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Biological Ensemble Modelling of the Eastern Baltic cod future

- so far & where to go from here

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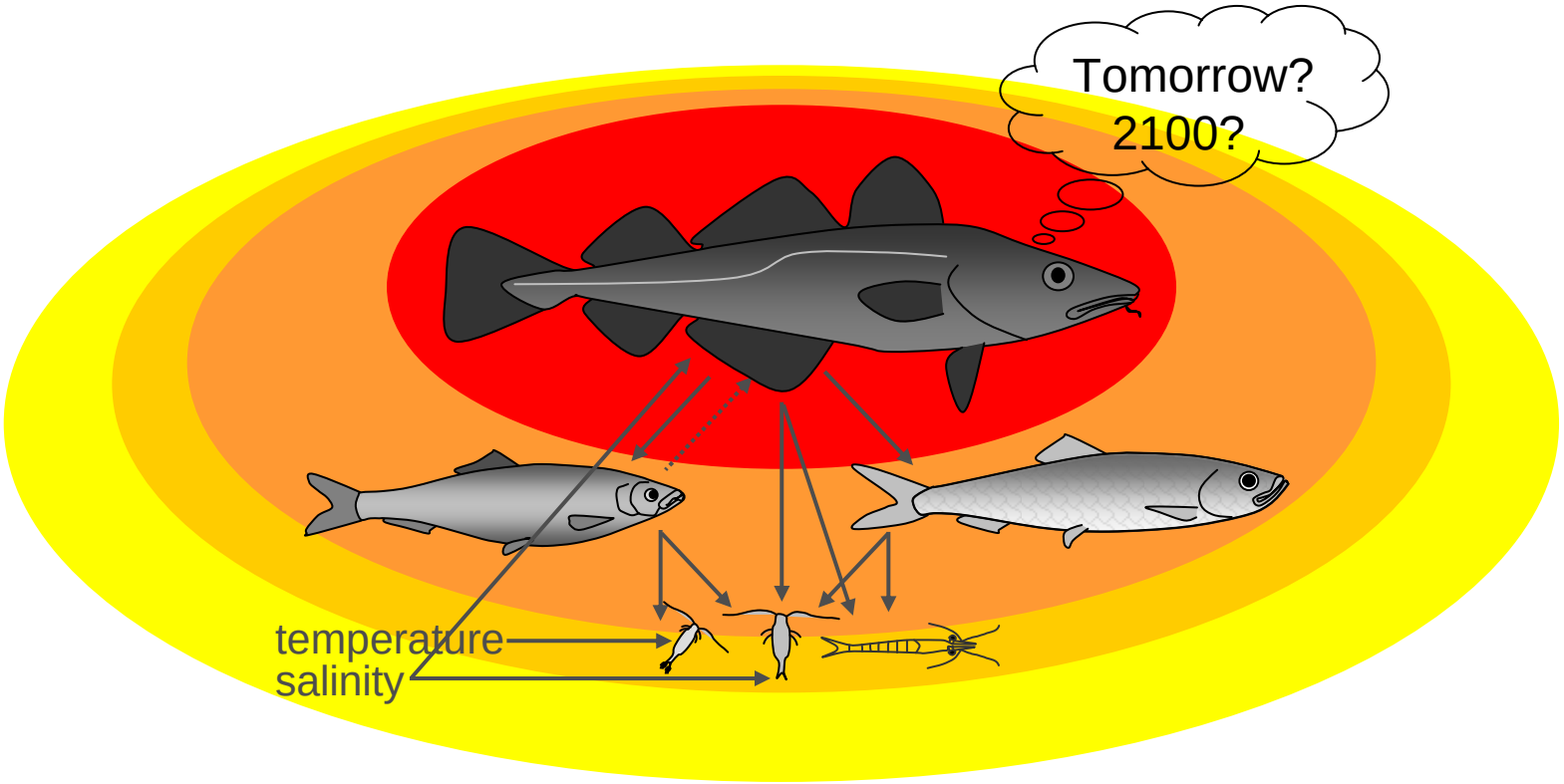
ICES International Council for the Exploration of the Sea
CIEM Conseil International pour l'Exploration de la Mer
ICES/HELCOM Working Group on
Integrated Assessments of the Baltic Sea (WGIAB)

How to project future fish populations?



