# Model-based integration of experimental results and human uses to identify management options for marine ecosystems under climate change

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*supported by*

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Biological Impacts of Ocean ACIDification

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Integrative Ecophysiology

# overview

*introduction:*

1. **marine systems under climate change**

*who cares?*

2. **stakeholder participation**

*what may happen?*

3. **experimental research**

*how to make sense of it all?*

4. **an integrative model**

*what have we learned so far?*

5. **summary and (preliminary) conclusions**

*introduction:*

# 1. marine systems under climate change

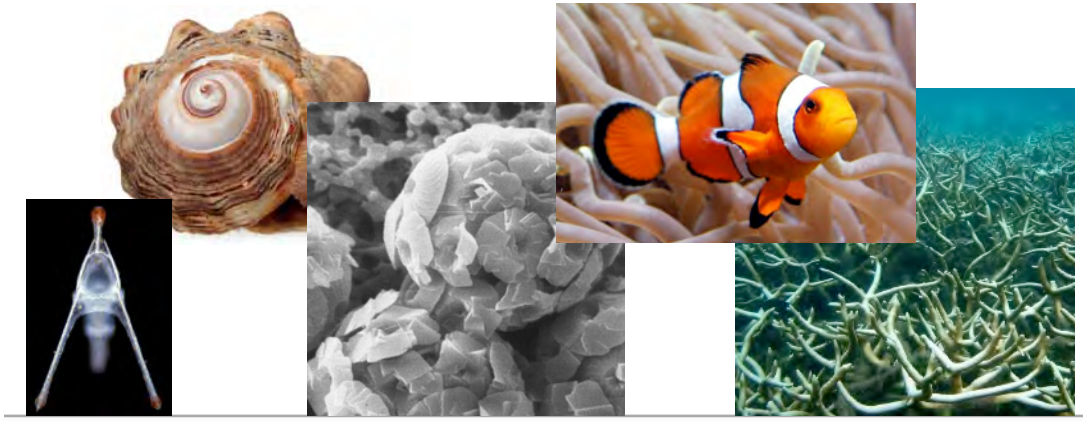
# ocean acidification research

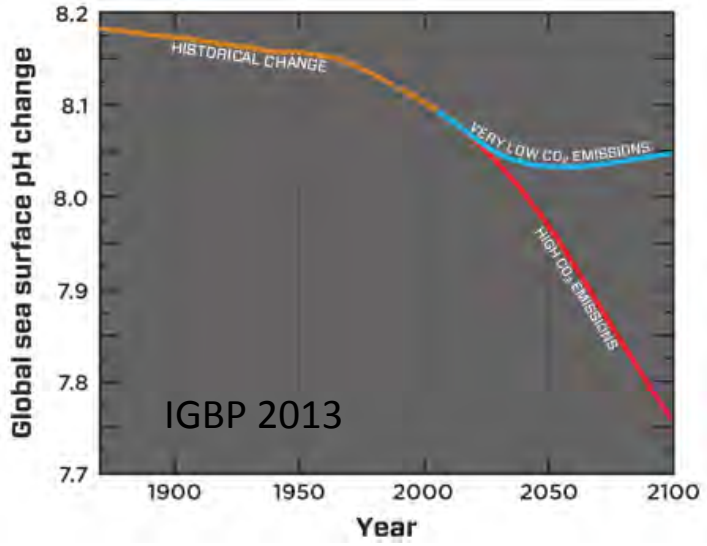


more $CO_2$ dissolves into the oceans…

- problems for calcifying organisms
- stressful for early life stages
- changing behaviour in some fish
- primary production and zooplankton?


