Did salmon have a marine or freshwater origin?

If we assume a marine origin, the ancestral condition was a homogeneous population, that became more structured as anadromy developed. If the ancestors were in freshwater, then the original condition was many isolated populations, that became more homogeneous when the ocean allowed them to mix.
Anadromous salmon

Common feeding area

Many breeding sites

Alaska

Common feeding area
Catadromous Atlantic eels

Many feeding sites

Breed
Fossil record of salmonids

*Eosalmo driftwoodensis*, described from B.C., and found in middle Eocene deposits (ca. 40 mya), was distinct from Coregonids and Thymallids.

A trout-like fossil was found in Idaho from the late Miocene (ca. 7 mya), somewhat resembling *Hucho*

Pliocene beds in Idaho and Oregon contained fossils indicating that the genera had diverged by about 5-6 mya, and the species of *Oncorhynchus* were largely established by this time

Reviewed by McPhail 1997
Recently, fossil sockeye salmon were discovered in the Skokomish River, flowing into Hood Canal. They are about 1 million years old and show divergence from pink salmon. They were deposited in lake sediments, and are now housed at the U of W’s Burke Museum.

Smith et al. 2007 Quaternary Research 68: 227-238

Post-glacial alluvium

Ancient lake sediments

Varves: sequential layers of clay and silt, clay and silt, etc. where the fossils were deposited
Order Salmoniformes

Suborder Esocoidei (northern freshwater: e.g., pike)
Suborder Argentinoidei (marine: smelt-like or weird)
Suborder Lepidogalaxioidei (1 Australian fw species)
Suborder Salmonoidei (7 families, 35 genera, 149 spp.)
Suborder Salmonoidei

Osmeridae (smelts: northern marine, freshwater, anadromous)

Plecoglossidae (1 diadromous species, the ayu, from Asia)

Salangidae (icefish or noodlefish, Asian freshwater and anadromous)

Sundasalangidae (Asian freshwater)

Retropinnidae (NZ smelts: freshwater, diadromous)

Galaxiidae (southern, freshwater and diadromous)

Salmonidae (northern, freshwater and anadromous)

3 (sub)families: Coregonidae, Thymallidae, Salmonidae
Coregonidae (whitefishes)

Iteroparous, sometimes anadromous fishes, in northern hemisphere lakes and rivers. Spawning takes place in fall, without parental care. Fecundity is high; eggs are small.

Least cisco, Coregonus sardinella
Iliamna Lake, Alaska
Whitefish (Coregonidae)

Mountain Whitefish

Lake Whitefish (Coregonus clupeaformis)

M. Malchoff, LCSG
Common whitefish

(Coregonus lavaretus)

http://www.jjphoto.dk/fish_archive/coregonus_lavaretus.htm
Pygmy whitefish, *Prosopium coulteri*
Thymallidae (grayling)

Four species, all in the genus *Thymallus*, including *T. arcticus* in North America
Grayling spawn in late spring, when ice breaks up. Males court with their huge dorsal fins but there is apparently no redd or parental care. Fecundity is high, and the small eggs hatch in about three weeks.
Salmonidae: salmon, trout and char(r)

1. *Salmo*: brown trout and Atlantic salmon; Atlantic only
2. *Oncorhynchus*: Pacific salmon and trout; Pacific only
3. *Salvelinus*: char(r); Atlantic and Pacific: circumpolar
4. Other genera, less familiar to us…
Hucho perryi

Hucho taimen
Brachymystax
Korea, Japan, China, eastern Russia

 LENOK

细鳞鲑

Brachymystax lenok
Salmothymus obtusirostris
Adriatic trout
Relative genetic similarity among salmonids based on polymorphic proteins

