The Status of North Pacific Marine Ecosystems -- Synthesis

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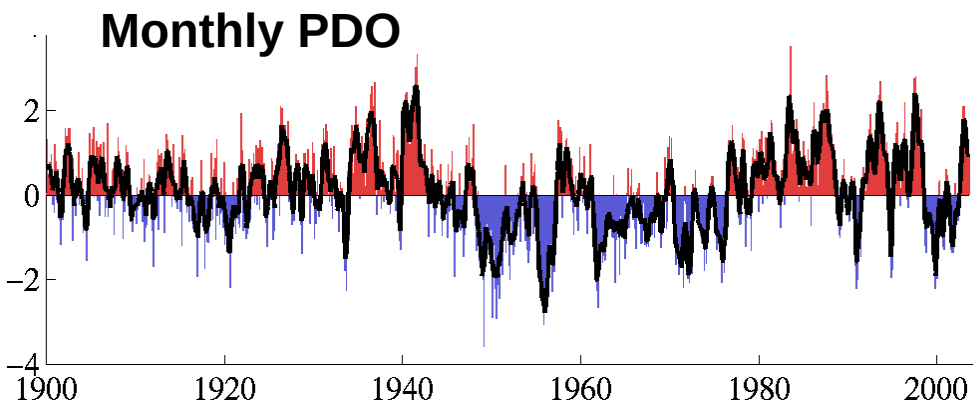
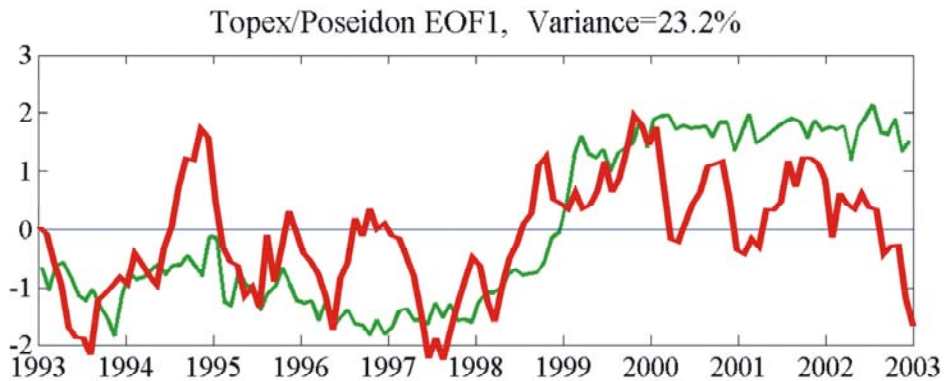
Climate

- positive phase of PDO from 1977 to 1999 (with 1989 uncertain)
- change to negative phase in 1999, but apparent return to positive phase in 2003



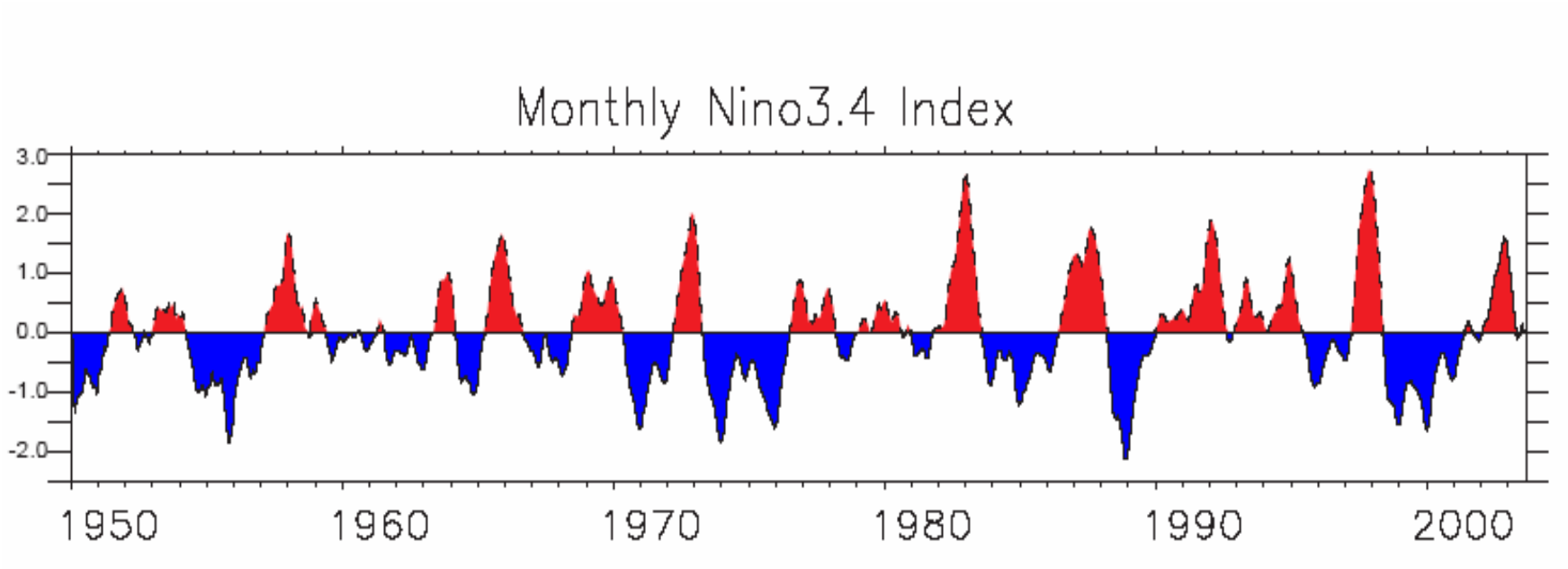
- An index derived from sea surface height (less variable than the PDO) shows the 1999 shift but not the 2003 change



TOPEX/POSEIDON Sea Surface Height Index (green); PDO (inverted – red)

Climate

- **ENSO:**
  - **large El Niño in 1997/98; large La Niña in 1998/99 (and possibly 1989?); moderate El Niño in 2002/03**



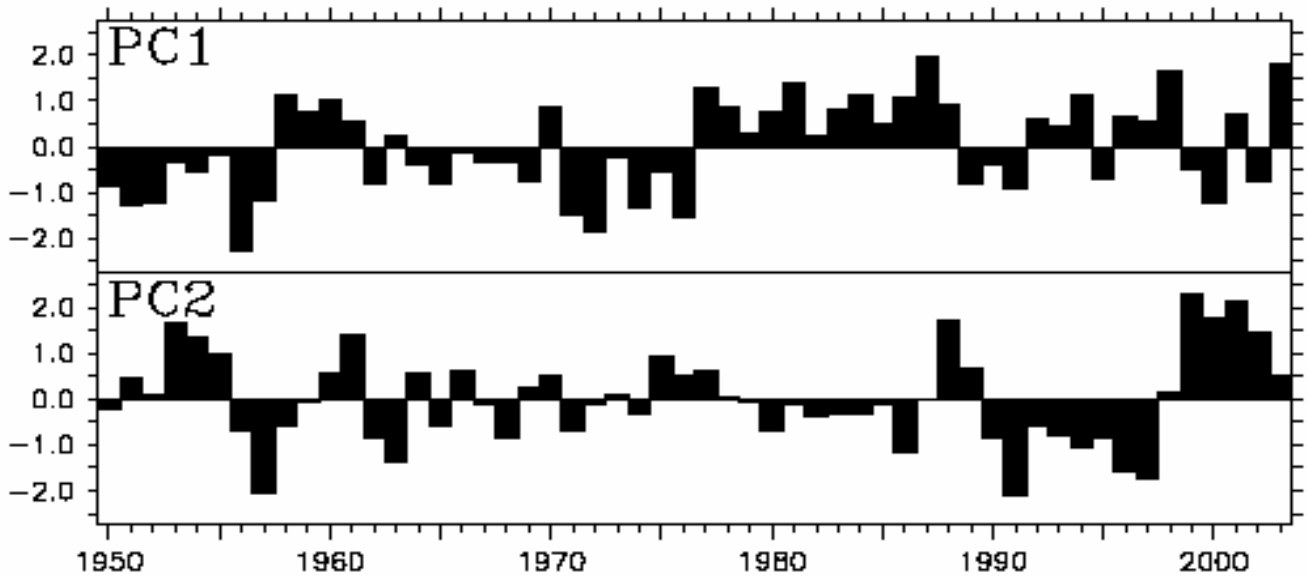
Climate

- **Key climate indices for North Pacific all show strong changes in 1976/77 during the shift from cold to warm phases of the PDO**
- **But – no consistent shift in these indices is seen in the late 1990's (NPESR Climate Chapter)**
- **Past 5 years (1999-2003) resemble neither the positive nor negative phases of the PDO**
  - **represents a second mode of variability not captured by the PDO**

