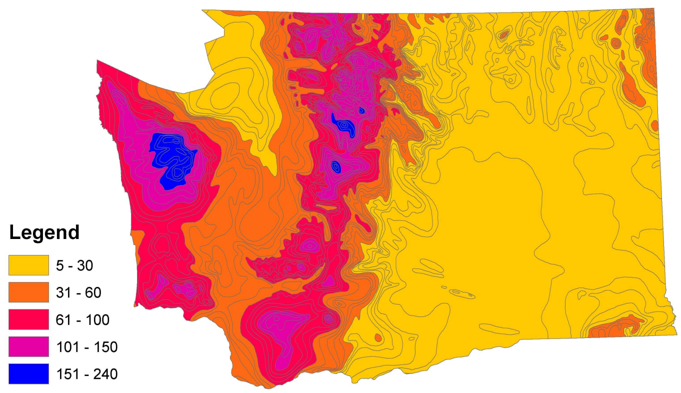
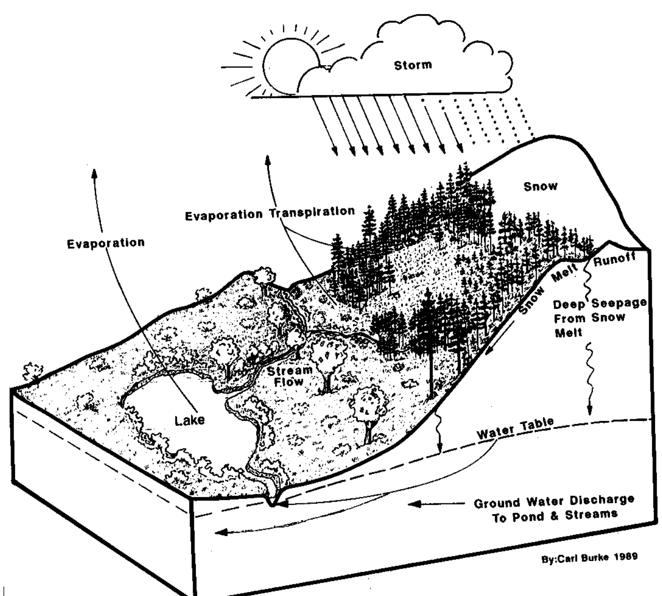
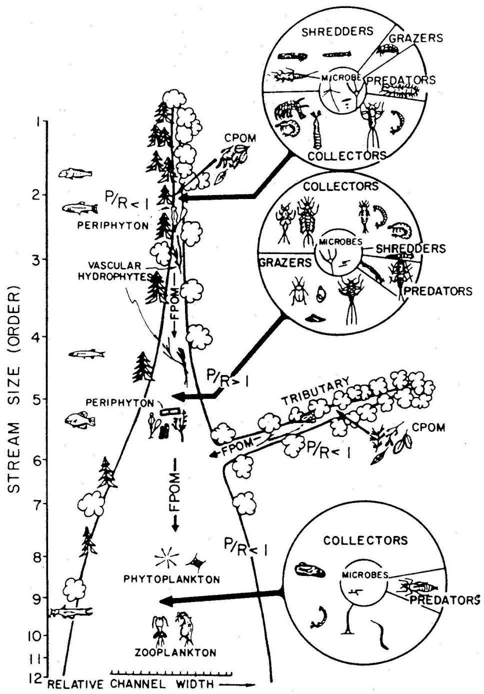
Washington State average annual precipitation