Biological Ensemble Modeling Approach *(BEMA)*

- compare projections *across models* and model types
- assess impact of model structure on the range of projected outcomes
- seek conclusions valid across models and scenarios

Ensemble Modelling

- *Ensemble modelling*: same scenarios & forcing across models
- common tool in global climate modelling (IPCC) and used in other biological fields
- Ecosystem Approach to Fisheries Management
  - account for climate effects, species interactions etc.
  → the diversity and complexity of models increase
- Biological Ensemble Modelling Approach: application in fisheries (e.g., future EB cod)
  - variation between models of different complexity?
  - causes of variation between models (e.g., structure, methodology)?
  - effect of ensemble weighting and composition?
  - general conclusions across models possible?

8 models of Eastern Baltic cod

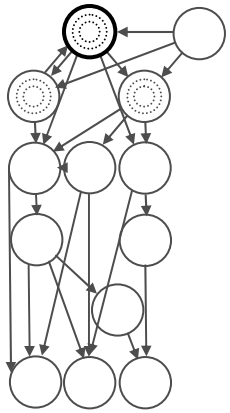
Single species

1. Wikström, A. et al.
   in prep.

2. Aro, E.; ICES (2008)

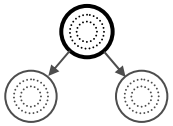
3. Müller-Karulis, B.
   in prep.

Food-web

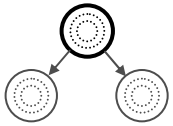


8. Tomczak et al.
   in prep.

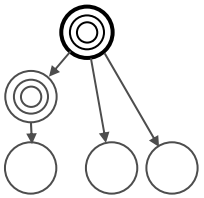
Multi-species



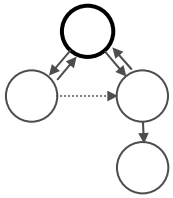
4. Heikinheimo, O. (2009)
   ICES J Mar Sci



5. Neuenfeldt, S; ICES (2004)



6. van Leeuween, A. et al. (2008)
   J Sea Research



7. Lindegren et al. (2009)
   Proc Nat Acad Sci

unstructured
age structured
size structured

(Gårdmark et al. In prep.)

Future Fishing and Climate scenarios

Fishing

- 3 fishing mortality (constant) scenarios:
  - mean F of 1996-2005 for all species ($F_{cod} \approx 1$, $F_{sprat} \approx 0.4$, $F_{herr} \approx 0.3$)
  - cod management plan target met ($F_{cod}=0.3$)
  - cod fishing ban ($F_{cod}=0$)

Climate

- 2 climate scenarios:
  - no climate change (mean historical levels)
  - climate change, regionally down-scaled IPCC scenario

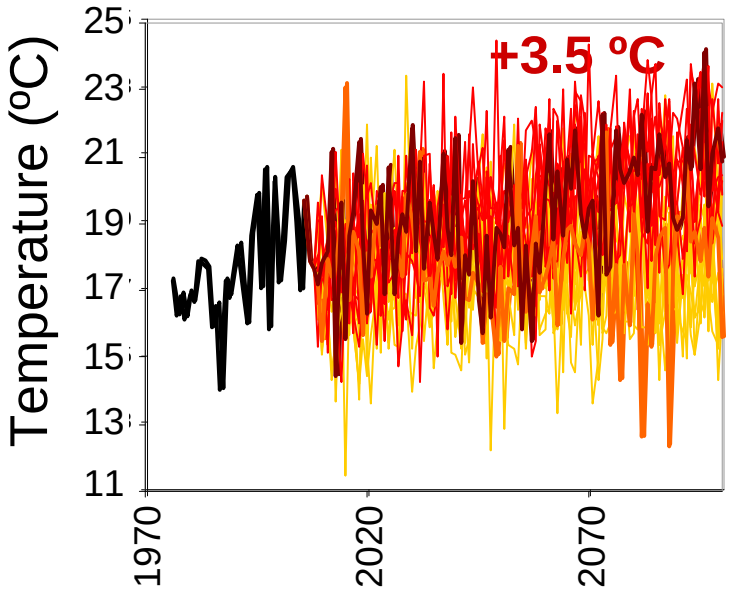
(ICES/HELCOM WGIAB 2009; Gårdmark et al. In prep.; historical estimates ICES SGMAB 2006)