Principal components of North Pacific winter (Nov – Mar) SST;

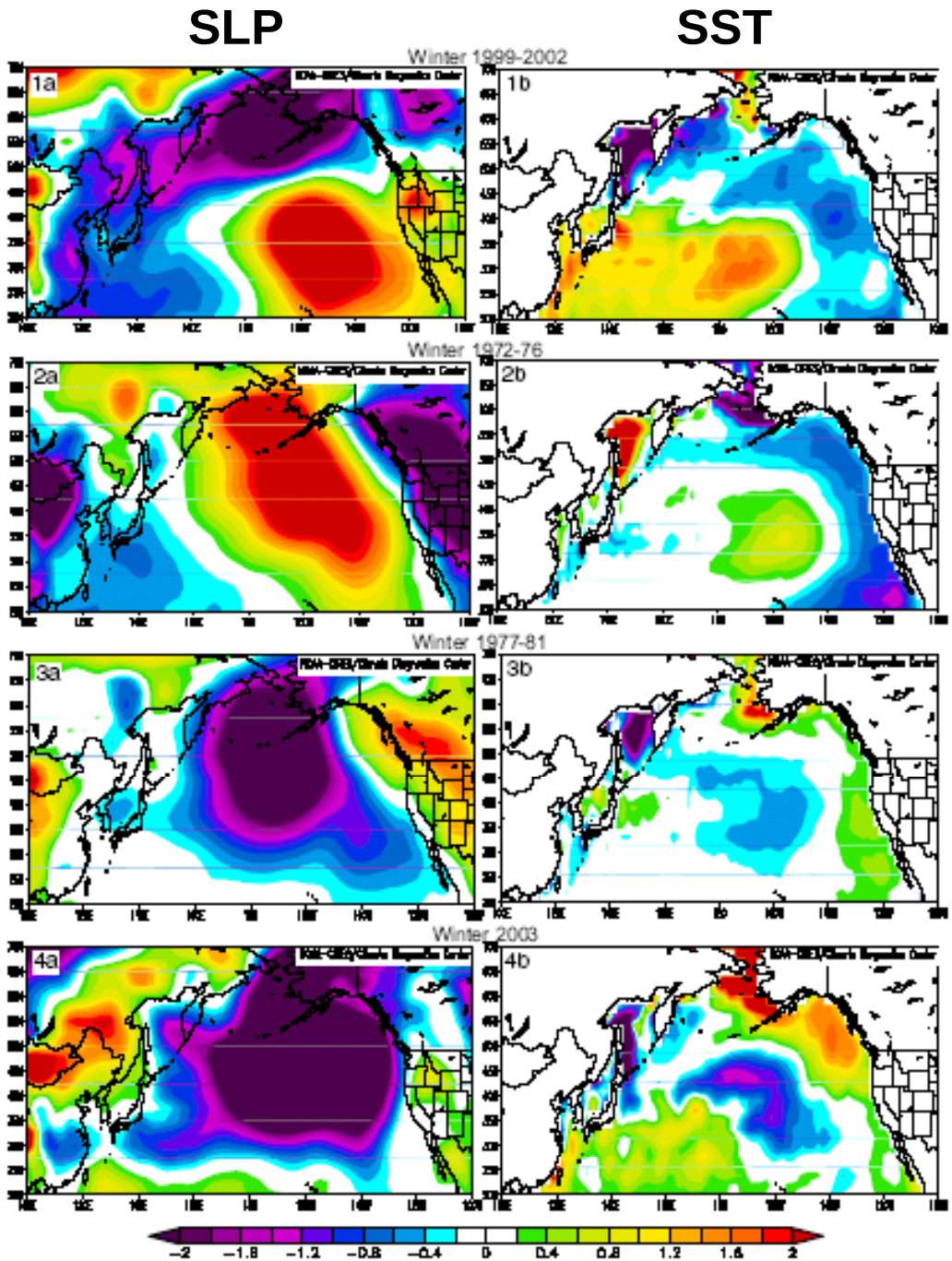
PC1 = PDO (E-W mode)

PC2 = N-S mode



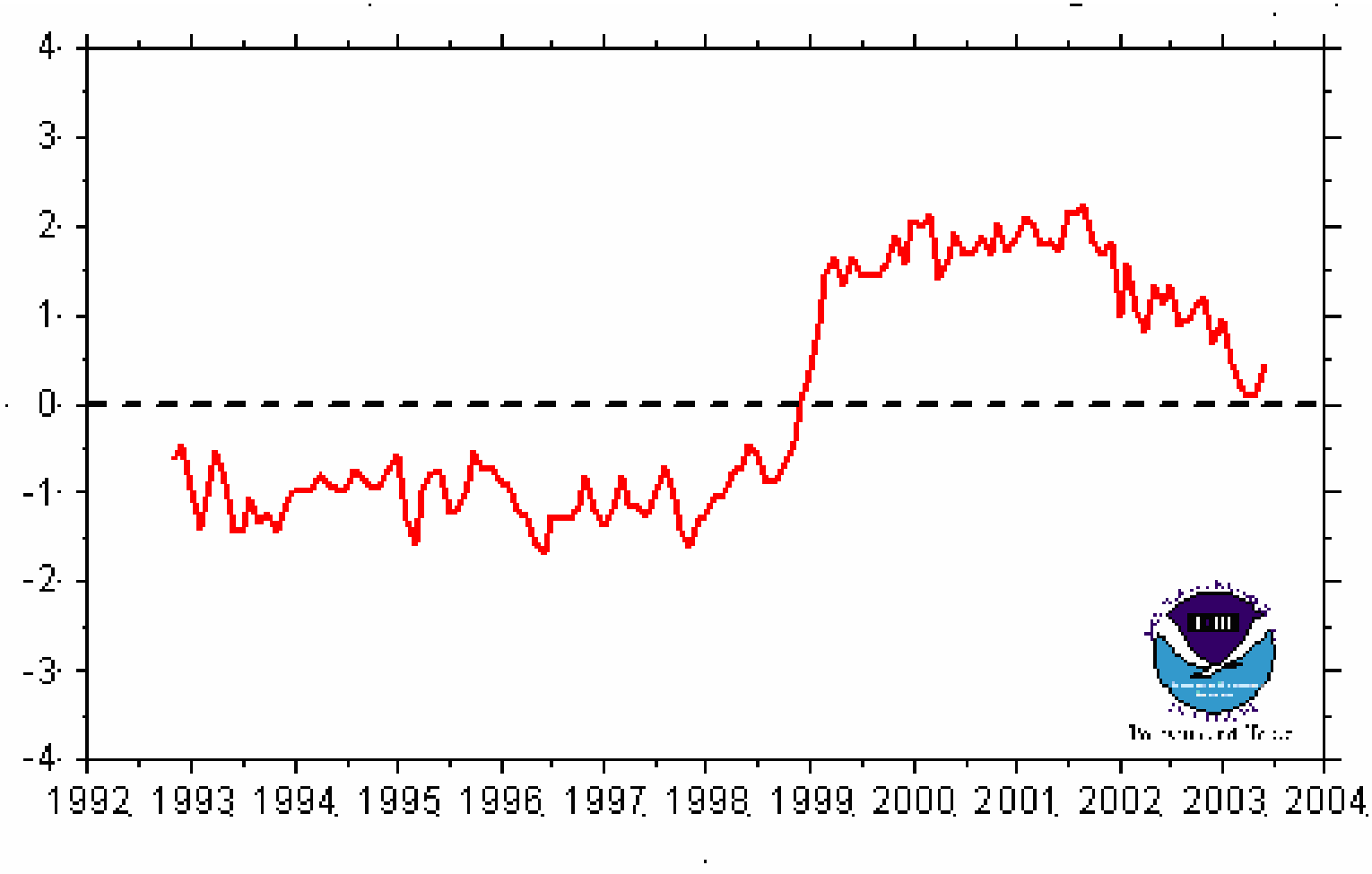
Climate

- **Spatial pattern of this second mode of variability shows strong North – South gradients**
- **Produces strong westerly winds across the Pacific at 45°N**
- **Result is some regions (e.g. Bering Sea) continue conditions during 1990's (warm); other regions (e.g. California Current) resemble conditions pre-1977 (cold)**



Climate

- **Spatial patterns of SLH and SST are consistent with observed variations in the North Pacific Transition Region**



Climate

- **The ENSO events since 1998 generated considerable warming in eastern Pacific in 1997/98, cooling in 1999 – 2000, but warming again in 2002**
- **Energetic zonal winds appear to have deepened the upper mixed layer in the eastern North Pacific (at least from 1999-2002), which had been shoaling throughout the 1990's**
  - **shallowest mixed layer was observed in 2003**
- **These unusual winds also forced a pulse of subarctic water into the California Current System, causing changes to the lower trophic levels**

