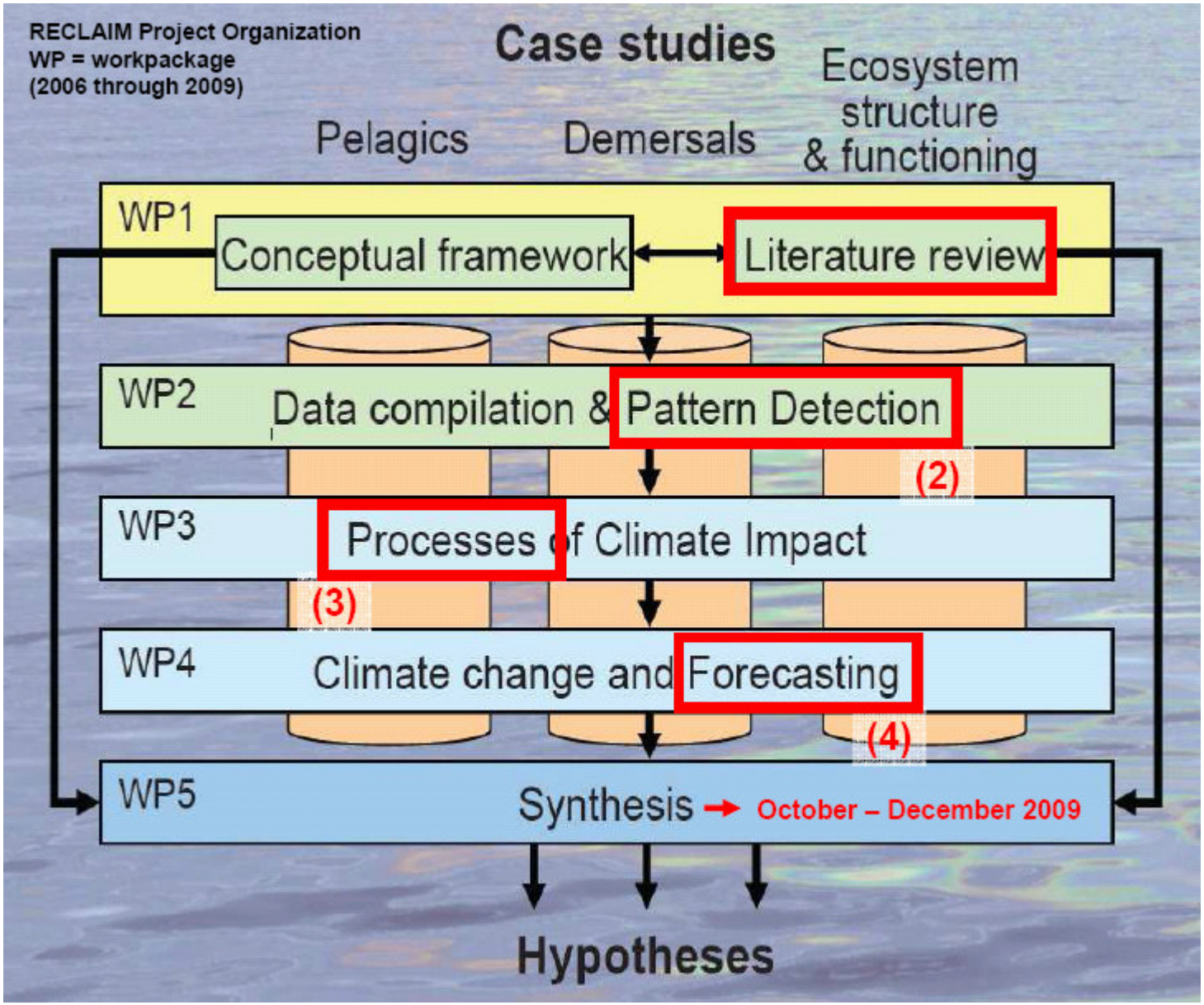
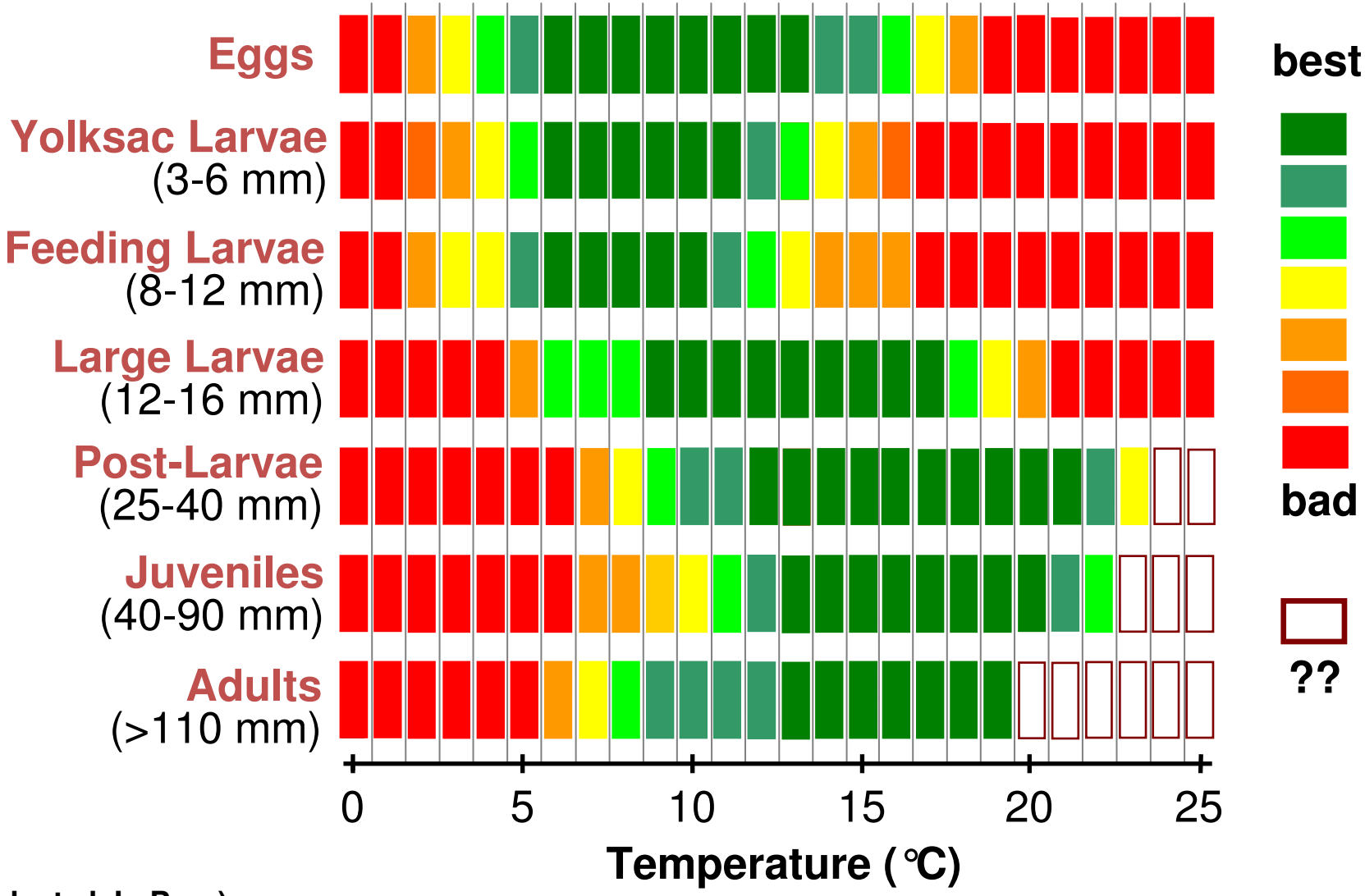
# Stefan Neuenfeldt DTUAqua


