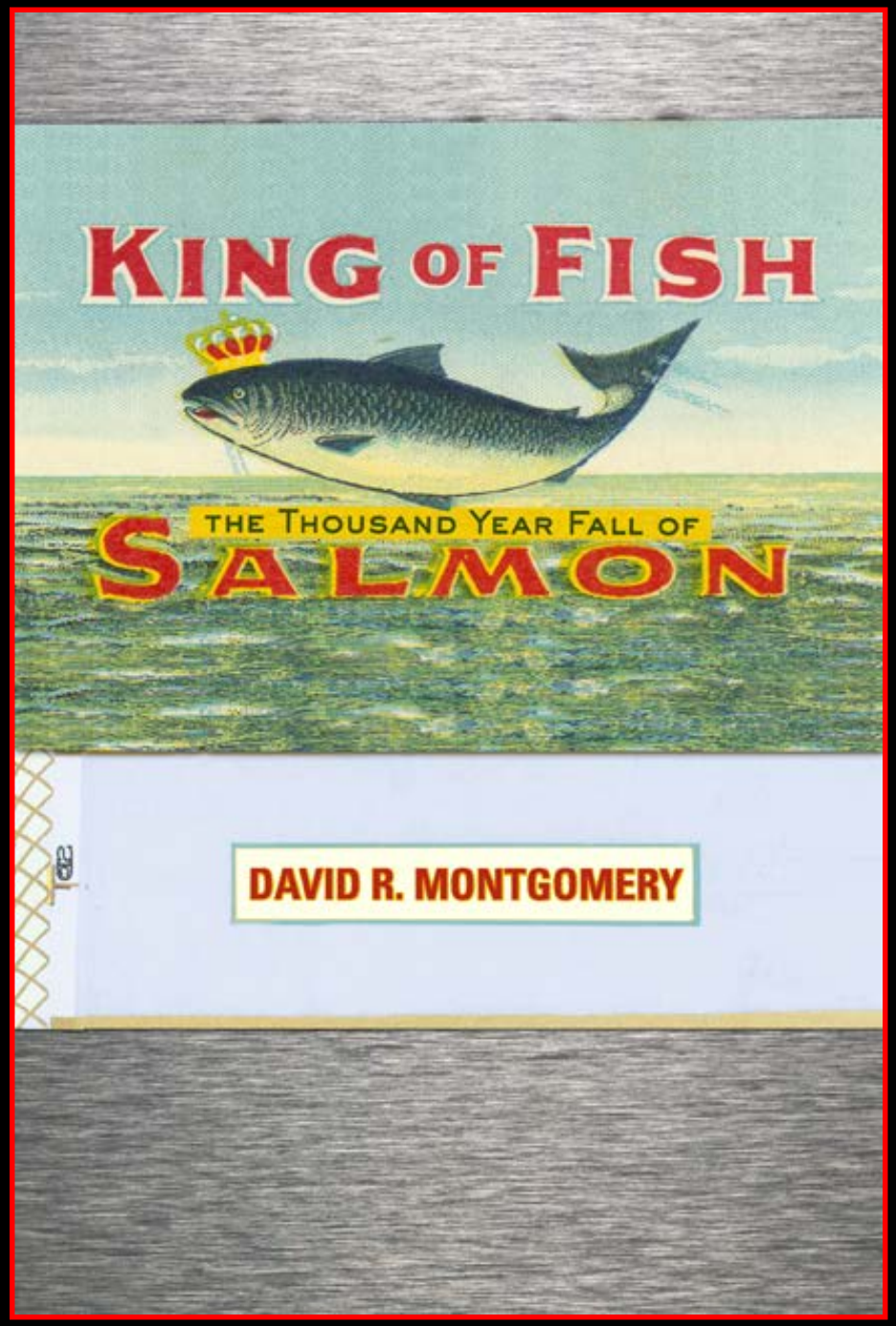
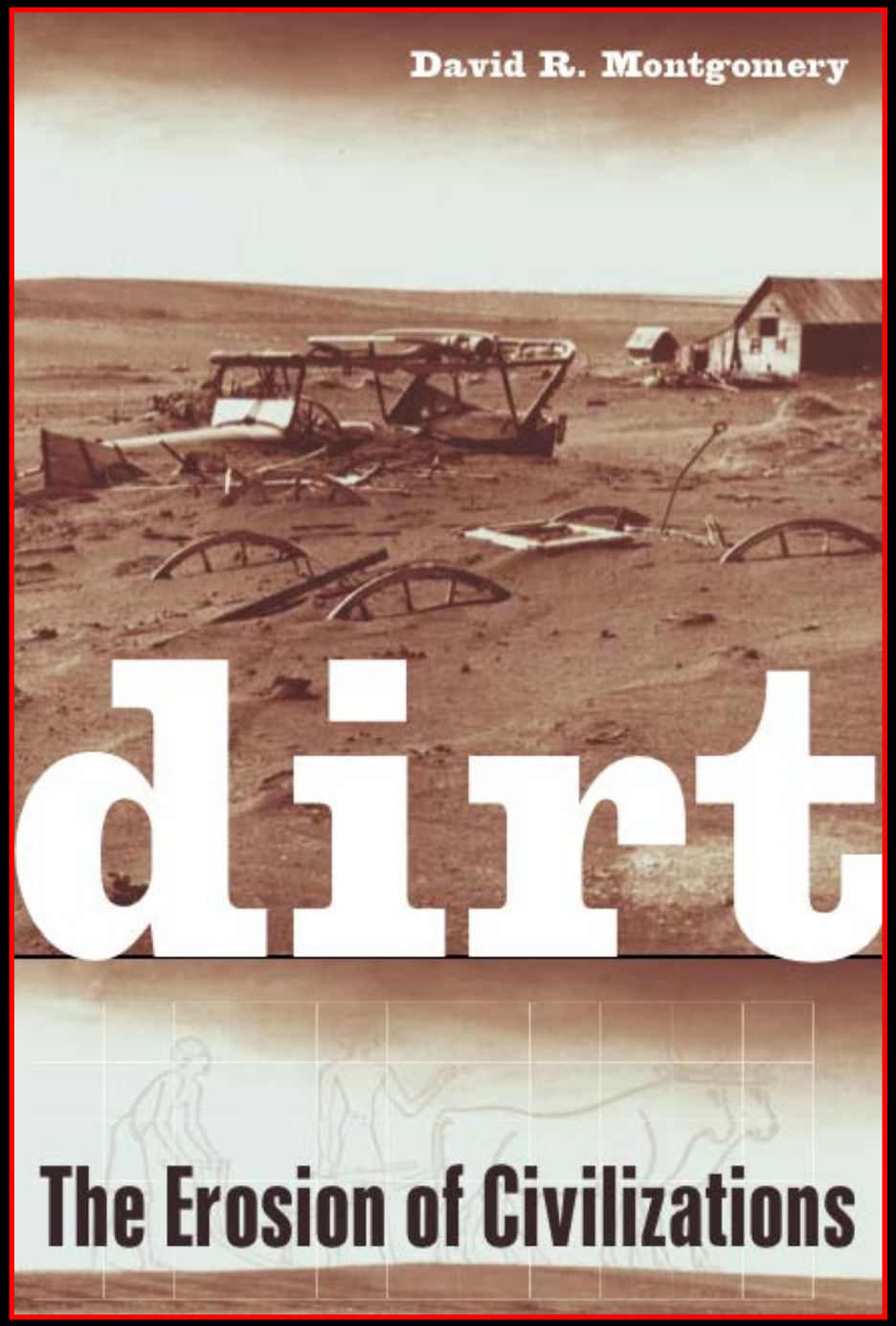

KING OF FISH
THE THOUSAND YEAR FALL OF
SALMON
DAVID R. MONTGOMERY


David R. Montgomery
dirt
The Erosion of Civilizations


CHINOOK
KING
MASU
AKA CHERRY
STEELHEAD
COHO
AKA SILVER
CHUM
AKA DOG
PINK
AKA HUMPY
SOCKEYE
AKA RED
O. masou
O. tshawytscha
O. kisutch
O. keta
O. gorbuscha
O. nerka
O. mykiss
O. clarki
O. gilae
O. rastrosus
CUTTHROAT
WESTERN TROUT
S. salar
S. trutta
ATLANTIC SALMON
BROWN TROUT
SALMO
PACIFIC SALMON
-ONCORHYNCHUS
20 MILLION YEARS AGO
ANCESTRAL SALMON
-EXTINCT-
SABER TOOTH
COOL FISH
THE SALMON FAMILY TREE
RAY TROLL 2003

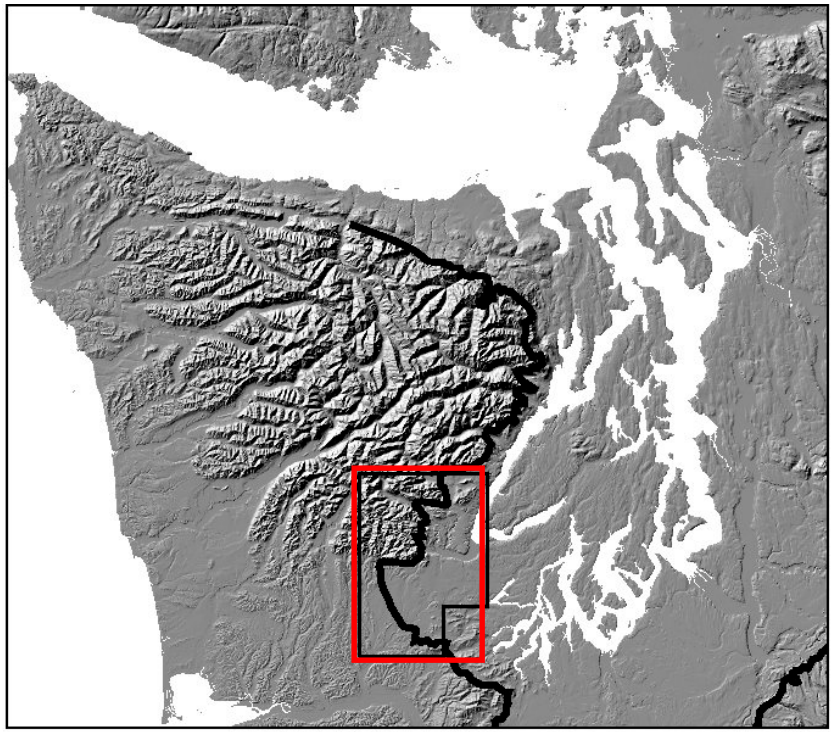
Classical Hypothesis for Pacific Salmon Evolution and Diversification

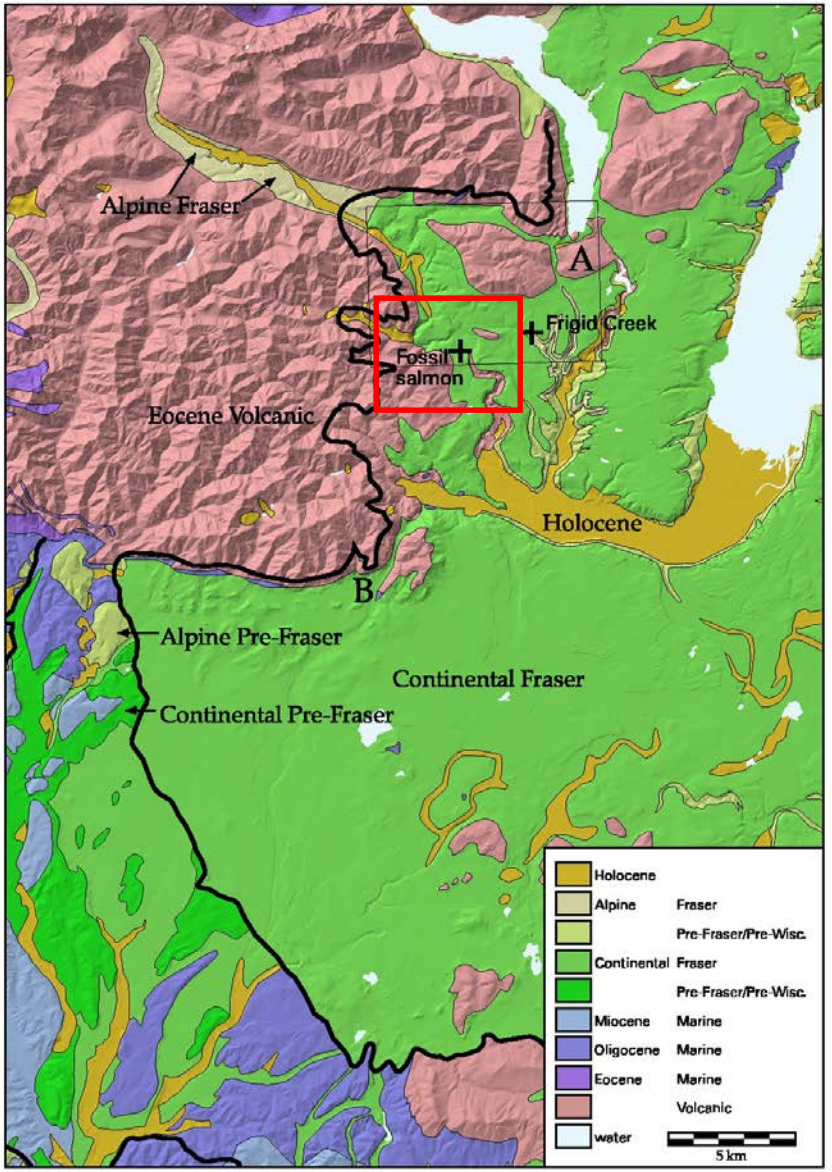
- Isolation during glacial advances
- Problem: Fossil salmon pre-date Pleistocene glaciations!

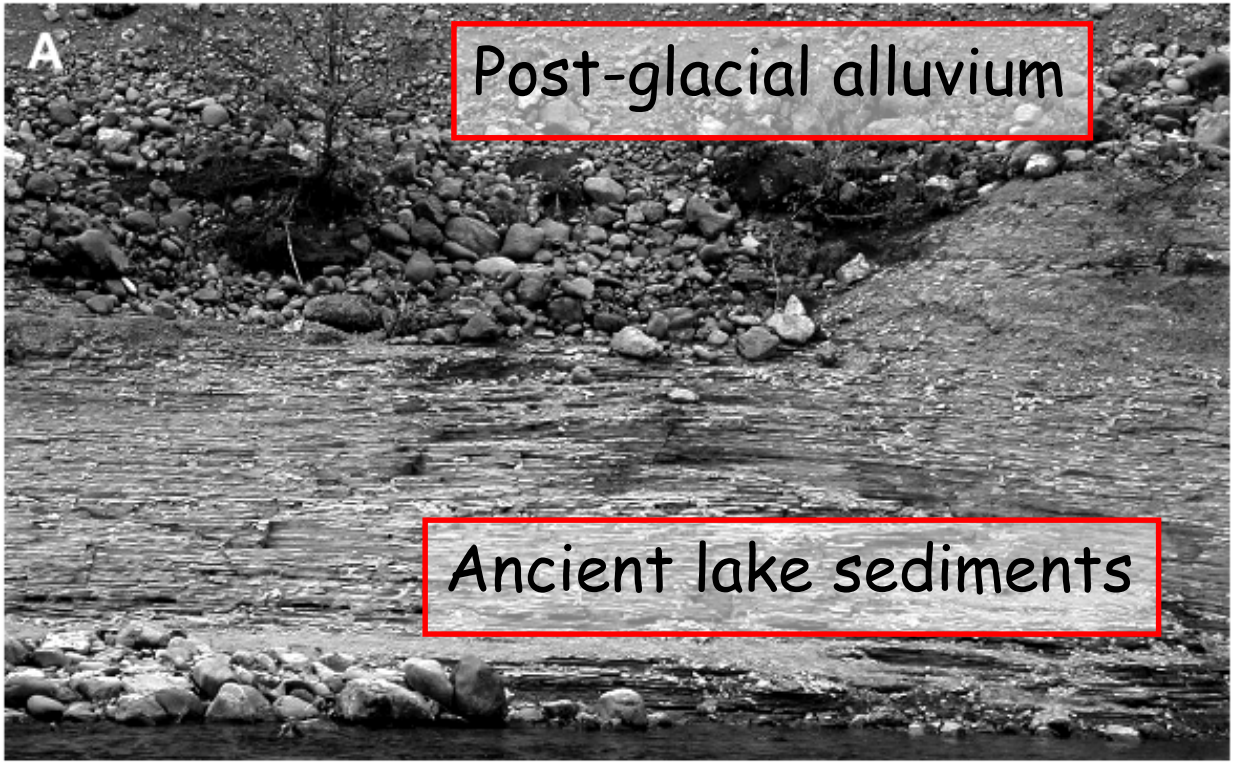
Evolution of the Pacific Salmon

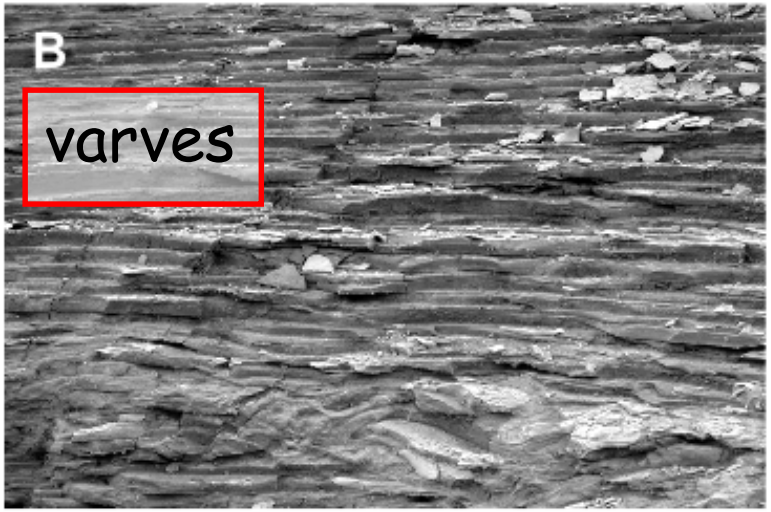
- Pacific salmon evolved between 20 million and 6 million years ago (Miocene).
- Radiation of Pacific salmon into distinct species coincides with uplift of Pacific Rim topography.

