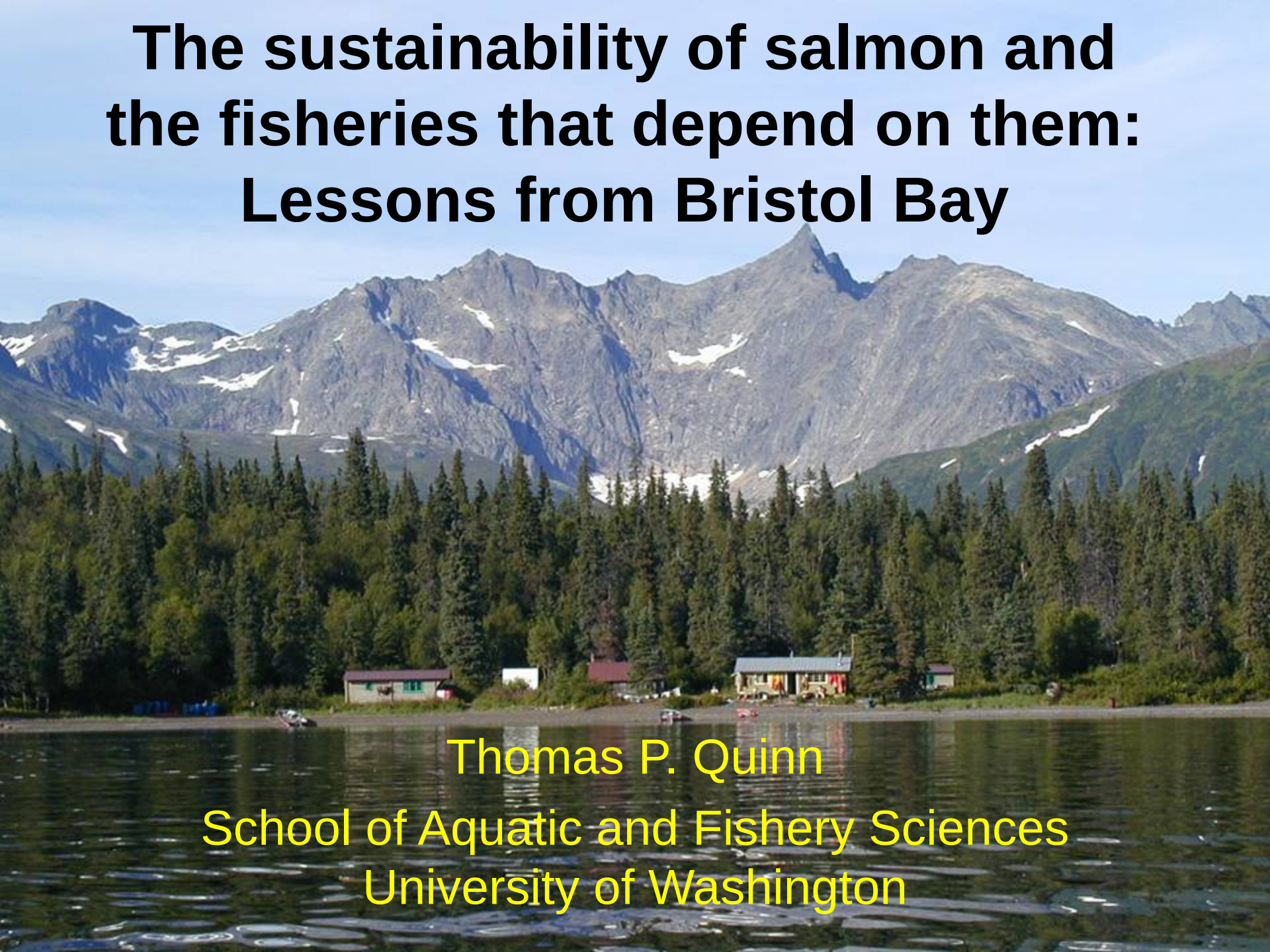
The sustainability of salmon and the fisheries that depend on them: Lessons from Bristol Bay



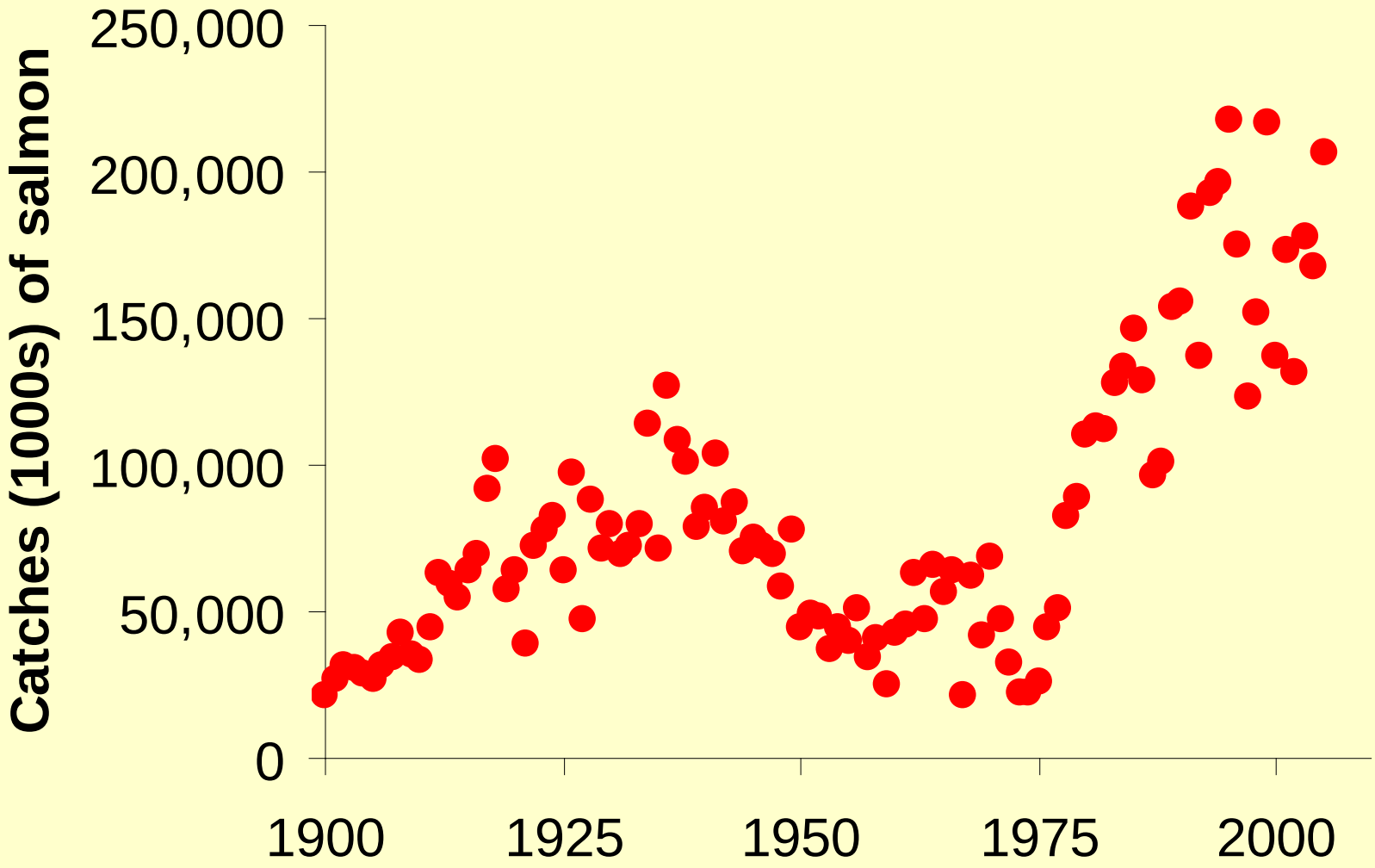
Thomas P. Quinn

School of Aquatic and Fishery Sciences
University of Washington

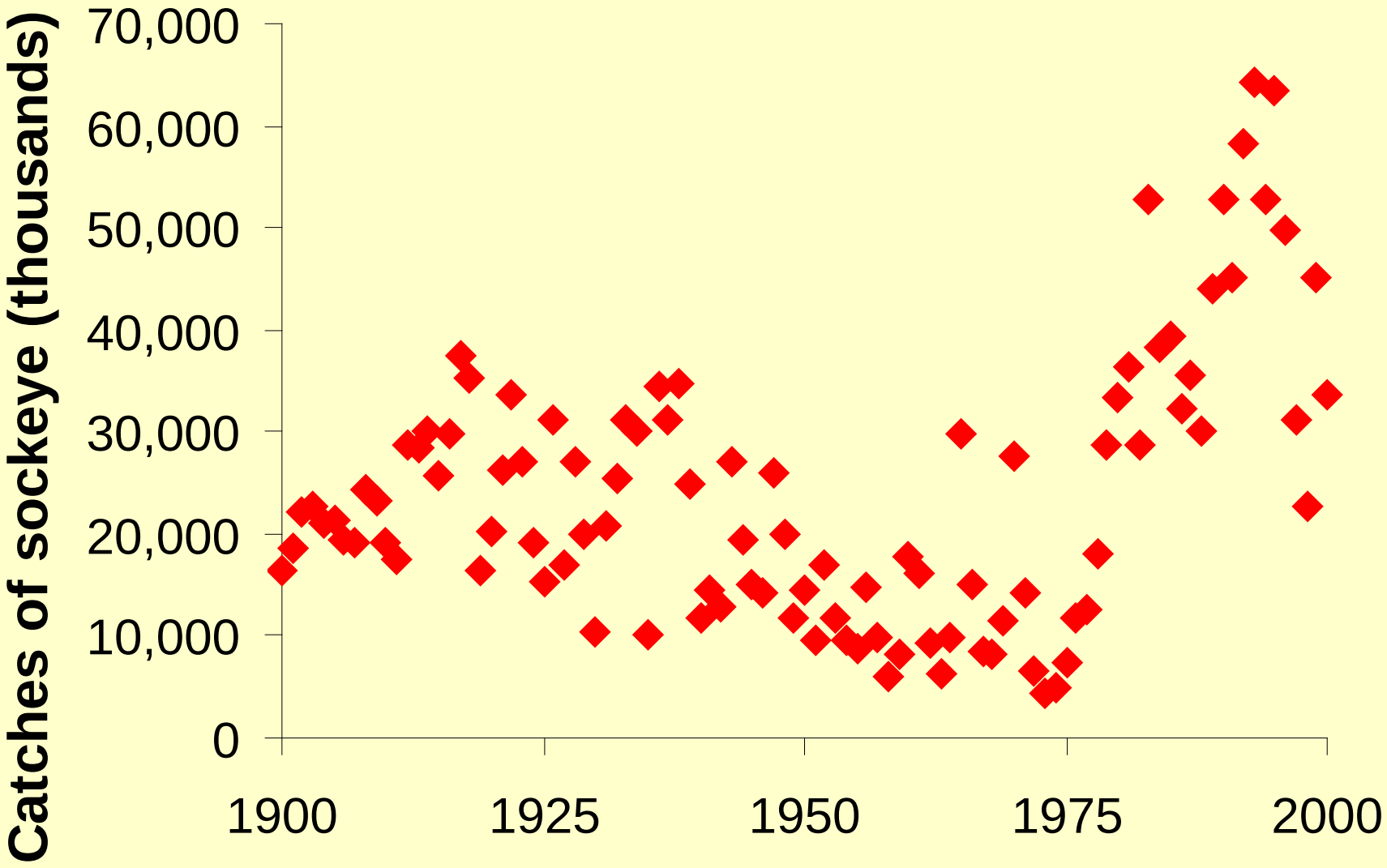
Theme: The importance of geographical scale in organizing the dynamics and structure of salmon populations, and the fisheries that depend on them

- Alaska
- Bristol Bay
- Five commercial districts
- One or more watersheds in each district
- One or several lakes in each watershed
- Different types of breeding habitats
- Different populations in each stream, etc.

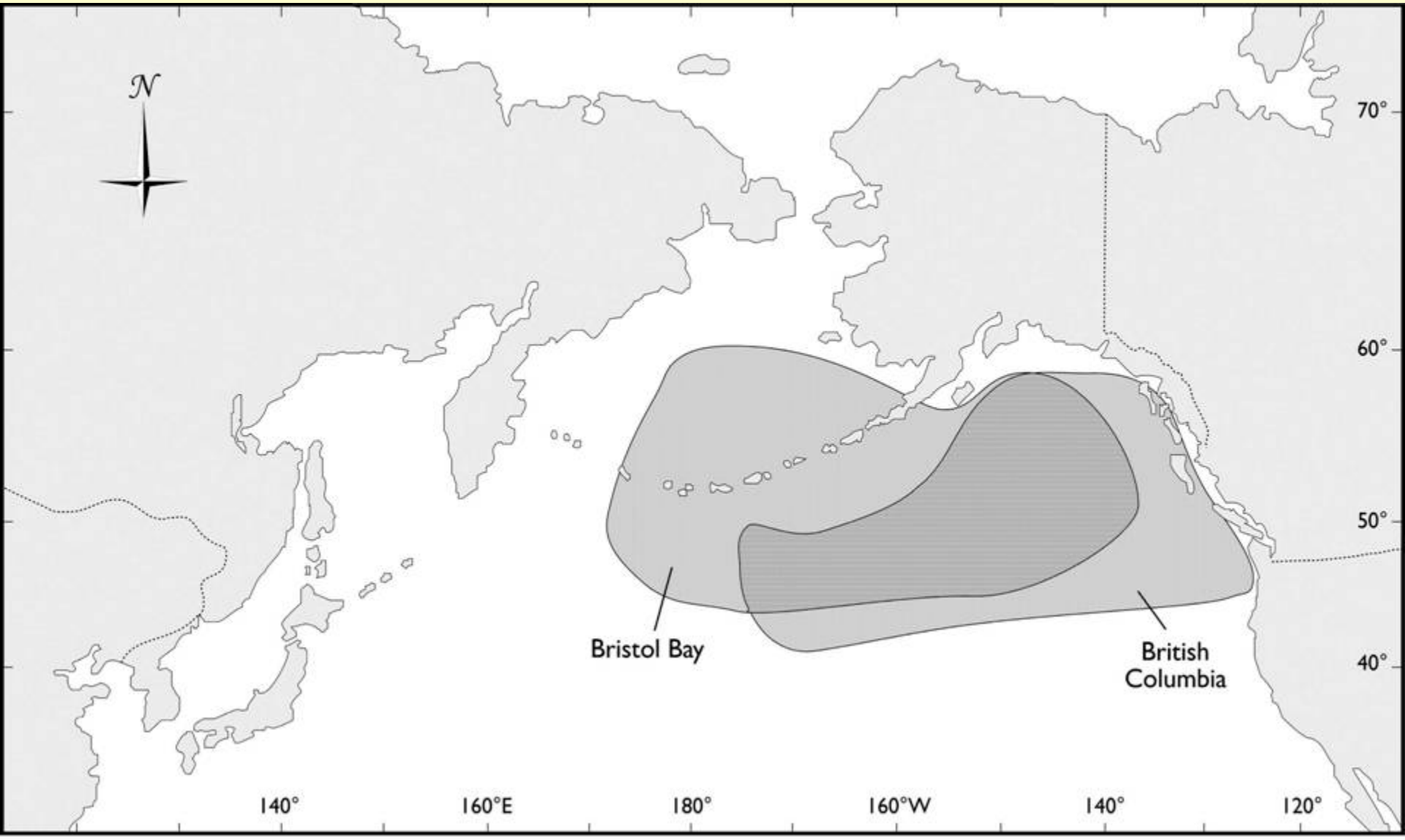
Commercial catches of all salmon species in Alaska (AK Dept. of Fish and Game data)



