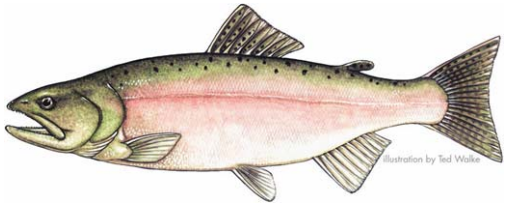
Forecasting the impacts of Global Warming on Pacific Salmon

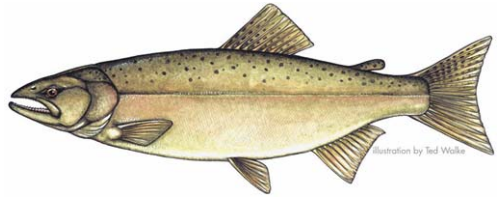
Pacific salmon species



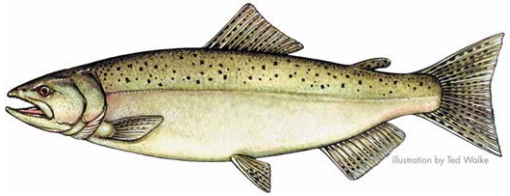
pink salmon (*O. gorbuscha*) — AVERAGE AGE: 2 years — RANGE: (2 years)

chum salmon (*O. keta*) — AVERAGE AGE: 4 years — RANGE: (3 – 6 years)

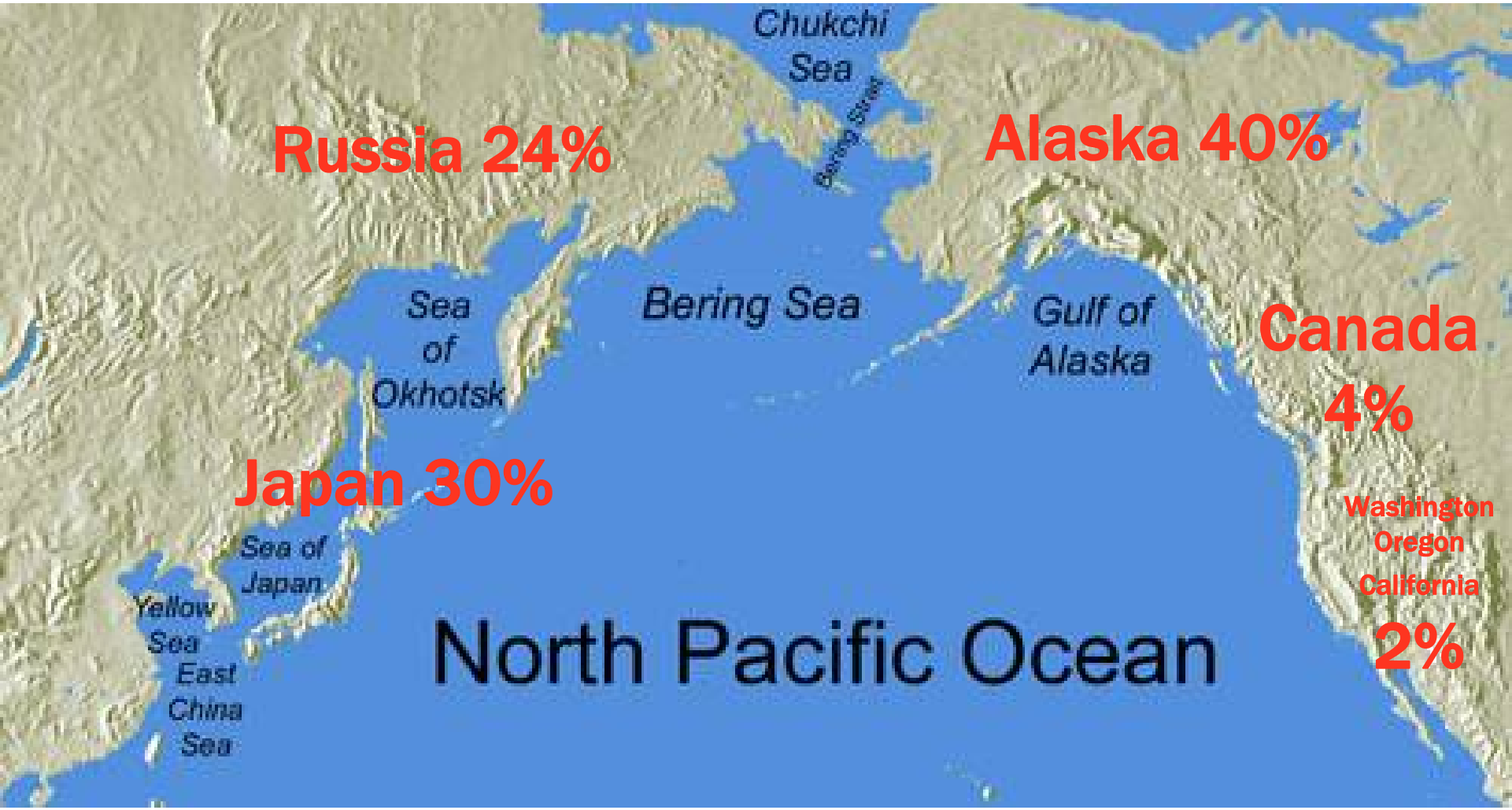
sockeye salmon (*O. nerka*) — AVERAGE AGE: 4 years — RANGE: (4 – 6 years)



