# Changes in sockeye salmon populations over the past 2,200 years: Inferences from lake sediments

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# Overview

- What have we learned from 20th century records?

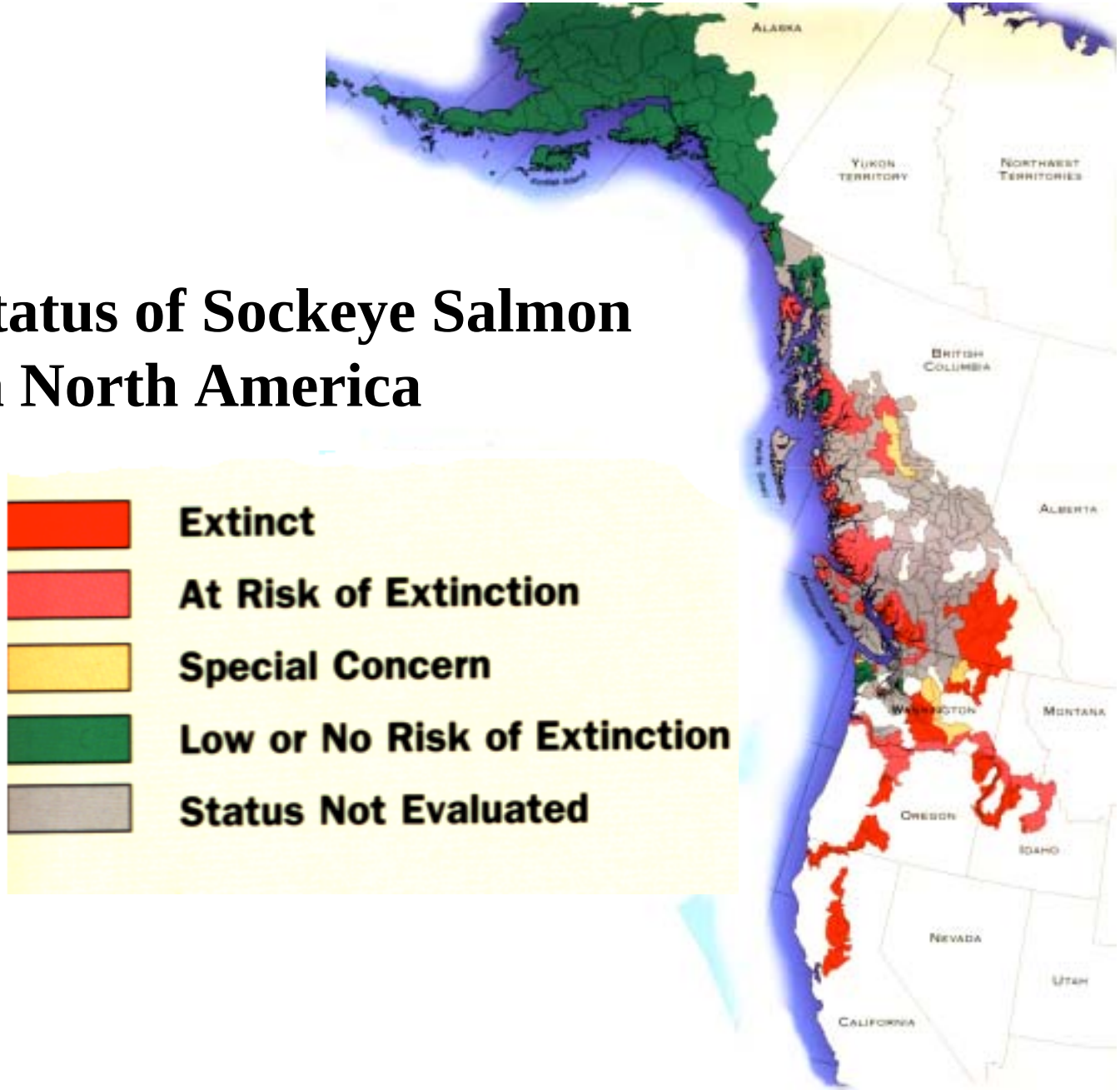
- What can we learn about salmon by studying lake mud and how is this done?

- How have salmon abundances varied in Alaska over the past 300 yrs?

- How have salmon abundances varied over the past 2200 years?

