A Strategy for Marine Ecosystem Studies in the First Half of the 21st Century

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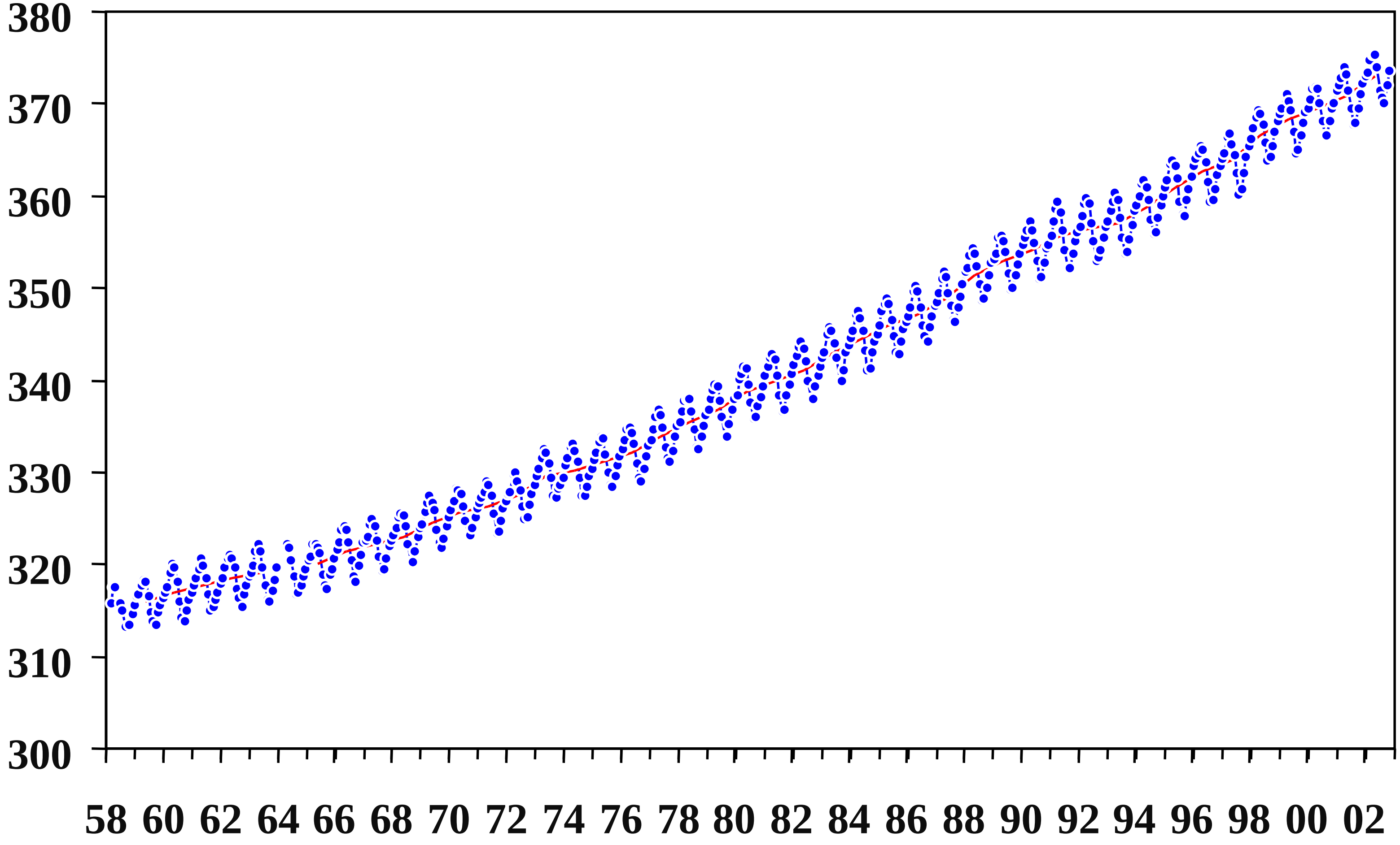
Human society is largely dependent on the ecosystem services (e.g., food supply, nutrient cycling, water supply, remineralization, culture and religious background, recreation, etc.) which are influenced by climate change.

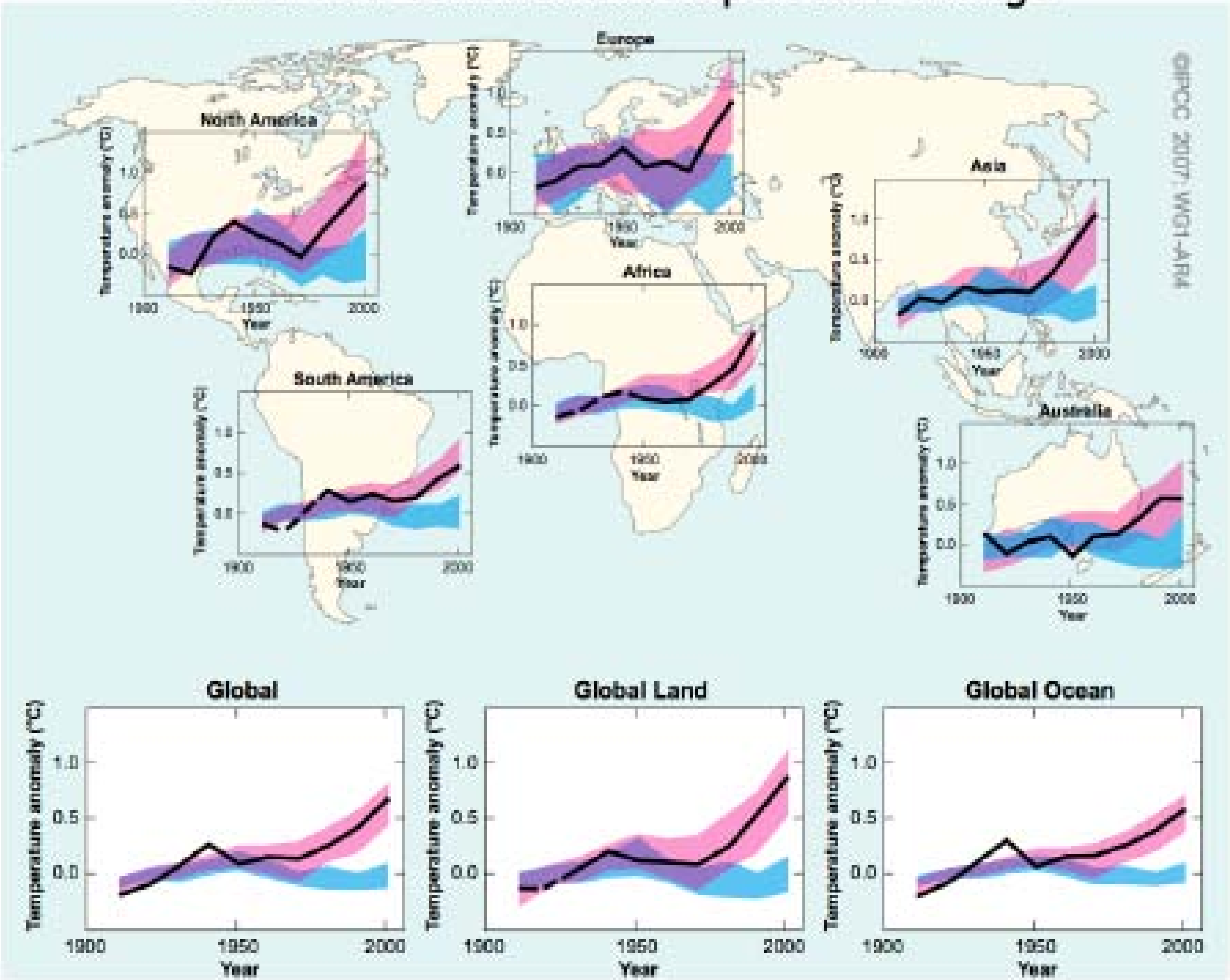
Impacts of longer scale (>100s years) climate change (climate shift) on human societies (and some cases, civilizations) were serious. Human history shows many examples of the serious impacts, such as destruction of local society, thrust, decay of civilization, etc.

