UiT

THE ARCTIC UNIVERSITY OF NORWAY

Factors affecting spatial and temporal distributions in the Barents Sea cod fishery

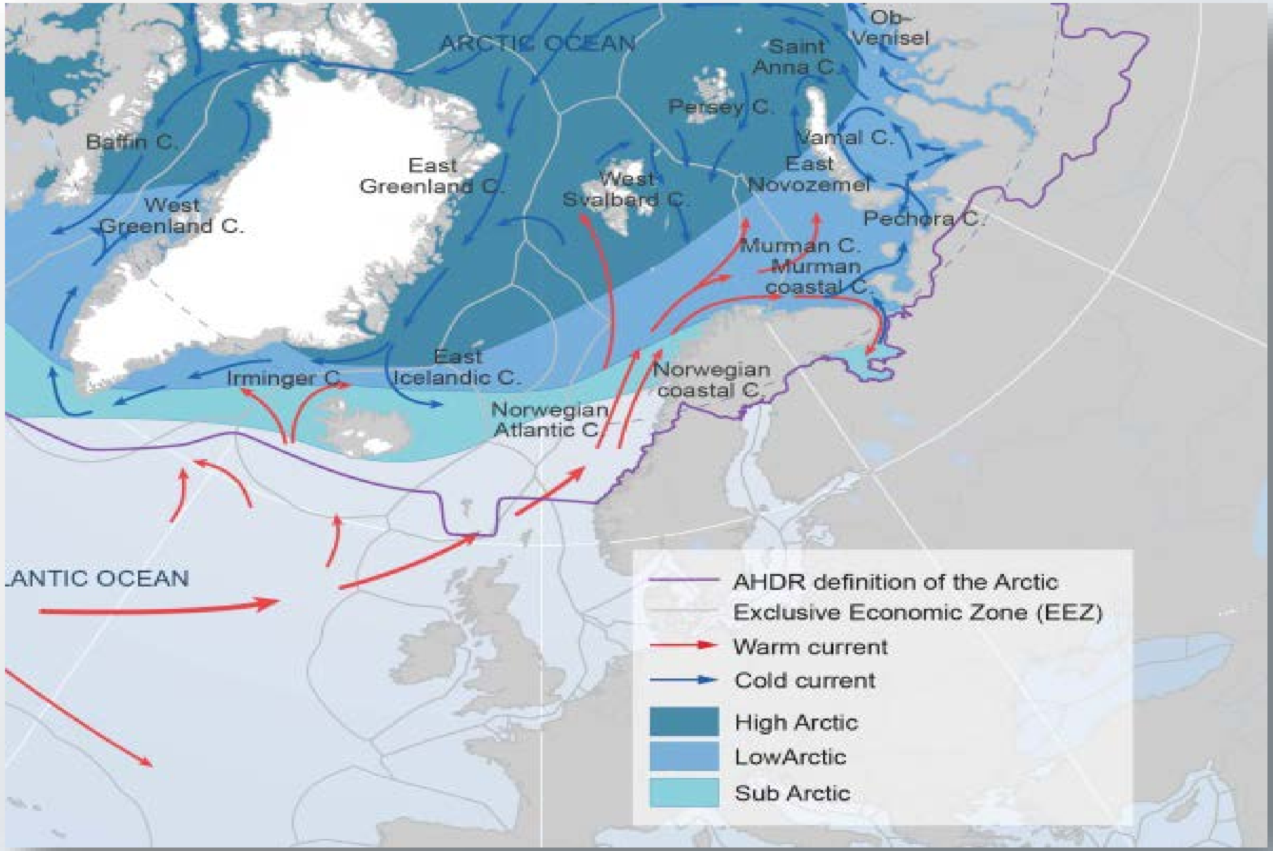
Arne Eide – UiT - The Arctic University of Norway

IIFET 2016 14 July 2016

Management challenges

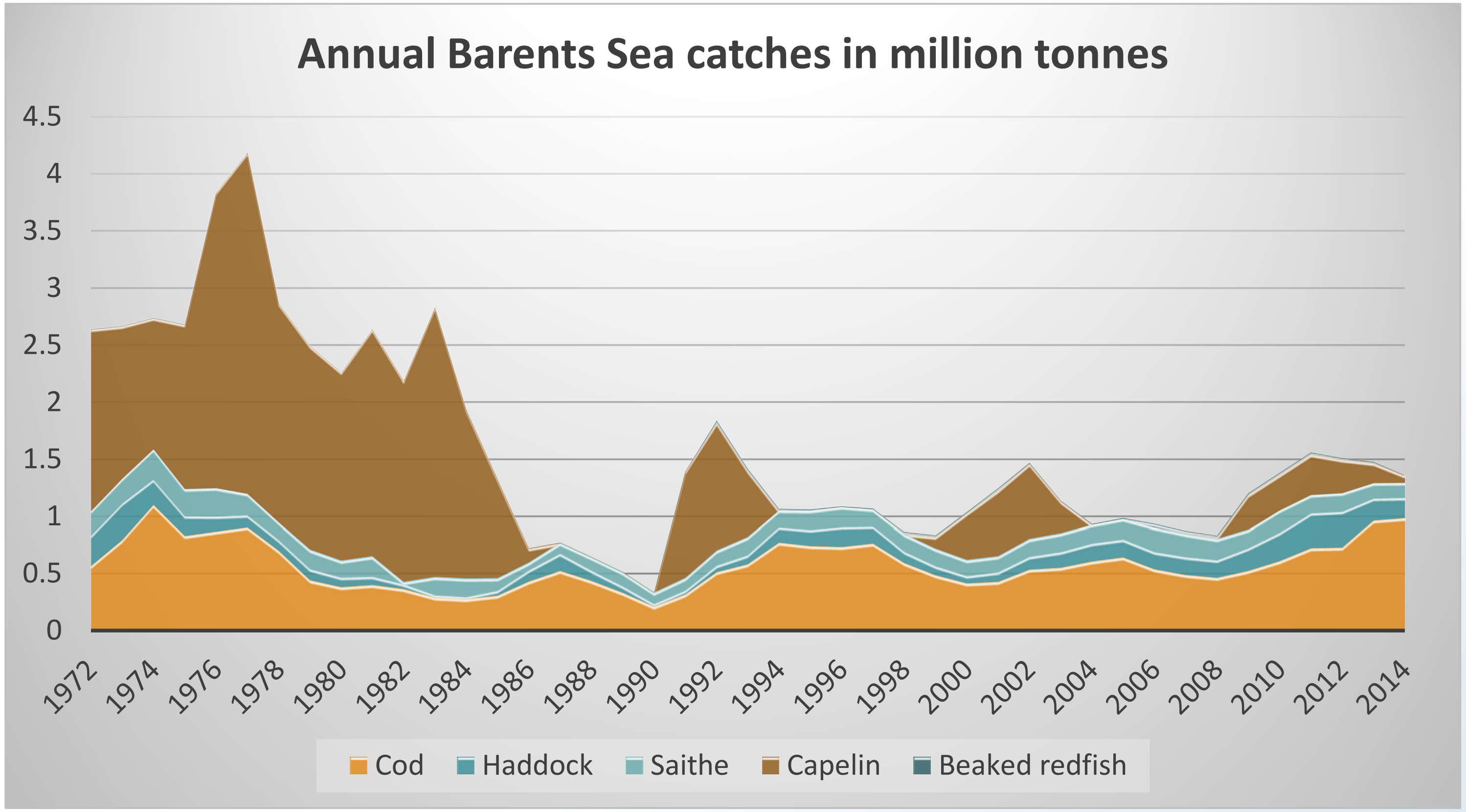
- Availabilities and densities of targeted fish stock resources
- Biological properties
- Ecosystem dynamics
- Environmental variability
- Economic optimisation
  - Shared stocks
  - Market dynamics

    (factor markets and consume markets)



(Source: Arctic Portal, Based on Arctic Human Development Report)

Characteristics of the Barents Sea Fisheries

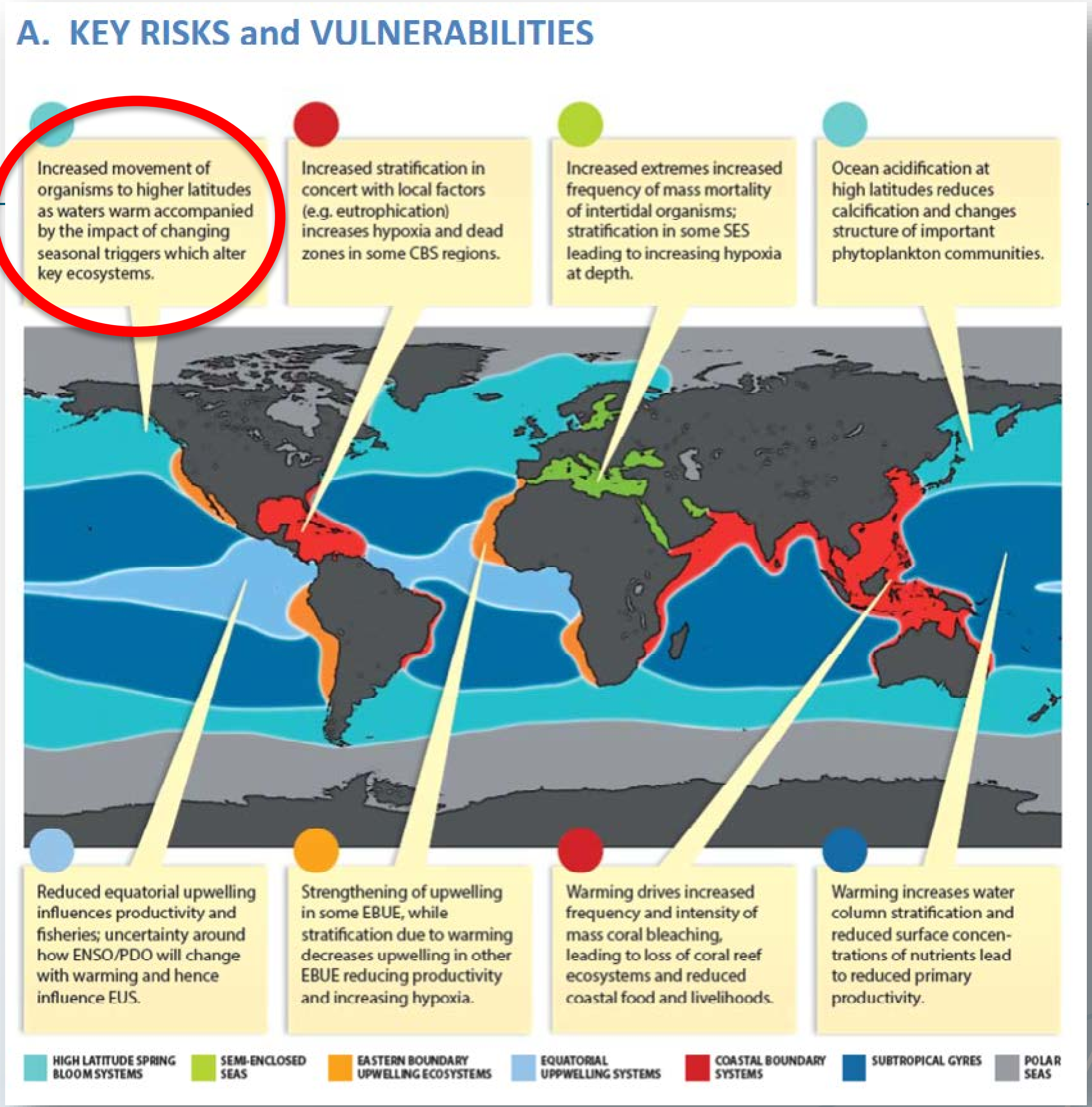


ICES data (AFWG 2015)

- Few dominating fish species
- Significant temporal and spatial fluctuations, within and between years
- High adapting capacity of ecosystems, as well as in the human systems

Spatiotemporal variation

- Significant variations in its natural state
- Natural adapting capacities of species and systems, including the human system