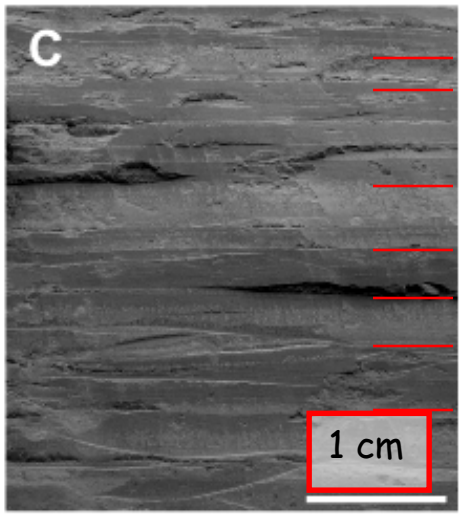
The Skokomish River fossil salmon locality is just upstream of the gorge of the South Fork at the edge of the Puget Lowland.







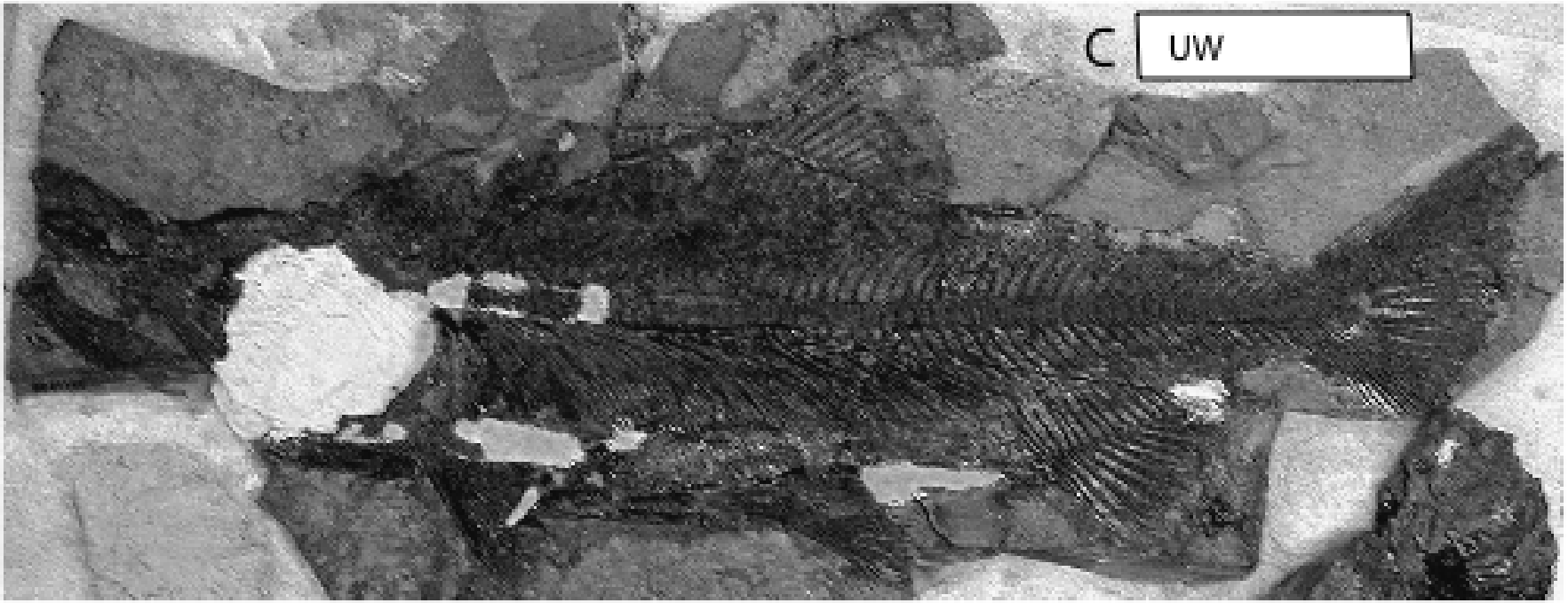




clay
silt
clay
silt
clay
silt
clay
silt

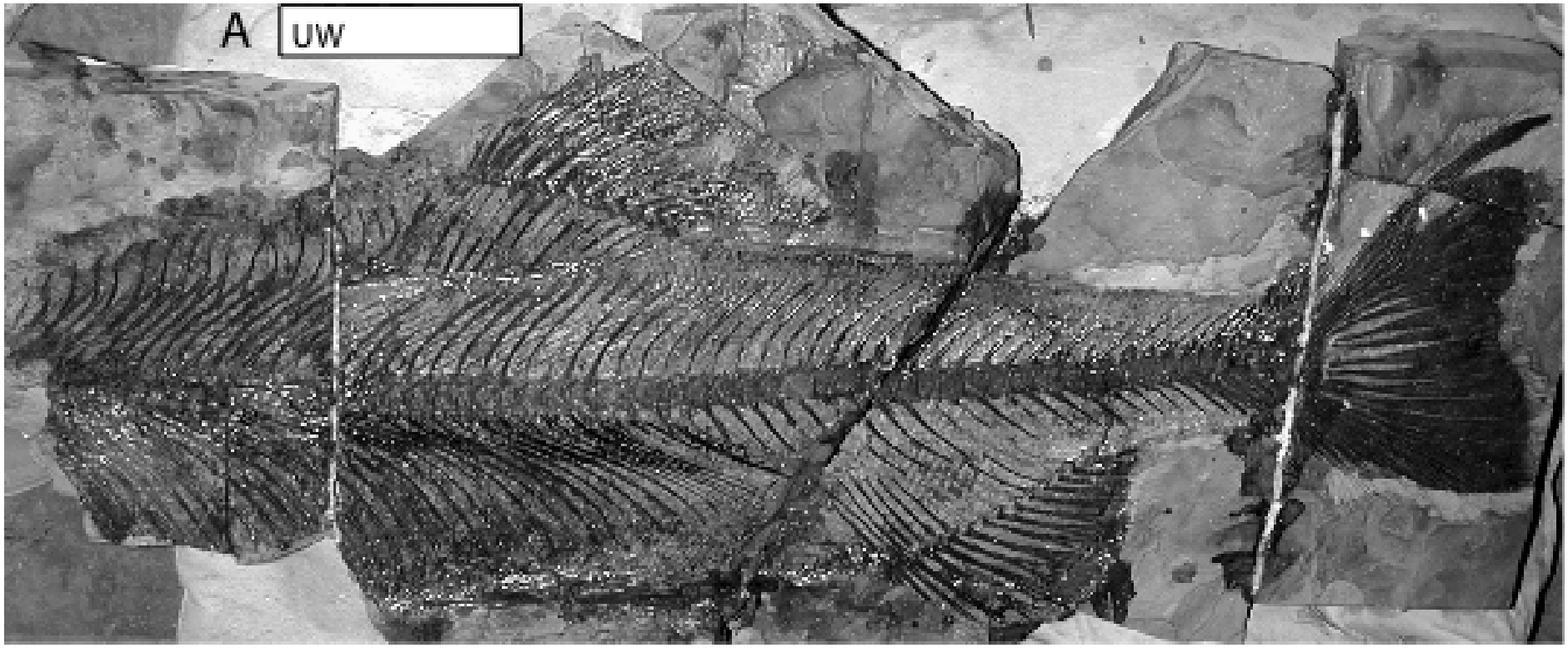
Sockeye Salmon

4 years old



Isotopic analyses indicate they were anadromous

Spawning population

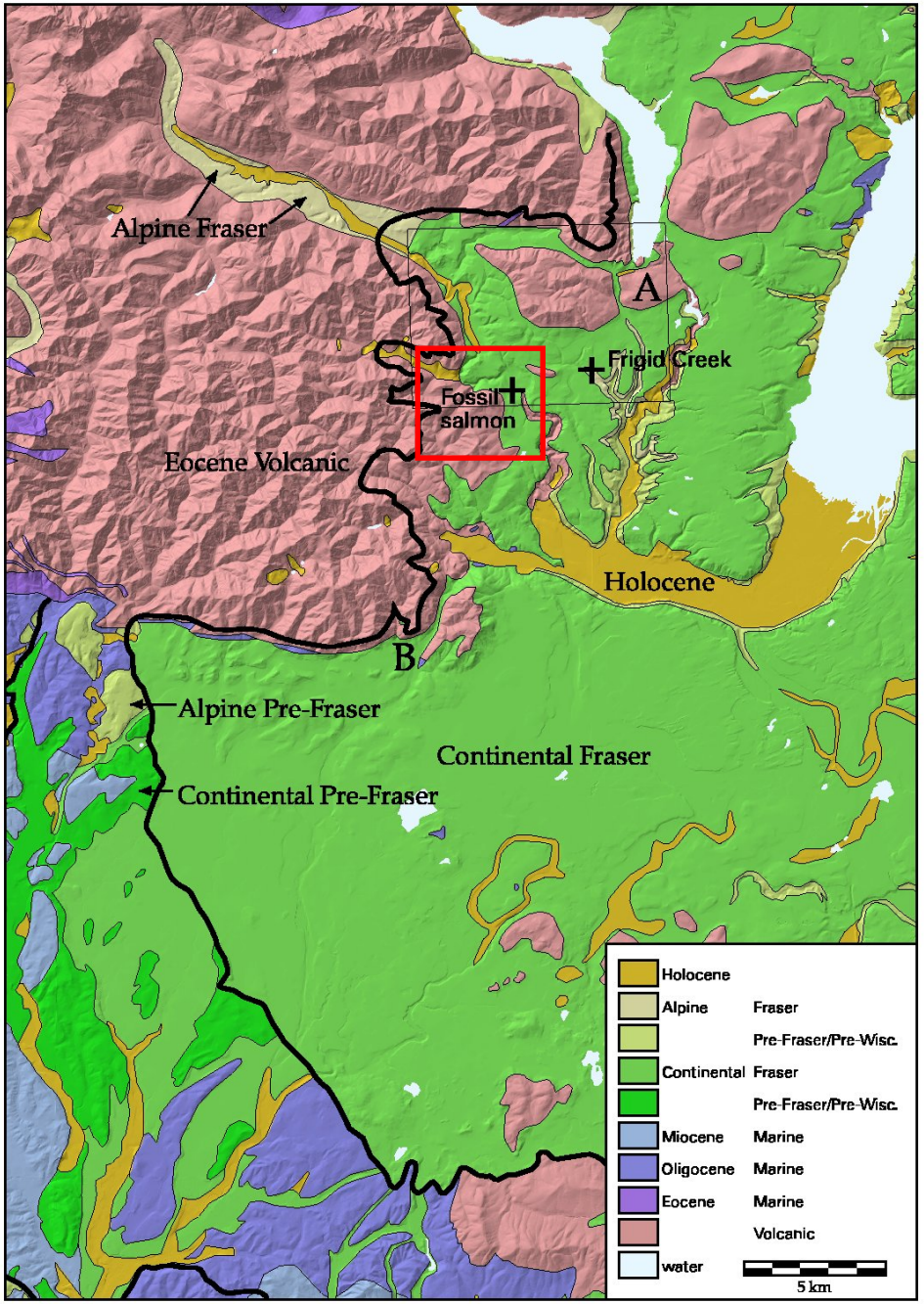


Major life history traits established by 1 million years ago

Fossil site is at the margin of the last advance of the Puget Lobe ice sheet, but wood samples from lake sediments are radiocarbon dead and therefore older than 50,000 years.

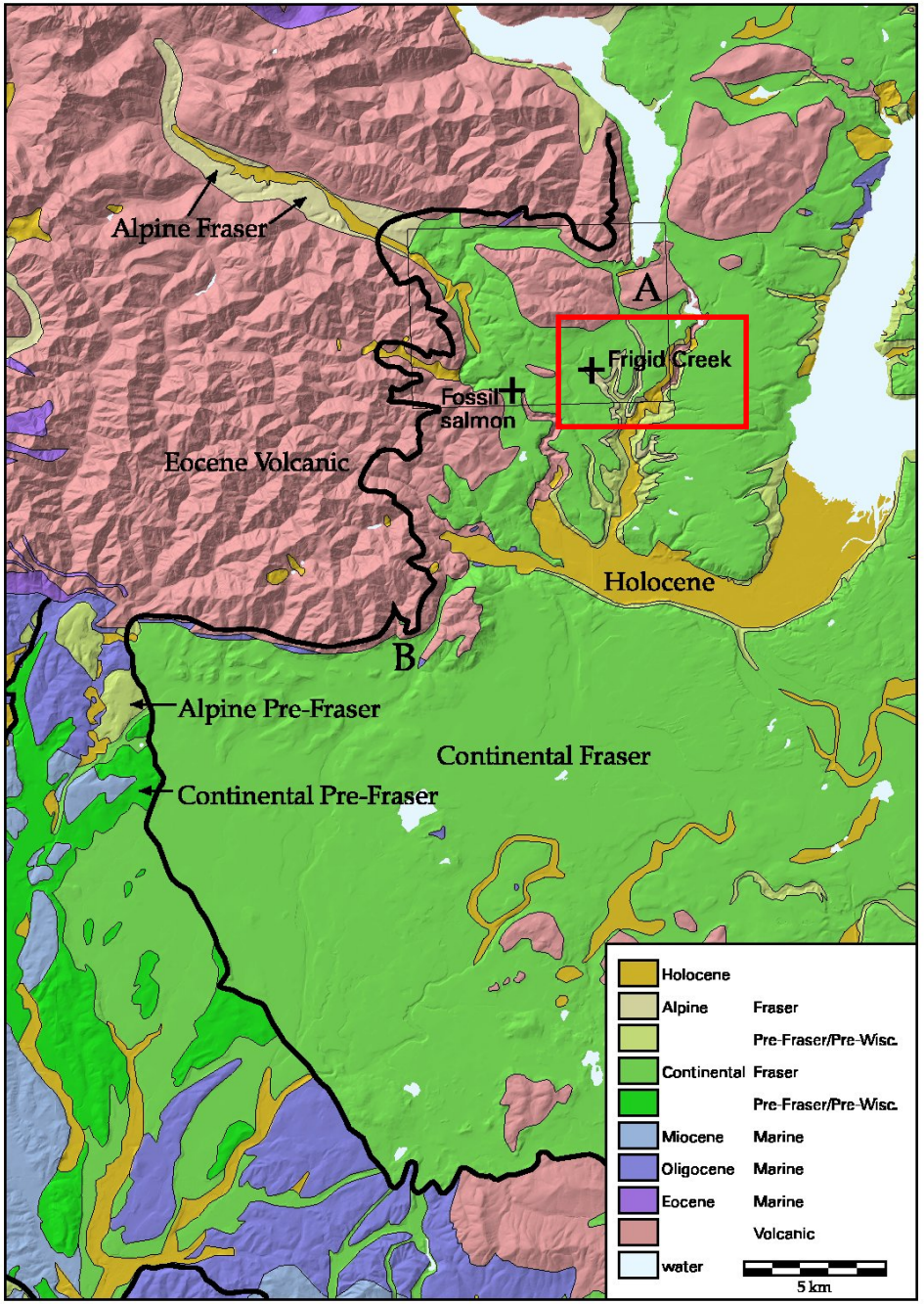
So the fossil salmon lake is from an older advance of the Puget Lobe.

But which one?



Westgate et al. (1987) reported similar lake sediments at Frigid Creek, a neighboring valley tributary to the North Fork Skokomish River.

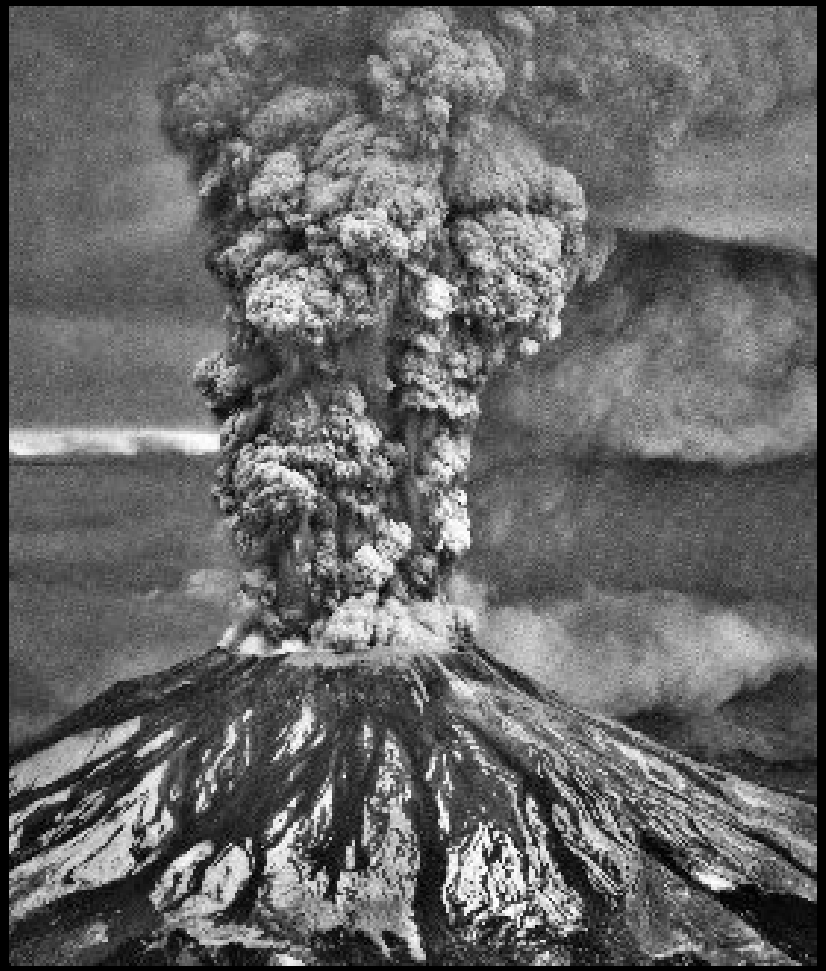
These ancient lake sediments contained Lake Tapps tephra, dated at 1 million years old at its type locality by fission track analysis.



