Adapting Marine Social-Ecological Systems to a World of Change: Lessons from the GLOBEC Experience

R. Ian Perry[1], Manuel Barange[2], Francisco Werner[3], Eileen Hofmann[4], Rosemary Ommer[5]

[1]Pacific Biological Station, Nanaimo, B.C., Canada

[2]Plymouth Marine Laboratory, Plymouth, UK

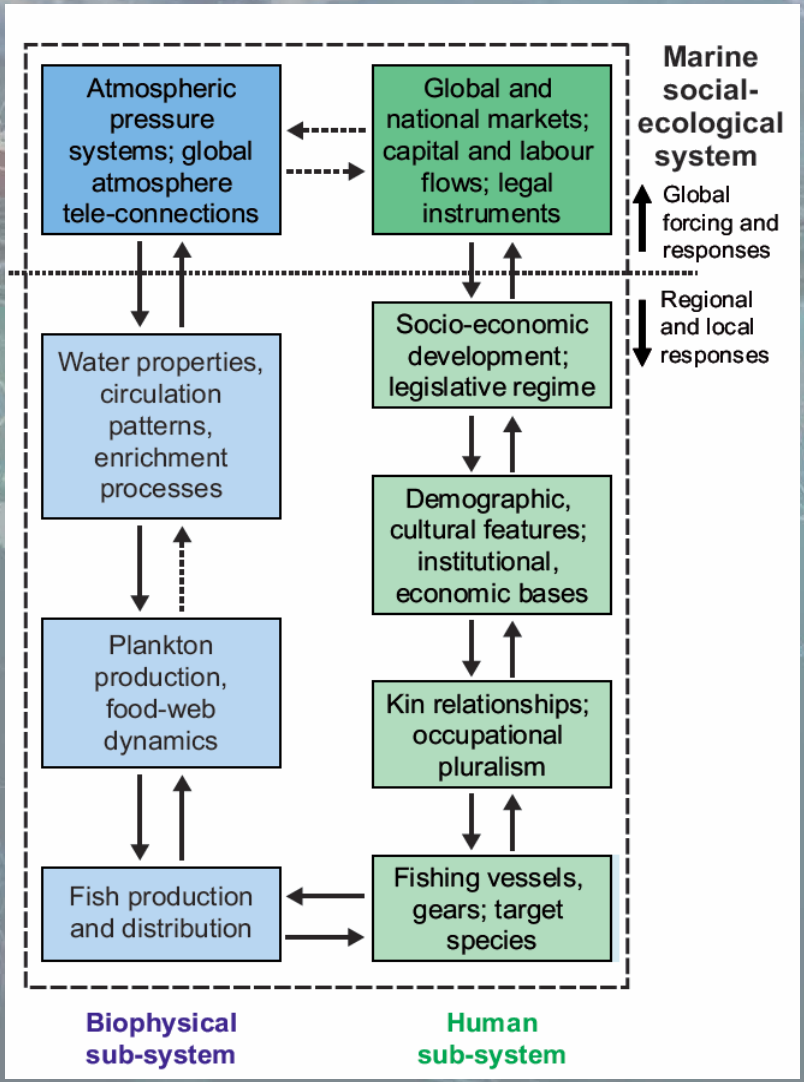
[3]Rutgers University, New Brunswick, NJ, USA

[4]Old Dominion University, Norfolk, VA, USA

[5]University of Victoria, Victoria BC Canada

Ian.Perry@dfo-mpo.gc.ca

Coupled marine social-ecological systems



Perry et al. 2010. In: Barange et al. Marine ecosystems and global change. OUP

Social-ecological systems:

- complex adaptive systems including social (human) and ecological (biophysical) sub-systems in two-way feedback relationships
- integrated concept of humans-in-nature
- delineation between human social and ecological systems is artificial

Berkes. In Press. In: Ommer et al. World Fisheries: a social-ecological analysis. Wiley-Blackwell.

Large-scale policy goal

Healthy marine social-ecological systems that:

- maintain desirable ecosystem services, such as:
  - human food security (the supply of food from the sea)
  - the role of the marine ecosystem in the global carbon cycle
  - ability to process and dispose of wastes
- maintain the ability to support human livelihoods, such as:
  - ability of people to obtain sustenance (economic, social, cultural, spiritual) from the sea
  - reduction of poverty

Drivers of change in marine social-ecological systems

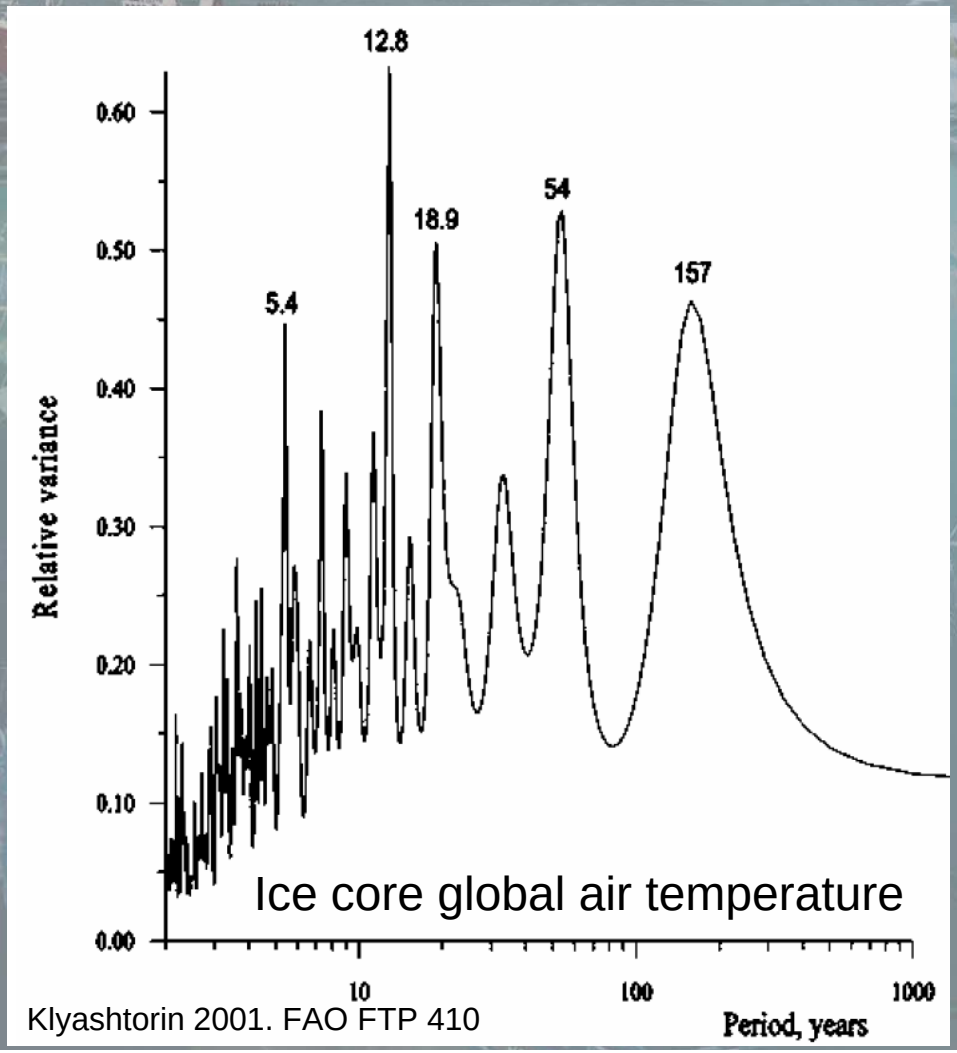
Biophysical drivers:

- environmental variability
- climate trends (change)
- acidification
- changes in oxygen concentration
- internal ecosystem dynamics (predator-prey; disease)

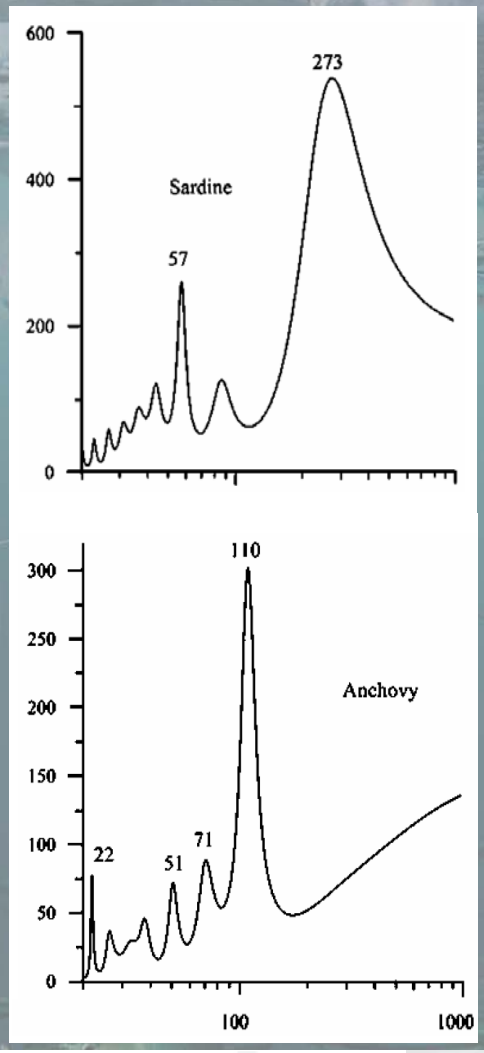
Human drivers:

- fishing
- habitat degradation
- contaminants
- introductions of exotic species
- mineral extraction
- demographic changes
- economic changes
- market / trade changes
- infectious diseases
- societal and international agreements
- law and property relations
- policy changes

Marine ecosystems are variable at seasonal, interannual, decadal, centennial and longer scales