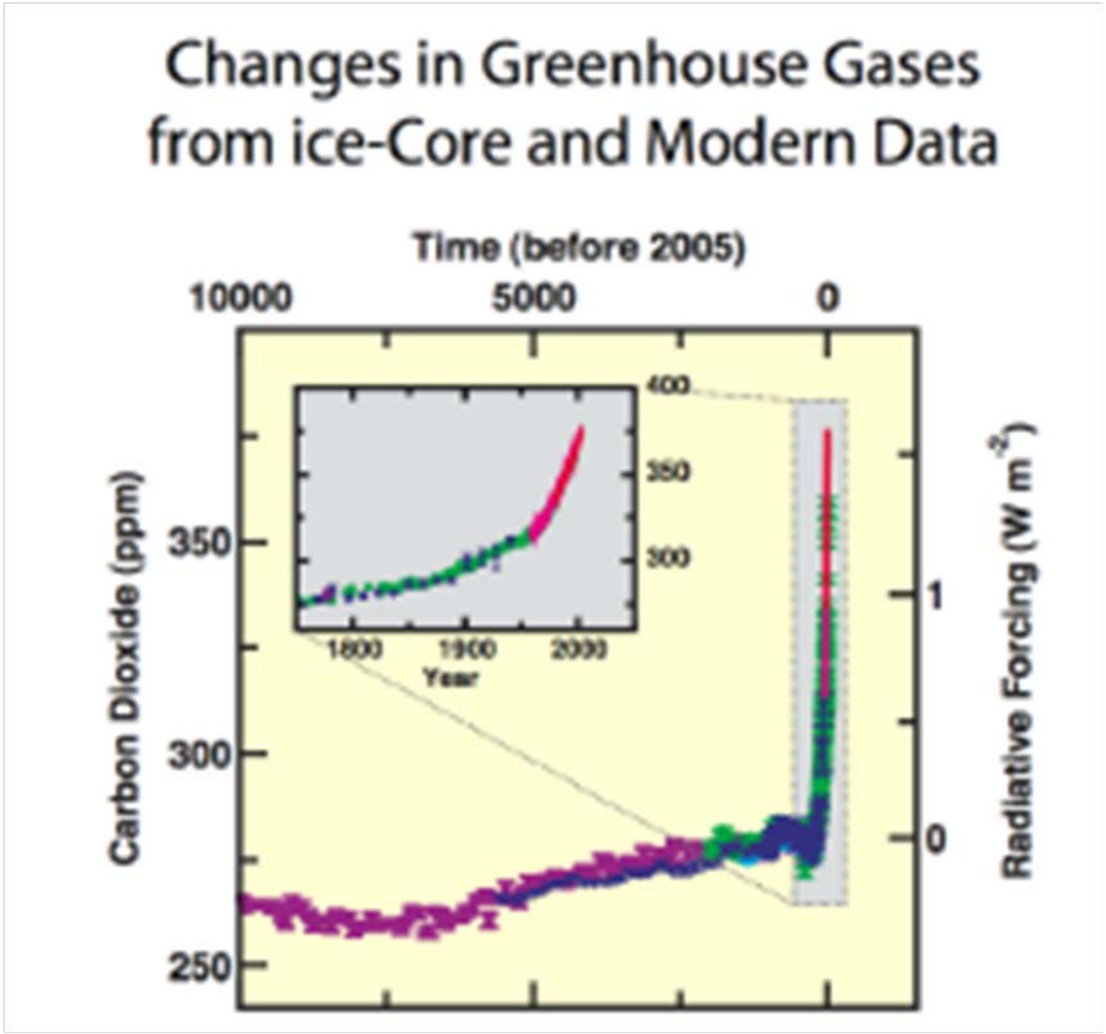
Compared with small societies (e.g., isolated Viking colony in Greenland was collapsed by the climate shift), present human society is relatively tolerant to the climate change due to global scale food supplying system and other social fundamentals. The tolerance of the present society, or civilization, is however not guaranteed against for more serious climate change than experienced previously.

CO_2 concentration (ppmv): Mauna Loa



Global and Continental Temperature Change

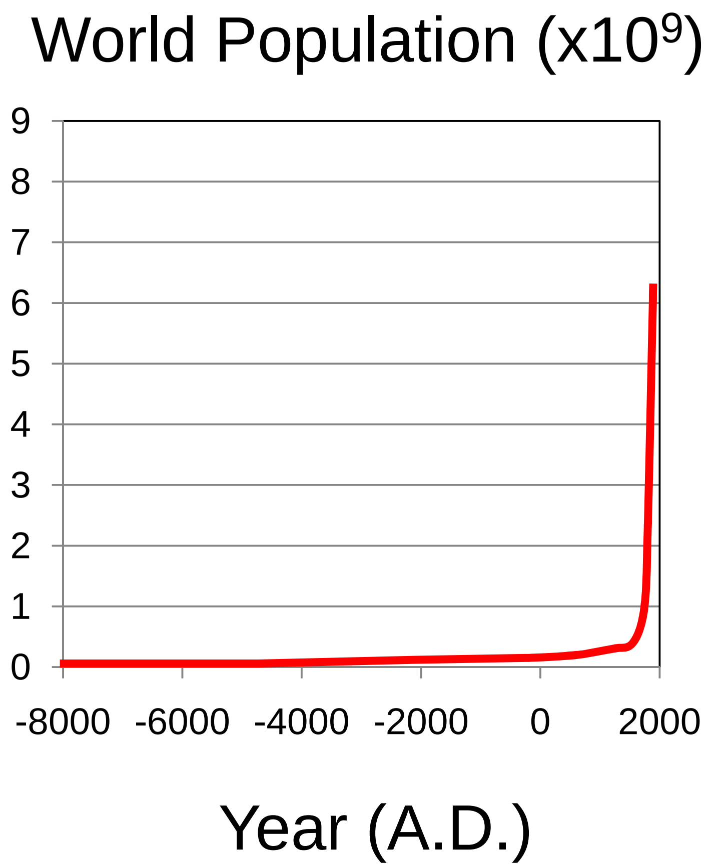




10,000 5,000 0

Time (before 2005)

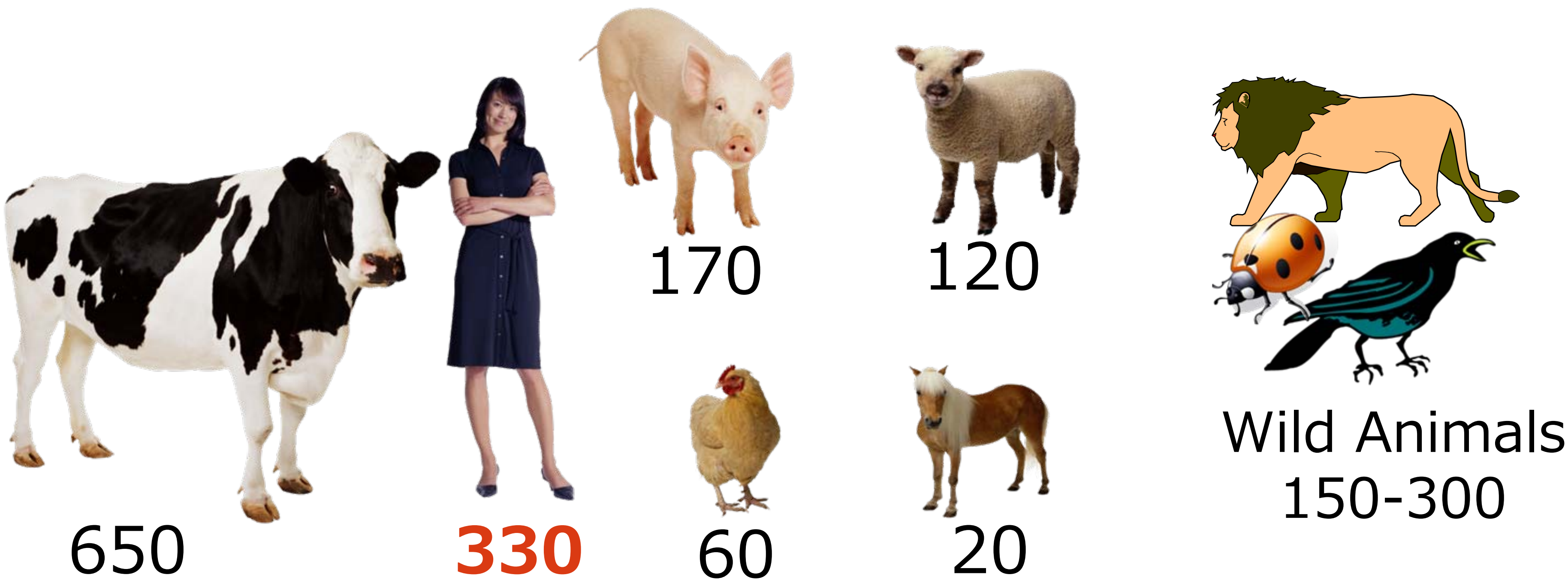
IPCC AR4



World Population (x10⁹)
9
8
7
6
5
4
3
2
1
0
-8000
-6000
-4000
-2000
0
2000
Year (A.D.)