Background and research question

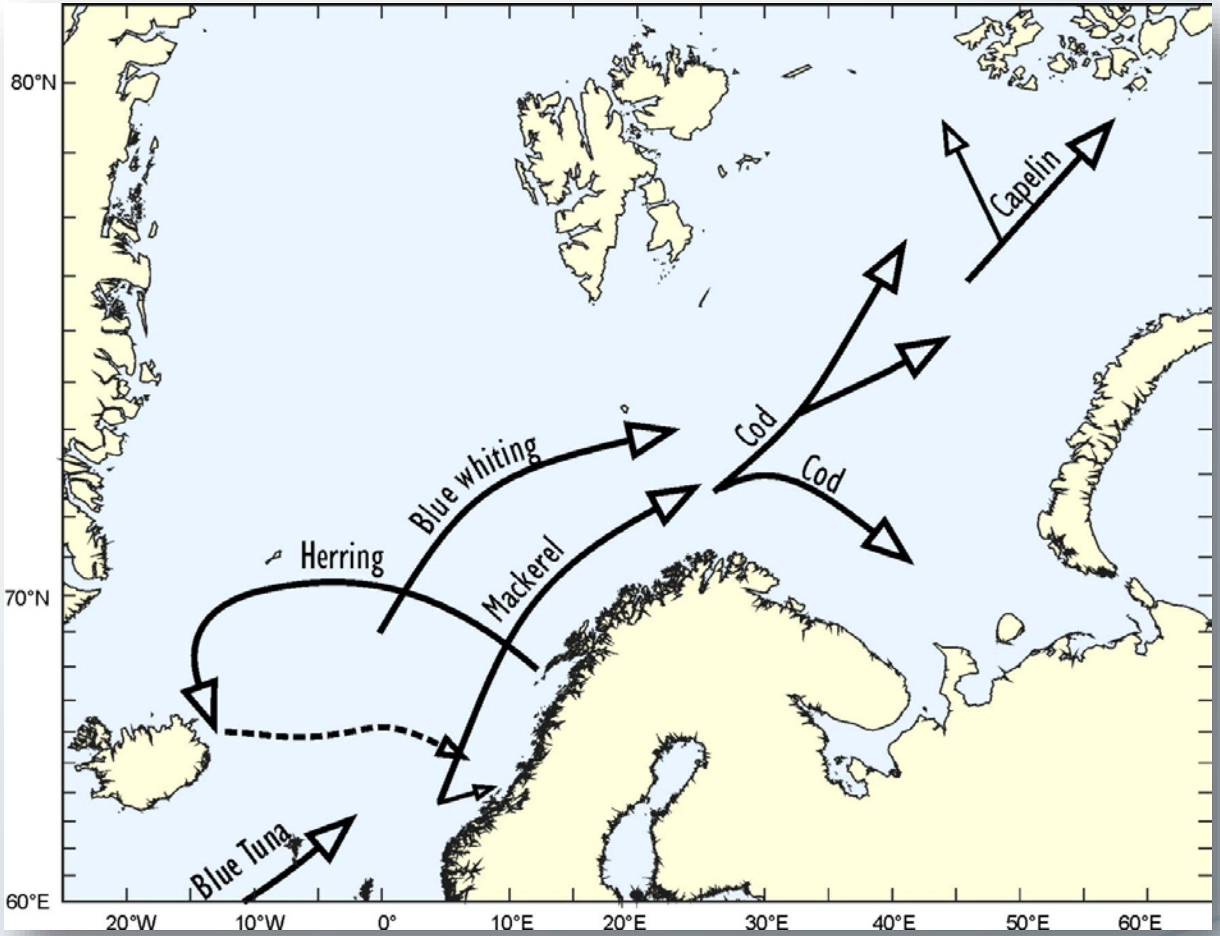
- Climate change is expected to influence the **spatial and temporal distribution of fish stocks**

- **Fleet performance** with and without climate change
  under varying management regimes and fishing aptitude
- Case study: **The Northeast Arctic cod fishery**
  – Possible distributional patterns
  – Different management alternatives are under varying assumptions on the fleets' fishing aptitude.

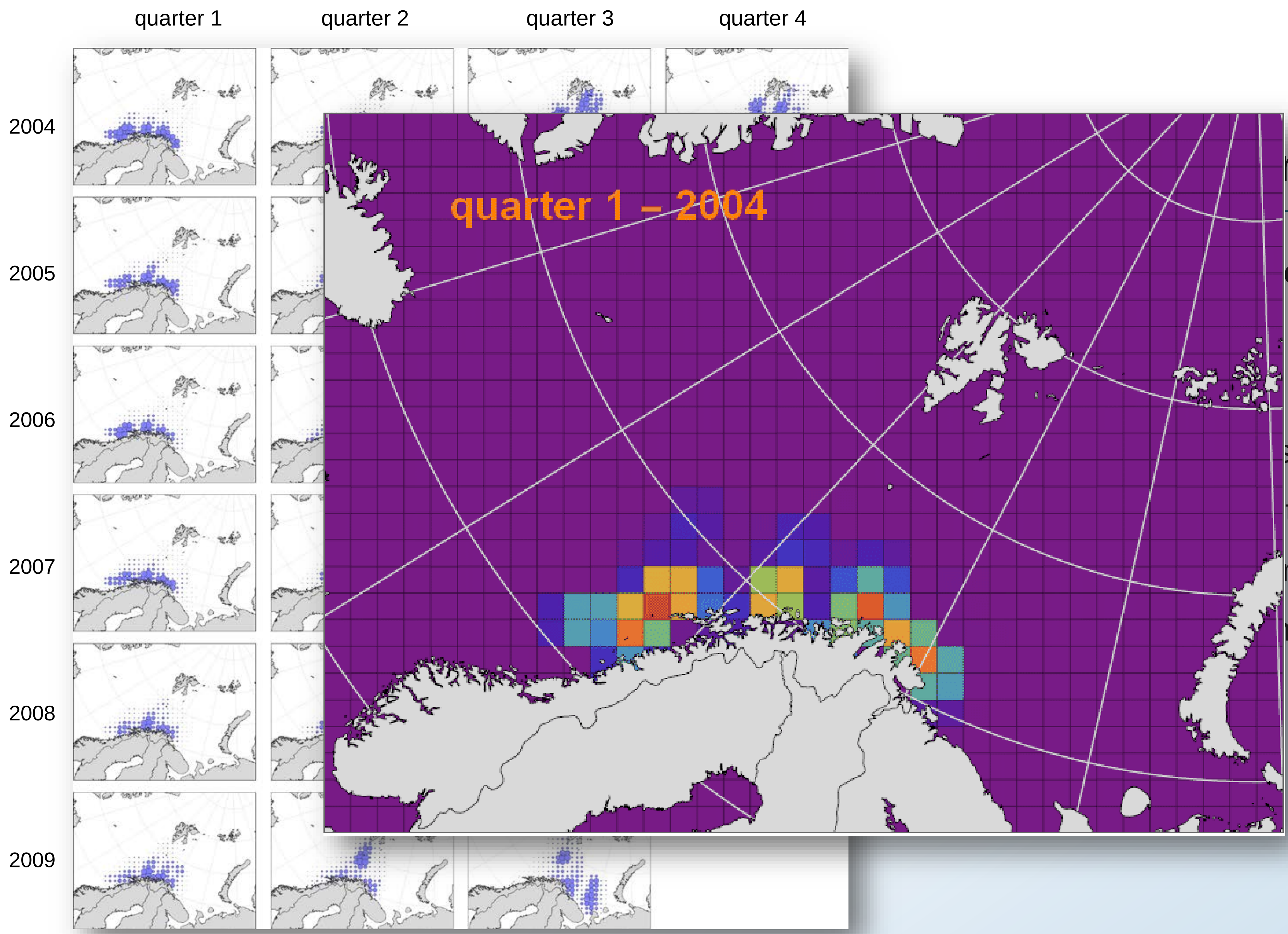
Changes in distribution patterns?

- Expected extension of the feeding area for some of the main fish populations as sea temperature increases.

  (The ACIA report, 2005)



(Source: Loeng et al. (2005)



(FishExchange)

n of catches

od catches by

system is

tions,

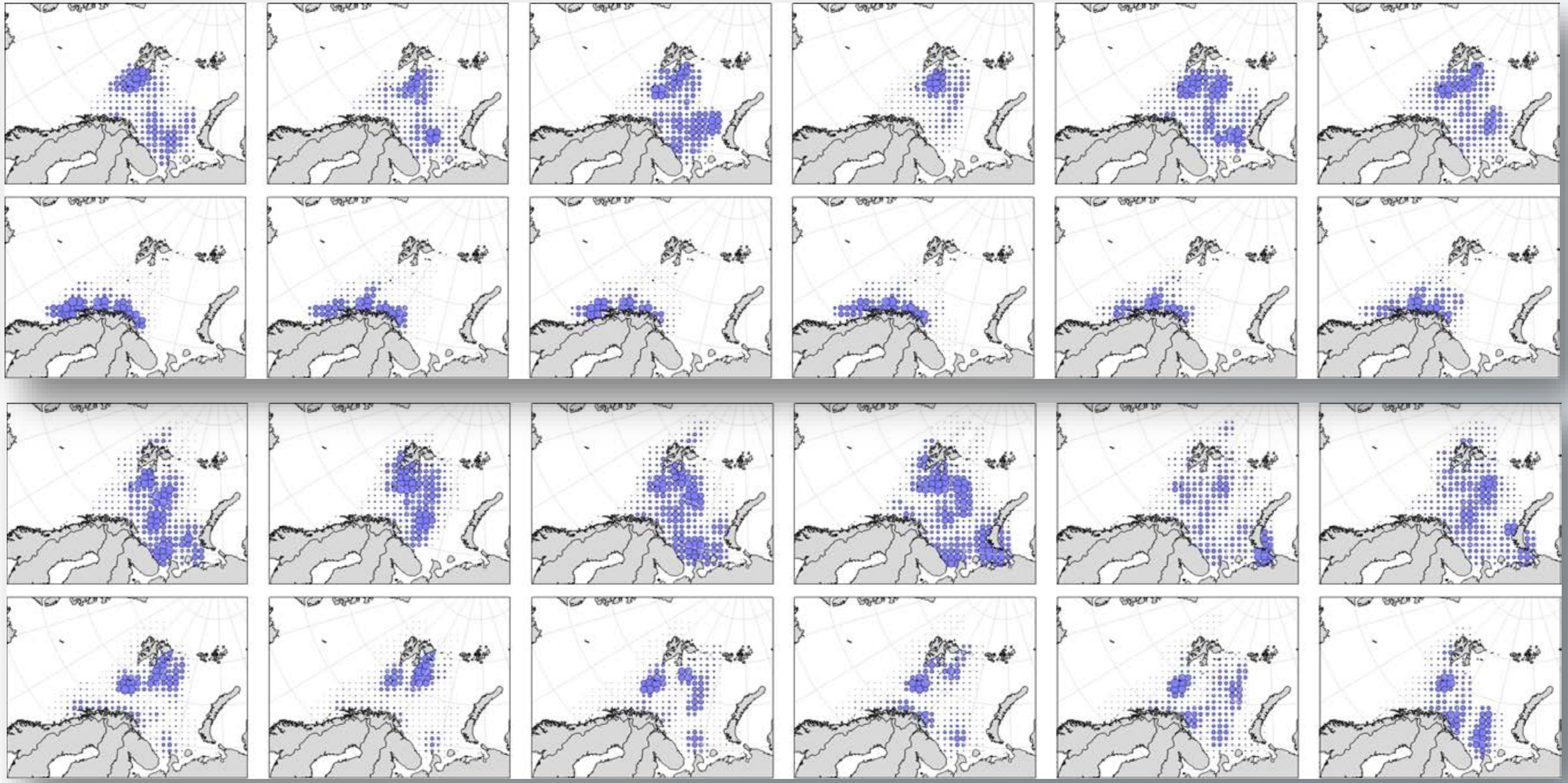
nt variations and

e and space.