RECLAIM Project Organization
WP = workpackage
(2006 through 2009)
Case studies
Pelagics
Demersals
Ecosystem structure & functioning
WP1
Conceptual framework
Literature review
WP2
Data compilation &
Pattern Detection
(2)
WP3
Processes of Climate Impact
(3)
WP4
Climate change and
Forecasting
(4)
WP5
Synthesis
October – December 2009
Hypotheses

# Concepts

# Example: Critical Life Stage & Temperature

## Sprat life stage growth potential vs temperature (Baltic Sea)




(Peck et al. In Prep)

# Cod: Critical life stages in recruitment process

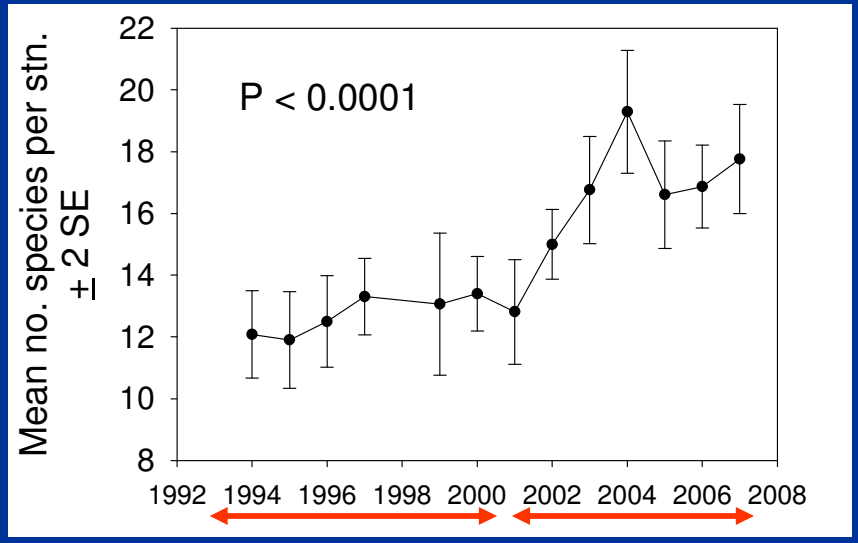
| Variable 1 | Variable 2 | Cod SD 25 |
|---|---|---|
| Egg production by SSB | egg production stage 1 | 0.78* |
| Egg production stage 1 | egg production stage 3 | 0.51 |
| Egg production stage 3 | larval abundance | 0.36 |
| Larval abundance | 0-group abundance | 0.80* |

*** correlation coefficient significant at p < 0.01**

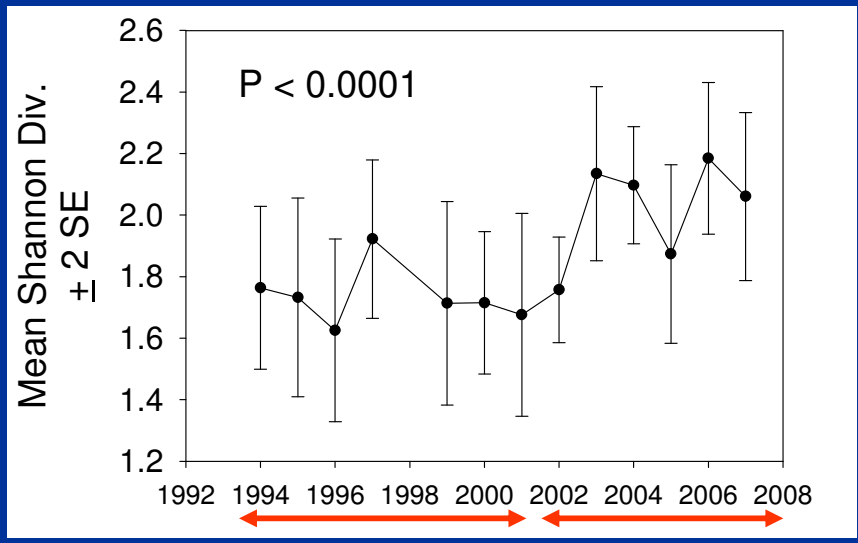
# Patterns

# Fish Biodiversity in the Kattegat, 1994-2007 (Research Fishery Surveys)

No. species



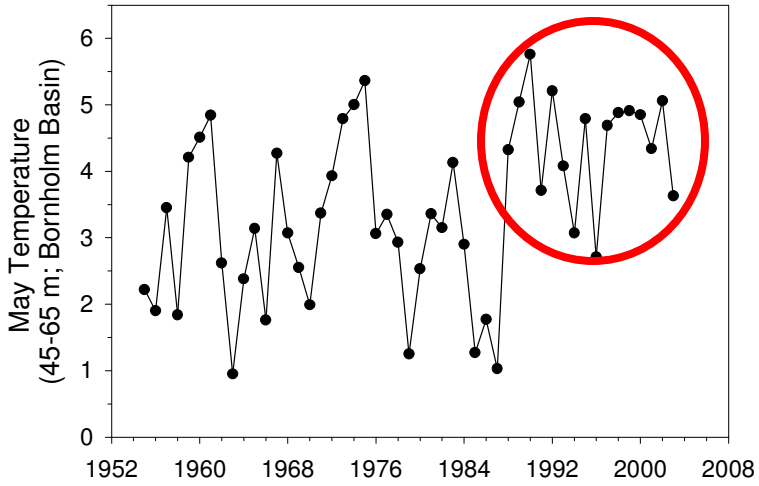

Shannon Diversity




Fish biodiversity has increased as temperatures have risen.

