Impacts of ocean warming, acidification and fishing on marine food-web dynamics and human user groups in the Barents Sea region

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Int. Symposium on Climate Change Effects on the World Oceans
Washington, June 5th 2018

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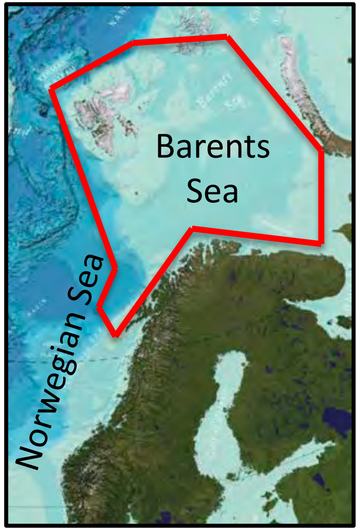
1. Introduction: Climate change in the Barents Sea



GEBCO

Driver scenarios for the Barents Sea

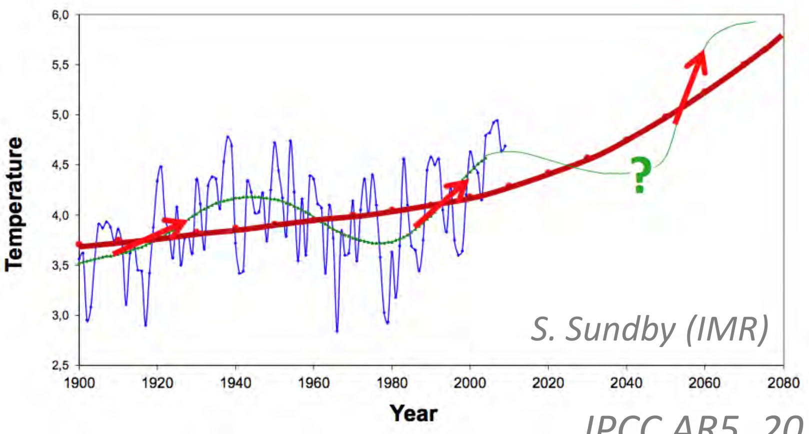
- Among the fastest warming ocean regions, and early ocean acidification (OA) projected

- Environmental driver scenarios:

  warming (OW) Temp. + 3.5°C

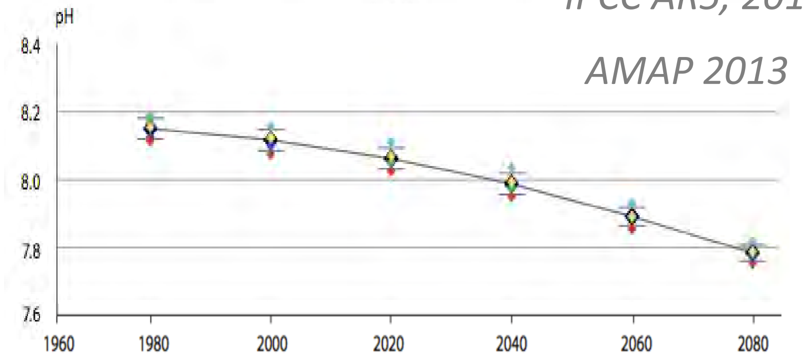
  acidification (OA) pH < 7.8

  until 2100 (RCP 8.5)



