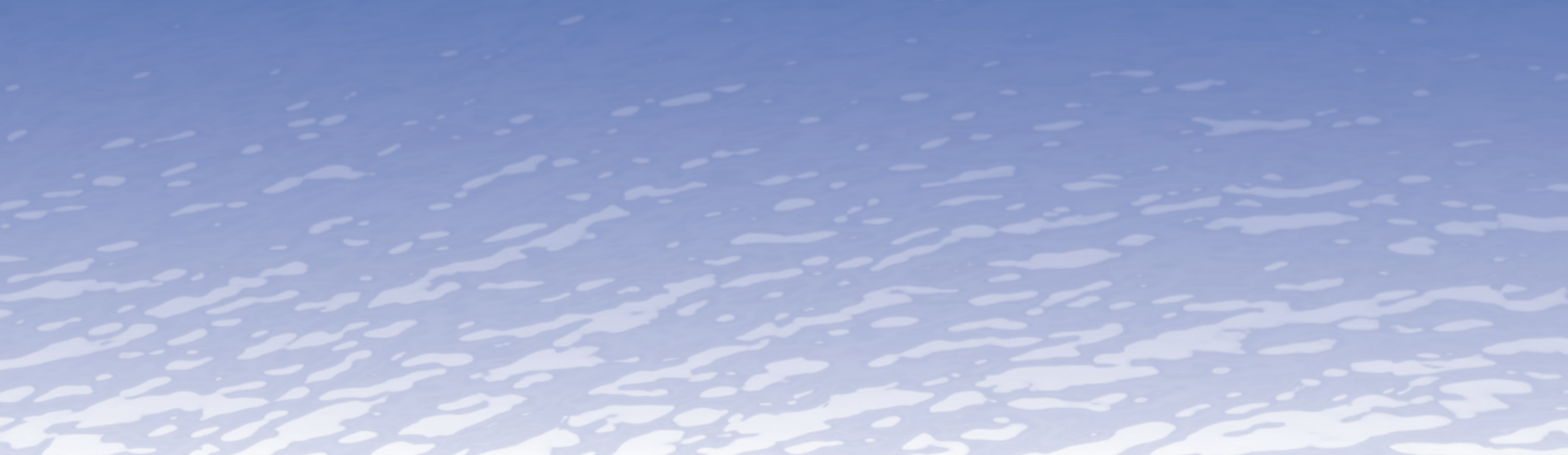


ADVISORY REPORT

Fisheries & Ecosystem Responses

To Recent Regime Shifts in the North Pacific

North Pacific Marine Science Organization

Since the late 1980s, marine ecosystems of the North Pacific have shifted to a different state. The extent of these changes varies with geographic location.

Off California, ecosystems have changed the most, and are now generally cooler and more productive. In the Bering Sea, changes have been minimal with warmer conditions continuing. Changes in the western North Pacific tend to have the opposite pattern to the North-East Pacific. Observing and monitoring of the ocean is required to recognise when conditions change to a new state. Marine resources managers must develop forward-looking approaches that consider significant and prolonged changes in ocean conditions.

introduction

In October 2003, the North Pacific Marine Science Organization was asked by the United States government for scientific advice on the implications of the 1998 regime shift for North Pacific fisheries. Following the strong 1997-1998 El Niño, the climate of the North Pacific took a rapid and striking change, the persistence of which is suggestive of a regime shift. Previous regime shifts have had serious implications for marine ecosystems, and consequently for fish populations and the fishing industry. NOAA Fisheries of the United States requested scientific advice from PICES that addresses six specific questions:

1. Has the North Pacific shifted to a different state or regime since the late 1980s?
2. What is the nature of the new state?
3. What are the ecosystem responses?
4. How long can the shift be expected to last?
5. Is it possible to predict when the regime will shift back and what indicators should be used to determine when it happens?
6. What are the implications for the management of marine resources?