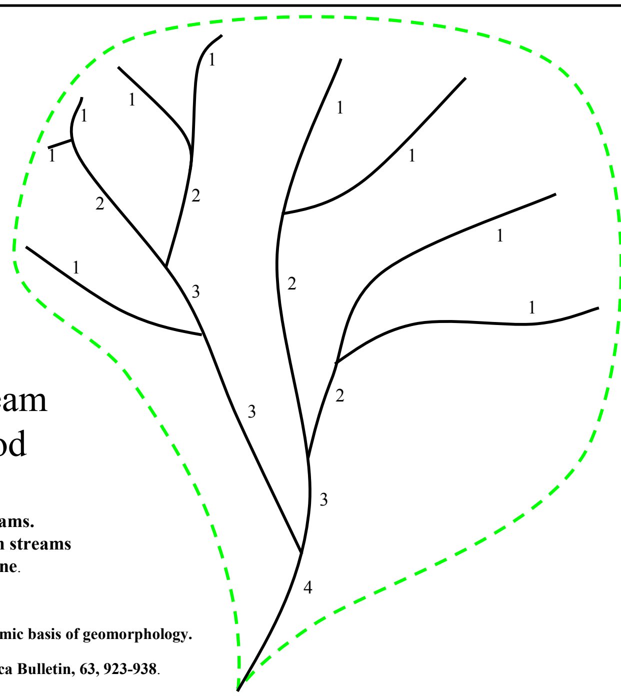
Watershed Functions



The River Continuum



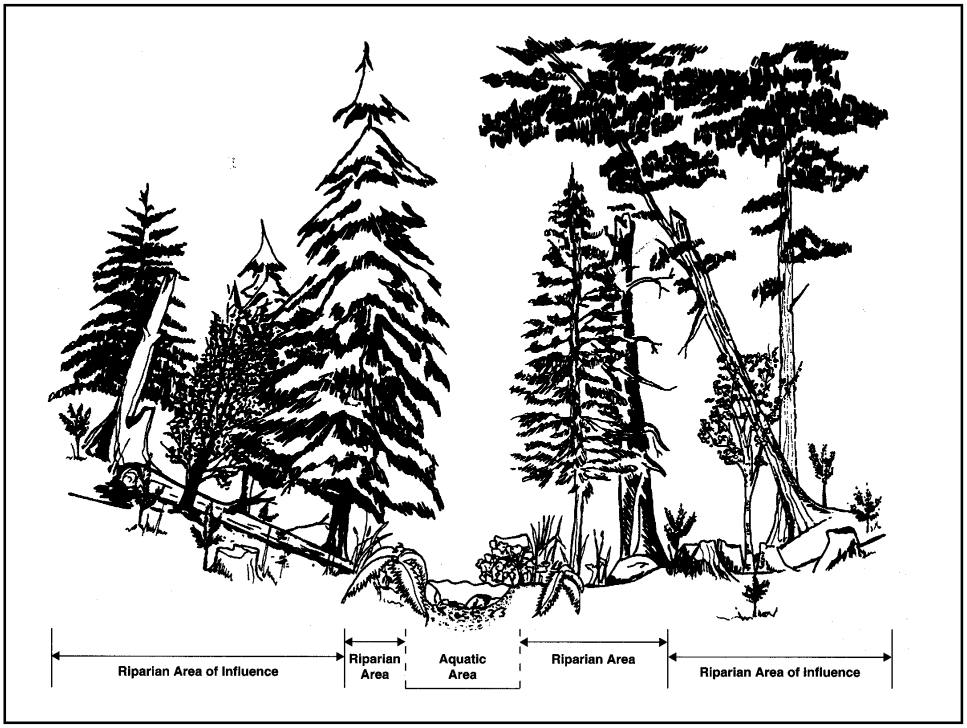
Strahler Stream Order Method

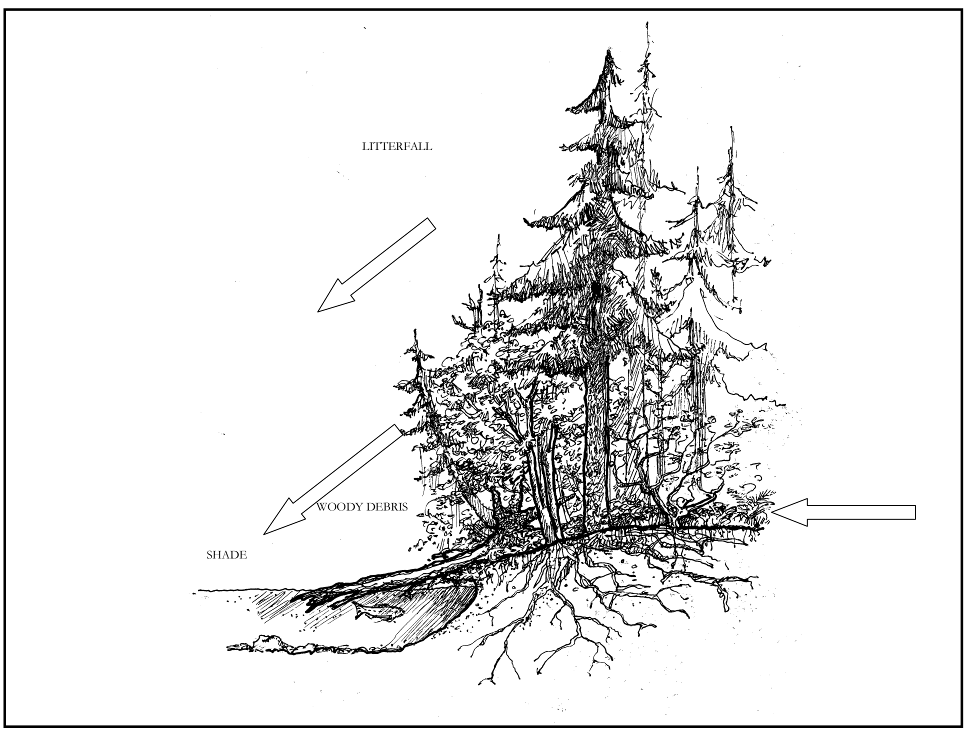


Start with smallest streams. Number increases when streams of equal number combine.

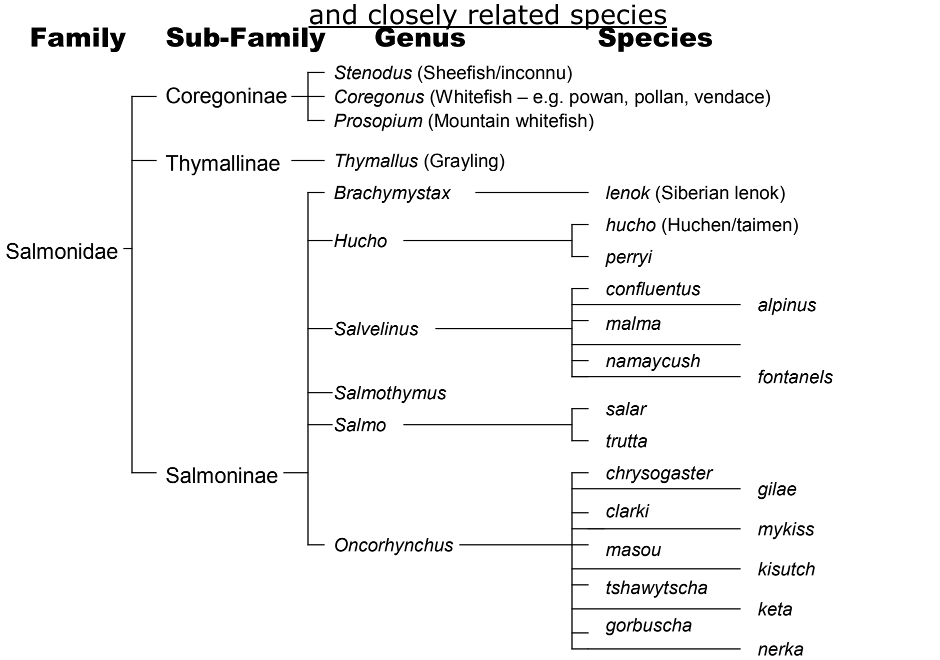
Strahler, A. N. (1952). Dynamic basis of geomorphology.

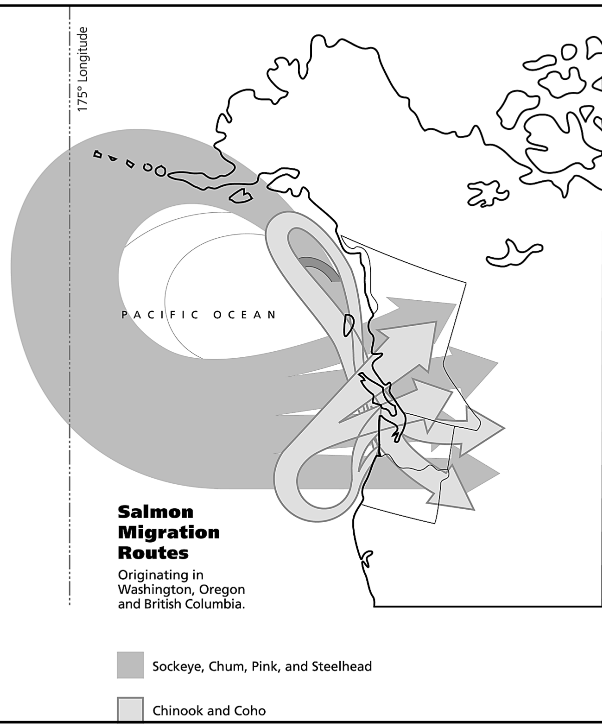
Geological Society of America Bulletin, 63, 923-938.

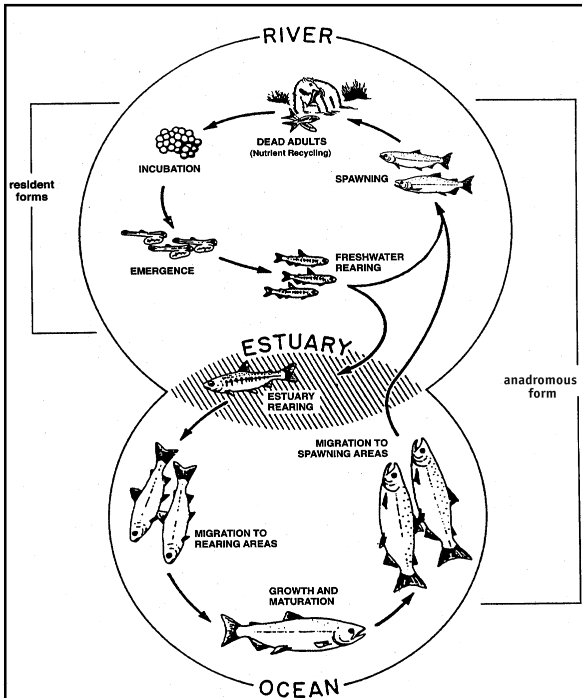

Riparian Area of Influence
Riparian Area
Aquatic Area
Riparian Area
Riparian Area of Influence


LITTERFALL
WOODY DEBRIS
SHADE

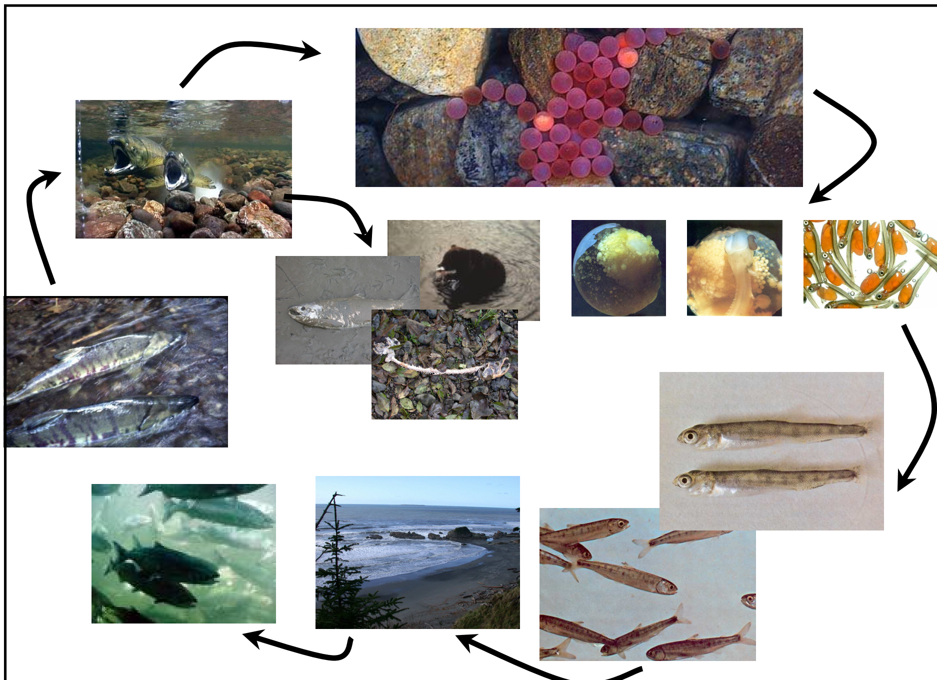
Hypothetical relationships between salmon and closely related species



