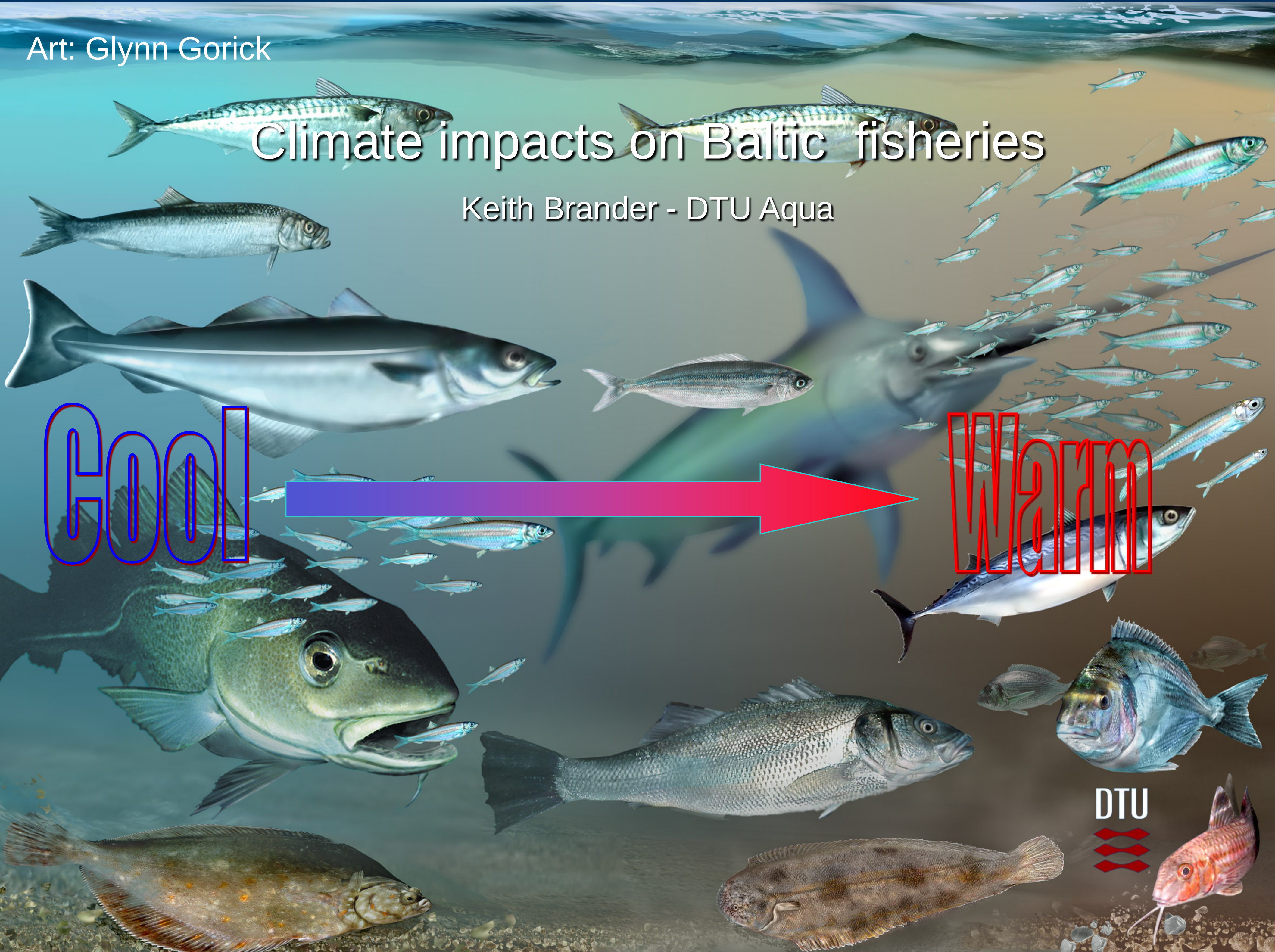
Art: Glynn Gorick

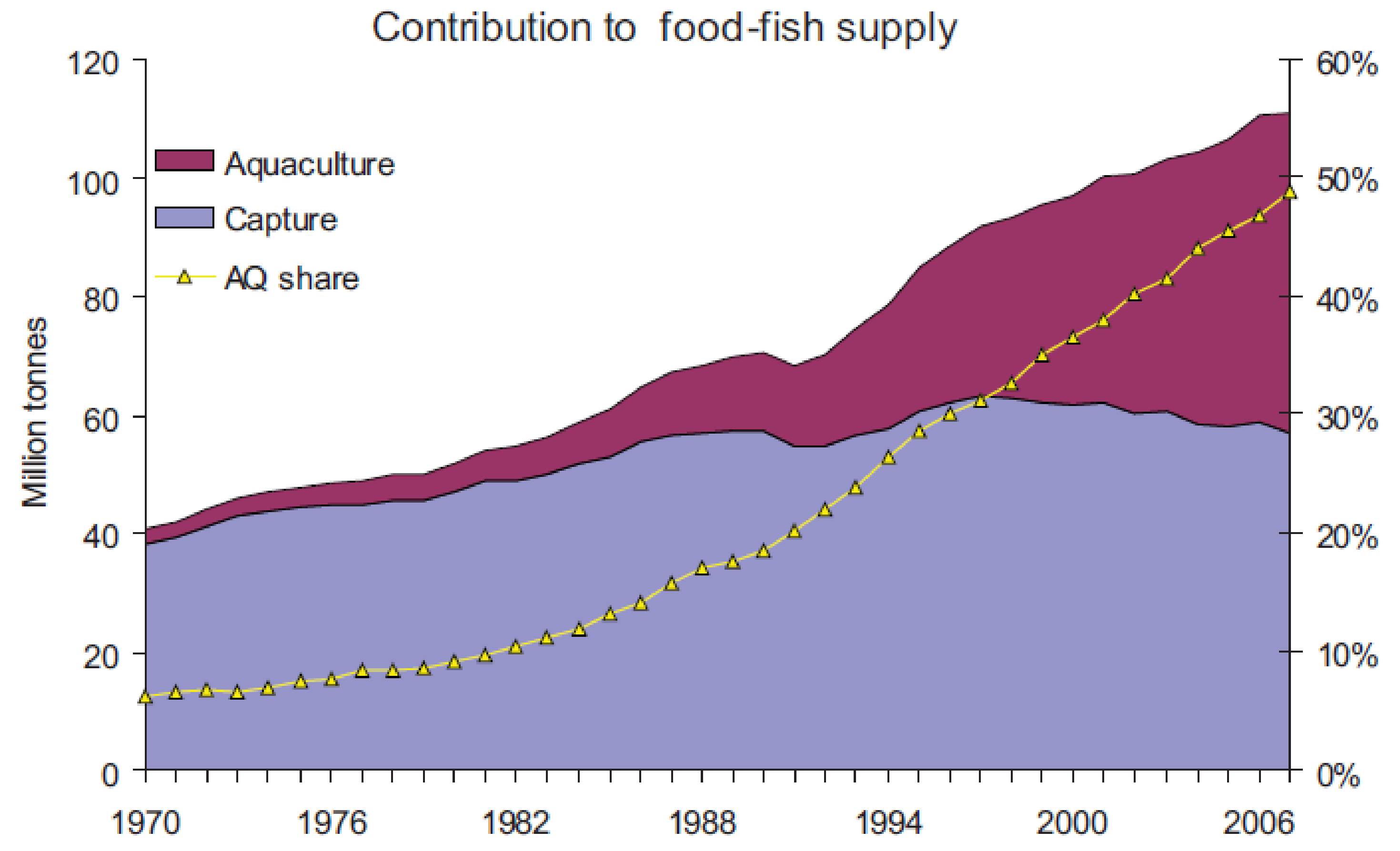
Climate impacts on Baltic fisheries

Keith Brander - DTU Aqua



Cool

Warm



Source: FAO, 2008b.

Sherman et al. ICES CM 2007/D:20

NE Atlantic is at the extreme end of global warming

California Current has been cooling!

