Integrating genetics into artificial propagation planning for salmonid re-establishment

Joshua Israel
University of California, Davis
Department of Animal Science
Center for Watershed Sciences
jaisrael@ucdavis.edu

Presentation topics

Artificial Propagation Research

Uncertainty and population re-establishment

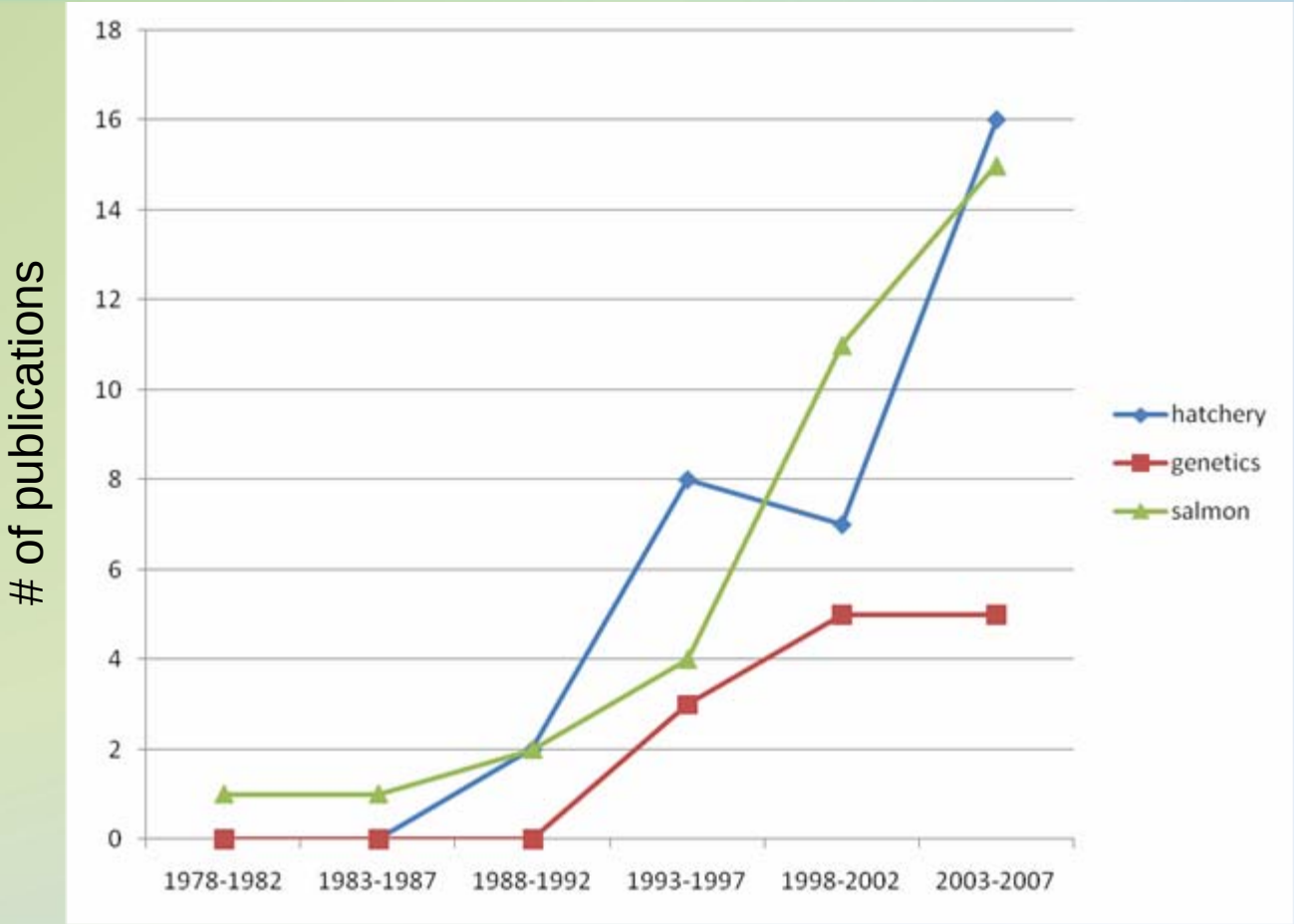
Integrating genetic methods into AP
for reintroduction & recovery

Genetic concerns in population
re-establishment

Potential applications
in California slamonid recovery

Making the most of artificial propagation
for reintroduction & recovery

Literature on “artificial propagation and _____



Studies with genetic focus increasing with technological advances

Genetic research and population re-establishment

Tremendous opportunity to observe:

- Colonization of new habitats
- Formation of new populations
- Invasions by nonnatives

Considerable opportunity for testing ecological and genetic theories surrounding evolutionary process:

- Adaptation (restoration engineering-biocoupling)
- Range expansions
- Founder effects
- Metapopulation structure

Uncertainty surrounding population re-establishment

Natural recolonization vs. reintroduction

Suitable source vs. straying populations

Appropriate levels of artificial propagation

Best development stage for releasing fish

Baird Station

Livingston Stone NFH

Iron Gate Hatchery

Natural re-establishment will be difficult

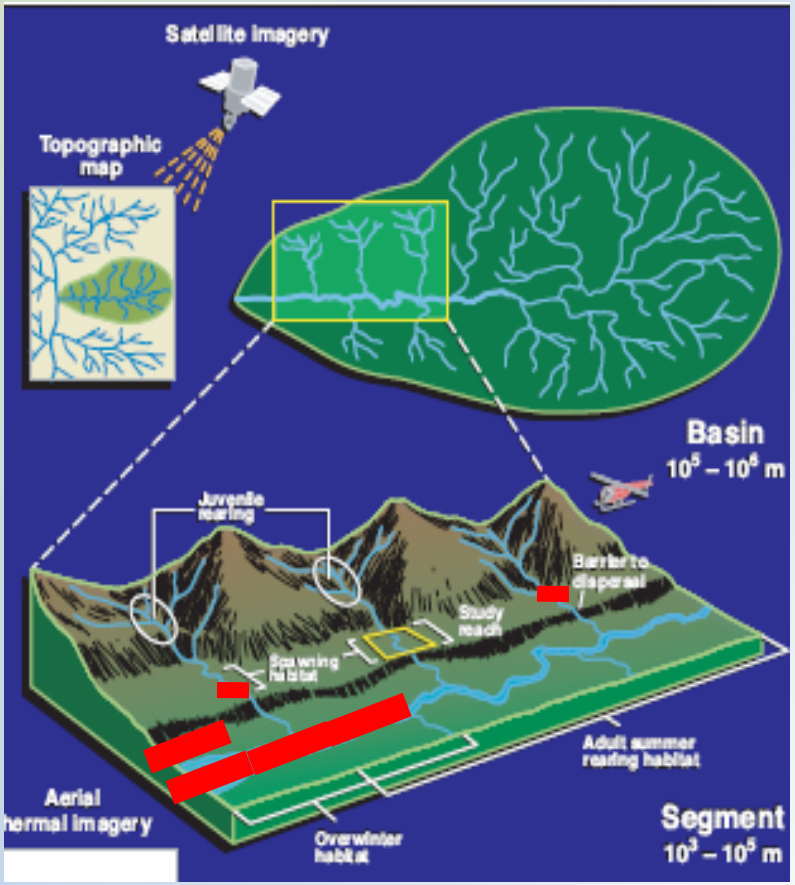
Physical processes interrupted or restricted along riverscape

- reduced habitat complexity
- stabilizing flows
- Migration barriers

Reduction in habitat leads to reduced survival in critical early life history stages

- Movements impeded
- Lack of refuges from harsh conditions

Decreases phenotypic plasticity



Modified from Fausch et al. 2002

Re-establishment with hatchery can also be difficult

Contributes to overall decline of natural spawning population

Reduction in reproductive success

Inbreeding among related individuals

Outbreeding among different ESUs

Domestication Selection

Potential threat to viability of natural populations

A balance between artificial propagation and natural colonization for population recovery

	Artificial propagation	**Natural Recolonization**
Mechanism	Human-assisted supported by biocoupling	Contemporary adaptation
Limitations	Requires experimental planning and monitoring	Founder Effect
Risks	Domestication Selection, loss of fitness,	Inbreeding Depression, Hybridization
Unnatural life-stage mortality	Likely	No
Opportunities for genetic evaluation	Yes	Yes
Opportunity for recovery	Yes if experimental design and adaptive triggers are recovery-directed	Stochastic events and population dynamics may reduce chance of success

