FACTS
Forage Fish Interactions

Optimal harvest of Baltic Sea herring under environmental change

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ICES Workshop on Including Socio-Economic considerations into the Climate-recruitment framework developed for clupeids in the Baltic Sea (WKSECRET), 2010

Rational

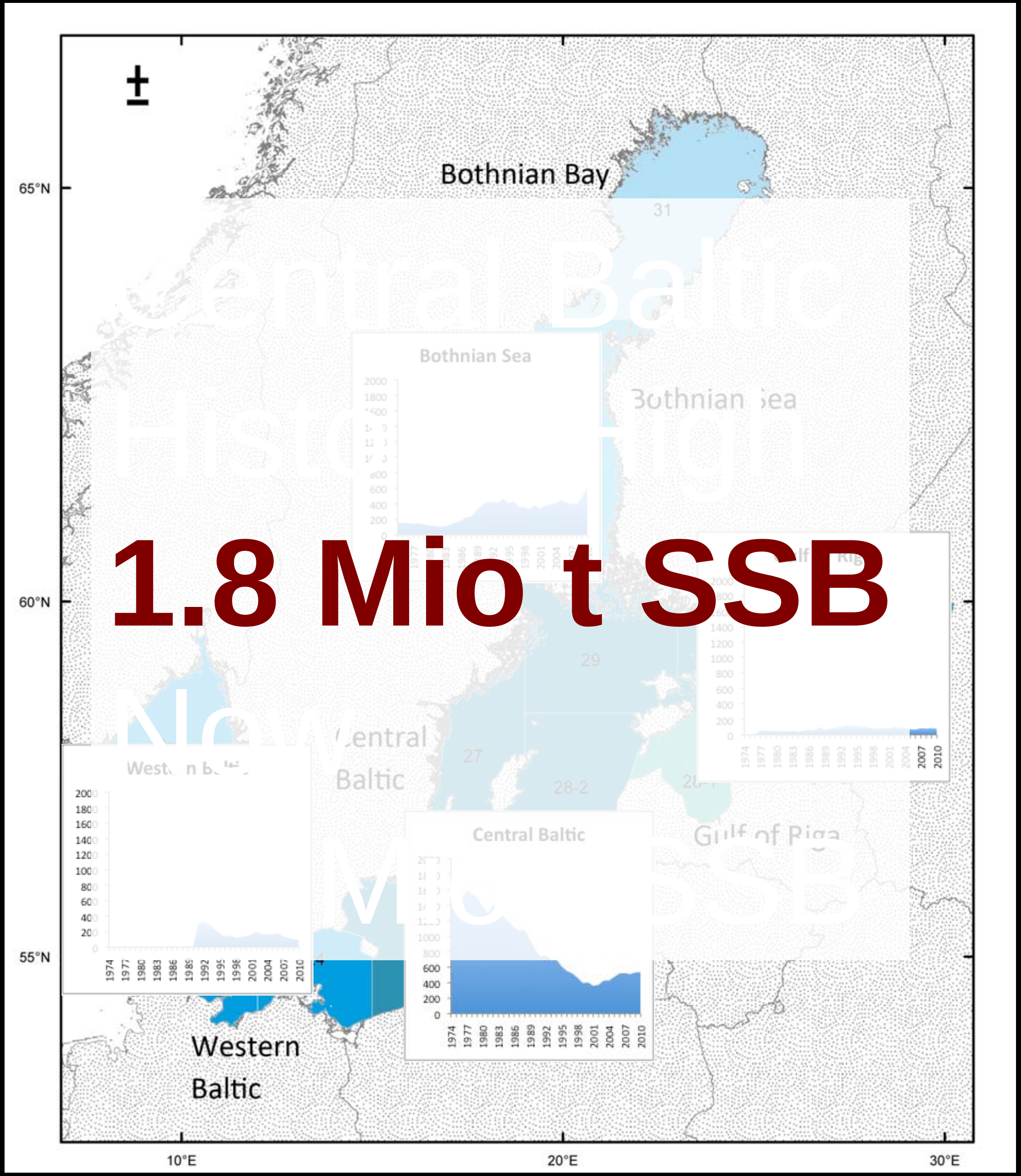
a) Effects of climate change on productivity of Baltic Herring