Commercial catches of sockeye salmon in Alaska (ADF&G data)



Bristol Bay fish dominate the western distribution of North American sockeye salmon




N
W
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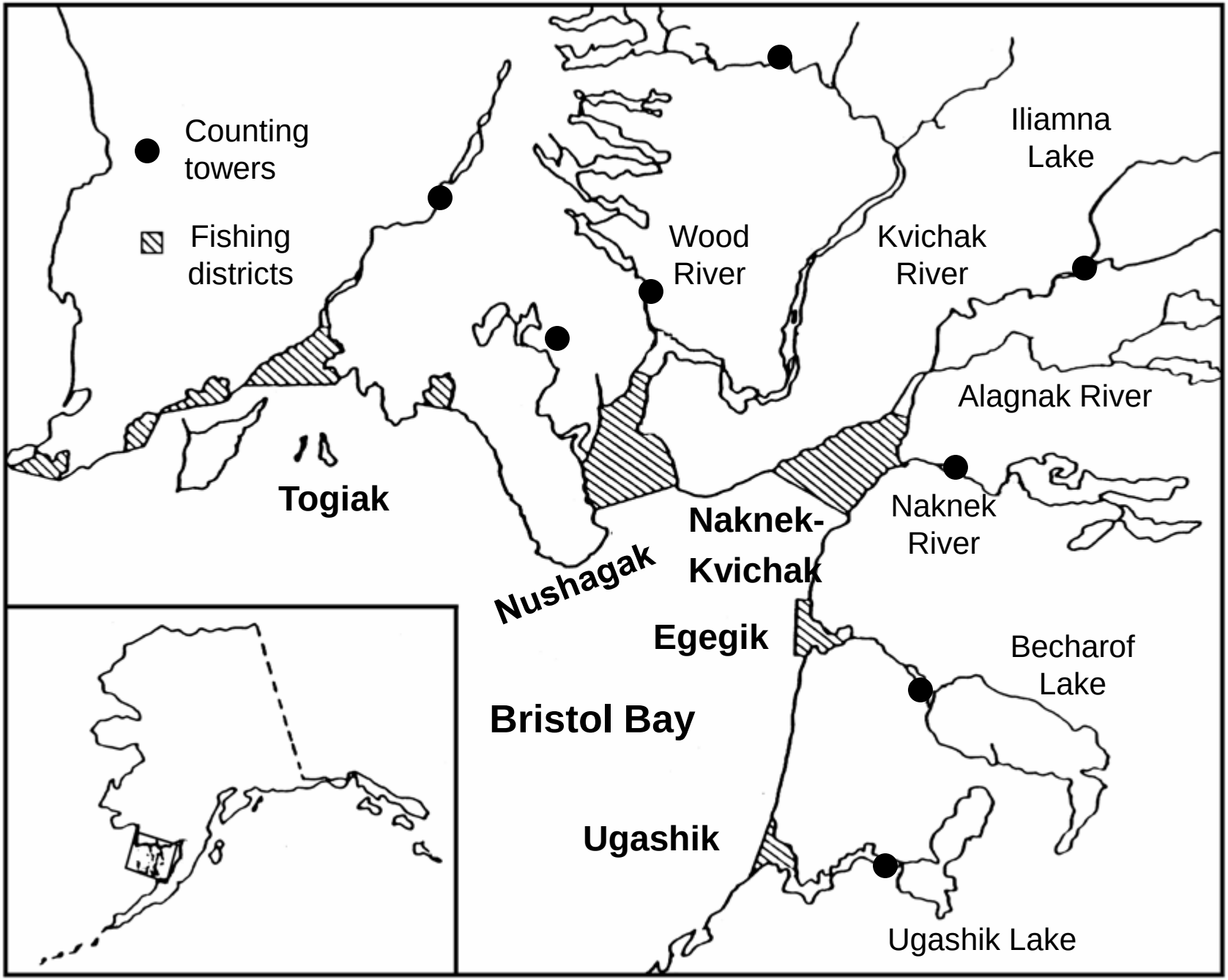
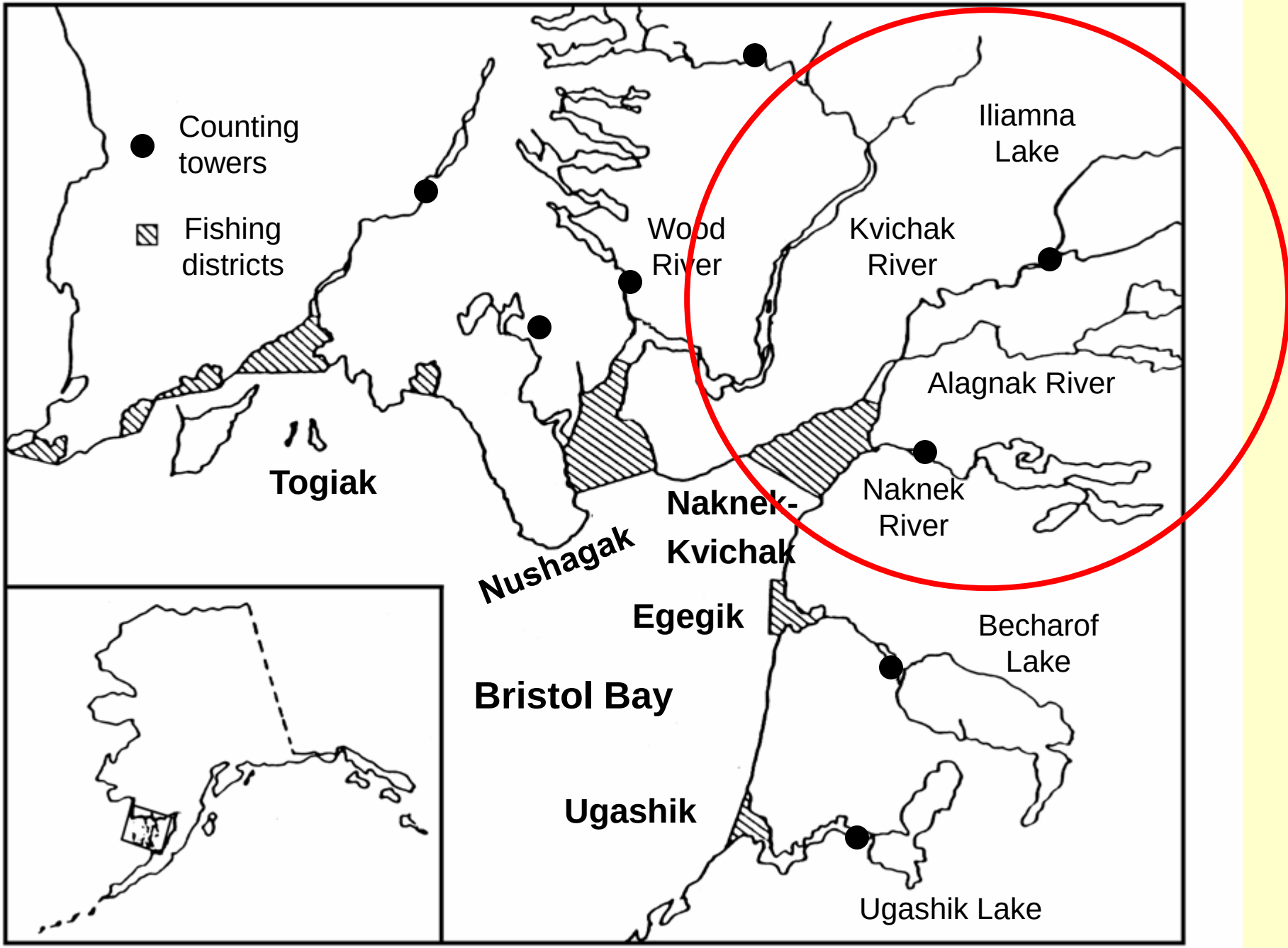

Counting towers
Fishing districts
Iliamna Lake
Wood River
Kvichak River
Alagnak River
Naknek River
Togiak
Naknek-Kvichak
Nushagak
Egegik
Becharof Lake
Bristol Bay
Ugashik
Ugashik Lake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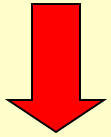
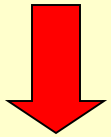
Geographical scales: Naknek-Kvichak district

Kvichak, Naknek, and Alagnak river drainages



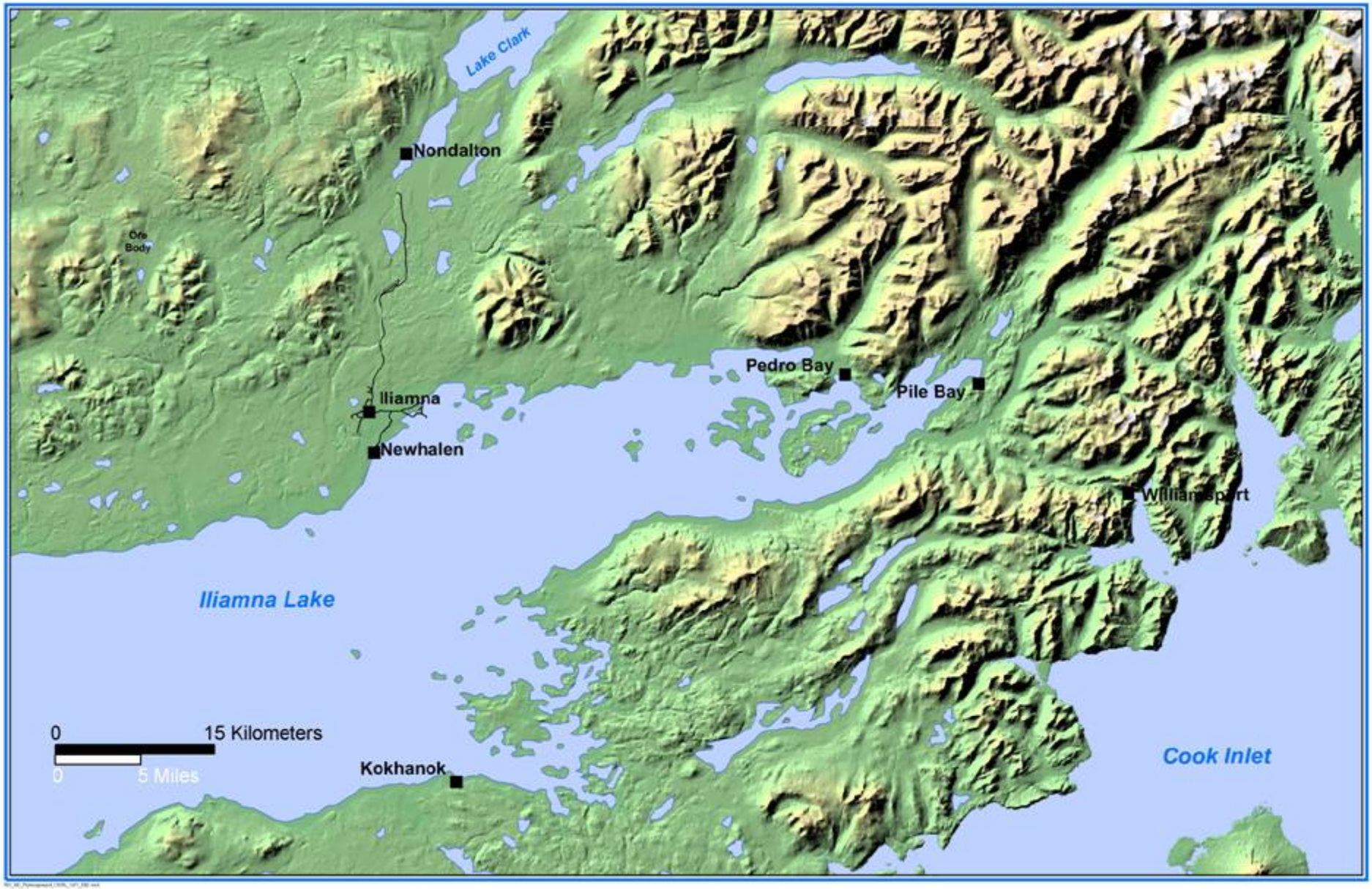
Iliamna Lake and Lake Clark (and other lakes)



River, creek, pond, mainland and island beach habitats

About 100 discrete breeding sites in the Kvichak system

The eastern end of Iliamna Lake, about 100 km long



Sockeye spawn in large rivers draining lakes

Sockeye salmon spawn in creeks of different sizes


Spring-fed
ponds are used
for spawning

Sockeye populations spawn on lake beaches:

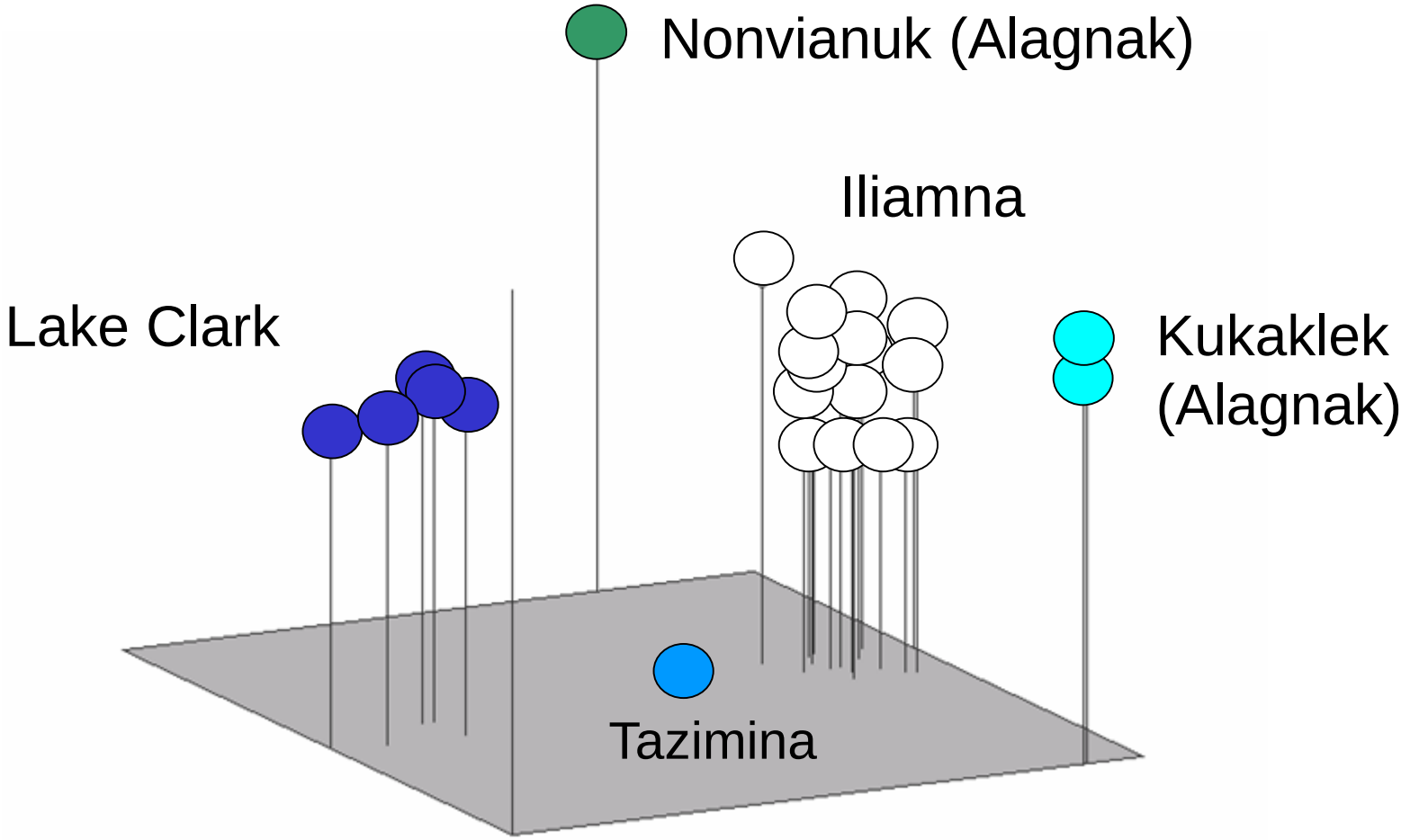
1) **Groundwater-fed beaches on shorelines and at river outlets**