Surveys and Norwegian catches

(NEA cod 2004-2009)

2004 2005 2006 2007 2008 2009



Winter surveys (February)

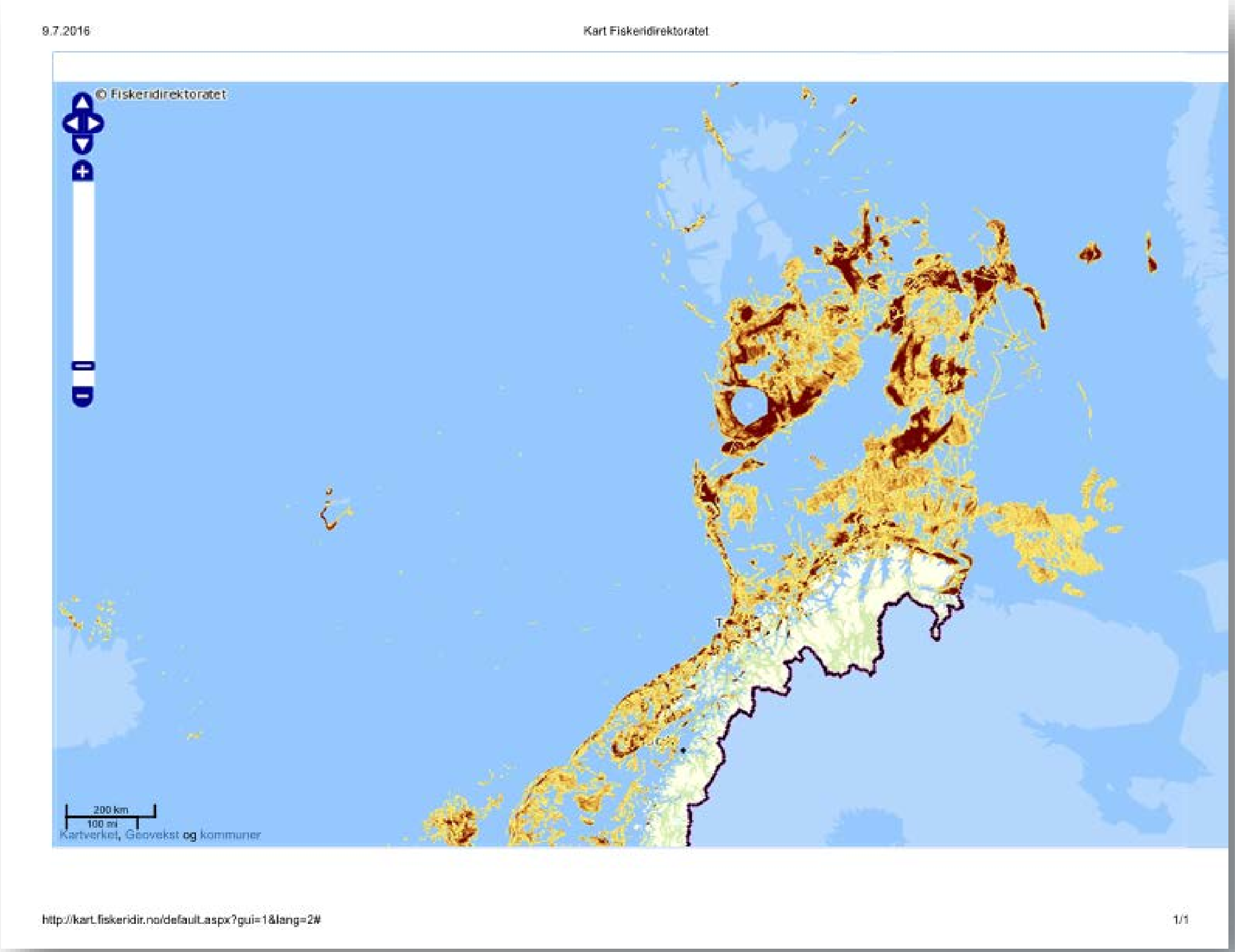
Catches (First quarter)

Eco-surveys (September)

Catches (Third quarter)

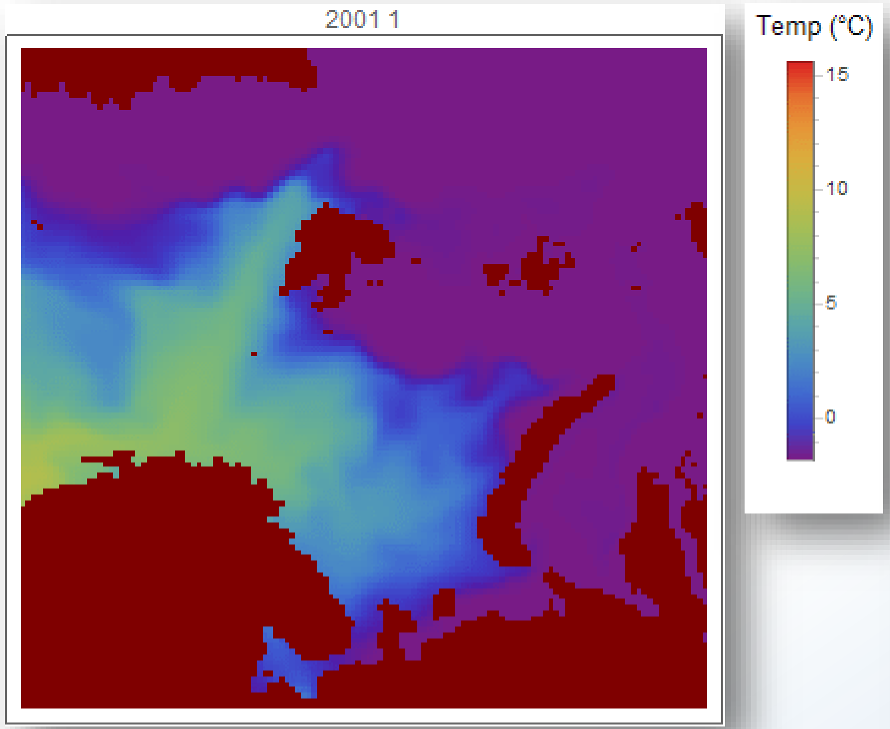
(FishExchange)

Distribution of Norwegian fishing activities in 2015

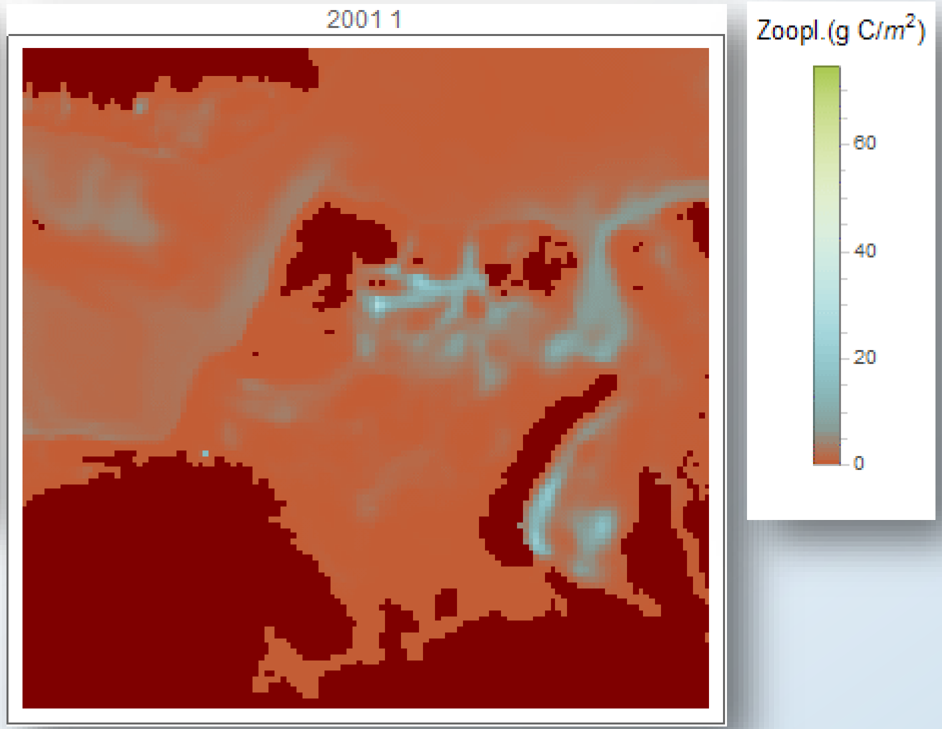


Results from the SinMod model (SRES A1B, 2001 – 2050)

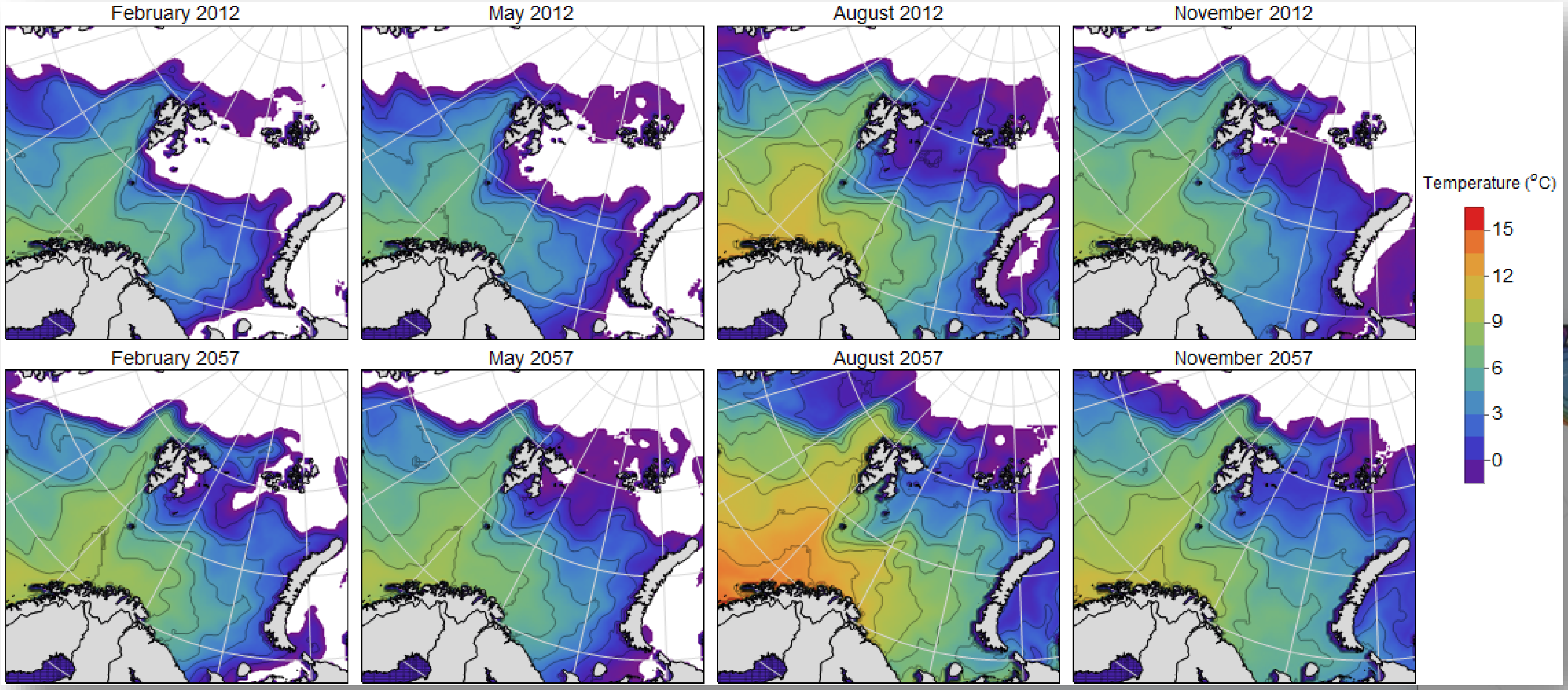
Ocean temperatures at 50 m depts.