b) Consider Species Interactions

c) Optimal harvest of Baltic Herring under changing climate

d) Develop a bio-economic model incorporating all these

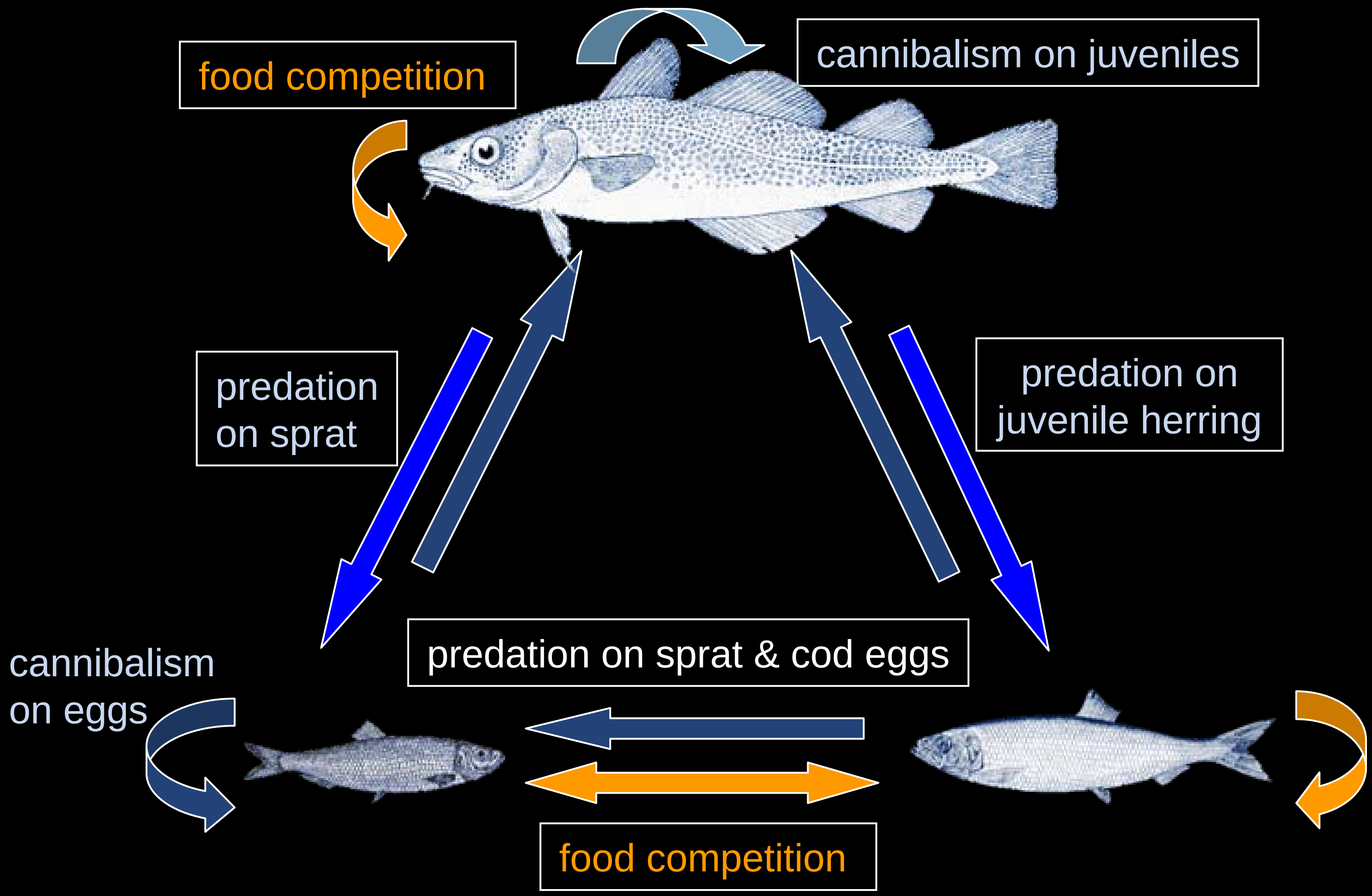
Atlantic Herring in the Baltic



1.8 Mio t SSB

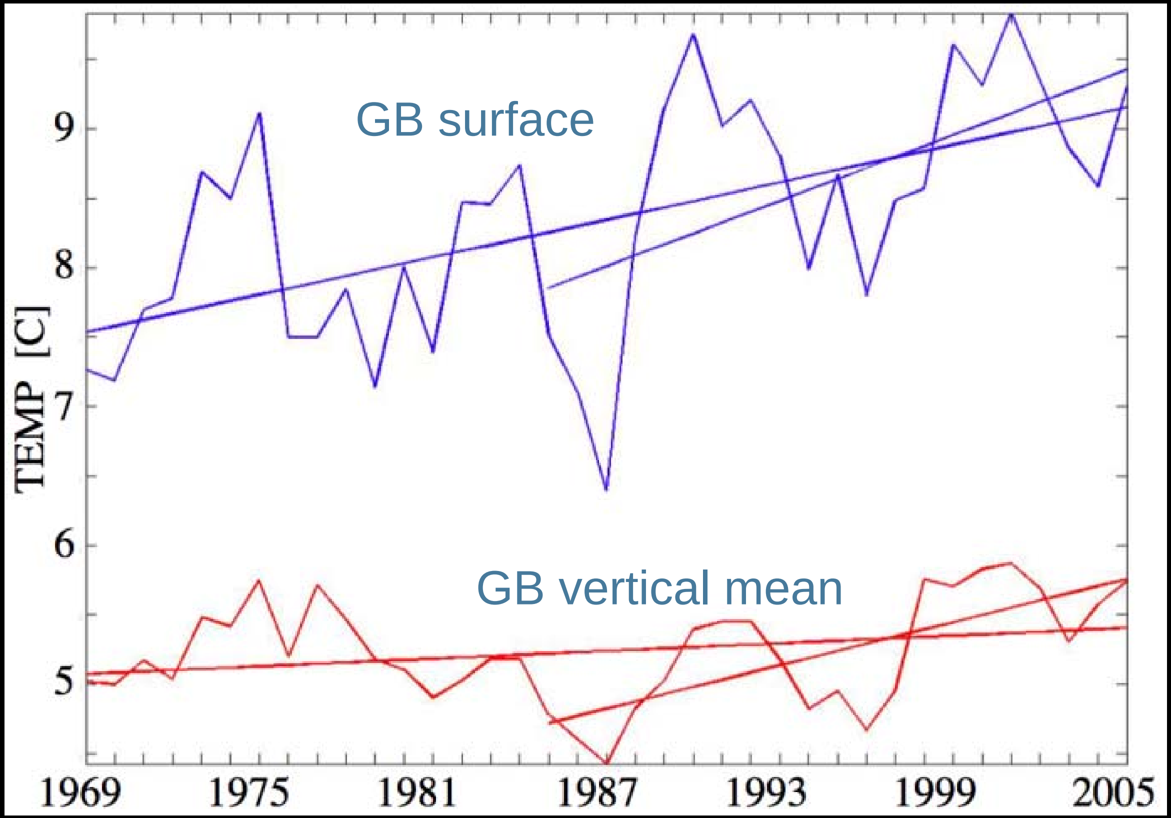
Jörn Schmidt - 19.05.2012

Species Interactions

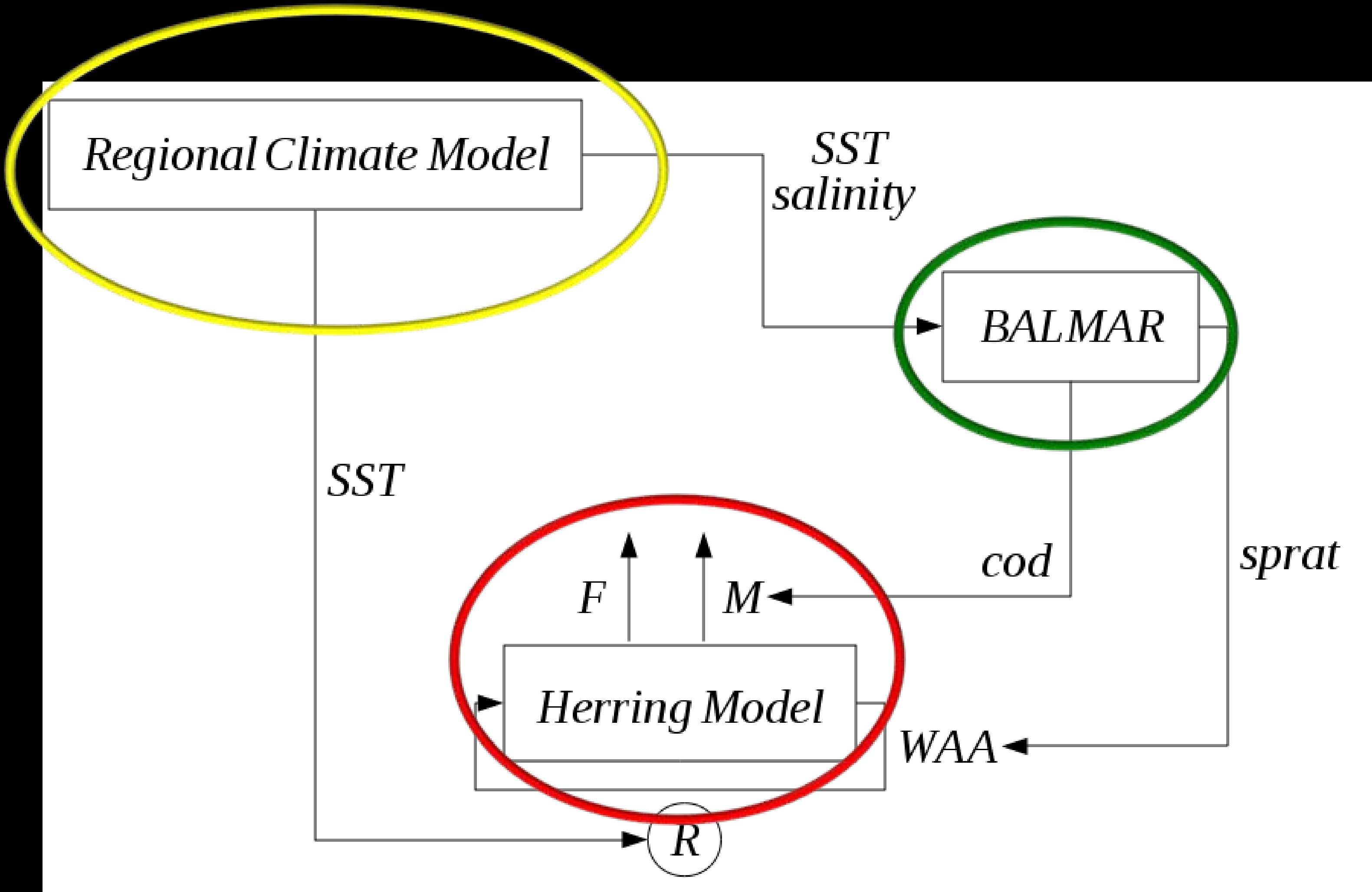


Climate Change indicative from past development

- General global warming trend
- Since mid-80s accelerated to ca. 0.4° C / decade



WKSECRET Modelling Scheme



Climate Model

- Output Max Planck Institute ECHAM4 GCM (Roeckner et al., 1999)
- Downscaling with the Swedish Meteorological and Hydrological Institute (SMHI) RCA2 RCM (Jones et al., 2004)
- Emission scenarios were derived from the Special Report on Emissions Scenarios (SRES) A2 (considered a high-emissions scenario) and B2 (low scenario), and using SST from 1961–1990 as a control run.

BALMAR food-web model

- Lindegren et al., PNAS 2009
- Any non-linear stochastic process (e.g. Generalized Lotka-Volterra models, Pimm 1982)
- Multivariate autoregressive models - MAR(1) Ives 1995, Ives et al. 1999, 2003, Ripa and Ives 2003
- Model parameters are estimated by fitting to observed time series data using ML-estimation (State-space model, Kalman filter)
- Time series: data on SSB, F, zooplankton and climate variables from 1974-2004

