NOAA National Marine Fisheries Service

Overview of Salmon Science and Future Needs

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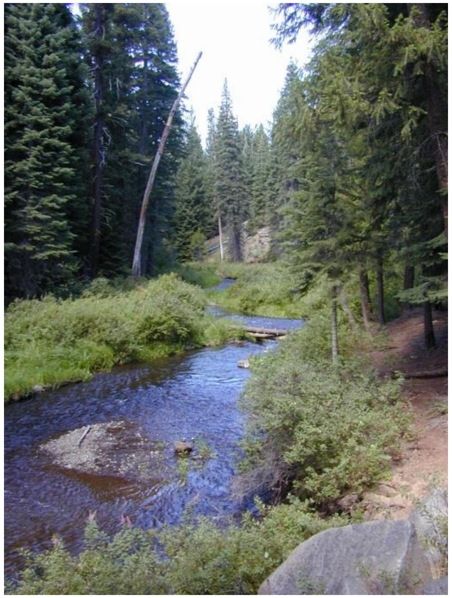
- Describe framework used to assess viability and extinction risk of Pacific salmon and steelhead and that forms the foundation of recovery planning for anadromous salmonids and their habitat
- Importance of processes
- Restoration of dynamic processes will allow fish to track changes in environmental conditions
- The capacity of watersheds to support viable populations has been reduced/constrained
- Future science needs to support management and recovery

Viable Salmonid Populations (VSP) Concepts



VSP Viable Salmonid Populations

Viability of populations are evaluated based on four parameters (VSP parameters):

- **abundance**
- **population growth rate**
- **spatial structure**
- **diversity**

ESU viability

- **catastrophic events**
- **long-term demographic processes**
- **long-term evolutionary potential**

McElhany et al. 2000. Viable salmonid populations and the recovery of Evolutionarily Significant Units. NOAA Technical Memorandum NMFS-NWFSC-42.

http://www.nwr.noaa.gov/1salmon/salmesa/pubs.htm

Critical data needs for viability assessments

Abundance

- **estimate of number of fish in population**
- **trends in abundance of population**
- **adult based estimates most desirable**

Population growth rate (productivity)

- **how well is a population "performing" in the habitats it occupies during the life cycle**
- **over entire life cycle – trends in abundance**
- **life-specific survival is of interest**

Critical data needs for viability assessments

Population growth rate (productivity)

- **Estimates of a population's growth rate that indicate a population is consistently failing to replace itself would suggest the population is not viable**
- **Low survival rates at one part of the life cycle might not immediately manifest in reduced adult abundance, but could indicate reduced resilience to variation in productivity elsewhere in the life-cycle.**

As examples:

Estimates of smolt production provide a measure of both a population's potential to increase in abundance during favorable ocean conditions and the population's ability to weather future periods of "poor" ocean conditions

Critical data needs for viability assessments

Spatial structure

- **distribution of fish within a population's freshwater distributional area**
- **habitat conditions are often quite heterogenous**
- **a highly restricted distribution of fish use or suitable habitat would pose risk**

Diversity

- **genetic**
- **life history (e.g., run timing)**
- **diversity of habitat allows for expressions of diversity of life histories**

VSP Checklist

- ❑ Abundance
- ❑ Productivity
- ❑ Spatial Structure
- ❑ Diversity

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- Individuals (within and between life stages)
- Populations
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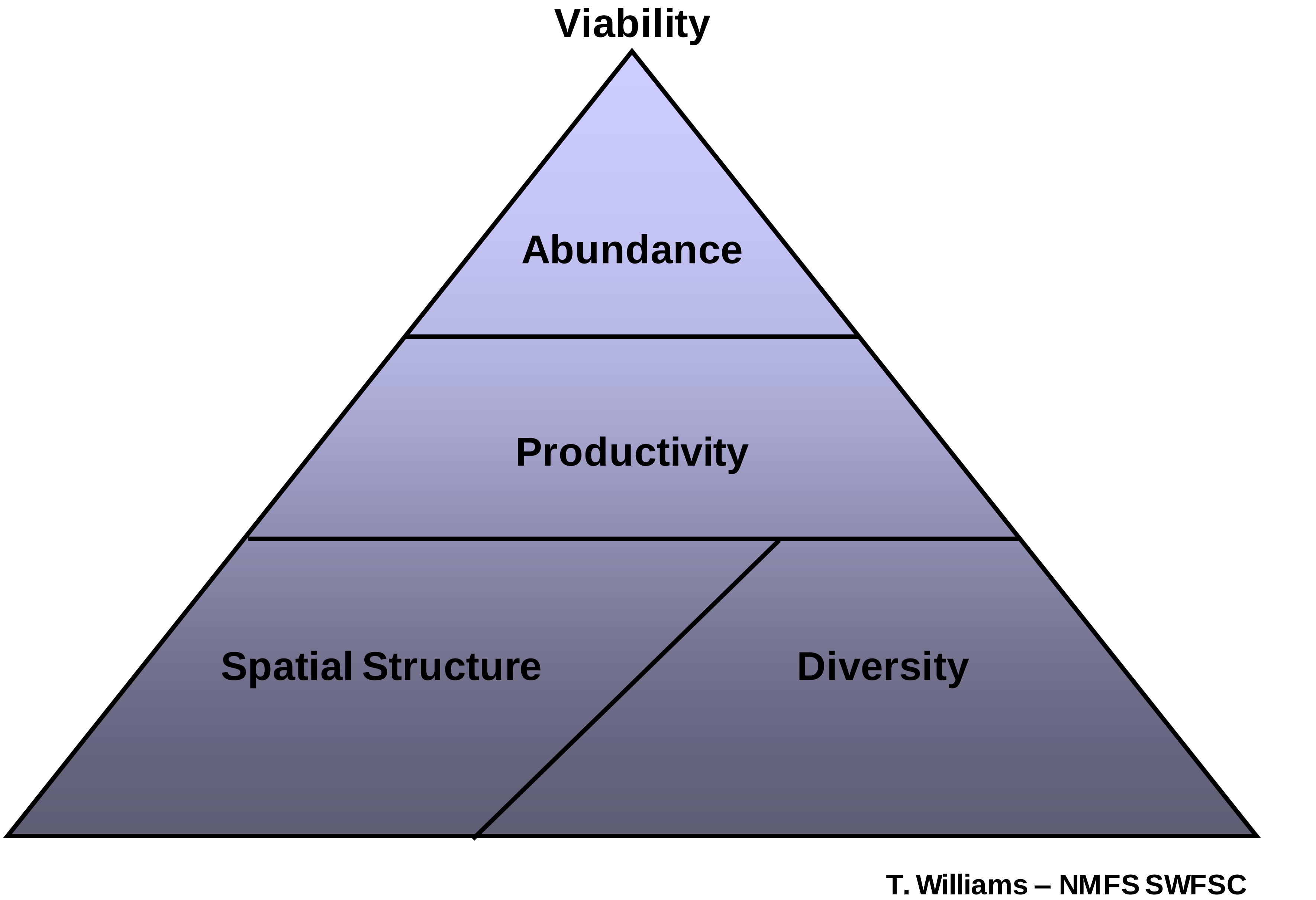
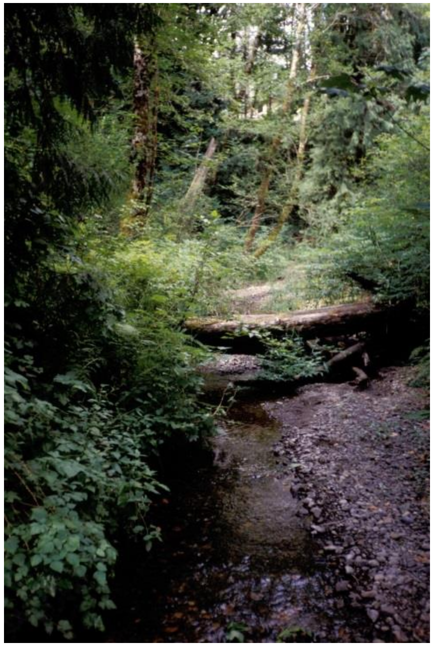
- ESUs
- Species

Photo: M. Capelli

Salmonid Populations and ESUs Persist by Tracking Changes in Environmental Conditions

- **Straying by adults**
- **Relatively high fecundity**
- **Juvenile dispersal**
- **Distribution of run-timing**
- **Distribution of age at ocean entry**
- **Overlapping generations** ***(Chinook and steelhead, coho to some degree)***
- **For steelhead, non-anadromous and anadromous life-history types**


Viability
Abundance
Productivity
Spatial Structure
Diversity
T. Williams – NMFS SWFSC