- **combination with other stressors?**
- **individual & population adaptation?**
- **ecosystem effects??**





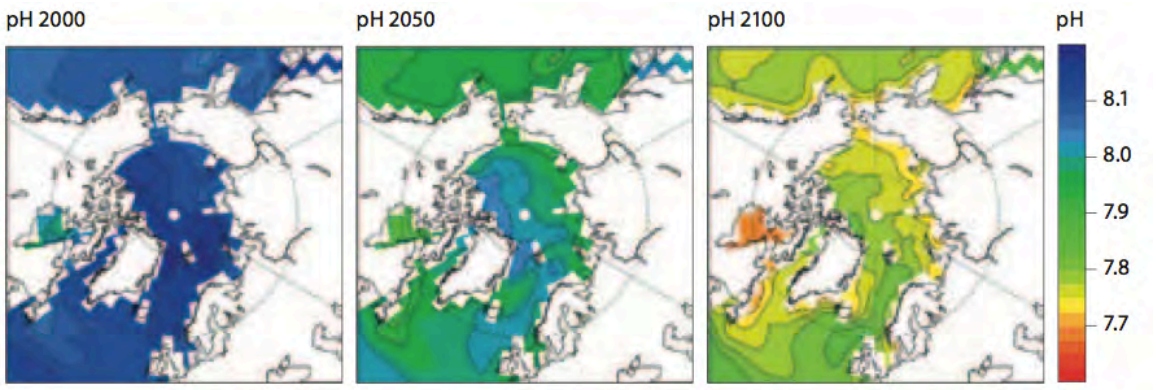
# a case study in Norway

- rapid warming and acidification observed and projected
- cultural and economic importance of oceans/fisheries
- use of marine areas for oil and gas extraction

➢ existing use conflicts


- successful fish stock management
- high level of education and wealth

➢ high adaptive capacity?