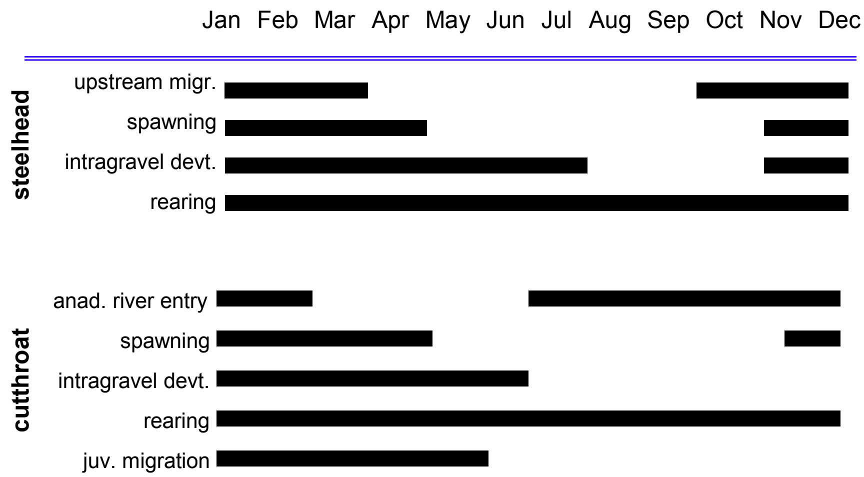




Source: Cederholm et al 1999
adapted from Spence et al 1996



Timing of freshwater life phases



Temperature Units

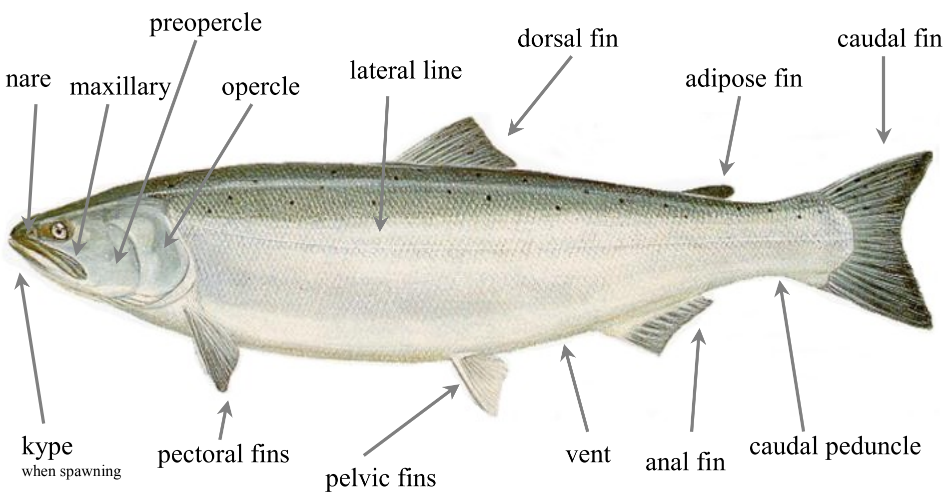
- The measure of how many degrees above 0 Celsius in one day.
- Different species have different TU requirements for their various developmental stages.

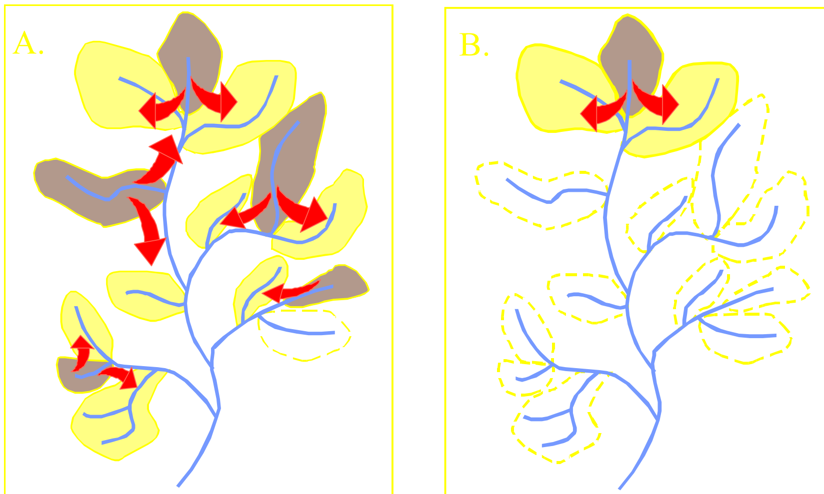
- Chum: 400 to 600 TU to hatch; 700-1,000 to absorb yolk
  150 – 300 days from start to yolk absorption
- Coho: In Oregon stream, average egg depostion to fry emergence was 110 days.400 to 600 TU to hatch; 700-1,000 to absorb yolk
  150 – 300 days from start to yolk absorption

Accumulated temperature units (ATUs) required to reach important embryonic development stages in commonly cultured salmonids in Alaska

SPECIES	STAGE	ATU's in °C
CHINOOK SALMON	To eyed stage	280
	To hatch	480-540
	To emergence	900-1000
CHUM SALMON	To eyed stage	300-350
	To hatch	475-525
	To emergence	900-1000
COHO SALMON	To eyed stage	220
	To hatch	400-500
	To emergence	700-800
PINK SALMON	To eyed stage	350-400
	To hatch	550-650
	To emergence	900-950
SOCKEYE SALMON	To eyed stage	230
	To hatch	500-550
	To emergence	900-1000
ARCTIC CHAR	To eyed stage	200
	To hatch	475
	To emergence	700
RAINBOW TROUT	To eyed stage	210-240
	To hatch	300-320
	To emergence	500-580
STEELHEAD	To eyed stage	250-270
	To hatch	360
	To emergence	