- Ongoing and future directions

# Status of Sockeye Salmon in North America




Source: Wolf and Zuckerman, 1999

# Stressors affecting salmon abundances: the 4 H's

## Harvest

Photo by Natalie Fobes, 1995

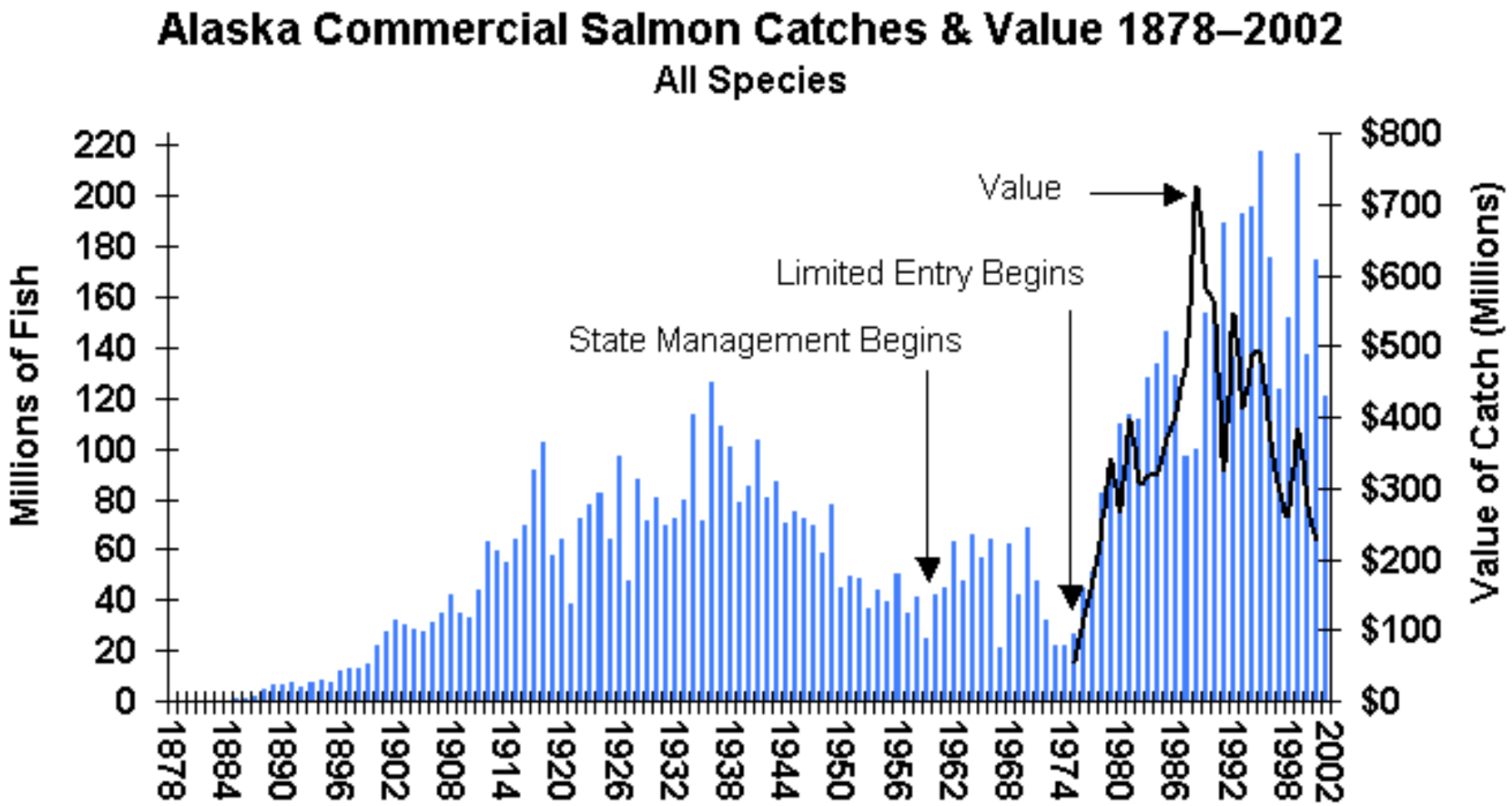
## Habitat destruction

Photo by Natalie Fobes, 1995

## Hatcheries

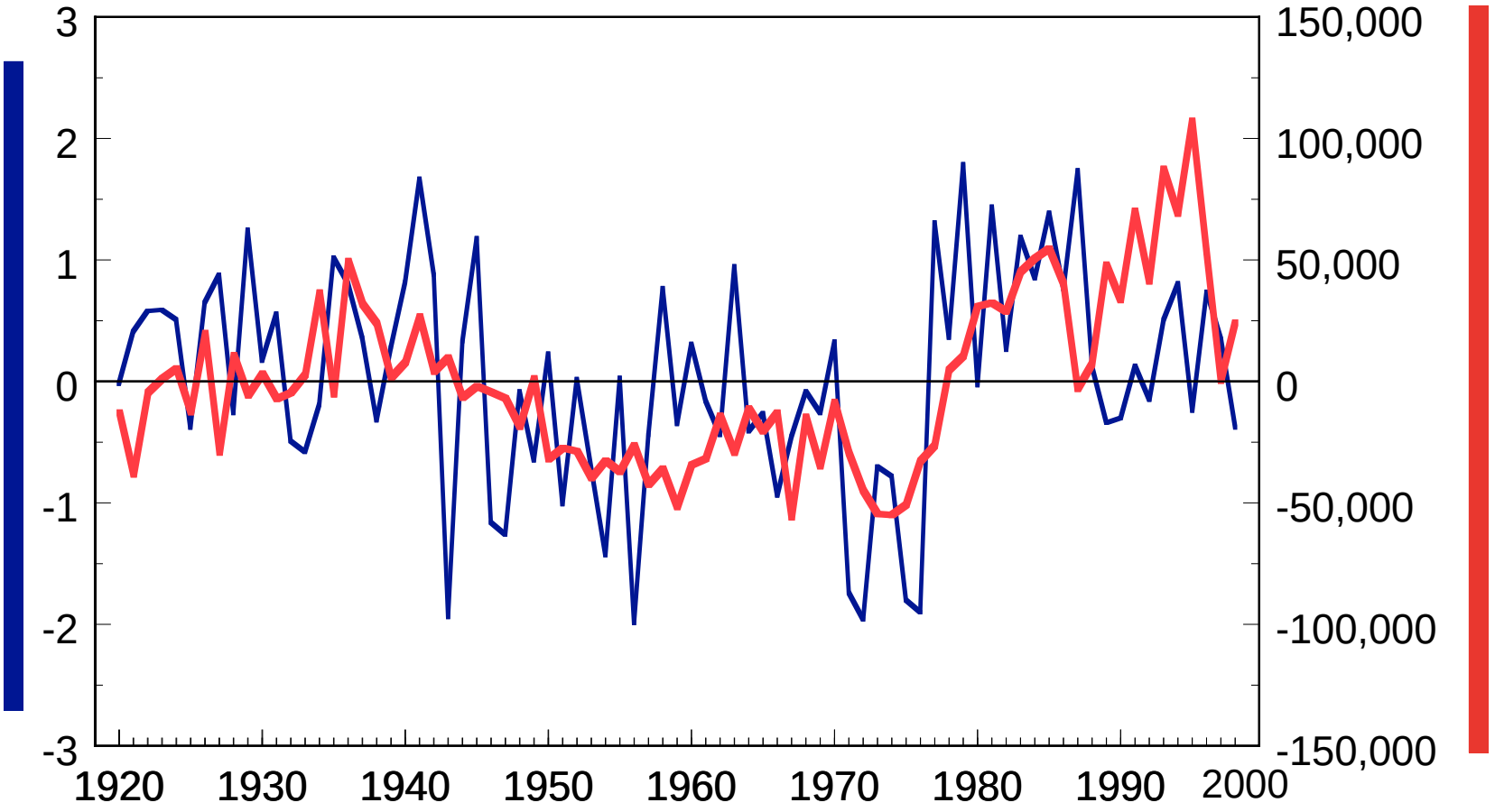
http://jcomm.uoregon.edu/~josh/salmon/mrh.html

