The Role of Nutrients in Rebuilding Lake and River Salmonid Populations

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Presentation Outline

- The role of marine derived nutrients (MDN) in Pacific Northwest ecosystems
- Evidence of nutrient loss
- Effect of nutrient loss on PNW ecosystems (aquatic and terrestrial)
- Strategies for restoring nutrients
- Conclusions

The role of marine nutrients from carcasses in Pacific Northwest ecosystems

The Emerging terminology

- the 'Anadromous Nutrient Pump' (Stockner 2003)
- the 'Nutrient Shadow' (Murota 2003)

"*Salmonids are the critical energy and nutrient link between aquatic and terrestrial ecosystems..*"

19 g Phosphorus

112 g Nitrogen

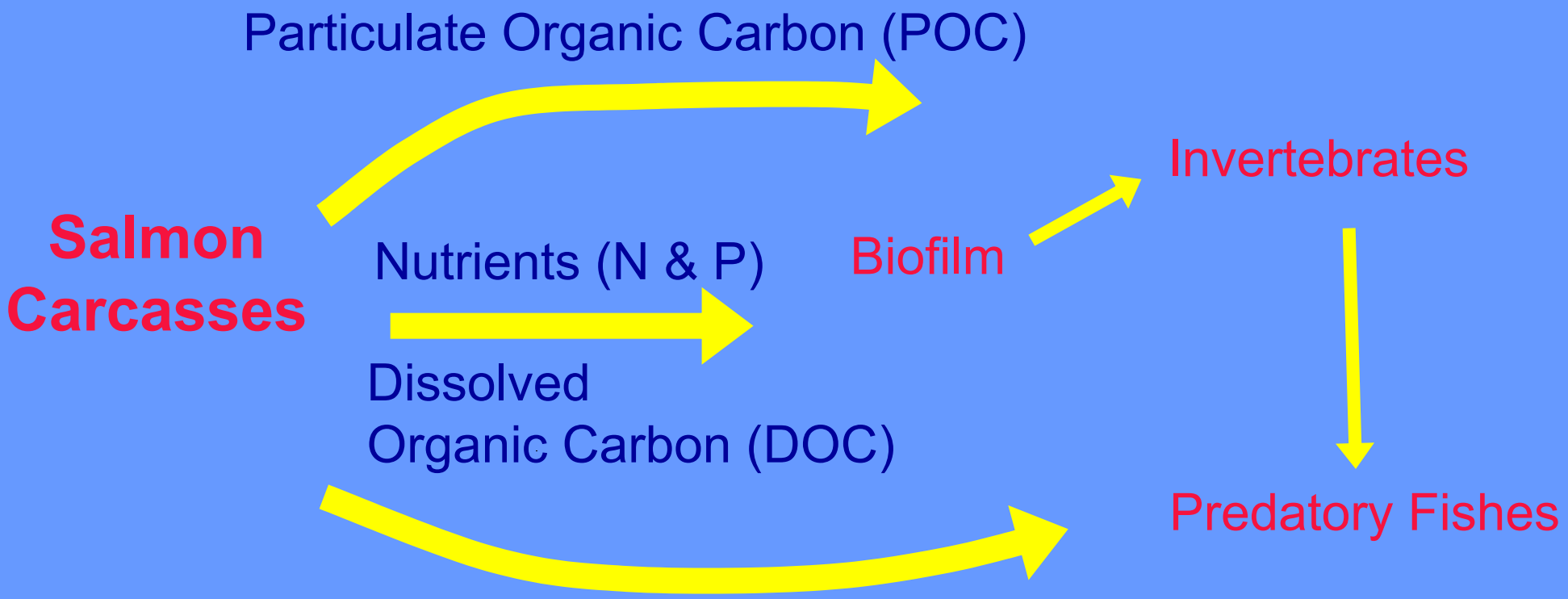
"The Nutrient Pump"

15 g Potassium

33 g Calcium

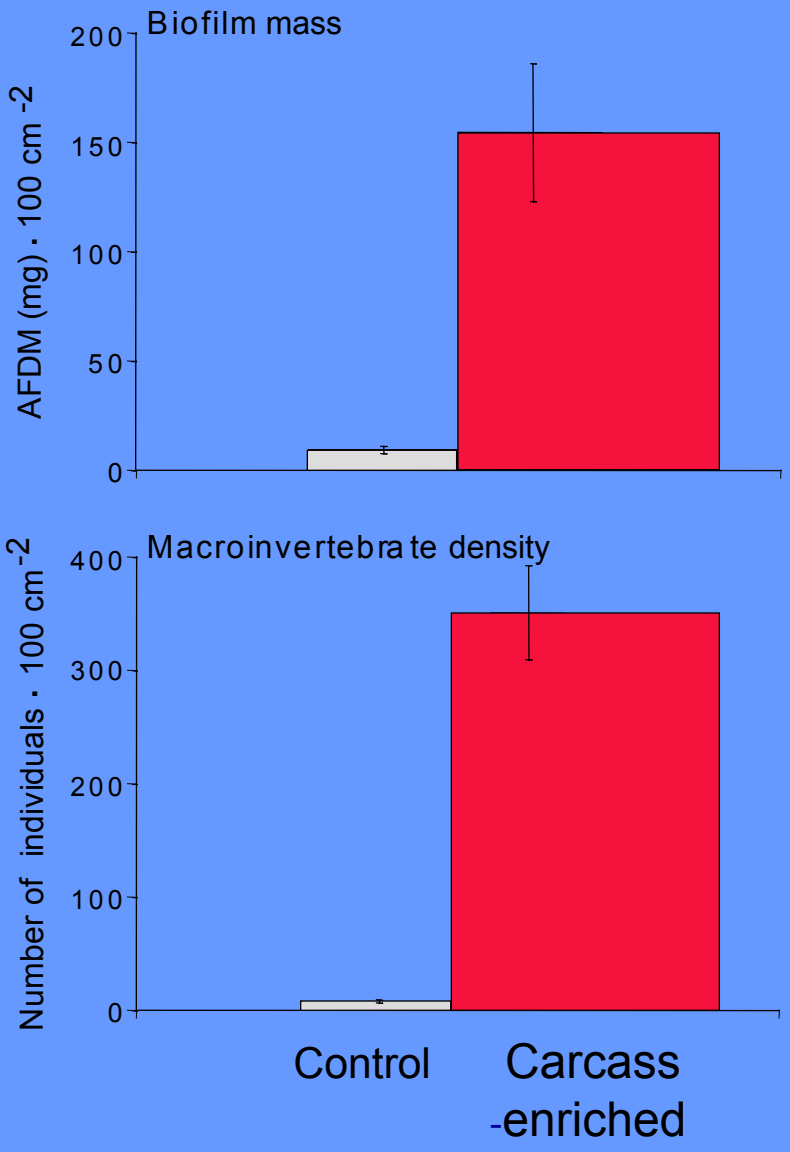
-Carcasses & Nutrients Enhance Biodiversity

-Salmon Nutrients Influence Aquatic Food Webs



- Benthic Insect Responses to Salmon Runs

Red = with carcasses, White = without



- Some examples of salmon/nutrient loss on PNW terrestrial ecosystems

- Reduced productivity, fewer predators and scavengers - Squamish R. eagles
- Sockeye/grizzly bears in Rivers Inlet, BC
- Timing of mink reproduction in Alaska (Ben-David)

- Recent data indicate that Salmon and Pacific Northwest terrestrial & aquatic ecosystems are intimately linked

- Reimchen et al. (2003) show strong links between salmon nutrients and riparian vegetation and tree growth on QCI.
- Jauquet et al. (2003) show multiple-links of salmon carcasses/nutrients to wildlife biodiversity and estuarine nutrient dynamics in Kennedy Creek, WA.
- review by Cederholm et al. (2000) identified 137 species of birds, mammals, amphibians and reptiles as predators/scavengers of salmon spawners.