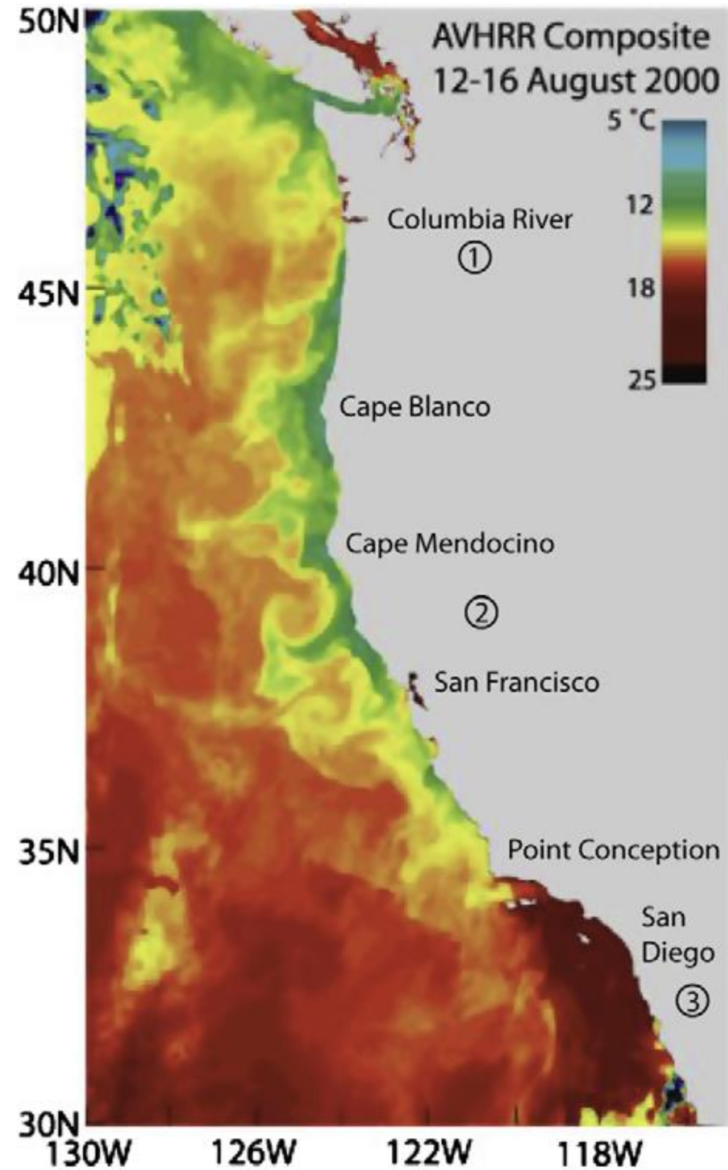
Photos: T. Williams

Natural disturbance events that influence salmonid populations throughout their range include:

- **wildfires**
- **landslides**
- **glaciers**
- **earthquakes**
- **volcanic eruptions**
- **floods**

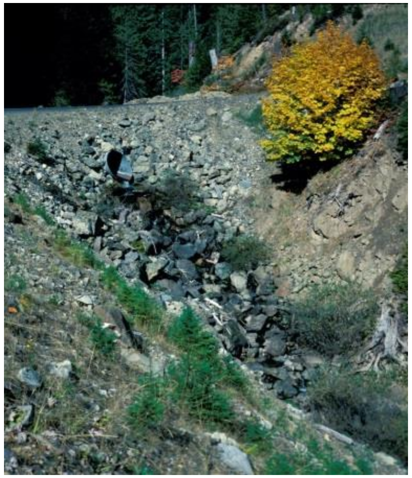
The California Current System is dynamic

This mid-summer surface temperature snapshot shows how complex and diverse "ocean conditions" are at any given time in response to variable weather, winds, ocean currents, etc.



Anthropogenic constraints that can influence the ability of salmonid populations to track changes in environmental conditions include:

- **migration barriers**
- **land management activities (e.g., timber, agriculture)**
- **fire (magnitude, frequency)**
- **Water withdrawl**



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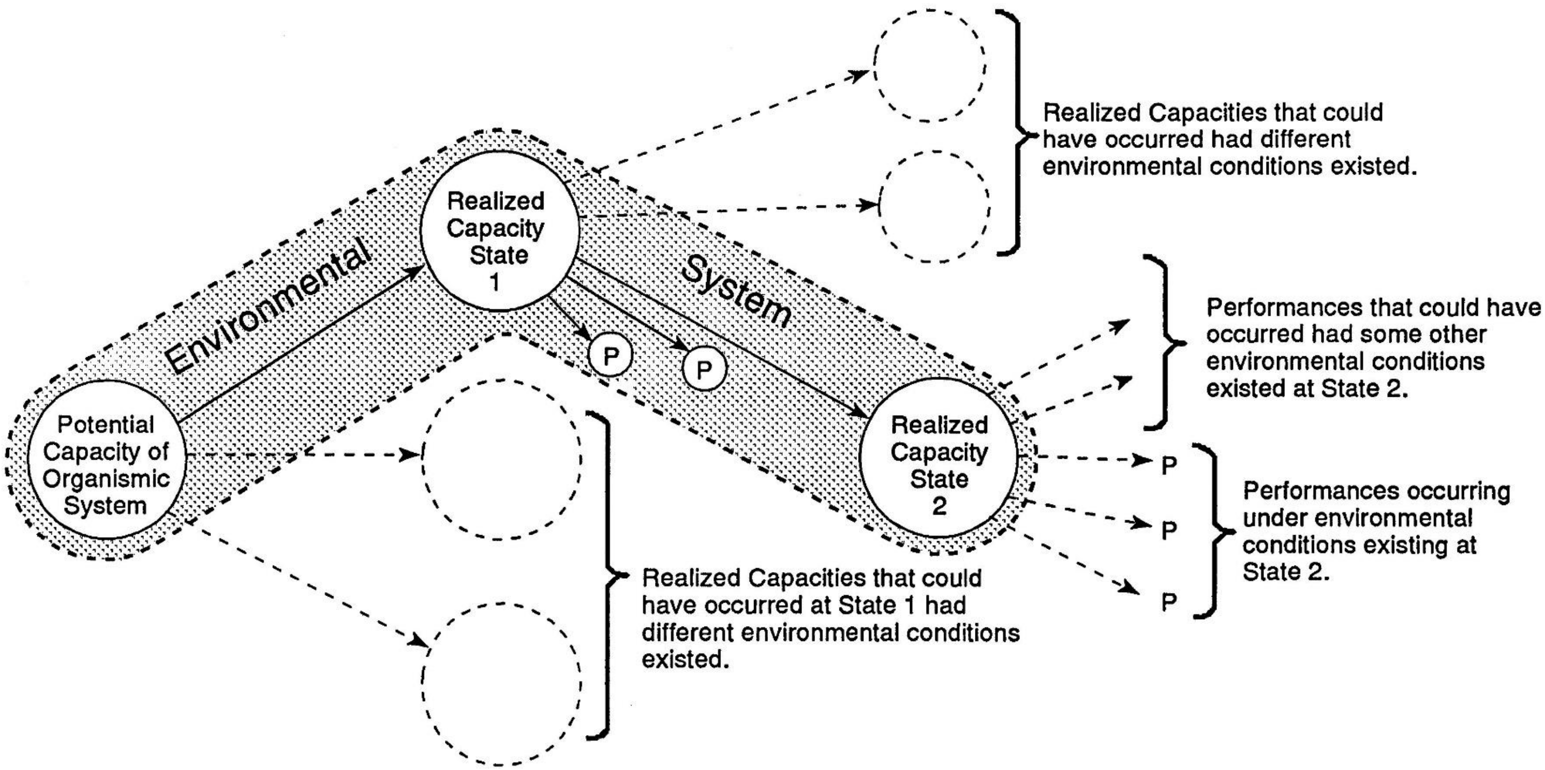
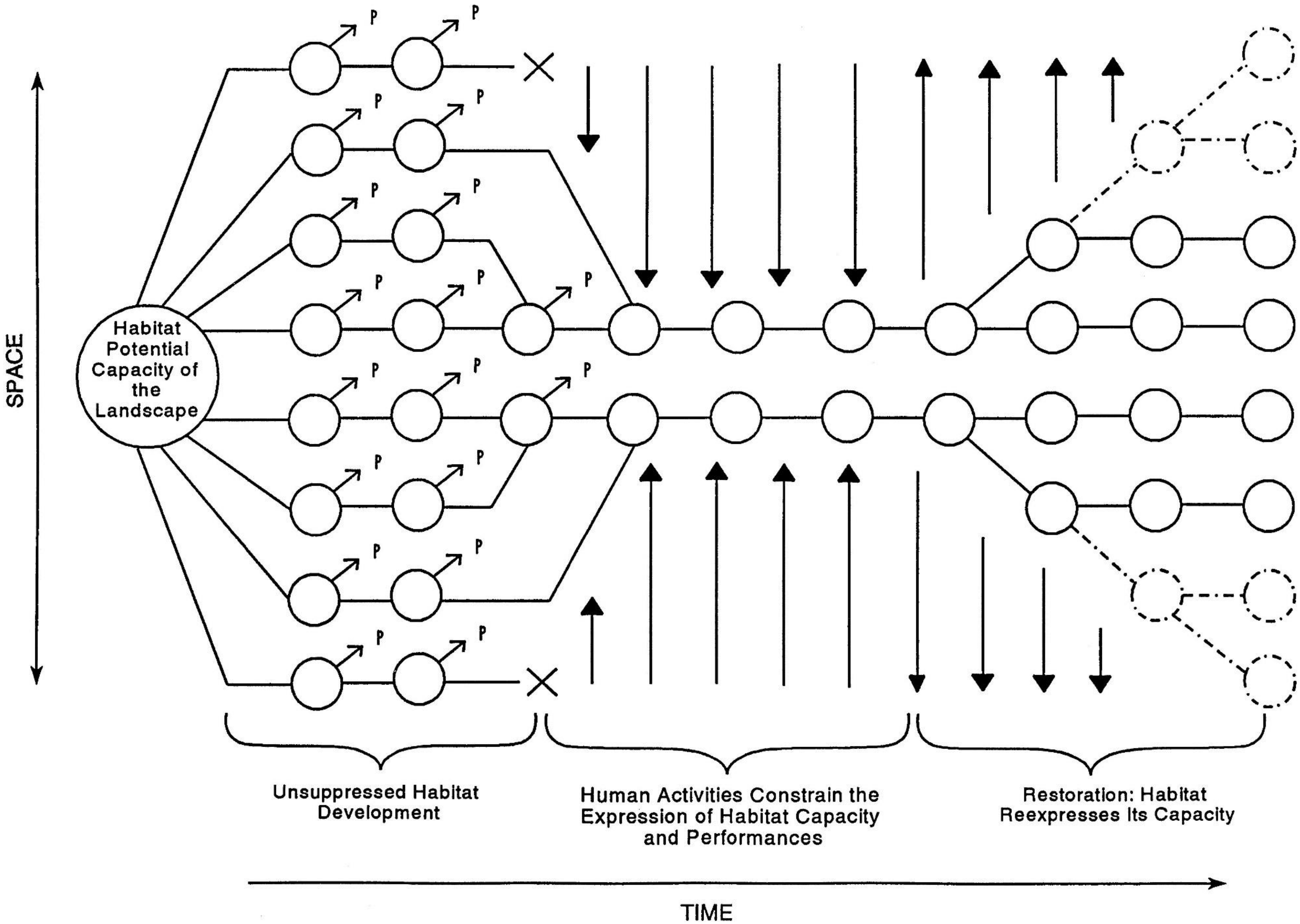


From Ebersole et al. 1997. Envir. Mgt. 21:1-14.