## Hydropower



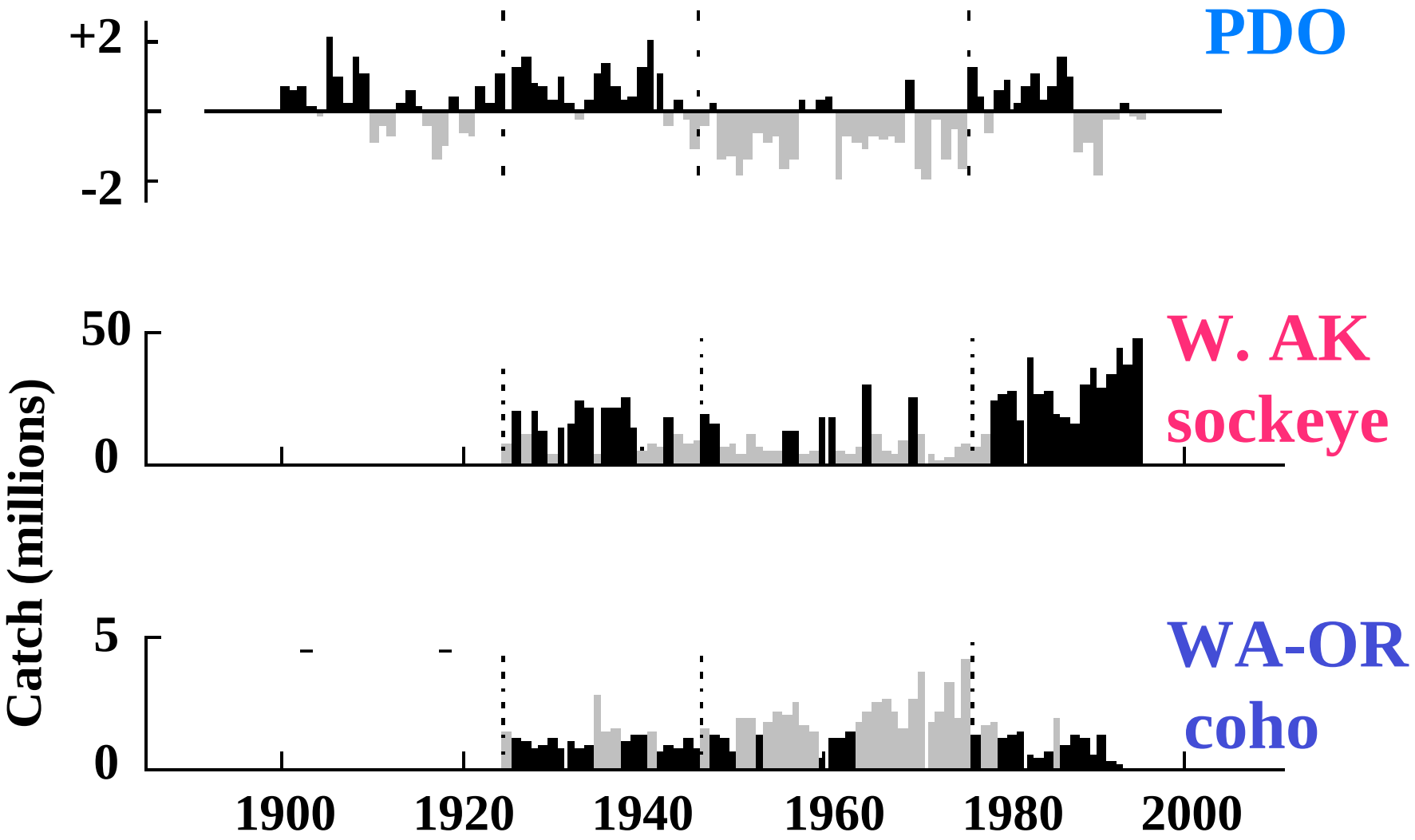

http://www.cf.adfg.state.ak.us/geninfo/finfish/salmon/catchval/history/all_1878.htm

# Alaskan salmon harvest co-varies with winter temperatures from the Gulf of Alaska



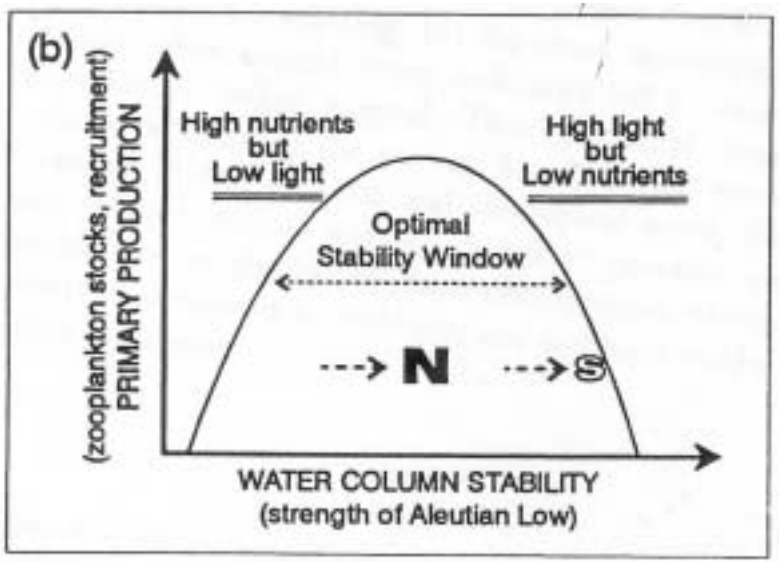

Data provided by Stephen Hare and Gunnar Knapp

# PDO vs. Alaska and Pacific Northwest Salmon



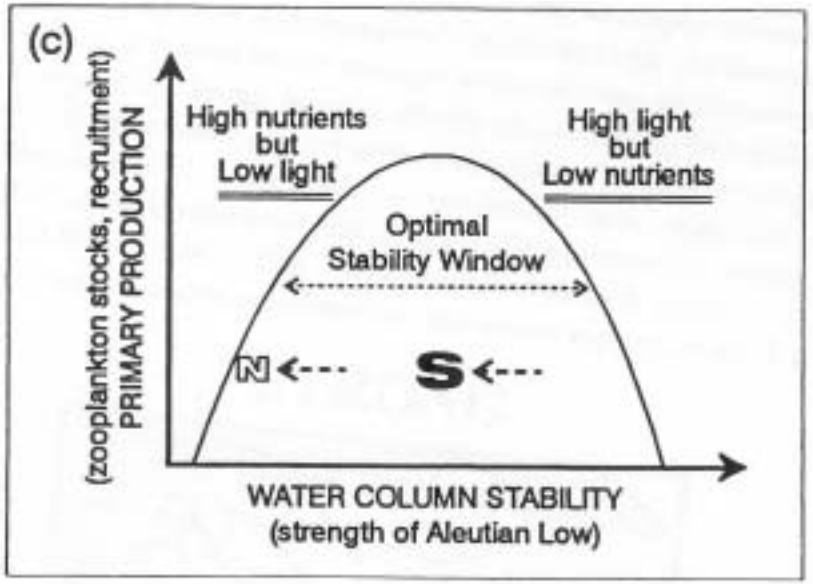

Mantua et al. (1997)