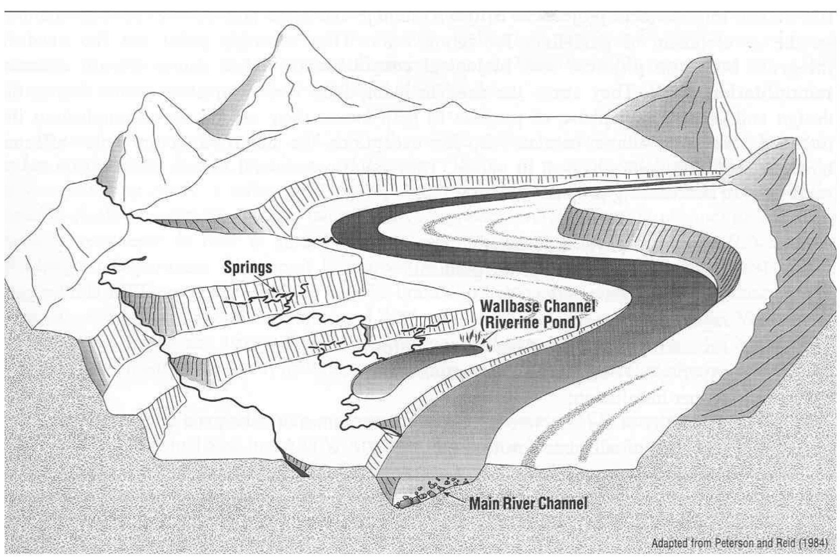
Adult salmon external anatomy





A) high quality habitats
B) Most high quality habitats lost

Redrawn from Rieman and McIntyre USDA-FS 1993



Total commercial harvest: Columbia River 1866-1993

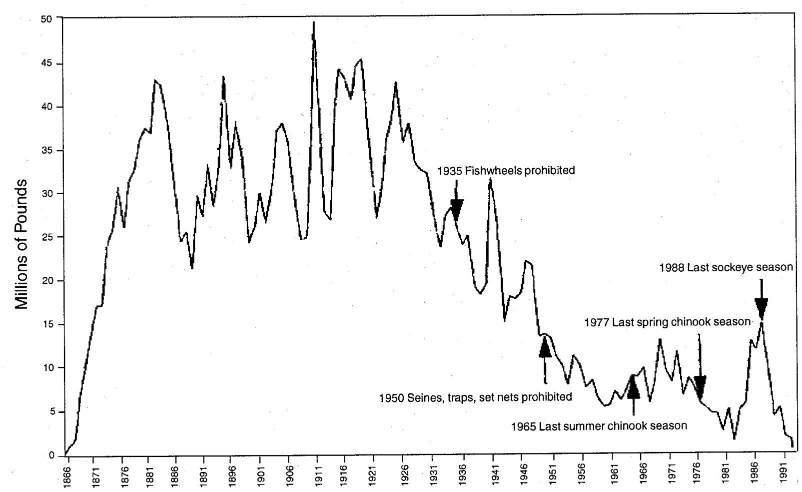


Figure 1. Total commercial harvest (pounds) of salmon and steelhead in the Columbia River from 1866 to 1993. From NRC (1996) based on data from the Oregon Department of Fish and Wildlife and the Washington Department of Fish and Wildlife.

Source: NRC 1996

Logging history

- Willamette National Forest, western Oregon – starts logging in 1875
  - During the first 3 decades 90% of cut timber was still near streams below 4,000 feet
  - By the 1970s, 65% of the timber cut occurred above 4,000 feet
  - In early 90s, to get same wood volume cut below 4,000 foot elevation, 5 times the number of acres was cut above 4,000 foot Hall et. Al 1992

Cumulative Effects

Fishing → **Overharvest** → **Underescapement**

Logging → **Sedimentation** → **Degraded Habitat**

Underseeding of Habitat

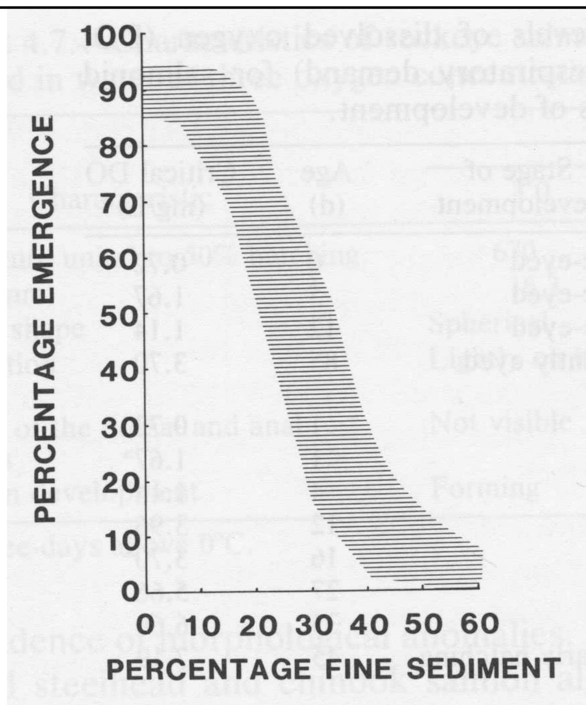
Outmigrants reduced

Adults reduced

Marine Derived Nutrients

Nine wildlife consumers with the strongest relationship as consumers to Pacific salmon

- Bald eagle
- Osprey
- Caspian tern
- Common merganser
- Harlequin duck
- Black bear
- Grizzly bear
- Orca
- River otter

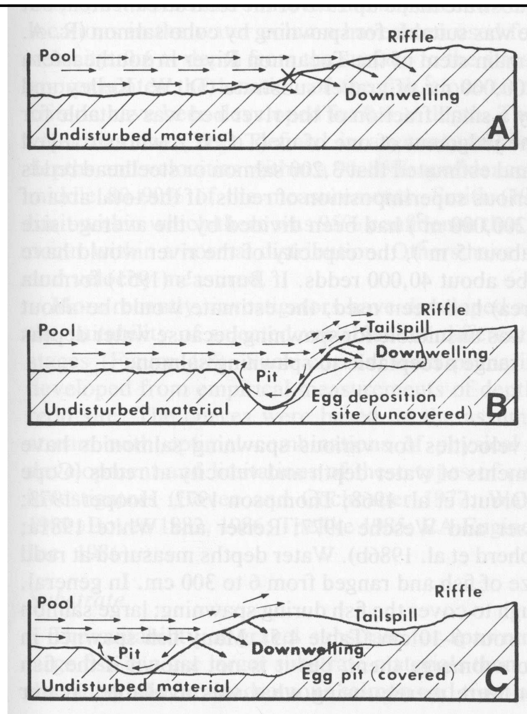


Salmon pre-spawning behaviorisms

- Schooling
- Jumping
- Nosing
- Excavation
- Digs: cover digs, male digs
- probing
- Crossover
- Quivering
- Male/male
- Lateral T-display
- Surfacing
- Bubble release

Salmon pre spawning behaviorisms

- External color patterns
- Sexual dimorphism
- Male/male aggression
- Female/female aggression
- Mouth display
- Precocious males
- Satellite males
- Female/male aggression
- mimicry

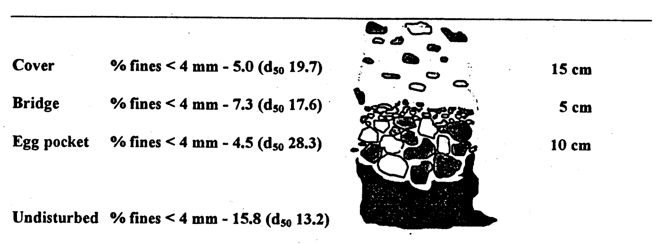


Salmon spawning behaviorisms

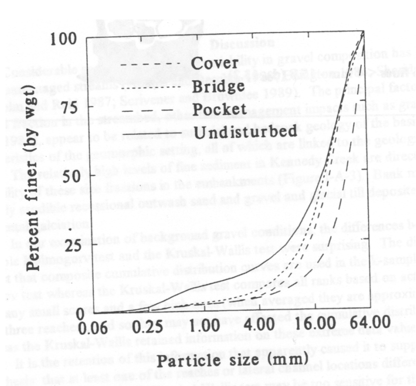
- Gamete release
- Gape
- Mouth display
- Precocious males
- Redd guarding
- Dorsal fin flare

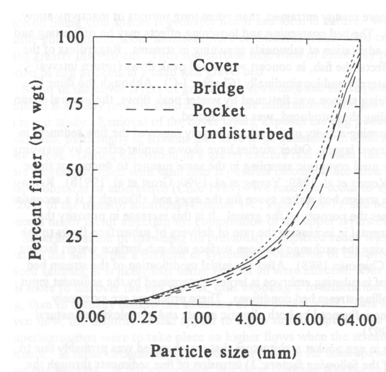
Salmon post-spawning behaviorisms

- Female cover digs
- New egg pocket preparation
- Redd guarding
- Flag tail
- Nutrient subsidy

