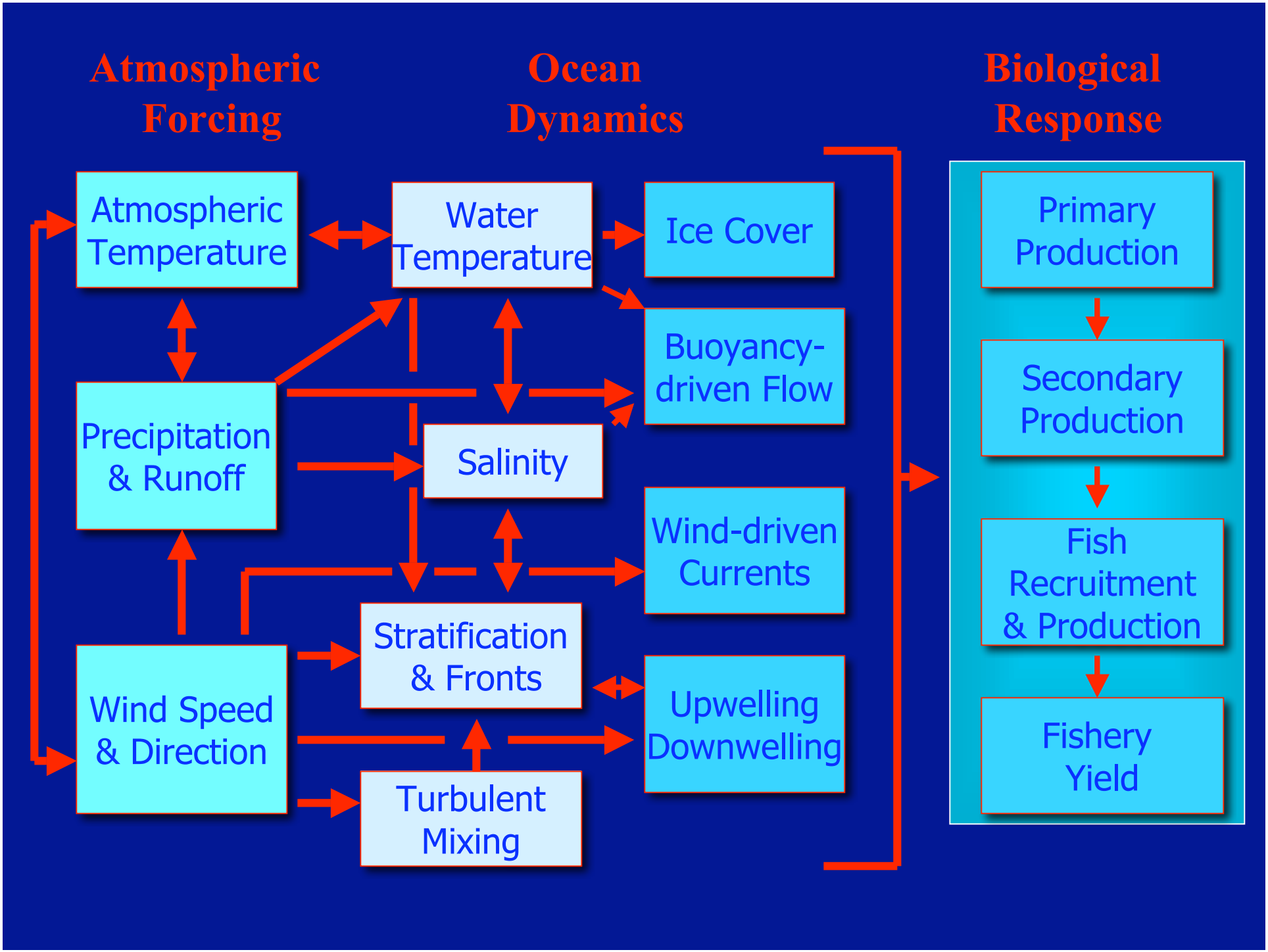
Climate Change and Carrying Capacity (CCCC) Mission

- Provide a strategy for determining the carrying capacity for higher trophics in the subarctic North Pacific (salmon, pollock, birds, mammals, etc.)
- Develop a plan for a cooperative study of how changes in ocean conditions affect the productivity of key fish species in the subarctic North Pacific and coastal zones of the Pacific rim

(1993)

1995 – PICES CCCC accepted as a regional program of the IGBP GLOBEC International Program

- Ultimate CCCC Goal: “to forecast the consequences of climate variability on the ecosystems of the subarctic Pacific”

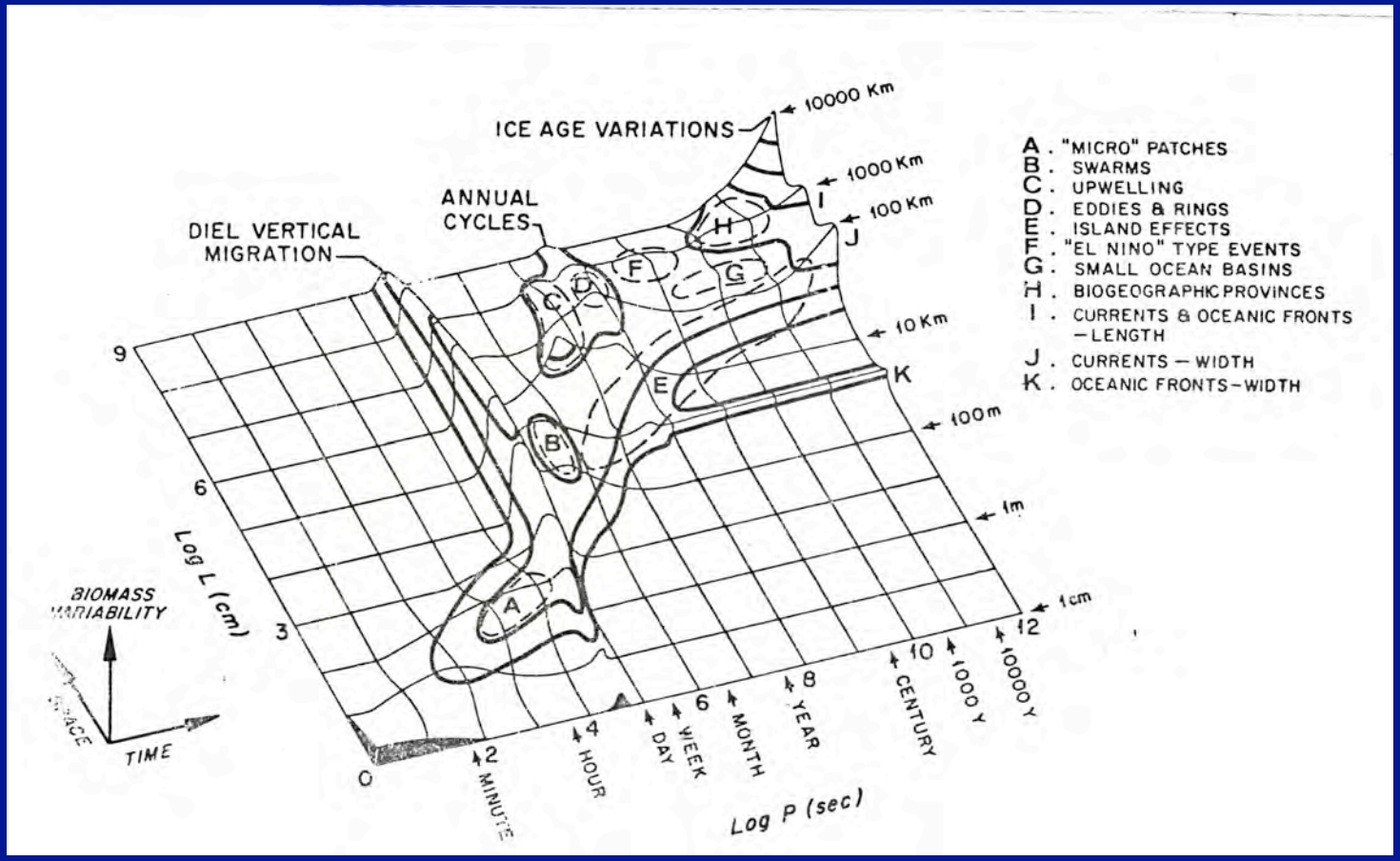

Atmospheric Forcing
Ocean Dynamics
Biological Response
Atmospheric Temperature
Water Temperature
Ice Cover
Buoyancy-driven Flow
Precipitation & Runoff
Salinity
Wind-driven Currents
Stratification & Fronts
Upwelling Downwelling
Wind Speed & Direction
Turbulent Mixing
Primary Production
Secondary Production
Fish Recruitment & Production
Fishery Yield