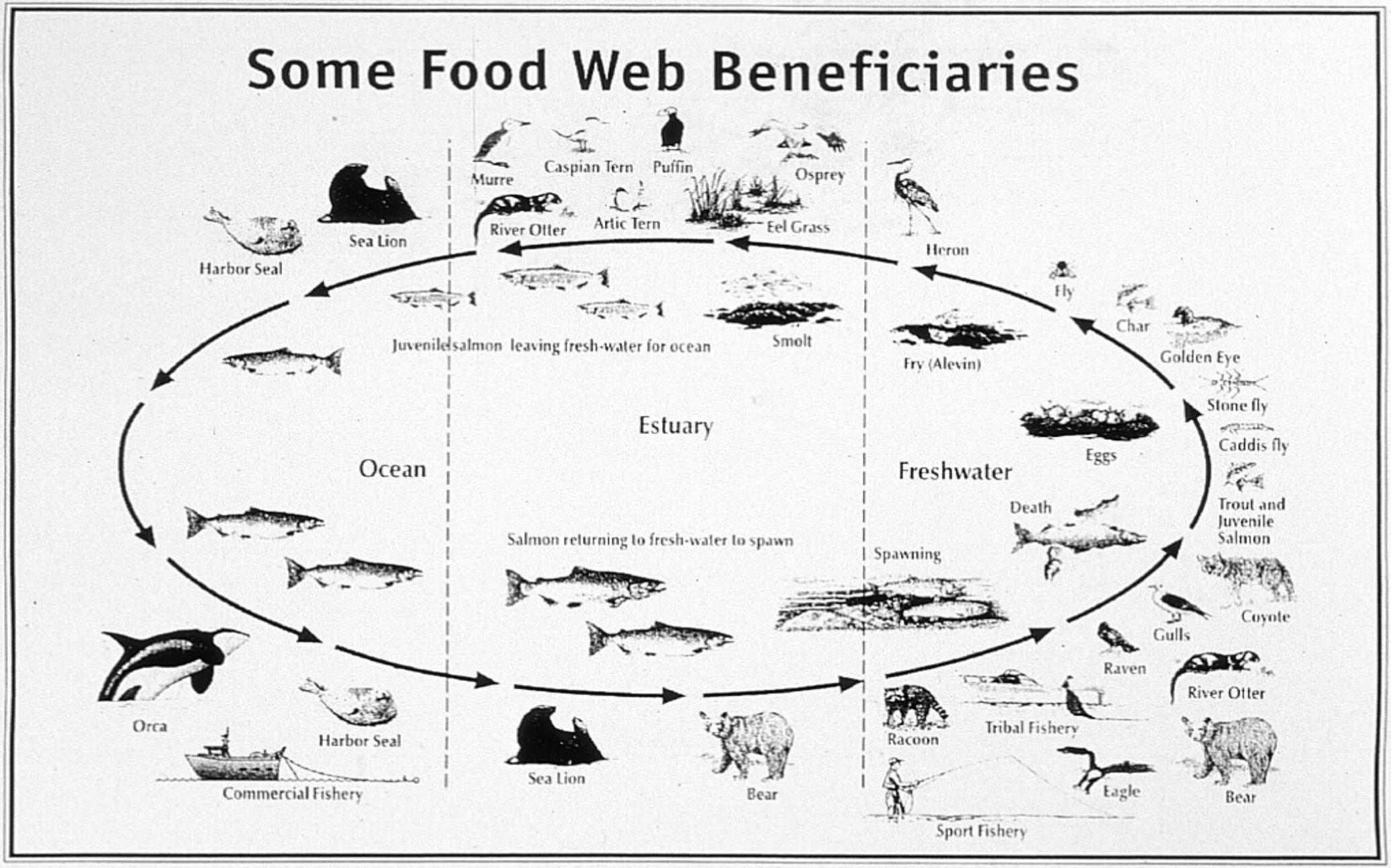


Figure 5. Some food web beneficiaries of Pacific salmon nutrient in freshwater, estuary, and ocean environments

- Studies show strong linkage between salmon nutrients and ecosystem production and biodiversity from stable isotope studies (^{13}C, ^{15}N)

- sediment cores from sockeye lakes (Finney et al., 2000)

- stream food web analyses (Bilby et al., 2000; Wipfli et al., 1998, 1999, 2002)

Sediment shakes salmon science

Population cycles of salmon vary drastically over millennia

By SCOTT SIMPSON

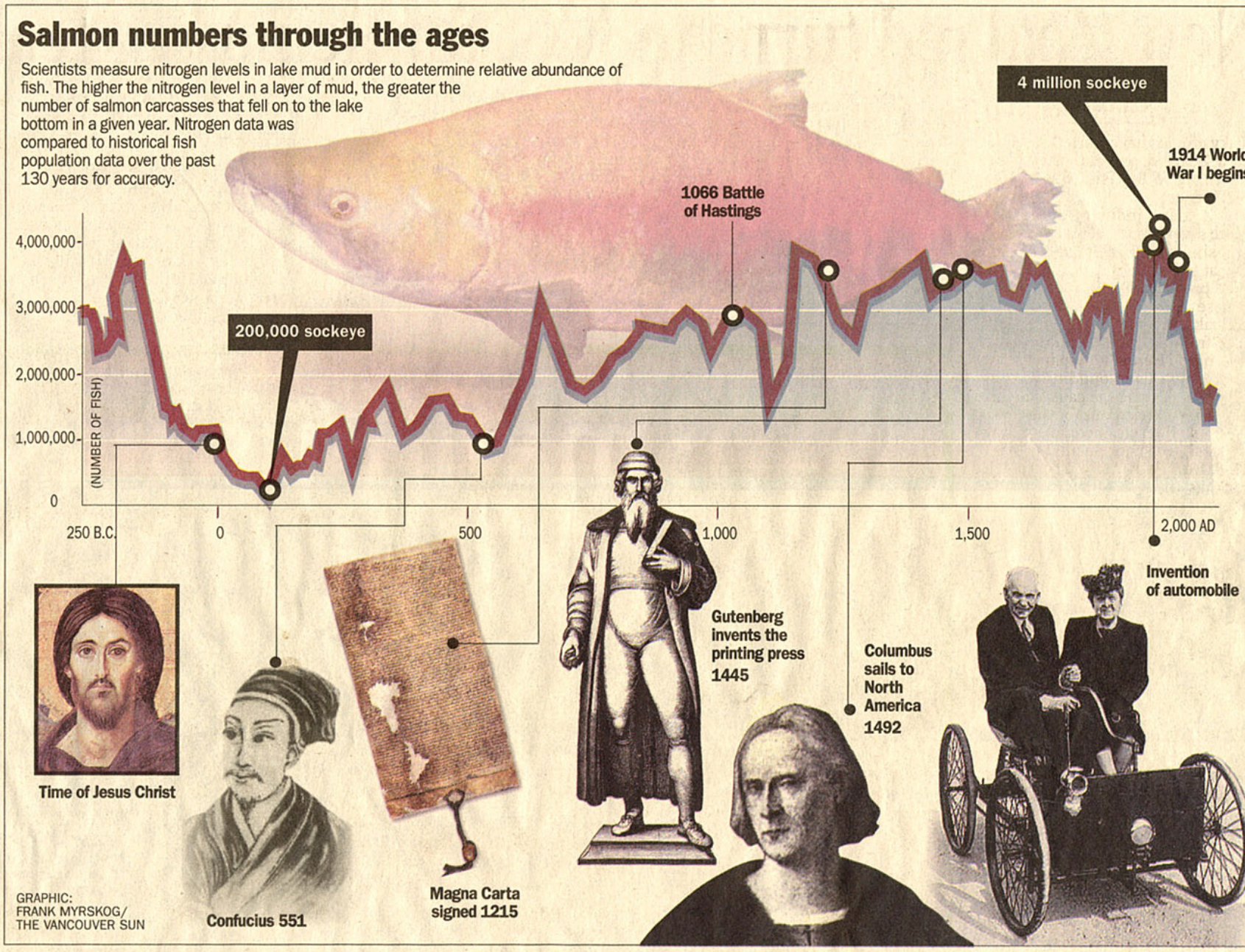
Pacific salmon populations were in drastic fluctuation for thousands of years before human activity began showing an impact on spawning stocks, according to a Canada-U.S. research team in an article to be published today in *Nature*.