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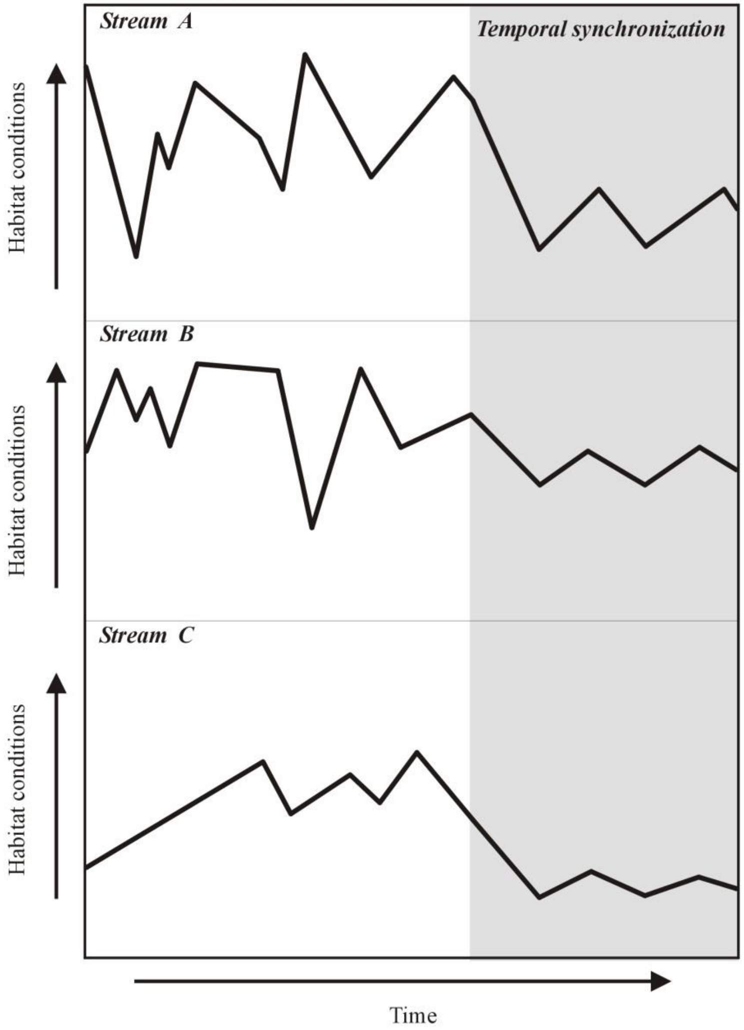
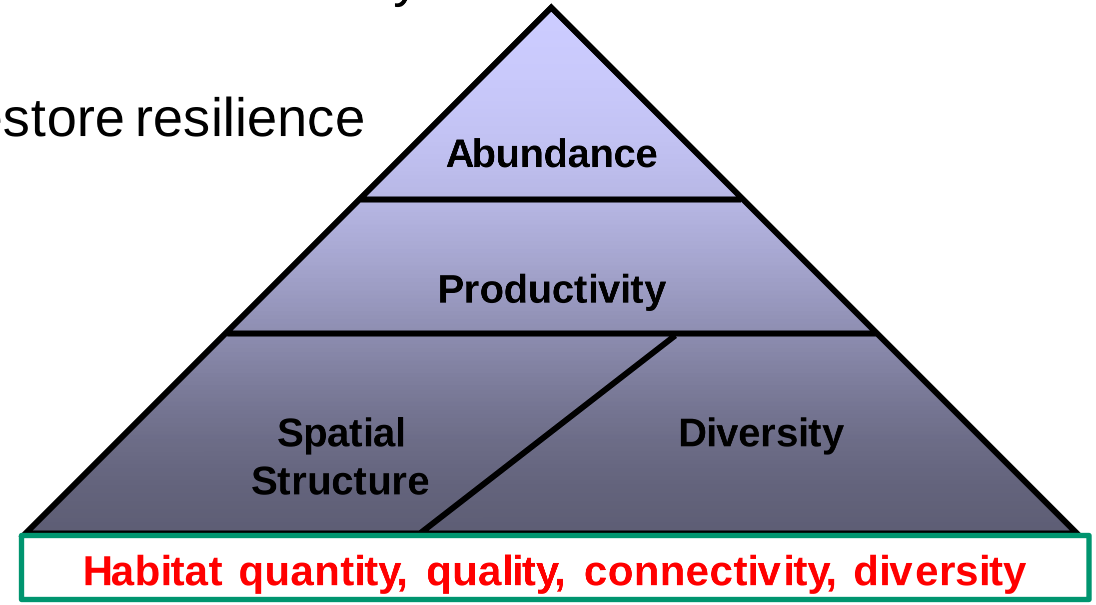


From: Williams and Reeves (2003). NOAA Tech. Memo. NMFS-NWFSC-56

The salmon approach to risk management

Diversity and Spatial Structure!

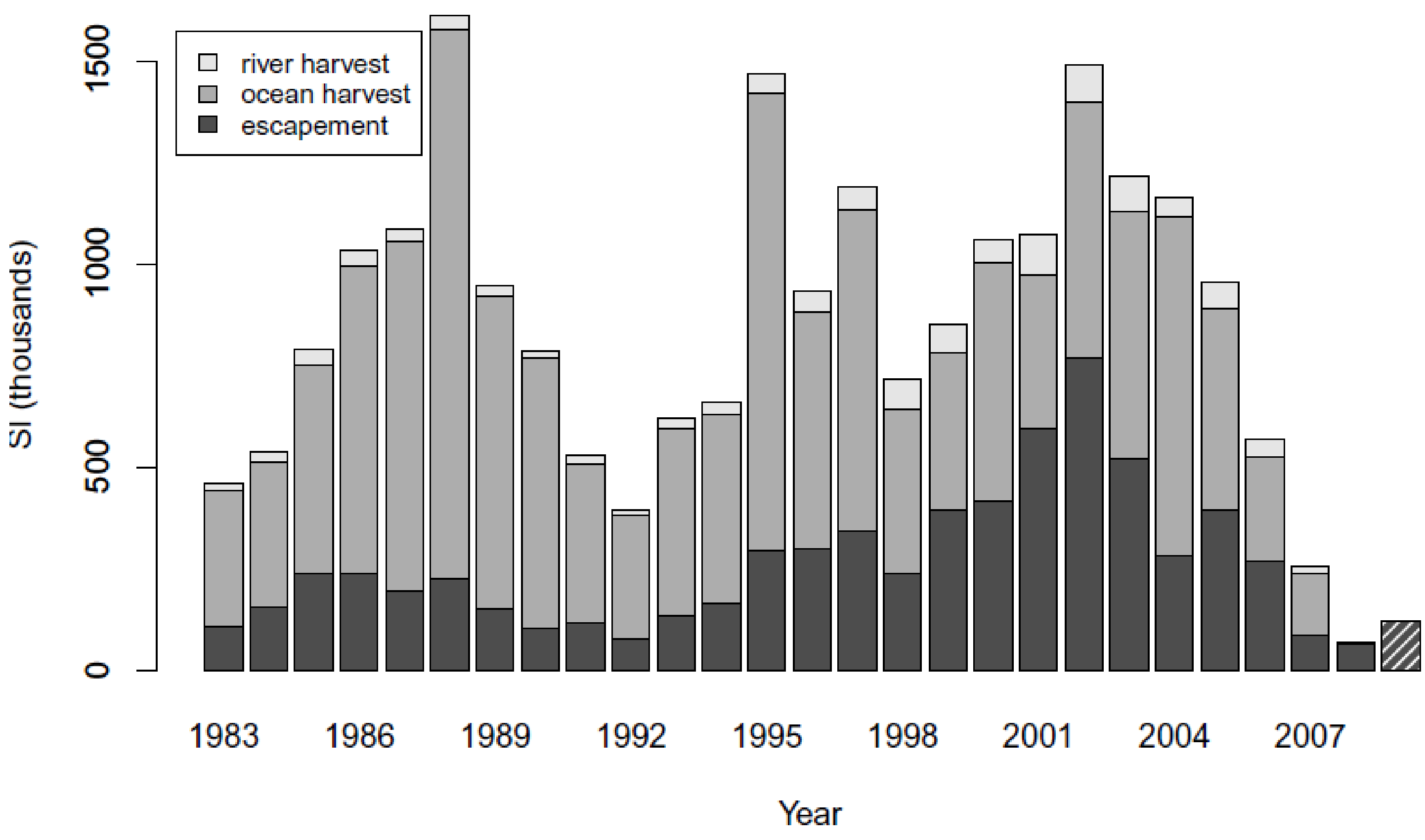
- Freshwater, estuary, and ocean habitat diversity "filters" environmental changes in ways that confront salmon with a variety of habitat conditions at the same time
  - This habitat diversity allows for the expression of diverse phenotypes/life-history types
  - Locally-adapted populations evolve diverse genotypes that are linked with their diverse life-history types
- Actions that simplify habitat options and diversity in life histories and genotypes reduce resilience
- Actions that restore diversity restore resilience