Uncertainty surrounding population re-establishment

Natural recolonization vs. reintroduction

Suitable source vs. straying populations

Appropriate levels of artificial propagation

Best development stage for releasing fish

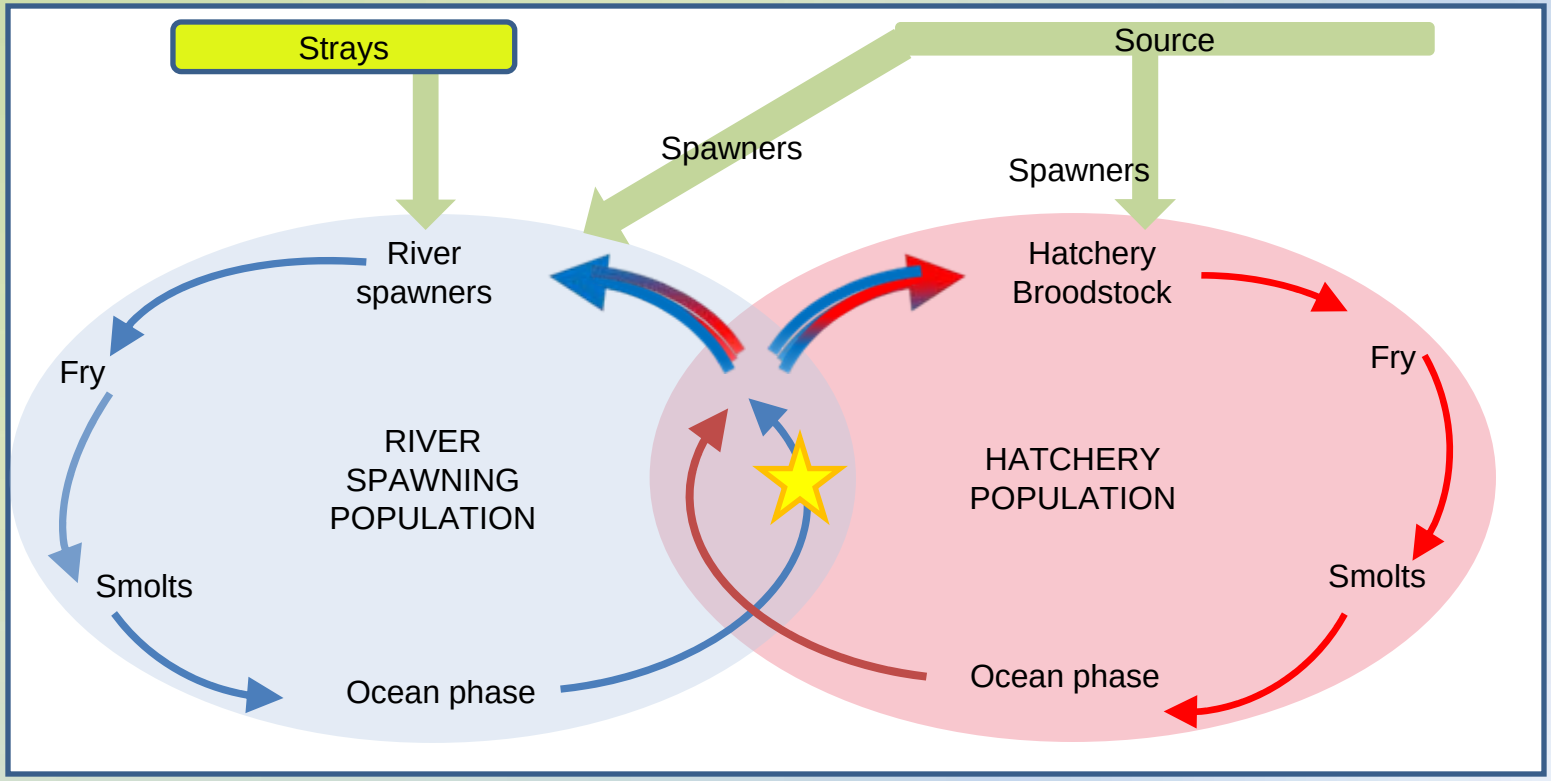
Baird Station

Livingston Stone NFH

Iron Gate Hatchery

Use AP to reinforce contemporary adaptation to designed environments

Biocoupling: Strategic restoration and recovery projects to favor biological and population processes