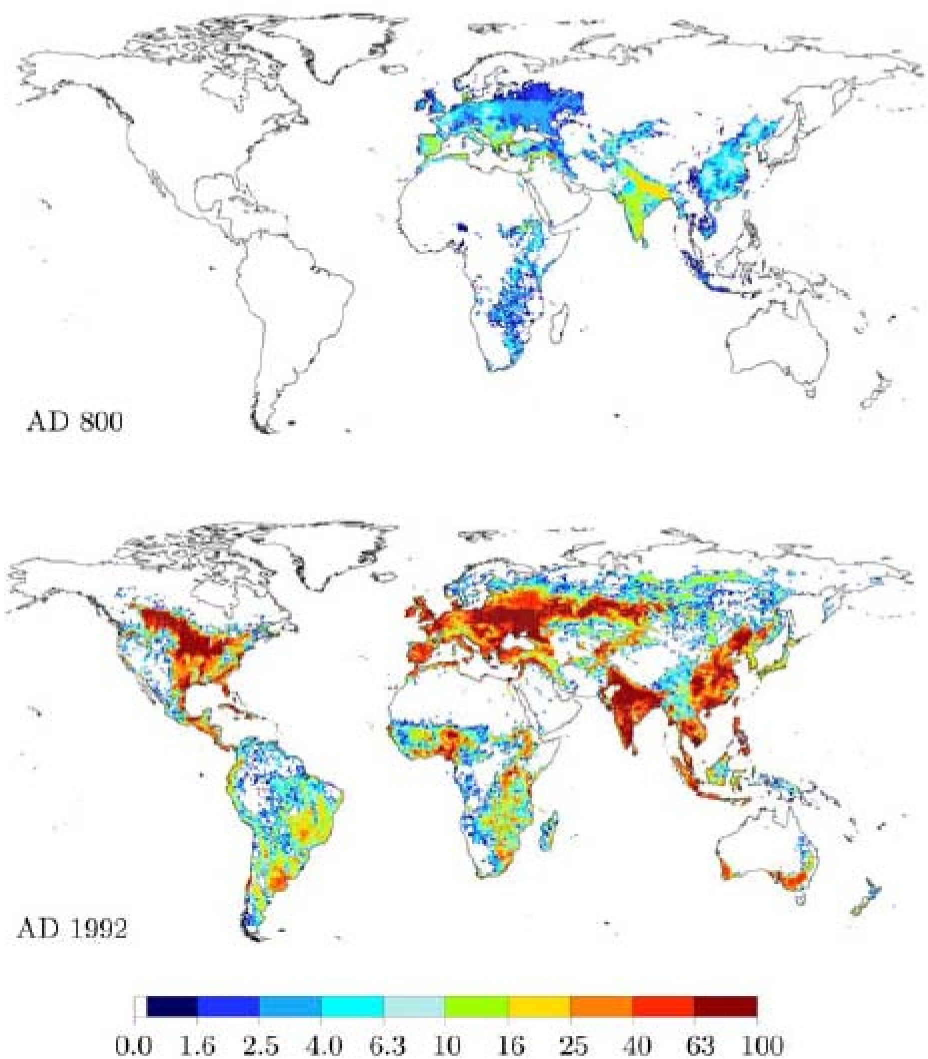
Weight of Terrestrial Animals

x10^{12} g: Tg

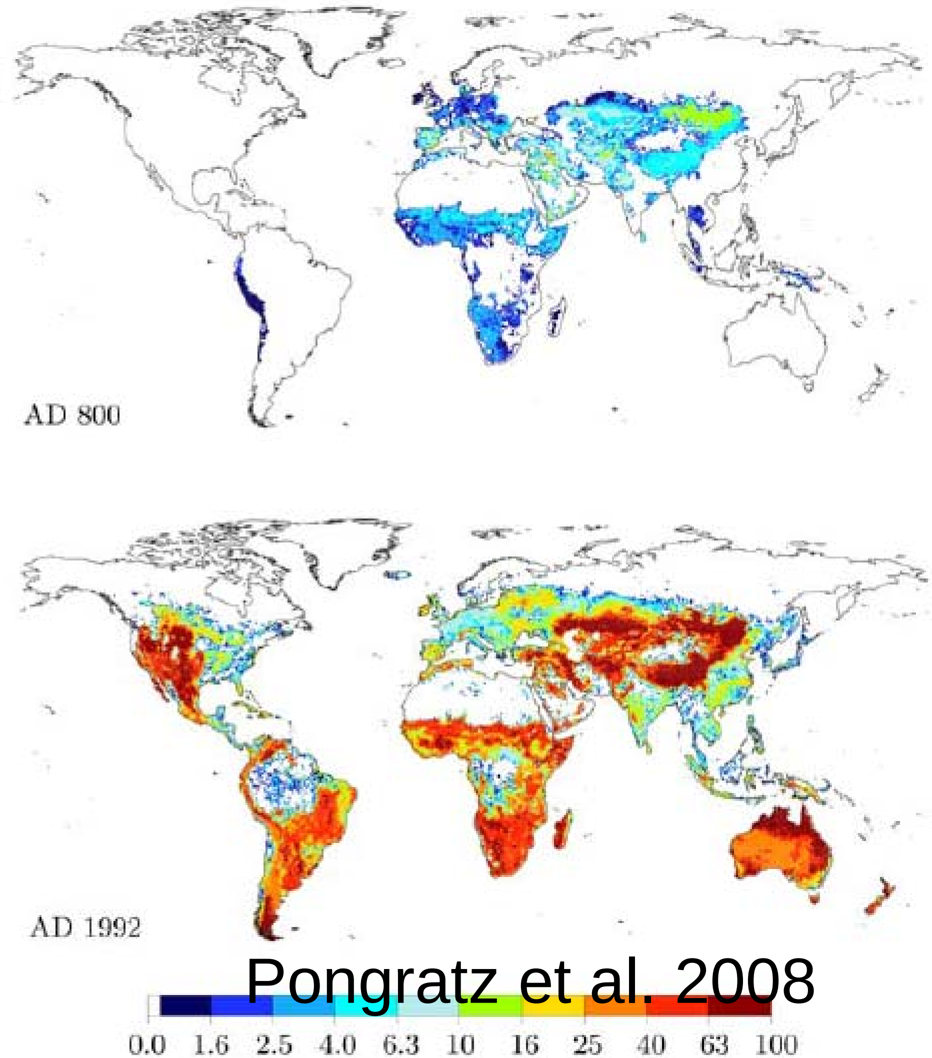


Land-use change

Cropland



Pasture



Pongratz et al. 2008

Land-use change

Potential vegetation: 99.55 x 10^6 km^2

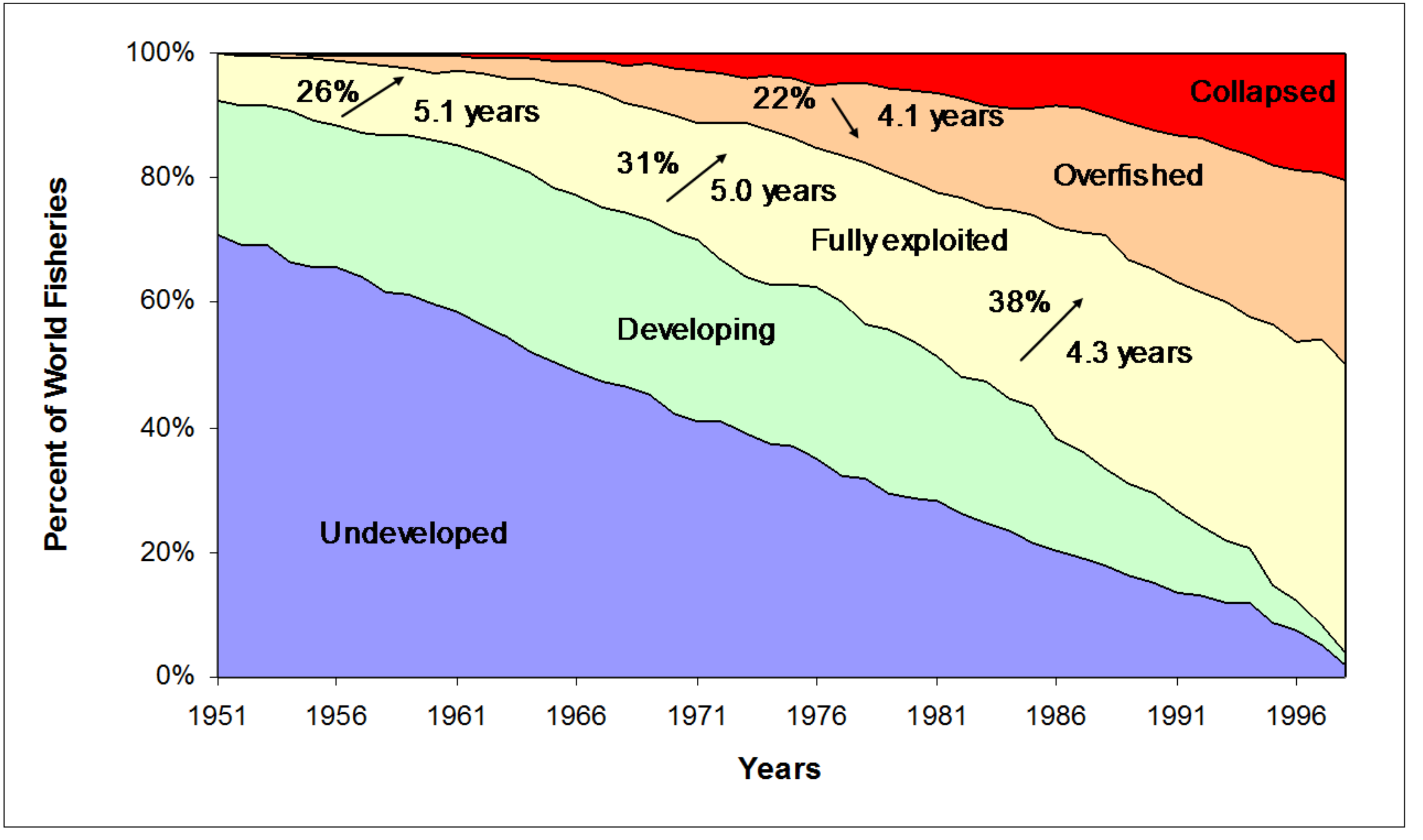
AD800→AD1992

Natural vegetation 96.75 x 10^6 → 51.16 x 10^6 km^2 (68%)

Total agriculture 2.80 x 10^6 → 48.39 x 10^6 km^2 (17200%)

48.6% of the potential vegetation

Exploitation of fisheries resources



(Froese and Pauly 2003)

On-going environmental change

Land use ： deforestation, desertation, urbanization

Water circulation ： irrigation, overdraft, damming

Loading to seas ： fertilizer, detergent, metals, PCBs

Climate gases： CO_2 (fossil fuel), CH_4 (rice field, livestock), CFCs

Ecosystem structure ： extinctions, habitat destruction/ fragmentation, overfishing, selective fishing of large fish.