Zooplankton densities integrated in the water column

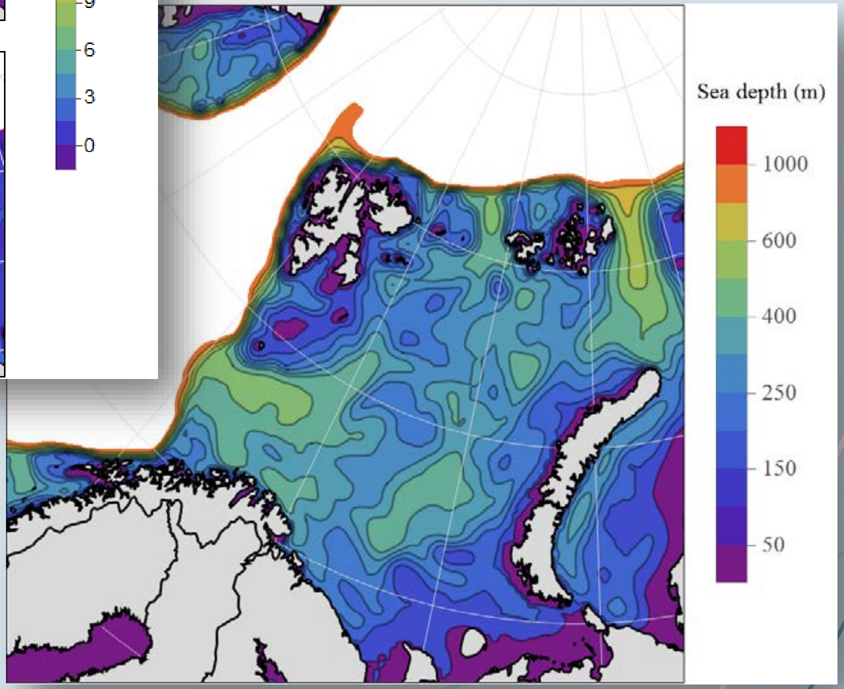


Temperature and ocean depth constrain the cod distribution

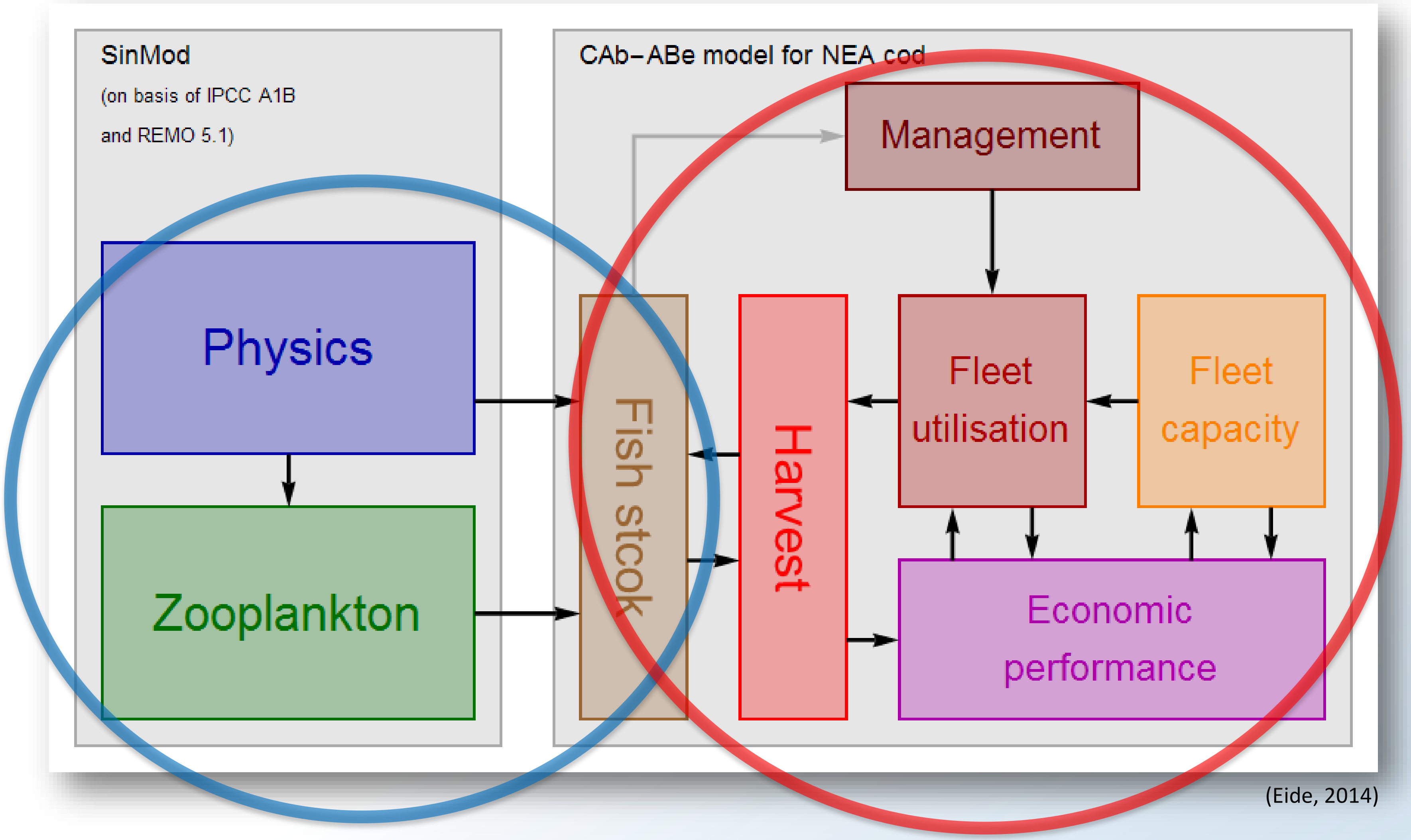


Ocean temperatures in 2012 and 2057

Bathymetric map of the Barents Sea



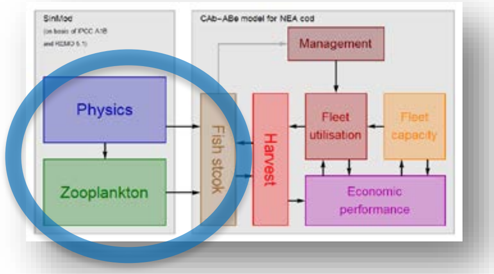
Flow chart – CAb-ABe model



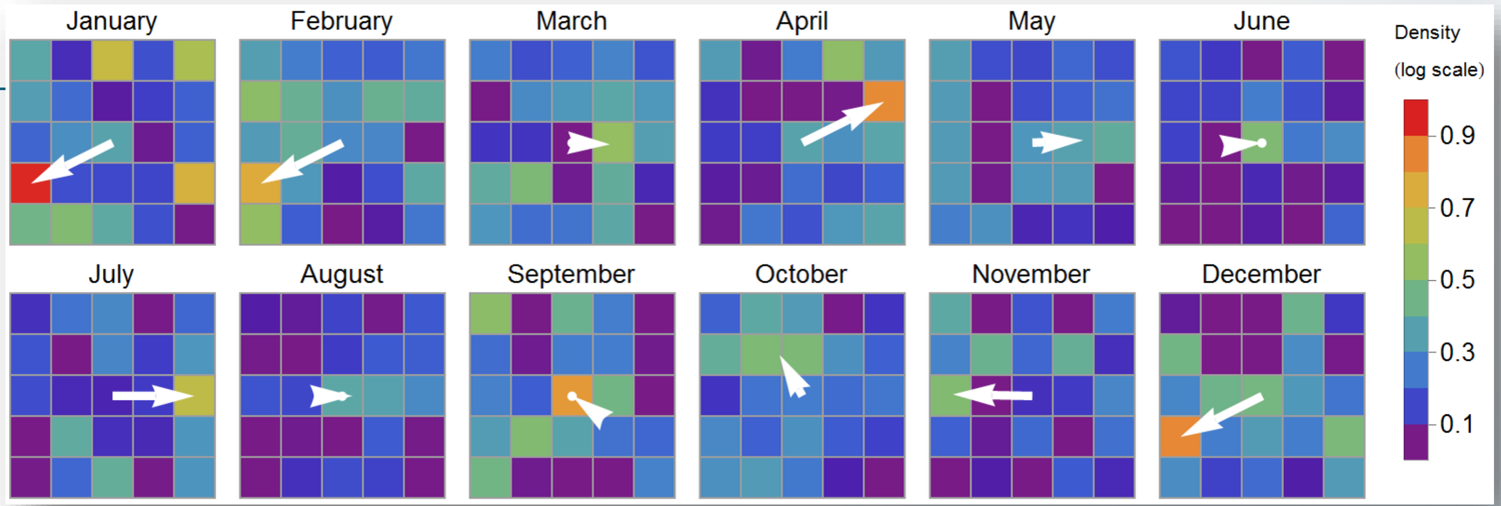
(Eide, 2014)

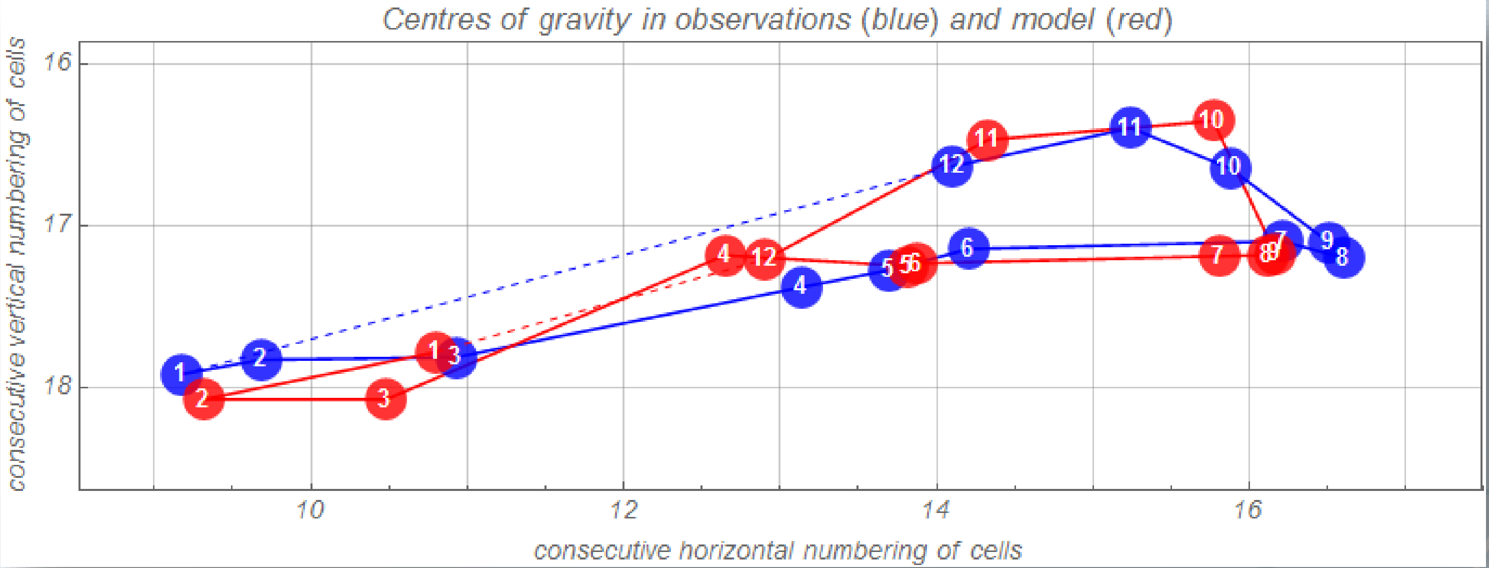
- The **SinMod model** has no feedback from the CAb-ABe model
- The **CAb-module** is the biological cellular automata model
- The **ABe-module** is the agent based fleet performance model