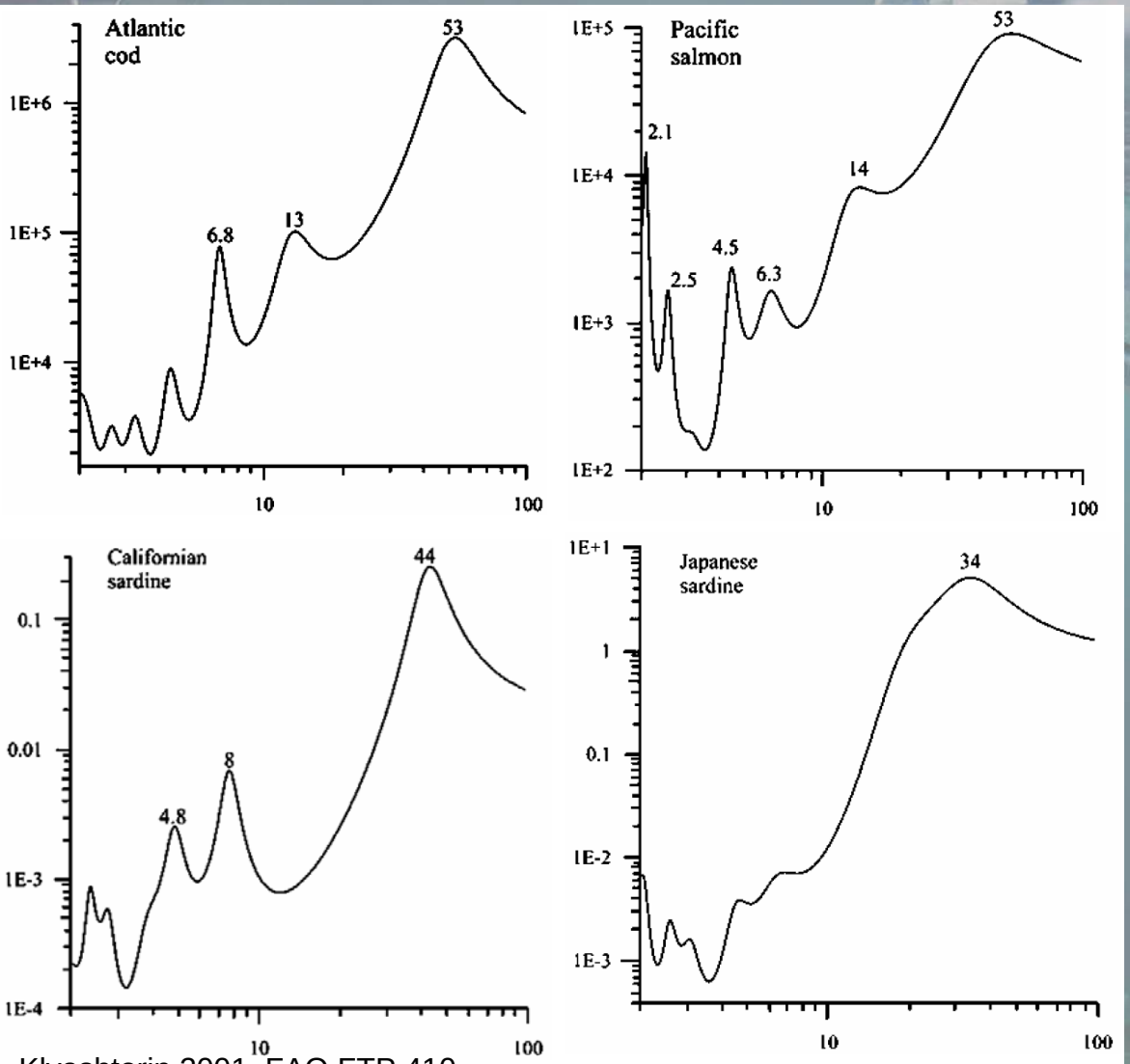
Klyashtorin 2001. FAO FTP 410



Global air temperature variability at 5, 13, 19, 54, 160 yrs

Small pelagic fish population variability at 22, 50, 70, 100-300 yrs

Human social sub-system also has characteristic time scales



Klyashtorin 2001. FAO FTP 410

Fisheries catch time scales of:
4-5,
6-8,
14,
30-50 yrs

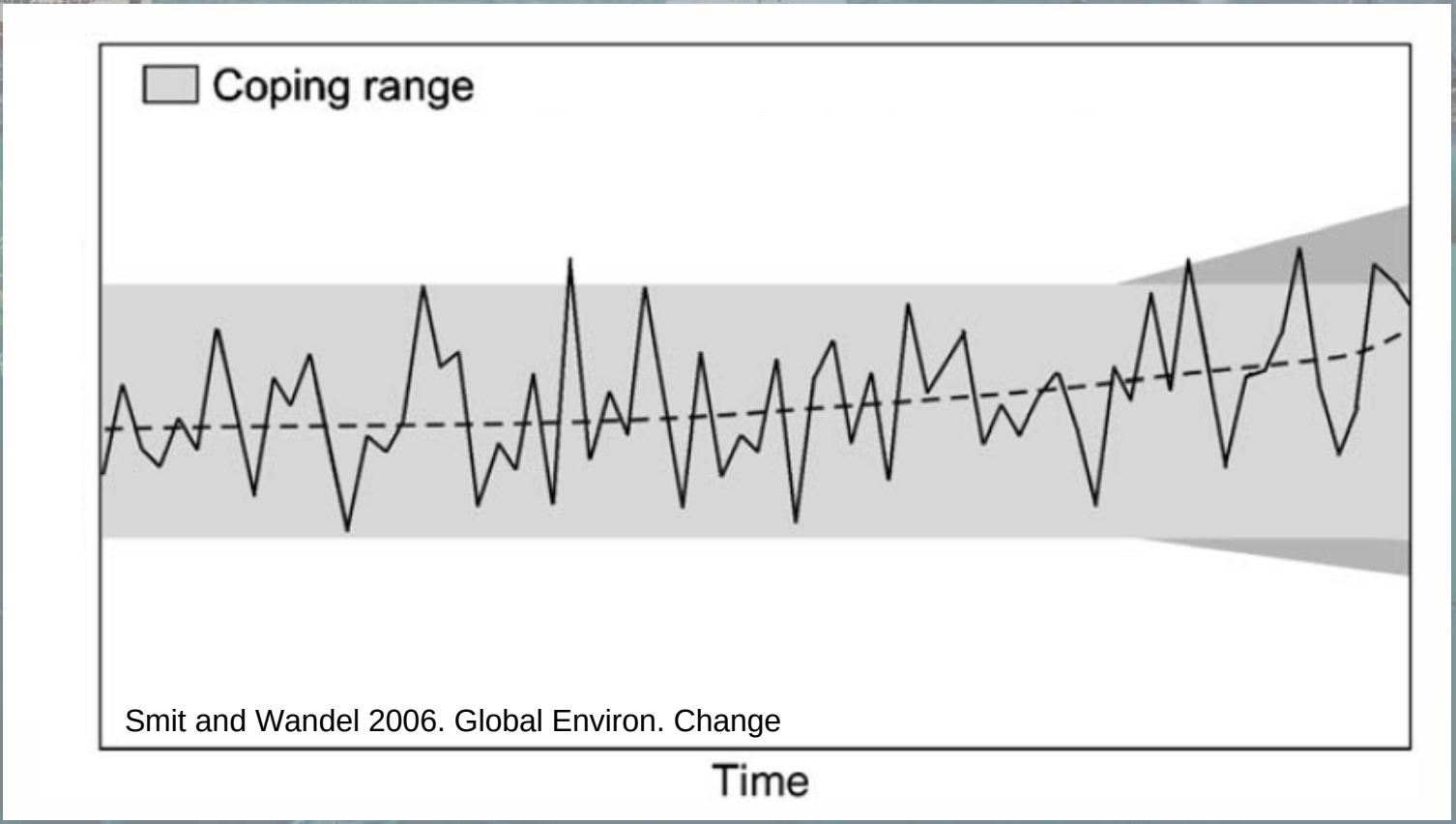
Human social system time scales of:
5 yrs (business cycle);
~ 30 yrs (working life)
~ 80 yrs (life span)

Perry et al., Climate Change Effects on Fish & Fisheries. Sendai, Japan, 2010

Fisheries and Oceans Canada | Pêches et Océans Canada

GLOBAL IGBP CHANGE

Human social systems cope with variability within their “normal” range of experience, and adapt to variability beyond their “normal” range.

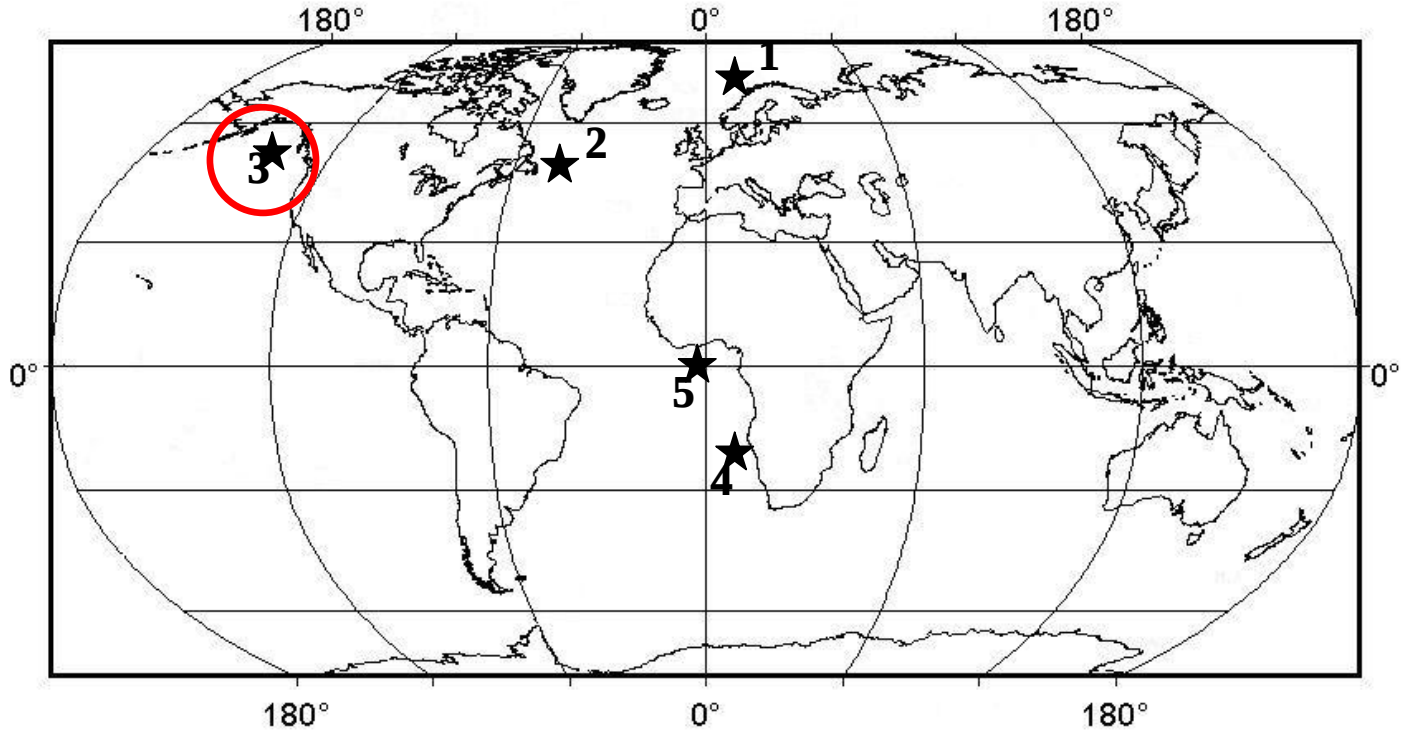


“Normal” range is therefore a scale issue, i.e. relative to the experience and adaptive capacities of the natural or human social systems