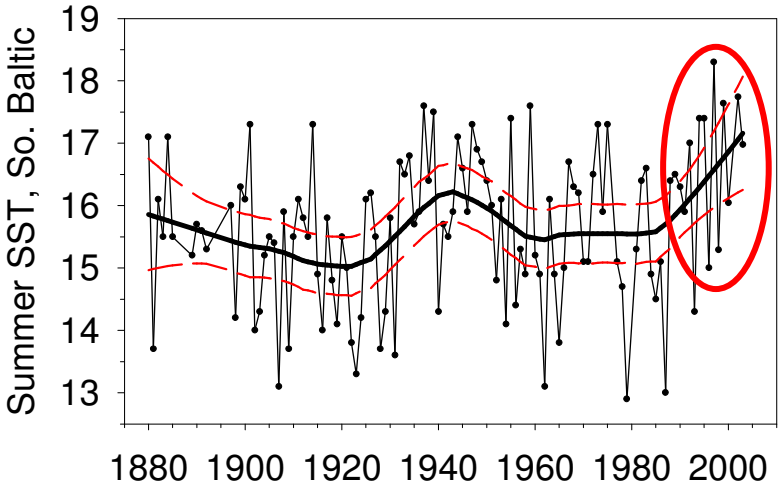
MacKenzie and Nielsen in prep.

Spring T at 45-65 m;
1955-2003




MacKenzie & Köster 2004:
Ecology

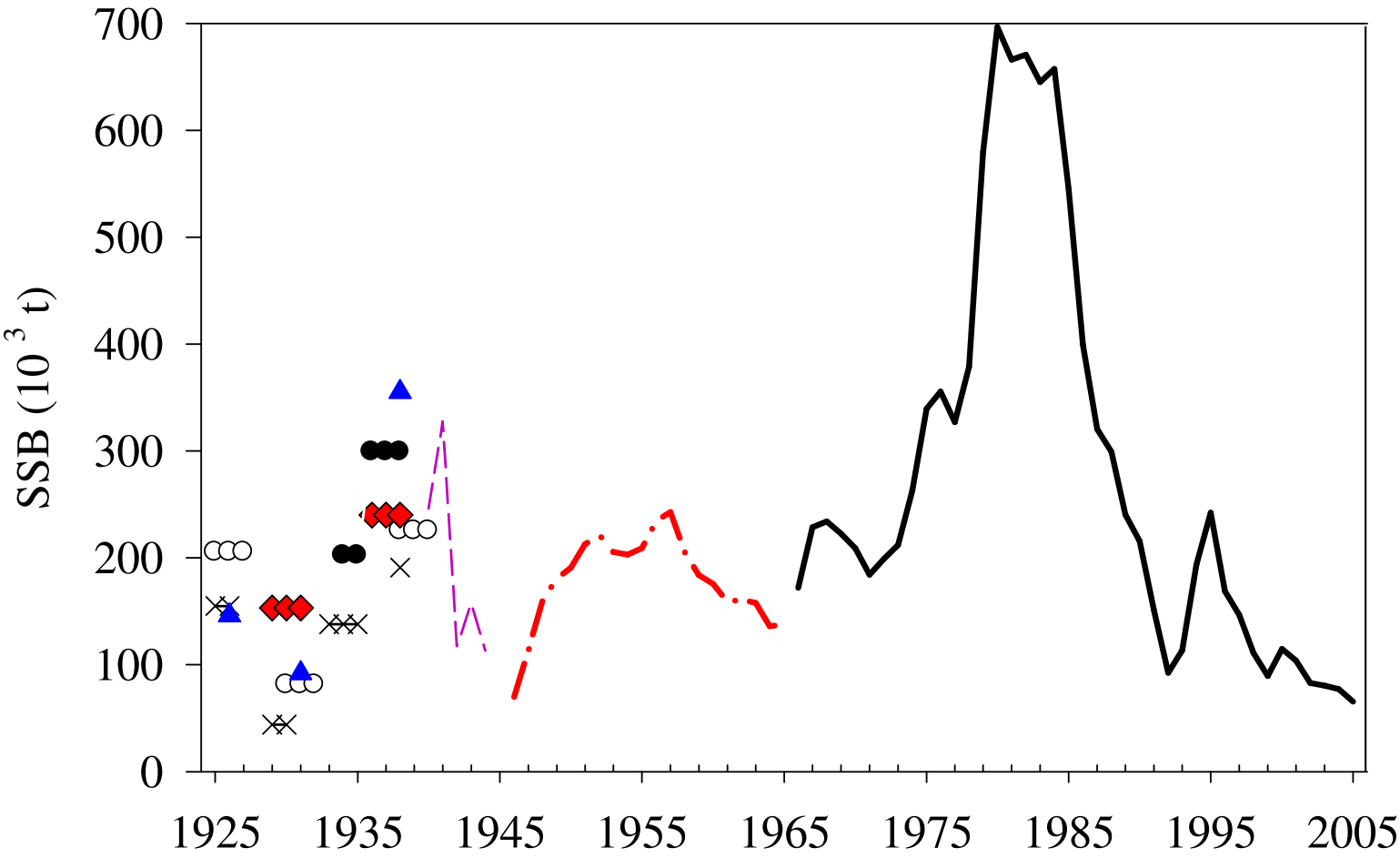
Summer SST
1880-2003




MacKenzie & Schiedek 2007:
Global Change Biol.