CCCC General Question

- "how do interannual and decadal variation in ocean conditions affect the species dominance, biomass, and productivity of the key zooplankton and fish species in the ecosystems of the PICES area?"
- Applied to:

Physical forcing	LTL Response
Ecosystem Interactions	HTL Response

Ocean Pattern and Process in Time and Space



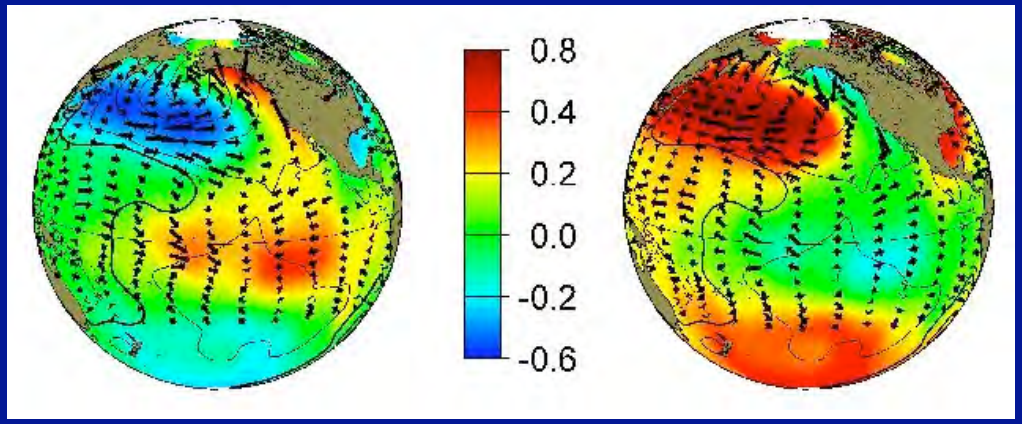
(from Haury et al., 1978)