Westgate, J. A., Easterbrook, D. J., Naeser, N. D., and Carson, R. J., 1987, Lake Tapps Tephra: An early Pleistocene stratigraphic marker in the Puget Lowland, Washington, Quaternary Research, v. 28, p. 340-355.

Salmon and Natural Disturbances

For millions of years salmon thrived in a landscape shaped by floods, volcanic eruptions, and natural disturbances.

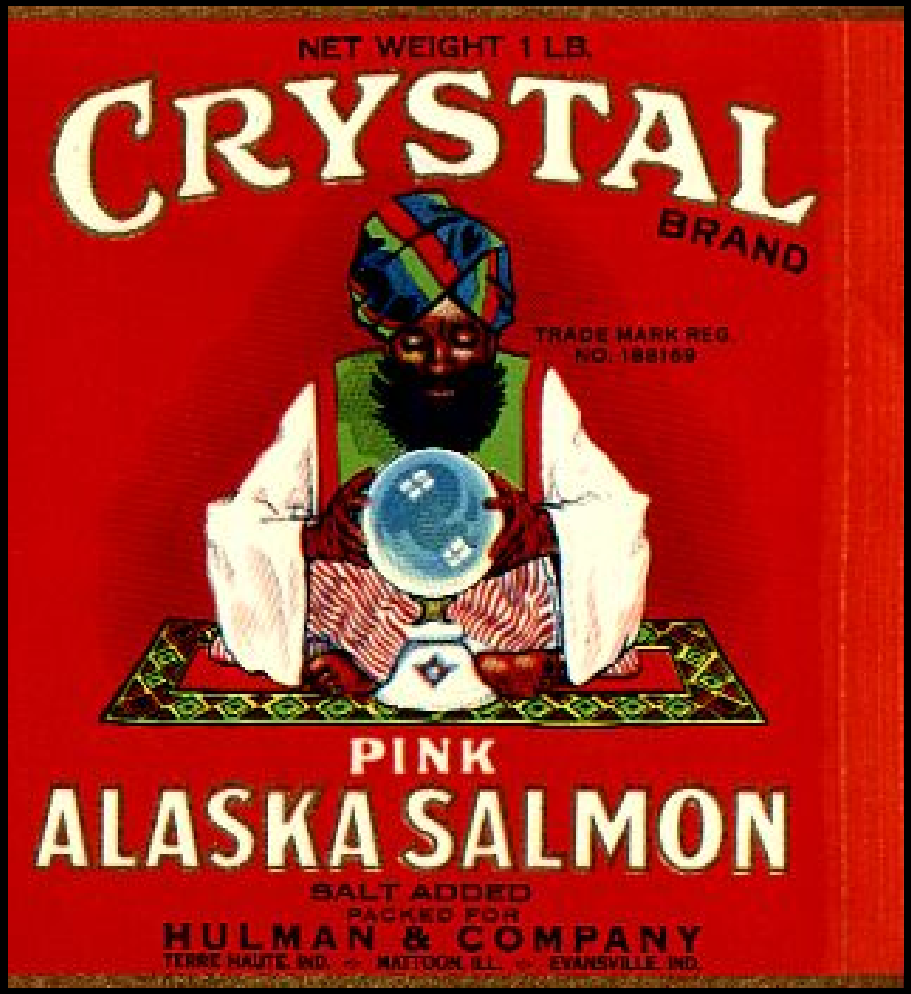


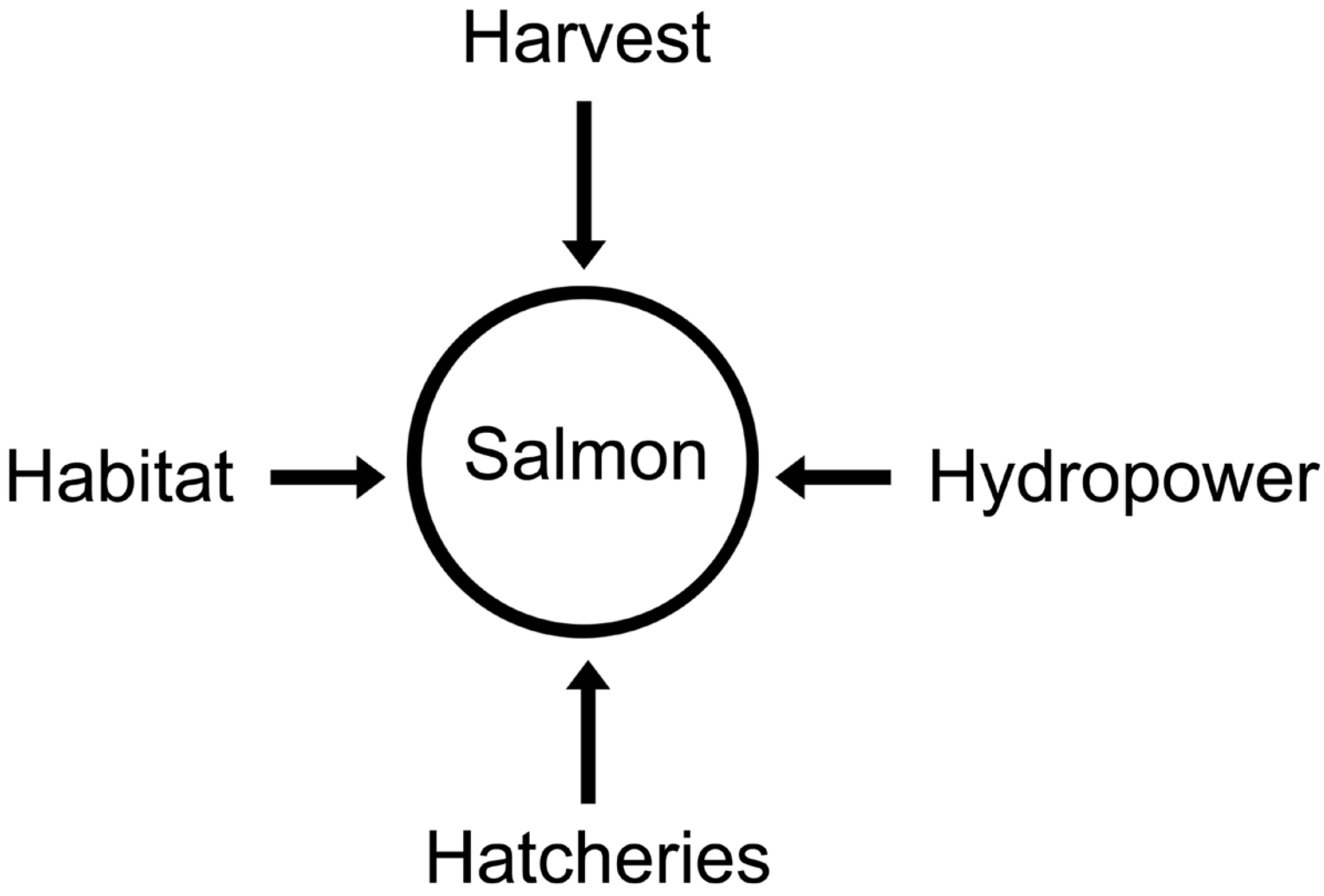
Status of Salmon Populations Today

Region	Percent of Historical Run Size
• Alaska	106
• British Columbia	36
• Puget Sound	8
• Washington	<2
• Columbia Basin	<2
• Oregon	7
• California	5
• California, Oregon, Washington, Idaho	5

Gresh, T., J. Lichatowich and P. Schoonmaker (2000) An estimation of historic and current levels of salmon production in the Northeast Pacific ecosystem: Evidence of a nutrient deficit in the freshwater systems of the Pacific Northwest. Fisheries, 25(1): 15-21.

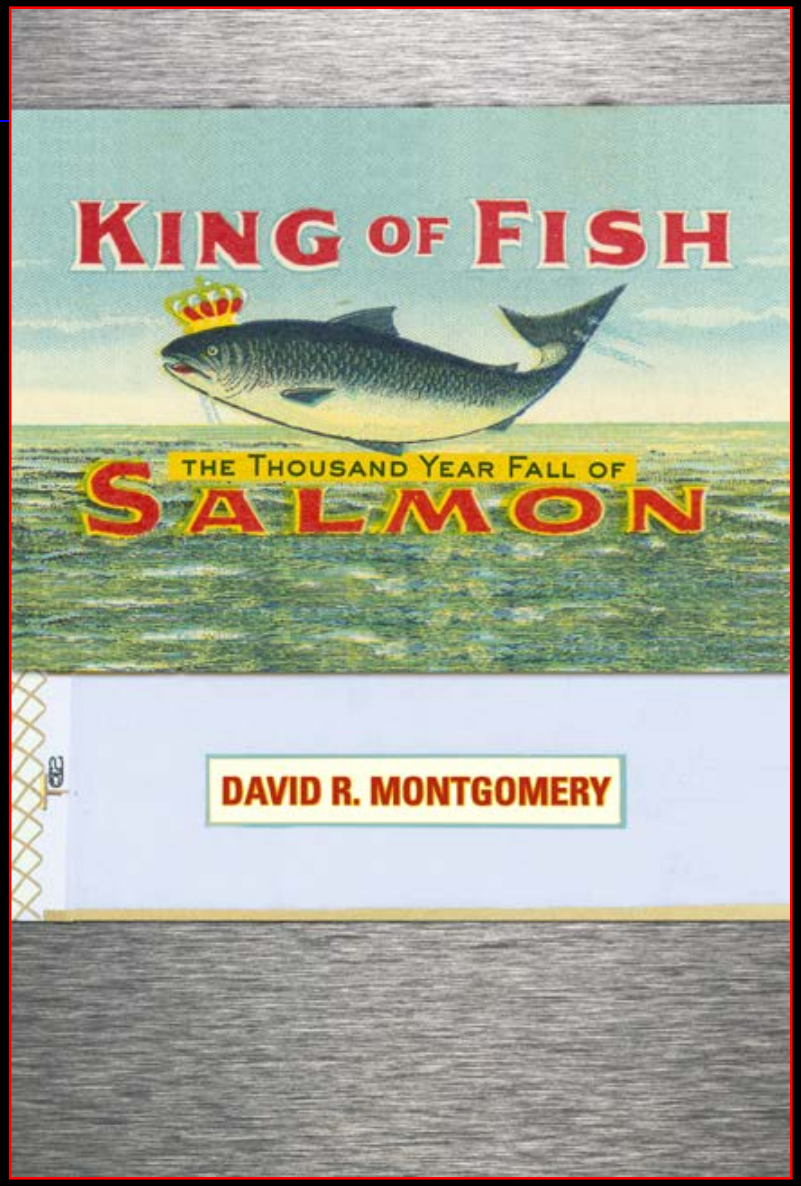
Will current strategies and restoration efforts work for Pacific salmon?




Harvest
Habitat
Salmon
Hydropower
Hatcheries

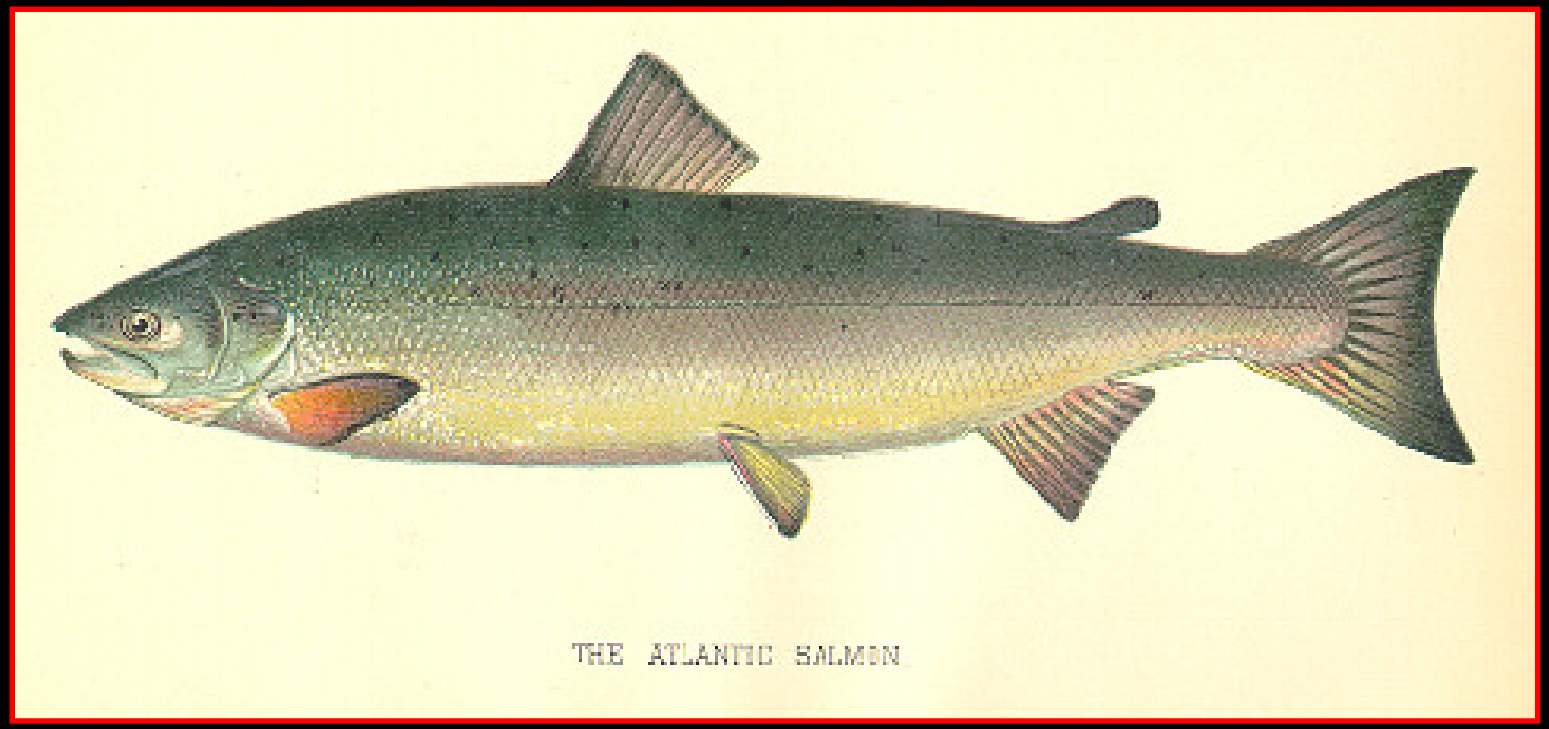
History, The 5th H

Strikingly similar pattern of changes to river systems and salmon crises in Great Britain, New England, and now the Pacific Northwest.



Harvest

The earliest recorded salmon-fishing legislation was an edict issued by King Malcolm II of Scotland in 1030 that established a closed season for taking "old salmon".



Habitat

A statute dating from the reign of Richard the Lion-hearted declared that rivers must be kept free of obstructions so as to permit a well-fed three-year-old pig, standing sideways in the stream, not to touch either side.

Hydro (dams)

An Act passed in the reign of King Robert the First, in 1318, forbade the erection of fixtures of any size or dimensions that would prevent the progress of salmon up and down a river.

George I Tries to Save the Salmon

In 1714 George I enacted a law to prevent blocking salmon from their spawning grounds in seventeen English rivers.

By 1868, all seventeen rivers protected by George I were either blocked or poisoned by pollution.
[habitat and hydro]

Alexander Fraser proposed steps to increase the number of salmon in Scottish rivers (1833):

(1) don't block the ability of salmon to migrate up or down stream [hydro];

(2) limit fishing intensity so as to not take the majority of the spawners [harvest];

(3) prevent habitat degradation that could damage the fishery [habitat].

"The cry of 'Salmon in Danger!' is now resounding throughout the length and breadth of the land. A few years, a little more over-population, a few more tons of factory poisons, a few fresh poaching devices … and the salmon will be gone—he will be extinct.