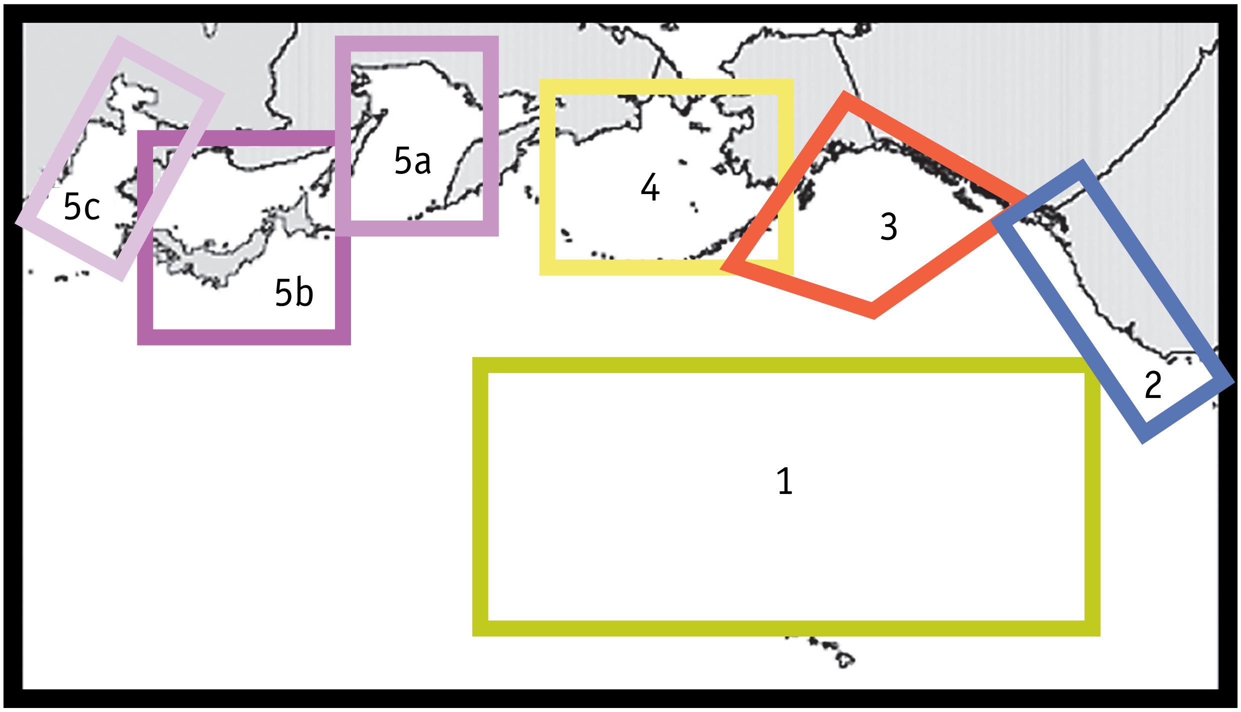
The North Pacific Marine Science Organization (PICES) is an intergovernmental organization whose members include Canada, China, Japan, Korea, Russia and the United States. PICES was formed in 1992 to provide a forum for scientists from throughout the North Pacific to compare observations and ideas. During its first decade, PICES focused on environmental variation and its impacts on marine ecosystems. Ocean/climate regimes and regime shift impacts on marine resources were considered at an international symposium in 1992 on climate change and northern fish populations (R.J. Beamish, editor), at a symposium in 1999 in Vladivostok, Russia, on the nature and impacts of North Pacific climate regime shifts which identified a strong possibility that a regime shift occurred in 1989 (S.R. Hare et al., editors), and a conference in La Jolla, USA in 2000 focused specifically on climate regimes, ecosystem consequences and impacts on fisheries (S.M. McKinnell et al., editors). As a result, the scientists of PICES have considerable expertise on ocean/climate regimes.

regimes & regime shifts

Around 1977, many species of plankton and fish in the North Pacific experienced changes in distribution, survival and abundance. The change was so abrupt (within a year or two) and so widespread (throughout the North Pacific) that it has become known as a regime shift; characterized by changes that may persist for decades and affect all levels of the marine ecosystem.

The two most probable causes were fishing and climate change, but as both fished and unfished species were affected, climate change and/or associated changes in ocean conditions became the focus of attention. However, the nature and extent of these changes were not fully appreciated until a decade or more after they had occurred. Once scientists began looking more closely at the historical records of the past 100 years, they found evidence for regime shifts in 1925, 1947, 1977 and 1989. Even older paleo-ecological records obtained from ancient tree rings show that regime shifts have occurred in the North Pacific for centuries although it appears that the durations of regimes has diminished from 50-100 years, to 20-30 years and even 10 years in most recent history.

