Predicting Impacts of Climate Change on Fish Production

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Technical University of Denmark

Experimental research on crop response to elevated CO_2 confirms Third Assessment Report (TAR) findings (medium to high confidence). New Free-Air Carbon Dioxide Enrichment (FACE) results suggest lower responses for forests (medium confidence).

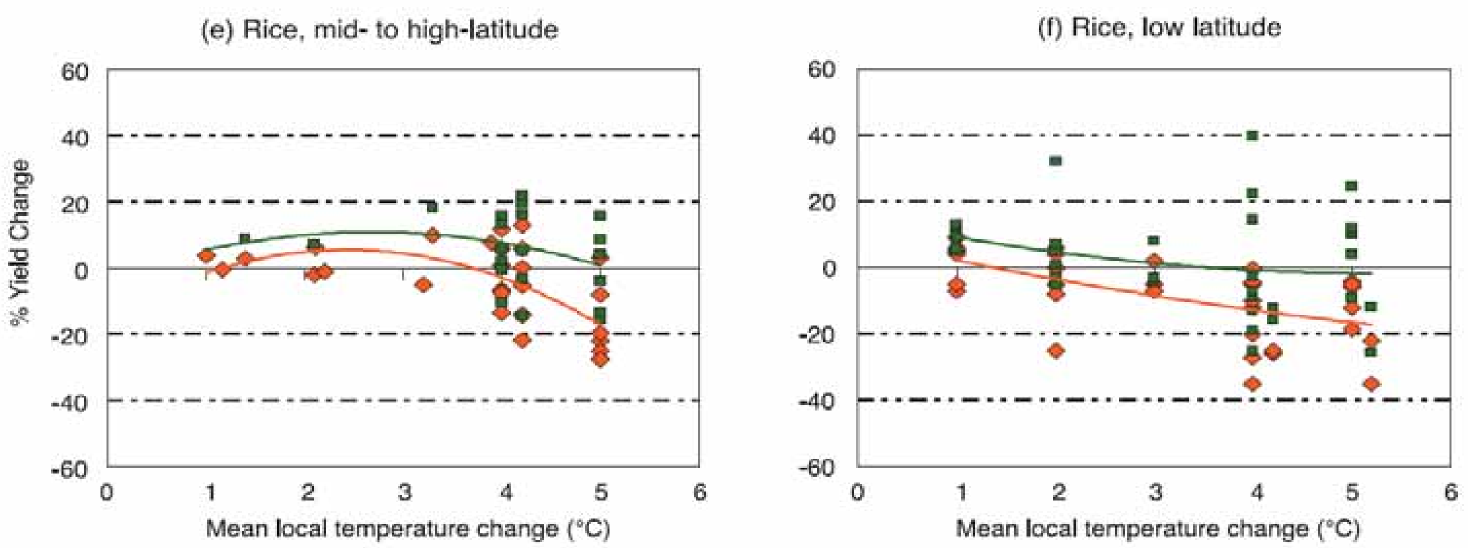

Figure 5.2. *Sensitivity of cereal yield to climate change for maize, wheat and rice, as derived from the results of 69 published studies at multiple simulation sites, against mean local temperature change used as a proxy to indicate magnitude of climate change in each study. Responses include cases without adaptation (red dots) and with adaptation (dark green dots). Adaptations+ represented in these studies include changes in planting,*

FACE experiments in Duke Forest

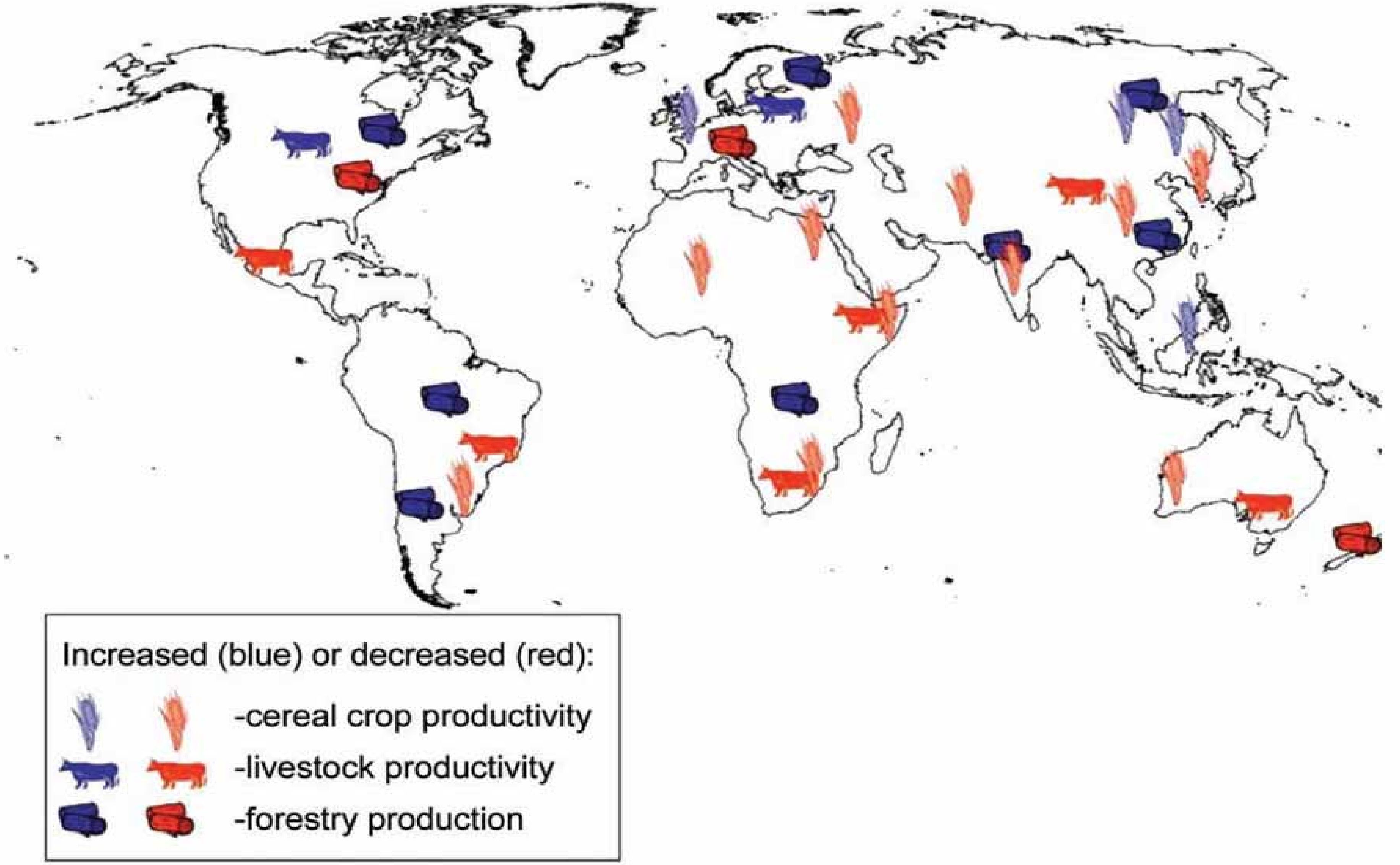

Figure 5.4. *Major impacts of climate change on crop and livestock yields, and forestry production by 2050 based on literature and expert judgement of Chapter 5 Lead Authors. Adaptation is not taken into account.*

What about fisheries predictions?