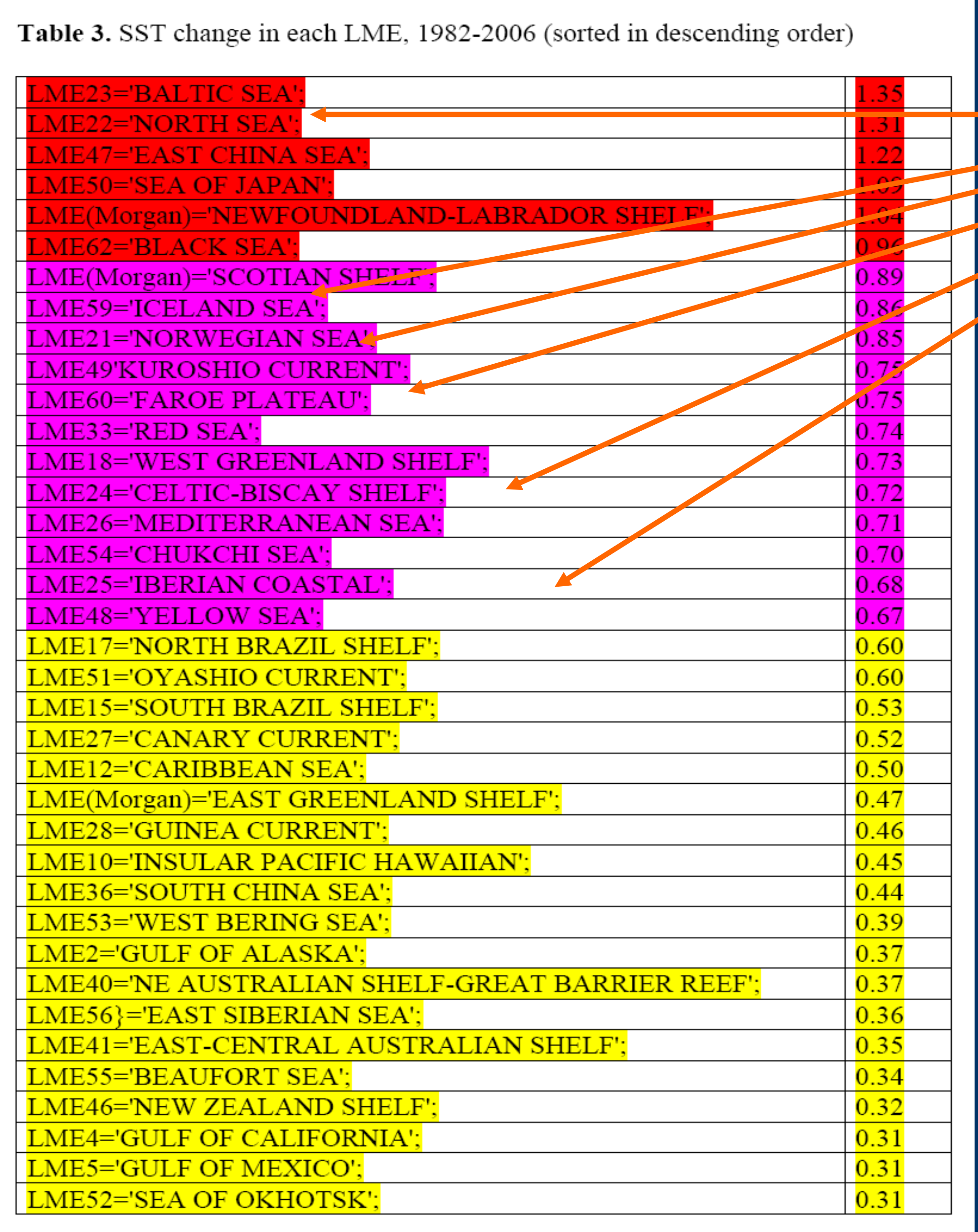
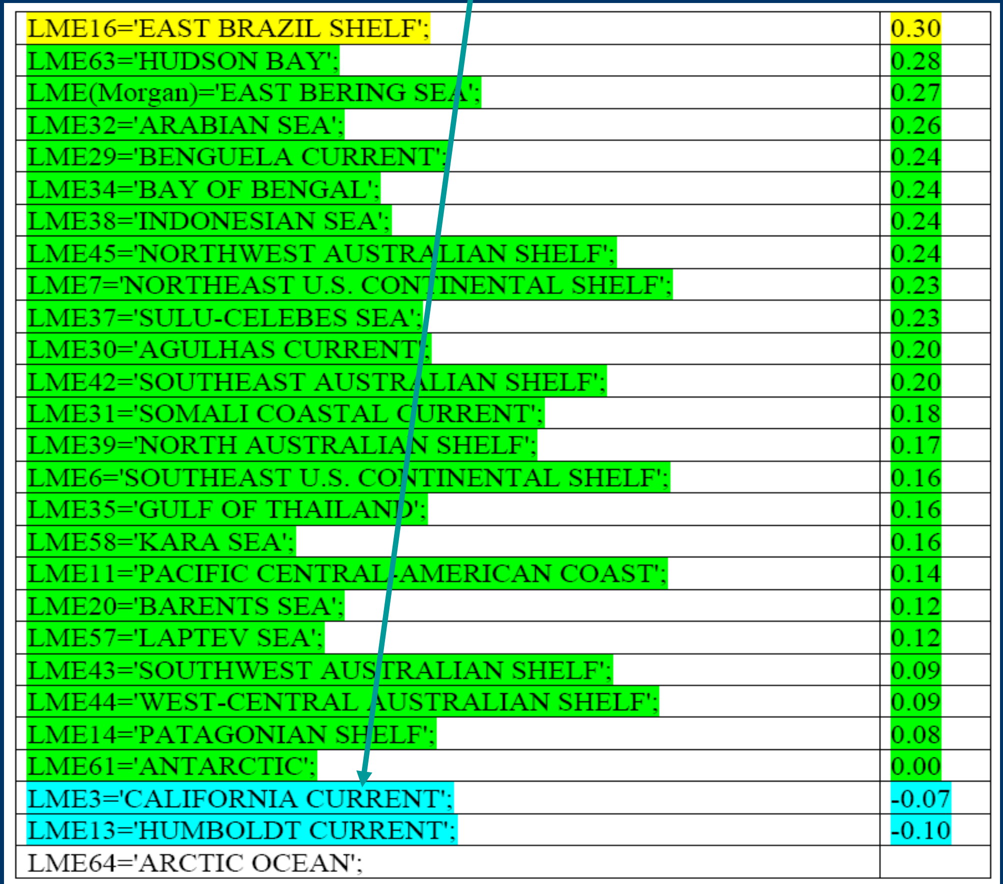


Table 3. SST change in each LME, 1982-2006 (sorted in descending order)

LME23='BALTIC SEA';	1.35
LME22='NORTH SEA';	1.31
LME47='EAST CHINA SEA';	1.22
LME50='SEA OF JAPAN';	1.09
LME(Morgan)='NEWFOUNDLAND-LABRADOR SHELF';	1.04
LME62='BLACK SEA';	0.96
LME(Morgan)='SCOTIAN SHELF';	0.89
LME59='ICELAND SEA';	0.86
LME21='NORWEGIAN SEA';	0.85
LME49'KUROSHIO CURRENT';	0.75
LME60='FAROE PLATEAU';	0.75
LME33='RED SEA';	0.74
LME18='WEST GREENLAND SHELF';	0.73
LME24='CELTIC-BISCAY SHELF';	0.72
LME26='MEDITERRANEAN SEA';	0.71
LME54='CHUKCHI SEA';	0.70
LME25='IBERIAN COASTAL';	0.68
LME48='YELLOW SEA';	0.67
LME17='NORTH BRAZIL SHELF';	0.60
LME51='OYASHIO CURRENT';	0.60
LME15='SOUTH BRAZIL SHELF';	0.53
LME27='CANARY CURRENT';	0.52
LME12='CARIBBEAN SEA';	0.50
LME(Morgan)='EAST GREENLAND SHELF';	0.47
LME28='GUINEA CURRENT';	0.46
LME10='INSULAR PACIFIC HAWAIIAN';	0.45
LME36='SOUTH CHINA SEA';	0.44
LME53='WEST BERING SEA';	0.39
LME2='GULF OF ALASKA';	0.37
LME40='NE AUSTRALIAN SHELF-GREAT BARRIER REEF';	0.37
LME56}='EAST SIBERIAN SEA';	0.36
LME41='EAST-CENTRAL AUSTRALIAN SHELF';	0.35
LME55='BEAUFORT SEA';	0.34
LME46='NEW ZEALAND SHELF';	0.32
LME4='GULF OF CALIFORNIA';	0.31
LME5='GULF OF MEXICO';	0.31
LME52='SEA OF OKHOTSK';	0.31



LME16='EAST BRAZIL SHELF';	0.30
LME63='HUDSON BAY';	0.28
LME(Morgan)='EAST BERING SEA';	0.27
LME32='ARABIAN SEA';	0.26
LME29='BENGUELA CURRENT';	0.24
LME34='BAY OF BENGAL';	0.24
LME38='INDONESIAN SEA';	0.24
LME45='NORTHWEST AUSTRALIAN SHELF';	0.24
LME7='NORTHEAST U.S. CONTINENTAL SHELF';	0.23
LME37='SULU-CELEBES SEA';	0.23
LME30='AGULHAS CURRENT';	0.20
LME42='SOUTHEAST AUSTRALIAN SHELF';	0.20
LME31='SOMALI COASTAL CURRENT';	0.18
LME39='NORTH AUSTRALIAN SHELF';	0.17
LME6='SOUTHEAST U.S. CONTINENTAL SHELF';	0.16
LME35='GULF OF THAILAND';	0.16
LME58='KARA SEA';	0.16
LME11='PACIFIC CENTRAL-AMERICAN COAST';	0.14
LME20='BARENTS SEA';	0.12
LME57='LAPTEV SEA';	0.12
LME43='SOUTHWEST AUSTRALIAN SHELF';	0.09
LME44='WEST-CENTRAL AUSTRALIAN SHELF';	0.09
LME14='PATAGONIAN SHELF';	0.08
LME61='ANTARCTIC';	0.00
LME3='CALIFORNIA CURRENT';	-0.07
LME13='HUMBOLDT CURRENT';	-0.10
LME64='ARCTIC OCEAN';	

Ocean climate

(not just temperature)

Wind
Cloud cover
Waves
Sea level

Temperature
Salinity
pH
Oxygen

Currents
Stratification
Turbulence
Upwelling
Frontal processes

Monsoon seasonality
ENSO, NAO, PDO

Human pressure on marine ecosystems

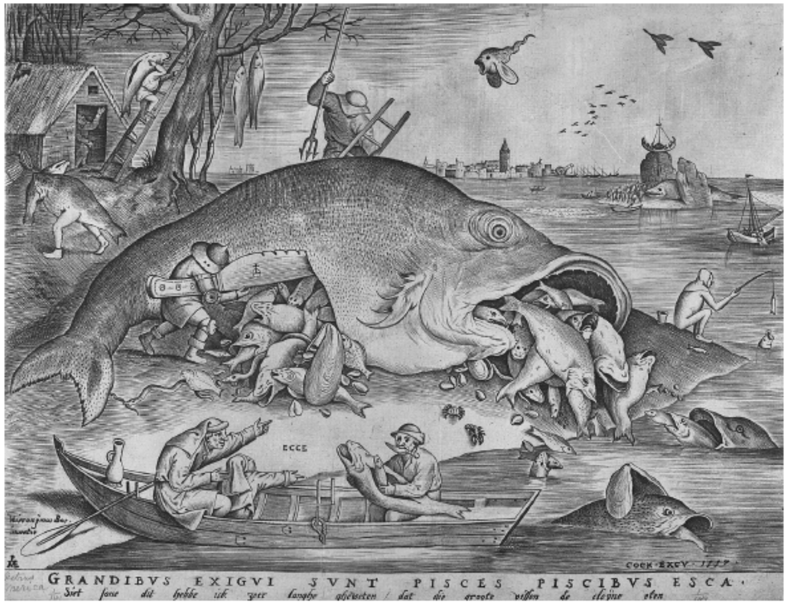
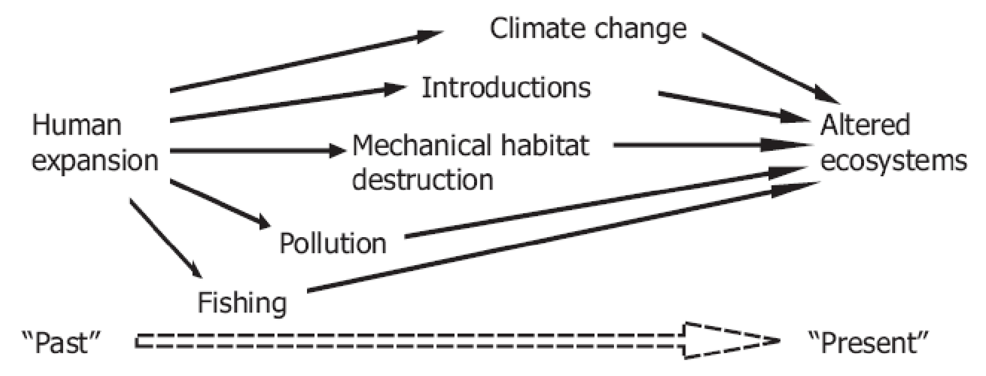


FIGURE 2: By the time Pieter Bruegel the Elder created *Big Fish Eat Little Fish* (1557), his fantastic illustration of a maxim from Dutch life, Europeans had been putting pressure on coastal and estuarine ecosystems for centuries. Early modern voyages to Iceland, Newfoundland, and New England were inspired by the inability of European marine ecosystems to produce enough for European appetites. The Metropolitan Museum of Art, Harris Brisbane Dick Fund, 1917 (17.3.859). Image © The Metropolitan Museum of Art.