On-going environmental change

global scale

abruptness

mass extinction

equivalent to geochronological transition

Paul J. Crutzen and Eugene F. Stoermer

“Anthropocene”

Human society expects “usual climate”

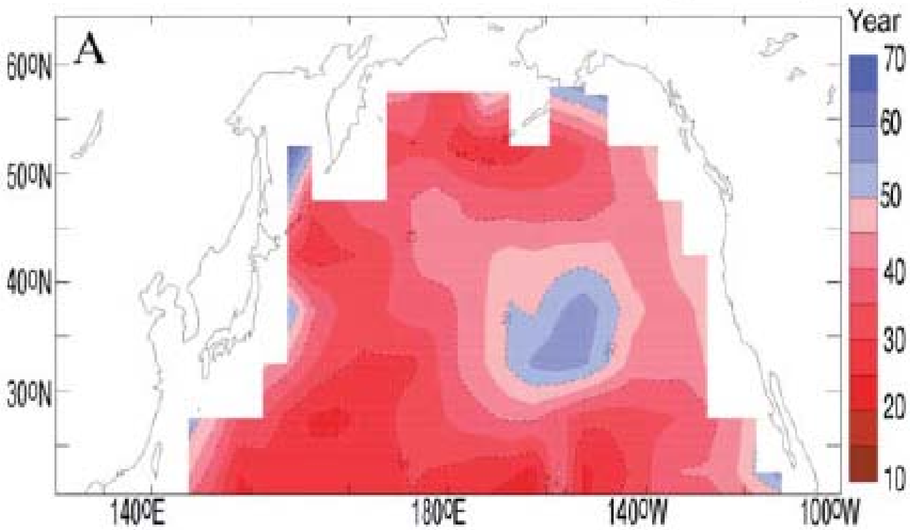
e.g., Agriculture is based on usual season growing. “Unusual” season growing and extreme events impact food supply.

Environmental change in the Anthropocene

- abrupt
- unsteady (at least for 100s years)
- the largest change for human society after agriculture (potentially largest after the appearance of *Homo sapiens*)

We can not expect “usual” climate variations in the near-future.
Empirical rules do not work.
Forecasting the future ecosystem is essential strategy to cope with the change

The year when the global warming impact on SST anomaly would equal the magnitude of natural variability



Overland and Wang 2007

Within 20-40 years from present, natural variability would be the principal forcing of the North Pacific ecosystem followed by global warming trend.

In order to forecast N. Pacific in the first half of the 21st century, we need to understand the intrinsic variability of the N. Pacific and the impact of global warming, simultaneously (i.e., we could not negligible both forcing). This makes it more difficult to forecast the N. Pacific before 2050 than 2100.

Forecasting the future physical oceanographic status

Great improvements of GCMs and regional models

Forecasting several months : Good agreement with reality.

>1 years : large differences

Forecasting the future ecosystems

Biogeochemical and biological statuses are dependent on the physics. "Small" differences in the physical forecast from reality lead serious errors in ecosystem forecast.

e.g.,

A few weeks shift in the timing of the water column stratification induces a distinct change in the phytoplankton response and export flux

1^{o}C diff. in winter SST causes large diff. in the surface nutrient concentration, the magnitude of phytoplankton bloom and following food-web and BGC dynamics

10 m diff. in mixed layer depth causes a significant diff. in the 1er production and nutrient consumption.

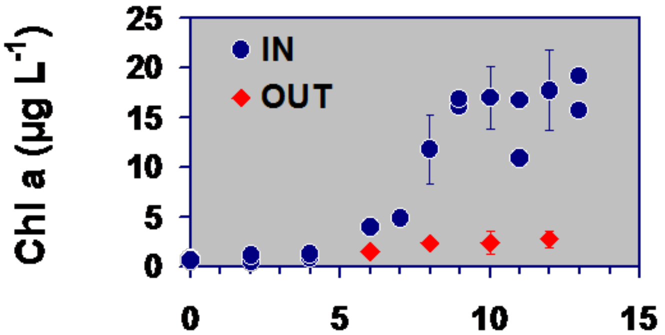
Forecasting the future ecosystems

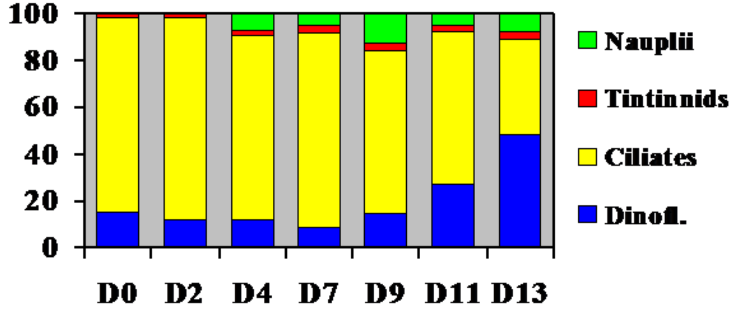
Ecosystem models are basically different from physical models. Due to millions of components and their parameters, simplification of the structure and functions is essential in the ecosystem model. This is partly due to the limited understanding of the ecosystem components, and their physiologies, life cycles, functions, genetic diversities, gene expression, etc.

The simplification is a factor of incorrect results.

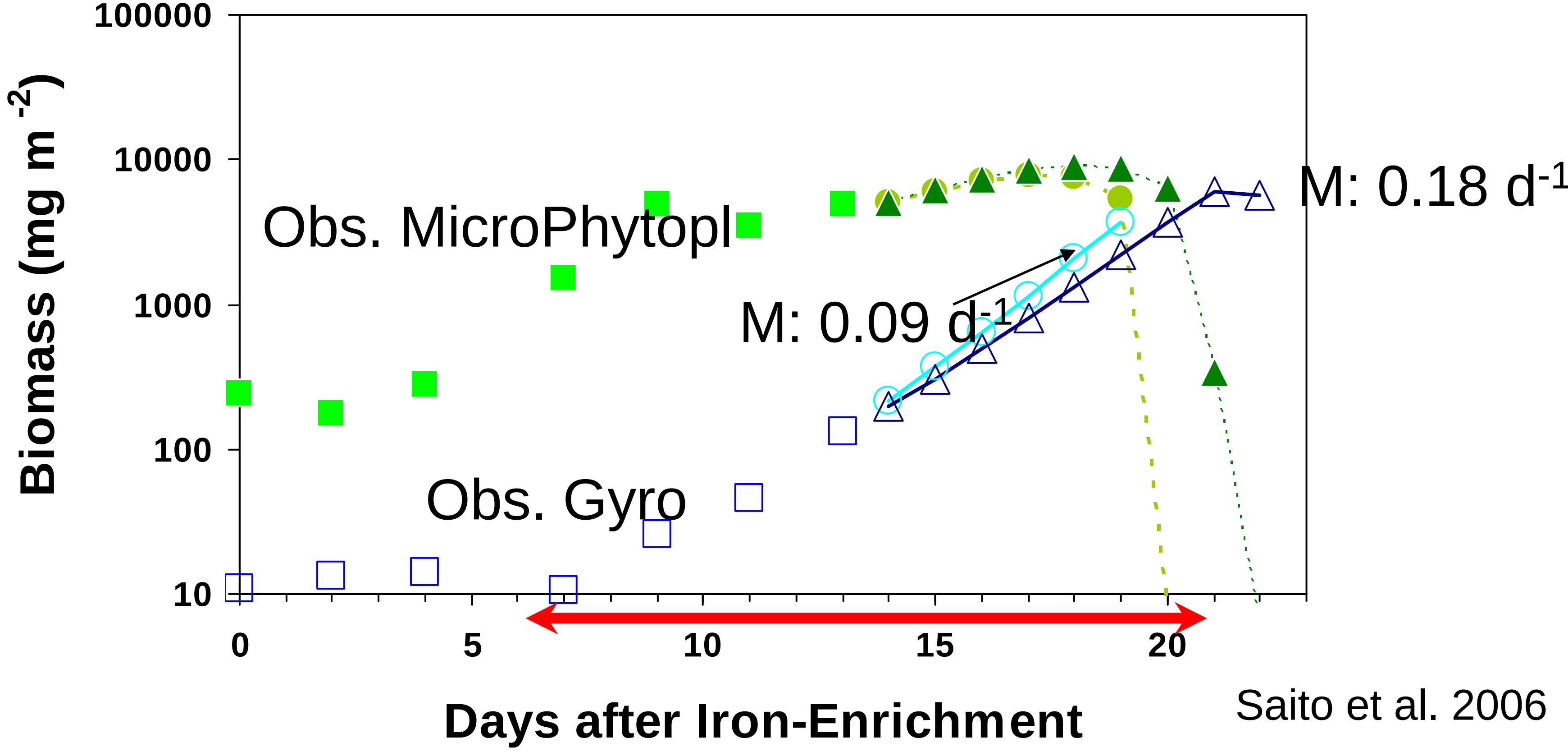
Minor species

Iron-enrichment exp.
in HNLC (SEEDS)