Productivity

Nutrients

- **Serious lack of consistent and high quality nutrient data for most regions of the North Pacific**
- **In the Gulf of Alaska and California Current Systems, nutrients declined from late 1970's to late 1990's, but have been increasing since 1999**

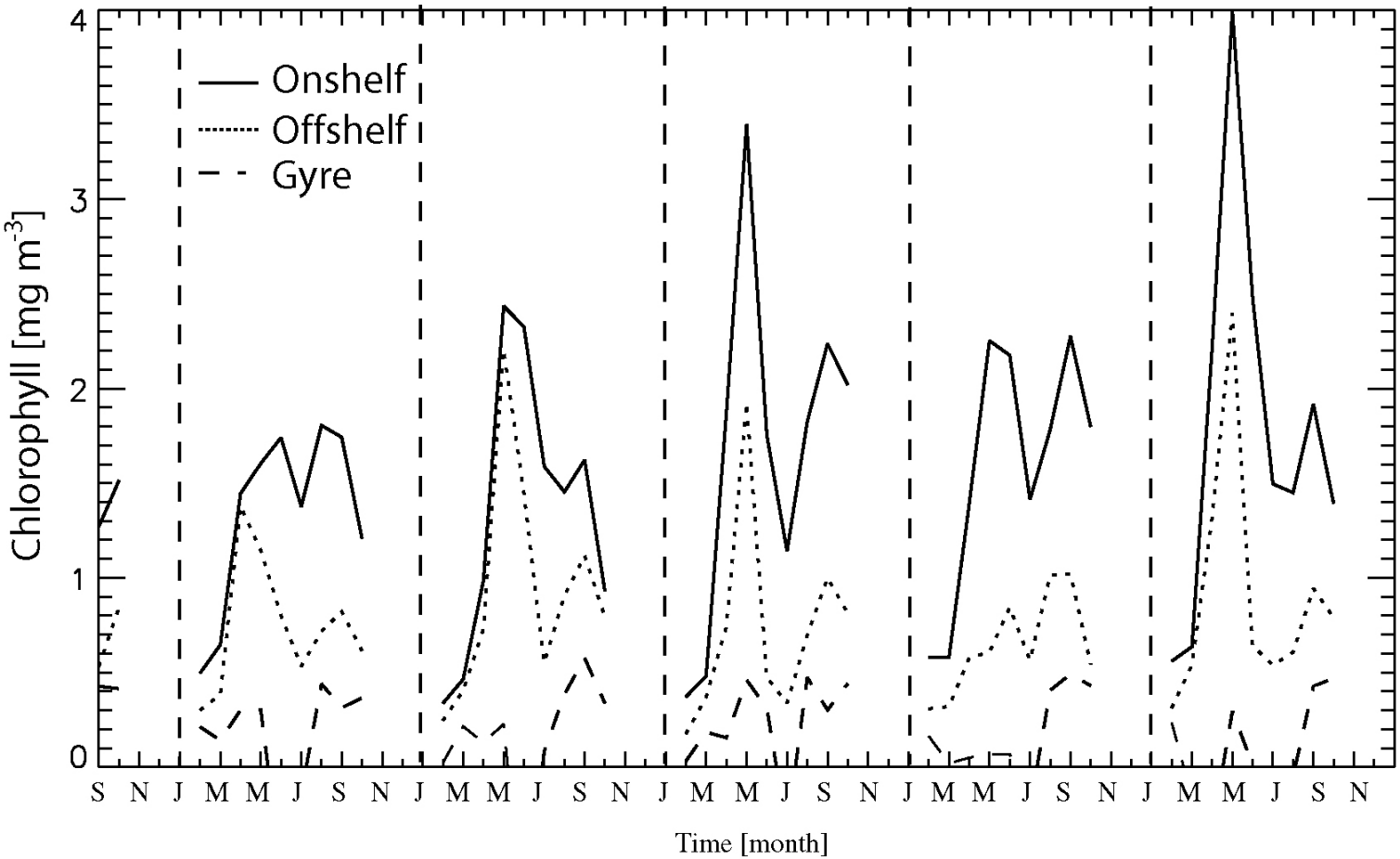
Productivity

Phytoplankton

- **Lack of consistent and detailed phytoplankton data for many regions of the North Pacific, although this may change with longer time series of satellite observations**
- **Consistent with declining nutrients, biomass of phytoplankton has been decreasing in the open ocean areas of the western and eastern North Pacific**
- **Since 1999, have observed increases in phytoplankton in the Yellow Sea, west coast of Japan, Gulf of Alaska, west coast of North America**
- **Higher nutrients associated with subarctic water mass intrusion into the California Current System produced a strong phytoplankton bloom in summer 2002 which sank to bottom and caused low oxygen problems**

Productivity

Phytoplankton



Chlorophyll *a* in the Gulf of Alaska (1998 – 2002)

Productivity

Phytoplankton

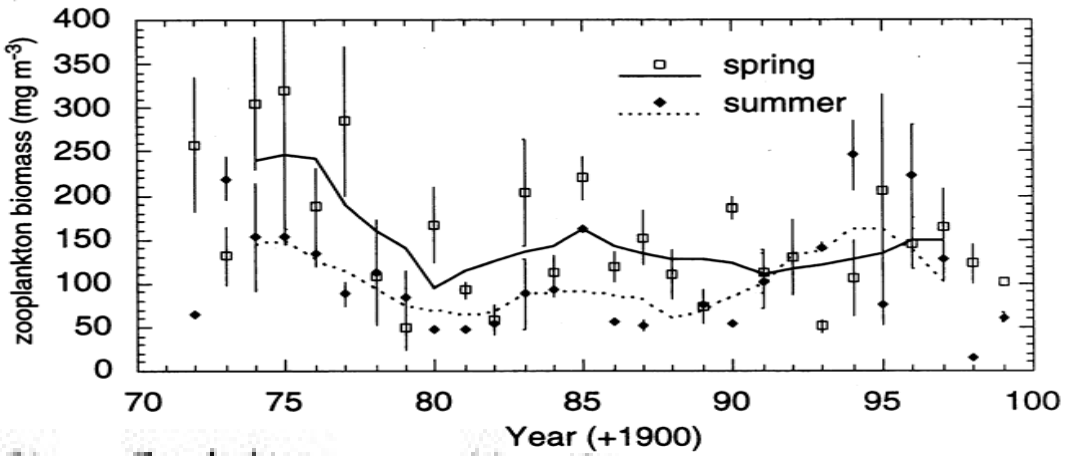
- **Unusual phytoplankton blooms have been increasing in frequency around the North Pacific**
  - **Coccolithophorids (*Emiliana huxleyi*) in the Bering Sea**
  - ***Pseudo-nitschia* spp. (producers of domoic acid) in the California Current System and the Gulf of California**
  - **Harmful algal blooms about Korea and in the East China Sea**