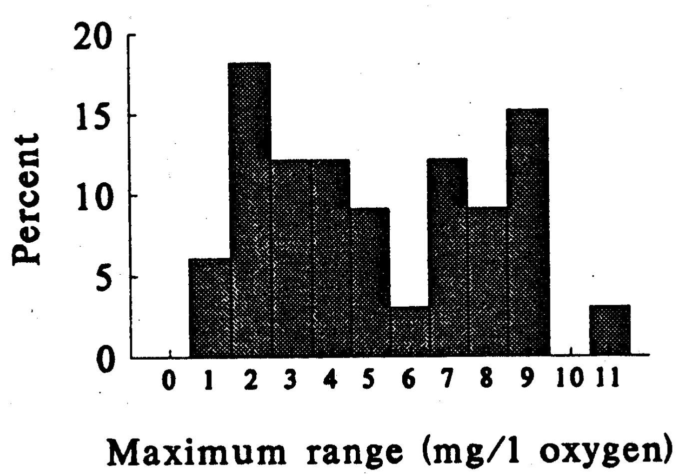


Egg pocket architecture of Kennedy Creek chum salmon redds determined by freeze core analysis



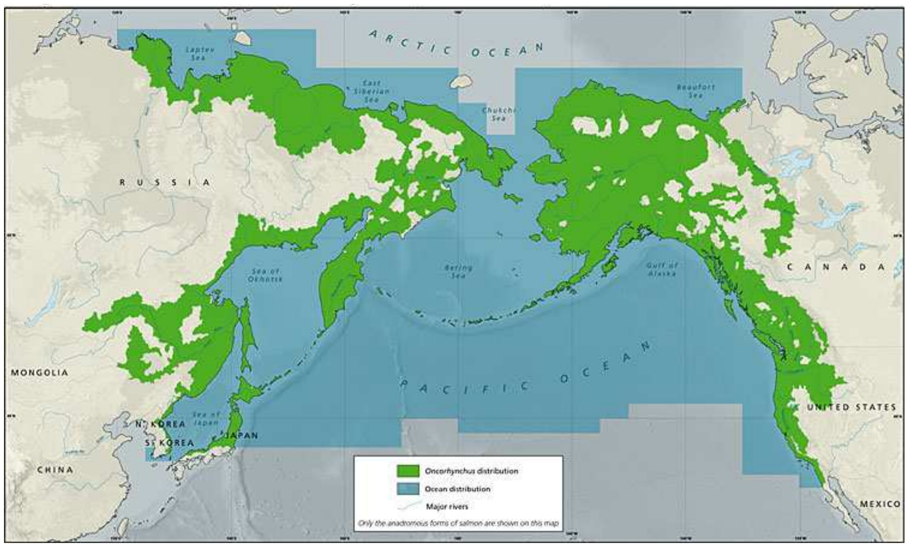


A comparison of gravel composition in the fall after spawning (top left) and in the spring prior to emergence. 12 egg pockets.

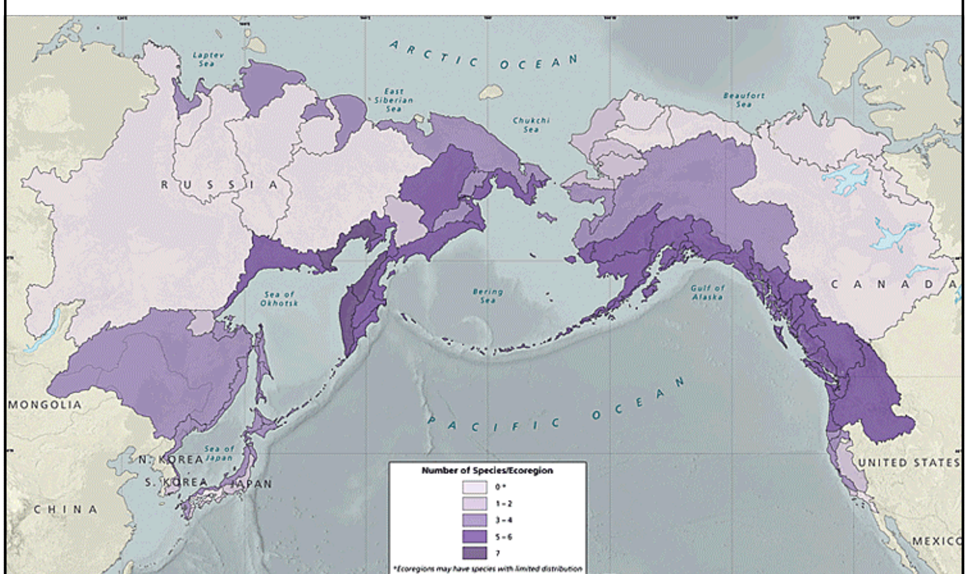


Maximum range of oxygen levels in chum salmon egg pockets during the incubation period (all egg pockets)

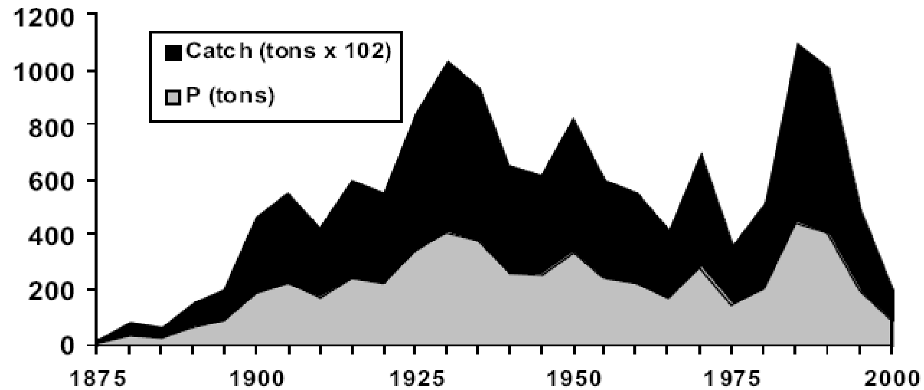
Original Distribution of Oncorhynchus



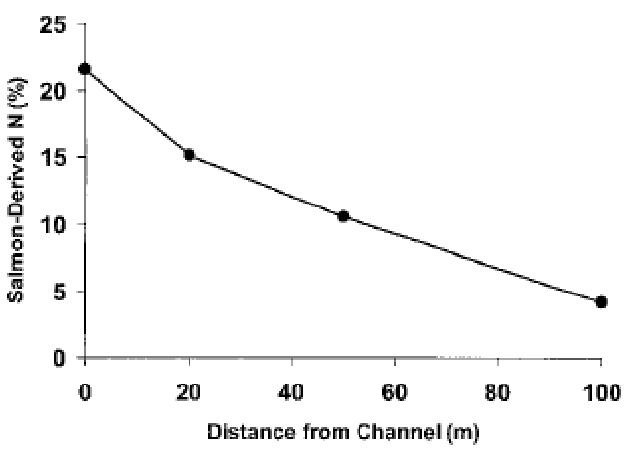
Pacific Salmon Diversity



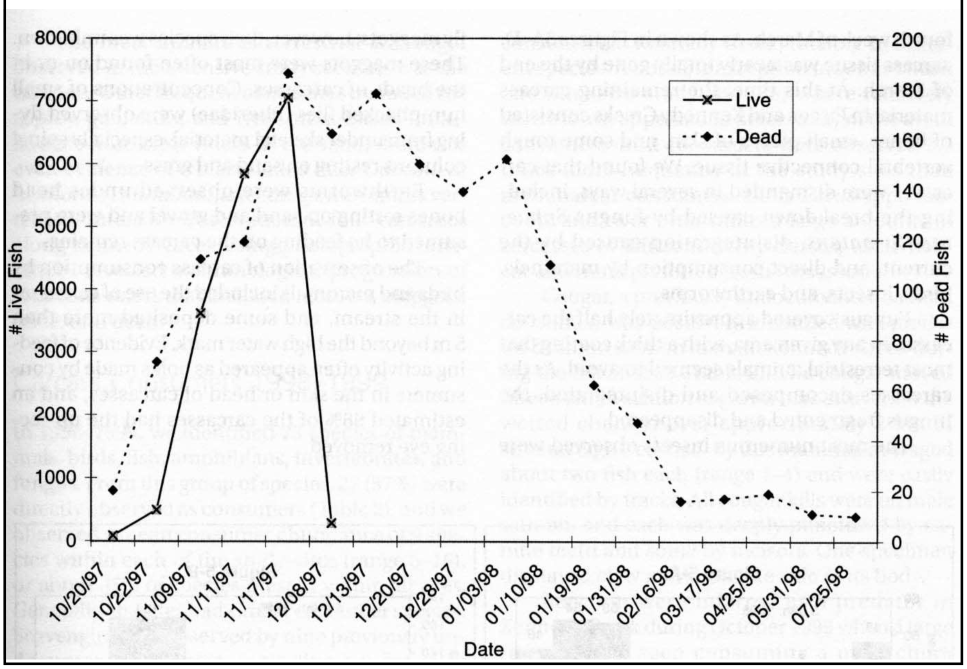
British Columbia salmon catch expressed in biomass and phosphorous equivalents (Fisheries and Oceans, BC)