Results of a specific model for SEEDS

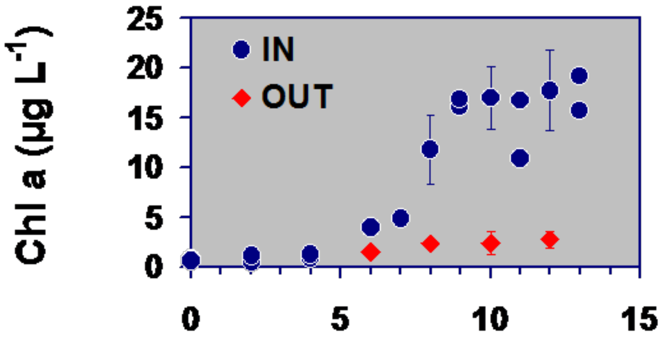


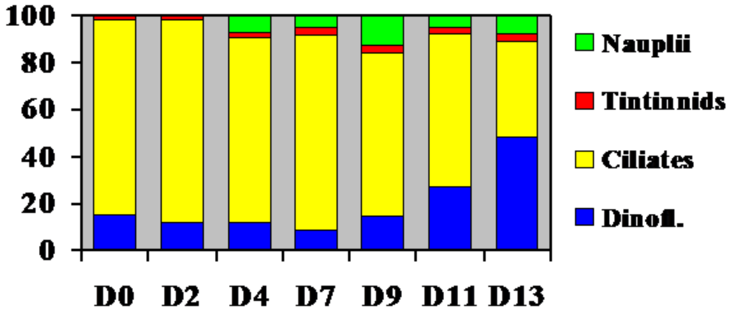
Saito et al. 2006

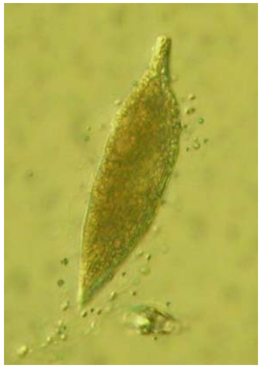
***Gyrodinium* sp. would graze down the diatom bloom after 14-15 days from the initiation (D6)**

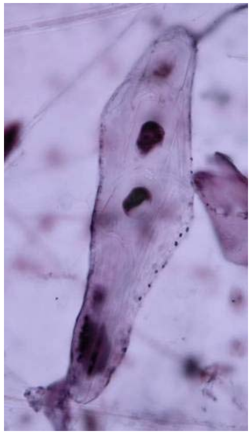
Minor species

Iron-enrichment exp.
in HNLC (SEEDS)







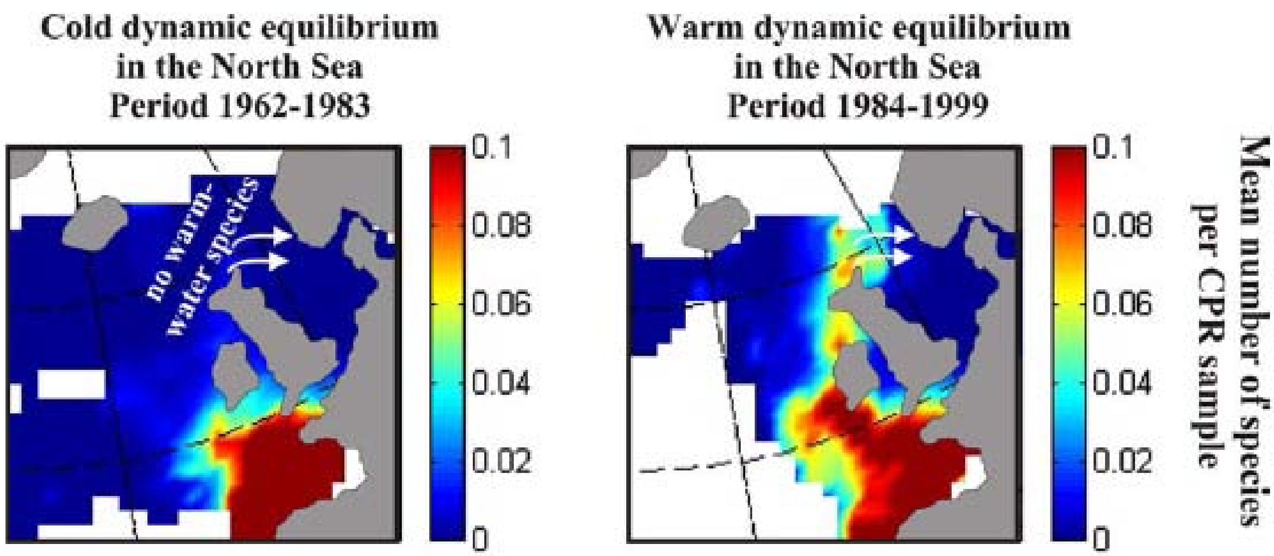


Gyrodinium sp. dominates during diatom bloom (a few weeks).

It is difficult to express the function of *Gyrodinium* in general ecosystem model.

Are there any “overlooked” ecosystem components which play an important role episodically? Maybe YES.

Changing distribution



Beaugrand 2004

Succession of dominant sp.,

eg, *C. finmarchicus* →*C. helgolandicus*

life cycle, physiology, timing of reproduction relative to one of predators …..

Succession of not only dominant components but minor

Other difficulties

disease, parasite
invasion species
unexpressed gene
extinctions
etc.

Forecasting the future ecosystems

There is no perfect PO model.

We do not fully understand ecosystems.

Does “forecast the future ecosystem s” make sense?

Request from societies

Human society is largely dependent on the ecosystem services. In the Anthropocene, the ecosystem change can impact seriously on local community, specific industry and whole the human society.

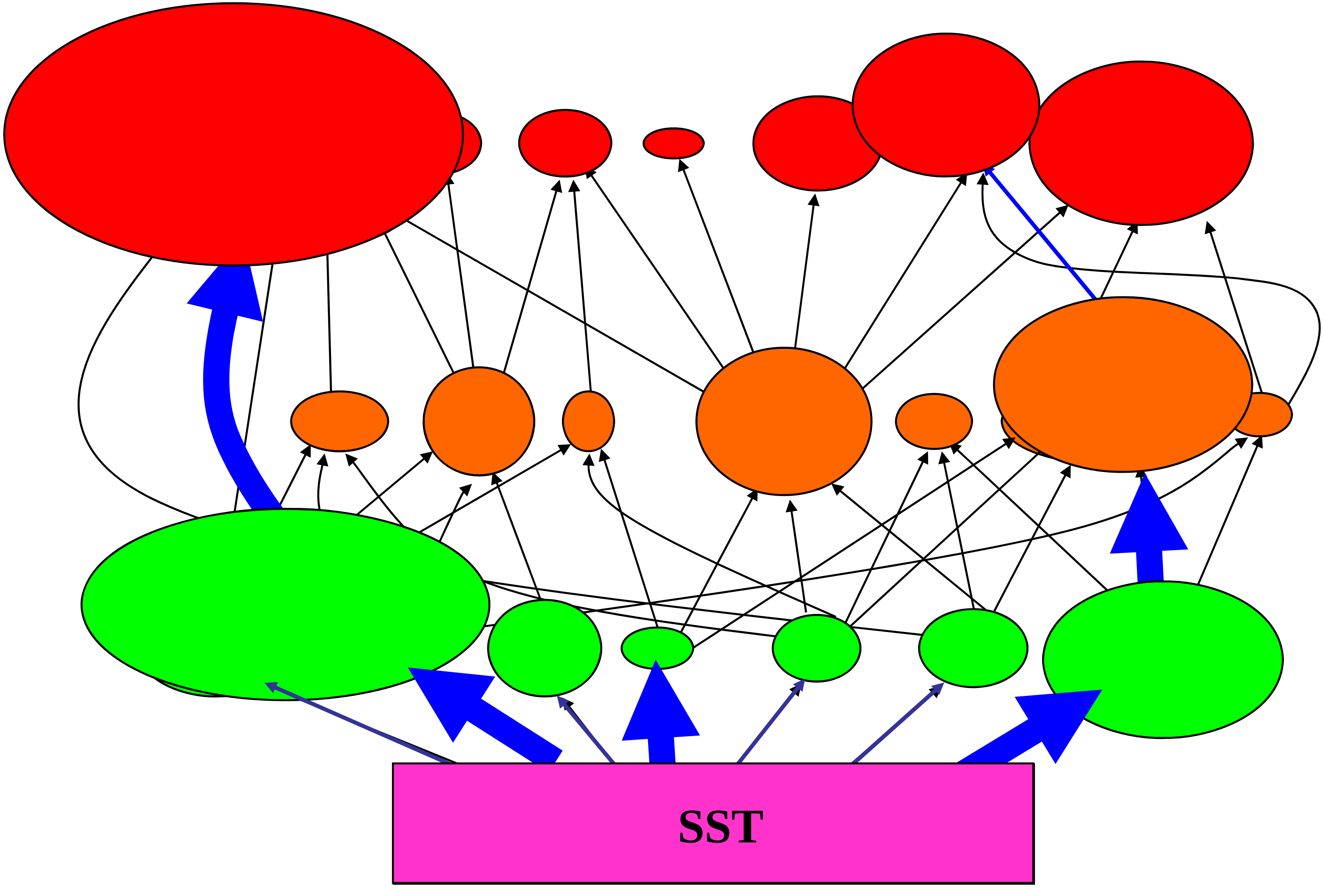
The ecosystem change is different from our previous experiences within a few hundreds years, and possibly, largest after the appearance of *Homo sapiens.* The changes are different from fluctuations, irreversible changes. Thus, we can not expect returning to the original status.