Local extinctions of particular fish species are expected at edges of ranges (high confidence).

Regional changes in the distribution and productivity of particular fish species are expected due to continued warming and local extinctions will occur at the edges of ranges, particularly in freshwater and diadromous species (e.g., salmon, sturgeon). In some cases ranges and productivity will increase [5.4.6]. Emerging evidence suggests that meridional overturning circulation is slowing, with serious potential consequences for fisheries (medium confidence) [5.4.6].

Why are predictions of fisheries productivity poor or non-existent?

- Ocean climate forecasts are inadequate
- We don’t live in the sea
- We don’t control the production systems
- We harvest hundreds of species, not just a few plants
- We have virtually no experimental basis
- Even if we could predict primary production, the transfer to harvested species is long and uncertain
- Climate is only one of many human impacts
- There is a lot of natural climate variability

How can we improve our predictions for fisheries?

- Better ocean models → model NPP (all scales)
- Analysis and models which aggregate and simplify
- Understand and represent trophic dynamics better
- Regional models with key local processes
- Experiments, comparative field studies, meta-analysis
- Control of production systems
- Analogues from the past
- Reducing fishing mortality

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Net primary production is a function of SST & Chl. The Control and Warming scenarios affect both

Control & warming — f1 (**SST**)

f2(**PAR**)

Control & warming — f3(**CHL**)

$$PP = 0.66125 \cdot D_{irr} \cdot P_{opt}^{B} \cdot \frac{E_0}{E_0 + 4.1} \cdot C_{sat} \cdot Z_{eu}$$

where P_{opt}^{B} **is a 7th order polynomial function of SST**; E_0 **is surface PAR**; D_{irr} is day length in hours; and $C_{sat} \cdot Z_{eu}$ **is the product of the surface chlorophyll and euphotic depth.**

