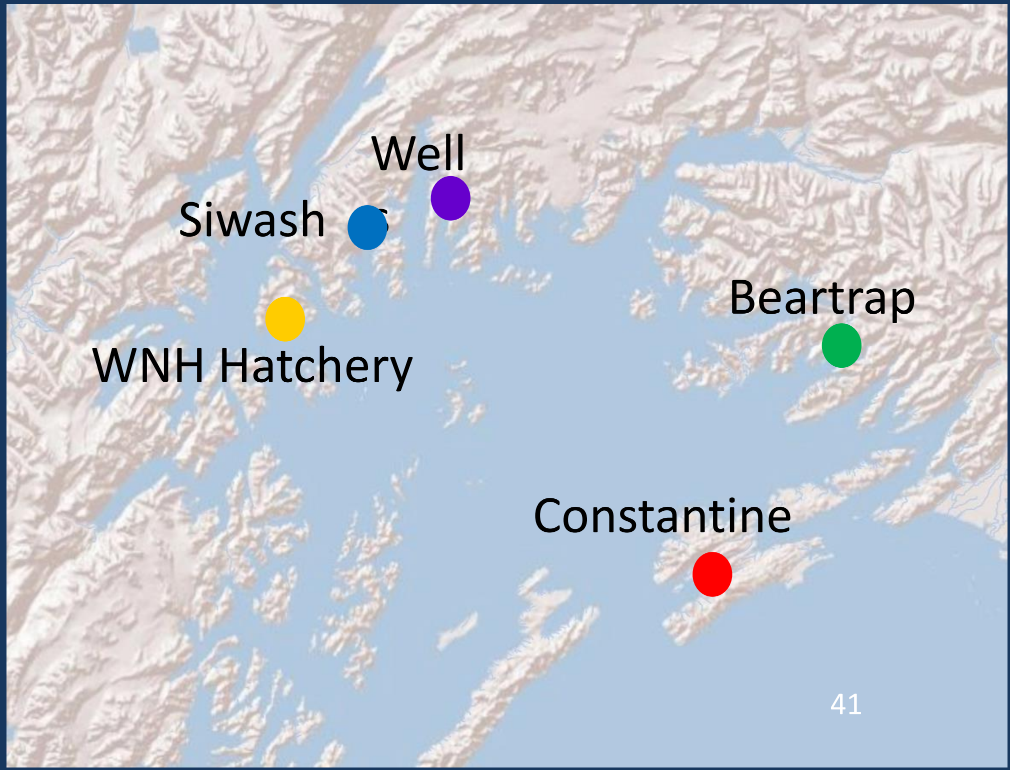
Time



Archived scale samples: 1964–1982



Contemporary tissues: 2008–2010



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Understanding Potential Genetic Effects of Straying

1. Conceptual framework linking fitness to genetic integrity
2. Hierarchical definition of straying
3. Simple models to describe mechanisms
4. Case studies to illustrate these concepts
   – PWS pink salmon
   – SEAK king salmon

Genetic Policy: Maintain fitness of wild stocks in presence of enhancement programs

1. Fitness is maintained by conserving genetic integrity
2. Genetic integrity is maintained by reducing introgression
3. Reducing introgression is maintained by reducing straying

Mechanisms affecting fitness

- Introgression of maladapted genes

  Cause: Non-local or domesticated stock

  Result: Reduced fitness = less productivity

- Loss of variation among sites

  Cause: Stocks become more similar

  Result: Reduced resilience = variable productivity

- Loss of variation within sites

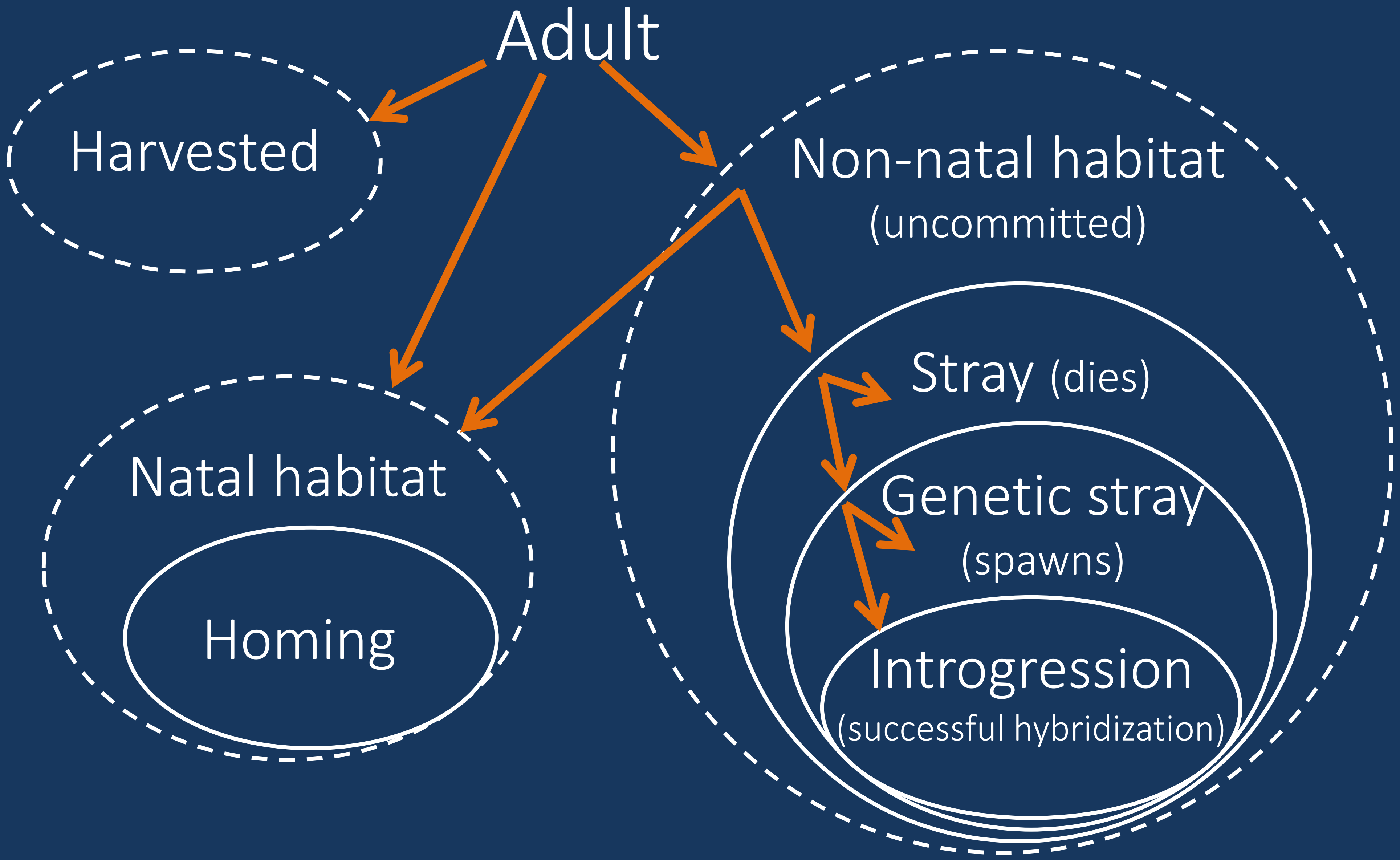
  Cause: Low hatchery broodstock sizes

  Result: Reduced fitness and resilience

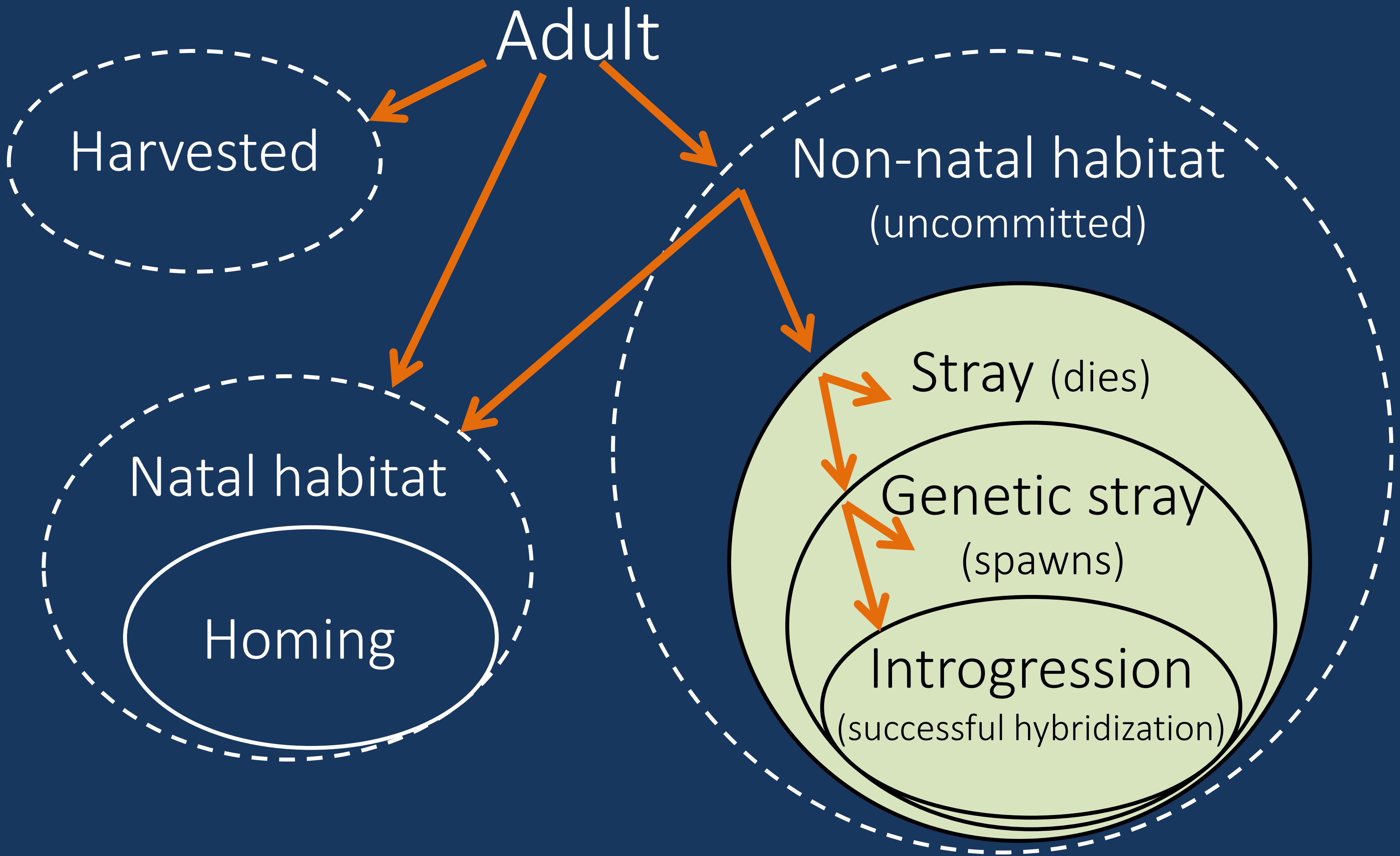
Local adaptations in wild fish may be lost if…