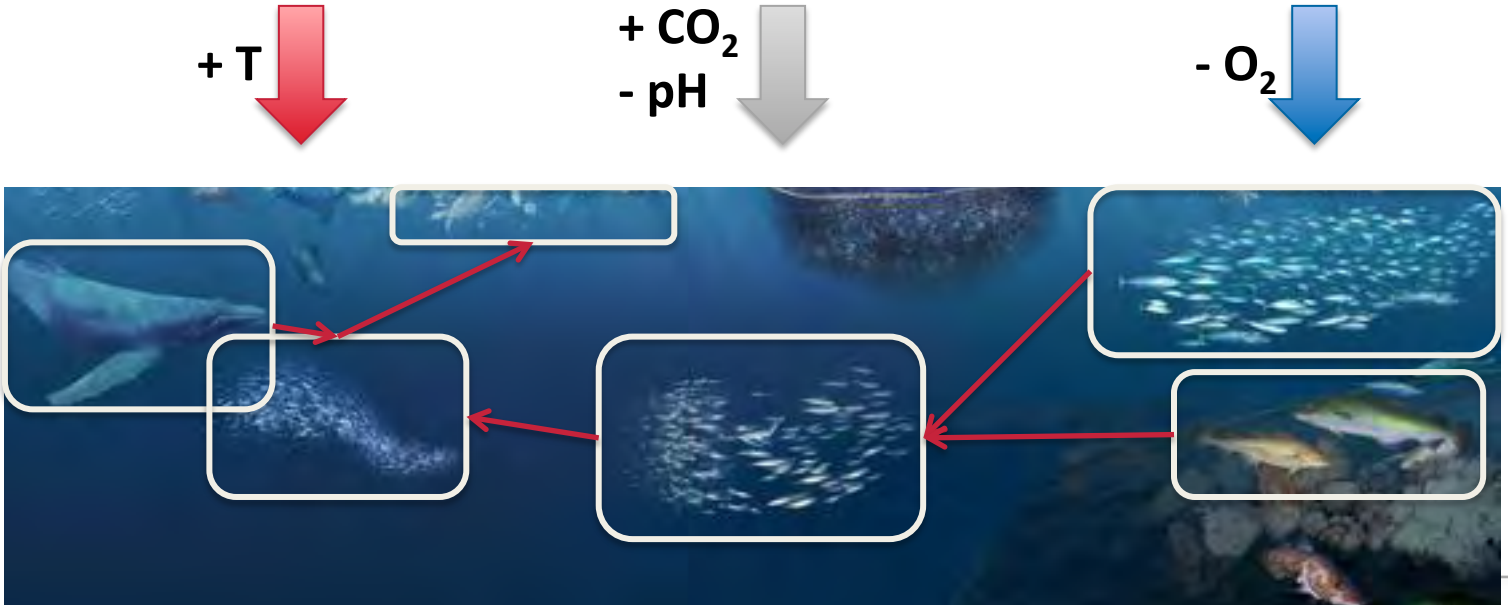

(AMAP 2013 / Denman 2011)

# a systems view: climate change & oceans



how will marine ecosystems change under:

- warming
- acidification
- hypoxia (lack of $O_2$)




Arild Sæther / IMR

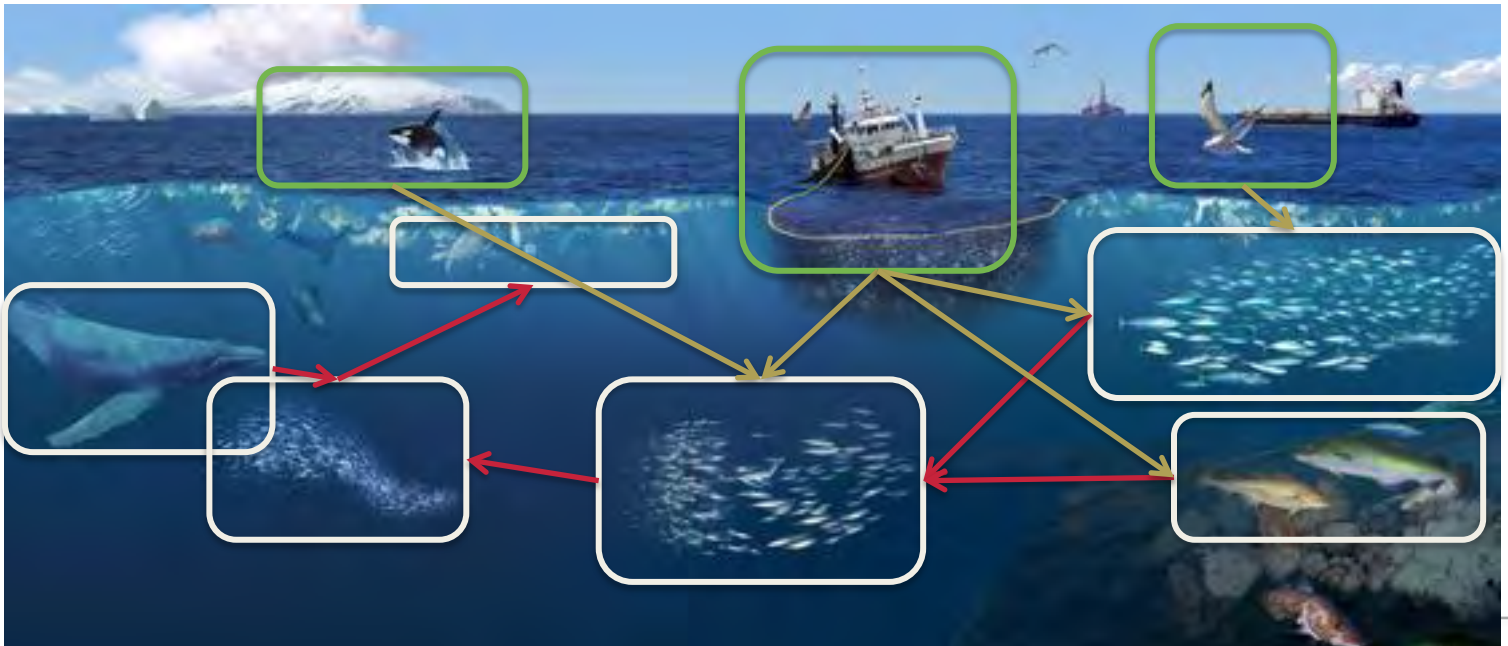
# ...and societies ?