Pacific Decadal Oscill.
Anomaly Patterns

SST – colors

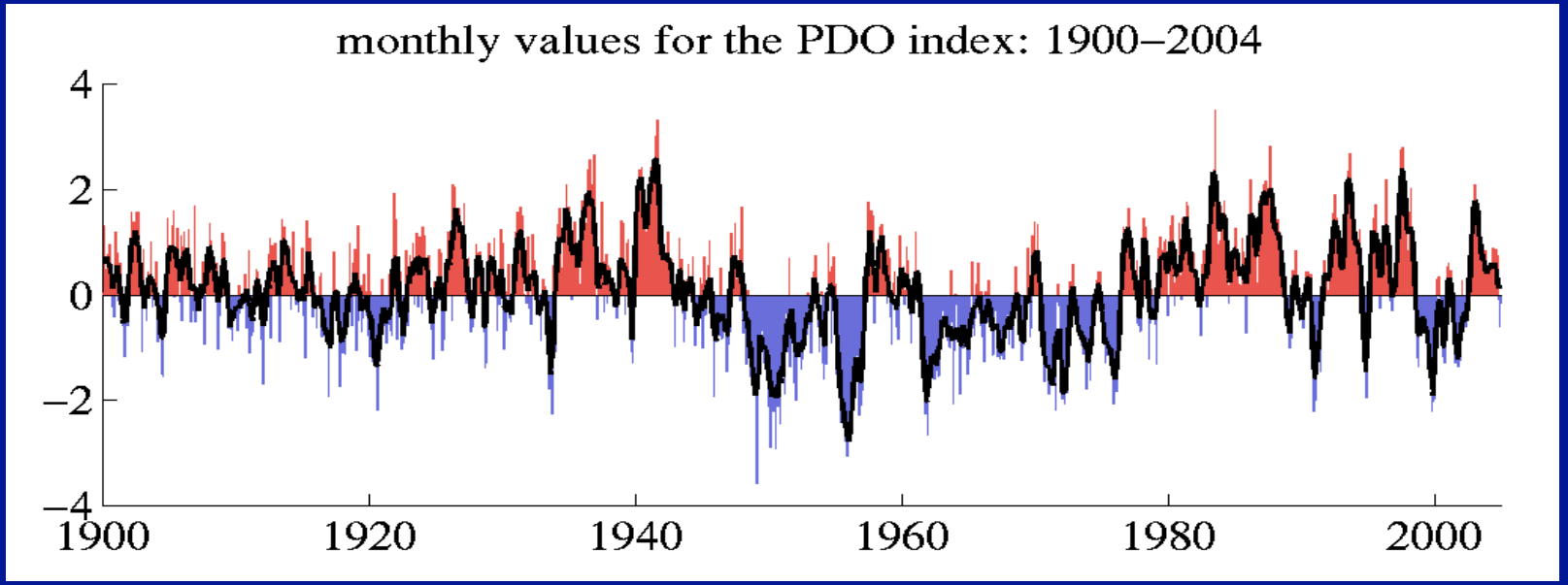
SLP – contours

Windstress - arrows

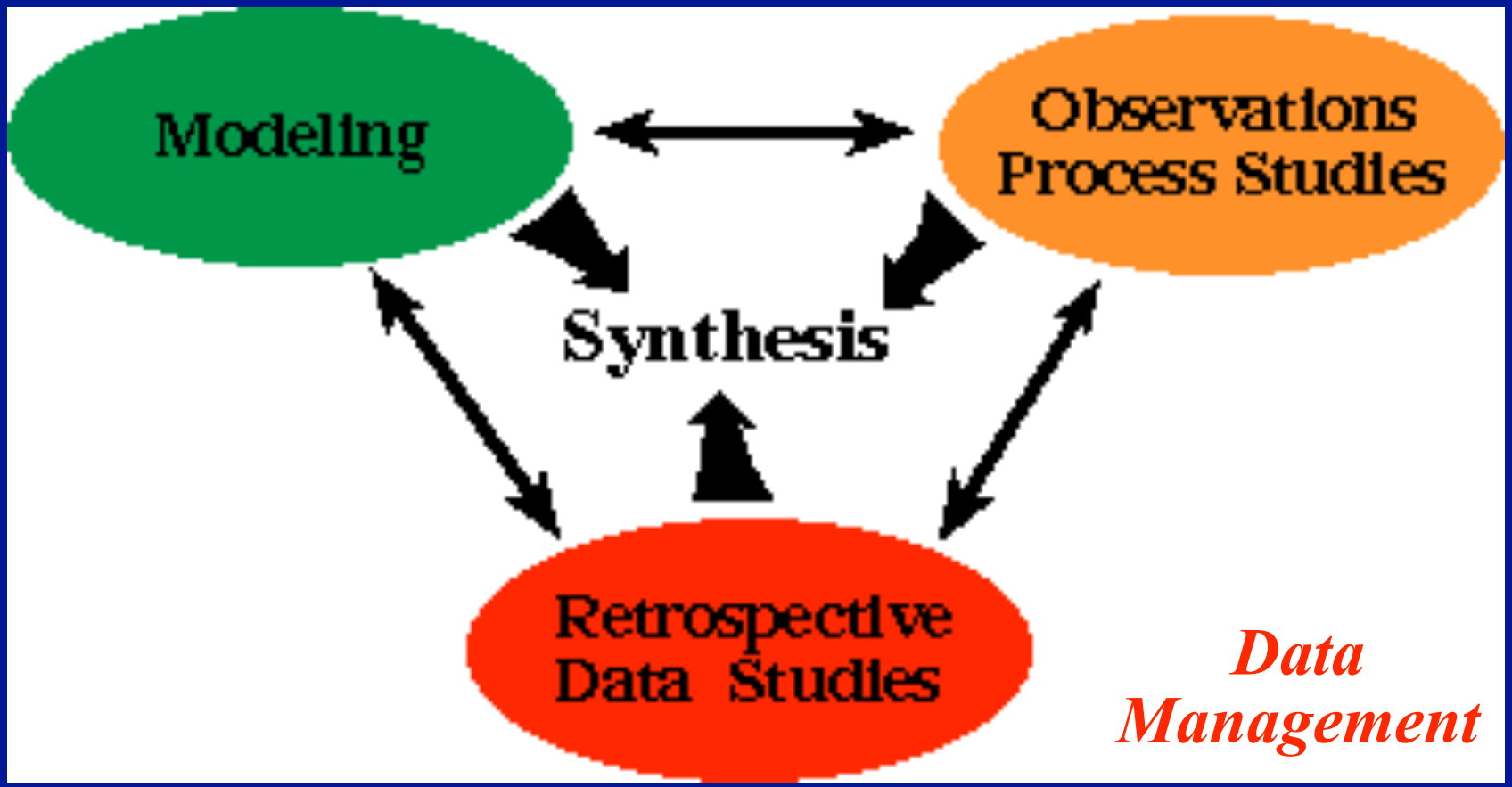


Warm phase

Cool phase



CCCC uses the GLOBEC Approach



1997-CCCC TOR revised to

- Integrate and stimulate national activities on the effects of climate variations on marine ecosystems of the subarctic North Pacfic
- Determine how the PICES scientific committee and WGs can support the program
- Identify national/international research programs with which CCCC could coordinate
- Provide scientific direction

CCCC Implementation Panel establishes 4 Task Teams (TT)

- MODEL – to advance the development of conceptual and modeling studies
- BASS (BASin Scale) – to develop the basin-scale component
- REX (Regional Experiments) – to develop interregional comparisons among national studies
- MONITOR (a little later) – review, improve and design a monitoring system for ocean and ecosystem observations in the NoPac; assist in developing a coordinated program to detect and describe events that strongly affect the NoPac; provide a liaison role to GOOS

CCCC
(2002 Qingdao Meeting)

- NEMURO Experimental Planning Team (NEXT) study group formed (1 yr)
  - Provide guidance for future modeling and synthesis of CCCC scientific activities
  - Develop a scientific strategy focusing on workshops to test specific hypotheses
    - Comparison of coastal ecosystems around the NoPac, using zooplankton and small fish as focal species
    - Latitudinal comparison of NoPac ecosystems using many spp. Design of future observational systems

CCCC
(2003 Seoul Meeting)

- NEXT SG provides final recommendations
  - CCCC should hold a major intercessional synthesis symposium around April 2006
  - CCCC should conduct detailed model-data comparisons using NEMURO for many different coastal systems
  - Hypothesis testing using both ECOSIM and NEMURO provides a powerful framework for examining ecosystem change
  - Need NEMURO documentation/training workshops

NEXT Hypothesis List (p. 1 of 2)

- The role of top predators (large fish, birds, MM) in NoPac food webs has varied over time (e.g., due to CC, whaling, fisheries, natural fluct.)
- NoPac wide changes in predatory fish (flatfish, pollock, cod) reflect common climate forcing as well as local fishing effects.
- Large-scale climate variability (e.g., PDO) causes simultaneous changes in both western- and eastern-side populations of small pelagics, but through different mechanisms.
- Sardine and anchovy population fluctuations are controlled by LTL productivity (bottom-up proc) during both increases and declines in their pops.

NEXT Hypothesis List (p. 2 of 2)

- Small but concurrent changes in combined predator populations (e.g., fish, and birds, which feed on a common resource like euphausiids) can be used as an indicator for detecting shifts in key unsampled prey pops.
- Overall marine productivity, esp. its magnitude, form (size, type), and seasonality is important in determining survival of commercially important NoPac spp. Two specific examples are:
  - Timing and availability of marine production in coastal regions of the NoPac, and its availability in a proper form for juvenile salmon is key in determining early ocean survival, and is susceptible to changing climate.
  - Differences in the vulnerability and timing of production cycles of zooplankton used by sardine, anchovy and saury in the recirculation region of the KE is responsible for the alternation of dominant spp. in the western Pacific.

CCCC
(2003 Seoul Meeting)

- CCCC-IP supports recommendation from BASS and REX TT to merge. Recommends formation of a new CCCC TT "Climate Forcing and Marine Ecosystem Response" (CFAME). PICES SB follows recommendation.
  - Identify potential co-chairs for CFAME prior to PICES XIII; Drs. Kerim Aydin (USA) and Akihiko Yatsu (JPN) nominated as chairs.
  - TOR for CFAME to be scoped out during workshop immediately preceeding PICES XIII (Honolulu).

The Building Blocks For Synthesis:

Modeling

Retrospective Studies

Observational Programs

Process Studies

Synthesis

- It's hard!
  - What to focus on
  - What to leave out
- There's never enough (any!) money
- No single way to do it
  - Multiple paths
  - Multiple groups of people
- No prescribed end product

Slide courtesy of Beth Turner

Why is synthesis so hard?

- Make general conclusions from specific information
  - Requires speculation and extrapolation
- Takes lots of time and interactive discussion
- Can't be done by large group, usually takes smaller group of 4 – 8 individuals, or several smaller groups which come together along the way

Slide courtesy of Beth Turner

Synthesis Process

- Data goes through processing & statistics to create
  - Information gets synthesized to create
    - Knowledge gets integrated into the political/management process to inform and enable
      - Action which (hopefully) will result in
        - Societal Benefit

Slide courtesy of Beth Turner

CCCC
(The Future)

- CCCC is the first and still the only cross-disciplinary, integrative science program of PICES; CCCC will likely continue until 2009 or until a new PICES program is developed and approved by SB/GC
- 19-21 April 2006 PICES-GLOBEC CCCC Symposium on "Climate Variability and Ecosystem Impacts on the North Pacific: A Basin-scale Synthesis" Honolulu, HI

CCCC Synthesis Symposium

- Three themes (each with 1 invited talk/paper):
  - Regime Shifts (Jim Overland and Shoshiro Minobe)
  - Ecosystem Productivity and Structural Responses to Physical Forcing (Sinjae Yoo and others)
  - Pan-Pacific Comparisons (Dave Mackas and others)
  - Closing Session will have 2 invited "perspectives" talks and a brief panel discussion (Makoto Kashiwai, John Davis)
- Symposium proceedings (invited and selected contributions) will be published as a special issue of *Progress in Oceanography*

Producing Ecosystem Status Reports

Regional Contributions to Ecosystem Analysis Reports

- Take advantage of existing regional summaries if available

Ask appropriate regional member nations to take lead on producing regional reports for future ESR updates.

- Bohai/Yellow/East China Sea -- Korea or China
- East/Japan/Okhotsk Sea -- Japan, Korea or Russia
- Oyashio/Kuroshio --Japan or Russia
- Bering Sea -- USA or Russia
- Alaska Current -- Canada or USA
- California Current – USA
- Pacific Basin/Transition Zone -- USA

The Next PICES Science Program

Study Group on Future Integrative Scientific Program(s)

The Study Group was recommended by the PICES Science Board to develop recommendations for one or more new Integrative Scientific Program(s) to be undertaken by scientists in PICES member countries. The Study Group will report directly to Governing Council. The Study Group will consist of the current (as of April 2005) membership of Science Board (including Chairmen of Technical Committees and the CCCC Program) plus up to 1 additional member from Canada, 2 additional members from China, 1 additional member from Japan, and 1 additional member from Russia.

