Open it and they will come: Examples of river reconnection & salmon (re)colonization from the Pacific

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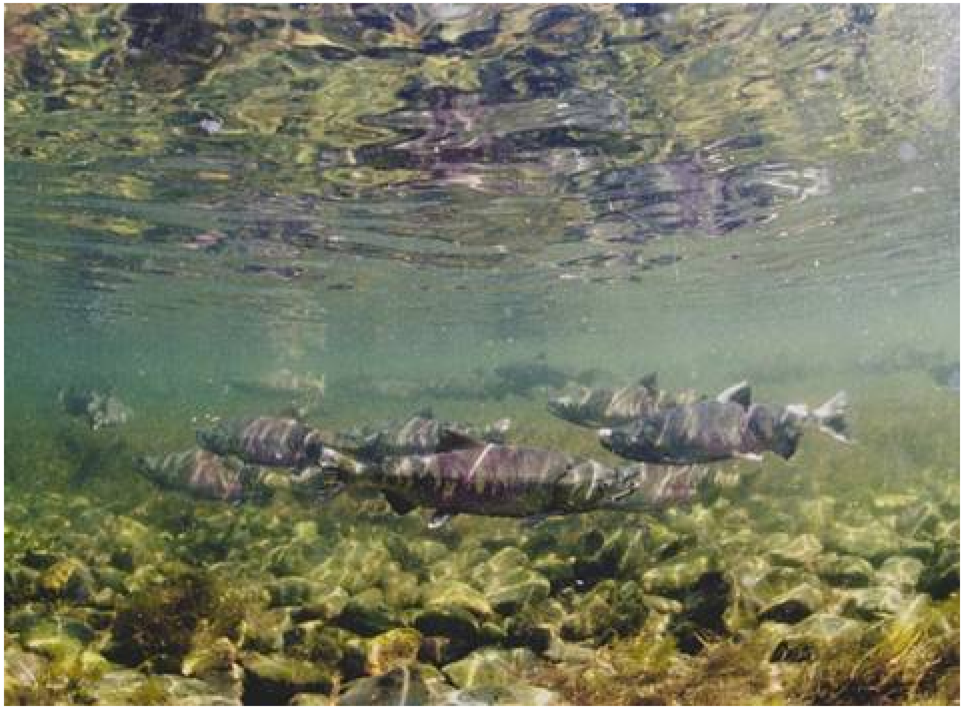
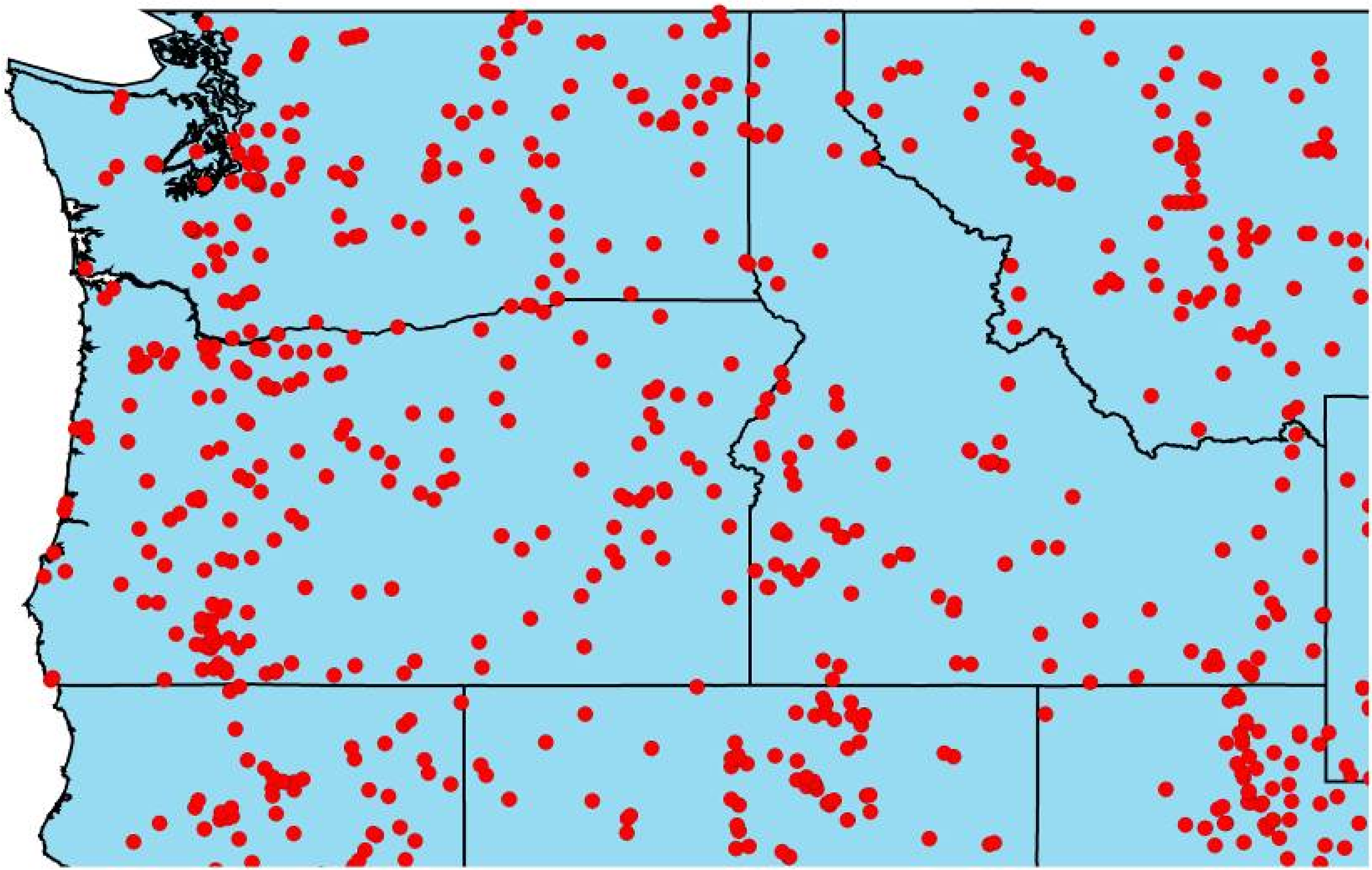


The Questions Posed

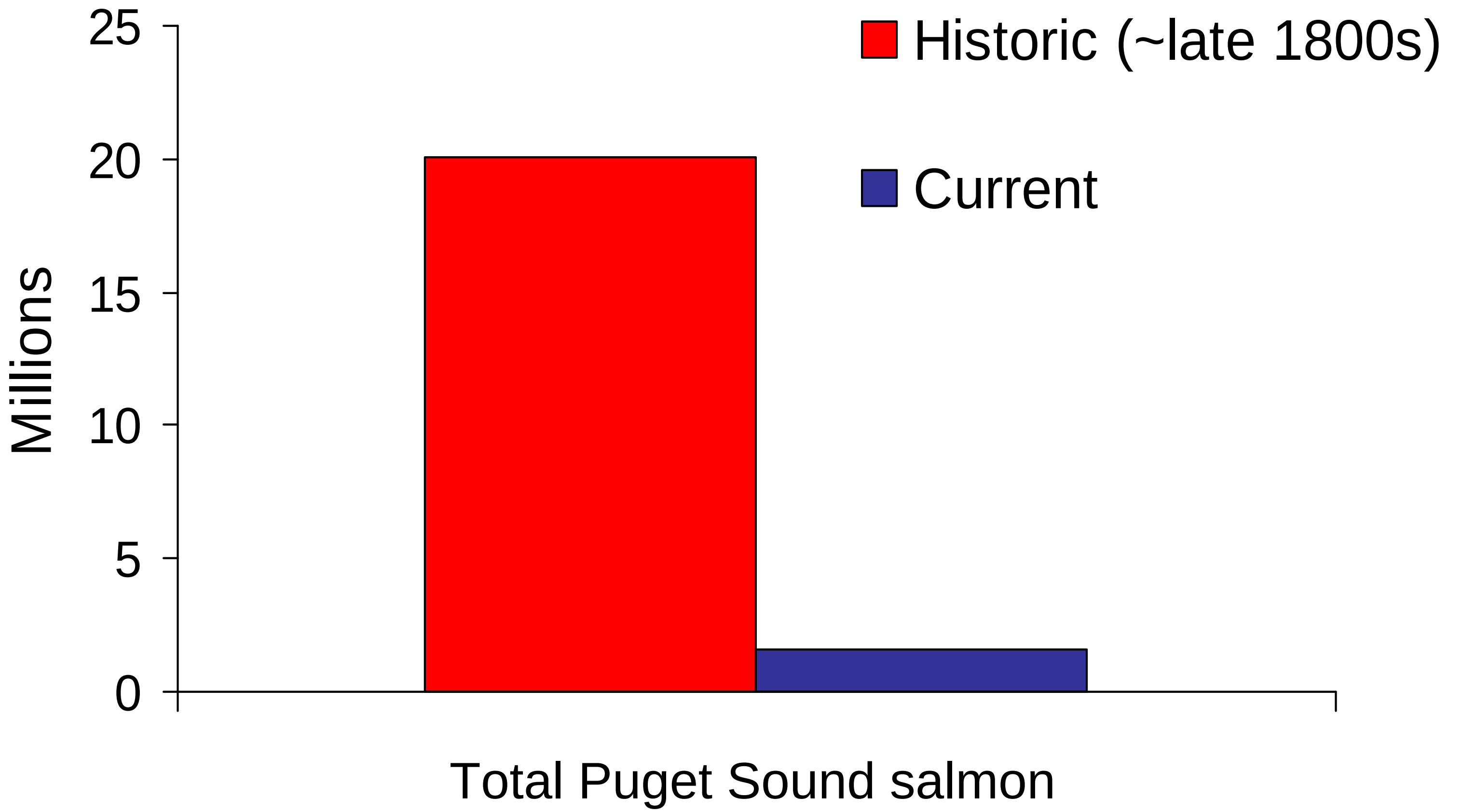
- Why implement river reconnection?
- Can diadromous species successfully colonize newly available habitats?
- What are the most important factors associated with colonization?
- How do we incorporate answers to the preceding questions into large-scale dam removal monitoring? The Elwha River case study

Dams & culverts in the Pacific Northwest block large amounts of diadromous habitat



Data source: National Inventory of Dams, US Army Corps Engineers

Habitat blockage is an important factor in diadromous population declines



Gresh et al. 2000

Why implement river reconnection?

– Access to historically available habitats

– Increase in population abundance

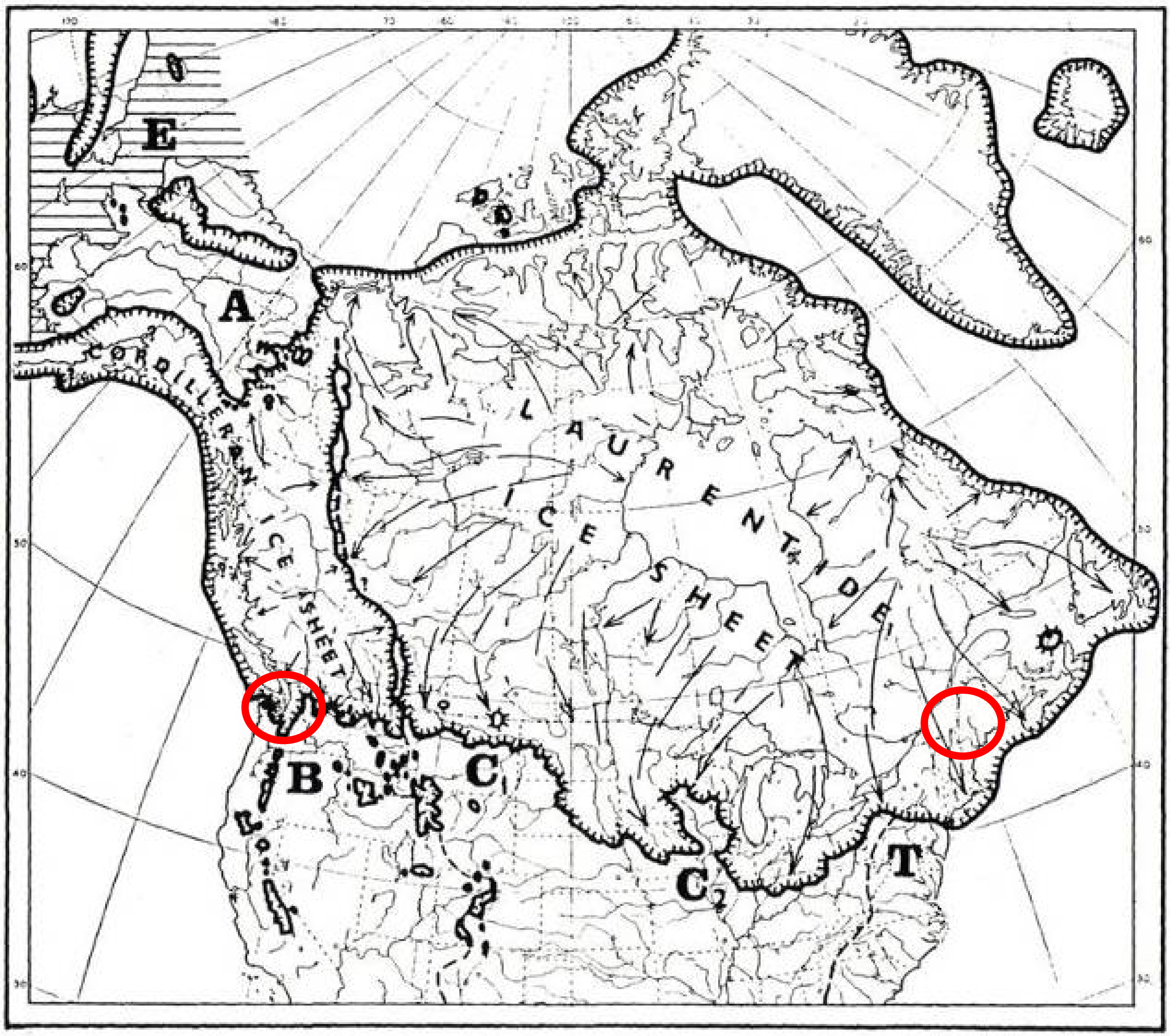
– Increased expression of life history strategies

– Greater spatial distribution for populations

– Un-interrupted movement of fish, sediment, wood, water, and energy

Can diadromous species successfully colonize newly available habitats?

Wisconsin glacial period ~110,000 - ~10,000 years ago



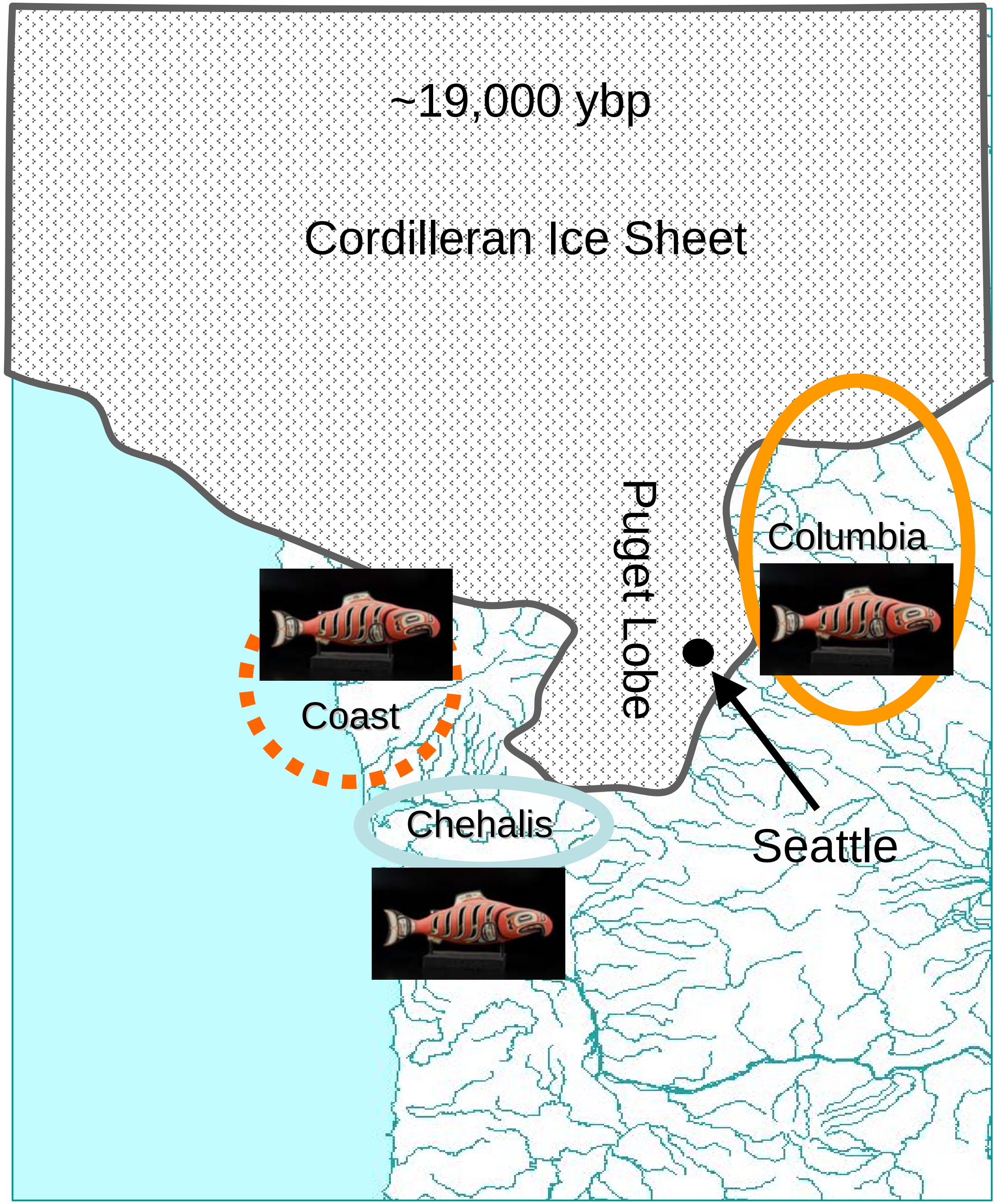
McPhail

& Lindsey

1970

Adapted from McPhail and Lindsey, 1986

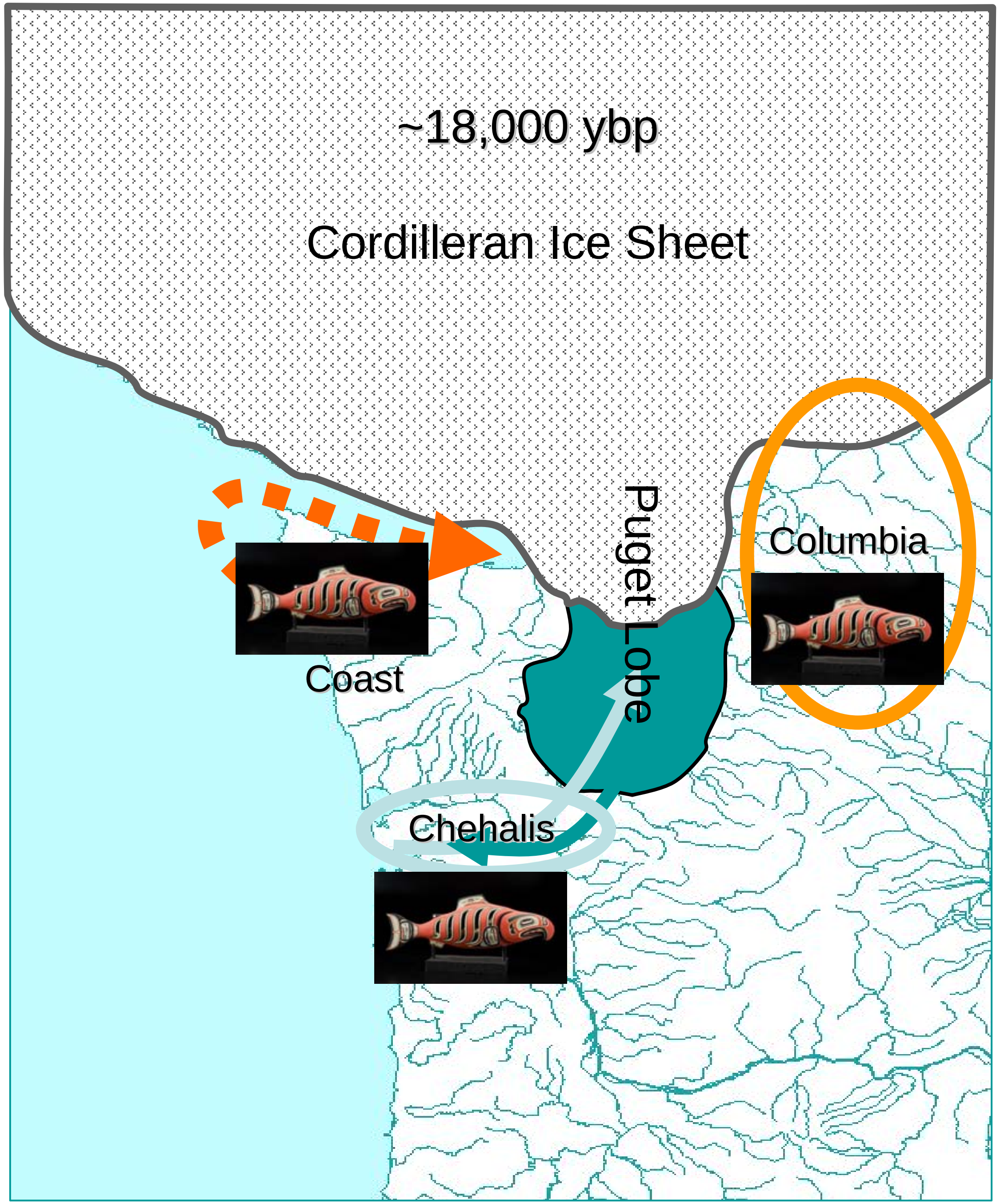
Upper Kaskawulch glacier near Mount Logan, Canadian Yukon. © Charles Houston