Using sediment samples from the bottoms of remote Alaskan lakes, a team of paleogeologists and marine biologists have unearthed evidence of the rise and fall of sockeye salmon populations over a period of time exceeding 2,000 years.

In some cases, the sediment shows that troughs in salmon abundance persisted for several human lifetimes.

Climate change is suggested as the cause — the researchers say they were shocked to document very low population numbers in the period between 100 BC to 300 AD, solely as a result of natural fluctuations in weather and ocean currents and temperature.

"This blows our notion of salmon population dynamics right out of the water," says paleolimnologist Irene Gregory-

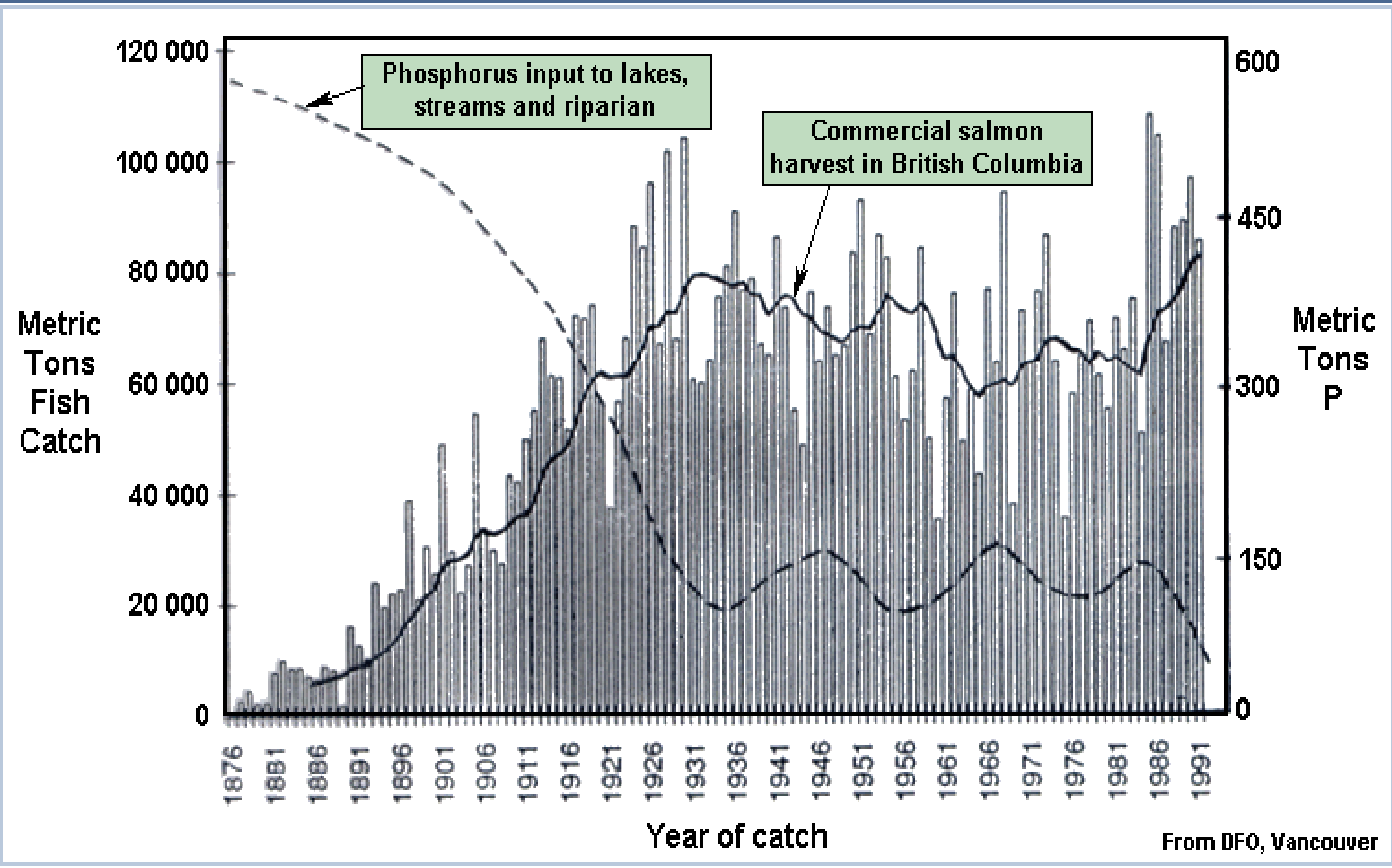


- Several studies chronicle the magnitude of salmon-nutrient loss

- British Columbia commercial landings of salmon (Larkin and Slaney 1997, Stockner and Ashley 2003)
- Pacific Northwest salmon nutrient audit (Gresch et al., 2000)
- Only 5-7% of historical pre-European MDN is currently reaching PNW ecosystems (WA, OR, ID, CA)
- Reservoir impoundment effects – e.g. Kootenay Lake, Arrow and Kinbasket lakes (Ashley et al., 1999, Stockner 2004)
- Dworshak Reservoir, Idaho (Stockner and Brandt 2006)

