Conserving salmon diversity in the age of Genomics

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Key questions in conservation

1. What are the units to conserve?
2. What is their status?
Hierarchical structure of *O. mykiss*

*Oncorhynchus mykiss*

*Oncorhynchus mykiss irideus*

Oregon Coast

Mid & N. Coast GCG

Umpqua River Basin

N. Umpqua River

Resident

Anadromous

Summer run

Winter run
The U.S. Endangered Species Act
definition of “species”

Recognized species
Recognized subspecies
Distinct population segment (verts only)
NMFS species def. for salmon

A DPS must be an Evolutionarily Significant Unit

Two ESU criteria

1. Substantial reproductive isolation (separate)
2. Importance to evolutionary legacy of the species as a whole (different; unique)

Extinction is permanent because it represents loss of the genetic blueprint for a certain type of organism
Isolation
[molecular genetics]

Adaptation
[Proxies, esp. ecology, life history]
Isolation
[molecular genetics]

Adaptation
[Proxies, esp. ecology, life history]

Increasing support for ESUs
Moritz 1994
Waples 1991
Dizon et al. 1992
Crandall et al. 2000
Diversity in adult migration timing

Stream-maturing (aka stream-type, premature migrating; spring Chinook & summer steelhead)

Enter fresh water months before spawning
Spawn in upper tributaries

Ocean-maturing (aka ocean-type, mature migrating; fall Chinook & winter steelhead)

Enter fresh water shortly before spawning
Spawn in mainstem or lower tributaries
Classical Quantitative Genetics paradigm

Most traits are controlled by many genes of small effect

Example: many thousands of genes are associated with height in humans

Parallel/convergent evolution involves solving the same basic problem with a different mix of genes
Hierarchical structure of *O. mykiss*

- *Oncorhynchus mykiss*
- *Oncorhynchus mykiss irideus*
  - Oregon Coast ESU
    - Mid & N. Coast GCG
      - Umpqua River Basin
        - N. Umpqua River
          - Resident
          - Anadromous
          - local population or stock
            - Summer run
            - Winter run
Isolation [molecular genetics]

Adaptation

Genomics?
The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation

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>200K SNPs steelhead; > 50K SNPs Chinook

- 99.99% of genes: same story
- One small part of 1 chromosome: very strong association of specific alleles vs run timing
Potential ramifications

Conventional paradigm: If an early run-time population is lost, it might be regenerated in ~ a century from existing late-run populations.

Major-effect gene paradigm: What if the only way to get an early run-time population is by having the early run-time gene?
Key questions

What is the distribution of genetic variants in space & time?
Association ≠ cause and effect
Dominance? What is phenotype of heterozygotes?
Interaction of genes and environment?
Did the early-migrating gene evolve only once?
How common are large-effect genes like this?
What procedures are already in place to conserve life-history diversity?
US Endangered Species Act (ESA)

Endangered species:

In danger of extinction …

Threatened species:

Likely to become an endangered species in the foreseeable future …
Two possible conservation scenarios

Klamath R. spring chinook are an ESU
- What about other 99.99% of the genes?
- What if other large-effect genes are found?

Klamath R. spring chinook are conserved within the larger Klamath R. ESU
- Might require listing entire ESU
- Who will conserve the genes necessary to produce the spring-run phenotype?
VIABLE SALMONID POPULATIONS

- Identify population structure within ESUs
- Assess population viability
  - Abundance
  - Productivity
  - Spatial structure
  - Diversity (genetic and life history)
- Assess ESU viability

McElhany et al. 2000 *Tech Memo*
Hierarchical Viability Criteria

ESU Status
SS, Div

Strata status

Pop Status

Pop Attributes
Abun, Prod, SS, Div
But ...

If a) the spring-run phenotype is lost locally
and b) the ability to produce spring Chinook depends on immigration

Then it might not be sufficient to conduct risk assessments independently for each ESU