2) **Rocky beaches on low-lying islands**

Fine substrate is typical on mainland beaches

Island beaches have no groundwater and large substrate

Kvichak Drainage: Genetic differentiation



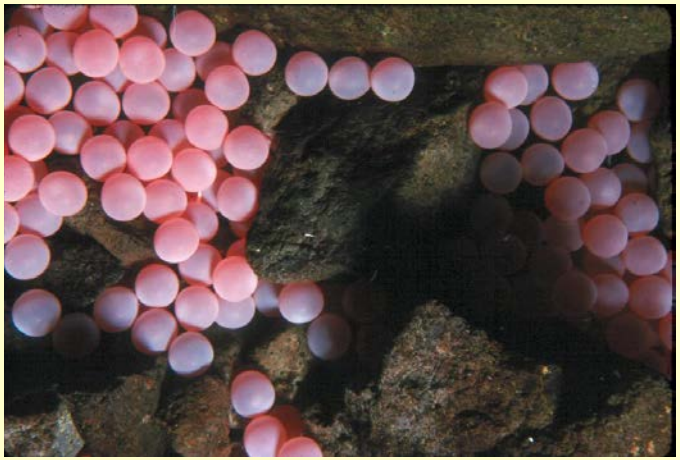
Jim Seeb, ADF&G

Microsatellite data only

The falls on the Newhalen River, draining Lake Clark into Iliamna Lake, may have been a bottleneck

Adaptive variation in life history traits

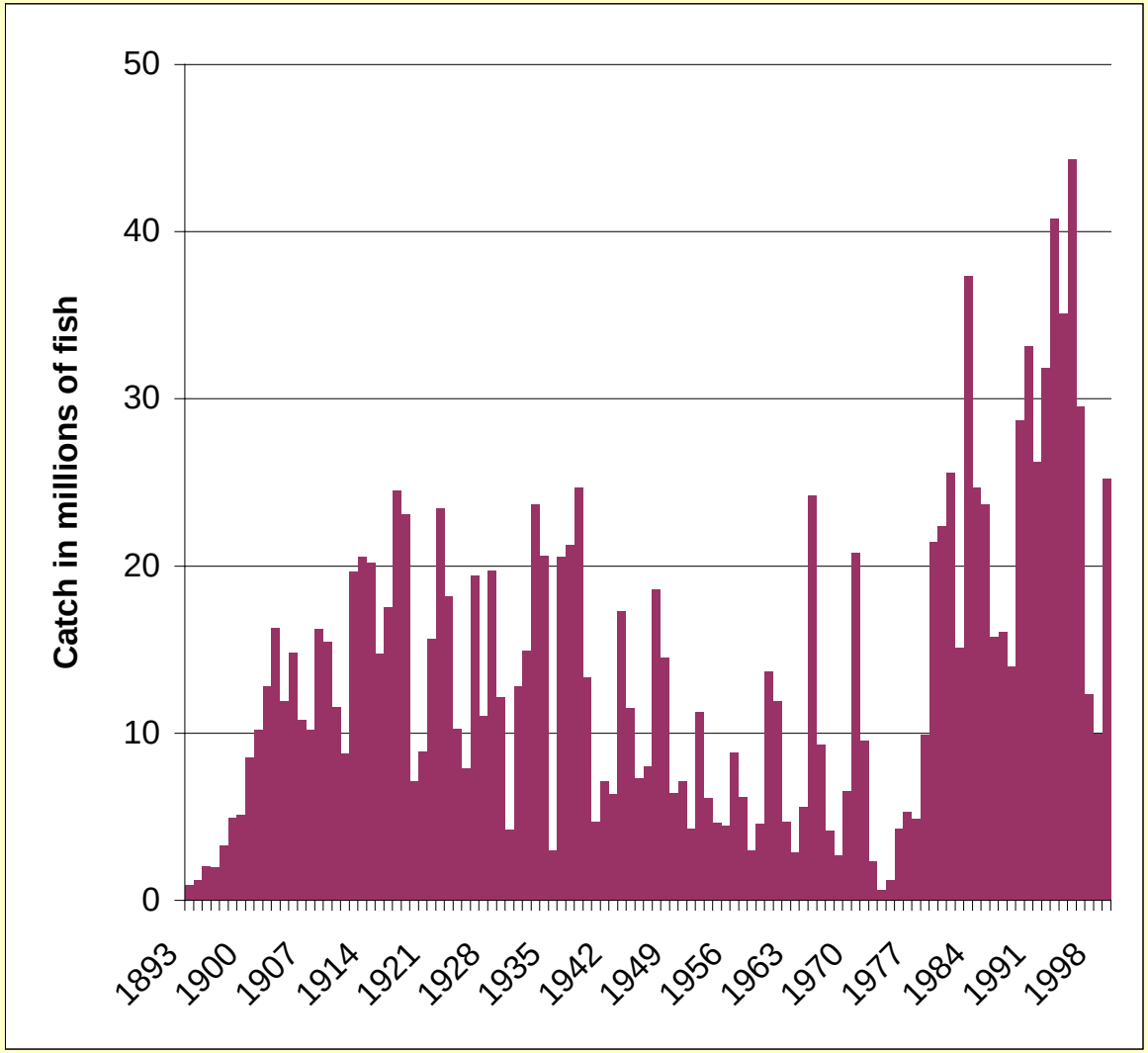
- Age at maturity
- Size at age
- Morphology
- Spawning date
- Egg size/fecundity



Geography and population structure

- **Population genetics are organized at the watershed scale, reflecting post-glacial colonization; contemporary gene flow is primarily among similar habitats**
- **Life history traits reflect both:**
  - **watershed conditions (e.g., growth rates differ among lakes, affecting smolt age)**
  - **spawning habitat (similar habitats produce similar phenotypes in different watersheds)**

Bristol Bay sockeye are a success story in sustainable fisheries management



Assets

One management agency with clear biological objectives

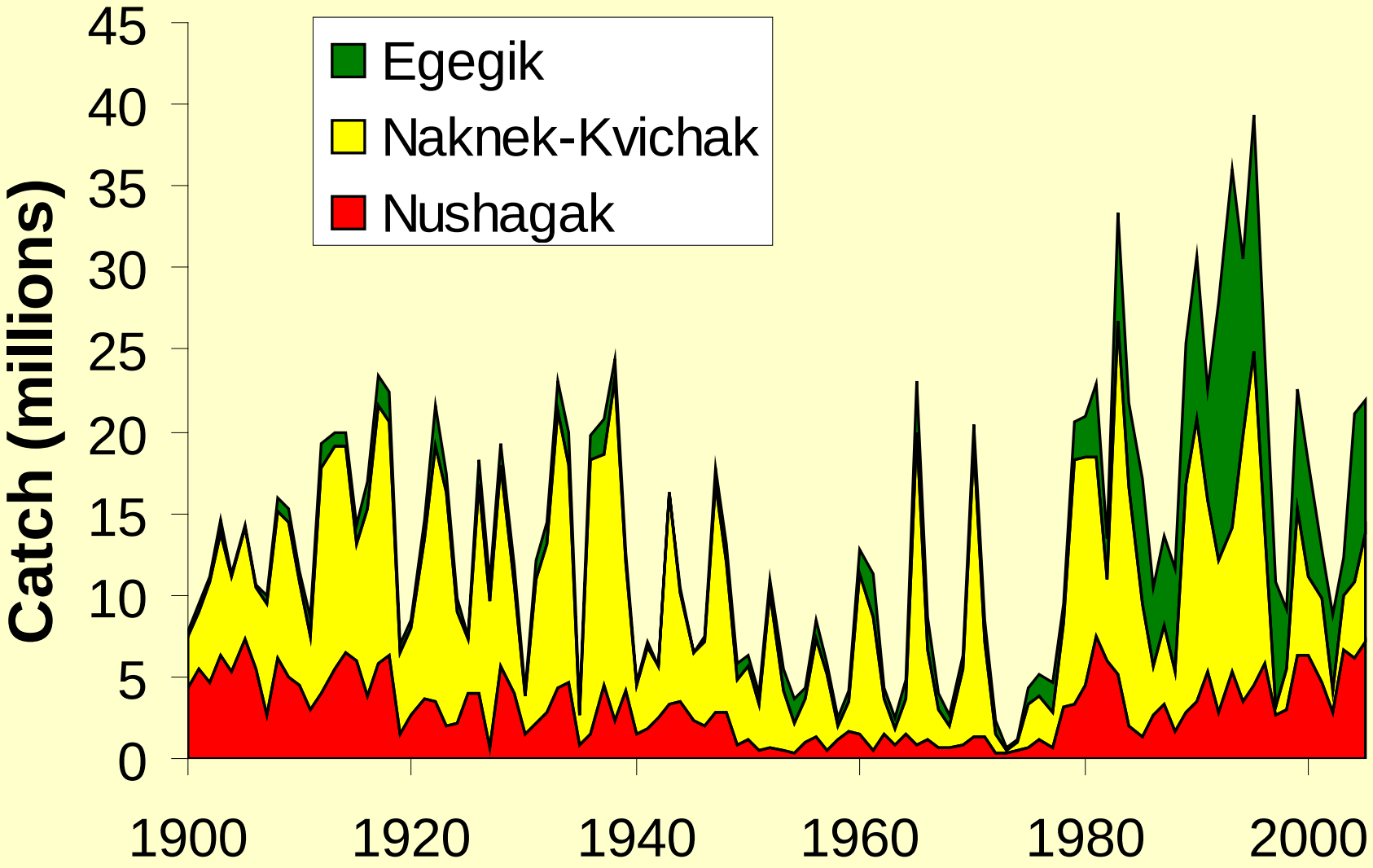
Good ocean conditions since about 1977

Elimination of high seas interceptions

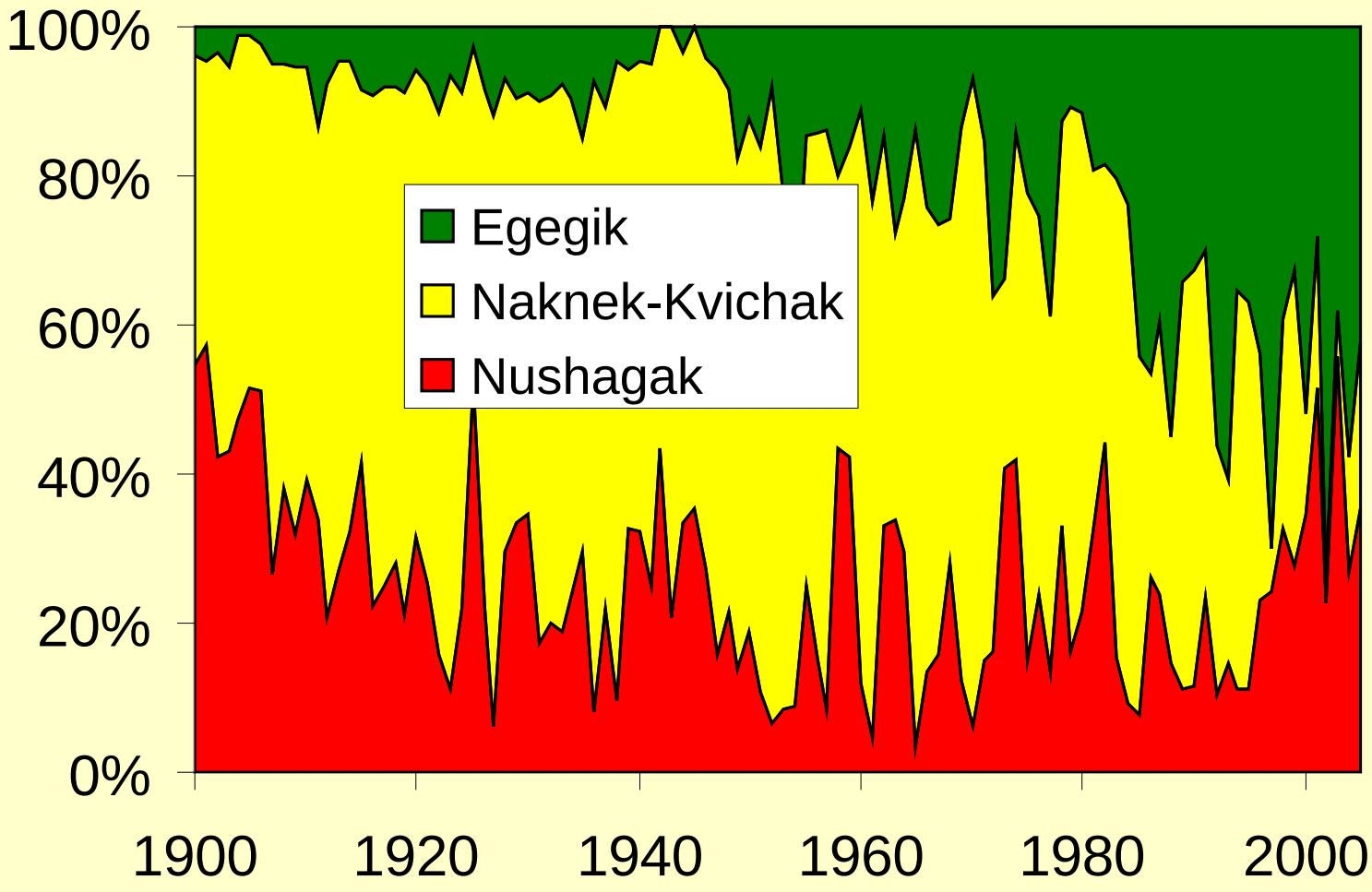
Population dynamics

- During the past century, Bristol Bay sockeye runs have fluctuated with climate processes
- However, districts, watersheds, and habitat types have not responded similarly to the changing conditions
- Thus the system as a whole is more stable than any component