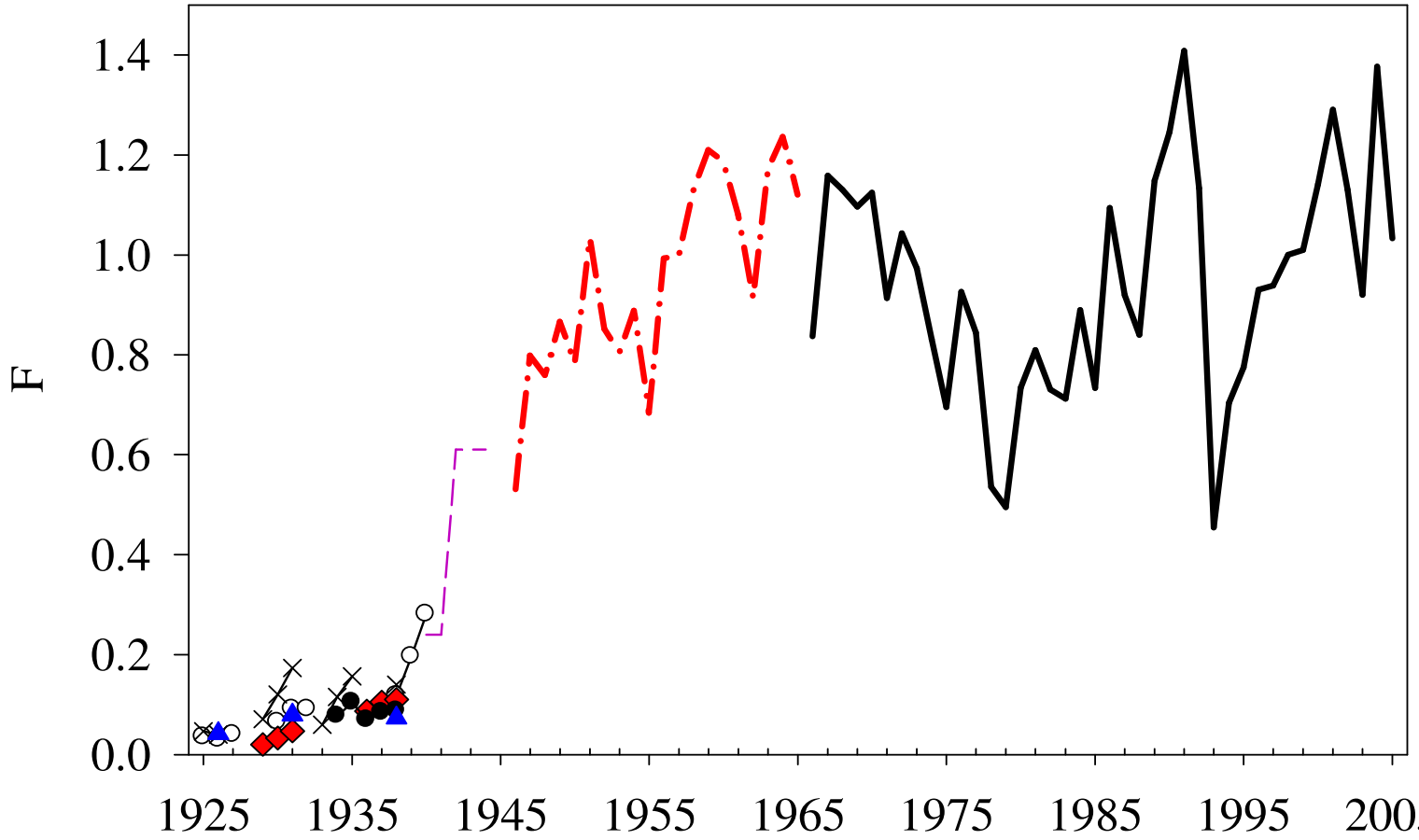
-warm conditions during 1990s-2000s

# Reconstruction of cod SSB:




Eero et al. (2009)

# Reconstruction of fishing mortality:

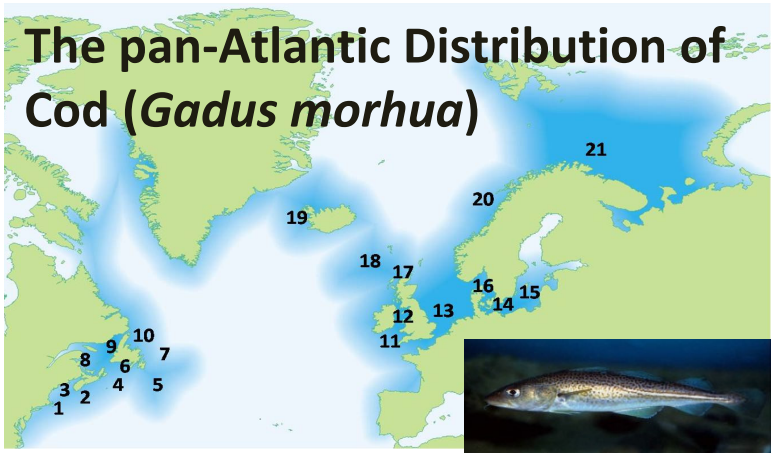


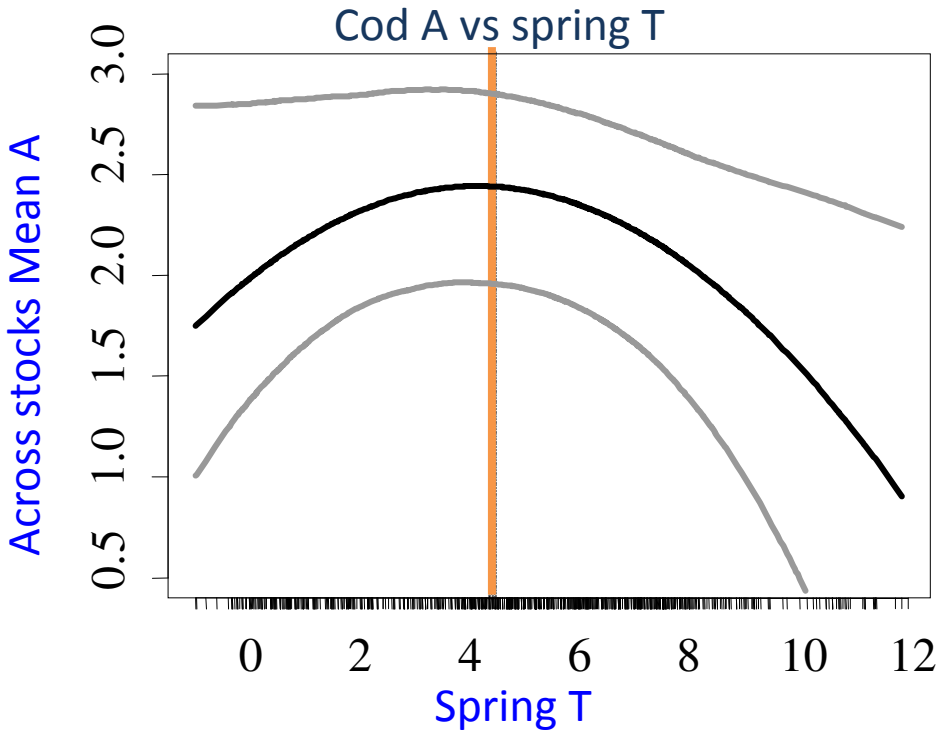

Eero et al. (2009)