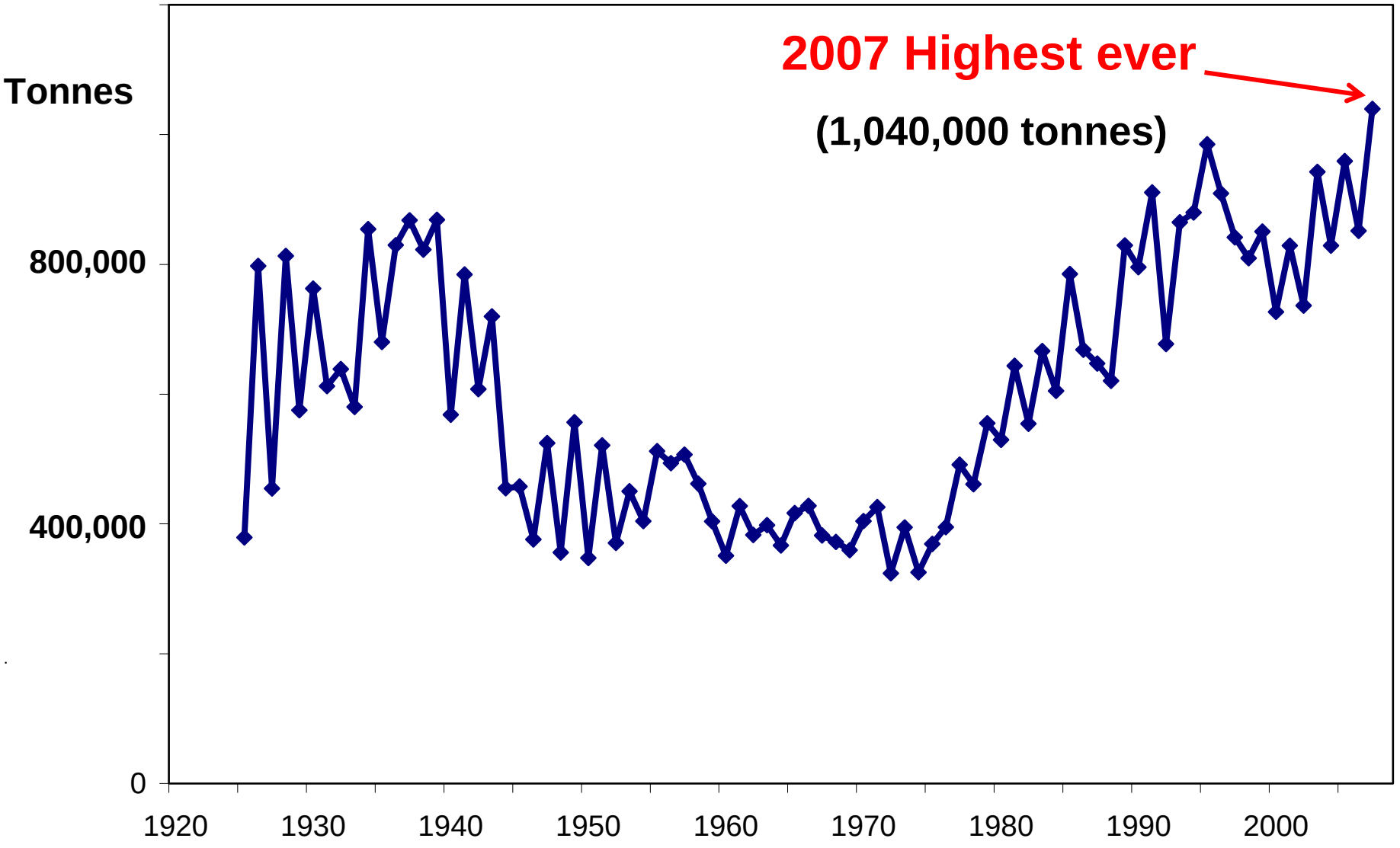
coho salmon (*O. kisutch*) — AVERAGE AGE: 3 years — RANGE: (2 – 4 years)



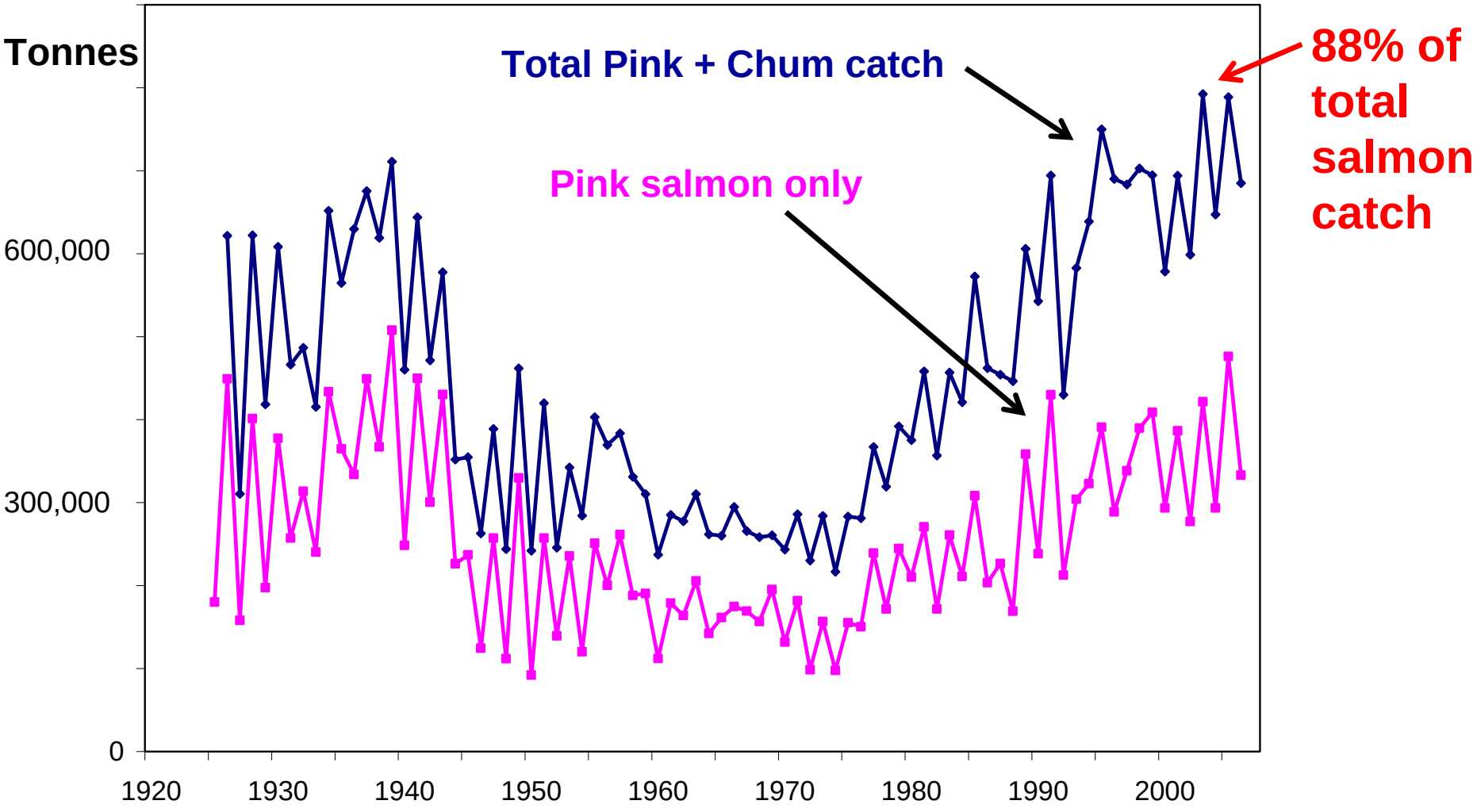
chinook salmon (*O. tshawytcha*) — AVERAGE AGE: 4 years — RANGE: (1 – 7 years)