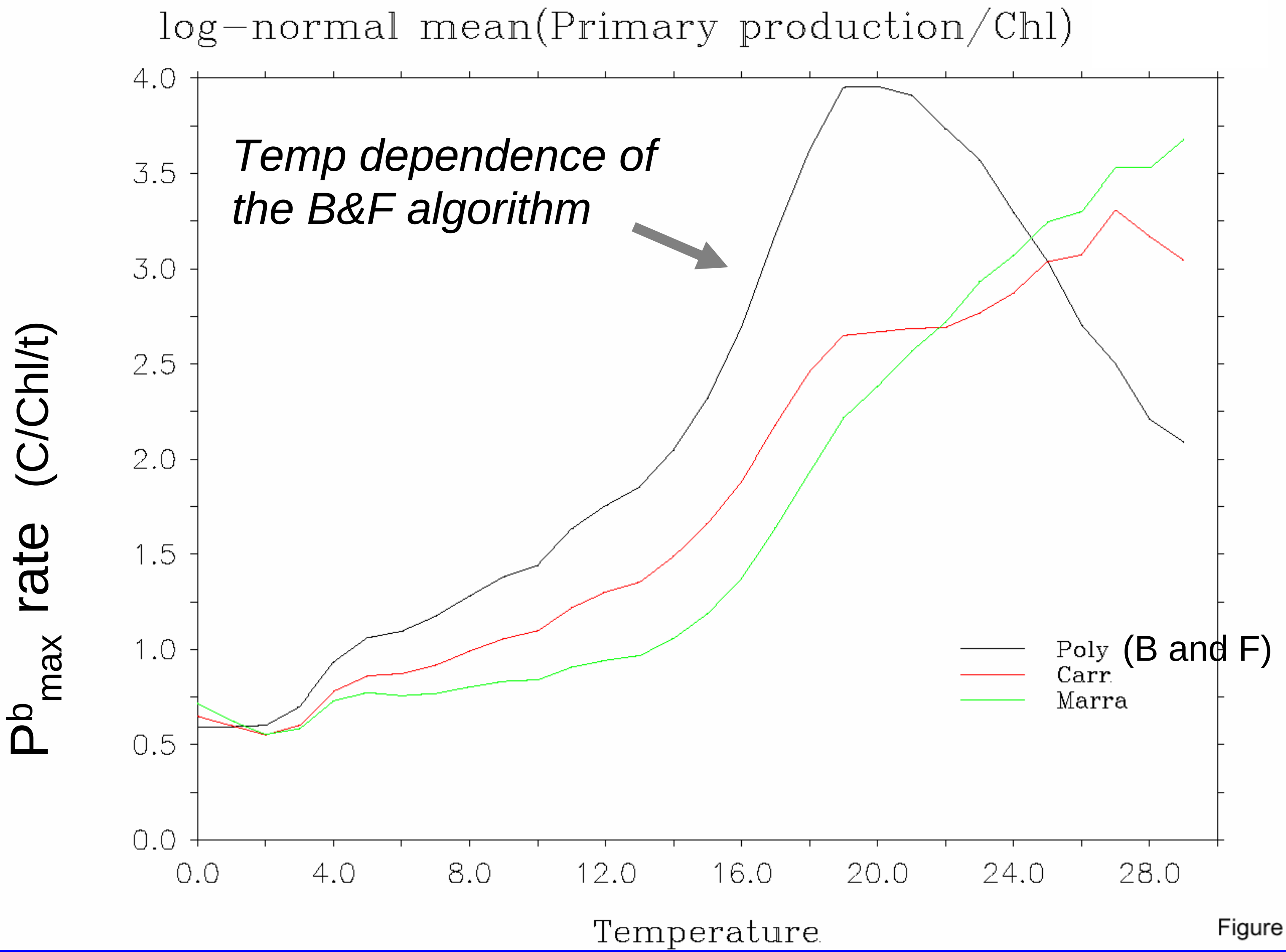

Figure 3

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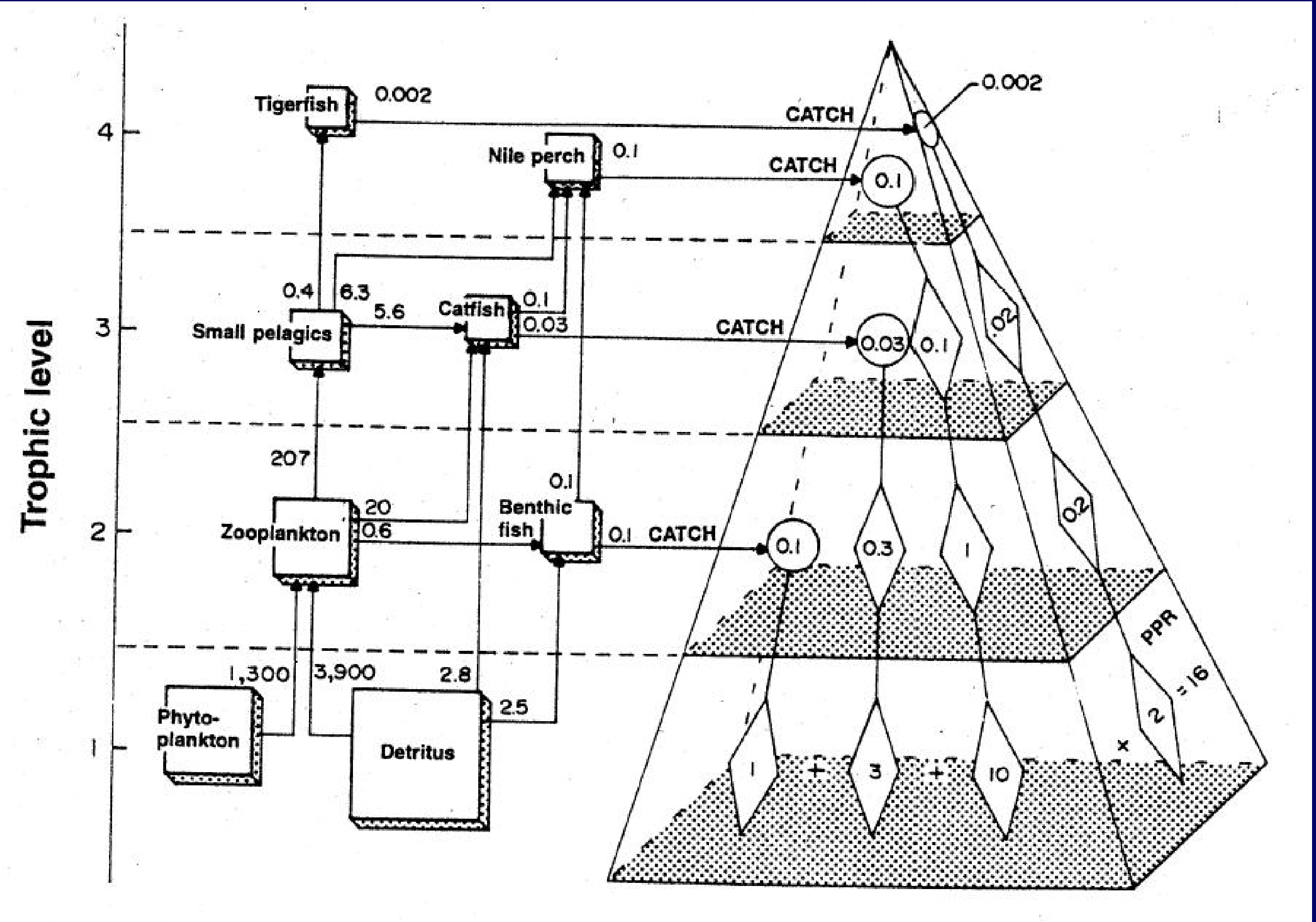
Transfer through the trophic pyramid



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PROCEEDINGS OF THE ROYAL SOCIETY B

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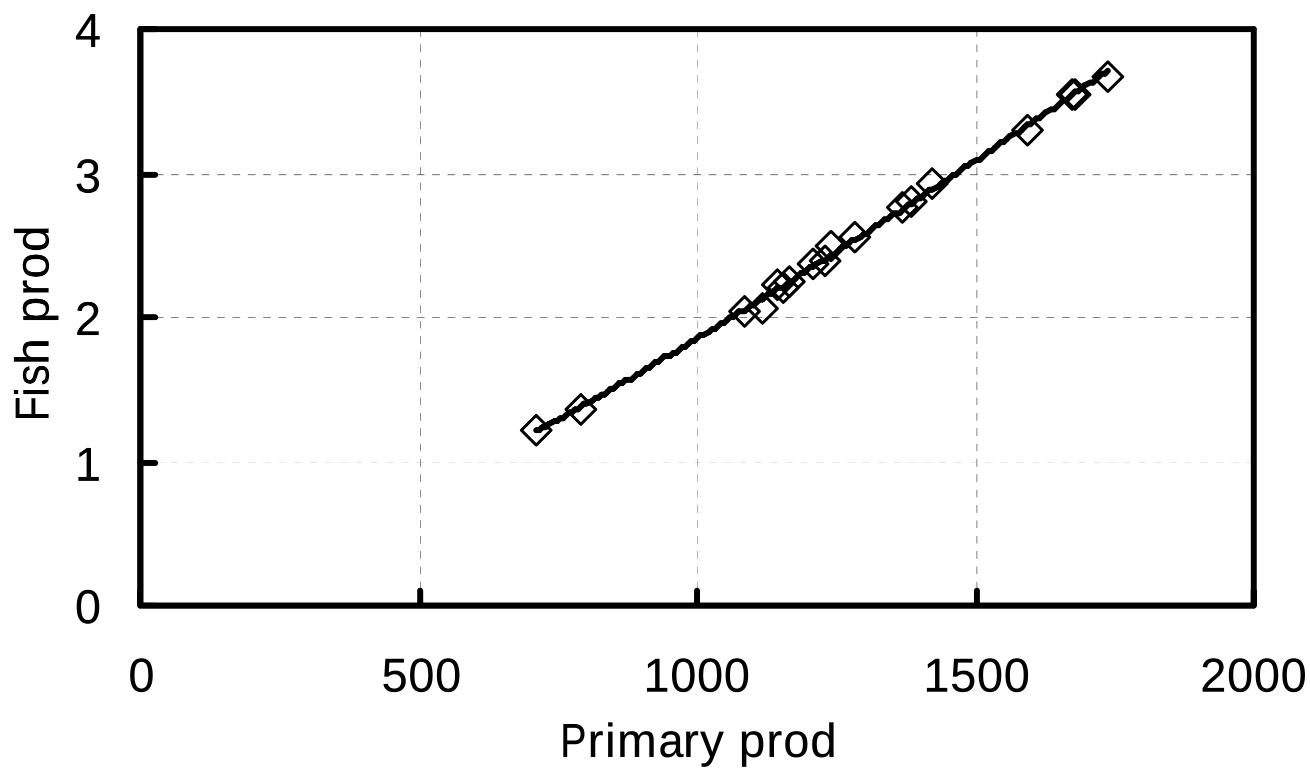
Global-scale predictions of community and ecosystem properties from simple ecological theory