- human societies use and value ecosystems
- and impact ecosystems: resource exploitation, pollution, etc.

➢ ***which relevant ecosystem services will be impacted?***

➢ ***how can human societies adapt in their use of these services?***



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*who cares?*

# 2. Stakeholder participation

# 2. stakeholders: representatives of society



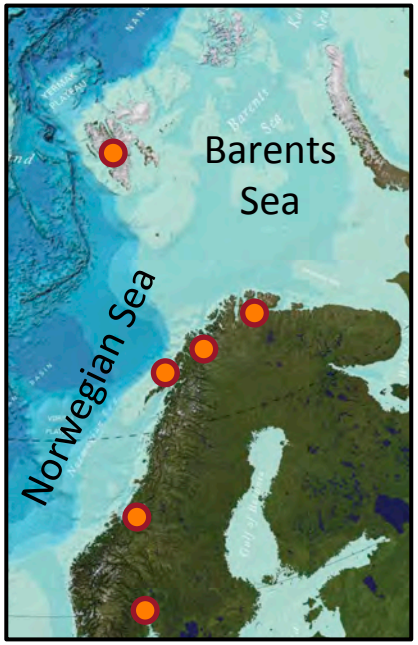
interviews and workshops with stakeholders:

- fisheries, tourism, environmental NGOs, governmental agencies

- integrate local knowledge & concerns
- communicate scientific knowledge & uncertainty

- supported by local experts: processes and scenarios

➢ identify relevant ecosystem elements and services



# stakeholder views & concerns



- changes already perceived: distribution shifts and immigrated species
- declines in some local fish stocks and seabird populations
- ecological concerns: stock recruitment, primary production
- differences in adaptive capacity:
  - industrial fisheries can adapt to stock size and distribution changes
  - small-scale fishers and tourism cannot easily adapt (esp. far north)

➢ report:
*Koenigstein & Goessling-Reisemann 2014*

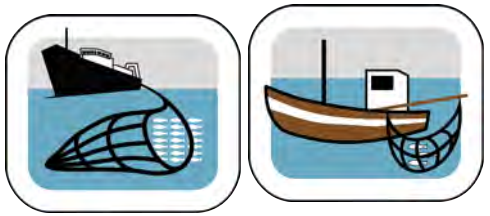
*zenodo.org/record/8317*

# Ecosystem services



Relevant ecosystem services in the region:

- **fisheries**
  (industrial and small-scale)



- **tourism & recreation**
  **(**sports fishing, whale & seabird watching)

- **carbon uptake & sequestration**


- biodiversity & cold-water coral reefs
- cultural, educational and existence values

*what may happen?*

# 3. experimental research

# experimental research approaches



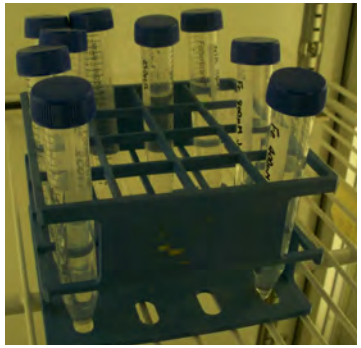
**ecosystem**

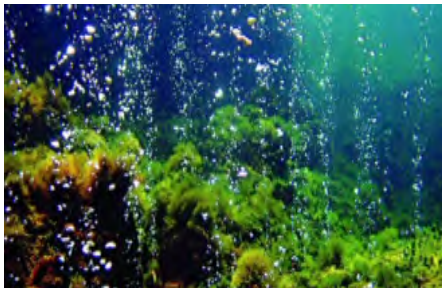
**community**

**population**

**organism**

**sub-organismal**



- biochemical, molecular, genetic analyses
- physiological experiments in aquaria
- mesocosm experiments
- cruise surveys
- ‚natural laboratories‘

# experimental effects on fish



- coordinated experiments with different life stages

**acidification**

- increased mortality in Atlantic cod eggs and larvae
- behavioral changes (laterality) in Atlantic cod juveniles

\+ zooplankton sensitivity, plankton bloom dynamics

➢ changes in food availability and energy content?