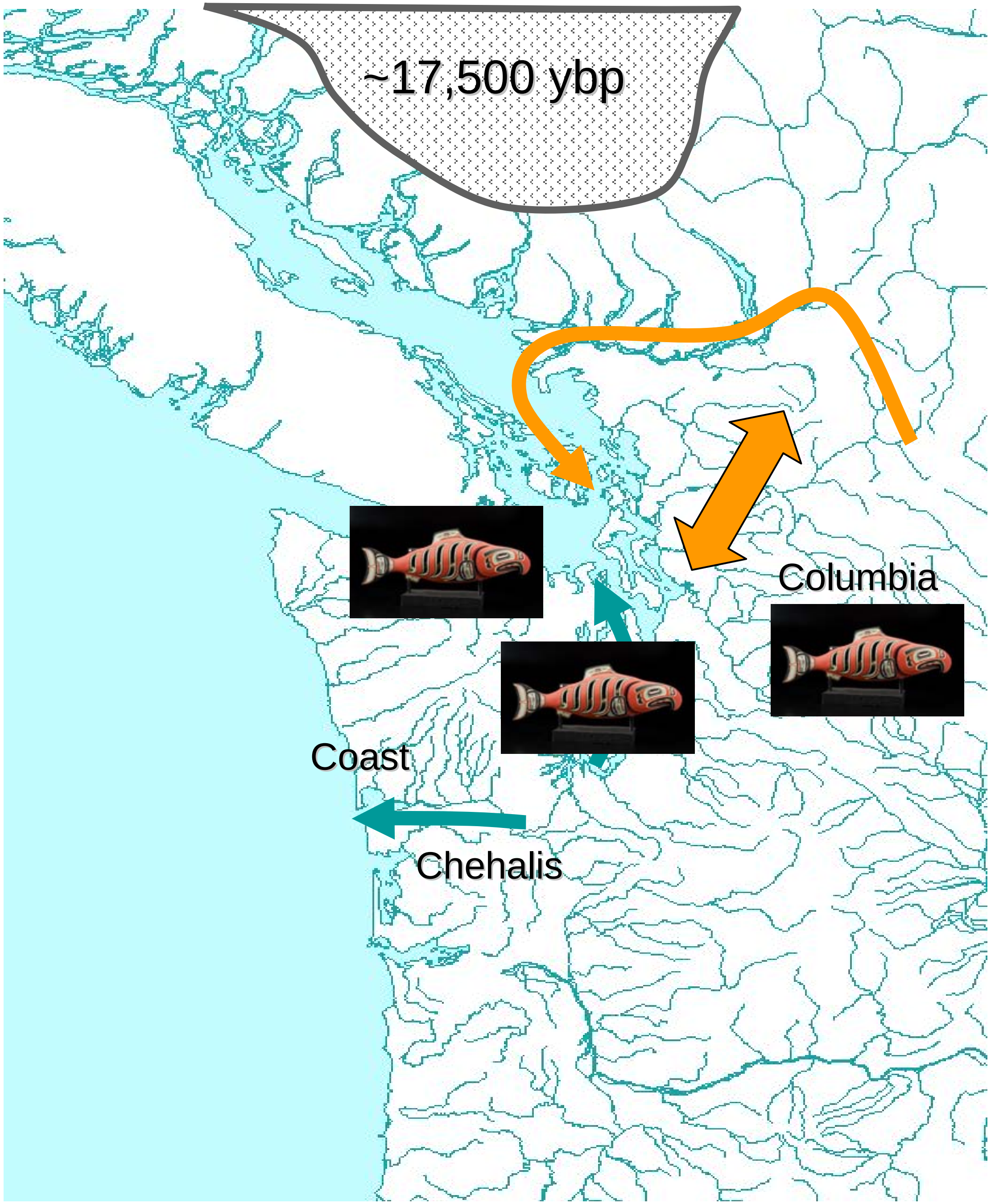
Adapted from

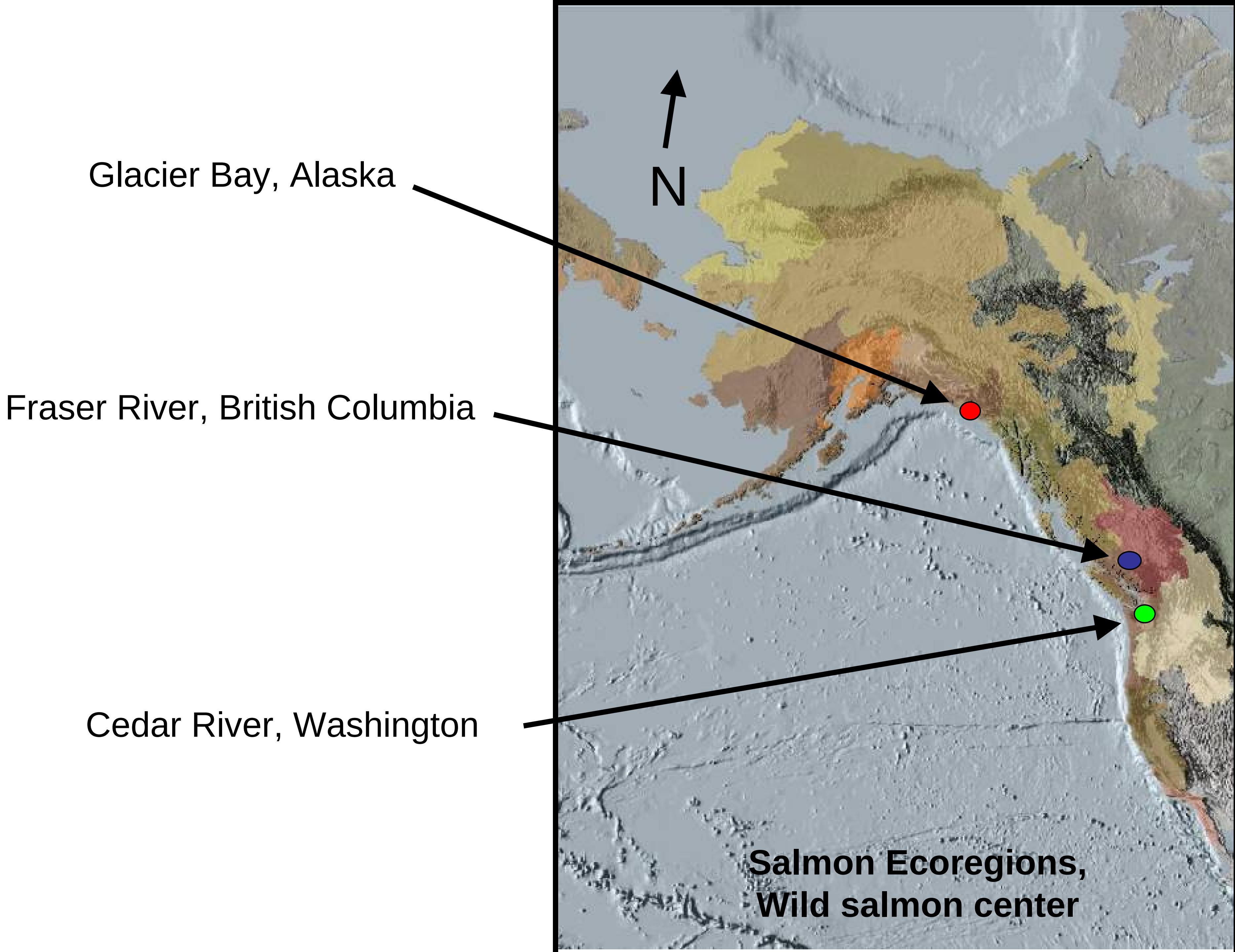
McPhail and

Lindsey, 1986

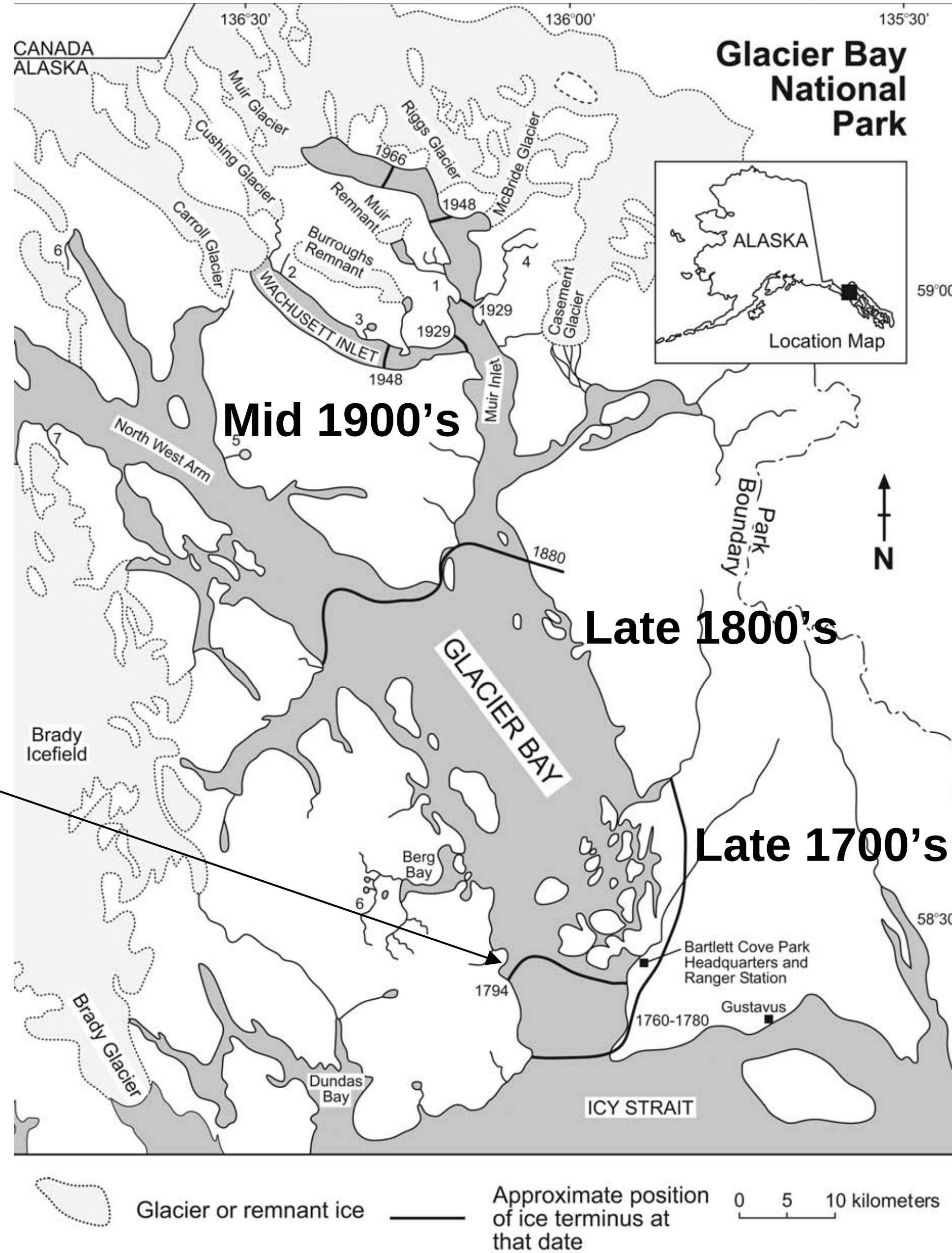


Adapted from McPhail and Lindsey, 1986



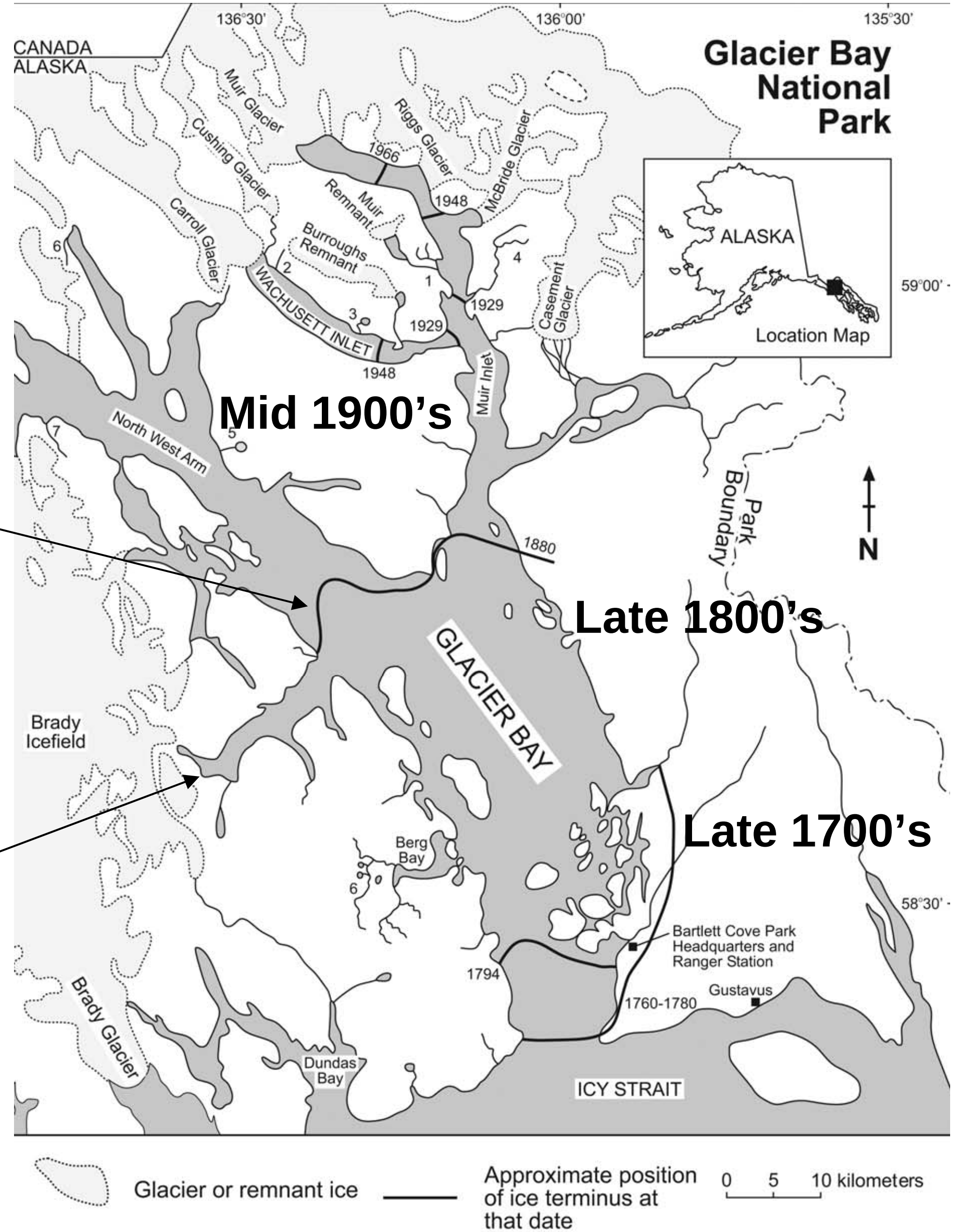

Glacier Bay, Alaska
Fraser River, British Columbia
Cedar River, Washington
N
Salmon Ecoregions,
Wild salmon center

Upper Kaskawulch glacier near Mount Logan, Canadian Yukon. © Charles Houston



Milner, A.M., C.L. Fastie, F.S. Chapin III, D.R. Engstrom, and L.C. Sharman. 2007. Interactions and linkages among ecosystems during landscape evolution. Bioscience 57: 237-247.

Upper Kaskawulch glacier near Mount Logan, Canadian Yukon. © Charles Houston



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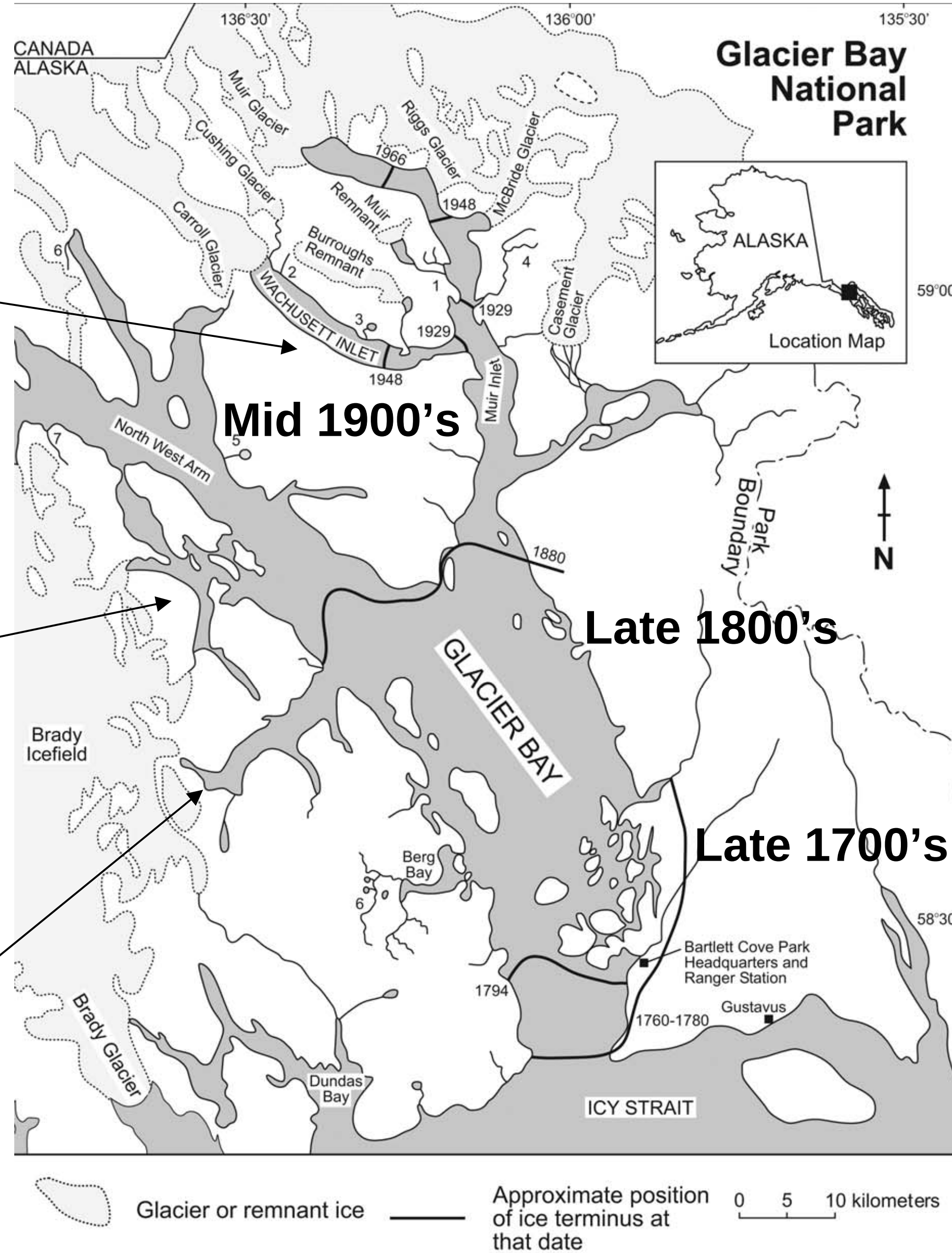
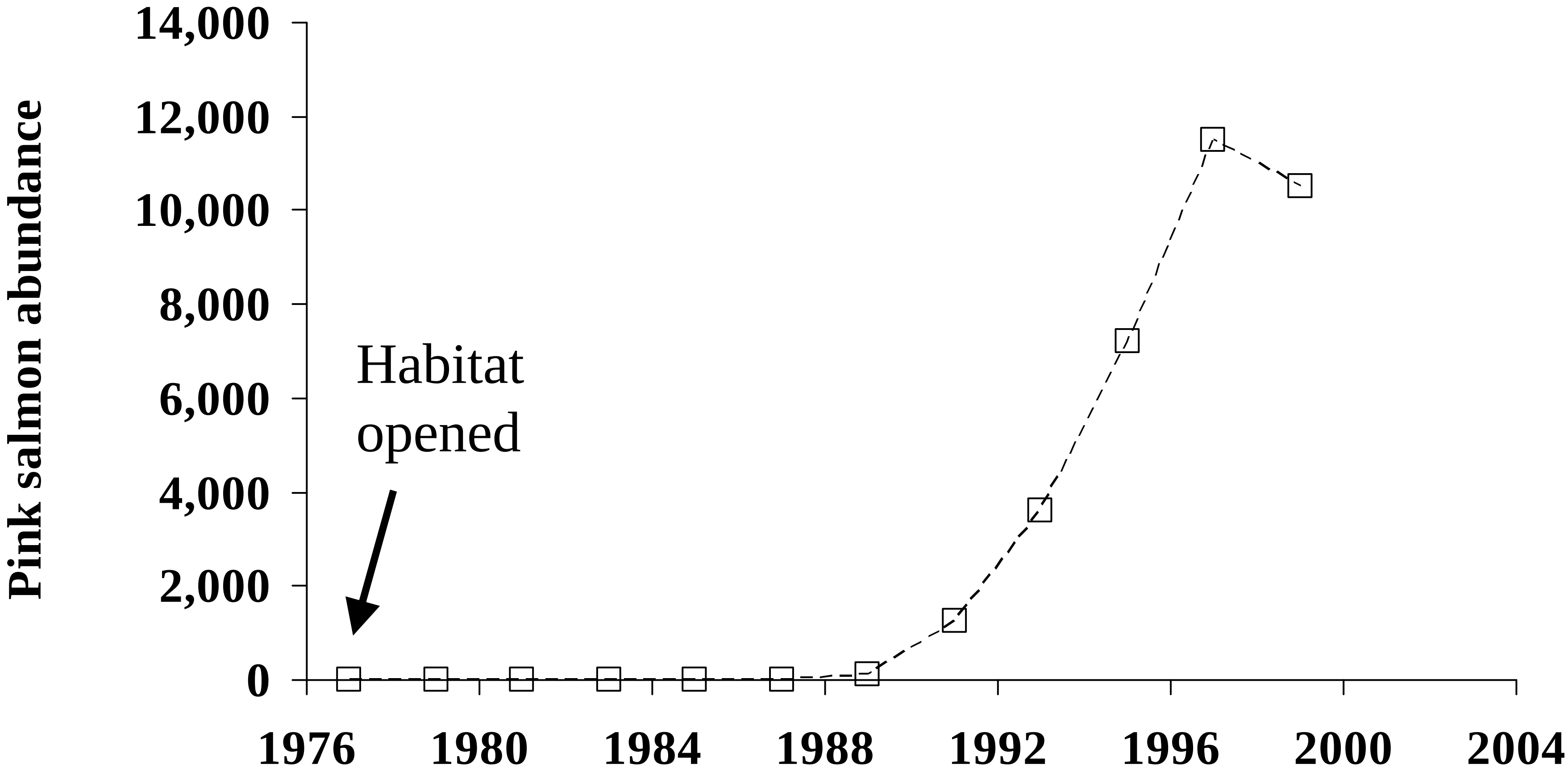
Upper Kaskawulch glacier near Mount Logan, Canadian Yukon. © Charles Houston



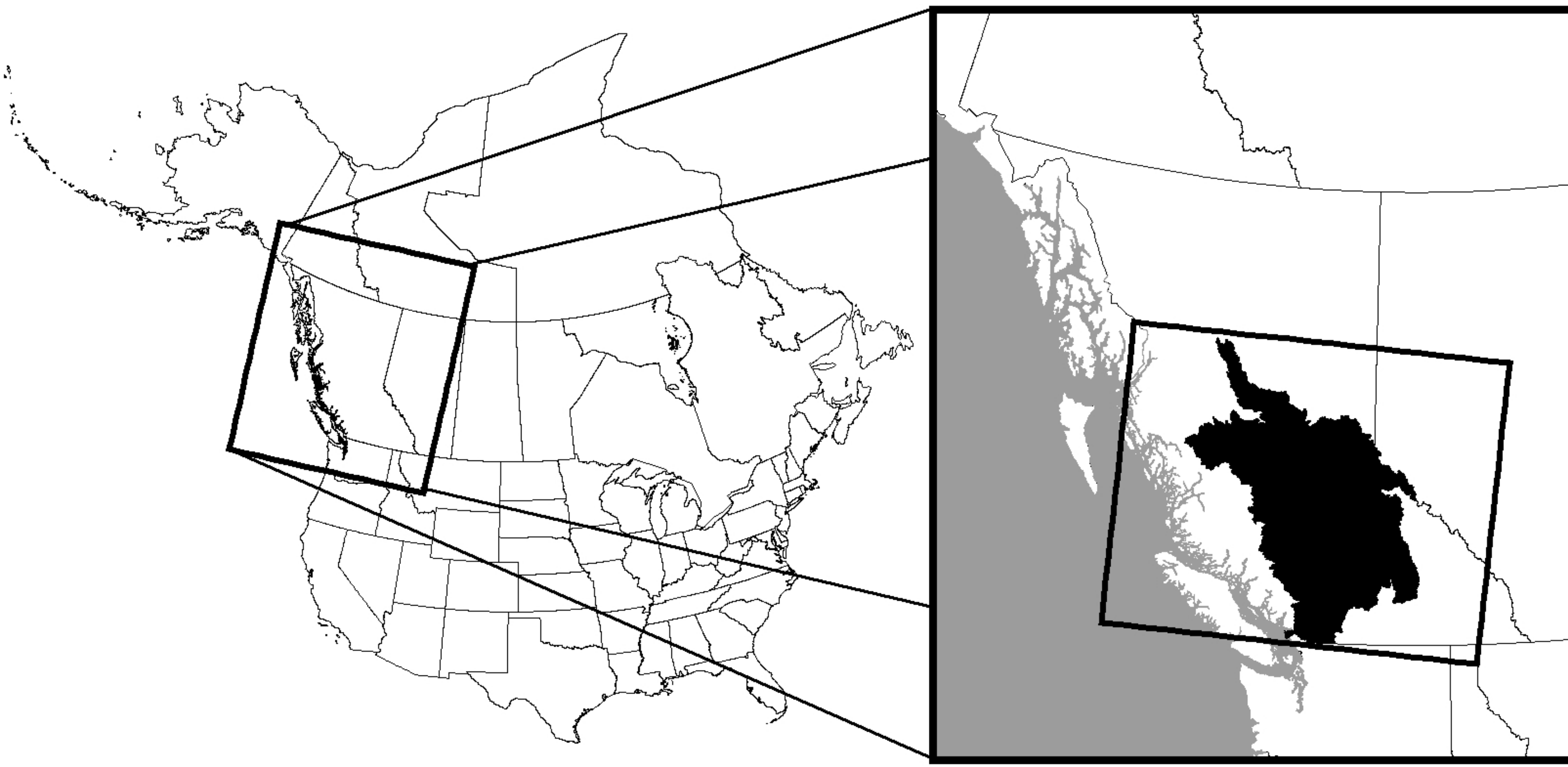
Milner, A.M., C.L. Fastie, F.S. Chapin III, D.R. Engstrom, and L.C. Sharman. 2007. Interactions and linkages among ecosystems during landscape evolution. Bioscience 57: 237-247.

Pink salmon successfully colonized newly created habitat in Glacier Bay, AK

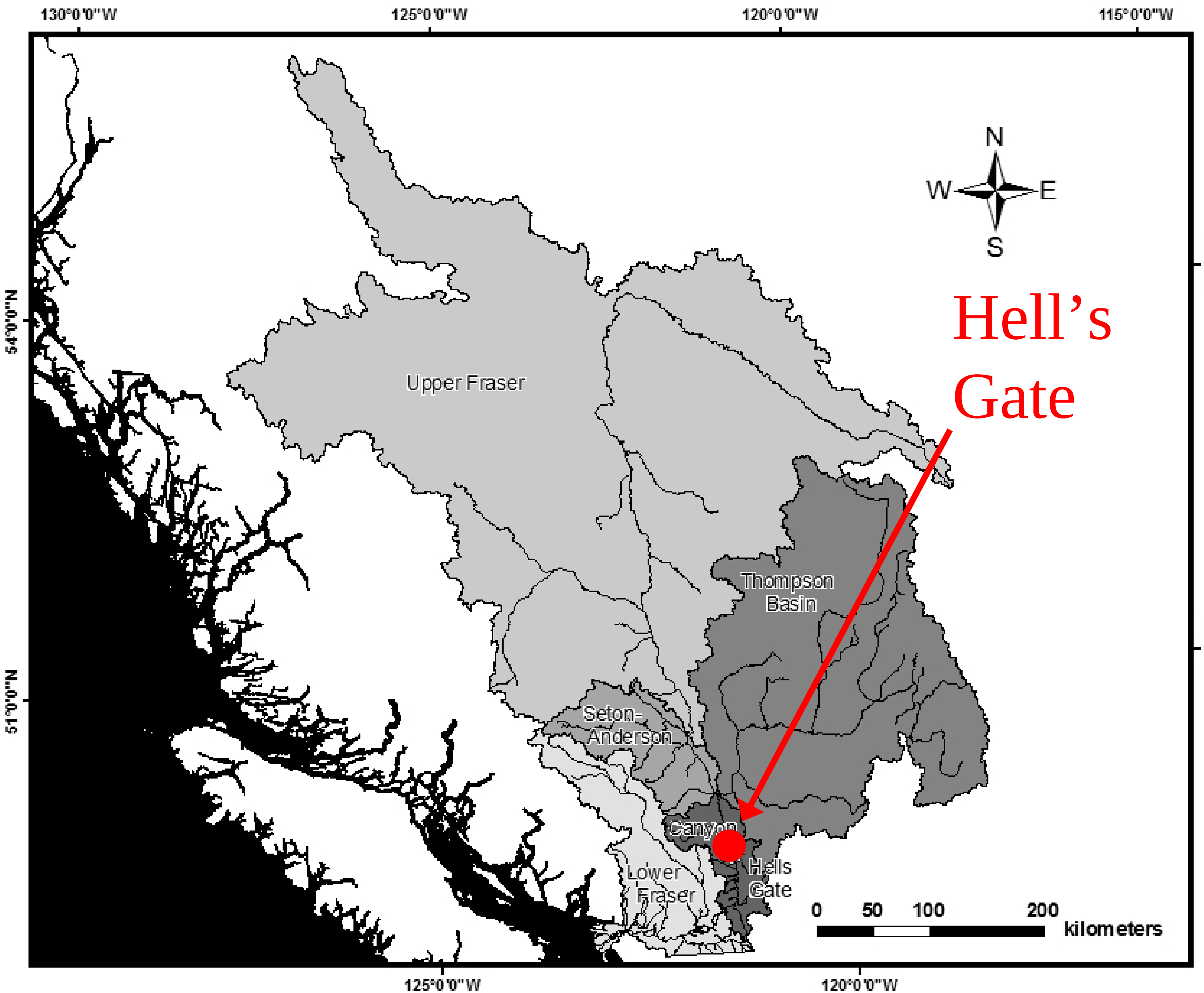


Milner, A.M., C.L. Fastie, F.S. Chapin III, D.R. Engstrom, and L.C. Sharman. 2007. Interactions and linkages among ecosystems during landscape evolution. Bioscience 57: 237-247.