Simon Jennings[1,*], Frédéric Mélin[2], Julia L. Blanchard[1], Rodney M. Forster[1], Nicholas K. Dulvy[1,†] and Rod W. Wilson[3]



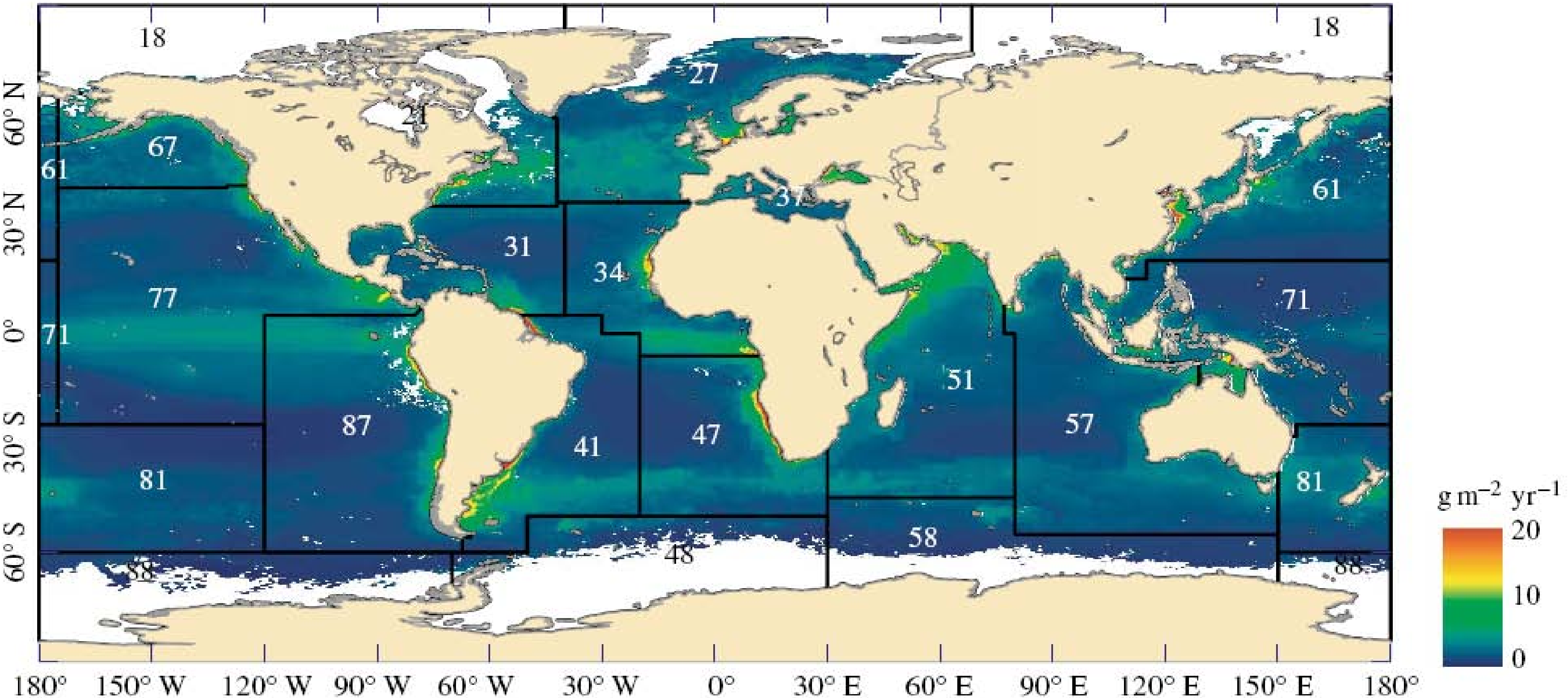


Figure 4. The distribution of teleost production. The overlays show the FAO fishing areas and their corresponding codes (see electronic supplementary material for further details).

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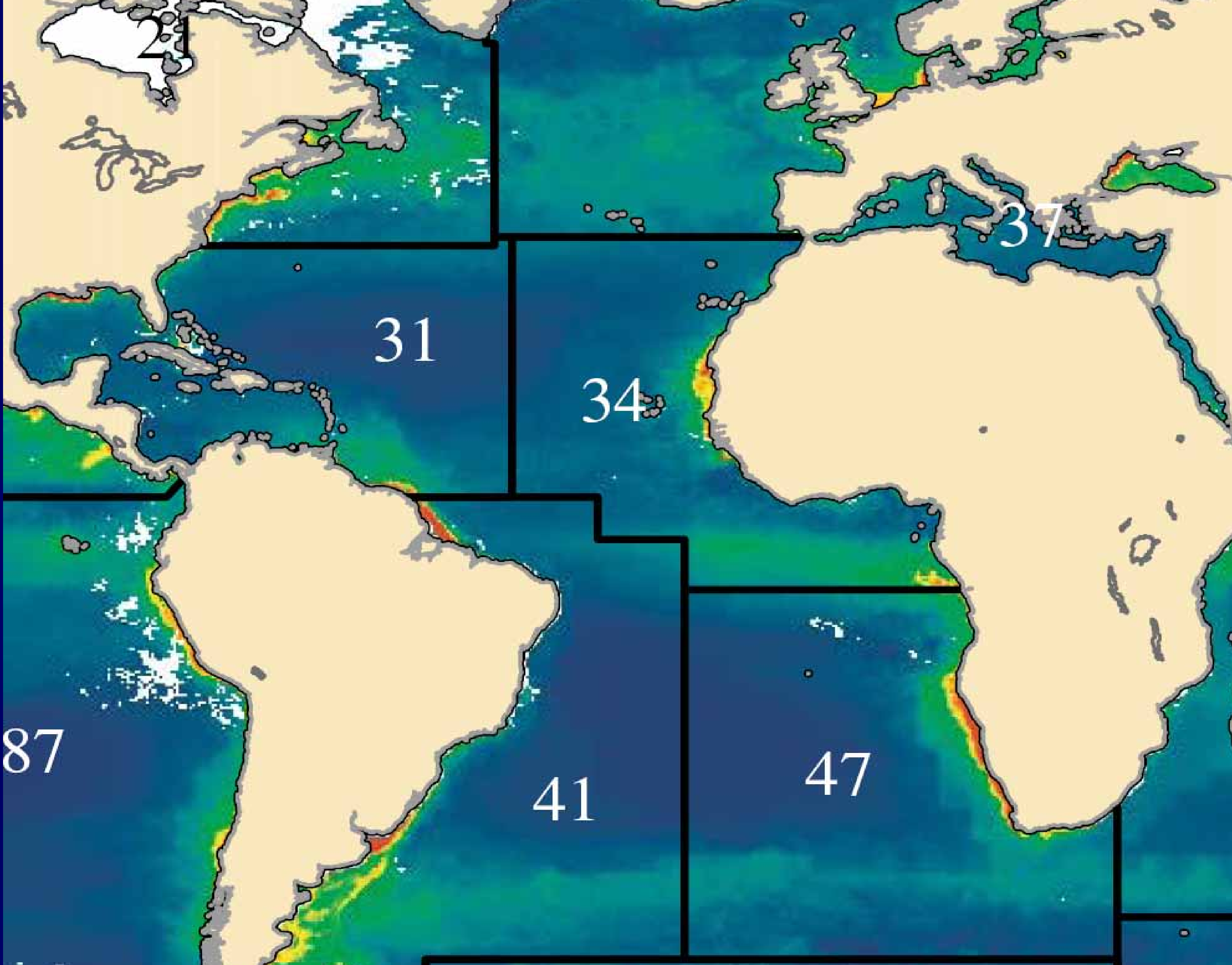
21
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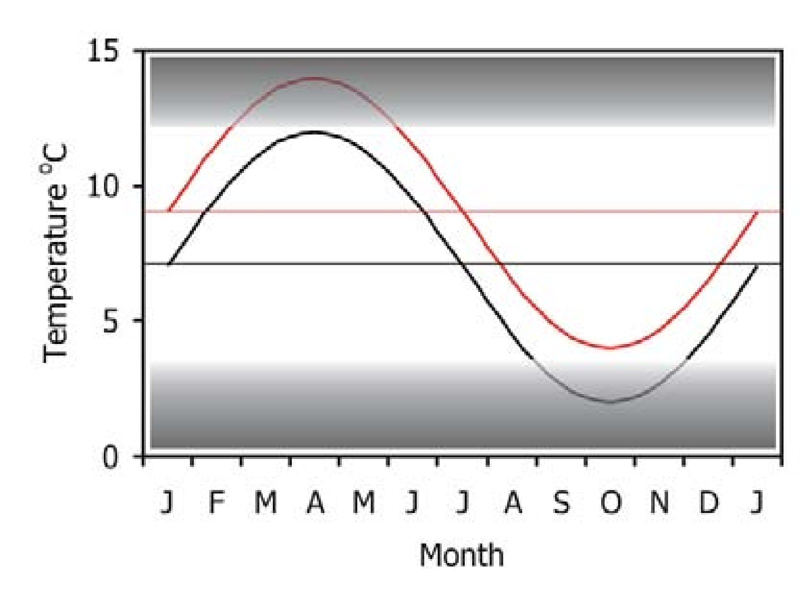
Experimental evidence