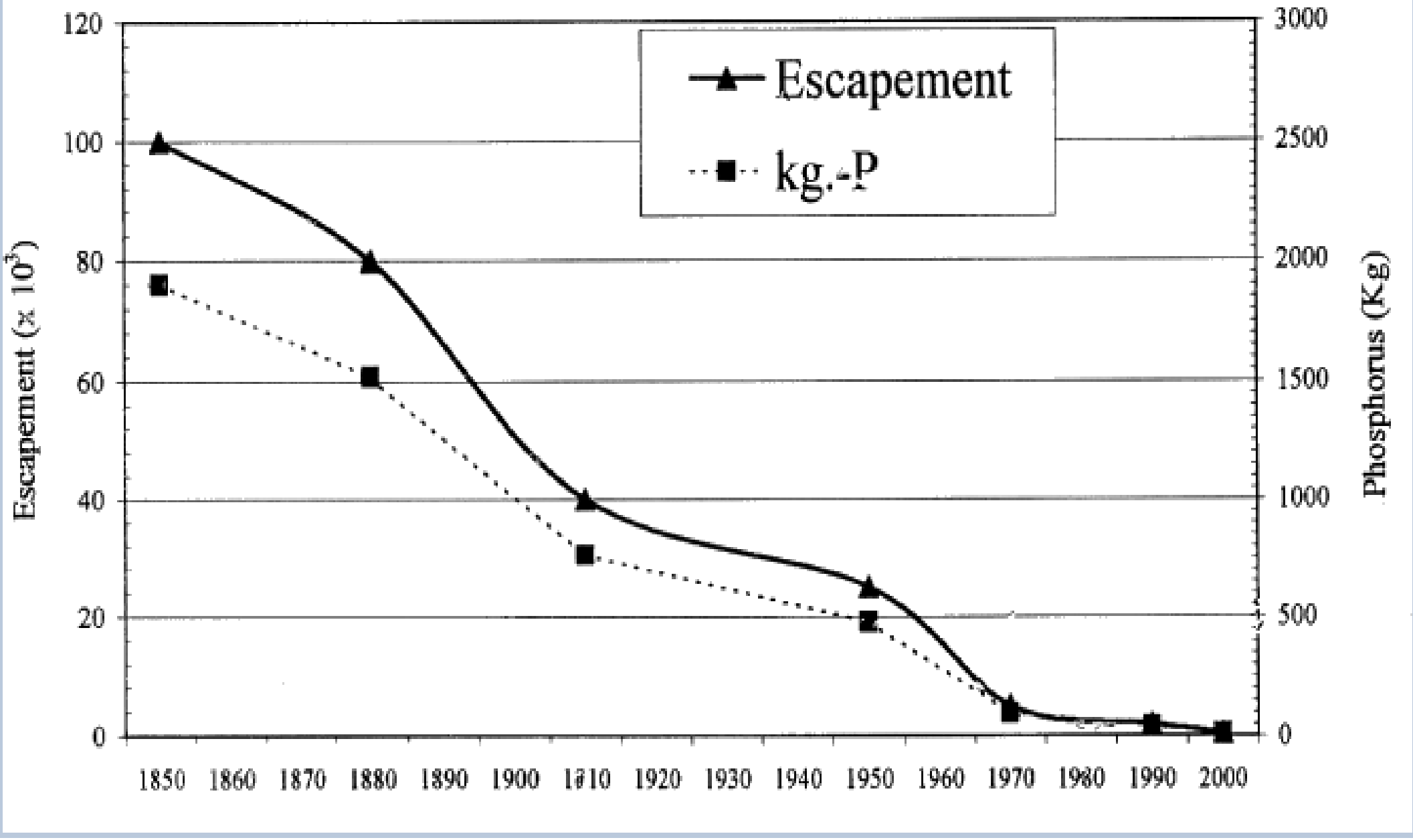

Skeena River Salmon Fisheries
Part of the Pack

Historic BC salmon catch



From DFO, Vancouver

Grande Ronde River System



Summary

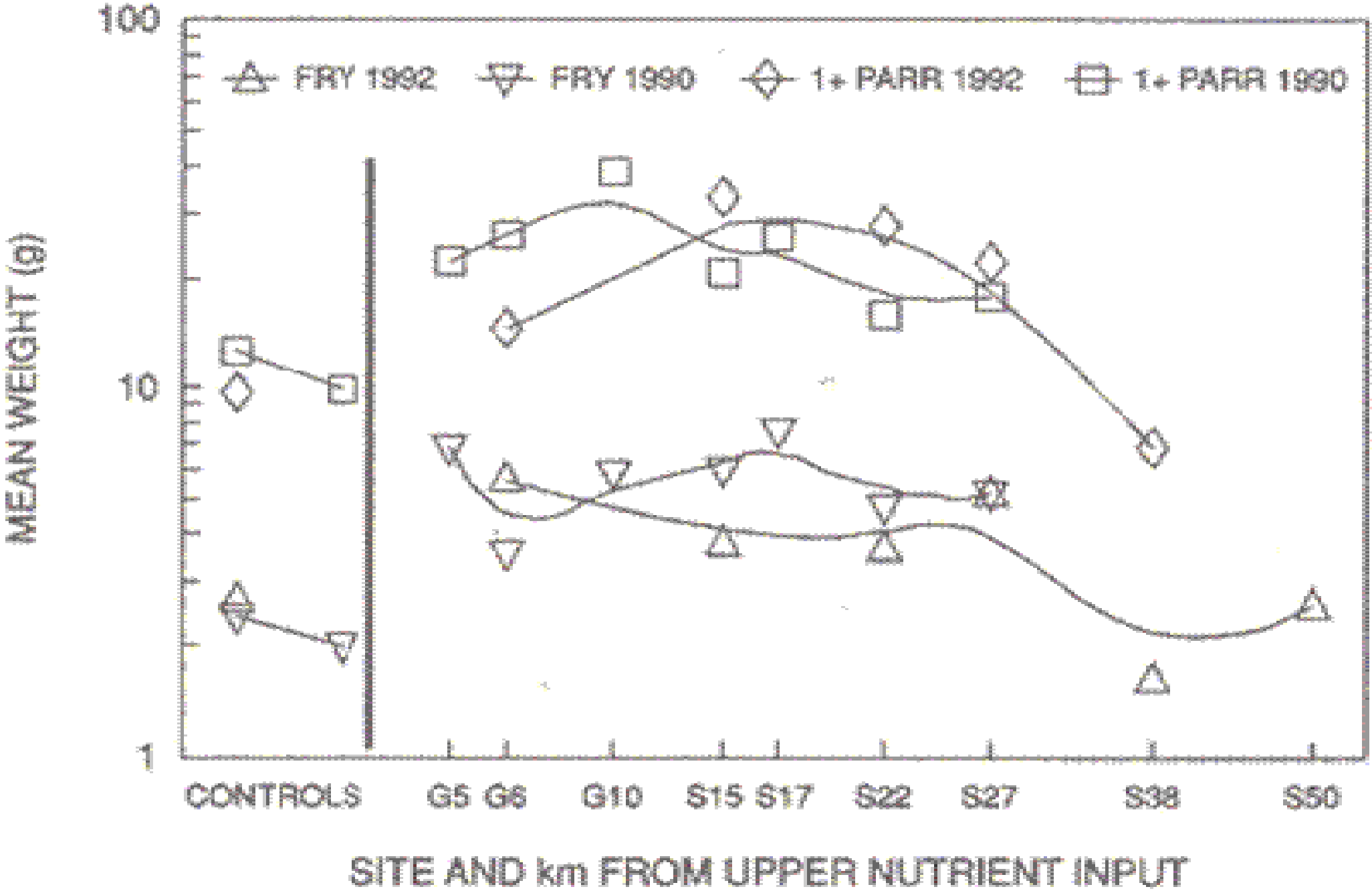
- Loss of salmon-nutrients has results in sharply declining stream and lake ecosystem productivity and biodiversity.
- These declines have occurred over many decades, and are often confounded by additional factors such as forestry, agriculture, hydroelectric development (dams).
- In most all salmon supported lakes/reservoirs the loss of salmon-nutrients has led to planktivore/piscivore stock collapses and in some cases extinction (Sockeye/Kokanee, Chinook, Coho)

What are some options for stock restoration/enhancement?

1. Stream Fertilization in BC

Salmon and Keogh rivers –
fertilization results

- Salmon River fertilization


100
10
1
MEAN WEIGHT (g)
FRY 1992
FRY 1990
1+ PARR 1992
1+ PARR 1990
CONTROLS
G5 G8
G10
S15 S17
S22
S27
S38
S50
SITE AND km FROM UPPER NUTRIENT INPUT