IPCC AR5, 2013

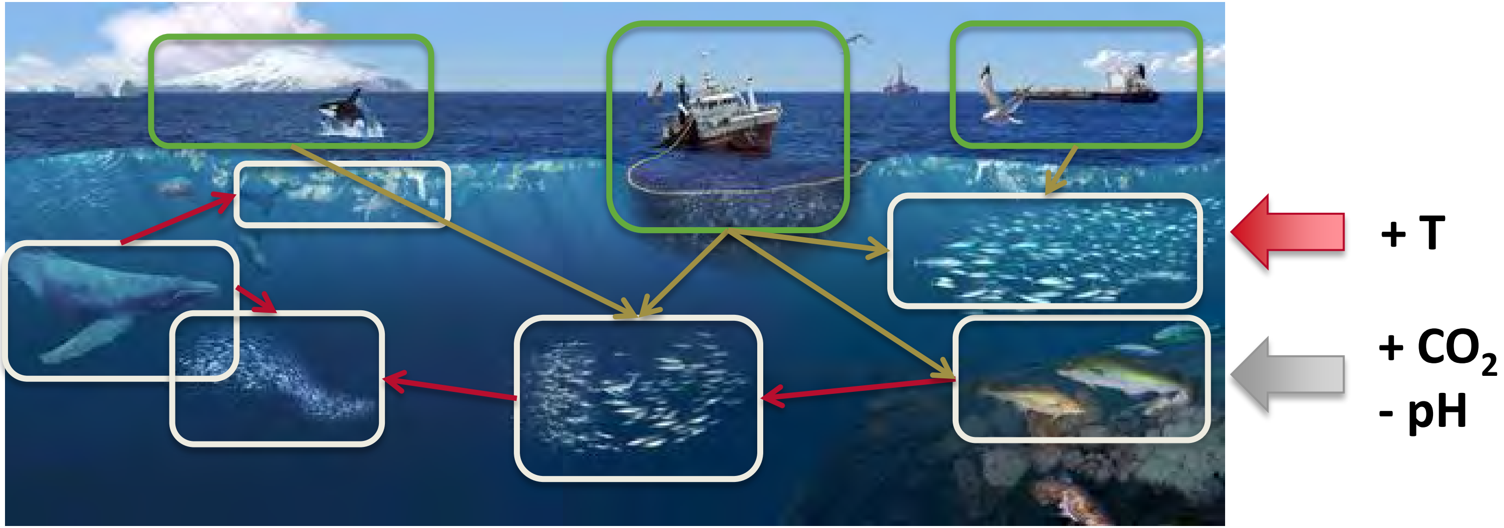
AMAP 2013



Multiple driver effects on marine systems?

- How will combined ocean warming and acidification affect the marine ecosystem?
- How will this interact with anthropogenic drivers and impact human users?

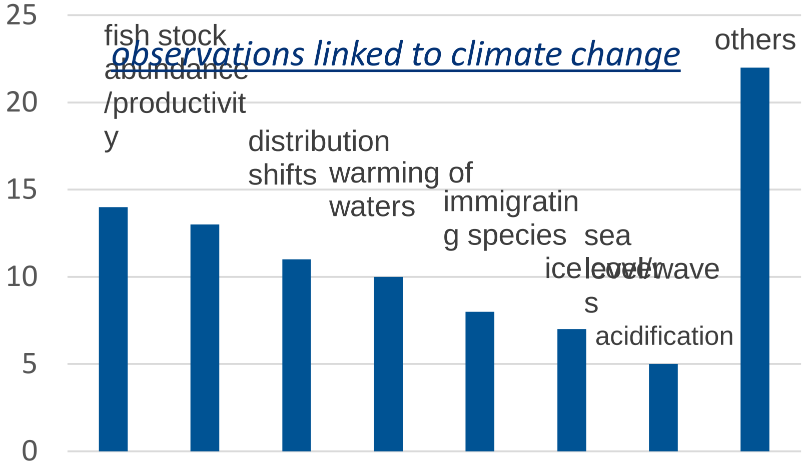
➢ Construct integrative models to link across levels and understand driver interactions
➢ Assess changes in ecosystem services and provide tools for managing trade-offs

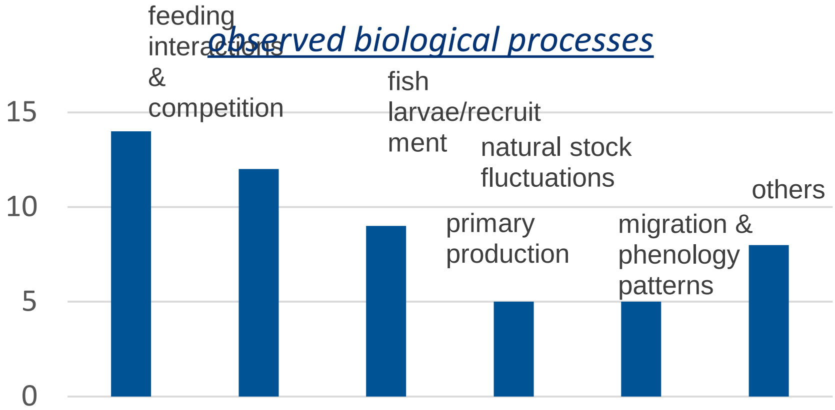


Arild Sæther / IMR

Stakeholder participation

- A wide range of climate change impacts is already perceived
- Natural ecosystem fluctuations and ecological processes are highly relevant for stakeholders





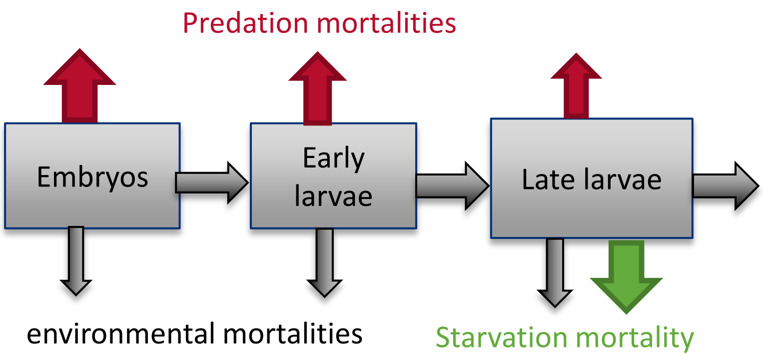
# of interviews with topic mentioned

Koenigstein et al. 2016 FMarS

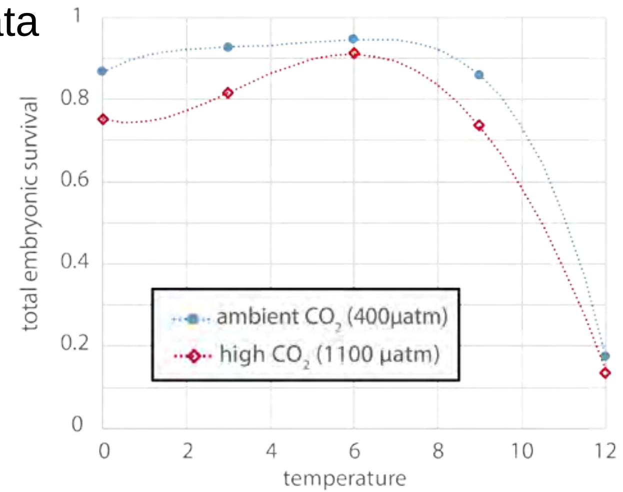
2. How will fish stock recruitment be affected?

