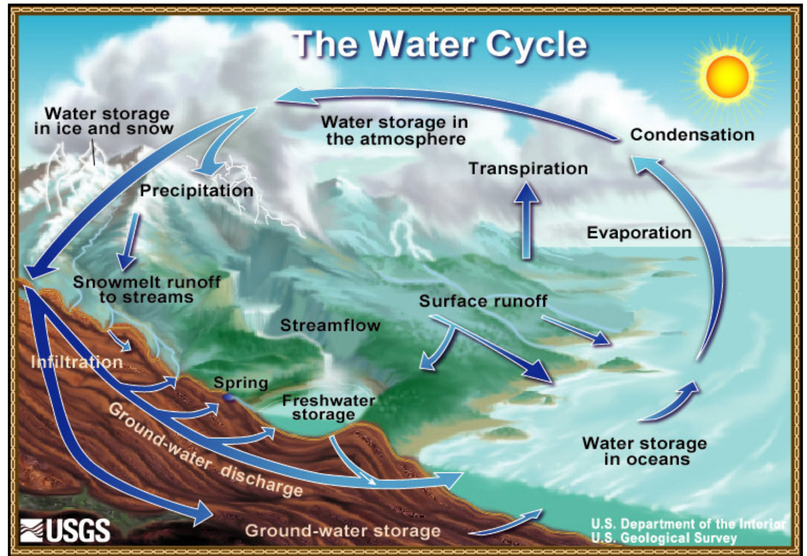
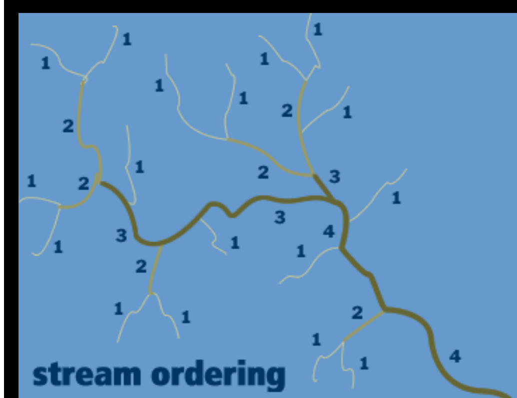
Rivers, Salmon & Riparian Forests

Carri J. LeRoy, Ph.D.
gCORE 2011





How we classify rivers:

Stream order increases only when 2 like streams come together…

1 + 1 = 2

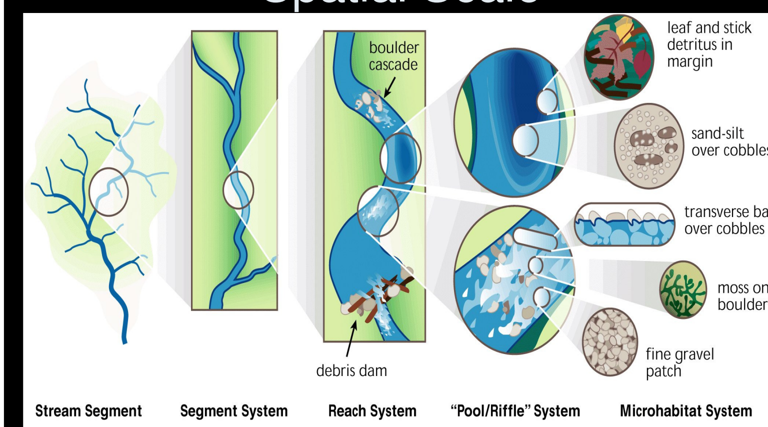
2 + 1 = 2

2 + 2 = 3

5 + 4 = 5

5 + 5 = 6

Spatial Scale



Stream Meanders

Big meanders: fine sediment & low gradient

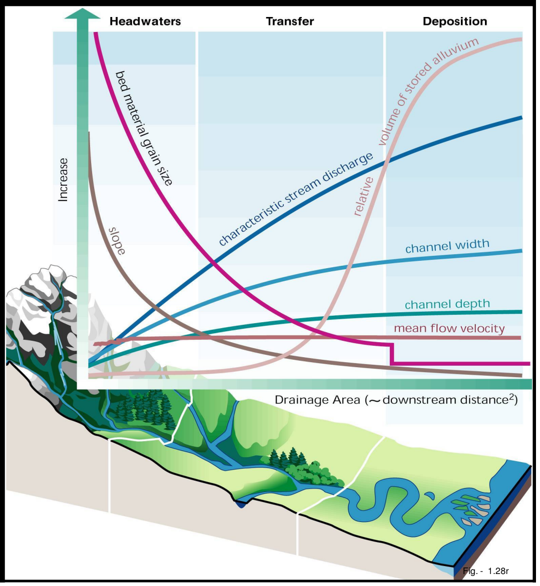
Small meanders: coarse sediment & high gradient

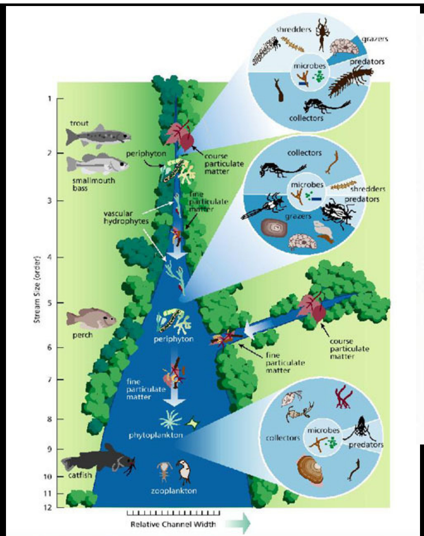
River Continuum Concept

- What changes as you move downstream?
  - Some things increase
  - Some things decrease
  - Some things stay the same
  - Work in groups of 3 to brainstorm…

- As discharge increases:
  - Channel Width increases
  - Channel Depth increases
  - Mean velocity is stable
  - Bed Material size decreases
  - Slope decreases
  - Sediment storage increases
  - Builds on Leopold & Maddock 1953

From Schumm & Lichty 1963





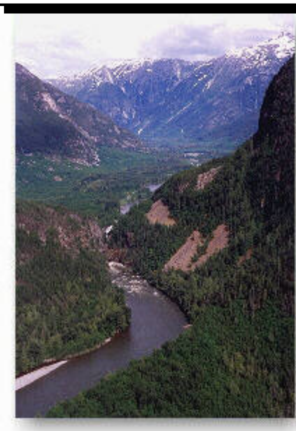


Image courtesy of U.S. EPA

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. Canadian Journal of Fisheries and Aquatic Sciences. 37:130-137

Riparian Zone

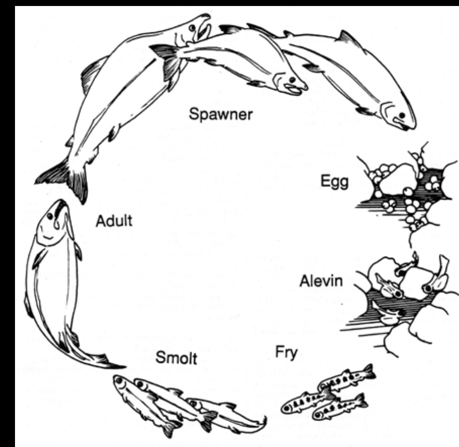
- "Riparian" comes from "*ripa*," Latin for river bank
- "Lacustrine" of lakes: "*lacus*," Latin for lake
- Quintessential ecotone – sharp boundary between terrestrial & aquatic ecosystems

