PACIFIC SALMON AND COASTAL ECOSYSTEMS
(read Schindler et al. 2003)

Pacific Salmon Species
The term *Pacific salmon* refers to species that are anadromous and are in the *Oncorhynchus* genus.

- Genus: *Oncorhynchus*
- Family: Salmonidae

Economic value
Commercial landings--$100s of million per year
Recreational fisheries–more difficult to quantify, but likely roughly equivalent.

LIFE-HISTORY
Anadromy—when an individual is born in freshwaters, migrates to the ocean to grow large, and then migrates back to freshwaters to spawn. This life-history strategy is thought to have evolved to take advantage of the relatively predator-free freshwaters for the vulnerable life-stages (eggs/fry/parr) as well as the better growing conditions of the ocean. There are non-anadromous versions of salmonids, such as rainbow trout and kokanee salmon.

Homing—salmon almost invariably return to spawn to the site where they were spawned. This has important consequences for salmon, such as strong local adaptations and population differentiation. However, there are often some small frequency of *straying*, individuals that go to different habitat, perhaps a bet-hedging strategy.

Semelparous—When an individual dies after spawning. Many salmon species are semelparous. This allows salmon to put everything into spawning (large eggs), and not save anything for the journey back out. Steelhead trout are not semelparous, instead they are *iteroparous*, having the ability to reproduce in multiple years.

Stream-type vs. Ocean-type—many species have juveniles that either go out to the ocean early after they emerge (ocean-type) and other life-history that rear in streams or rivers for 1+ years (stream-type).

SPECIES DIVERSITY
Some of the West coast salmon species:

Steelhead—(*Oncorhynchus mykiss*) Anadromous version of rainbow trout. Anadromous and iteroparous. This species has incredible flexibility in their life-history.

Chinook (aka King or Tyee)—(*Oncorhynchus tshawytscha*). Largest of the Pacific salmon. Least abundant of the five semelparous salmon. Spawners can either be olive or maroon and black gums.

Coho (aka Silvers)—(*Oncorhynchus kisutch*). Spawn in small streams with moderate gradient along the coast. Spawners often have maroon/red sides and the males have exaggerated hooked noses. Spawners are ~ 2-5 kg.

Sockeye (aka Reds or Kokanee for the land-locked version)—(*O. nerka*). Bright red with green heads. Sockeye juveniles generally rear in lakes, so this species is dependent on connections between river and lake ecosystems. Second most abundant salmon species. Farthest migration of this species is 1600 km to Redfish Lake. Mature at 2-4 kg.

Chum (aka Dog or Keta)—(*O. keta*). Spawners are greenish, with white tips on fins, and vertical stripes. Generally spawn in lower reaches of rivers. All are anadromous and semelparous. Spawners are 3-6 kg.

Pink (aka Humpies or Humpback)—(*O. gorbuscha*). Males have exaggerated hump, often with dark brown backs and white bellies. Smallest of the Pacific salmon (~2 kg). Often spawn in low gradient coastal streams with smaller sediment. They mature at 2 years old. Most abundant salmon species. Are semelparous.

Life-Cycle

- *Egg*—salmon eggs are buried by the mother salmon in a gravel nest, under 20-50 cm of gravel.
- *Redd*—salmon nest
- *Aelvin*—hatchling salmon with external yolk sac.
- *Fry*—young salmon that has emerged from the gravel (now without external yolk sac).
- *Parr*—young salmon that are rearing in freshwaters (older than fry).
- *Smolt*—transitional stage as the young salmon readies itself to migrate out to the ocean.
- *Immatures* (oceanic)—salmon growing up in the ocean.
- *Spawning adults*—sexually mature salmon that have returned to the spawning grounds.

STATUS OF SALMON

Management: Given that salmon are locally adapted populations, salmon management has increasing focused on managing groups of populations, such as *Evolutionary Significant Units* (in United States) or *Conservation Units* (Canada). This management is difficult, controversial, and often uneasily tried to balance the needs of people (hydroelectric, water) vs. salmon.

