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The future of Baltic Cod - modelling interactions between climate, food-web dynamics and fisheries

Thanks to:
Jörgen Ripa, Department of Theoretical Ecology, Lund University
Anders Nielsen, DTU Aqua

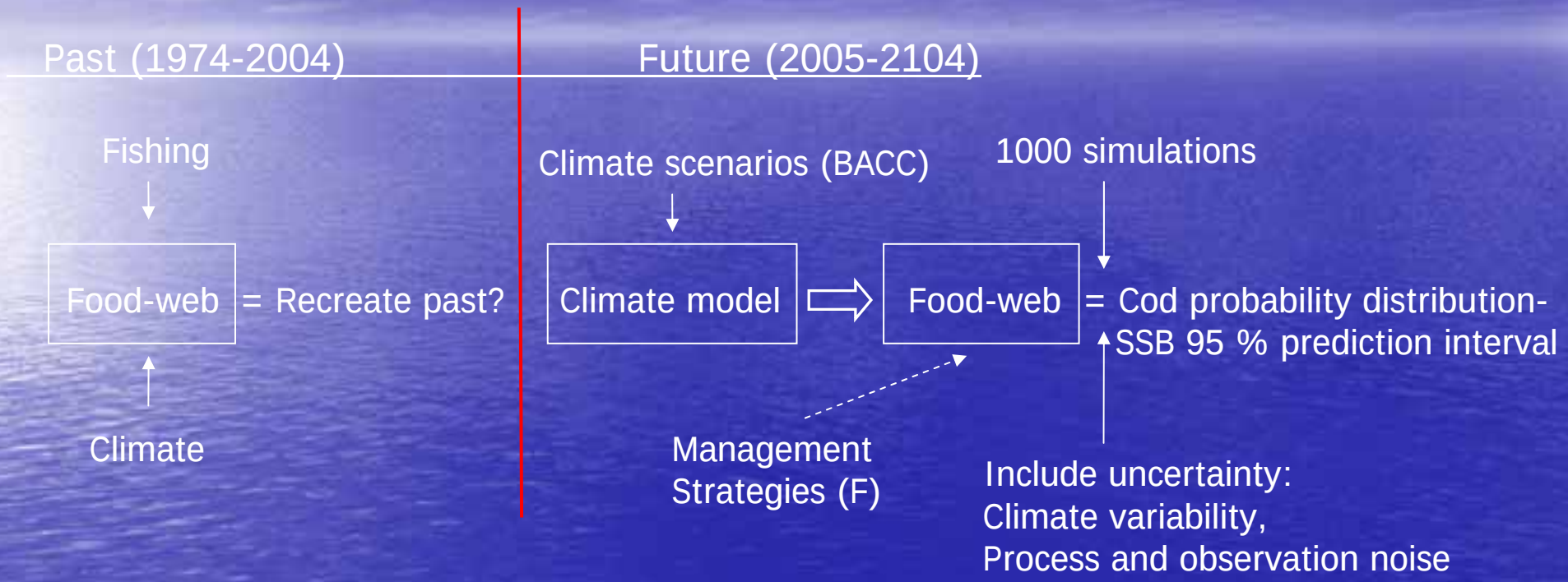
Artist

Overview

- Introduction – Can we predict the future of Baltic cod?
  - coupled food-web and climate model approach
- Can we recreate the past?
  -A generalized Baltic sea upper-trophic food-web model, MAR(1)
- Climate scenarios for the 21st century (BACC) – a climate model approach
- Model runs – Future scenarios?
- Conclusions and perspectives