Early life stage model for Barents Sea cod

- An early life stage model to integrate temperature and acidification effects on Atlantic cod recruitment
- Experimentally quantified egg and larval survival rates and development times under T/pCO_2 combinations [Stiasny et al. 2016, Dahlke et al. 2017]
- Estimating additional field mortalities by fitting to field data



$$M = \left(n + e_T + a_{T,C} + p * P + \frac{S}{F}\right) * \ dt$$

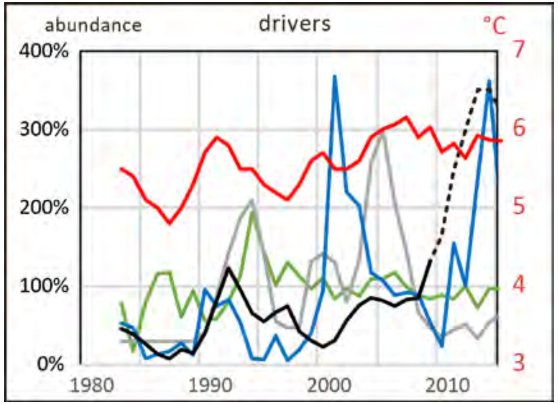


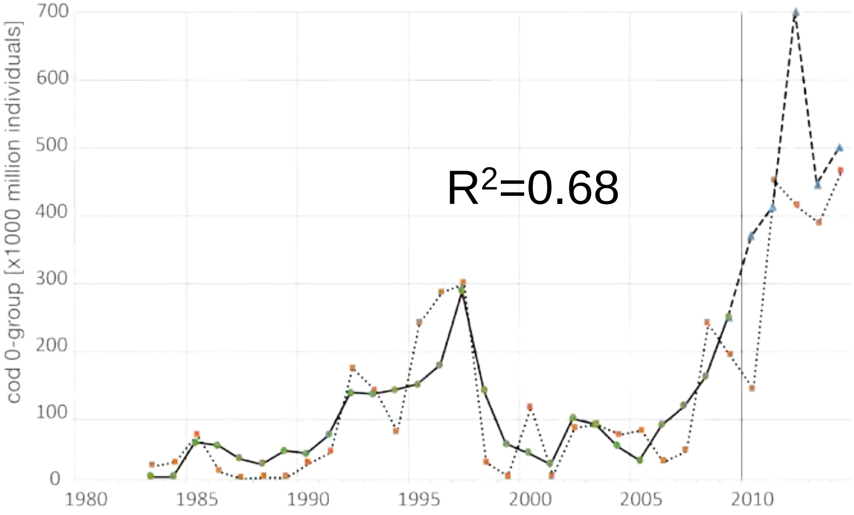
➢ *Koenigstein et al., GCB 2018*

Early life stage model for Barents Sea cod

- Calibration to cod age-0 recruitment and driver time series (temperature, mesozooplankton, herring…) *[Bogstad et al. 2015; ICES 2016; Eriksen et al. 2016]*

➢ Reproduces historical fluctuations in age-0 recruitment and recent increase



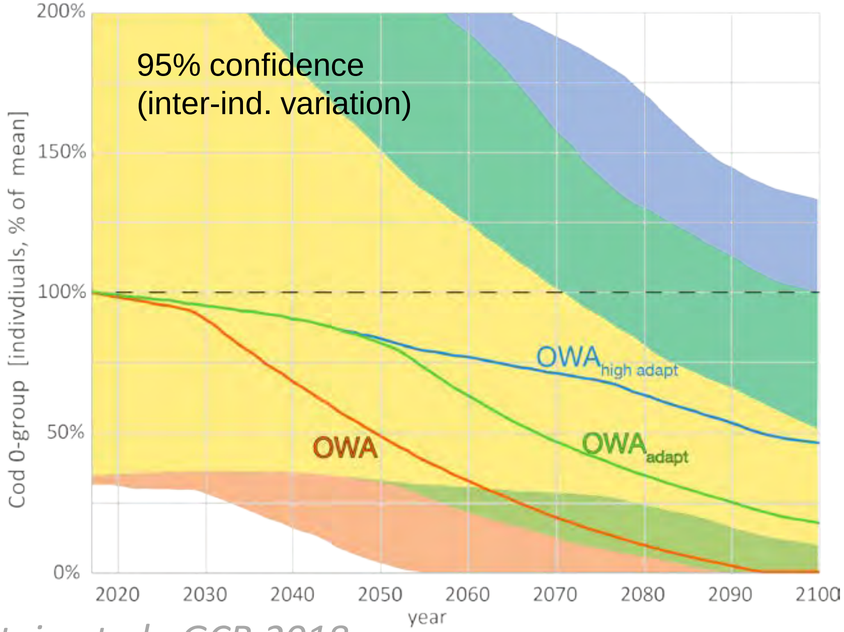


Koenigstein et al., GCB 2018

Future Barents Sea cod 0-group recruitment success

- Additive effect of warming and acidification
- ➢ Recruitment failures possible after 2055