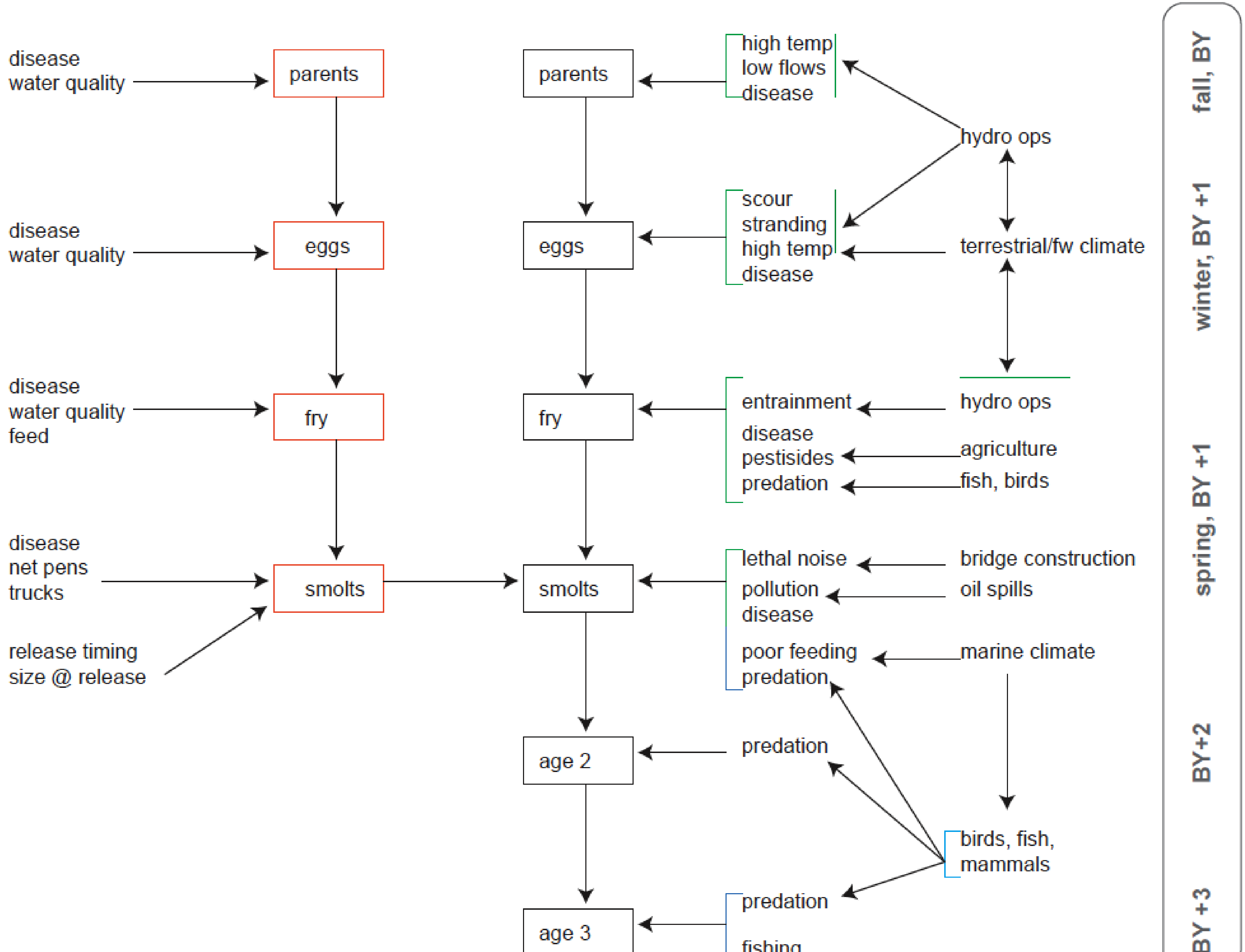


The largest commercial landings of salmon observed in California occurred in 1988 when more than 1.3 million Chinook salmon (14.4 million pounds) and 51,000 coho salmon (319,000 pounds) were landed.

From 1996 – 2000 the average number of spawning fall-run Chinook salmon in the Central Valley was 365,700

In 2008 the number of spawners was 66,000





Lindley et al. 2009 NOAA TM NMFS-SWFSC-447

Coastal Upwelling is a key process supporting exceptional productivity off the West Coast

- upwelling and related winds and ocean currents vary within and between years and decades

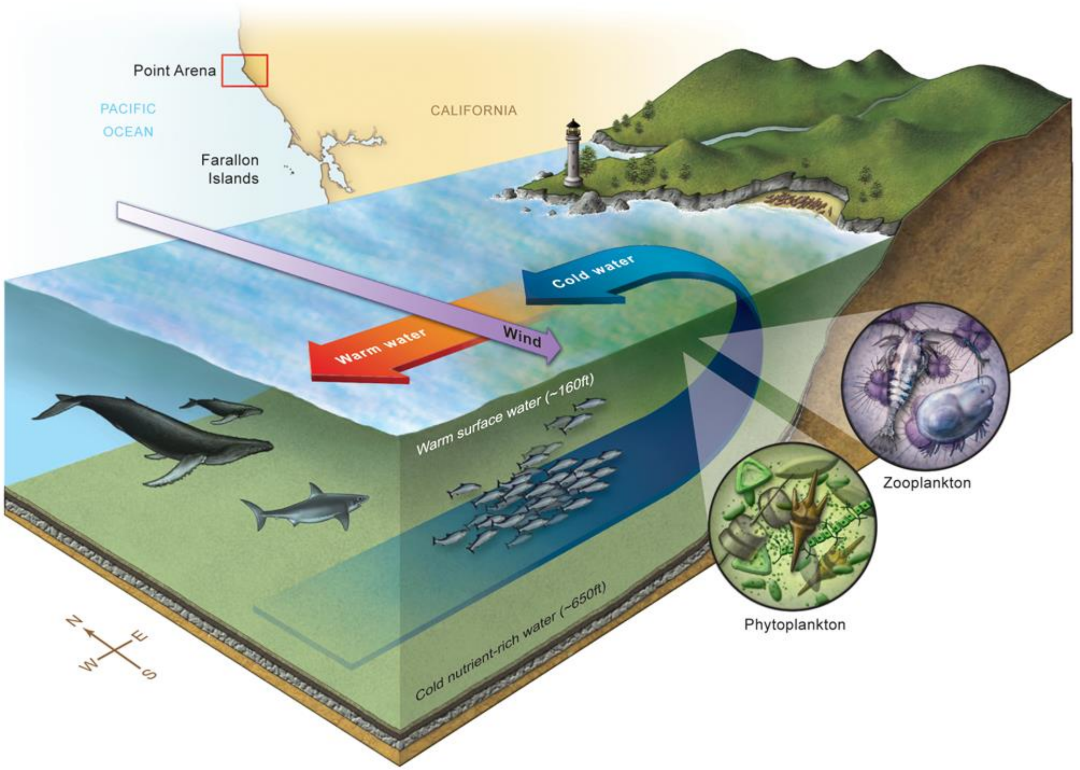
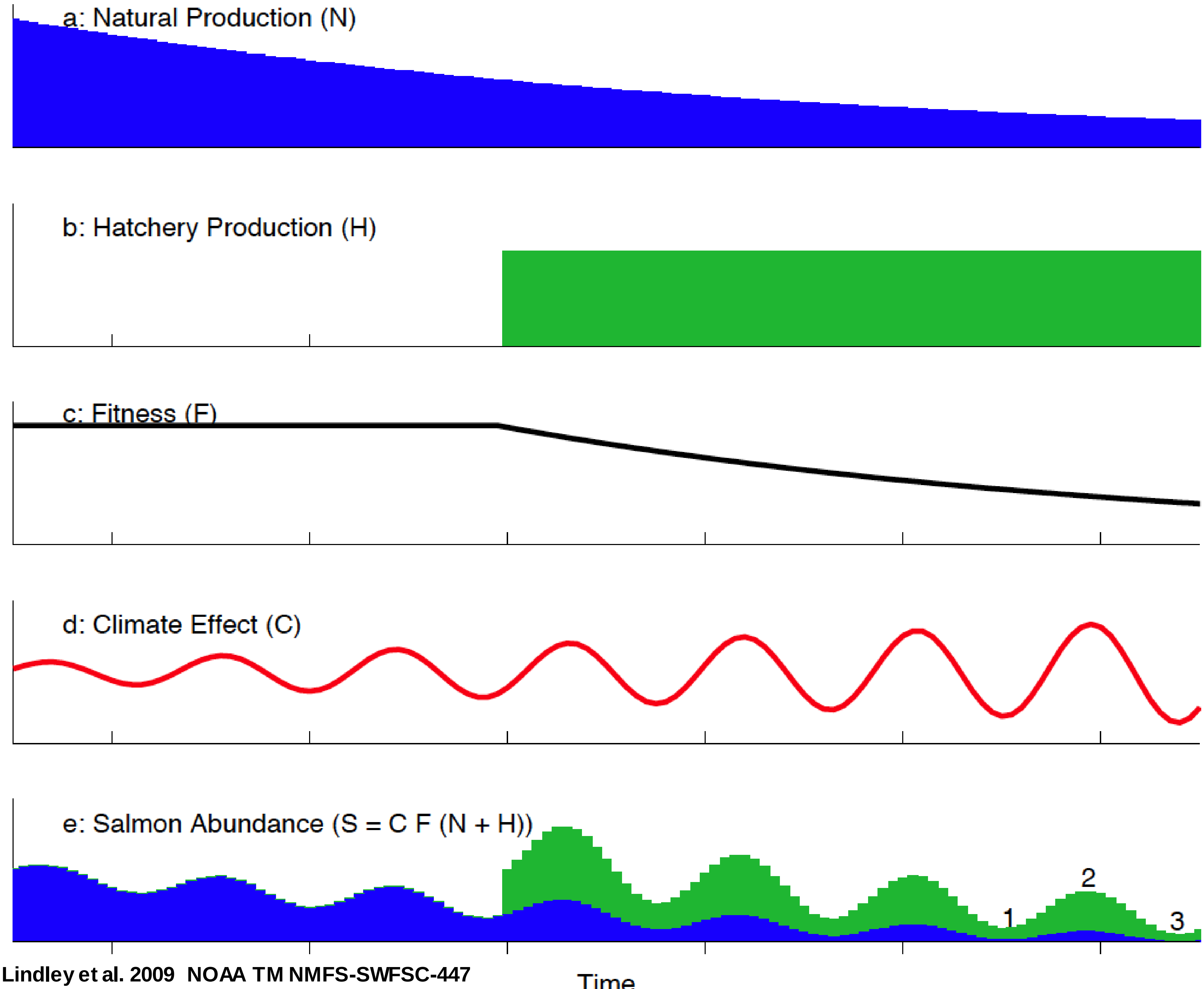