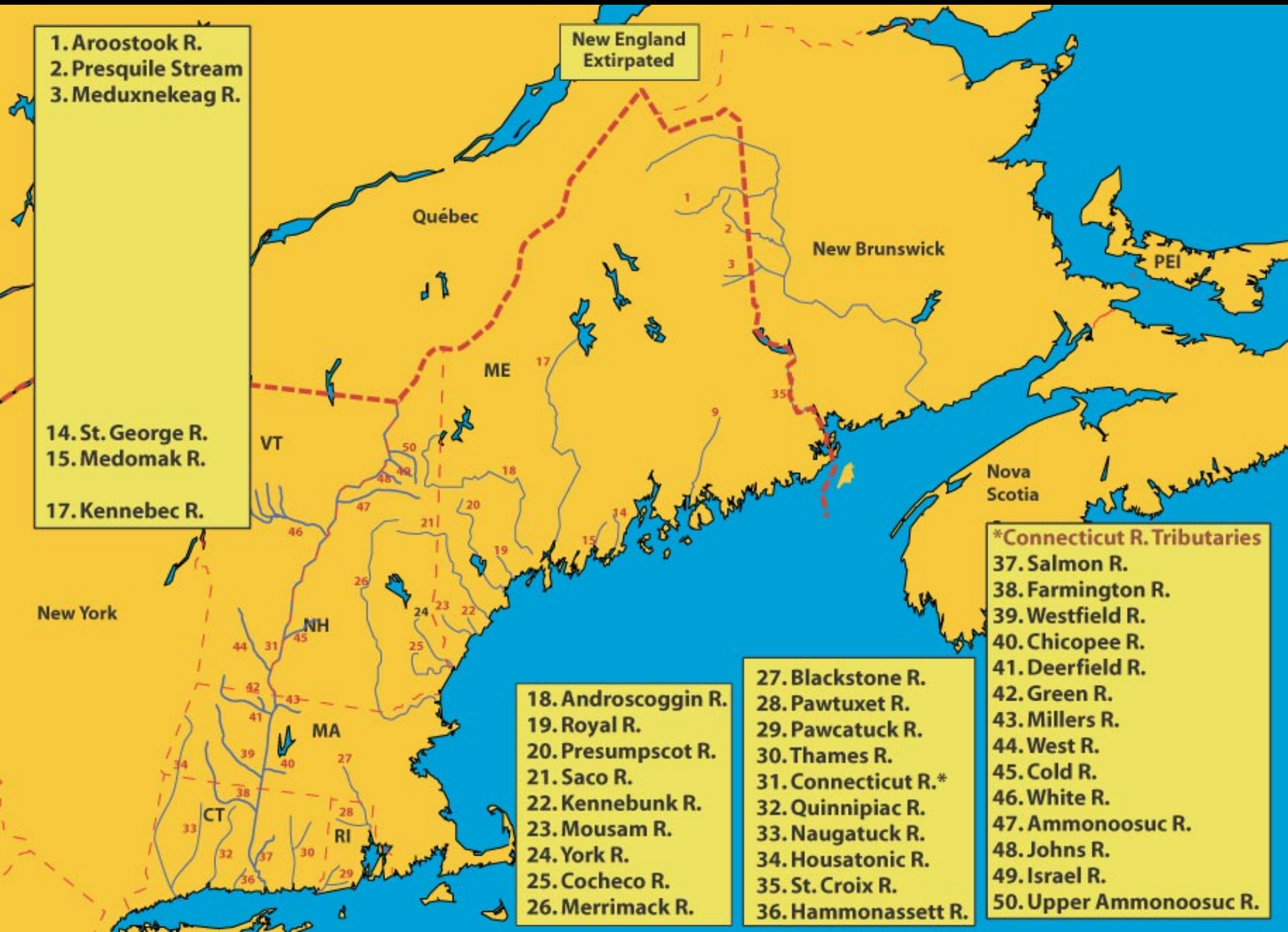
Shall we not step in between wanton destruction … and so ward off the obloquy which will be attached to our age when the historians of the nineteen-sixties will be forced to record that: 'The inhabitants of the last century destroyed the salmon'…"

— Charles Dickens (1861).

New World Salmon

"If the Pigeons plagued us by their abundance, the Salmon gave us even more trouble. So large a quantity of them enters into this river that at night one is unable to sleep, so great is the noise they make in falling upon the water after having thrown or darted themselves in to the air."

— N. Denys (1672 , p. 199).


1. Aroostook R.
2. Presquile Stream
3. Meduxnekeag R.
14. St. George R.
15. Medomak R.
17. Kennebec R.
New England Extirpated
Québec
New Brunswick
PEI
Nova Scotia
ME
VT
NH
MA
CT
RI
New York
*Connecticut R. Tributaries
37. Salmon R.
38. Farmington R.
39. Westfield R.
40. Chicopee R.
41. Deerfield R.
42. Green R.
43. Millers R.
44. West R.
45. Cold R.
46. White R.
47. Ammonoosuc R.
48. Johns R.
49. Israel R.
50. Upper Ammonoosuc R.
18. Androscoggin R.
19. Royal R.
20. Presumpscot R.
21. Saco R.
22. Kennebunk R.
23. Mousam R.
24. York R.
25. Cocheco R.
26. Merrimack R.
27. Blackstone R.
28. Pawtuxet R.
29. Pawcatuck R.
30. Thames R.
31. Connecticut R.*
32. Quinnipiac R.
33. Naugatuck R.
34. Housatonic R.
35. St. Croix R.
36. Hammonassett R.

The proliferation of small dams gradually blocked salmon from New England's rivers.

Between 1820 and 1880 over one hundred and fifty fishery laws relating to salmon were passed by the state of Maine.

Enforcement, provided for at the local level, was virtually nonexistant.

Greatworks Dam, Penobscot River

Key factors in British and New England salmon declines

Local control and lax enforcement

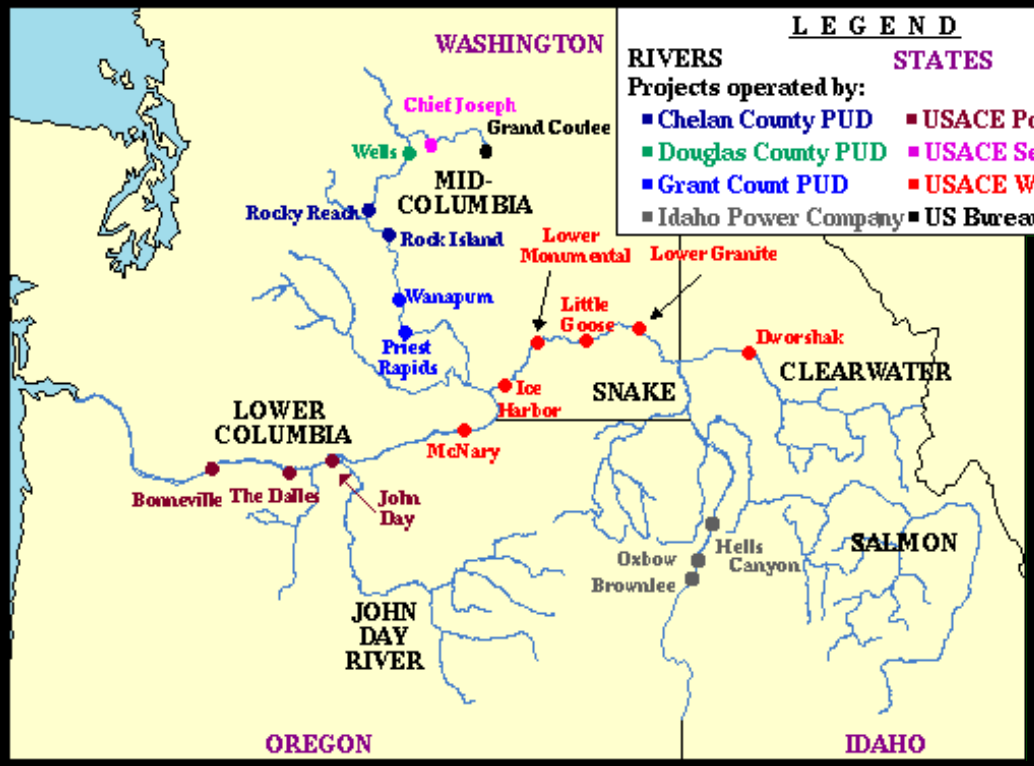
Gradual accumulation of many individual habitat impacts

Over-reliance on hatcheries at the expense of habitat

Lack of long-term planning

For > 100 years the Pacific Northwest has been repeating the choices that led to the decline of the Atlantic salmon.

Harvest


LEGEND
RIVERS
STATES
Projects operated by:
Chelan County PUD
Douglas County PUD
Grant Count PUD
Idaho Power Company
USACE Portland District
USACE Seattle District
USACE Walla Walla District
US Bureau of Reclamation
WASHINGTON
Chief Joseph
Grand Coulee
Wells
MID-COLUMBIA
Rocky Reach
Rock Island
Lower Monumental
Lower Granite
Wanapum
Little Goose
Priest Rapids
Dworshak
CLEARWATER
Ice Harbor
SNAKE
LOWER COLUMBIA
McNary
Bonneville
The Dalles
John Day
Oxbow
Hells Canyon
Brownlee
SALMON
JOHN DAY RIVER
OREGON
IDAHO


TO-4847
500'
10-17-56

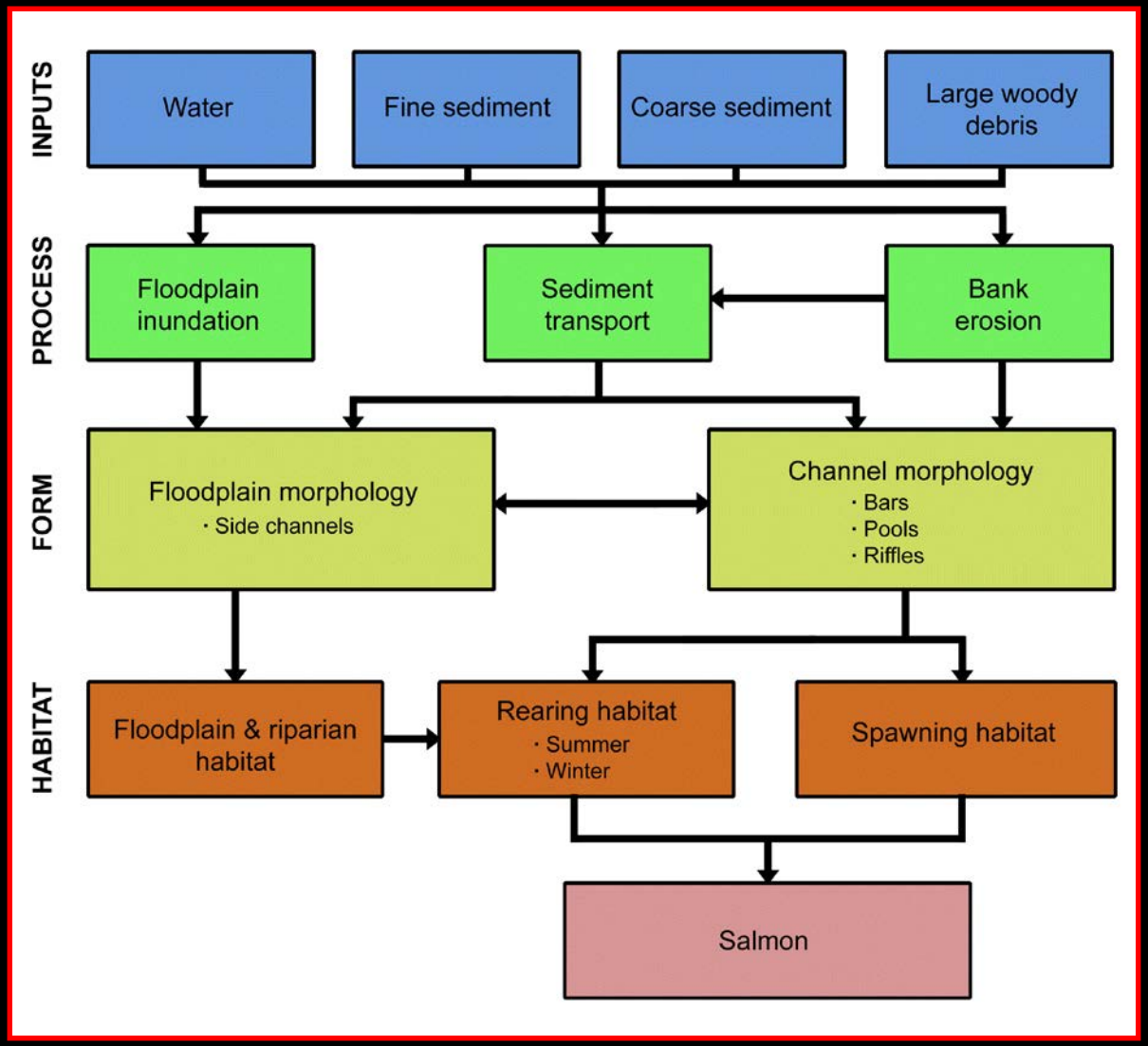
Hydro


OPERATION FISH RUN II
CORPS OF ENGINEERS

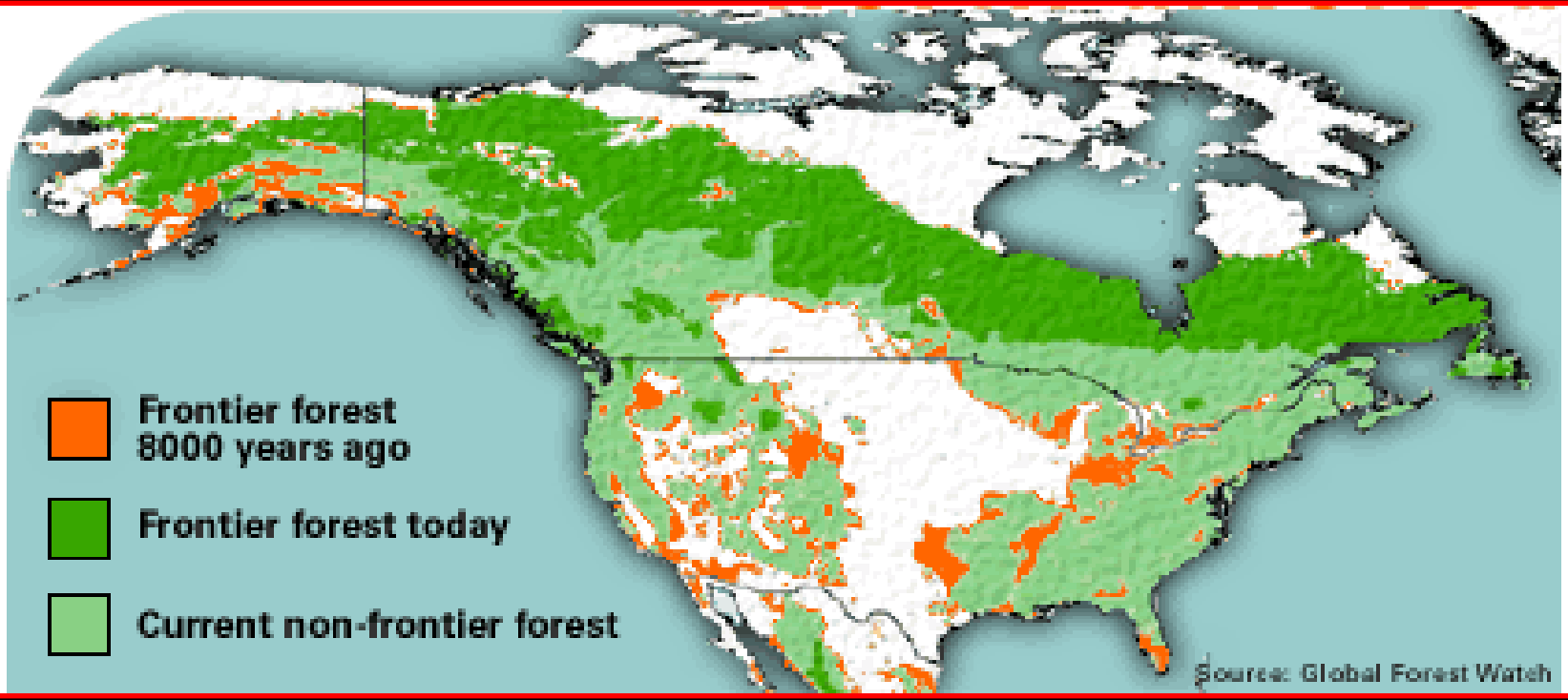
Habitat


MOVED 25 feet
CIR. OF STUMP 25 FEET
SPRUCE SPAR TREE 180 FEET HIGH

The supply and transport of water, sediment, and wood interact to structure salmon habitat.