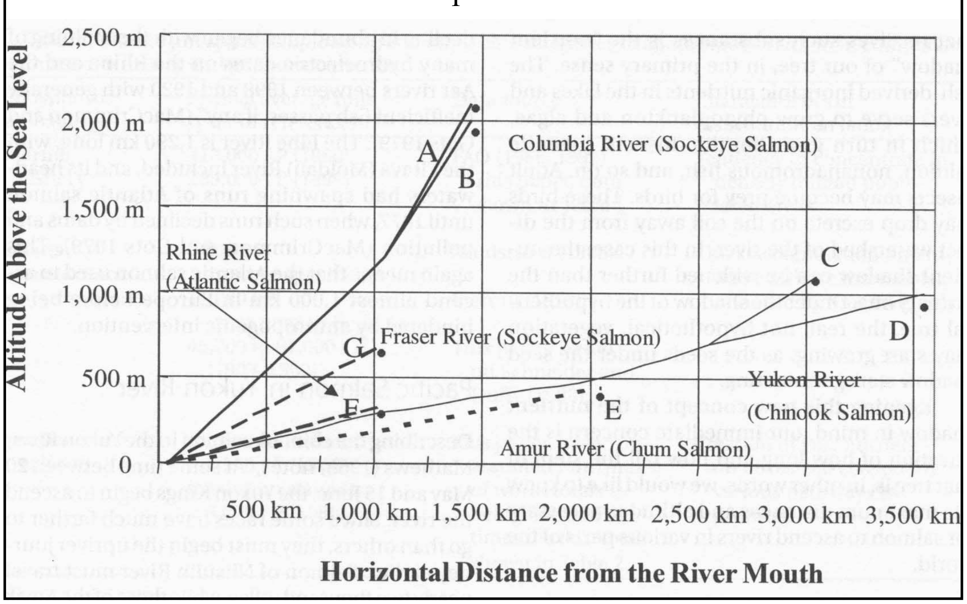
The proportion of salmon-derived N in salmonberry foilage at Kennedy Creek by distance from the channel.
Bilby et al. 2003



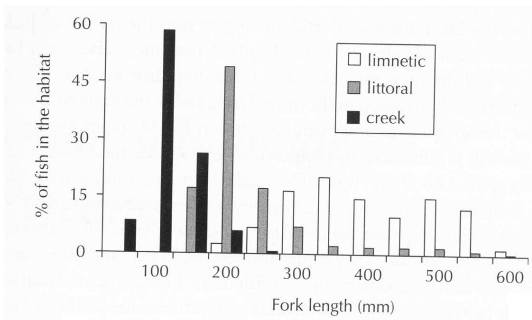
Kennedy Creek Chum Adult Live and Dead counts

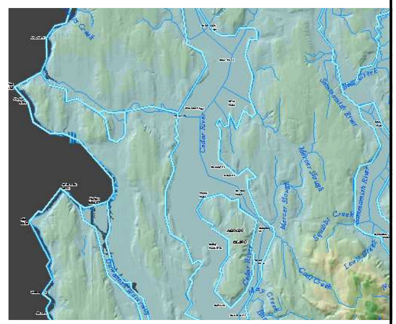


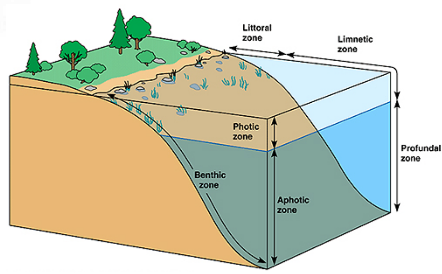
Extent of fish distribution in relation to altitude and distance. Demonstrates nutrient dispersal.



Fork length distribution of cutthroat trout of a lake Washington tributary. Creek underrepresents YOY trout. (from Quinn 2005)



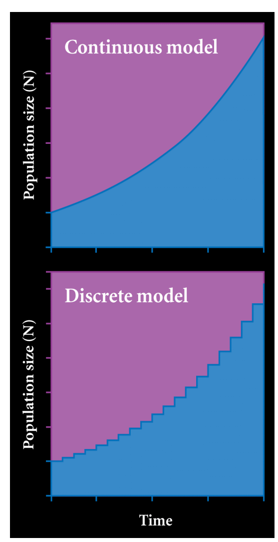




Limnetic = lake, open water,
Littoral = shore, coastal

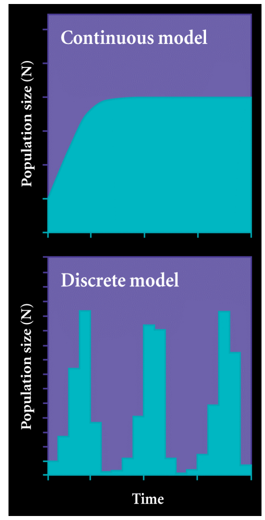
Density-Independent Population Growth

- Simple models describe how idealized populations would grow in an infinite environment.
- In these models, populations increase to infinity or decrease to zero.
- Continuous Model
  - Reproduction occurs in the population at all times.
- Discrete Model
  - Populations reproduce only at certain times.



Density-Dependent Population Growth

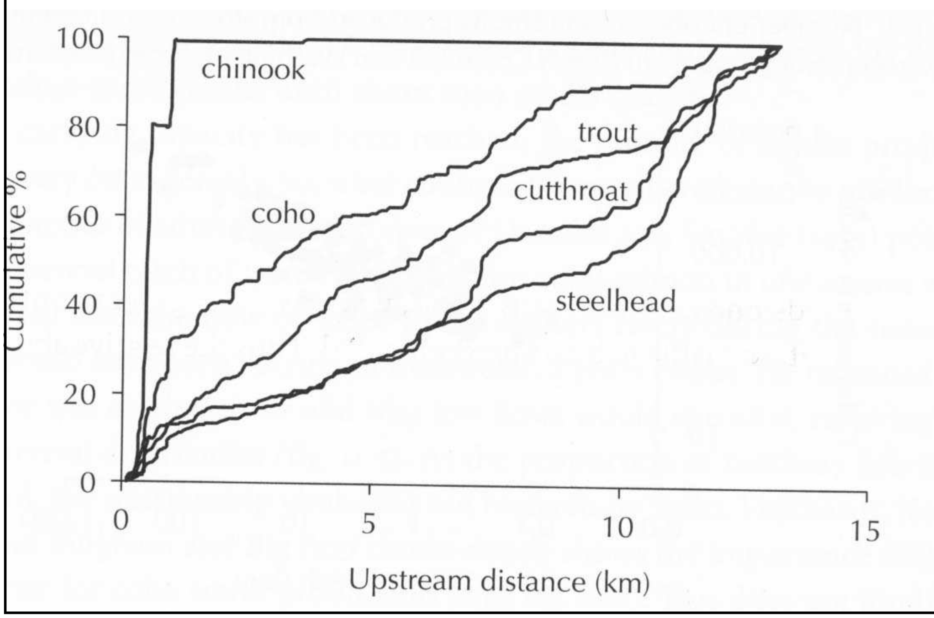
- In density dependent population growth, the per capita growth rate decreases as the population approaches a carrying capacity.
- When population growth rate depends on current population size, the population smoothly approaches carrying capacity.
- When there is a delay such that population growth depends on past population sizes, the population may cycle or have chaotic dynamics.