Salmon Life history

Salmon return to their natal stream to spawn

Adults live in the ocean for 1-5 years

Smolting is the process of adapting to new salty environment



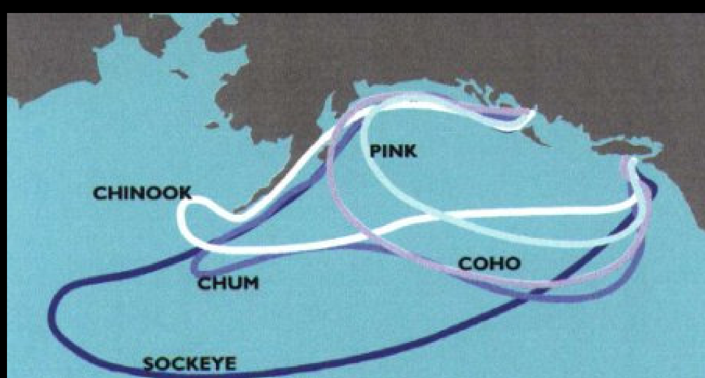
Females dig redds in gravel for eggs

Eggs hatch in 8-12 weeks

Alevin retain a yolk sac for nourishment

Fry feed on stream insects

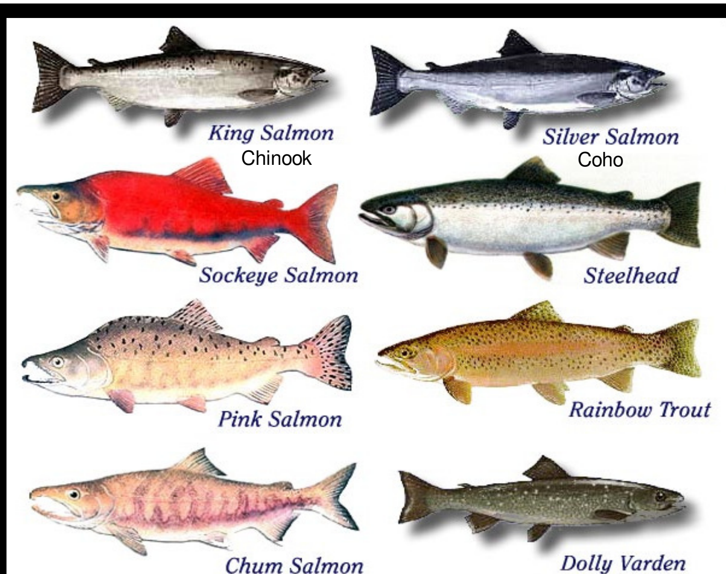
Salmon oceanic migration



David W. Welch 1996

Salmon Species

- 5 salmon species spawn in WA: *Oncorhynchus*
- Chinook: *O. tshawytscha*
- Sockeye: *O. nerka*
- Pink: *O. gorbuscha*
- Chum: *O. keta*
- Coho: *O. kitsutch*

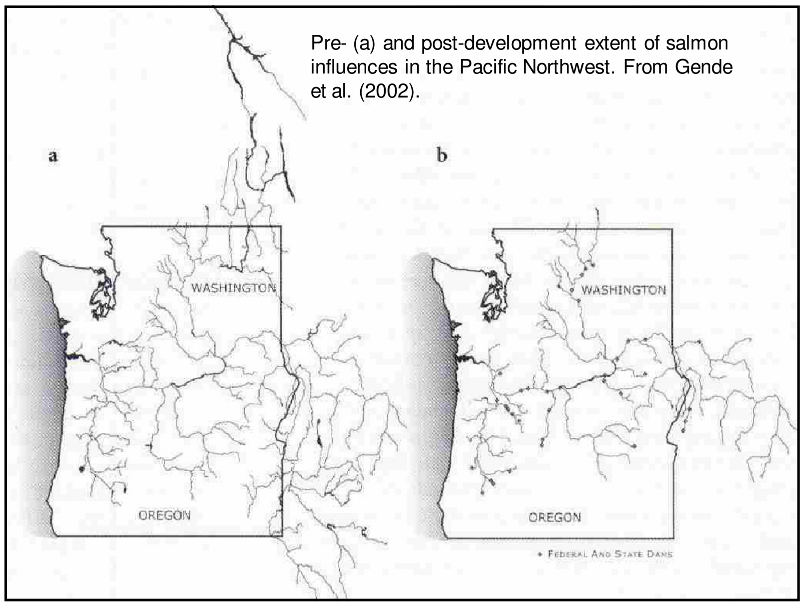


Ecosystem influences of salmon

- Major nutrient input to streams and forests
  - Carcasses, eggs, sperm, feces, & feces/urine of scavengers feeding on salmon
- Food resource for large predators & scavengers
  - Bears move between 50-90% of carcasses inland (Reimchen 2000).

Ecosystem influences of salmon

- Stream systems as conduits for salmon inputs to forests
- Influences of dams and development

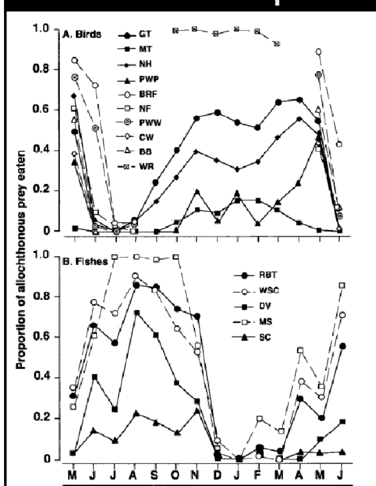


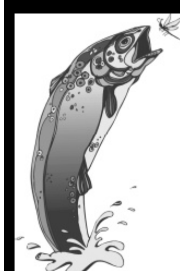
Pre- (a) and post-development extent of salmon influences in the Pacific Northwest. From Gende et al. (2002).

Ecosystem influences of salmon

- Stream systems as conduits for salmon inputs to forests
- Influences of dams and development
- Aquatic insects feed on salmon in-stream and emerge into the forest
  - Salmon-derived nutrient subsidies to birds, bats, spiders, trees, etc.