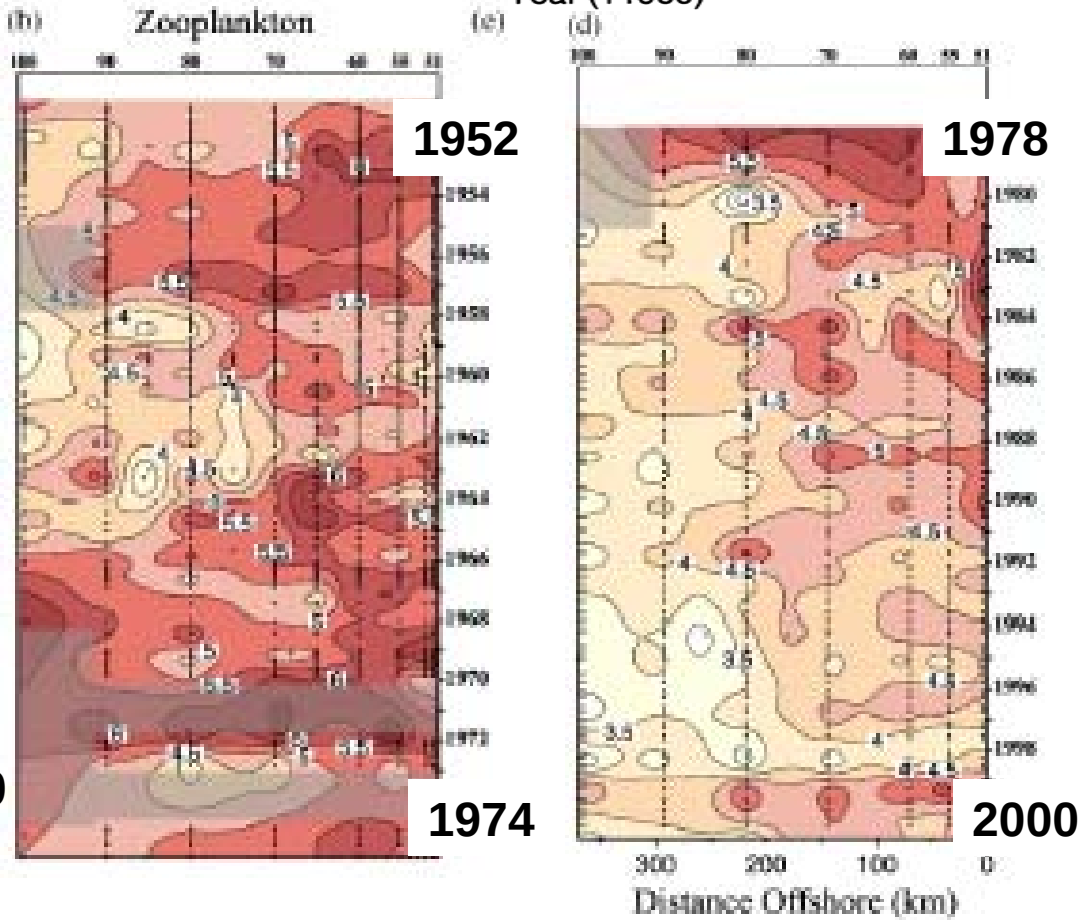
Productivity

Zooplankton

- **Consistent with long-term changes in phytoplankton, zooplankton biomass has been decreasing in the Oyashio waters of the western Pacific and in coastal California over past 30 years (but California appears to be increasing since 1999)**

Sea of Okhotsk



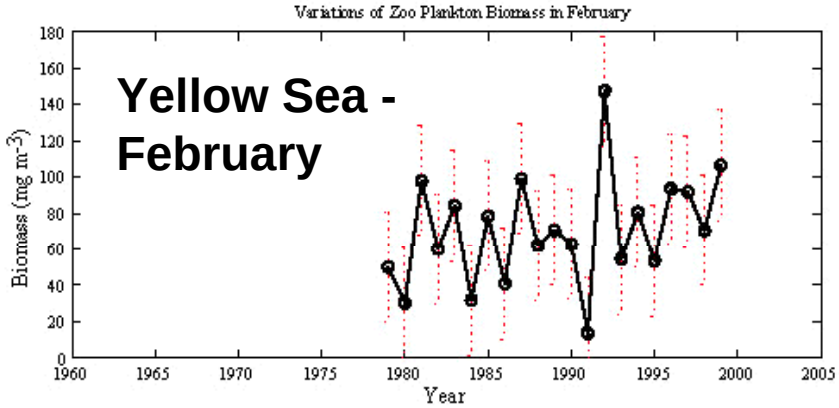


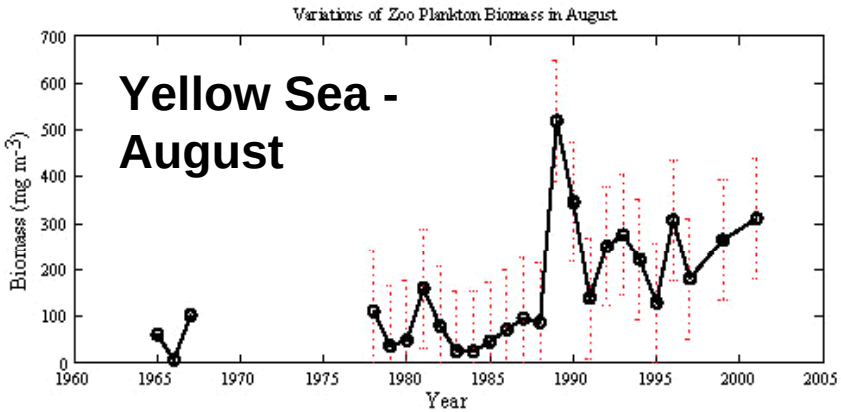
CalCOFI grid line 80

Productivity

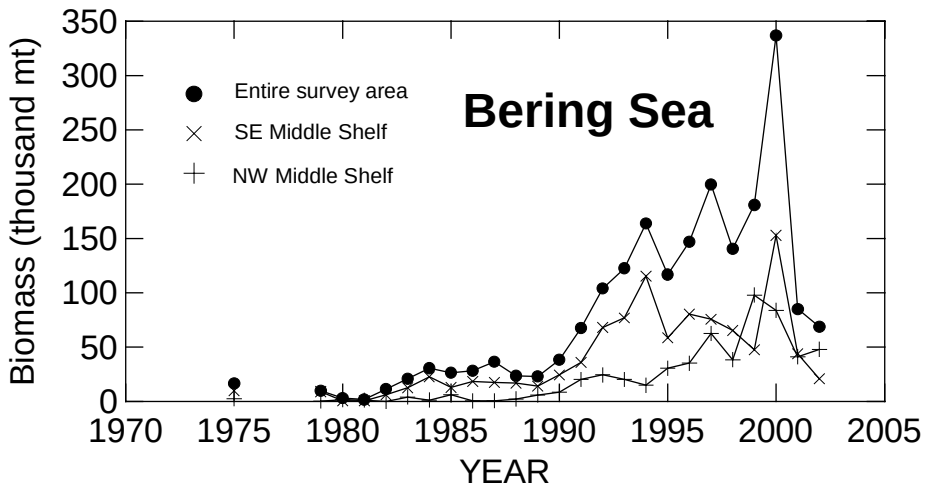
Zooplankton

- **But zooplankton biomass has been increasing in the Yellow Sea and coastal Gulf of Alaska**





- **Unusual blooms of gelatinous zooplankton have occurred, in particular in the Bering Sea**



Productivity

Zooplankton

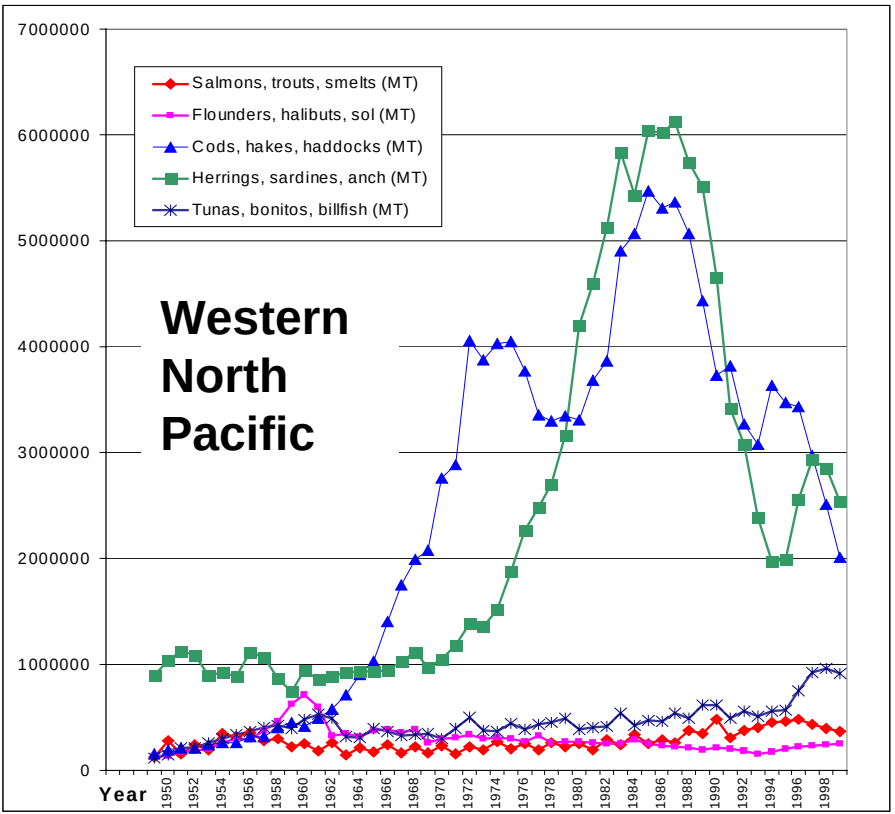
- **Zooplankton species composition along coastal North America and in the Gulf of Alaska has varied with sea temperature, with previously rare southern species increasing in abundance concurrent with El Niño events.**