Chukchi Sea
Bering Strait
Russia 24%
Alaska 40%
Sea of Okhotsk
Bering Sea
Gulf of Alaska
Canada 4%
Japan 30%
Sea of Japan
Yellow Sea
East China Sea
Washington
Oregon
California
2%
North Pacific Ocean

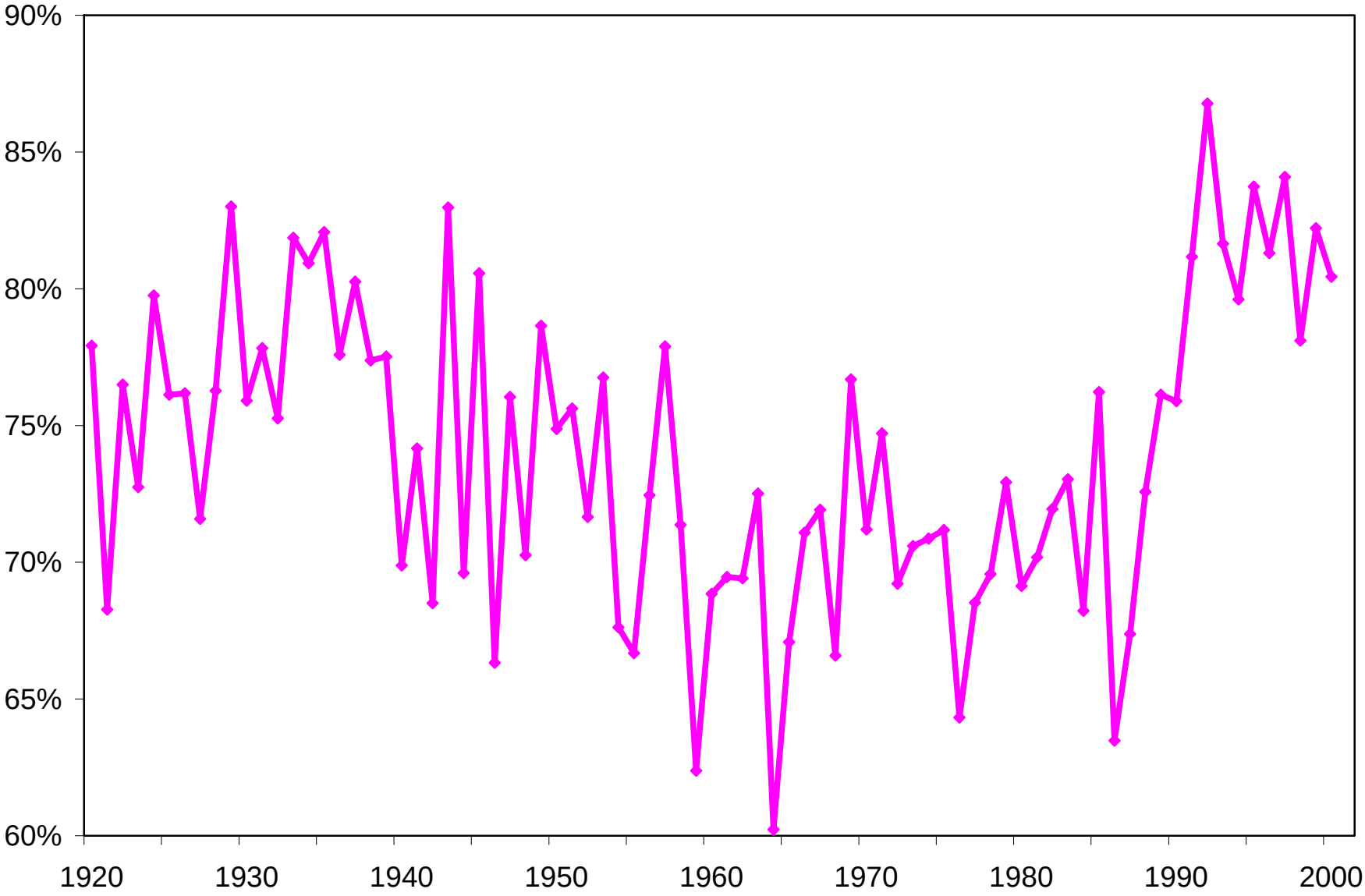
Pacific salmon catch by all countries



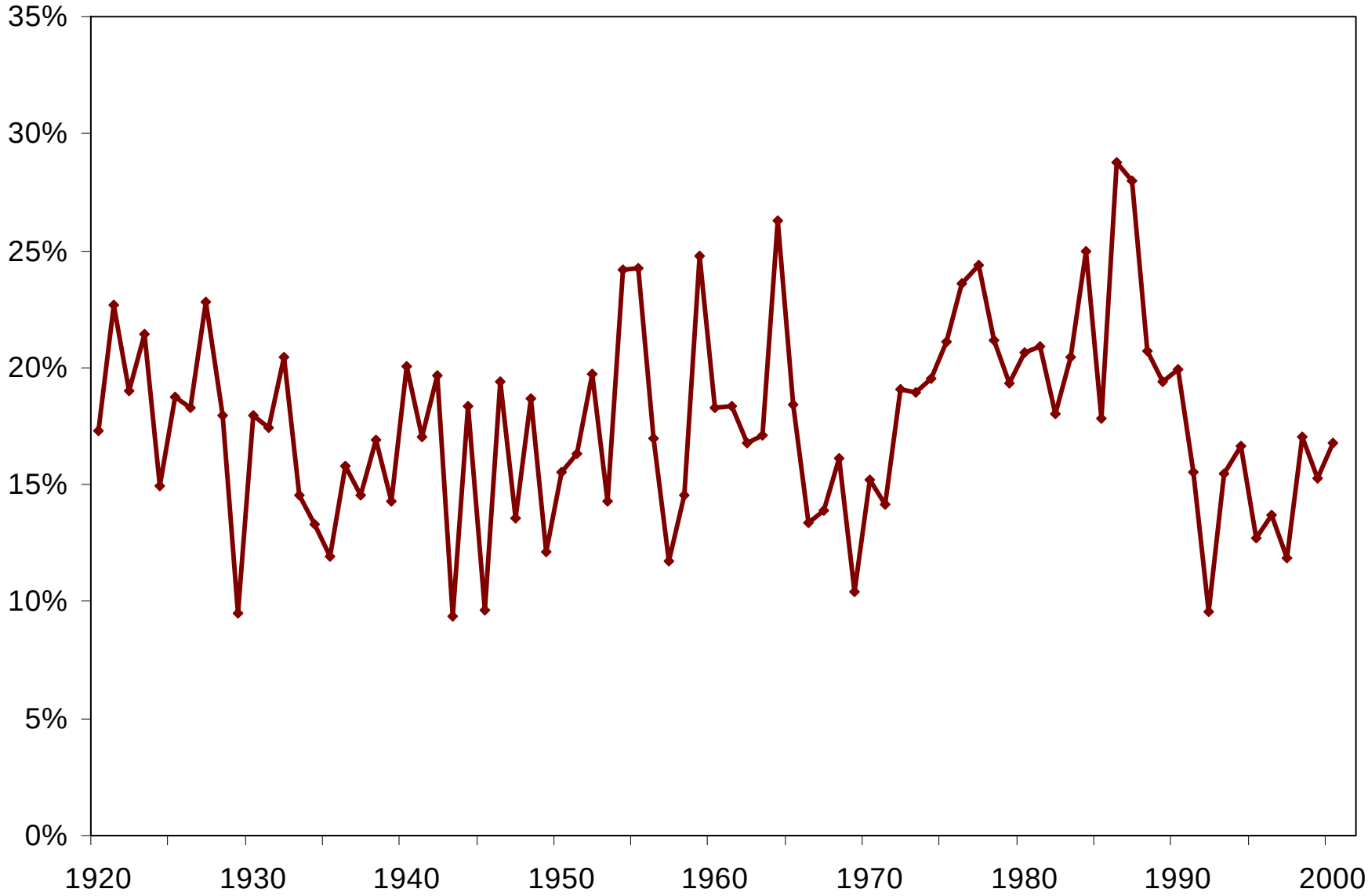
Pink and chum salmon catch by all countries is increasing