# Processes

# Cod Maximum Reproductive Rate and Spring Temperature

Cod in North Atlantic:
-21 stocks



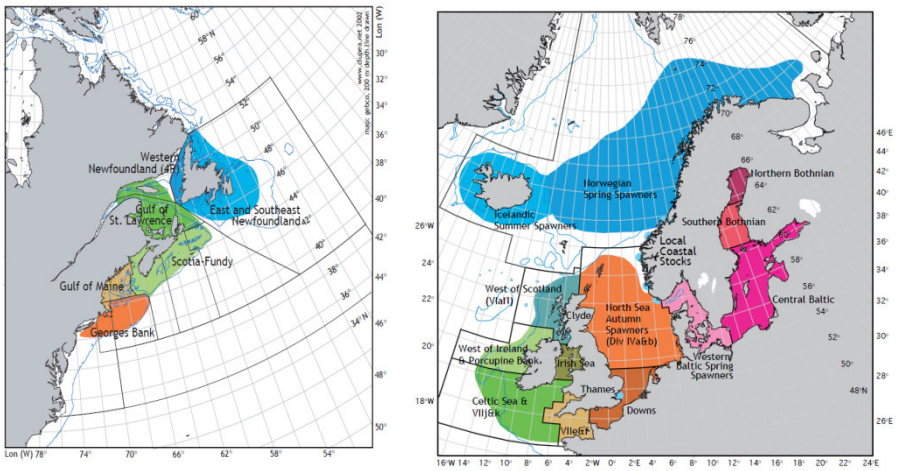

Positive effect up to ~4.5°C

Negative effect above ~6°C

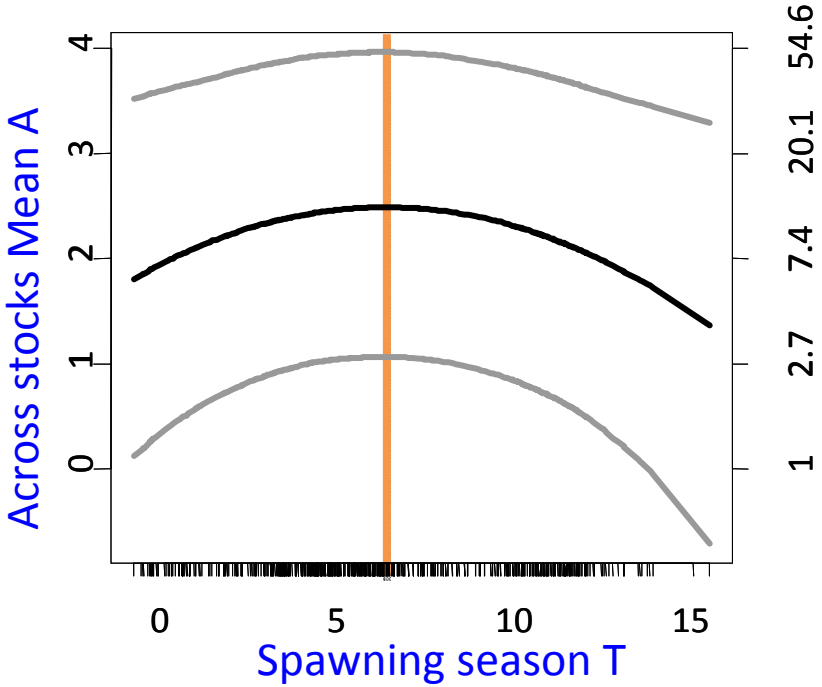
Mantzouni et al. Submitted
ICES J. Mar. Sci.

# Herring Maximum Reproductive Rate and Spring Temperature

-16 herring stocks in N. Atlantic




Herring A vs T




Positive effect up to ~6.5°C

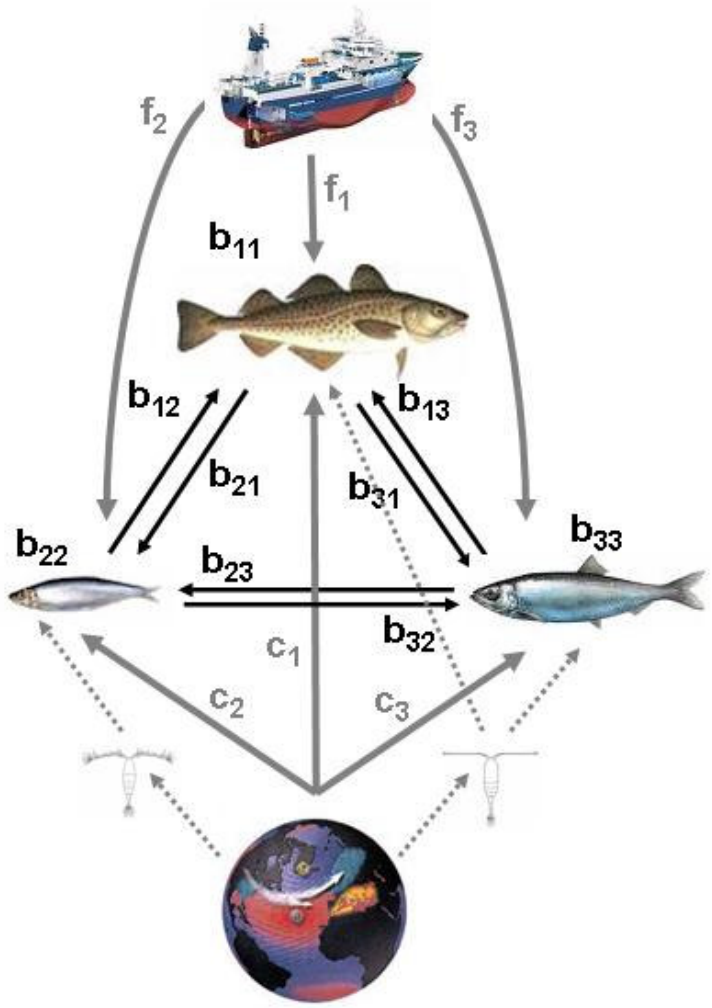
Negative effect above ~8°C

Mantzouni et al. ICES CM 2008 and In prep.