CA model

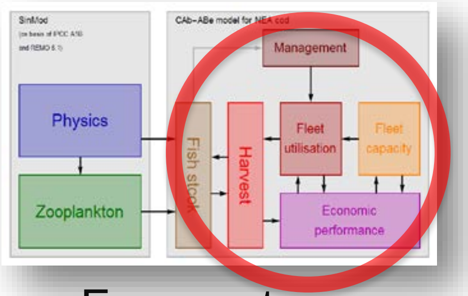


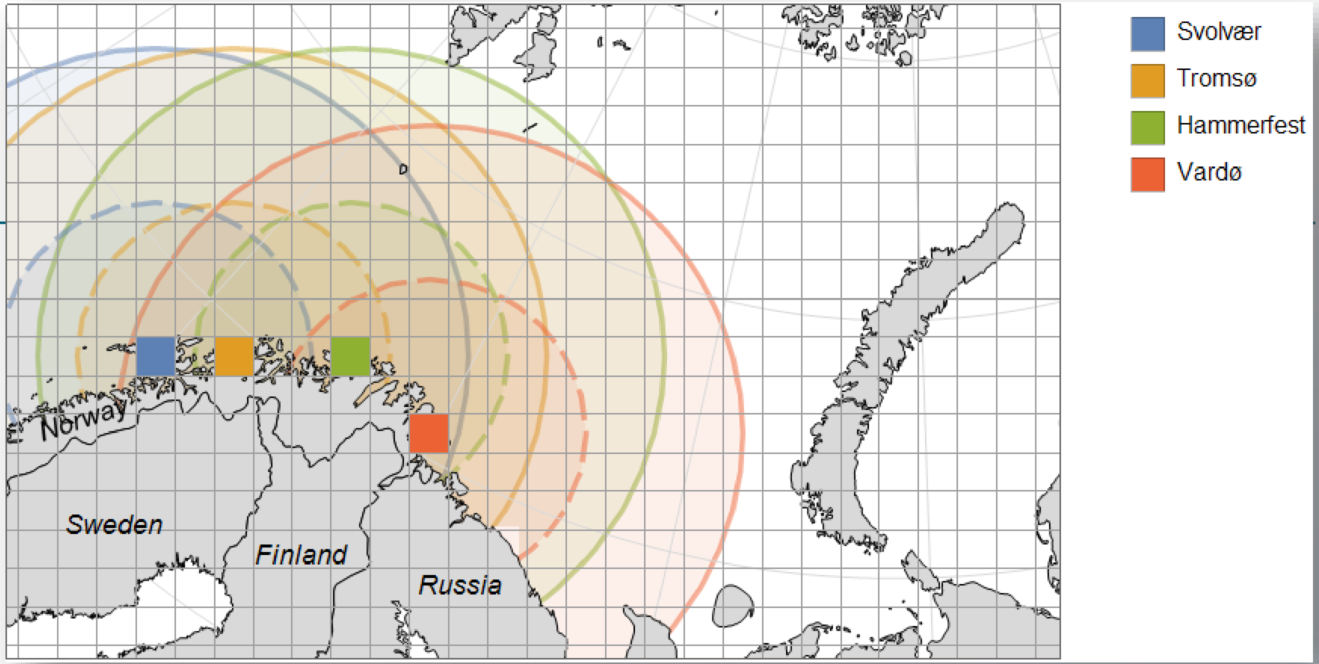
- Rules based on observed centres of gravity 2004 – 2009 (blue disks below)
- Rules (above) obtained by minimising sum of squares between observed and estimated (red disks below) centres of gravity





Fleet model (ABe)



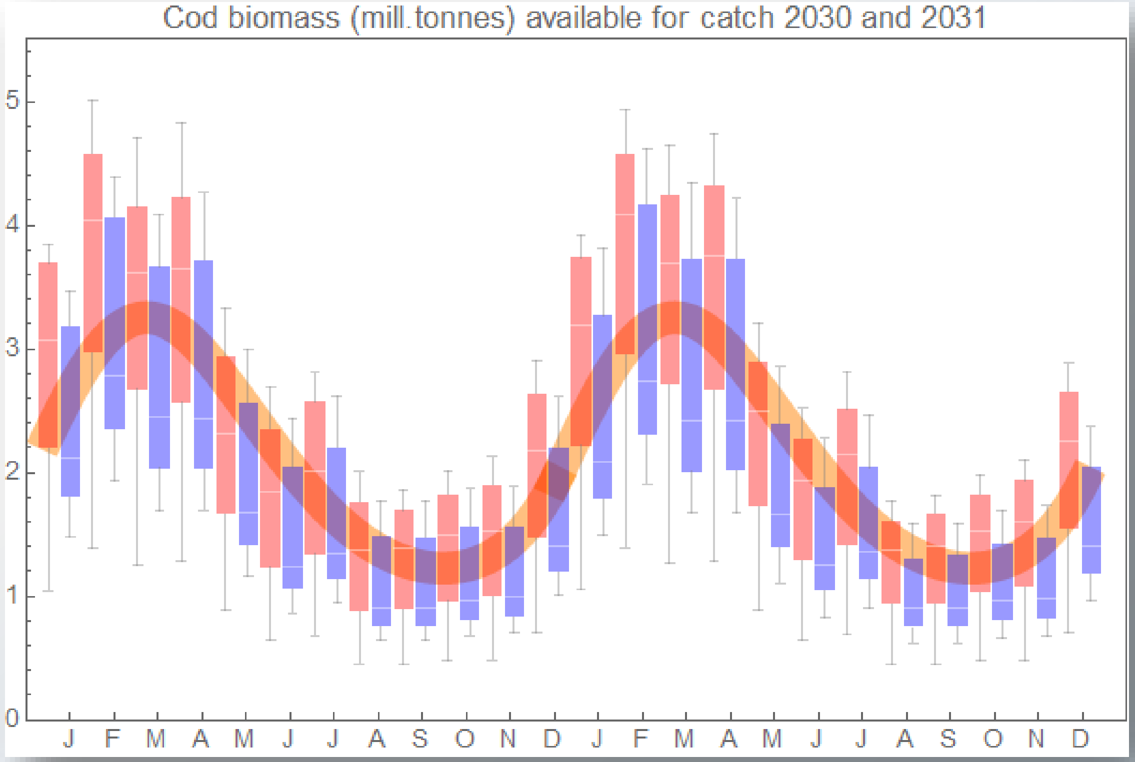


- Four ports
- Two vessels groups:

  coastal and high sea fishing vessels
- Profit maximising behaviour under varying fishing aptitude (summed up in the smartness parameter: s)
- Fleet utilisation depends on management constraints and contribution margins
- Fishing effort in cell j at time t is $e_{j,t} = \frac{\left(\frac{re_{j,t}}{vc_{j,t}}\right)^s}{\sum_{i=1}^{n}\left(\frac{re_{i,t}}{vc_{i,t}}\right)^s} E_t$ (re: revenue, vc: variable cost, E: total effort)

Within-year fluctuations in the NEA cod fishery

- The fleets adapt to seasonal variability
- The difference between peak season and low season in the cod fishery is amplified by increased distance to fishing grounds in low the season

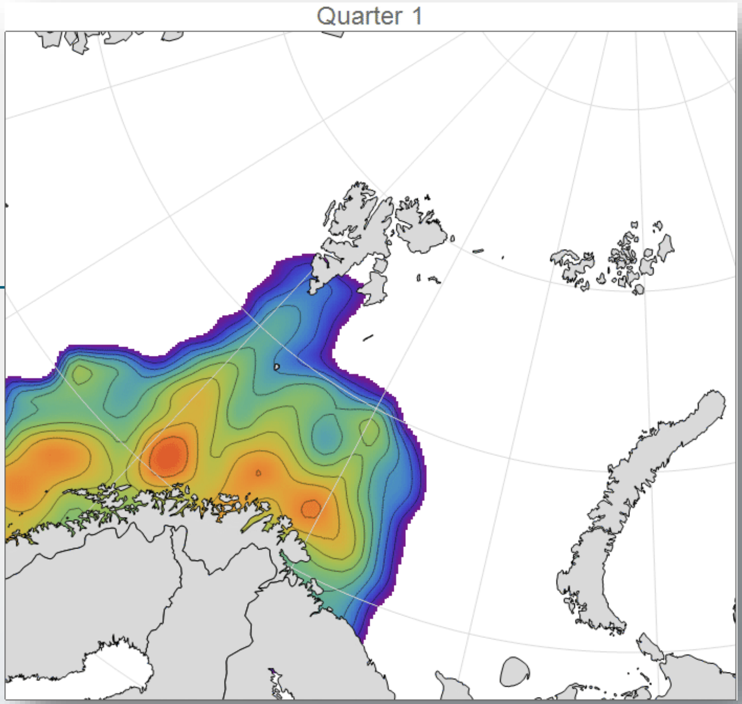


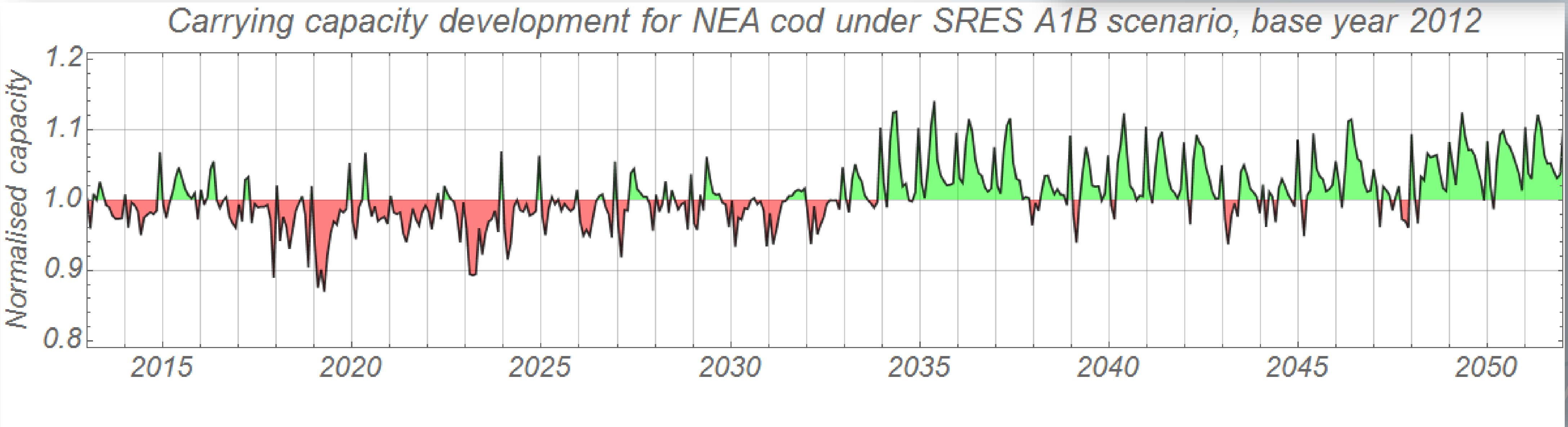
- **Thick orange curve**: Estimated catchability profile in the cod fishery (Eide et al., 2003)
- **Box-Whisker plot**: Results from CAb-ABb-simulations; Blue: current climate; Red: A1B climate

Environmental carrying capacity

Right: Combined distribution maps from catches and survey data 2004-2010

Below: Anomalies of environmental carrying capacity of cod, estimated on basis of temperature, depth and zooplankton constraints.