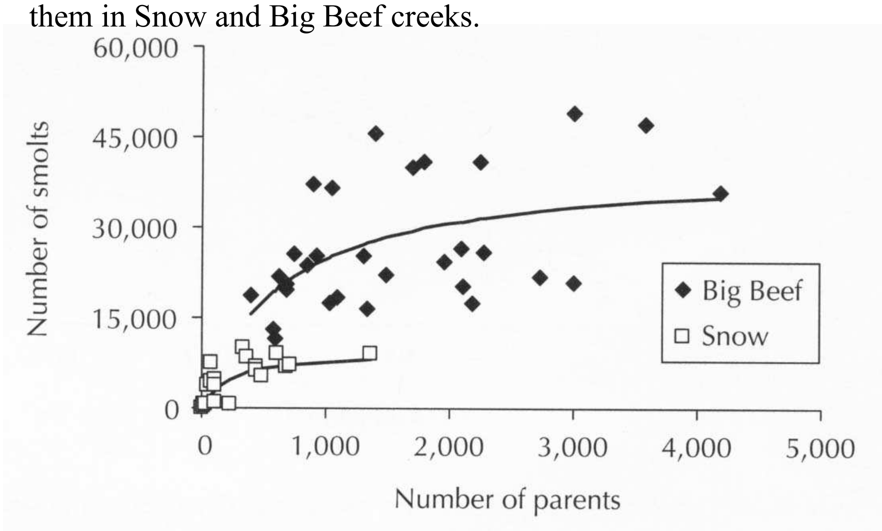
Density-Dependent and Density-Independent Effects on Populations

- In many habitats, the forces that limit population sizes are independent of population density. For example, extreme weather events may decrease populations.
- For most species, density-dependent factors limit birth rates or increase death rates at least some of the time. This type of population determination often is referred to as "regulation."
- Disease outbreaks and starvation are two factors that may increase with population density.

Cumulative distributions of YOY measured upstream from the mouth of the Sitkum River, Quileute River, WA coast.(from Wild Samon Center)

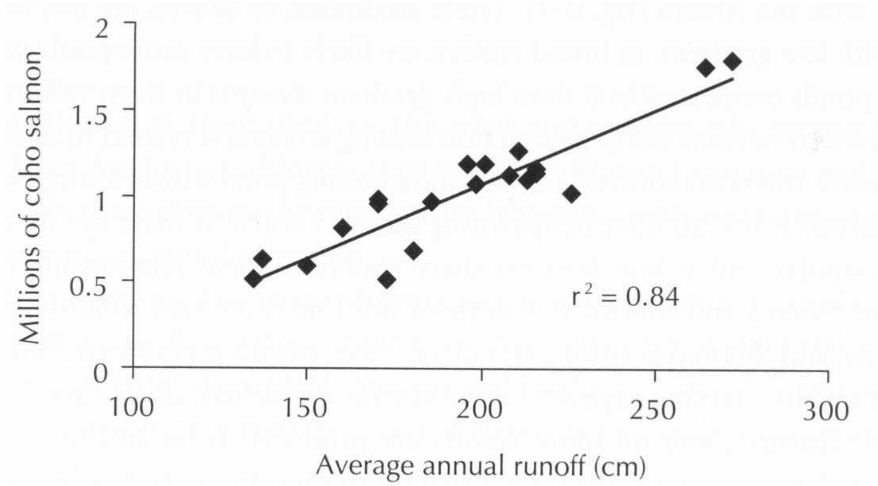


Numbers of spawning adult coho salmon and smolts produced by them in Snow and Big Beef creeks.



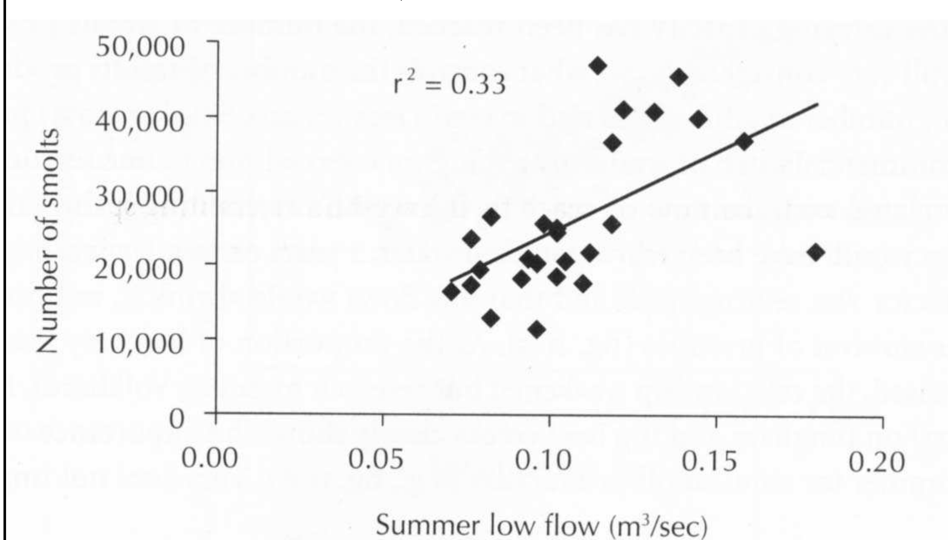
What differing stream characteristics would cause these different smolt/adult relationships?

Relationship between the catch of adult coho salmon and an index of stream runoff in western WA during the summer 2 years earlier.
(from Smoker 1955)



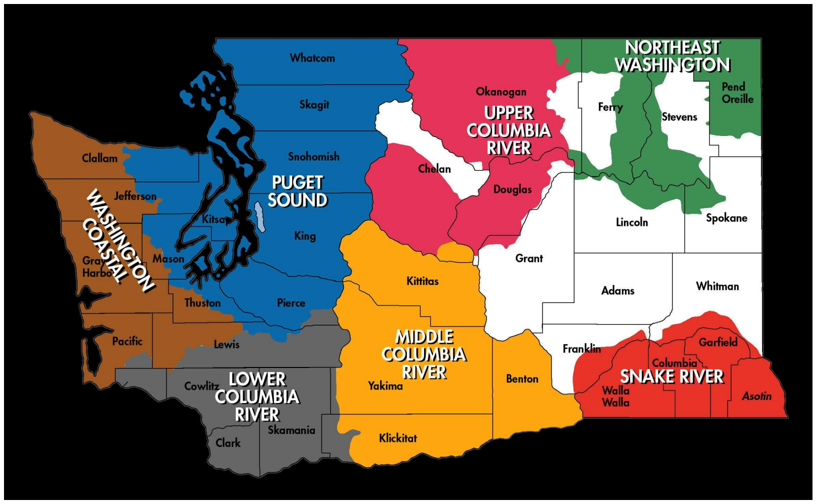
What explains this relationship?