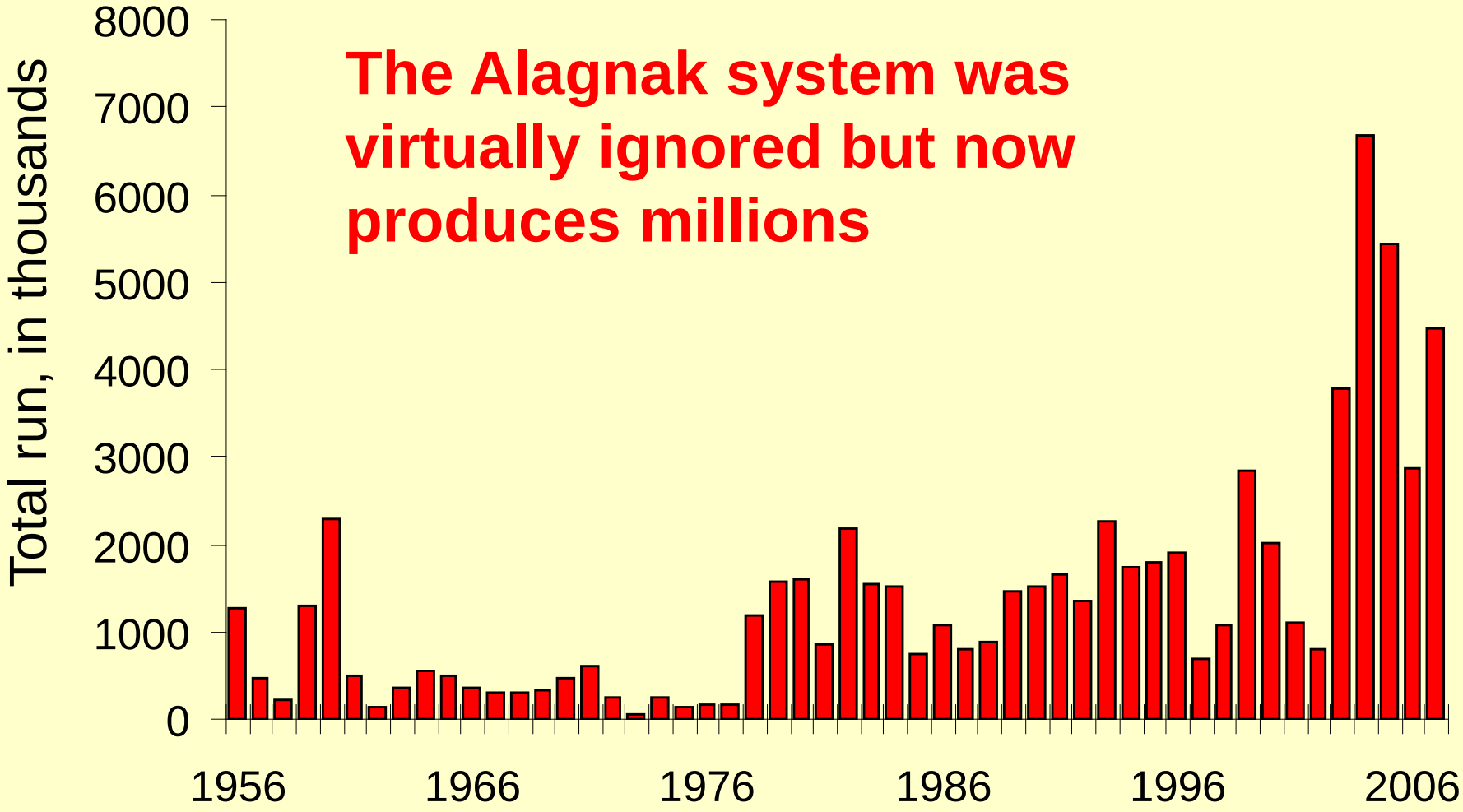
Shifting catches in the three major districts



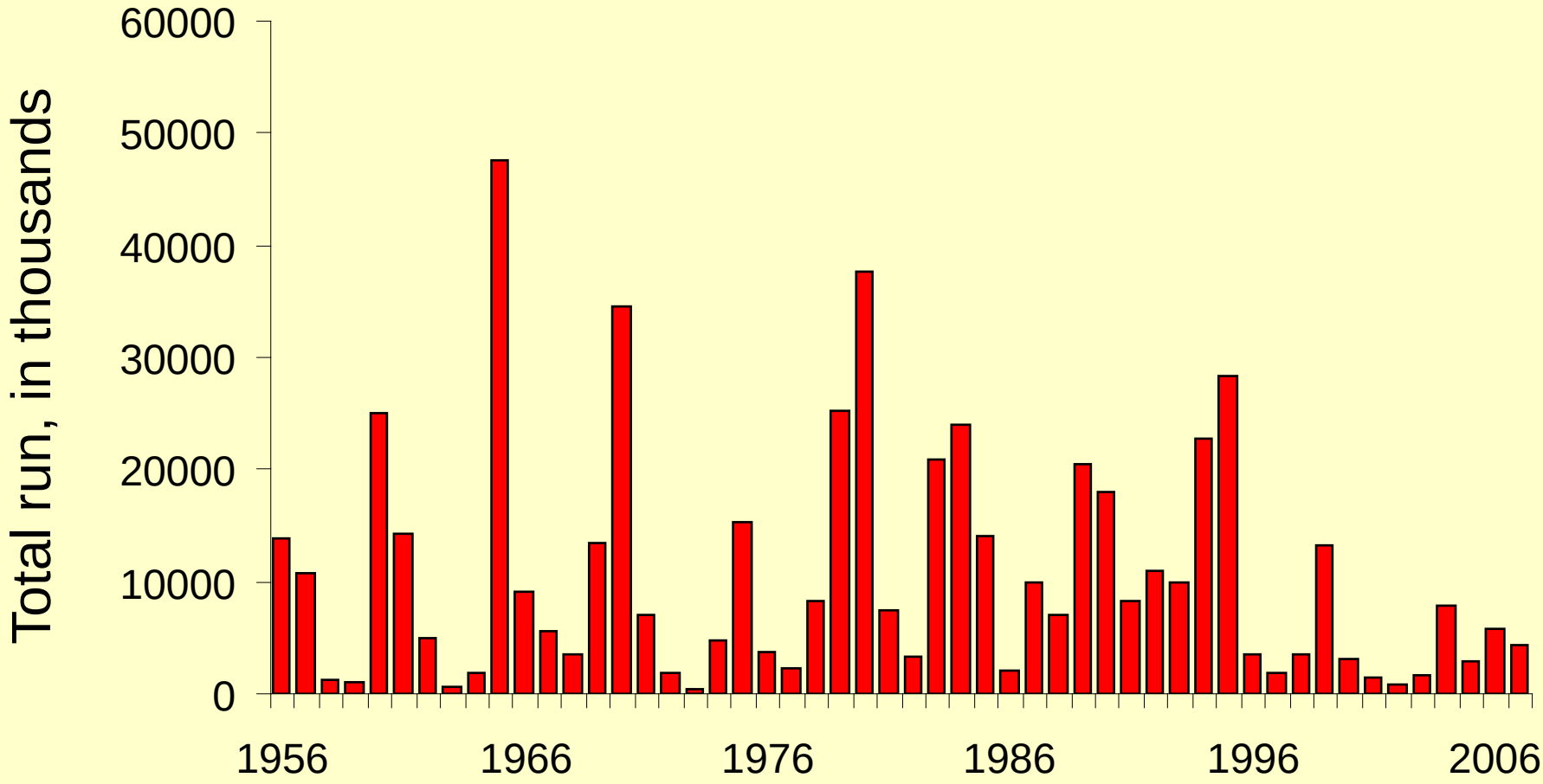
Egegik has boomed while Naknek-Kvichak declined



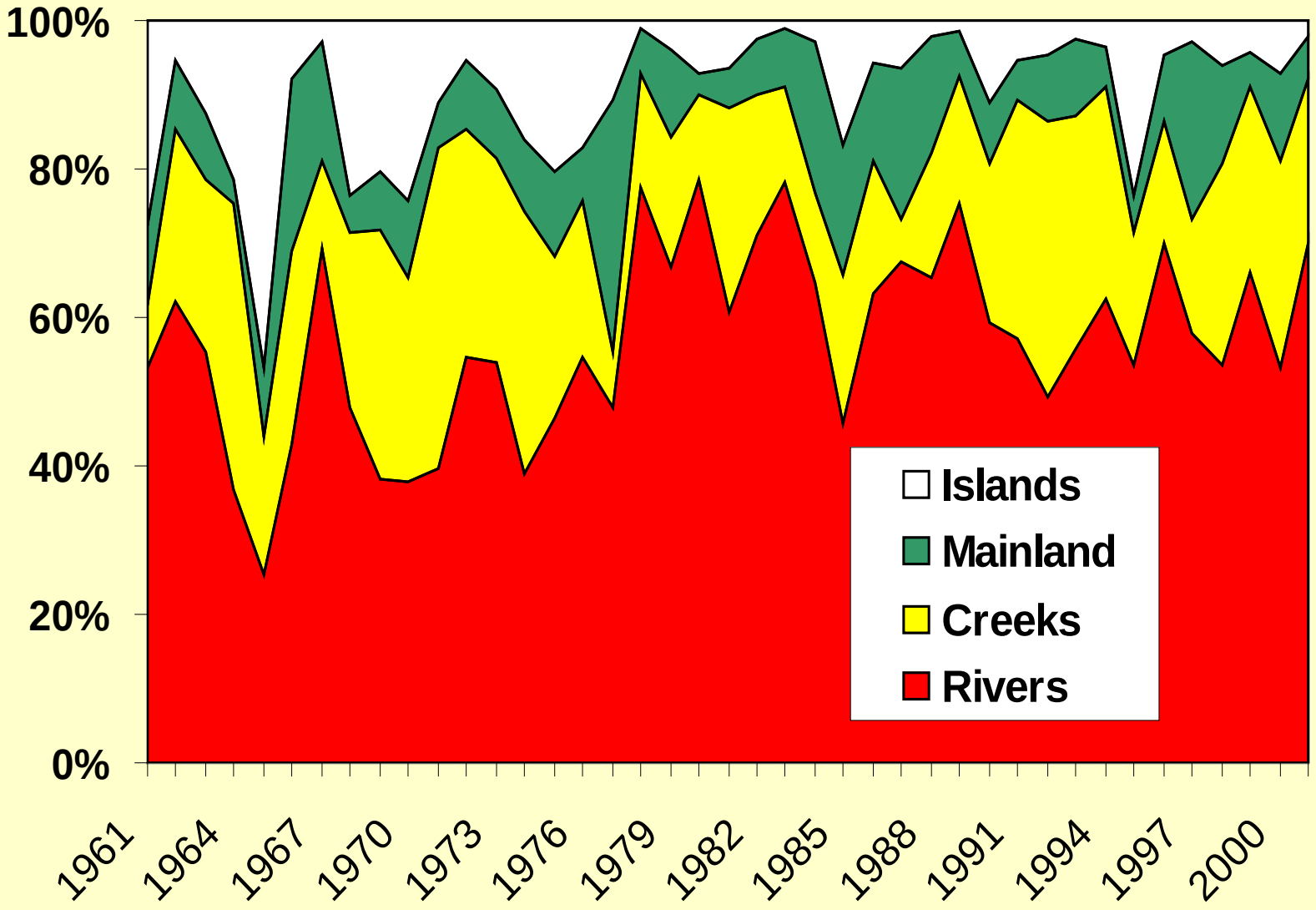
Within one district, the Naknek-Kvichak, the runs have varied dramatically



While the Kvichak system's once legendary abundance levels have not been seen lately



Within Iliamna Lake, the habitats producing most of the salmon have shifted over time



Thus at many spatial scales, productivity has varied. Within one system, how synchronous are patterns of productivity?

1) Assemble 60 years of stream-specific abundance estimates

2) Use age at maturity data to build brood tables

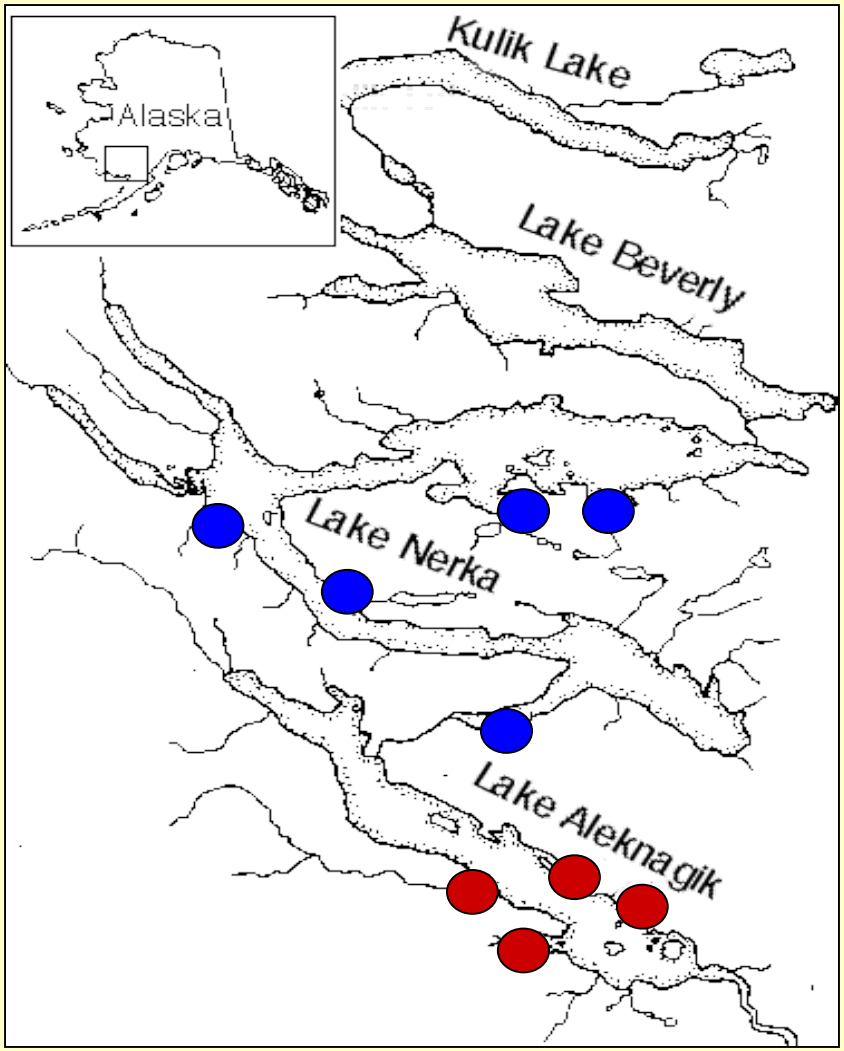
3) Expand for the fishery using age-specific catch rates