- Keogh River fertilization – summary results

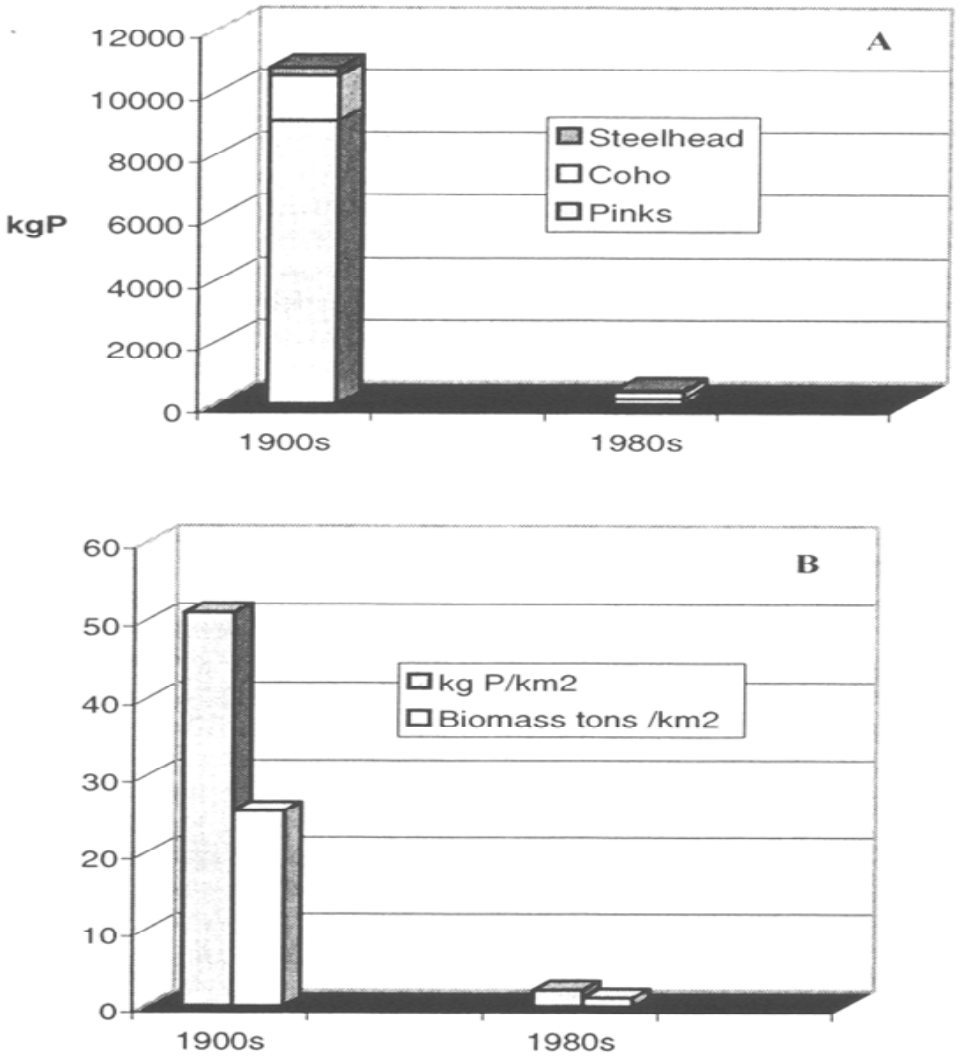
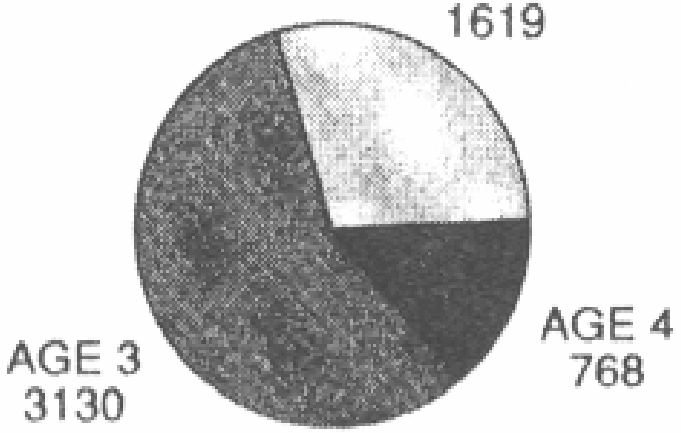
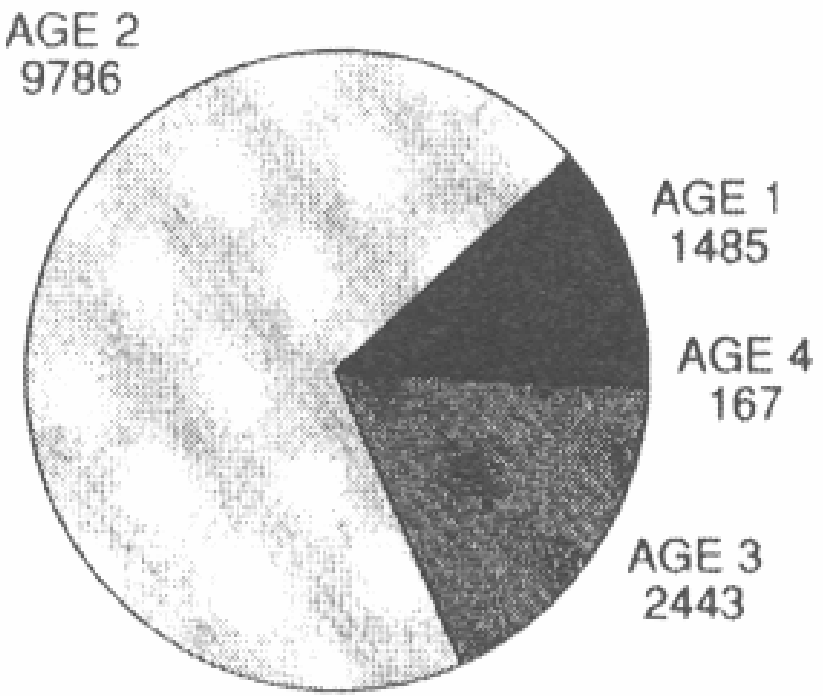


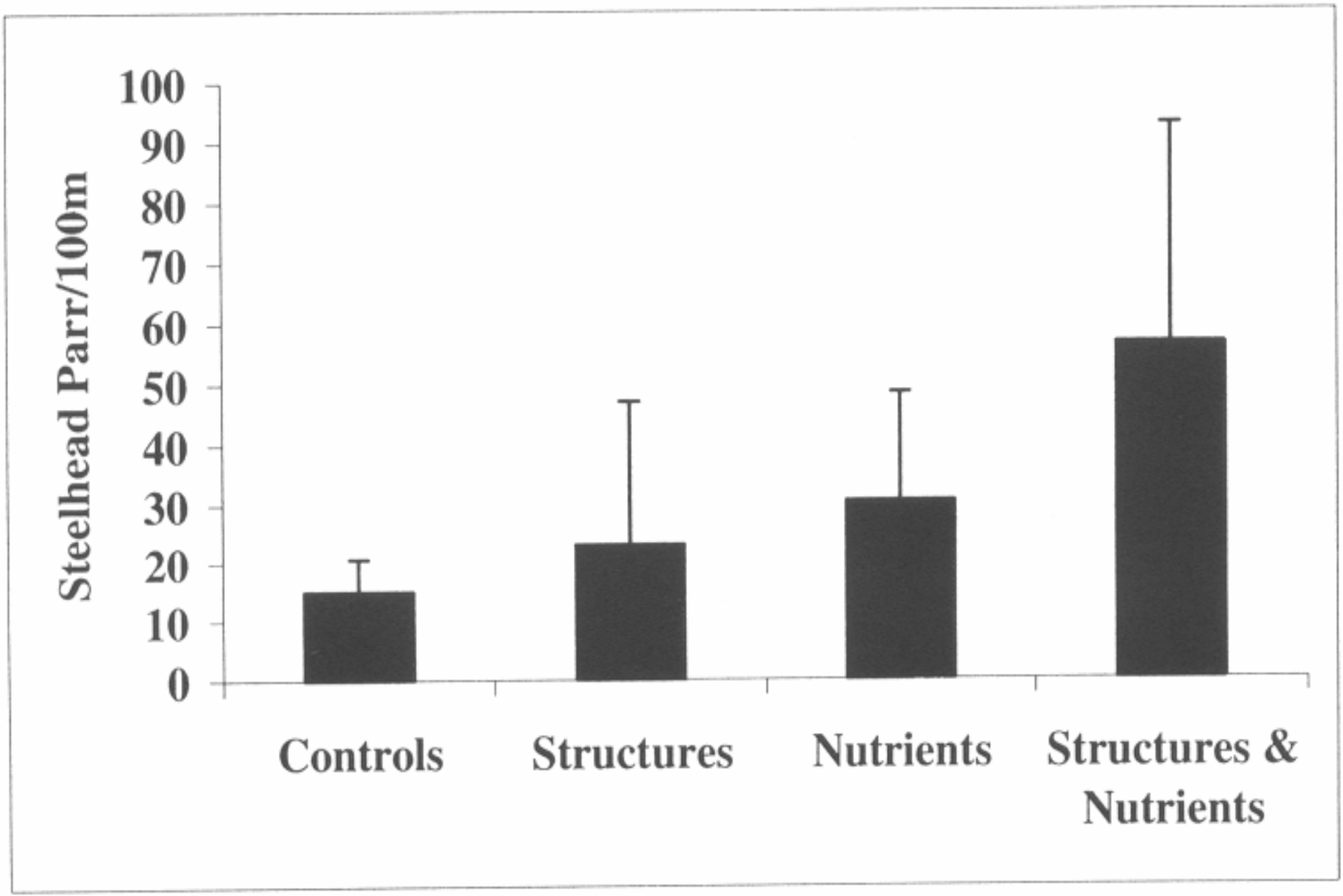
FIGURE 4. A. Estimated total P contributions from adult salmon accruing to the Keogh River and estuary in the predisturbance early 1900s and in the 1980s. B. Total kg P input and autotrophic biomass production potential in Keogh River normalized to km² wetted area before and after disturbance. (B. Ward, B.C. Ministry of Fisheries,