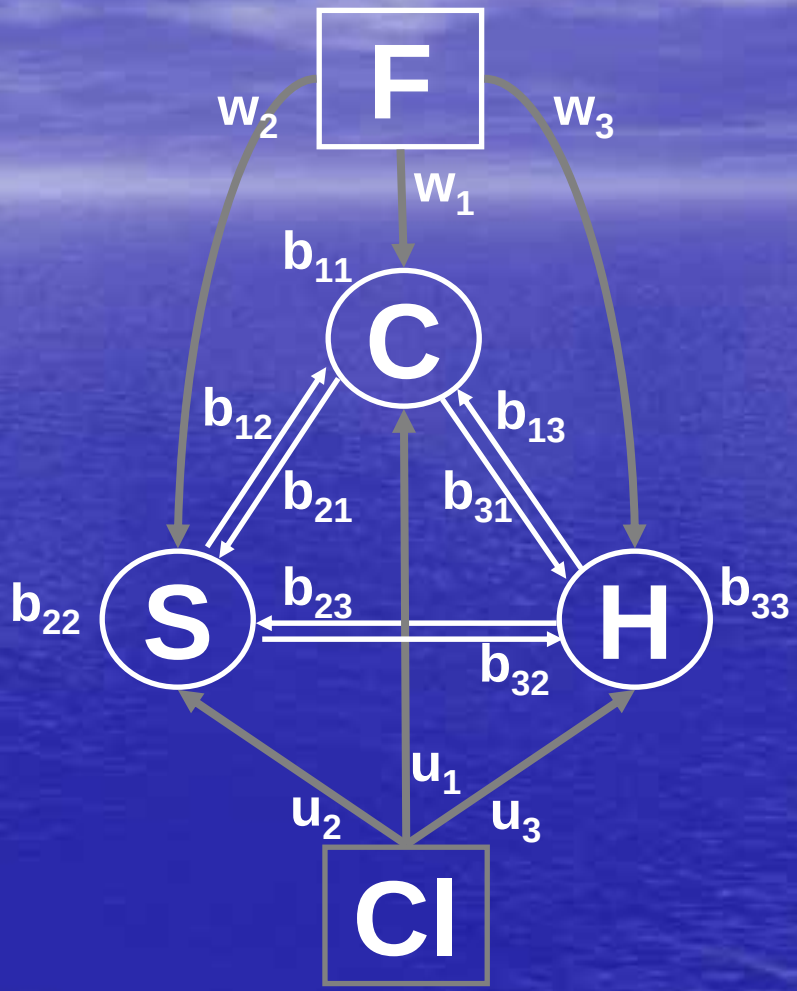
Can we predict the future of Baltic cod?

- No, but we can model a number of possible/probable scenarios



A generalized Baltic Sea upper-trophic food web

- A. Fishing effects: biomass, demography, evolutionary changes, habitat degradation
- B. Climate effects: direct/indirect on recruitment, growth
- C. Species interactions: density dependence, predator-prey, competition



$$n_i(t) = f_i\left[n_1(t-1), n_2(t-1), \ldots\ldots, n_s(t-1), w_i(t-1), U_i(t-1), \varepsilon_i(t-1)\right]$$

The Food-web model

- Any non-linear stochastic model (e.g. Generalized Lotka-Volterra models, Pimm 1982)

$$n_i(t) = f_i\left[n_1(t-1), n_2(t-1), \ldots\ldots, n_s(t-1), w_i(t-1), U_i(t-1), \varepsilon_i(t-1)\right]$$

"Linear approximation at N*"

"From species to food-web"