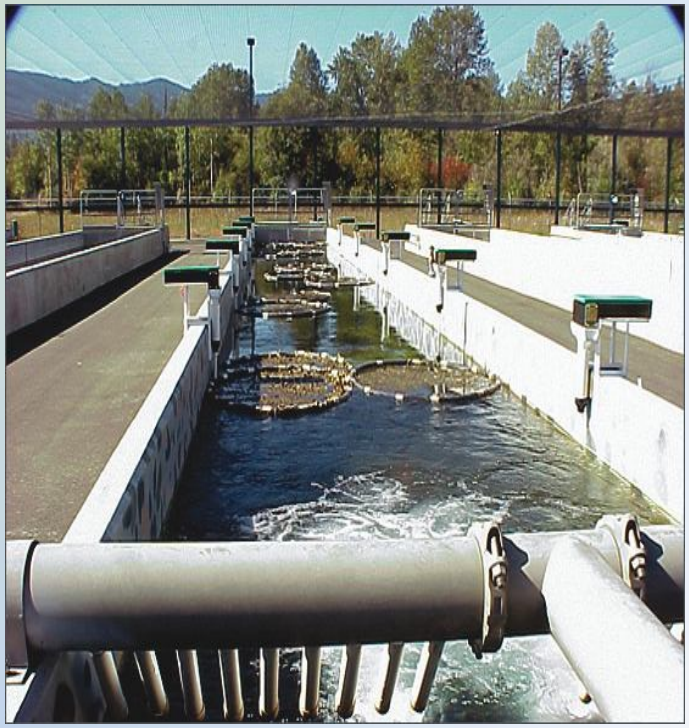
<u>AP can increase survival of fish representing desired outcome</u>

Guidance for AP management

Flagg et al. (1999)

•NMFS multidisciplinary scientists

•Conceptual framework for conservation hatcheries



Hatchery Science Review Group (2004)-

•Panel of independent, state, tribal, and federal scientists

•3 years to assemble and apply best available science

•Assessed more than 200+ hatcheries.

CDFG Recommendations for Conservation Hatcheries (2006)

•Developed as part of state Coho Recovery plan

Hatchery Genetic Management Plans

Necessary for AP activities involving ESA-listed species

Also used to evaluate AP impacts to ESA-listed species

100+ questions

Performance Indicators	Program Effects on ESA species
Management Objectives	Water Source
Facilities	Broodstock origin and identity
Broodstock collection	Mating
Incubation and rearing	Release
Research	Citations

Risk aversion measures applied to minimize likelihood for adverse genetic & ecological effects to listed fish

Molecular tools for AP

Minimizing risks, Maximizing diversity

1. Broodstock management
2. Identification of origin for individuals
3. Quantification of changes in fitness
4. Monitoring population demography

Molecular markers as tags

SNP and EST-linked microsatellite markers

- Establish familial relationships among returning spawners
- Identify pedigree groups for tracking ecological or life history characteristics
- Maintain genetic diversity and N_e in the hatchery
- Monitor contribution of the hatchery to river spawning population

Molecular markers as tags

Parentage-based tagging (Anderson & Garza 2006)

Collecting genetic information for adult spawners effectively identifies all offspring in cohort.

Provides method for evaluating survival of founding families in areas where returning fish can be collected at weirs, hatcheries, and monitoring sites

Genetic concerns for re-establishment

1. *Alteration of genetic diversity*
2. *Decrease in fitness*
3. *Reduction in effective population size*

<u>What groups do these issues matter for</u>

Source population

Hatchery population

Naturalized population

Straying individuals

Alteration of genetic diversity

Source- Pre-action characterization of baseline

Hatchery- aver. 10-20% natural-origin broodstock annually (HSRG 2004)

Naturalized-Max. risk limit of 30% hatchery origin naturally-spawning fish

Strays- characterization of closely related popn's

Decrease in fitness

Source- Pre-characterization of ‘wild’ reproductive biology.

Hatchery- Ensure every spawner has an equal opportunity to produce, modified hatchery env’t

Strays- containment plan, risk metrics and criteria, placement of hatcheries

Naturalized -

(Ford 2002)