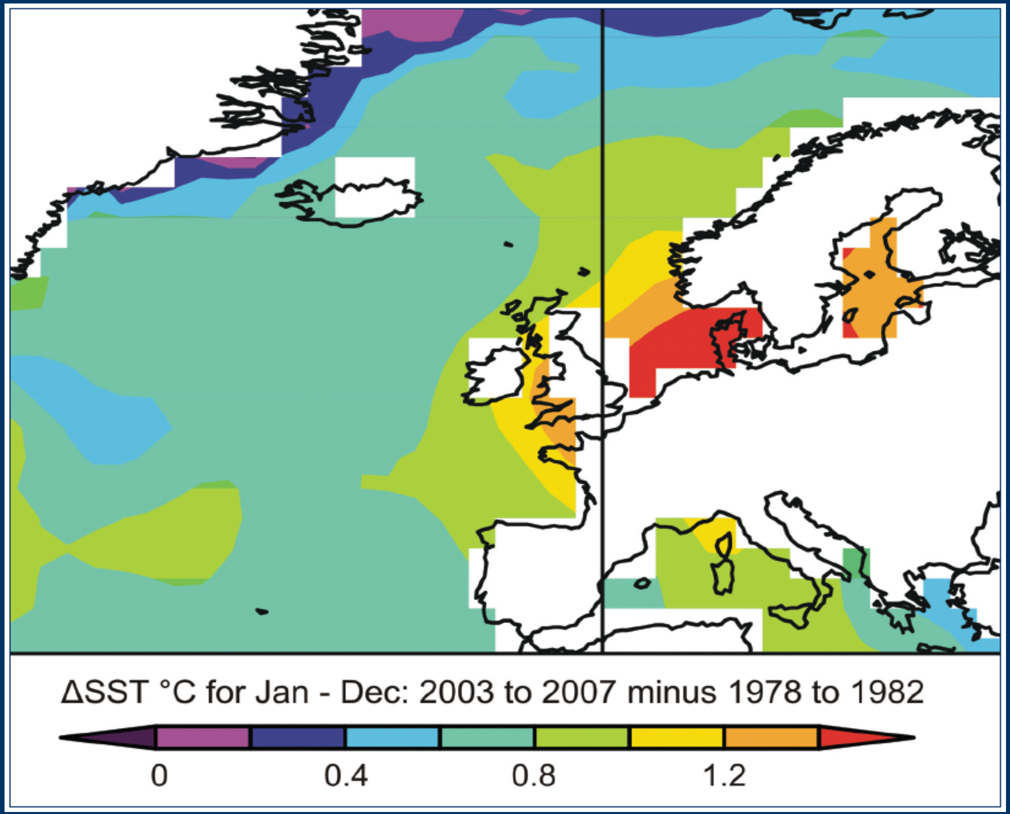


Climate is an important factor in the changes in distribution, abundance and seasonality of fish (100), benthos (88), plankton (83) and seabirds (20) in the NE Atlantic

ICES Cooperative Research Report
Rapport des Recherches Collectives

No. 293
November 2008

The effect of climate change on the distribution and abundance of marine species in the OSPAR Maritime Area



ΔSST °C for Jan - Dec: 2003 to 2007 minus 1978 to 1982

Species richness has been increasing in the North Sea (and in the Bay of Biscay) *Global Change Biology 14: 453 - 460*

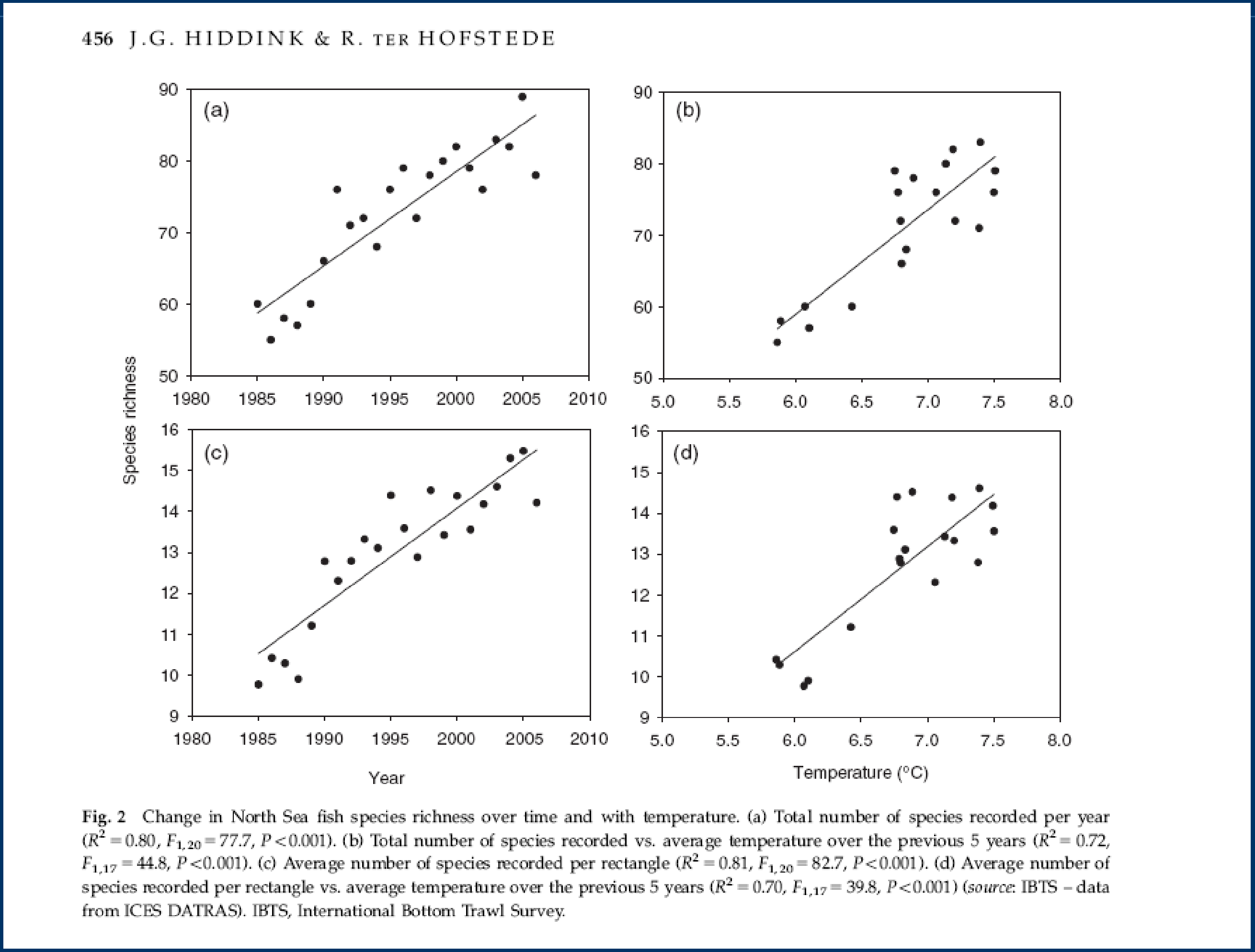


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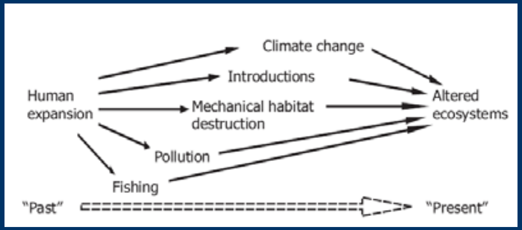
Fig. 2 Change in North Sea fish species richness over time and with temperature. (a) Total number of species recorded per year ($R^2 = 0.80$, $F_{1,20} = 77.7$, $P < 0.001$). (b) Total number of species recorded vs. average temperature over the previous 5 years ($R^2 = 0.72$, $F_{1,17} = 44.8$, $P < 0.001$). (c) Average number of species recorded per rectangle ($R^2 = 0.81$, $F_{1,20} = 82.7$, $P < 0.001$). (d) Average number of species recorded per rectangle vs. average temperature over the previous 5 years ($R^2 = 0.70$, $F_{1,17} = 39.8$, $P < 0.001$) (*source*: IBTS – data from ICES DATRAS). IBTS, International Bottom Trawl Survey.