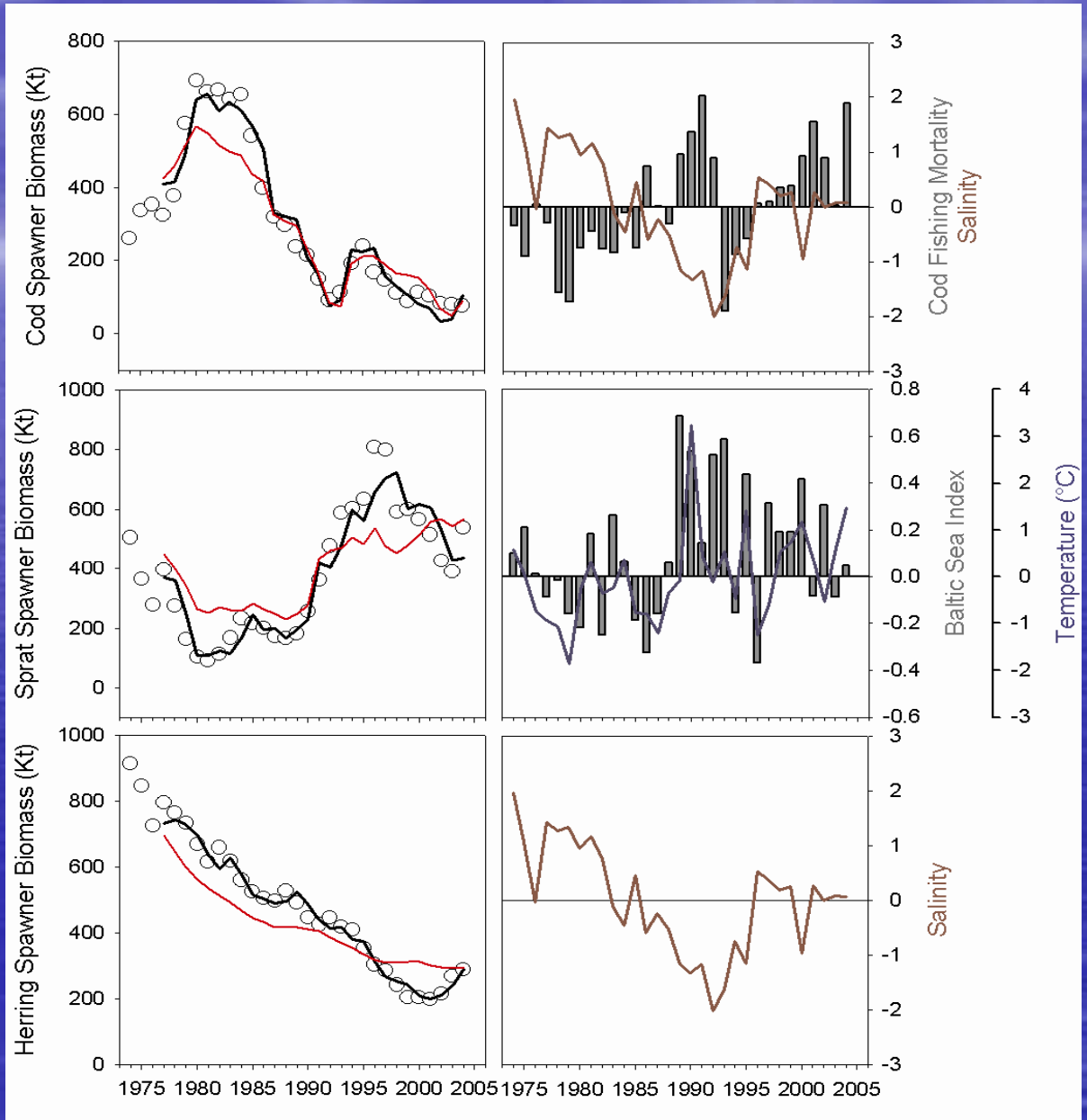
- Multivariate autoregressive models - MAR(1)
  Ives 1995, Ives et al. 1999, 2003, Ripa and Ives 2003

$$\mathbf{X}(t) = \mathbf{A} + \mathbf{B}\mathbf{X}(t-1) + \mathbf{C}\mathbf{U}(t-1) + \mathbf{E}(t)$$

Fit statistically to time series using ML-estimation (State-space model, Kalman filter)
Time series: data on SSB, F and climate from 1974-2004

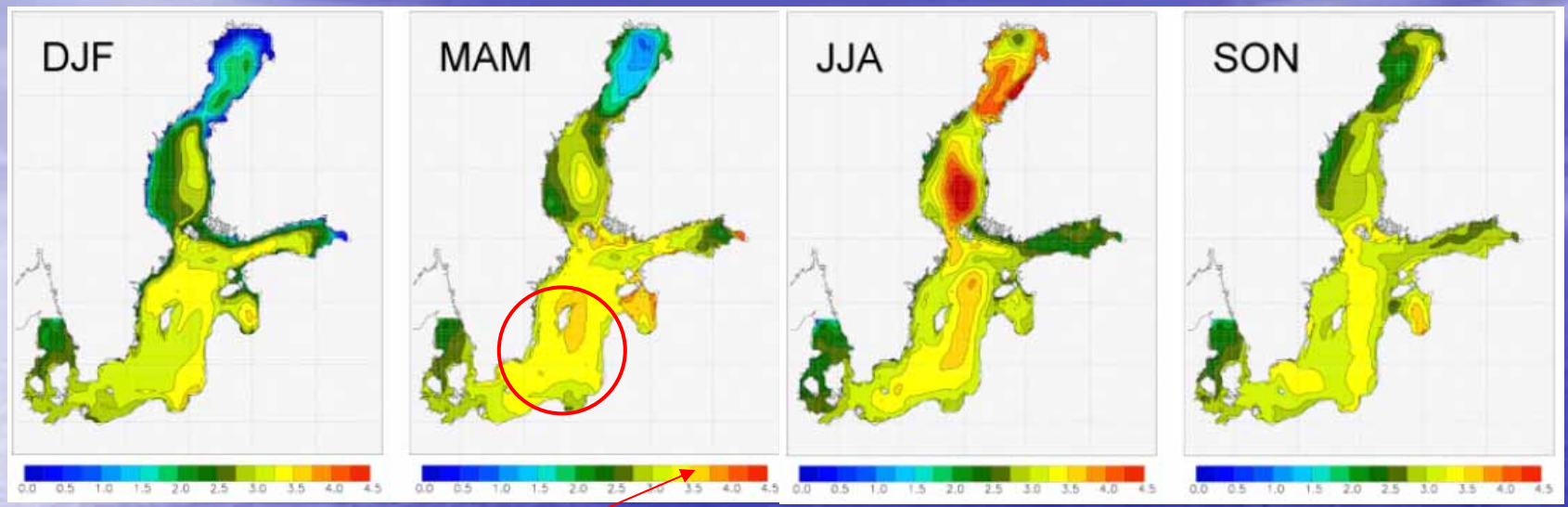
Can we recreate the dynamics of Baltic cod?