Fraser River



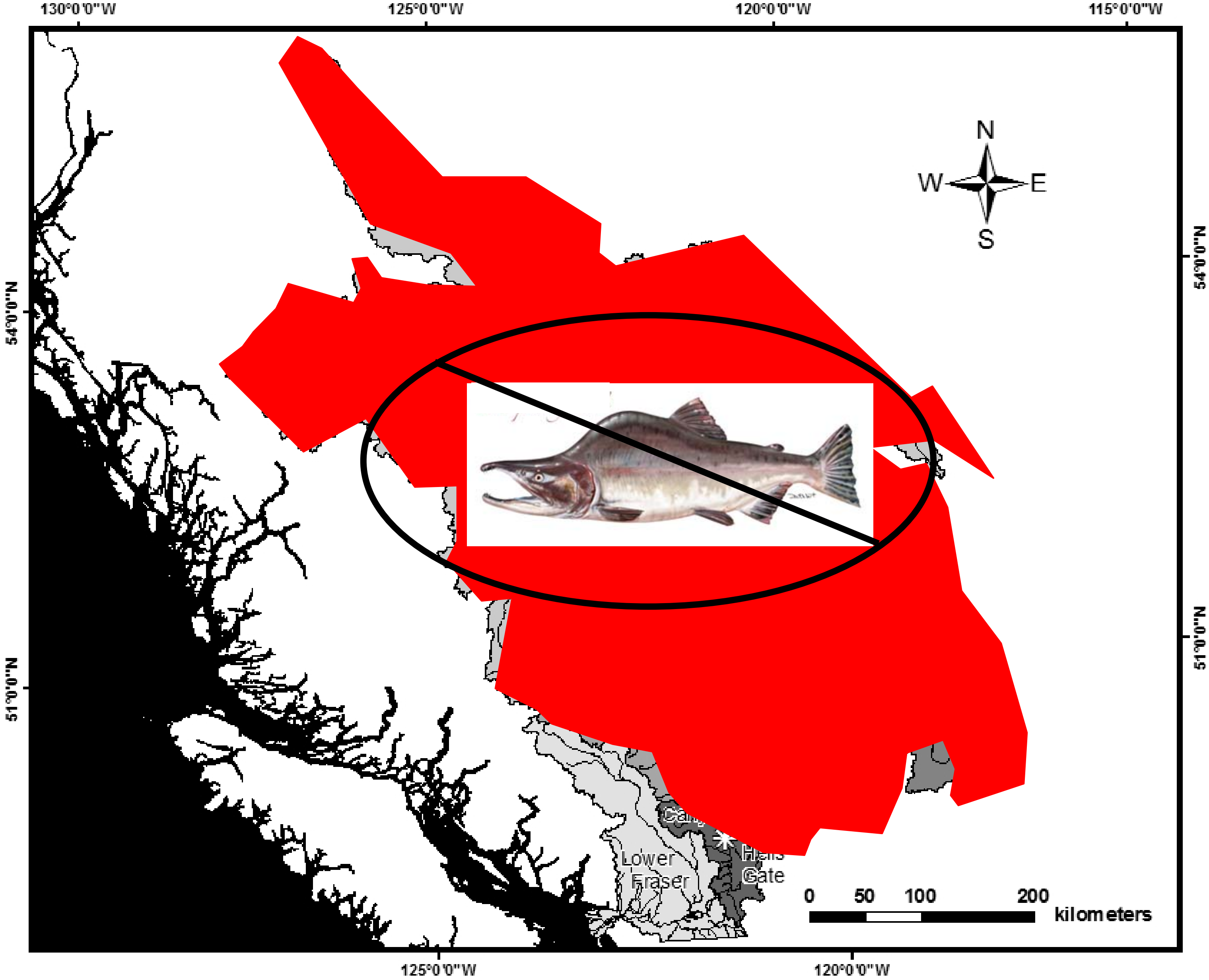
Fraser River



Hell's Gate 1897

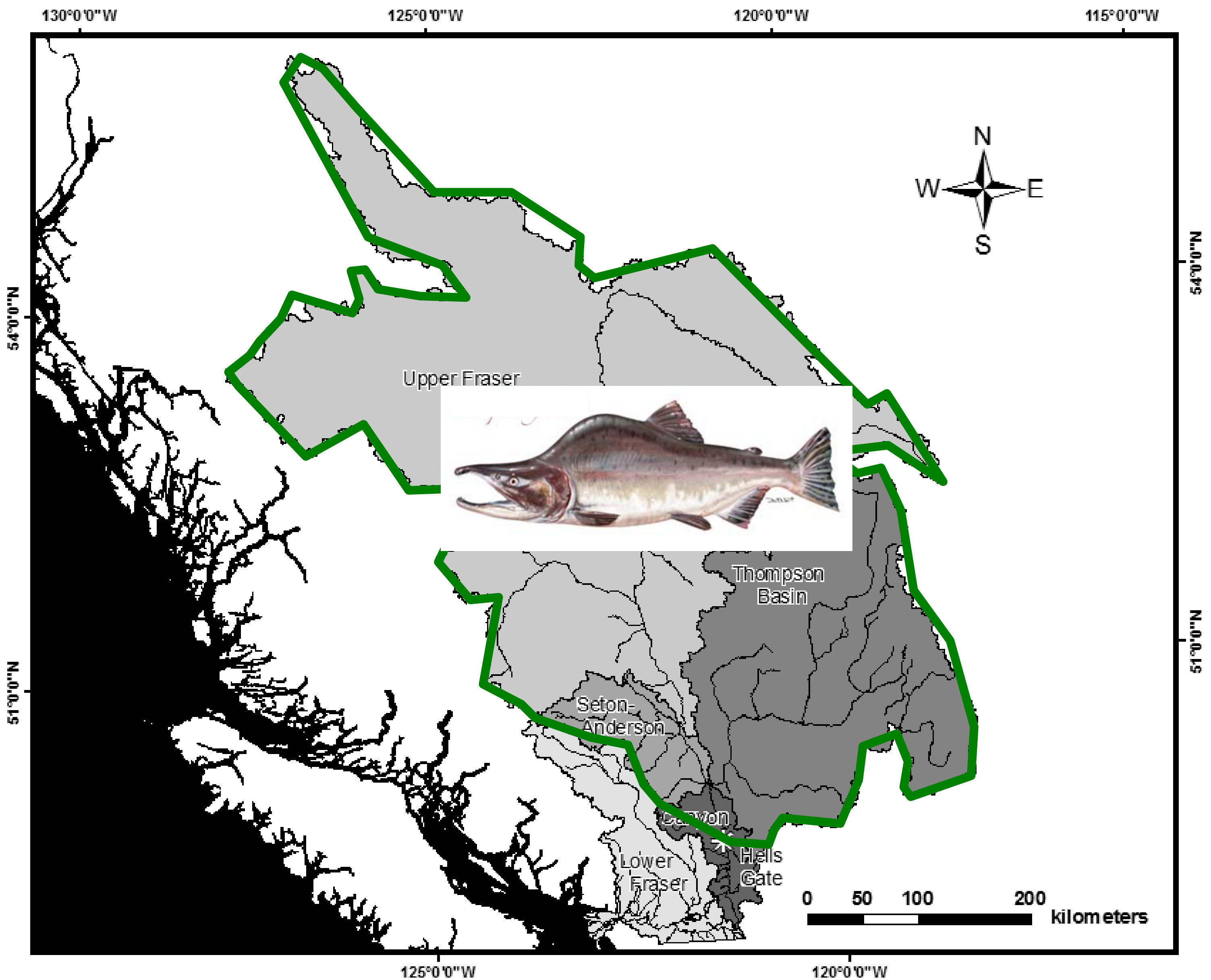
Hell’s Gate 1914

Hell's Gate landslide cut off the majority of the Fraser River to pink salmon



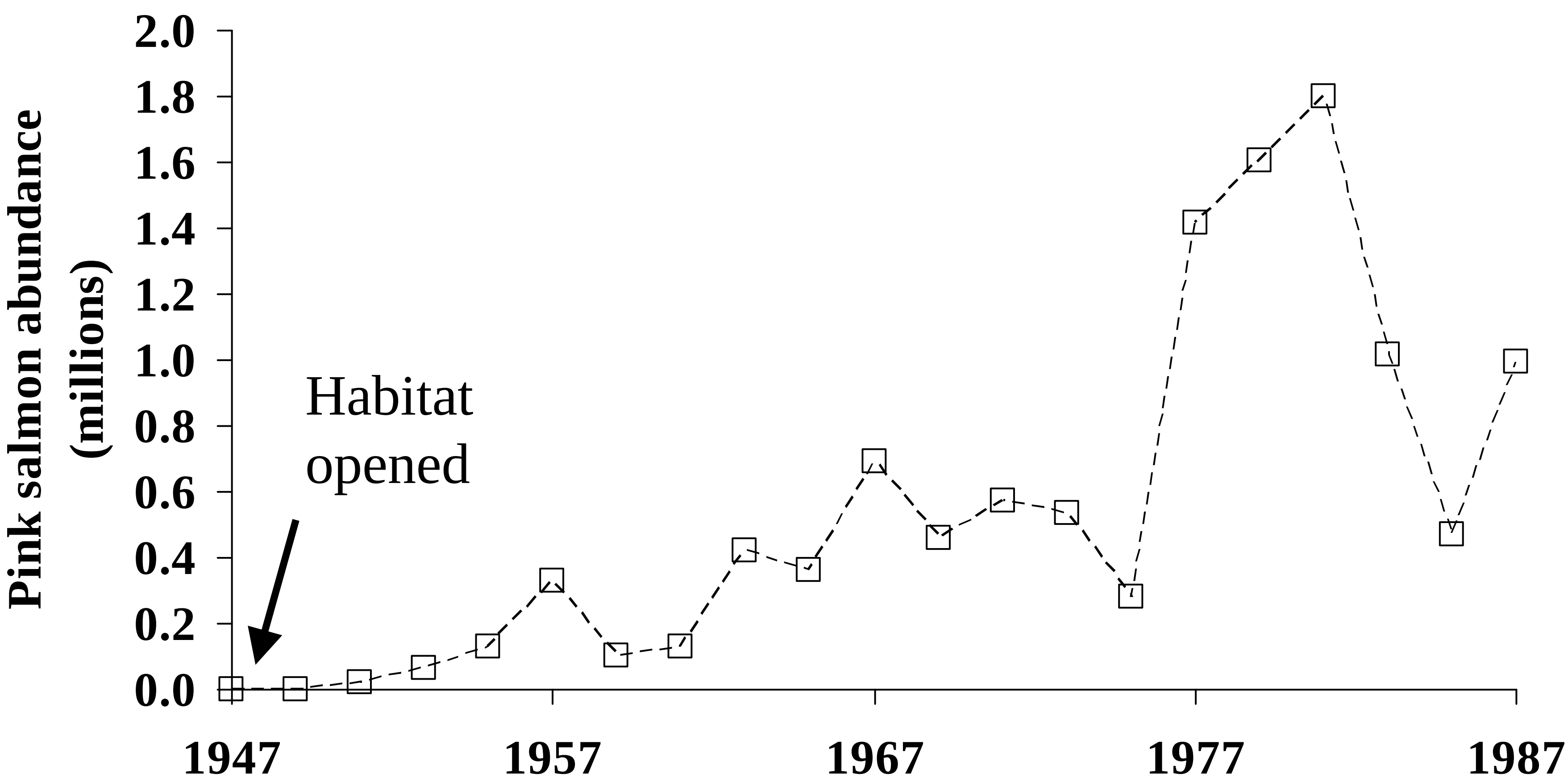
Hell’s Gate 1946

Hell's Gate fish ladders put in to allow passage for Fraser River salmon

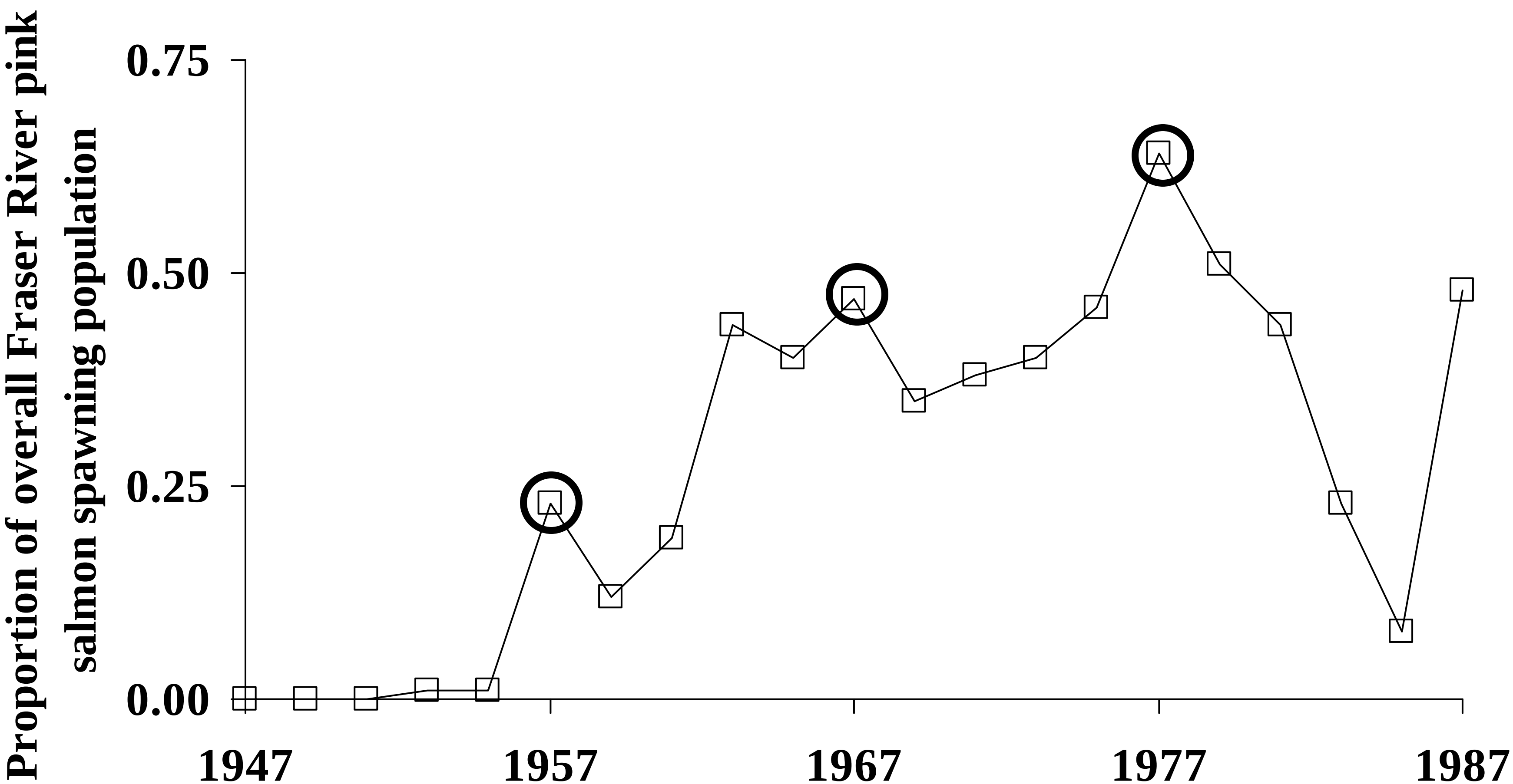


Pink salmon successfully colonized above Hell's Gate

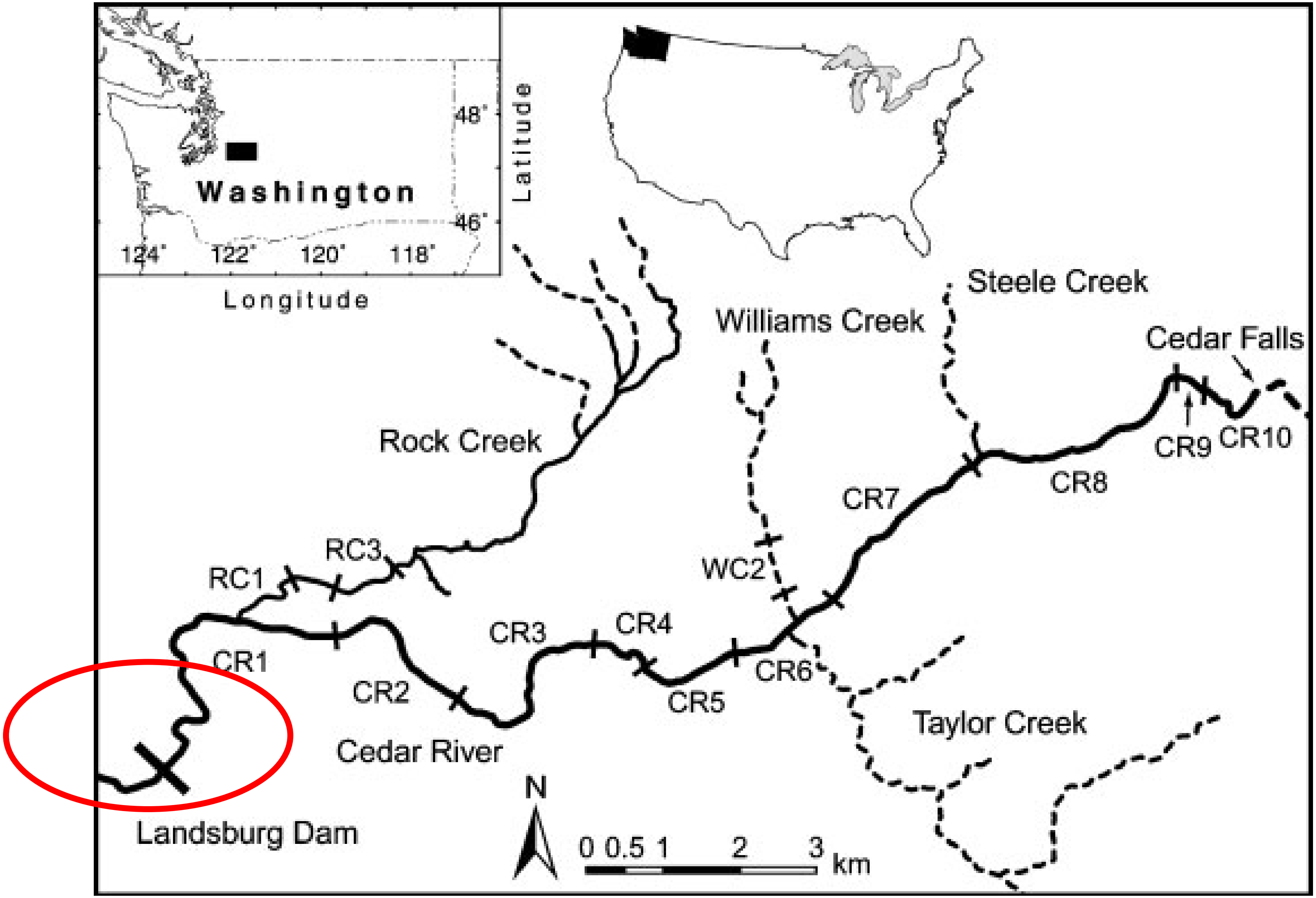
Source population size – hundreds of thousands



A major portion of Fraser river pink salmon now spawn above Hell’s Gate



Cedar River

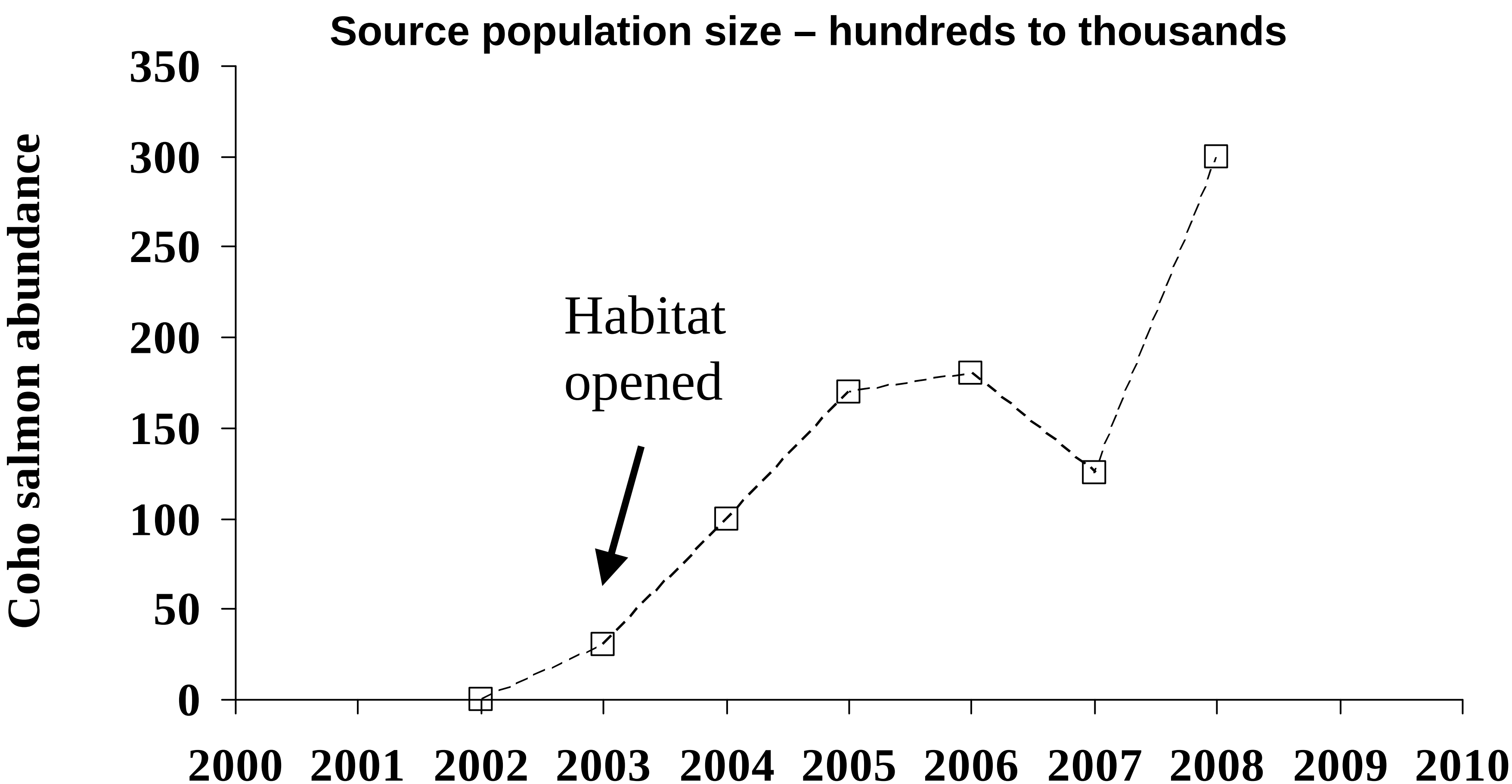

Washington
48˚
46˚
124˚
122˚
120˚
118˚
Latitude
Longitude
Steele Creek
Williams Creek
Cedar Falls
Rock Creek
CR9
CR10
CR8
CR7
RC3
RC1
WC2
CR4
CR3
CR1
CR6
CR2
CR5
Taylor Creek
Cedar River
N
Landsburg Dam
0 0.5 1 2 3 km

Cedar River

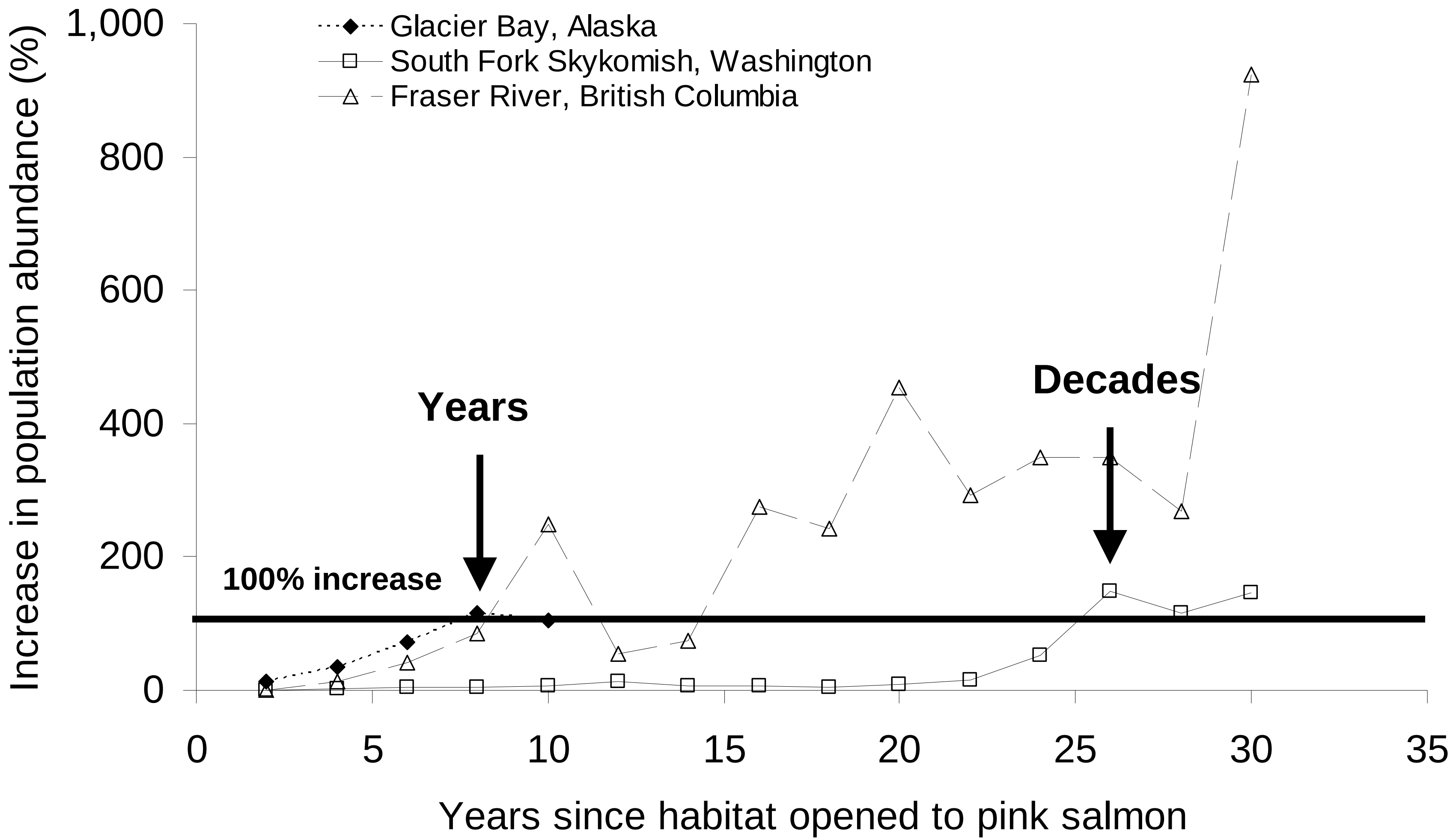
Cedar River

http://www.seattle.gov/UTIL/About_SPU/Water_System/Water_Sources_&_Treatment/CedarRiverBiodiversity/Fish/Fishdocs/SPU01_003186.asp

Coho salmon successfully colonized above Landsburg diversion

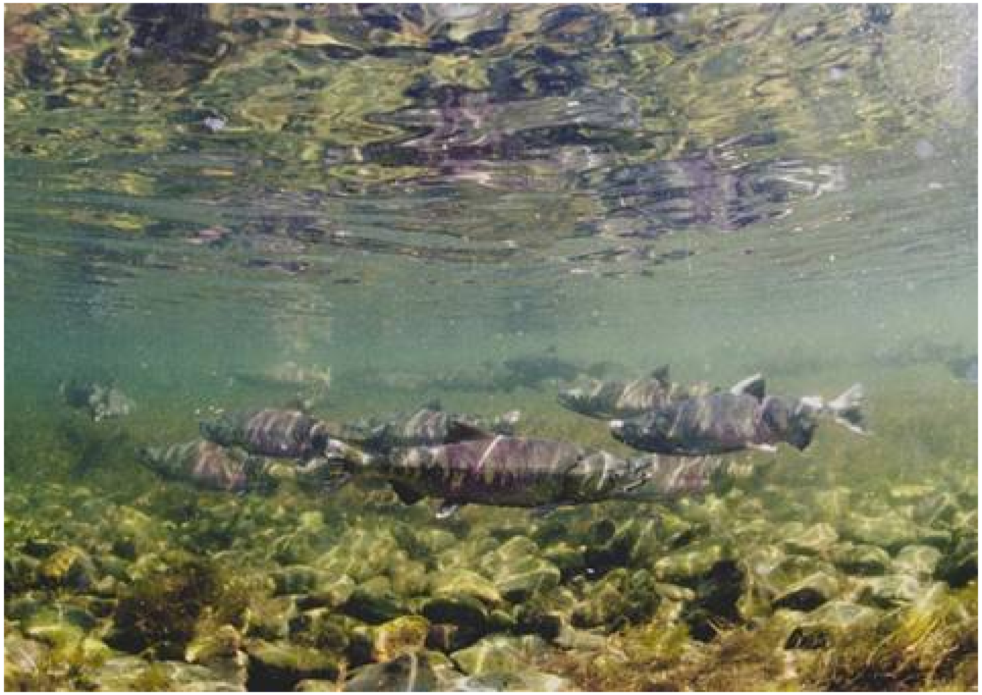


Diadromous species can successfully colonize newly available habitats



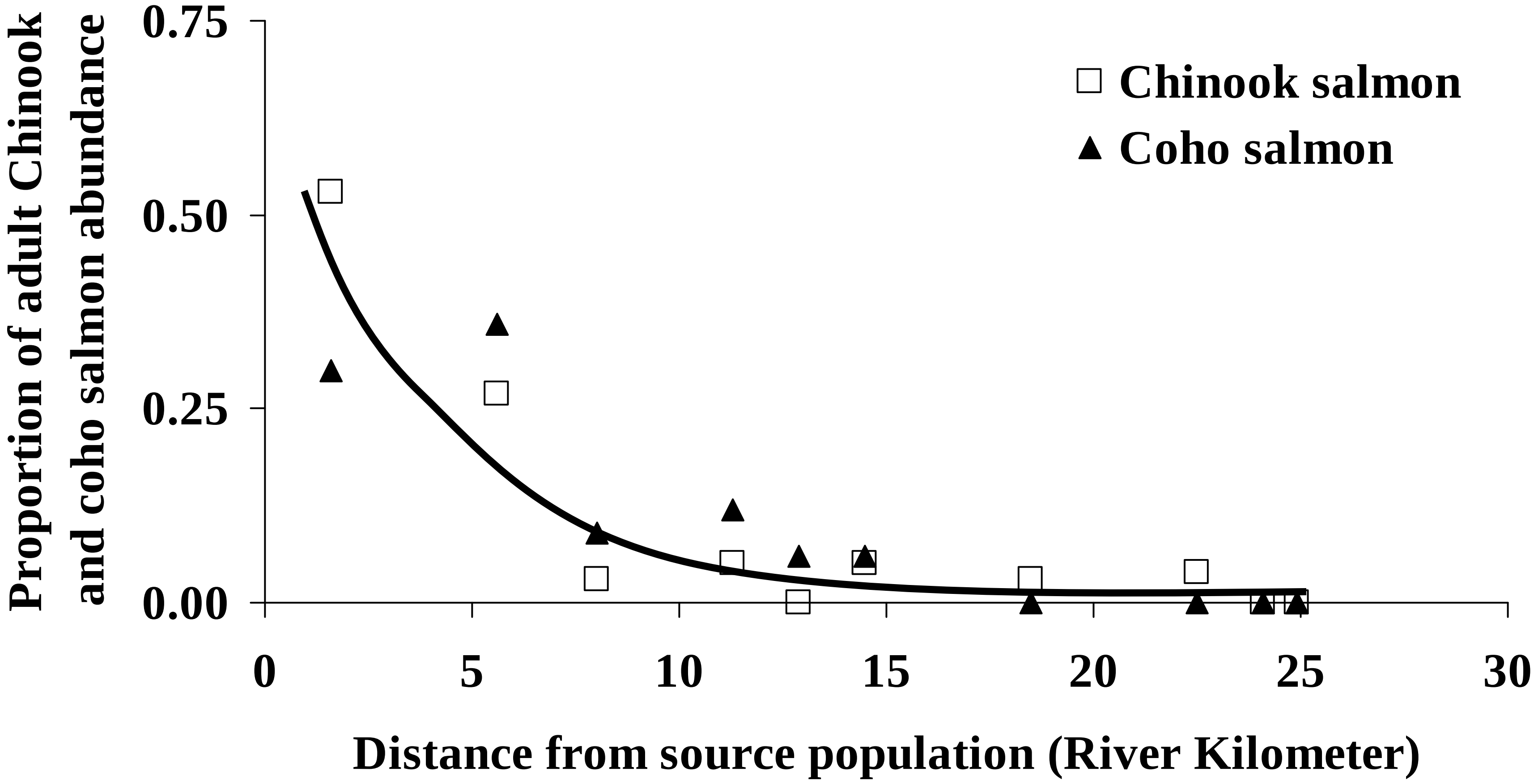
What are the most important factors associated with colonization?