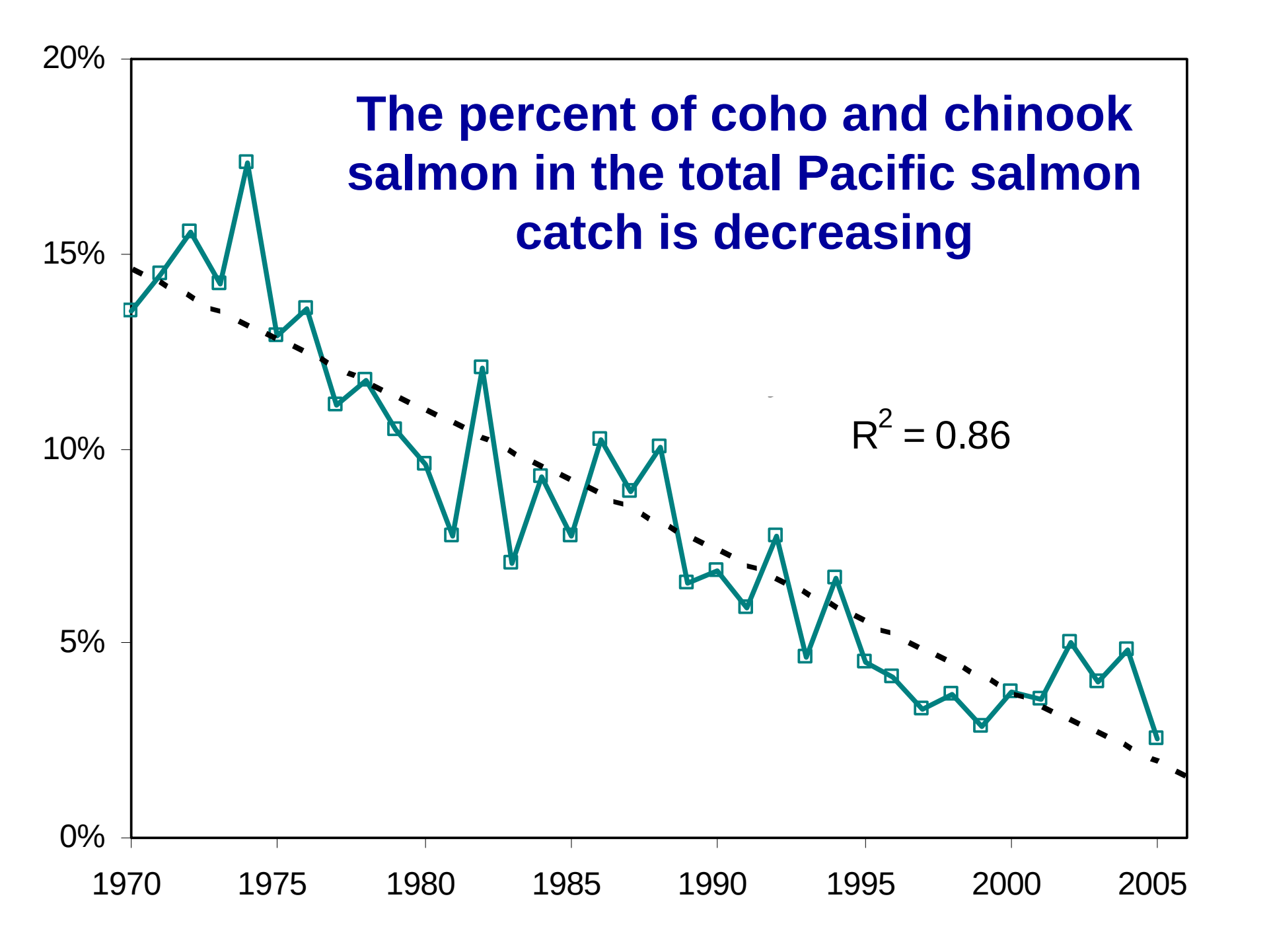


The percent of pink and chum salmon in the total Pacific salmon catch

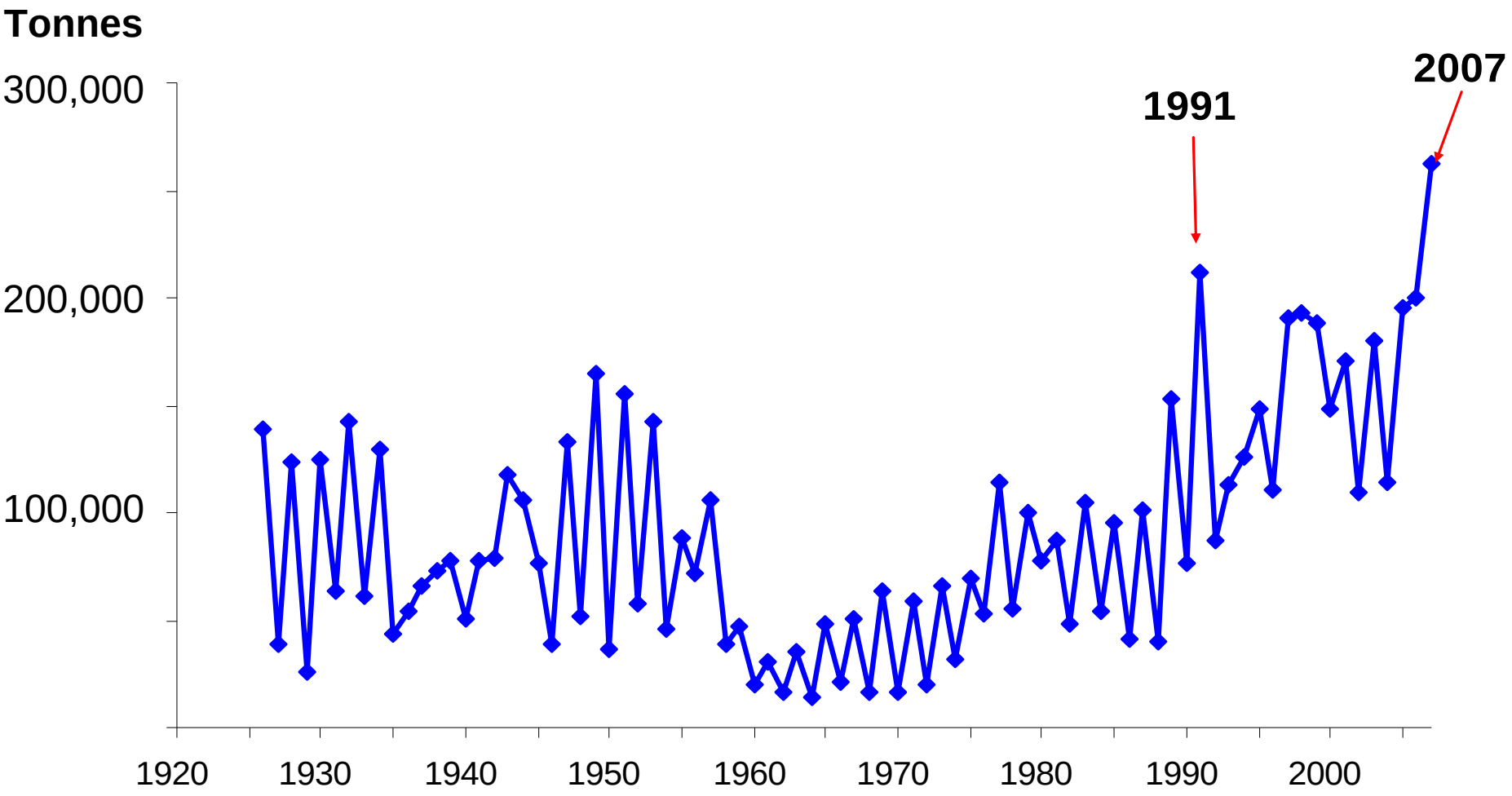


The percent of sockeye salmon in the total Pacific salmon catch