Members: Kuh Kim, Mike Dagg, Yukimasa Ishida, John Stein, Mike Foreman, Igor Shevchenko, Jeff Napp, Hal Batchelder, Suam Kim, Jake Rice (CAN)

SG-FISP

Terms of Reference

- Solicit ideas (short 1-page descriptions) from PICES Committees, the CCCC Program, and more broadly as appropriate, concerning future major scientific endeavors for PICES.
- Compile, review and assess the responses; develop themes of potential interest to all member countries, and present the results to Governing Council at PICES XIV, indicating preferences of the Study Group if more than one theme is recommended.
- Disseminate findings and recommendations after meeting with Governing Council, and seek feedback from the PICES scientific community.
- Present revised themes and recommendations for proceeding with the implementation of the selected theme(s) to Governing Council at its interim meeting in spring 2006.
- Provide the final report to Governing Council and make an open forum presentation on the preferred theme(s) at PICES XV.

MODEL

- LTL models and coupling to physical models and HTL models
- NEMURO – North Pacific Ecosystem Model for Understanding Regional Oceanography (also from workshop held in Nemuro, JP)
  - 11 state variables, incl. Fluxes of both N and Si
- Collaborations with BASS to couple NEMURO to HTL (ECOPATH; ECOSIM)

BASS

- Develop CCCC activities in the deep basins
- Comparison of WSG and ESG
  - Science board symposium (1997)
- Advisory Panel on Iron Fert. Expt (IFEP; 1999)
  - Coordinate an Fe fert. Expt and examine LTL responses (species composition; export flux rates)
- Develop LTL-HTL linkages with MODEL

REX

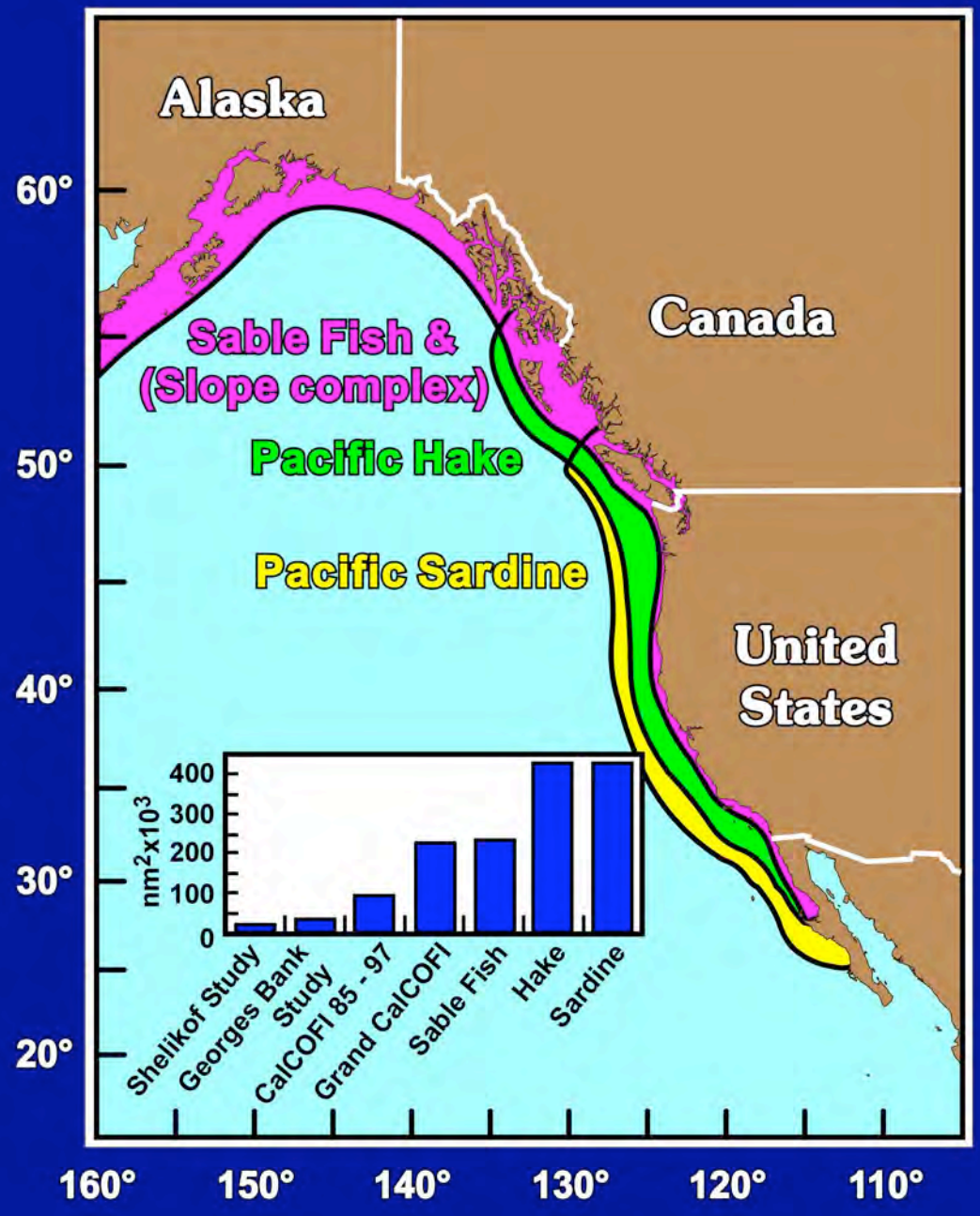
- REX played an integral role in information exchange in the early development of national GLOBEC-CCCC programs
- Workshop series on small pelagics, esp. herring (life history data; size-at-age)
- Working with MODEL to develop and add a “Fish” box to NEMURO (January 2002 workshop)

MONITOR

- Both backward and forward looking responsibilities
- Retrospective analysis of existing datasets
- Design of future observational systems
- Nature & Impacts of No Pac Regime Shifts
  - Science Board Symposium (1999)
- Fledgling CPR program (Advisory Panel)
  - 5 north-south transects per year (Mar-Aug)
  - 1 east-west transect per year (June-July)