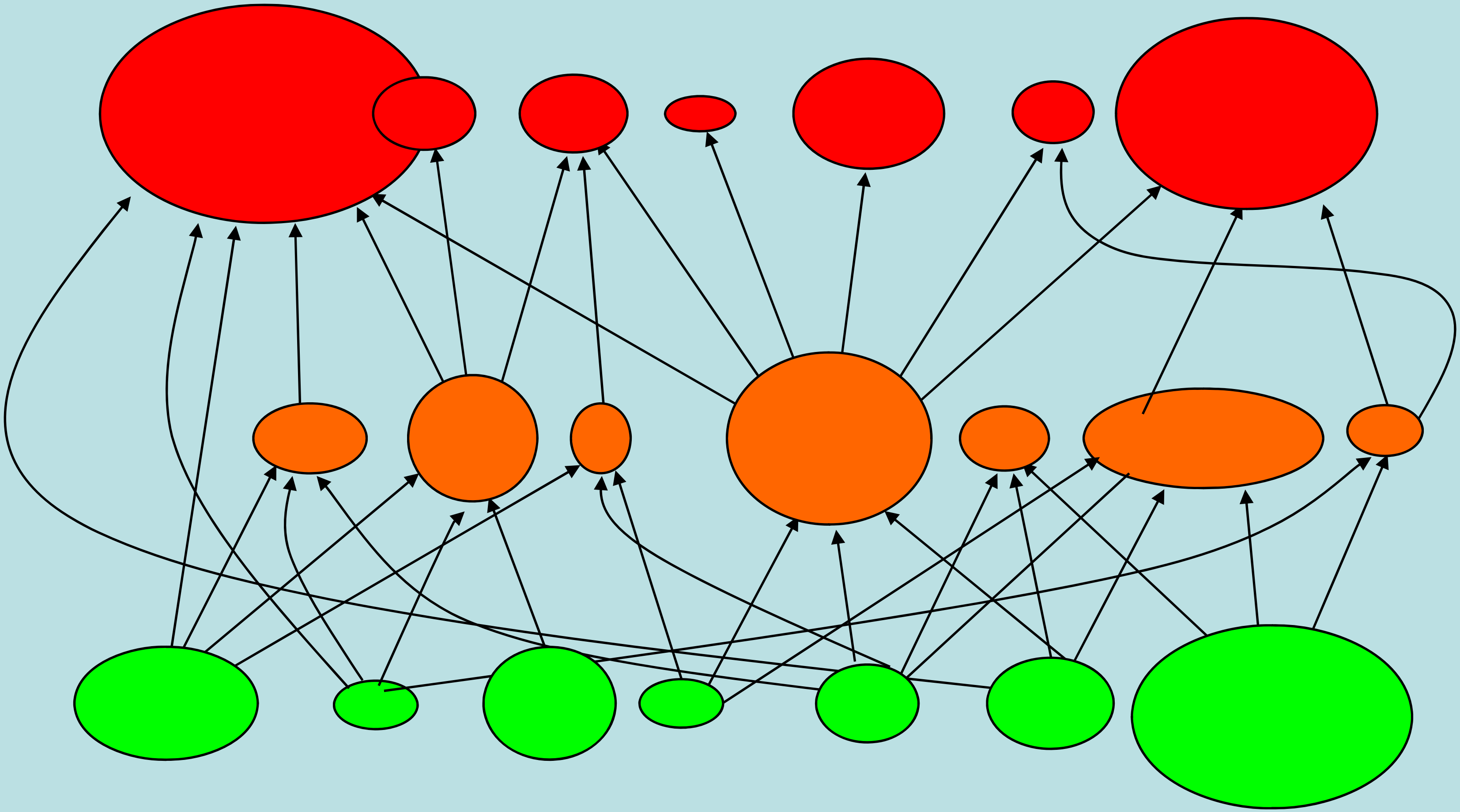
Forecasting future ecosystem is essential to cope with the changes and to sustain our society.

Proposed strategy

1. Developing a general ecosystem model, such as eddy-resolving 3D-NEMURO, under IPCC or other climate scenarios to understand the change comprehensively and supply the basic scenarios of the future North Pacific ecosystems to specific models.

2. Understanding the mechanisms of the present ecosystem responses to perturbations. Understanding sensitive processes in the ecosystem (vulnerability, amplifier, key-stone species, etc) to perturbations


SST



Proposed strategy in PICES

1. Developing a general ecosystem model, such as eddy-resolving 3D-NEMURO, under IPCC or other climate scenarios to understand the change comprehensively and supply the basic scenarios of the future North Pacific ecosystems to specific models.

2. Understanding the mechanisms of the present ecosystem responses to perturbations. Understanding sensitive processes in the ecosystem (vulnerability, amplifier, key-stone species, etc) to perturbations.

3. Developing specific models to forecast the selected ecosystem or selected part of the ecosystem process which change seriously impacts the society.

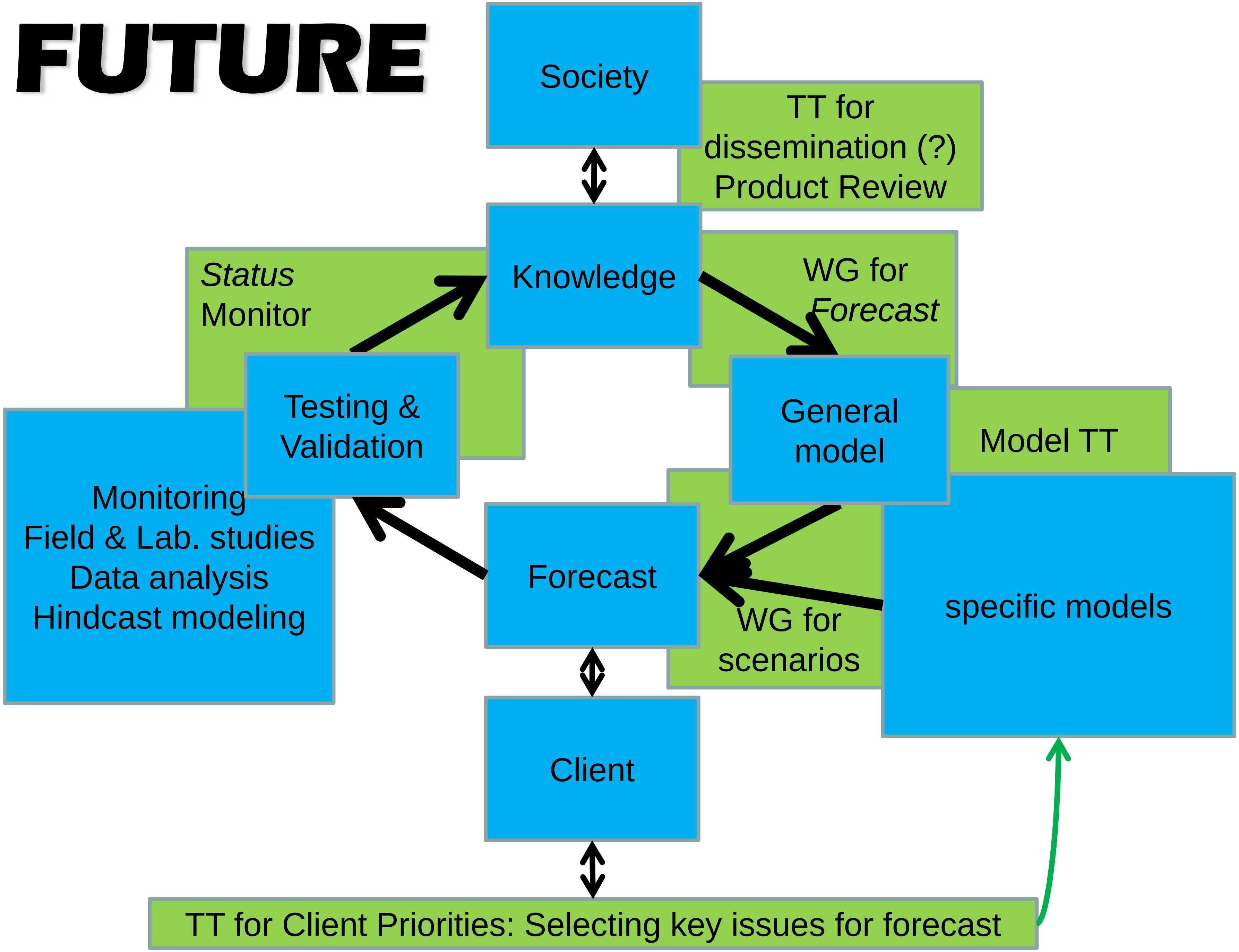
Proposed strategy in PICES

1. Developing a general ecosystem model.
A part of the FUTURE forecasting activity. Global (basin) scale and regional scale.