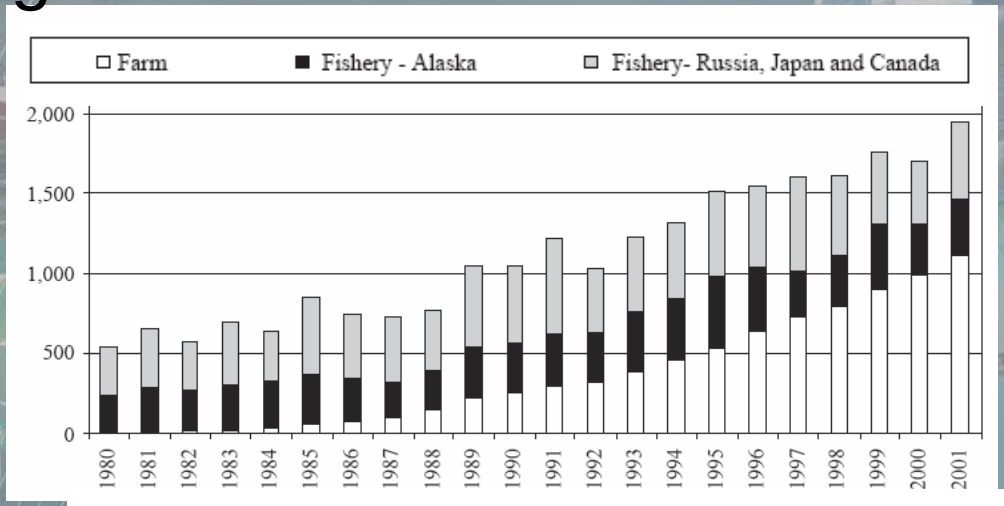
Environmental changes and the impacts of globalisation on marine social-ecological systems

Case Studies in which:

- large scale atmospheric/climate changes and/or intensive fishing led to significant marine ecosystem changes

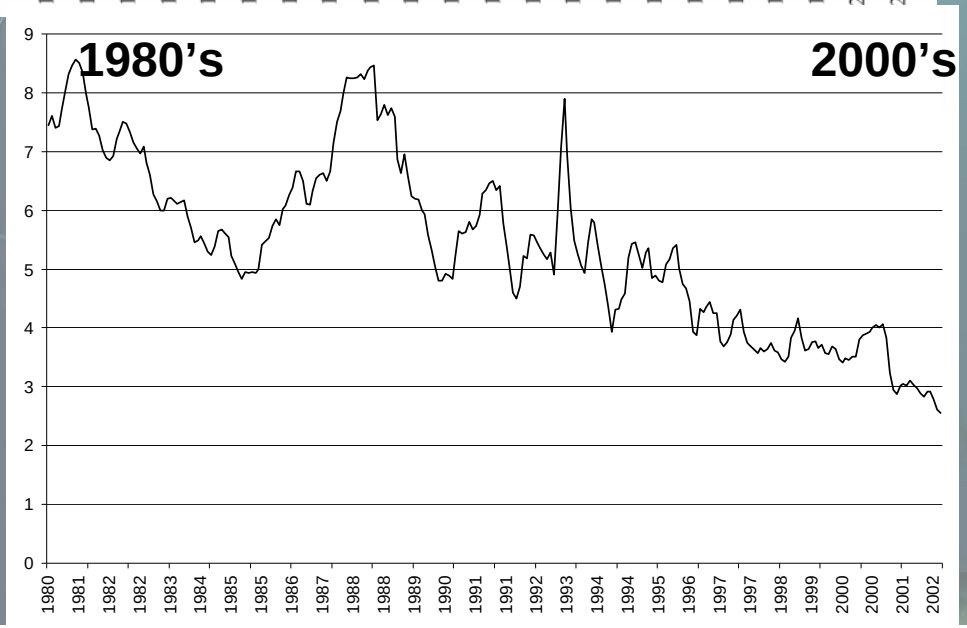


Environmental changes and the impacts of globalisation on marine social-ecological systems



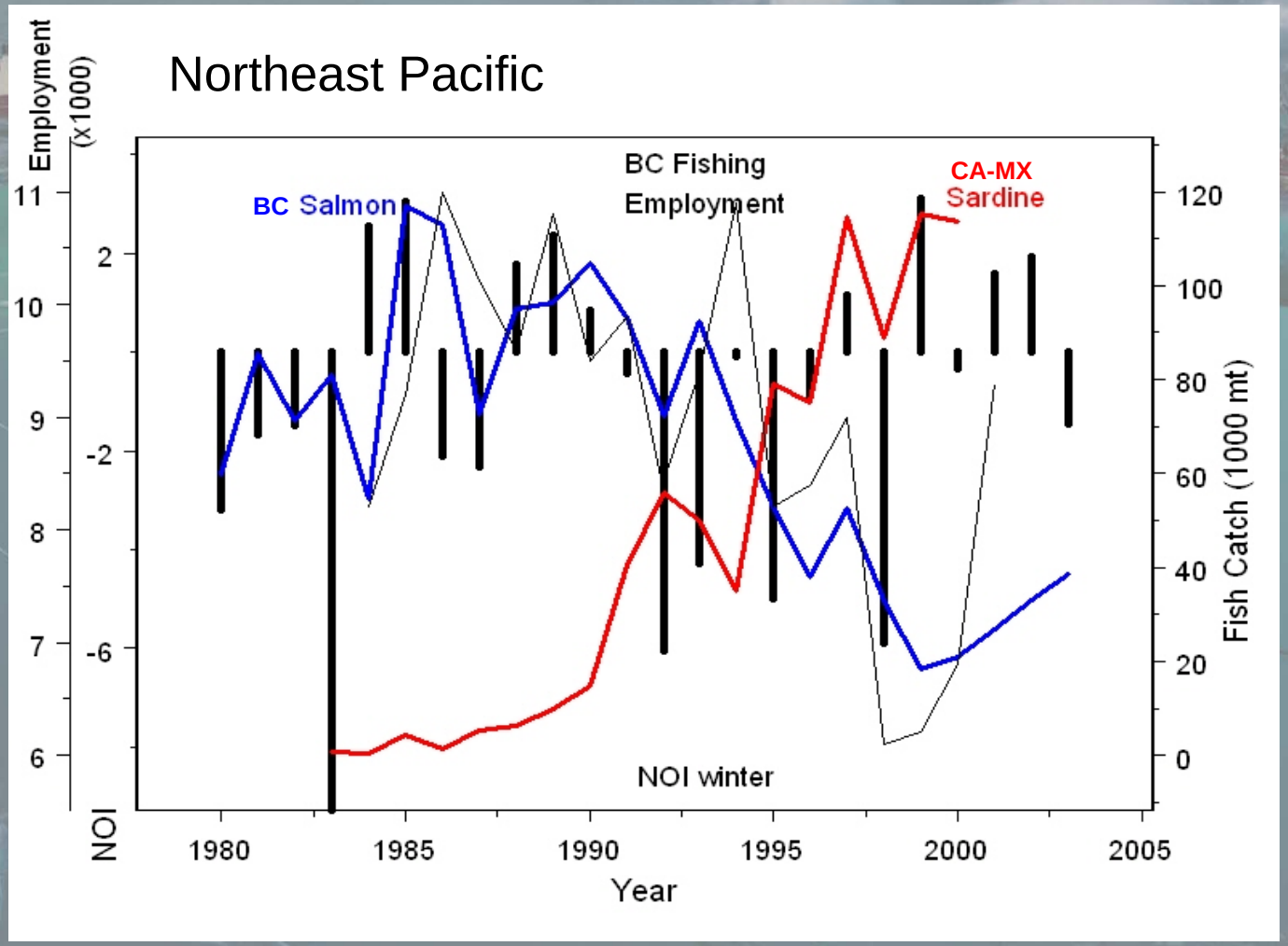
World salmon supply (x1000 t), 1980 – 2001