**warming**

- faster metabolism, higher growth & consumption
- thermal stress, lower max. size

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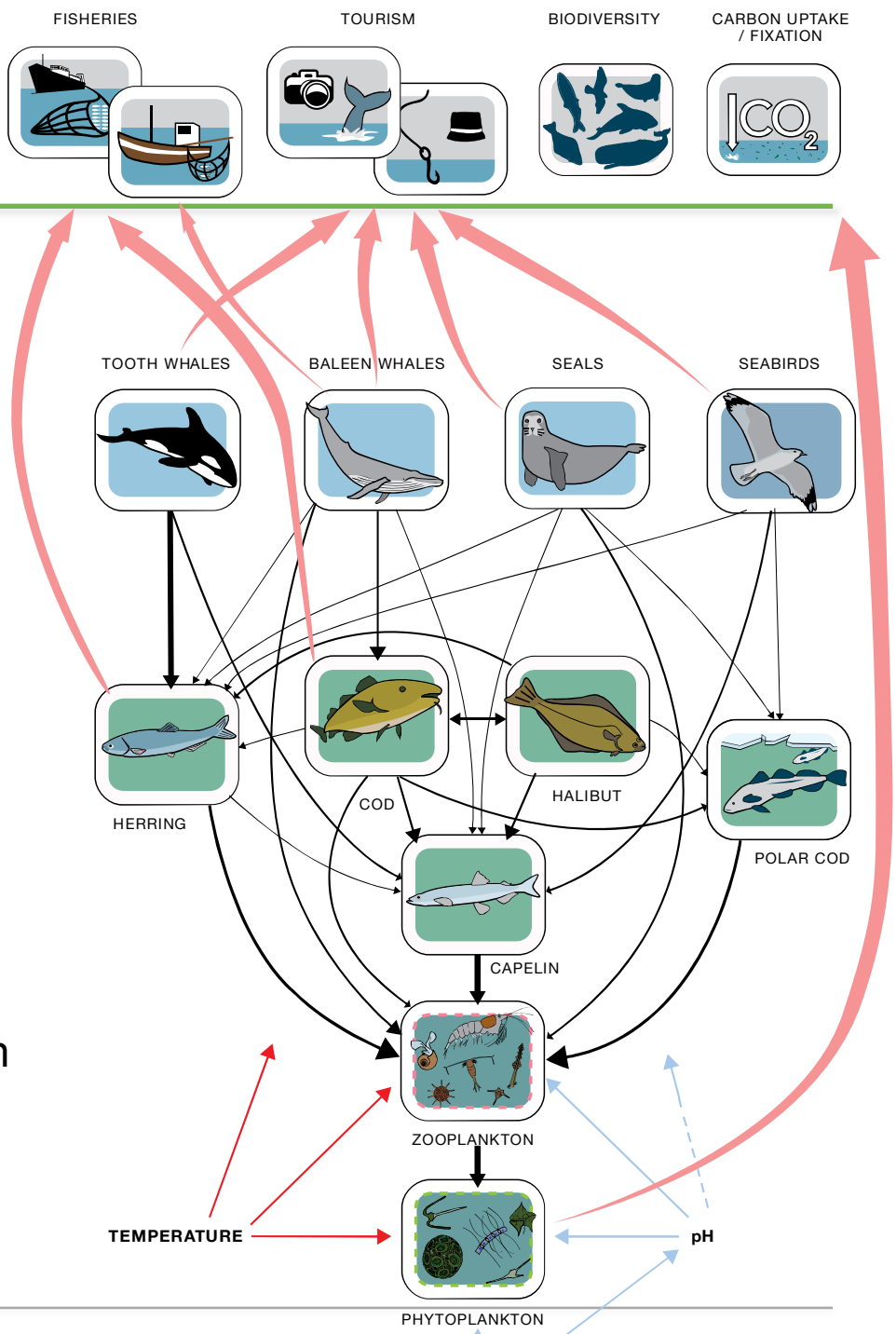
*how to make sense of it all?*