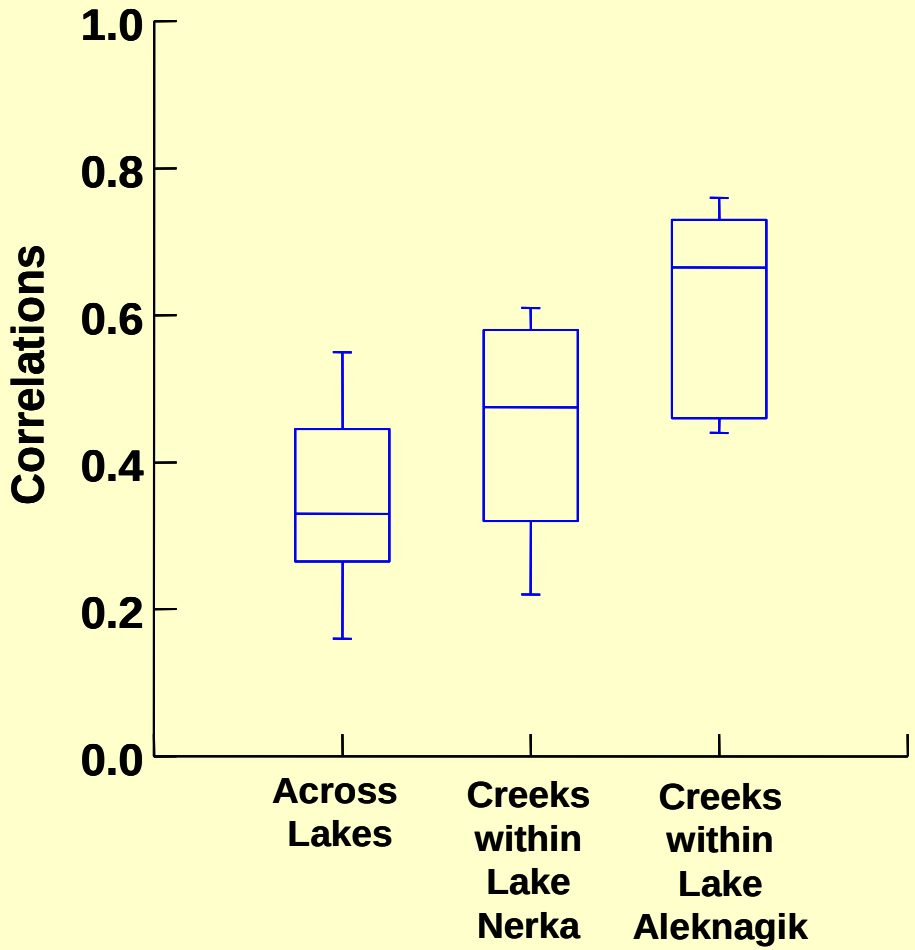
4) Estimate population-specific spawner-recruit relationships to account for density-dependence

5) Look for correlations in the residuals from those relationships

Lauren Rogers and Daniel Schindler

The S – R relationships of discrete populations are more correlated within than between lakes, and in a smaller lake than a more complex, larger one

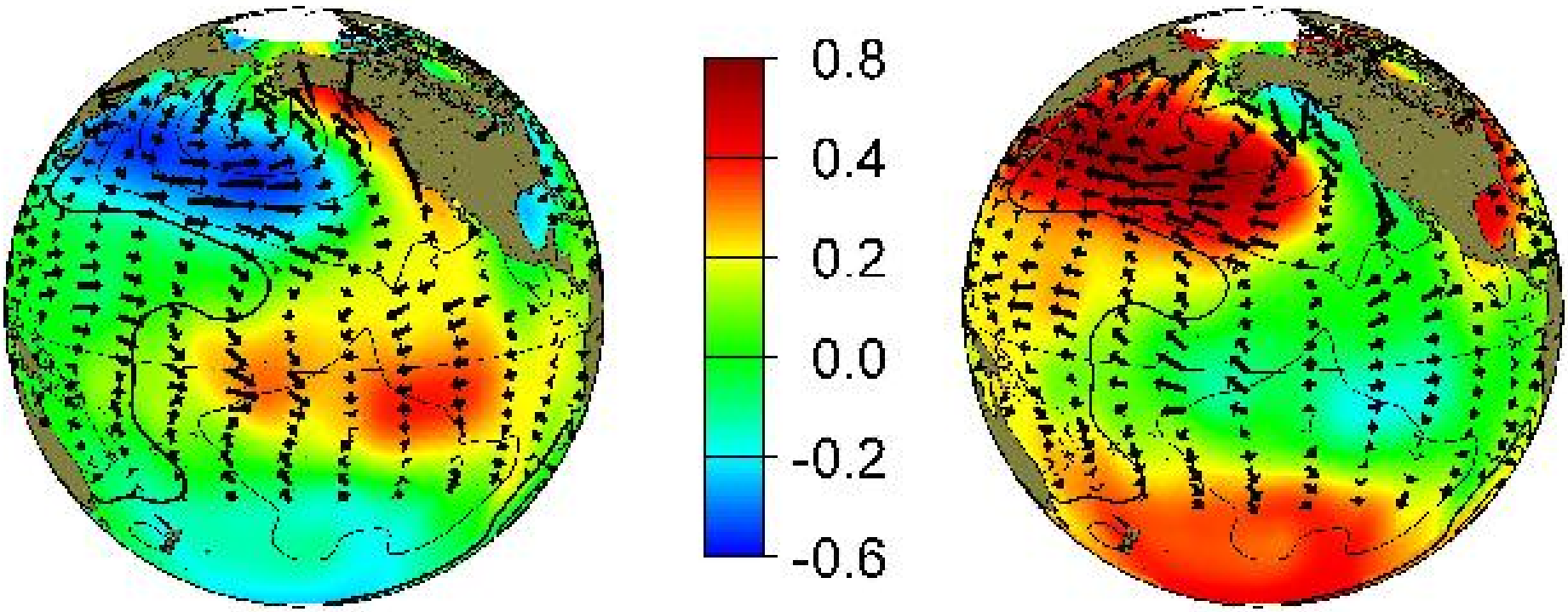




Climate processes in freshwater and at sea affect salmon survival and growth

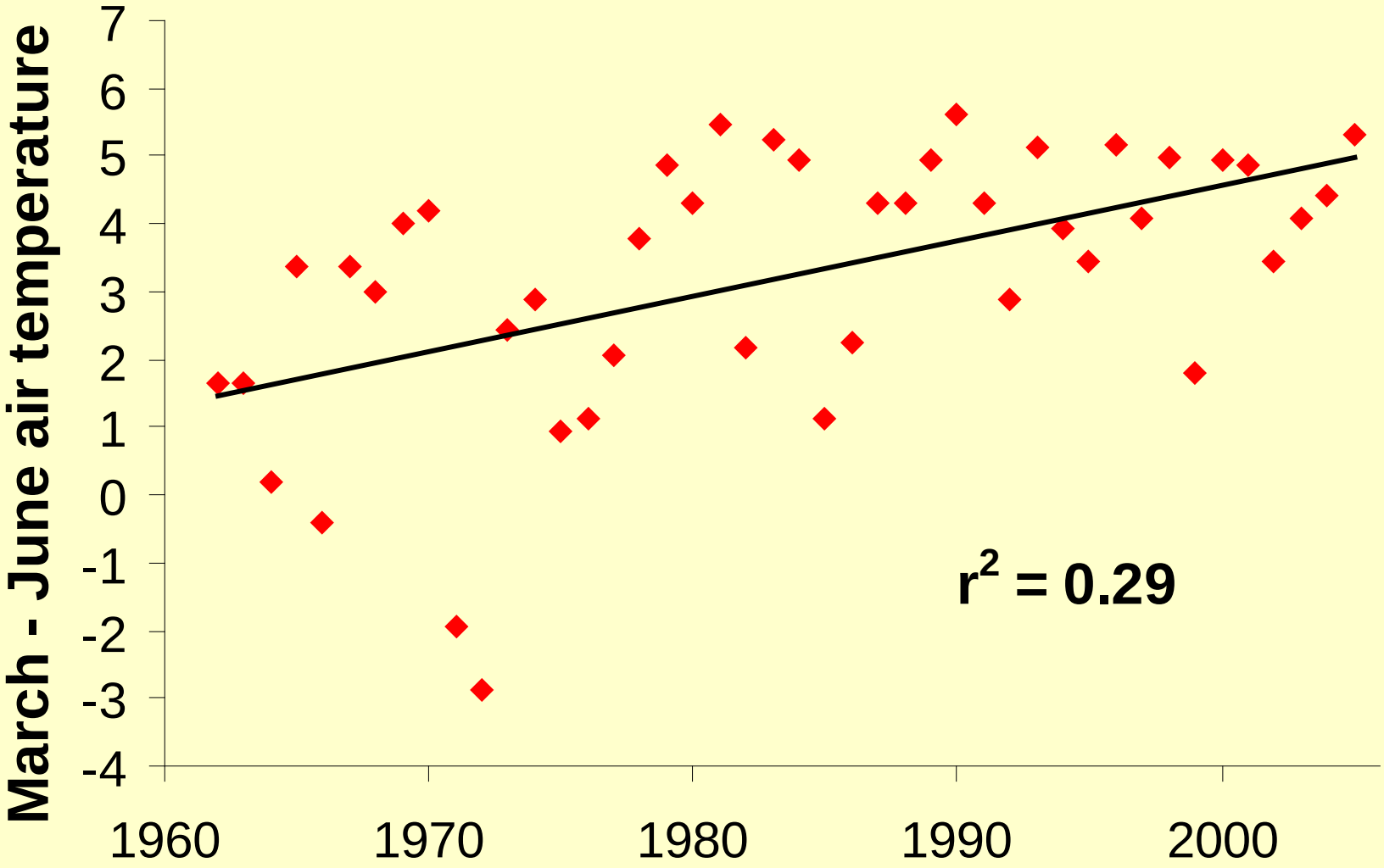
Warm Phase

Cool Phase

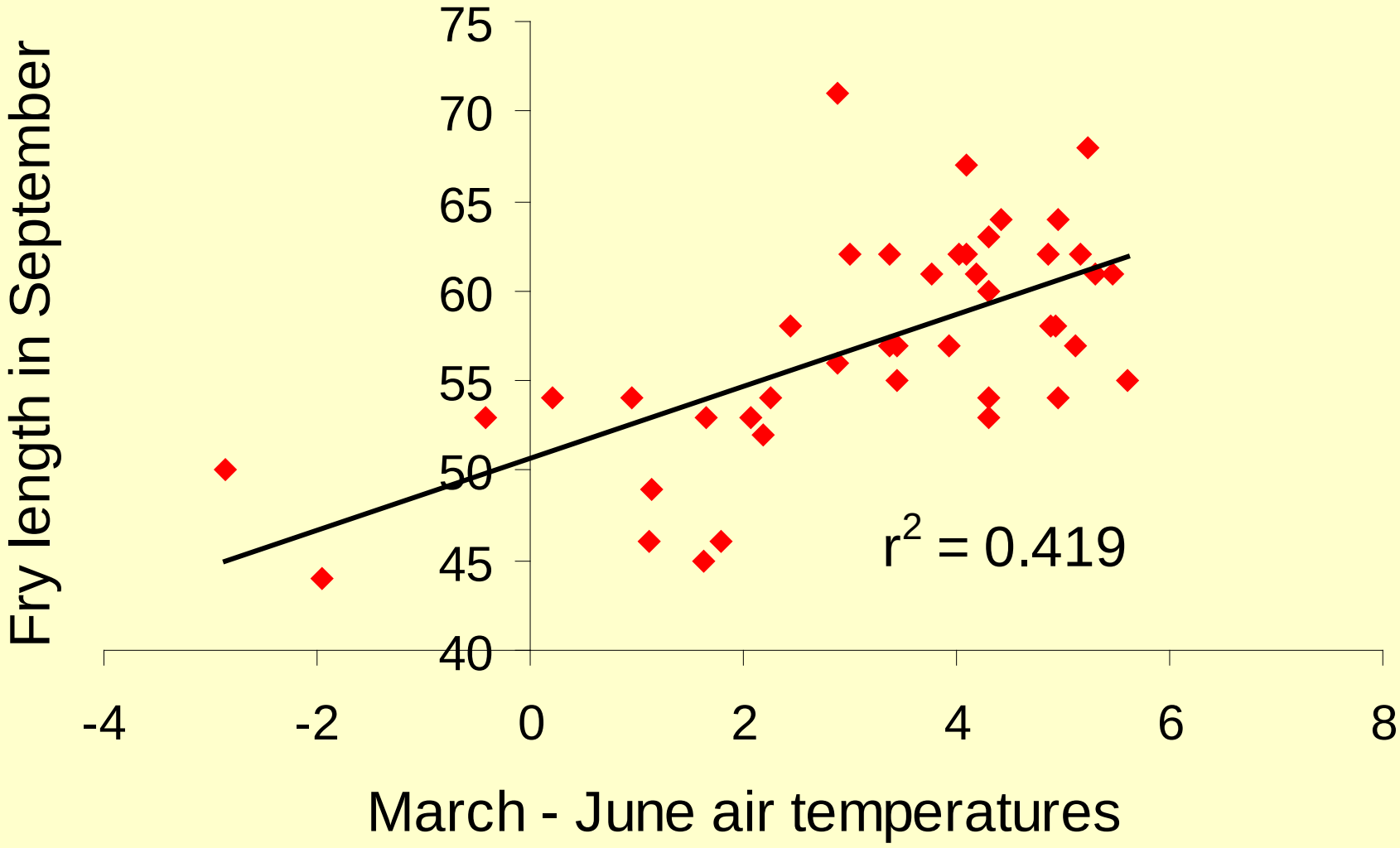


http://tao.atmos.washington.edu/pdo/

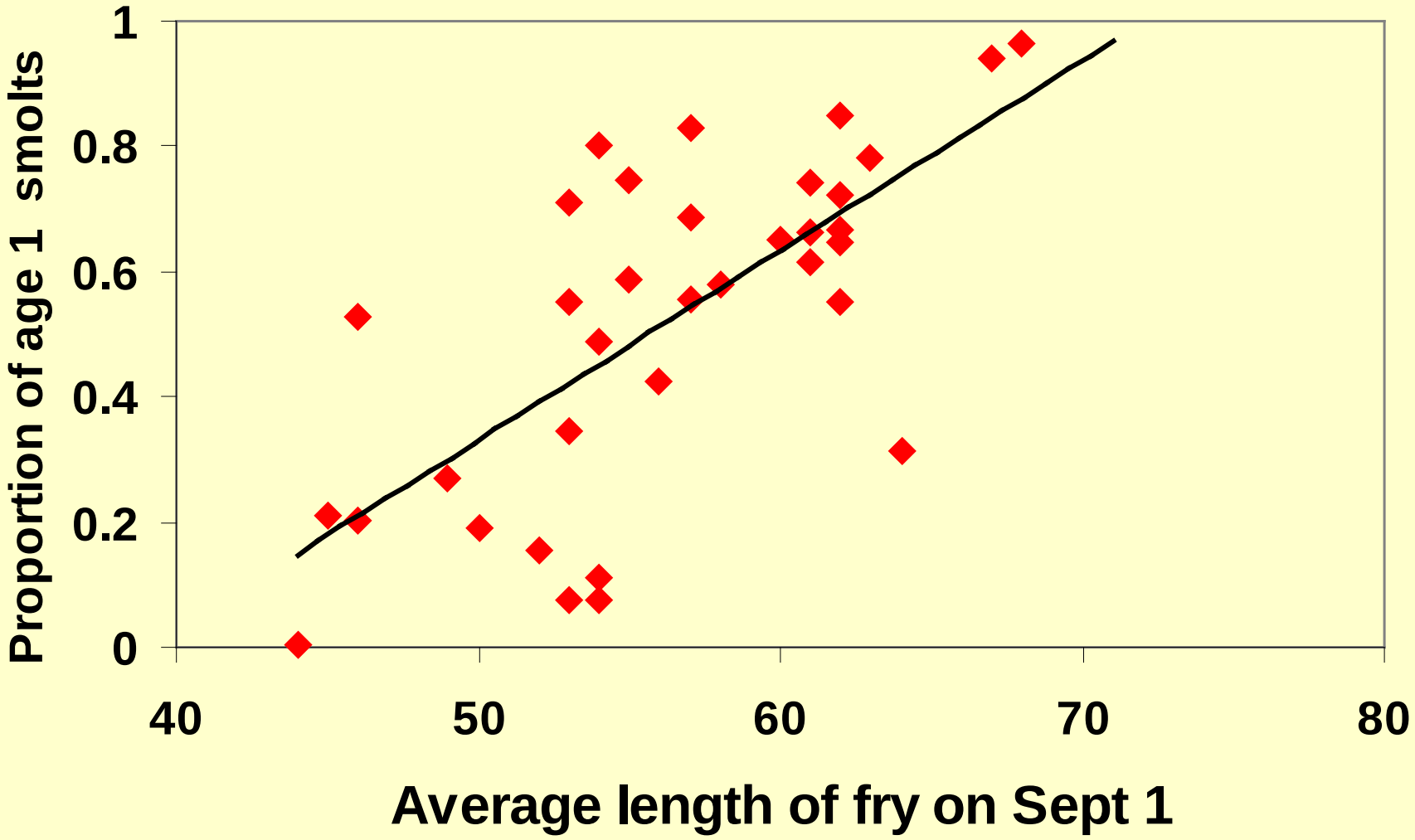
Environmental variation is evident in long-term records



Warm conditions accelerate juvenile sockeye salmon growth in Iliamna Lake



When fry grow rapidly, they tend to leave the lake after 1 rather than 2 years. Unfortunately, these young smolts have much lower survival rates at sea than older smolts.