In response to the request for advice, PICES established a Study Group on Fisheries and Ecosystem Responses to Recent Regime Shifts (FERRRS). FERRRS was chaired by Dr. Jacquelynne King (Canada); the full membership is listed on the back cover of this summary. The Study Group met February 9-10, 2004, in Victoria, Canada, to organize activities and to outline the reporting requirements. At a workshop held June 14-16, 2004, in Seattle, USA, FERRRS Study Group reviewed the background material prepared by its members and developed answers to the six questions.



Five regions of the North Pacific for which information on oceanic conditions and ecosystems was compiled and reviewed:

1 Central North Pacific

2 California Current System

3 Gulf of Alaska

4 Bering Sea and Aleutian Islands

5 Western North Pacific comprised of

a Sea of Okhotsk

b Tsushima Current region and Kuroshio/Oyashio region

c Yellow Sea and East China Sea

1 Has the North Pacific shifted to a different state or regime since the late 1980s?

Yes, based on North Pacific climate and ocean indices, there were regime shifts in 1989 and in 1998. Not all North Pacific ecosystems have responded to the 1998 regime shift, however there is growing evidence that several regional ecosystems have responded to varying degrees to this shift. The 1998 regime shift had the greatest impact in the most southerly regions (i.e., the Central North Pacific and the California Current System), less of an impact in the Gulf of Alaska, and little impact in the Bering Sea.

2 What is the nature of the new state?

The new ocean climate regime since 1998 has a north-south pattern of variability. In the eastern North Pacific, surface waters have cooled in southern regions, but this effect diminishes northward so that surface waters have continued to warm in the most northern regions. The dominant atmospheric pressure systems over the North Pacific (the Aleutian Low and the North Pacific High) have intensified which has strengthened the winds along the western United States that cause deep water to rise to the surface, but has also strengthened the winds off Canada and South-East Alaska that cause surface waters to sink to deeper depths. The opposite gradient has occurred in the western North Pacific.

Ocean climate regimes are defined on scales of decades, yet there are only 5 years of data available since 1998 with which to assess the new state. In addition, an El Niño event in 2002/03 complicated the characterization of the new state. Some of the remarkable oceanographic responses to the 1998 regime shift include:

Central North Pacific – warmer and thicker upper water layer:
- abrupt warming of surface waters
- increase in the height of the sea surface
- deepening of the thermocline (the abrupt transition from warm upper layers to cold deep layers)

California Current System – return to less stratified, cooler conditions:
- cooling of coastal waters
- enhanced southward flow of water and organisms
- decreased stratification
- deepening of the thermocline

Gulf of Alaska – return to cooler, stormy conditions:
- increased storm intensity
- deepening of mixed layer depth

Bering Sea and Aleutian Islands – no apparent regional response:
- surface waters have continued to increase in temperature
- sea ice extent has continued to diminish

Western North Pacific – pattern of responses opposite to the eastern North Pacific:

- harsher winter conditions in the Sea of Okhotsk
- more sea ice in the Sea of Okhotsk
- in southern regions, surface waters have continued to warm

3 What are the ecosystem responses?

Biological production has improved in the southern regions of the eastern North Pacific and in the northern regions of the western North Pacific.

Not all North Pacific ecosystems have responded to the 1998 regime shift, however there is growing evidence that most ecosystems are responding to this shift. The 1998 regime shift had the greatest impact in the California Current System, less of an impact in the Gulf of Alaska, and virtually no impact in the Bering Sea.

Ecosystem responses to ocean climate regime shifts are most quickly detected in lower trophic levels, such as phytoplankton, zooplankton and invertebrates. These organisms reproduce quickly which makes changes in their abundance apparent shortly after a regime shift has occurred (usually within a year). However, because these species also respond to year-to-year environmental changes, several years are required to distinguish regime changes from ordinary interannual variations. In fish populations, the response to regime shifts may not be apparent immediately. These animals live longer, and changes in the survival of eggs, larvae or juveniles that affect abundance may not be measureable until that year class is old enough to be caught in scientific surveys or in fisheries. This lag time can range from 2-3 years for fish such as Pacific herring or Pacific sardine and up to 15 years for some rockfish species. Surveys directed to larval or juvenile fish can be used to detect changes in fish populations sooner, but these types of surveys are not conducted in most regions.