- Natural barriers
- Distance from source population
- Habitat area & type
- Source population size & stray rate
- Colonizing population productivity
- Life history adaptations
- Interaction/competition with other established species
- Ocean conditions

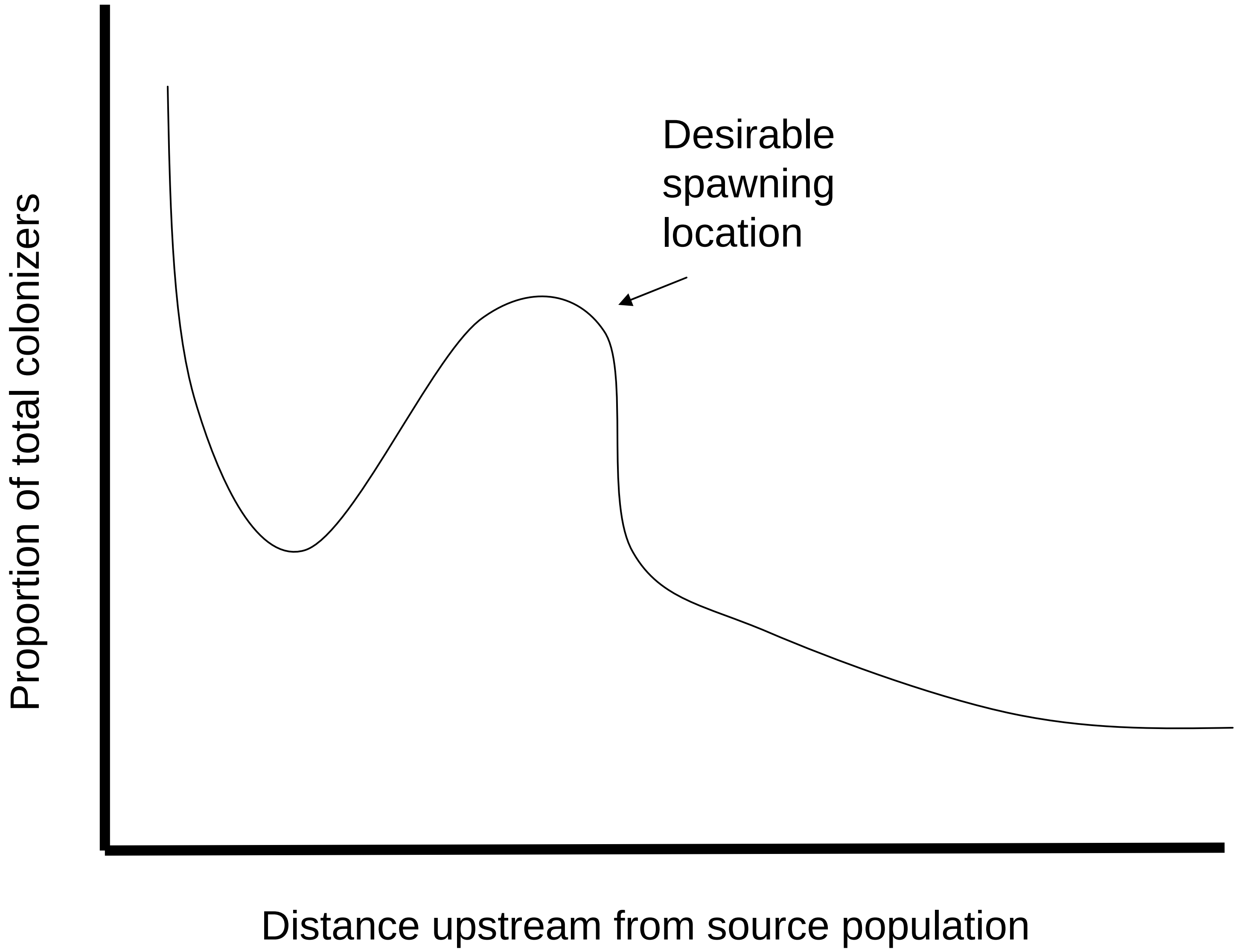


Distance from source population

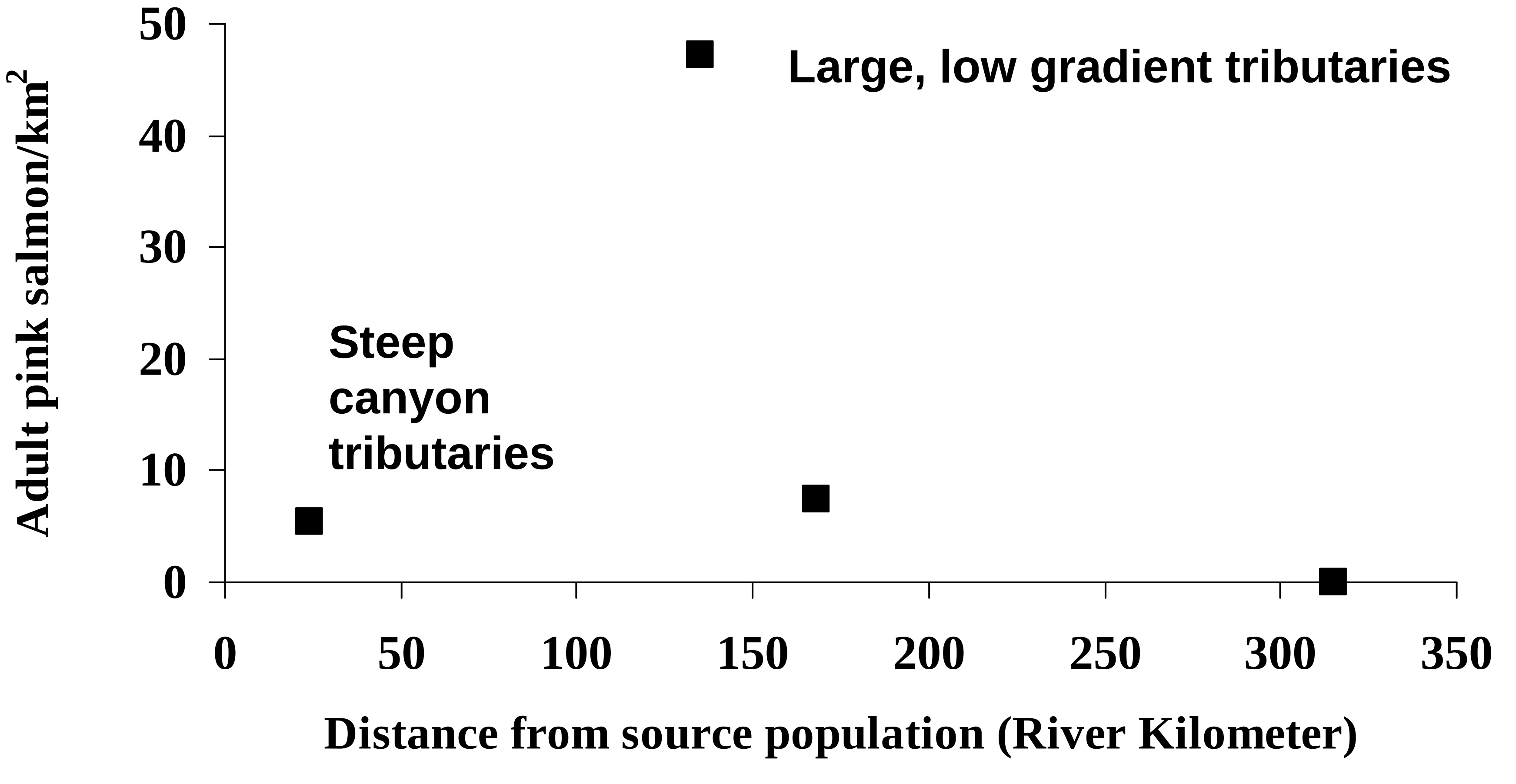
Cedar River Chinook & coho salmon decreased with distance from source population



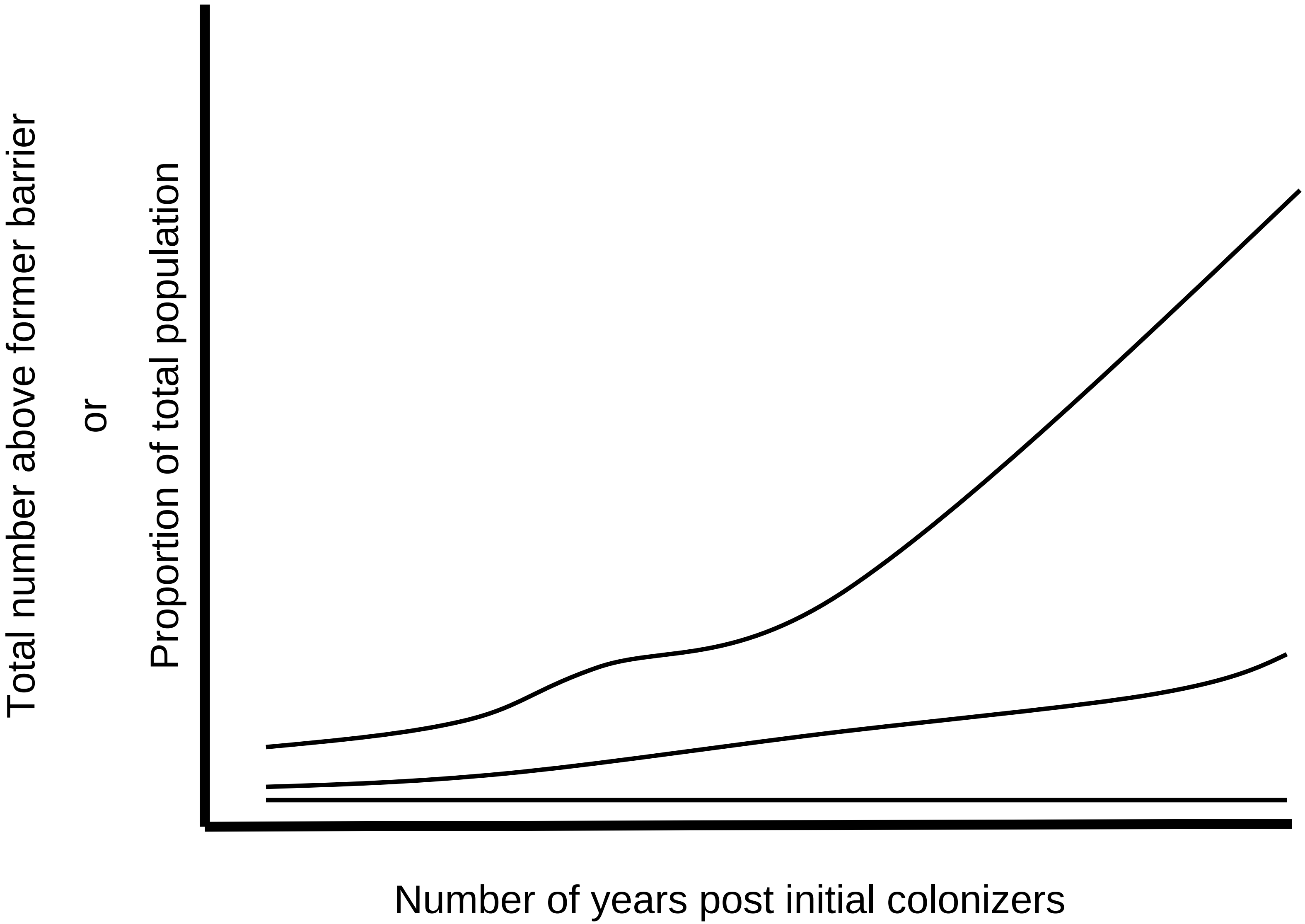
Habitat quality and type



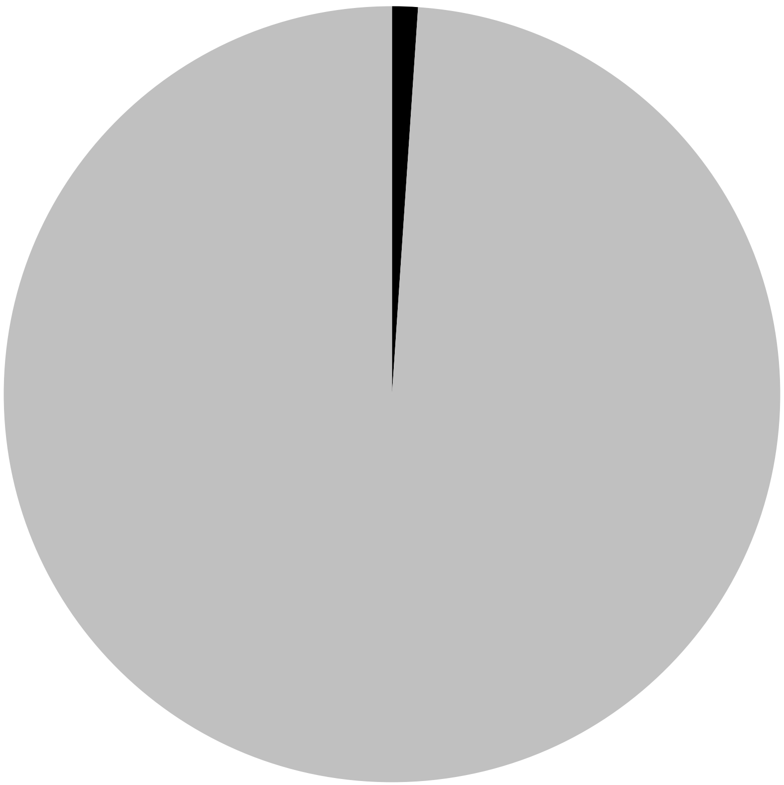
Fraser river pink salmon density varied by habitat area & type with distance from source population



Population size and stray rate



Population size and Straying



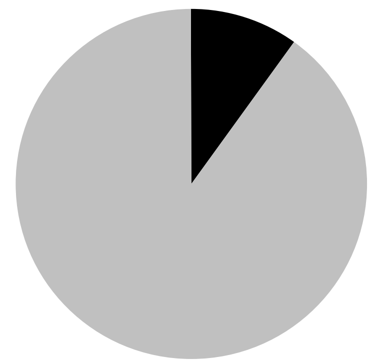
Population size – 10,000

Stray rate – 1%

strays - 100

Black – strays

Grey - homed

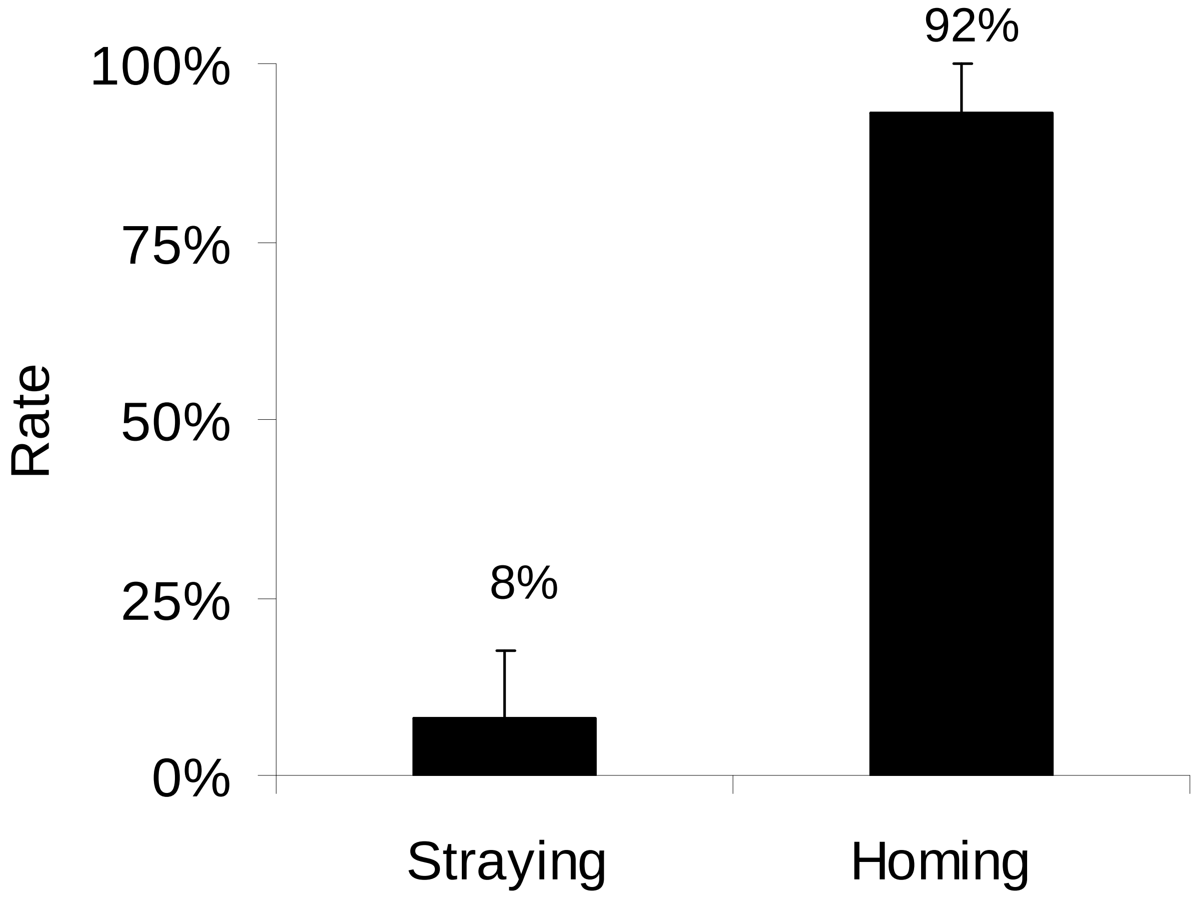


Population size – 1,000

Stray rate – 10%

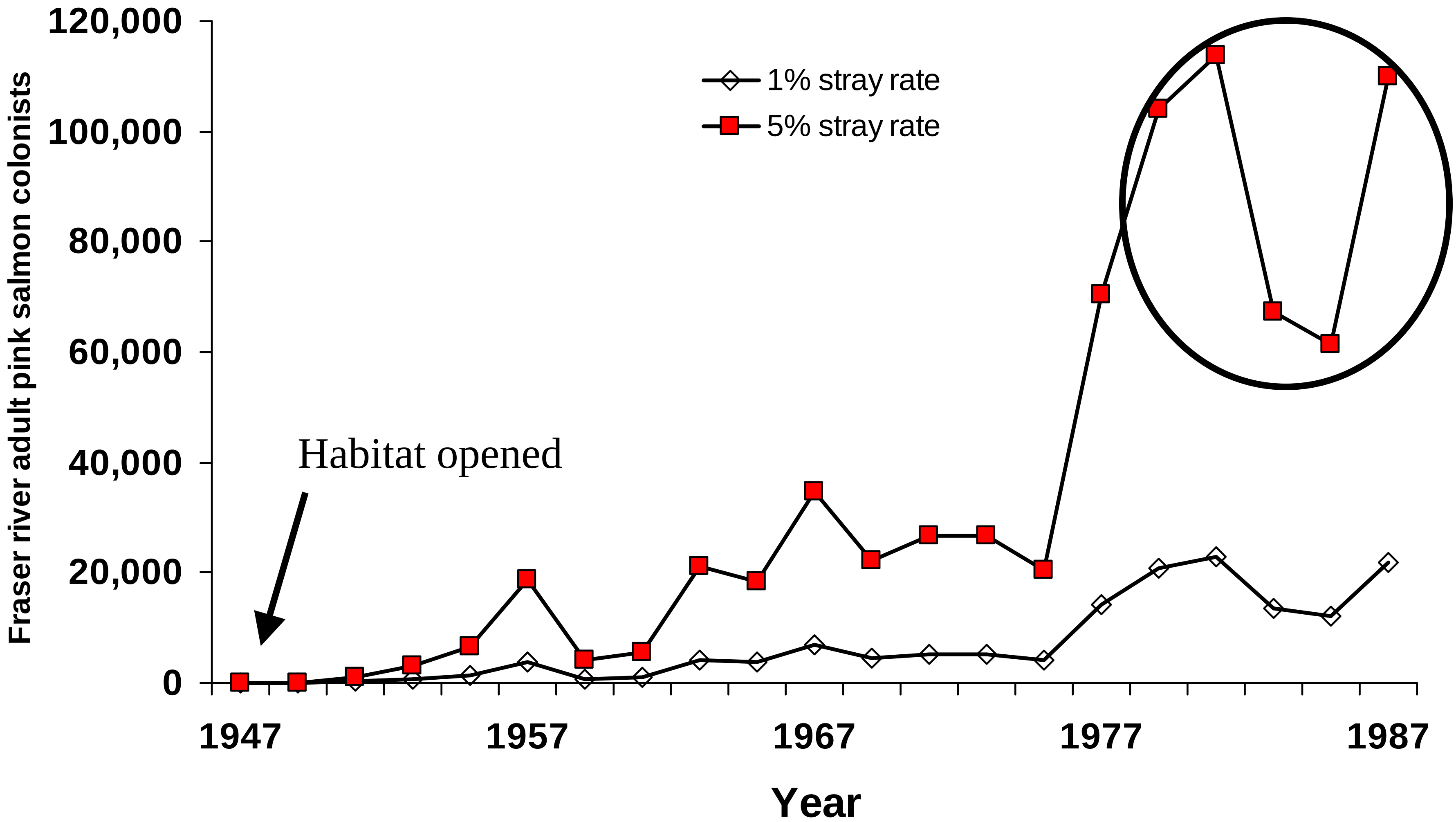
strays - 100

Salmonids typically home to natal streams rather than stray

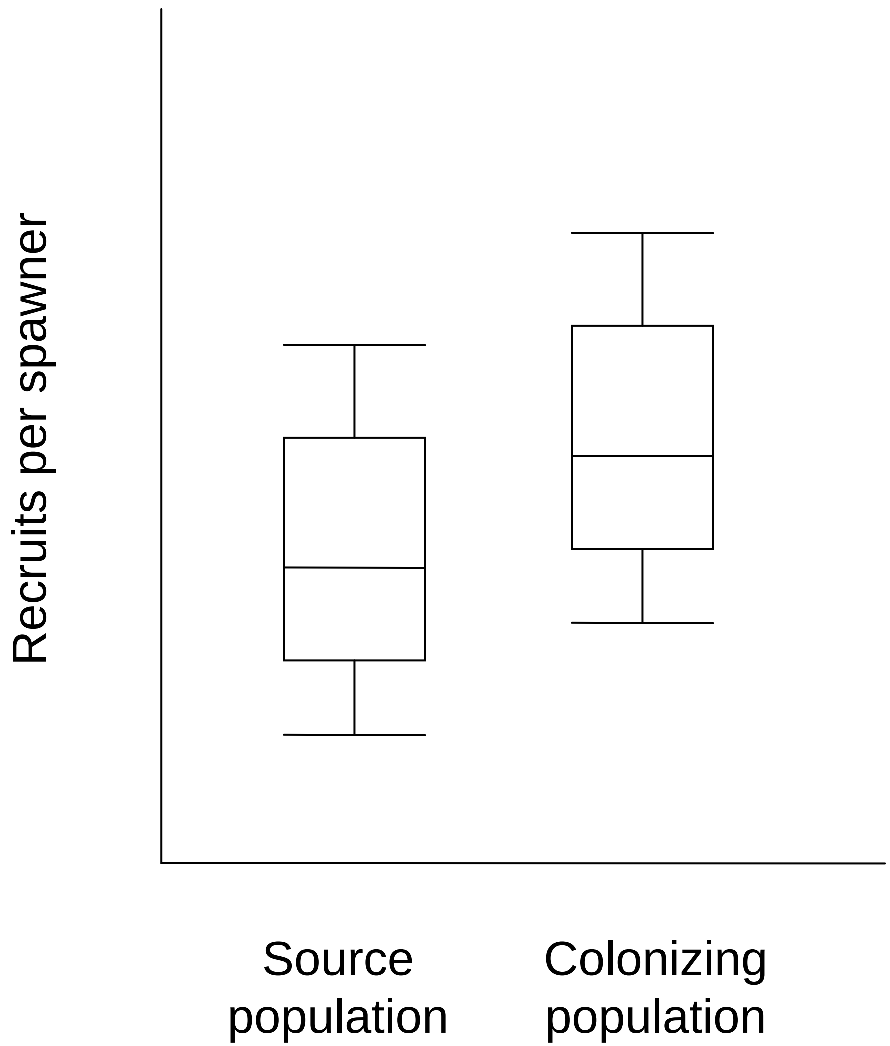


Hendry et al. 2004

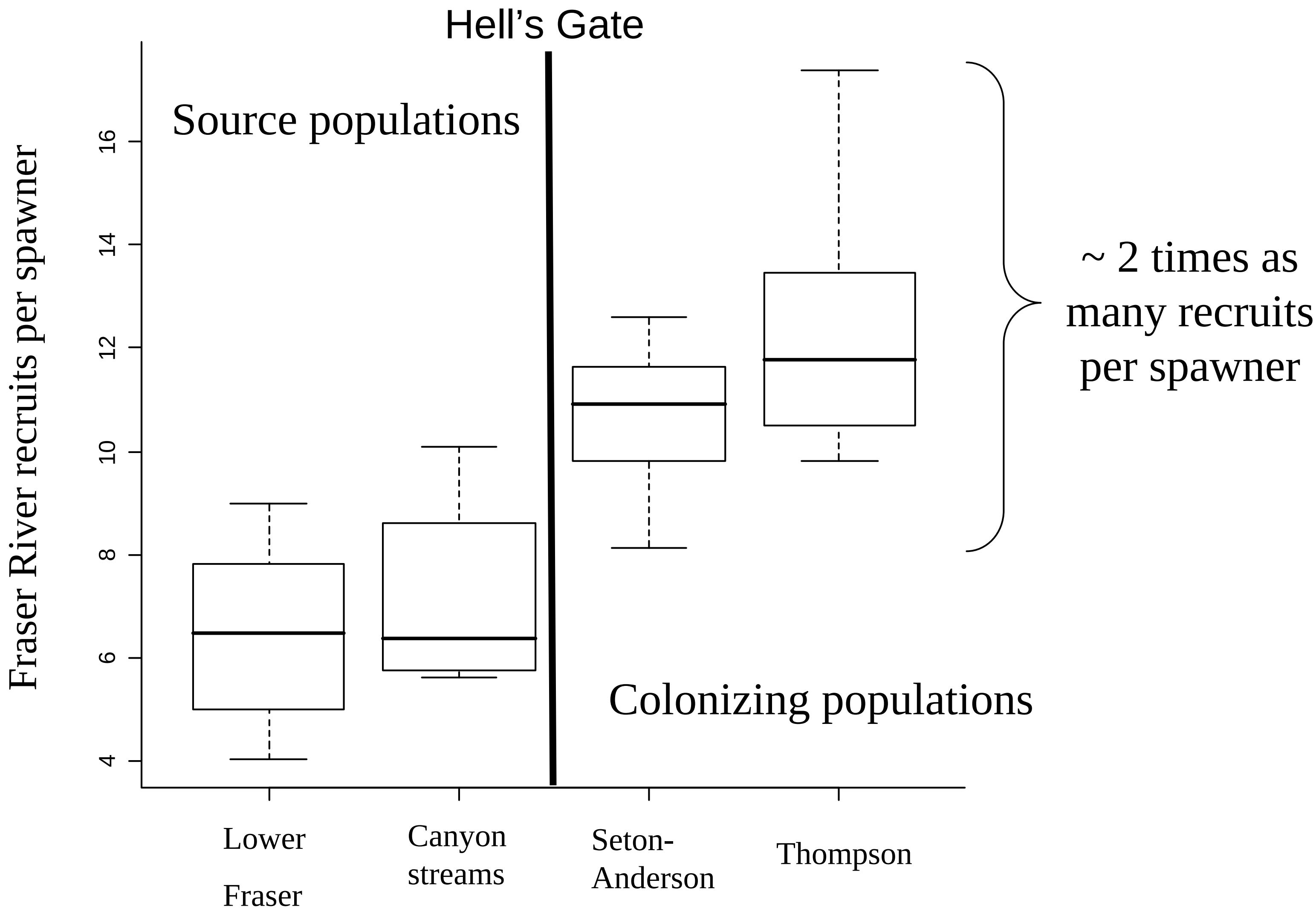
Stray rate will be a large driver in determining the number of colonists