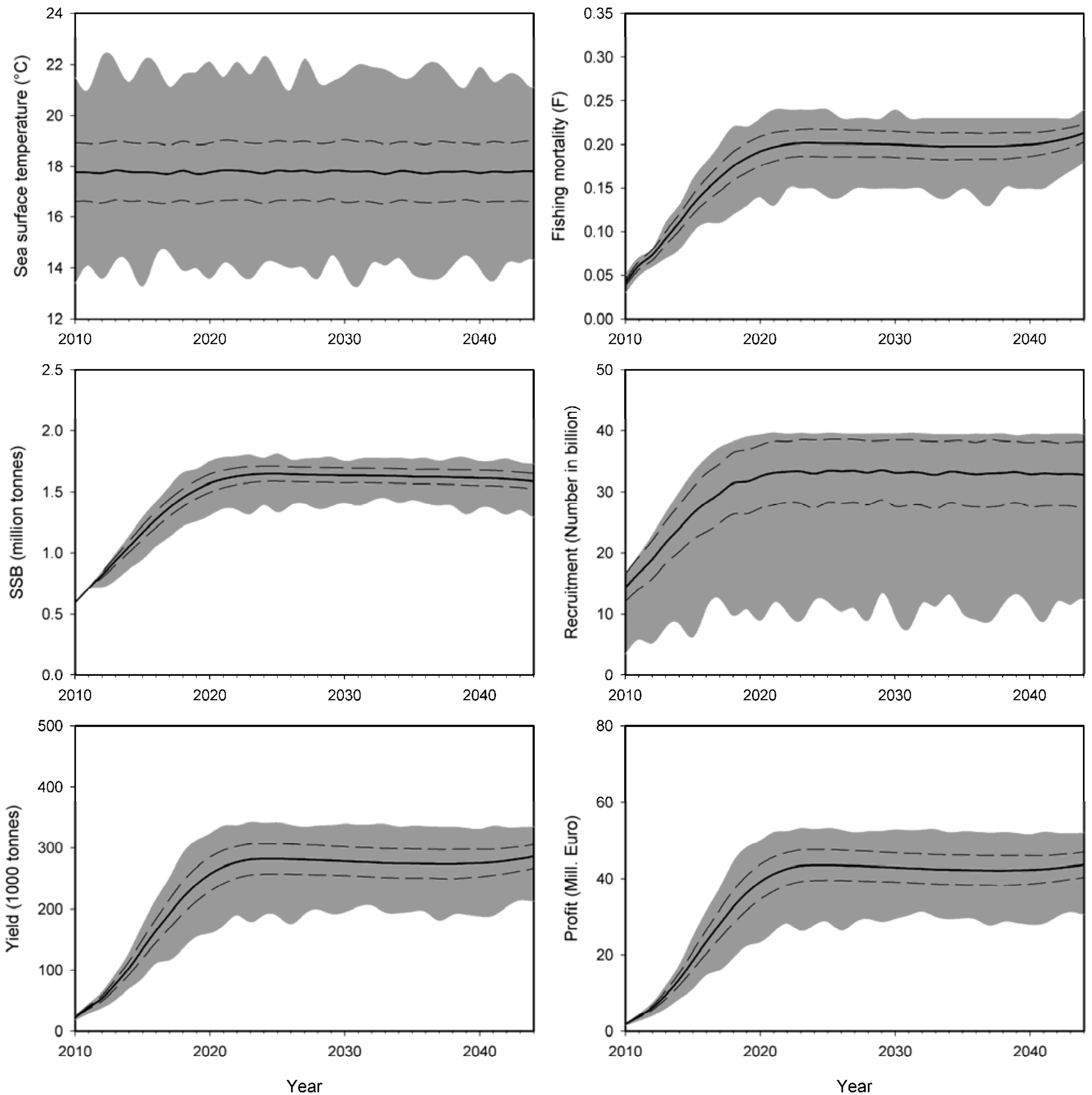
Age-structured ecological-economic model (herring) 1/2

- Age-structured (8 age-classes) to meet standard assessment
- Weight-at-age dependent on sprat biomass
- Predation mortality dependent on cod biomass
- Residual natural mortality average from last 5 years
- Temperature dependent Ricker-Type S/R

Age-structured ecological-economic model (herring) 2/2

- Harvest costs dependent on stock size and effort (derived from Bjorndal and Nostbakken → North Sea)
- Age specific price (Finnish Statistics Yearbooks)
- Maximise profit
- Interest Rate of 7%
- Slightly non-linear objective function (eta=0.1)