# Link between climate and salmon likely an indirect one, driven by changes in ocean productivity




**During +PDO, warmer coastal temperatures result in greater water column stability which favors production in north but not in south**

**During -PDO, cooler coastal temperatures result in less stable water column which favors production in south but not in north**

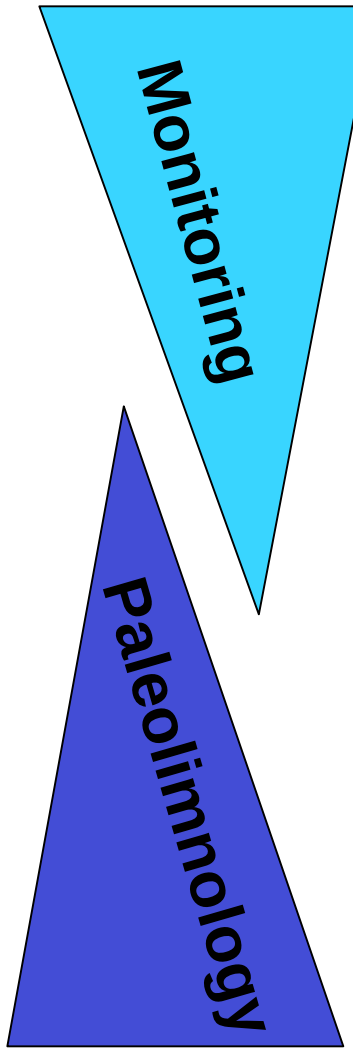



Gargett, 1997

# Summary from 20th Century records

- **Historical records of salmon abundances complicated by multiple stressors and influences**
- **Periods of salmon abundance in AK correspond to warm coastal temperatures/ +PDO and are likely an indirect response to climate, one mediated by changes in ocean productivity**
- **Alaska and PNW salmon abundance patterns are out-of-phase & show ~ 3 multi-decadal regimes**
- **Periodicity and persistence of regime shifts unknown due to short data set**

# Developing and applying a paleolimnological approach for reconstructing past sockeye salmon abundances




Hours

Days

Years

Decades

Centuries

Millenia

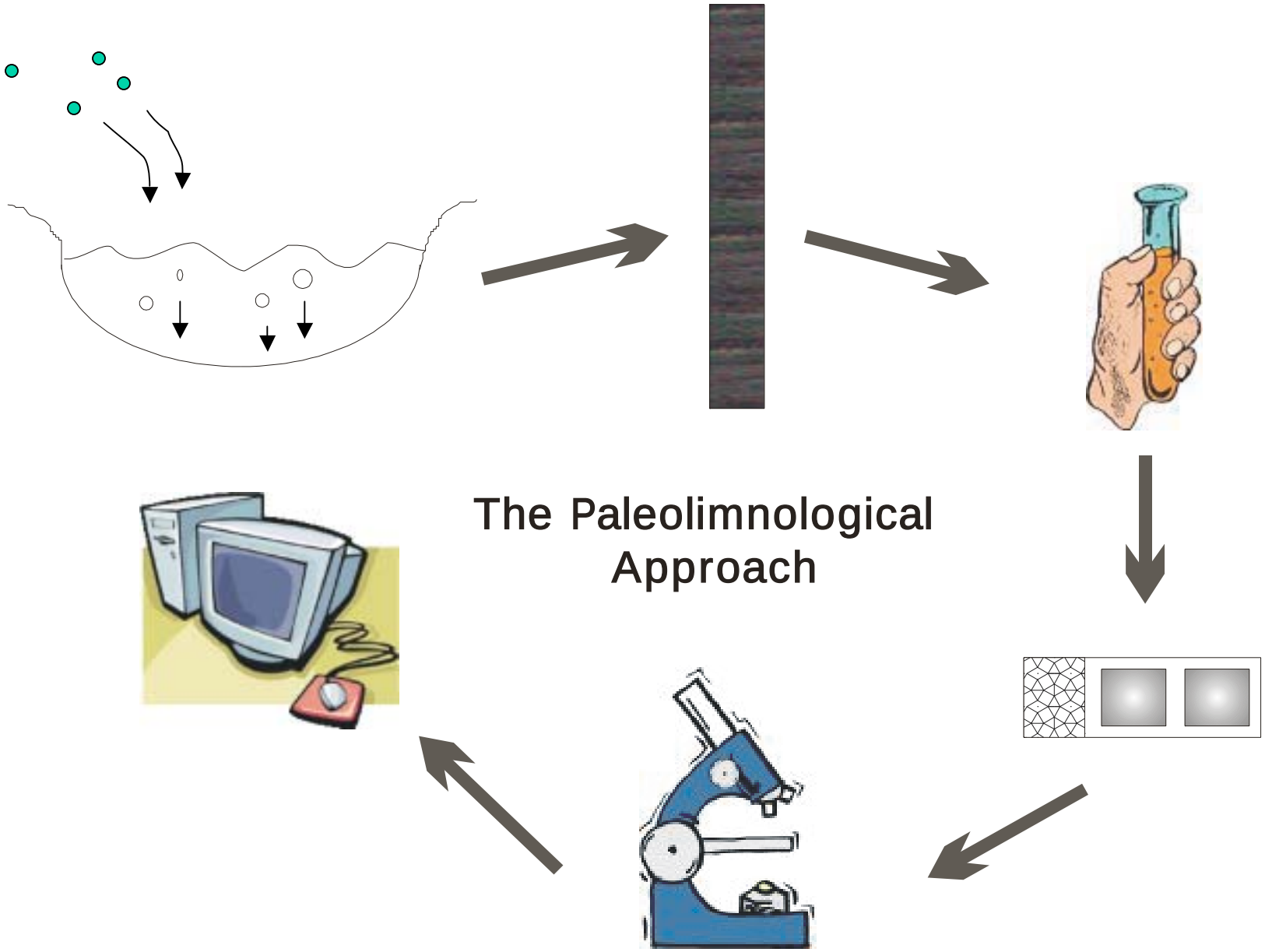
• **Paleolimnology**,

is the study of biological, chemical and physical indicators preserved in lake sediments to infer past environmental conditions

# A paleo-perspective may answer key questions in salmon management

- what are the patterns in salmon variability prior to the 20$^{th}$ century?
- can we attribute pre-20$^{th}$ salmon trends to climate variability?
- what has been the impact commercial fishing?

→ paleolimnological studies also allow us to reconstruct the food web dynamics of nursery lakes and explore the importance of “salmon-derived nutrients” in recruitment


The Paleolimnological Approach

## Salmon are recorded in sediments as a nutrient signal

-Shortly after spawning, sockeye die and their carcasses decompose

-in some lakes, salmon-derived nutrients are the largest source of nutrients to the nursery lakes

-organisms living in the lake respond to changes in nutrient loading and are preserved in the sediment

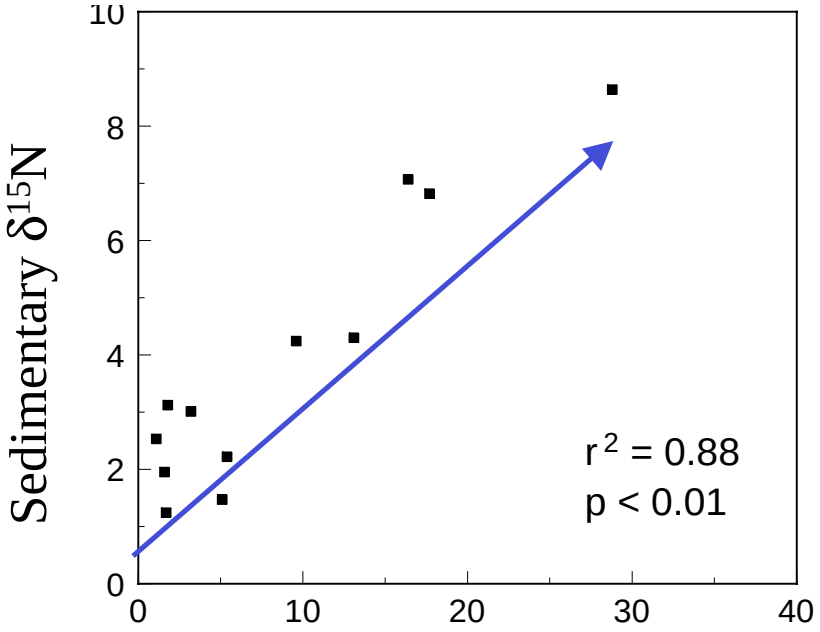
Photo by Hiromi Naito, 1995

# Our paleolimnological approach relies on a examining a suite of indicators

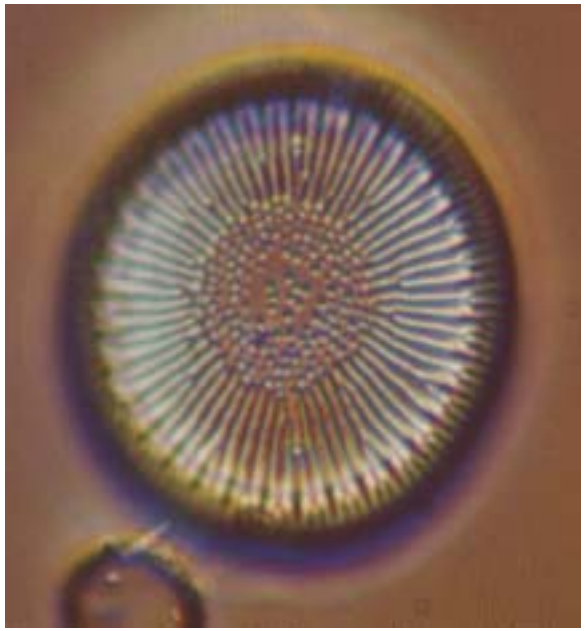
- $\delta^{15}N$

-represents a ratio of $^{15}N/^{14}N$

-salmon are enriched in $^{15}N$ & transfer this signal to nursery lake ecosystems