- Adaptation scenarios: 5% and 20% OA mortality compensation/generation
- ➢ High adaptation rate needed to prevent recruitment failures until end of century



- o *Linear increases in T and pCO_2*
- o *Constant food and egg production*

Koenigstein et al., GCB 2018

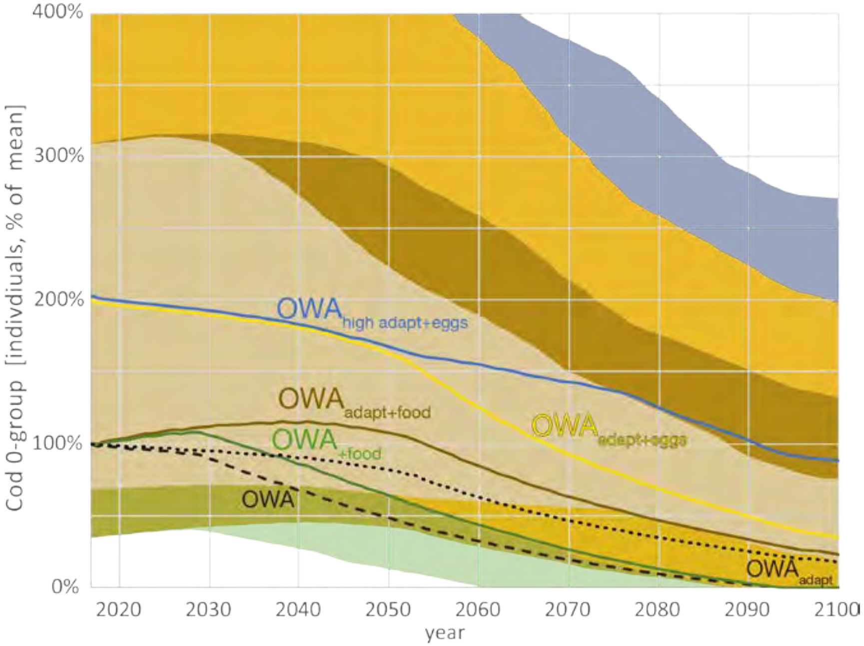
Cod 0-group recruitment success: biotic driver scenarios

- Increasing food abundance only buffers short-term impacts

➢ Increased egg production (spawning stock) has higher long-term potential for compensating impacts

a. *increasing food*

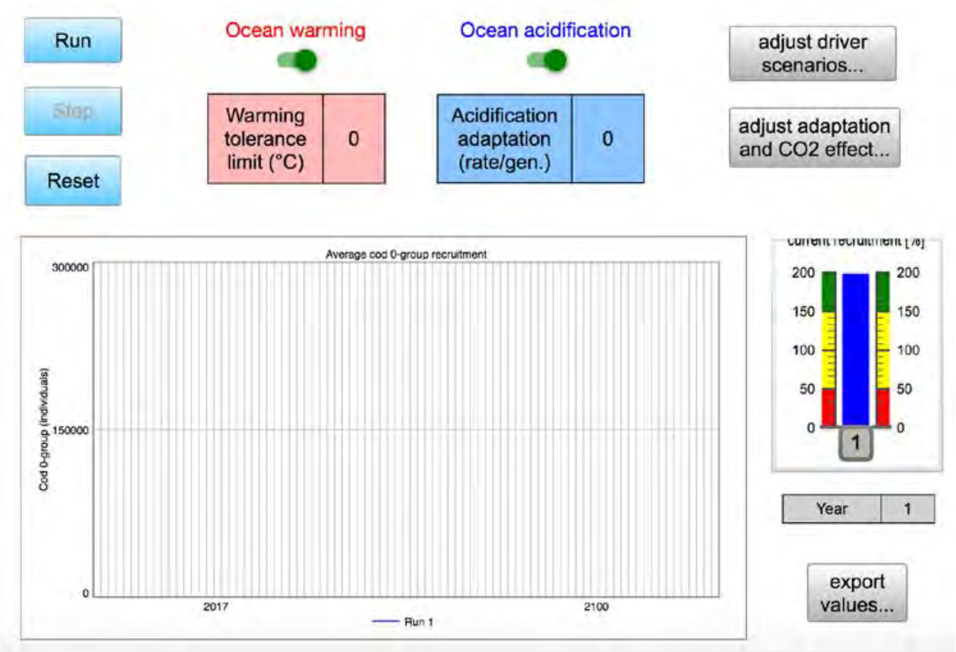
b. *high egg production*



Online model / tool

- Explore different driver scenarios, adaptation rates etc. in online model
- SCREI: *Simulating Cod Recruitment under Environmental Influences*