As with regional oceanographic conditions, the ecosystems of different regions have different responses to regime shifts. Specific responses to the 1998 shift include:

Central North Pacific – decreased productivity throughout the food web:

- northward shift in the low chlorophyll surface waters (Transition Zone Chlorophyll Front)
- decrease in the survival of monk seal pups in the northern atolls of the northwestern Hawaiian Islands
- eastward shift in the summer albacore tuna troll fishing grounds from predominately oceanic waters to coastal waters, indicating a shift in tuna distribution

California Current System – increased productivity:

- phytoplankton biomass increased in both amount and seaward extent
- zooplankton biomass increased throughout the California Current System and the species composition returned to patterns similar to those during the mid-1980s
- groundfish reproductive success has improved since 1999
- Pacific salmon marine survival has improved since 1999
- the 1999 year class of Pacific hake was the largest since 1984

Gulf of Alaska – increased productivity in some areas:

- primary production increased in British Columbia
- Pacific salmon marine survival increased in British Columbia
- increase in shrimp abundance in northern Gulf of Alaska in 1998-2001
- there was a strong year class of pollock, Pacific cod and sablefish in 1999

Bering Sea and Aleutian Islands – productivity conditions remained unchanged:

- no detected ecosystem response to the 1998 regime shift

Western North Pacific – productivity changes are variable, with some increases in northern regions and no apparent responses in southern regions:

- Sea of Okhotsk zooplankton biomass increased
- changes in the near surface fish community were evident with Japanese sardine, previously a dominant species, replaced by herring, capelin and Japanese anchovy
- walleye pollock biomass in the Sea of Okhotsk decreased markedly, but walleye pollock still remain the most abundant species
- no detected ecosystem response to the 1998 regime shift in the southern regions

4 How long can the shift be expected to last?

It is currently not possible to predict when a regime will end because there is not a good understanding of the mechanisms involved in regime shifts. Earlier regimes have lasted 20 or 30 years, but most recent regimes have lasted only about 10 years. Therefore, one might expect the current regime to last a decade or more, although it is currently not possible to predict with certainty.


5

Is it possible to predict when the regime will shift back, and what indicators should be used to determine when this happens?

It is currently not possible to predict when a regime shift will occur. However, it is possible to detect regime shifts soon (within 5 years) after they have occurred. The phrase "shift back" implies that for climate, ocean systems and ecosystems there are only two possible states. It is important to note that regimes are not characterized by two states. As such, a regime shift will not necessarily imply a shift back to a previously observed state. The multiple physical and ecological processes that cause regime shifts are currently not well understood. Research must continue to investigate the mechanisms and triggers for regime shifts.

Because they have proven to be reasonable indicators of past regime shifts, ***existing climate and ocean indices should continue to be used as indicators of changes in climate and North Pacific ocean conditions***. Research must continue to develop and test new indicators such as sea surface height and ocean color from satellites. These may be reliable indicators, because they integrate many processes of ecological importance (thermal structure, circulation, primary production), and satellite technology makes these data consistently and regularly available.

Monitoring programs to develop indices that are more directly related to the productivity of fish populations should be a high priority. Research must continue on identifying the mechanisms by which climate change produces an ecosystem response. This research is critical to efficiently and quickly recognize the climate signals that cause shifts in marine populations.


6

What are the implications for the management of marine resources?

Marine resource management agencies need to develop policies with explicit decision rules and the subsequent actions to be taken as soon as there are indications that a regime shift has occurred. These decision rules need to be included in long-range policies and plans.

Including the effects of regime shifts in the management of marine resources is critical to sustaining their productivity. There are numerous examples globally of the undesirable consequences of failing to detect or acknowledge climate impacts on fish populations. Stock assessment advice should consider the different environmental conditions and alternative management strategies that could be expected in different regime periods and how this may impact the productivity of stocks.

Ecosystem changes resulting from natural disturbances provide opportunities for some species to persist when there is competition for limited resources. In managed systems where fishing is regulated, ecosystems will continue to shift and evolve in response to environmental disturbances. Marine resource managers must recognize that human activities may worsen the effects of natural disturbances. Managers should also recognize that the lifespans of species may have evolved in response to decadal patterns of climate and ocean variability. Short-lived species are able to rapidly expand and re-colonize regions when favorable environmental conditions occur. In contrast, long-lived species may rely on having several years to produce young, which allows their populations to endure long (decadal) periods of poor ocean conditions. These survival strategies require different management responses.