# 4. an integrative model

# 4. the model

- multi-species model in a system dynamics framework:
  - graphical interface
  - hierarchical, modular structure
- biomass flow through food web: reproduce dynamics
- links and indicators for ecosystem services
- primary production and zooplankton dynamics



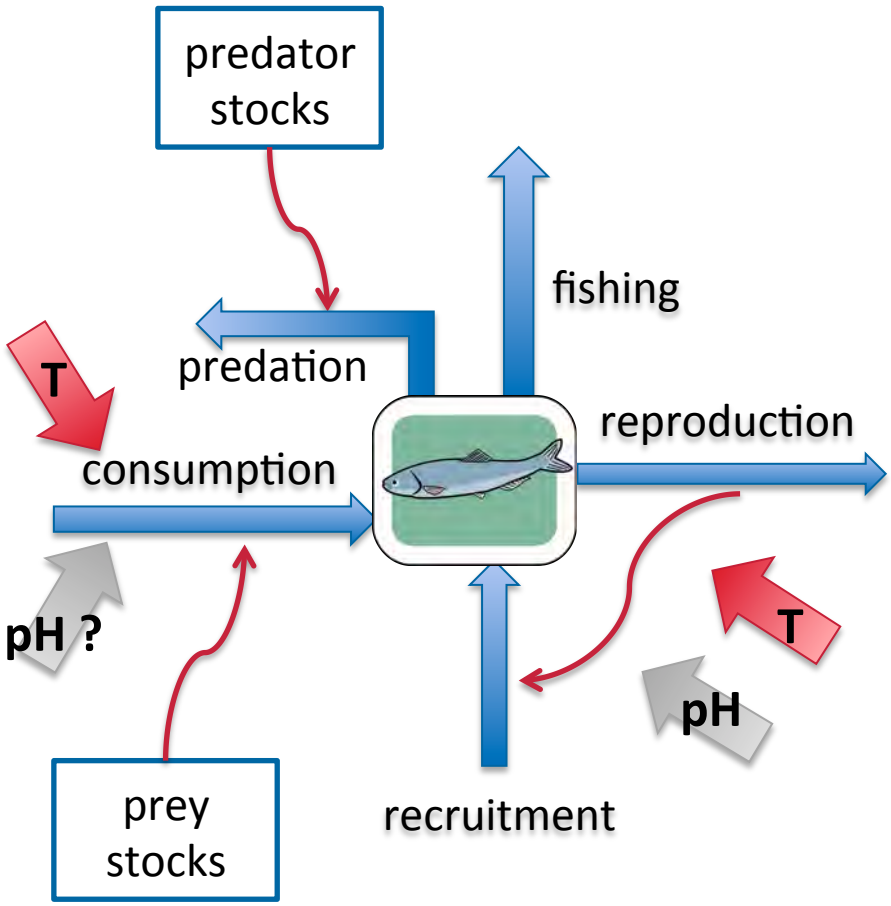
# population processes



- biomass compartment determined by biological processes
- predation / consumption connect species

