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)

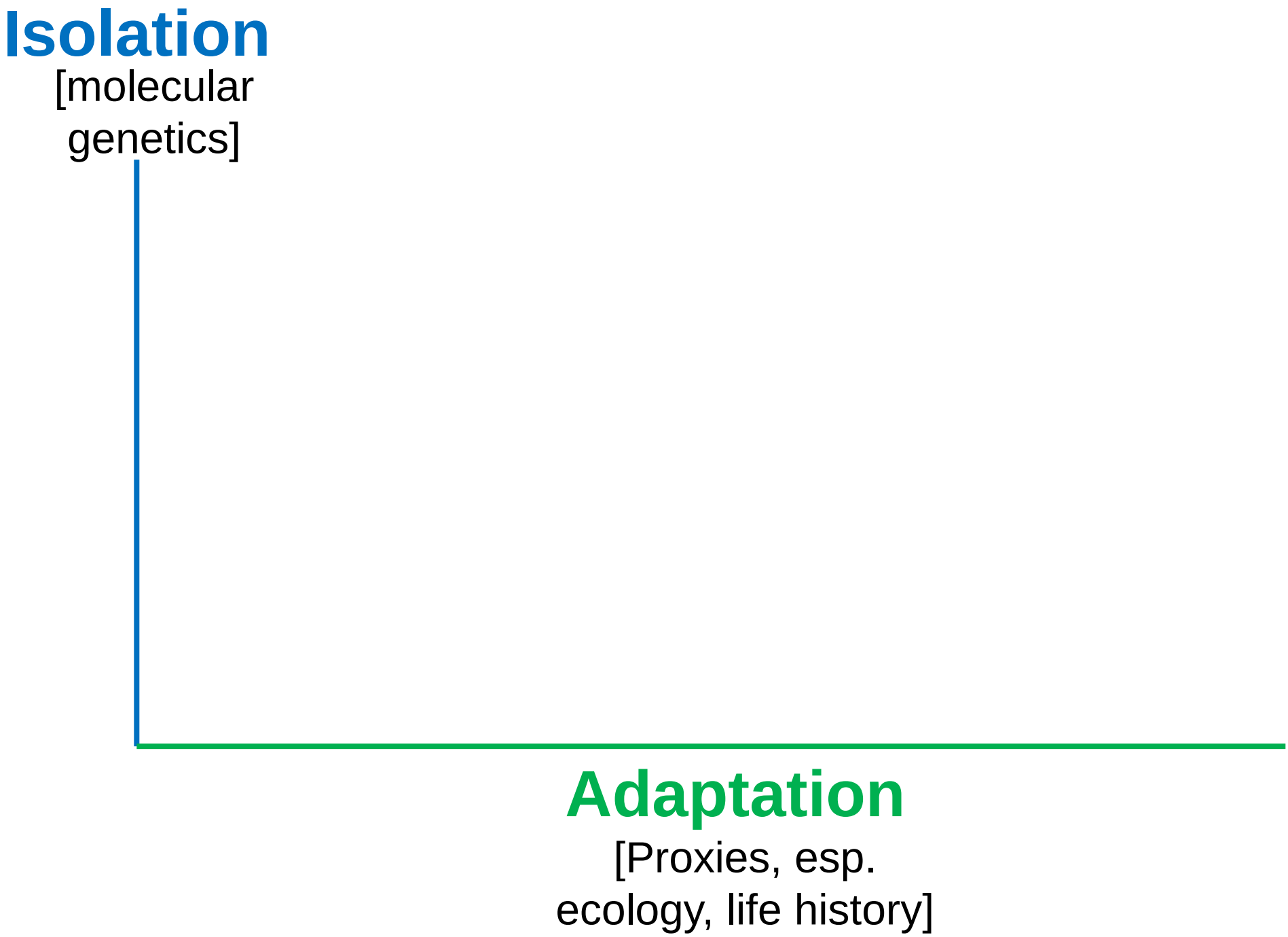
NMFS species def. for salmon

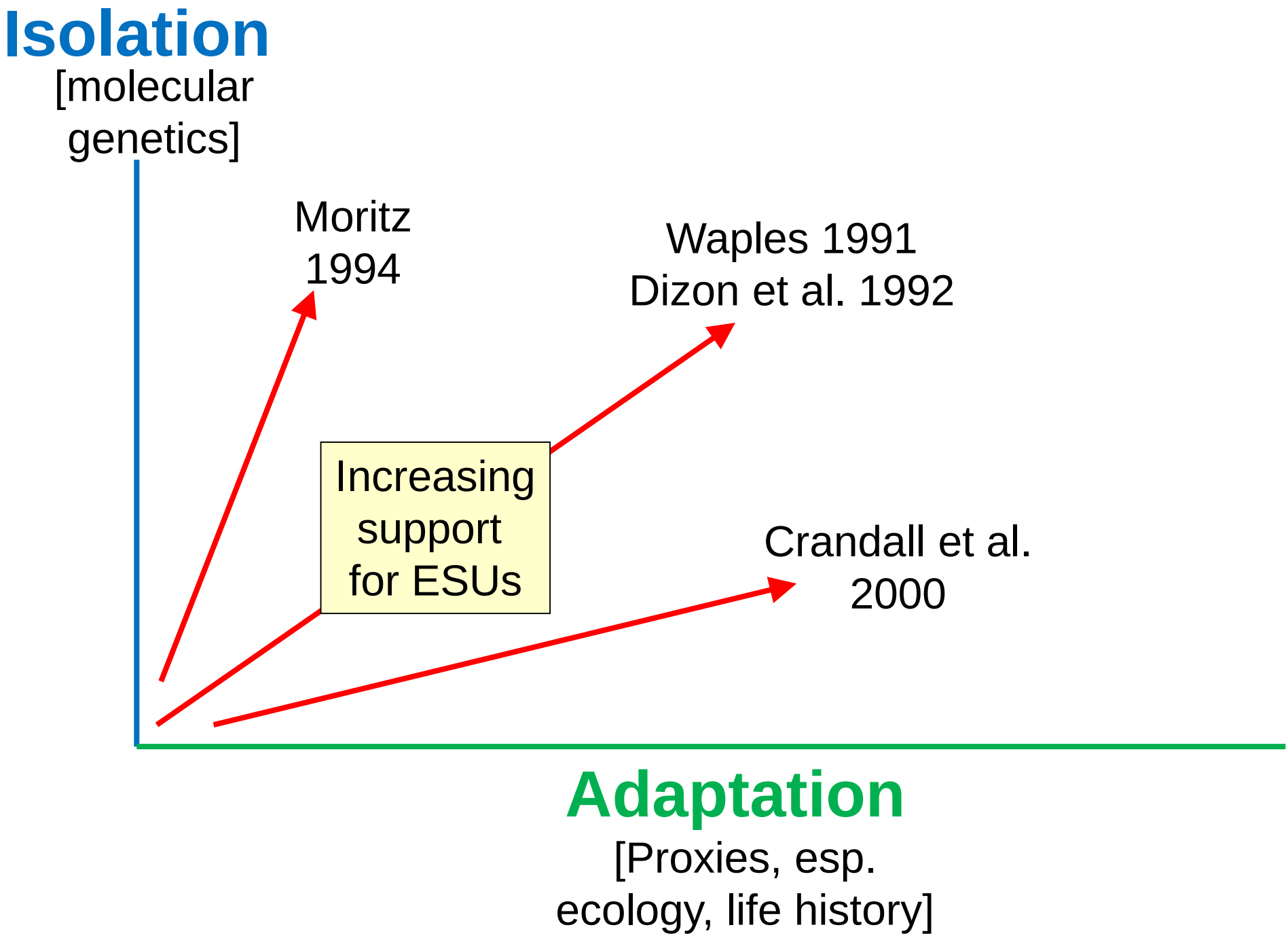
A DPS must be an Evolutionarily Significant Unit

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]
Moritz 1994
Waples 1991
Dizon et al. 1992
Increasing support for ESUs
Crandall et al. 2000
Adaptation
[Proxies, esp. ecology, life history]