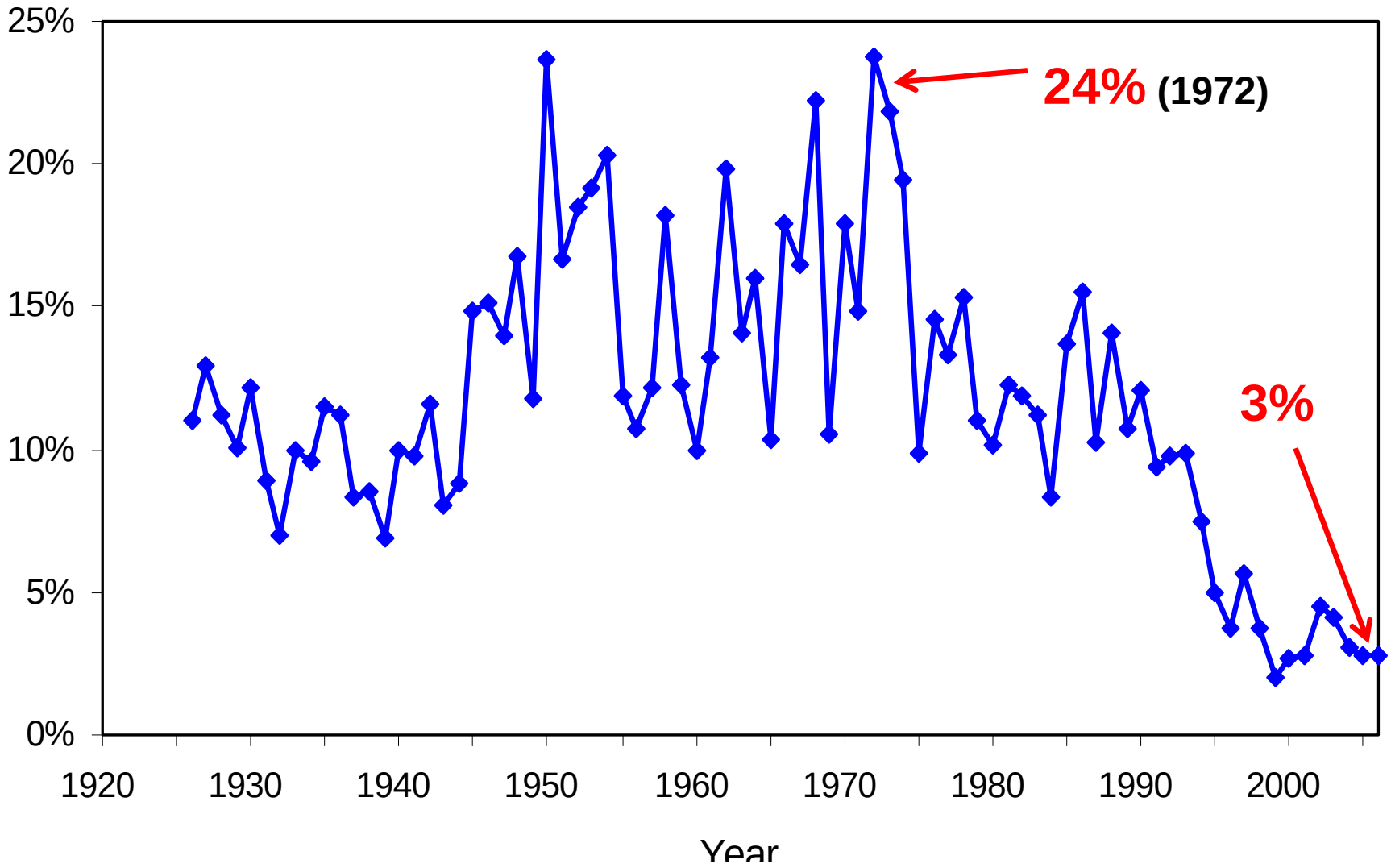



The percent of coho and chinook salmon in the total Pacific salmon catch is decreasing
$R^2 = 0.86$
20%
15%
10%
5%
0%
1970
1975
1980
1985
1990
1995
2000
2005