# Forecasting

# The BALMAR food-web model

- A. Species interactions: density dependence, predator-prey, competition
- B. Fishing effects: biomass, demography etc
- C. Zooplankton – growth and recruitment
- D. Climate effects – recruitment
- E. Bio-economics

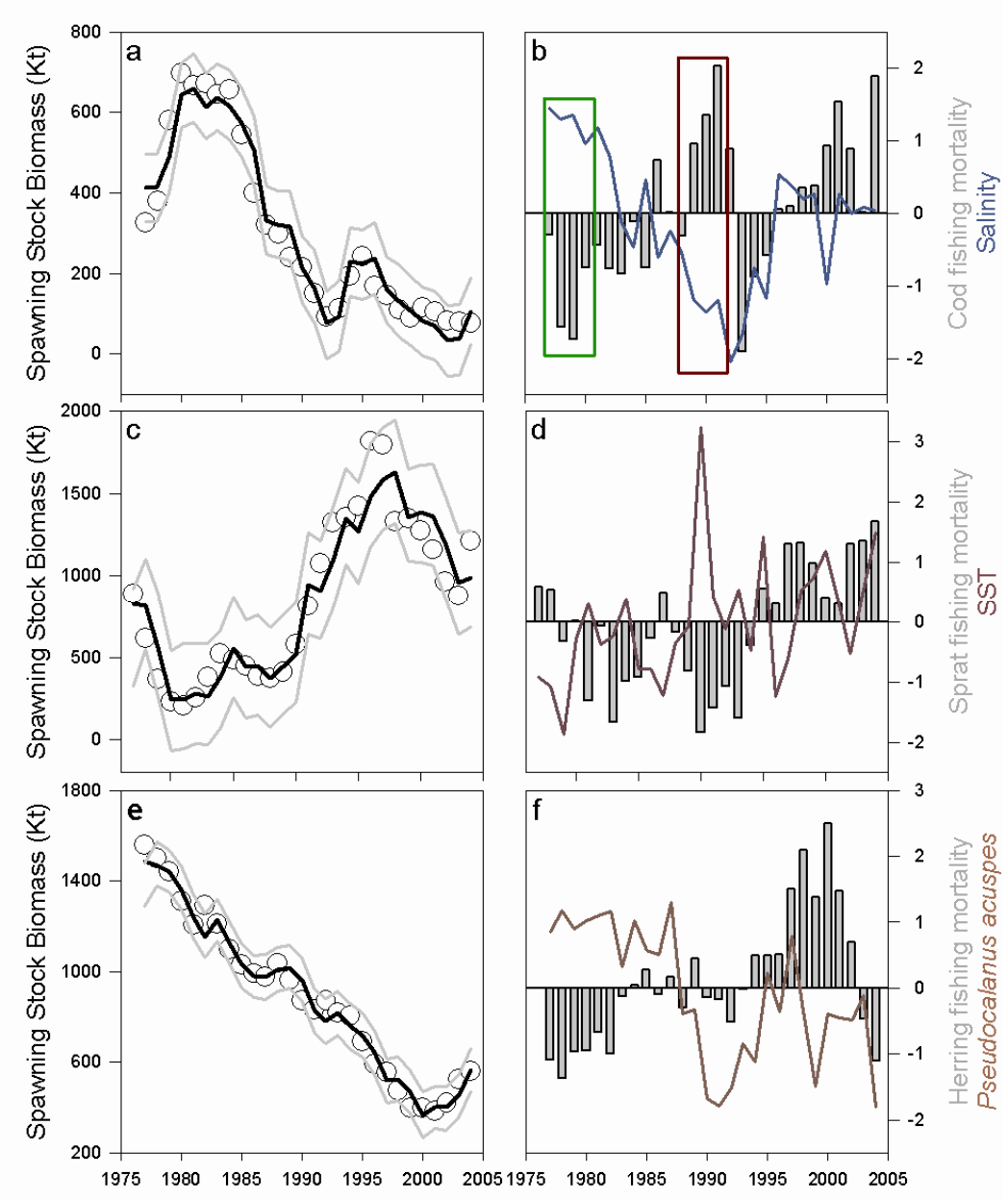



(Lindegren et al., PNAS 2009)

Validation

# Can we recreate the food-web dynamics?

- Recreate past dynamics and inter-annual variability of cod (a), sprat (c) and herring (e)
- Variables and parameters make biological sense
  - fishing
  + climate/zoopl. recruitment
  +/- predator-prey,
  -/- competition
- Residuals – normal, independent
- Hindcast simulations