- Recreate past dynamics and inter-annual variability
- Variables and parameters make biological sense
  - fishing
  + climate recruitment
  +/- predator-prey, competition
- Residuals – normal, independent
- Hindcast simulations

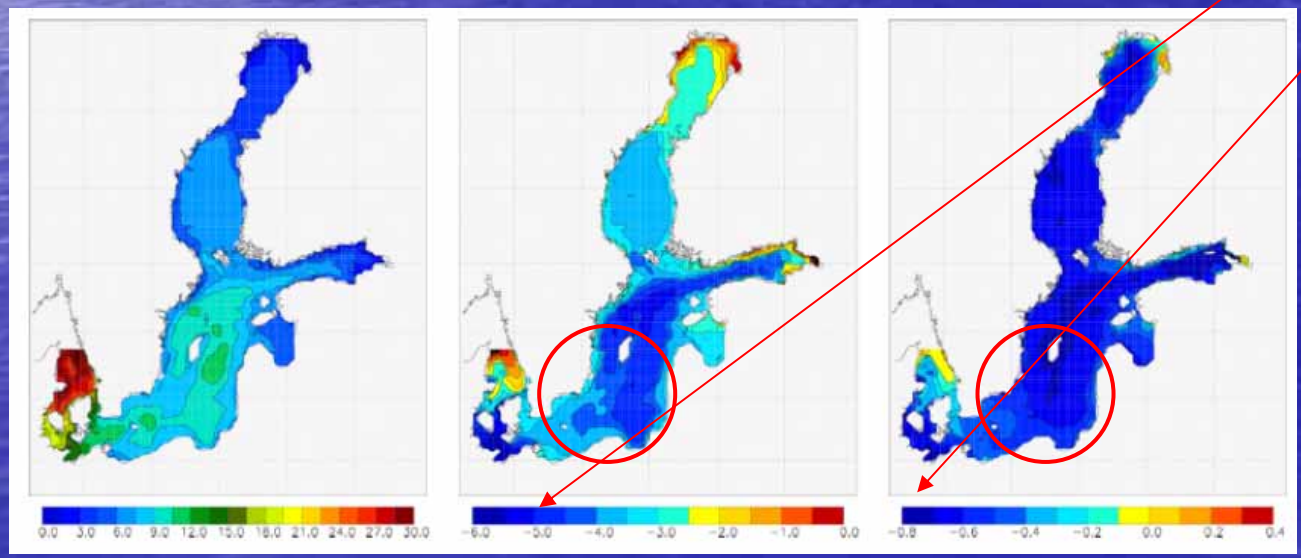


Observed (circles), fitted (black) and simulated (red)

Climate scenarios for the 21st century (BACC)