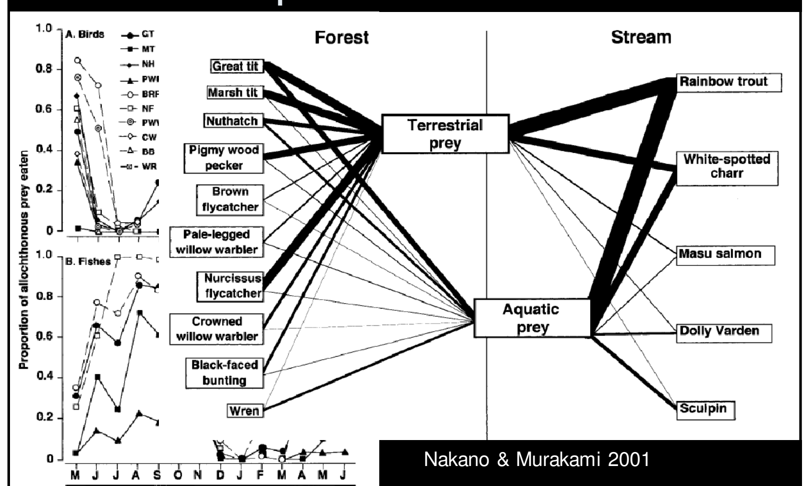
Reciprocal Subsidies



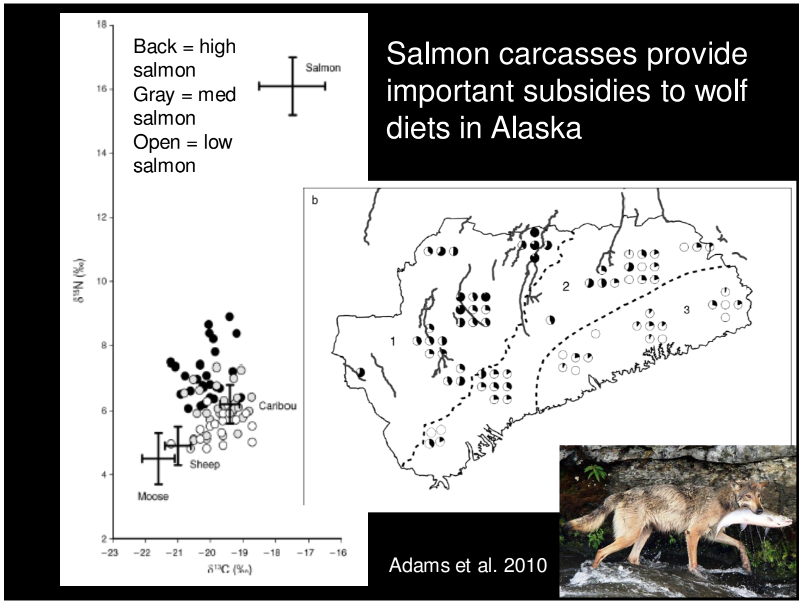


Nakano & Murakami 2001

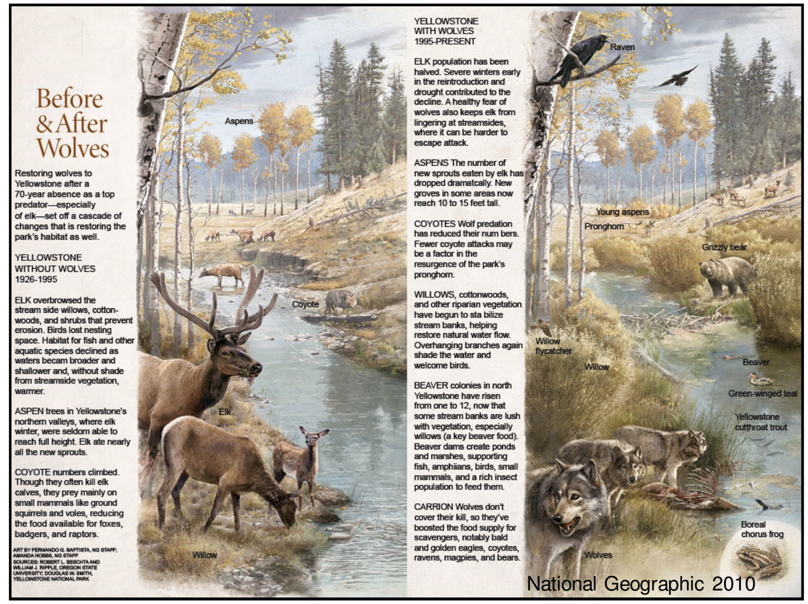
Reciprocal Subsidies



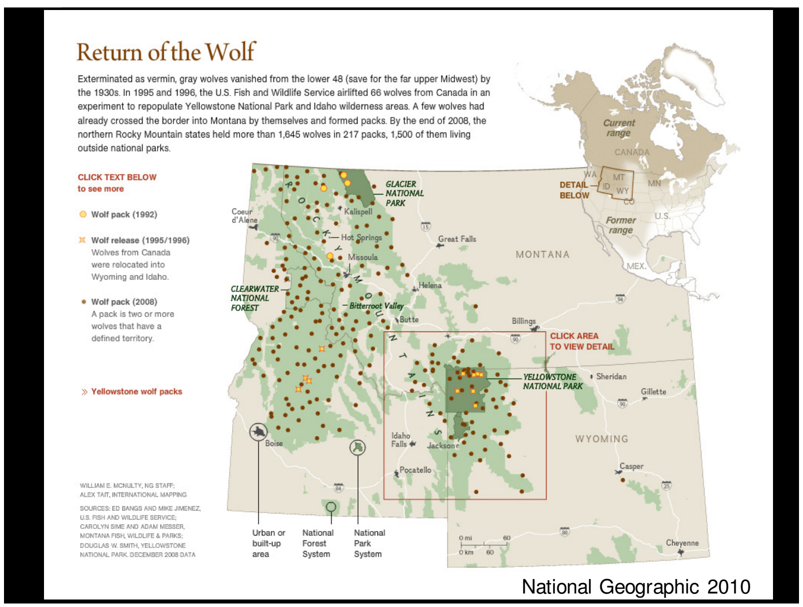
Nakano & Murakami 2001



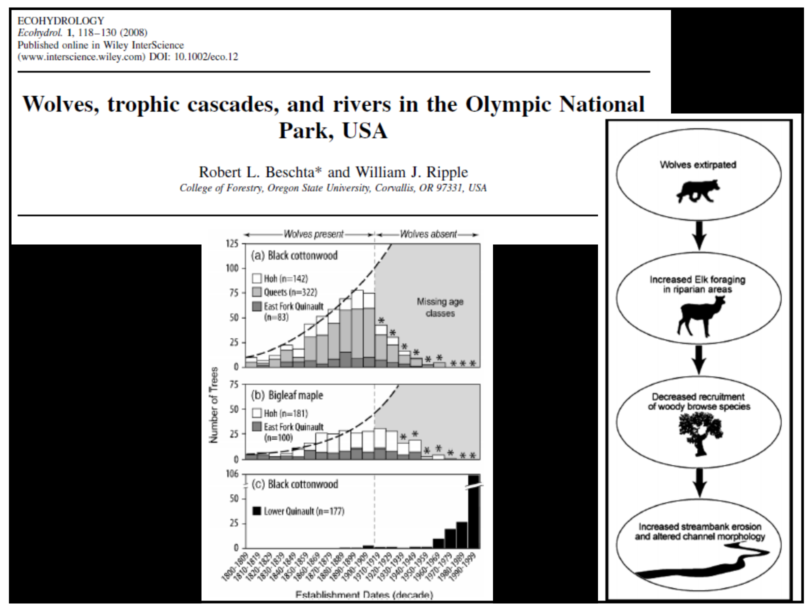
Back = high salmon
Gray = med salmon
Open = low salmon
Salmon
Caribou
Sheep
Moose
δ15N (‰)
δ13C (‰)
Salmon carcasses provide important subsidies to wolf diets in Alaska
Adams et al. 2010



Before & After Wolves
Restoring wolves to Yellowstone after a 70-year absence as a top predator—especially of elk—set off a cascade of changes that is restoring the park's habitat as well.
YELLOWSTONE WITHOUT WOLVES 1926-1995
ELK overbrowsed the stream side willows, cottonwoods, and shrubs that prevent erosion. Birds lost nesting space. Habitat for fish and other aquatic species declined as waters became broader and shallower and, without shade from streamside vegetation, warmer.
ASPEN trees in Yellowstone's northern valleys, where elk winter, were seldom able to reach full height. Elk ate nearly all the new sprouts.
COYOTE numbers climbed. Though they often kill elk calves, they prey mainly on small mammals like ground squirrels and voles, reducing the food available for foxes, badgers, and raptors.
YELLOWSTONE WITH WOLVES 1995-PRESENT
ELK population has been halved. Severe winters early in the reintroduction and drought contributed to the decline. A healthy fear of wolves also keeps elk from lingering at streamsides, where it can be harder to escape attack.
ASPENS The number of new sprouts eaten by elk has dropped dramatically. New groves in some areas now reach 10 to 15 feet tall.
COYOTES Wolf predation has reduced their numbers. Fewer coyote attacks may be a factor in the resurgence of the park's pronghorn.
WILLOWS, cottonwoods, and other riparian vegetation have begun to stabilize stream banks, helping restore natural water flow. Overhanging branches again shade the water and welcome birds.
BEAVER colonies in north Yellowstone have risen from one to 12, now that some stream banks are lush with vegetation, especially willows (a key beaver food). Beaver dams create ponds and marshes, supporting fish, amphibians, birds, small mammals, and a rich insect population to feed them.
CARRION Wolves don't cover their kill, so they've boosted the food supply for scavengers, notably bald and golden eagles, coyotes, ravens, magpies, and bears.
Aspens
Coyote
Elk
Willow
Raven
Young aspens
Pronghorn
Grizzly bear
Willow flycatcher
Willow
Beaver
Green-winged teal
Yellowstone cutthroat trout
Wolves
Boreal chorus frog
National Geographic 2010



Return of the Wolf
Exterminated as vermin, gray wolves vanished from the lower 48 (save for the far upper Midwest) by the 1930s. In 1995 and 1996, the U.S. Fish and Wildlife Service airlifted 66 wolves from Canada in an experiment to repopulate Yellowstone National Park and Idaho wilderness areas. A few wolves had already crossed the border into Montana by themselves and formed packs. By the end of 2008, the northern Rocky Mountain states held more than 1,645 wolves in 217 packs, 1,500 of them living outside national parks.
CLICK TEXT BELOW to see more
Wolf pack (1992)
Wolf release (1995/1996) Wolves from Canada were relocated into Wyoming and Idaho.
Wolf pack (2008) A pack is two or more wolves that have a defined territory.
Yellowstone wolf packs
GLACIER NATIONAL PARK
CLEARWATER NATIONAL FOREST
YELLOWSTONE NATIONAL PARK
MONTANA
WYOMING
Current range
Former range
CANADA
U.S.
MEX.
DETAIL BELOW
CLICK AREA TO VIEW DETAIL
Urban or built-up area
National Forest System
National Park System
National Geographic 2010