Finney et al., 2000

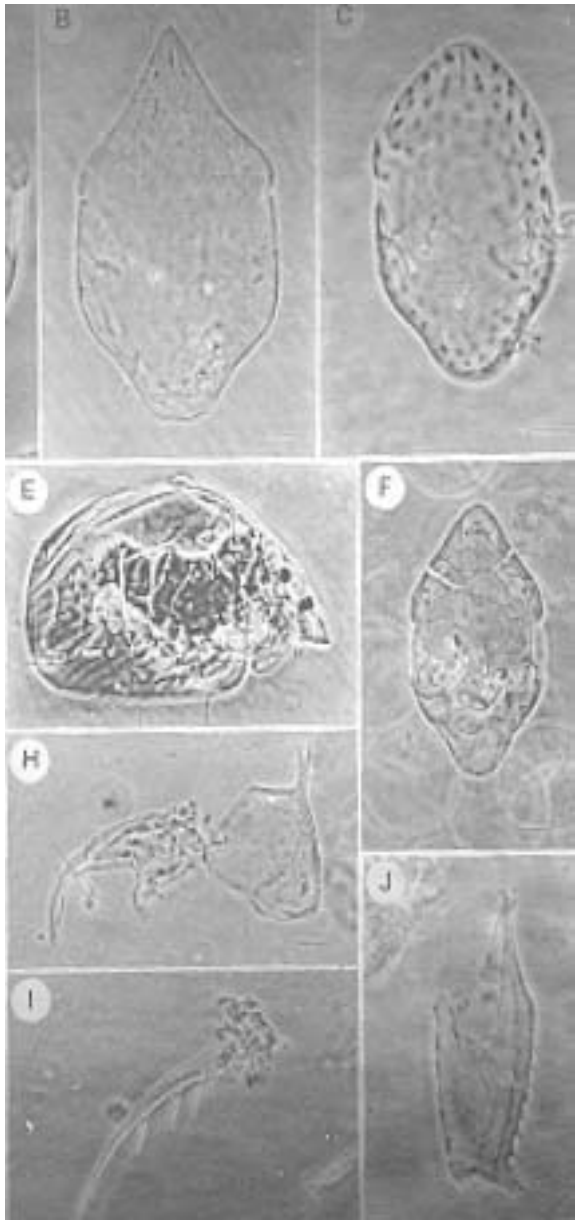


- **Diatoms**

-a group of siliceous algae that preserve well in lake sediments

- glass cell wall is used to make taxonomic identifications to species level or lower

-sensitive to changes in nutrients



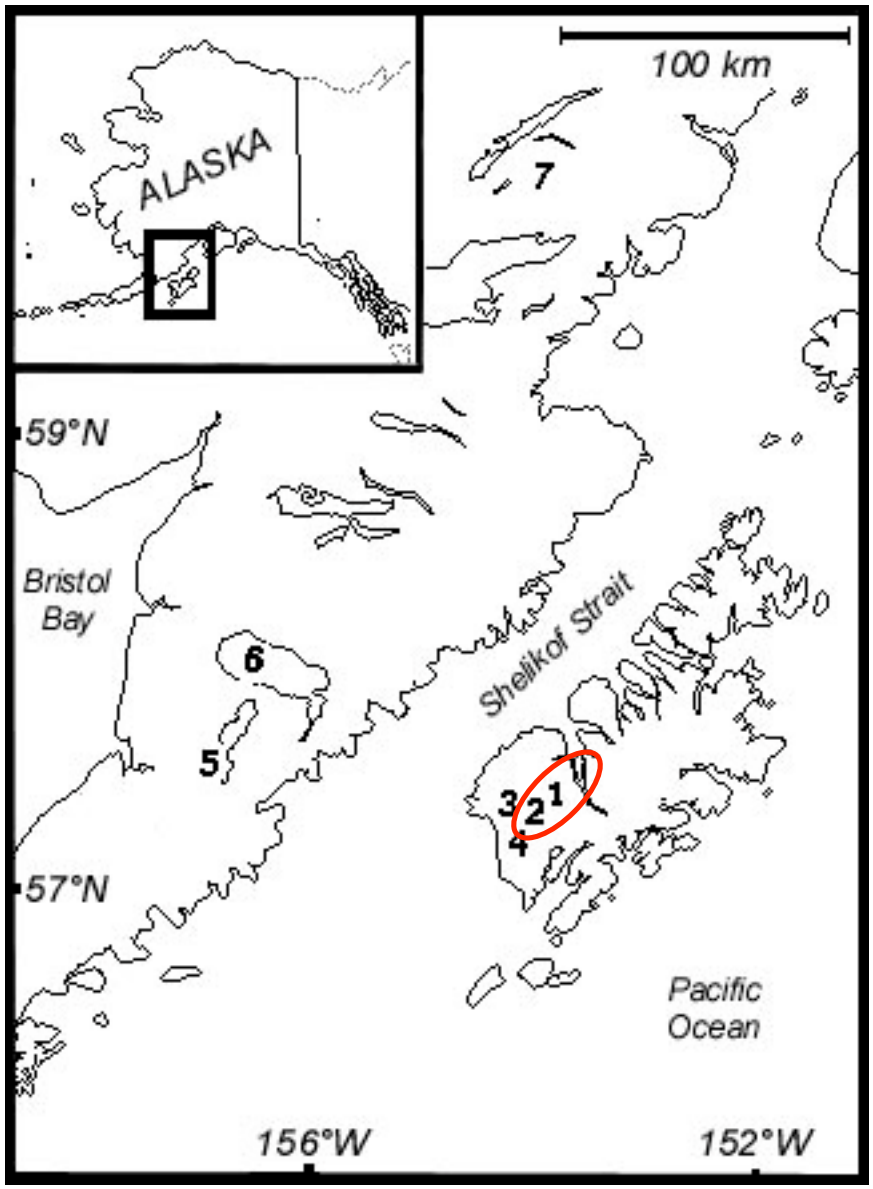

(Hann, 1990)