SST increase with 3.5 ˚C and Salinity decrease with 5 or 0.8 psu



From: MacKenzie et al. 2007

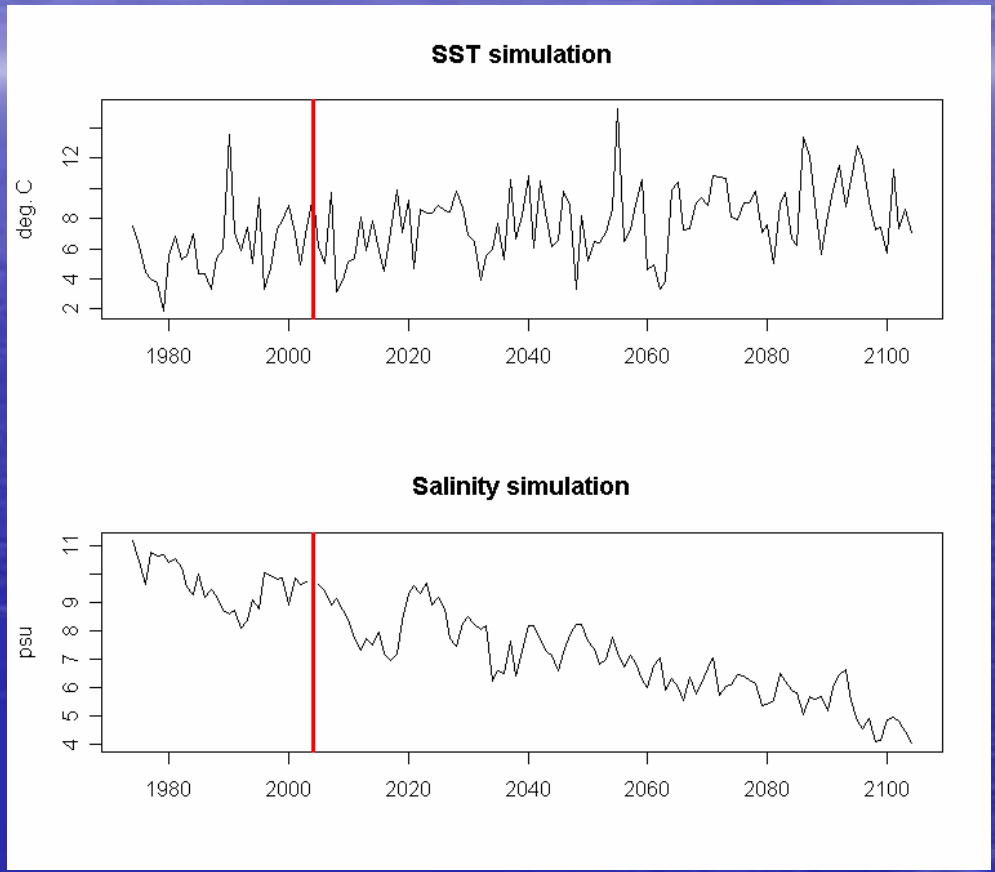
The Climate model (Ripa and Lundberg 1996)

Marine climate is “red shifted” (e.g. Steele 1985, Pimm and Redfern 1988)

x(t) = alpha*x(t-1) + sigma*randn

where:
-sigma = sqrt(Var_noise*(1-alpha^2))