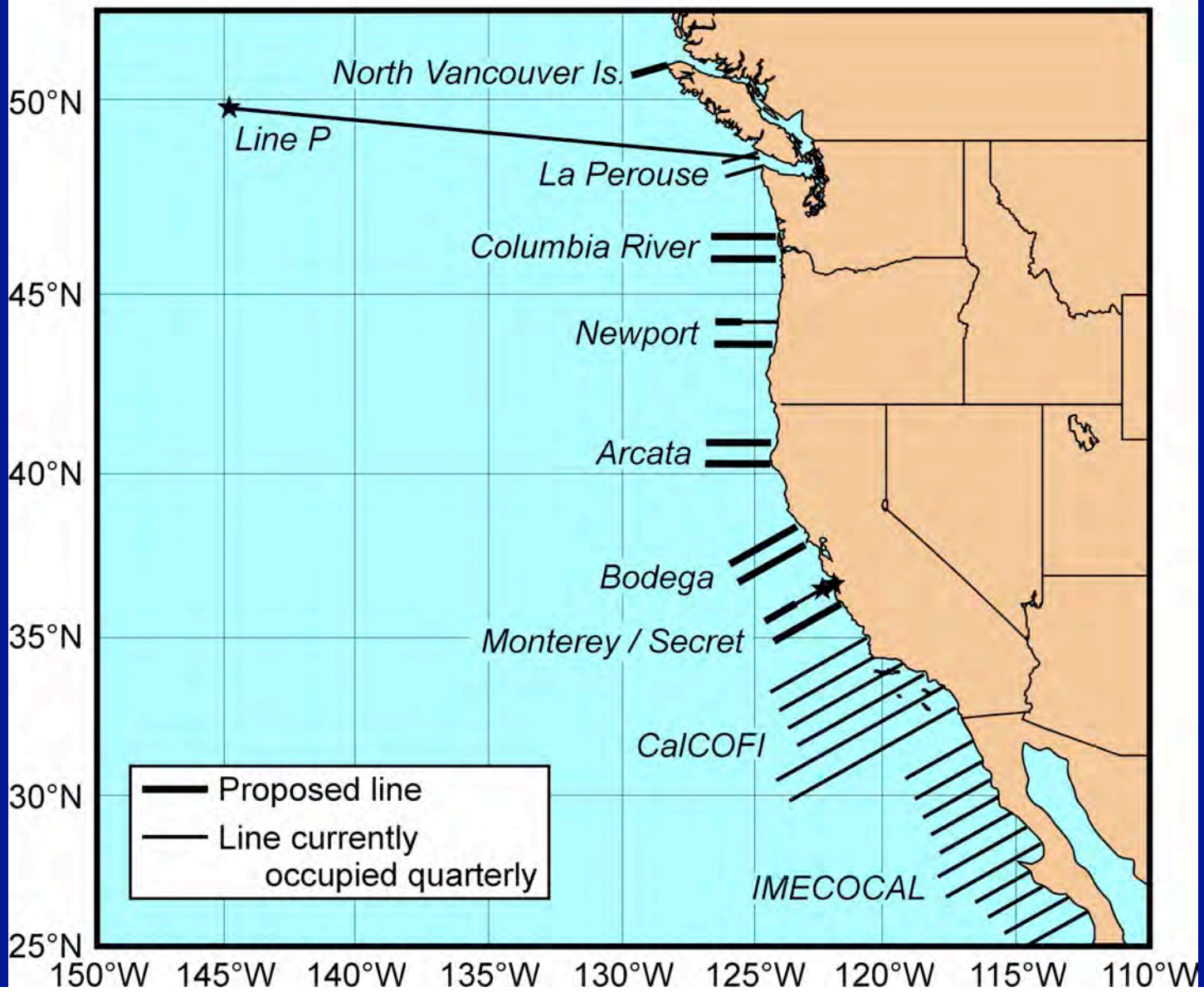
SURVEYS AND MARINE FISH POPULATIONS

Studies need to be carried out on a population or basin scale, but most surveys cover smaller areas.



A Proposed California Current Survey Plan

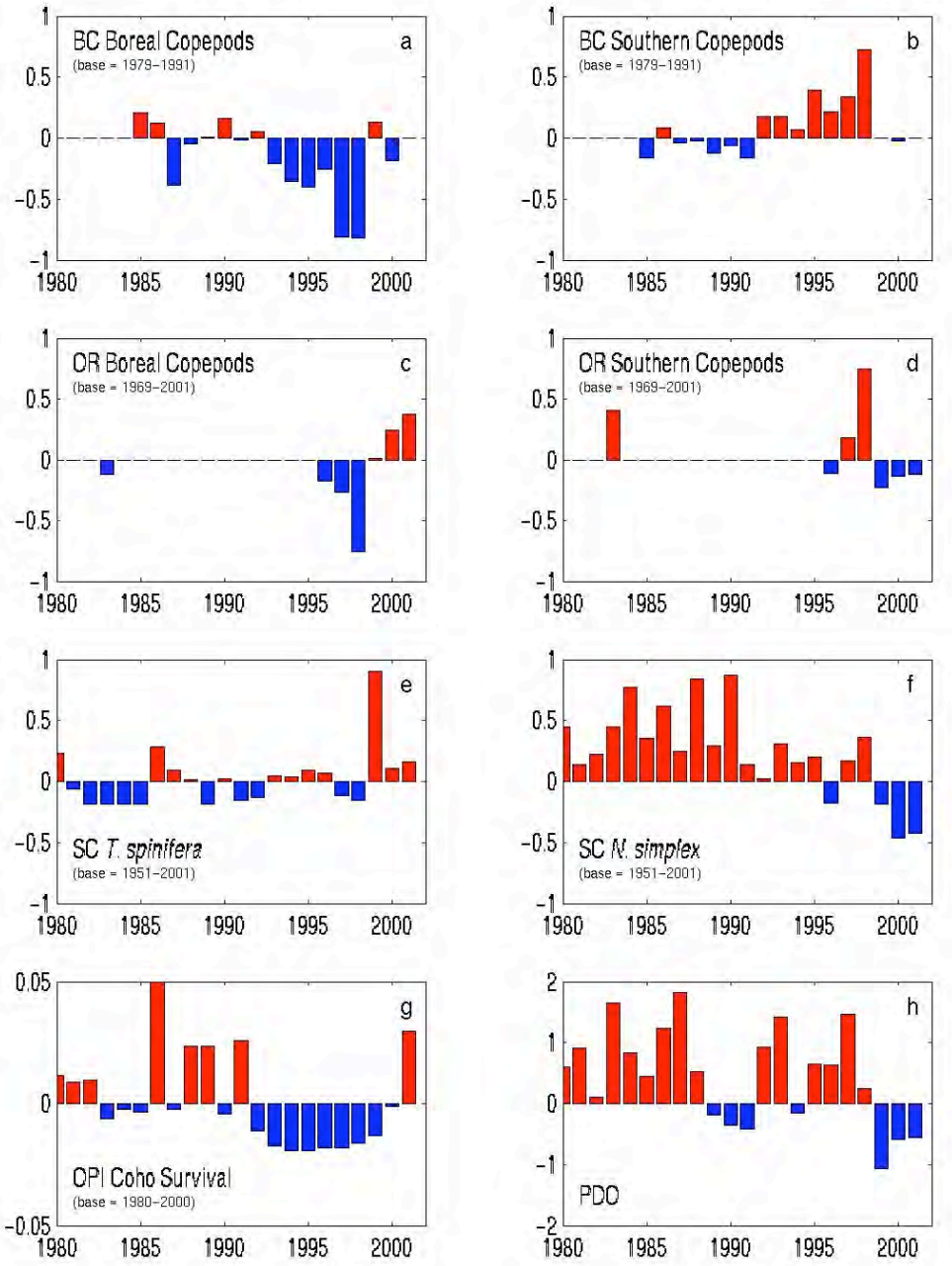
[February 2002 Edition]



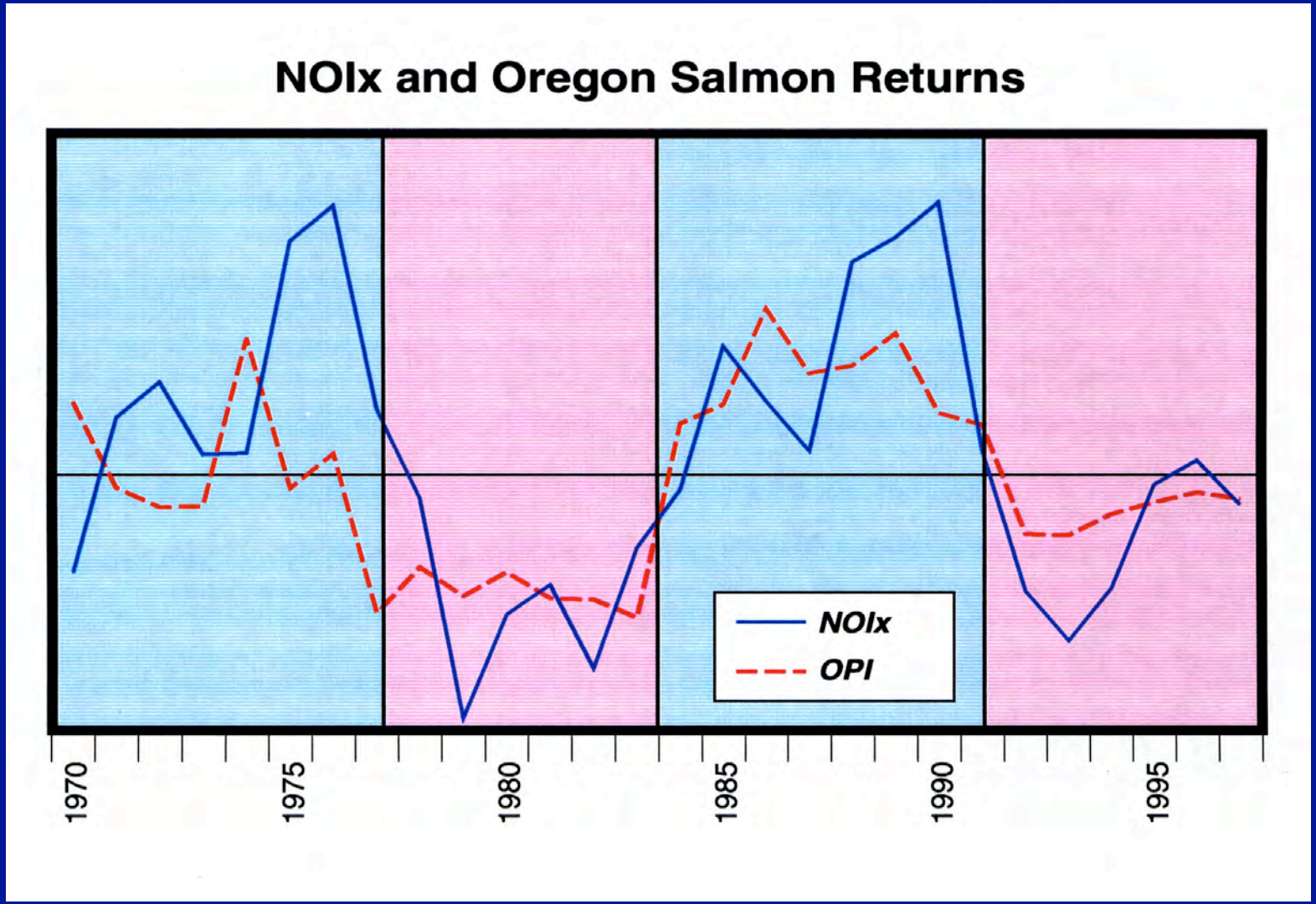
1998 Regime Shift?