Illustration by Fiona Morris



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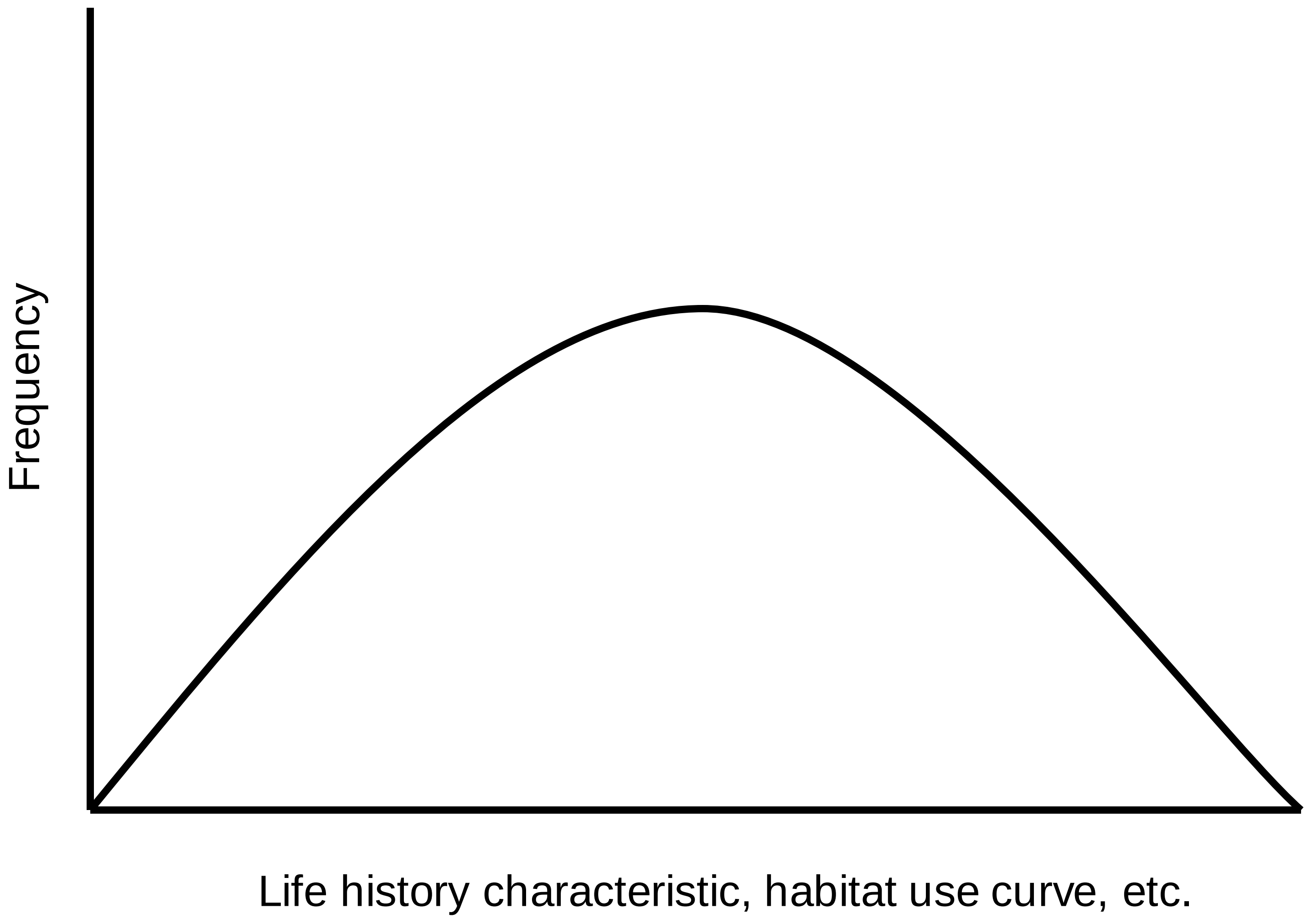
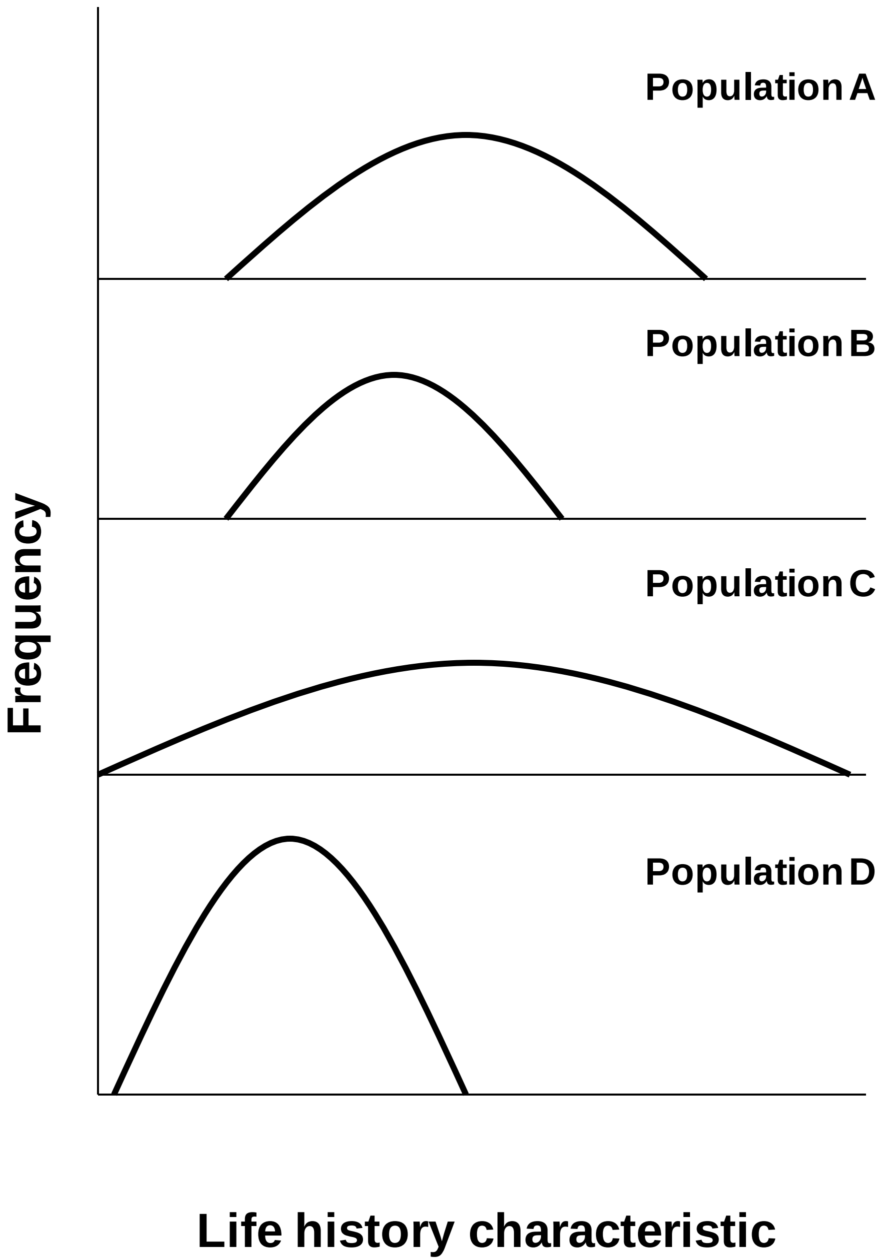
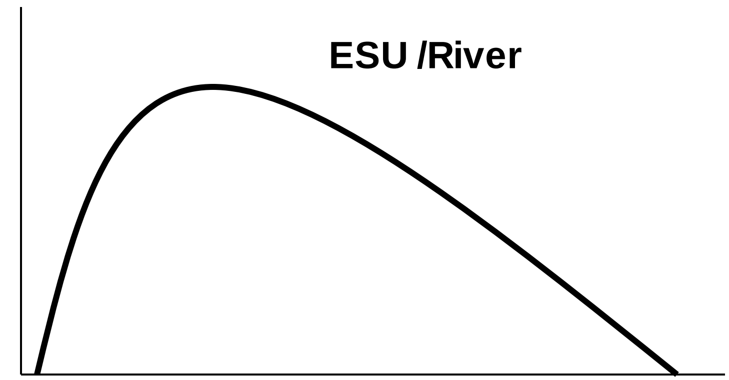


Frequency
Life history characteristic, habitat use curve, etc.