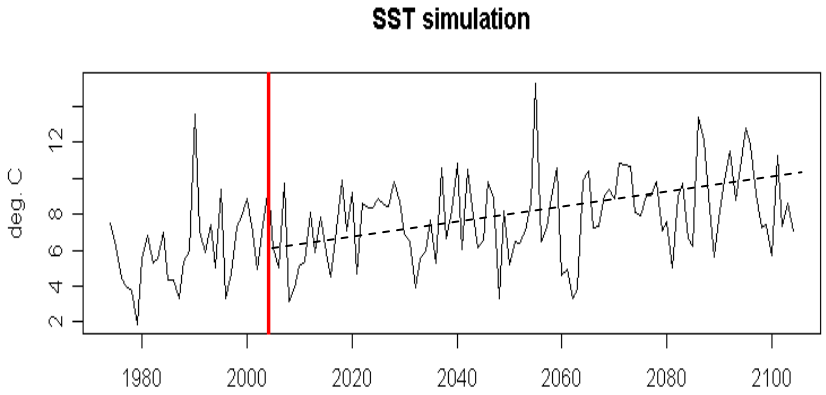


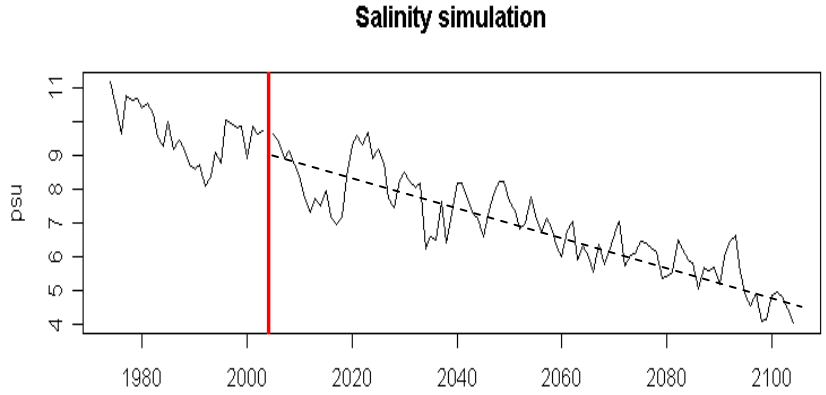

Observed (circles), fitted (black) and CI (grey)

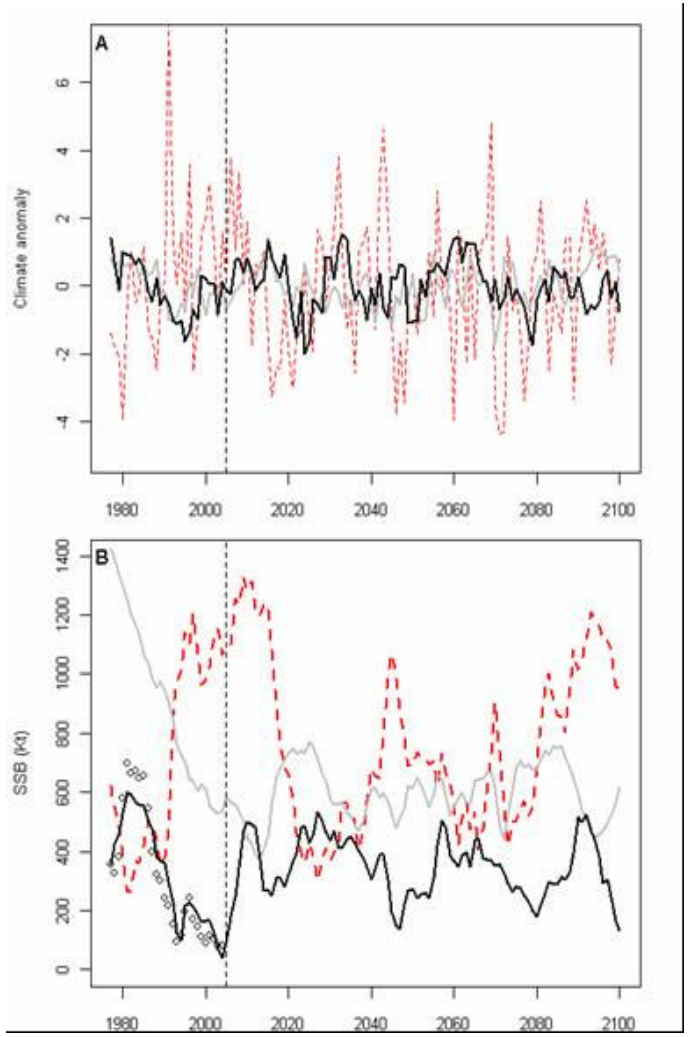
(Lindegren et al., PNAS 2009)

# Transient climate time series and food-web response

## - the AR(1) climate model (Ripa and Lundberg 1996)




Transient time series of SST and salinity are modelled using the autocorrelation, mean and variance of past time series. Add climate trend by adding 3.5 ˚C or subtracting 0.8/5 psu over 100 years.

# Future climate and management scenarios

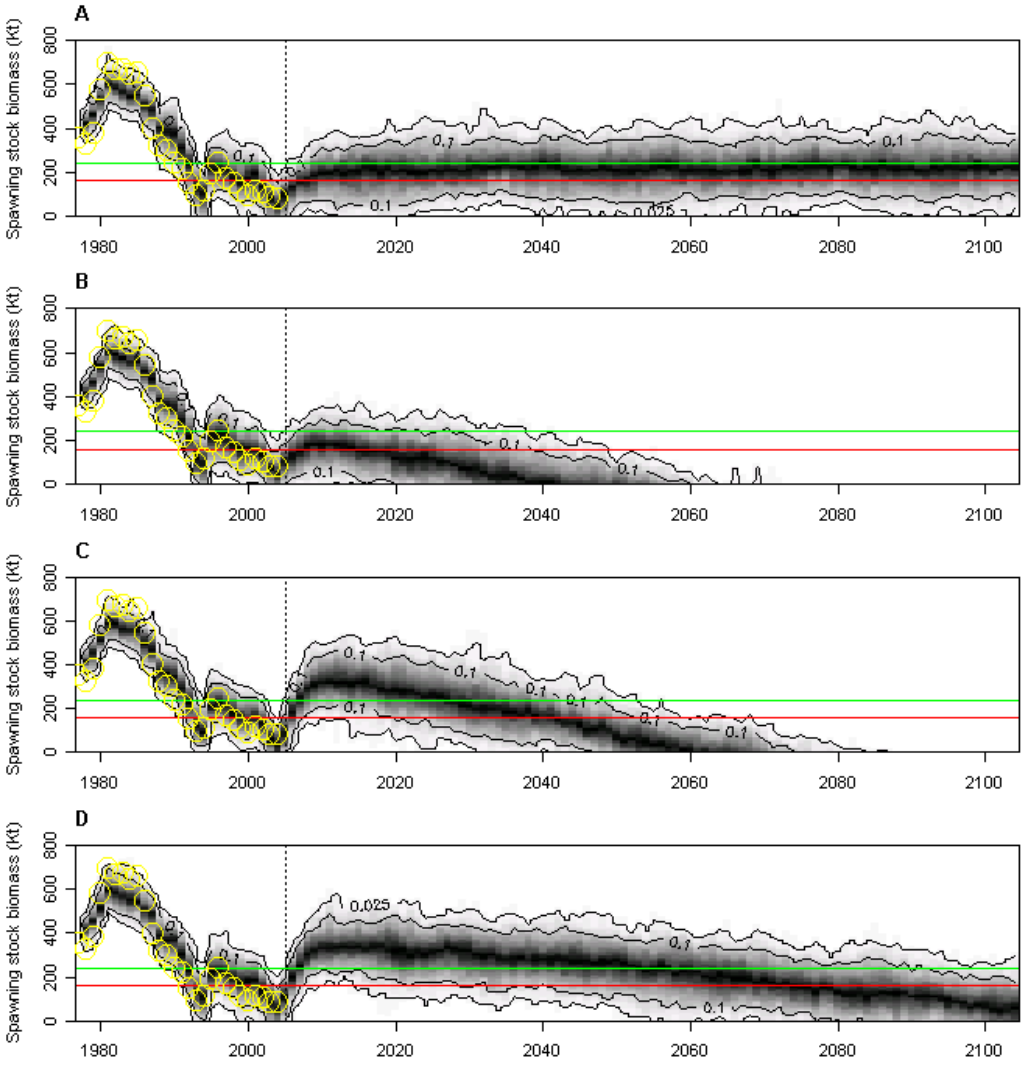
- Couple Climate model - Food web model. Climate and F scenarios.
  - 1000 runs including climate variability and stochastic noise