- Rainbow trout (*Oncorhyncus mykiss*) 2ºC rise causes increased appetite, growth, protein synthesis, O_2 consumption in winter, but negative effects in summer
- Temperature effects interact with other global changes including falling pH, rising nitrate and ammonia to increase metabolic costs.



Morgan, McDonald & Wood 2001, Global Chnage Biol. 7: 345-355

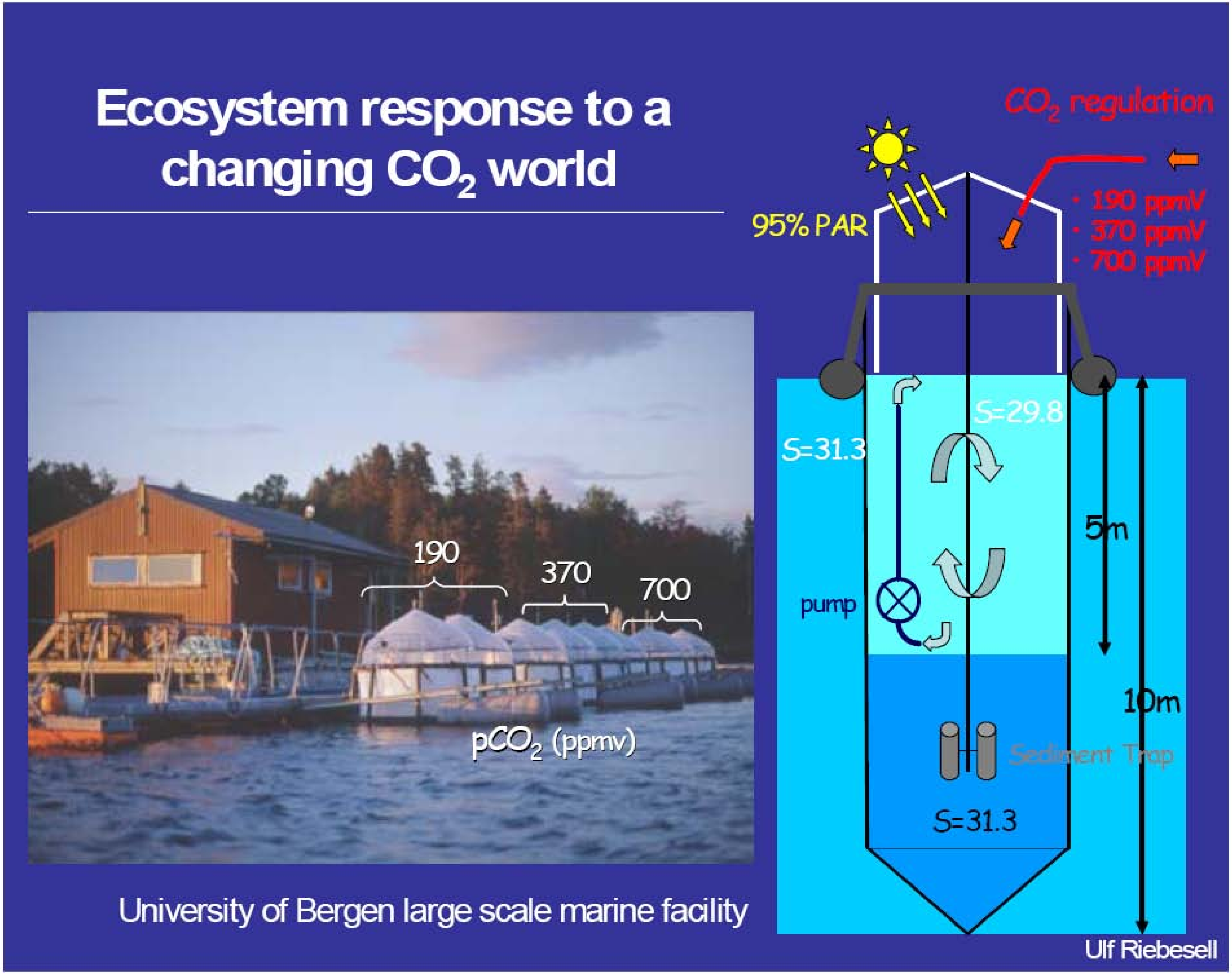


Figure 19. An example of mesocosm experiments being conducted by the University of Bergen.