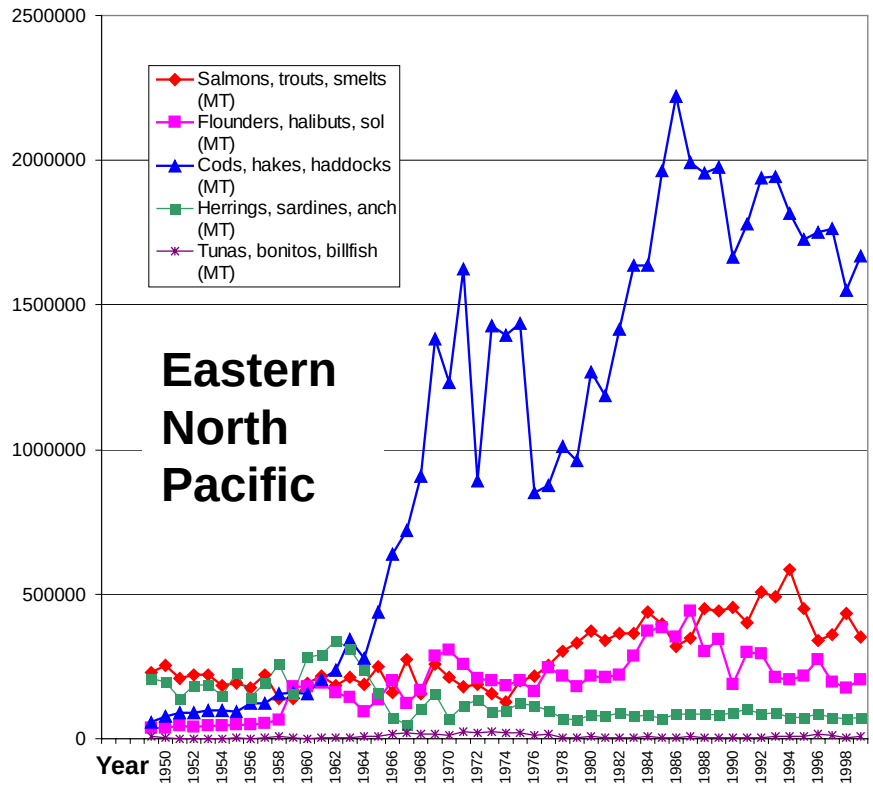
- **The seasonal timing of peak zooplankton biomass, principally due to *Neocalanus*, moved 30-60 days earlier in both the eastern and western subarctic North Pacific as a result of the warmer and shallower mixed layer.**

- **In the eastern North Pacific, the timing of the biomass peak has returned to near-normal since 1999**

Living Resources

- **FAO statistics for the eastern and western North Pacific suggest:**
  - **similar patterns of the cod-hake group in both regions from 1950-2002, although with less of a decline in the eastern North Pacific in the 1990's;**
  - **synchrony of the small pelagics group with the cod-hake group in the western Pacific in the 1980's**

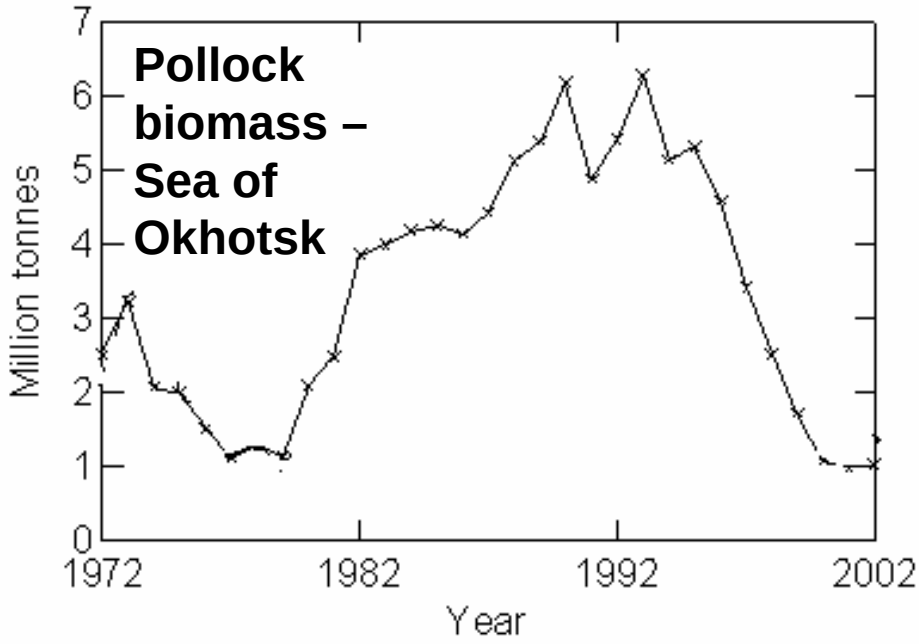




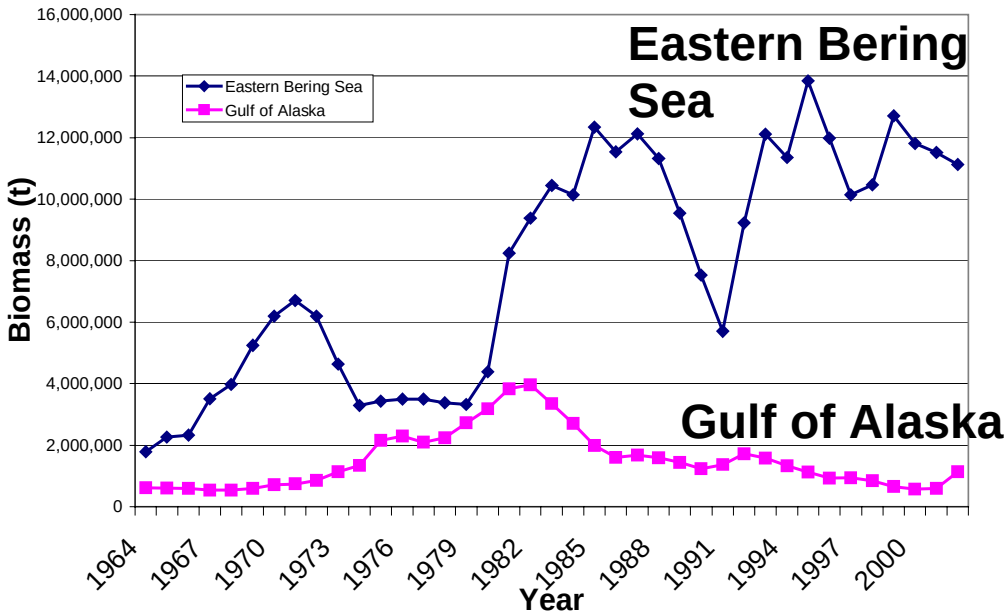
Living Resources

Subarctic Coastal Systems

- **Fish fauna dominated by gadids, flatfishes, crustaceans, with walleye pollock the major species caught**
  - **Recent catches of Walleye pollock in Sea of Okhotsk, Oyashio, coastal Gulf of Alaska, and off North Korea declined by large percentage from 15 years earlier;**
  - **Only eastern Bering Sea has maintained a large and stable biomass of pollock**



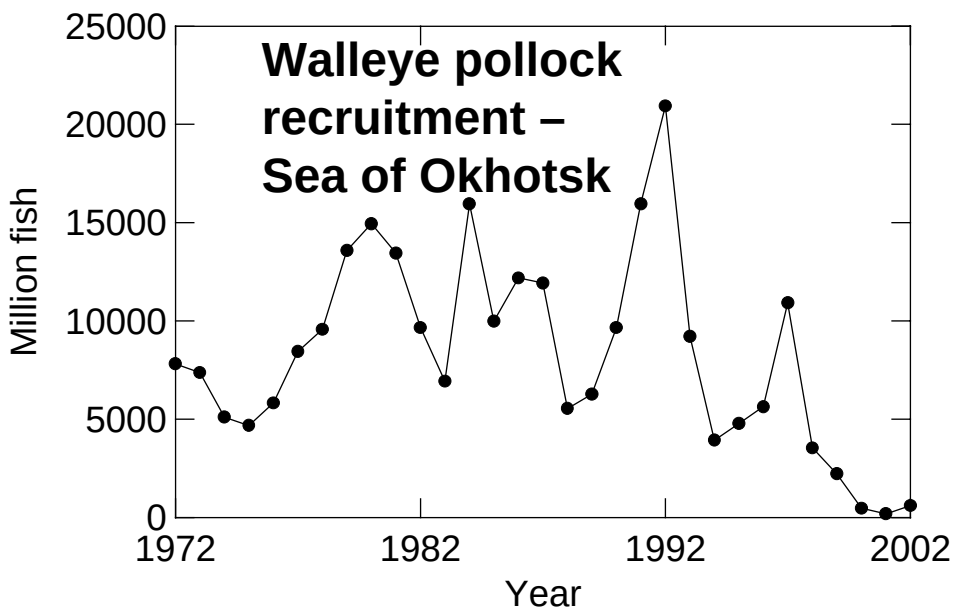
Walleye Pollock Biomass (age 3+)

