California Salmon in a Changing Climate

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http://www.epa.gov/climatechange/science/recenttc_triad.html
Figure 30. (a) Water-year fractions of total precipitation as rainfall, and (b) water-year centroids of snowmelt timing in the Merced River basin, in response to PCM-simulated climates; heavy curves are 9-yr moving averages.

T: development time

F: scour

T: mortality, spawn timing

O: distribution, growth, maturation, fecundity, survival,...

T & F: migration timing

T: growth, survival

F: migration timing

T: development time

F: scour
<table>
<thead>
<tr>
<th>Species</th>
<th>winter</th>
<th>spring</th>
<th>summer</th>
<th>fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>winter chinook</td>
<td>adults enter FW; fry migrate downstream</td>
<td>adults migrate to headwater springs; smolts enter ocean</td>
<td>adults spawn in headwater springs</td>
<td>fry emerge, rear in springs</td>
</tr>
<tr>
<td>spring chinook</td>
<td>adults in ocean, fry in river</td>
<td>adults enter FR, smolts enter ocean elev. pools</td>
<td>adults hold in high-rivers above barriers to fall chinook</td>
<td>adults spawn in rivers above barriers to fall chinook</td>
</tr>
<tr>
<td>fall chinook</td>
<td>eggs and fry in lower river</td>
<td>smolts enter ocean all in ocean</td>
<td></td>
<td>adults enter FW</td>
</tr>
<tr>
<td>late-fall chinook</td>
<td>adults enter FW and spawn in river</td>
<td>fry in river, smolts (1 y.o.) enter ocean</td>
<td>parr in FW</td>
<td>parr in FW</td>
</tr>
<tr>
<td>steelhead</td>
<td>adults enter FW</td>
<td>adults spawn in small trib.; smolts enter ocean</td>
<td>parr in FW</td>
<td>parr in FW</td>
</tr>
</tbody>
</table>
Fig. 9. Illustration of cumulative effects associated with different life stages of Pacific salmon. It is possible to increase population size, or drive the population to extinction, by only slight changes in survivorship at each life history stage. See Consequences: Cumulative effects for full explanation.
2°C warming
8°C warming
Fig. 6. (A) Total North Pacific catch of pink, chum, and sockeye salmon from 1926 to 1995. (B) Relationship between total catch (solid line) and general atmospheric circulation index (ACI) dotted line, from 1950 to 1995 (ACI is shown to 1996). (C) The relationship between total catch (solid line) and the regime index (broken line) from 1950 to 1995. Note that the CoSum form demonstrates the persistence of trends before and after the change in the late 1970's.
Difference of the monthly average wind-stress curl (N/m²), calculated as 2X-1X, for (a) Apr, (b) May, (c) June, (d) July, (e) August, (f) September. From Snyder, 2003. Geophys Res Let 30: 1823.
CO₂ concentrations 647,428 BC to 337 BC

- Eocene Dome C, Antarctica (Sagardih et al., 2009)
- Vulcano Station, Antarctica (Gammel et al., 2003)

CO₂ concentrations 8947 BC to 1975 AD

- Lower Dome, East Antarctica (Shand et al., 1999)
- Siple Station, West Antarctica (Eccles et al., 1999)

CO₂ concentrations 1959 AD to 2006 AD

- Dome Fuji, Antarctica (Shindle et al., 2000)
- Cape Vema, Atlantic Ocean (Shindle and Tang, 2000)
- South pole, Antarctica (Svensen and Tang, 2000)
- Lomellina Island, Italy (Chinnell et al., 2001)
- Shackleton Island, Antarctica (Shindle et al., 2002)

http://www.epa.gov/climatechange/science/images/atmosph_conc_co2-lg.gif