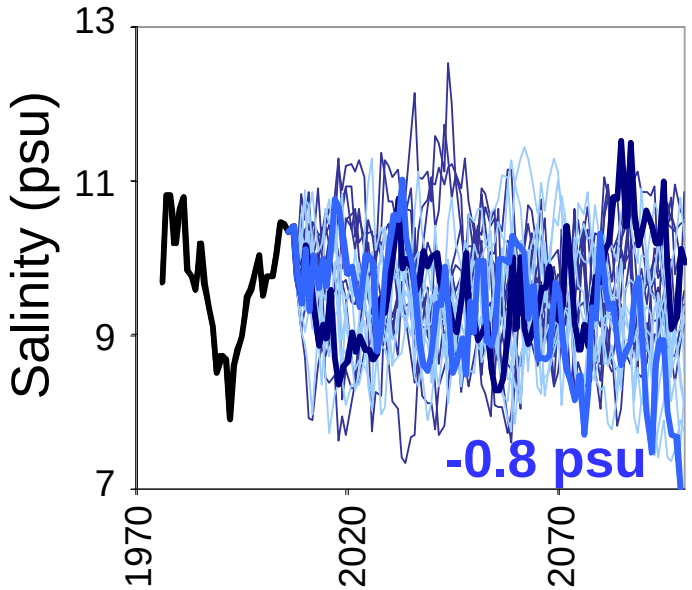
Climate change scenario: an *example*

Hydrographic forecasts

- Global Circulation Model → 3-D Regional Atmosphere & Ocean Model → temperature & salinity forecasts 2071-2100 (Meier 2006)

- temperature & salinity time-series (2006-2100) based on the observed mean, variance & auto-correlation 1972-2005 (i.e., 10 runs were simulated using an AR(1) model; Ripa and Lundberg 1996)



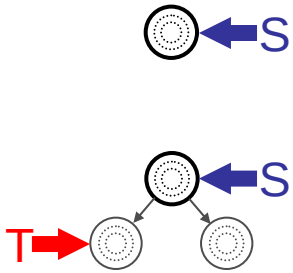


(ICES/HELCOM WGIAB 2009; Gårdmark et al. In prep.; historical data SMHI)

Hydrographic effects on modelled fish

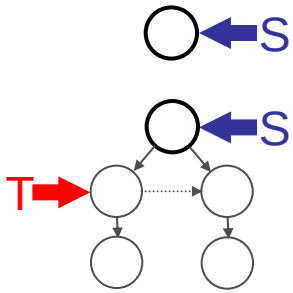
Salinity → cod recruitment
(Heikinheimo 2006, fitted to new data)

Temperature → sprat recruitment
(Baumann et al. 2002, fitted to new data)



Salinity → cod biomass

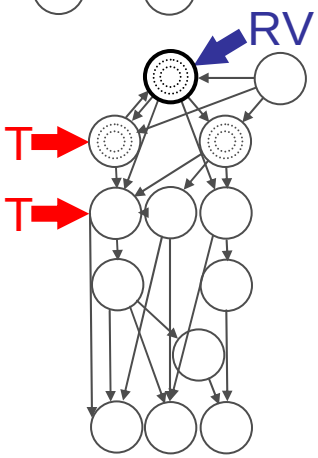
Temperature → sprat biomass



Reproductive volume → cod egg production

Temperature → sprat egg production

Temperature → zooplankton biomass
(some groups)