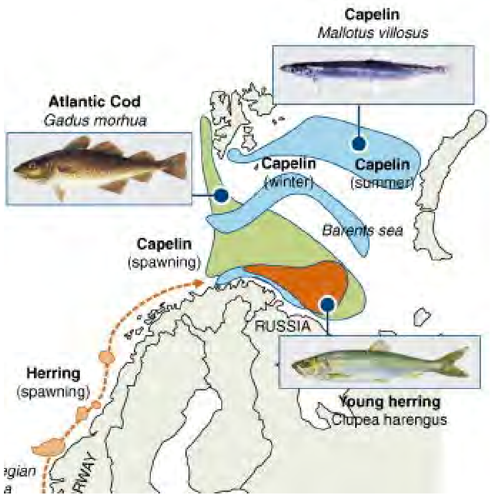
www.oceanchange.uni-bremen.de/SCREI



3. Food-web shifts under combined drivers?

- Fish stocks in the Barents Sea show typical interdependent fluctuations and are heavily fished

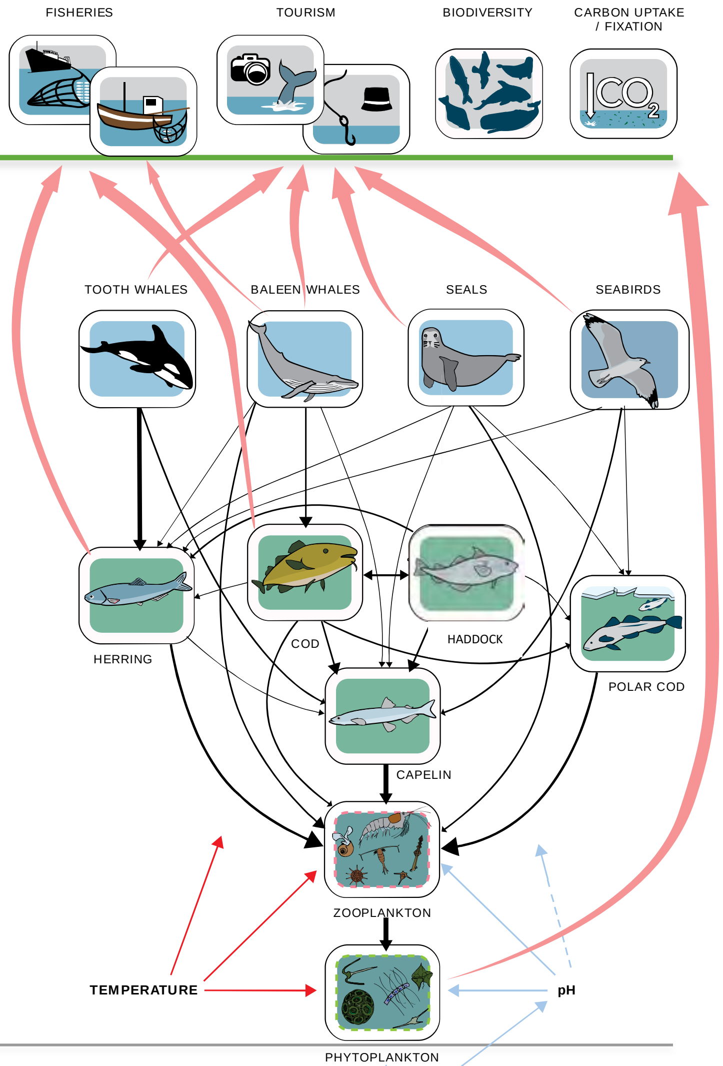
➢ Indirect and combined impacts under climate change?