➢ uses assessment and survey data, catches, consumption & growth estimates

➢ experimental results are / will be integrated in processes

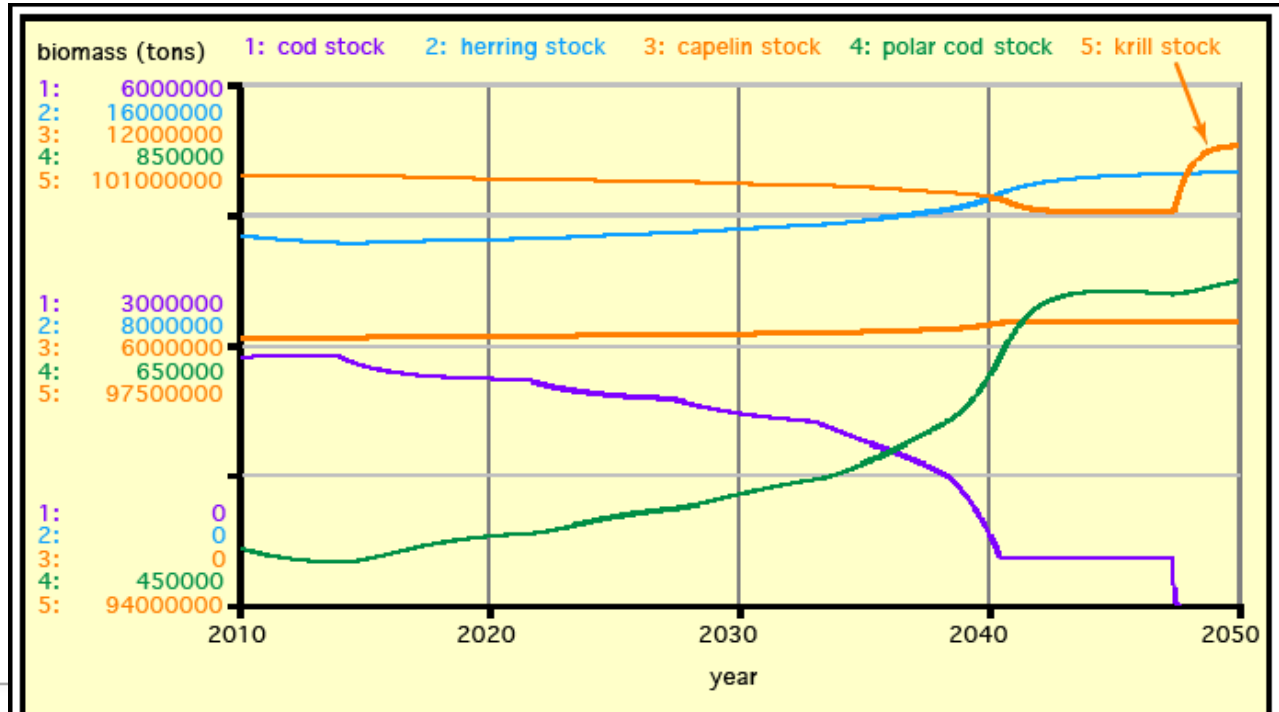


# model behavior *(work in progress)*



- changes in processes affect stock and community dynamics
- example test run:
  - putative acidification impact on cod *(violet line)* causes food web changes *(without temperature change)*

- live simulation sessions with stakeholders
- interactions between climate change scenarios and management decisions (quota)



*what have we learned so far?*

# 5. summary and conclusions

# summary



**ecosystem:**

- warming may promote high states and shifts of fish stocks in the Barents Sea
- fish population resilience to acidification will depend on adaptation in early life stages
- indirect impacts to be expected: links between fish stocks, seabird and whale populations