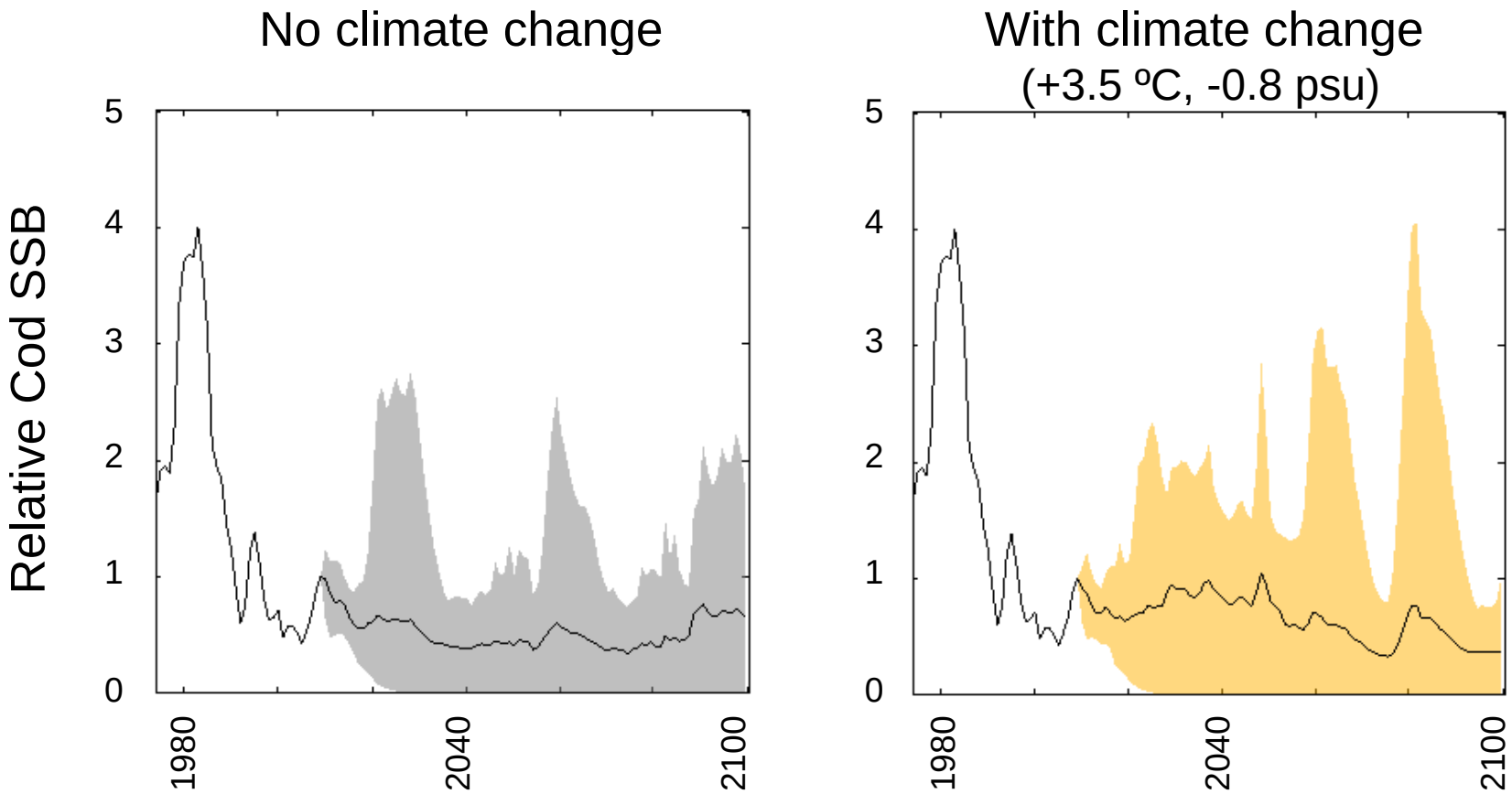


(ICES/HELCOM WGIAB 2009; Gårdmark et al. In prep.)