- Boreal Copepods increase
- Southern Copepods decline
- Shift in euphausiid species composition in SoCal
- Marked increase in Coho survival

Parallel pattern in PDO, but the mechanisms are not known

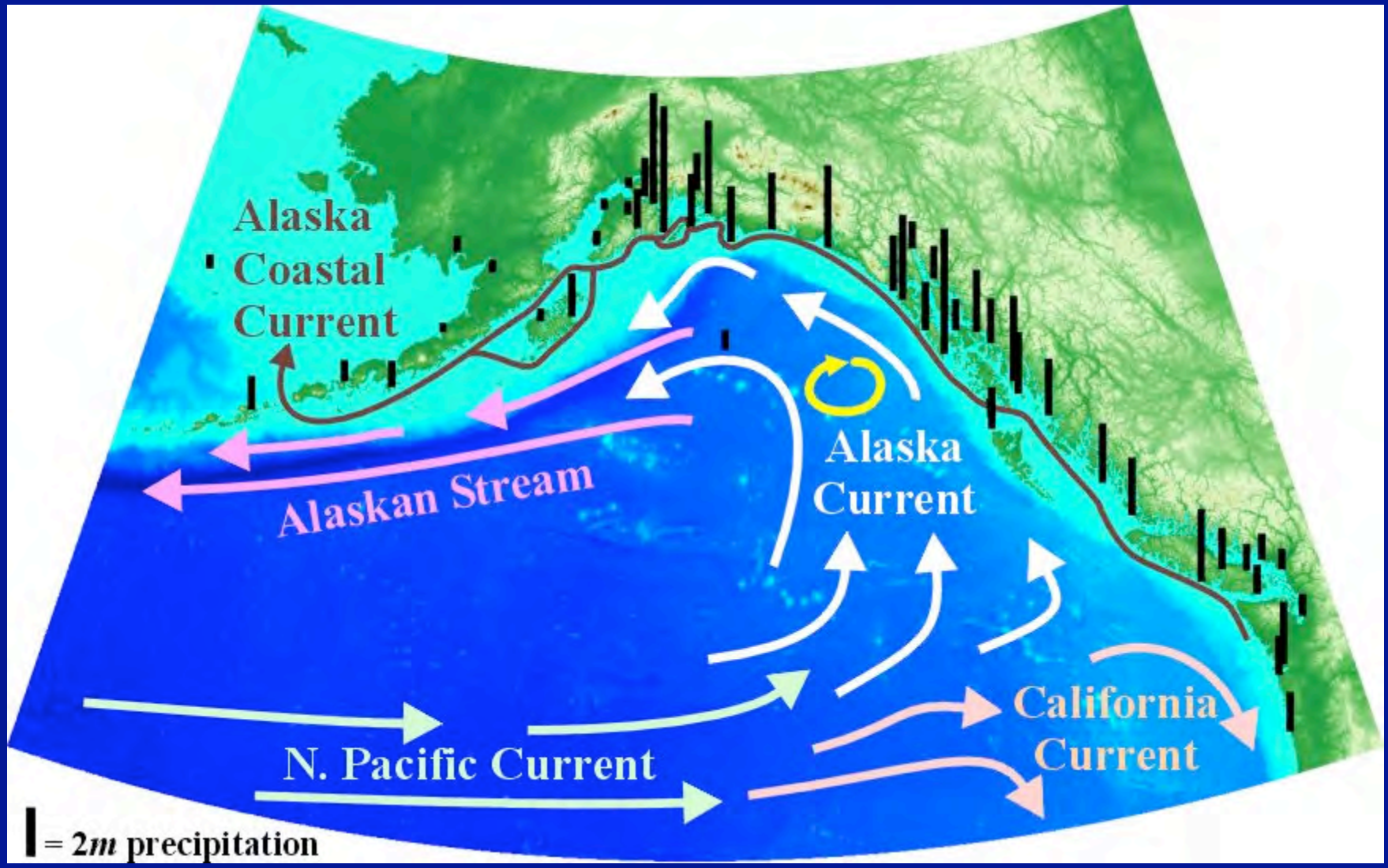


Evidence for Climate Connections to Salmon Catch?



(figure courtesy of F. Schwing)

Introduction: Gulf of Alaska Circulation



• The **Alaska Coastal Current** is a wind and buoyancy driven coastal current directly influencing the distribution of freshwater, biota and pollutants around the Gulf of Alaska

S1: Science Board Symposium (0.75 day) Technological advances in marine scientific research

S2: BIO/MEQ Topic Session (1 day) Food web dynamics in marginal seas: Natural processes and the influence of human impacts

S3: BIO/POC/FIS Topic Session (0.5 days) The importance of biophysical coupling in concentrating marine organisms around shallow topographies

S4: BIO/FIS/CCCC Topic Session (0.5 days) Responses of upper trophic level predators to variation in prey availability: an examination of trophic level linkages

S5: FIS Session (0.5 days) Comparison of the productivity of marginal seas with emphasis on the western Pacific (Japan/East Sea, Yellow Sea and East China Sea) with a focus on small pelagics

S6: FIS Topic Session (0.5 day) Physical forcing of walleye pollock life history and population structure: new approaches to identifying critical temporal and spatial scales

S7: MEQ Topic Session (0.5 day) Eutrophication, harmful algal blooms, and nutrients

S8: POC/FIS Topic Session (1 day) Detection of regime shifts in physics and biology

S9: PICES CCCC - GLOBEC Joint Session (during GLOBEC OSM, Oct. 18, morning) ENSO and decadal scale variability in North Pacific ecosystems

S10: PICES CCCC - GLOBEC Joint Session (during GLOBEC OSM, Oct. 18, afternoon) Coupled biophysical processes, fisheries, and climate variability in coastal and oceanic ecosystems of the North Pacific (S11 is poster session with this title)

S12: TCODE Electronic Poster Session. Data systems to support technological advances in observation systems

Topics for Potential Collaboration between ICES/PICES (CCC/CCCC) (1)

1) Climate change/variability effects on shelf (and maybe high seas) fisheries
2) Coherence of zooplankton and fish population responses over large spatial and long temporal scales. NAO oscillations (GSA; gadoid outbursts); PDO regime shifts. Are changes in the two northern hemisphere ocean basins teleconnected, perhaps through the AO?
3) Comparative studies of coastal fish stocks (esp. herring) between ocean basins. Comparisons could include techniques (age determination), recruitment studies, assessment methodology, acoustics, stock identification, etc.
4) Coupled physical-biological model development (this may occur to some extent in Qingdao)

Topics for Potential Collaboration between ICES/PICES (CCC/CCCC) (2)

5) Harmful Algal Blooms (HABs) are global phenomena that might benefit from cross ocean comparison. A few HAB (PICES WG15) members are members of the ICES WG on HAB also, but PICES members would like to see a more formal liaison established. Purpose would be to identify common problems and approaches.
6) Index development. PICES is beginning to produce Ecosystem Status Reports, which will include relatively simple indices of ocean conditions. The Atlantic has the NAO index and CCC is looking for transport indices. Question: Are indices too site specific to benefit from cross-basin considerations? Both ICES and PICES are involved in monitoring the physical and biological conditions in their regions, and both are concerned with how to assess and make available the output of existing and planned monitoring systems. How exactly are ecosystem status reports created? SYNTHESIS!!!!