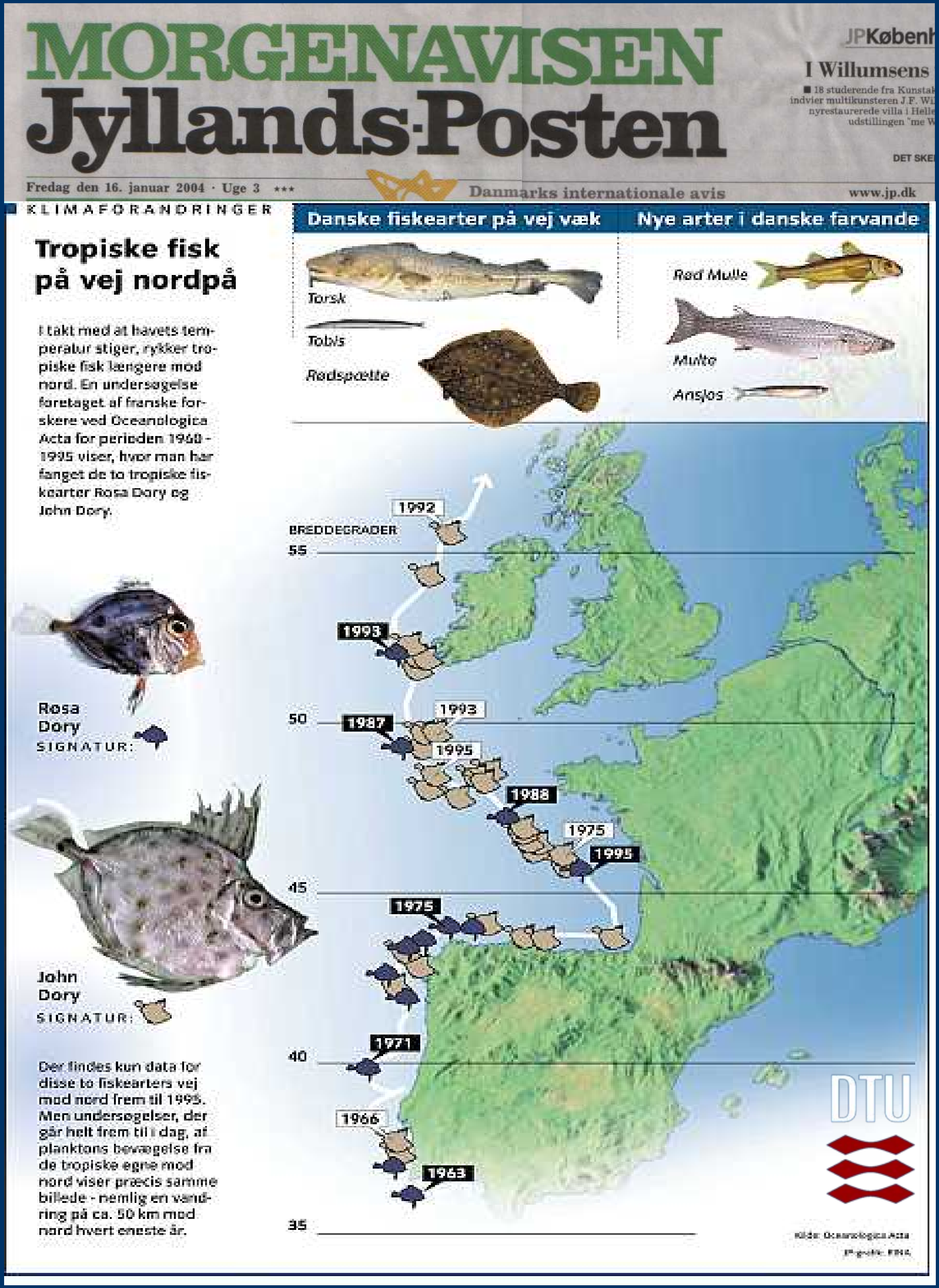
Where we are now



- **Long history of changes to marine ecosystems**
- **Pressures accumulate and interact**
- **There is no pristine state for conservation**

Change is rapid in the sea

- Distributions change
- Productivity changes
- Some species decline and others become more abundant



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JPKøbenh

I Willumsens

■ 18 studerende fra Kunstak
indvier multikunsteren J.F. Wi
nyrestaurerede villa i Helle
udstillingen "me W

DET SKE

KLIMAFORANDRINGER

Tropiske fisk på vej nordpå

I takt med at havets temperatur stiger, rykker tropiske fisk længere mod nord. En undersøgelse foretaget af franske forskere ved Oceanologica Acta for perioden 1960-1995 viser, hvor man har fanget de to tropiske fiskearter Rosa Dory og John Dory.

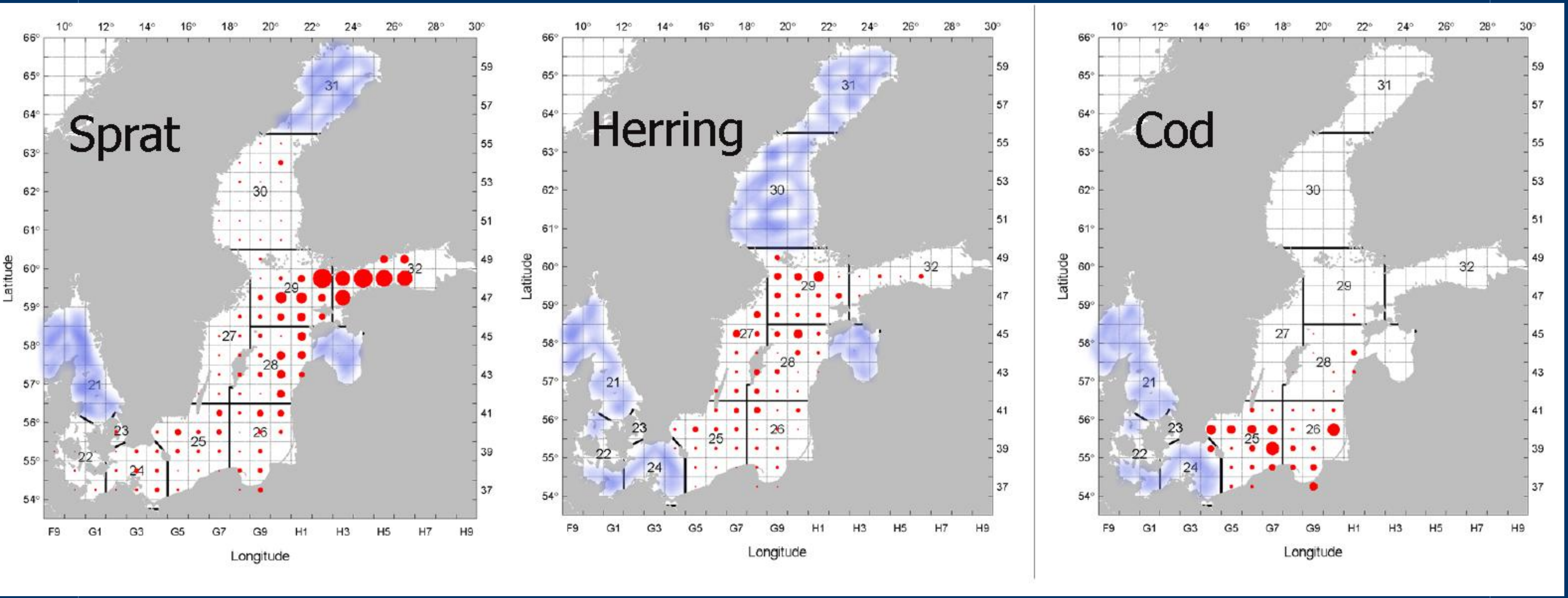
Der findes kun data for disse to fiskearters vej mod nord frem til 1995. Men undersøgelser, der går helt frem til i dag, af planktons bevægelse fra de tropiske egne mod nord viser præcis samme billede - nemlig en vandring på ca. 50 km mod nord hvert eneste år.

Kilde: Oceanologica Acta

JP-grafik: [illegible]

Biomass of adult cod, sprat and herring in the Baltic Sea 1975-2013 (thousand tons; source ICES)

Distribution of cod, sprat and herring in the Baltic Sea Q4 2012 (blue areas unsampled; source ICES Advice May 2013)



Drivers of change in cod biomass in the Baltic Sea

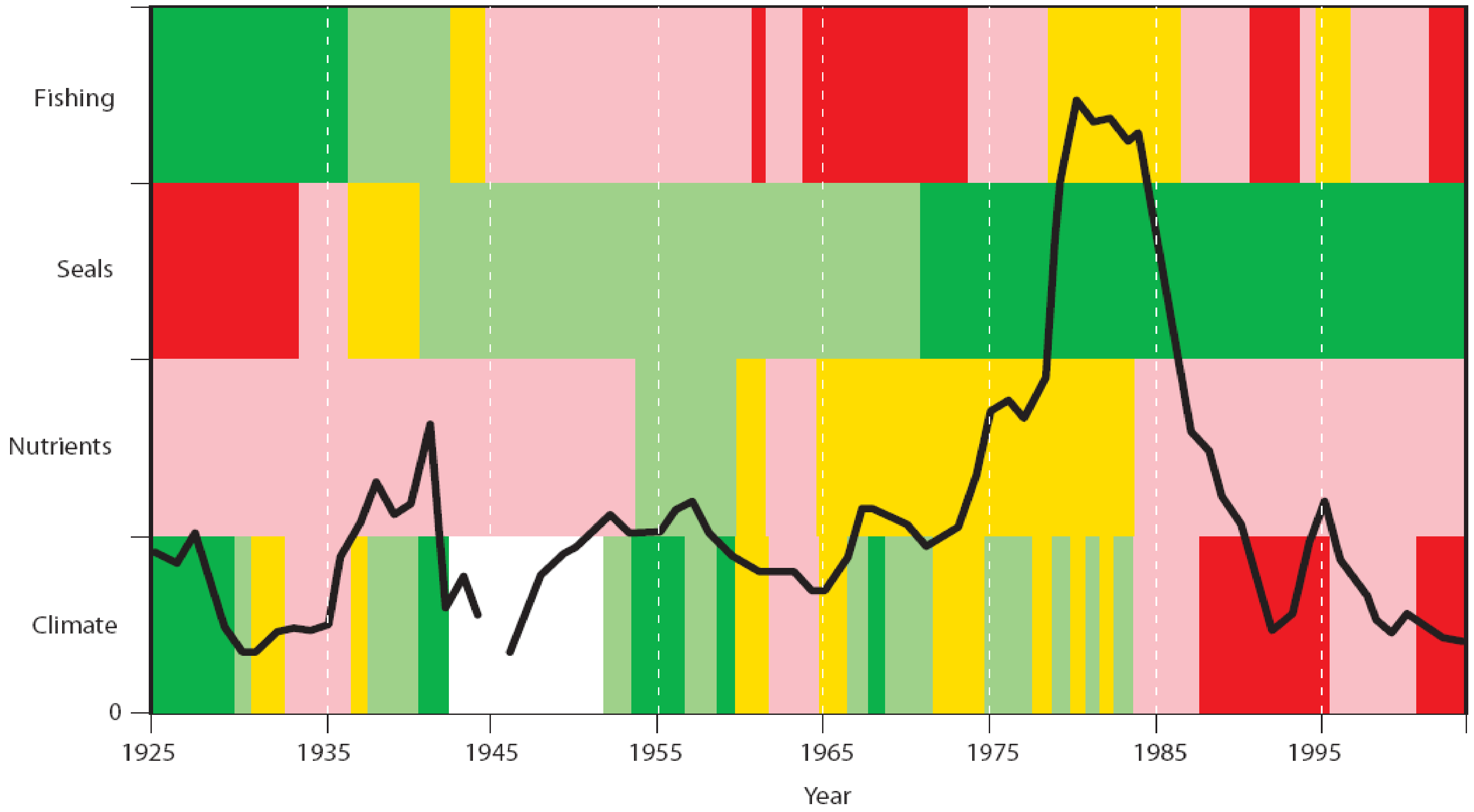
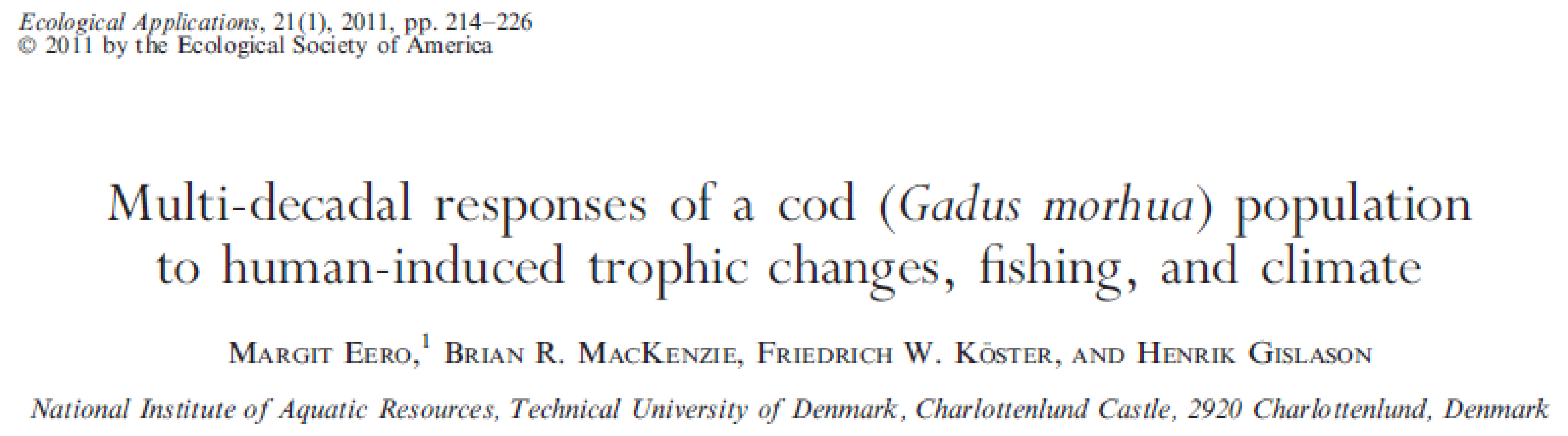