- **Cladocerans**

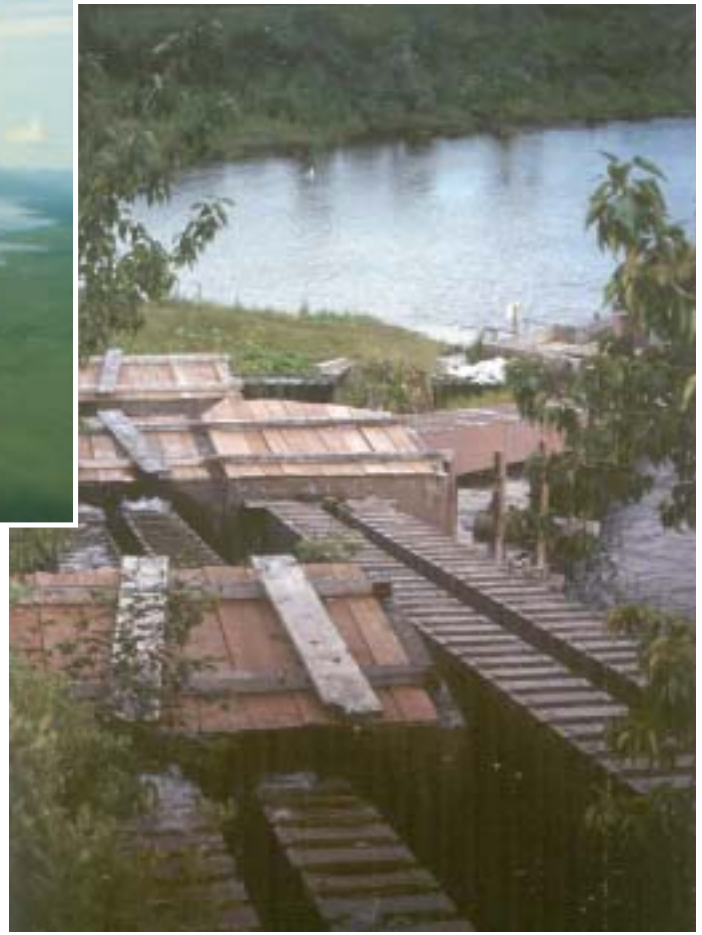
- a group of zooplankton

- their exoskeletons are made of chitin which preserves well in lake sediments

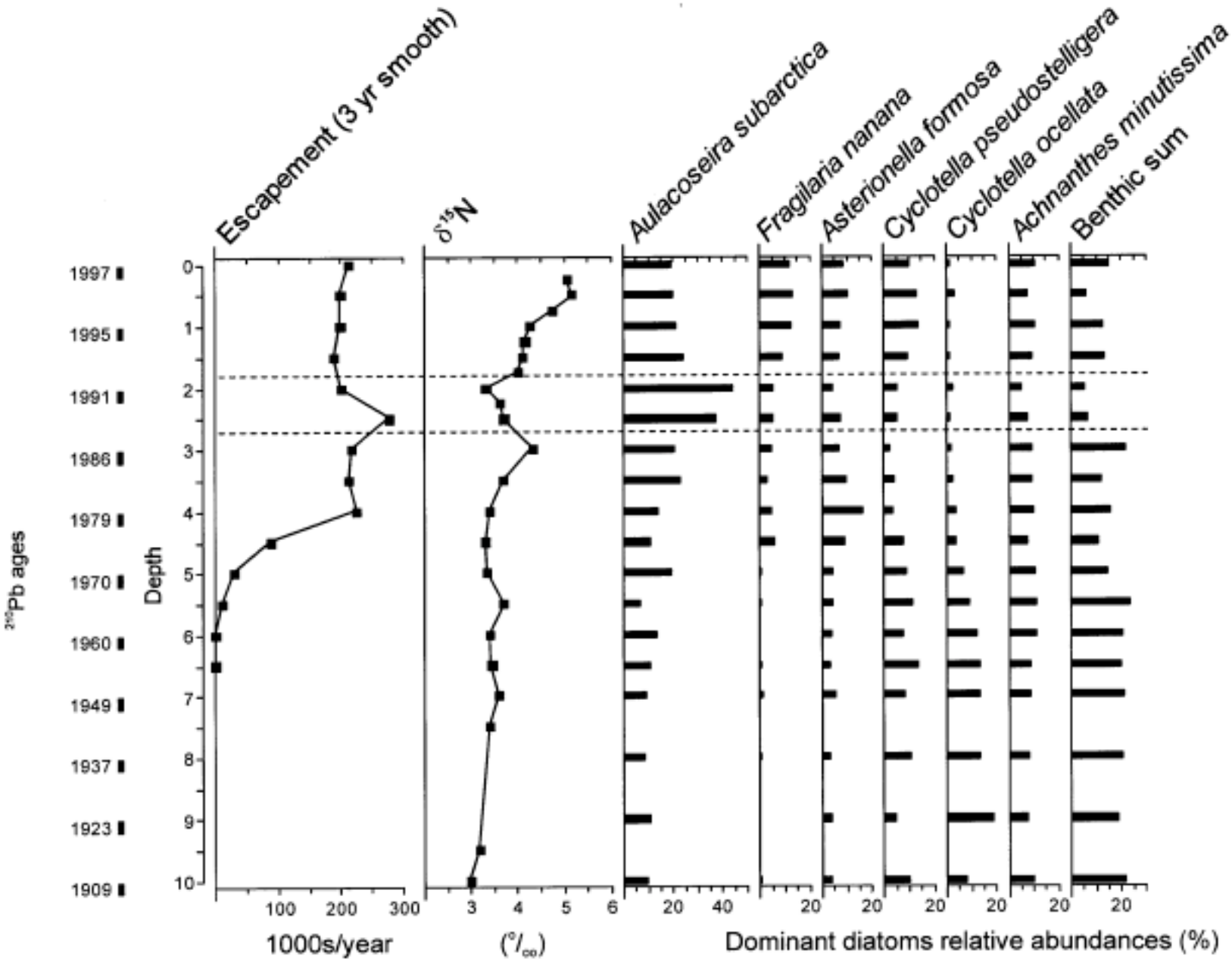
- occupy an intermediate position in trophic structure of lakes, therefore may reflect changes in salmon through a bottom-up response (i.e. linked with primary production) or a top-down response (i.e. predation)


ALASKA
100 km
7
59°N
Bristol
Bay
6
5
Shelikof Strait
1
2
3
4
57°N
Pacific
Ocean
156°W
152°W

**Frazer Lake (reference lake) has steep waterfall at lake's outlet. Fish ladders now allow passage over falls**



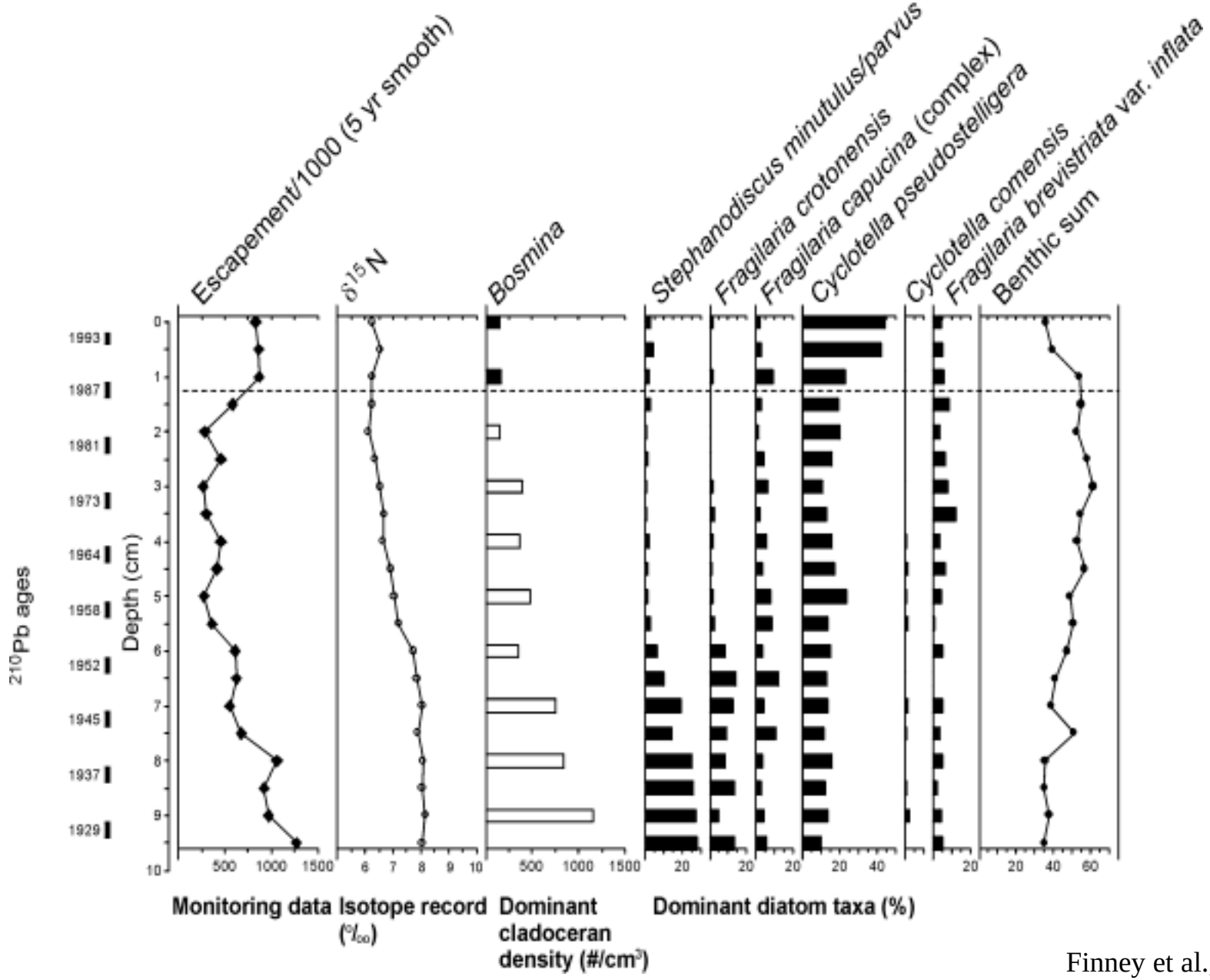
# Frazer Lake ~80 yr record




Gregory-Eaves et al., 2003

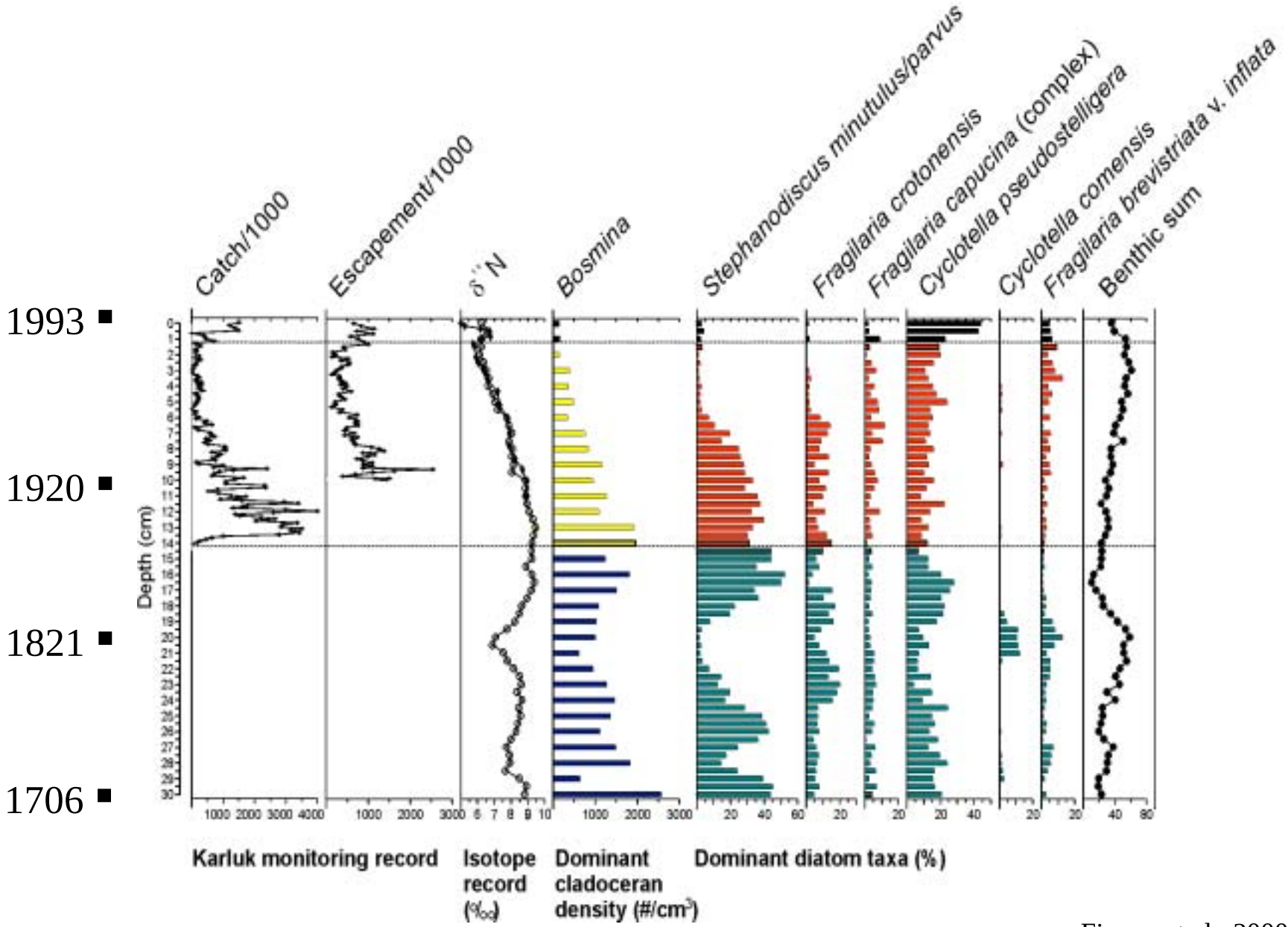
# Karluk Lake, a natural salmon lake with a long history