Number of coho salmon smolts leaving Big Beef Creek, WA as a function of the average flow during the 45-day period the previous summer with lowest flows. (from WDFW and USGS)

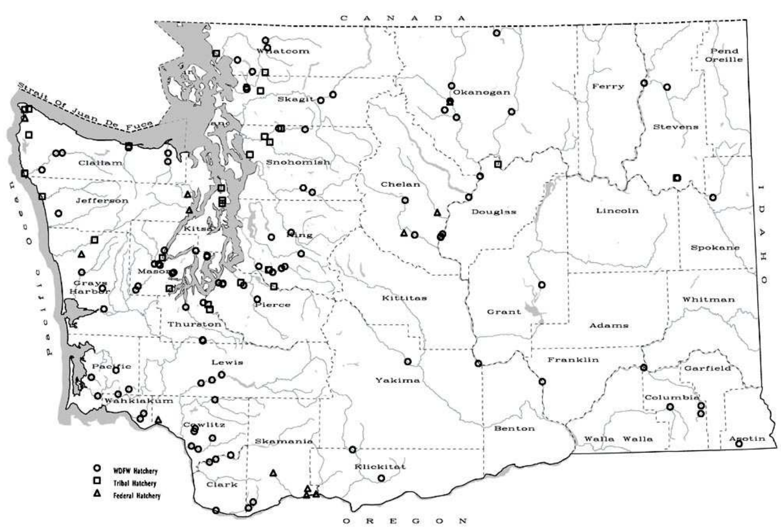


Fish Populations

Areas of Fish Listings



State, Tribal, and Federal Hatcheries



6 reasons why hatcheries fail

- Data demonstrate that hatcheries are not solving the problem – salmon continue to decline despite decades of hatchery production

- Hatcheries are costly to run, and divert resources from other areas such as habitat restoration

Reason 3 and 4

- Hatcheries are not sustainable in the long term, requiring continual input of money and energy *($56.5 million/yr for WA state hatcheries – 1 billion investment)*

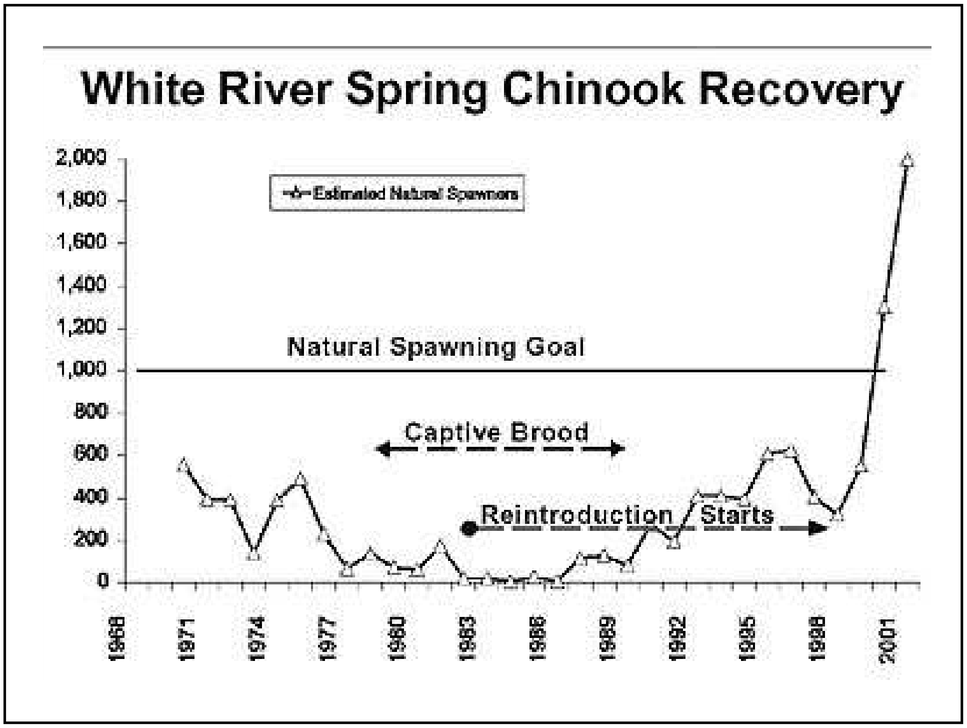
- Hatcheries are a genetically unsound approach to management that can adversely affect wild populations

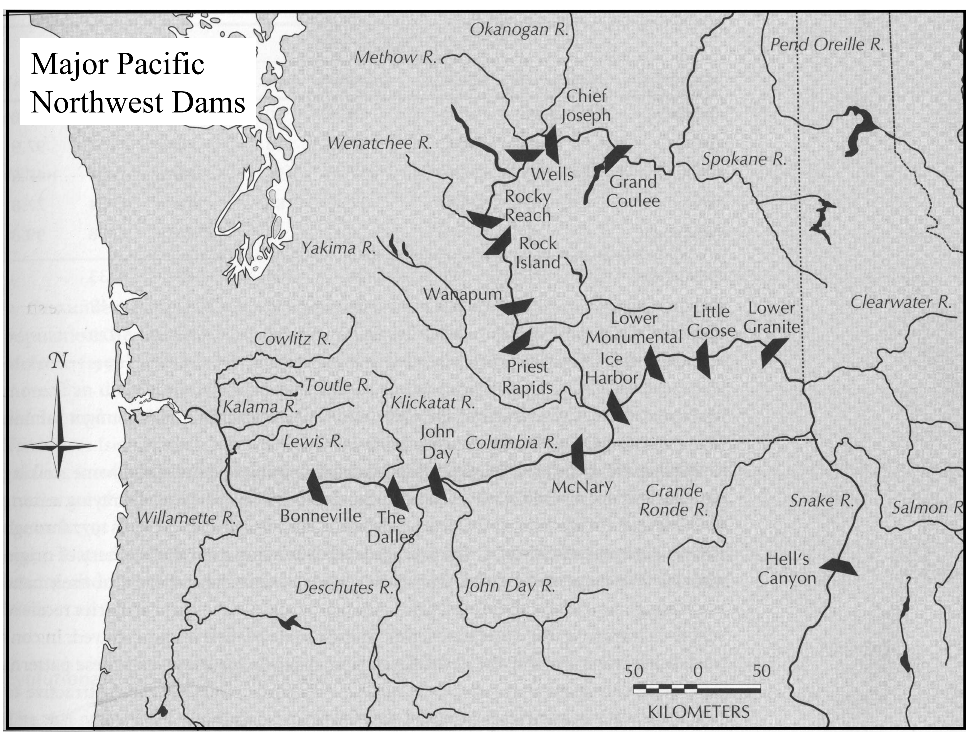
Reason 5 and 6

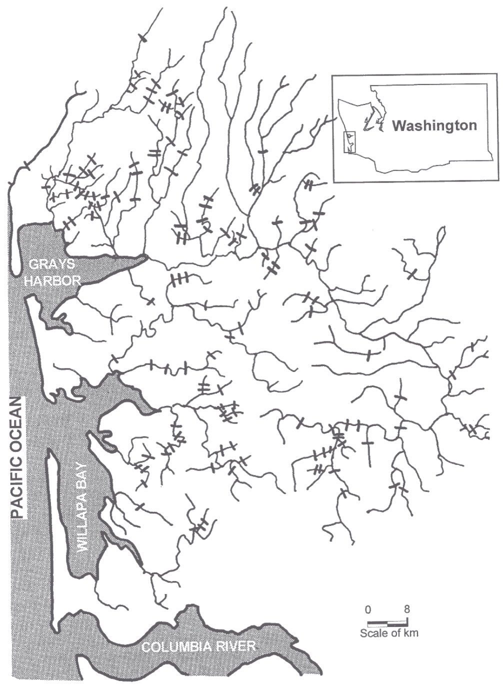
- Hatchery production leads to increased harvest of declining wild salmon populations

- Hatcheries conceal from the public the truth of real salmon decline.

State Hatchery production in Washington


White River Spring Chinook Recovery
Estimated Natural Spawners
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Natural Spawning Goal
Captive Brood
Reintroduction Starts
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001


Major Pacific Northwest Dams
Okanogan R.
Methow R.
Pend Oreille R.
Chief Joseph
Wenatchee R.
Wells
Grand Coulee
Spokane R.
Rocky Reach
Rock Island
Yakima R.
Wanapum
Lower Monumental
Little Goose
Lower Granite
Clearwater R.
Cowlitz R.
Ice Harbor
Priest Rapids
Toutle R.
Kalama R.
Klickatat R.
Lewis R.
John Day
Columbia R.
McNary
Grande Ronde R.
Snake R.
Salmon R
Willamette R.
Bonneville
The Dalles
Hell's Canyon
Deschutes R.
John Day R.
N
50 0 50
KILOMETERS



Distribution of Western Washington Splash Dams

Source: Gene Deschamps