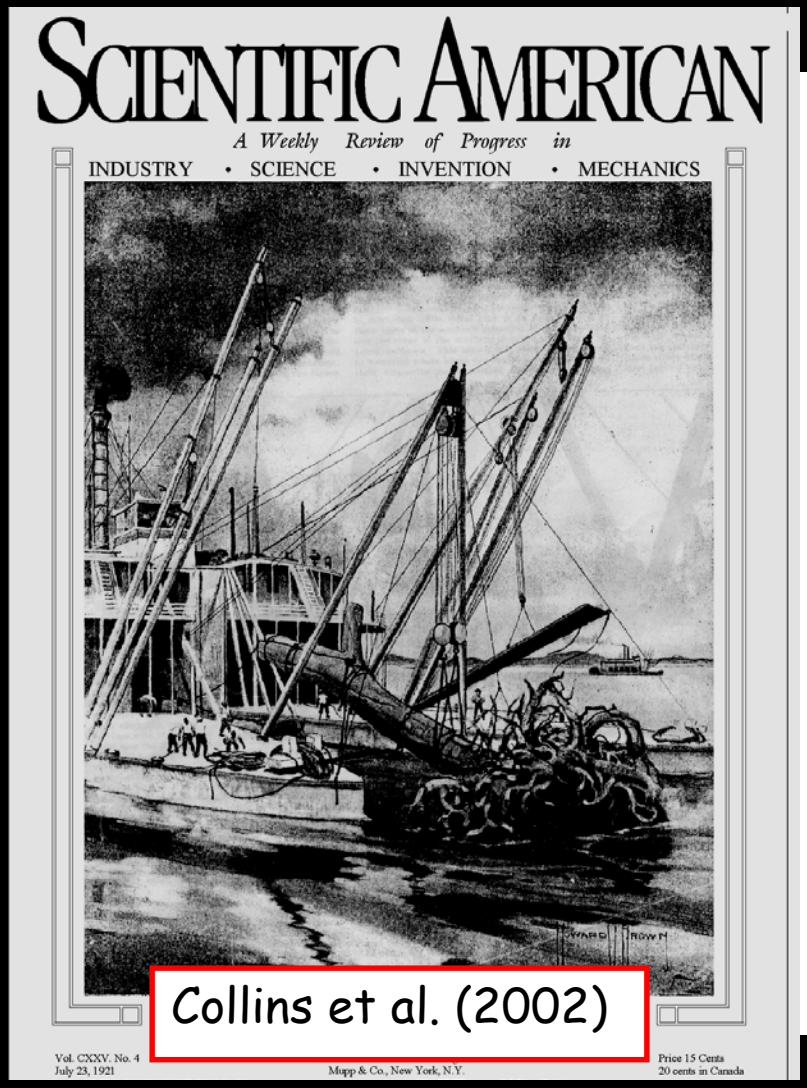


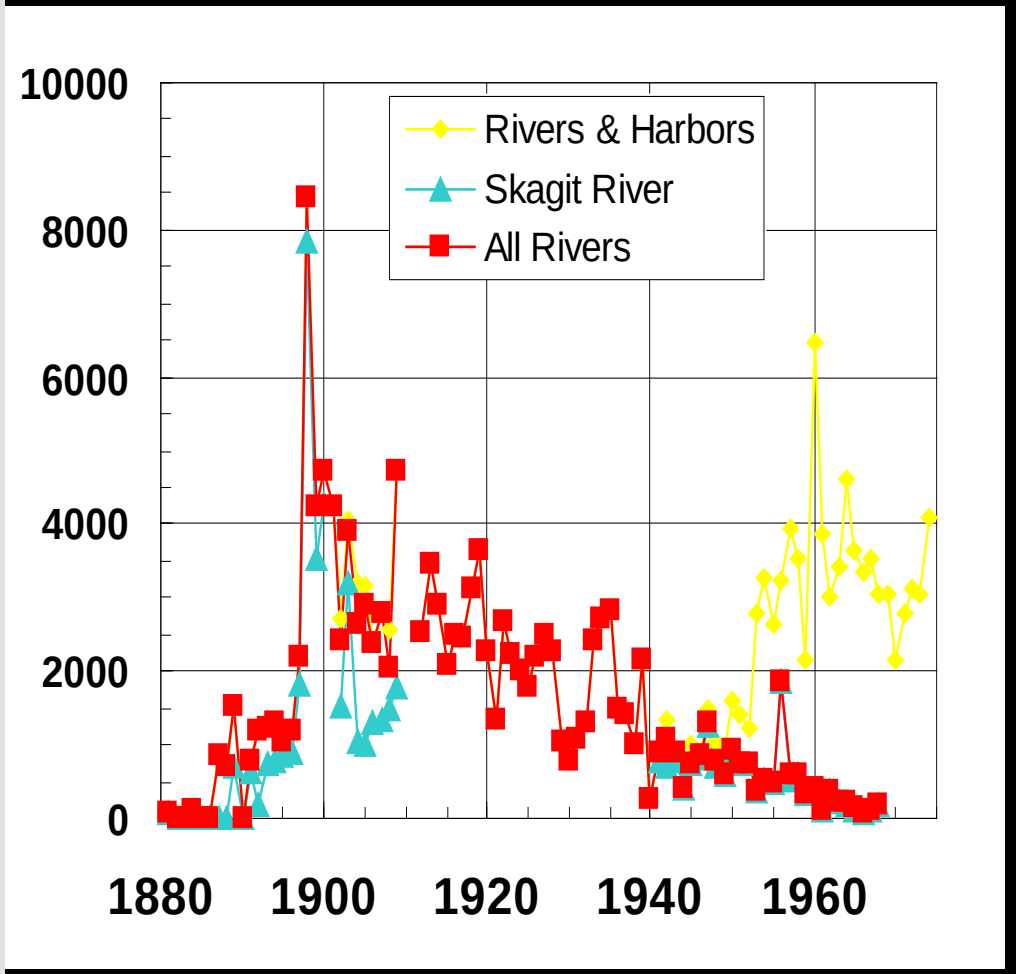
How well do we know what we are trying to restore?



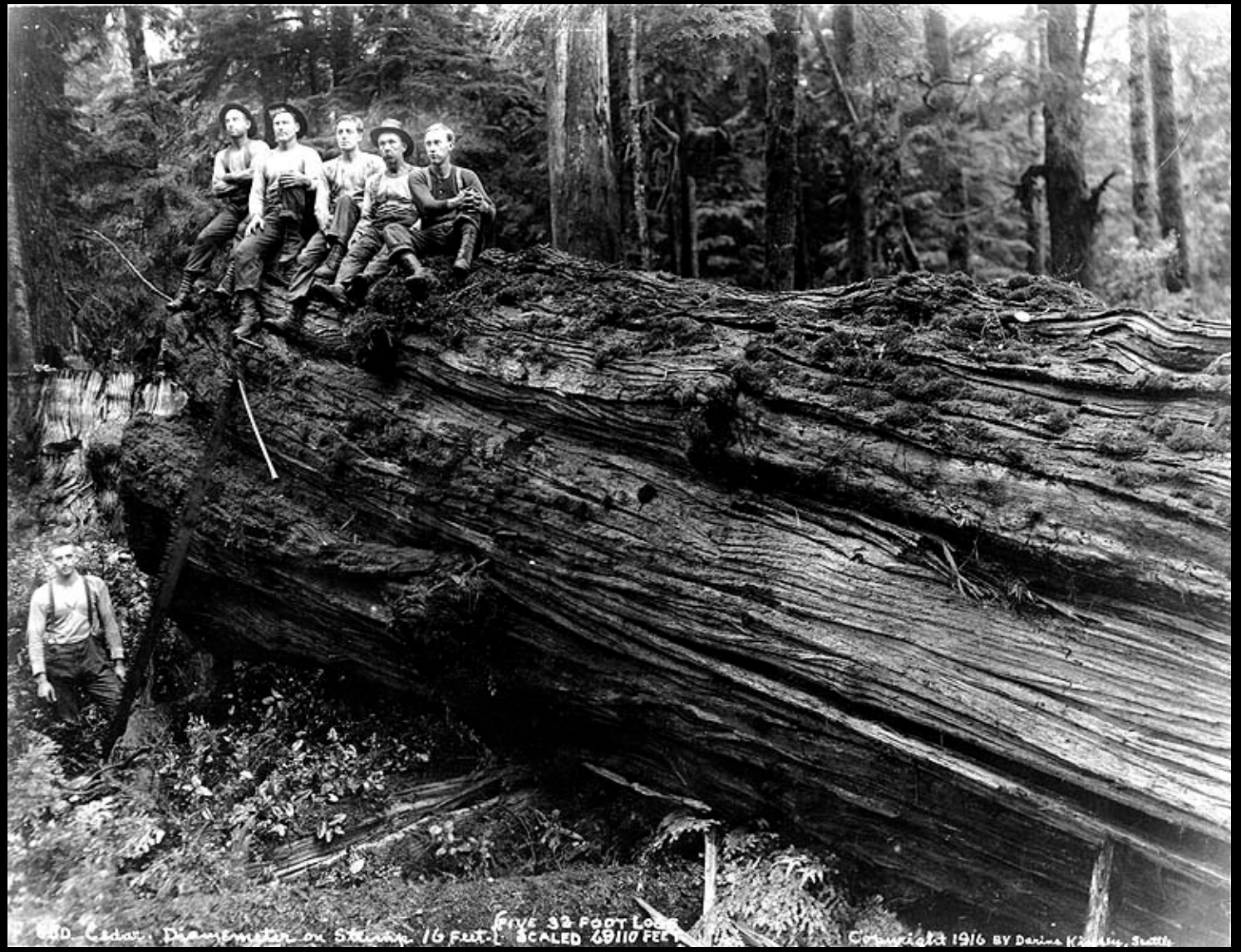
Most studies of fluvial systems come from areas that no longer host "frontier forests". How representative is our understanding of wood in world rivers?

Army Corps of Engineers aggressively "de-snagged" American Rivers

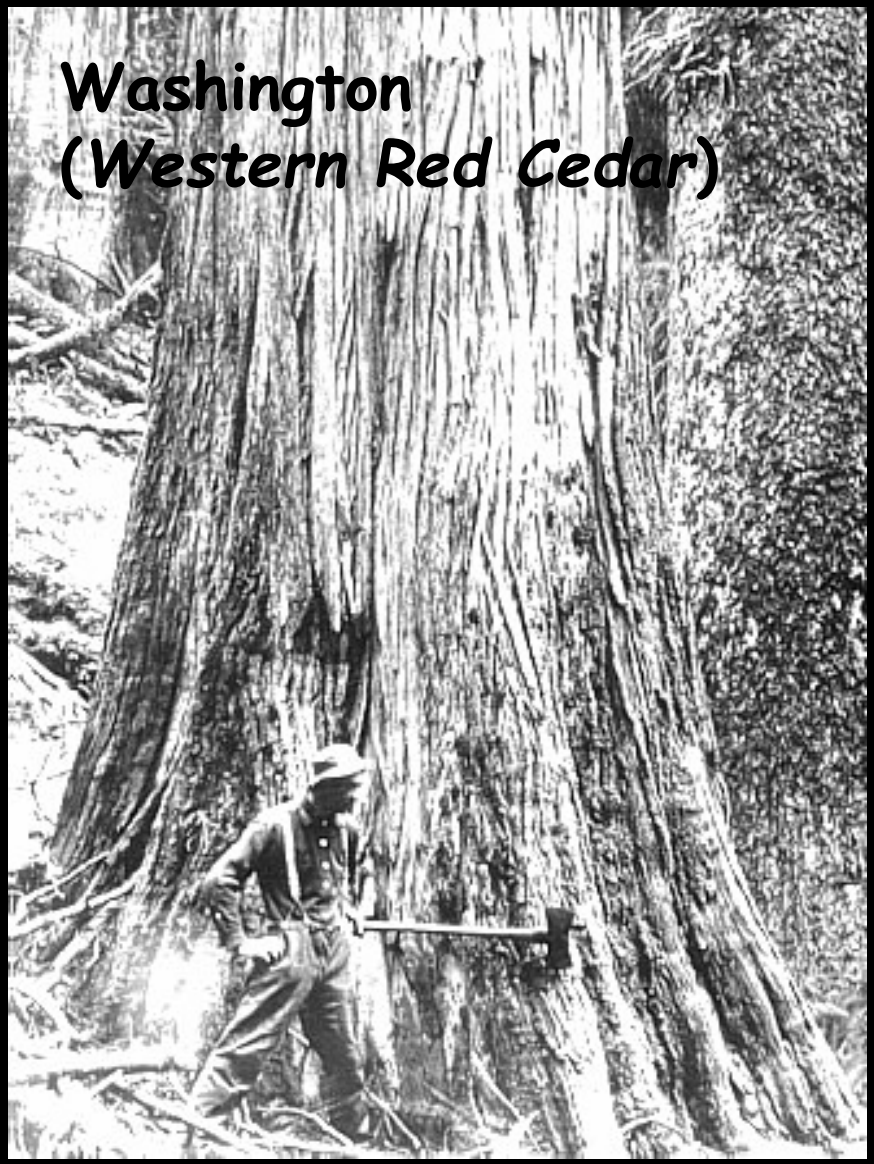


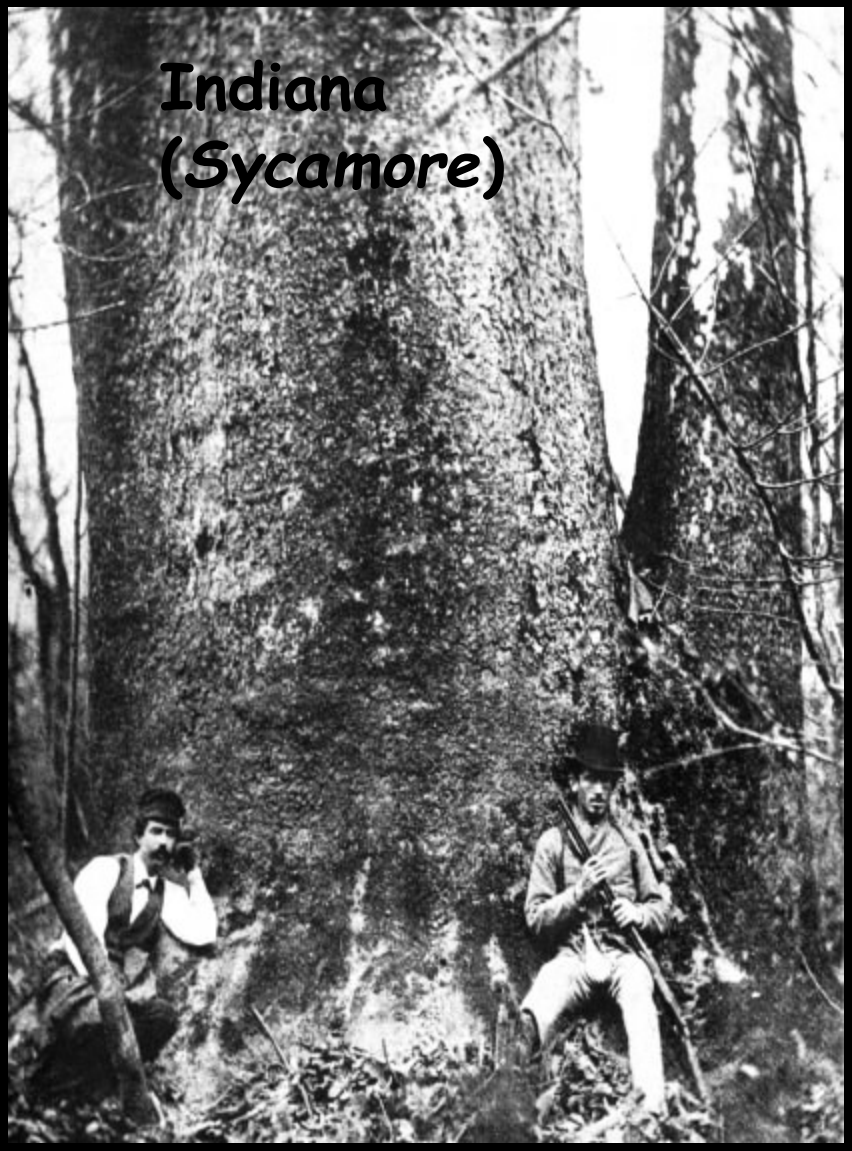


Big trees influenced big rivers



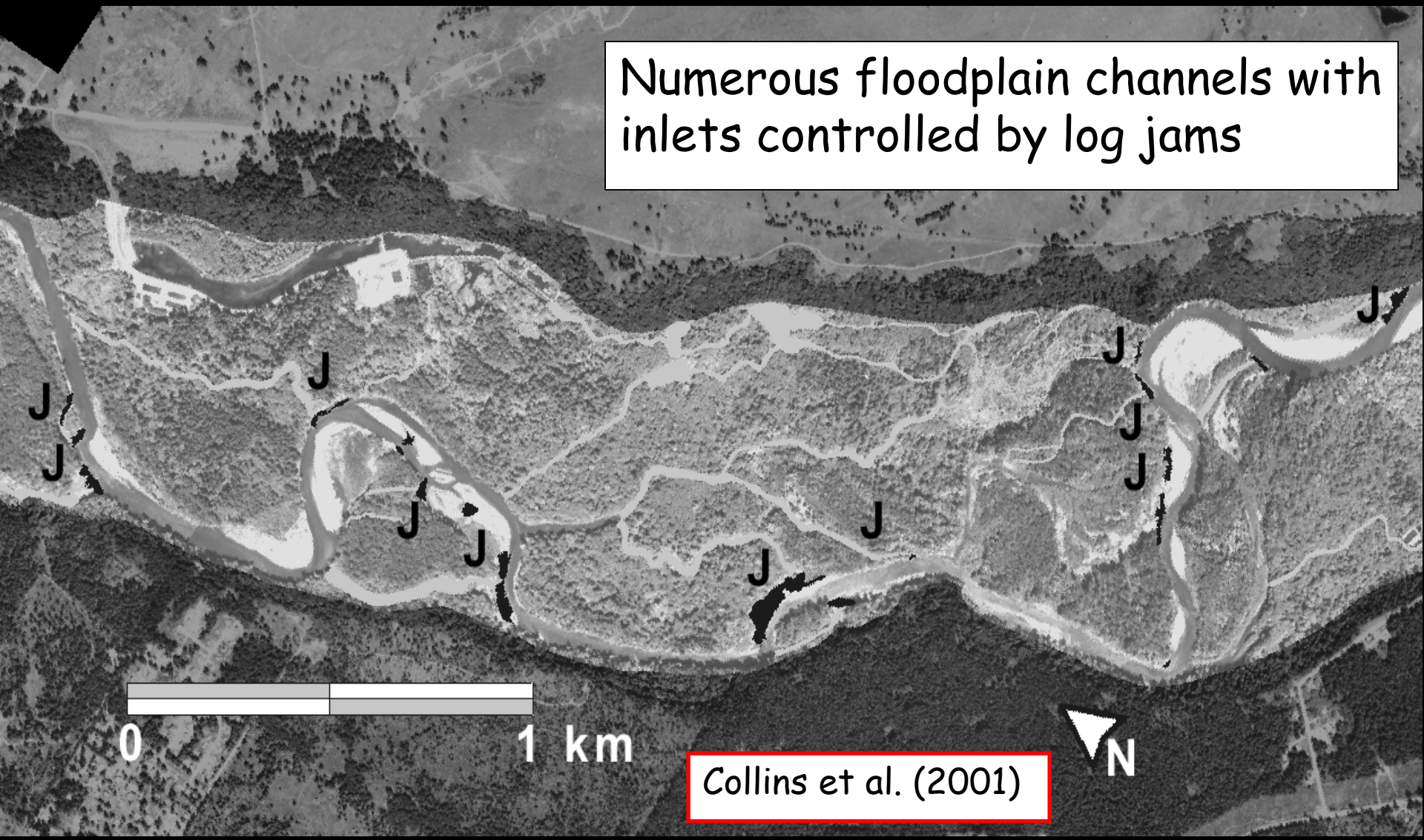
Big trees were not limited to the Pacific Northwest