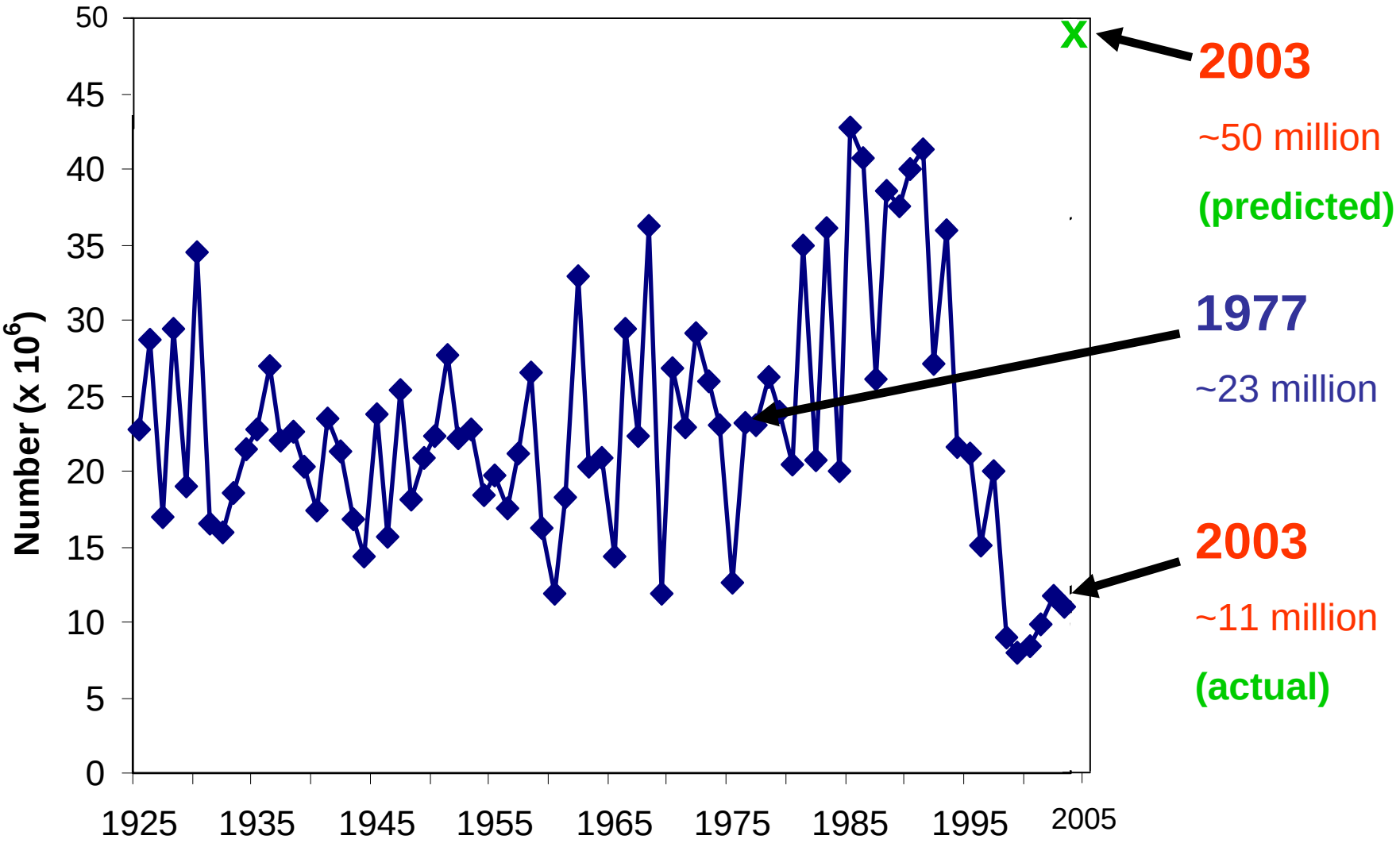
Catch in Russia is increasing and recent estimates may be 30% higher than reported