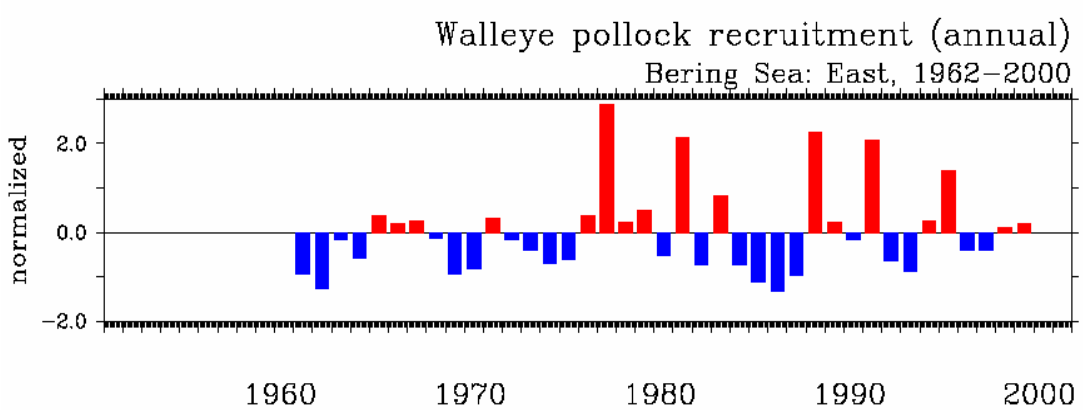


Living Resources

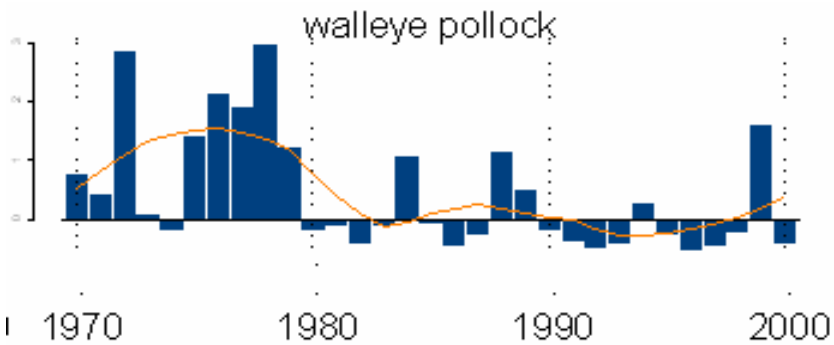
Subarctic Coastal Systems

- **Pollock recruitment has general been low recently, therefore low biomass may be driven by environmental conditions**
- **High and stable biomass in eastern Bering Sea, with conservative management actions, suggests it is important to recognise good recruitment pulses and manage conservatively**





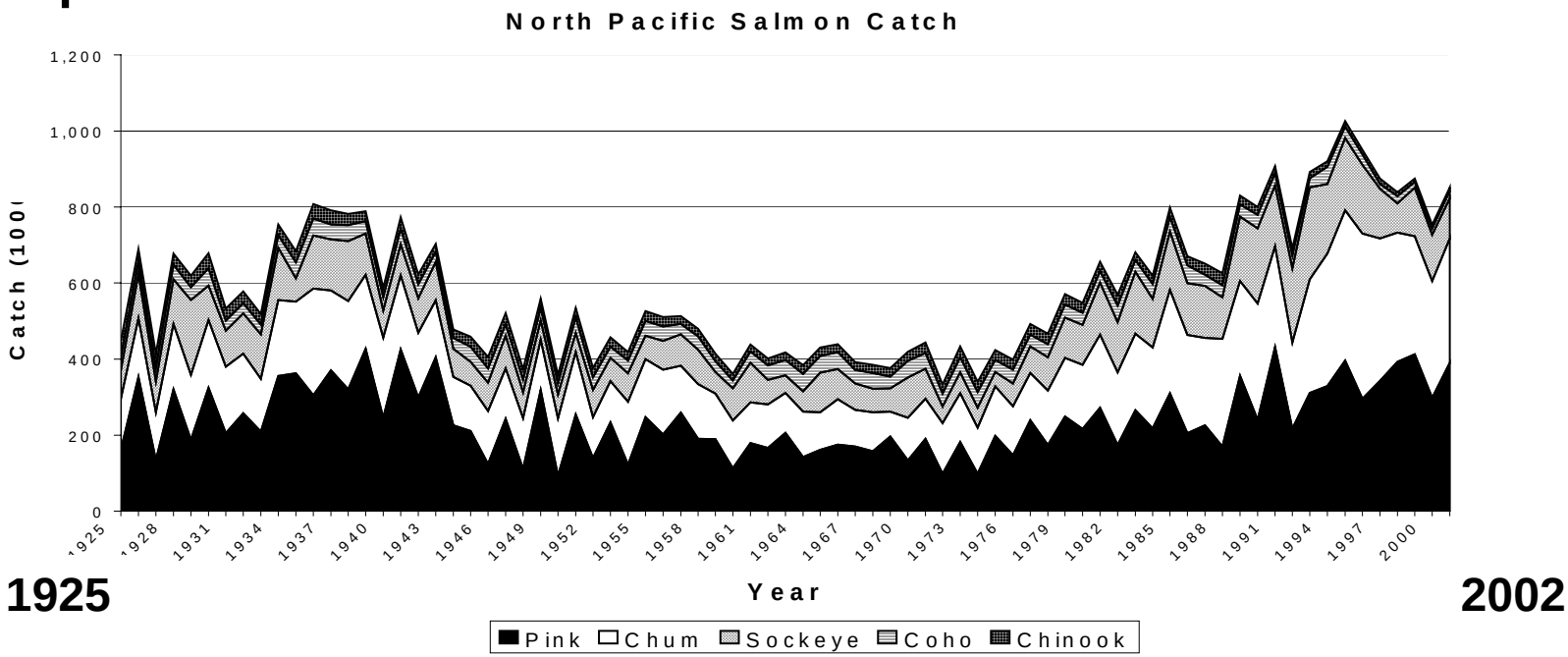
Gulf of Alaska



Living Resources

Central Oceanic Gyres

- **Western and eastern subarctic gyres are dominated by Pacific salmon**
- **Total catches of all salmon species were at historical high levels through 1990's, largely driven by large hatchery releases**
- **Regional differences are important, with stocks in SE part of range experiencing problems during 1990's; there are signs of improvement since 1999**