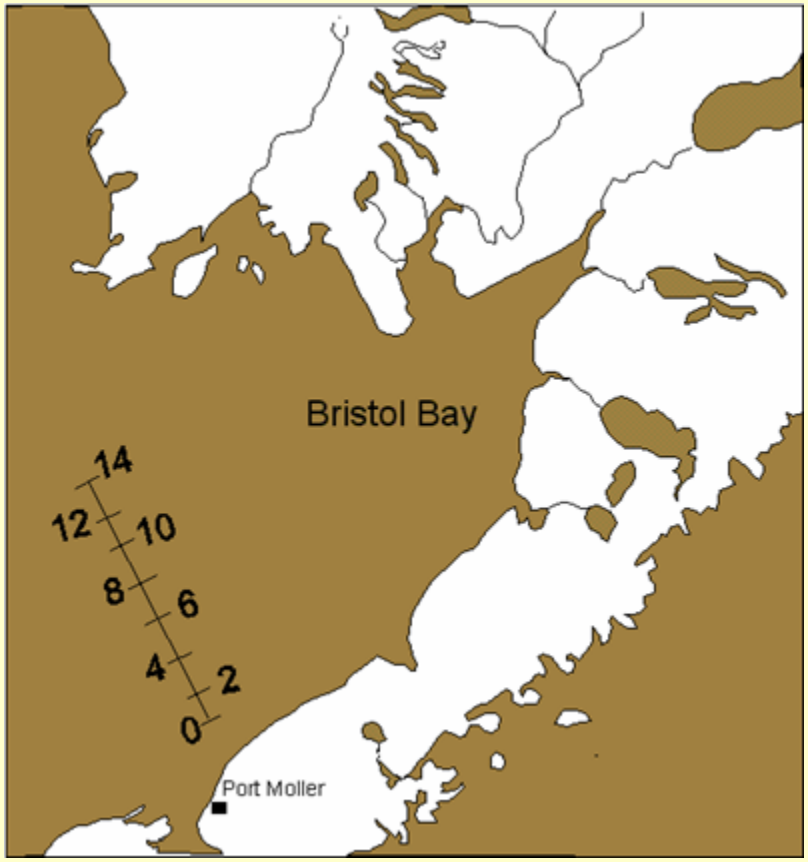
The salmon display diversity and variability but what about the fisheries?

Fisheries: The human biocomplexity

- 2000 drift gillnet boats (mobile but costly)
- 1000 shore-based “set net” permits
- Subsistence fisheries (very local)
- Commercial fisheries: 25 June to 15 July
- The huge runs (tens of millions), short season, remote location, and big tides all constrain the fishing and processing

Fisheries management

- First a pre-season forecast
- Then a test fishery to estimate run size and age composition about a week before fish enter the districts



Commercial catch sampling and tower counts of the escapement

District and in-river test fishing

Used to estimate the buildup of fish in a commercial district since the last opening, and the number of fish between the commercial fishery and the escapement tower, respectively.

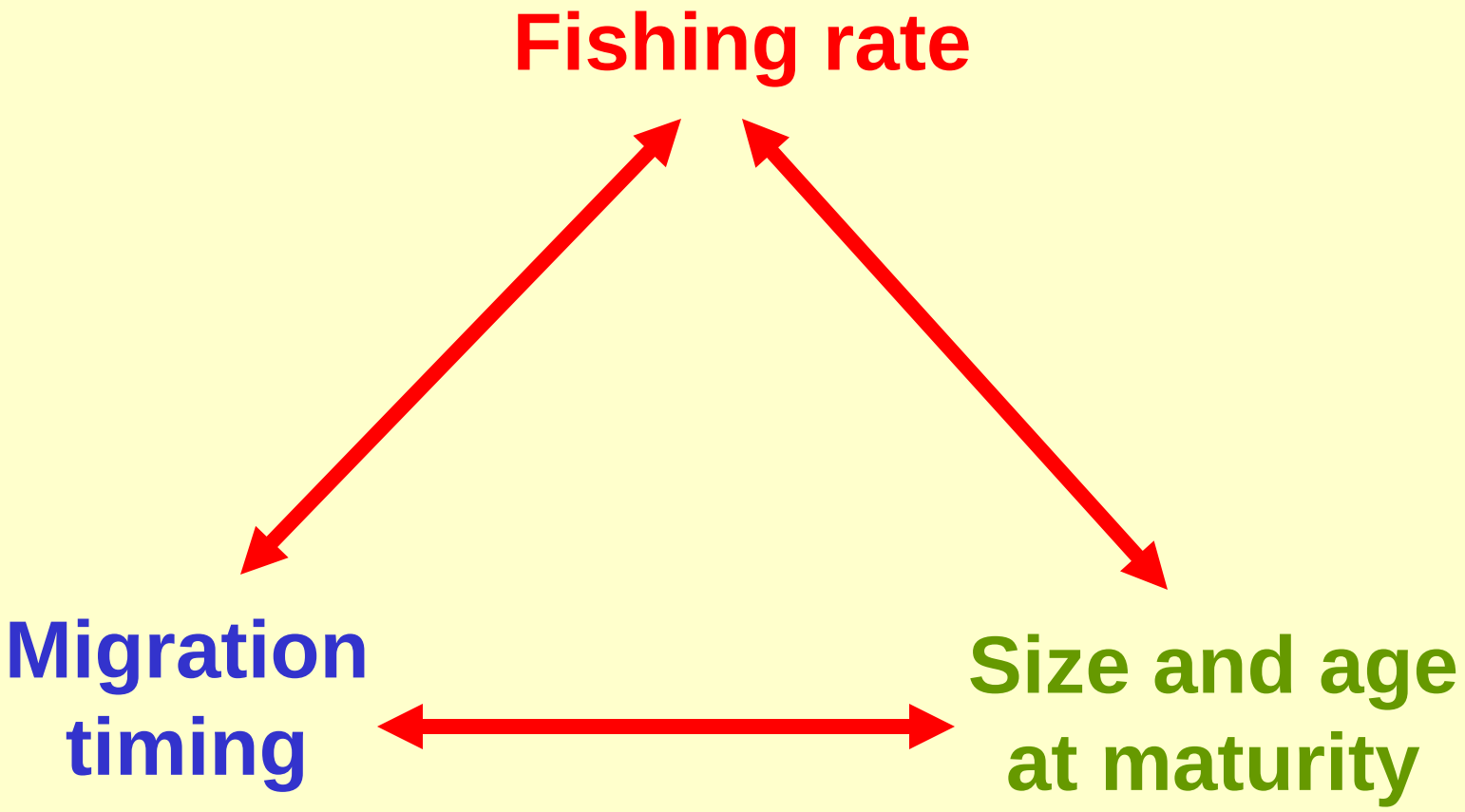
Lots of scale reading for age analysis, and lots of stressful meetings

Helpful input from famous UW professors

A key to this sustainability is management by escapement goal

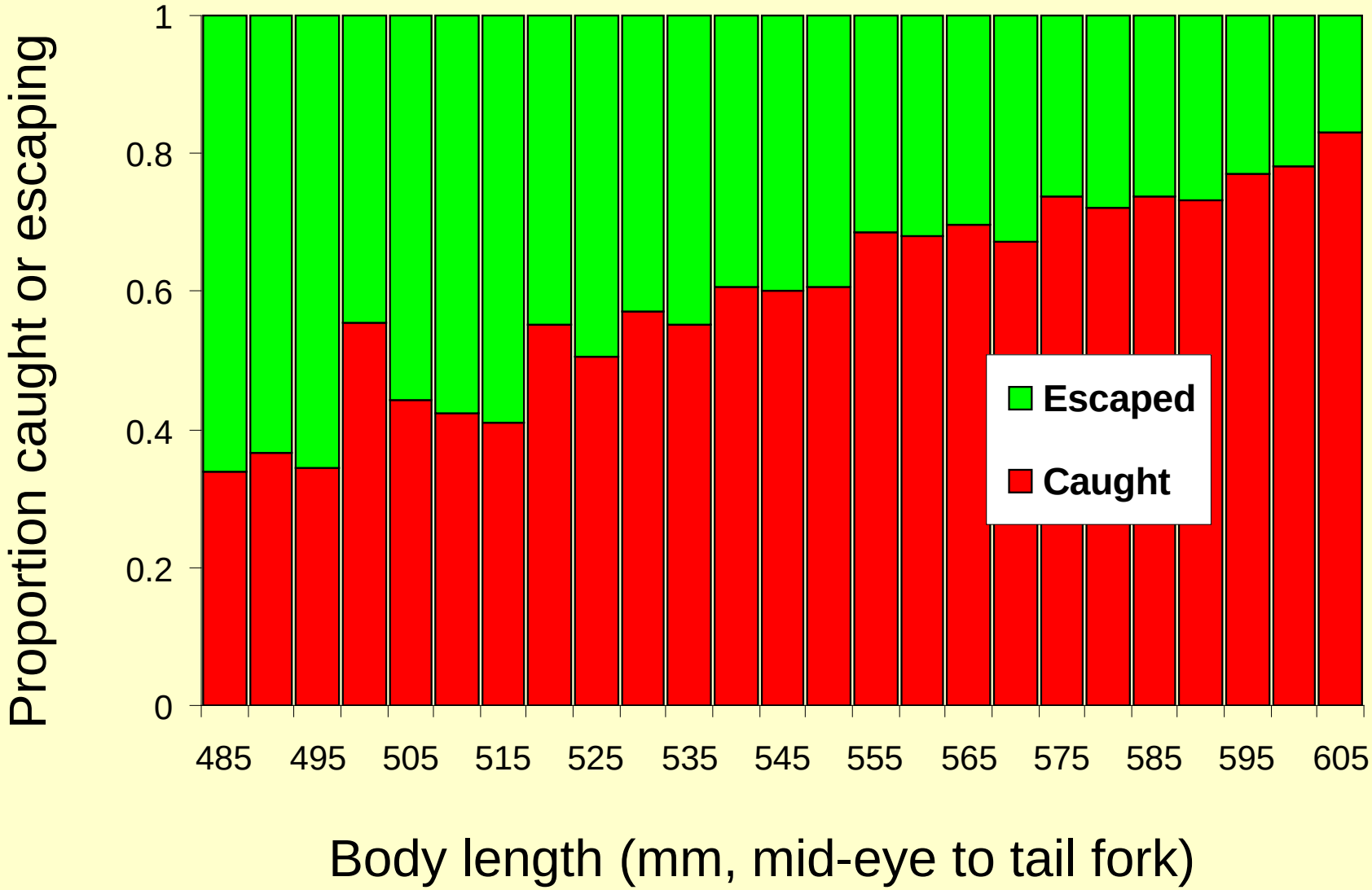
The fishery is regulated to assure that a target number of fish “escape” the fishery to spawn, assuring the long term productivity of the stock.

However, discrete breeding populations cannot be managed separately, only counted after the fisning is over.

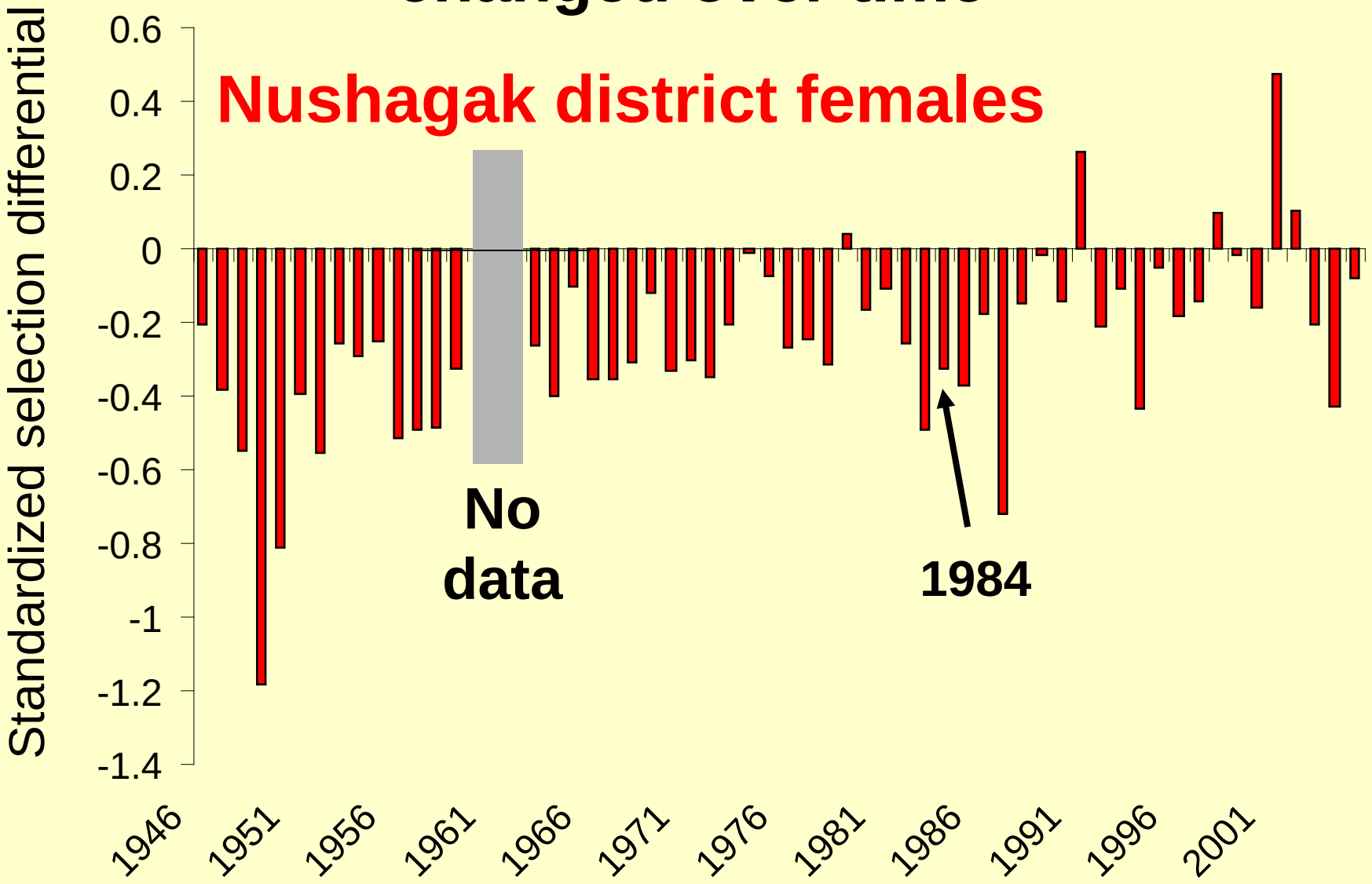


Fishing can have selective effects within populations, and on entire populations within a system