1. Hatchery fish are genetically different from wild fish
2. Hatchery fish stray into wild spawning areas
3. Stray hatchery fish spawn with wild fish
4. Hatchery fish genes introduced into wild fish gene pool (Introgression)

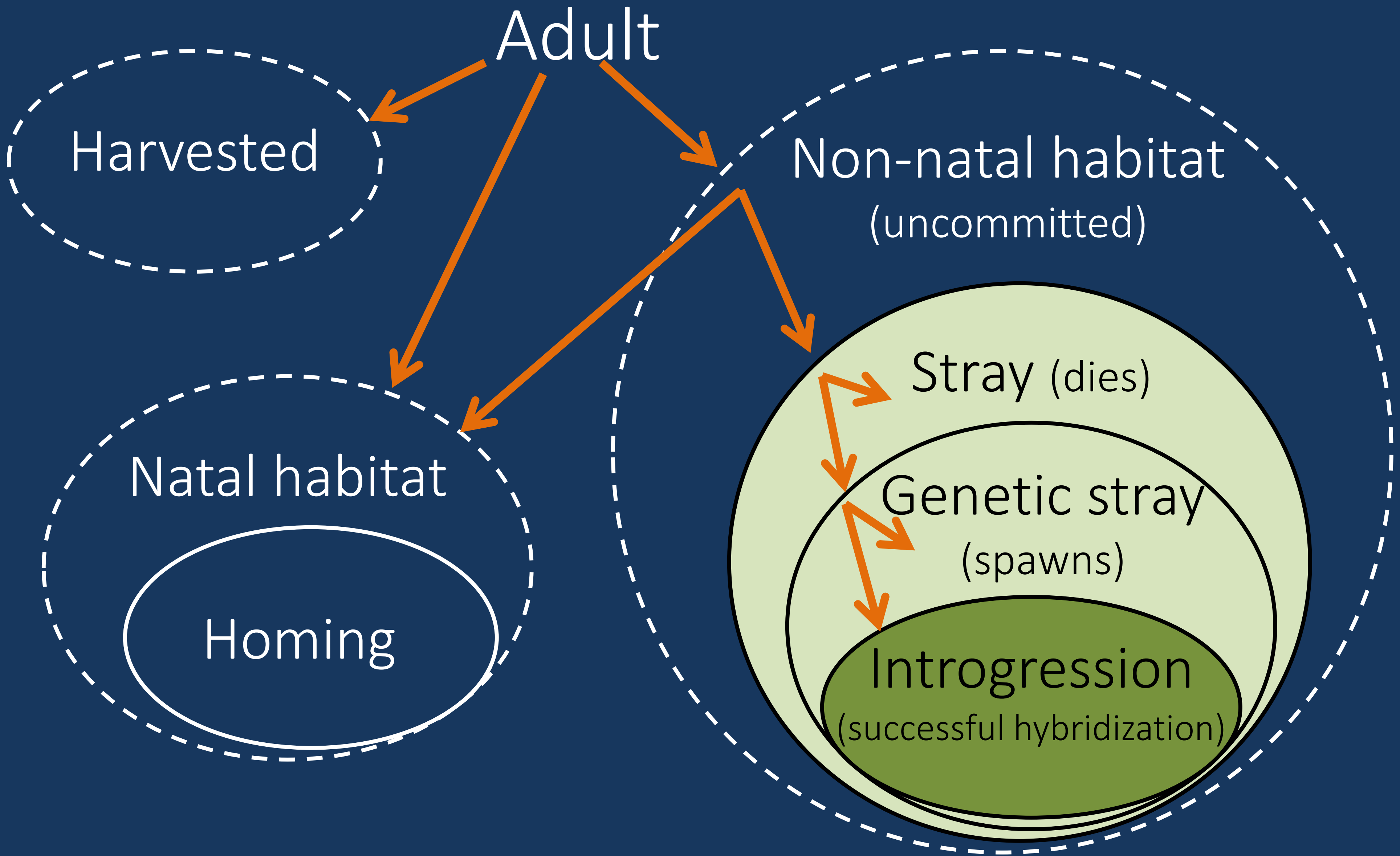
Straying definitions



Straying definitions



Straying definitions

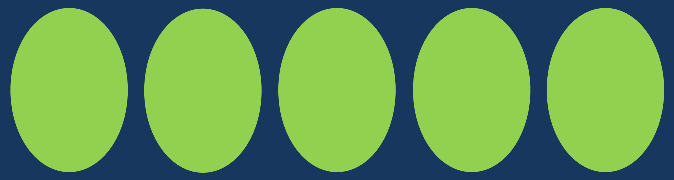


Local adaptations in wild fish may be lost if…

1. Hatchery fish are genetically different from wild fish
2. Hatchery fish stray into wild spawning areas
3. Stray hatchery fish spawn with wild fish
4. Hatchery fish genes introduced into wild fish gene pool (Introgression)

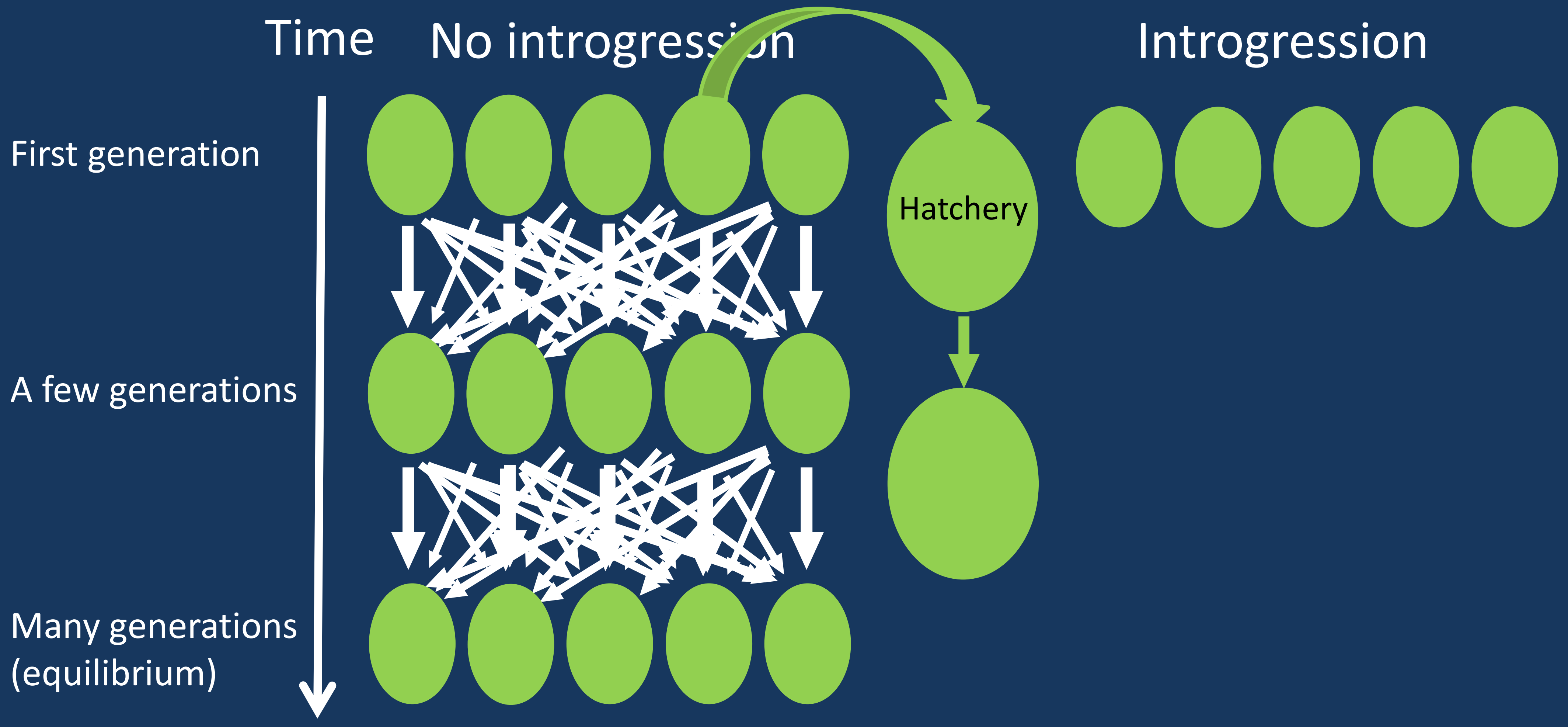
5. Effect of introgression depends on:
   - Degree of adaptation among wild stocks
   - Divergence between hatchery and wild stocks
     - Non-local hatchery broodstock
     - Domestication of hatchery broodstock