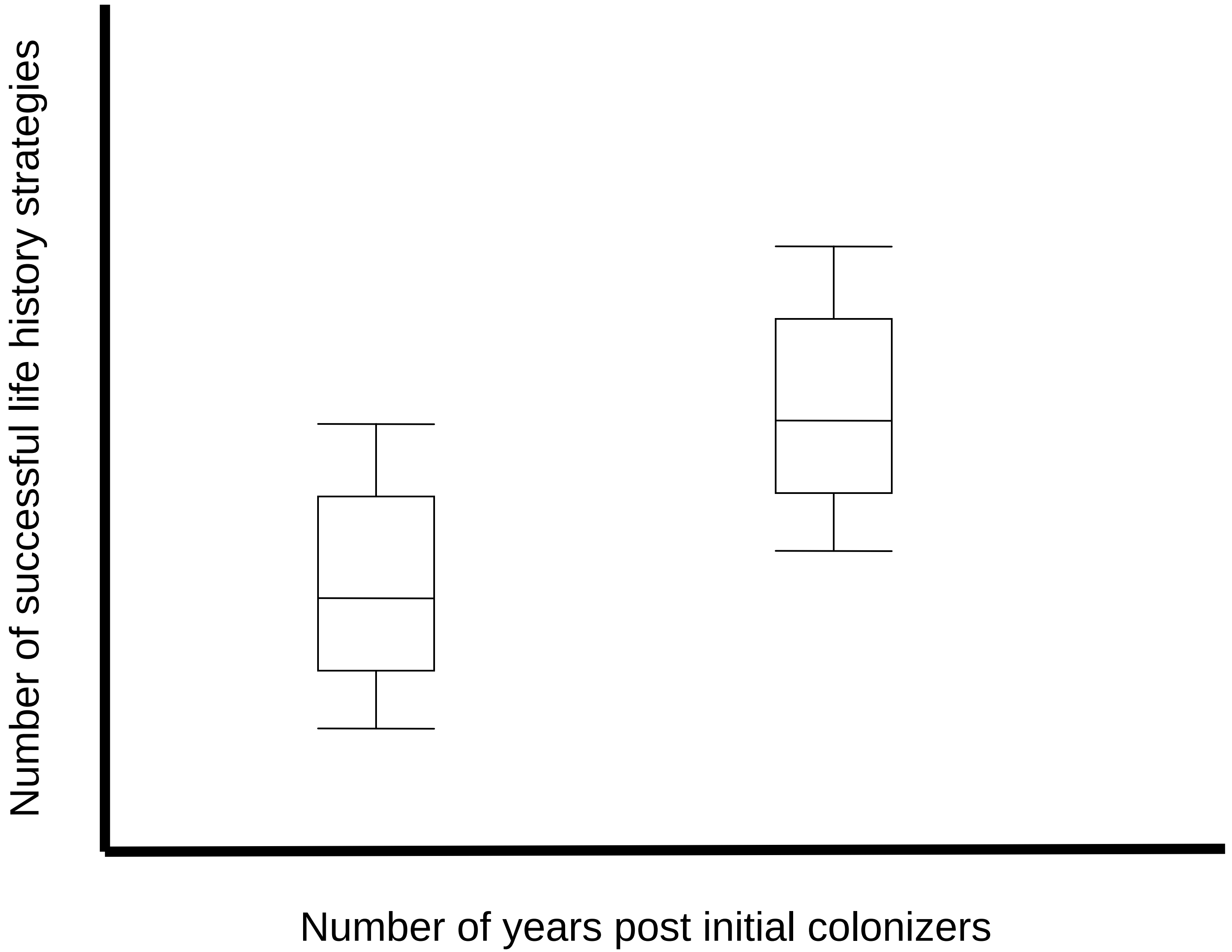
Colonizing population productivity



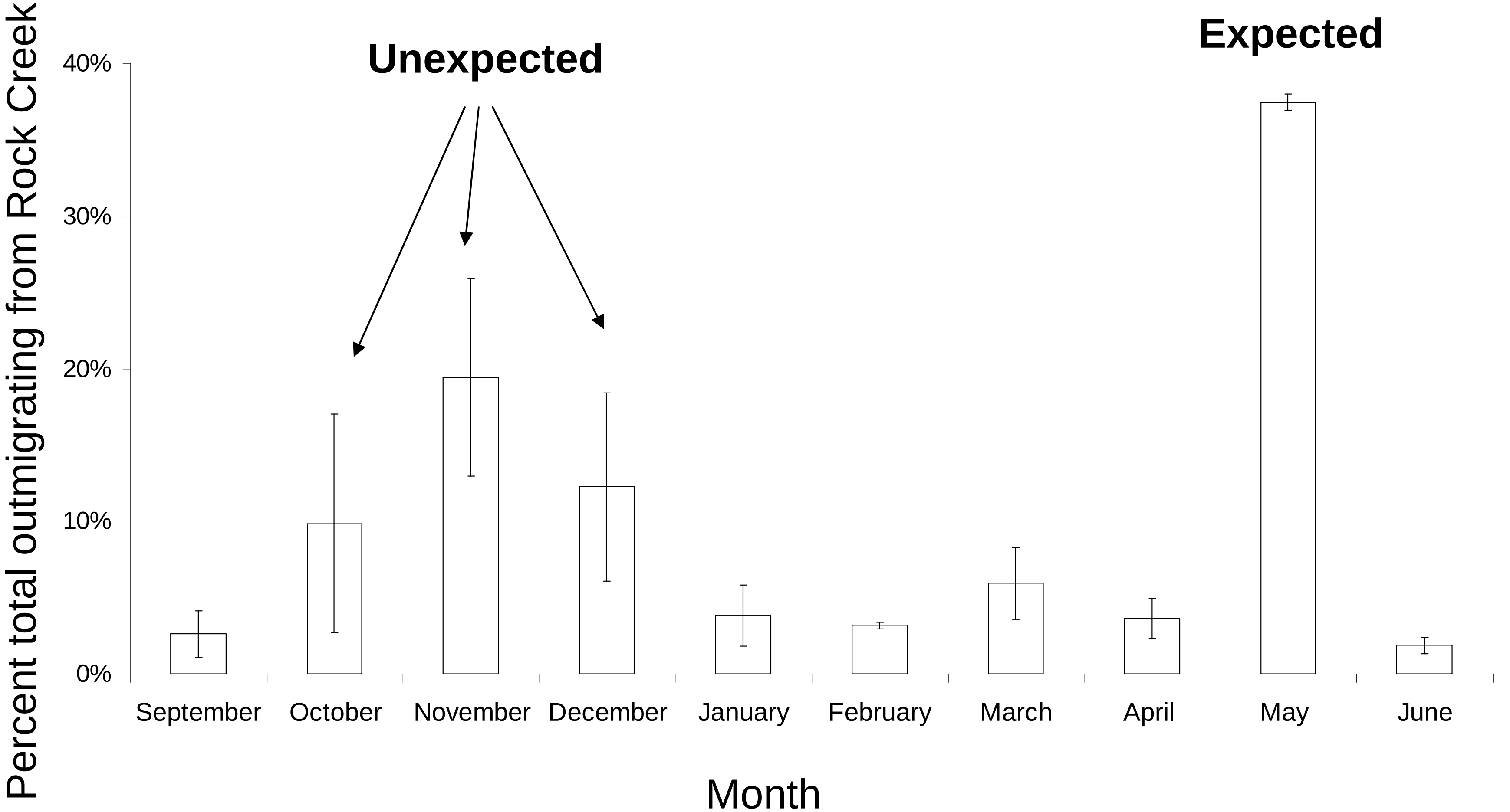
Colonizing Fraser River spawning populations are more productive



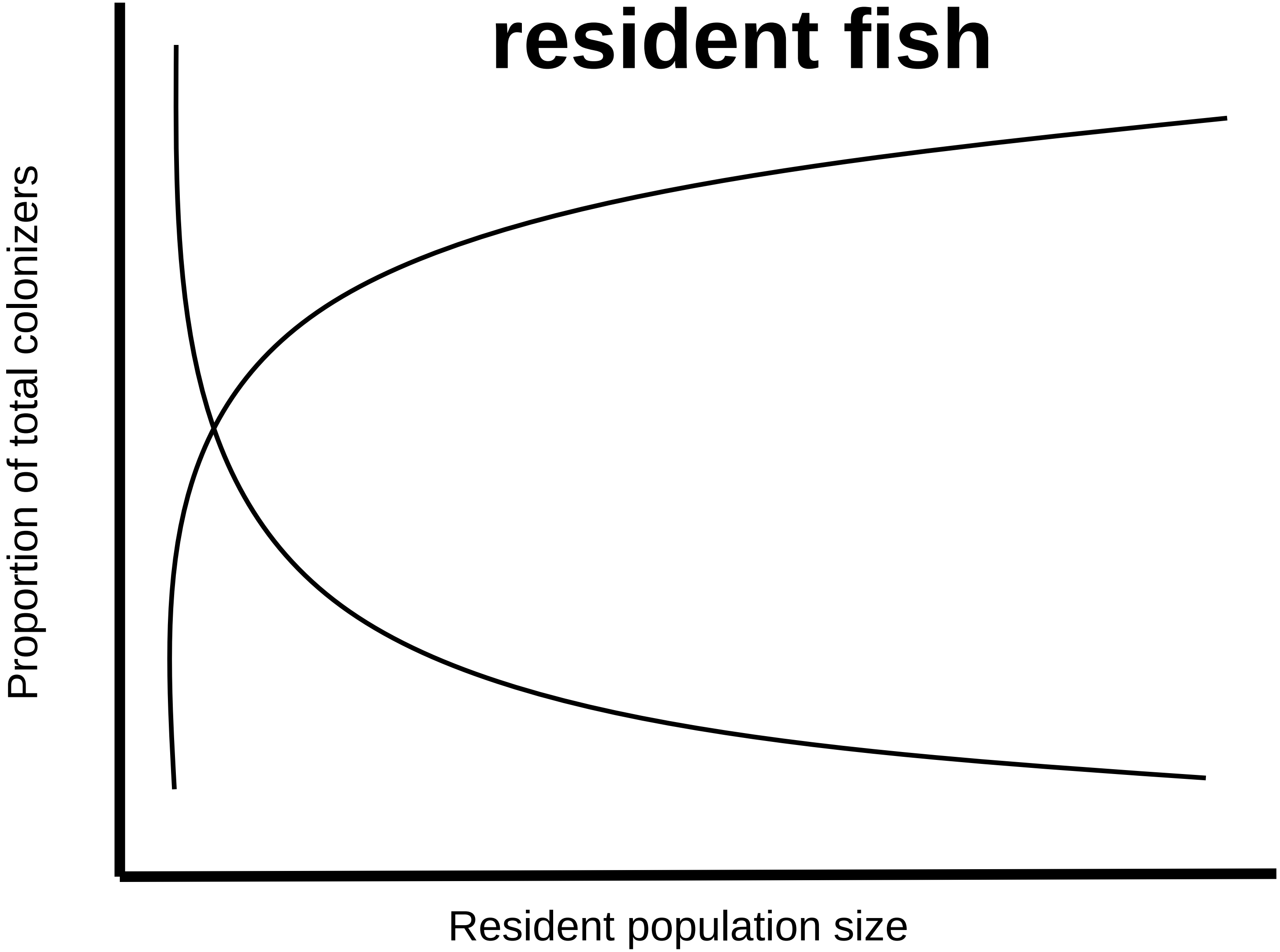
Successful Life History Adaptation



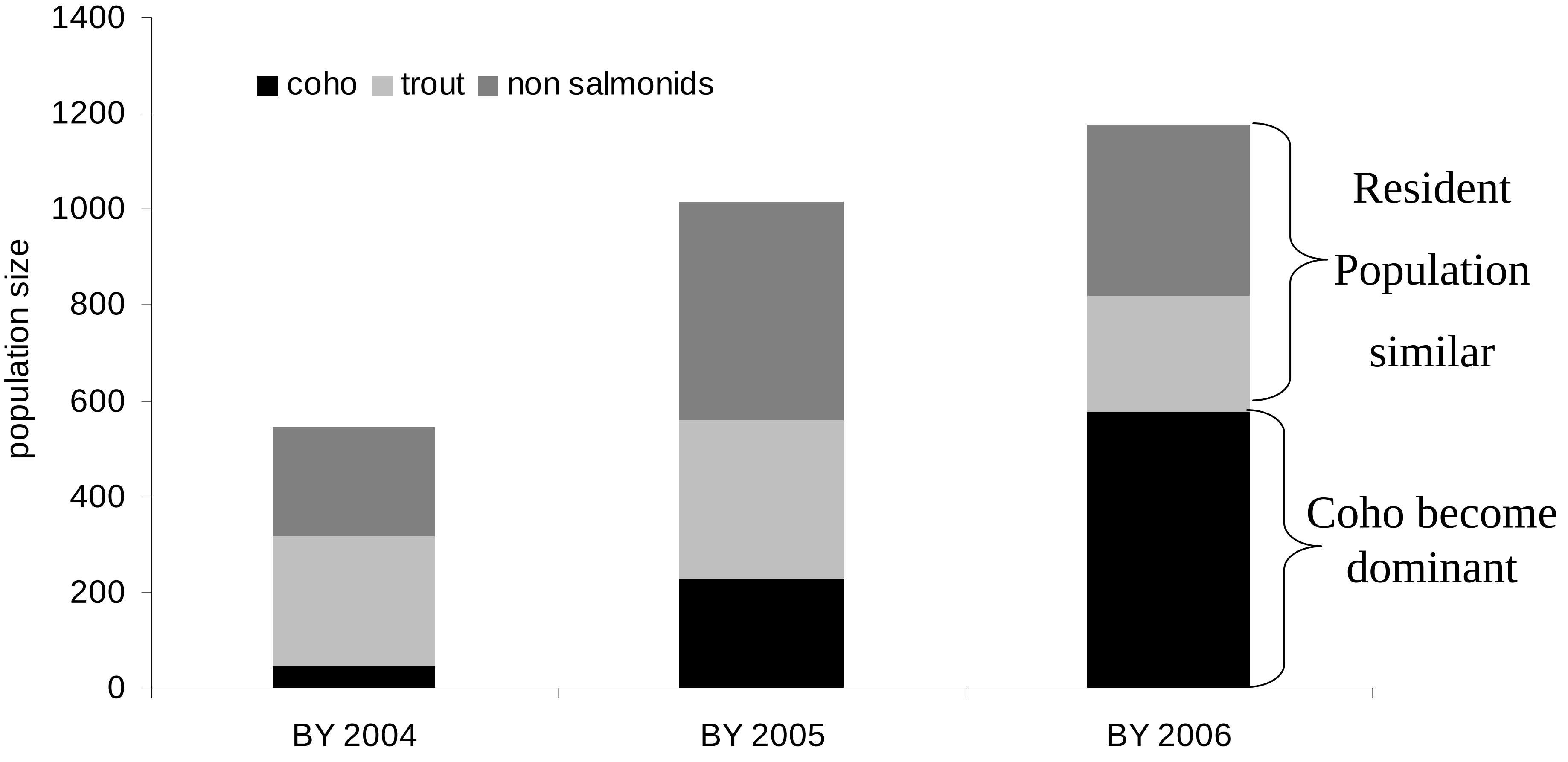
Most juvenile coho outmigrated in the Spring and Fall from the Cedar River



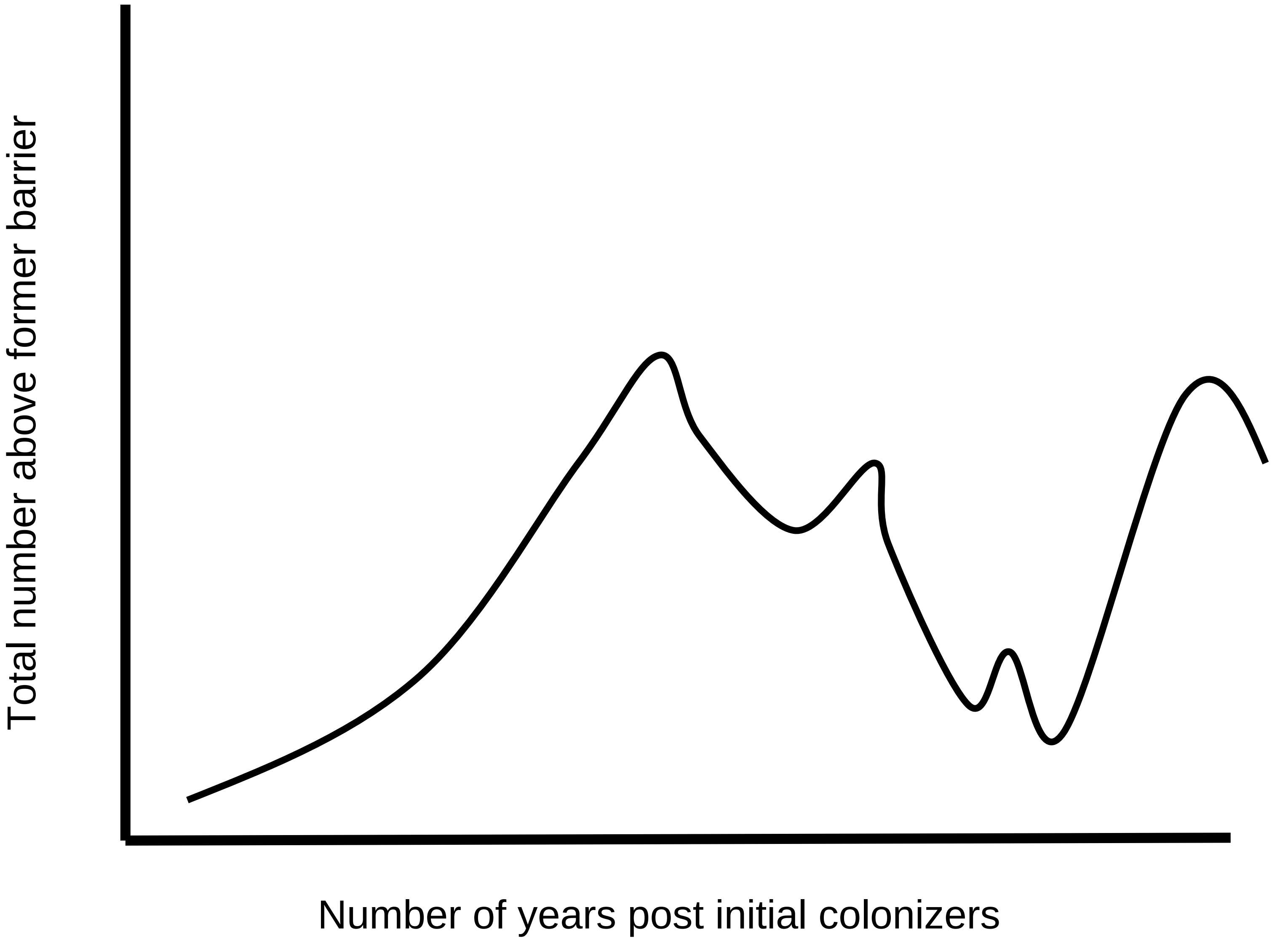
Interaction and competition with resident fish



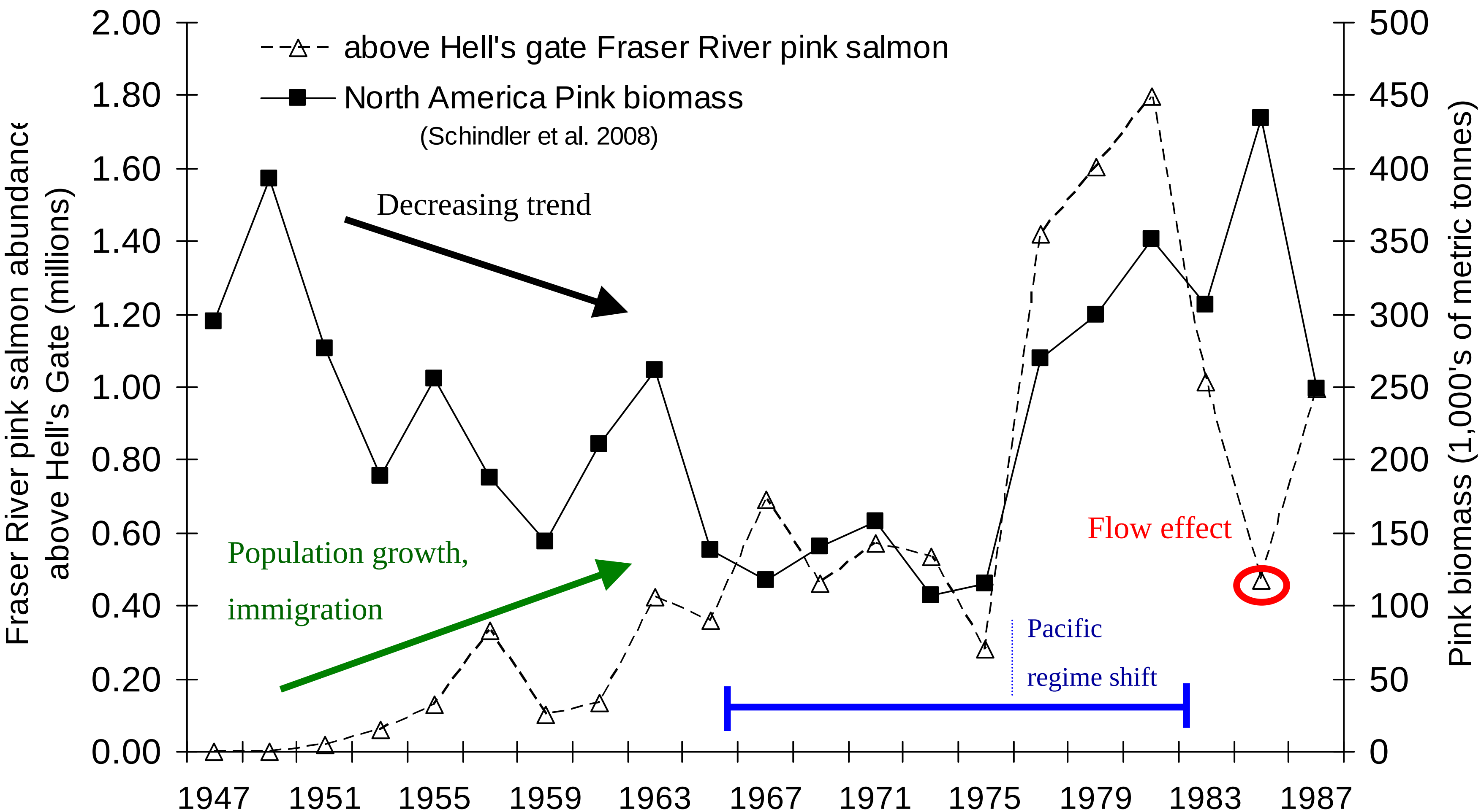
Juvenile coho salmon in a tributary of the Cedar River became the numerically dominant salmon species within years of reintroduction



Climate and ocean conditions



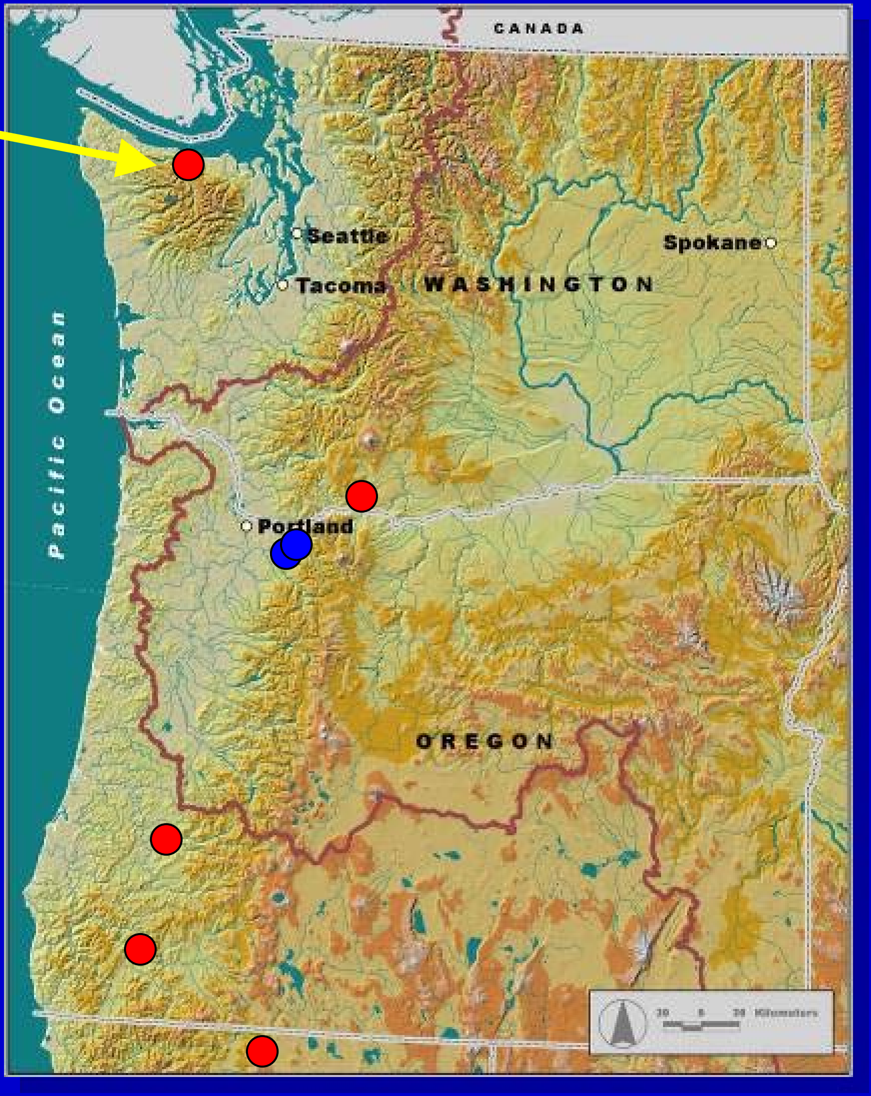
Increasing abundance in pink salmon across the North America