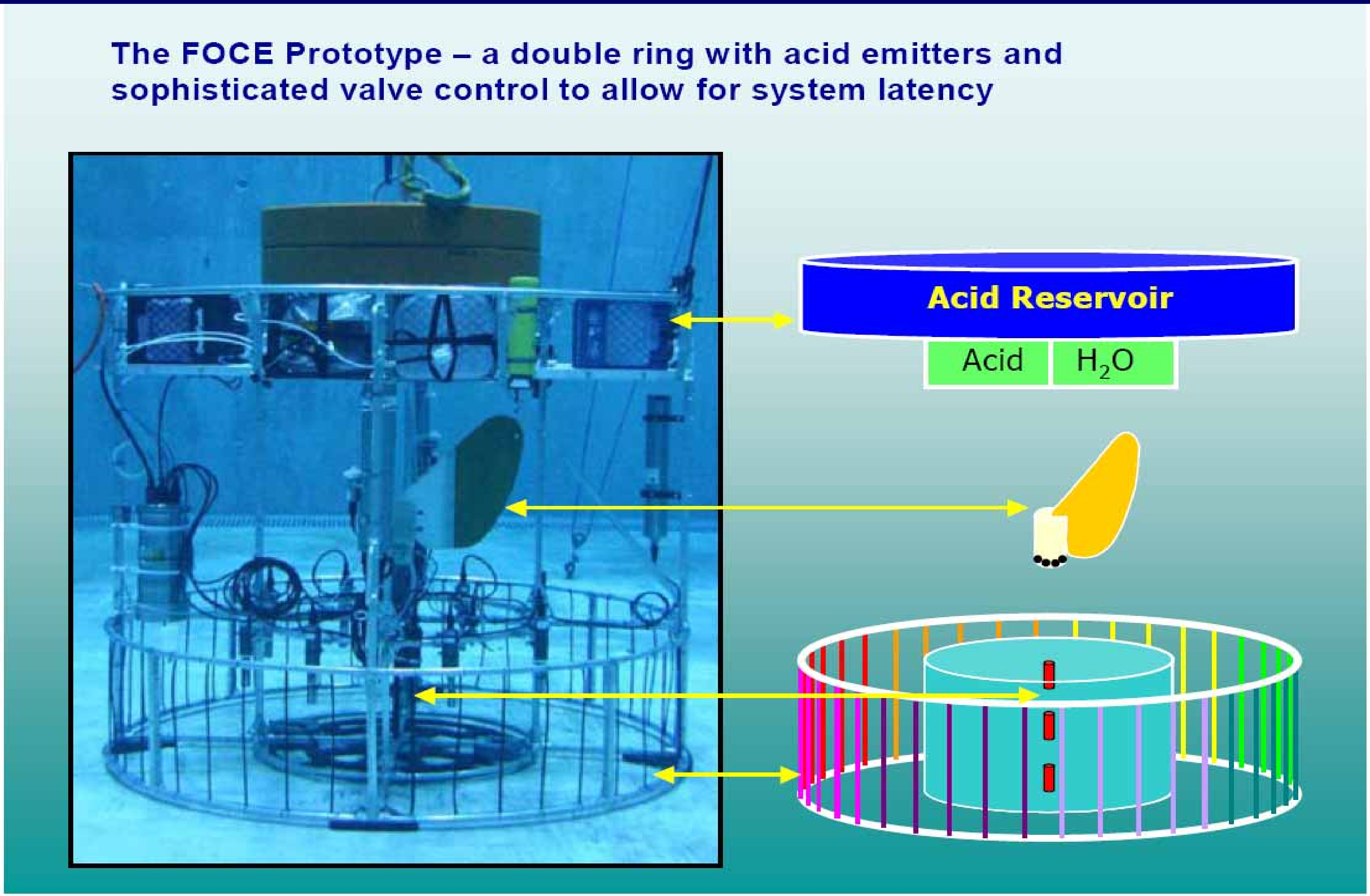
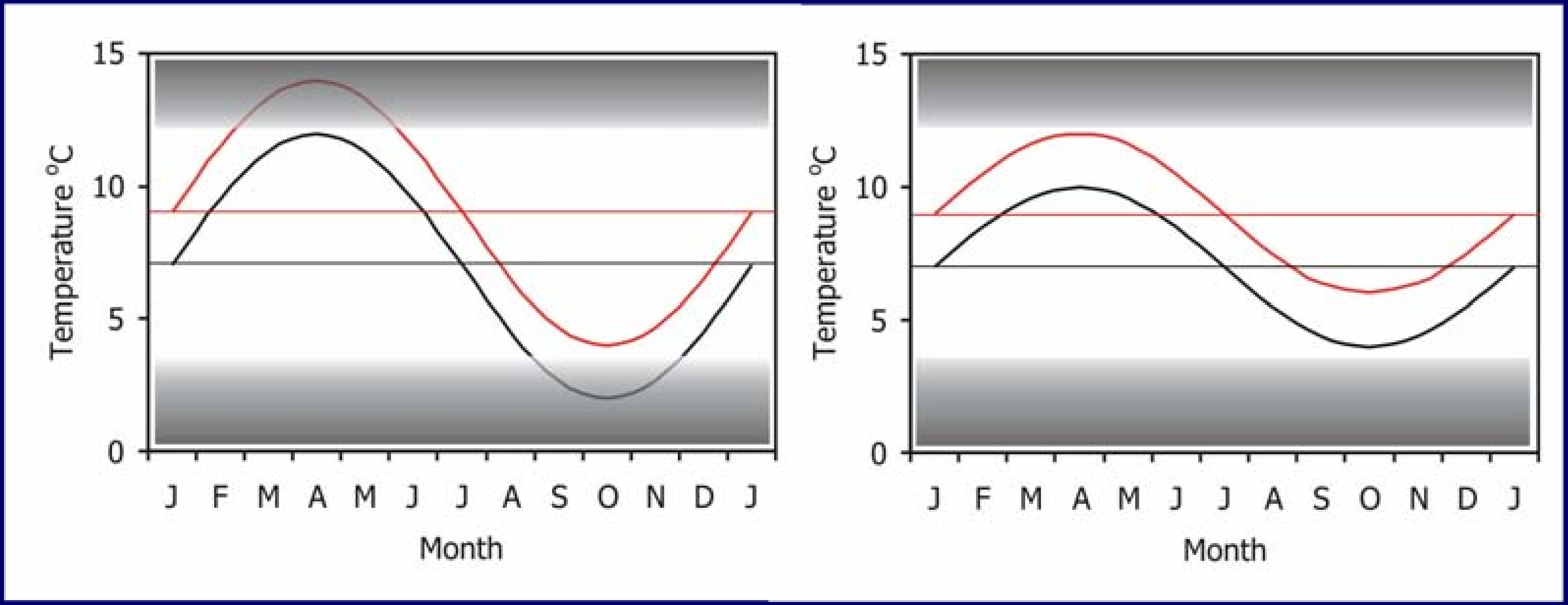


Figure 20. Concept sketch of Free Ocean CO_2 Enrichment Experiment (FOCE) where experiments in the seas emulate future conditions (courtesy P. Brewer).