General: Many populations of salmon are extinct, some are endangered or threatened, and some are doing great. For example, Bristol Bay sockeye salmon (the largest sockeye salmon fishery in the world) has sustained high levels of fishing for over 100 years. It is now the most productive it has been in the last century.

Population diversity
(these numbers are for populations in the lower 48 states from Gustafson et al. 2007)

Spp	**# pops. extant (extinct)**	**Extinct (%)**
Steelhead (stream-type)	118 (54)	31
Steelhead (ocean-type)	318 (19)	19
Chinook (stream-type)	104 (54)	54
Chinook (ocean-type)	133 (21)	21
Sockeye	38 (34)	47
Coho	135 (50)	27
Chum	89 (23)	21
Pink	18 (9)	18

THREATS TO SALMON POPULATIONS
Threats to salmon have been categorized into the 4H's (plus 2C's). Salmon declines can be attributed to a combination of all of these factors.

Hydroelectric—dams without passages directly block salmon migration, decreasing habitat and causing extinction of populations. These extinction have been unevenly distributed across the landscape. Dams without passages may also increase mortality of migrating salmon both directly (warming water temperatures) and indirectly (warming water temperatures which increases potential predators).

Habitat—Salmon need cold, clean water. Riparian cover destruction, pollution, fine sediment—all of these degradations can decrease salmon survival.

Hatcheries—There is a long history of attempting to supplement native salmon runs with hatchery salmon. However, there is increasing research showing that hatcheries may dramatically decrease native salmon survival through: subsidizing human fisheries; breeding with native fish causing the lose of native (adapted) genotypes; competition between hatchery and wild fish (both in the ocean and in freshwaters).

Harvest—commercial and recreational fisheries also take a substantial portion of returning fish. It can be difficult to allocate catches in mixed stock fisheries.

and others such as:

Climate—Marine survival is incredibly variable, and due to patterns of upwelling. There are annual and decadal patterns in productivity.

Competition—There is increasing evidence that competition on the high seas between hatchery and wild fish.

IMPACTS OF SALMON ON FRESHWATERS

- Salmon are large and can reach extraordinarily high densities on spawning grounds relative to the size of the constrained freshwaters where they spawn.
- This is probably a function of their anadromous and semelparous life-history.
- Due to these high densities and sizes, salmon can have important impacts on coastal ecosystems.
- This has raised concerns that salmon population losses have had substantial ecosystem consequences.

Ecosystem engineering—Salmon, during digging their nests, physically modify stream ecosystems. Thus, they are an example of a ecosystem engineer.

Salmon nest-digging

- Physically shapes streams
- Exports fine sediments and nutrients
- Is a disturbance of benthic stream algae and invertebrates (reduces their abundance).

Salmon-derived nutrients

Salmon act as a “conveyor belt” of nutrients from the ocean to confined freshwaters. The adults bring back in more nutrients than their offspring. What about steelhead?

- Salmon-derived nutrients are dispersed to riparian areas via several pathways
  - Biotic
    - Direct (grizzly dragging carcass up into riparian area)
    - Indirect (grizzly excreting urea from salmon into riparian area)
  - Abiotic
    - Hyporheic flow transports dissolved nutrients
    - Floods deposit carcasses into floodplains
- The impacts of salmon-derived nutrients are fairly controversial and seem context-dependent.
  - Experiments that have experimentally added carcasses often see increased algal growth.
    - But these experiments don’t include ecosystem engineering impacts of salmon.

- Paleolimnology studies have found that salmon population declines are associated with declines in primary productivity.

- Direct consumption of salmon nutrients is probably important for growth of a variety of consumers (such as grizzly bears and rainbow trout).

- Scientists have suggested that salmon declines have caused a "cultural oligotrophication" of coastal North America. Furthermore, there has been a suggested feedback loop for salmon populations, where nutrients from the parents increase future salmon production. To replace these nutrients, there have been many artificial fertilization attempts.