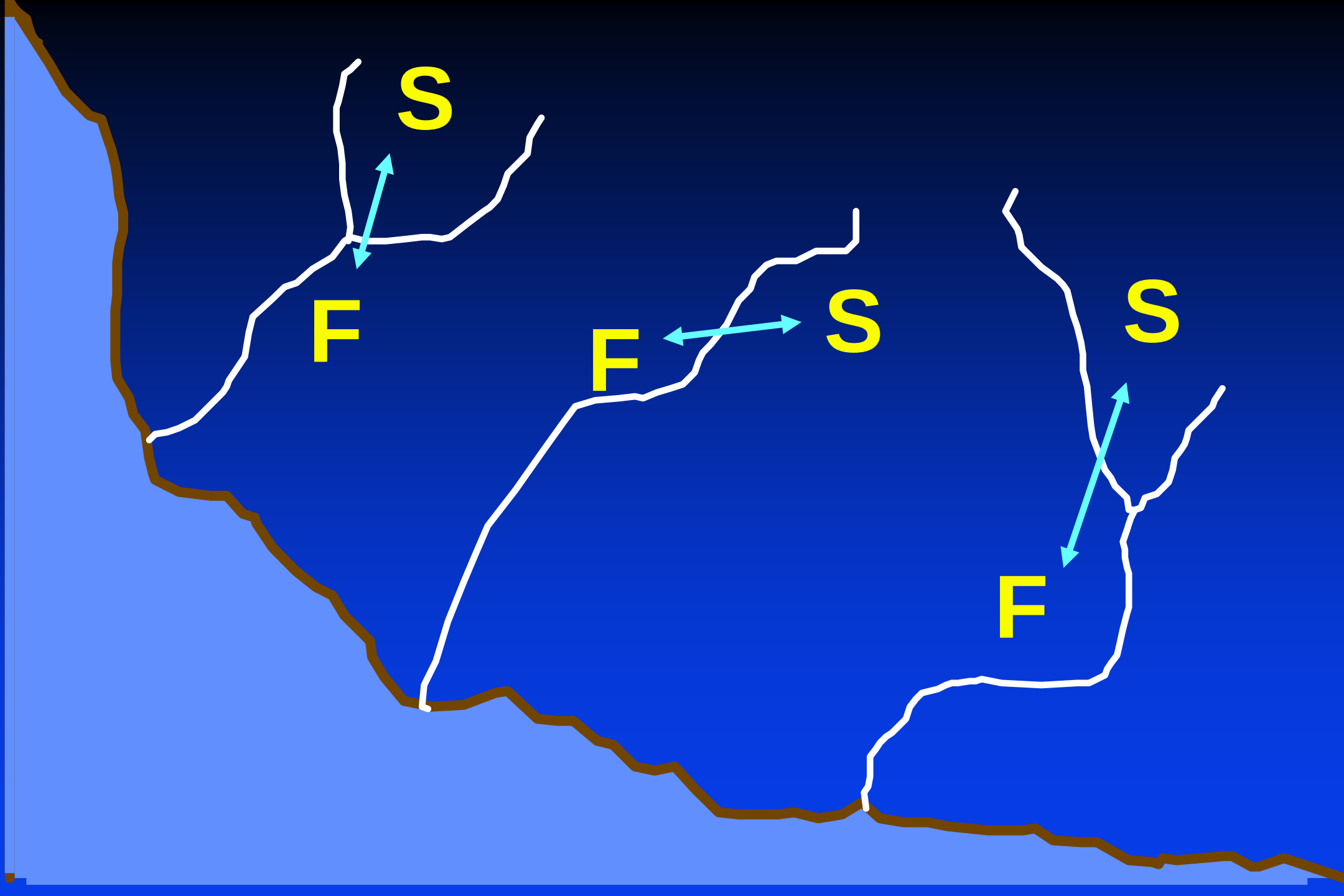
Diversity in adult migration timing

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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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