Variables with affect colonization	Likely to disperse and colonize	Not likely to disperse and colonize
Natural barriers	Few, small	Many, large
Distance from source population	Near	Far
Habitat area & type	Large, preferred	Small, not preferred
Source population size	Large	Small
Source population stray rate	High	Low
Colonizing population productivity	High	Low
Life history adaptation	Adaptable	Not adaptable
Interaction/competition with other established species	Positive, co-evolved	Negative, new interaction
Current ocean conditions	Favorable	Unfavorable

Notable dam removals in the Pacific Northwest

- Elwha River
- White Salmon River
- Sandy River
- Little Sandy River
- Calapooia (Umpqua) River
- Rogue River
- Klamath River

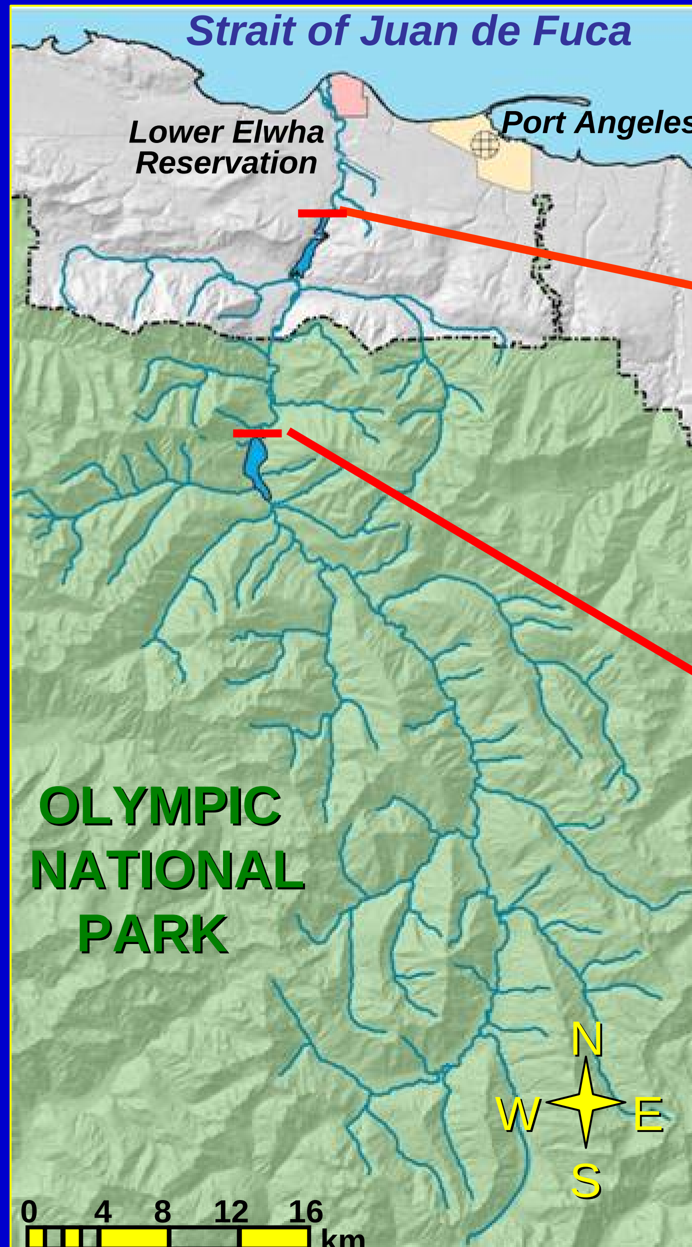


The Elwha River

Olympic Peninsula

• approx. 18 million m^3 behind dams

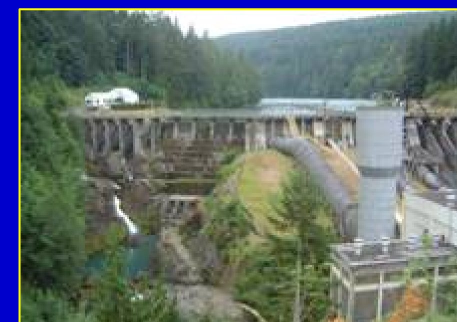
•dams to be removed 2011



Washington State

Elwha Dam

1913



Glines Canyon Dam

1927

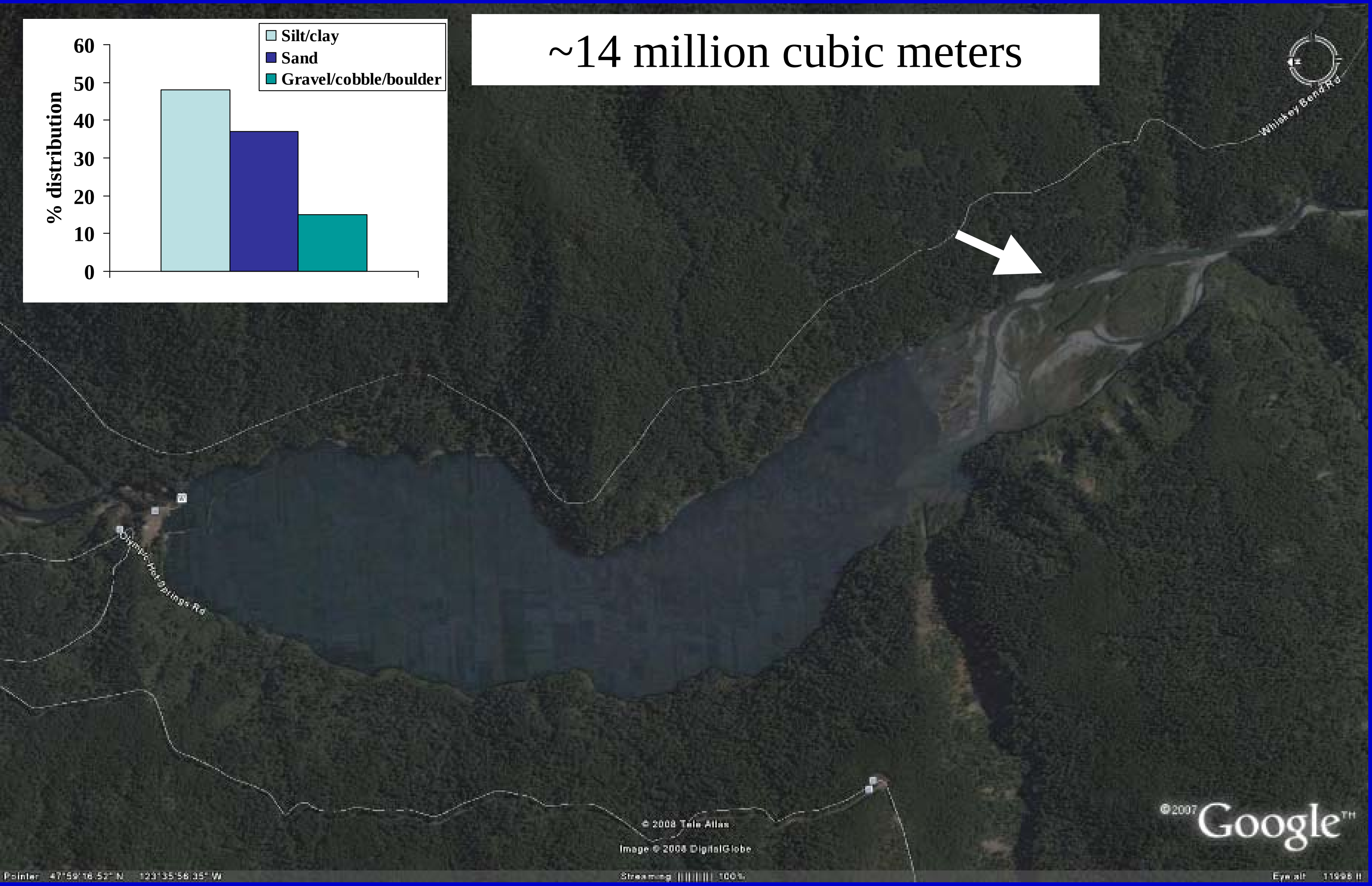
How will the dams be removed?

http://www.interactive-earth.com/home.htm

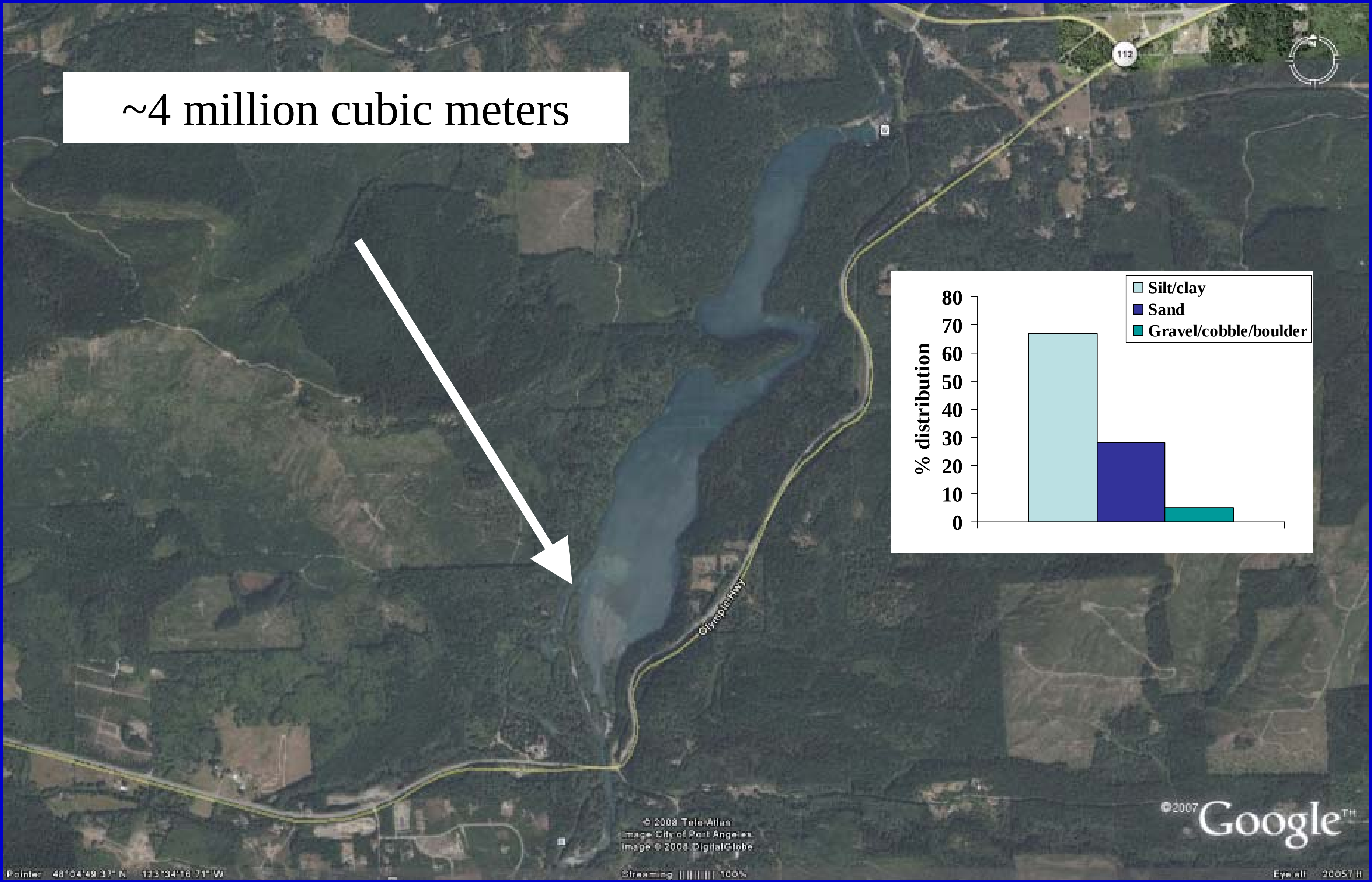
glines_removal.exe

What about the sediment? Lake Mills

~14 million cubic meters



What about the sediment? Lake Aldwell



What about the sediment?

- How much will erode downstream?
- What will be the concentrations be?
- How long will concentrations be elevated?
- How much will the river aggrade?

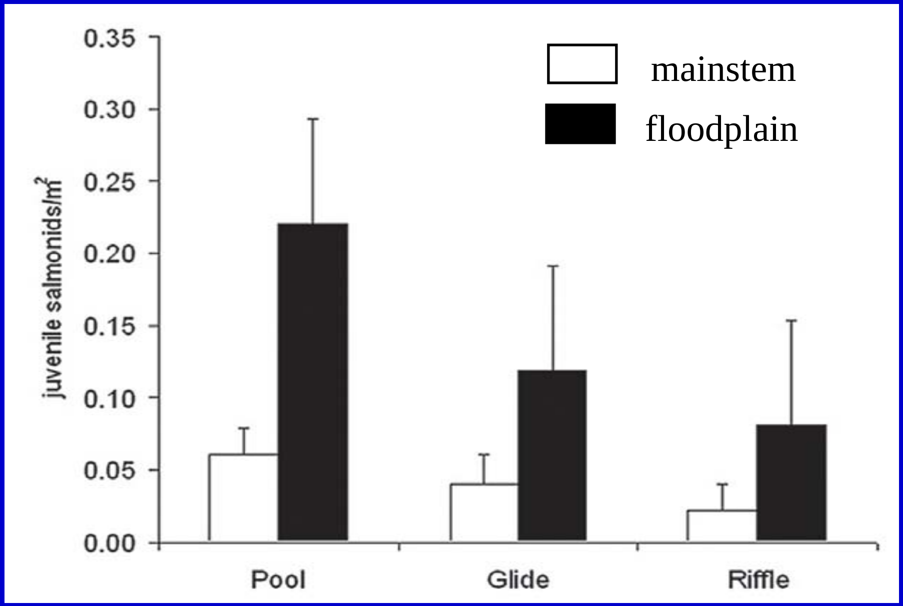
- Fine sediments – 60%
- Coarse sediments – 25%
- Storm event – 18 to 531mg/l (ave ~30mg/l)
- ~20mg/l
- Up to 6,110mg/l immediately below delta
- 2 to 5 years
- Average – less than 0.3 m
- Up to 1m

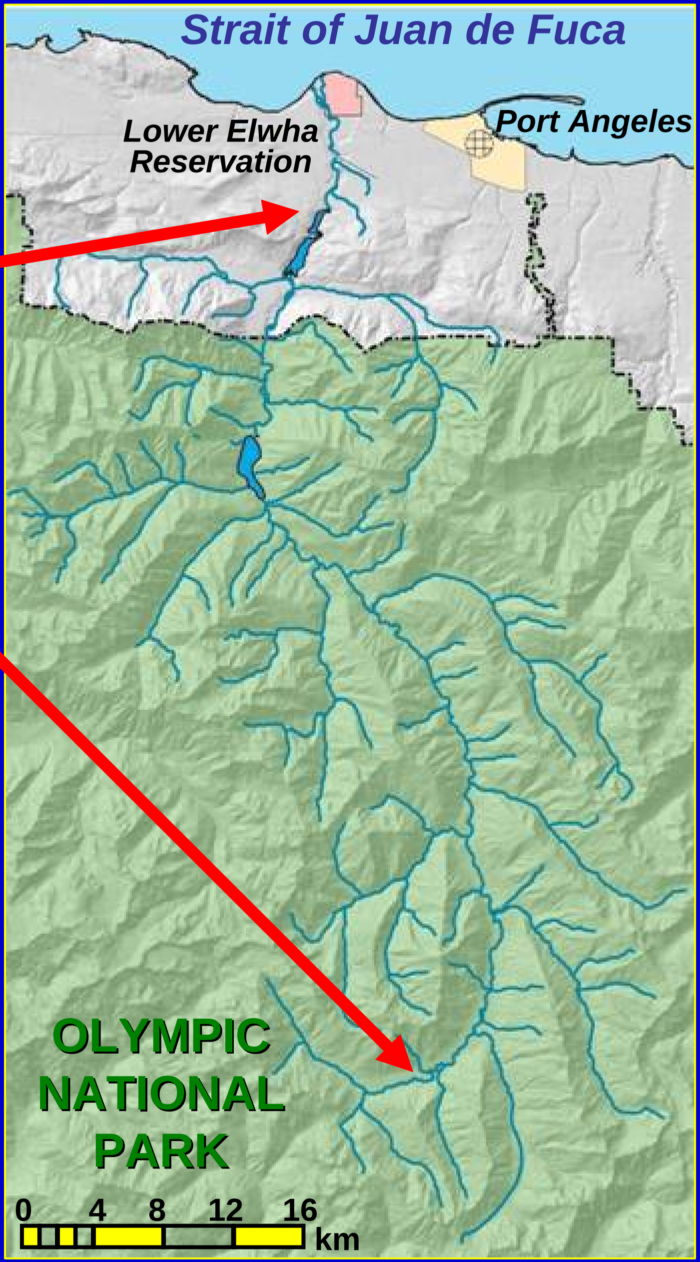
Questions

- How will ecosystem processes and condition change with the removal of the Elwha River dams?
  - Primary & secondary productivity
  - Fish community response
- How do channel & floodplain dynamics affect primary & secondary productivity and fish community response?

Impacts of the dams
Blockage to upstream migration

- 146 km of mainstem and tributary habitat
- Floodplain channels





Impacts of the dams

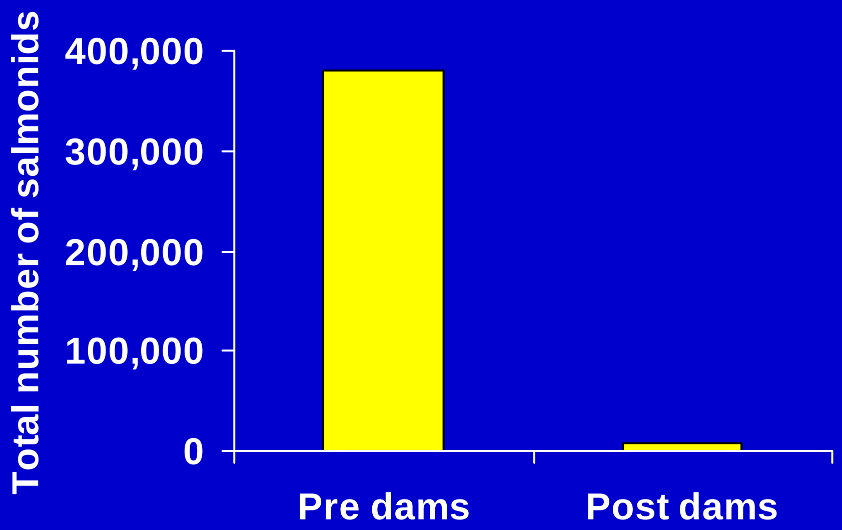
Reduced habitat quality

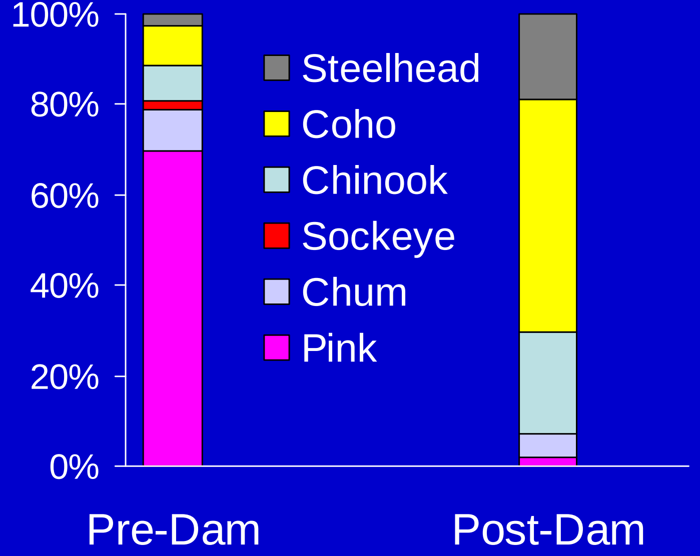
Reduced river movement

Impacts of the dams

Loss, reduced, and altered salmonid populations

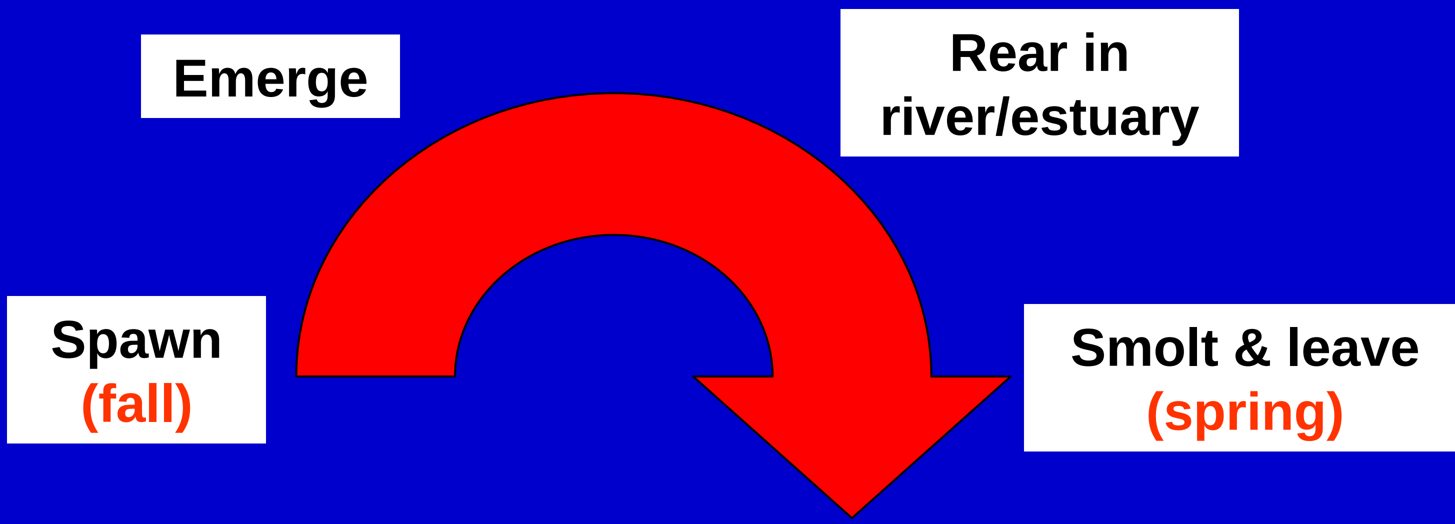
- Over 90% decline in salmonid abundance
- Extirpation of upstream stocks
- Shift in species composition





Impacts of the dams

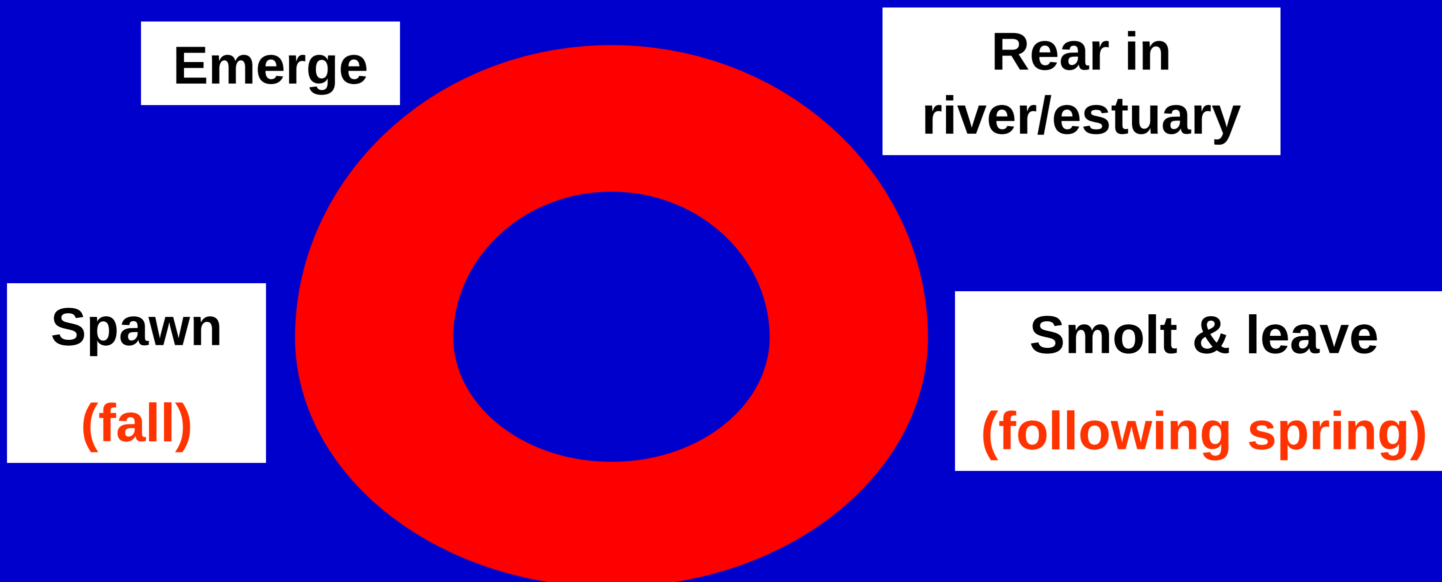
Decreased Chinook life history diversity



Ocean-type Chinook

Impacts of the dams

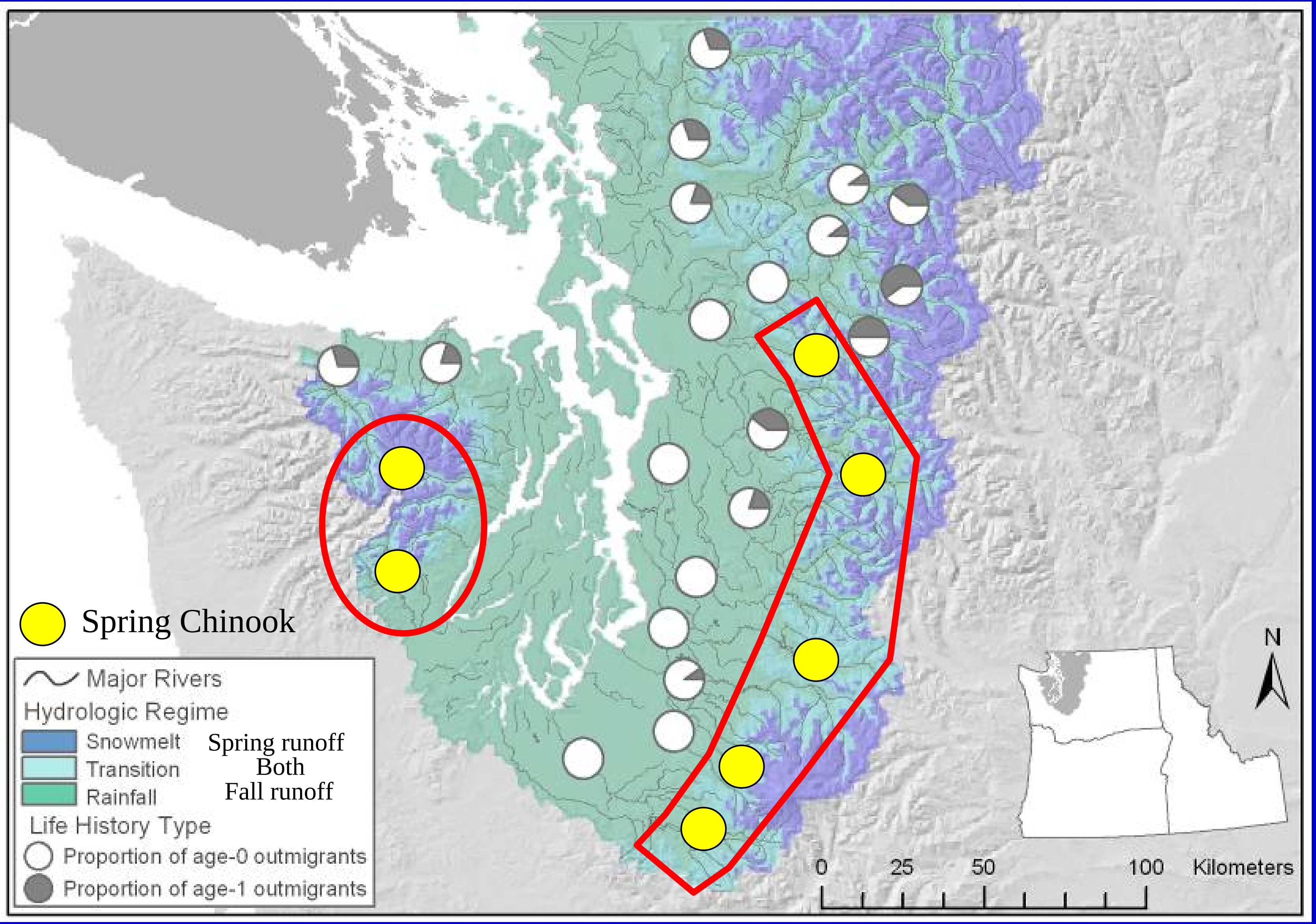
Decreased Chinook life history diversity