Eagle et al 2004. Marine Policy



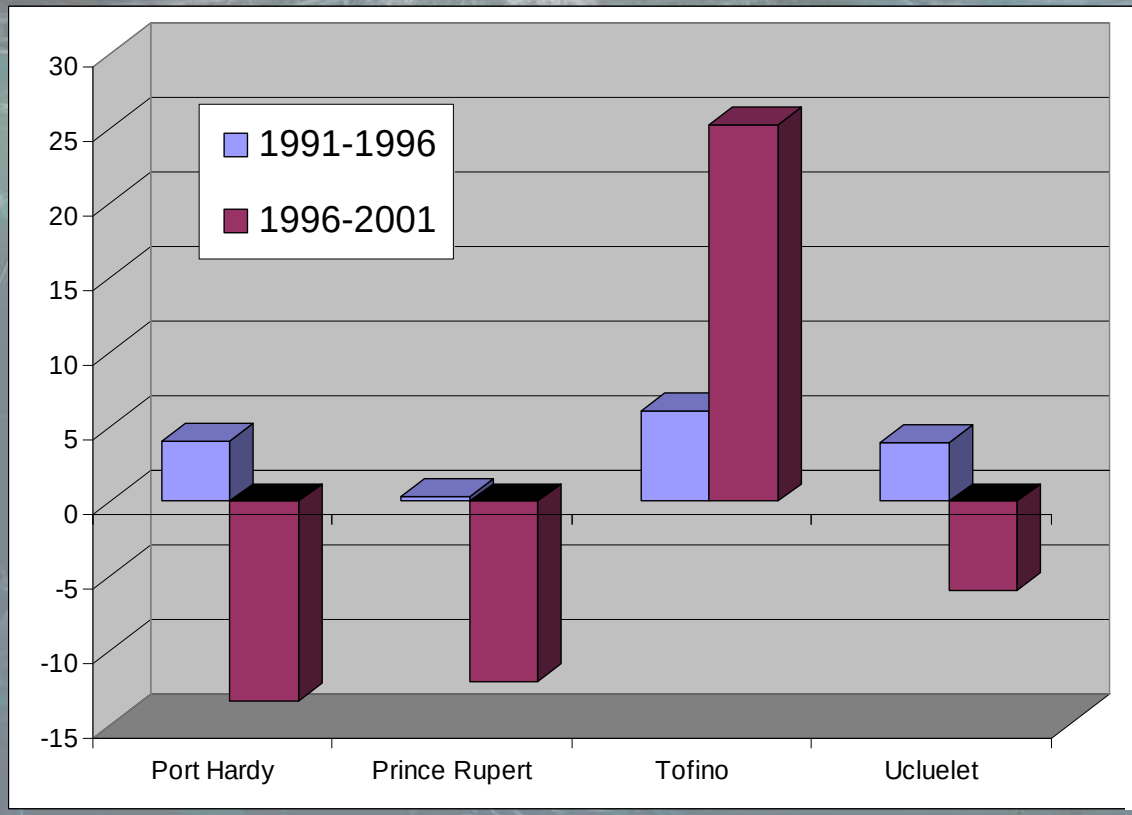
Salmon price (US$/kg) (Norwegian farmed salmon), 1980 - 2001

Environmental changes and the impacts of globalisation on marine social-ecological systems

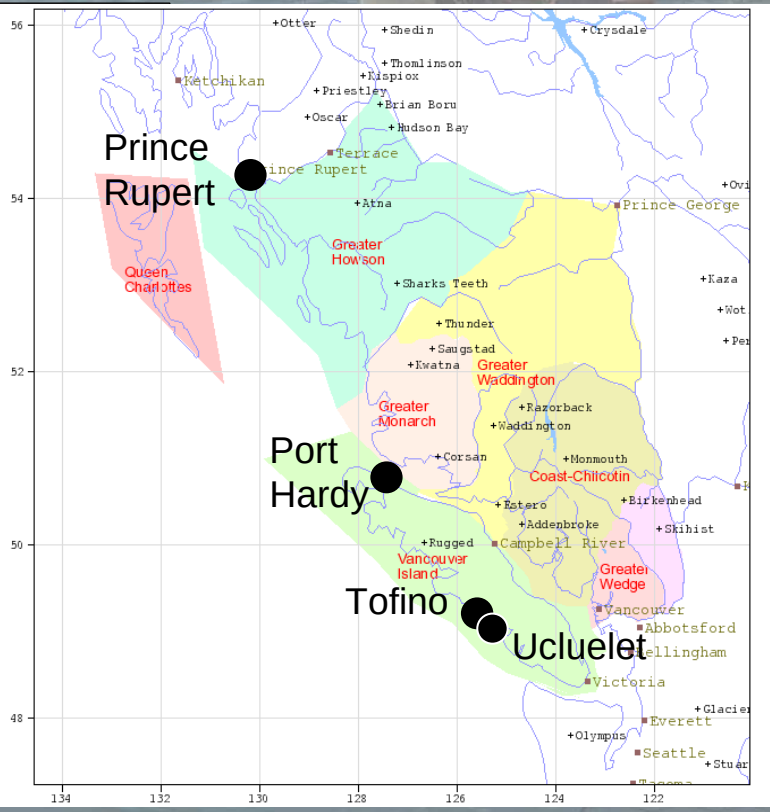


Environmental changes and the impacts of globalisation on marine social-ecological systems

% Change in population of coastal towns



Northeast Pacific



Ommer and Coasts Under Stress Team. 2007. McGill Queens University Press

Synthesis of responses of fishing-dependent human communities to global changes

- at short time scales
  (coping strategies – relatively quick to start, somewhat reversible):
  - intensification of effort
  - diversification of species and gears fished
  - migration
  - “hibernation”
- at longer time scales
  (adapting strategies – slower to implement, difficult to reverse):
  - political reform
  - capacity building
  - restructuring
  - community closure

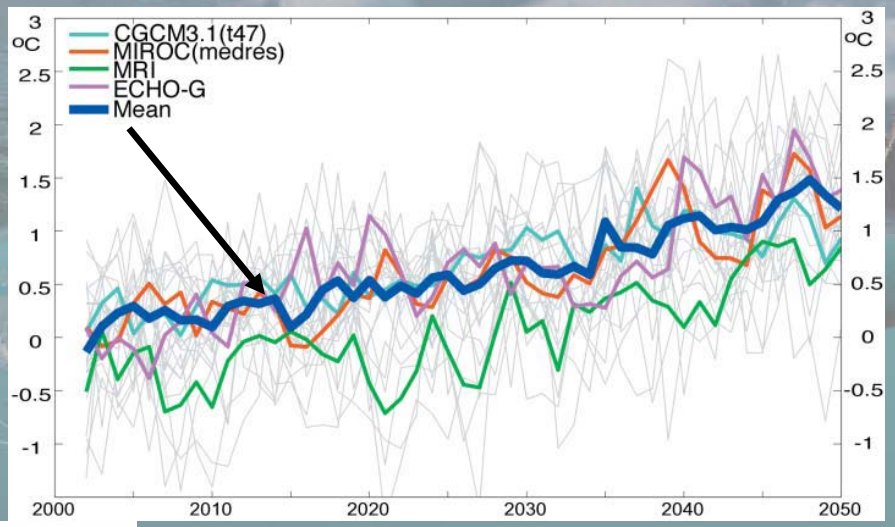
Variability of past marine ecosystem changes has been relatively small

"From all available records, changes in the physical environment and on basic ecosystem levels have been subtle over the last two millennia: sea surface temperatures and sea surface salinities in most regions that have been studied changed by at most 10% (SST 2 °C, SSS 3–5 psu). Primary productivity … in these regional to local environments may have fluctuated by 20–30%."