Local stock, no adaptation among sites, no domestication

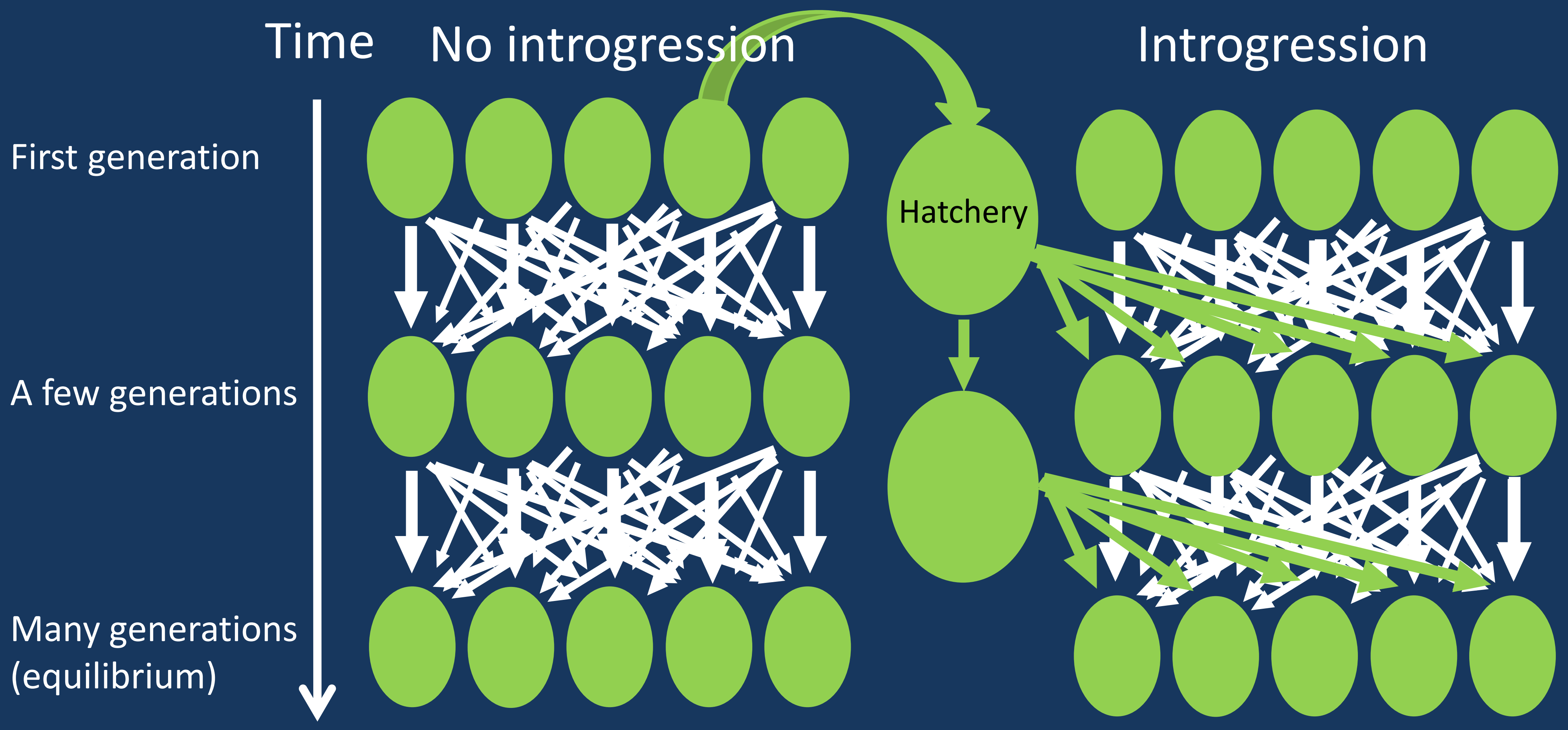


Each of these ovals represents a wild pink salmon population
Differences in color will represent differences in adaptation
Here, all 5 populations are genetically the same

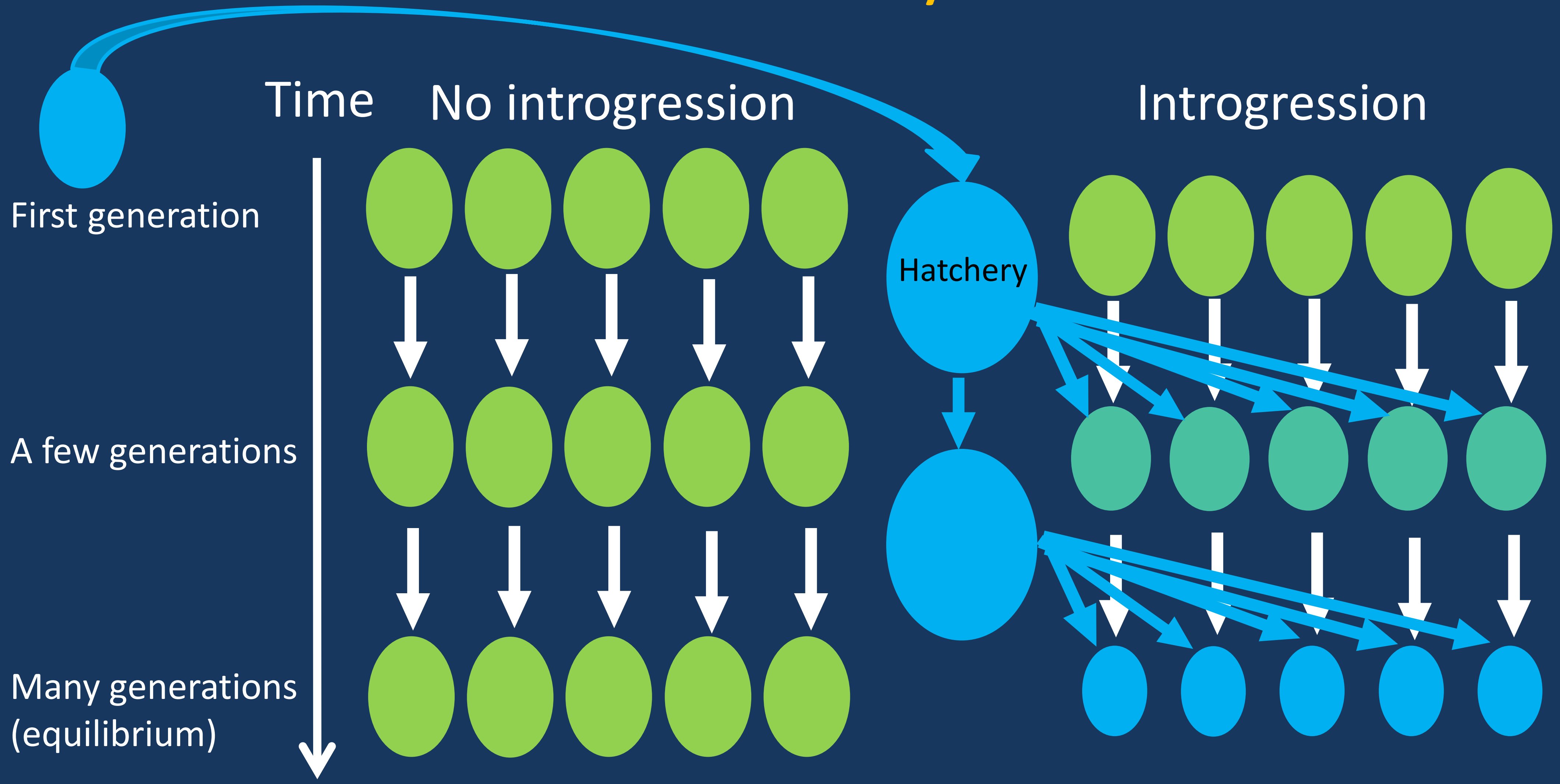
Local stock, no adaptation among sites, no domestication



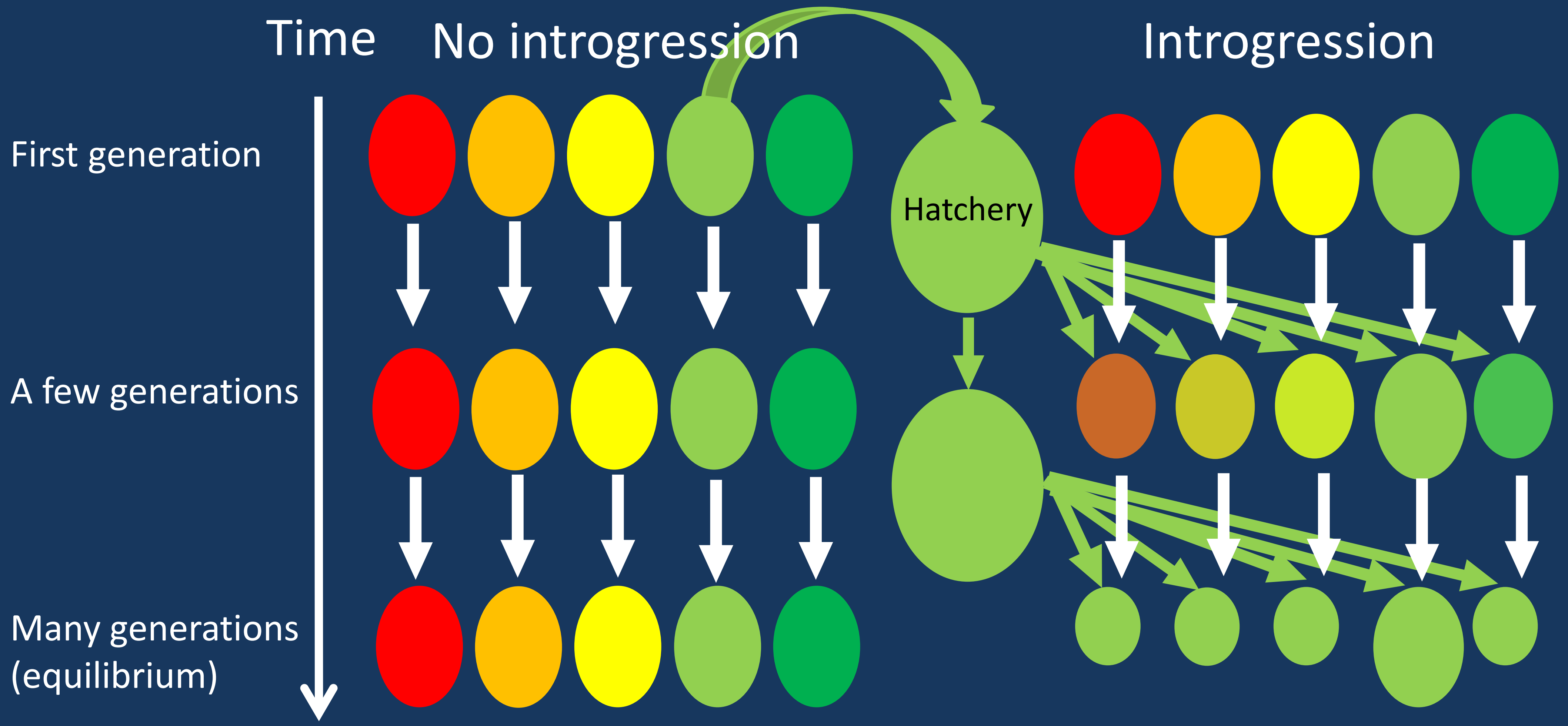
Local stock, no adaptation among sites, no domestication