Topics for Potential Collaboration between ICES/PICES (CCC/CCCC) (3)

7) Atlantic has a long record of CPR studies. Pacific CPR studies have only just begun—seems like their could be mutual interests. (Some of this is occurring already through Sonia Batten's involvement in the Pacific CPR program)
8) Comparative GLOBEC-like studies on gadoid species. Walleye pollock in Pacific, Atlantic cod in Atlantic. Both are major fisheries in their respective basins, both have experienced major changes in time (through fisheries and environmental variation).
9) Teleconnections: If they occur, are they propagated through the atmosphere or ocean: AO, ocean circulation through the arctic, large-scale mid-latitude propagation of atmospheric pressure systems.

Topics for Potential Collaboration between ICES/PICES (CCC/CCCC) (4)

10) Ecosystem based approaches to managing living marine resources. Environmental information/input to stock assessment.
11) Comparative studies of high latitude, marginal subpolar seas—the Bering Sea and the Barents Sea. Both marginal seas have valuable gadoid stocks, strong interannual and longer-term variability in both physics and biological resources and strong influences of ice. There are some differences that make a comparison interesting. The Bering Sea has relatively little advection with large changes in ice cover extent interannually. The Barents Sea is highly advective, but also has large changes in ice cover (?). Zooplankton populations in the two systems may be changing through time (Atlantic—changes in advective input of Calanus→capelin/herring→cod; Pacific—changes in small copepod populations along the shelf-break and inner-shelf front). Growth and survival of fish. Fate of primary production.

In the interests of completeness—more suggestions…

Comparisons of bathypelagic and mesopelagic fishes: estimations of biomass/density in the two oceans; what is their role in oceanic ecosystems?; how do species composition compare?; what species are cosmopolitan?

The role of forage fishes for marine mammals and sea birds: How much do they eat? What is the comparative anthropogenic legacy?

Comparative species diversity: Why does the Pacific have 6 species of salmon and the Atlantic one? What does the Pacific have 10-12 species of smelt and the Atlantic two? Why does the Pacific have 60+ species of rockfish and the Atlantic two? This probably applies to many other taxa, including zooplankton? *[probably the age of the ocean basin and the time available for speciation; or is it something else?]*

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If there is a general agreement that CCC-CCCC collaborations are worth exploring, then the next step is:

CCC and CCCC Chairs work intercessionally (between now and our annual meetings—ICES (Sept) and PICES (Oct) to develop:

- a strategy for the collaboration **(A CLEAR ACTION PLAN)**
- specific topic for either collaborative working group or a workshop
- approach both PICES and ICES with specific proposal for 7C's workshop/WG
- Future discussions:
  - Geir Ottersen and Hal Batchelder are both attending a Bering Sea meeting (which will include discussion of potential Bering-Barents comparisons; early Sept 2002)
  - Ian Perry (chair of PICES science board) is attending ICES ASC (Copenhagen, September 2002)
  - Ken Drinkwater, Geir Ottersen, Keith Brander are attending PICES XI (Qingdao; October 2002)

PICES

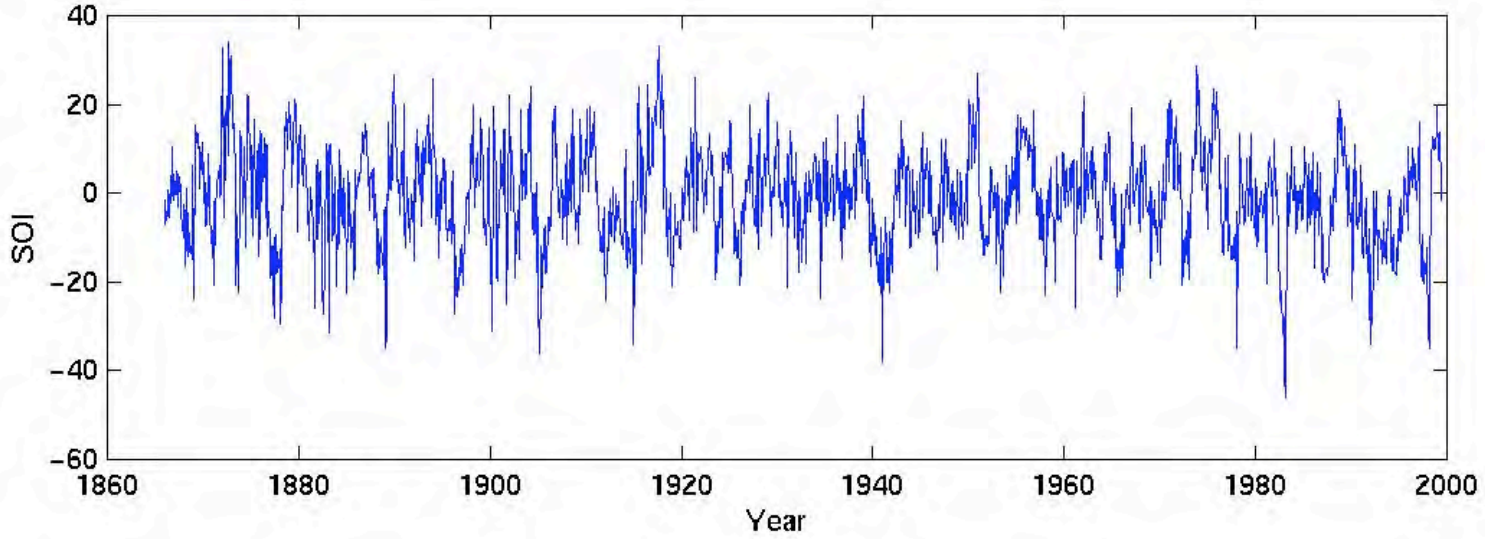
North Pacific Marine Science Organization

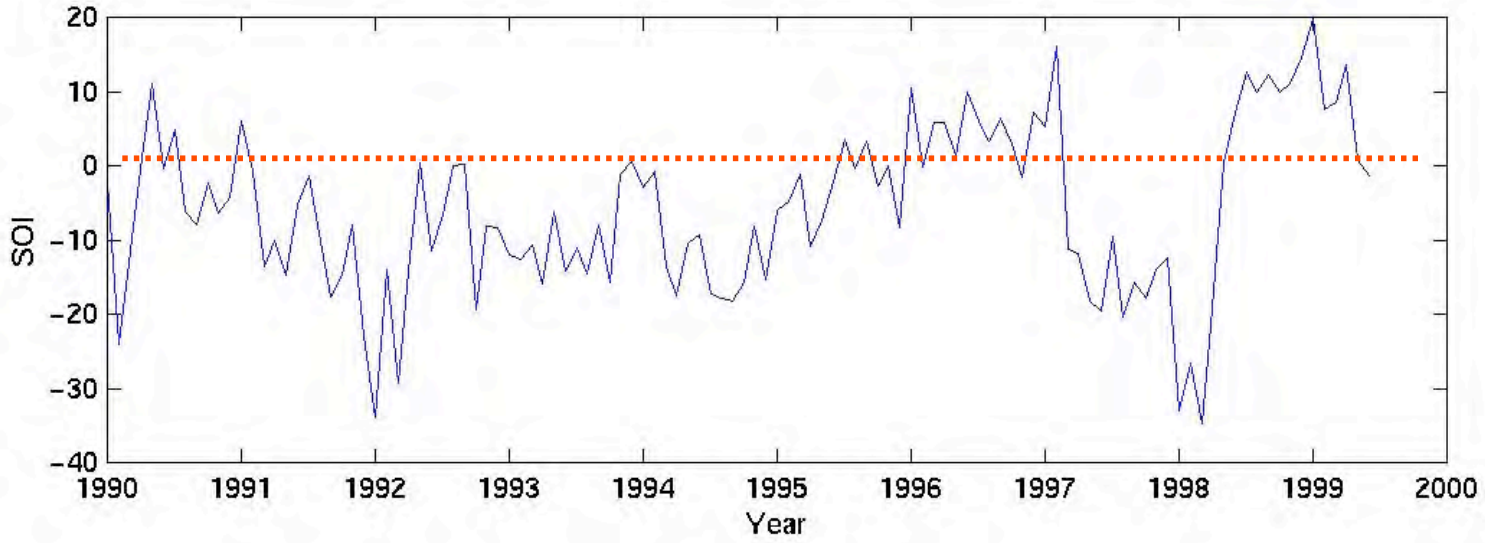
An intergovernmental scientific organization that was established and held its first meetings in 1992. Its present members are Canada, People's Republic of China, Japan, Republic of Korea, Russian Federation, and the United States of America.