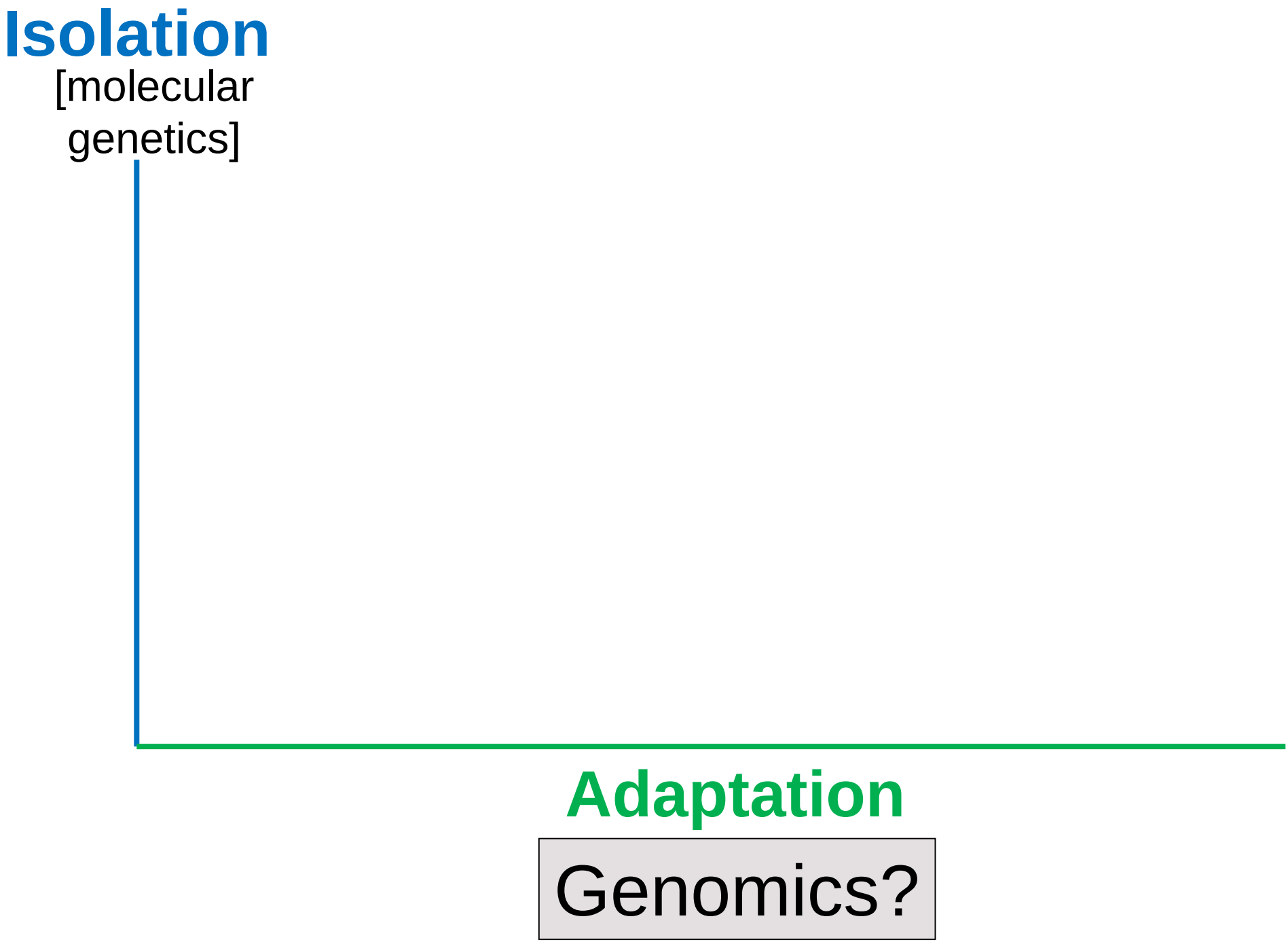
Resident

Anadromous

local population or stock

Summer run

Winter run


Isolation
[molecular genetics]
Adaptation
Genomics?

SCIENCE ADVANCES | RESEARCH ARTICLE

August 2017

EVOLUTIONARY GENETICS

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

Daniel J. Prince,[1,2] Sean M. O'Rourke,[1*] Tasha Q. Thompson,[1*] Omar A. Ali,[1] Hannah S. Lyman,[1] Ismail K. Saglam,[1,3] Thomas J. Hotaling,[4] Adrian P. Spidle,[5] Michael R. Miller[1,2†]

>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?