Williams et al. In Preparation

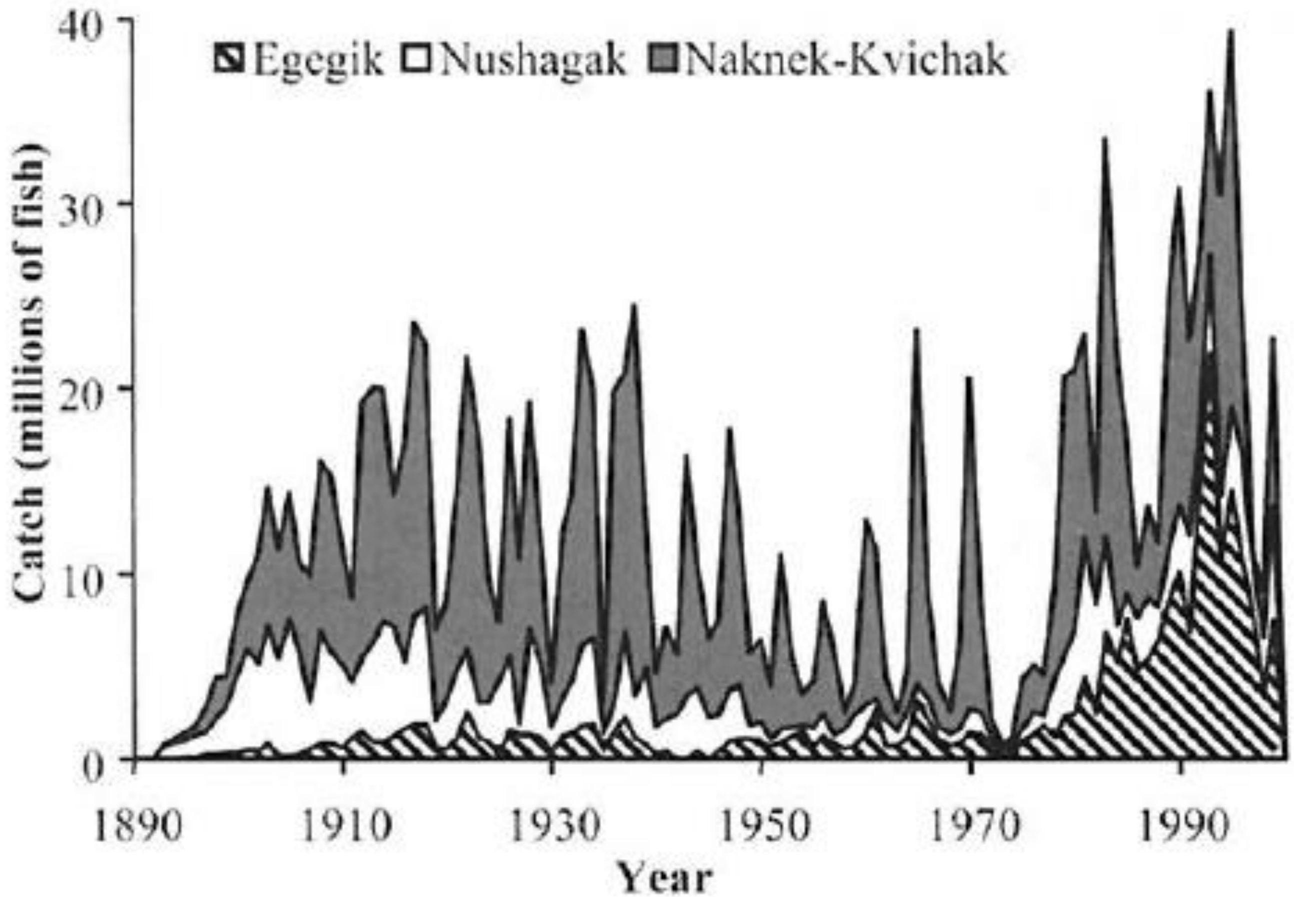


Fig. 3. Catch history of the three major fishing areas within Bristol Bay, Alaska. Contributions of the minor districts, Ugashik and Togiak, have averaged 4.6% since 1955.

Hilborn et al. 2003 Proceedings of the National Academy of Sciences 100:6564-6568

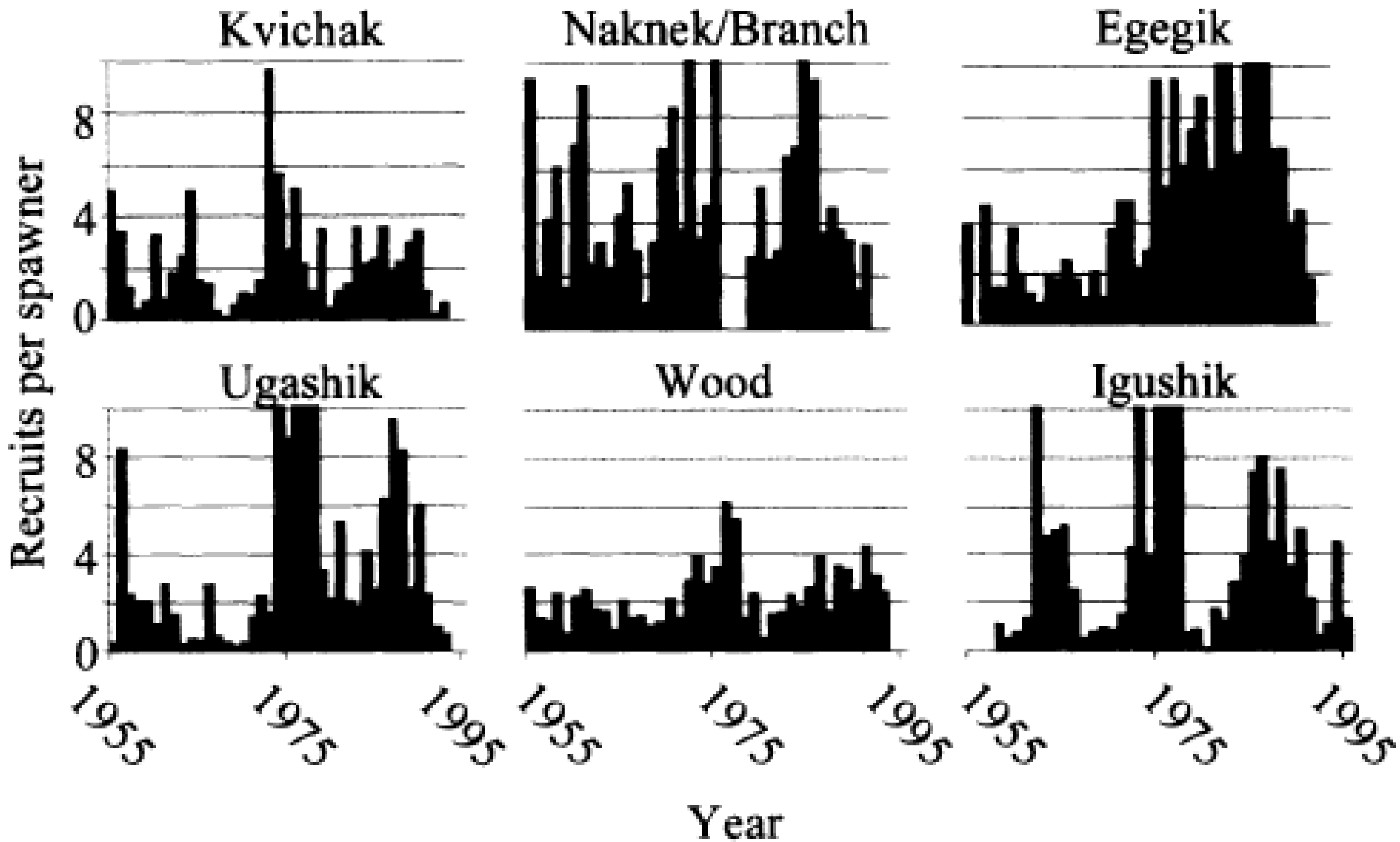
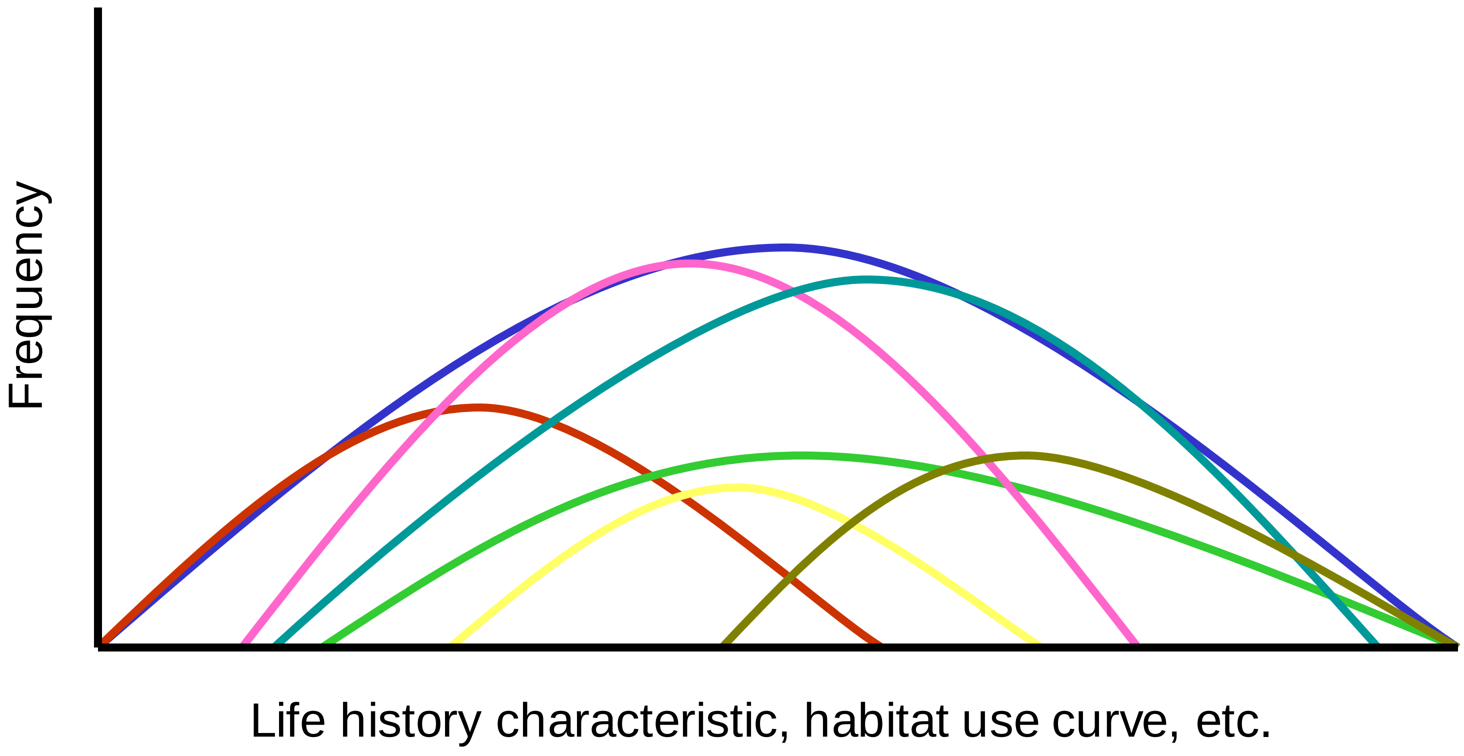