Cury et al. 2008

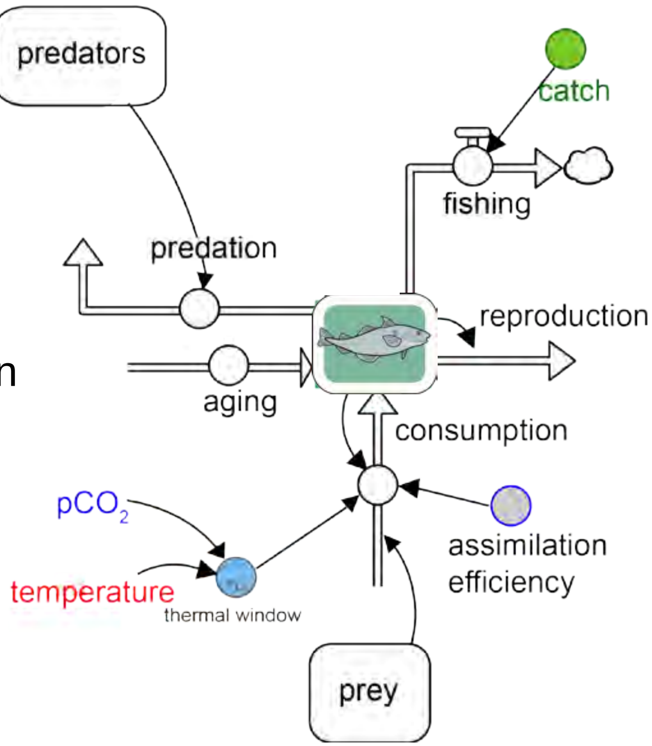
Barents Sea multi-species model

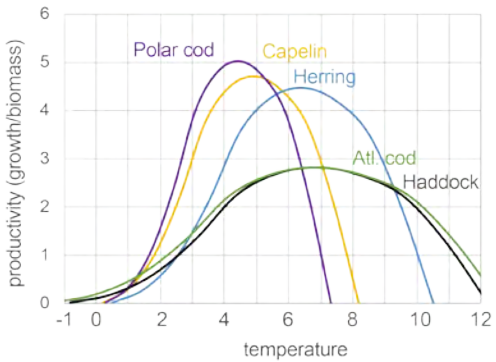
- Most important species and their feeding interactions included
  - o **links** to societal uses (stakeholder input): fisheries, coastal tourism, cultural value

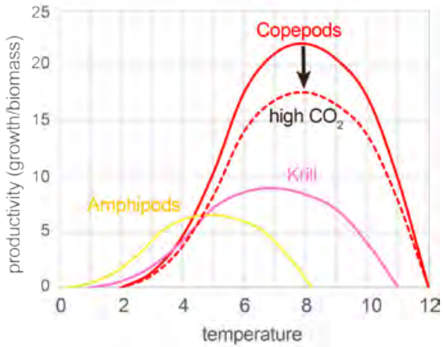


Biological processes / driver integration

- Processes determine stock biomass
- Thermal reaction norms describe temperature dependence of productivity *[Pörtner et al. 2010; 2014]*
- Acidification: metabolic energy loss (→20% at 1100µatm)
  - o compensated (50%–90%) by increased consumption

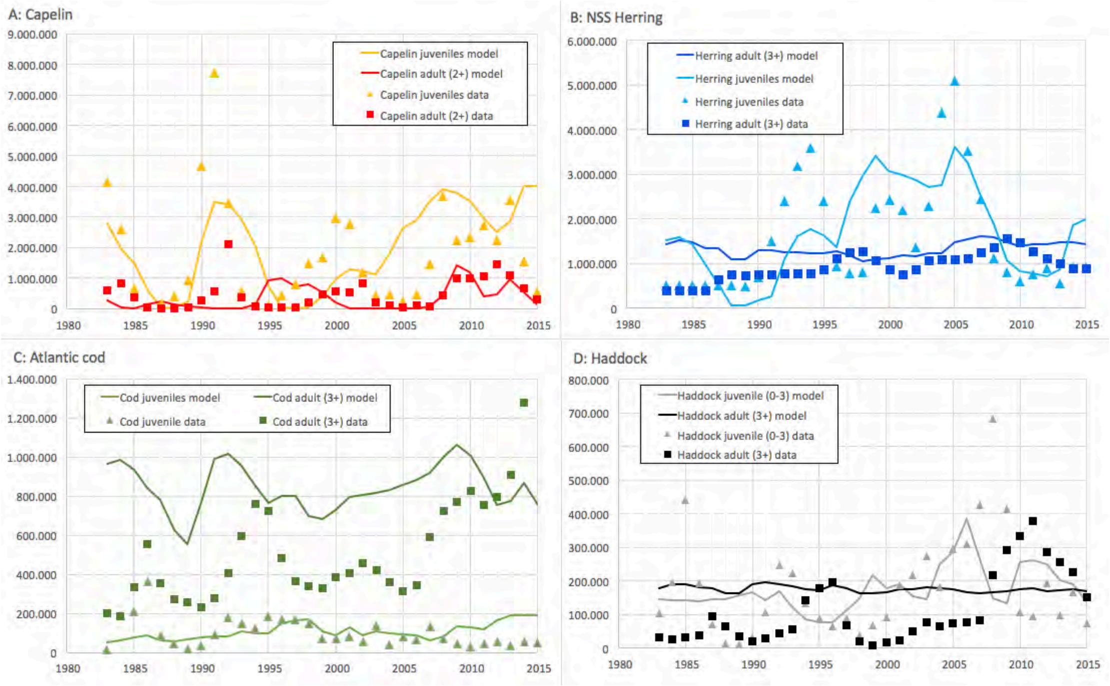






Model calibration

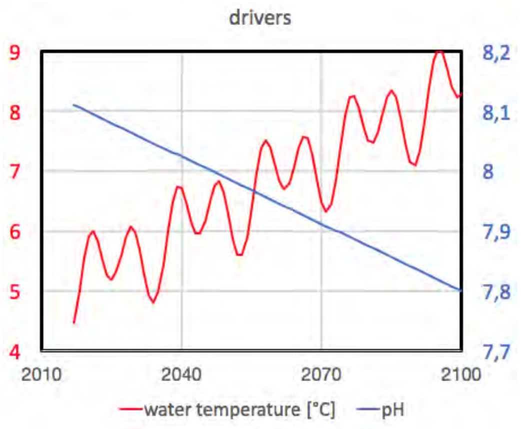
- Preliminary calibration (feeding interactions, nat. mort):
  Population biomass estimates and fluctuation patterns reproduced