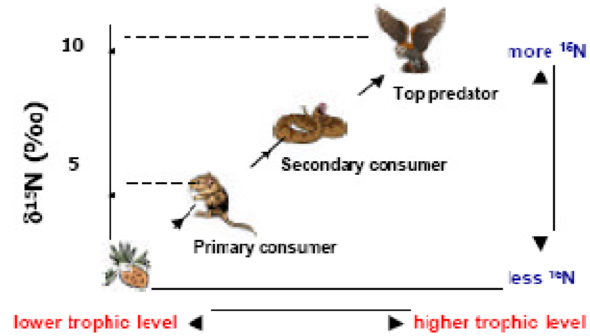


ECOHYDROLOGY
Ecohydrol. 1, 118–130 (2008)
Published online in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/eco.12
Wolves, trophic cascades, and rivers in the Olympic National Park, USA
Robert L. Beschta* and William J. Ripple
College of Forestry, Oregon State University, Corvallis, OR 97331, USA
Wolves present
Wolves absent
(a) Black cottonwood
Hoh (n=142)
Queets (n=322)
East Fork Quinault (n=83)
Missing age classes
(b) Bigleaf maple
Hoh (n=181)
East Fork Quinault (n=100)
(c) Black cottonwood
Lower Quinault (n=177)
Number of Trees
Establishment Dates (decade)
Wolves extirpated
Increased Elk foraging in riparian areas
Decreased recruitment of woody browse species
Increased streambank erosion and altered channel morphology

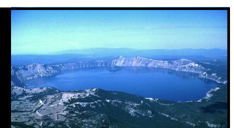
Ecosystem influences of salmon

- Direct fertilization of forests through S-DN (Helfield & Naiman 2001, 2002)

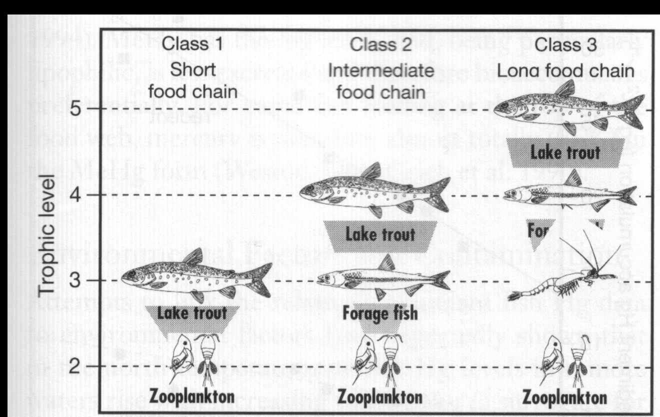
- Because ^{15}N is preferentially retained during excretion, animals alter the nitrogen isotope ratio of their food.



Food web studies



δ15N increases up food chain



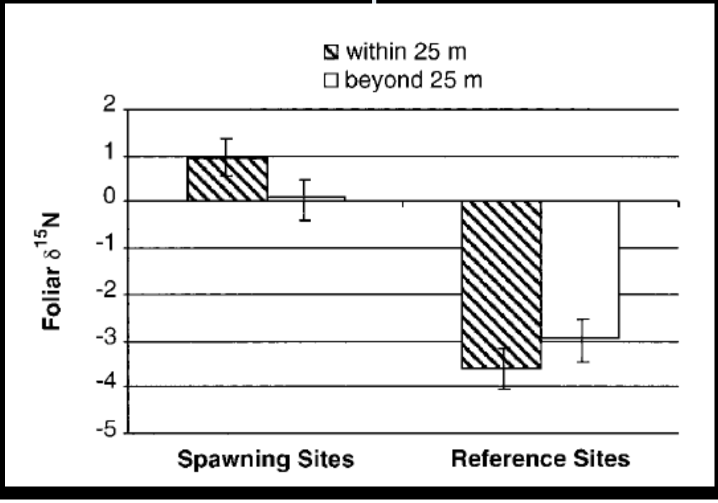
Marine derived nutrients

- $\delta^{15}N$ signatures are significantly higher for marine-derived nutrients (salmon carcasses, sea bird droppings, etc.) because marine food webs are more complex
- We can track these inputs isotopically

Helfield & Naiman 2001

- Compared plants in spawning to control reaches
- Found significantly higher lower C:N ratios and significantly higher $\delta^{15}N$ for spawning reaches (spruce, devil's club, hemlock, but not alder = nitrogen fixed from atmosphere)
- Up to 25% of N came from carcasses!

Sitka spruce



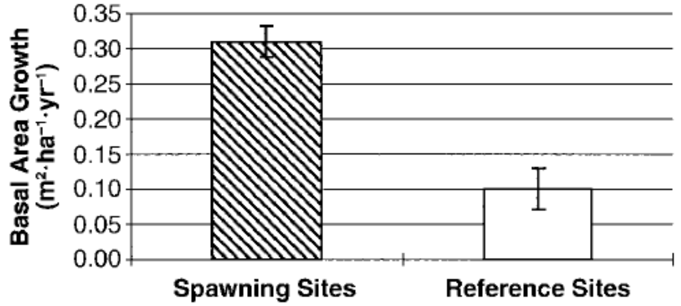
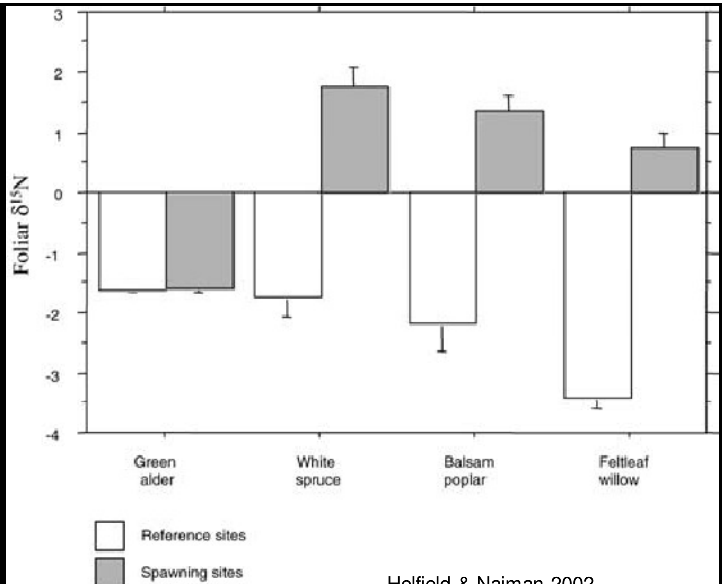
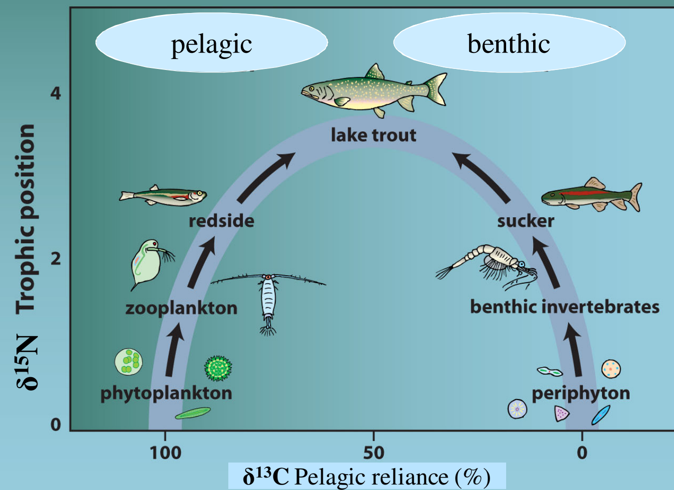


FIG. 4. Annual basal area growth per unit area of riparian Sitka spruce at spawning and reference sites. Values are means ± 1 SE.