Fig. 4. Number of recruits per spawner for different Bristol Bay sockeye salmon stocks. Values >10 were truncated; the maximum was 27.4 for the Ugashik River in 1978.

Hilborn et al. 2003 Proceedings of the National Academy of Sciences 100:6564-6568



Williams et al. In Preparation

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LETTERS

Population diversity and the portfolio effect in an exploited species

Daniel E. Schindler[1], Ray Hilborn[1], Brandon Chasco[1], Christopher P. Boatright[1], Thomas P. Quinn[1], Lauren A. Rogers[1] & Michael S. Webster[2]

One of the most pervasive themes in ecology is that biological diversity stabilizes ecosystem processes and the services they provide to society[1–4], a concept that has become a common argument for biodiversity conservation[5]. Species-rich communities are thought to produce more temporally stable ecosystem services because of the complementary or independent dynamics among species that perform similar ecosystem functions[6]. Such variance dampening within communities is referred to as a portfolio effect[7] and is analogous to the effects of asset diversity on the stability of financial portfolios[8]. In ecology, these arguments have focused on the effects of species diversity on ecosystem stability but have not considered the importance of biologically relevant diversity within individual species[9]. Current rates of population extirpation are probably at least three orders of magnitude higher than species extinction rates[10], so there is a pressing need to clarify how population and life history diversity affect the performance of individual species in providing important ecosystem services. Here we use five decades of data from *Oncorhynchus nerka* (sockeye salmon) in Bristol Bay, Alaska, to provide the first quantification of portfolio effects that derive from population and life history diversity in an important and heavily exploited species. Variability in annual Bristol Bay salmon returns is 2.2 times lower than it would be if the system consisted of a single homogenous population rather than the several hundred discrete populations it currently consists of. Furthermore, if it were a single homogeneous population, such increased variability would lead to ten times more frequent fisheries closures. Portfolio effects are also evident in watershed food webs, where they stabilize and extend predator access to salmon resources. Our results demonstrate the critical importance of maintaining population diversity for stabilizing ecosystem services and securing the economies and livelihoods that depend on them. The reliability of ecosystem services will erode faster than indicated by species loss alone.

The recent focus on ecosystem-based management of renewable resources emphasizes species interactions and how these are affected by human activities within exploited ecosystems. However, there is growing recognition that population diversity within exploited species can contribute to their long-term sustainability and should be incorporated more explicitly into management and conservation schemes[11,12]. For example, it has been argued[11] that population diversity reduced the temporal variability of sockeye salmon fisheries in Bristol Bay because of complementary dynamics in different components of the stock complex. Similar phenomena are now appreciated qualitatively in other marine ecosystems[12]. However, at present there are neither quantitative estimates of the strength of portfolio effects produced by population and life history diversity in exploited species, nor an objective assessment of the benefits of population diversity to human economies and ecosystem services in general.

From 1950 to 2008, sockeye salmon supported the most valuable fisheries in the United States (landed value, US$7,900,000,000), and 63% of the associated revenue came from Bristol Bay (see Supplementary Information for details). The total economic value of this fishery is considerably higher when considering the retail, cultural and recreational value of these fish. Income from sockeye salmon in Bristol Bay is the major source of personal income for most Bristol Bay communities, and landing taxes provide the major funding for local school districts. Thus, the interannual reliability of this fishery has critical and direct consequences for the livelihoods of people in this region.

Population diversity within the stock complex of Bristol Bay sockeye substantially reduces the interannual variability experienced by the commercial fishery, which intercepts sockeye salmon as they enter each of the nine major rivers of this region (Fig. 1a). Each river stock contains tens to hundreds of locally adapted populations distributed among tributaries and lakes (Fig. 1b and Supplementary Fig. 1). This remarkable diversity in sockeye reflects their ability to thrive in a wide range of habitat conditions, the reproductive isolation of populations by precise homing to natal spawning sites, and their capacity for microevolution[13]. Thus, the Bristol Bay sockeye fishery integrates across substantial population diversity both within and among watersheds.

Annual sockeye returns to the Bristol Bay stock complex were considerably less variable (coefficient of variation (standard deviation divided by mean), CV = 55%) than those observed for individual rivers (average CV = 77%; Fig. 1c) for 1962–2008. Annual returns to individual populations spawning in streams of the Wood River system, where long-term detailed population assessments are available (Fig. 1b), were more variable (average CV = 95%) than both the aggregate of these streams (CV = 67%) and the total returns to the Wood River (CV = 60%; Fig. 1c). Thus, annual sockeye returns become increasingly more stable across the complexity hierarchy ranging from individual spawning populations to stocks associated with the watersheds of major rivers and, eventually, to the regional stock complex of Bristol Bay.

The degree of temporal covariation among portfolio assets controls the strength of portfolio effects[8,14]; the buffering effects of asset diversity on variability of the aggregate portfolio become weaker as asset dynamics become more synchronous. Analysis of the covariation among river stocks and among stream populations (that is, the analogues of assets in an investment portfolio) showed that annual sockeye returns were only weakly synchronous (and some negatively correlated) both within and among the watersheds of Bristol Bay. This lack of synchrony among populations of Bristol Bay sockeye occurred despite many commonalities in their migration corridors, nursery habitats and seasonal timing of migrations between freshwater and marine environments. Furthermore, strong shifts in climatic conditions

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To be viable (i.e., persist) – fish (and their communities) need to be able to track changes in the environment