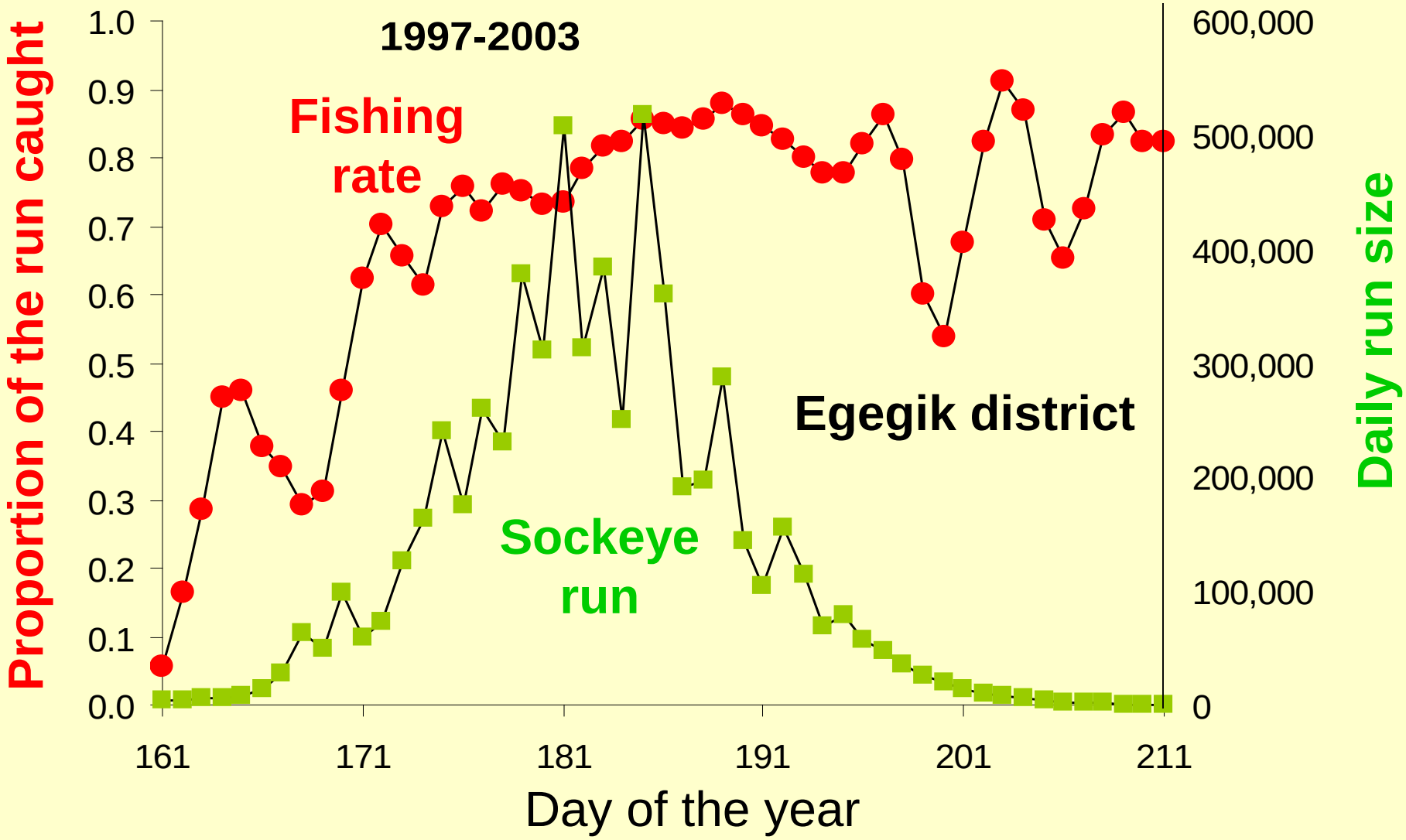
The fishery tends to catch larger fish (e.g., Nushagak district females, 1984)



The fishery selection patterns have changed over time



Fishing may be restricted early in the season until it is clear that the escapement goal will be met; fishing then increases.



Date - selective fishing could:

- Over-exploit late-migrating populations
- Over-exploit late migrants within populations


31899
BEER BOTTLE MAMA
44260
JOE MAMA


Photo: Robert Kope

Photo: Robert Kope


64437

Bristol Bay has the largest subsistence salmon harvest in Alaska: ~ 148,000 fish/yr

Photo: Carol Ann Woody

Geography and fisheries

- **Fisheries differ in:**
  - potential income
  - cost of operations
  - mobility (response to run fluctuations)
  - native participation
  - value to local economies
  - interception of single or mixed stocks

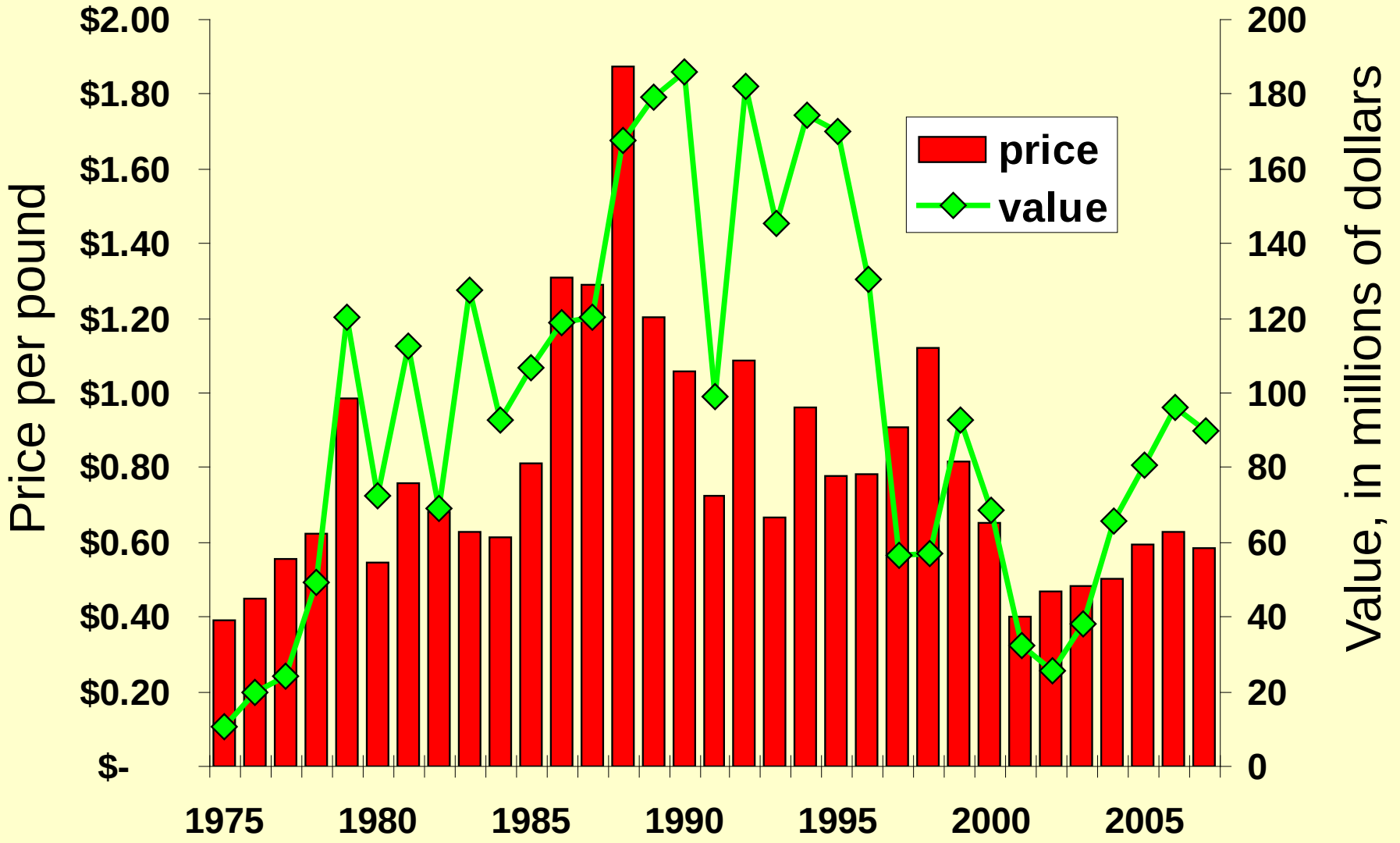
Bay-wide success or local failure?

- Huge runs to one district provide no benefit for set net fisheries elsewhere, and subsistence fishermen at “the end of the line” rely on the system reaching its escapement goal

The human side of the story

- For all of the excitement over the biological success, the social and economic success is mixed
- It was once possible to clear $50,000 in a 6 week season but no longer
- Permit prices plummeted

The economics of the fishery have varied greatly (even in un-adjusted dollars)



In 1988 a sockeye was worth about the same amount of money as a barrel of oil but today the same salmon is worth about the same as a Big Mac.

?

Salmon net pens in Chile

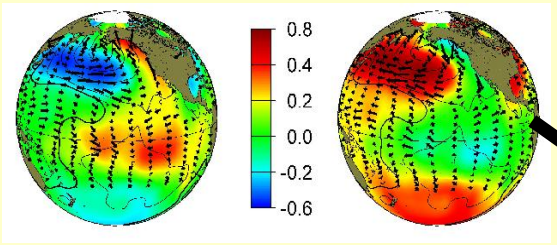
The biocomplexity of Bristol Bay

The fleet

$ $

The managers

The climate



The fish

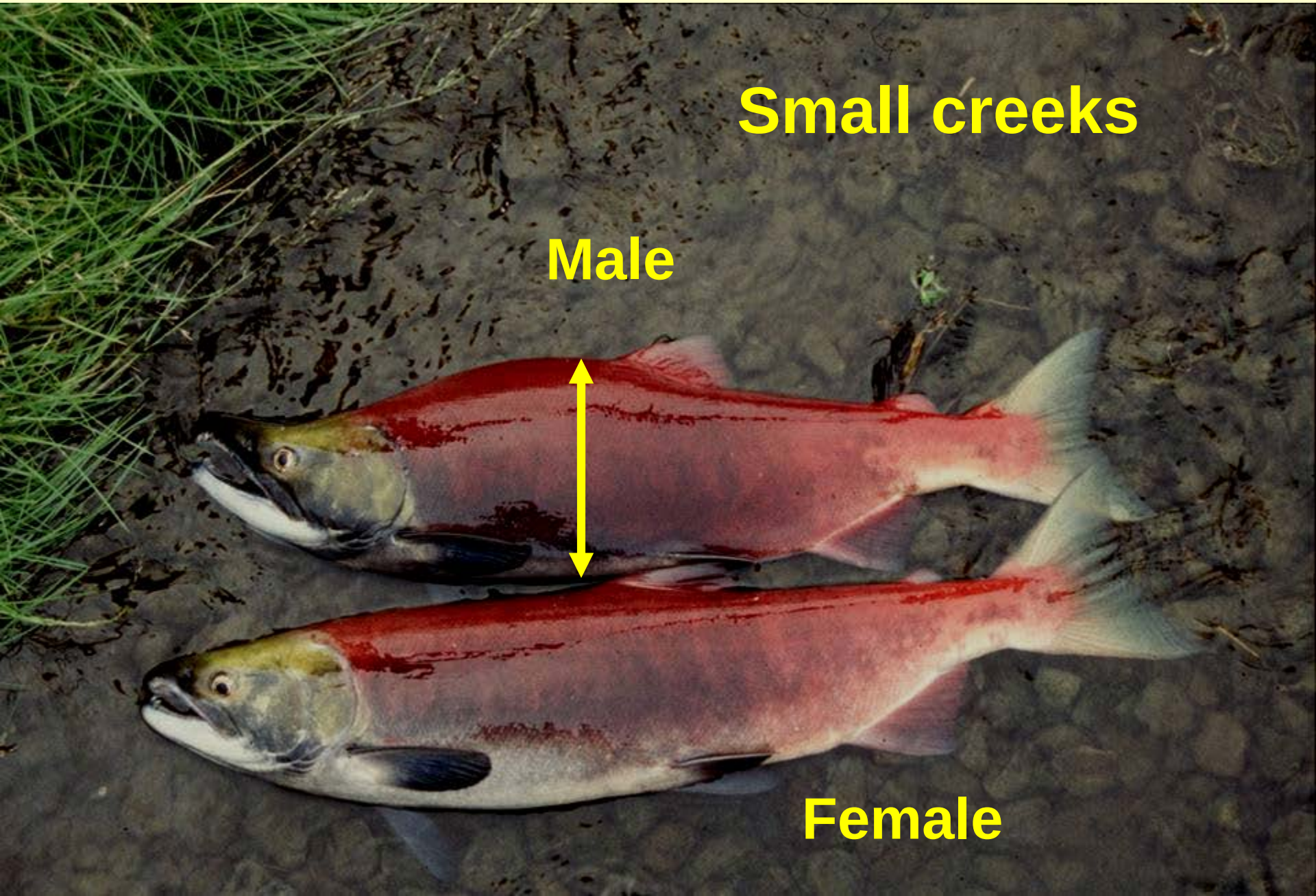
General Lessons

- **Biocomplexity stabilizes total productivity over a range of spatial scales in both fish and human systems**
- **Systems that are productive in one epoch may be much less productive in other epochs**
  - **Maintain the stock structure**
  - **What seems unimportant now may be very important later**
- **The regulatory structure must allow human systems to adapt**