PERSPECTIVE

Evolutionary Applications September 2018

Genomics and conservation units: The genetic basis of adult migration timing in Pacific salmonids

Waples & Lindley

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

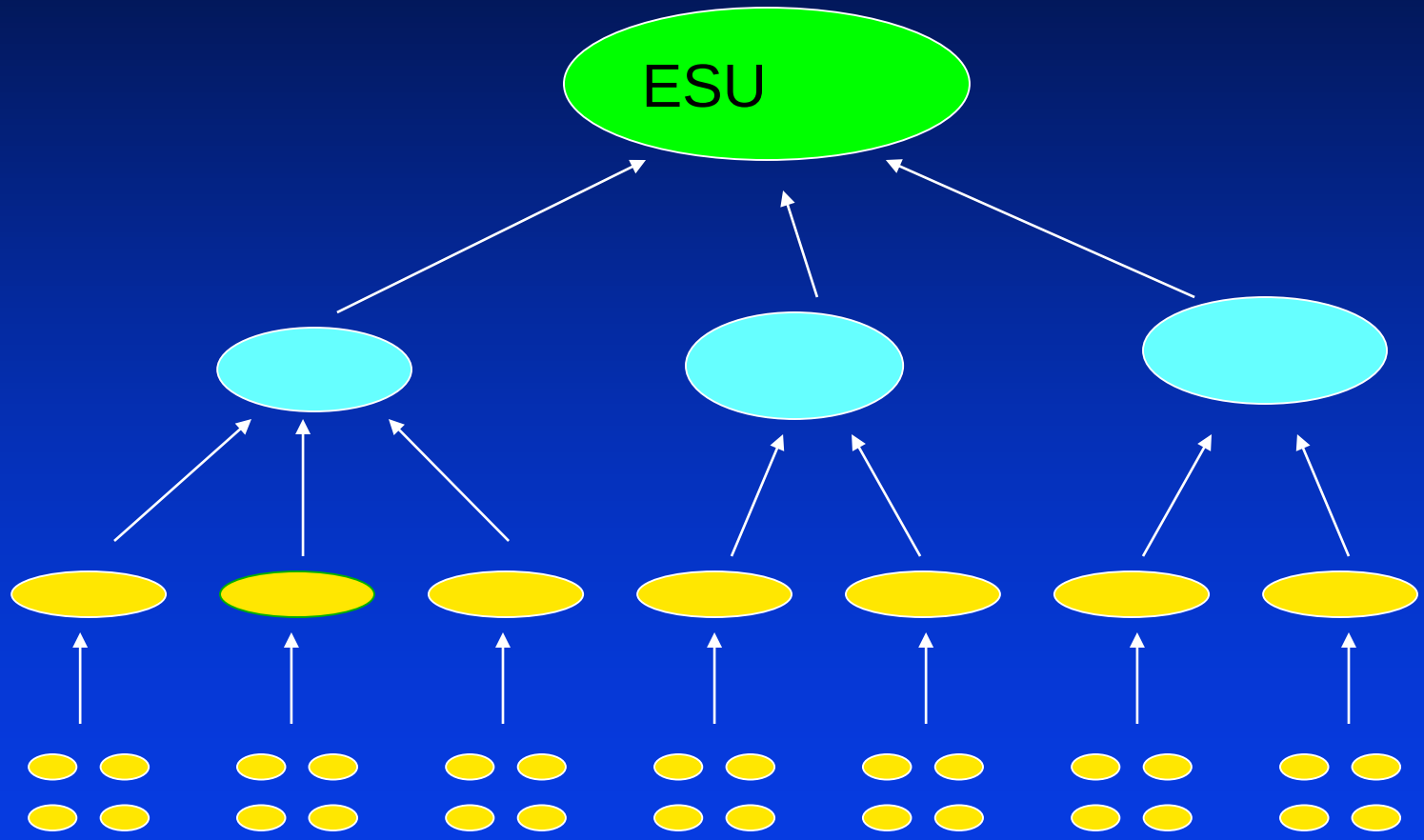
ESU Status

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