Schematic effect of a 2º C increase in temperature.
Shading represents temperature regions with progressively more adverse effects.

The mean temperatures are the same in both panels but seasonal amplitude is reduced in the right panel and neither pattern enters the adverse region.

Climate change may of course affect the amplitude of such seasonal cycles as well as the mean.



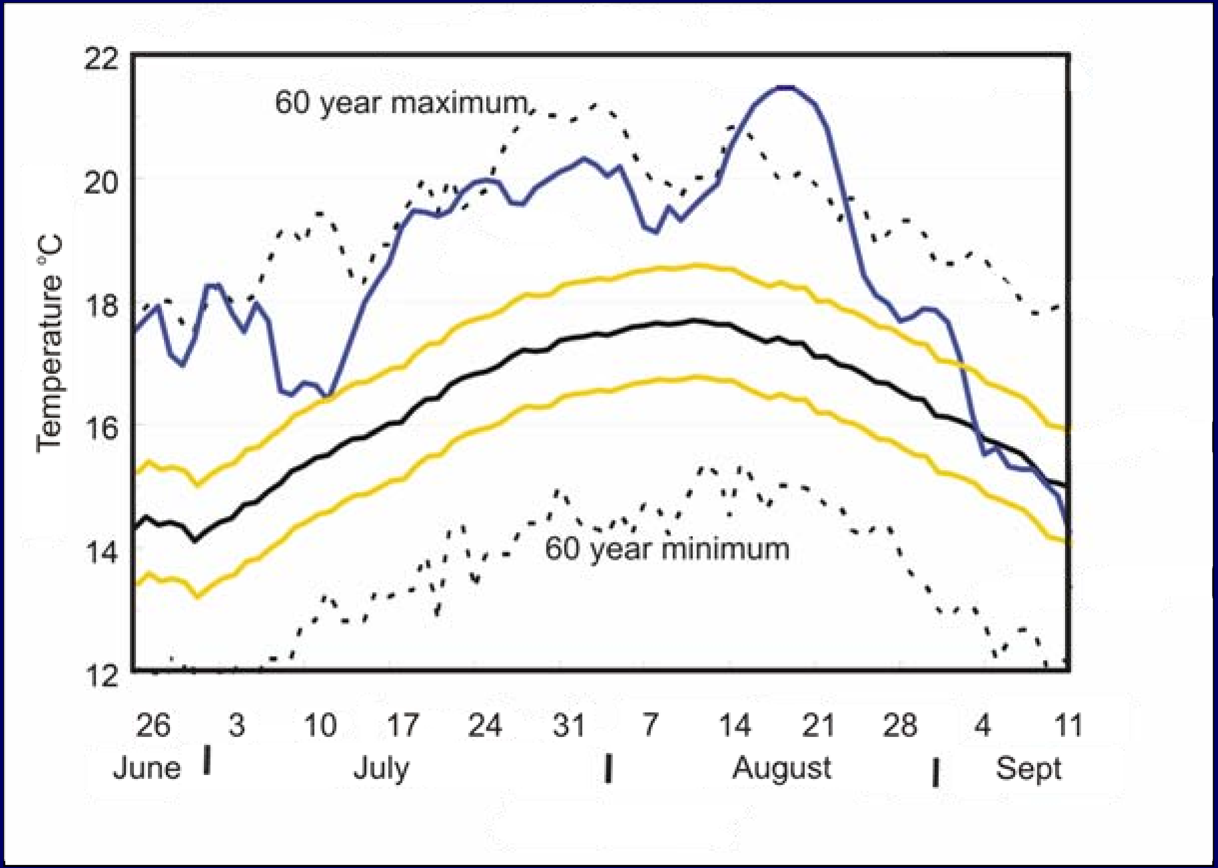
Climate variabilty and extremes

- Major impacts of climate over the next decades will probably be due to climate variability and extreme events

Temperature at Hell's Gate (Fraser River, BC) in 2004 (blue line)

60-year mean (black solid line), ±1 standard deviation (yellow lines), and 60-year minimum and maximums (dashed black line).

For several days in mid-August Fraser River water temperatures as measured at Hell's Gate were the highest ever recorded



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Control of production systems

- Reducing fishing mortality
- Aquaculture
- Stocking, ranching etc.
- Spatial planning of sea use
- Transformation (*akin to agricultural revolution)*

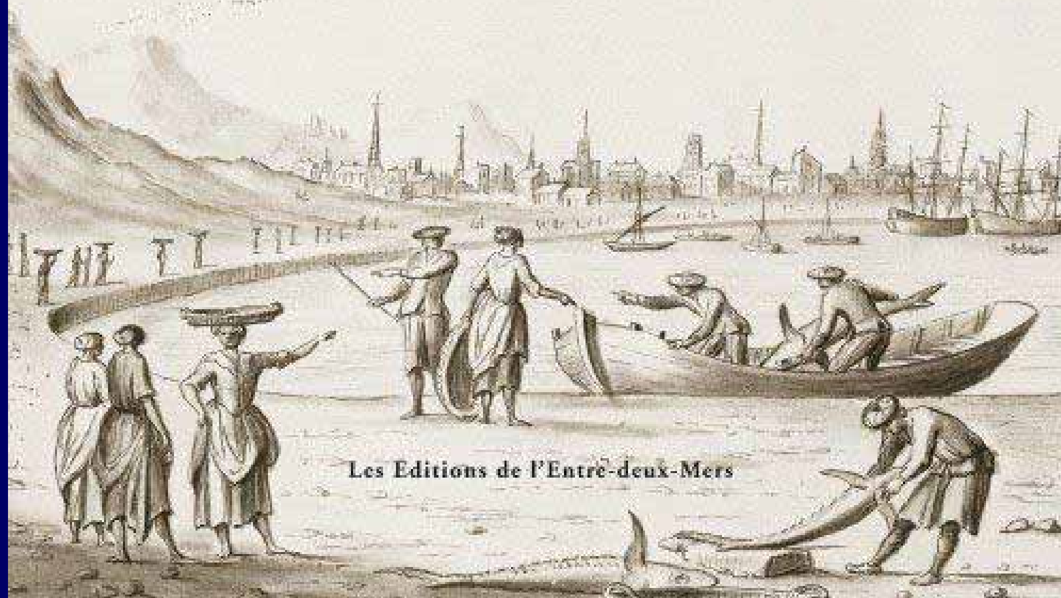
Procès Verbaux des visites faites par ordre du Roy concernant la pesche en mer (1727)