Helfield & Naiman 2002

Food Web Structure Using Stable Isotopes

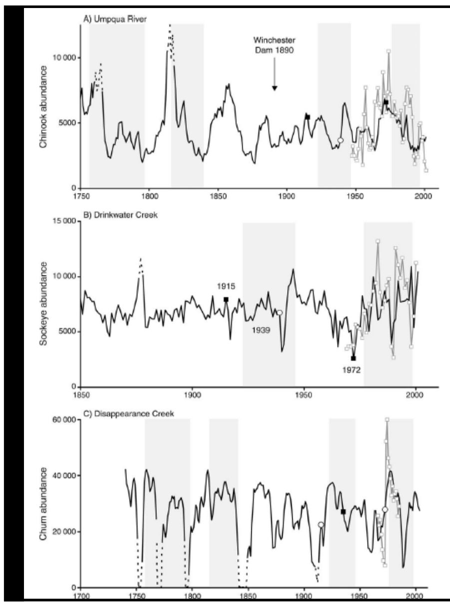


Ecosystem influences of salmon

- Direct fertilization of forests through S-DN (Helfield & Naiman 2001, 2002)
  - Change leaf litter inputs
  - Alter large woody debris inputs
  - Change light levels reaching the stream
  - Alter riparian vegetation structure
    - Food for herbivores
    - Architecture for nesting birds
    - Interactions with beaver and other mammals

Ecosystem influences of salmon

- Quantification of historic salmon runs through tree-ring analysis



^{15}N tracers and tree ring width show fluctuations in salmon deposits in riparian systems with a 1-yr lag

RECONSTRUCTION OF PACIFIC SALMON ABUNDANCE FROM RIPARIAN TREE-RING GROWTH

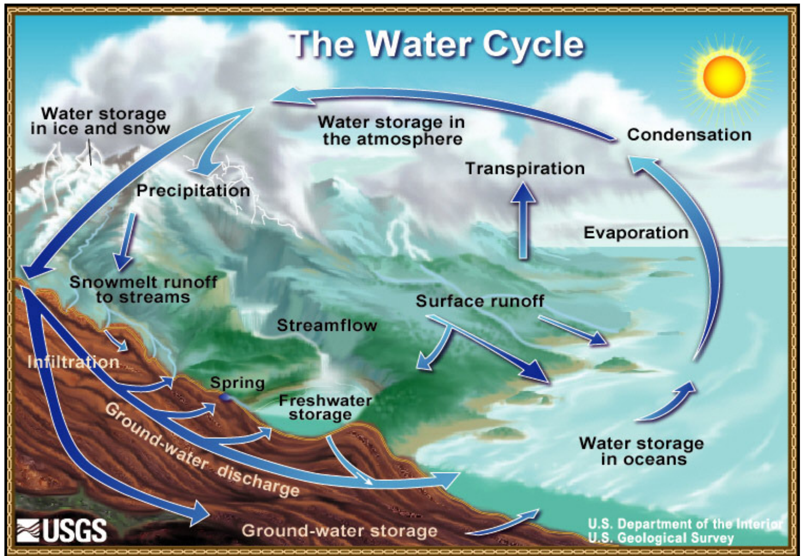
D. C. Drake and Robert J. Naiman

Drake & Naiman 2007

Other cool stable isotopes

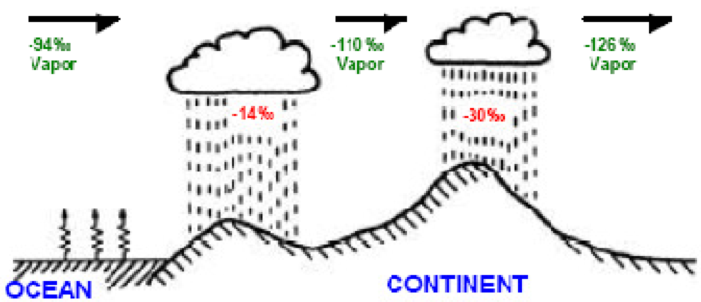
Isotope Tracers (like Mark S. mentioned…)

- ^{18}O and ^{2}H
- ^{13}C



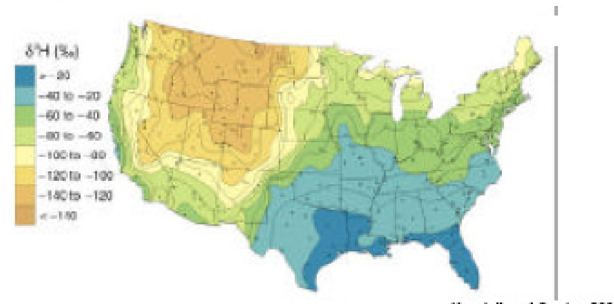
Fractionation occurs at many of these transition points

- As water evaporates from the ocean, most of the lighter isotopes form vapor but the heavier isotopes fall as rain.



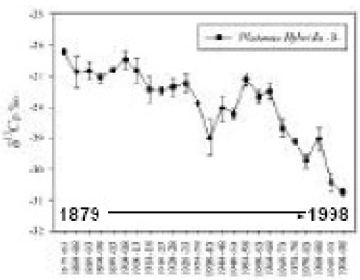
Another orographic phenomenon!

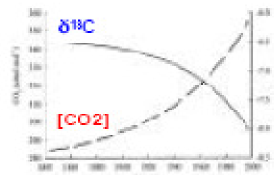
- As precipitation events move across the continent, local water sources end up with distinct hydrogen isotope ratios.
- Animals feeding/drinking in these areas will also incorporate these distinct values into their tissues.



Kendall and Coplen 2001

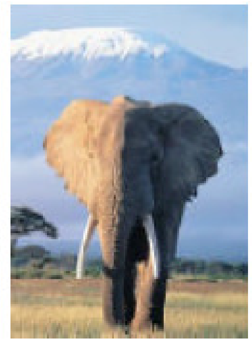
- Paleo-ecologists use carbon isotopes to identify global climate change effects through time.

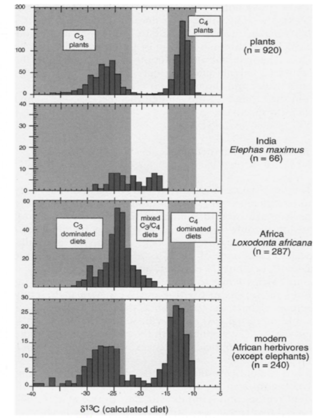




Dongarra and Varrica 2002

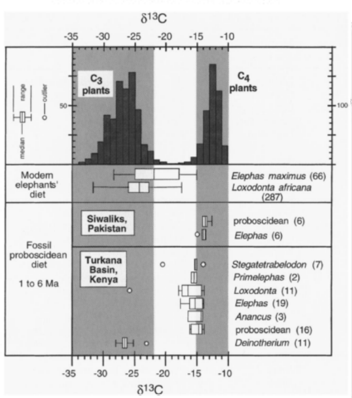
- Because animals do not alter the carbon isotope ratio of their food... YOU ARE WHAT YOU EAT!

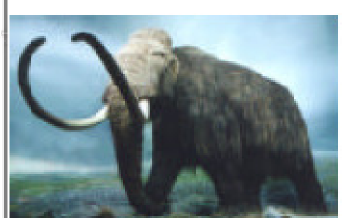




Cerling et. al 1999

- Even paleo-ecologists can use carbon isotopes (in teeth) to determine the diets of extinct animals.





Cerling et. al 1999

Threats to salmon

- 4 H's:
  - Habitat destruction, Hydroelectric dams, over-Harvest of rare stocks, and competition with Hatchery fish
- Pesticides / pollutants
- Sedimentation
- Climate change / stream temp

Habitat loss

Hydropower

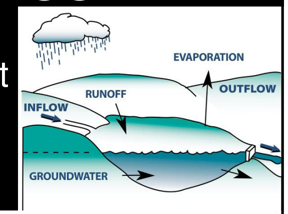
Bonneville dam fish ladder. Photo John Harrison

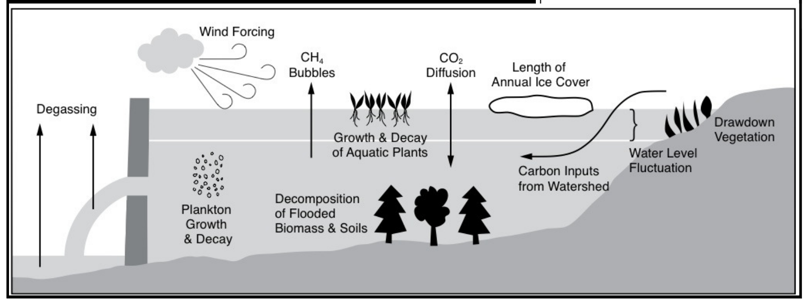
Hydropower

- Why?
  - Power
  - Transportation
  - Irrigation
  - Flood "control"
  - Recreation