- Individuals (within and between life stages)
- Populations
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- ESUs
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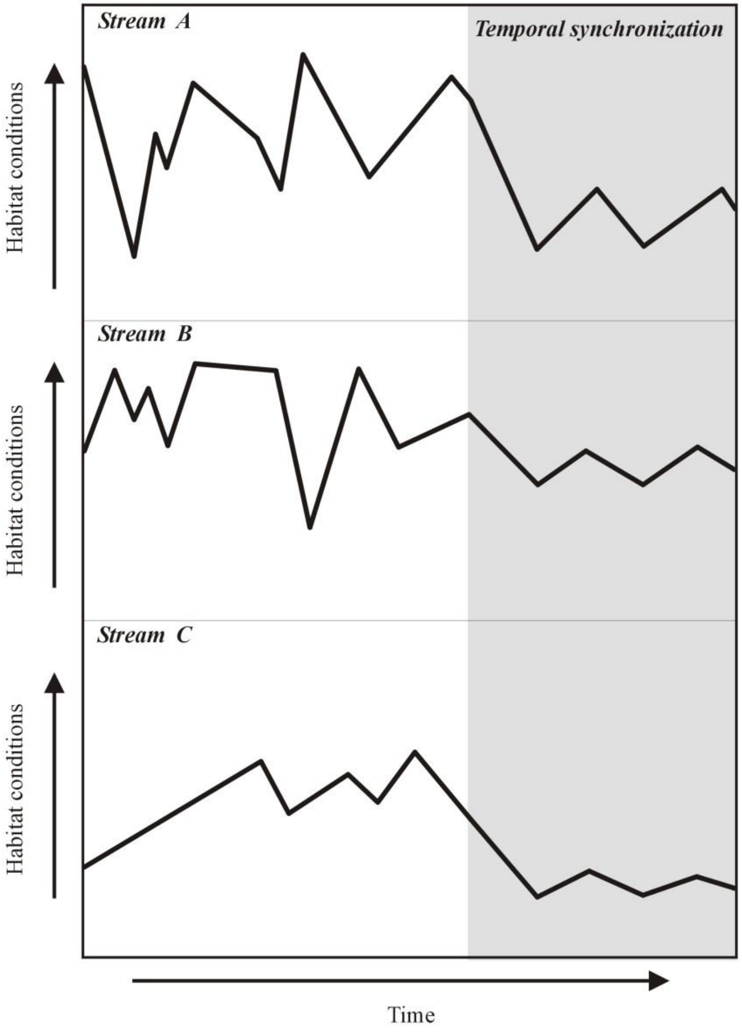
Photo: M. Capelli



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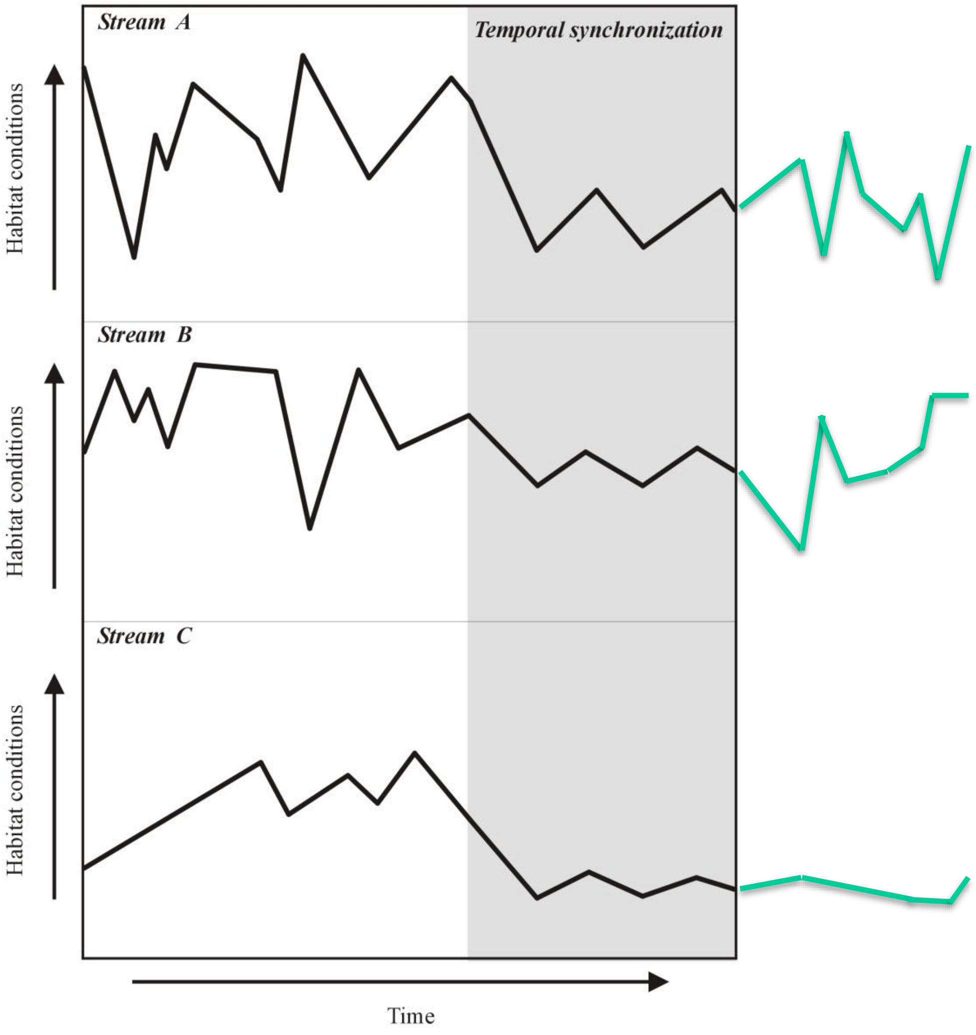

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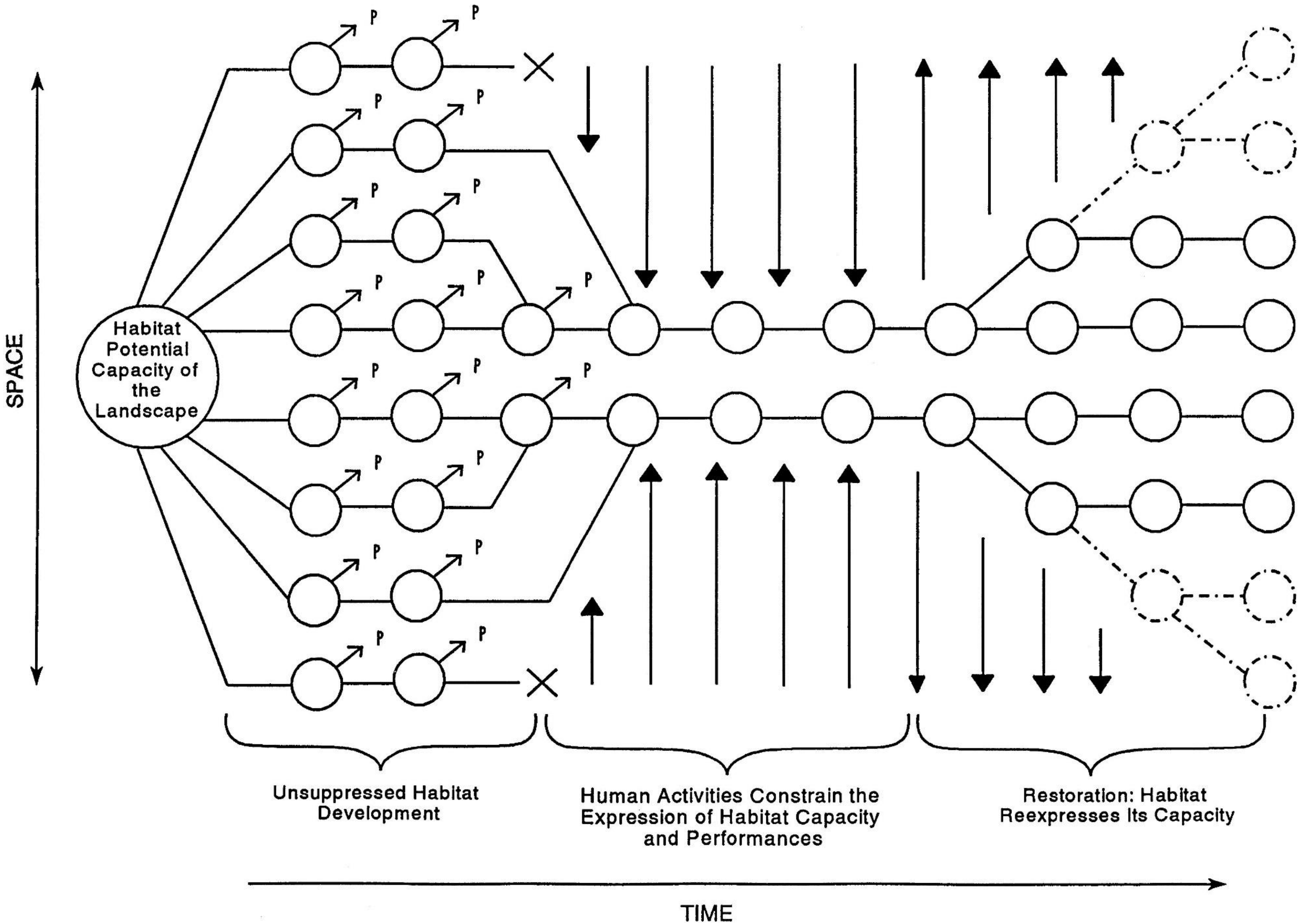

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Tracking a dynamic and changing environment

- **Individuals, populations, groups of populations**
- **Movement across the landscape - connectivity**
- **Expectations need to recognize differences in time and location of re-establishing viable and persistent wild fish populations based on species and specific life-history characteristics of fish and events/conditions shaping environmental conditions.**

High level science/monitoring needs:

- Need for information on ocean harvest of Klamath River fall-run Chinook salmon as marking/tagging will change with shift to Fall Creek and eventually no hatchery tagging/marking after 8 years.
- Expanded monitoring of age-specific natural- and hatchery-origin Chinook salmon spawning in natural areas upstream of Iron Gate; age-specific estimates of catch in river fisheries
- Habitat-based estimates of Chinook salmon production (smolts)
- Coho salmon distribution, movement, and abundance surveys
- Establish basin-wide coordination for monitoring and research
- Expanded basin-wide disease monitoring