Forecasting the impacts of Global Warming on Pacific Salmon
### Pacific salmon species

<table>
<thead>
<tr>
<th>Species</th>
<th>Average Age</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pink Salmon (O. gorbuscha)</td>
<td>2 years</td>
<td>(2 years)</td>
</tr>
<tr>
<td>Chum Salmon (O. keta)</td>
<td>4 years</td>
<td>(3 – 6 years)</td>
</tr>
<tr>
<td>Sockeye Salmon (O. nerka)</td>
<td>4 years</td>
<td>(4 – 6 years)</td>
</tr>
<tr>
<td>Coho Salmon (O. kisutch)</td>
<td>3 years</td>
<td>(2 – 4 years)</td>
</tr>
<tr>
<td>Chinook Salmon (O. tshawytcha)</td>
<td>4 years</td>
<td>(1 – 7 years)</td>
</tr>
</tbody>
</table>
Japan 30%
Russia 24%
Alaska 40%
Canada 4%
Washington
Oregon
California 2%
Pacific salmon catch by all countries

2007 Highest ever
(1,040,000 tonnes)
Pink and chum salmon catch by all countries is increasing

88% of total salmon catch

Total Pink + Chum catch

Pink salmon only

Pink and chum salmon catch by all countries is increasing.
The percent of pink and chum salmon in the total Pacific salmon catch
The percent of sockeye salmon in the total Pacific salmon catch

![Graph showing the percent of sockeye salmon in the total Pacific salmon catch from 1920 to 2000. The graph indicates variability in the percent over time, with peaks and troughs.]
The percent of coho and chinook salmon in the total Pacific salmon catch is decreasing.
Catch in Russia is increasing and recent estimates may be 30% higher than reported.
% of the total catch by Canada

![Graph showing the percentage of the total catch by Canada from 1920 to 2000. The graph indicates significant fluctuations with a peak of 24% in 1972 and a decline to 3% by 2000.](image-url)
British Columbia Pacific salmon catch

Number (x 10^6)


1977 ~23 million
1997 ~50 million (predicted)
2003 ~11 million (actual)
2003 ~50 million (predicted)
• Trends in Pacific salmon abundance indicate that natural trends in climate strongly affect production.

• What is the mechanism?

• What causes the abrupt shifts in the trends in climate?
Historic sockeye salmon abundance

Hatchery Production
Hatchery production of chum salmon (NPAFC data)
Hatchery production of pink salmon (NPAFC data)

Number of fish

1993 1995 1997 1999 2001 2003 2005

Canada
Japan
Russia
Alaska

1,000,000,000
2,000,000,000
3,000,000,000

Canada
Japan
Russia
Alaska
Pink salmon hatchery - Russia
Russian hatcheries

• NPAFC data indicates that there are 41 hatcheries producing 600,000,000 pink and chum salmon

• In 2007, about 895,000,000 pink and chum salmon were produced
Russian hatcheries

• There may be 10 more hatcheries on Sakhalin Islands by 2010.

• These 10 hatcheries could produce about 500,000,000 more pink and chum salmon.

• There may be 19 more hatcheries built after 2010, producing ~1,000,000,000 pink and chum salmon, if production doesn’t decline.
Japanese hatcheries

- Japan hatcheries produce ~2,000,000,000 juvenile chum salmon, contributing to ~60% of the total catch
## Estimated annual hatchery production by all countries in 2006/2007

<table>
<thead>
<tr>
<th></th>
<th>Russia</th>
<th>Japan</th>
<th>Alaska</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hatchery</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>pink</strong></td>
<td>474,000,000</td>
<td>147,200,000</td>
<td>808,600,000</td>
<td>1,429,800,000</td>
</tr>
<tr>
<td><strong>chum</strong></td>
<td>421,000,000</td>
<td>2,000,000,000</td>
<td>541,200,000</td>
<td>2,962,200,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>895,000,000</td>
<td>2,147,200,000</td>
<td>1,349,800,000</td>
<td>4,392,000,000</td>
</tr>
<tr>
<td><strong>Adult</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>pink</strong></td>
<td>18,960,000</td>
<td>5,888,000</td>
<td>32,344,000</td>
<td>57,192,000</td>
</tr>
<tr>
<td><strong>chum</strong></td>
<td>12,630,000</td>
<td>60,000,000</td>
<td>16,236,000</td>
<td>88,866,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>31,590,000</td>
<td>65,888,000</td>
<td>48,580,000</td>
<td>146,058,000</td>
</tr>
</tbody>
</table>

- Japan/Alaska/Russia → 3% for chum salmon
- Japan/Alaska/Russia → 4% for pink salmon
Catch of chum salmon produced in hatcheries in 2006/2007

- **Japan** catches 60 million chum salmon (~60% of total catch)
- **Russia** catches 9 million chum salmon produced in hatcheries (~9% of total catch)
- **Alaska** catches 11 million chum salmon produced in hatcheries (~11% of total catch)

Exploitation rates are estimated as 100% for Japan and 70% for Russia and Alaska.
Catch of pink salmon produced in hatcheries in 2006/2007

- **Japan** catches 7 million chum salmon (~3% of total catch)
- **Russia** catches 13.3 million chum salmon produced in hatcheries (~4% of total catch)
- **Alaska** catches 22.4 million chum salmon produced in hatcheries (~10% of total catch)

Exploitation rates are estimated as 100% for Japan and 70% for Russia and Alaska.
• Hatcheries in 2006/2007 contributed approximately 282,000 t to the total **chum salmon** catch or 80%

• Hatcheries in 2006/2007 contributed approximately 57,000 t to the total **pink salmon** catch or 17%
Major factors affecting the future abundance of Pacific salmon as an aggregate of species

- Global warming
- Natural climate trends
- Hatcheries
- Fishing
- Freshwater habitat
Mechanism (1)

• Rapid, early marine growth is necessary for good survival to increase lipid storage for first ocean winter
Mechanism (2)

- Earlier spring in ocean
- Changes carrying capacity – favours pink and chum salmon
- Less favourable for coho and chinook salmon
Conclusions

- Pacific salmon abundance is strongly affected by natural trends in climate.
- The recent warming of the subarctic Pacific has increased the capacity to produce pink and chum salmon but not coho and chinook salmon.
- Hatcheries are a major contributor to stock and recruitment relationships.
Conclusions

• Earlier plankton production may favour pink and chum salmon
• Coho and chinook salmon may be in trouble at the southern limit of their distribution
• A common mechanism regulating marine survival may be the rate of growth in the first few months up to the summer solstice
• It is important to determine what causes the shifts in trends in climate