Dams and the RCC

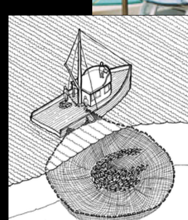
- Serial Discontinuity Concept

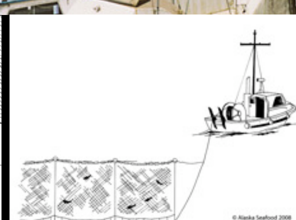




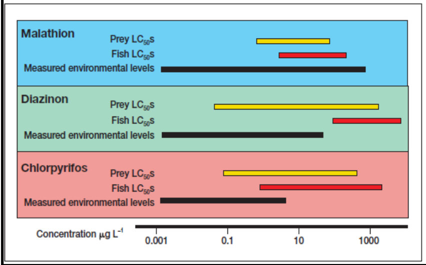
over-Harvest

- Trolling
- Seining
- Gill-netting





Hatcheries

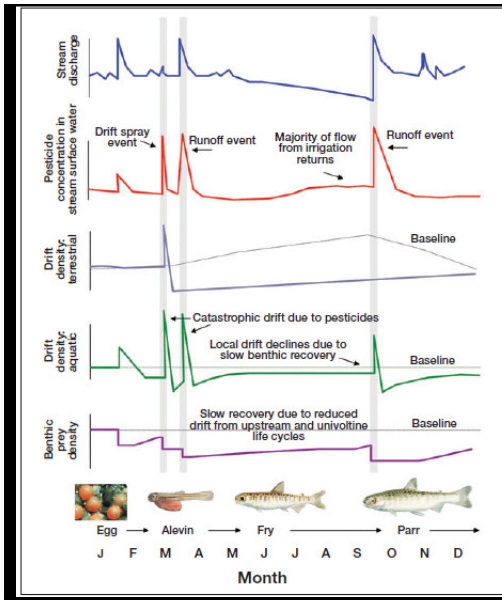


In a nutshell:

- Pesticides contaminate aquatic habitats via spray drift and surface runoff
- Pesticides in the environment can be highly toxic to non-target primary producers and invertebrates
- Endangered Pacific salmon rely on the productivity of aquatic communities for growth and survival
- Our understanding of the bottom-up effects of pesticides on aquatic food webs remains limited
- Coordinated, multidisciplinary research on pesticides and aquatic food webs is needed to improve salmon recovery under the US Endangered Species Act

LC_{50} = concentration at which 50% die

Macneale et al. 2010



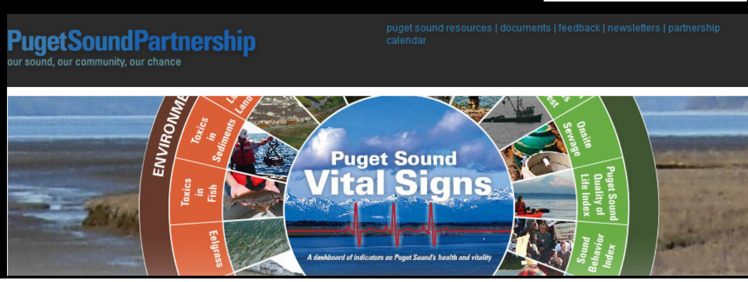
Macneale et al. 2010

Salmon restoration

- Puget Sound Partnership
- The Nature Conservancy
- Elwha Dam removals

http://www.video-monitoring.com/construction/olympic/js.htm

The Nature Conservancy. Protecting nature. Preserving life.

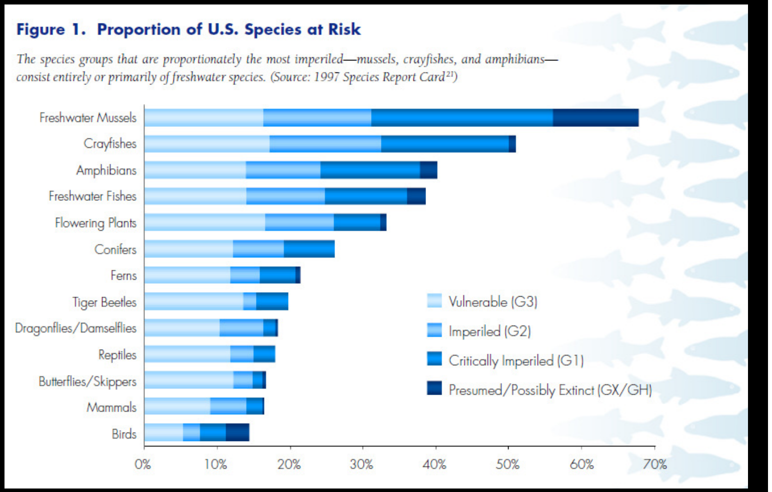


Dam removals

- For river function
- For species
- For cultural reasons
- ~600 dams have been removed in the past 50 years (American Rivers)

http://www.americanrivers.org/our-work/restoring-rivers/dams/background/faqs.html

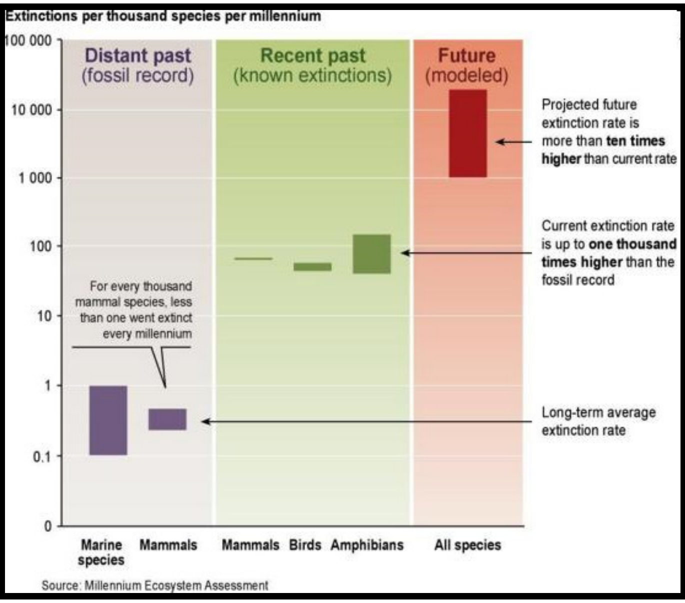
Human Impacts and Stream Systems

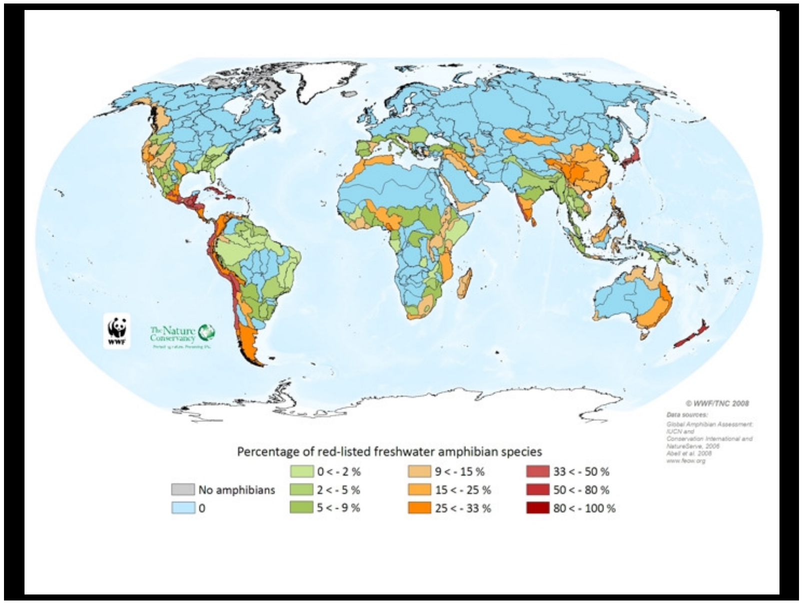


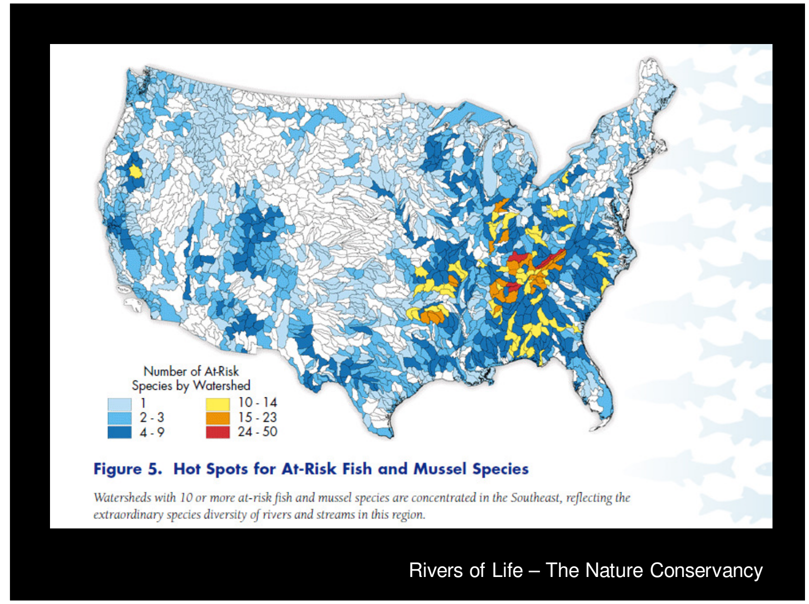
Rivers of Life – The Nature Conservancy

Freshwater extinctions

- 2/3 freshwater mussels at risk of extinction; (1 in 10 already extinct)
- 1/2 crayfish species in jeopardy
- 50% turtles are threatened
- over 40% stoneflies are at risk
- About 40% freshwater fishes and amphibians at risk
- 18% of dragonfly and damselfly species are at risk.