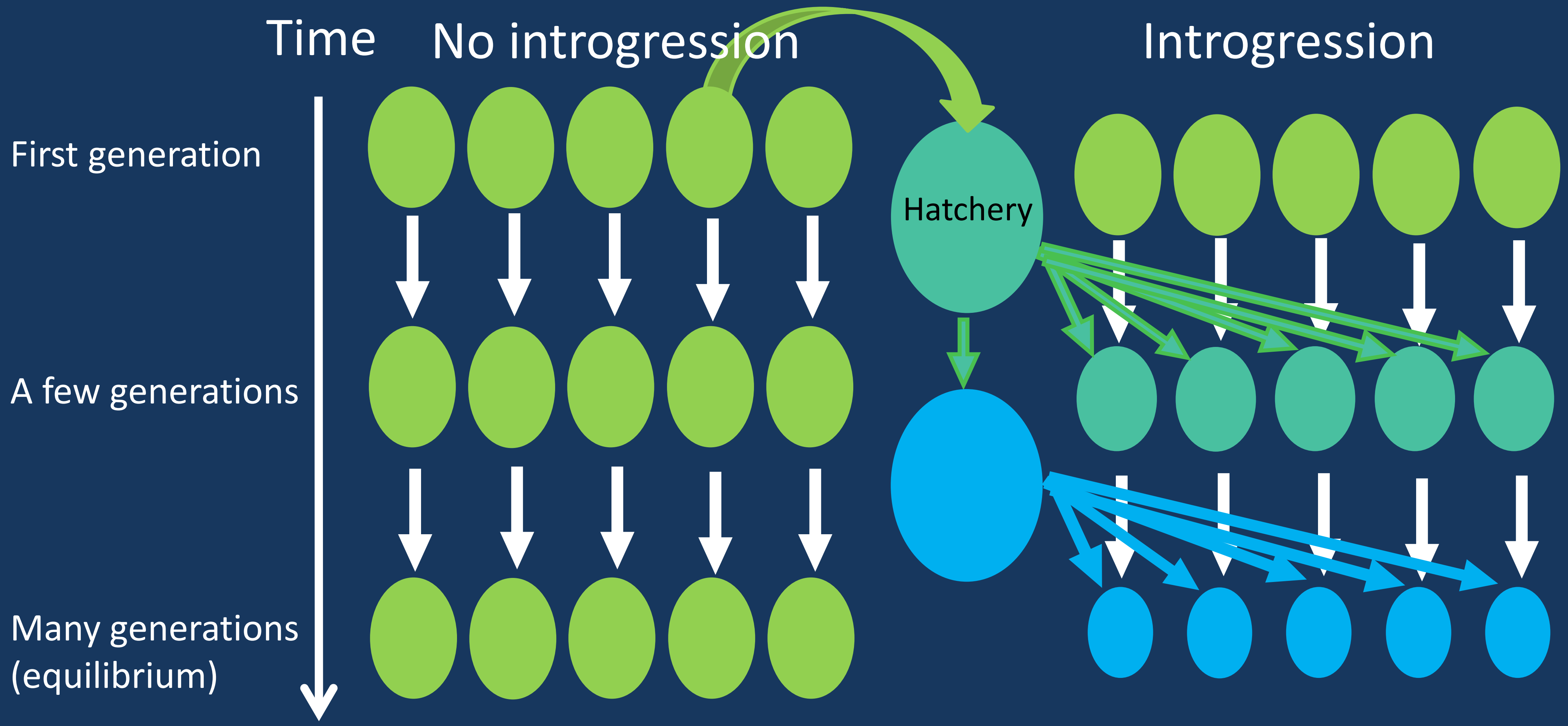
No adaptation among sites and non-local hatchery stocks



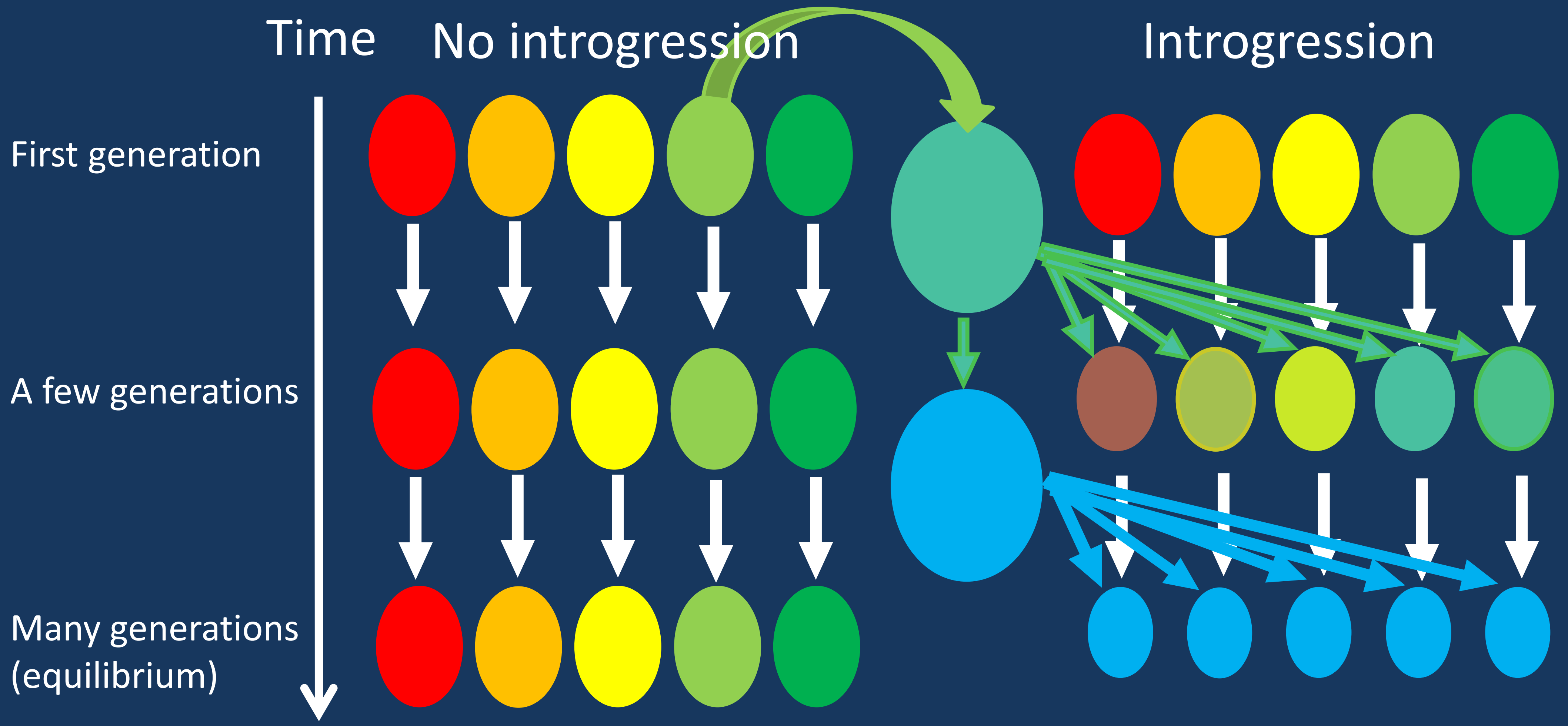
Adaptation among sites, local stock



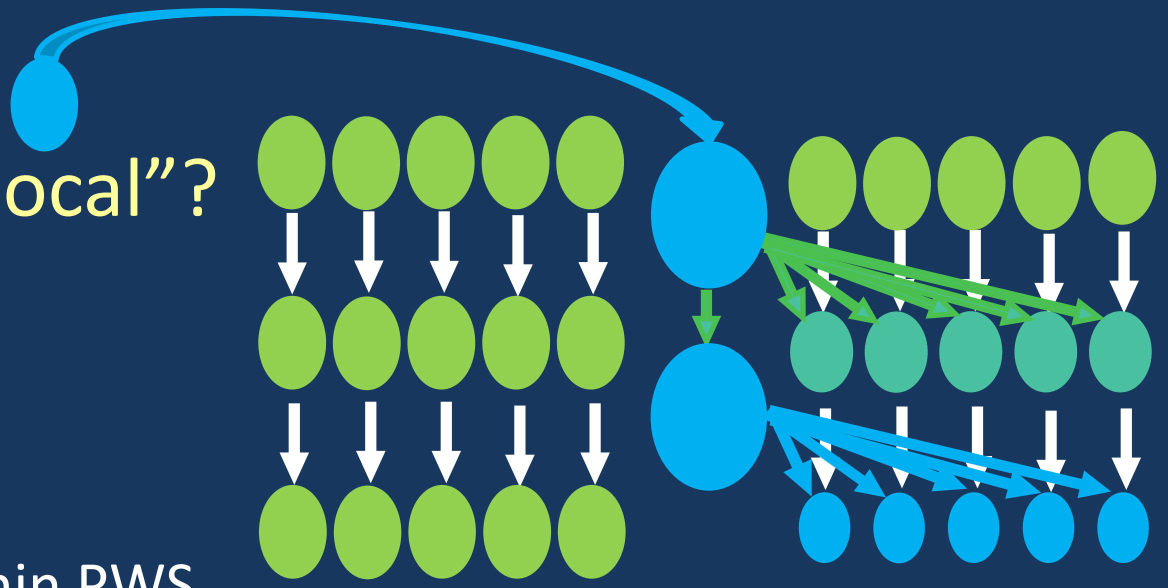
No adaptation among sites and domestication



Adaptation among sites and domestication



Case study: PWS pink salmon



Can hatchery stock be considered "local"?