# Karluk Lake ~80 year record



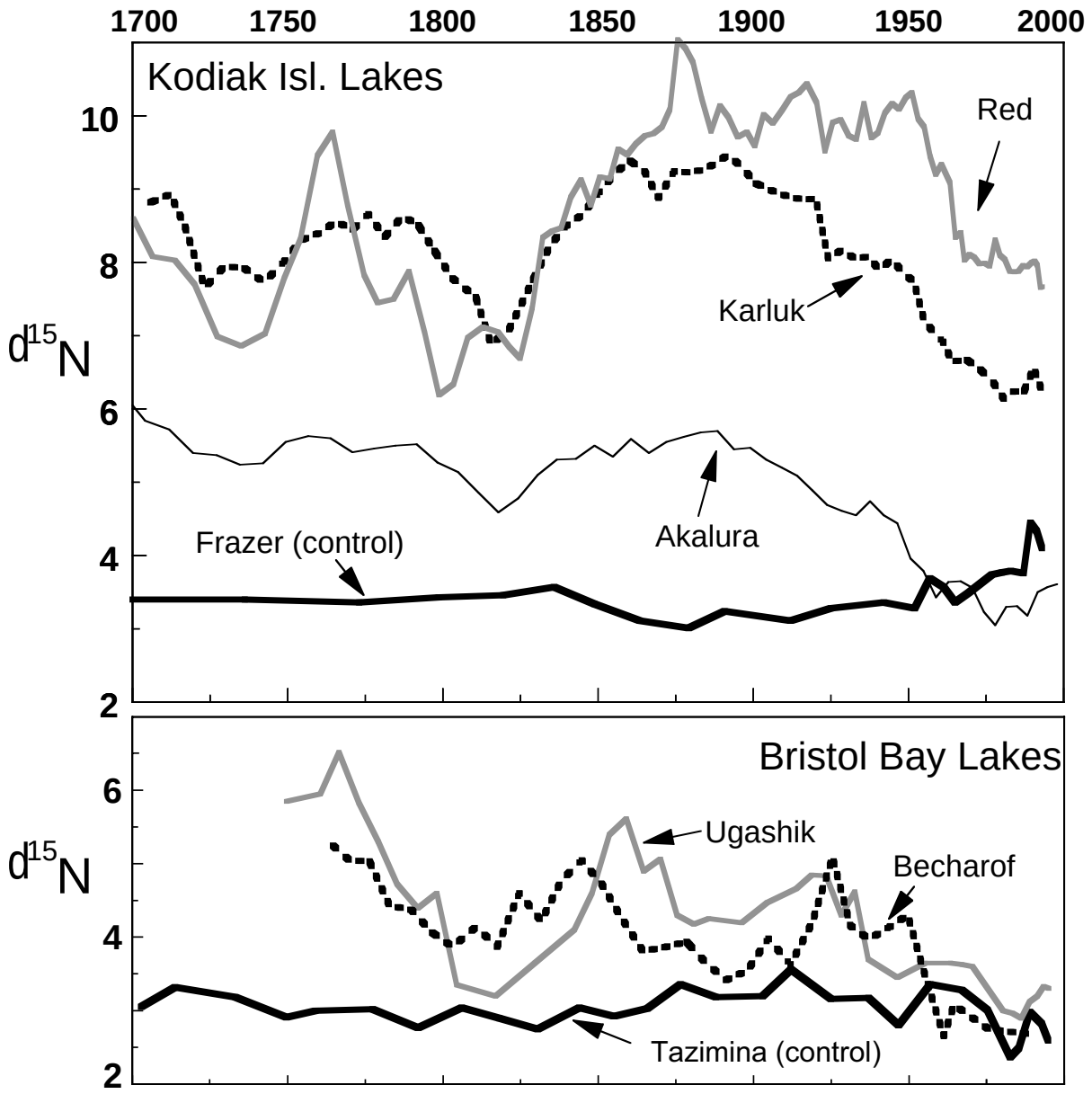

Finney et al., 2000

# Karluk Lake ~ 300 year record



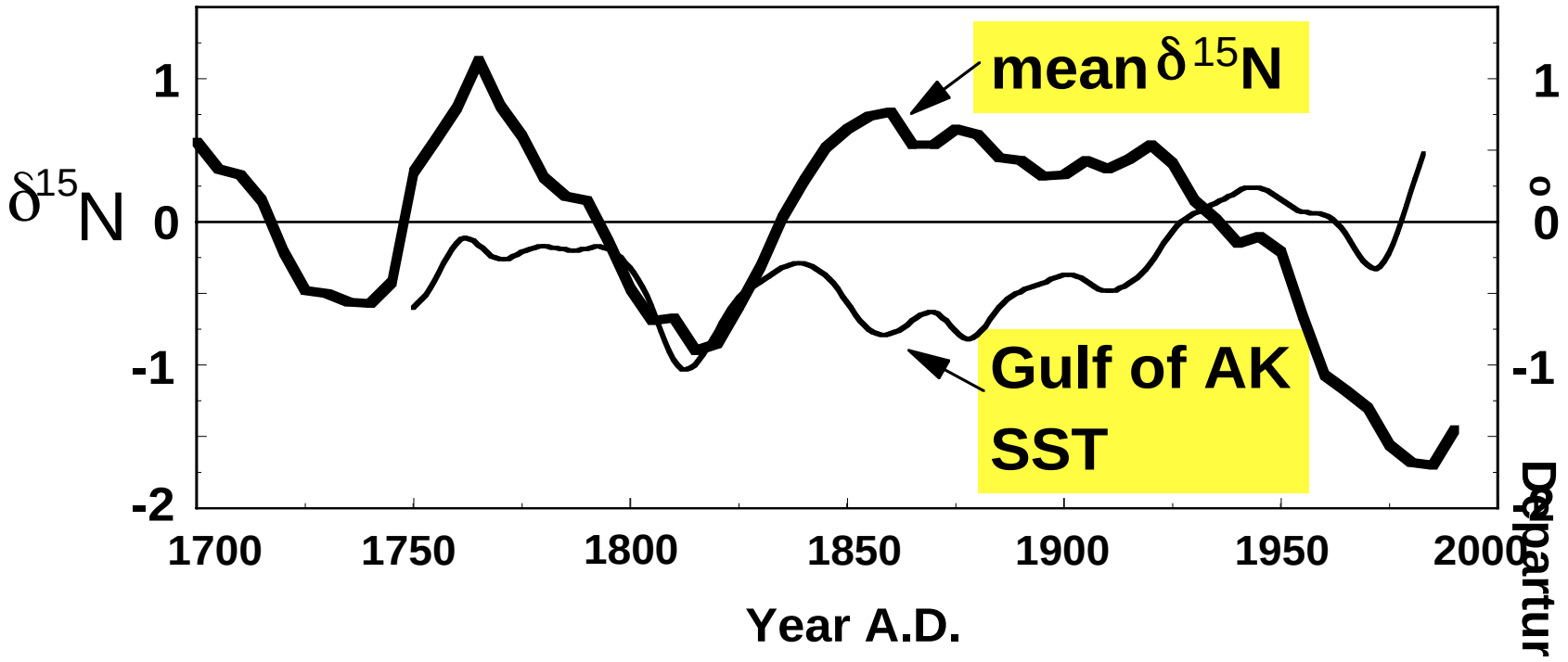

Finney et al., 2000

**Regional ~300 year composite**



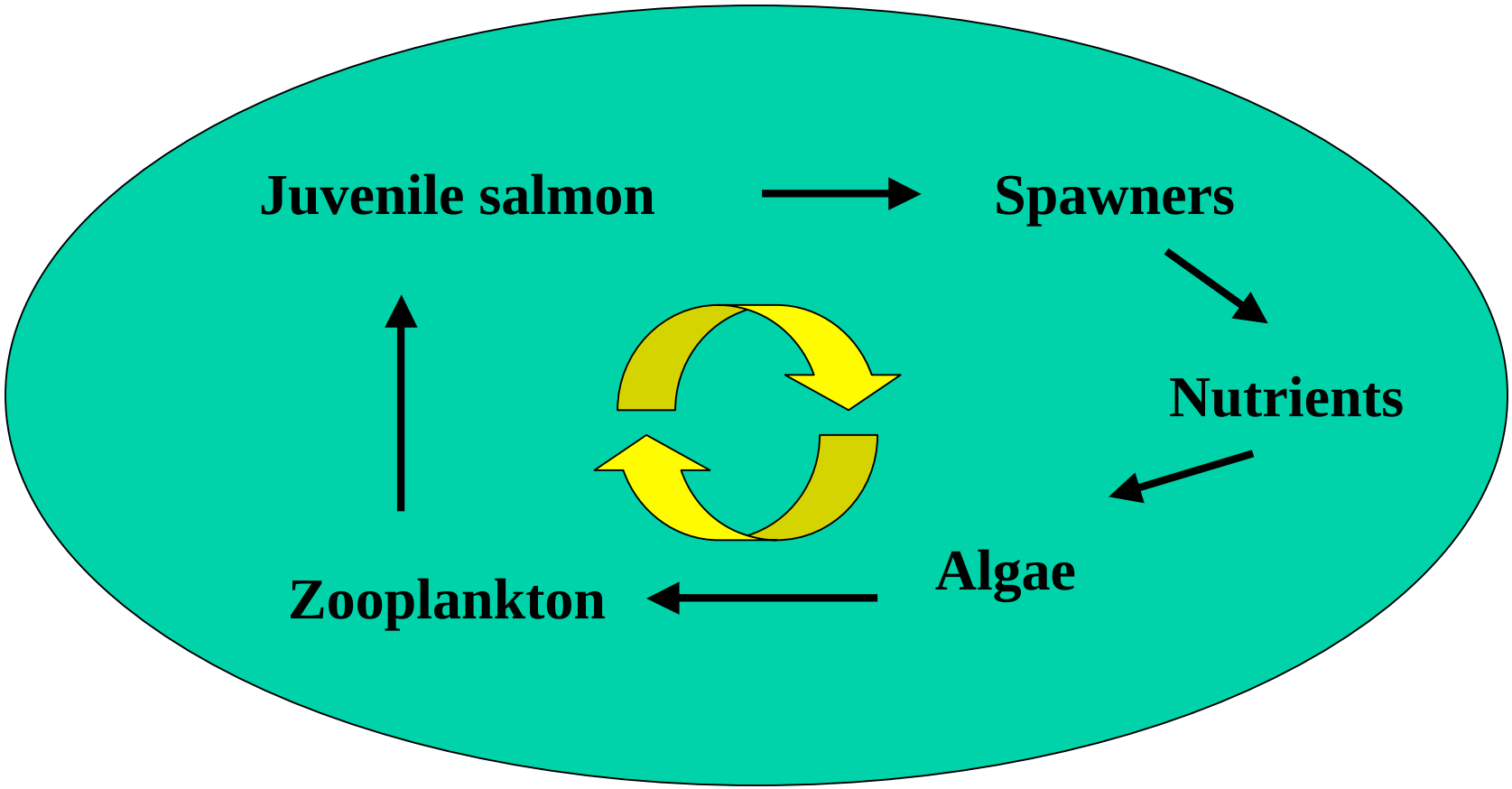

Finney et al., 2000

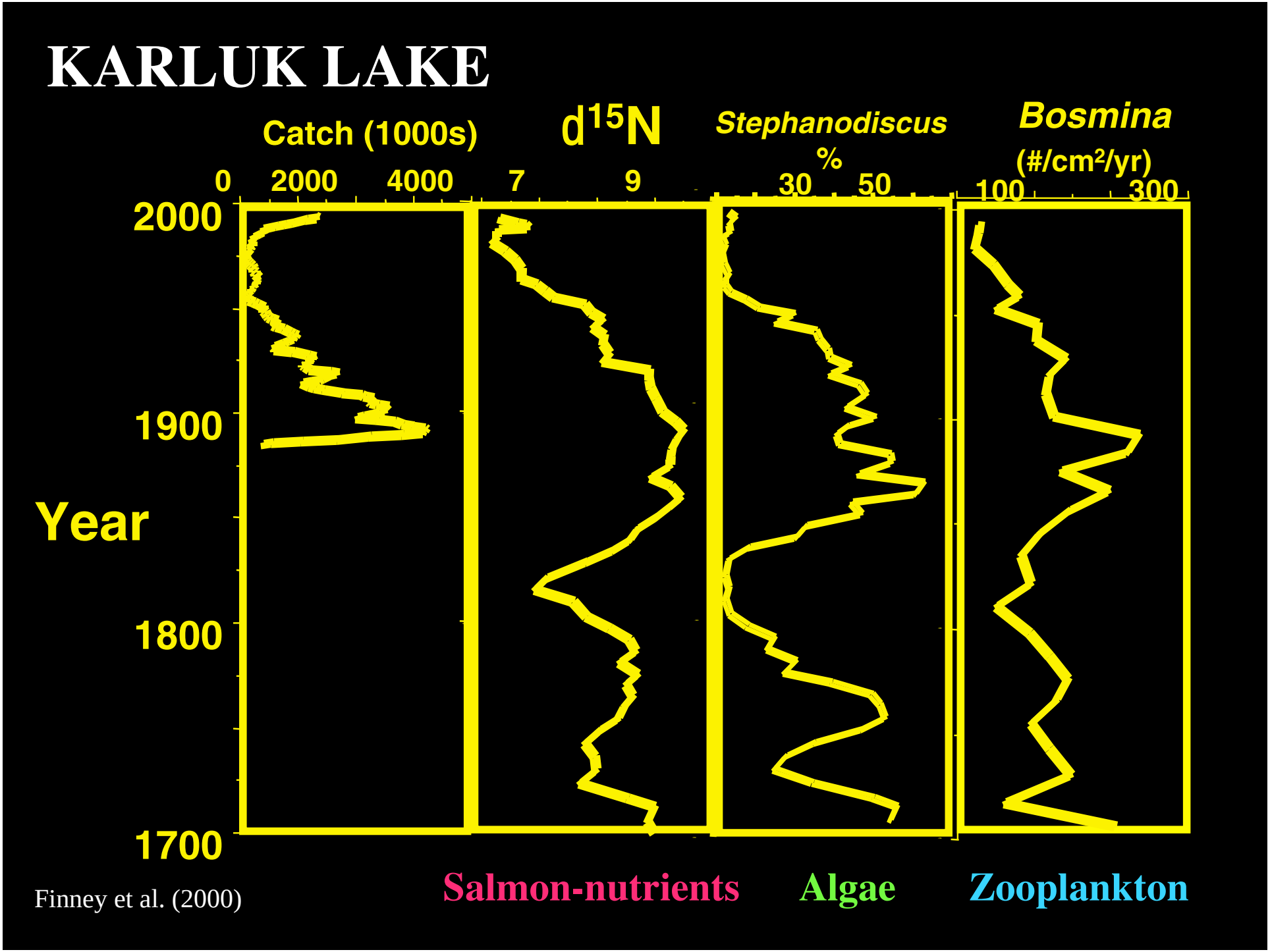
# Climatic forcing:
# Likely driver for regional salmon trends