Fig. 14.2. Positive and negative effects of fishing, seals, nutrients and climate on the biomass of cod (black line) in the Baltic Sea during the 20th century. The large increase in cod biomass (and catch) during the 1970s is believed to be due to the simultaneous occurrence of positive (or less negative) effects of all four factors. The color scale from green to dark red represents levels of the forcing factor ranging from beneficial to detrimental and is based on quintiles of the ranges for each factor. Source: Eero et al. (*Proceedings of the ICES Annual Science Conference* 2008/J:08).



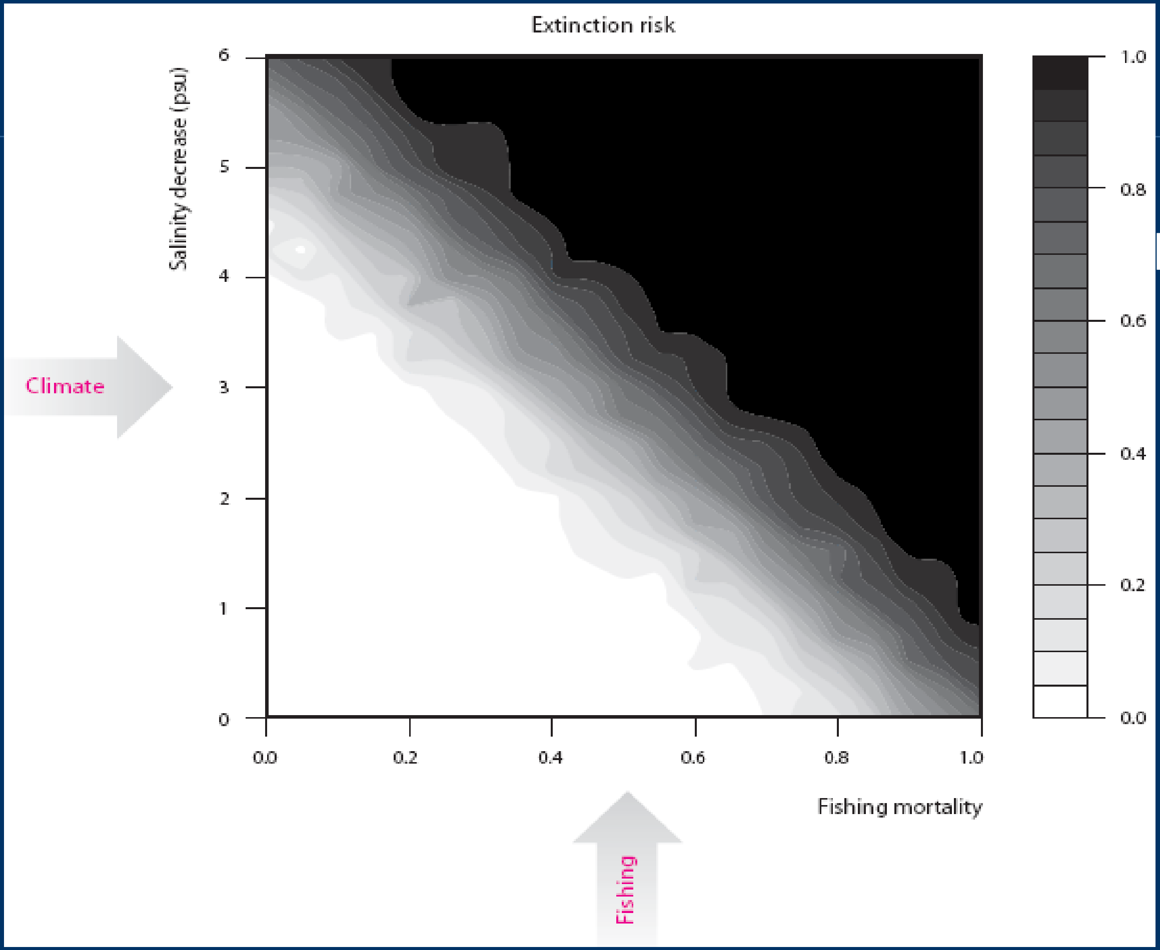
Ecological Applications, 21(1), 2011, pp. 214–226

Multi-decadal responses of a cod (*Gadus morhua*) population to human-induced trophic changes, fishing, and climate

MARGIT EERO,[1] BRIAN R. MACKENZIE, FRIEDRICH W. KÖSTER, AND HENRIK GISLASON

National Institute of Aquatic Resources, Technical University of Denmark, Charlottenlund Castle, 2920 Charlottenlund, Denmark

the pressures often interact



Risk that cod will disappear from the Baltic

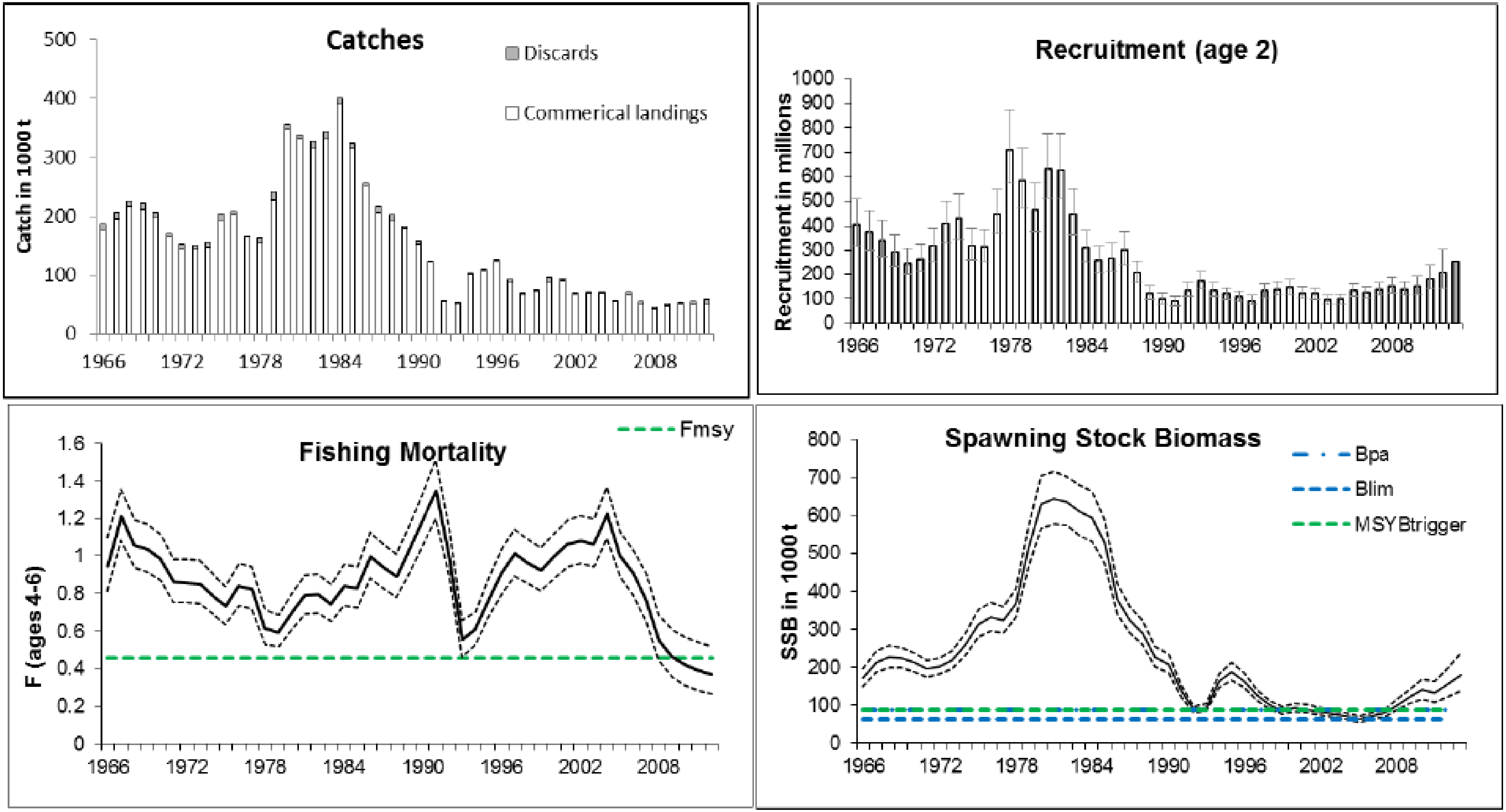
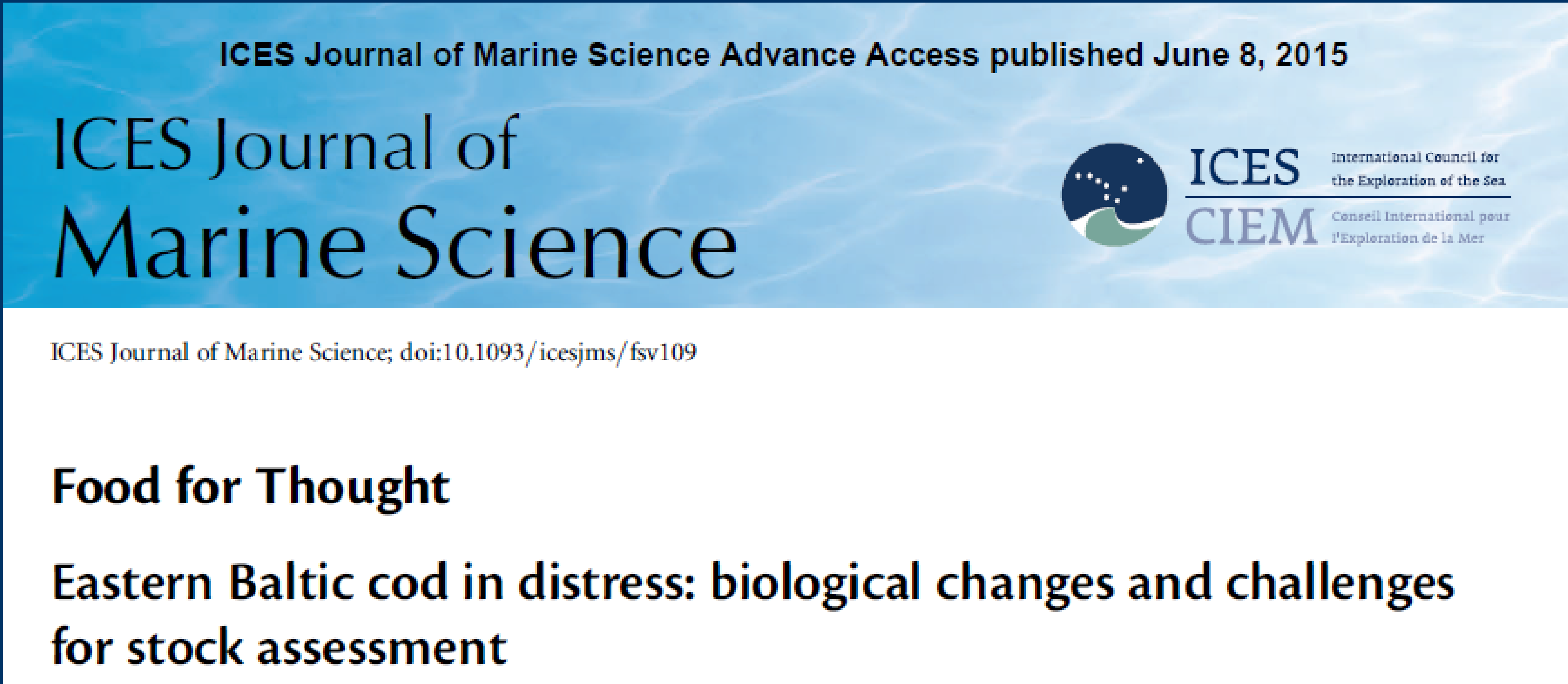