"Yes"

- All stocks originated within PWS
- "Local" under *Genetic Policy*
- Very shallow population structure within PWS

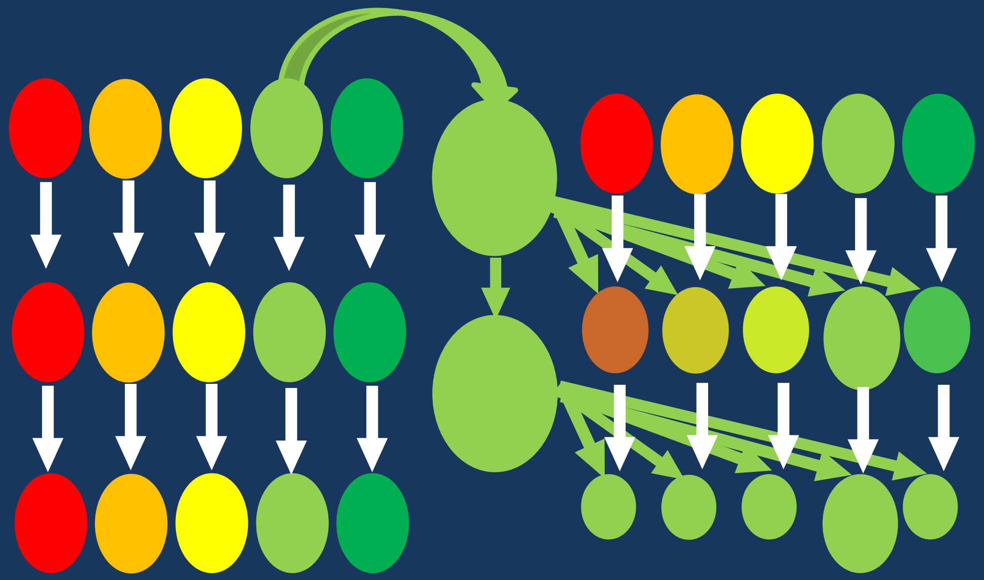
"Maybe"

- Hatchery stocks selected based on run timing for management needs
- East-side stock used in west-side hatchery

"No"

- PWS hatchery fish in Lower Cook Inlet not "local" under *Genetic Policy*

Case study: PWS pink salmon



Is there adaptation among spawning sites?

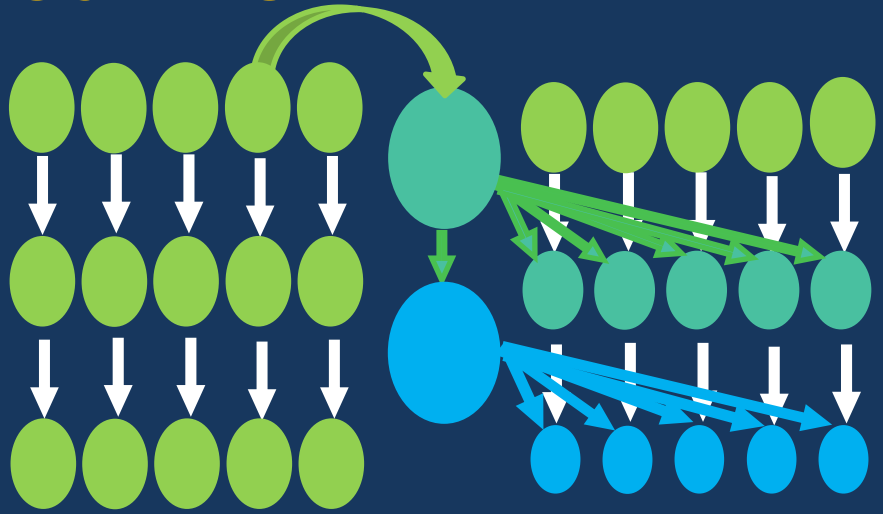
"Yes"

- Observed life history differences:
  - Upstream/intertidal spawning in streams
  - Run timing differences among districts

"No"

- Life history differences could be genetically and/or environmentally mediated
- Small genetic differentiation at neutral loci is consistent with high natural gene flow

Case study: PWS pink salmon



Are hatchery pinks domesticated?

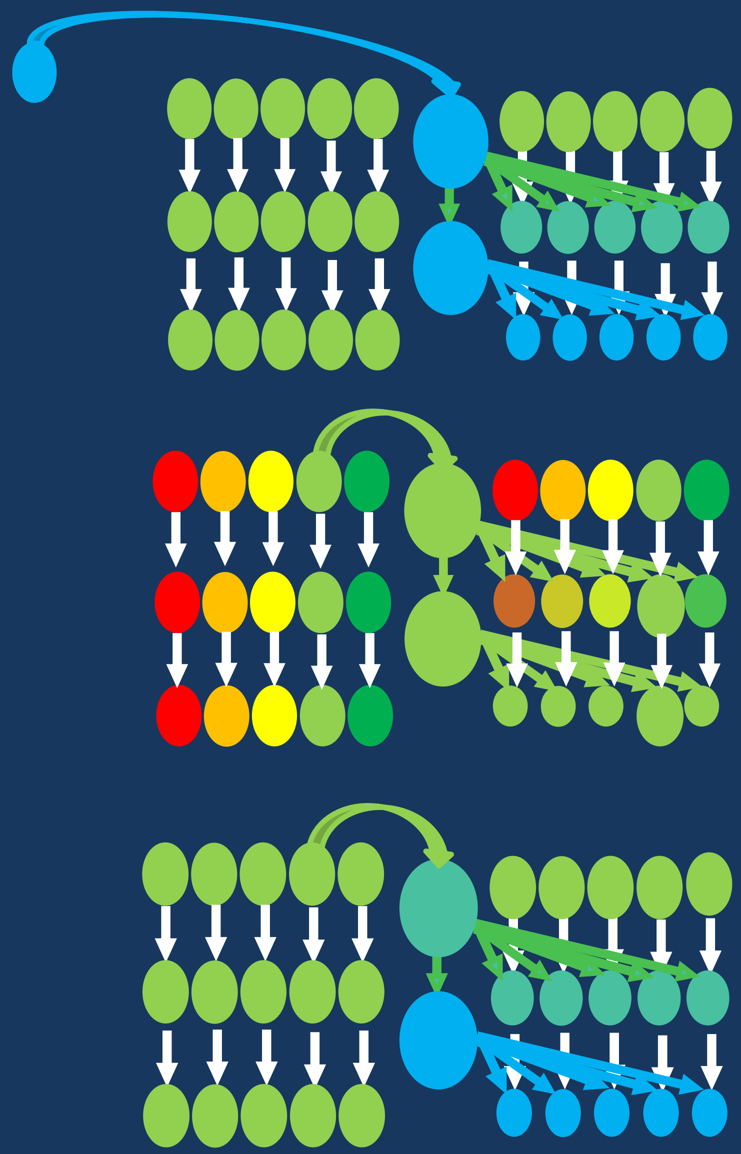
"Yes"

- Domestication documented in other Pacific salmon species
- Lack of selection could allow retention of genes maladapted for wild environment

"No"

- Less opportunity for selection for pink salmon in PWS than other Pacific salmon species:
  - Shorter hatchery residence and fewer life stages
  - Pink salmon egg to fry mortality in hatchery is small
  - Hatcheries do not purposely select for traits

Case study: SEAK king salmon



Can hatchery stock be considered "local"?

– All SEAK stocks
– Hatcheries in sensitive zone use nearby stocks

Is there adaptation among spawning sites?

– Larger genetic differences
– More diverse life histories

Are hatchery kings domesticated?

– One stock purposely divergent
– Longer hatchery residence increases potential

Straying low due to hatchery siting

Farragut River may be a concern

Is genetic effect negative for wild stock sustainability?

Productivity increases in PWS may be due to environmental conditions, not enhancement: replacement not augmentation

However…

Estimates of wild-origin returns to PWS from AHRP study indicate largest wild returns on record

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Carrying capacity is the number of organisms that an ecosystem can sustainably support.