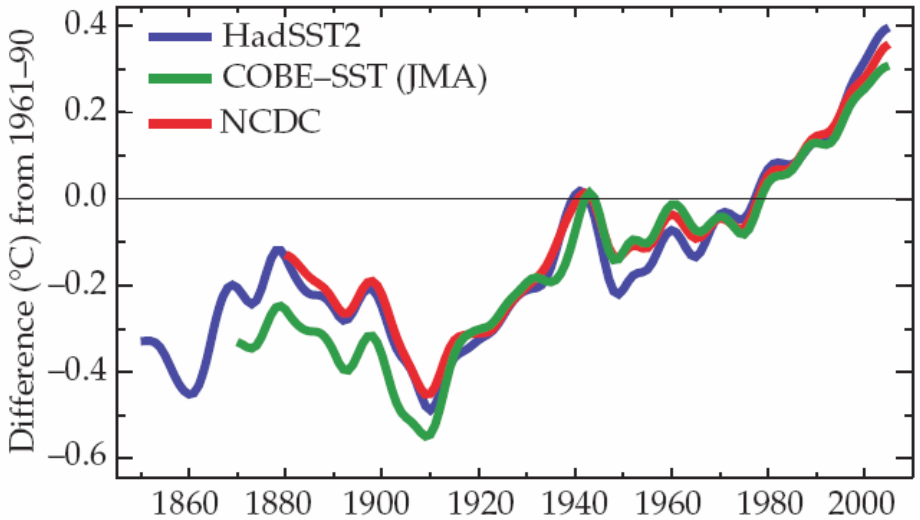
Emeis et al. 2010. J. Marine Systems

Expected future climate changes go beyond the ranges of past variability

Projected winter sea surface temperature anomalies relative to 1980–1999 for the central North Pacific Ocean



Overland and Wang 2007 Eos Trans. AGU 88



Trenberth et al. 2007 IPCC Report

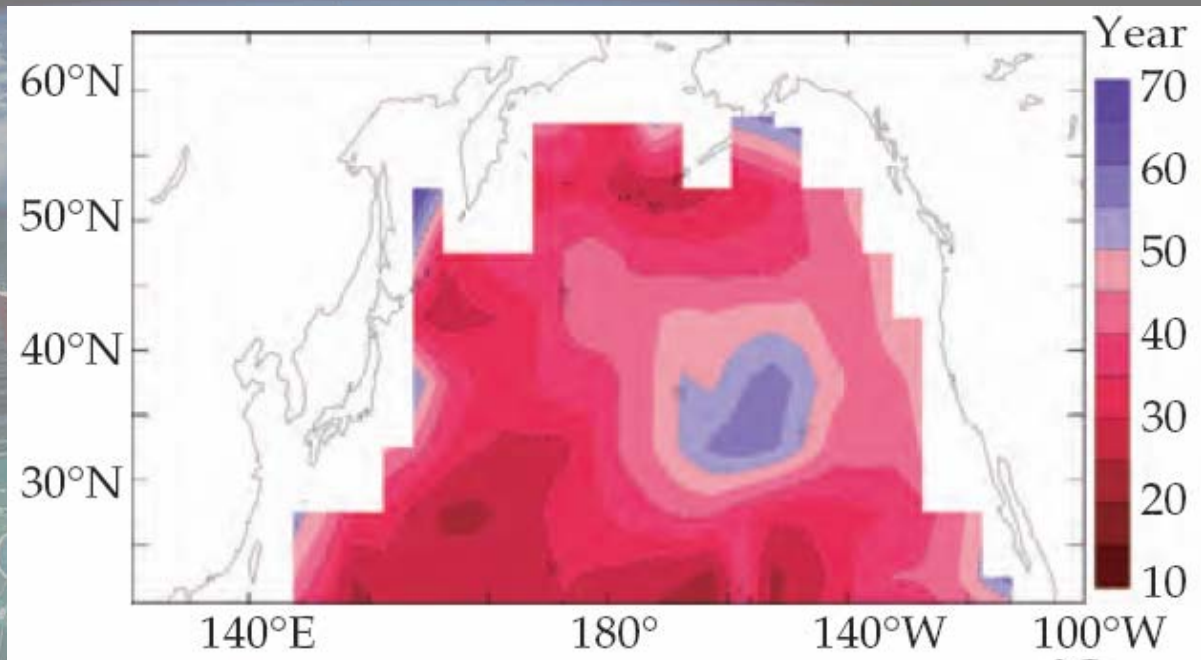
Smoothed annual global SST anomalies, relative to 1961–90

Several factors complicate predictions of climate change impacts

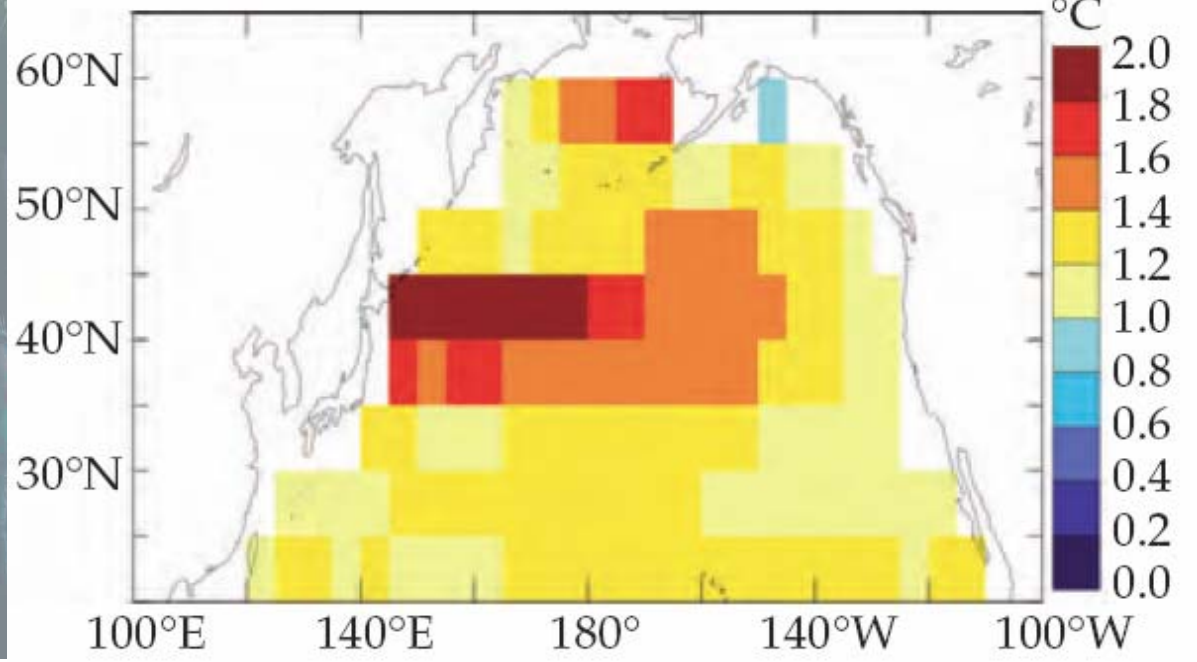
- local expressions of global-scale predictions
  - e.g. details of changes in fish distributions; threshold effects
- disruption of existing communities as species respond at different rates to warming conditions
- changes of seasonality – mismatch of life cycle timing
- uncertainties about how nutrient inputs and productivity will respond to warmer conditions
- declines in adaptive capacities of marine ecosystems to climate change due to effects of fishing and habitat loss, e.g. shorter life spans, loss of sub-populations

Result is: increased uncertainty

Expected future changes go beyond ranges of past variability



Estimated year (2000+) when the net warming exceeds the magnitude of current variability.



Projected winter SST change for 2040–2049 minus 1980–99. Changes are in the range of 1–2°C.