Acknowledgements

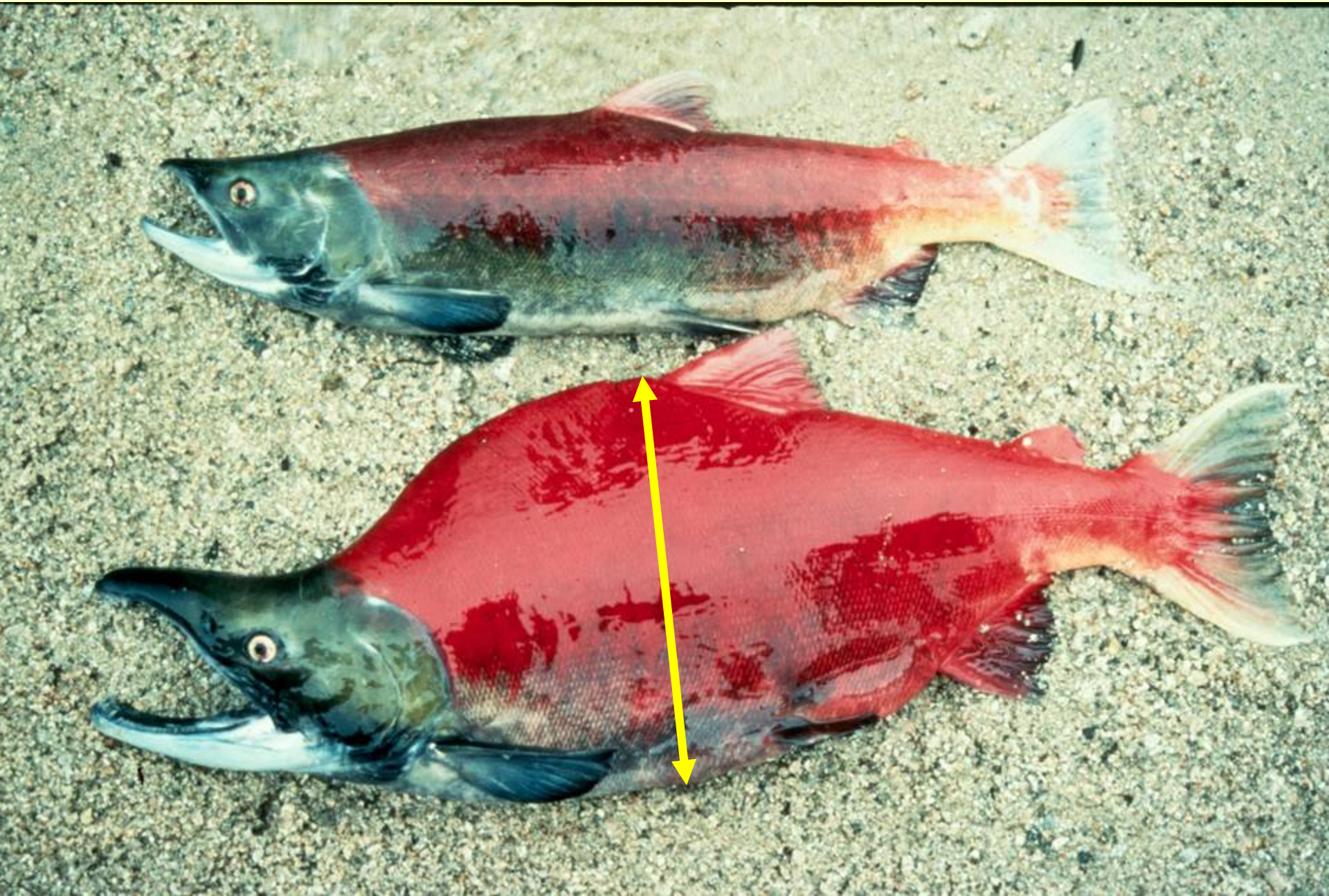
- The FRI pioneers who started the program
  - Bud Burgner, Ole Mathiesen, Don Rogers
- Ray Hilborn, Daniel Schindler, and the field crews
- Alaska Department of Fish and Game

Morphology differs among habitat types

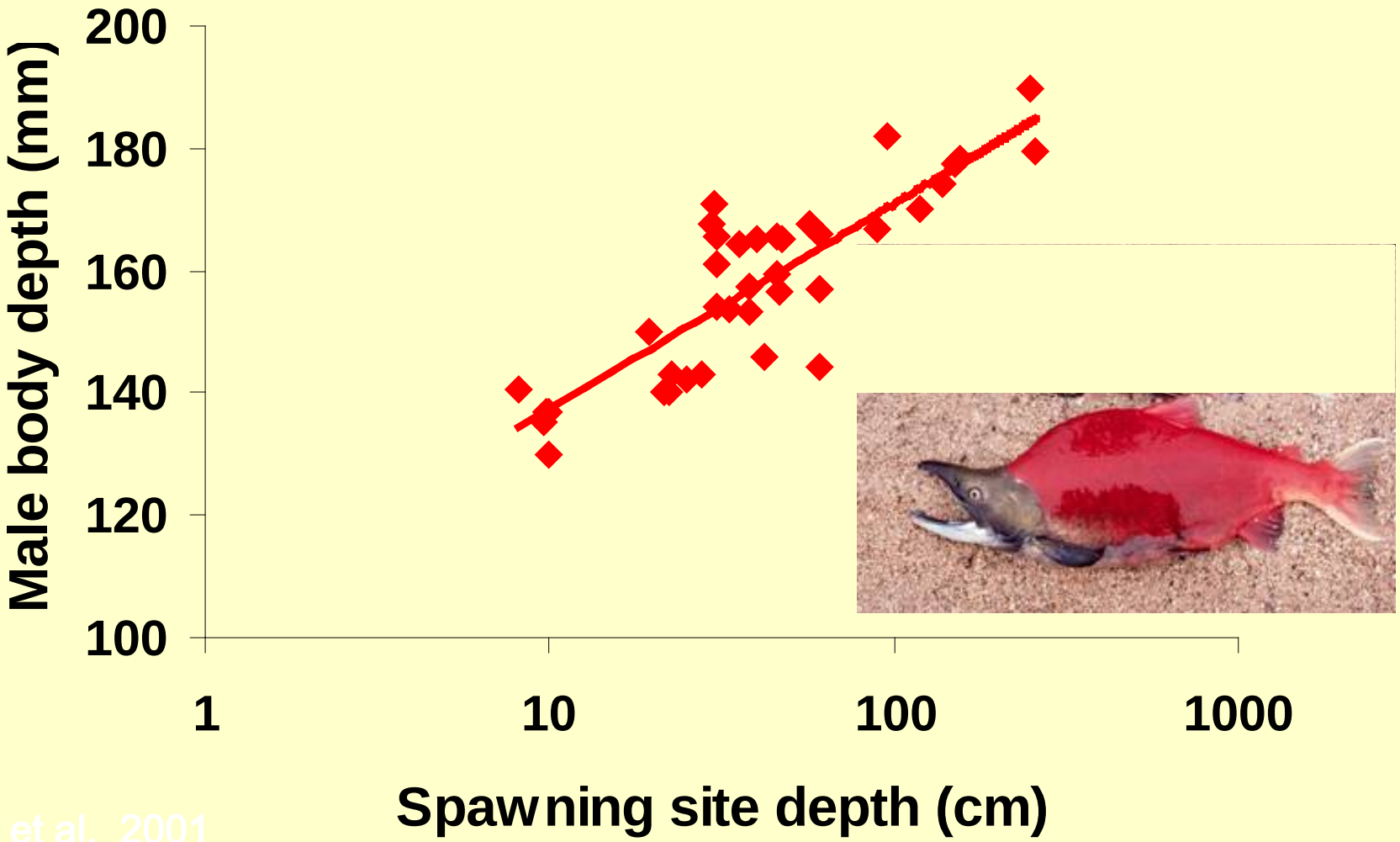


Sockeye from larger creeks and rivers

Beach spawning sockeye salmon



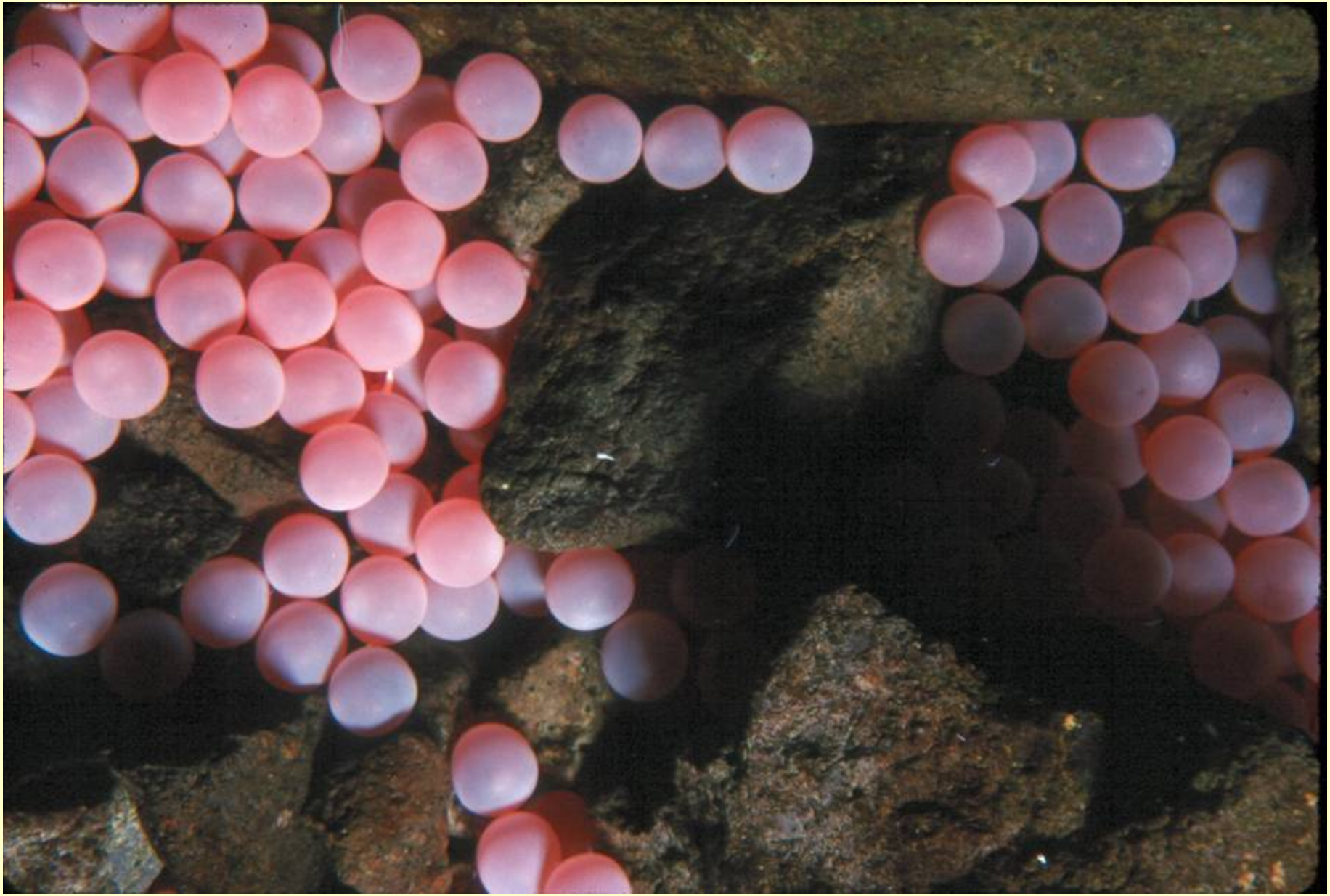
Depth of the spawning site and body depth of male sockeye salmon



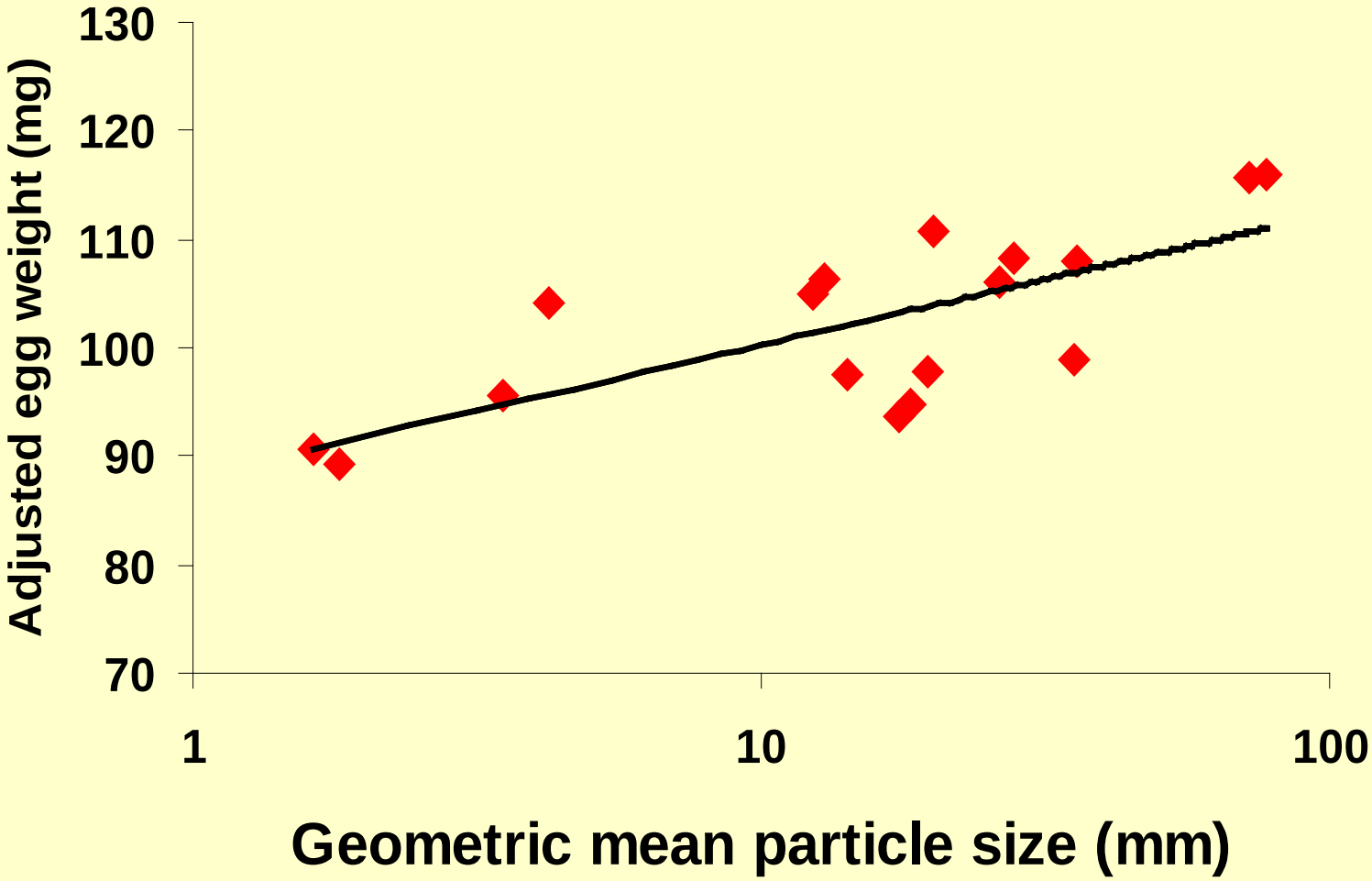
Quinn et al. 2001

Otolith collections reveal consistent differences in age structure and length at age

Average egg size is correlated with gravel size



Gravel size and egg size of different sockeye salmon populations



Quinn et al. 1995, and additional unpublished data