Figure 8.4.3.1 Cod in Subdivisions 25–32. Summary of stock assessment (weights in thousand tonnes). Predicted values are shaded. Top right: SSB and F for the time-series used in the assessment. Management target fishing mortality cannot be displayed due to the difference in reference F age range compared to the current assessment.

The SSB has increased in recent years and is now estimated to have been above B_{pa} since 2008. Fishing mortality has declined and is now estimated to be below F_{MSY}, since 2009. The abundance of the 2006–2011 year classes is above the average of the last 20 years.

”One of the most successful stock recoveries in recent times”

- Fishing mortality declined
- Biomass increased
- Recruitment increased (why?)
- These positive developments were partly ascribed to effective management



ICES Journal of Marine Science Advance Access published June 8, 2015

ICES Journal of
Marine Science

ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science; doi:10.1093/icesjms/fsv109

Food for Thought

Eastern Baltic cod in distress: biological changes and challenges for stock assessment

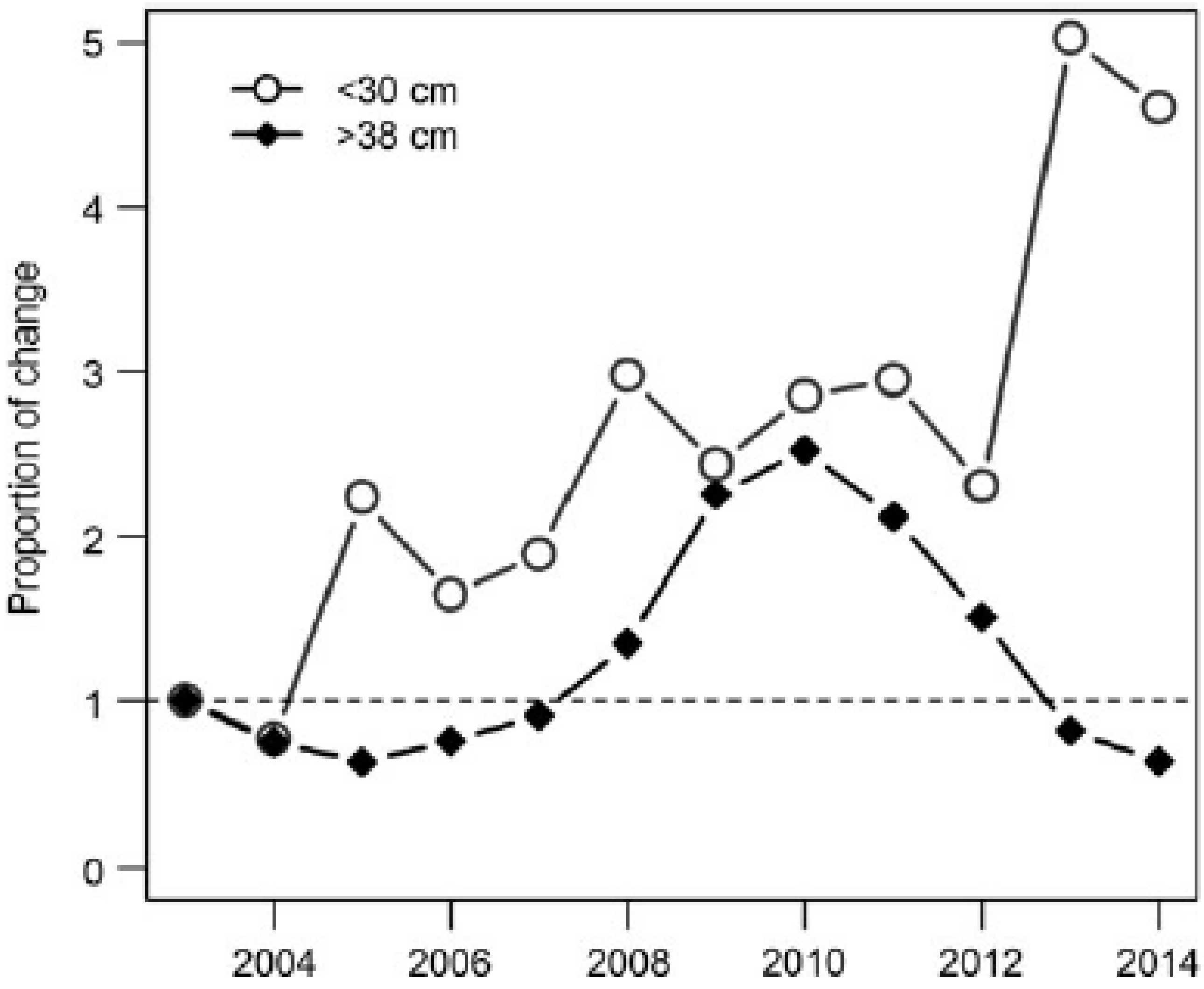


Figure 1. Change in biomass of juvenile (<30 cm) and market-size cod (>38 cm) in 2004 – 2014 relative to 2003, based on data from International Bottom Trawl Surveys (geometric mean of Q1 and Q4 surveys) in the entire central Baltic Sea.

Why is the EB cod in difficulty?

- Range is restricted
- Condition is poor
- Parasites

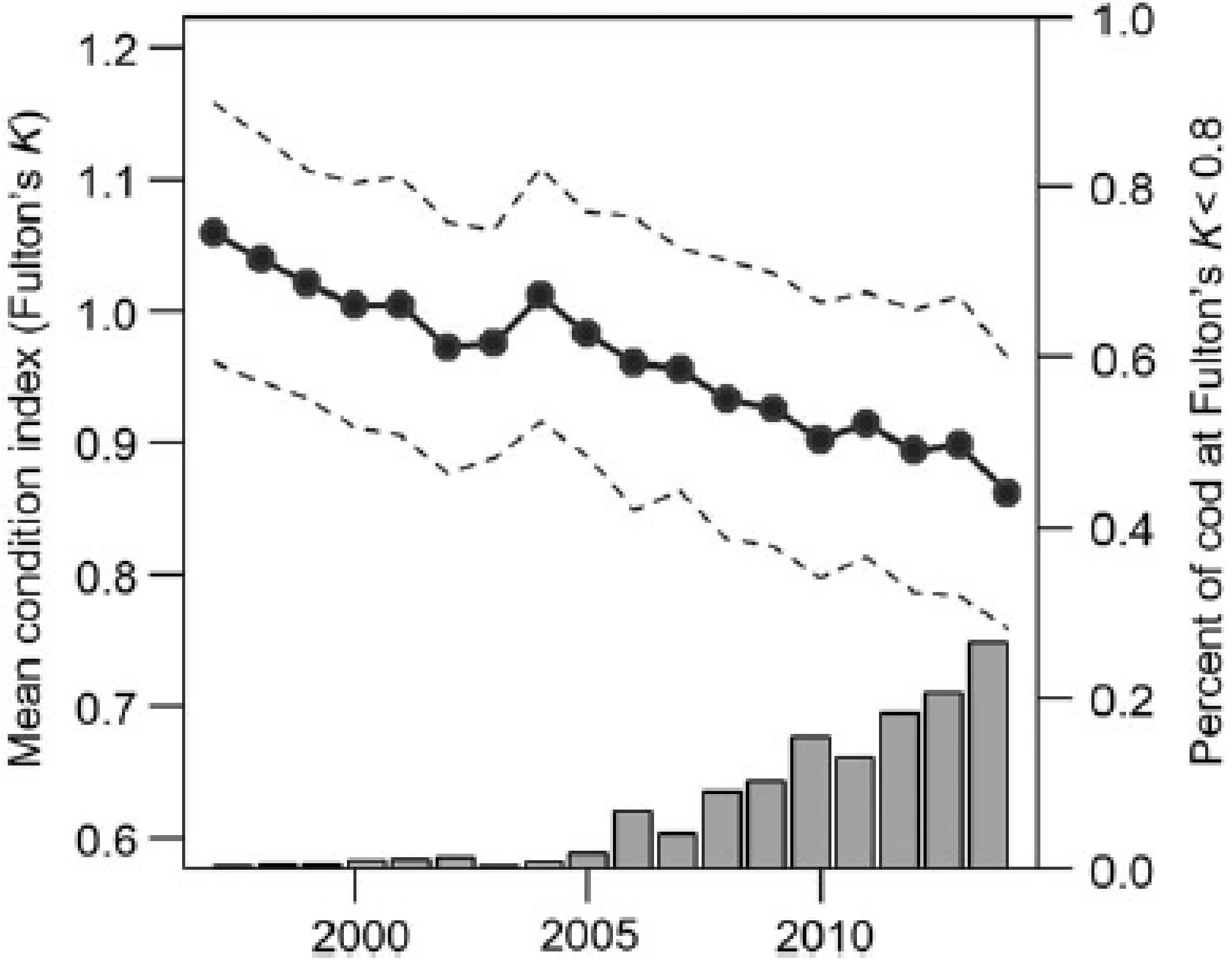


Figure 2. Average condition (Fulton's K) of 40–60 cm cod in Bornholm Basin with the standard deviation (the lines) and the proportion of cod with Fulton's K < 0.8 (the bars).