Note wide spatial variability

Overland and Wang. 2007. EOS Transactions

Climate change impacts will not occur all-at-once

Rapid time scales (a few years)

- increasing temperatures → negative impacts on fish physiology:
  - changes in distributions of marine species,
  - changes in timing of life history events - short life span, rapid turnover species (plankton, squid, small pelagic fishes) likely most affected.

- Intermediate time scales (years to a decade),
  - temperature-mediated physiological stresses and phenology changes impact recruitment success and abundances.
  - changes in abundance alter species composition, with possible consequences for ecosystem structure and productivity.

- Long time scales (decade +),
  - predicted impacts depend upon changes in oceanic net primary production and transfer to higher trophic levels.
  - models show high variability so predictions have low confidence.

Important to consider climate change relative to other drivers of change in marine social-ecological systems

Climate Change likely greater, but less immediate, challenge for

- highly-regulated (managed) systems,
- slowly varying (e.g. higher latitude) systems

Other Drivers of Change (e.g. fishing, strong environmental variability) likely more immediate challenges for

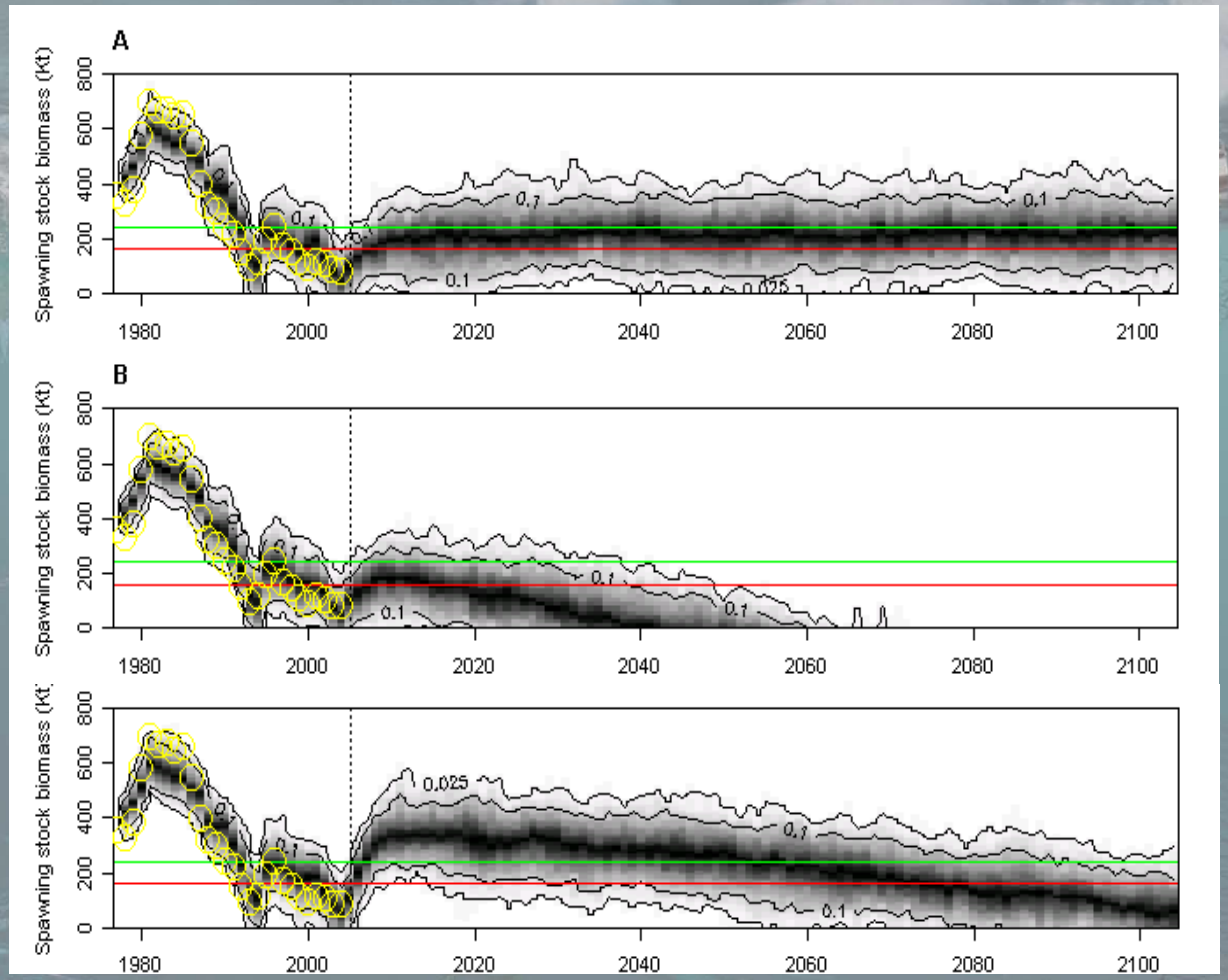
- poorly-regulated (managed) systems (South China Sea?),
- highly variable (e.g. small-pelagic upwelling?) systems

Modelling interactions of climate and fishing as forcing factors for Baltic Sea cod

Status-quo fishing and status-quo climate (i.e. fishing is controlled)

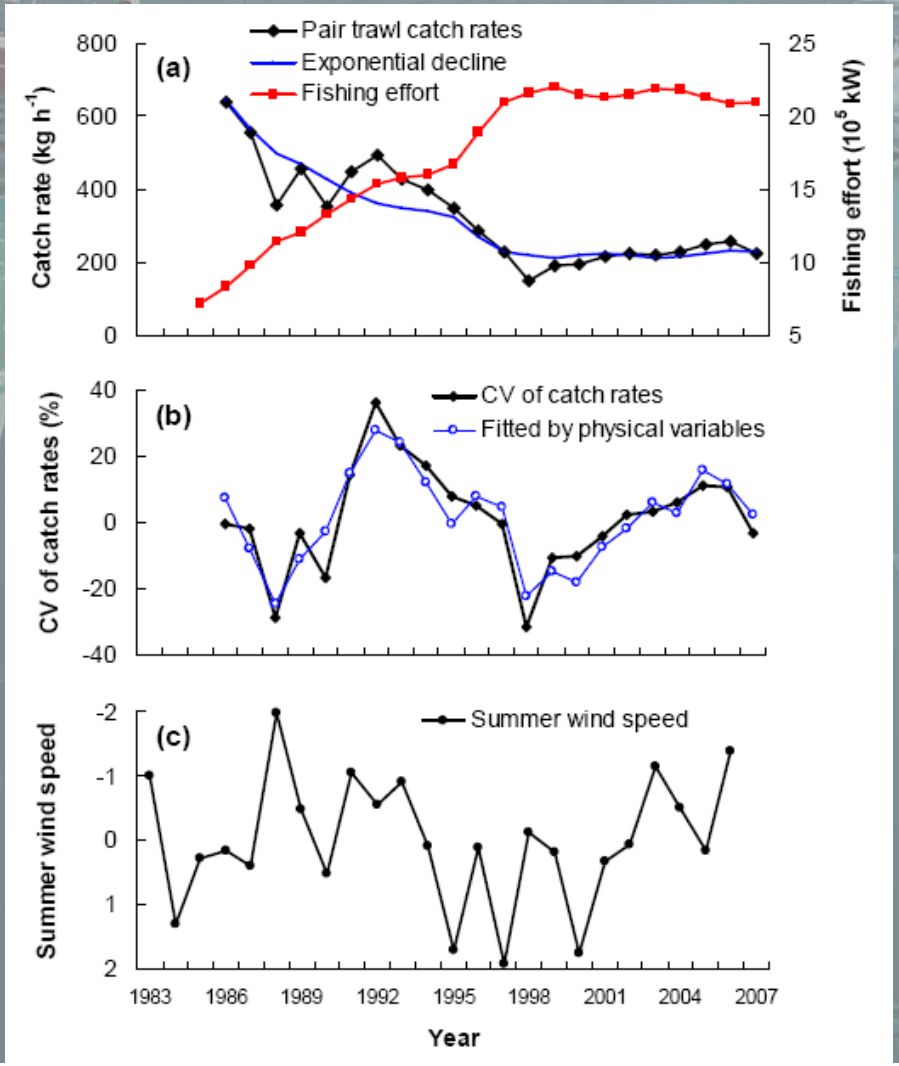
Climate change (SST + 3.5°C, psu – 4.8) + mean fishing mortality