% of the total catch by Canada



British Columbia Pacific salmon catch

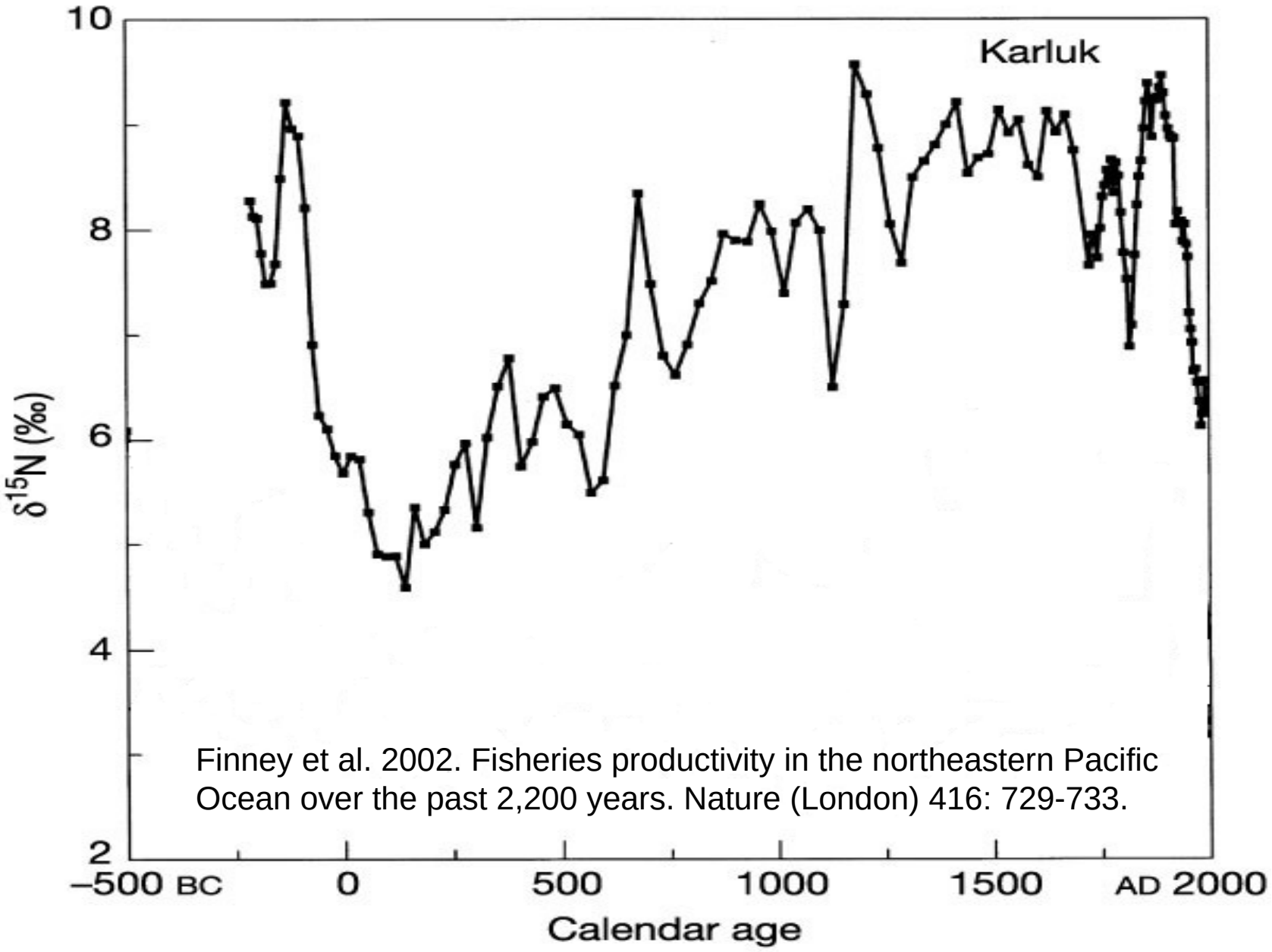


- Trends in Pacific salmon abundance indicate that natural trends in climate strongly affect production.

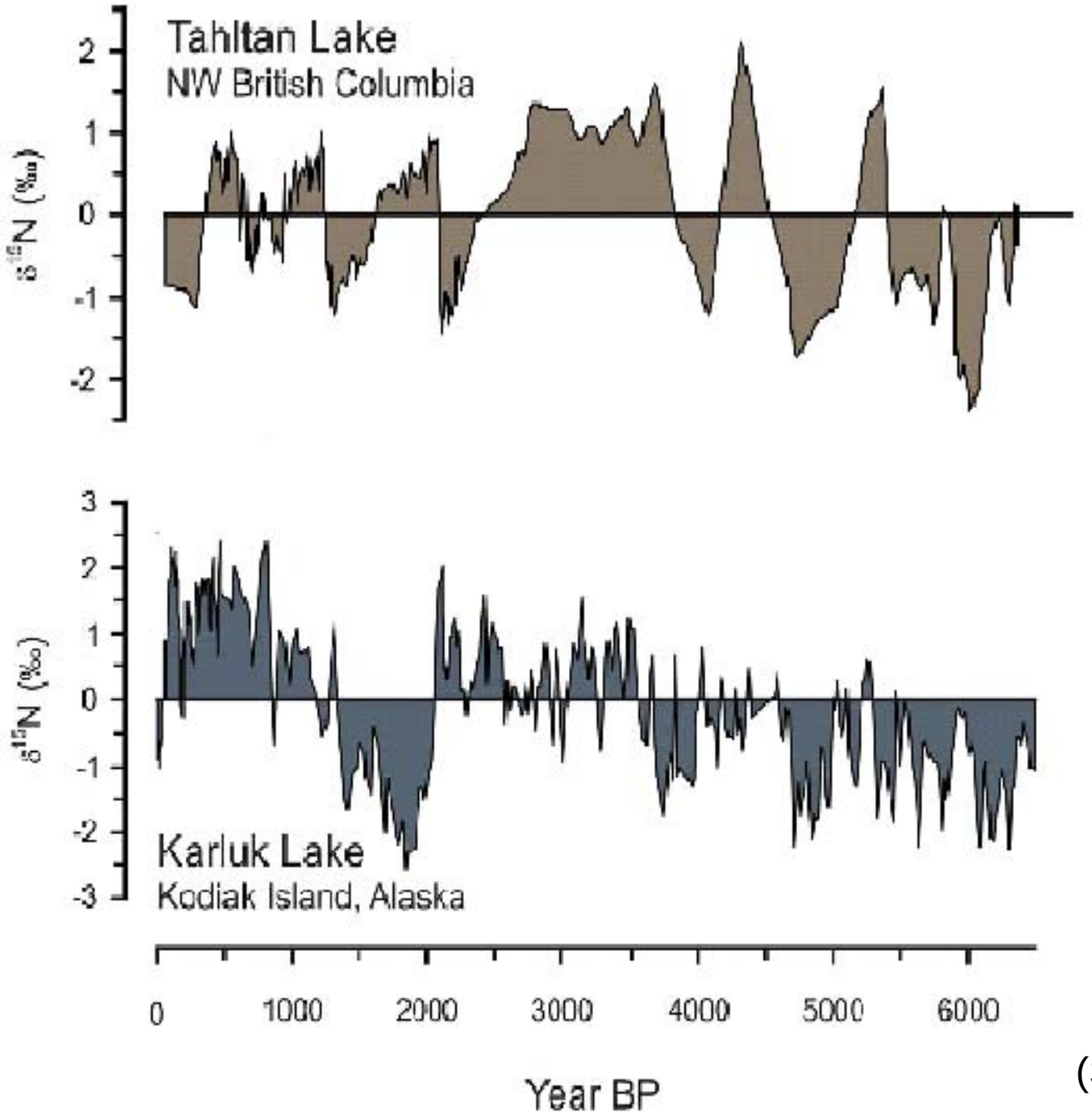
- What is the mechanism?

- What causes the abrupt shifts in the trends in climate?