Future with intense cod fishing: *example*

Range of projected outomes

F_{cod}=1.08 (mean of 1996-2005)

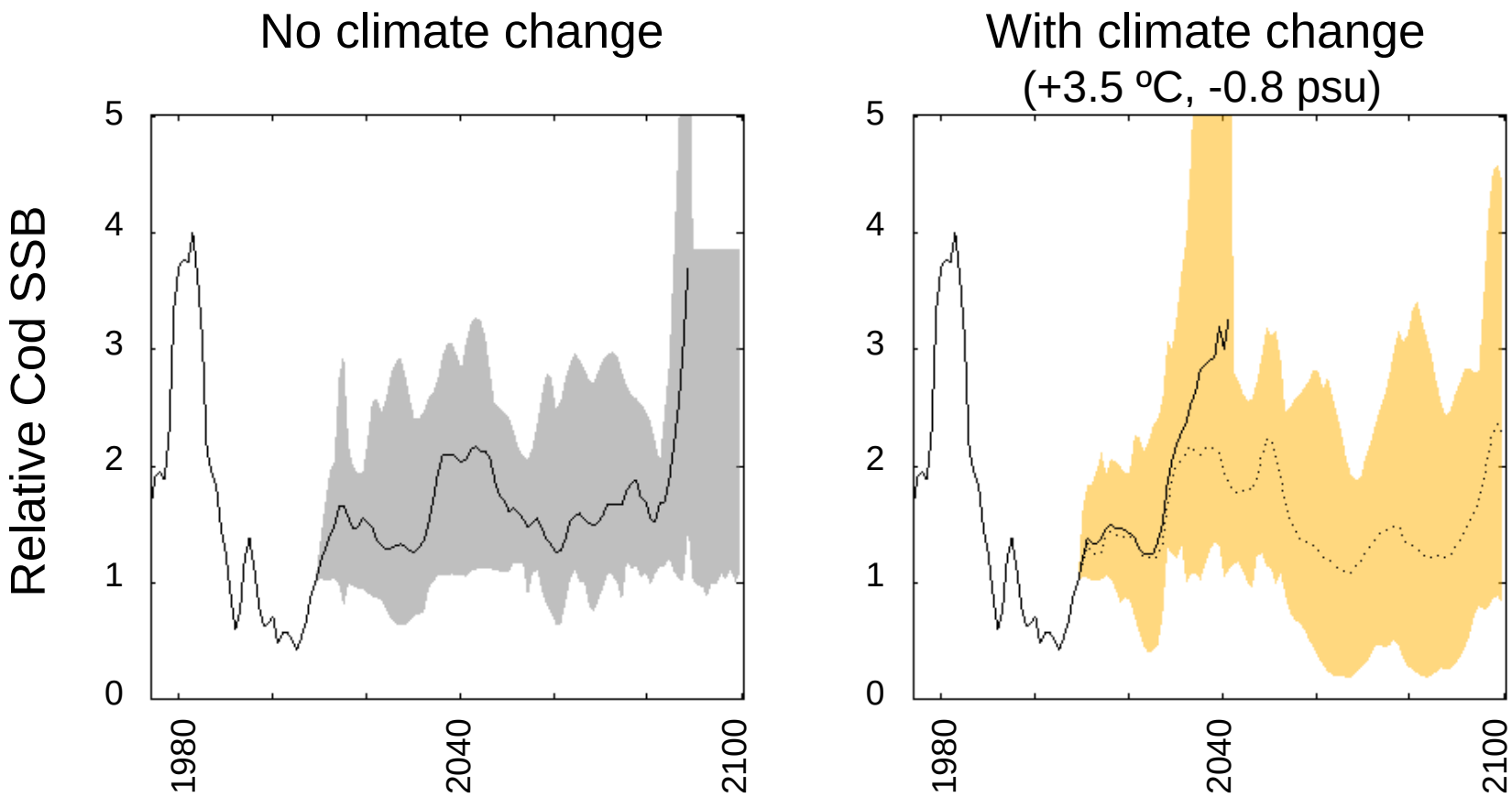


(Gårdmark et al. In prep.)