UNFERTILIZED YEARS



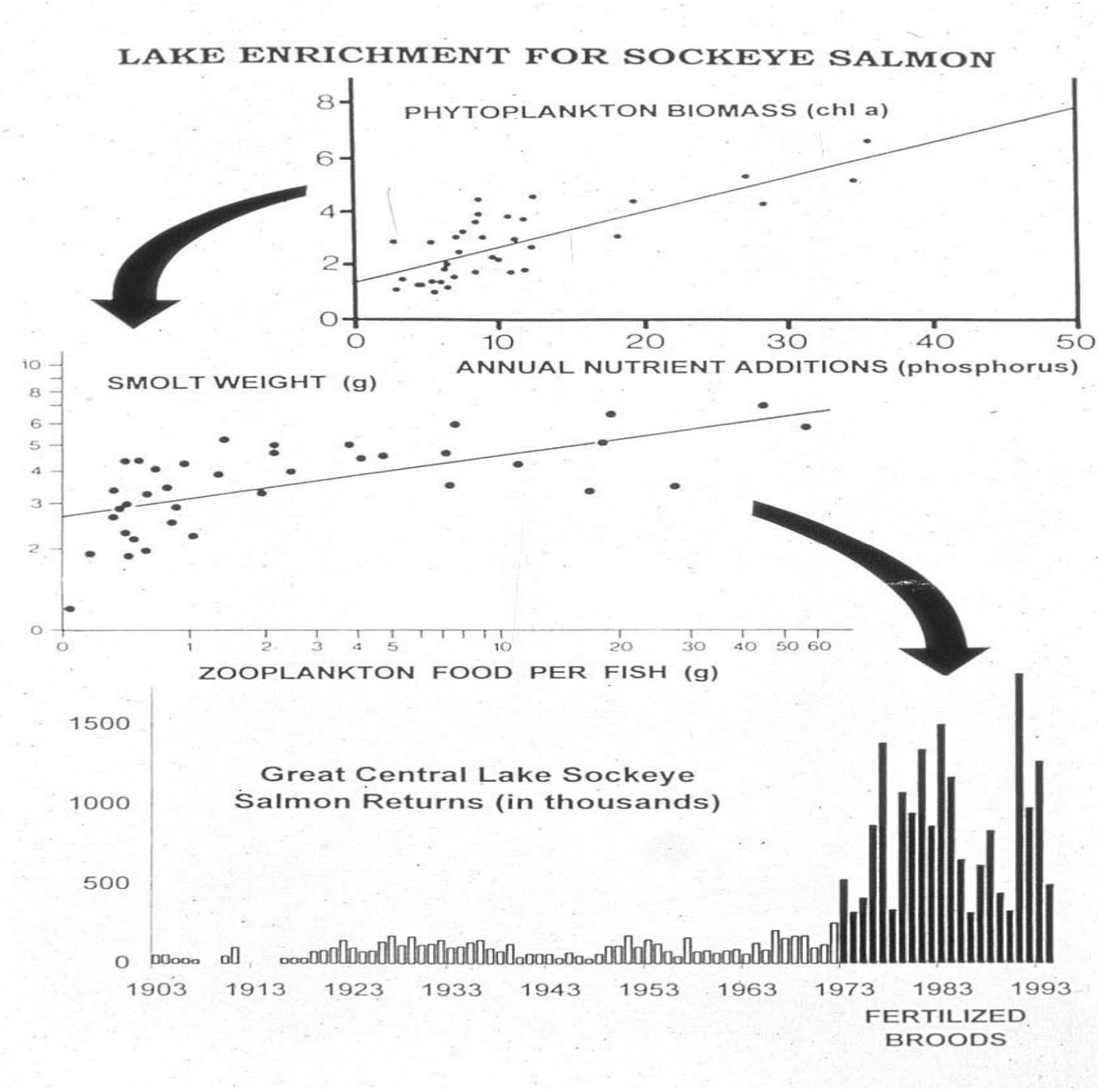
FERTILIZED YEAR
1987 (FULL EFFECT)


Steelhead Parr/100m
100
90
80
70
60
50
40
30
20
10
0
Controls
Structures
Nutrients
Structures & Nutrients

2. Lake Fertilization

Nutrient Supplementation – British Columbia's Lake Enrichment Program 1975-2005

Why it works so well....