2. Understanding the mechanisms
Fundamental of the forecast accuracy. The most important part of the FUTURE process study, including field and lab experiments, retrospective data analysis, hindcast modeling, monitoring, integrated field campaign, etc

3. Developing specific models.
Selecting "important" issues by FUTURE communication activity form clients, general public and scientific community. Task team and/or WG activities for specific issue, integrating information, development of the model.

FUTURE


Society
TT for dissemination (?) Product Review
Knowledge
Status Monitor
WG for *Forecast*
Testing & Validation
General model
Model TT
Monitoring
Field & Lab. studies
Data analysis
Hindcast modeling
Forecast
specific models
WG for scenarios
Client
TT for Client Priorities: Selecting key issues for forecast

Population Outbreak of Marine Life

POMAL

Study for the prediction and control of
the population outbreak of marine life
in relation to environment change

Funded from AFFRC, Japan

SUPRFISH

Studies on Prediction and Application of Fish Species Alternation

STOPJELLY

Studies on Prediction and Control of Jellyfish Outbreak

I M B E R JAPAN
Japanese Integrated Marine Biogeochemistry and Ecosystem Research

SUPRFISH

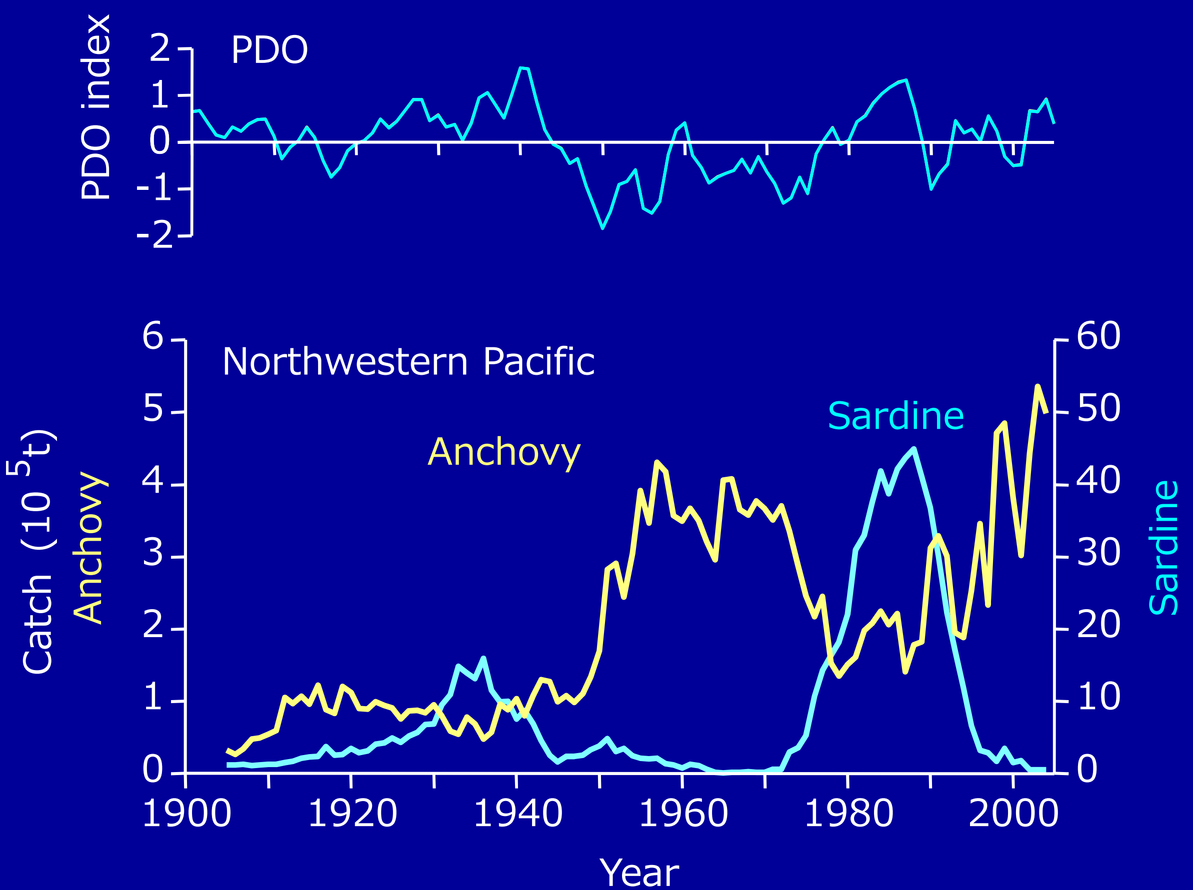
Population Outbreak of Marine Life

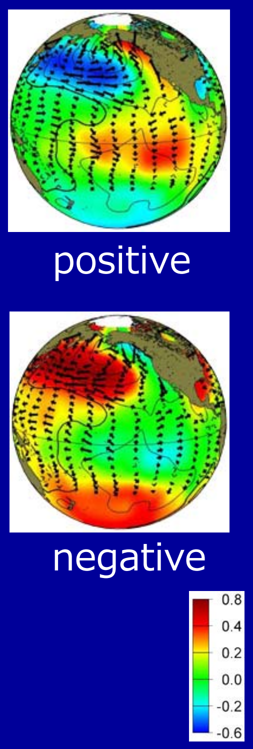
Understanding comprehensively the past fish species alteration

- Physical processes inducing fish alternation
- Responses of lower trophic levels to physical forcing
- Responses of pelagic fish to physical and biological changes

Developing the forecasting technique of fish species alternation

Scientific advice for the resource management policy based on natural scientific studies



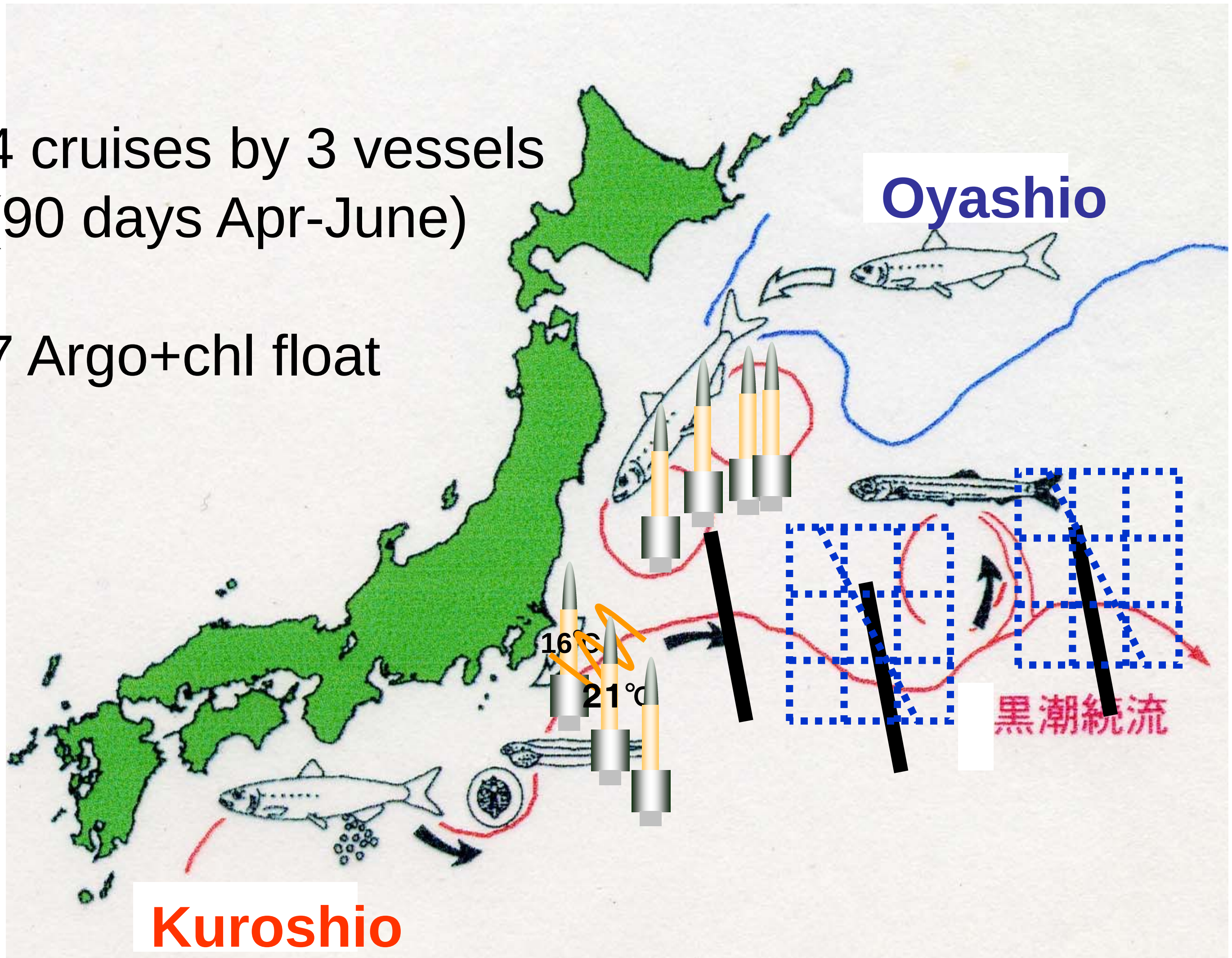


Mantua & Hare (2002)