Future with cod management target F: *example*

Range of projected outomes

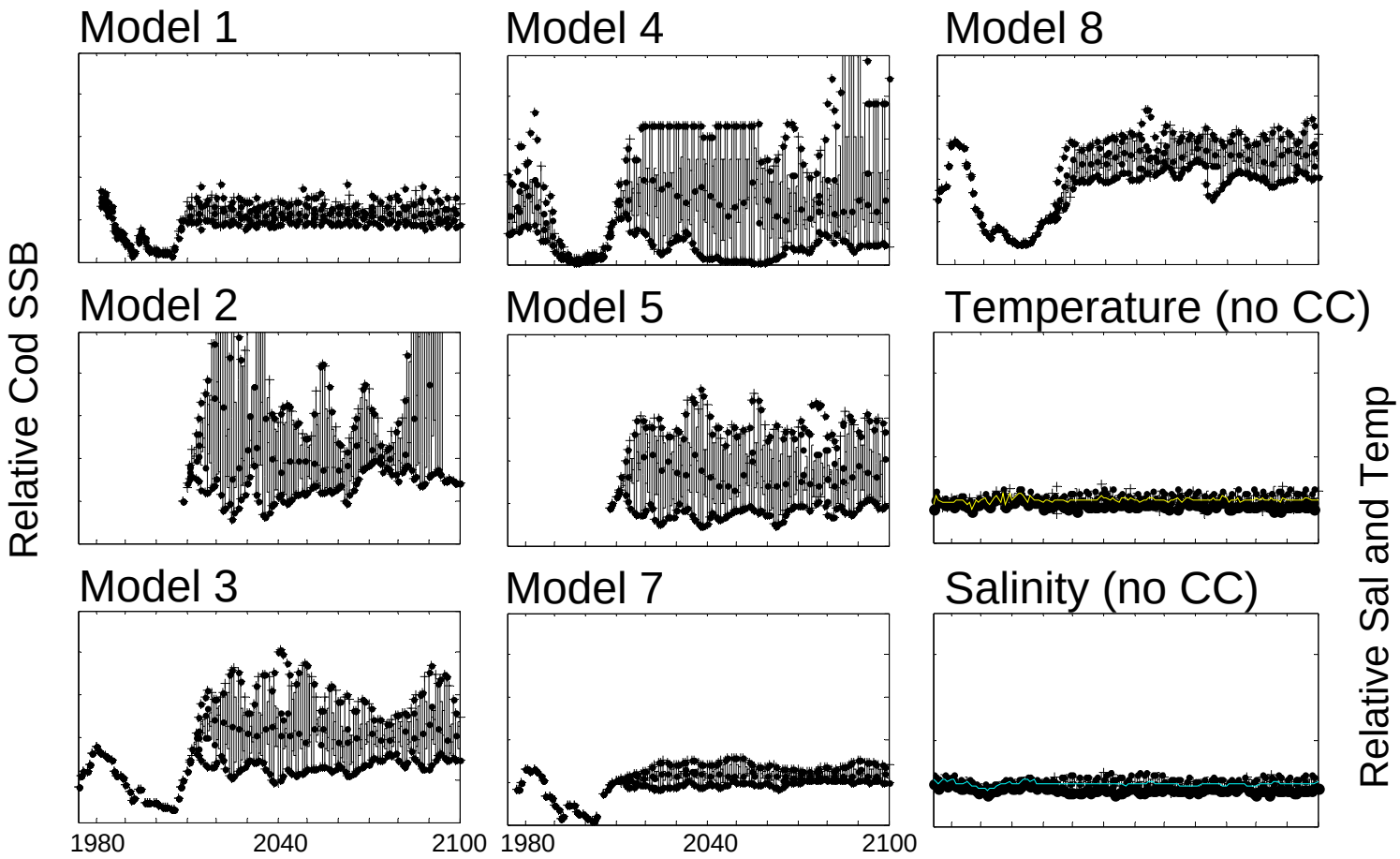
F_{cod}=0.3 (target F in EU cod management plan)



(Gårdmark et al. In prep.)

Structural causes of variability?