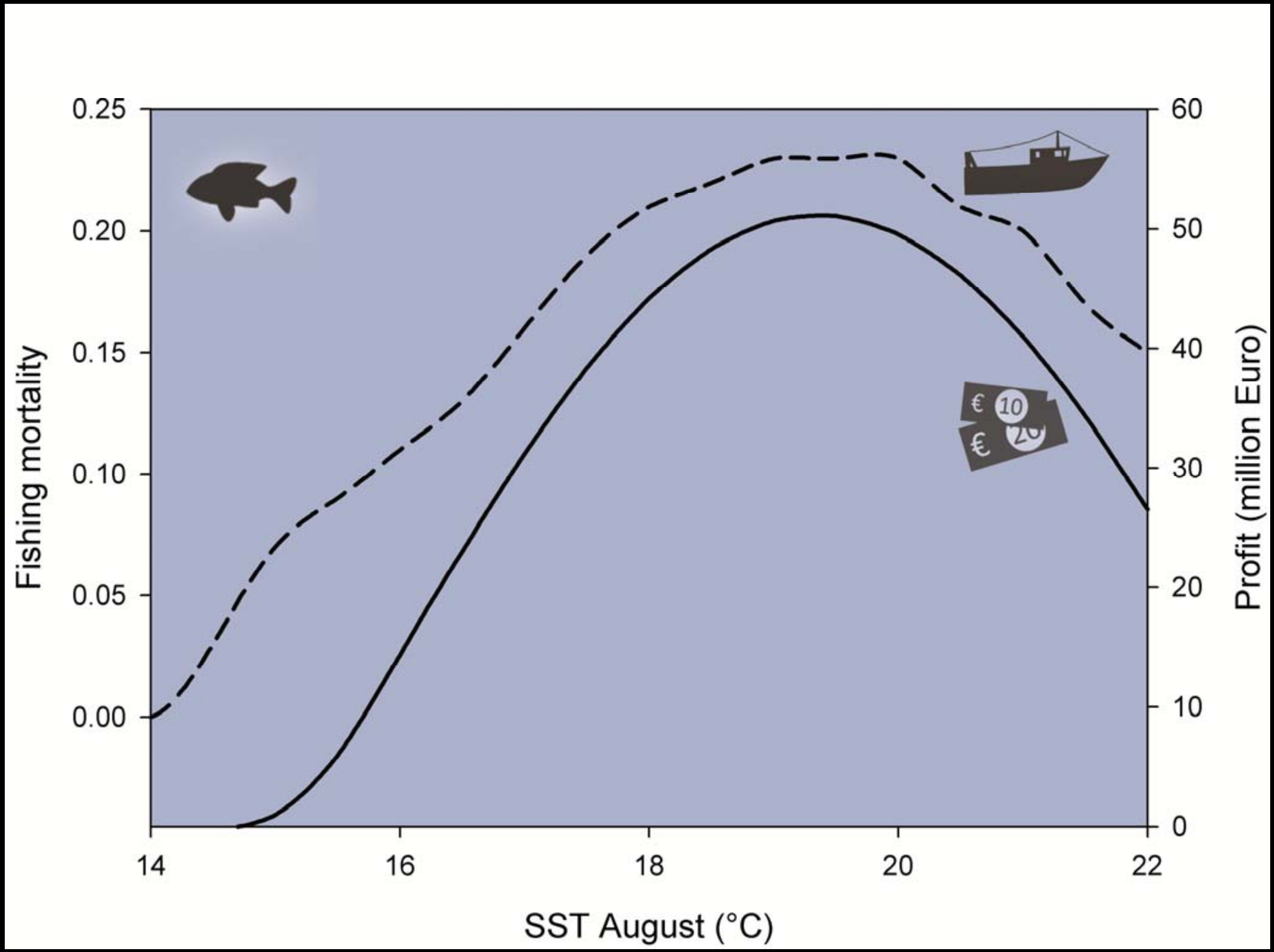
Results
NoCC



Results all Scenarios
Year 2040

Scenario	SSB (1000 t)	F	Yield (1000 t)	Profit (Mio. €)
NoCC	**1617** *±62*	0.2 *±0.01*	275 *±23*	42.17 *±3.85*
B2 (1.07° C)	**1735** *±60*	0.24 *±0.02*	339 *±26*	52.76 *±4.23*
A2 (1.45° C)	**1785** *±48*	0.25 *±0.01*	370 *±23*	57.38 *±3.73*

Sensitivity Analysis



Steady state values year 30 from 40 year simulation

Conclusion

- Successfully build an age-structured optimisation model
- Incorporated environment through temperature dependent S/R relationship
- Optimal Harvest Level
  - increasing with increasing temperatures
  - Increasing with increasing interest rates

Thank you for your attention!