Pink *Oncorhynchus gorbuscha*

Sockeye *Oncorhynchus nerka*

Chum *Oncorhynchus keta*

Coho Salmon *Oncorhynchus kisutch*

Chinook *Oncorhynchus tshawytscha*

Masu *Oncorhynchus masu*

Rainbow trout

*Salmo gairdneri (mykiss)*

Cutthroat trout *Salmo clarki*

Relative similarity among salmonids based on mitochondrial DNA

Sockeye *Oncorhynchus nerka*

Pink *Oncorhynchus gorbuscha*

Chum *Oncorhynchus keta*

Rainbow trout

*Salmo gairdneri (mykiss)*

Coho *Oncorhynchus kisutch*

Chinook *Oncorhynchus tshawytscha*

Relative similarity among salmonids based on analysis of mtDNA

Hypothesized relationships among *Oncorhynchus* species
The evolution of salmonid life history patterns

- Did anadromy evolve from freshwater or marine residence?
- How did female parental care evolve, along with fall spawning, egg burial and large eggs?
- Why do salmonids deposit carotenoids in their muscle, and transfer them to their eggs?
- If carotenoids are so useful, why doesn’t everybody use them?
Compared to other freshwater fishes, salmonids:

- Are larger at maturity
- Mature earlier in life
- Have much larger eggs, and consequently fewer eggs for their size
- Spawn in fall (mostly) rather than spring, with a long incubation period
- Have female parental care, and egg burial
- Are often but not always semelparous
Rajasingh et al. (2007) CJFAS hypothesized:

1) Anadromy and redd construction came first. The demands on muscle performance made the anti-oxidant properties of carotenoids valuable for adults.

2) The surplus carotenoids were secondarily used to enhance embryo survival, and also transferred to the skin and linked to sexual selection.

3) Non-anadromous forms (e.g., kokanee) evolved enhanced uptake mechanisms in carotenoid-limited environments.
Just a very little bit about carotenoids

- They are not manufactured by any animals but are obtained by eating plants that make them (e.g., phytoplankton), or animals that store them (e.g., crustaceans).
- They are strong anti-oxidants, enhancing performance of muscles under oxidative stress, though hard evidence for benefits is limited.
- Their properties may also enhance fertilization and embryo survival in salmonids, though evidence is mixed on this point.
- Despite the ubiquity of carotenoid-rich prey in the diets of many fishes, few have red skin and virtually none other than salmonids develop rich red flesh and red eggs.
- If they are so useful, why don’t other species make use of them?
  - Why don’t all salmon species get equally red?
  - What about “white” chinook salmon?
  - How is redness linked to other traits?
Carotenoid pigment concentrations vary greatly among salmonid species
Concentrations of carotenoid pigments in eggs of different salmonid species. Data compiled from various sources by Craik (1985).
Fertilization success and survival of embryos and alevins may be enhanced by carotenoid concentration (Craik 1985).
At moderate temperatures (4 – 8 °C), rainbow trout embryo mortality was associated with reduced carotenoid pigment concentration (Craik 1985).
White Chinook salmon

• Chinook salmon populations vary greatly in redness, with Alaskan populations typically much more red (i.e., in the skin) than southern populations
• There are also distinctly “white” chinook salmon, and the frequency of this form varies among populations. Northern populations seem to have higher incidence of this form than southern ones.
• This trait is heritable.
Puget Sound chinook salmon
Elva Creek chinook: photo by Jon Moore
### % white Chinook

<table>
<thead>
<tr>
<th>River or region</th>
<th>% white Chinook</th>
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<tbody>
<tr>
<td>Chilkat River</td>
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<td>Taku River</td>
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<tr>
<td>Stikine River</td>
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<td>Bella Coola River</td>
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<tr>
<td>Willamette River</td>
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<tr>
<td>Southern coast</td>
<td>1.5</td>
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</tbody>
</table>

#### Alaska (mean = 17.1%)
- Alaska

#### British Columbia (mean = 14.3%)
- British Columbia

#### Washington (mean = 2.3%)
- Washington

#### Oregon (mean = 0.67%)
- Oregon

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Hard et al. (1989)

CJFAS