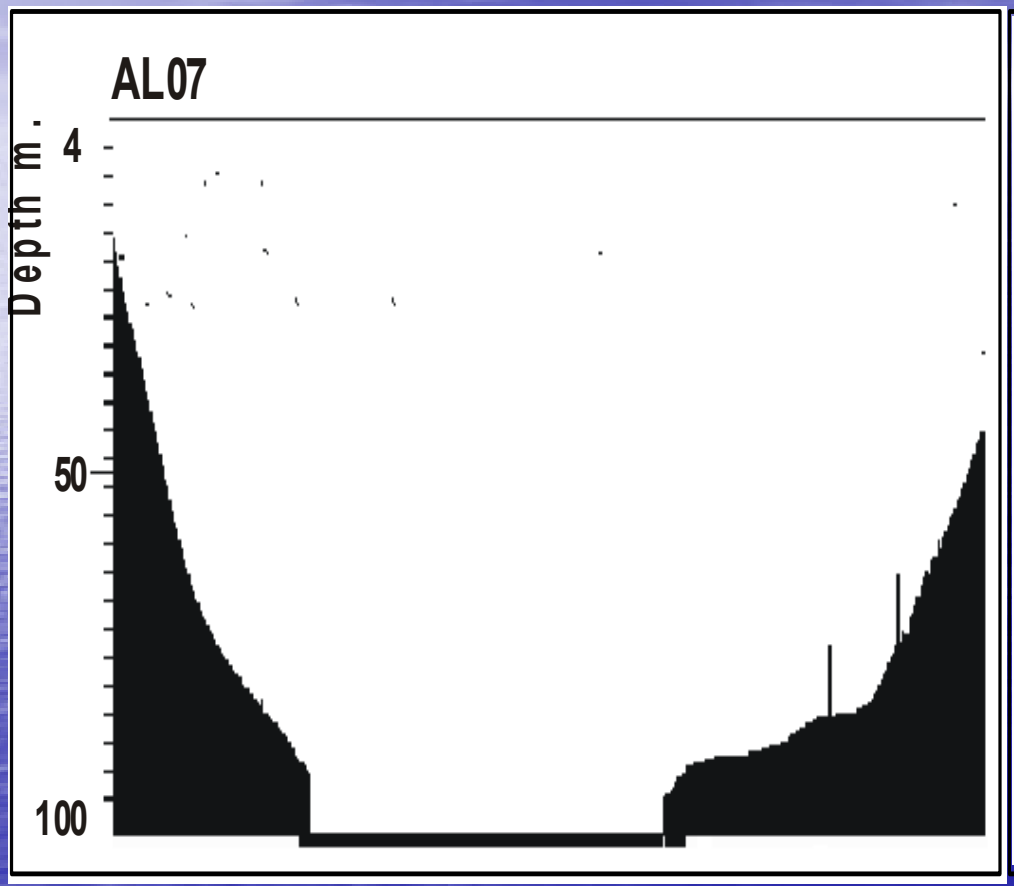


Hydroacoustic Assessment of Pelagic Fish Abundance

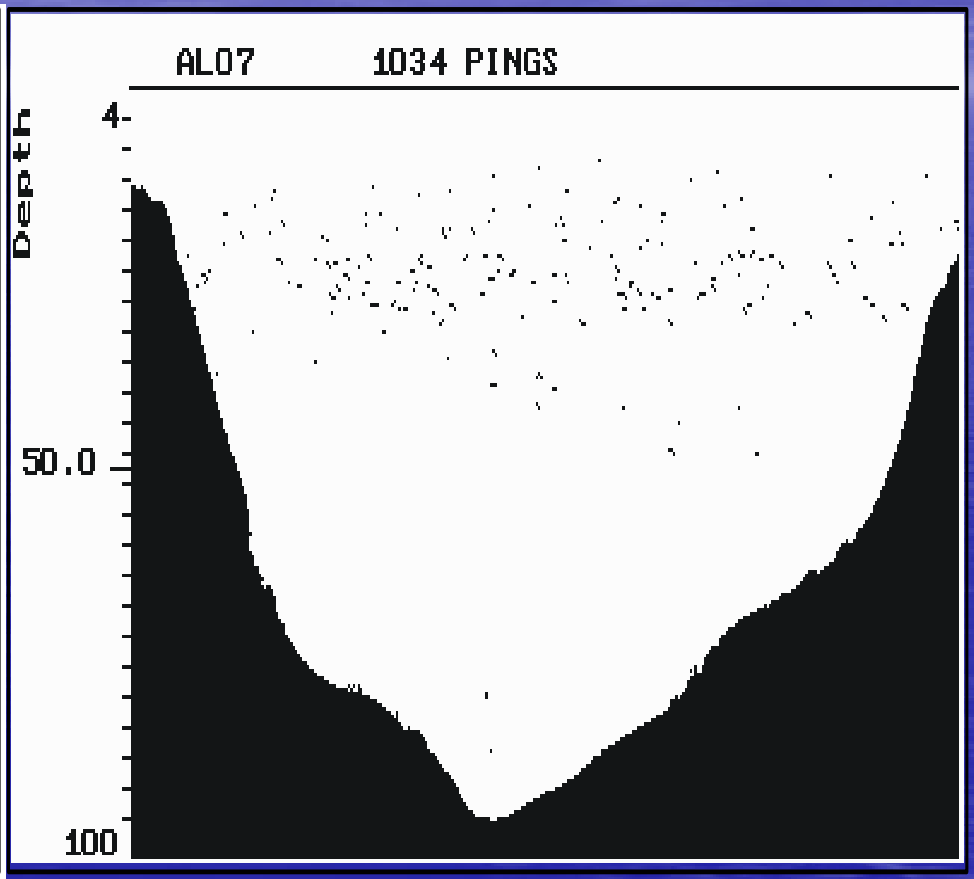
Conducted Each Fall

Hydroacoustic transects of Kokanee before and 3 years after nutrient supplementation

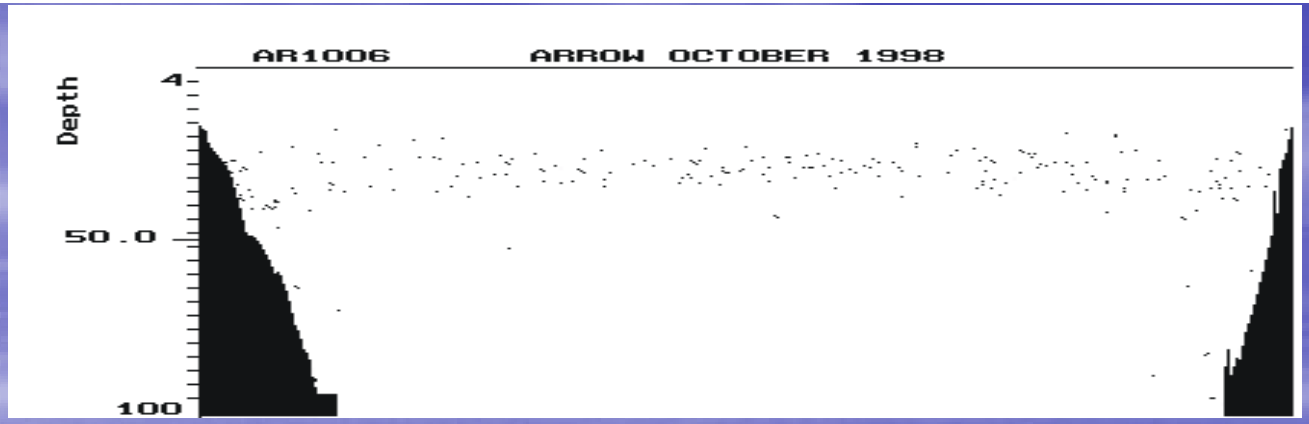
1998 (before)



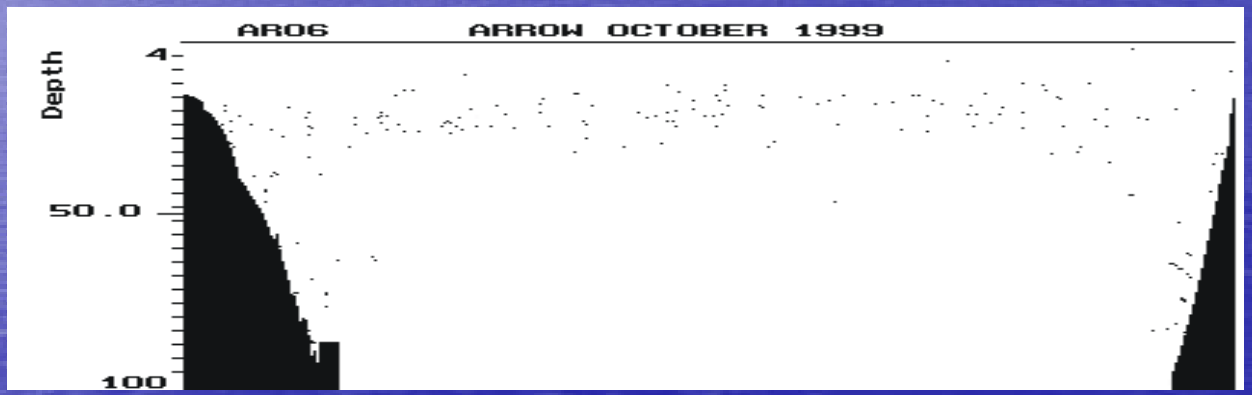
2002 (after)