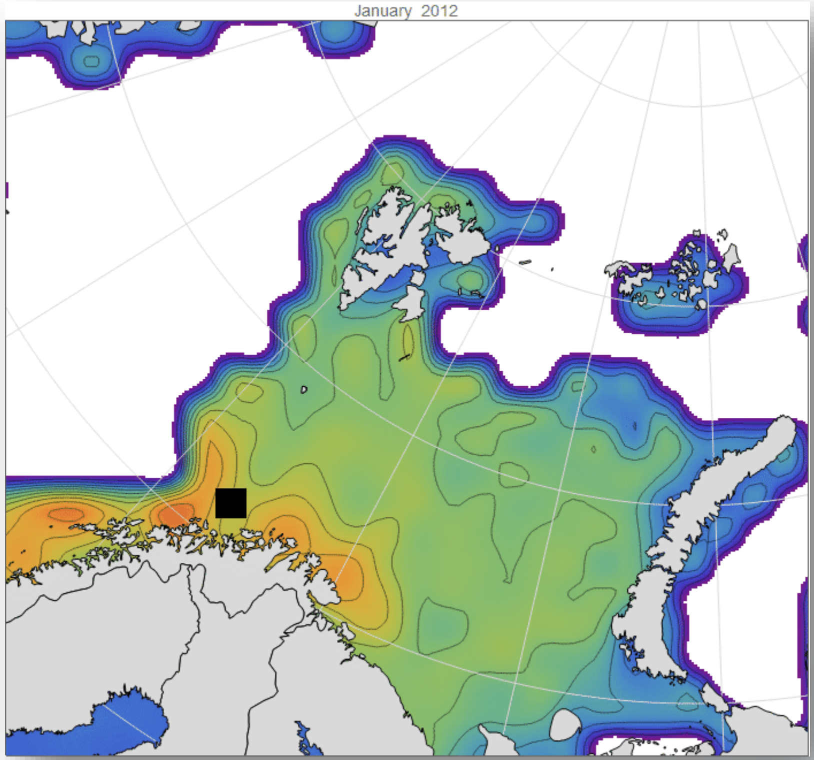




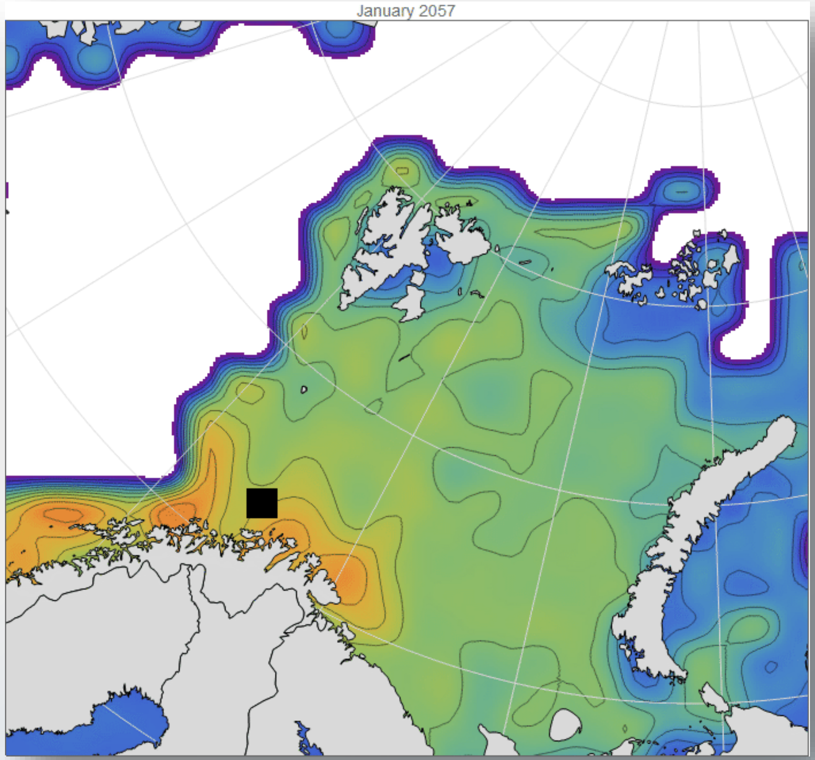
(Eide, 2014)

Environmental carrying capacity distribution

2012



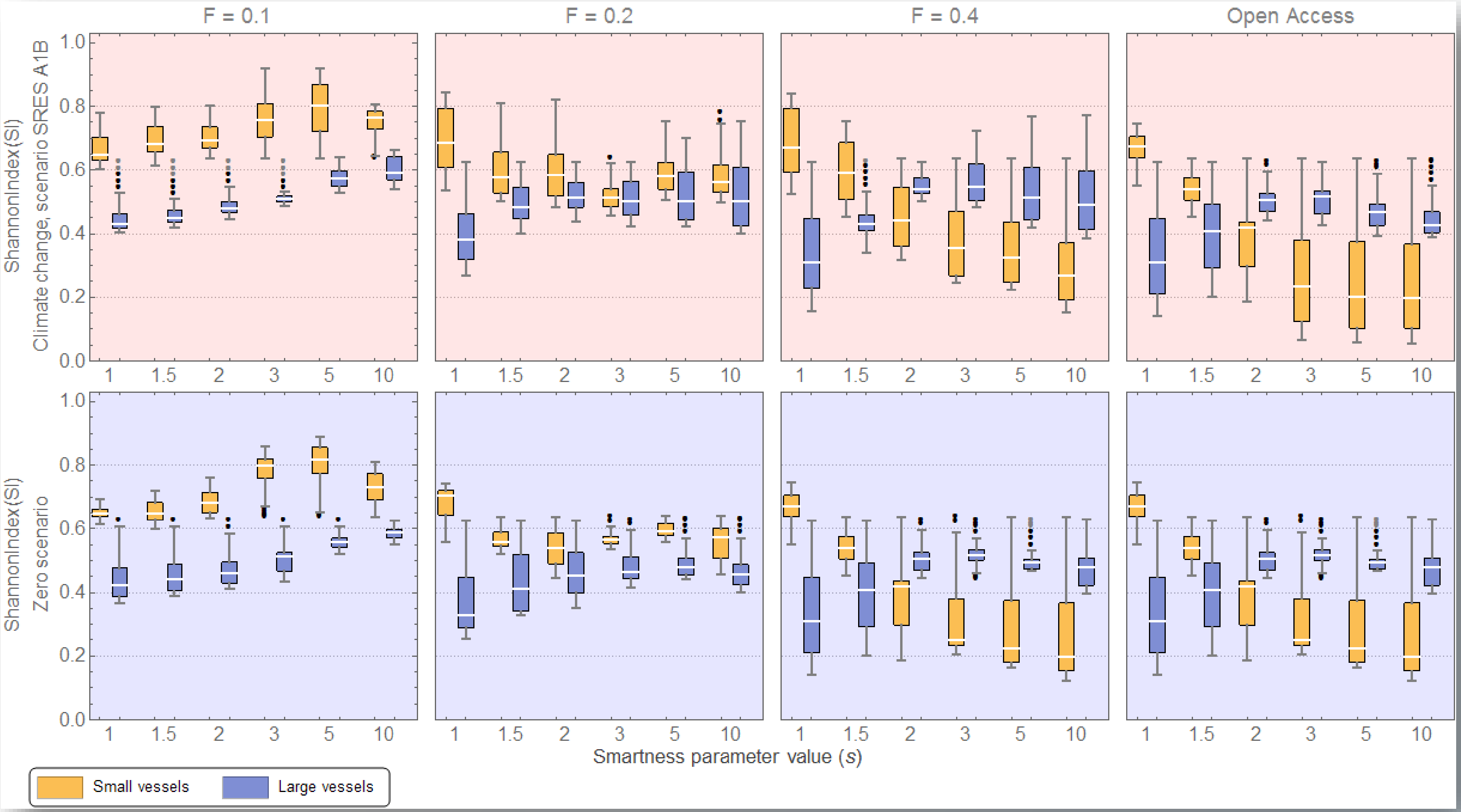
2057



Black squares: Biomass centres of gravity

- The deep-sea area to the left prevents further expansion in that direction
- Northeastward (to the right) a slight expansion is seen

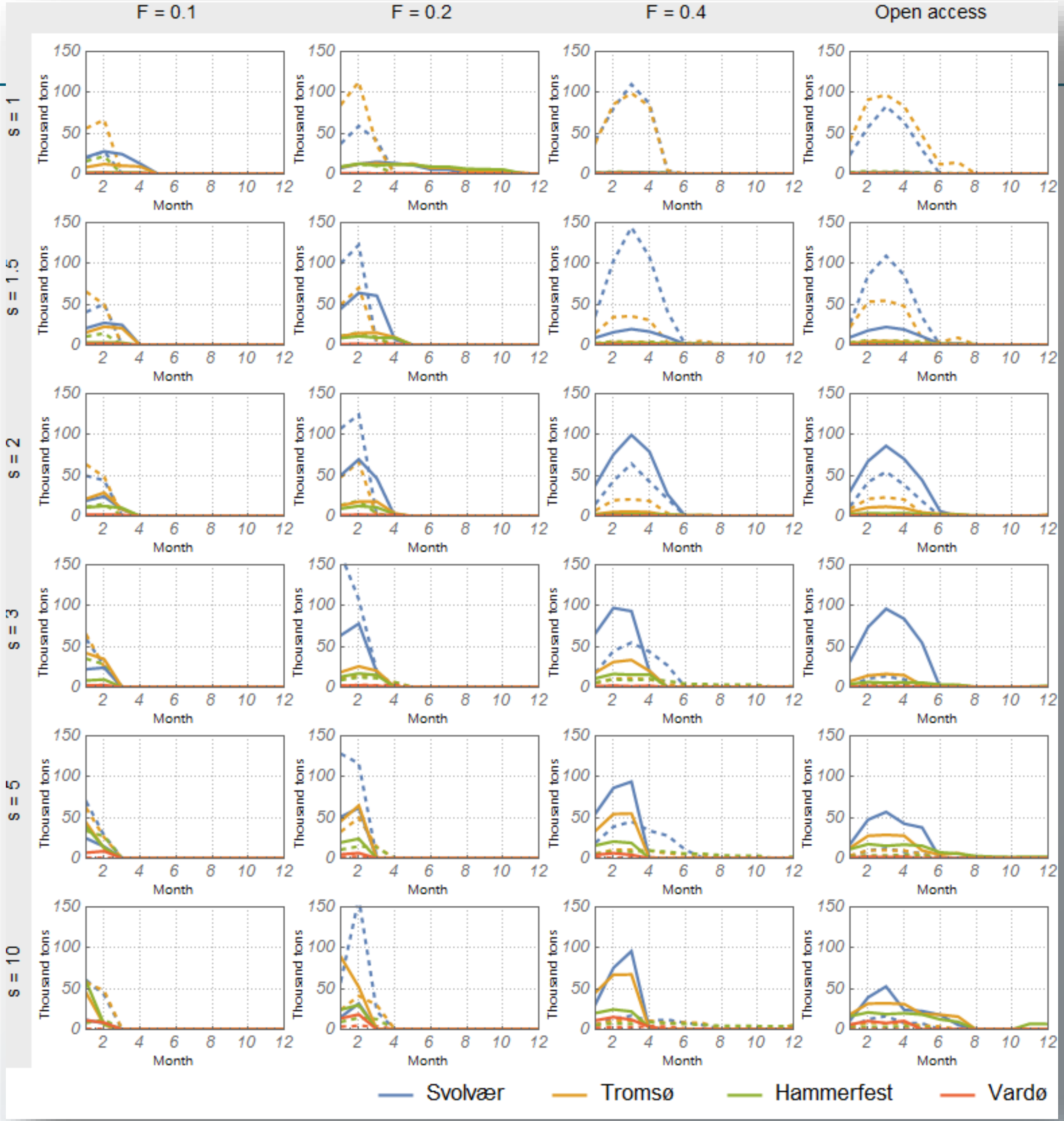
Fleet diversity (all years)