Percentage of red-listed freshwater amphibian species
No amphibians
0
0 < - 2 %
2 < - 5 %
5 < - 9 %
9 < - 15 %
15 < - 25 %
25 < - 33 %
33 < - 50 %
50 < - 80 %
80 < - 100 %
© WWF/TNC 2008


Number of At-Risk Species by Watershed
1
2 - 3
4 - 9
10 - 14
15 - 23
24 - 50
Figure 5. Hot Spots for At-Risk Fish and Mussel Species
Watersheds with 10 or more at-risk fish and mussel species are concentrated in the Southeast, reflecting the extraordinary species diversity of rivers and streams in this region.
Rivers of Life – The Nature Conservancy

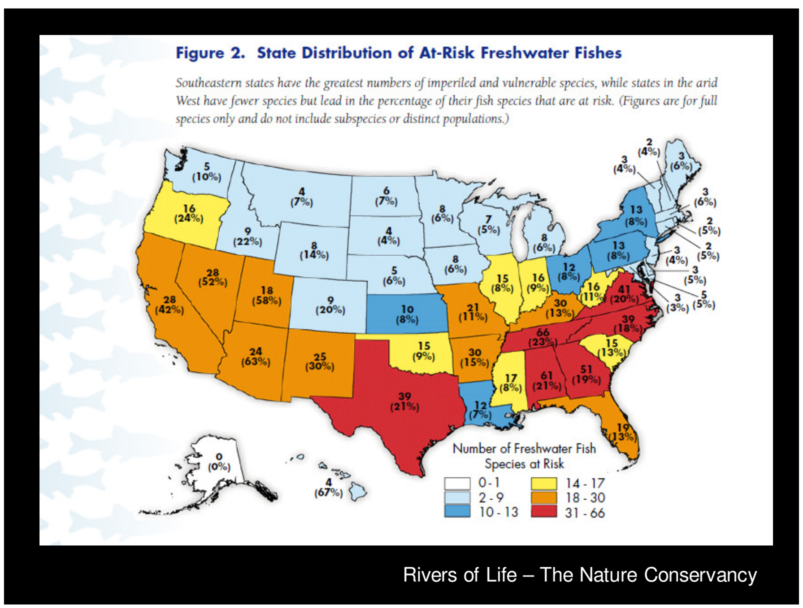


Figure 2. State Distribution of At-Risk Freshwater Fishes
Southeastern states have the greatest numbers of imperiled and vulnerable species, while states in the arid West have fewer species but lead in the percentage of their fish species that are at risk. (Figures are for full species only and do not include subspecies or distinct populations.)
Number of Freshwater Fish Species at Risk
0 - 1
2 - 9
10 - 13
14 - 17
18 - 30
31 - 66
Rivers of Life – The Nature Conservancy

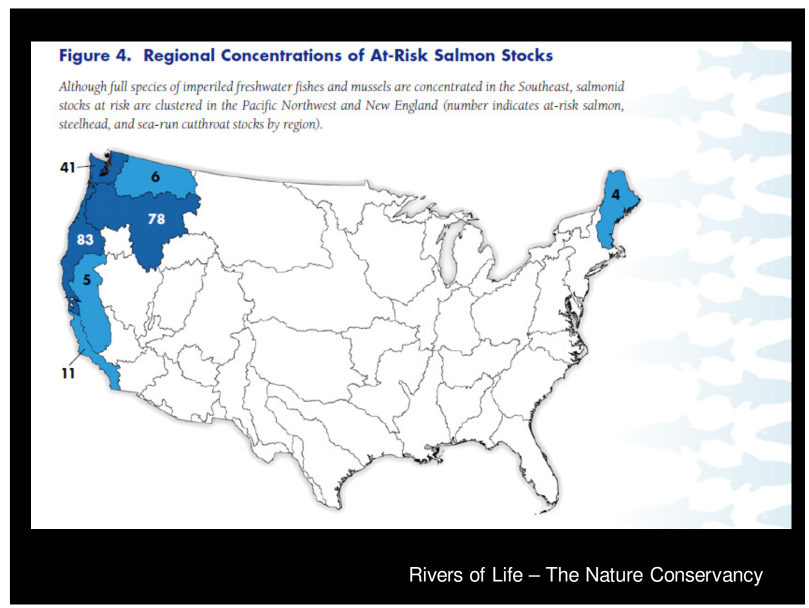


Figure 4. Regional Concentrations of At-Risk Salmon Stocks
Although full species of imperiled freshwater fishes and mussels are concentrated in the Southeast, salmonid stocks at risk are clustered in the Pacific Northwest and New England (number indicates at-risk salmon, steelhead, and sea-run cutthroat stocks by region).
41
6
78
83
5
11
4
Rivers of Life – The Nature Conservancy

Threatened or endangered fish species in WA

Threats to Freshwaters

- Habitat alteration
  - Altered hydrology, channelization, land use
- Invasive species
- Contaminants
  - Runoff, atmospheric deposition, medical waste, pesticides
- Overexploitation
- Climate change

National River Restoration Science Synthesis (NRRSS)

- Synthesis of all riparian restoration projects in the US

POLICY FORUM

ECOLOGY

Synthesizing U.S. River Restoration Efforts

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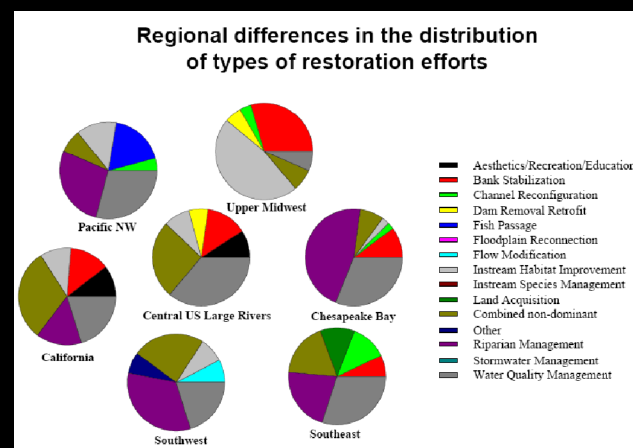
The importance of rivers and streams for fresh water, food, and recreation is well known, yet there is increasing evidence that degradation of running waters is at an all-time high (1). More than one-third of the rivers in the United States are listed as impaired or polluted (2), and freshwater

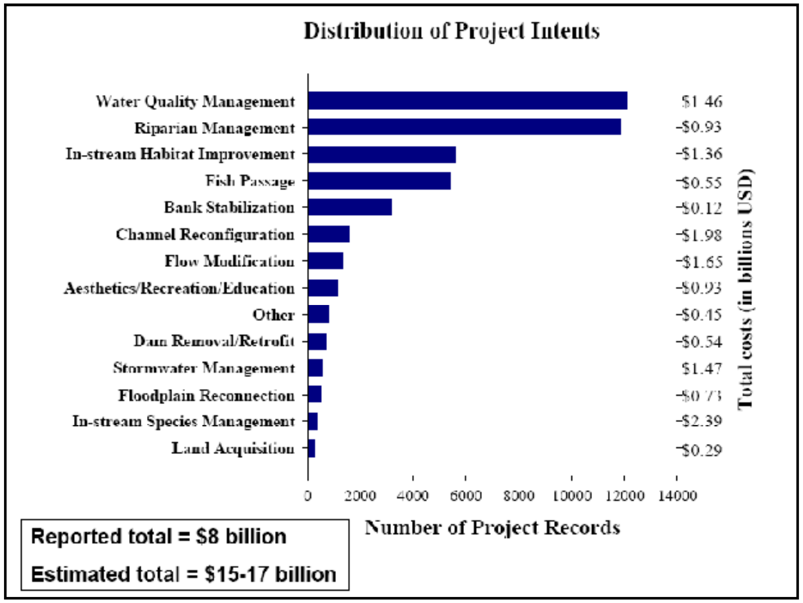
We found that existing restoration databases are highly fragmented and often rely on ad hoc or volunteer data entry. Thus, we developed methods for the unbiased collection and cataloging of river and stream restoration projects. Here, we report a synthesis of information on 37,099 projects in the