Driver scenarios for model projections

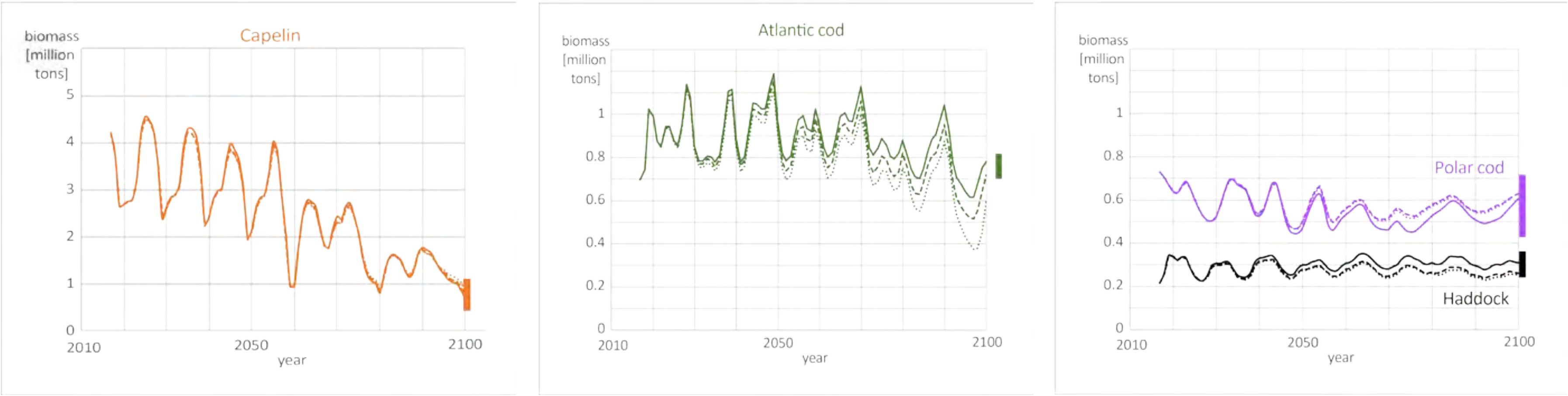
- Warming: continuing fluctuations + linear increase
- Acidification: linear decrease in pH

- Assumed constant (for now):
  - Primary production
  - Recruitment
  - Fisheries management (stock-catch relation)



Impacts of OWA on the foodweb

- Warming: decreases in Capelin (+Atlantic cod, polar cod)
- Acidification impacts depend on trophic position and feeding compensation
  - indirect positive impacts possible (Polar cod)



95% conf.

—— warming only

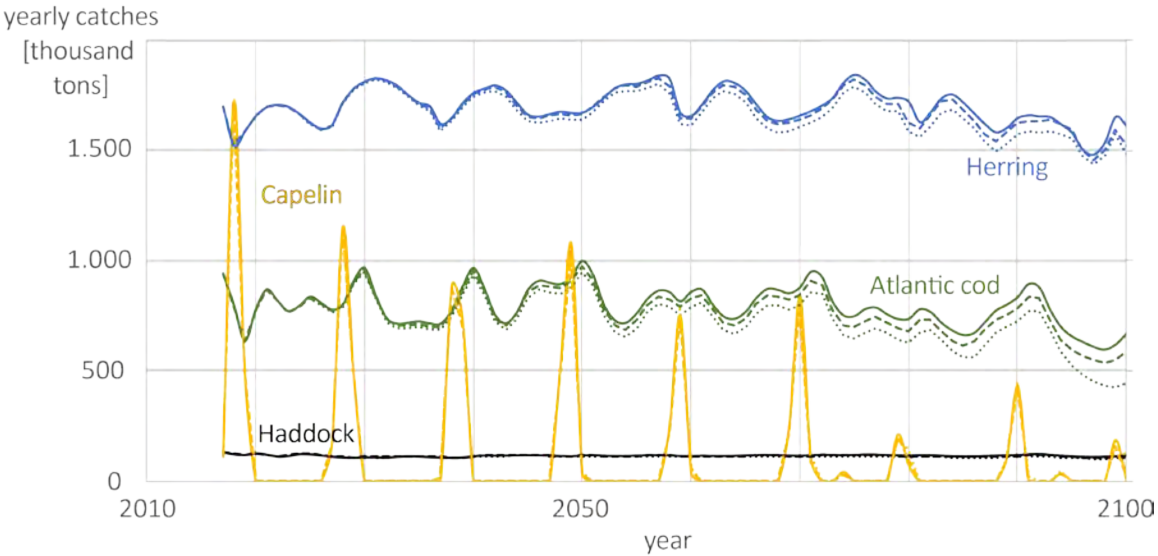
- - - - warming + acidification (**90%** feeding compensation)

.... warming + acidification (**50%** feeding compensation)

Preliminary results!
Koenigstein et al. in prep.