Historic sockeye salmon abundance



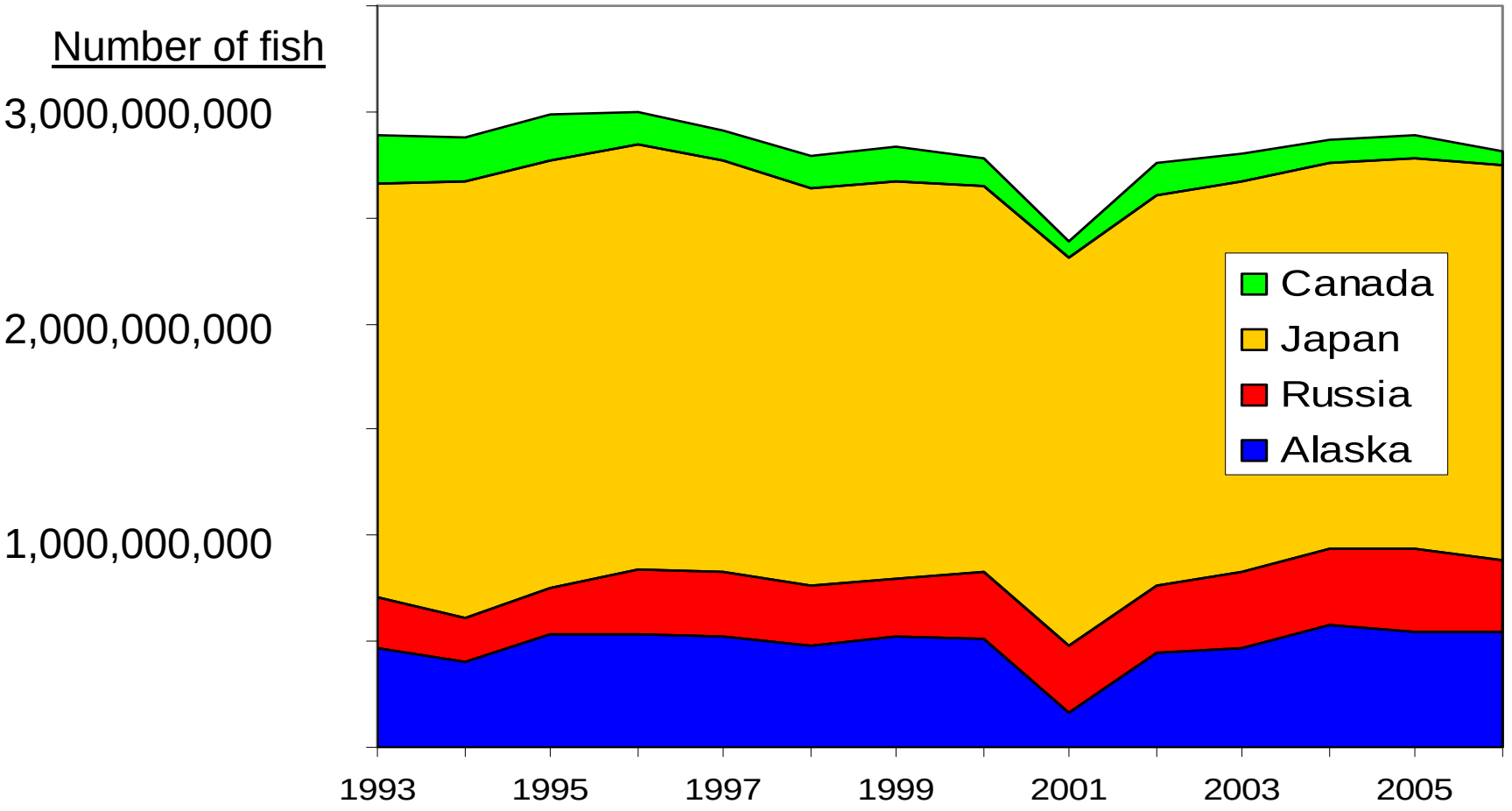
Finney et al. 2002. Fisheries productivity in the northeastern Pacific Ocean over the past 2,200 years. Nature (London) 416: 729-733.


Tahltan Lake
NW British Columbia
$\delta^{15}N$ (‰)
2
1
0
-1
-2
3
2
1
0
-1
-2
-3
Karluk Lake
Kodiak Island, Alaska
0
1000
2000
3000
4000
5000
6000
Year BP

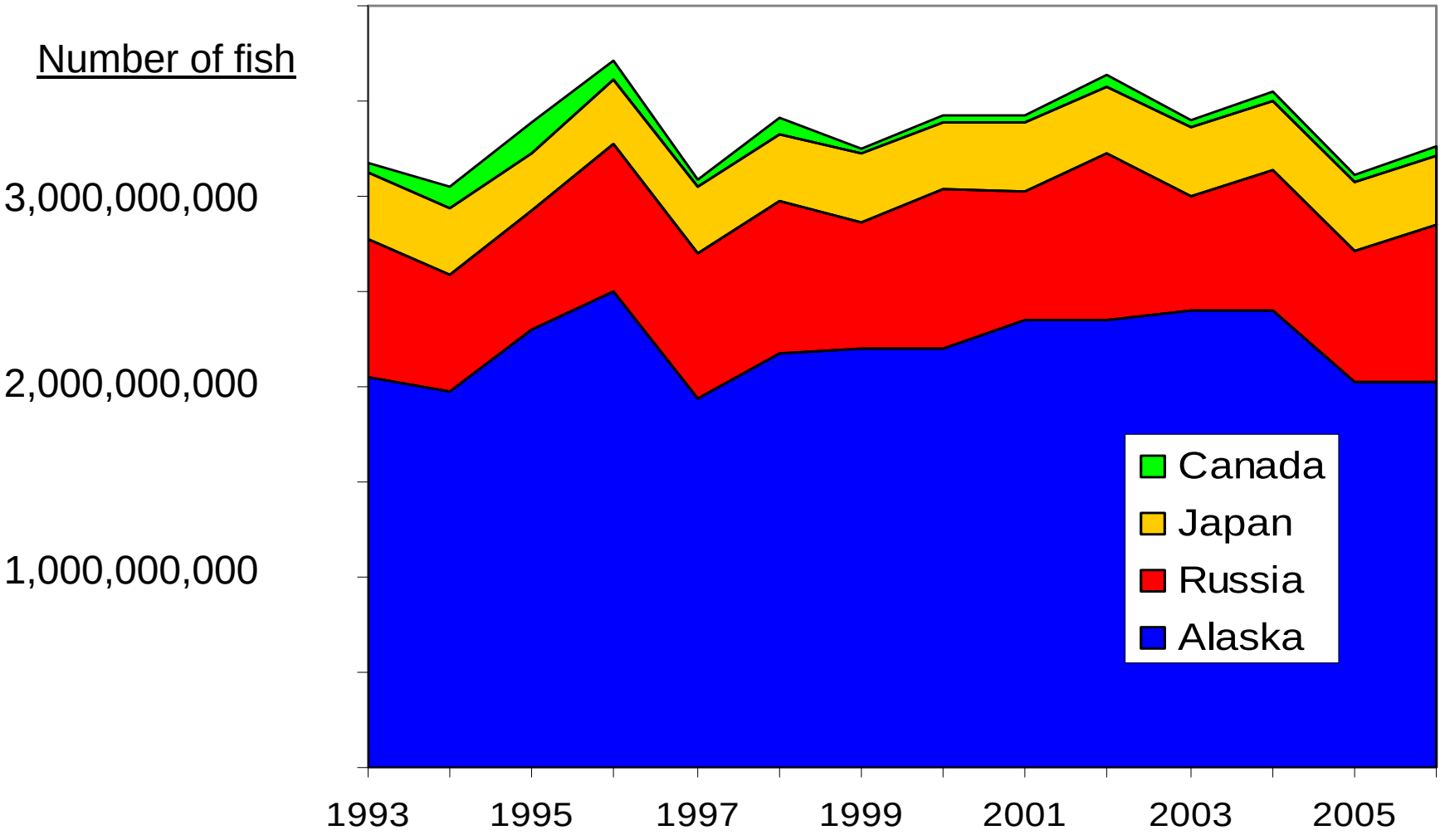
(Selbie 2008)

Hatchery Production

Hatchery production of chum salmon (NPAFC data)



Hatchery production of pink salmon (NPAFC data)




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

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

- *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