For short-lived species, scientists are very likely to detect the processes that influence the production of these populations. They must incorporate these processes into their advice. Using a minimum stock size below which the stock must not fall may be the best protection for short-lived species. It might mean that there are periods when no fishing is possible on these species.

For long-lived species, changes in the abundance of the stock due to regime shifts will be slower. For these species, the number of new fish produced each year is only a fraction of the mature stock size, and their longer life span ensures a relatively long reproductive cycle. This enables these populations to endure prolonged periods of unfavorable environmental conditions. In addition to using a minimum stock size limit, maintaining a population with a wide range of fish of different ages should be a paramount fisheries management goal for long-lived, late maturing species.

overall recommendations

Given the importance of ocean climate regimes to ecological systems, four recommendations for incorporating regime shift concepts into fishery management activities are:

1. accept the regime concept for marine ecosystems – a wealth of historical evidence suggests regime shifts are a natural and recurring part of marine ecosystems

2. develop and maintain a comprehensive observational program to monitor changes in climate, ocean systems and their ecosystems

3. develop climate indices to aid ecosystem monitoring efforts, and support research into how these climate indices are linked to the climate system (e.g., variability of El Niño events)

4. use integrated stock assessments, in which scenarios of potential future regime conditions can be evaluated to determine where and how fisheries and ecosystems are most vulnerable, and to conduct analyses of different fisheries management strategies

PICES Study Group on FISHERIES AND ECOSYSTEM RESPONSES TO RECENT REGIME SHIFTS

CANADA
William Crawford
Institute of Ocean Sciences
Fisheries and Oceans Canada
Sidney, British Columbia

Jacquelynne King (Chair)
Pacific Biological Station
Fisheries and Oceans Canada
Nanaimo, British Columbia

David Mackas
Institute of Ocean Sciences
Fisheries and Oceans Canada
Sidney, British Columbia

Gordon McFarlane
Pacific Biological Station
Fisheries and Oceans Canada
Nanaimo, British Columbia

Jake Schweigert
Pacific Biological Station
Fisheries and Oceans Canada
Nanaimo, British Columbia

CHINA
Qi-Sheng Tang
Yellow Sea Fisheries Research Institute
Qingdao

Jin-Ping Zhao
First Institute of Oceanography
State Oceanic Administration
Qingdao

JAPAN
Akihiko Yatsu
Fisheries Biology and Ecology Division
National Research Institute
of Fisheries Science
Yokohama

KOREA
Suam Kim
Dept. of Marine Biology
Pukyong National University
Pusan

RUSSIA
Victor Lapko
Sakhalin Research Institute of
Fisheries and Oceanography
Yuzhno-Sakhalinsk

UNITED STATES
Harold Batchelder
College of Oceanic
& Atmospheric Sciences
Oregon State University
Corvallis, Oregon

Jennifer Boldt
Alaska Fisheries Science Centre
NOAA Fisheries
Seattle, Washington

Anne Hollowed
Alaska Fisheries Science Centre
NOAA Fisheries
Seattle, Washington

Alec MacCall
Santa Cruz Laboratory
NOAA Fisheries
Santa Cruz, California

Nathan Mantua
Climate Impacts Group
University of Washington
Seattle, Washington

James Overland
Pacific Marine Environmental Lab
NOAA Oceanic & Atmospheric Research
Seattle, Washington

Jeffrey Polovina
Pacific Islands Fisheries
Science Center
NOAA Fisheries
Honolulu, Hawaii

Franklin Schwing
Pacific Fisheries Environmental Lab
NOAA Fisheries
Pacific Grove, California

PICES
Alexander Bychkov
PICES Secretariat
Sidney, British Columbia

Skip McKinnell
PICES Secretariat
Sidney, British Columbia

Ian Perry
Pacific Biological Station
Fisheries & Oceans Canada
Nanaimo, British Columbia

This report can also be found on the PICES Website (http://www.pices.int/publications/brochures/default.aspx).

It is an abstract of a larger report entitled:
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