1925 **2002**

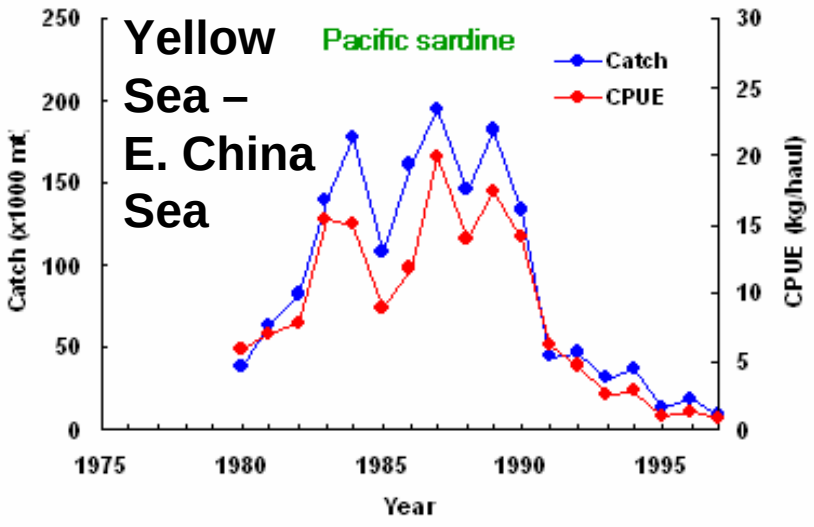
Living Resources

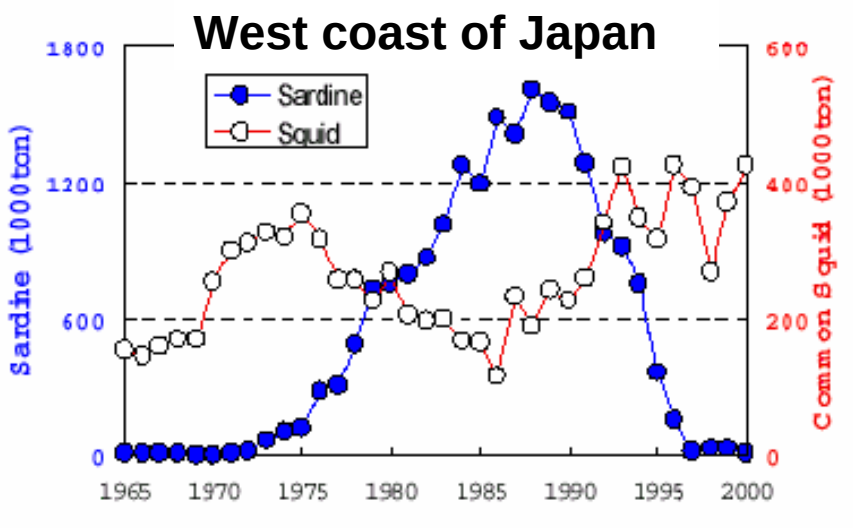
Temperate Coastal and Oceanic Systems

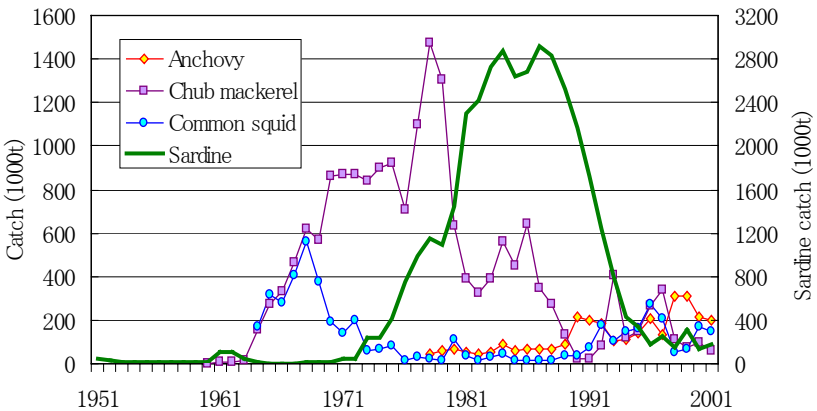
- **Significant fisheries for short-lived pelagic species, as well as demersal species on the continental shelves**
- **Abundances of sardines (in particular) show large fluctuations, often with species replacements:**
  - **Sardine reached very large biomasses in mid-late 1980's in western Pacific (Japan), Yellow Sea – East China Sea, Gulf of California, but then collapsed in early 1990's**
  - **The one region out of synchrony with this pattern is the California Current System, which used to be in phase with Japanese sardine, but remained low in the 1980's and increased in the 1990's.**
  - **It may be that the natural ability of this stock to increase during favourable conditions was damaged when it was overfished in the mid 20th Century, and it has taken some time to recover this ability**