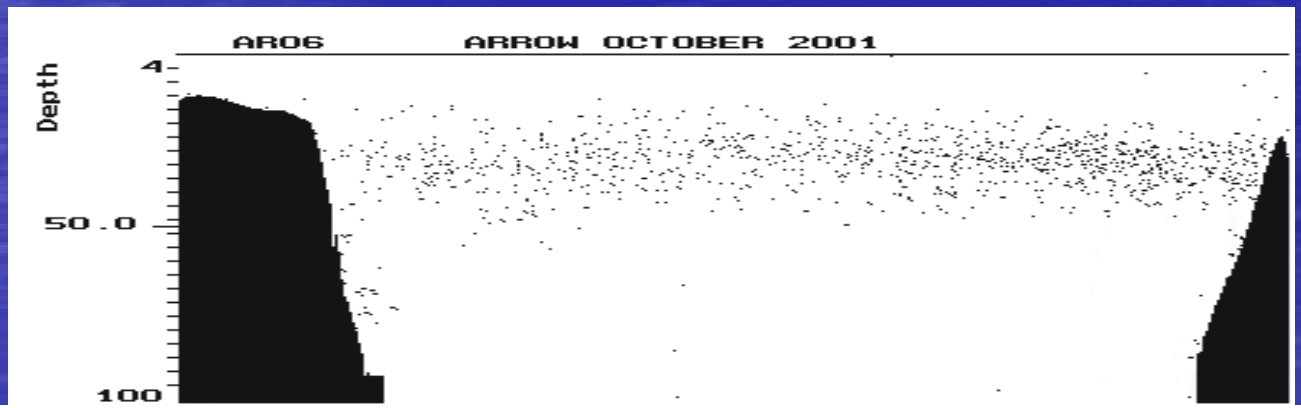
Arrow lakes-
1998
control yr



1999
1st treated yr



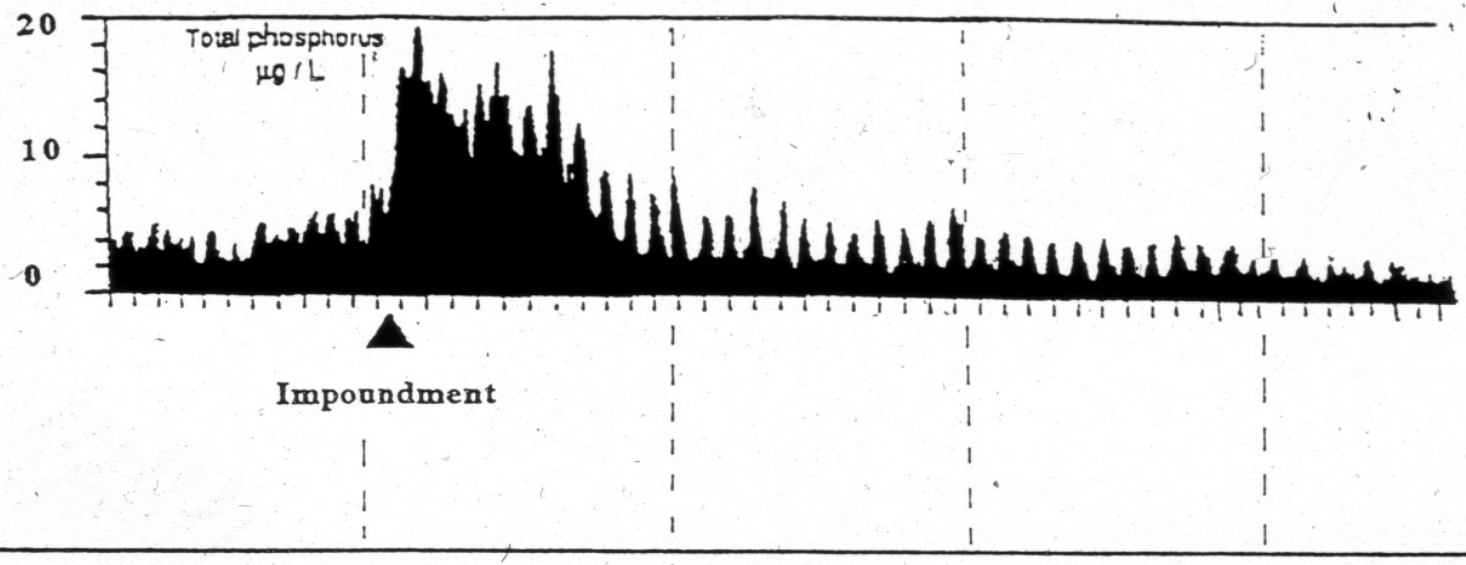
2000
2nd treated yr



3. Reservoir fisheries restoration

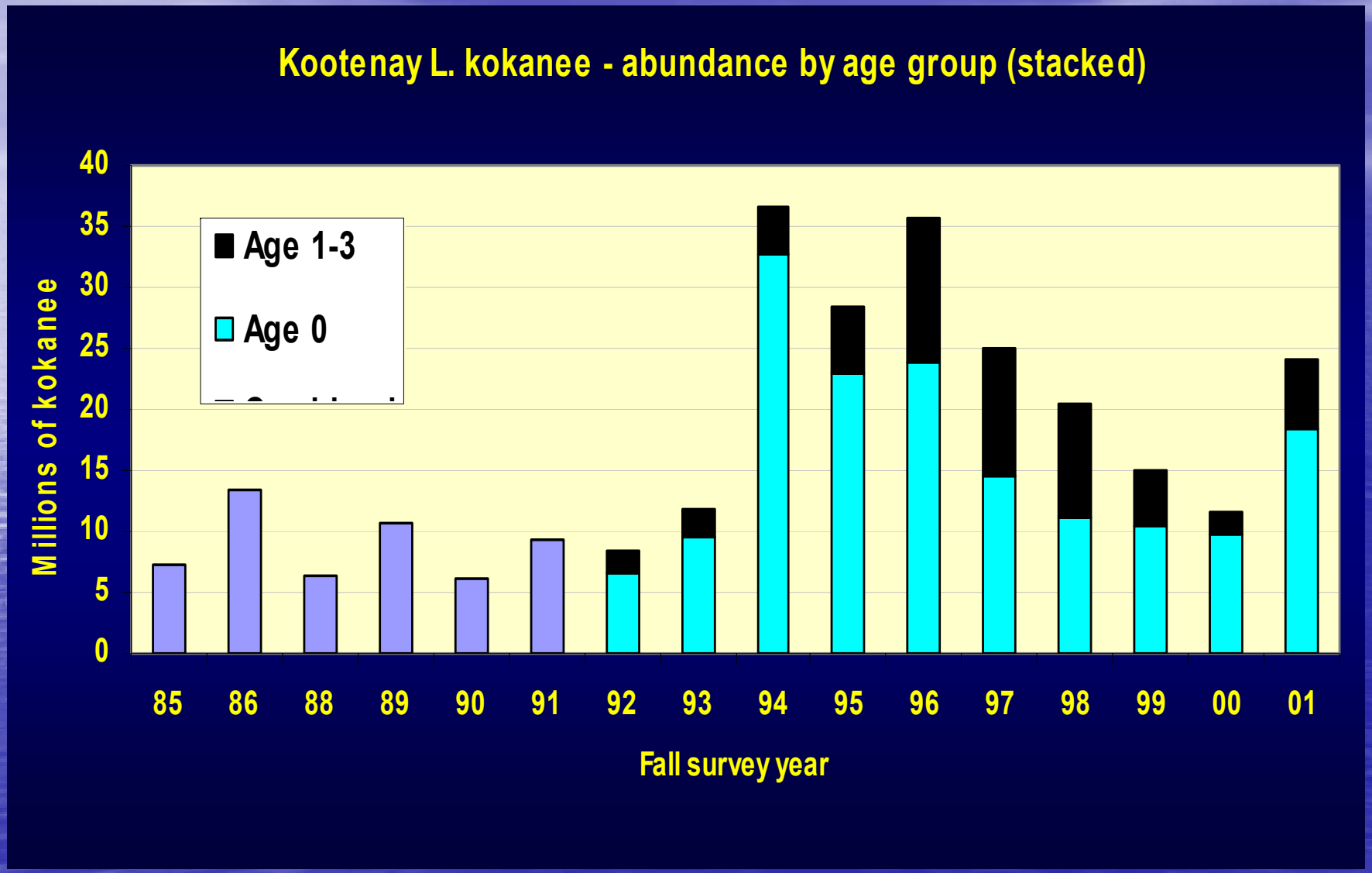
- most all reservoirs in Canada go through a "boom and bust" cycle of productivity (aging).
  - Causes:
    - –increased water retention time
    - –increased sedimentation rates
    - –loss of littoral productivity
    - –cultural oligotrophication (Stockner et al., 2000)

Temperate Lake/River impoundment production response, >45°N latitude



Phase	*Pre-*	*'Boom'*	*Transition*	*'Bust'*	*Post-*
Year		1-5	5-8	8-15	perpetuity
Production ($gC \cdot m^{-2}y^{-1}$)	50-70	100-120	80-100	40-60	30-50
Total P	2-4	10-14	6-8	2-4	1-3
Trophic state	oligotrophic	mesotrophic	oligotrophic	ultra-oligotrophic	ultra-oligotrophic
Fish prod.	low	moderate	low	very low	very low
Transparency	high	low	moderate	high	very high


CASCADE


Kootenay L. kokanee - abundance by age group (stacked)
Millions of kokanee
40
35
30
25
20
15
10
5
0
Age 1-3
Age 0
85
86
88
89
90
91
92
93
94
95
96
97
98
99
00
01
Fall survey year

- The strategy..

- the rationale for 'nutrient supplementation' is to restore the salmon-nutrients to 'historic' optimal levels to enable the ecosystem to provide sufficient 'natural' forage production to substantially increase juvenile salmonid growth, production and survival (the 'jump-start' phase). In time the integrity (biodiversity) of the entire terrestrial/aquatic ecosystem will respond to any increased abundance of returning adult salmonids, e.g. BC's Great Central Lake. However in those systems where anadromy has been permanently lost, i.e. some PNW reservoirs, annual supplementation may always be required to sustain fisheries potentials (e.g. Kokanee, bull trout).

Sources of nutrients:

1. Wild spawning salmon – best source of N,P, carbon and fatty acids.
2. Pacific salmon carcasses (hatchery) – next best source.
3. Organic and/or inorganic nutrients – N and P with some carbon is important

Important Caveats

- Endorsement of supplementation for fisheries restoration does not mean society can return to disposing of wastes in river and streams!

- Nutrients (N,P,C) can only be added in precise amounts in balanced ratios under carefully controlled and monitored conditions!

Conclusions

- The Pacific Northwest (and North Pacific Rim) is unique, and it requires the "**Anadromous Nutrient Pump**" to maintain its terrestrial and freshwater productivity – Salmon are the '**keystone species**'.
- Nutrient enrichment of lakes and streams should be viewed as an **interim** measure which is highly effective when all components of the ecosystem recover (e.g. terrestrial, riparian) and key external factors like over-fishing and habitat loss are managed on a sound scientific 'ecosystem'

It all starts here……