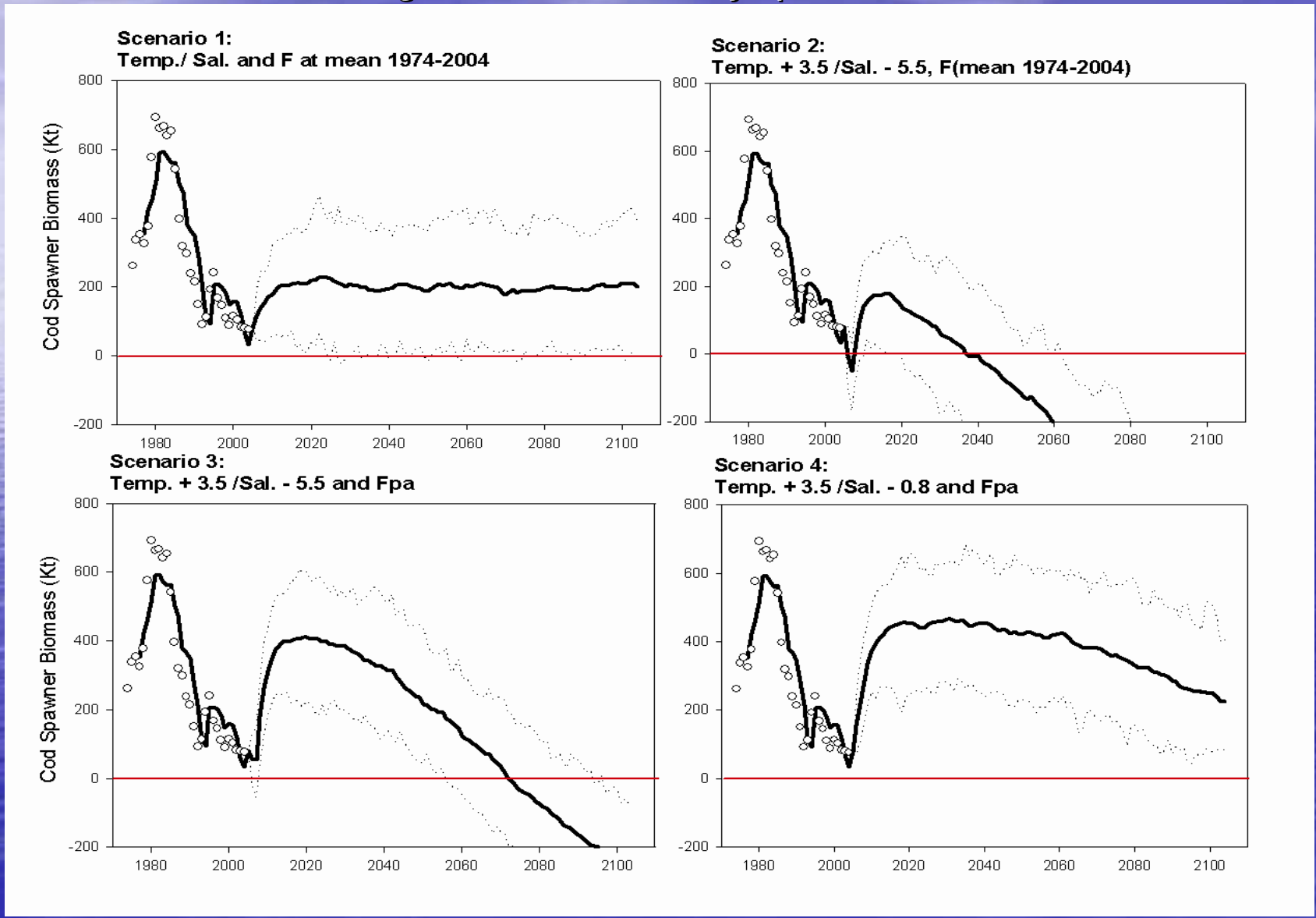
-alpha is the degree of autocorrelation
If = 0 “white”, If > 0 – “red”



= Construct future “red shifted” time series of SST and salinity using the alpha, mean and variance of past time series. Add climate trend by adding 3.5 ˚C or subtracting 0.8-5 psu over 100 years.

Can we predict the future of the Baltic cod?

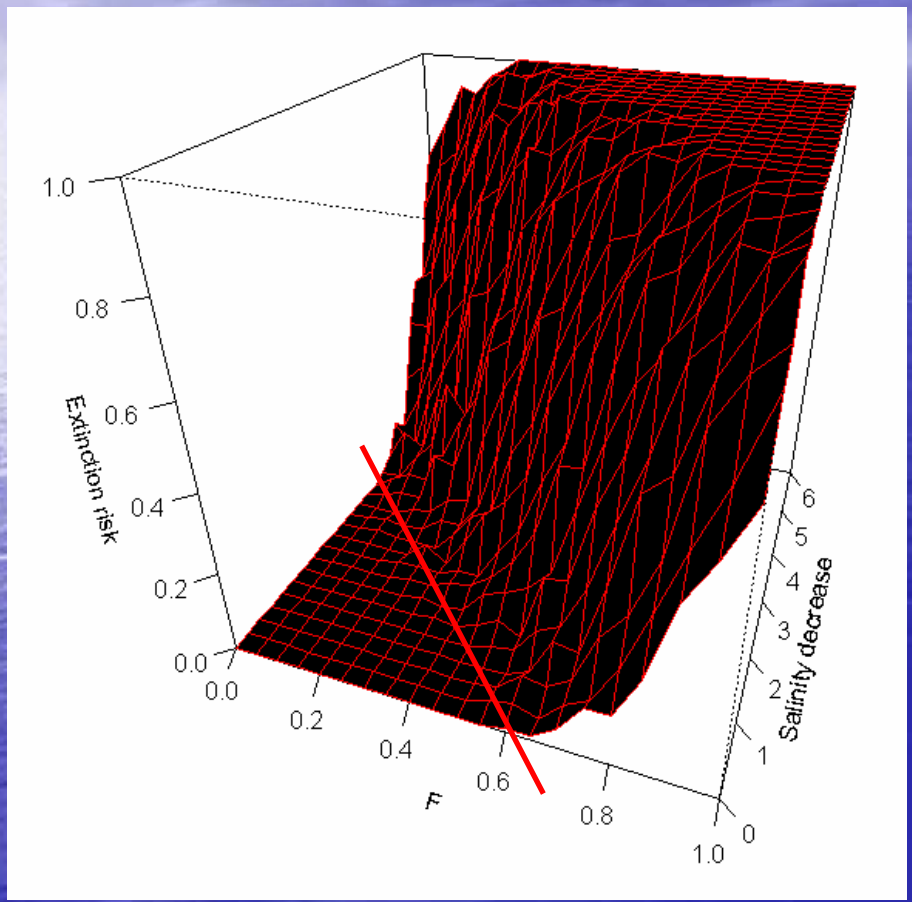
- Couple Climate model - Food web model. Climate and F scenarios.
  - 1000 runs including climate variability, process and observation noise