Stream-type Chinook

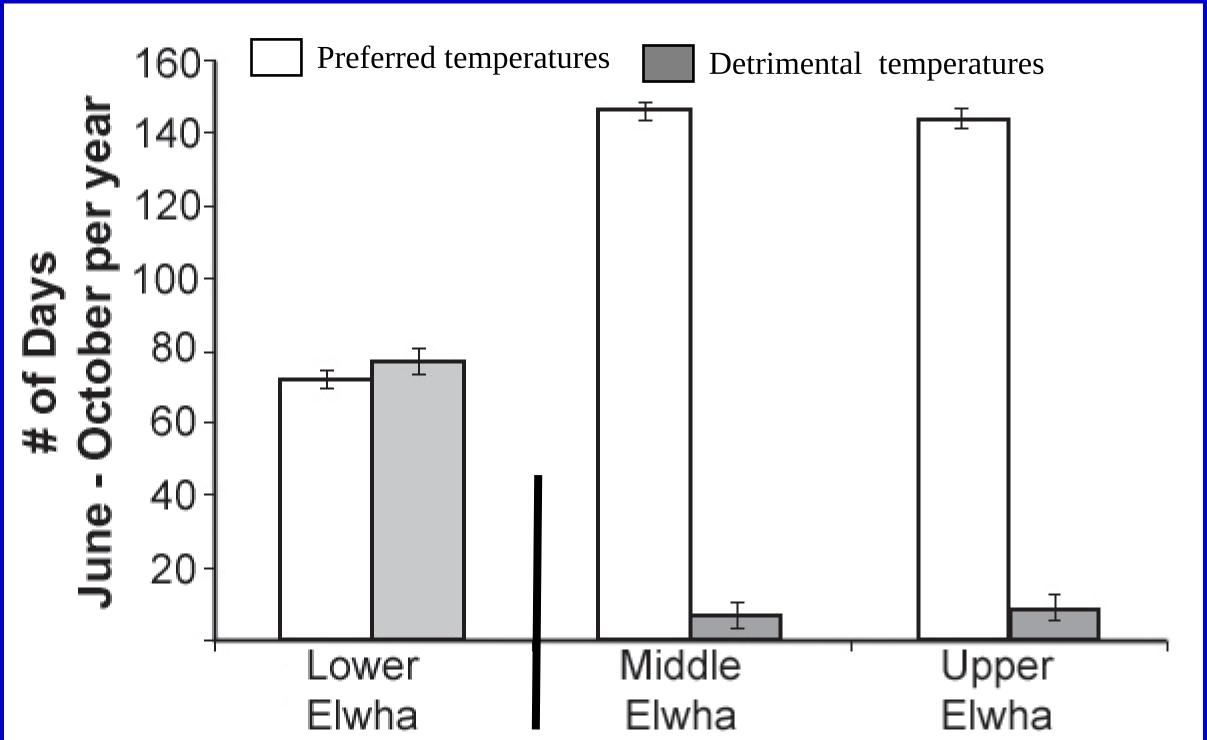
Impacts of the dams

Decreased Chinook life history diversity



Impacts of the dams

Decreased Chinook life history diversity

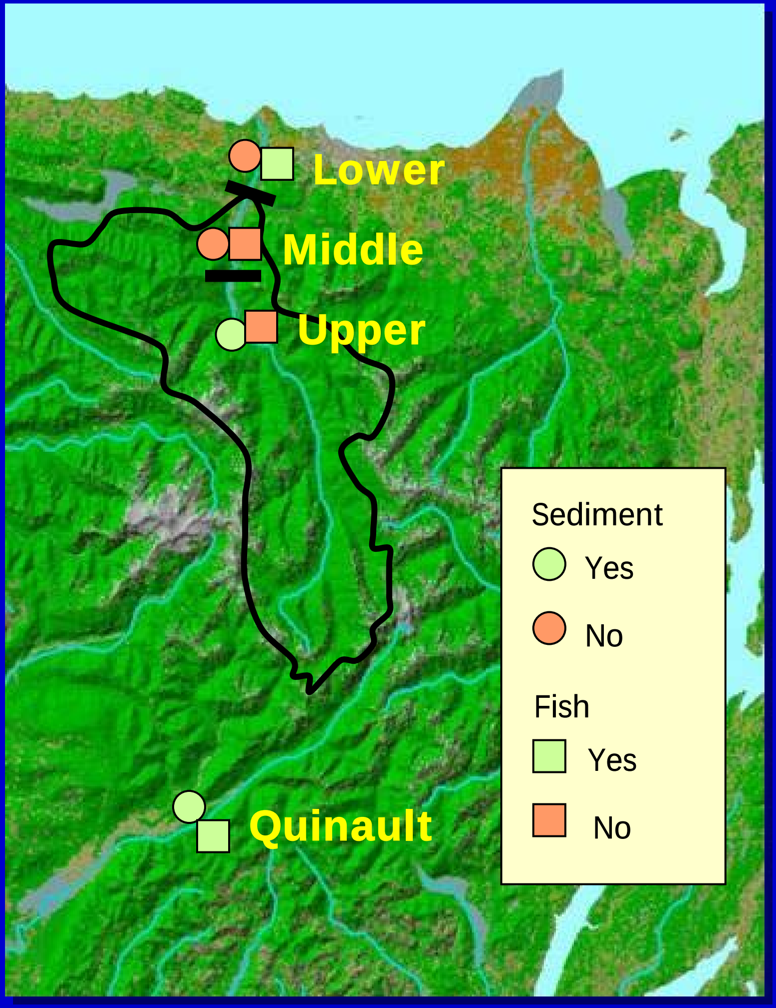


Elwha dams

Study design

- Two main changes:
  - Loss of downstream transport of sediment & wood
  - Loss of upstream migration of salmon

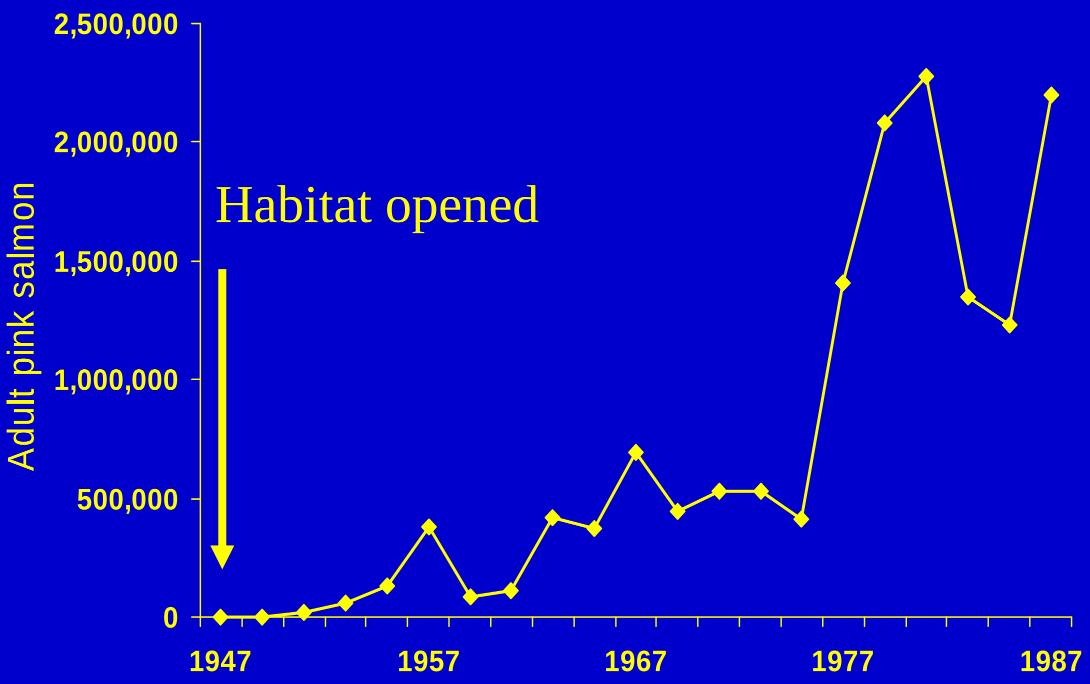
Reach	Sediment	Fish
Quinault	Yes	Yes
Upper Elwha	Yes	No
Middle Elwha	No	No
Lower Elwha	No	Yes



Fish community response

Do salmonids succeed in colonizing new habitats?

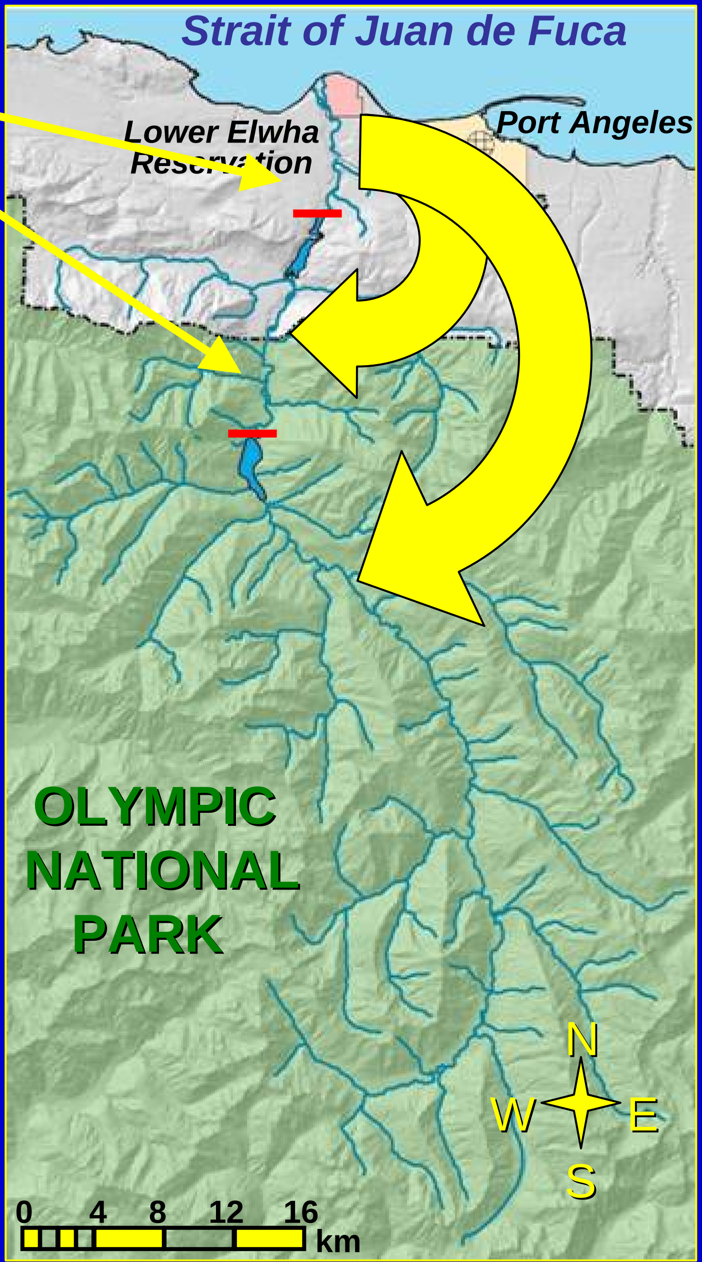
- Yes
- Straying
- Newly created or reopened habitats
- Establish self-sustaining populations in years to decades
- Success
  - Specific life history adaptations
  - Geomorphic and ecological conditions



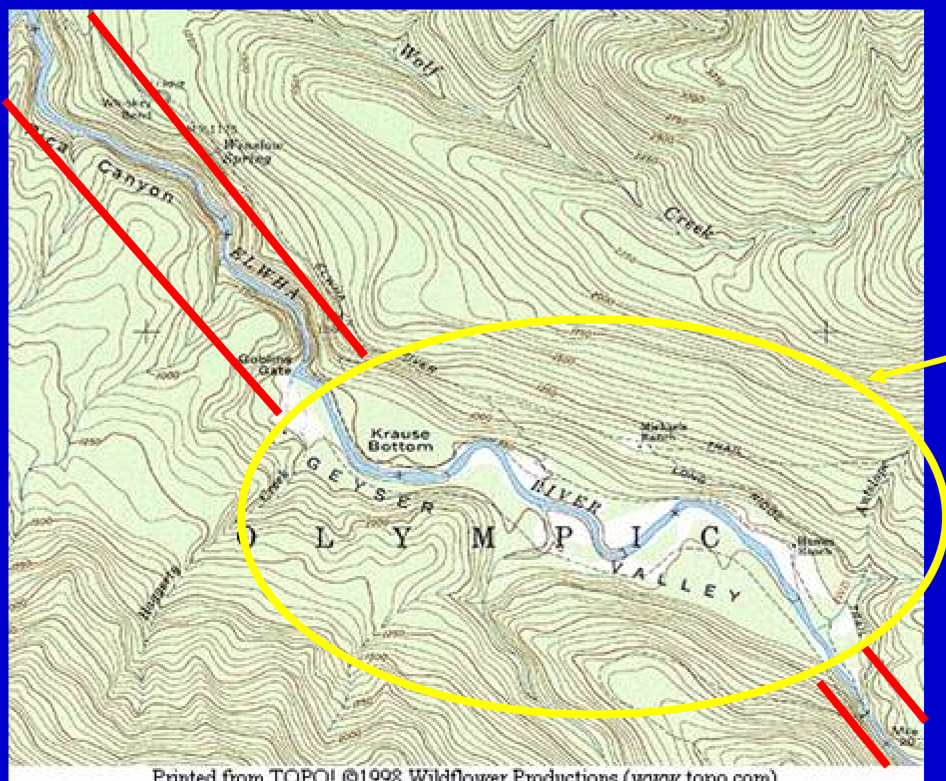
Fraser River DFO, unpublished data

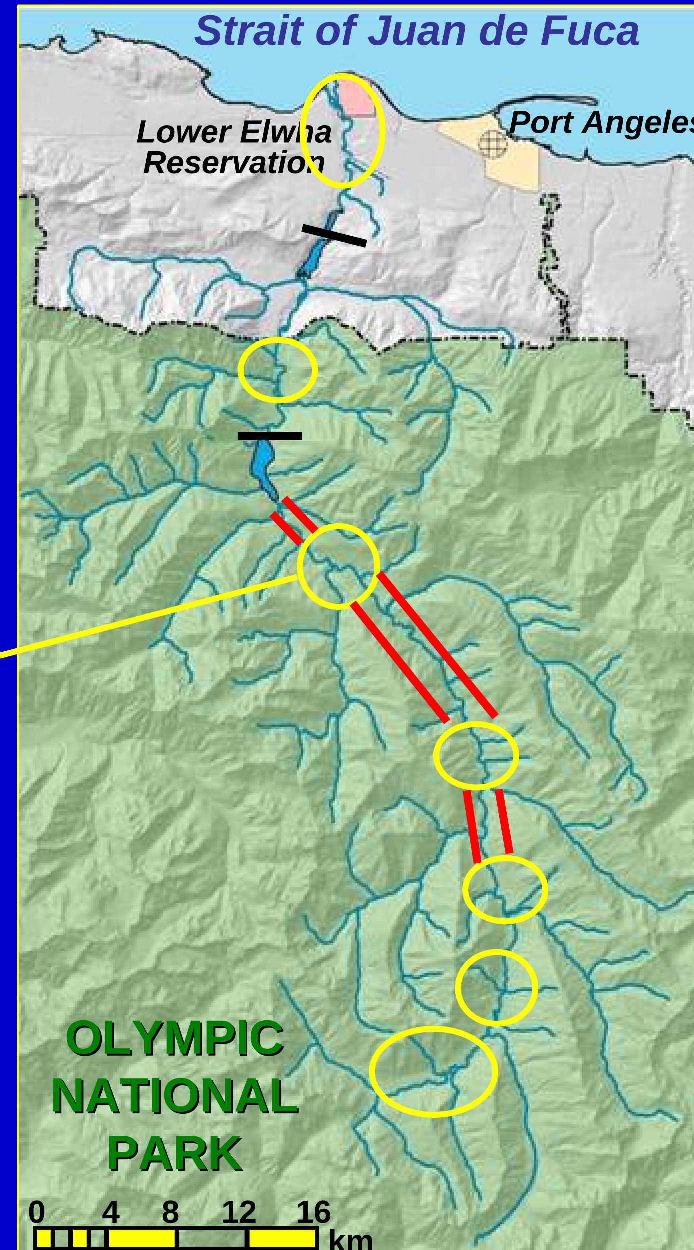
Elwha ecosystem response to dam removal

- Channel & floodplain dynamics
  - Increase in sediment & wood supply
    - Channel widening & aggradation
    - Increase in channel migration rate
  - Decrease in riparian stand age
  - Change in floodplain channel characteristics
- Salmon recolonization
  - Upstream movement of anadromous fish



Bounded alluvial valleys





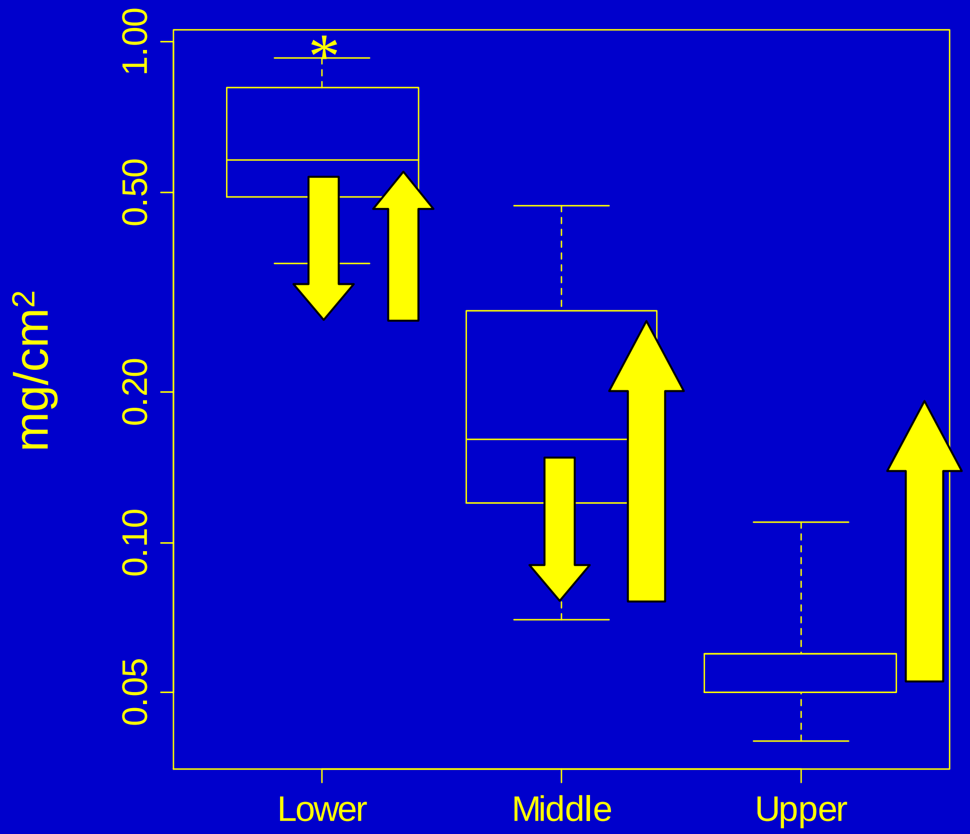
Canyon reach

Dams

Alluvial valley

Primary productivity
Longitudinal patterns

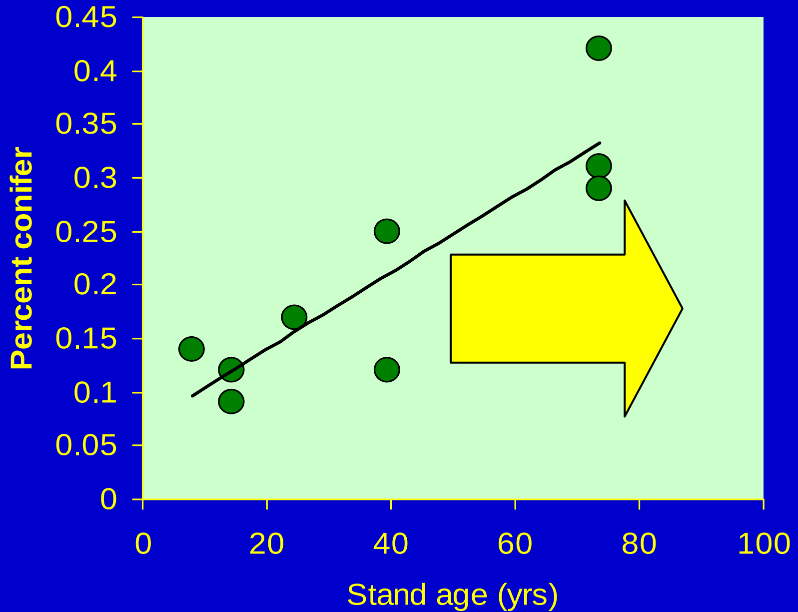
organic matter density (AFDM)

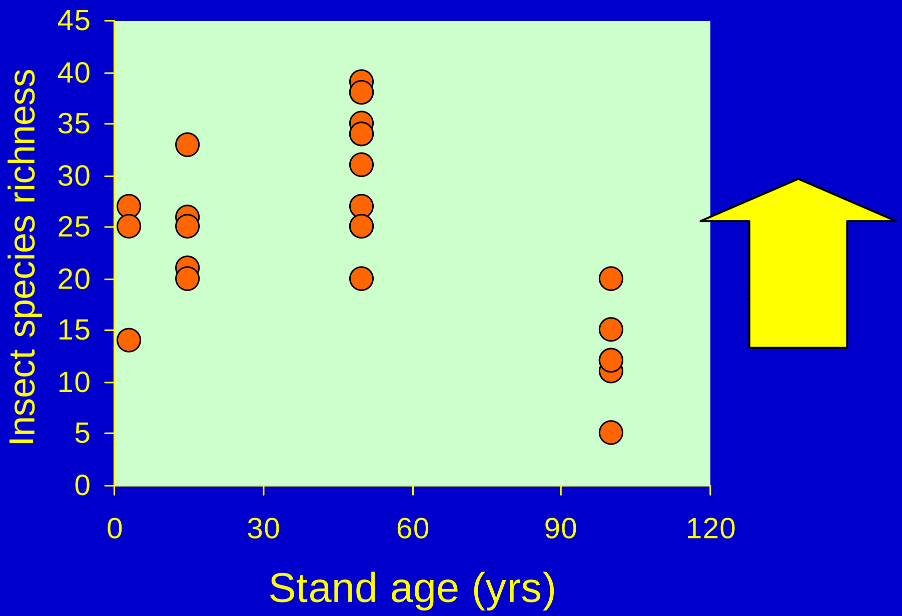


Secondary productivity
Channel & floodplain dynamics

Secondary productivity
Channel & floodplain dynamics

Stand age – surrogate for channel dynamics



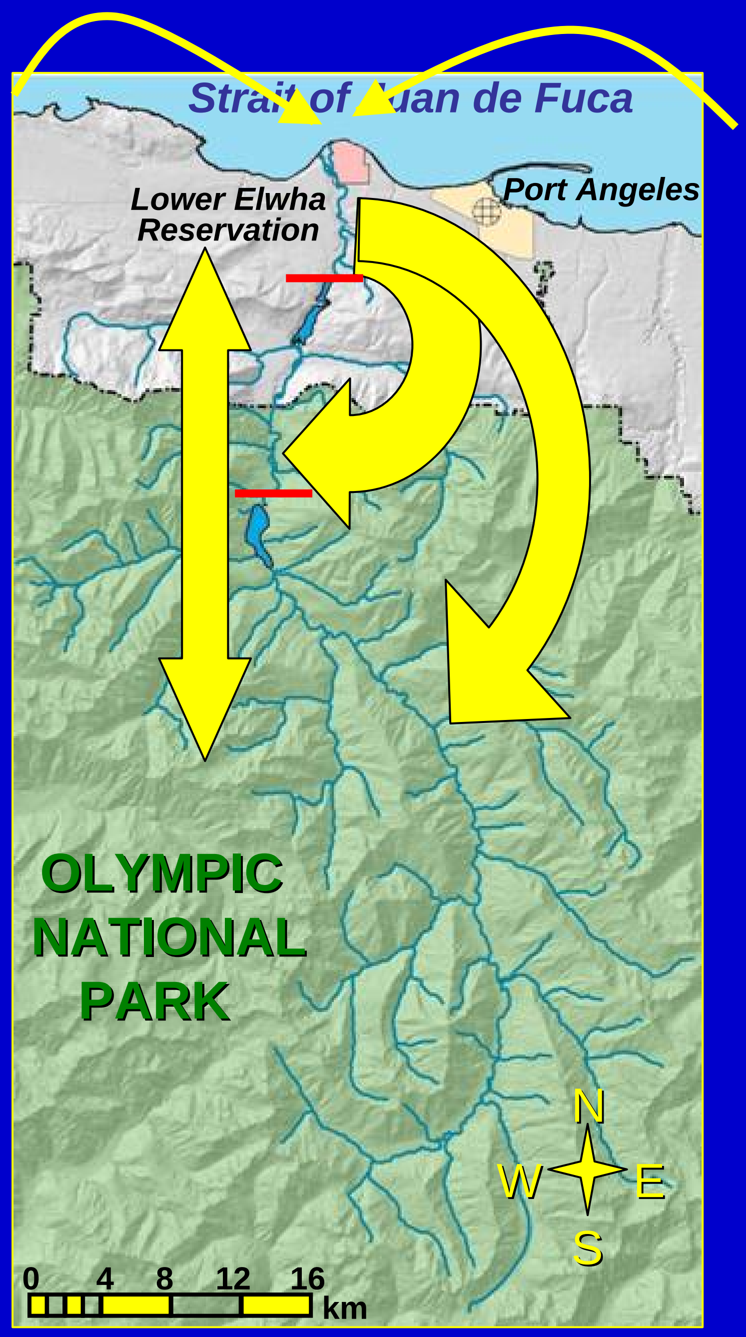


- Decreased stand age
- Increase in channel dynamics
- Sediment increase
- Detrital input