- Promote and coordinate marine research in the northern North Pacific and adjacent seas especially northward of 30 degrees North

- Advance scientific knowledge about the ocean environment, global weather and climate change, living resources and their ecosystems, and the impacts of human activities

- Promote the collection and rapid exchange of scientific information on these issues

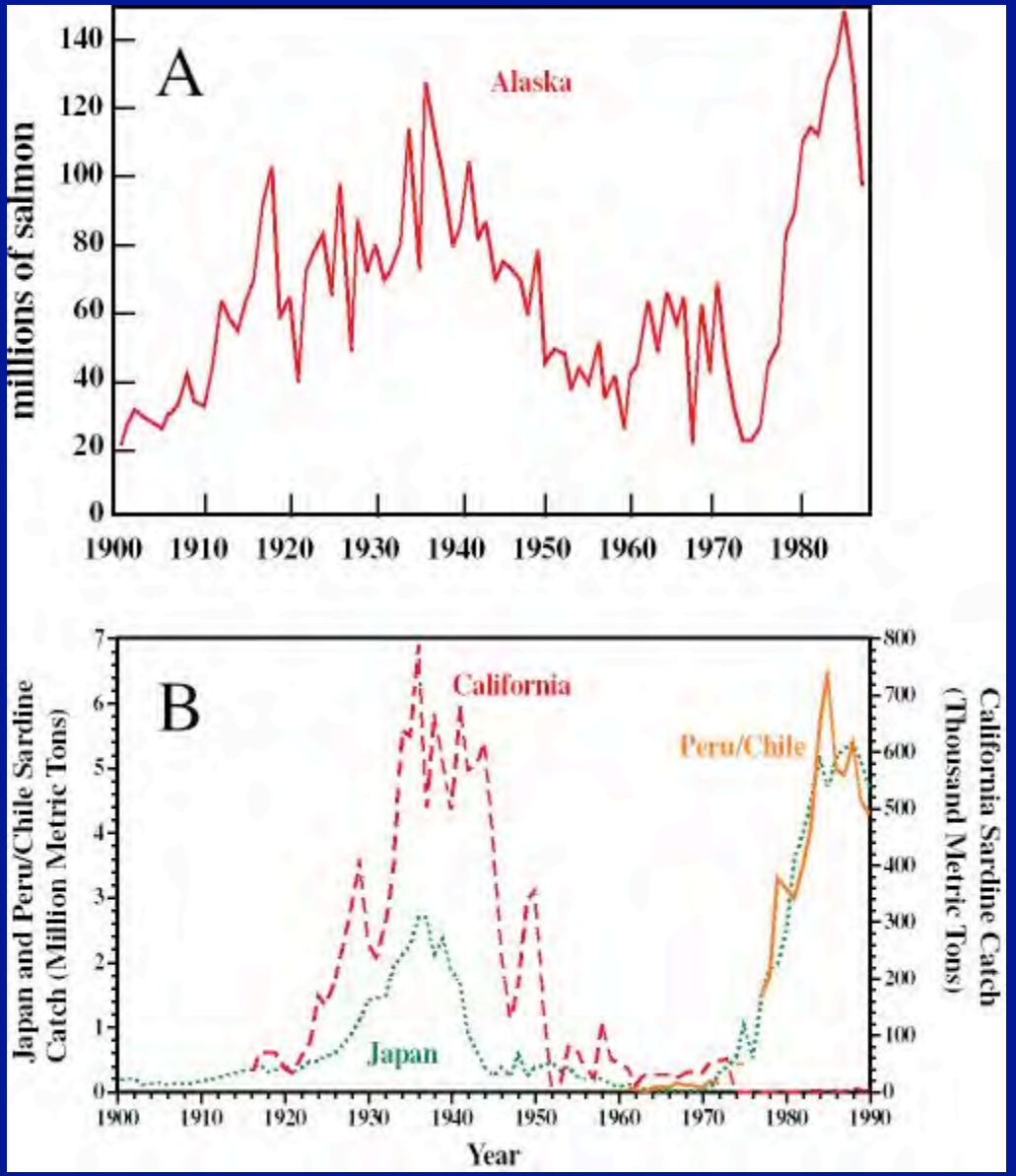




SOI=10*(Pdiff – Pdiffave)/SD(Pdiff)

Pdiff=Tahiti SLP–Darwin SLP; Pdiffave=long-term mean diff; SD(Pdiff)=long-term SD

Synchronous Population Fluctuations?



Distribution of Steller Sea Lions (from North Pacific Universities Marine Mammal Research Consortium website)

1-CCSS; 2-CCSN; 3-SE-SCAK; 4-EBS; 5-WBS; 6-OKH; 7-OY-KU; 8-JASE; 9-BOHAI; 10-EACH

WSG-Western Subarctic Gyre; ESG-Eastern Subarctic Gyre

Distribution of Steller Sea Lions (from North Pacific Universities Marine Mammal Research Consortium website)

Ecosystem Status Report

- Summarize what is known about the NoPac ecosystem (every 1-2 years?) [climate, oceanographic and fisheries data]
- Identify data gaps requiring further study
- Ecosystem based management of marine fisheries requires integration of environmental data into traditional stock assessment advice
- First ESR to be available in draft form for 2002 PICES Mtg

ESR – Proposed Outline (1)

- • Intro/Scope
  - • Status of Monitoring & databases
- • Hydrography & Climate
  - • Large Scale features and indices (ENSO, PDO, NPI)
  - • Regional features and indices (e.g., regional seas ice cover indices, annual air and ocean temperature anomalies, salinity anomalies, precipitation anomalies)
- • Chemistry
  - • CO2 concentration
  - • Dissolved O2 levels
  - • Nutrient levels and sources
  - • Trace metals and organic pollutants: sources and levels in seawater, sediments and biota

ESR – Proposed Outline (2)

- Biology

  Phytoplankton (chl, production, species composition and distribution, size composition, timing of spring bloom, harmful algal bloom number and extent)

  Zooplankton (biomass, species composition and distribution, size composition, summarized by feeding type)

  - Fish, shellfish and squid (catch including bycatch and discards; mariculture activities, biomass, recruitment, species composition and distribution, size or age composition, mean weight at age, stock condition (number of stocks that are increasing, stable, and decreasing), rates of fish desease occurrence, diet, larval and egg abundance and distribution)
  - Non-commercial benthos (biomass, species composition and distribution, size composition, summarized by feeding type)
- Marine mammals and birds (number, reproductive perormance and diet)
- Number and type of nonnative species (introduced exotics)

ESR – Proposed Outline (3)

- Ecosystem Analysis and Predictions
  - Status of modeling
  - Identification of human and natural processes influencing ecosystem change (diagnostic models)
  - Prediction of future ecosystem status (prognostic models)
- Outstanding scientific questions and recommendations