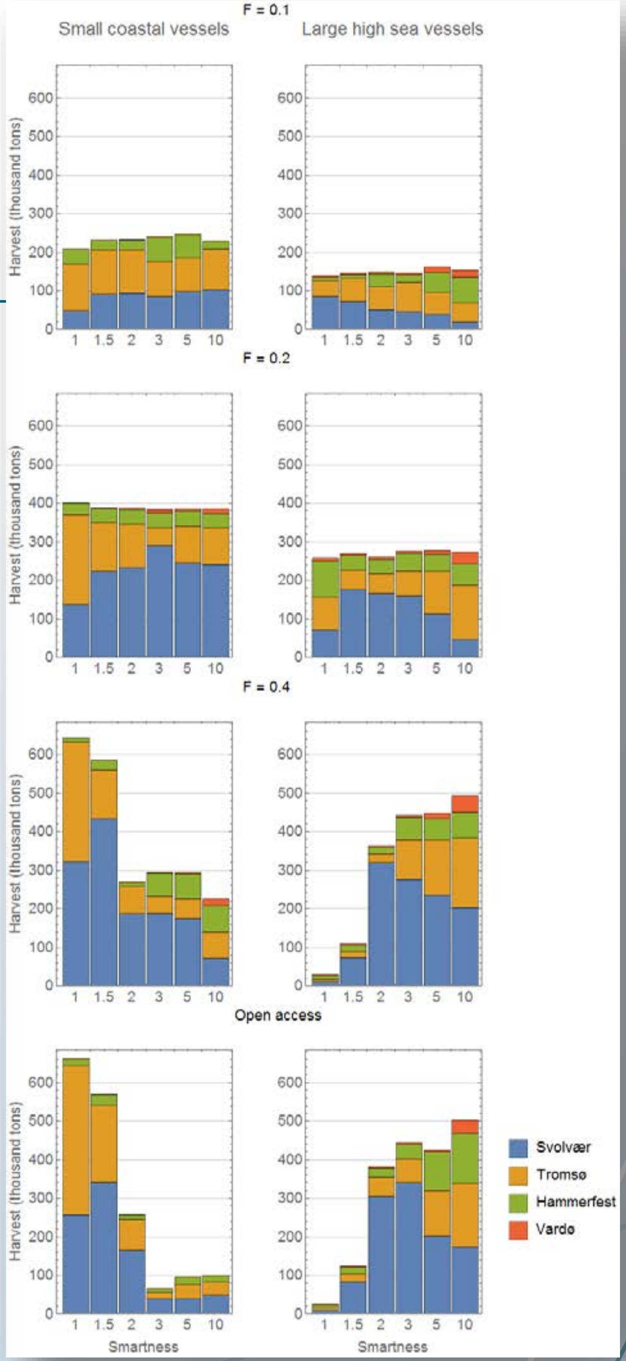


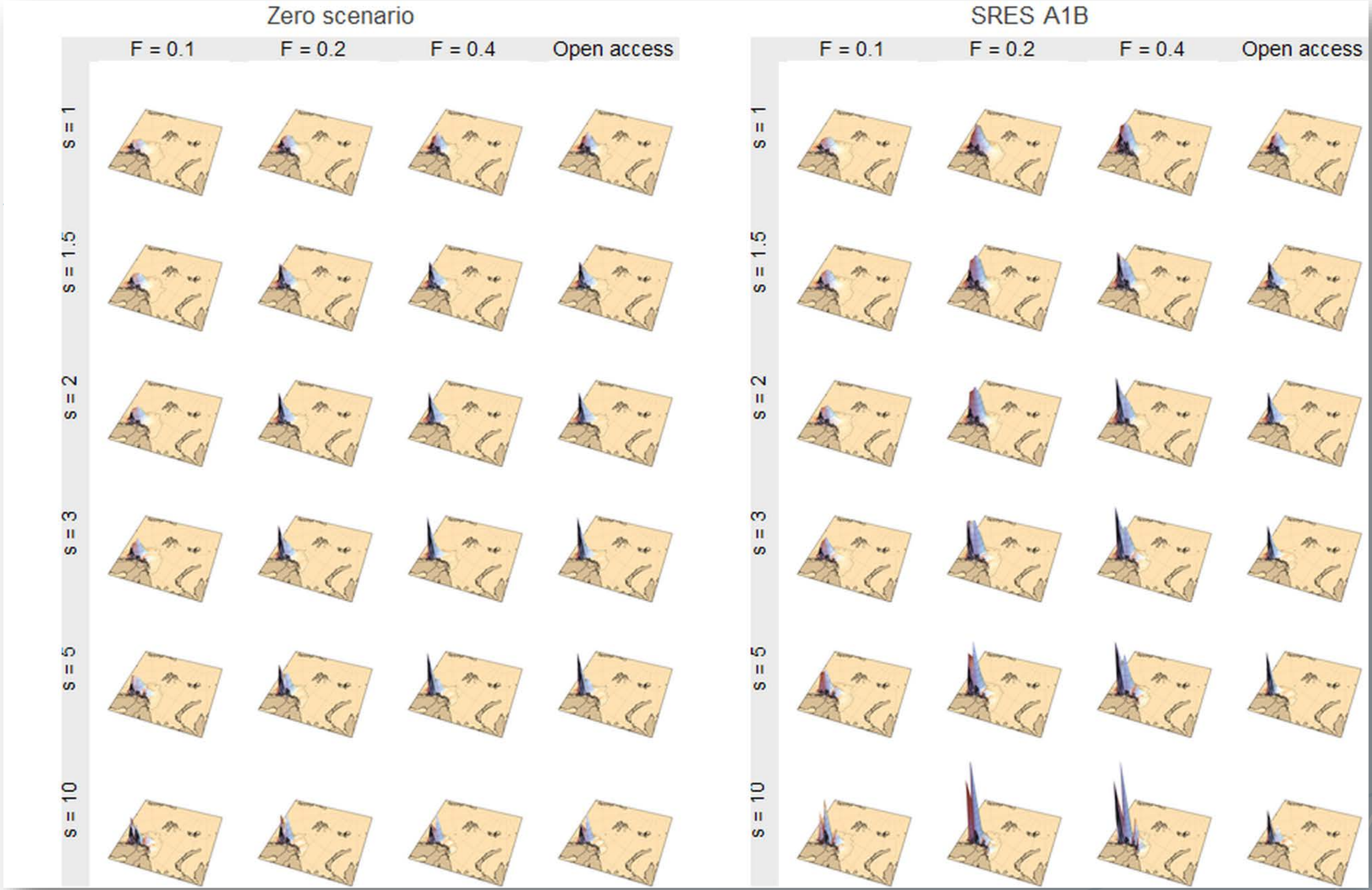
A1B scenario results (last year, 2052)

Catch distributions on

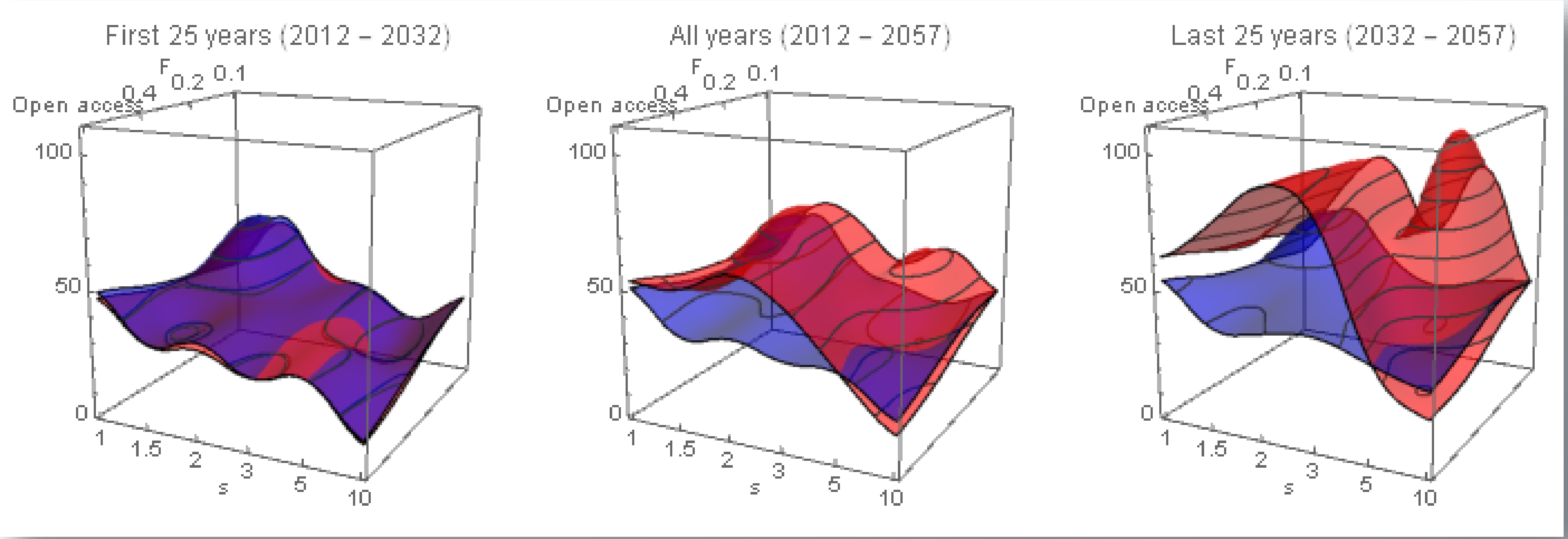
- Seasons
- Ports






Zero scenario
SRES A1B
F = 0.1
F = 0.2
F = 0.4
Open access
F = 0.1
F = 0.2
F = 0.4
Open access
s = 1
s = 1.5
s = 2
s = 3
s = 5
s = 10
s = 1
s = 1.5
s = 2
s = 3
s = 5
s = 10

Relative profits depending on exploitation levels and fishing aptitude

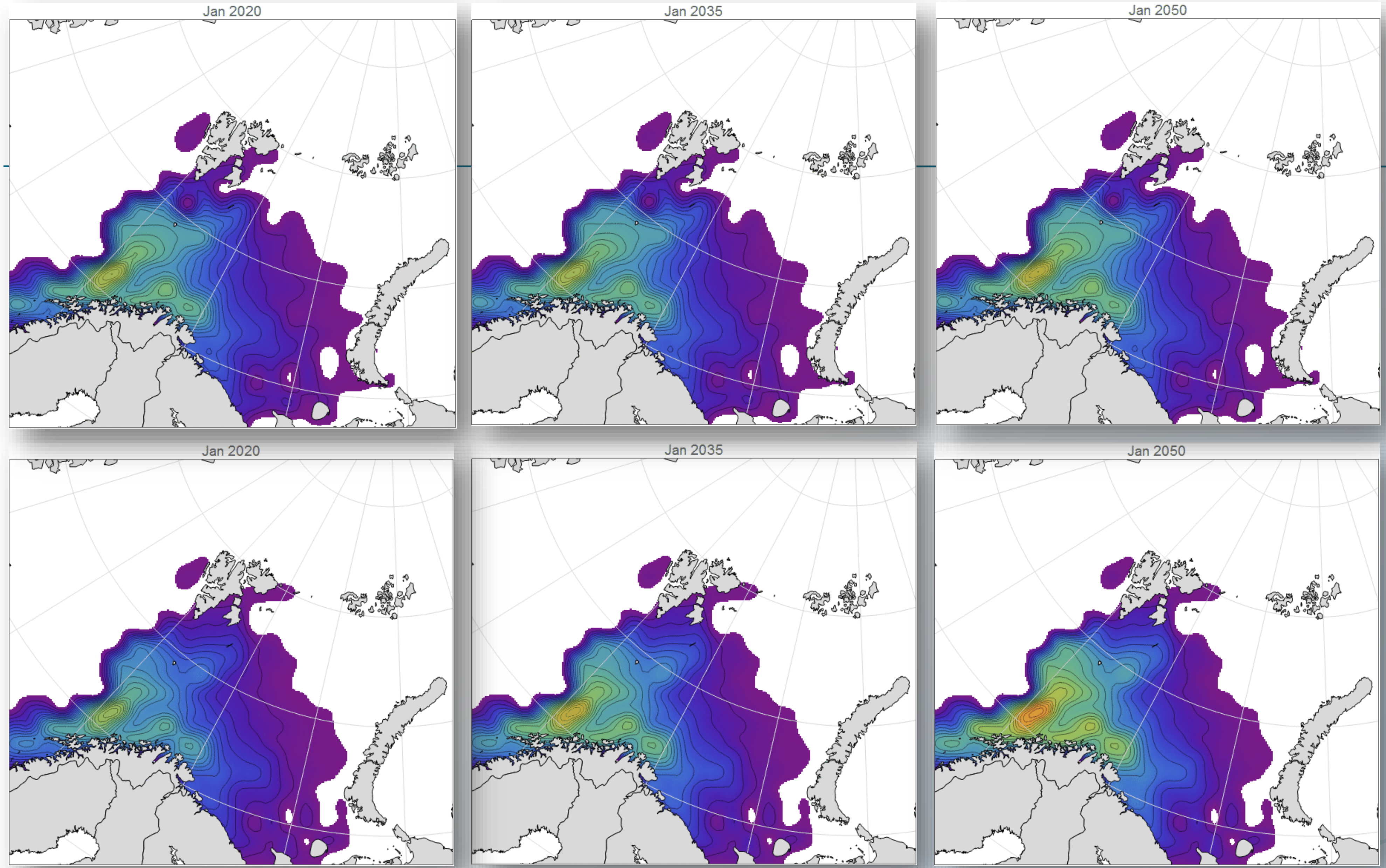


- Blue: Zero scenario (as today)
- Red: Climate scenario (A1B)