**society:**

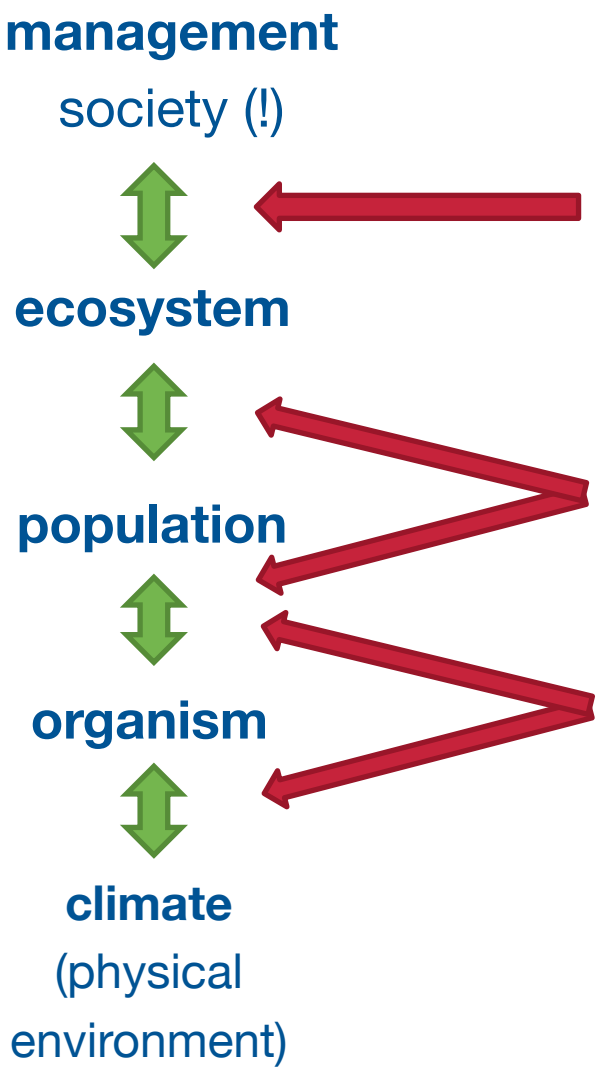
- differences in adaptive capacity:
  industrial vs. coastal fishers and tourism
- additionally: impacts on culture and education

➢ probably higher vulnerability of communities
in the far north

➢ helpful knowledge to investigate (and increase) social-ecological system resilience

# conclusions: linking levels of description






- **stakeholder participation** from early on:
  - focus on relevant ecosystem services
  - make model accepted and understood
- **food web links** among species and ecosystem services / anthropogenic drivers
- **experimental results:** integrated in biological process model

# conclusions: participatory modeling

- biological processes help to integrate experimental results

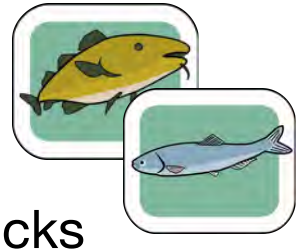
➢ increase mechanistic understanding and extrapolate into the future

- stakeholders can represent society and value potential changes

➢ a purpose-built model for communication, learning, and exploring adaptation strategies

# upcoming work

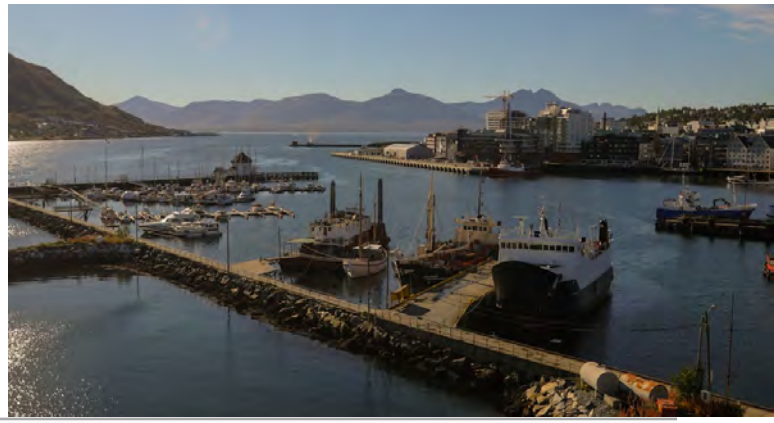




- integrate early life stages module:
  acidification and warming effects on cod and herring stocks

- stakeholder workshop: Tromsø, June 2015

➢ valuation of expected changes and identification of societal adaptation options



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| | |
|---|---|
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