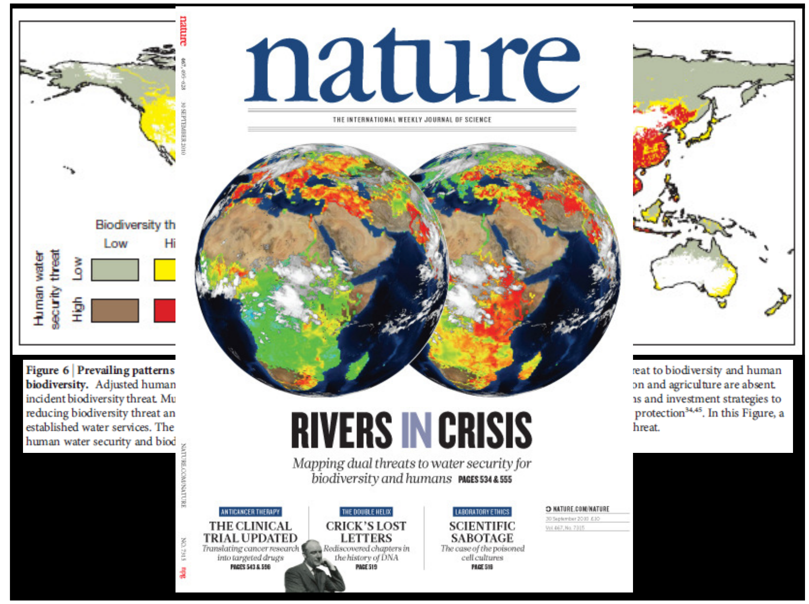
cess or failure of the project. We identified a priori 13 categories of restoration and classified each project according to its stated goal [see table, page 637 and (17) part c].

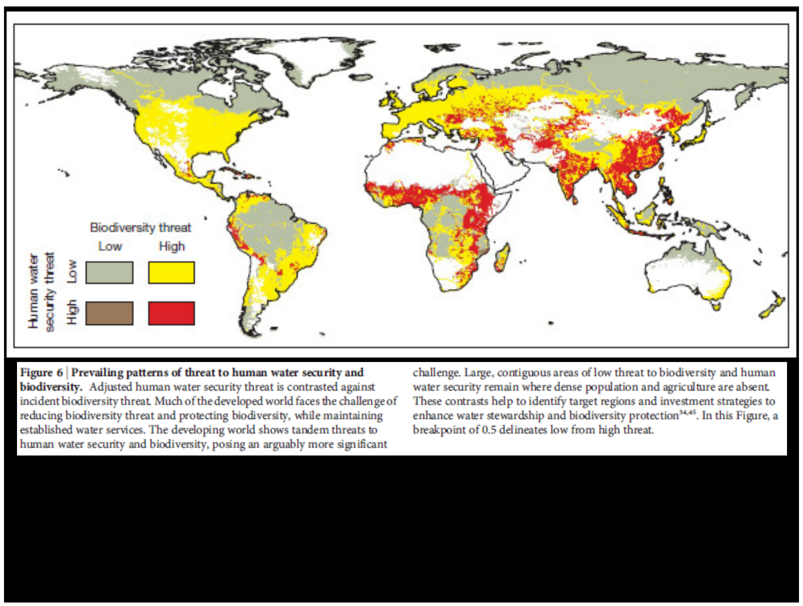
The number of river restoration projects increased exponentially during the last decade, paralleling the increase in news media and scientific reports [fig. S1 (17) part d]. However, restoration efforts varied across geographic regions. Most projects (88%) are from the Pacific Northwest, the Chesapeake Bay watershed, or California (see figure, below). Data from national coverage sources [(17) part b] made up <8% of projects in the NRRSS database. Thus, while federal funding supports some tracking efforts, national restoration databases are not tracking the majority of projects and lack information on the regional differences in expenditures and effort found with our approach.

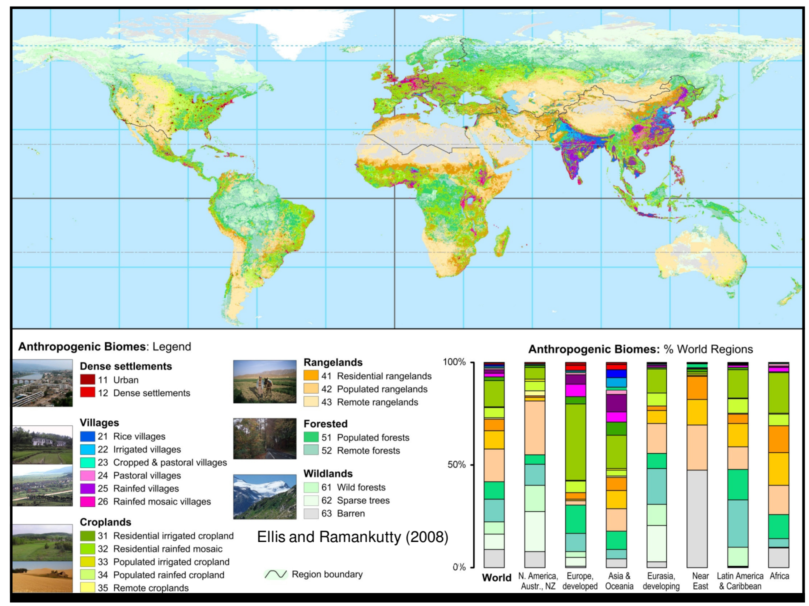
Restoration based on US region




Distribution of Project Intents
Water Quality Management
Riparian Management
In-stream Habitat Improvement
Fish Passage
Bank Stabilization
Channel Reconfiguration
Flow Modification
Aesthetics/Recreation/Education
Other
Dam Removal/Retrofit
Stormwater Management
Floodplain Reconnection
In-stream Species Management
Land Acquisition
$1.46
~$0.93
~$1.36
~$0.55
~$0.12
~$1.98
~$1.65
~$0.93
~$0.15
~$0.54
$1.47
~$0.73
~$2.39
~$0.29
0
2000
4000
6000
8000
10000
12000
14000
Number of Project Records
Total costs (in billions USD)
Reported total = $8 billion
Estimated total = $15-17 billion


nature
THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE
RIVERS IN CRISIS
Mapping dual threats to water security for biodiversity and humans PAGES 534 & 555
THE CLINICAL TRIAL UPDATED
CRICK'S LOST LETTERS
SCIENTIFIC SABOTAGE


Biodiversity threat
Low
High
Human water security threat
Low
High
Figure 6 | Prevailing patterns of threat to human water security and biodiversity. Adjusted human water security threat is contrasted against incident biodiversity threat. Much of the developed world faces the challenge of reducing biodiversity threat and protecting biodiversity, while maintaining established water services. The developing world shows tandem threats to human water security and biodiversity, posing an arguably more significant challenge. Large, contiguous areas of low threat to biodiversity and human water security remain where dense population and agriculture are absent. These contrasts help to identify target regions and investment strategies to enhance water stewardship and biodiversity protection[34,45]. In this Figure, a breakpoint of 0.5 delineates low from high threat.


Anthropogenic Biomes: Legend
Dense settlements
11 Urban
12 Dense settlements
Villages
21 Rice villages
22 Irrigated villages
23 Cropped & pastoral villages
24 Pastoral villages
25 Rainfed villages
26 Rainfed mosaic villages
Croplands
31 Residential irrigated cropland
32 Residential rainfed mosaic
33 Populated irrigated cropland
34 Populated rainfed cropland
35 Remote croplands
Rangelands
41 Residential rangelands
42 Populated rangelands
43 Remote rangelands
Forested
51 Populated forests
52 Remote forests
Wildlands
61 Wild forests
62 Sparse trees
63 Barren
Ellis and Ramankutty (2008)
Region boundary
Anthropogenic Biomes: % World Regions
100%
50%
0%
World
N. America, Austr., NZ
Europe, developed
Asia & Oceania
Eurasia, developing
Near East
Latin America & Caribbean
Africa