$$\frac{pNOB}{pHOS+pNOB} > 0.7$$

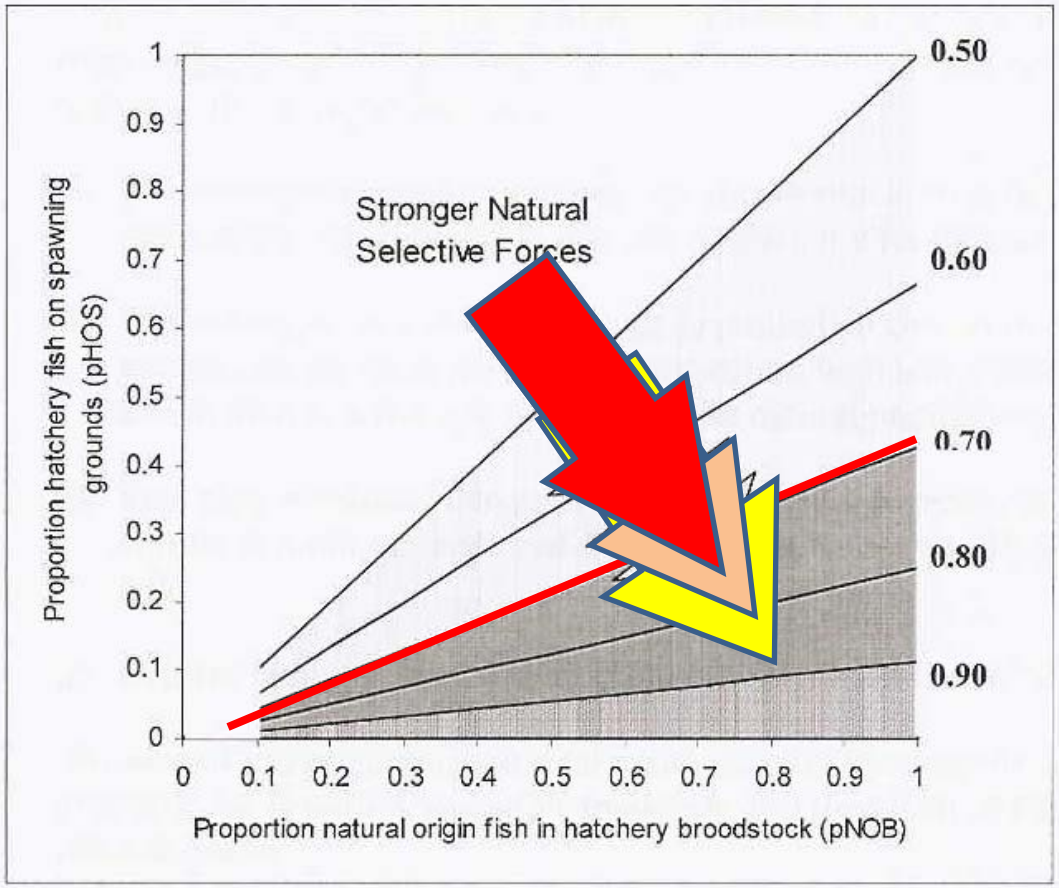


Figure 1. Proportionate effects of natural selective forces in integrated hatchery programs at equilibrium; values to the right indicate the ratio pNOB/(pHOS+pNOB); pNOB must be >0.1 to account for genetic drift.

Reduction in effective population size

Source- Long term brood collection, viability of source pop'n

Hatchery- high juvenile survival rate can swamp population, culling full-sib eggs

Naturalized- Natural-origin fish > total number of broodstock fish, selective fishery

Strays- Risks from non-target stocks quite high compared to supplemental hatchery, difficult to control

Potential opportunities in California

Fall/Spring Chinook/steelhead (Klamat

Winter Run Chinook (Battle Creek)

Green sturgeon
(middle Sacramento)

Spring Run Chinook (Yuba River)

<u>Native Delta Fishes</u>

Delta smelt
Sacramento perch
Longfin smelt

Fall/Spring Run Chinook
& steelhead (San Joaquin)

Winter run re-establishment in Battle Creek

Extensive efforts to remove migration barriers and provide flows

Genetic management
at segregation weirs
to reduce passage
of straying stocks.

Genetic evaluation of founder effect of recolonizing winter run Chinook

Possible AP if founder effects seems to be limiting

- Repatriation of Livingston Stone juveniles
- Remote Site Incubators of Livingston Stone eggs
- Recovery hatchery with WRC adults returning to Battle Ck.

Spring run re-establishment in Yuba River

Feather River hatchery spring run straying between Daguerre Pt. and Engelbright dams

Evaluate introgression between different ESUs of salmon

Origin of naturally spawning Spring run in Yuba River ?

Weir for segregation and re-establishment

Genetically monitor and possibly restrict proportion of fish that are Feather River hatchery origin spawning in Yuba.