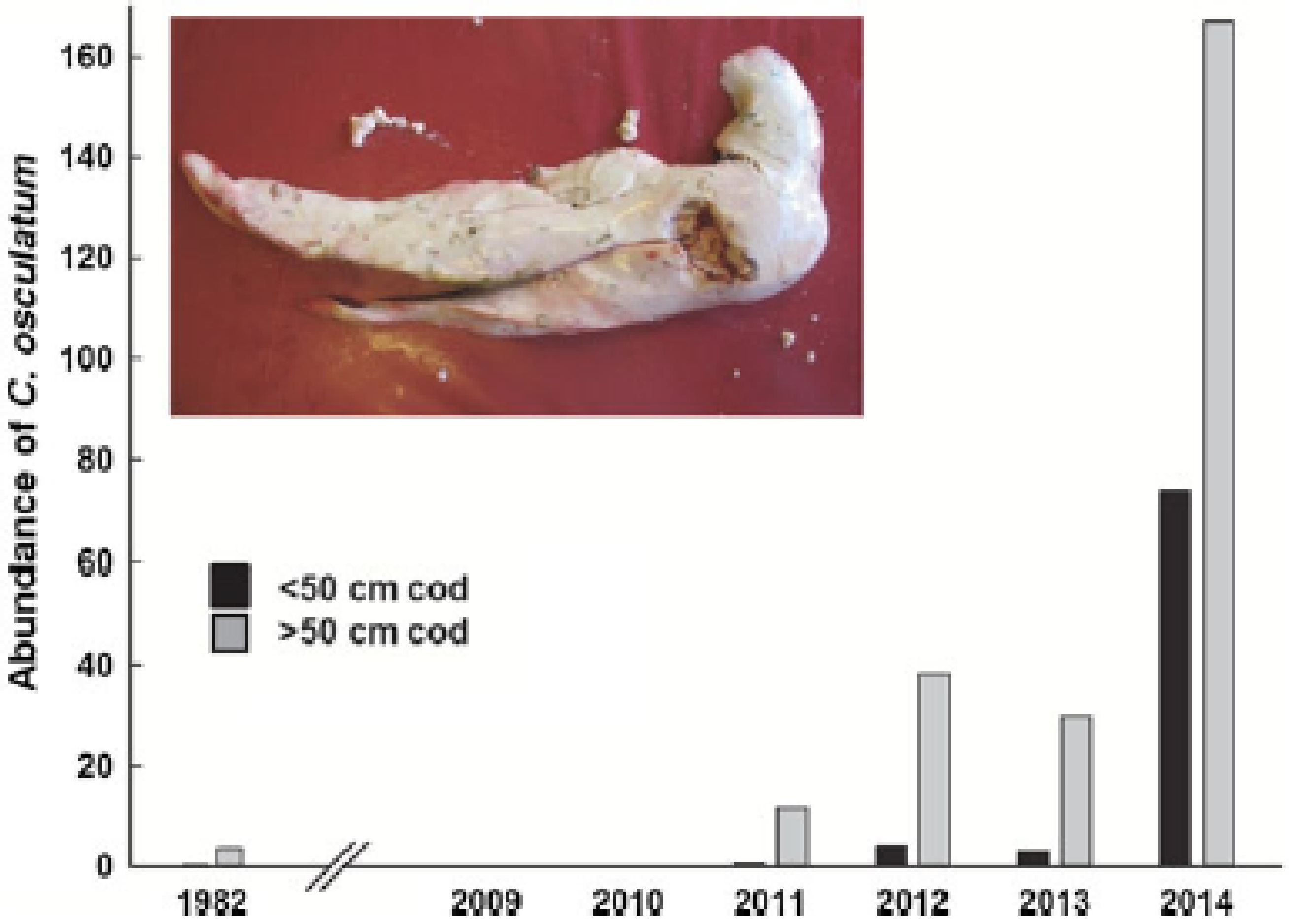


Figure 3. Abundance (number of parasites per fish with infected and uninfected included) of the parasite C *osculatum* in cod liver [data from Bornholm and Gdańsk Basins, ca. 100 – 300 cod sampled $year^{-1}$; modified from Haarder *et al.* (2014), Mehrdana *et al.* (2014), and M. Podolska *et al.* (pers. comm.); no data available for 2009 – 2010]. Photo shows a cod liver infected with C *osculatum* (K. Buchmann).

Age reading is unreliabe

- International quality control lacking
- Recent biological changes probably make it more difficult

Climate change is shifting the goalposts

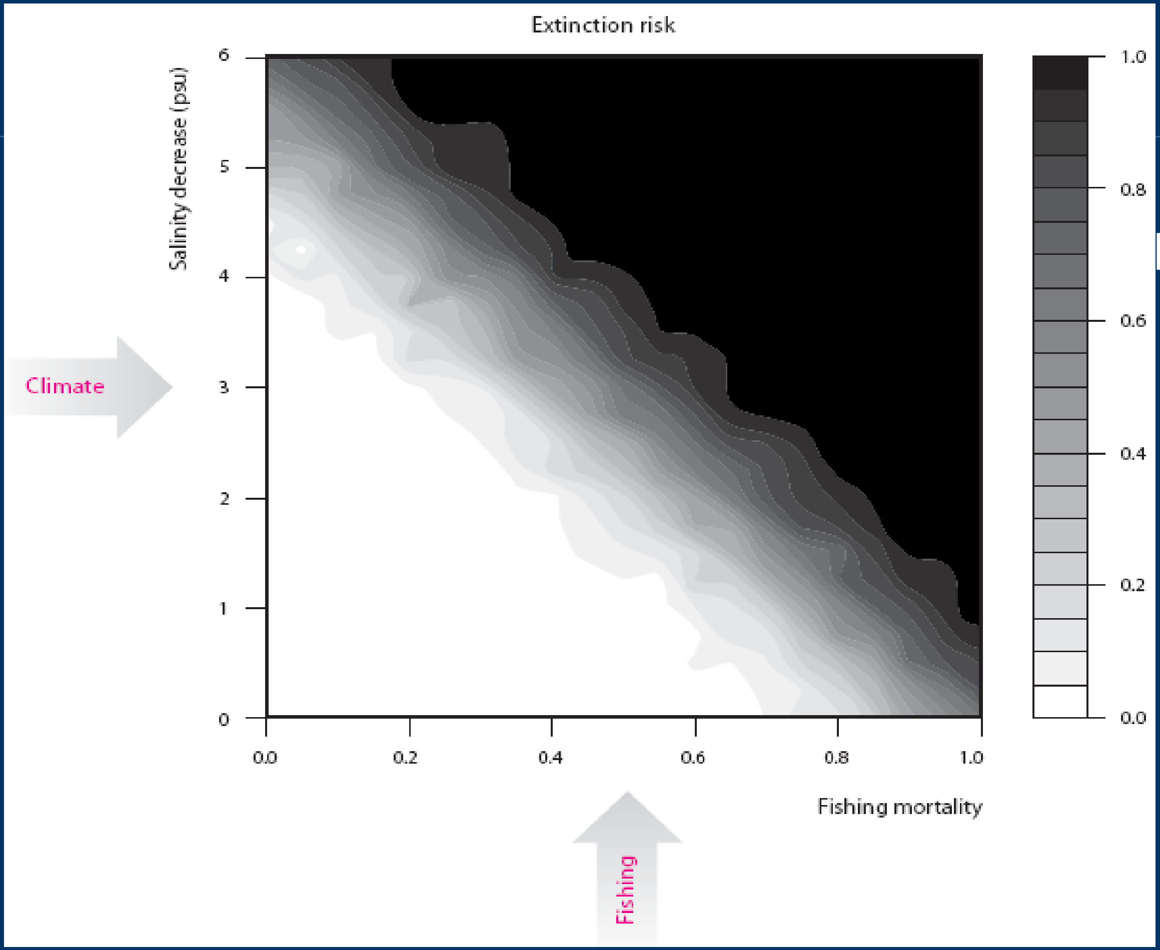
- Altered biomass and F reference levels for fisheries
- There is no fixed ”healthy ecosystem state”

Is more biodiversity always a good thing?

How far will acidification and hypoxia alter marine ecosystem states and productivity?

What about the role of marine ecosystems in carbon sequestration?

the pressures often interact



Risk that cod will disappear from the Baltic

- Why do we need better projections of fisheries?
- Who will use the information?
- What time and space scales are needed?
- Are relevant projections available and understood?
- How much are users willing to pay for them?
- How reliable do projections have to be?

Adaptation IPCC report

Key adaptations for fisheries and aquaculture include policy and management to:

1. maintain ecosystems in a state that is resilient to change
2. enable occupational flexibility
3. develop early warning systems for extreme events

(*medium confidence*).

Adaptation – who does it?