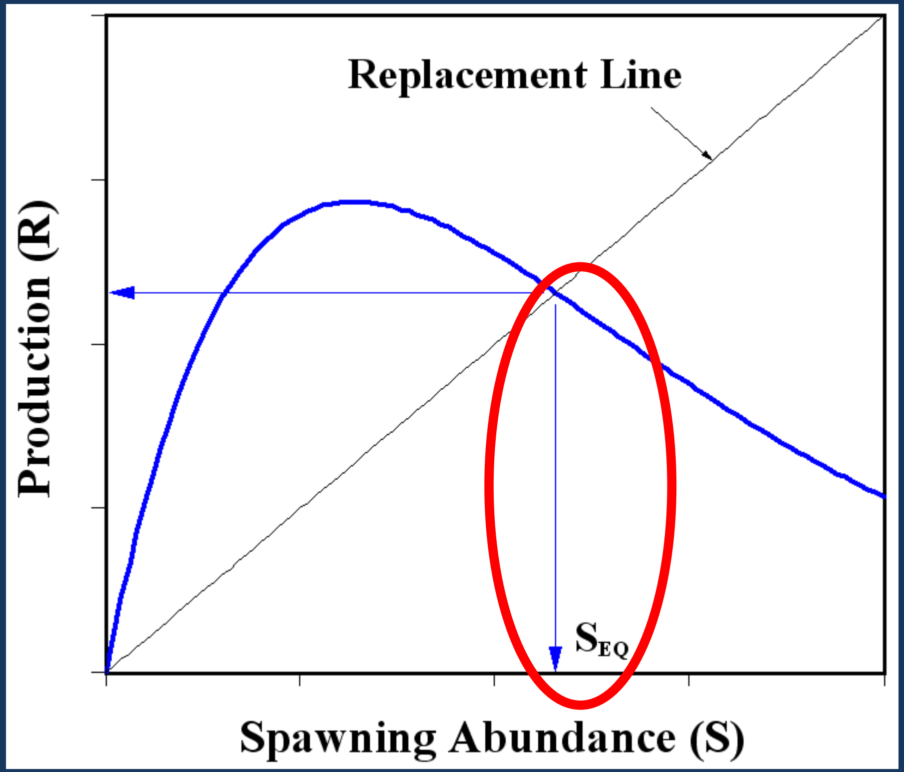
– Changes over time
  - Abundance of predators
  - Supply of food
  - Competition
  - Physical factors affect distribution and productivity; “Patchiness”

Usually defined for a single species or population in a defined, more uniform area (e.g., sheep in a pasture or fish in a lake)

Much more difficult in a large, variable area and with multiple species.

Carrying capacity in production models

- Expected annual abundance of spawners when the stock has not been subject to fishing (S_{eq})
- Number of spawners that produce the same number of recruits



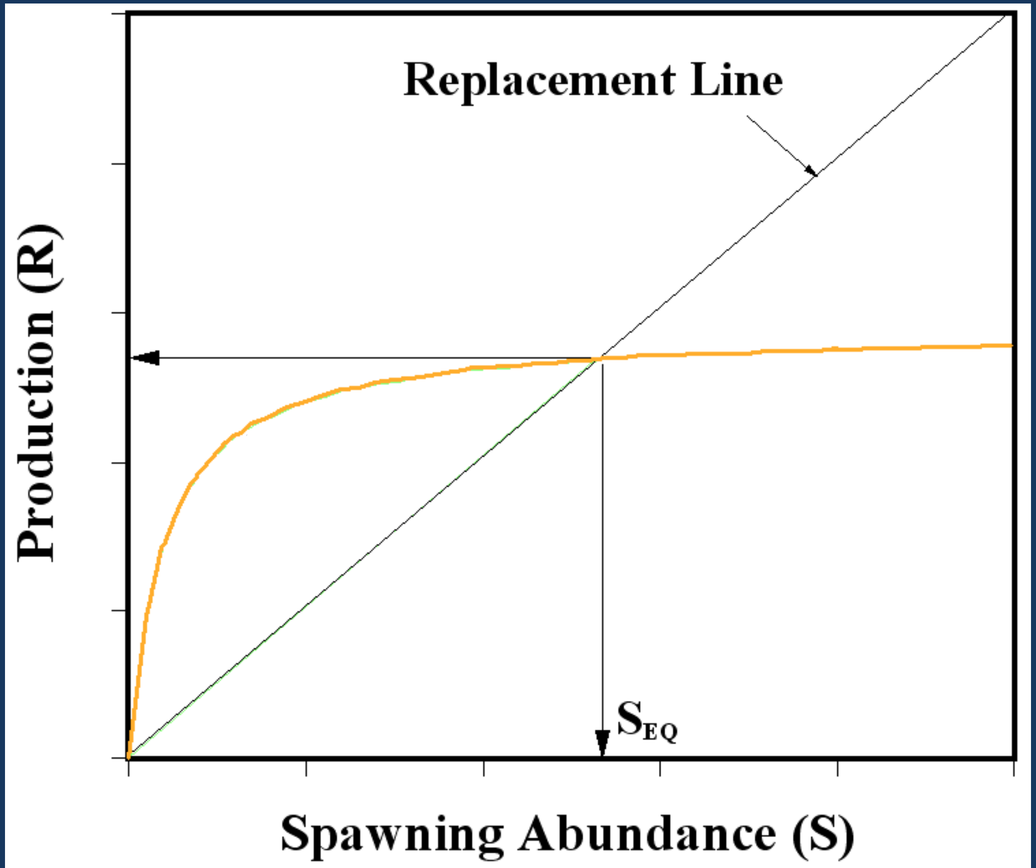
Factors affecting carrying capacity in freshwater

- Limited spawning ground (Among adults)
  - Superimposition of redds
  - Spawning in marginal areas
  - Egg retention/death
  - Interference of spawning from aggression

- Limited rearing resources (Among juveniles)
  - Trophic production in lakes
  - Quantity/quality of riparian habitats

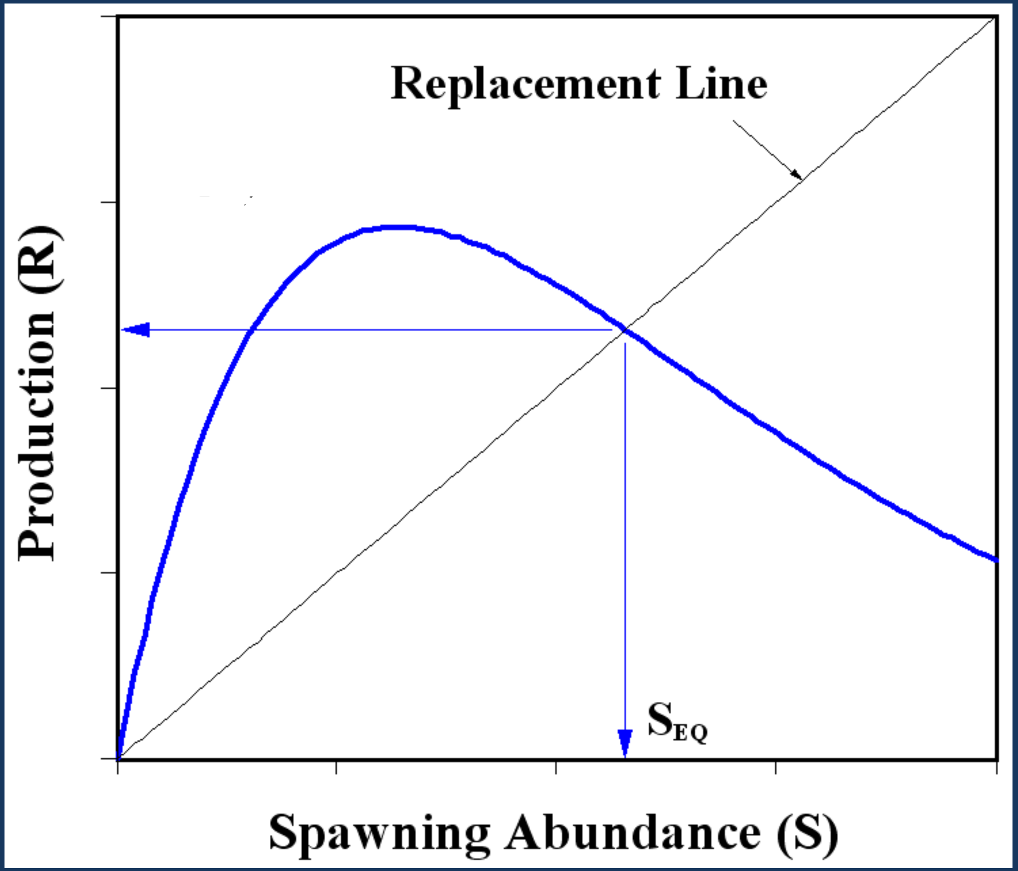
Carrying capacity in production models

Simple compensation



Beverton-Holt

Overcompensation



Ricker

Quinn, T.J., and R. B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, New York.

Carrying capacity in marine environment

Why is carrying capacity of the ocean hard to measure?

- Many different species with varying relationships
- Large scale environment with varying conditions “patchiness”
- Complexity means no simple answers

Where could salmon reach carrying capacity?

	Juvenile	Immature	Adult
Freshwater	rearing		spawning
Marine	nearshore	open ocean	open ocean

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RCs Submitted in July 2018

"...recent scientific publications...have provided cause for great concern over the biological impacts associated with continued release of very large numbers of hatchery salmon into the North Pacific..."

10 peer-reviewed scientific documents submitted in support

Areas of concern

1. Salmon abundance and biomass
2. Diet and feeding ecology/trophic effects
3. Interspecies interactions (correlations)
4. Phenotypic and life history changes
5. Population resiliency

Questions implicit with respect to areas of concern

- Are pink salmon a major driver of North Pacific ecosystem?
- Does pink salmon abundance affect other species?
- Does alternating pink abundance drive patterns in other species?
- Do patterns indicate system is near carrying capacity?
- Will more hatchery pink salmon compound the effect?