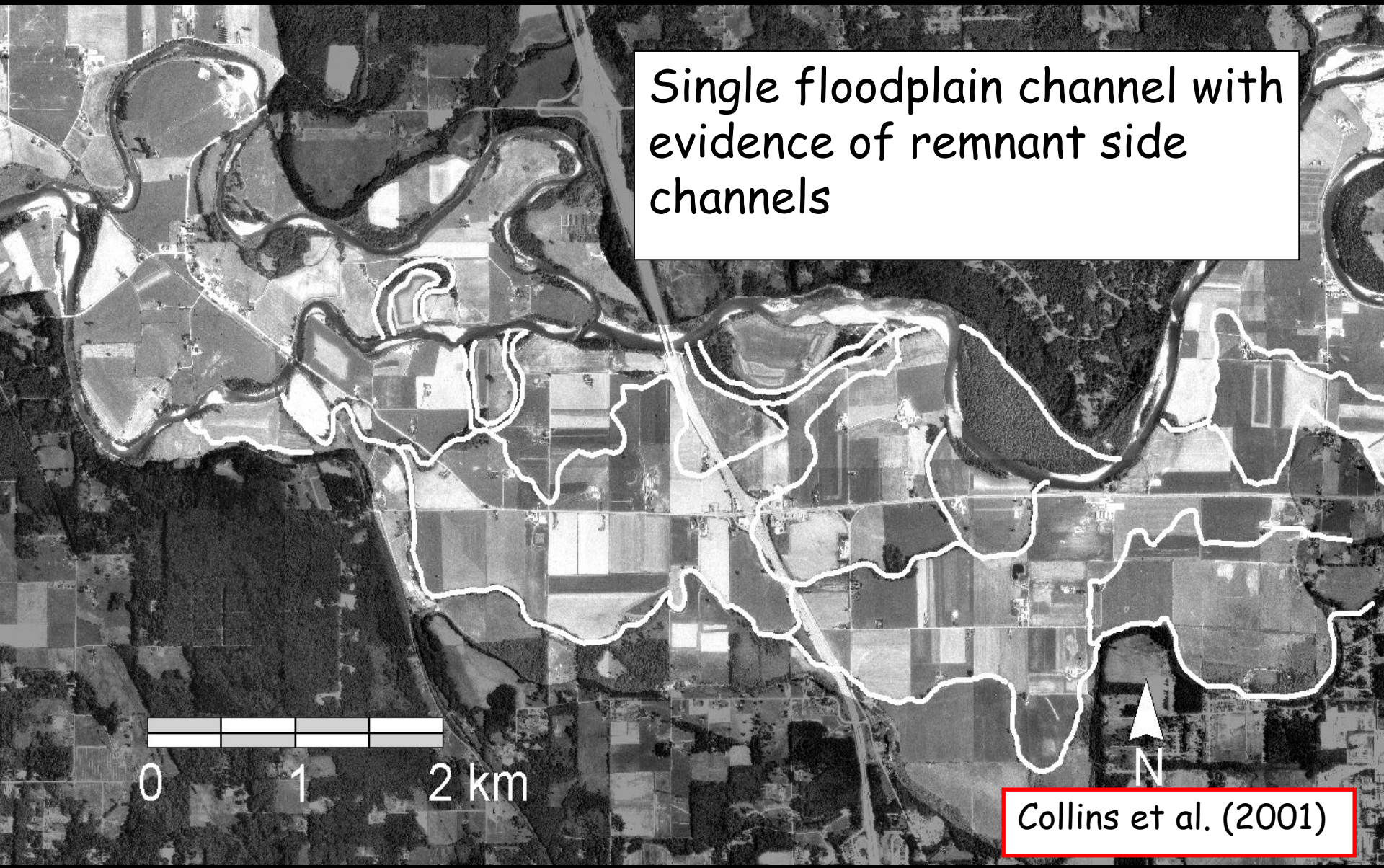


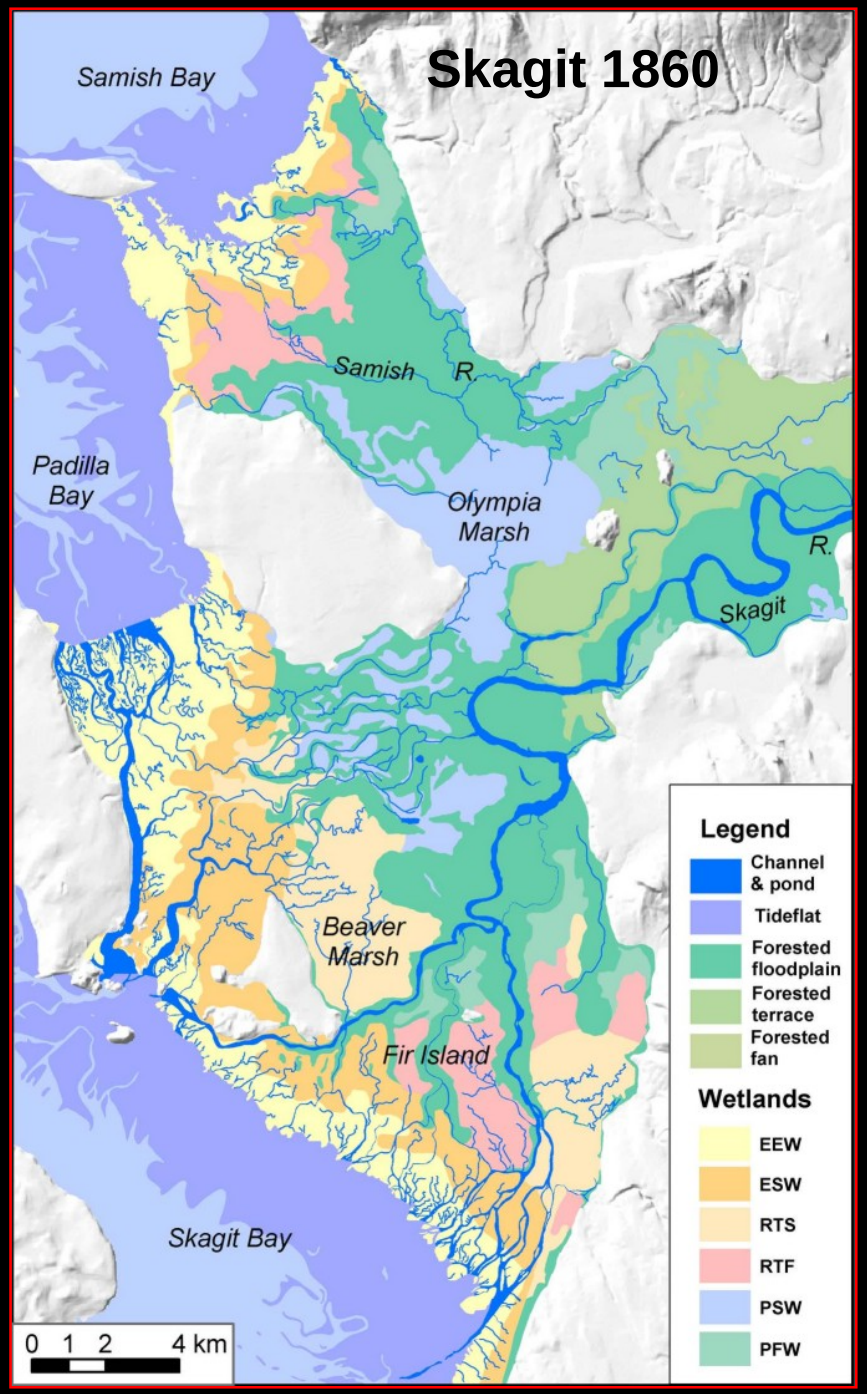
Nisqually River

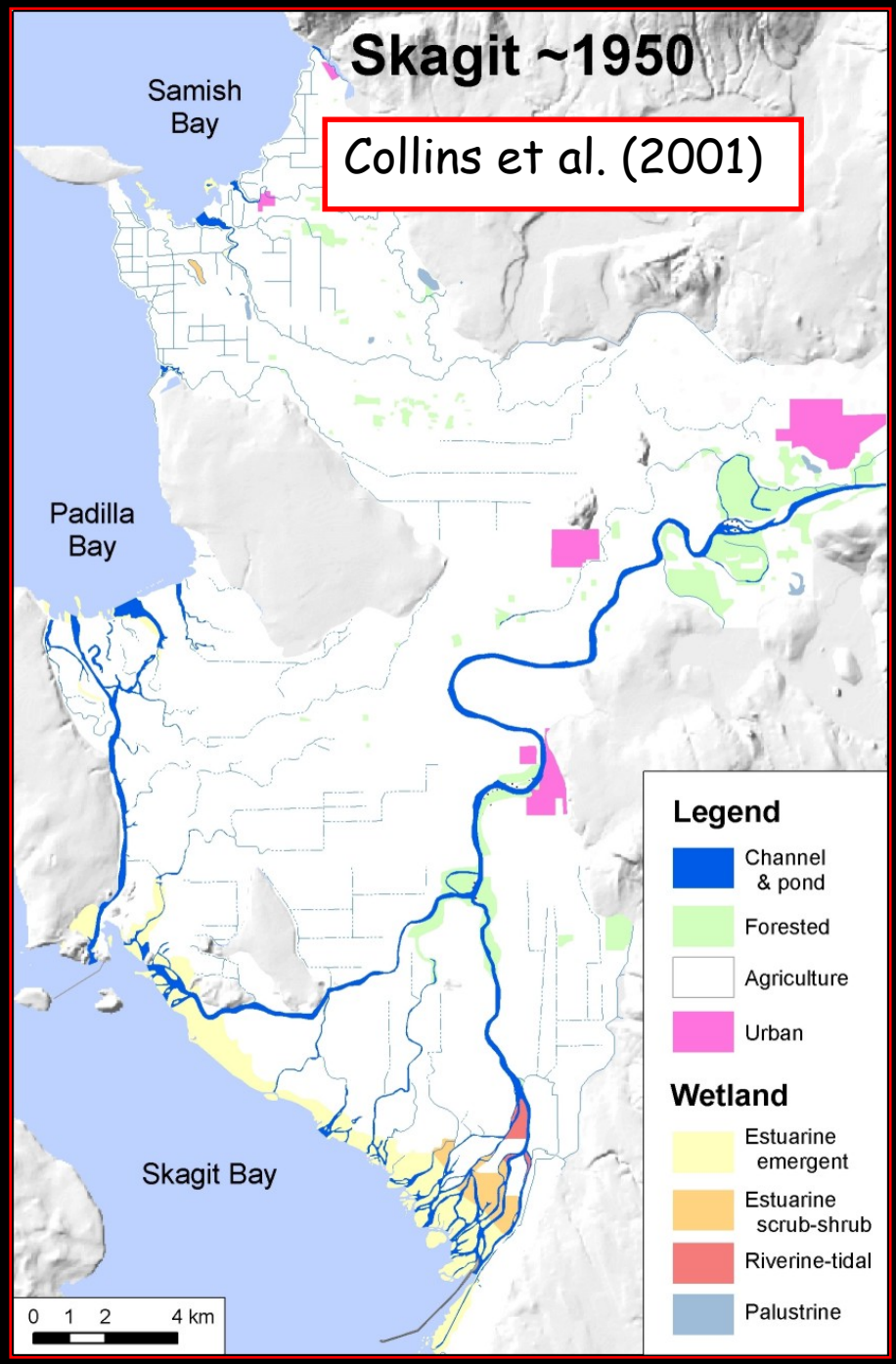
Nisqually River Floodplain



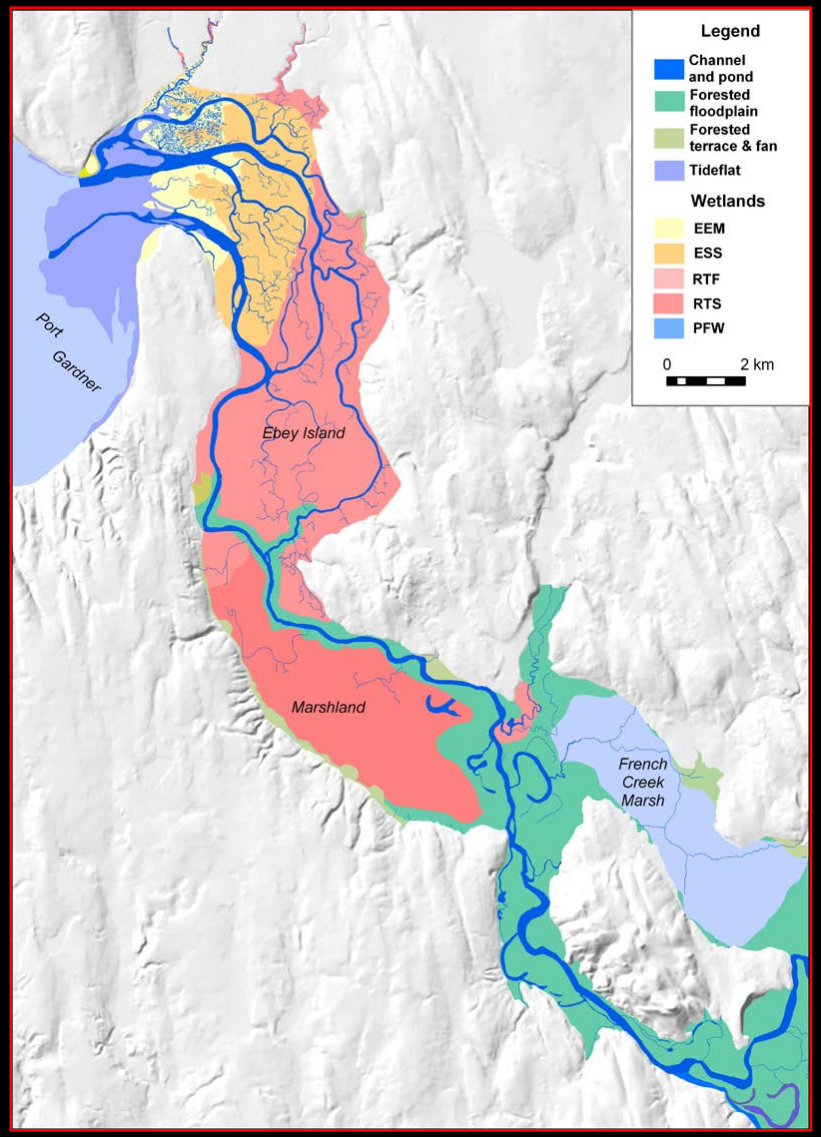
Stillaguamish River, Washington

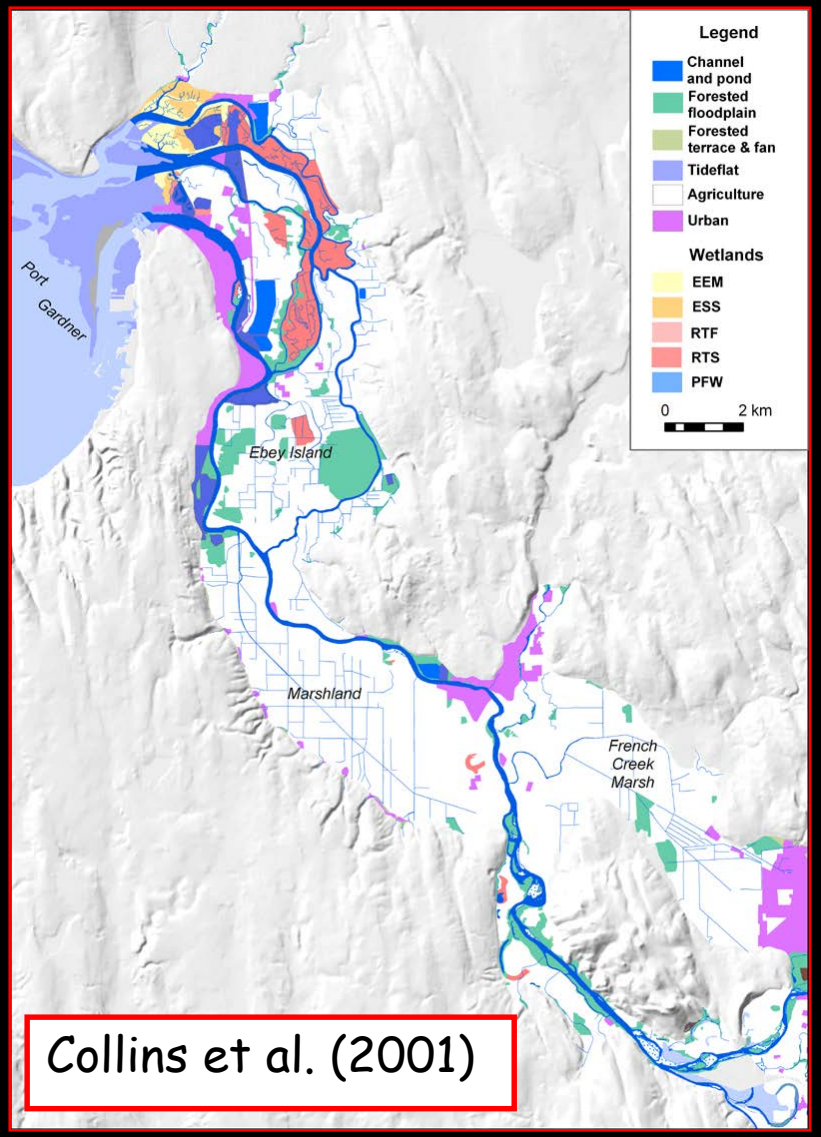



Skagit 1860
Samish Bay
Samish R.
Padilla Bay
Olympia Marsh
Skagit R.
Beaver Marsh
Fir Island
Skagit Bay
0 1 2 4 km
Legend
Channel & pond
Tideflat
Forested floodplain
Forested terrace
Forested fan
Wetlands
EEW
ESW
RTS
RTF
PSW
PFW


Skagit ~1950
Collins et al. (2001)
Samish Bay
Padilla Bay
Skagit Bay
0 1 2 4 km
Legend
Channel & pond
Forested
Agriculture
Urban
Wetland
Estuarine emergent
Estuarine scrub-shrub
Riverine-tidal
Palustrine

Huge losses of side channels and valley bottom wetlands along most major Puget Sound rivers, yet the story for each river is unique.