Salmonid re-establishment in San Joaquin River

All salmonids extirpated

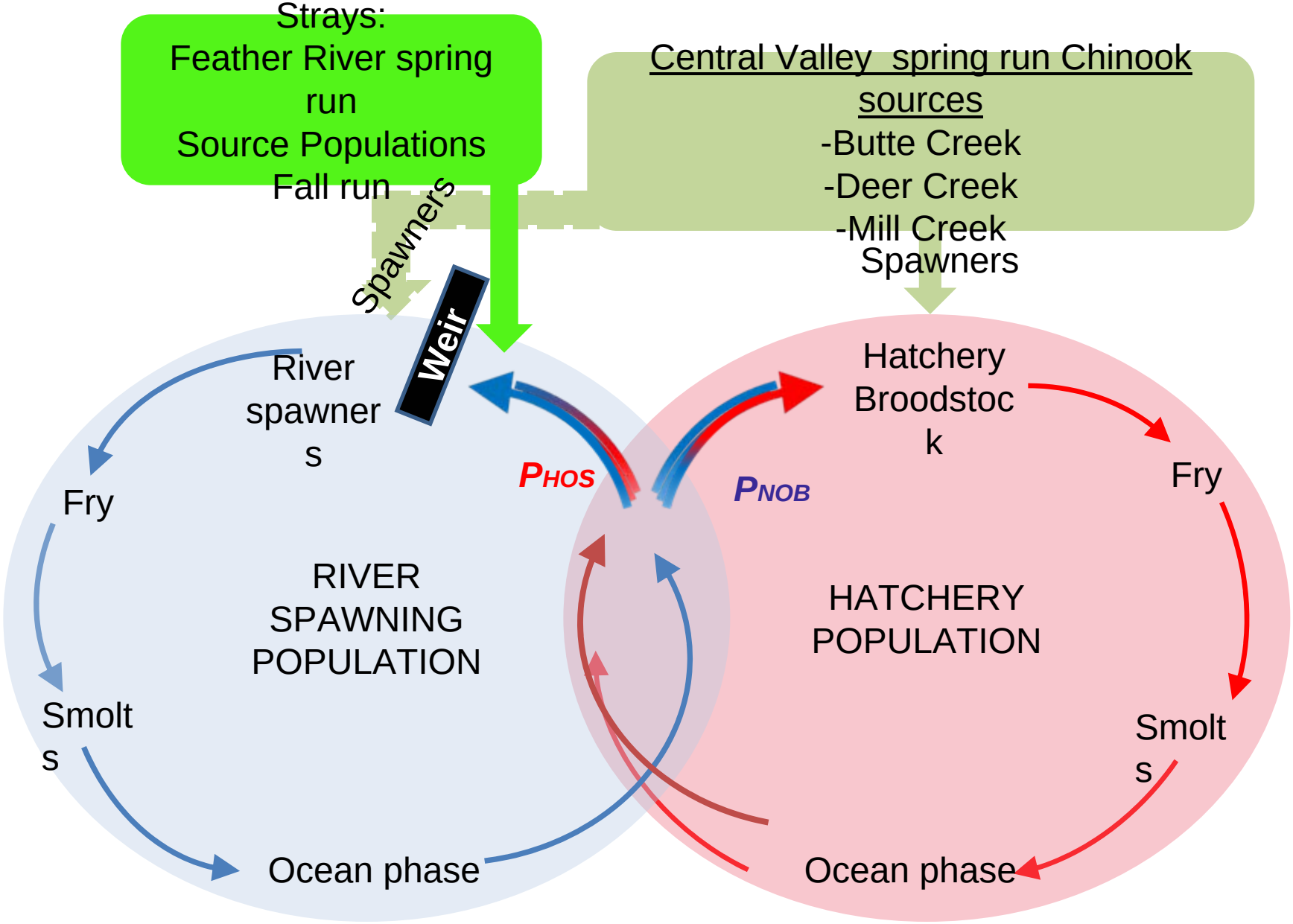
Settlement requires return of Fall and Spring Chinook by 2012

Experimental populations of Chinook

Employ genetic to track multiple introduced stocks to evaluate survival of stocks and adapt strategies

Genetics and intensive monitoring used to reduce hatchery impacts on natural spawning fish

$P_{NOB} > P_{HOS}$ ensures lower genetic risks



Essential molecular studies in re-establishment

- Evaluation of source populations diversity for planning breeding and stocking strategies.
- Pedigree studies of natural population and controlled experiments among hatchery and river spawning populations
- Domestication studies to assess genetic effects of cohort interbreeding between natural and hatchery populations

Goal: Re-establish salmon population utilizing AP

- Reinforce natural processes favoring desired life history types in river and hatchery
- Restrict hatchery supplementation and create barriers (weirs) to keep straying within containment limits.
- Use selective fishery and full marking to reduce hatchery-origin escapement and minimize straying
- Provide resources for monitoring and prepare for adapting through further experimentation and observation.