1. Salmon abundance and biomass

Ruggerone & Irvine (2018) Numbers and biomass of natural- and hatchery-origin pink salmon, chum salmon, and sockeye salmon in the North Pacific Ocean, 1925-2015

- Only available estimates
- Compiled available data to make “best” estimates
- Relies upon many assumptions – critical data are absent

Assumptions (selected):

- Does not include non-NPAFC countries (N. Korea & China)
- Reported harvest incomplete – Russia poaching
- Expanded escapement for areas with incomplete coverage (e.g. AK & BC)
- Spawning abundance estimated from harvest data and harvest rate - many areas (e.g. Asia)

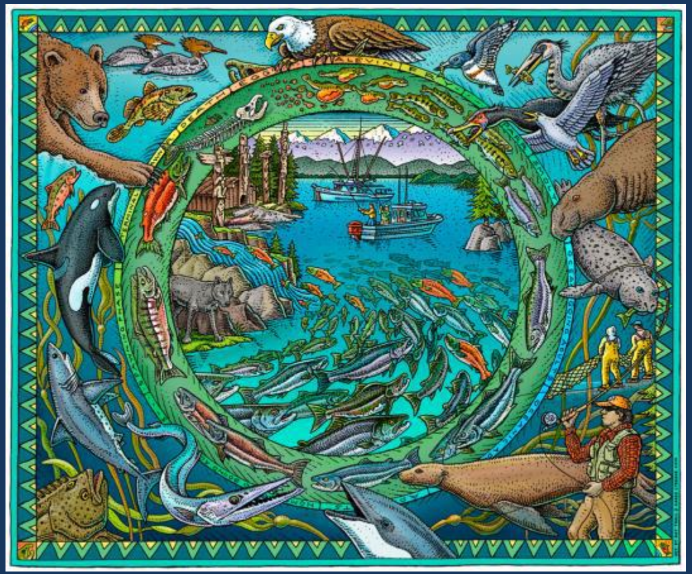
2. Diet and feeding ecology/trophic effects

Myers et al. (2004) Diet Overlap and Potential Feeding Competition Between Yukon River Chum Salmon and Hatchery Salmon in the Gulf of Alaska in Summer

Davis (2003) Feeding Ecology of Pacific Salmon (Oncorhynchus spp.) in the Central North Pacific Ocean and Central Bering Sea, 1991-2000

Aydin (2000) Trophic Feedback and Carrying Capacity of Pacific Salmon (Oncorhynchus spp.) on the high seas of the Gulf of Alaska

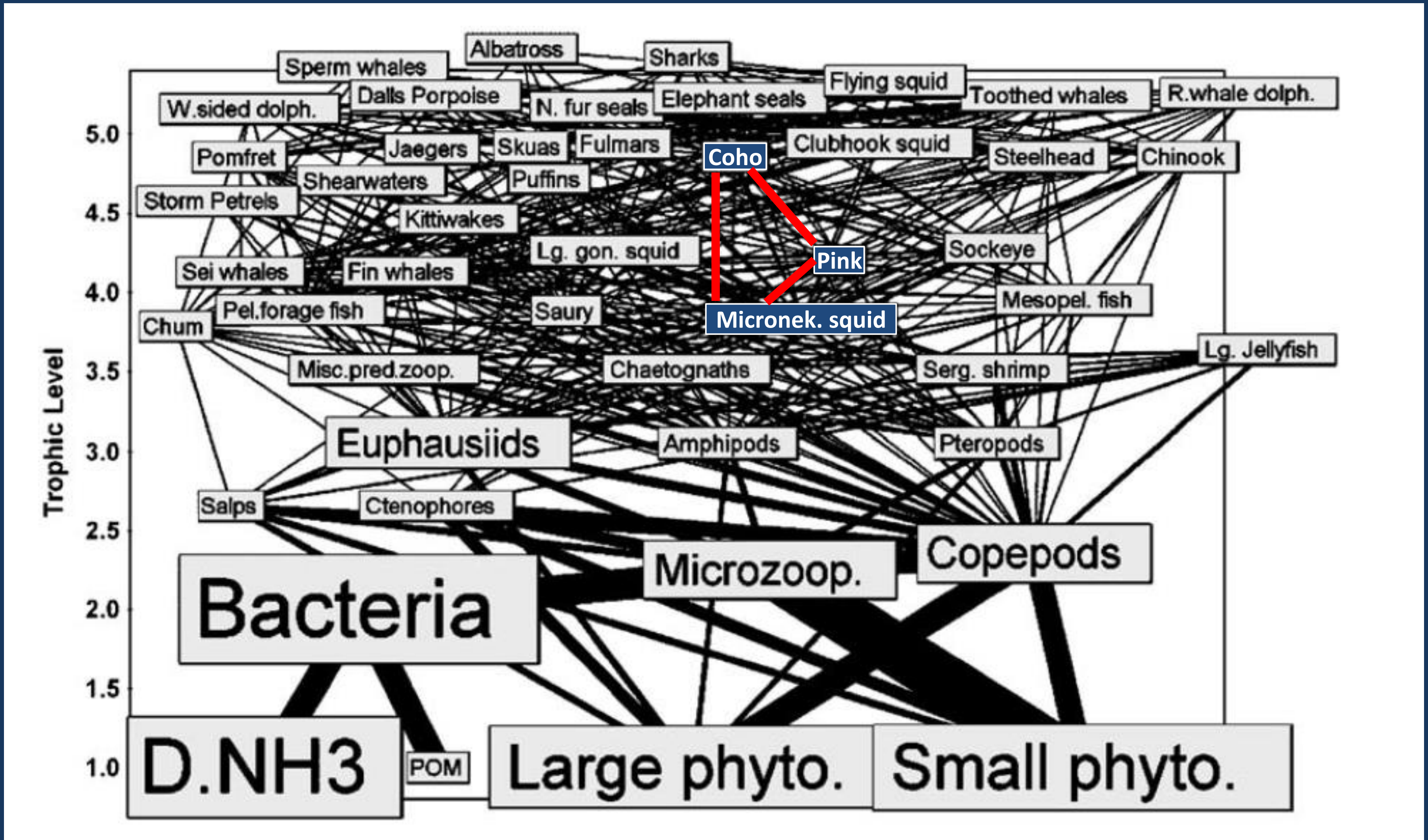
- Research into feeding ecology and diet overlap
- Critical information for understanding relationships and complexity
- Basic research needed
  - How do salmon experience ocean environment (e.g. The Blob)
  - Not necessarily designed to test hypotheses of effect



Ray Troll & Karen Lybrand

North Pacific Ocean ecosystem

It is complicated... along the way.



Shaul & Geiger (2016) Effects of climate and competition for offshore prey on growth, survival, and reproduction potential of coho salmon in southeast Alaska

Aydin, K.Y., et al. (2005) Linking oceanic food webs to coastal production and growth rates of Pacific salmon (*Oncorhynchus* spp.), using models on three scales. Deep-Sea Research II 52:757-780

3. Interspecies interactions (correlations)

Do the strong abundance cycles of odd- and even-year runs of pink salmon affect inter-specific growth and survival?

Springer et al. (2018) Transhemispheric ecosystem disservices of pink salmon in a Pacific Ocean macrosystem

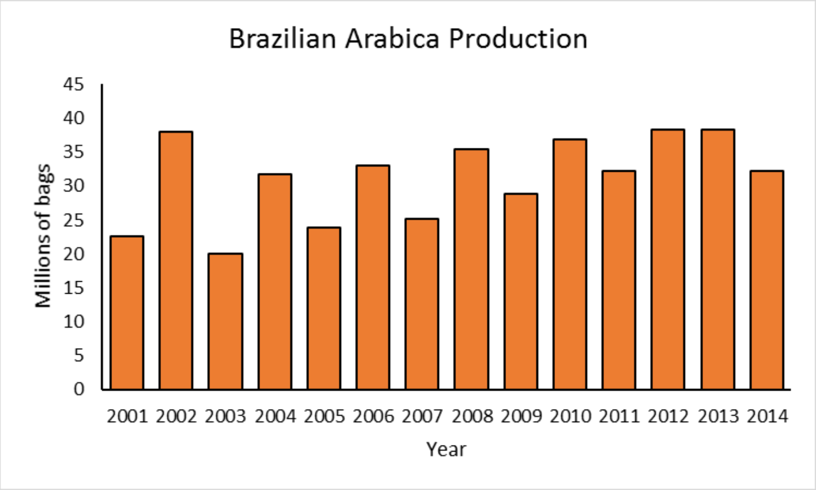
Batten et al. (2018) Pink salmon induce a trophic cascade in plankton populations in southern Bering Sea and around the Aleutian Islands

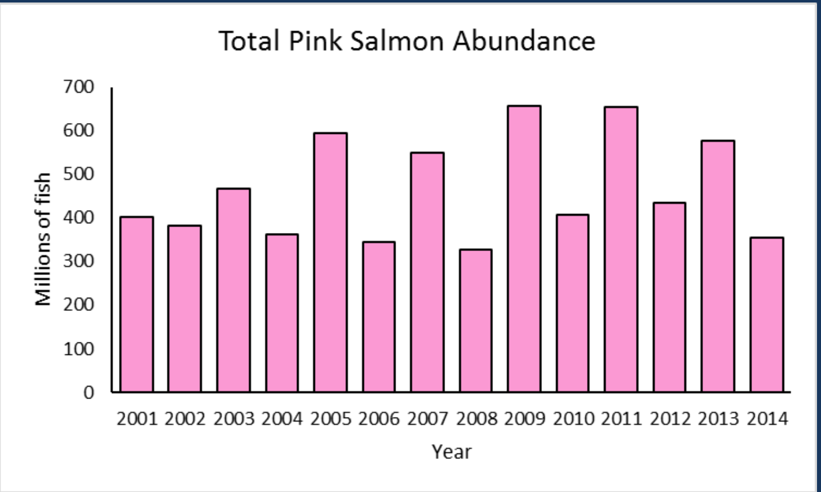
Use Ruggerone & Irvine data to find correlations
Draw conclusions but do not test hypotheses

Shaul & Geiger (2016) Effects of climate and competition for offshore prey on growth, survival, and reproduction potential of coho salmon in southeast Alaska