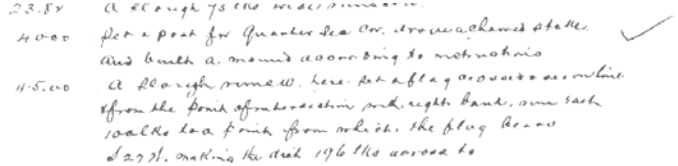




Collins et al. (2001)

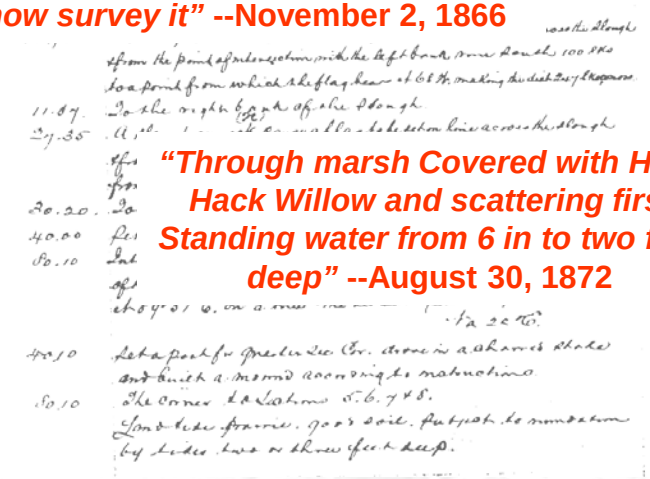
Estimating historical aquatic habitat in wetlands:
Historical wetland habitats, Skagit River estuary

Seasonal water depths from GLO field notes help describe historical wetland habitat

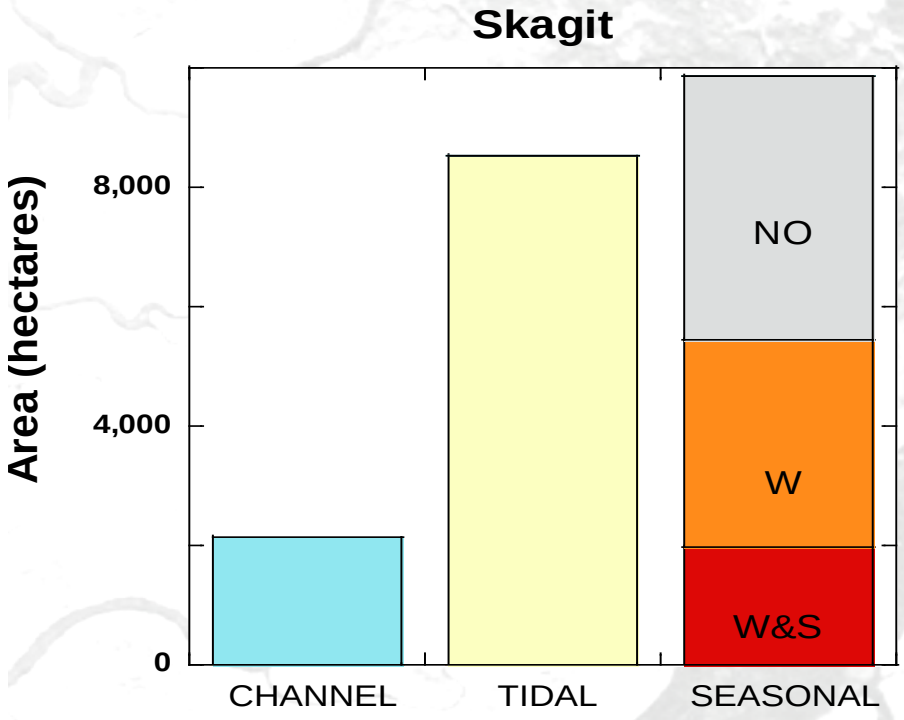


Descriptions of wetlands in Skagit Flats:

"The water was 2 ½ feet deep and appeared to be deeper father northward, we therefore consider it unfit for cultivation and impracticable to now survey it" **--November 2, 1866**

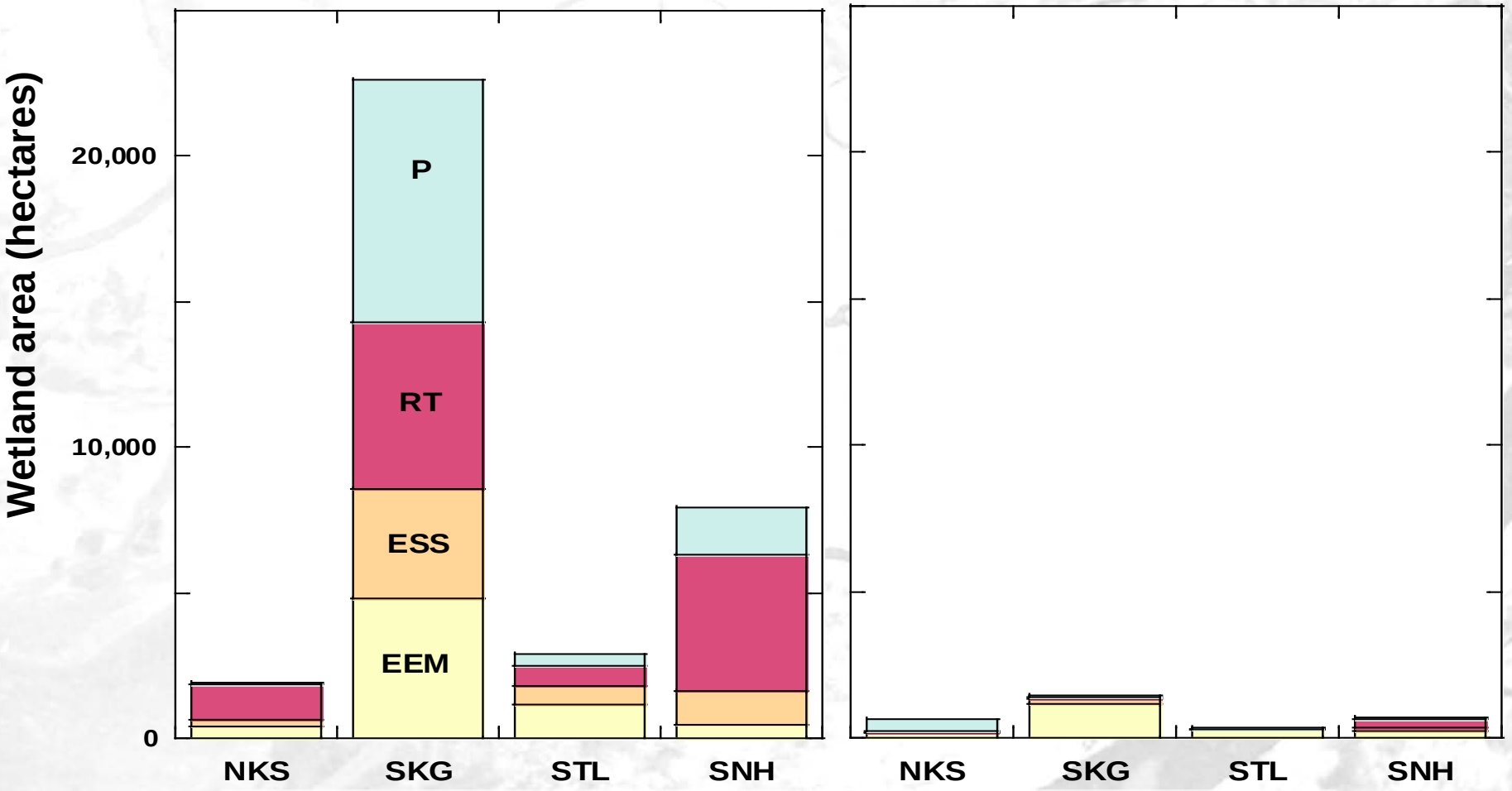


"Through marsh Covered with Hard Hack Willow and scattering firs. Standing water from 6 in to two feet deep" **--August 30, 1872**



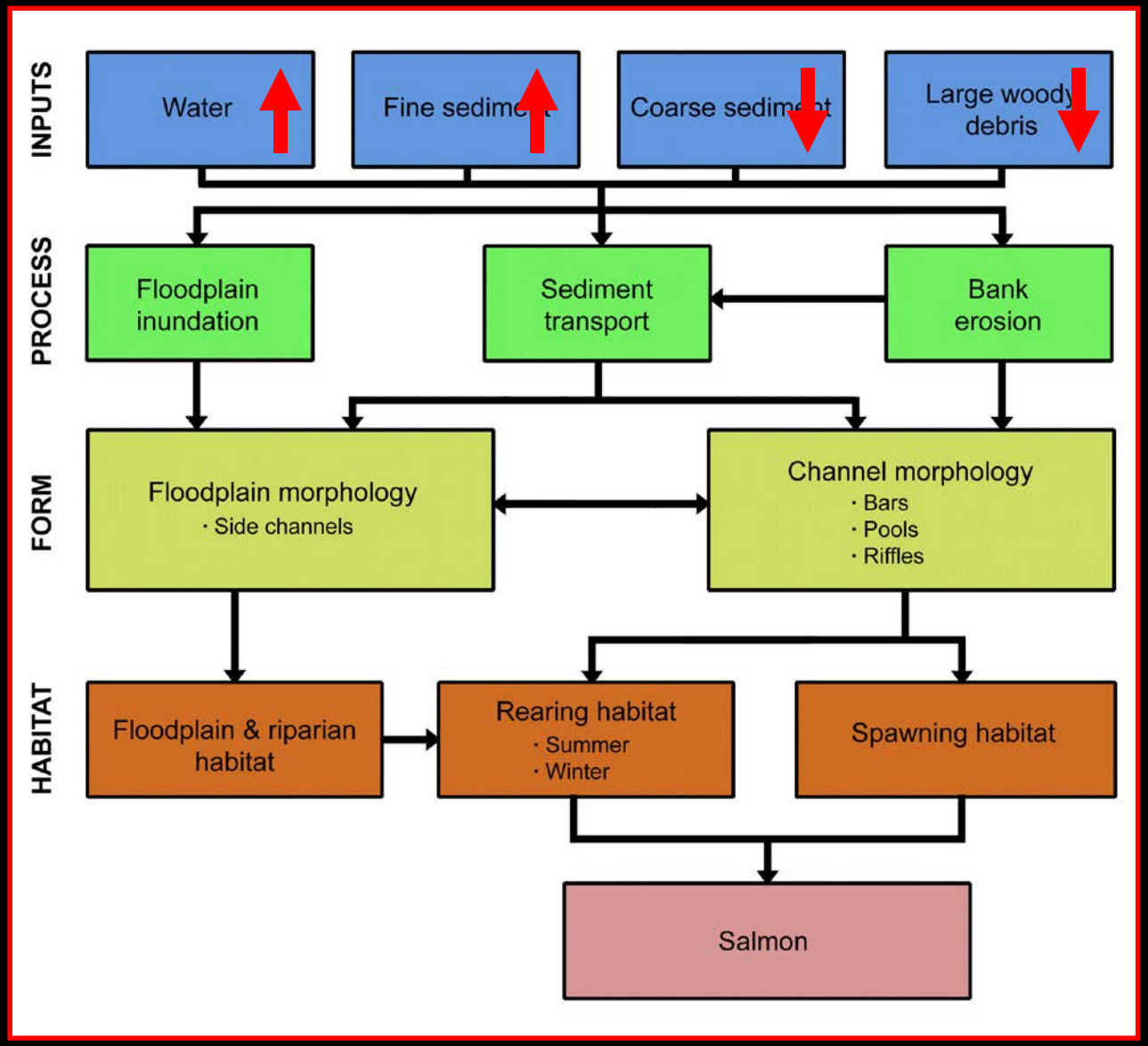
Seasonal inundation (> 1 ft for most of season):
W: winter W&S: winter & summer

Change to wetland area in four North Sound estuaries/deltas

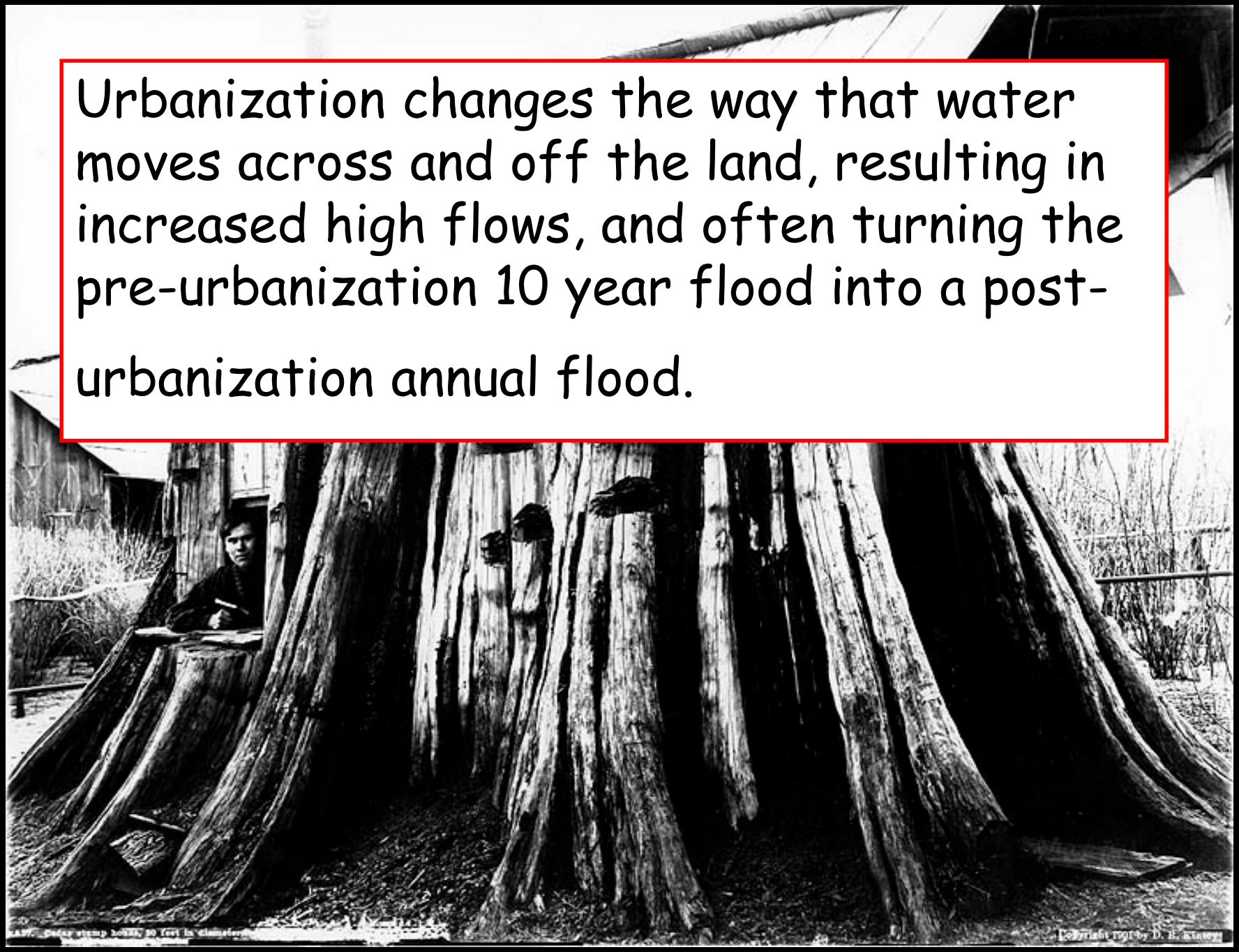


EEM=estuarine emergent; ESS=estuarine scrub-shrub; RT=riverine-tidal; P=palustrine

Urbanization increases water and fine sediment, and decreases coarse sediment and large woody debris

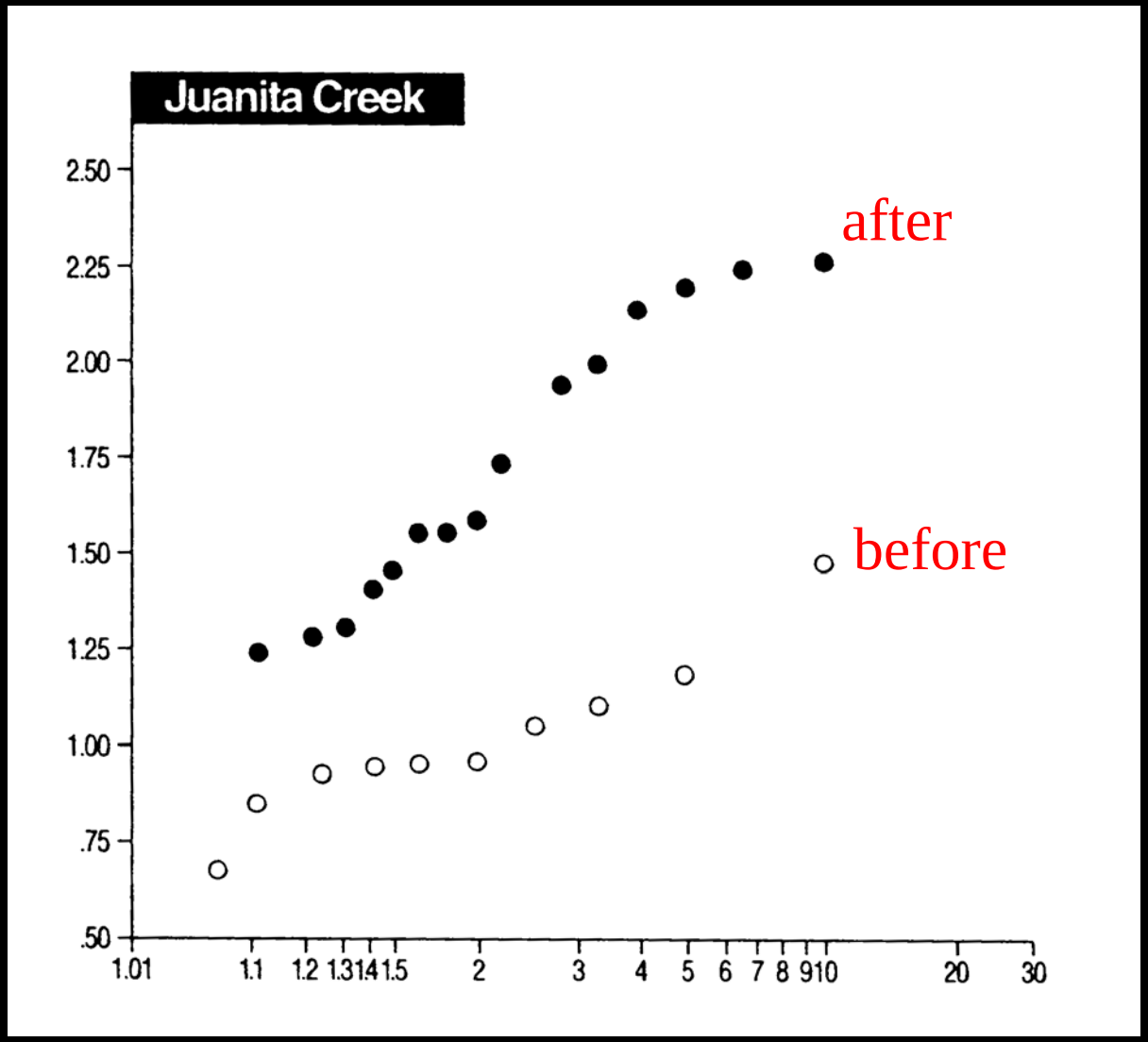


Urbanization changes the way that water moves across and off the land, resulting in increased high flows, and often turning the pre-urbanization 10 year flood into a post-urbanization annual flood.