Impacts on fisheries

- Current management regime buffers warming and acidification impacts
- Catch declines in Capelin, (Atlantic cod)



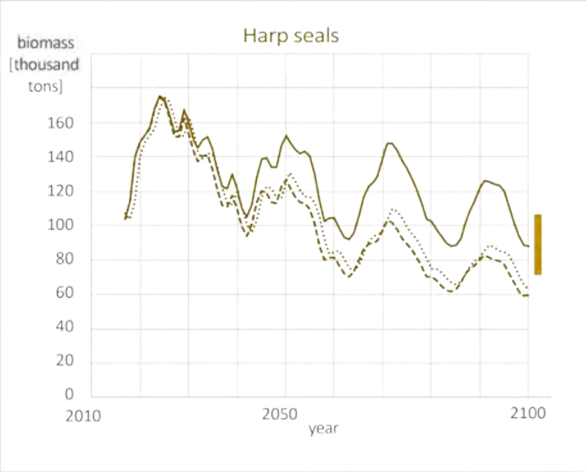
Preliminary results!
Koenigstein et al. in prep.

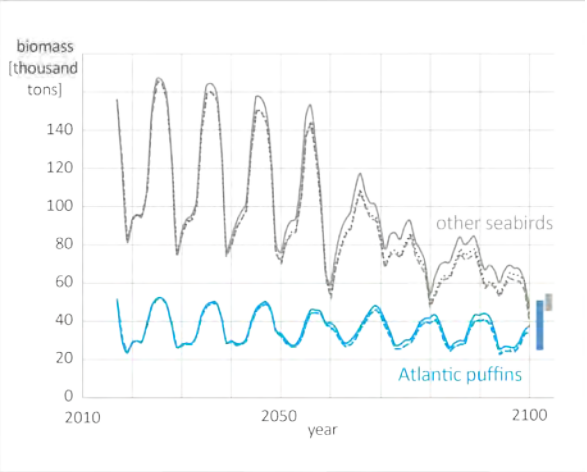
Further impacts: top predators

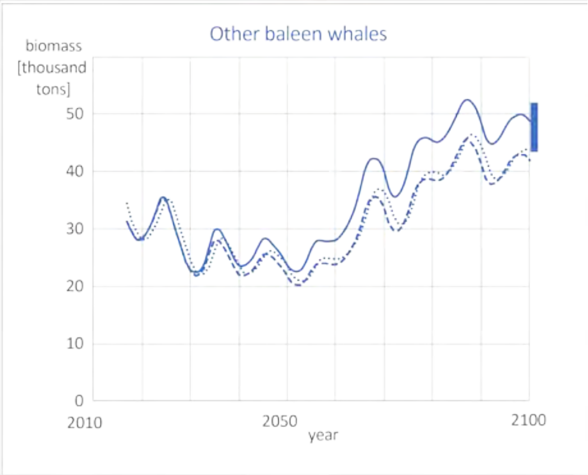
- Indirect impacts on top predators through food availabilty: declines in seals and seabird populations

- Will impact tourism/recreation and cultural services
- ➢ Ecological trade-offs need to be considered in management

Preliminary results







➢ Summary & conclusions

1. **Atlantic cod recruitment:**
   - Reductions in cod recruitment under OW and OA in the 2nd half of the century (RCP 8.5)
     - ➢ should be considered in management of spawning stock
   - Experimental data can explain empirical 0-group recruitment and assess variability
   - Only high adaptation to OA mortality (>20% per gen.) prevents recruitment failures until 2100
     - ➢ More investigation needed on transgenerational adaptation to acidification

2. **Barents Sea food-web** (preliminary results):
   - Thermal windows and food-web interactions can reproduce fluctuations in fish biomasses
   - Combined impacts of warming and acidification (metabolic energy loss) depend on trophic position and feeding compensation: Capelin strongly impacted by OW, cod/harp seals by OA
   - Food-web mediated impacts on top predators cause relevant trade-offs among human uses
     - ➢ need to be better investigated and considered in EBM

➢ Conclusions: Integrative models for ecosystem-based management

- Integrative models with explicit physiological and ecological processes can help to
  - incorporate laboratory and field data and scale up to population and ecosystem responses
  - assess multi-stressor impacts on marine ecosystems, understand food-web behavior under climate change

➢ Models as boundary objects for interdisciplinary integration

➢ Identify ecological trade-offs among human uses, serving as tools for ecosystem-based management

Acknowledgements / Contributors

Experimental research	Flemming Dahlke, Daniela Storch, Felix Mark (AWI Bhv) Martina Stiasny, Catriona Clemmesen (Geomar Kiel)
Expert advice Norway	Bjarte Bogstad, Øyvind Fiksen, (Uni Bergen, IMR)
	Maria Fossheim (UiT), Jon Fuglestad, L.-O. Reiersen (AMAP)
Stakeholder & workshop support	Annette Breckwoldt (ZMT/AWI)
	Jannicke Falk-Andersson (UiT)
	Nicola Beaumont (PML)
	Knut-Yngve Børsheim (IMR Bergen)
Graphic design (icons)	Leonard Rokita

BIOACID Biological Impacts of Ocean ACIDification

Bundesministerium für Bildung und Forschung

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