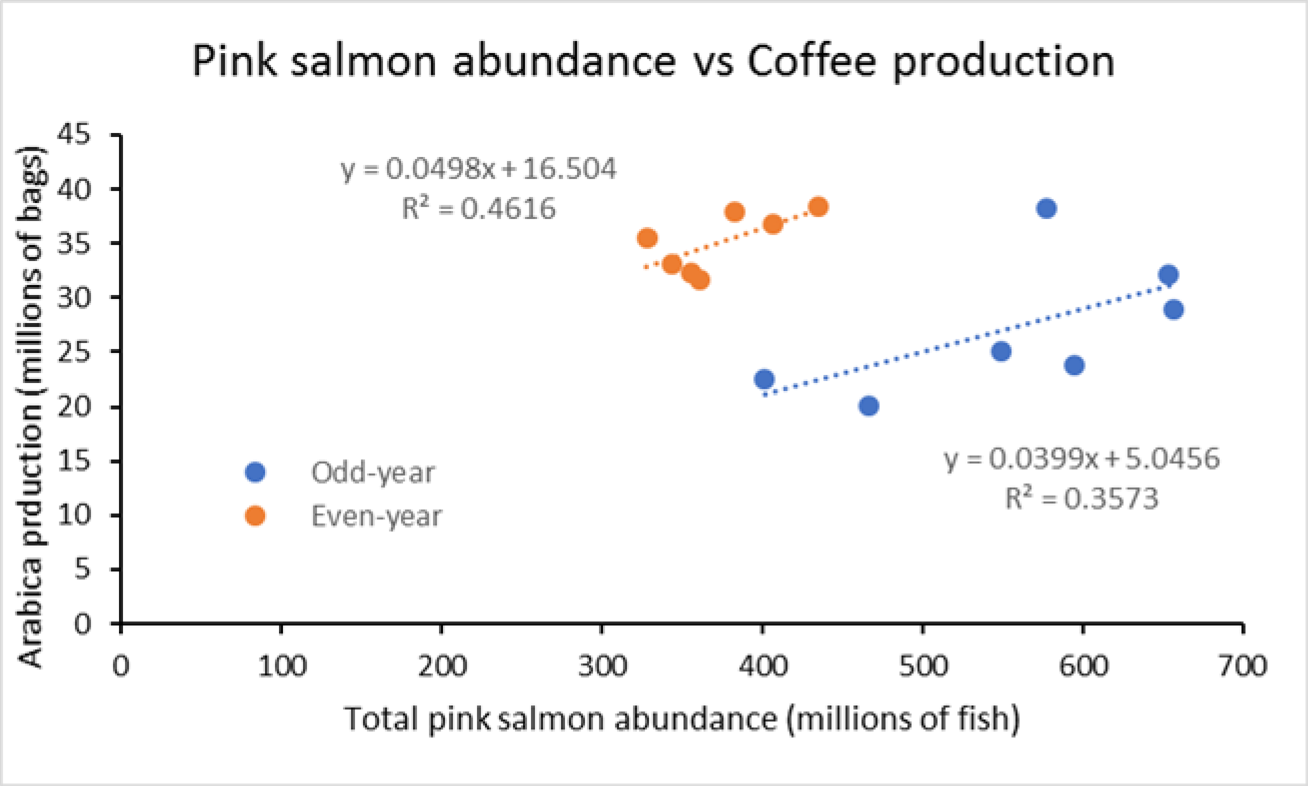
Have a hypothesis – a good example of trying to better understand interactions
Missing key piece of linking data – squid abundance

Correlation ≠ Causation





Need plausible, testable hypothesis



data sources: http://www.casabrasilcoffees.com/brazilian-arabica-and-conilon-robusta-production-by-state/
Ruggerone and Irvine (2018)

4. Phenotypic and life history changes

Is high salmon abundance causing phenotypic and life history changes in other species of salmon?

Studies that document changes in size at age, age at maturity and body size

Lewis et al. (2015) Changes in Size and Age of Chinook Salmon Oncorhynchus tshawytscha Returning to Alaska

Jeffrey et al. (2017) Changes in body size of Canadian Pacific salmon over six decades

Shaul & Geiger (2016) Effects of climate and competition for offshore prey on growth, survival, and reproduction potential of coho salmon in southeast Alaska

see also Ohlberger et al. (2018) Demographic changes in Chinook salmon across the Northeast Pacific Ocean

4. Phenotypic and life history changes

Purpose of some studies was to document changes

- not to test the cause
- postulate potential causes

Studies such as Jeffrey et al. examined trends over time and tested for potential correlates

- looked at many variables
- different species responded differently

5. Population resilience

Is hatchery production augmenting or replacing natural production?

OR

Are wild salmon populations resilient to large scale hatchery releases over a prolonged period?

- Not directly related to the statement in the emergency petition
- Study found
  - Hatchery production was to support recovery
  - natural production responded positively to stopping hatchery releases

Jones et al. (2018) Population viability improves following termination of coho salmon hatchery releases

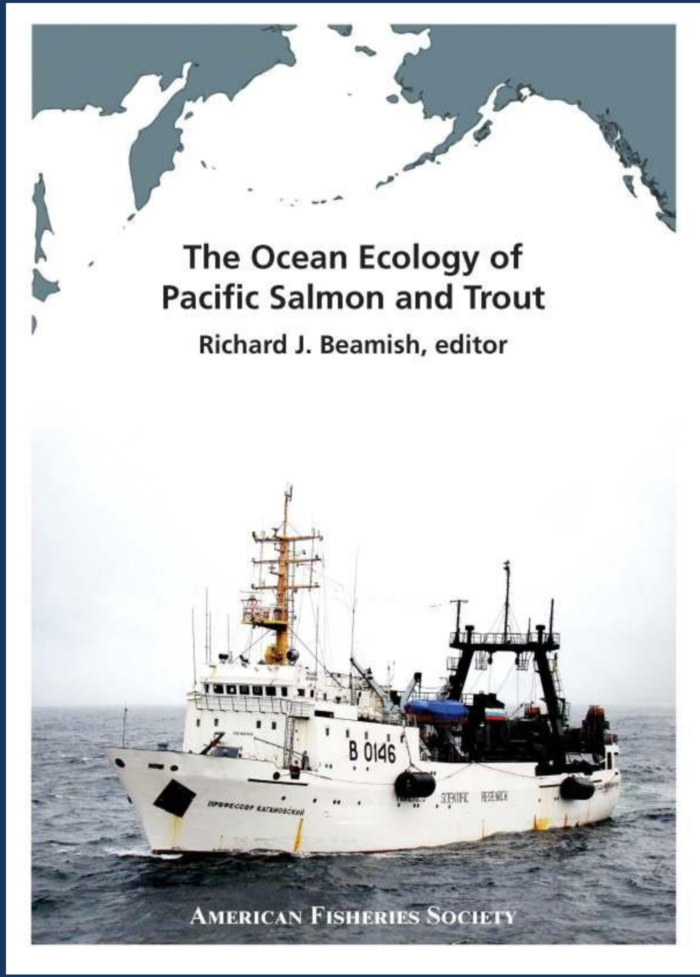
Summary

Measuring ocean carrying capacity and knowing when reached is a complex issue

- Contribution of hatchery salmon also difficult to assess

Much research in this area

- No comprehensive unequivocal assessment
- Requires piecing together bits of data and information
  - Quality, applicability, and utility



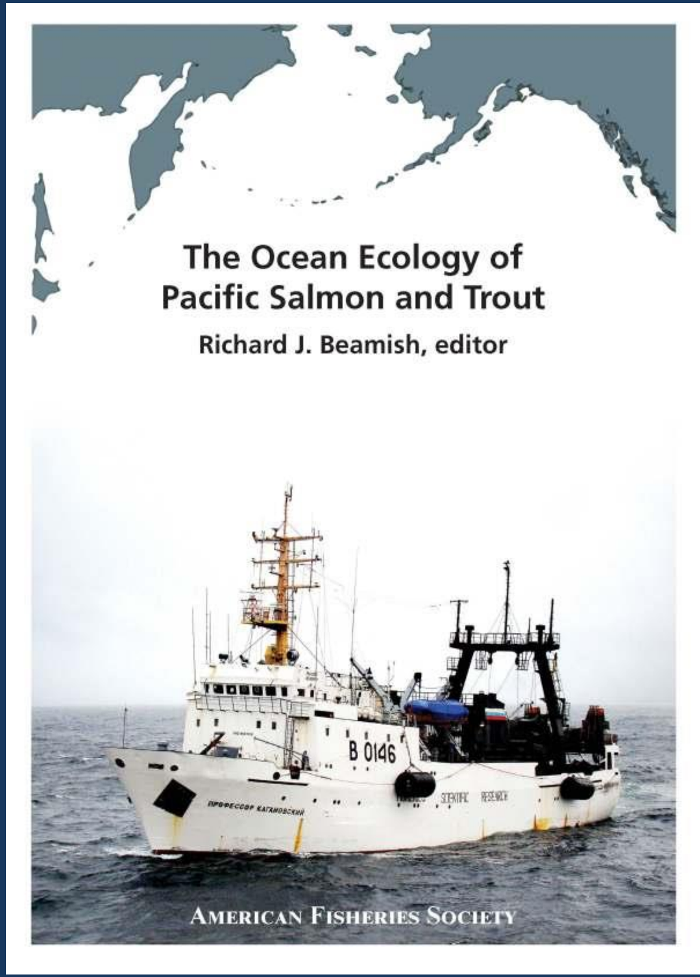
Summary

Next steps

- Rigorously designed studies to answer specific question(s)with testable hypotheses, identify data needs

Not within capacity of ADF&G

- Collaborate with other researchers
- Coordinate and guide research with other agencies and countries (NOAA, NPAFC, IYS)



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Precautionary Approach
SSFP 5 AAC 39.222(c)(3) and (5)

(5)

(A) a precautionary approach, involving the application of prudent foresight that takes into account the uncertainties in salmon fisheries and habitat management, the biological, social, cultural, and economic risks, and the need to take action with incomplete knowledge, should be applied to the regulation and control of harvest and other human-induced sources of salmon mortality; a precautionary approach requires

(3)

(N) conservation and management decisions for salmon fisheries should take into account the best available information on biological, environmental, economic, social, and resource use factors;

(O) research and data collection should be undertaken to improve scientific and technical knowledge of salmon fisheries, including ecosystem interactions, status of salmon populations, and the condition of salmon habitats;

(P) the best available scientific information on the status of salmon populations and the condition of the salmon's habitats should be routinely updated and subject to peer review;

Identified research needs

1. Continue building genetic baselines for pink and chum salmon
2. Estimate hatchery contribution to harvests in LCI and Kodiak
3. Design and implement comprehensive surveys for hatchery strays
4. Collaborate with other efforts (IYS, NPAFC or OCC) on studies:
   - Testing hypothesized links between pink salmon and other species
   - Examining nearshore ecology of pink salmon juveniles
5. Extend AHRP-related studies
6. Design program to evaluate hatchery release strategies to improve homing and reduce straying