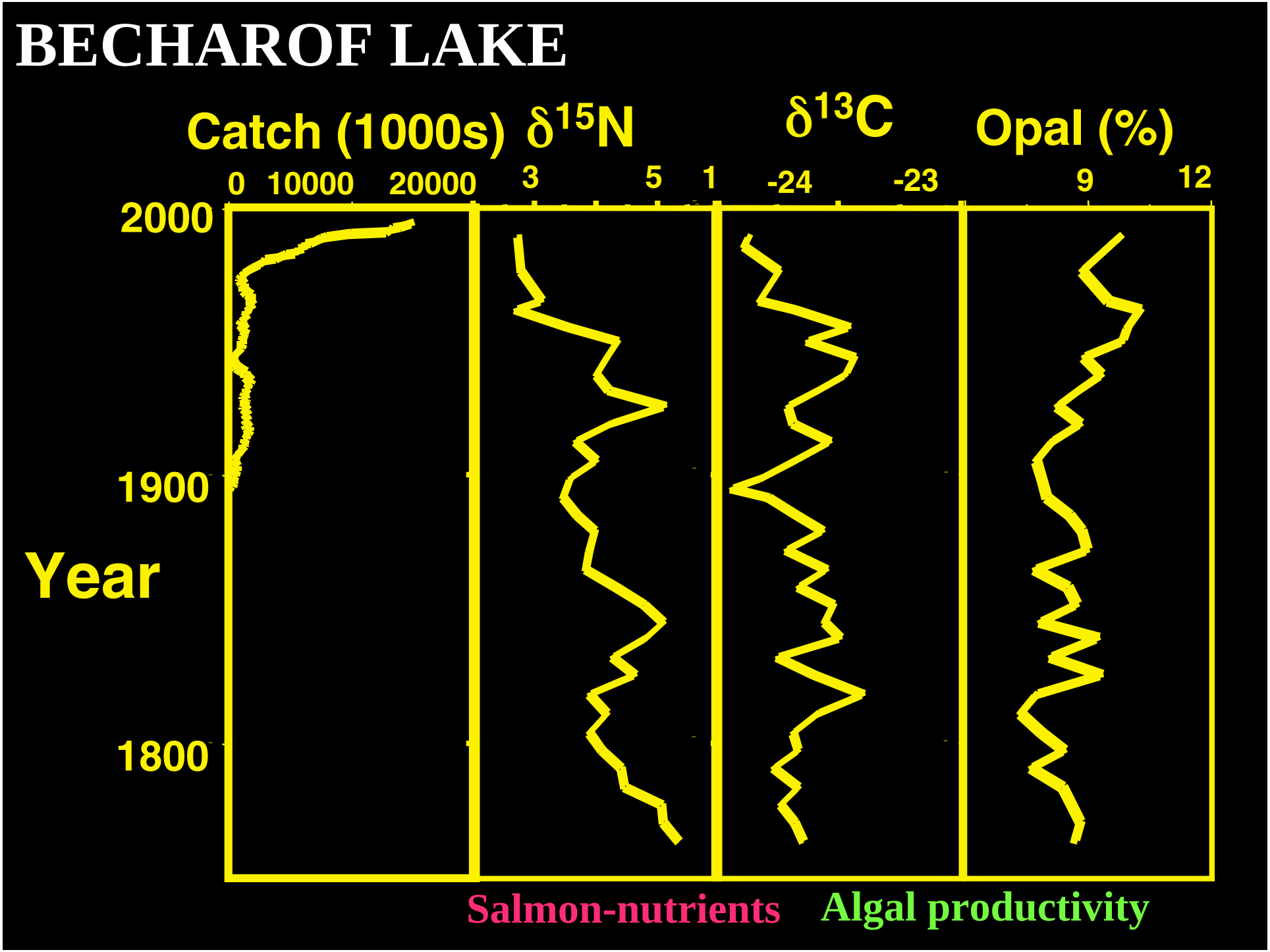

Finney et al., 2000

# 300 yr paleo records also show salmon nutrients drive the carrying capacity of some nursery lakes





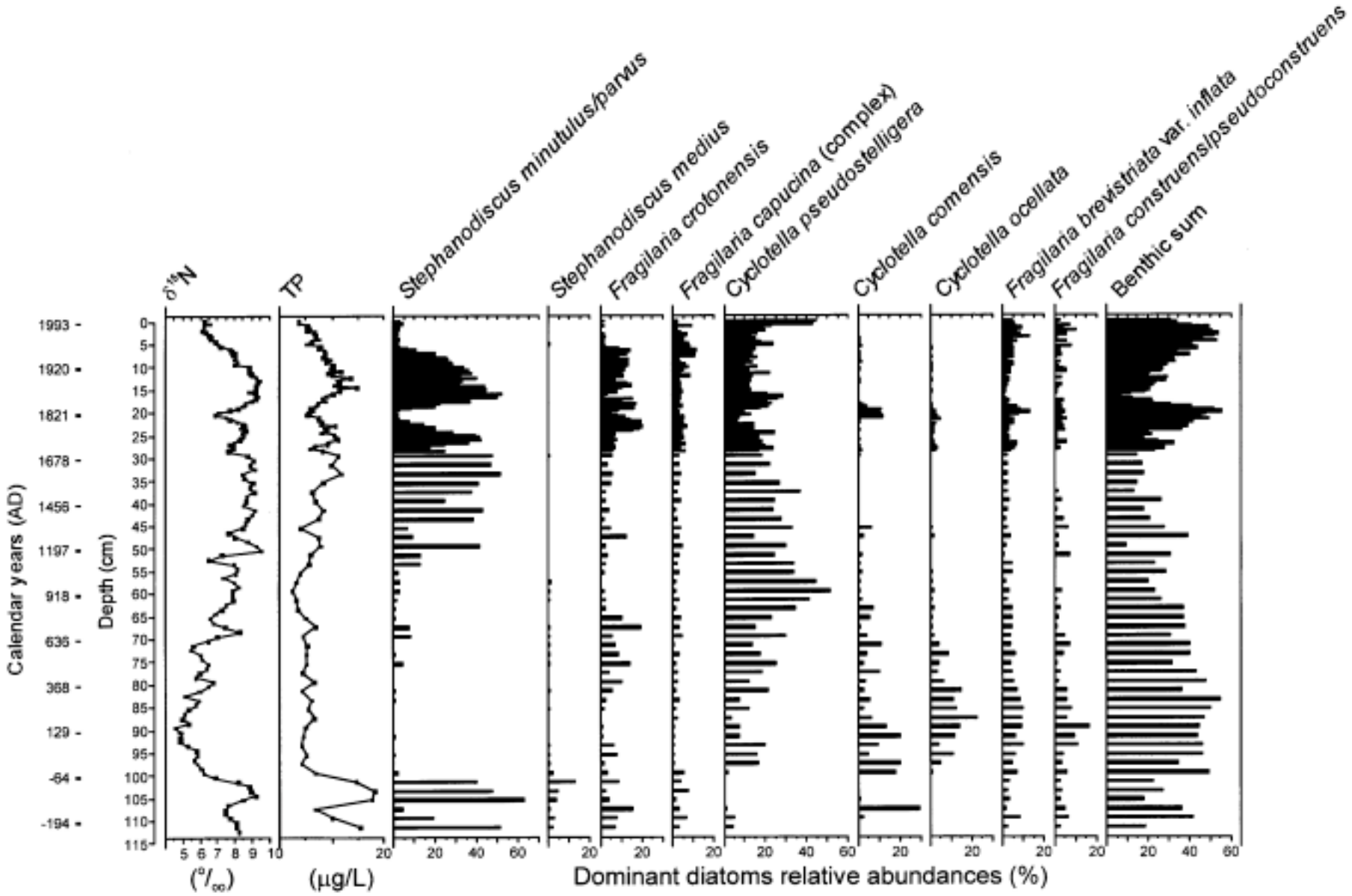

Finney et al. (2000)


BECHAROF LAKE
Catch (1000s)
δ15N
δ13C
Opal (%)
0
10000
20000
3
5
1
-24
-23
9
12
2000
1900
1800
Year
Salmon-nutrients
Algal productivity

# Management implications of salmon-nutrients

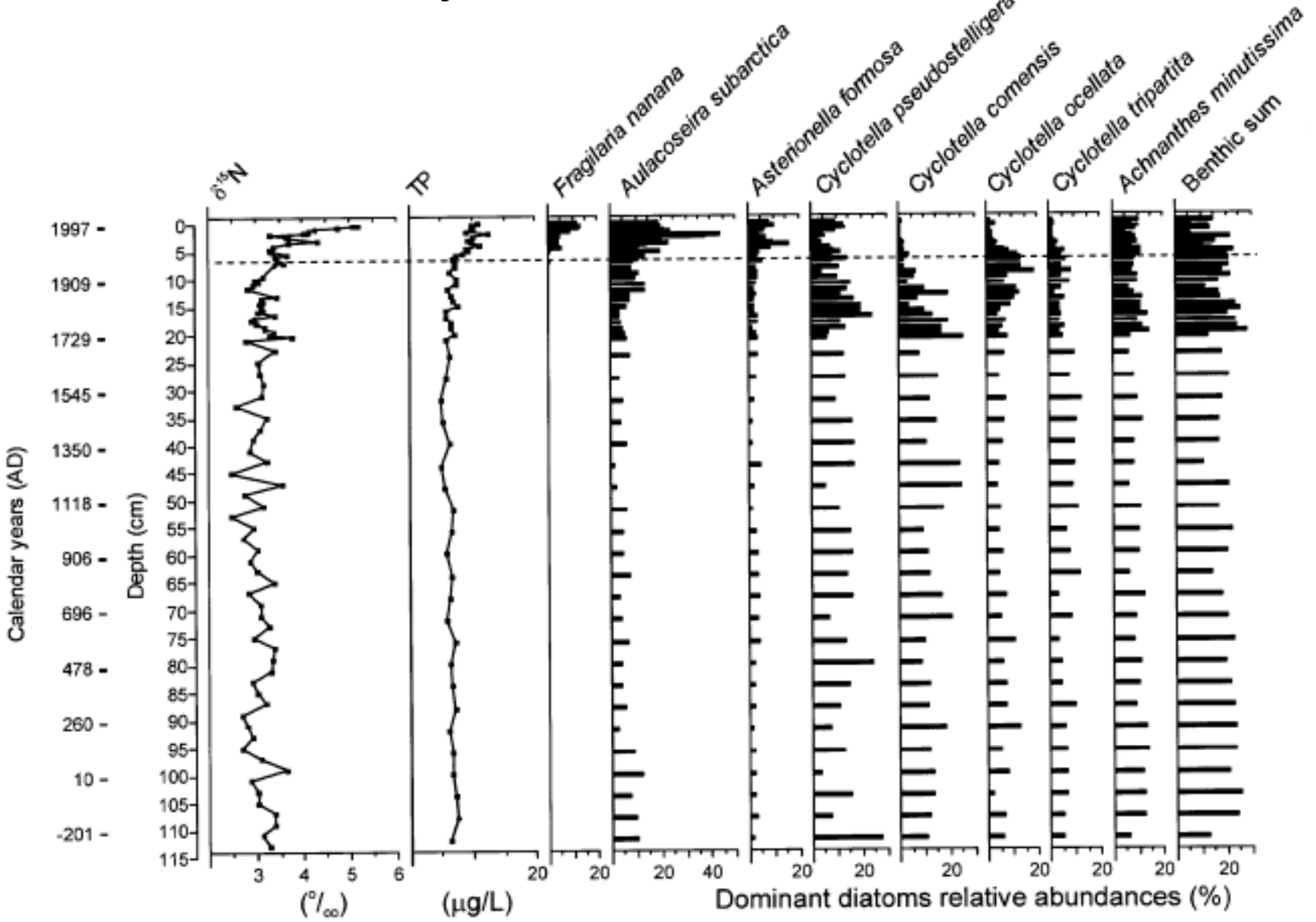
- **Salmon-derived nutrients can drive lake productivity**
- **Gradient in "fertilizer effect": Importance depends on lake characteristics and spawner densities**
- **Role of salmon-derived nutrients should be assessed, and where important, incorporated into escapement quotas**
- **Monitoring data only covers period when salmon harvest has been extensive, so hard to evaluate role of salmon-derived nutrient over short time scale**

# Looking over longer time scales… Karluk Lake ~2200 yr record




Finney et al., 2002; Gregory-Eaves et al., 2003

# Frazer Lake ~2200 year record




Gregory-Eaves et al., 2003