Moscrip and Montgomery, JAWRA, 1997

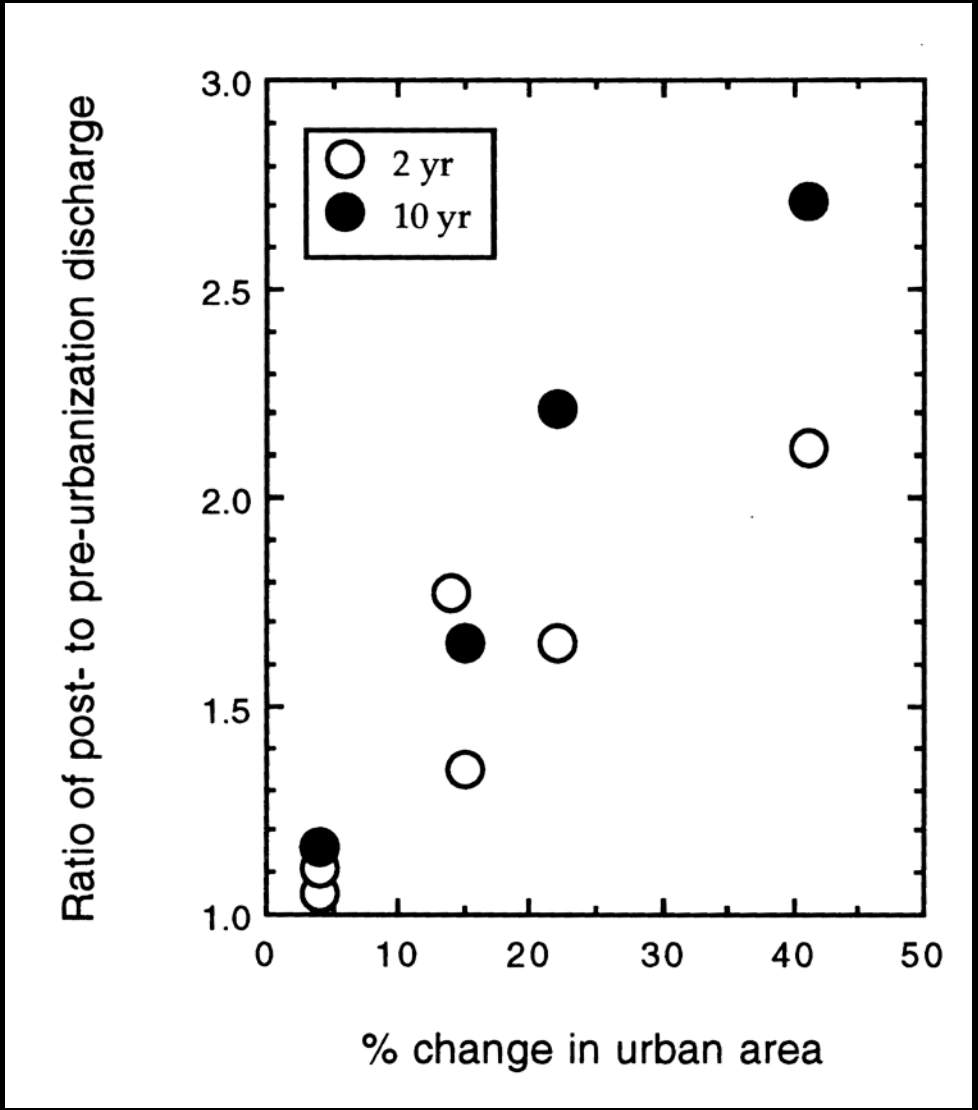
Discharge (cfs)



Recurrence interval

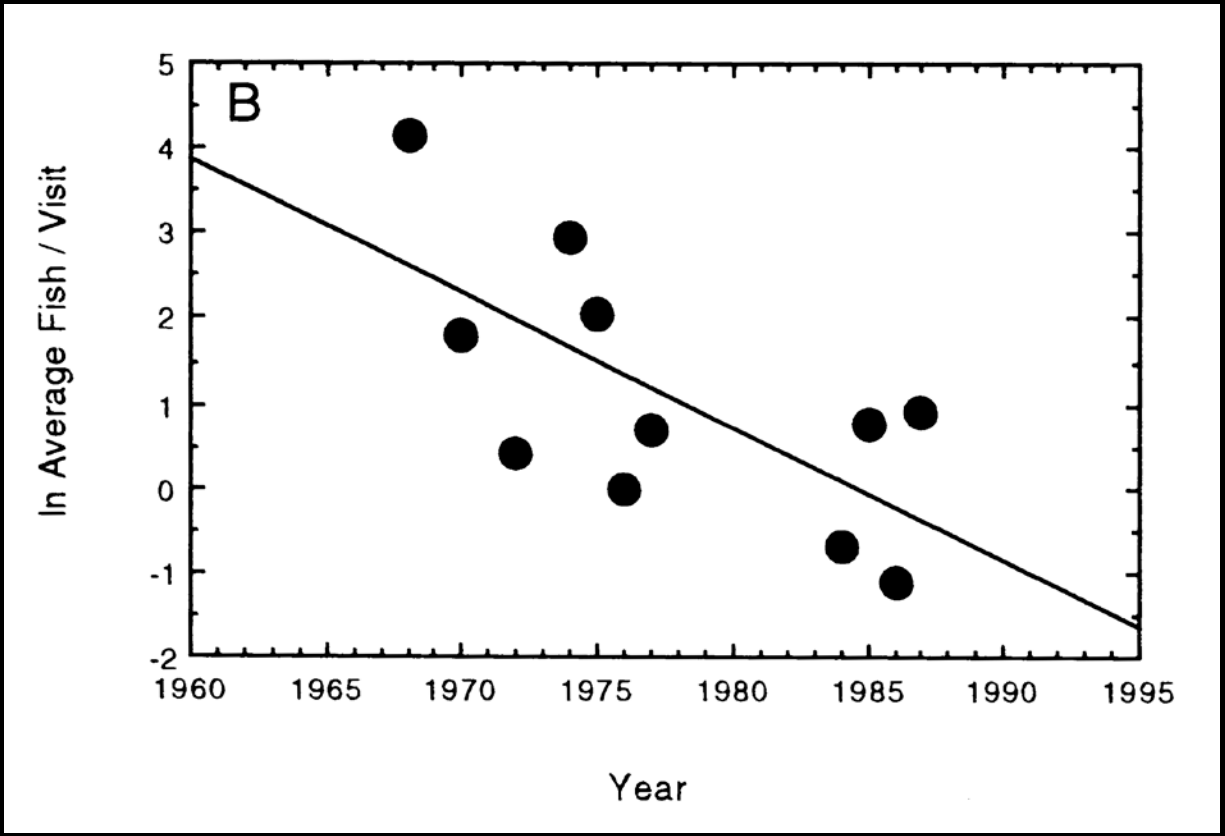
Moscrip and Montgomery, JAWRA, 1997

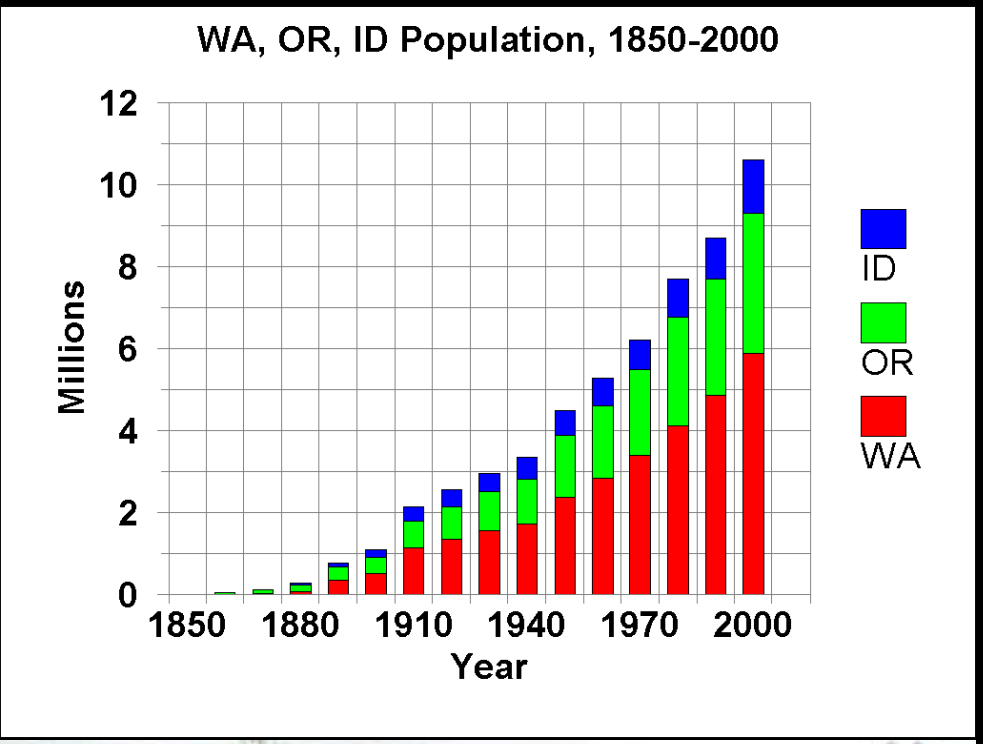
Discharges increase in proportion to % change in urban area



Moscrip and Montgomery, JAWRA, 1997

Salmlon abundance decreased during urbanization

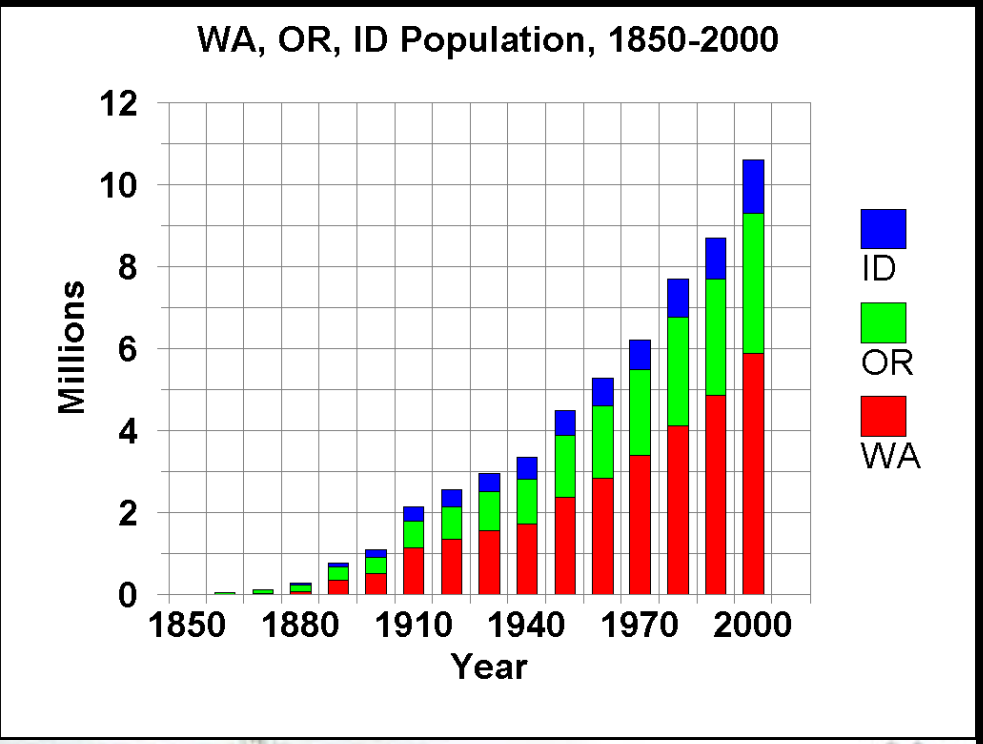




Puget Sound Partnership recommendations essentially ignore the adverse impacts likely to occur due to future development.

On October 26, 2006, fourteen "so-called" experts sent a letter to the Puget Sound Partnership expressing concern over failure to adequately address management of stormwater runoff from future development.

Doug Beyerlein
Susan Bolton
Derek Booth
Tom Holz
Thom Hooper
Richard Horner
James Karr
DeeAnne Kirkpatrick
John Lombard
Chris May
Gary Minton
David Montgomery
David Somers
Cleve Steward



The Plan rolls up individual basin (or watershed) plans that themselves do not address potential impacts from future development…

"The strategies listed are not likely to be sufficient to achieve ecosystem goals…"

Puget Sound Parternship, Page 43, Appendix A, report of scientific working group.

NPDES permits only require adherence to the state stormwater manual, which itself states:

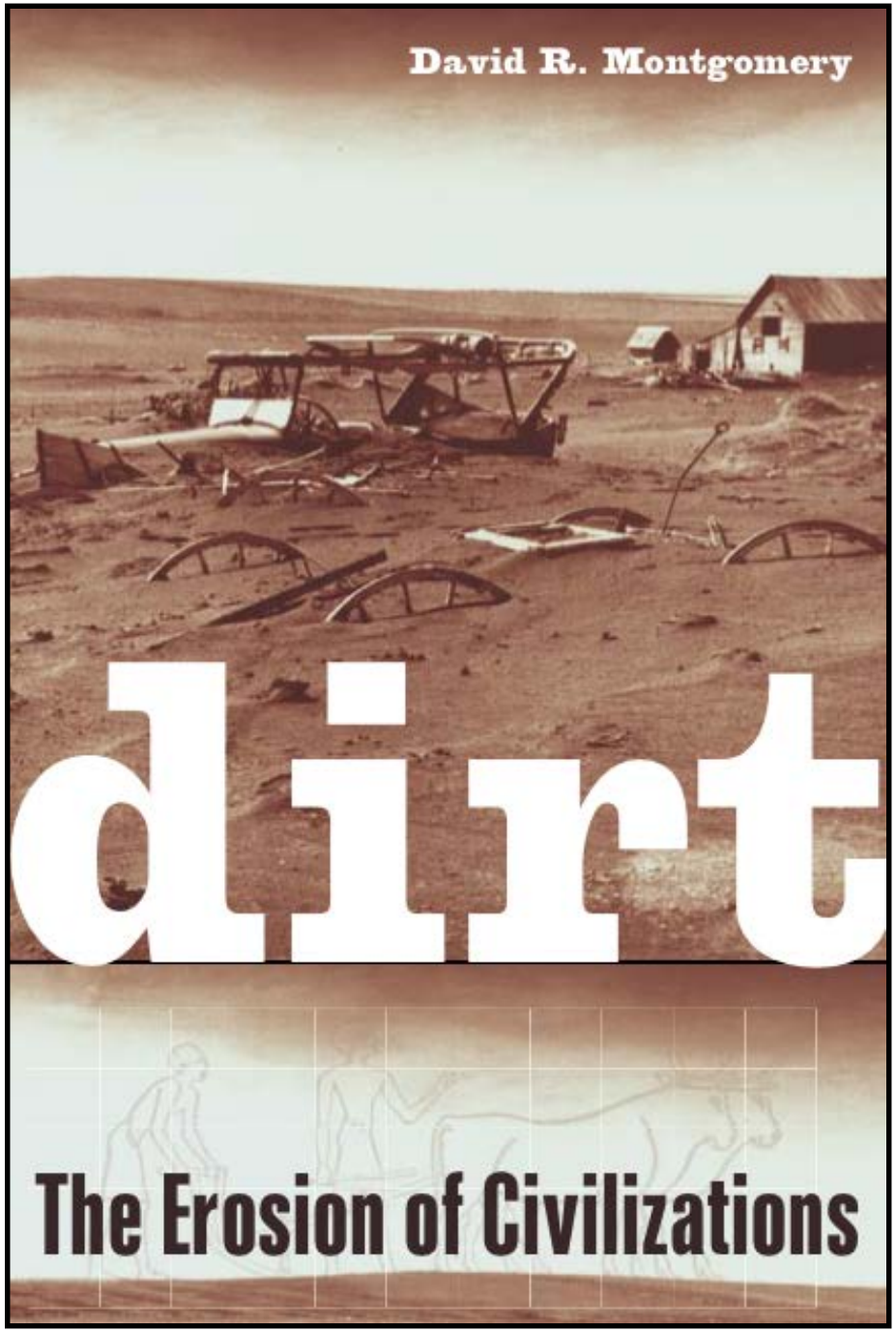
"Land development as practiced today is incompatible with the achievement of sustainable ecosystems."

When the Master Builder's Association threatened to pull out of the Partnership, the effort to re-examine stormwater runoff recommendations apparently was abandoned, despite the acknowledged failure to adequately address impacts from future development.

Provide some refuge for the salmon, and provide it quickly, before complications arise which may make it impracticable, or at least very difficult. … If we procrastinate and put off our rescuing mission too long, it may be too late to do any good. After the rivers are ruined and the salmon gone they cannot be reclaimed … all the power of the United States cannot restore salmon to the rivers after the work of destruction has been completed.

— Livingston Stone (1892)

One of the few strategies that might work over the long run would be to create a network of Salmon Sanctuaries by restoring forested river corridors along river floodplains.


David R. Montgomery
dirt
The Erosion of Civilizations