Living Resources

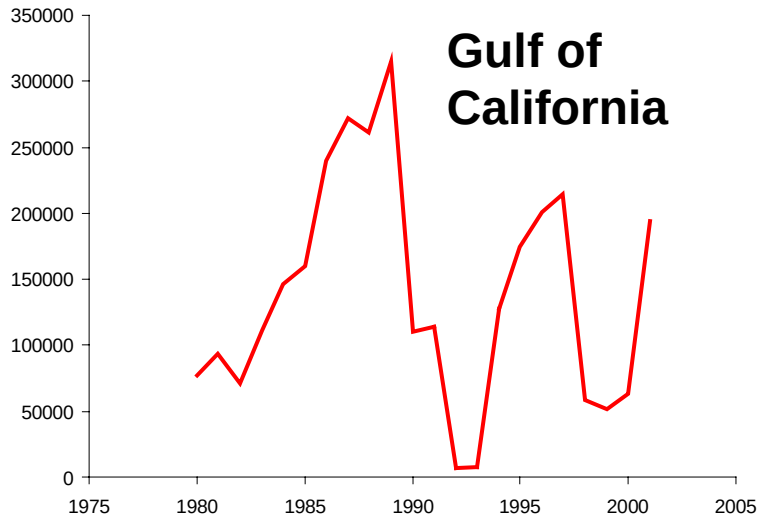
Temperate Coastal and Oceanic Systems





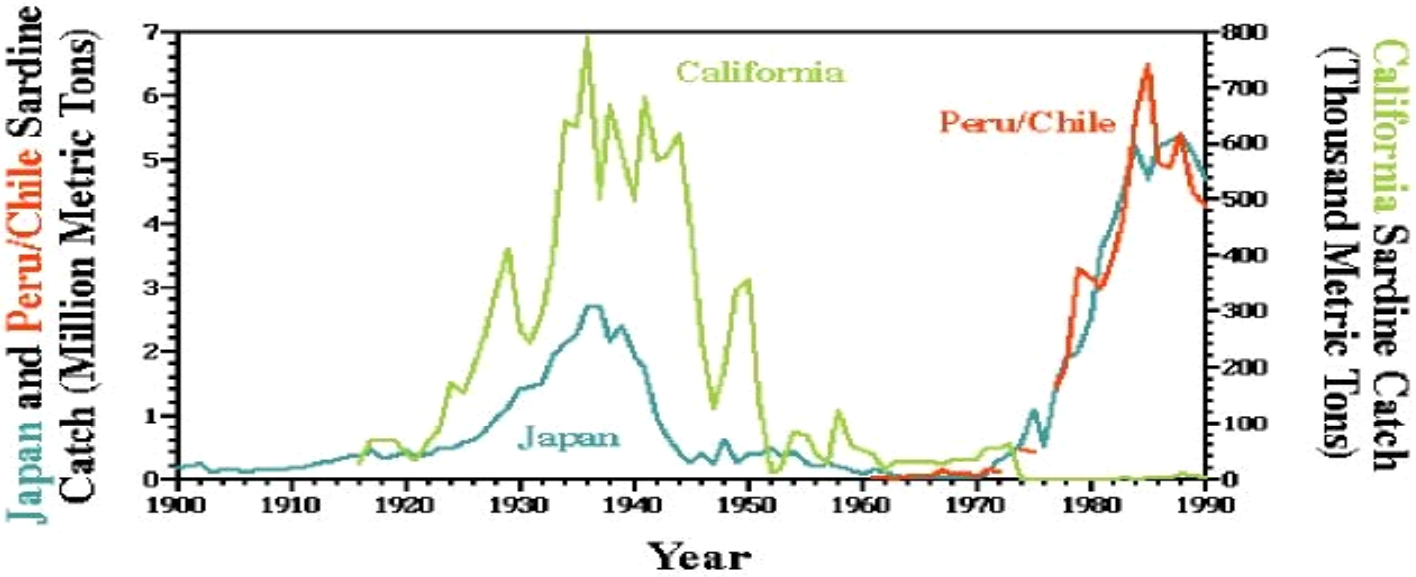


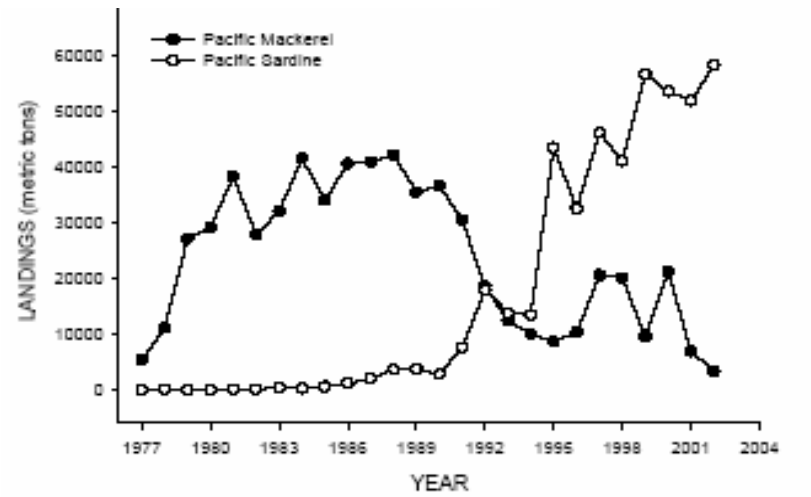
East coast of Japan



Living Resources

Temperate Coastal and Oceanic Systems





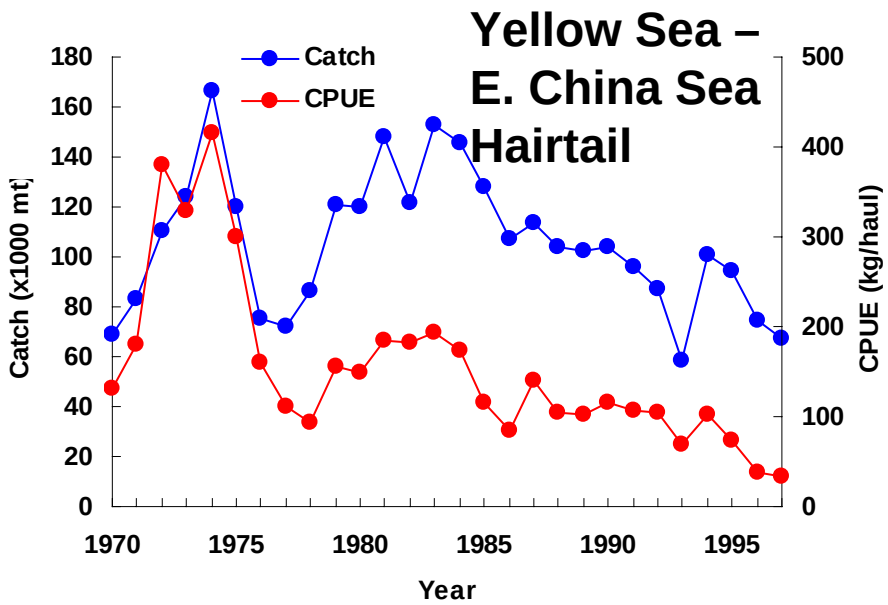
Living Resources

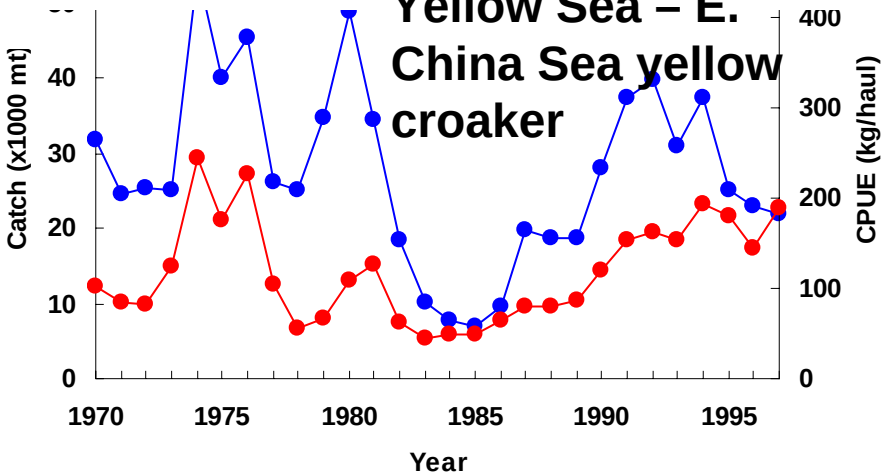
Temperate Coastal and Oceanic Systems

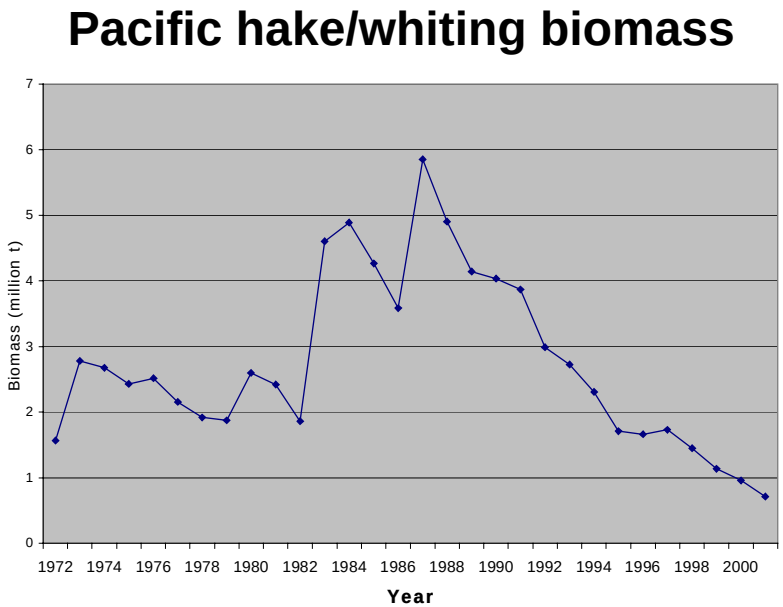
- **Demersal species have declined on the continental shelves**
  - **In the Yellow Sea – East China Sea:**
    - **catch rates of hairtail have declined since the 1980's**
    - **small yellow croaker, which were increasing, appear to have levelled off in the late 1990's**
  - **In the California Current System**
    - **Pacific hake/whiting has been declining since the mid-1980's**
    - **Several rockfish (*Sebastes*) species have declined over the 1990's, and have been formally declared "overfished"**

Living Resources

Temperate Coastal and Oceanic Systems







Living Resources

Summary of Fish

- **Many commercially-important demersal species have declined over past 10-20 years**
  - **may have resulted from unfavourable environmental conditions (e.g. on recruitment) and heavy human exploitation (e.g. Yellow Sea; California rockfish)**
- **Remarkable synchrony in fluctuations of small pelagic fishes, especially sardine**
  - **this synchrony suggests significant control by environmental conditions**
  - **but human exploitation may affect ability of stocks to respond to favourable conditions (e.g. California Current System)**
- **Total abundances of Pacific salmon have been high, driven largely by hatchery releases, although there are important regional differences among stocks**

Living Resources

Marine Mammals

- **Steller sea lions occur in most of the subarctic coastal systems**
  - **they are generally at low population abundances in all regions except eastern Gulf of Alaska (which is a small stock)**
- **Mass mortalities of marine mammals have occurred in the California Current System, and in the Gulf of California**
  - **in the former case due to HAB's, which are also implicated in the latter case**

Other Items

Human Population

- North Pacific rim ranges from lightly to heavily populated areas
- Proportions of population living within 100 km of coast range from 15% (Russia) to 100% (Korea)
- Projected population growth rates over next 5 years range from -0.2% (Russia) to 0.8% (Canada, USA)
- Continuing population increases and urbanisation will stress marine ecosystems of the North Pacific

Contaminants and Habitat Modifications

- A major gap in this report

Mariculture

- China, Japan, Korea account for 74% of world aquaculture (FAO)
- Average annual rate of increase in China 14%
- Likely to have important impacts, but not well described in report

Key Messages

- **North Pacific climate is different now than during past 30 years.**
  - **atmospheric pressure systems suggest a pattern different than the “typical” PDO, with more North-South variation rather than East-West**
  - **result is continuation of “warm” conditions in Bering Sea, “cool” conditions in Sea of Okhotsk, but a switch to different conditions in southern regions (e.g. “cool” in California Current)**
- **Strong El Niño of 1997/98, strong La Niña of 1999, and weak El Niño of 2002/03 added further variability and unpredictability**
- **Unusual plankton blooms have occurred in the past 5 years, and harmful algal blooms are increasing**
- **Fishing adds further unpredictability**
  - **A number of stocks in eastern and western North Pacific have been heavily exploited**
  - **Pacific salmon has been at historic abundances, but with some regional stocks in difficulty**
  - **Active and conservative management has helped to maintain important stocks (e.g. walleye pollock in eastern Bering Sea)**

Key Messages (Continued)

- **Fluctuations of some small pelagic fish stocks appear to be largely under environmental control, e.g. sardine**
  - **however, example of California Current System suggests that ability to respond to environmental variations may be affected by human actions**
- **Intensive mariculture is well-established and continues to increase dramatically, particularly in parts of the western Pacific**
- **Significant issues that exist for improving understanding of North Pacific marine ecosystems include:**
  - **Lack of information on nutrients, plankton, un-exploited fish species**
  - **Near-shore and inter-tidal environments**
  - **Continuation, and expansion, of ocean observing programs**

Next Steps

- **Discuss the content and messages of this overview**
- **Discuss how to ‘operationalise’ preparation of the PICES North Pacific Ecosystem Status Report**
- **Develop Indices (?)**
  - **PDO is an obvious one, but are there others?**
  - **Phytoplankton**
    - **Something using SeaWiFS?**
    - **Harmful algal blooms**
  - **Fish**
    - **Walleye pollock might be good for subarctic systems**
    - **Sardine for temperate warm-water systems?**

The environment in the North Pacific has been more variable within the last 5 years than within the last 10-30 years. The North Pacific is now in a period of stronger environmental changes AND strong direct human forcing. The region is in a period of greater uncertainty, both as to the possibility of "surprises" and to the causes of future changes. It has made the North Pacific Ocean much more difficult to predict.

Marine ecosystems in the North Pacific are very sensitive to environmental changes that occur on time scales from several years to decades. Human impacts may be increasing this sensitivity by reducing the natural capacity of marine ecosystems to buffer changes on these time scales. Long-lived fishes, in particular bottom fishes, appear to be most susceptible to these interactions of natural climate variability and human caused changes, although there are indications that human actions may also affect the ability of short-lived mid-water fishes to recover from changes in climate