Climate change (psu - 0.8) and fishing at its calculated sustainable level



Lindegren et al. In press. Proc. Roy. Soc. B

Fishing dominates climate variability in the South China Sea marine social-ecological system



Northern South China Sea

Top: relationship of declining catches and increasing effort

Middle: residuals after removing fishing effort

Bottom: (one) environmental control variable (summer wind)

Relationships with environmental variables were evident only after removing the effect of fishing

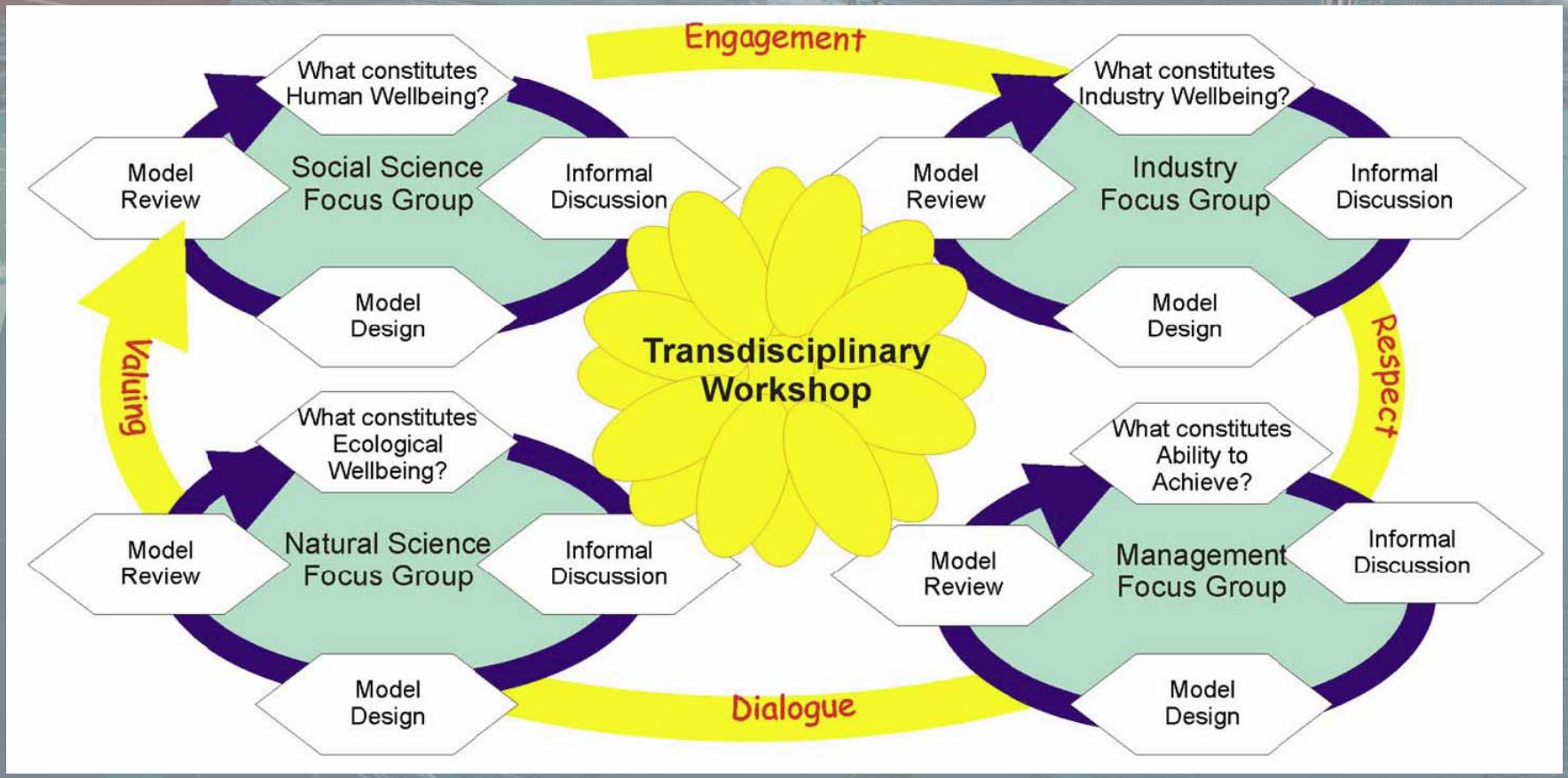
Qiu et al. 2010. Progress in Oceanography

Enhancing adaptive capacities of marine social-ecological systems to variability and uncertainty good step towards adapting to climate change

Biophysical systems	Human social systems
Reduce overall fishing pressure	Adopt a livelihoods approach
Shift exploitation to functional groups (& new fishing opportunities)	Current policies may not be appropriate under climate change
Do not focus on biomass alone: maintain life spans; sub-populations	Increased uncertainties require more monitoring
Adapt fishing and stock rebuilding to current productivity conditions	Governance: active communication and involvement with stakeholders
Do not decrease trophic level of fish communities	New agreements may be needed for special problems (e.g. migratory stocks)

Management and policy measures for adapting marine social-ecological systems to global change

Involve stakeholders



An engagement and dialogue model to develop ecosystem objectives for the South African sardine fishery

Paterson et al. 2010. Mar. Policy

How to maintain marine ecosystem services and support human livelihoods? (1)

- Climate change is but one of many drivers of change in marine social-ecological systems
- Climate change impacts: overall theme is uncertainty (= Surprise!)
- Climate change likely to appear first as environmental variability,
  - usual human social system coping mechanisms will apply
- At longer time scales as changes persist and move beyond "normal" conditions, human social systems will need to adapt
- Managing human drivers of change will help mitigate climate change impacts (e.g. EBM: "do first things first")
- Are current human strategies to cope with and adapt to environmental variability proxies for adapting to climate change?

How to maintain marine ecosystem services and support human livelihoods? (2)

Develop and promote capabilities for observing, assessing, and adapting marine social-ecological systems to change:

- observing systems (for entire social-ecological system)
- coupled physical-biological-human social system modelling
- indicators
- regional assessments
- marine management tools, e.g.
  - ecosystem-based management
  - stock rebuilding strategies that take account of changes in marine productivity conditions
  - marine protected area designs which take into account future climate variability

Acknowledgements

The participants in GLOBEC (Global Ocean Ecosystem Dynamics)

Participants in the GLOBEC Summary for Policymakers workshop (March 2010):

Brian McKenzie, Cassandra De Young, Mike Sinclair, Keith Alverson, Luis Valdes, Wendy Watson-Wright, Salvador Lluch-Cota, Dawn Ashby, Keith Brander, Wendy Broadgate, Brad deYoung, Owen Gaffney

GLOBEC: A core project of:

- International Geosphere – Biosphere Program (IGBP)
- Scientific Committee on Oceanic Research (SCOR)
- Intergovernmental Oceanographic Commission (IOC)

- main project years: 1999 - 2009