- Populations, species, ecosystems
  - Behaviour, distribution, phenology
  - Acclimatization and shifts in balanced polymorphism
  - Genetics
- People
  - Autonomous
  - Planned

Adaptation – decisions and time scales

thanks to Alistair Hobday, CSIRO, Hobart

What to wear
Aerators
Feed cycles
Farm maintenance
Extreme weather response
Stocking/harvest time
Quota purchase
Labour needs
Equipment purchase
Feed management
Port location
Pond construction
Selective breeding
Farm location
Fishery infrastructure
Future of fishery

Decision lead time

7-10 days

Minimal warning time
Reactive management

Weather forecasting

Weeks to months

Early window for implementation of strategies to minimise impacts

Seasonal forecasting

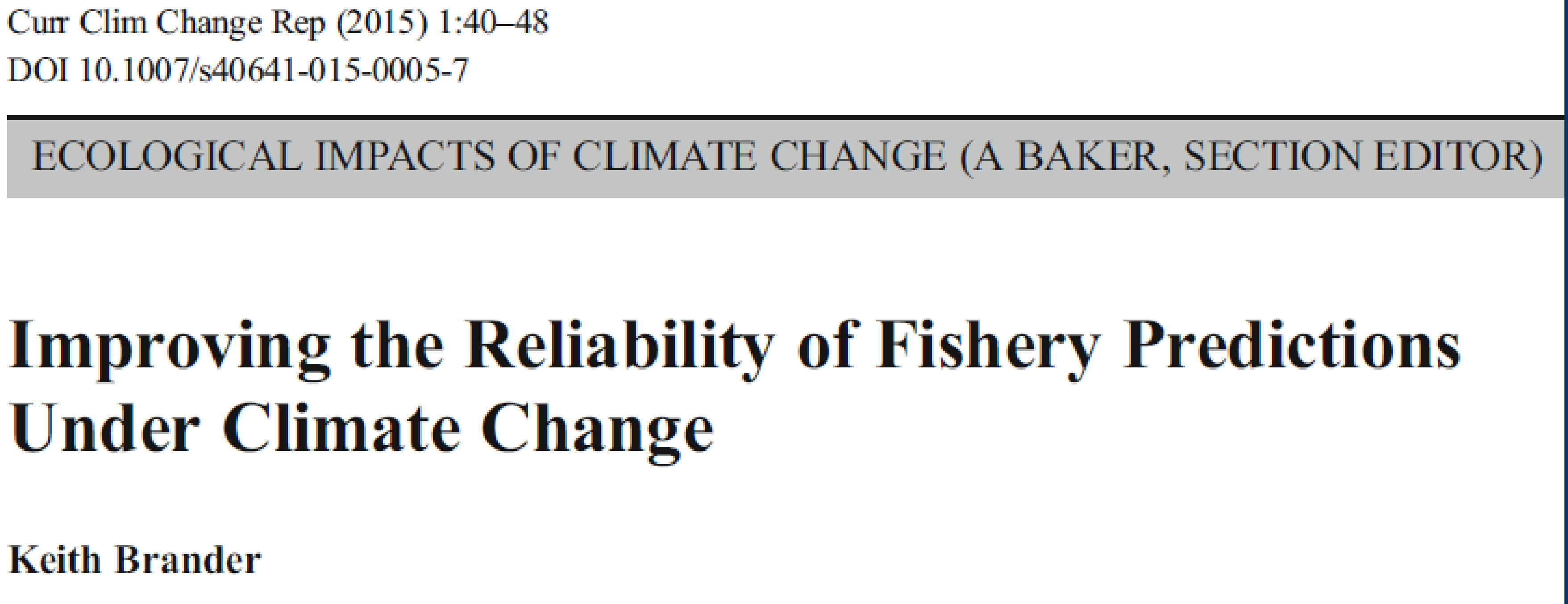
Decades to centuries

Long term planning

Climate projection

Why is it difficult to make credible predictions of fisheries productivity?

- Ocean climate forecasts are inadequate
- We don’t live in the sea
- We don’t control the production systems
- We harvest many 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



Curr Clim Change Rep (2015) 1:40–48
DOI 10.1007/s40641-015-0005-7

ECOLOGICAL IMPACTS OF CLIMATE CHANGE (A BAKER, SECTION EDITOR)

Improving the Reliability of Fishery Predictions Under Climate Change

Keith Brander

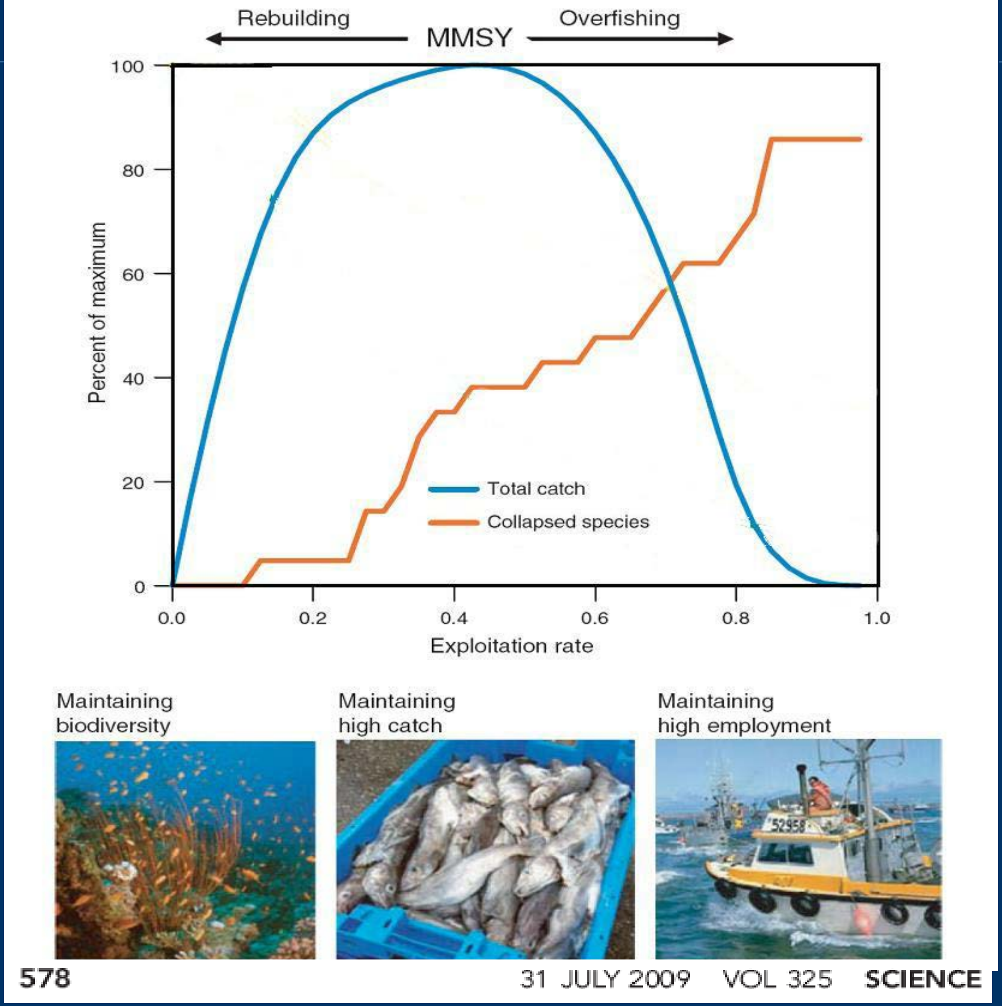
How do we estimate the reliability of our projections in a complete and consistent way and how do we present this information?

Summing up

- Climate is already affecting marine ecosystems
- Fisheries have always been affected by climate - productivity (recruitment, growth, mortality, distribution) is affected
- Climate can increase as well as decrease fish productivity
- In spite of the complexity of understanding and managing fisheries production we can propose some robust win-win strategies
- We may be just in time to avert the worst for both fisheries and climate

Artist:Glynn Gorick

Objectives pull in different directions

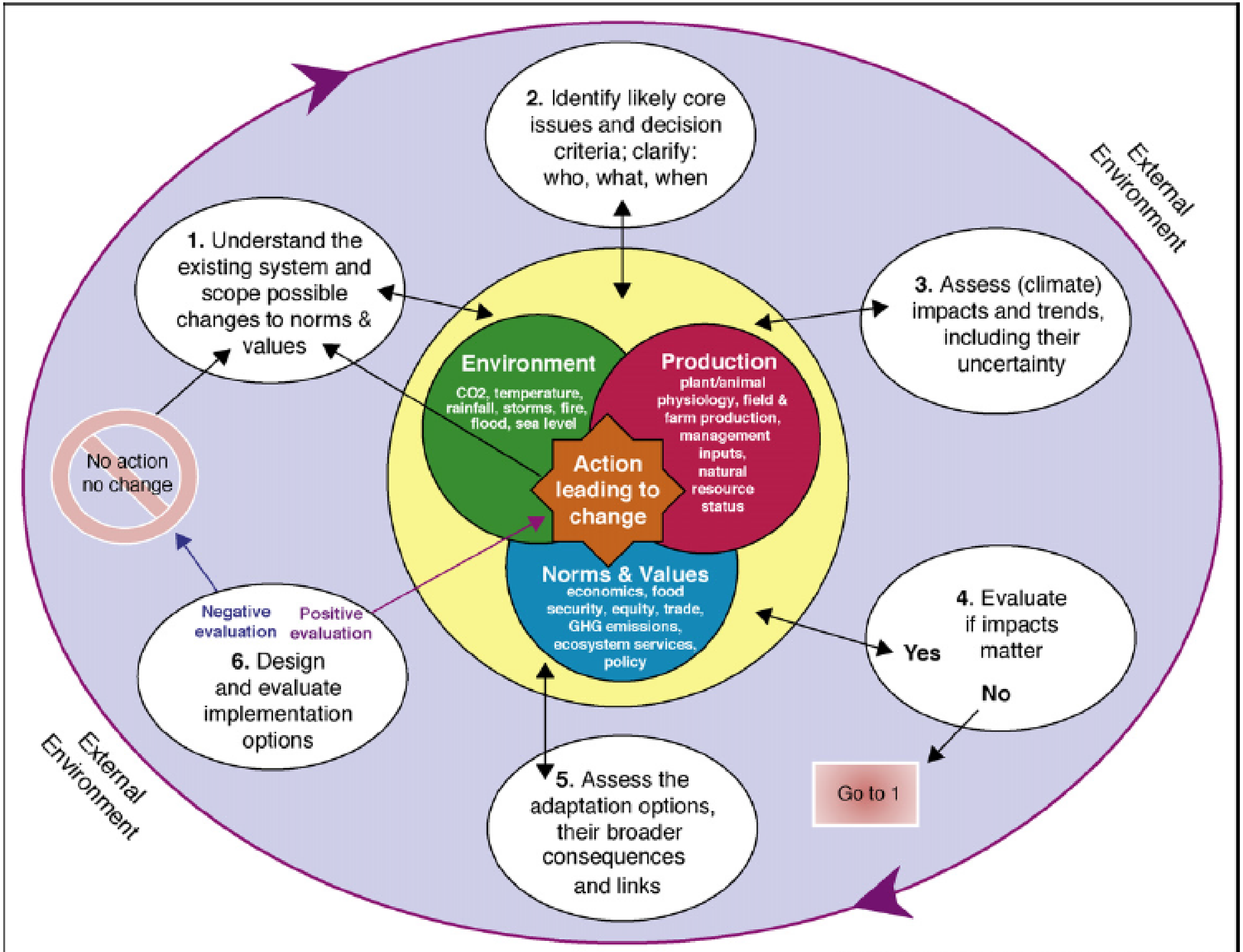


Maintaining biodiversity

Maintaining high catch

Maintaining high employment

578 31 JULY 2009 VOL 325 **SCIENCE**



Current Opinion in Environmental Sustainability

The adaptation cycle, the 'engine' of adaptation science, is based on a reflective analysis-action continuum (modified from Howden *et al.* [22]).