Conclusions (some parts are not included in this presentation)

- **Management decisions** has the greatest potential of affecting stock development
- **A diverse fleet structure** reduces the economic vulnerability towards system perturbations
- The effect increasing **fishing aptitude** has on fleet diversity depends on the overall level of resource exploitation
- Changes in current **spatial distribution patterns** may be less pronounced than expected (both the distribution of stock biomasses and fishing activities)

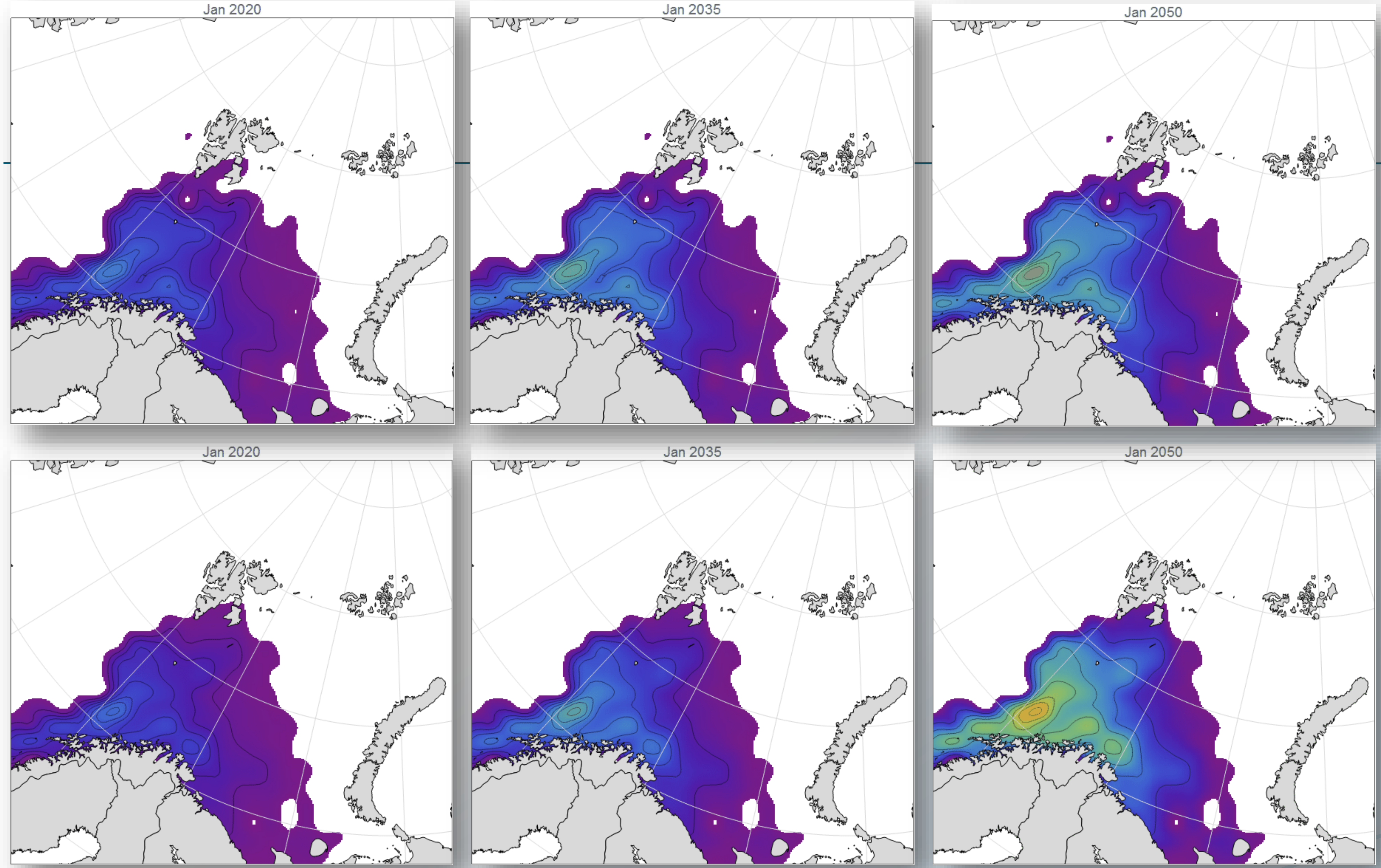
Biomass F = 0.4 smartness = 2



Zero scenario

A1B scenario

Biomass Open access smartness=10

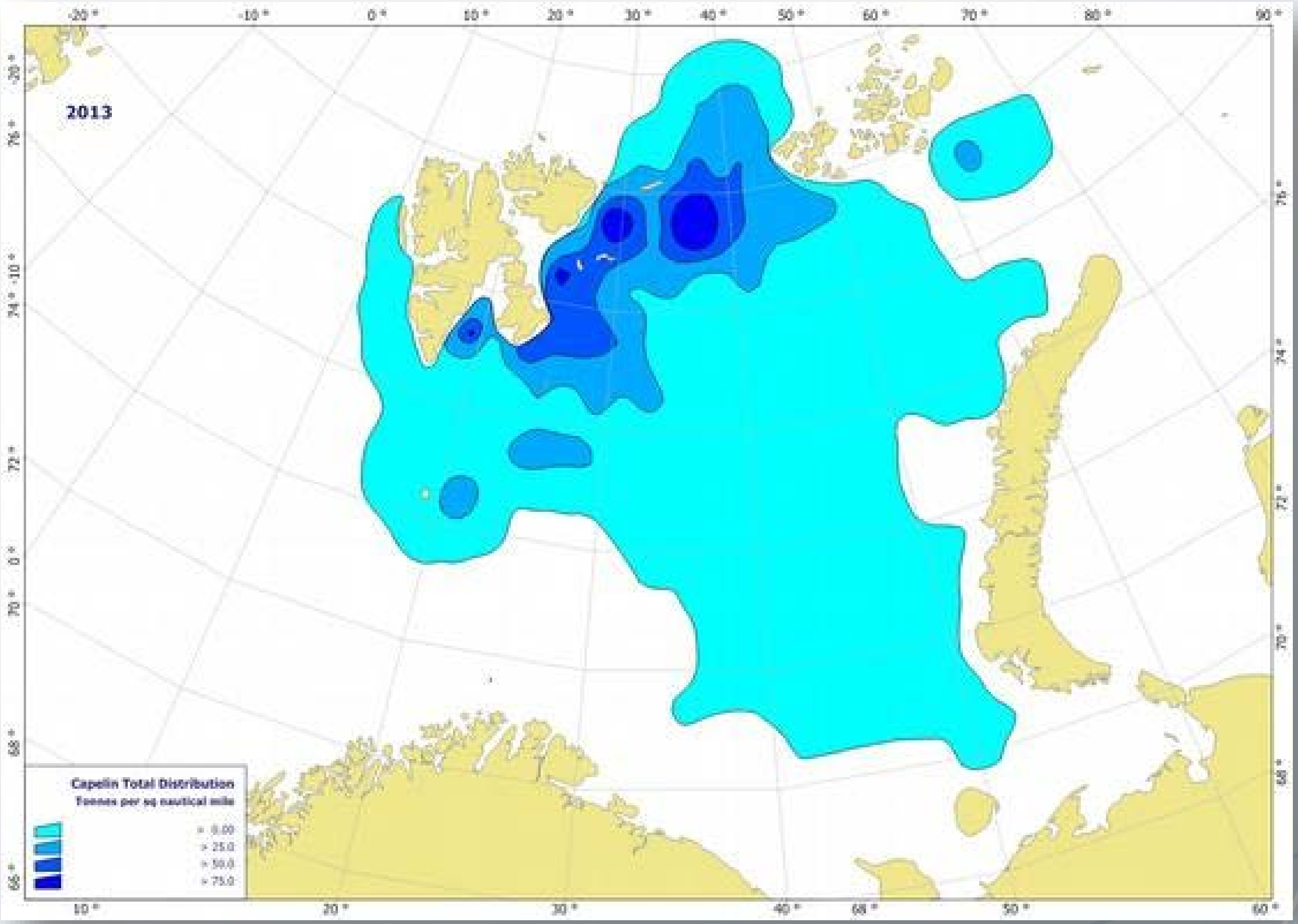


Zero scenario

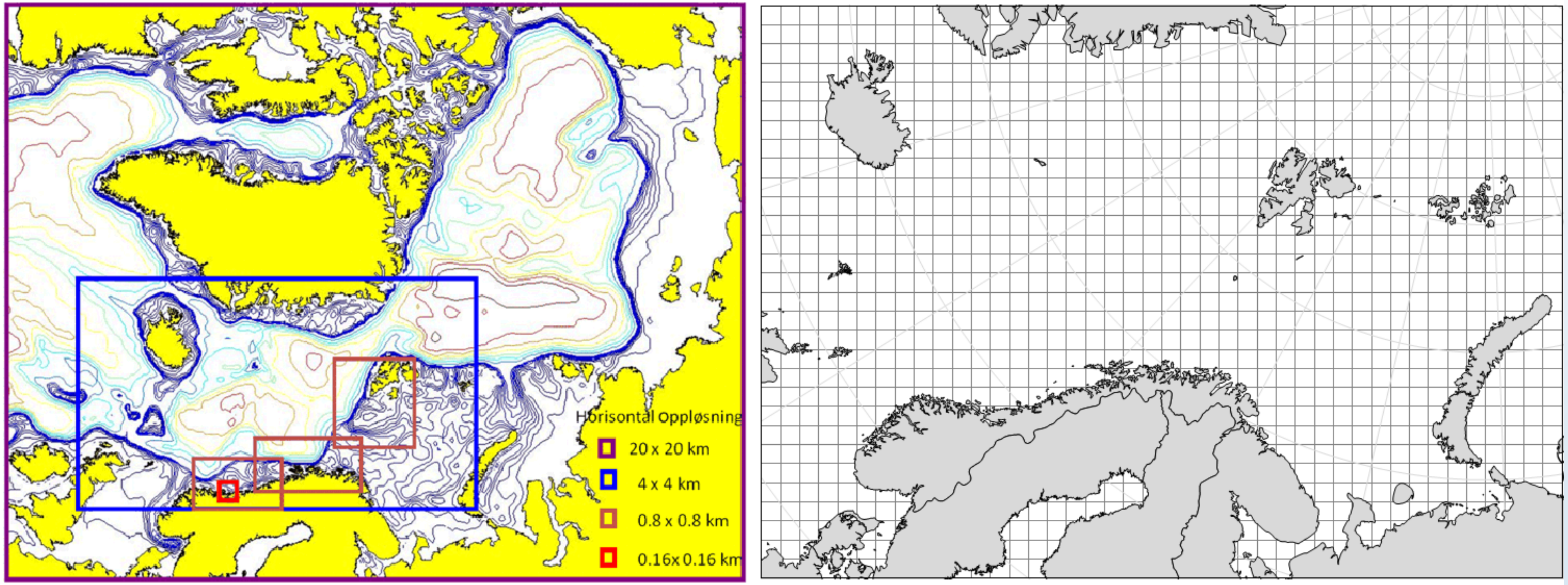
A1B scenario

Barents Sea capelin, distribution area 2013

- Typical western distribution, being an important prey stock for cod (and haddock)
- Also being more vulnerable for herring predation, which is not the case with an eastward distribution
- In the years 2004-2007, capelin were also present west and north of Svalbard. This is outside their usual distribution area (Ingvaldsen and Gjøsæter, 2013)



The Northeast Arctic Cod Fishery



- Available geographical resolutions in the *SinMod* model (left panel) and the 80 km x 80 km grid which is used in the ecosystem model (right panel)

Fleet diversity

- *Horizontal axes*: Diversity index of small scale vessels
- *Vertical axes*: Diversity index of high sea vessels

- *Blue*: Current climate
- *Red*: A1B scenario climate

- *F*: Fishing mortality rate
- *s*: Smartness parameter