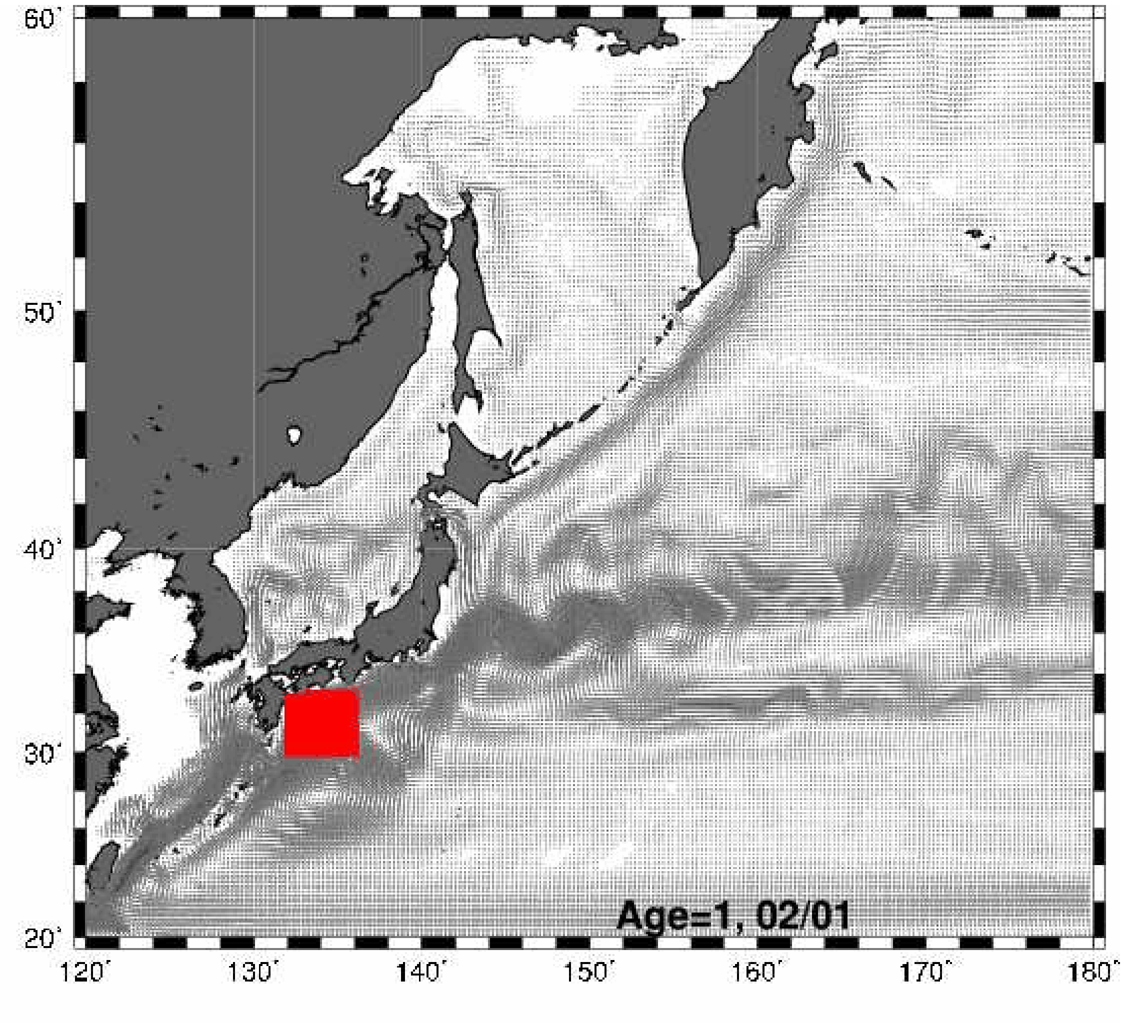
Field campaign in Spring 2008

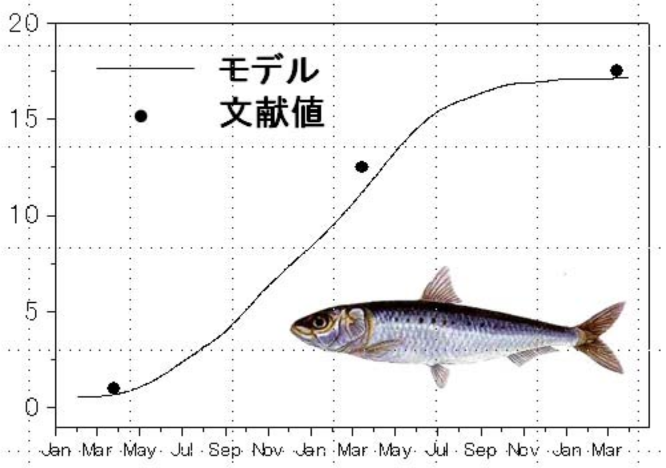
4 cruises by 3 vessels
(90 days Apr-June)

7 Argo+chl float



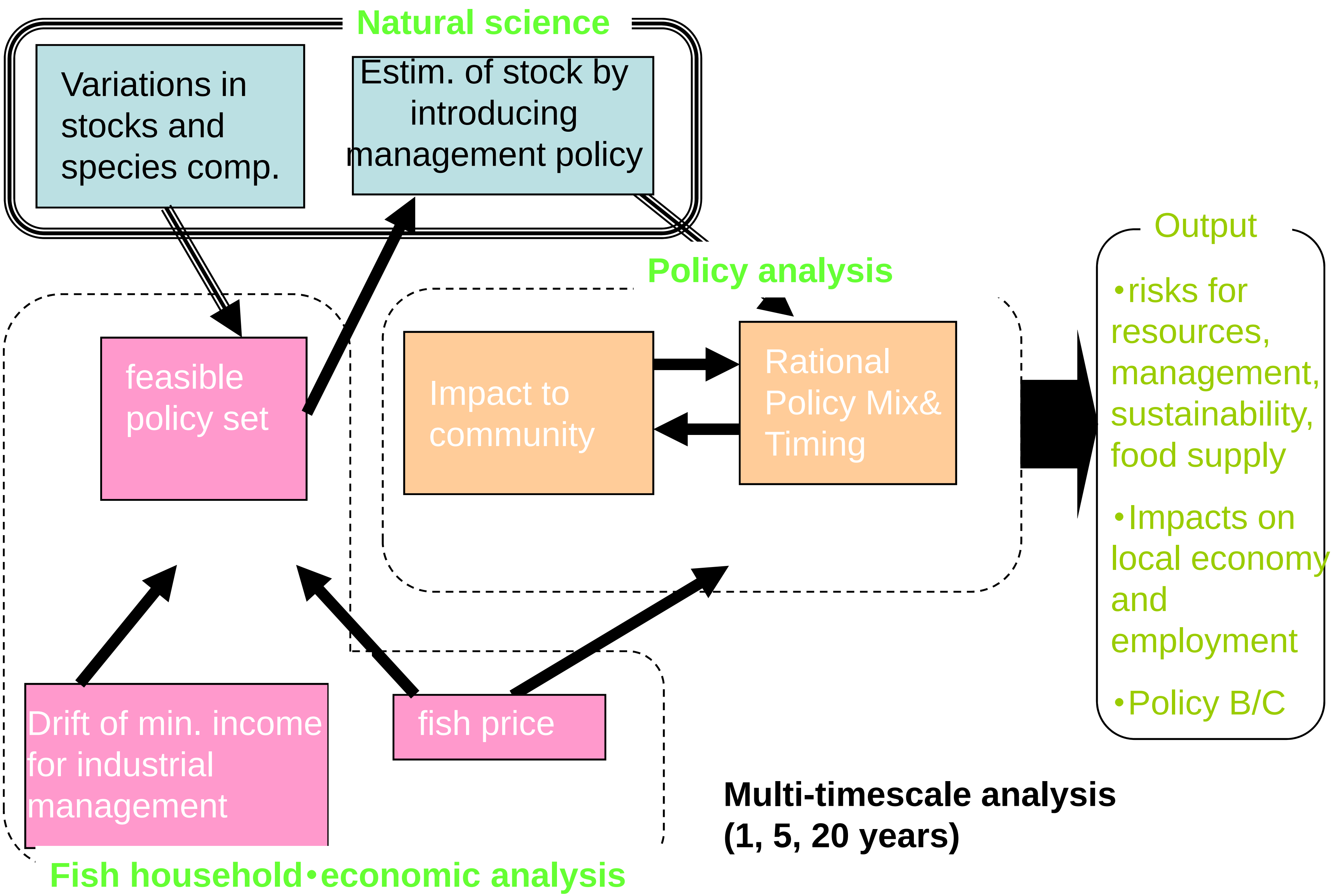
Ecosystem model + fish IBM





Okunishi et al in press

Fisheries management model based on a forecasting scenario



Understanding the mechanisms of ecosystem responses to past and present perturbations is essential for forecasting in the Anthropocene in which empirical rules do not work.