par François Le Masson du Parc

PÊCHES & PÊCHEURS

du domaine maritime aquitain au XVIII^{e} siècle

AMIRAUTÉS DE BAYONNE & DE BORDEAUX



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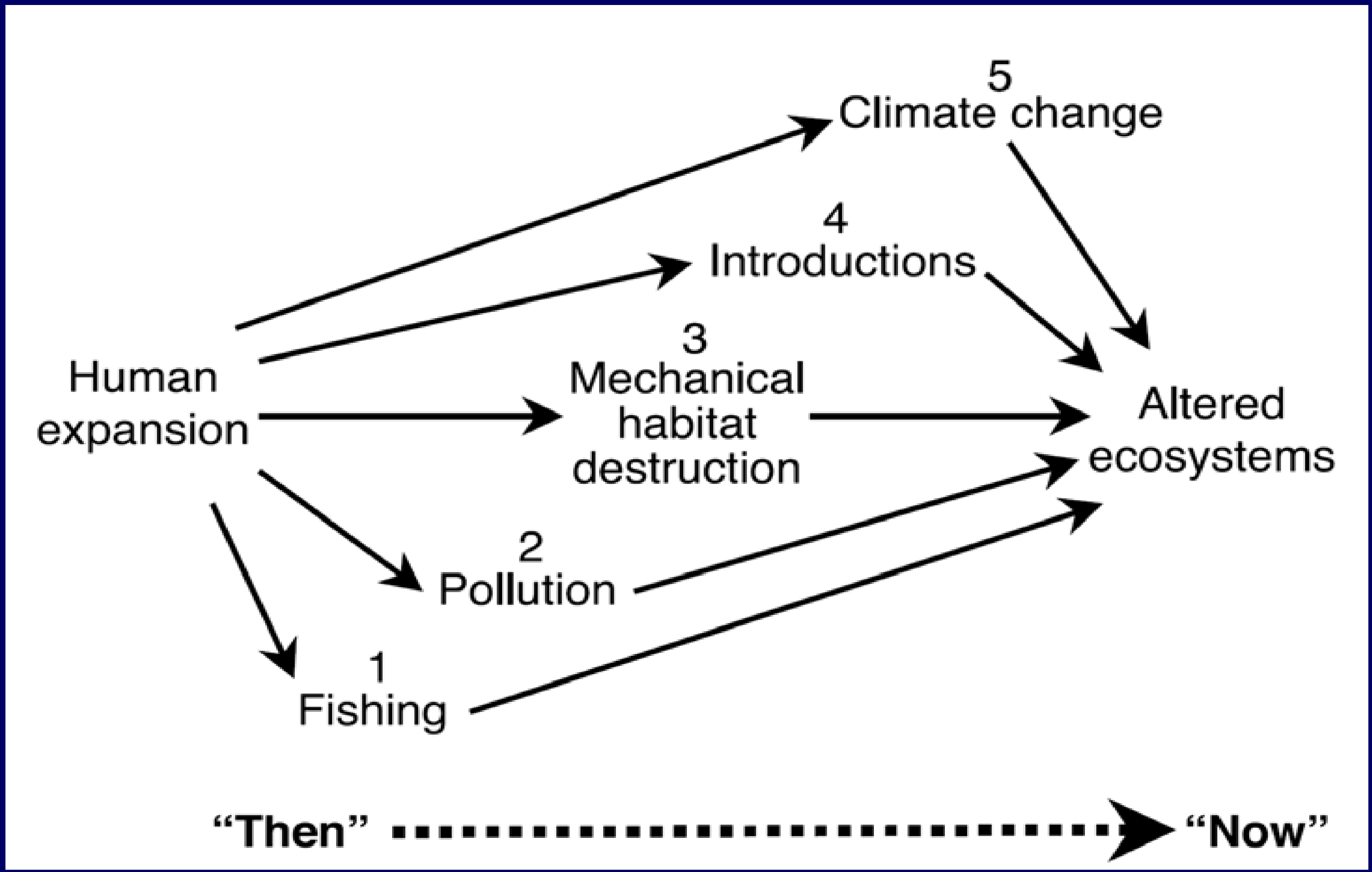
As policy makers grapple with the global problems of marine ecosystem management, a historical perspective is needed to envision what oceans have produced in the past and what they might produce in the future

What are the priority issues for management of marine ecosystem?



Keith Brander

Historical Overfishing and the Recent Collapse of Coastal Ecosystems
Jeremy B. C. Jackson, *et al.*
Science **293**, 629 (2001);
DOI: 10.1126/science.1059199

Message

Reduce overexploitation and habitat loss

Reducing overfishing will also:

- Achieve MSY
  - stable or increased catch for less effort
- Adapt to climate
  - by restoring populations and ecosystems to a more resilient state
- Mitigate carbon use
  - less fishing effort and use of fuel

This is a triple-win strategy

What kind of marine ecosystem do we want?

- Restore to earlier state ?
- Maximise food production ?
- High amenity value ?
- Increase carbon uptake ?

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The Danish fish fauna during the warm Atlantic period (ca. 7000–3900 BC): Forerunner of future changes?

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Abstract

Vast amounts of fish bone lie preserved in Denmark's soil as remains of prehistoric fishing. Fishing was particularly important during the Atlantic period (ca. 7000–3900 BC, i.e. part of the Mesolithic Stone Age). At this time, sea temperature and salinity were higher in waters around Denmark than today. Analyses of more than 100,000 fish bones from various settlements from this period document which fish species were common in coastal Danish waters at this time. This study provides a basis for comparing the fish fauna in the warm Stone Age sea with the tendencies seen and predicted today as a result of rising sea temperatures. One example concerns the anchovy (*Engraulis encrasicolus*), which lived in the Stone Age sea, and has become more numerous in Danish waters since the mid-1990s. Other warm water fishes represented among the Stone Age bone samples include smoothhound (*Mustelus* sp.), common stingray (*Dasyatis pastinaca*), European sea bass (*Dicentrarchus labrax*), black sea bream (*Spondyliosoma cantharus*) and swordfish (*Xiphias gladius*). Surprisingly, Atlantic cod (*Gadus morhua*), whose biomass in the Kattegat and eastern Baltic Sea is presently at record low levels, was one of the most frequently caught species in the Danish Stone Age sea. These results demonstrate that major changes to the fish fauna near Denmark will occur as climate changes. However, exploitable cod populations can potentially be maintained in waters near Denmark, including the North Sea, but the vulnerability to climate change and the risk of stock collapse will increase at present high fishing mortalities.