F_{cod}=0.3 (target F) and no climate change, all runs



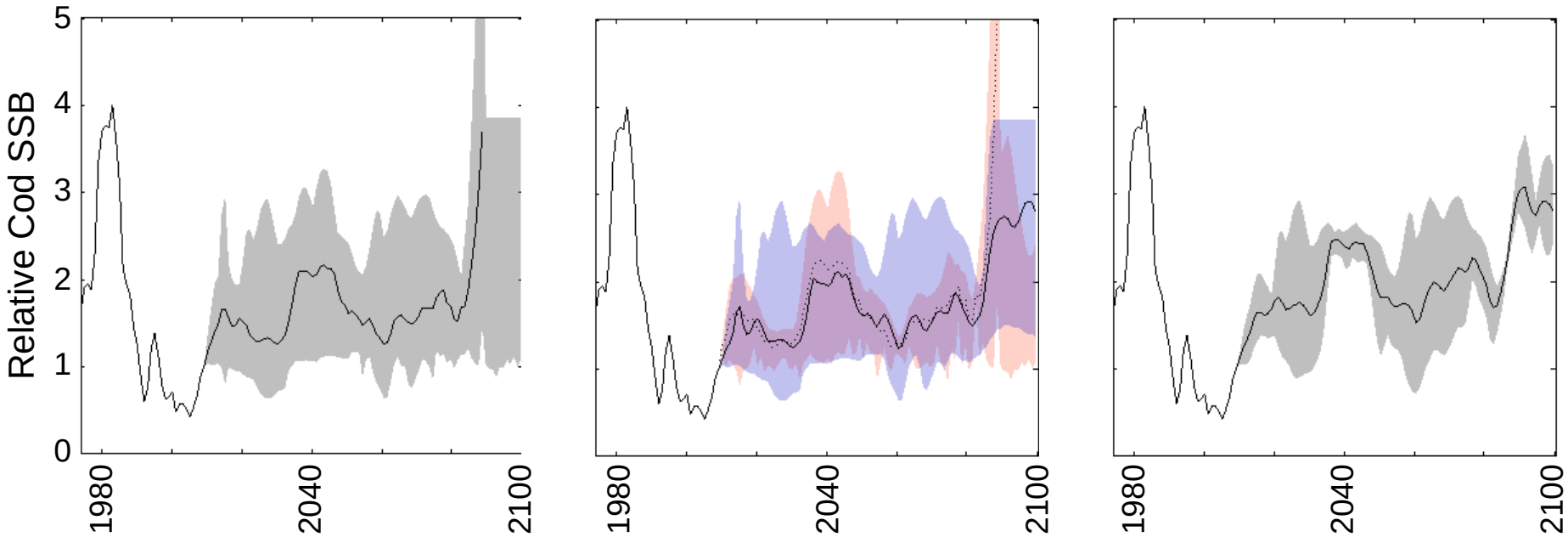
(Gårdmark et al. In prep.)

Weighting & ensemble sub-sets

Range of projected outomes

F_{cod}=0.3 (target F) and no climate change, run 1

All models | Single vs Multi-species | Ensemble sub-set



(Gårdmark et al. In prep.)

Conclusions across models?

Fishing	Climate	Relative Cod SSB_{2100}			
		Extinct	Decrease $< SSB_{2009}$	Increase $> SSB_{1995}$	Rebuilt $> SSB_{1980s}$
Intense (F=1.08)	current	3,7	1,2,4,5,6,7,8	8	none
	climate change	3,4,7	1,2,4,5,8	8	none
Mngmt plan target met (F=0.3)	current	none	4,5	1,2,3,5,7,8	2,3,4,5,7,8
	climate change	none	1,2,4,5,7	1,2,3,5,7,8	2,3,4,5,8
Fishing ban (F=0)	current	none	1,4	1,5,7,8	1,2,3,4,5,7,8
	climate change	none	1,4,7	1,2,5,7	2,3,4,5,8

(Gårdmark et al. In prep.)

Conclusions

- Eastern Baltic cod *example*
  - no recovery if fishing returns to mean levels of 1996-2005
  - recovery if following the managemen plan (even under climate change)

- Biological Ensemble Modelling Approach (BEMA)
  - collate and compare possible future population developments
  - provides and communicates the range of projected outcomes
  - enables conclusions *across* models and scenarios
  - assist in management advice

- tool for biological model development
  - identify critical uncertainties and knowledge gaps
  - identifying structural causes of model ensemble variability
    → focused collection of field or experimental data
    → need for further model development (e.g., interactions, feedbacks and improved S-R models)

Thanks!

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Thanks to: ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea 2009