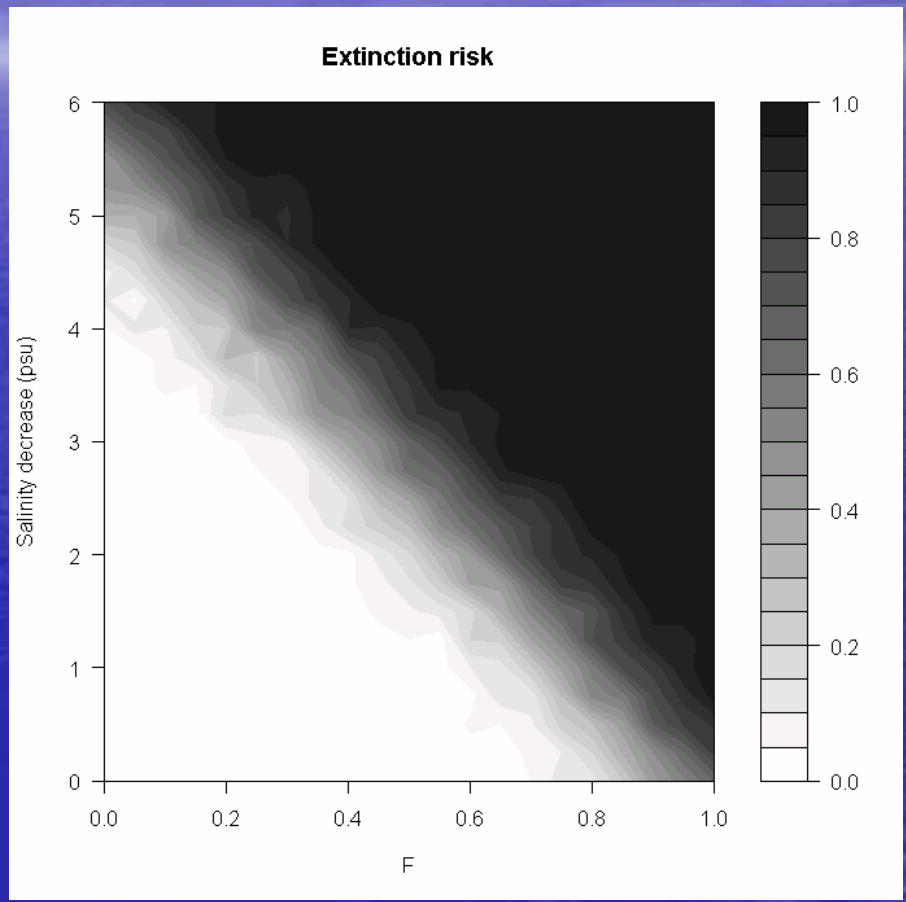


Can we prevent the Baltic cod from extinction?

Extinction risk analysis:

-100 simulations for every combination of salinity and fishing mortality (F). (~48 000)
Extinction risk = % of simulations where SSB<0.





-Current F_{pa} (0.6) not “precautionary” enough. Adjust F_{pa} according to climate conditions.

Conclusions and future perspectives

- We may provide probable forecasts for the future.
- Based on models integrating effect of species interactions, climate and fishing.
- Coupling food-web and climate models - future scenarios
- Using multiple simulations we should address uncertainty, including climate variability and stochastic processes
- Compare forecasts from several models – MSVPA, SMS, Ecopath, MAR(1) to arrive at robust predictions for the future.

Thank you!

“Prediction is very difficult, especially of the future.”
- Niels Bohr