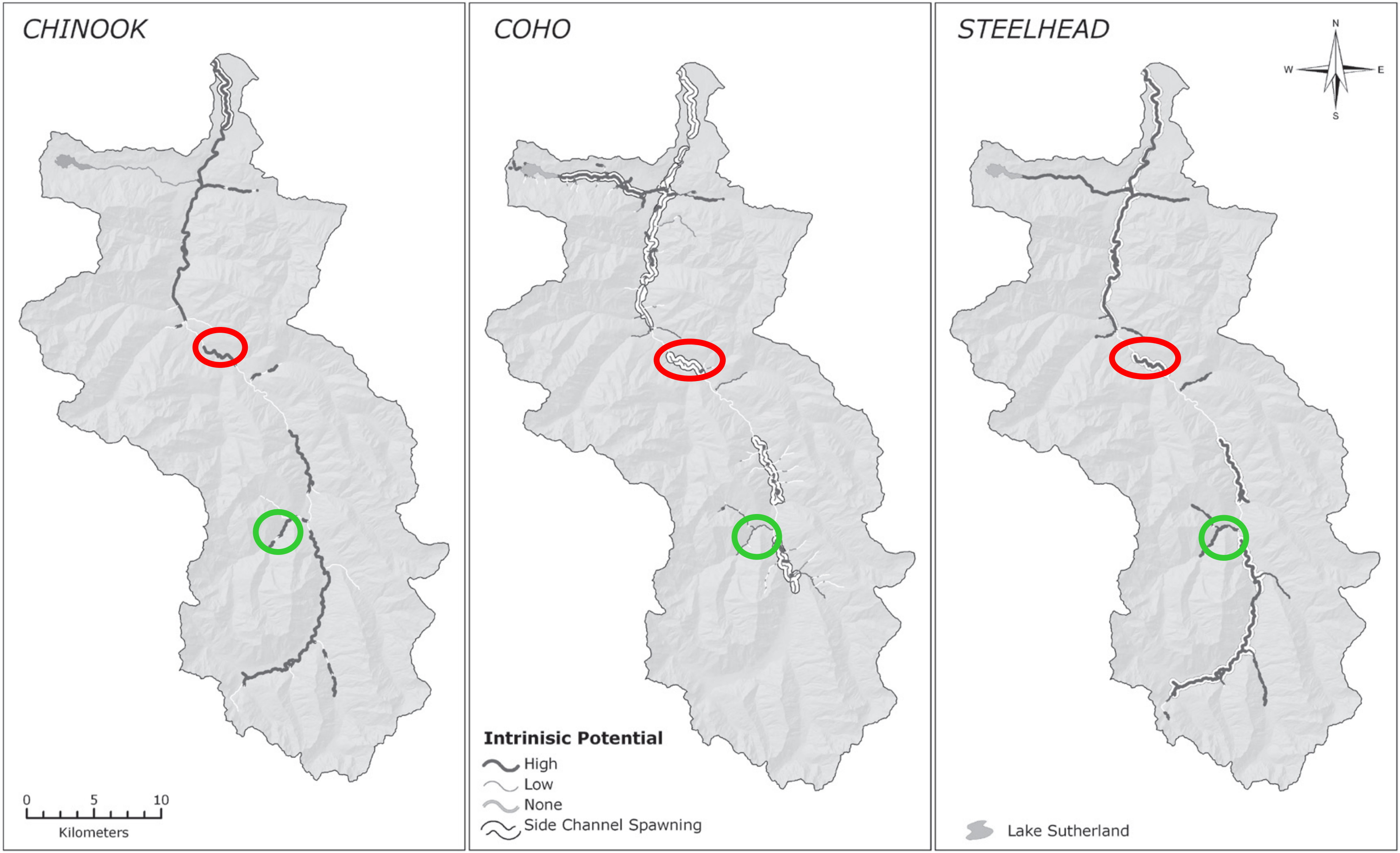
Fish community response

Recolonization

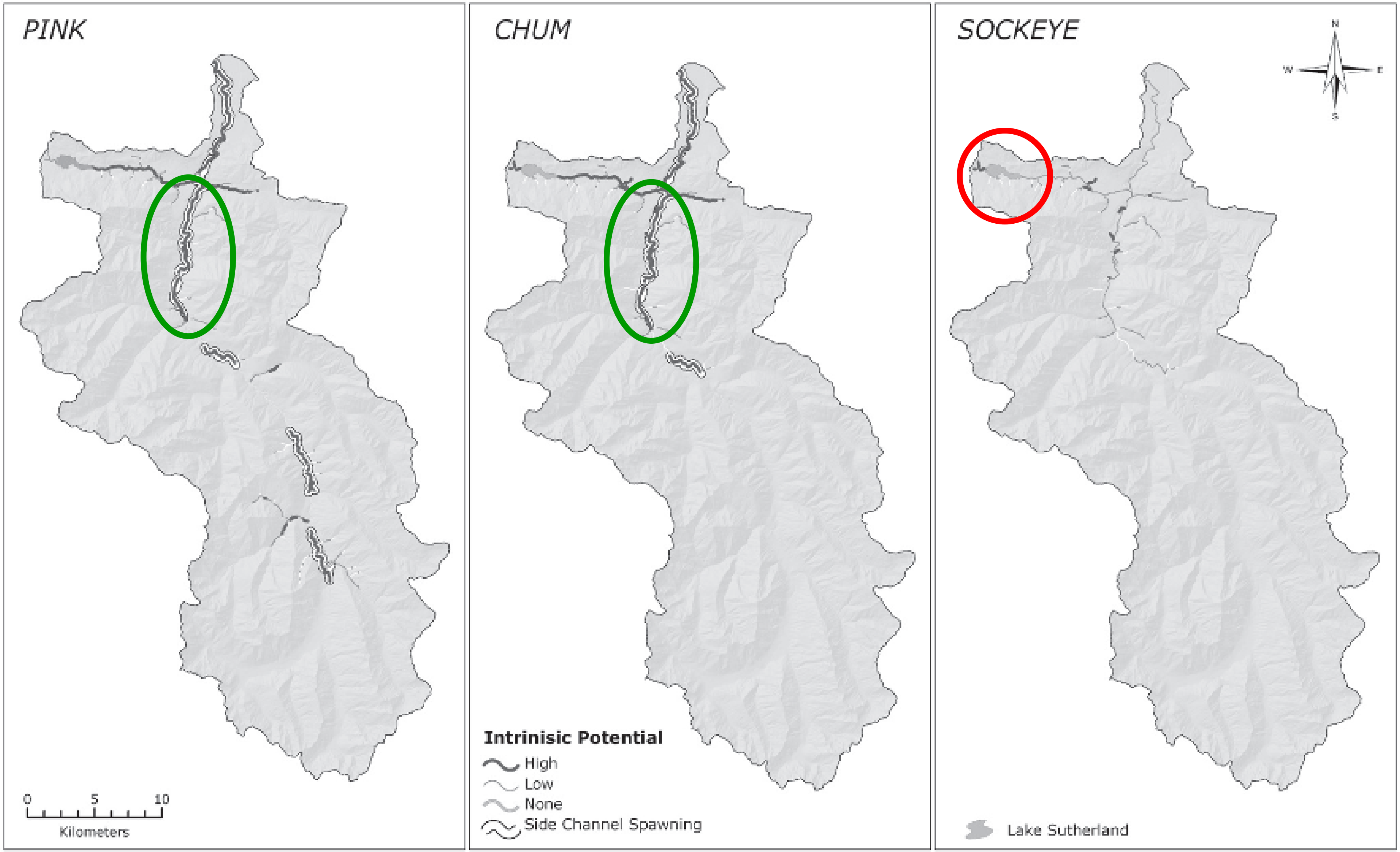
- Chinook & coho
- Pink & chum
- Sockeye, Steelhead/rainbow, char, & cutthroat



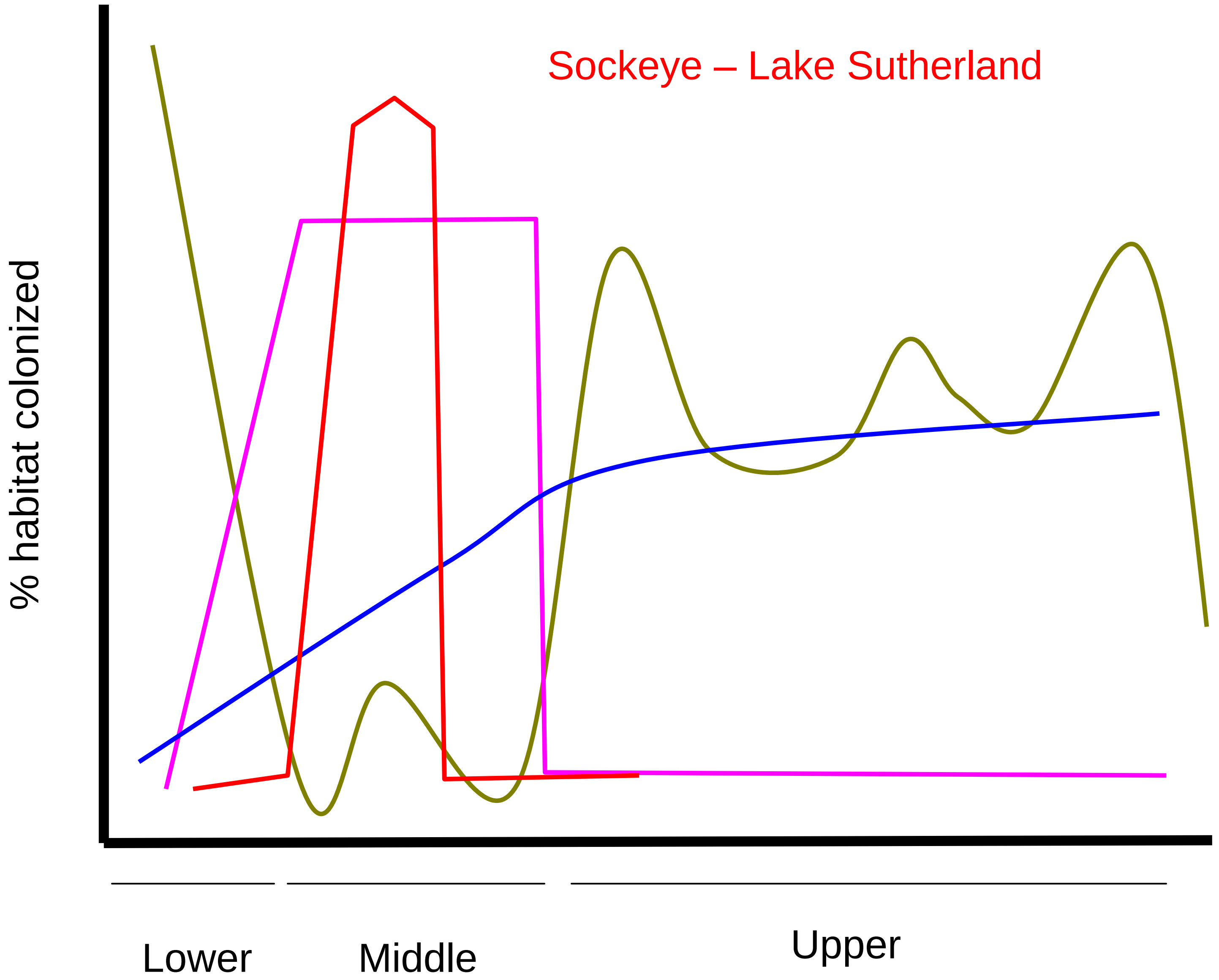
Fish community response



Fish community response



Predicted response by species



Steelhead, char, & cutthroat – positive interaction w resident fish

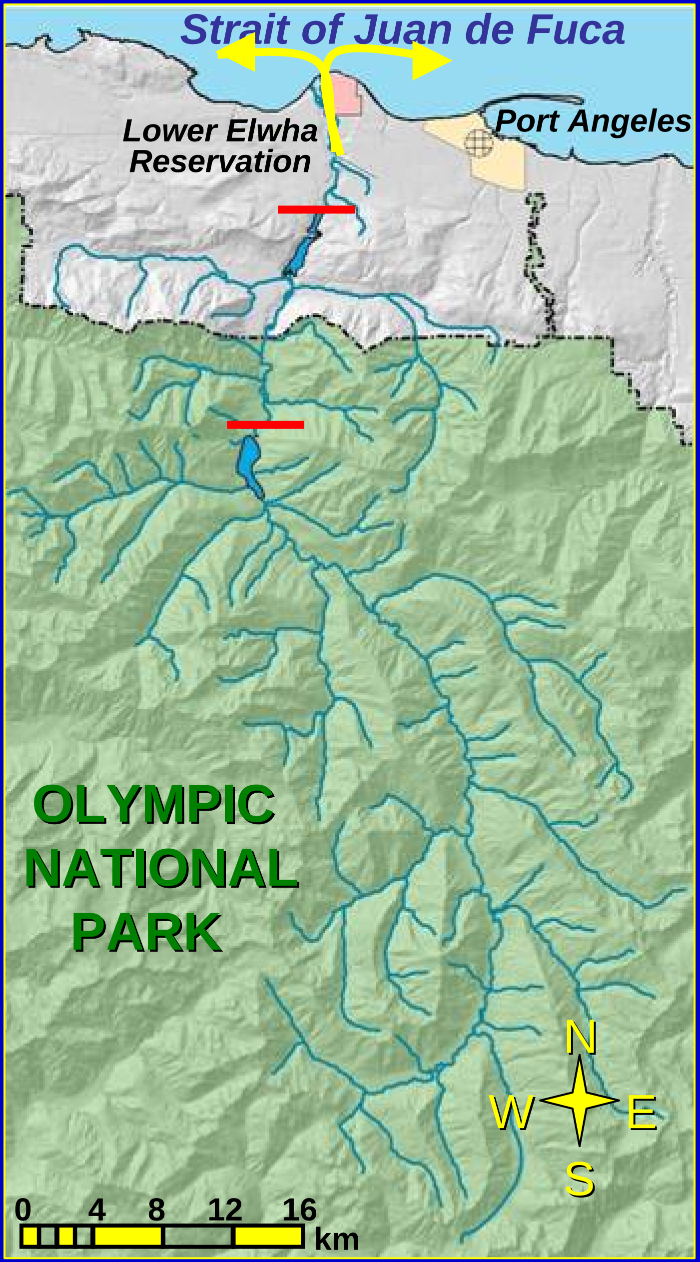
Chinook, coho – habitat type & quality and distance

Chum, pink – natural barriers

Fish community response

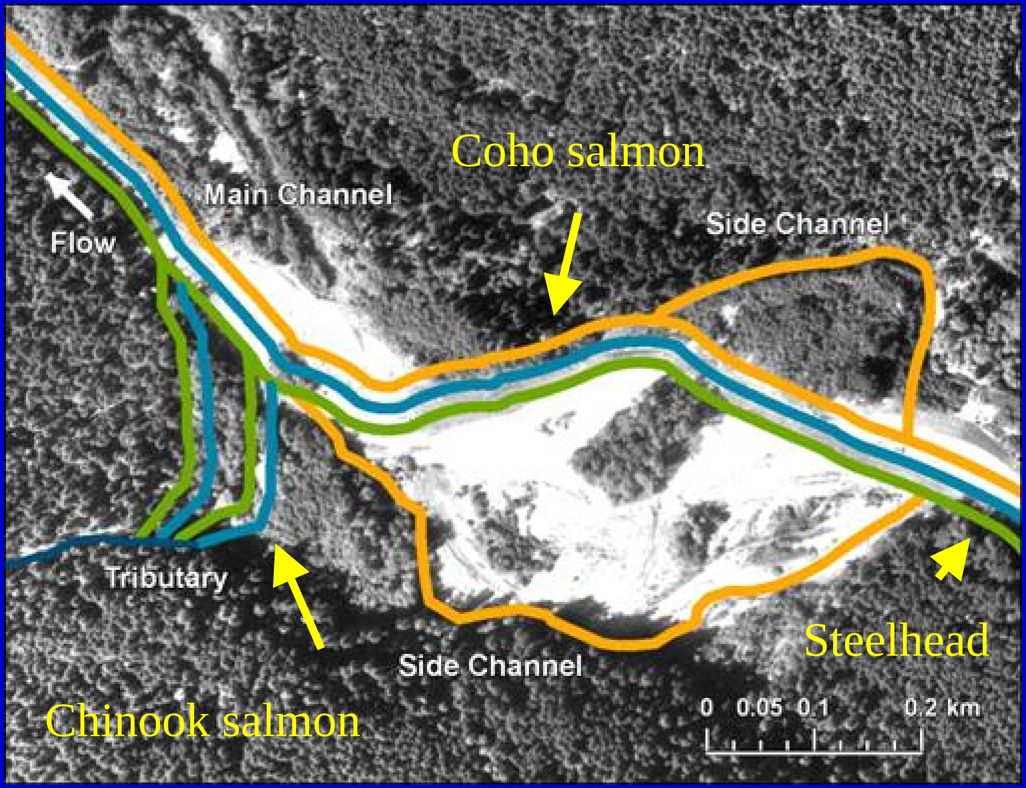
Straying away from sediment source

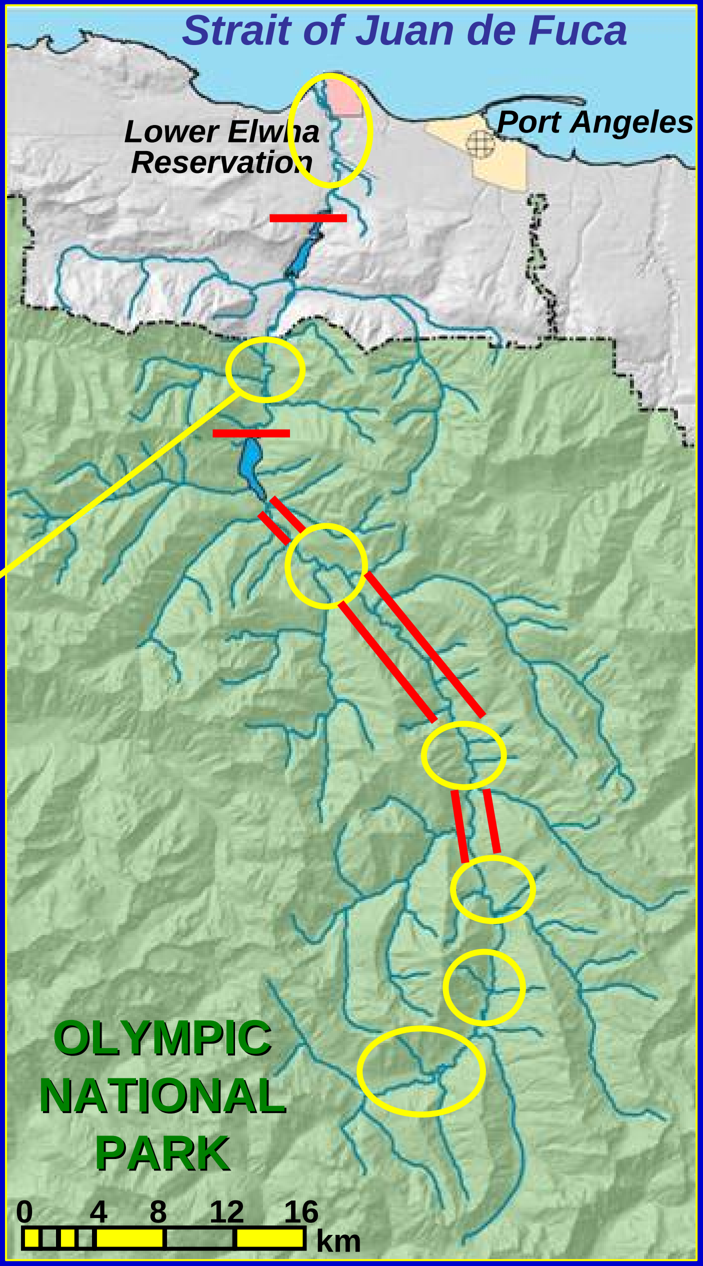
- High sediment load in a short time period
  - Deleterious effects on salmon
- Straying away from Elwha
- Mt. St. Helens
  - Stray rates increased from 16% to 45%



Fish community response

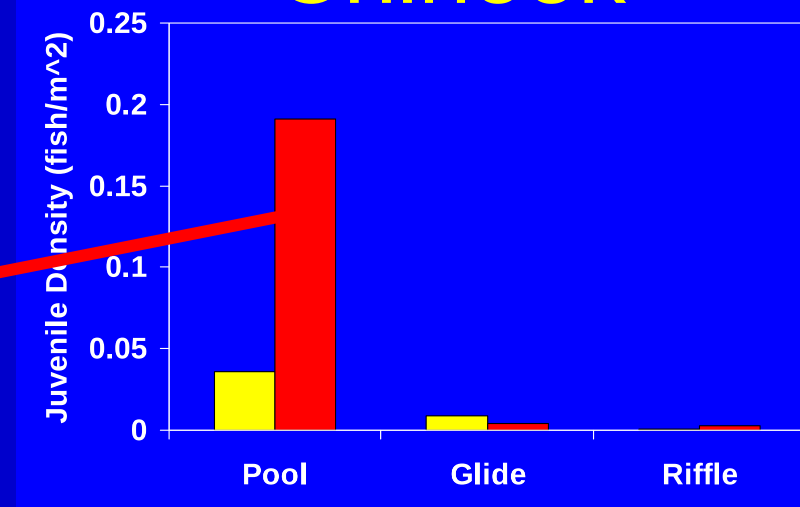
Buffering effects -
Dams & floodplains



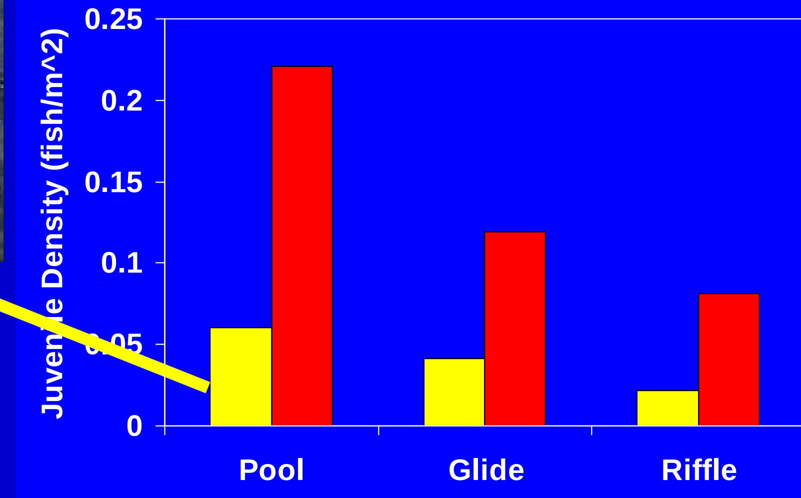


Fish community response
Elwha main stem v. floodplains

Chinook

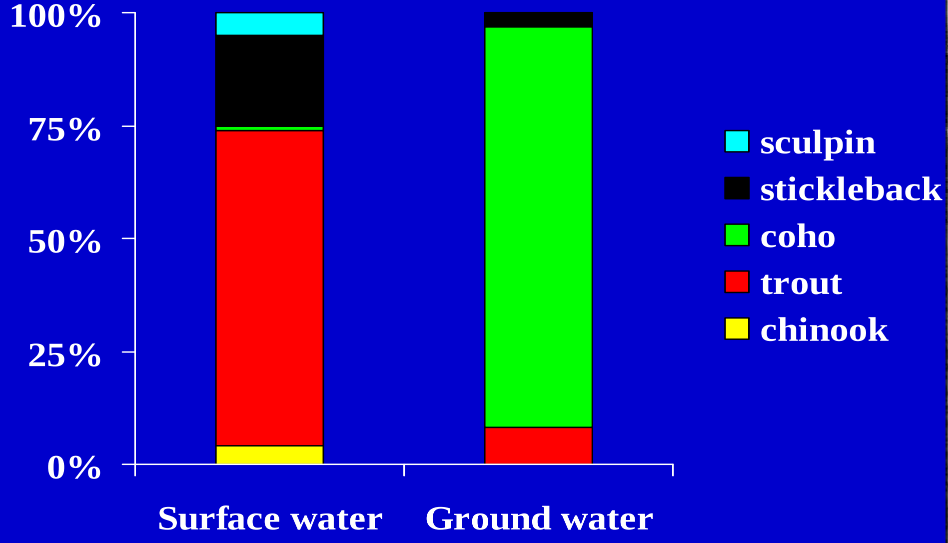


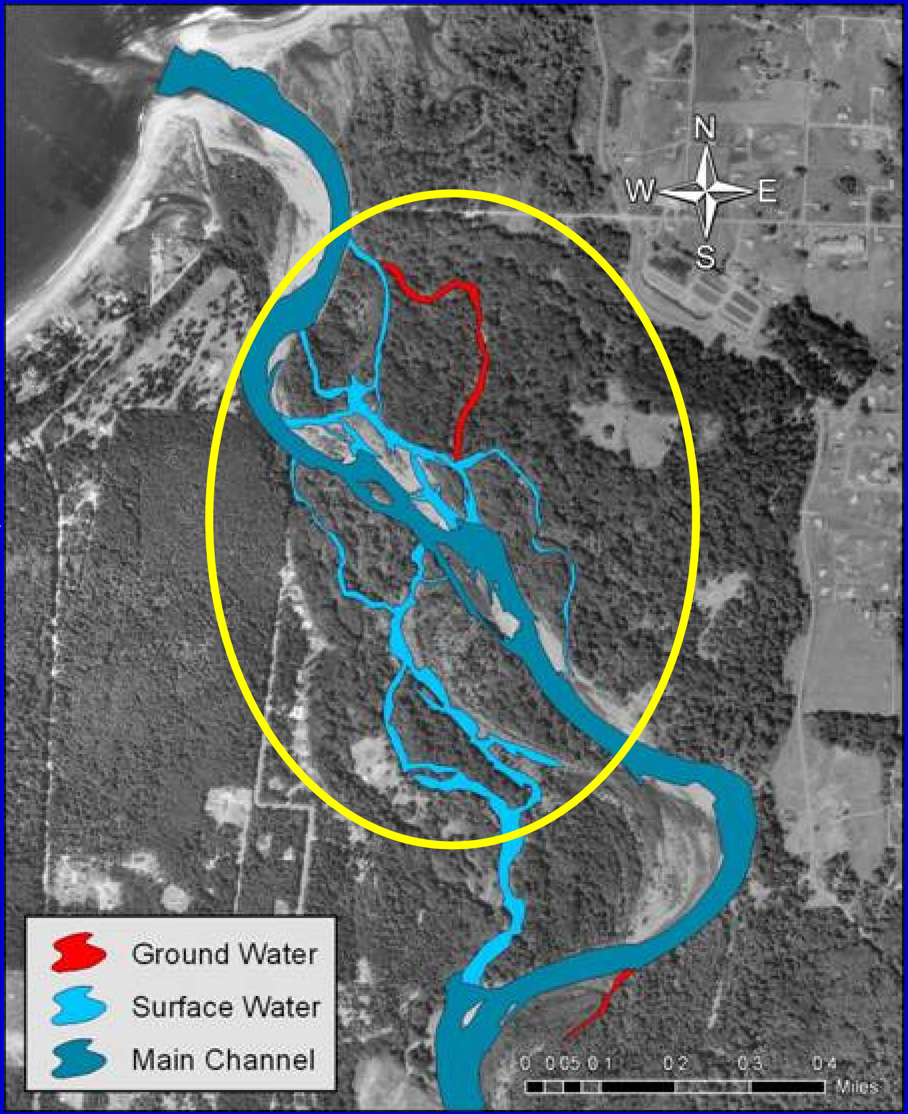
Steelhead



Fish response

Channel & floodplain dynamics





Elwha River hypotheses summary

- Channel widening, aggradation, increased migration & shift in floodplain characteristics

- Primary & secondary productivity
  - Initial decrease – sediment
  - Long term increase – marine derived nutrients & detrital input

- Salmonids will establish self-sustaining populations in the middle & upper Elwha
  - Lower river, other watersheds & resident populations

- Sediment impacts
  - Stray rates
  - Floodplain channels

Elwha resources

Elwha papers

http://pc.ctc.edu/coe/publications.htm

Dam removal resources

http://www.lib.berkeley.edu/WRCA/damremoval/index.html

Elwha watershed information resource

http://www.elwhainfo.org/

EIS statements

http://www.nps.gov/olym/naturescience/elwha-restoration-docs.htm

Elwha fish restoration plan

http://www.nwfsc.noaa.gov/assets/25/6760_06202008_151914_ElwhaPlanTM90Final.pdf

"Big Unknowns" facing diadromous species restoration efforts

- Are our diadromous populations large enough to recover?
- Can you still exploit diadromous populations at the same time you are attempting to recover them?
- Do our restoration efforts focus on the appropriate cause and at the appropriate scale?
- How will climate change effect ecosystem response to our restoration efforts?

"Big knowns" about diadromous species restoration efforts

- Colonization and population initiation starts with a few individuals.
- Many diadromous populations are inherently productive.
- The more causes you identify, the more relevant the larger scale becomes.
- Climate change has occurred in the past but…

The Ultimate Known

- We don't need to teach an ecosystem what to do. We just need to give it the opportunity to do it.