a. Status-quo F and climate

b. Climate change and F at mean

c. Climate change and $F_{pa}$ = 0.6

d. Climate change (psu -0.8), $F_{pa}$




Biomass reference levels: $B_{pa}$ (green) and $B_{lim}$ (red)

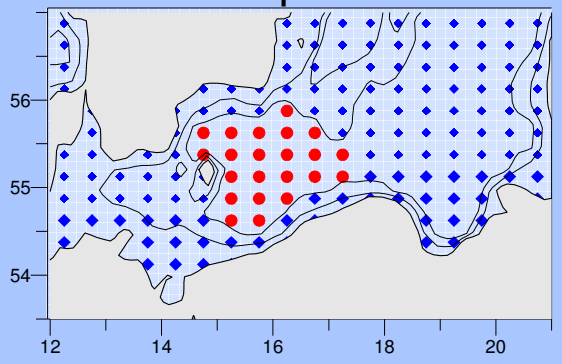
(Lindegren et al. in prep.)

# Synthesis

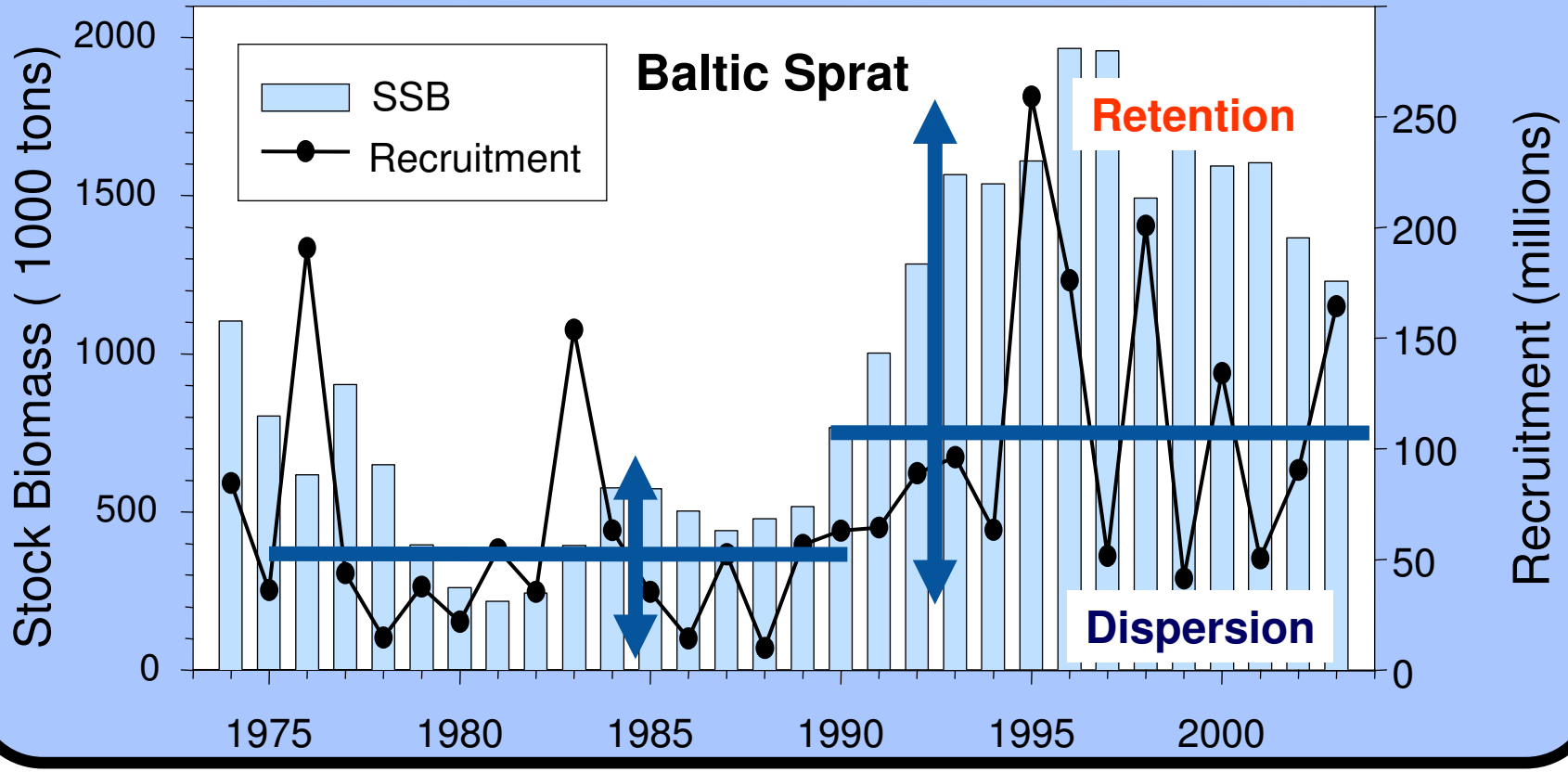
**2) Lagrangian transport model**

**1) Hydrodynamic Model (3d)**

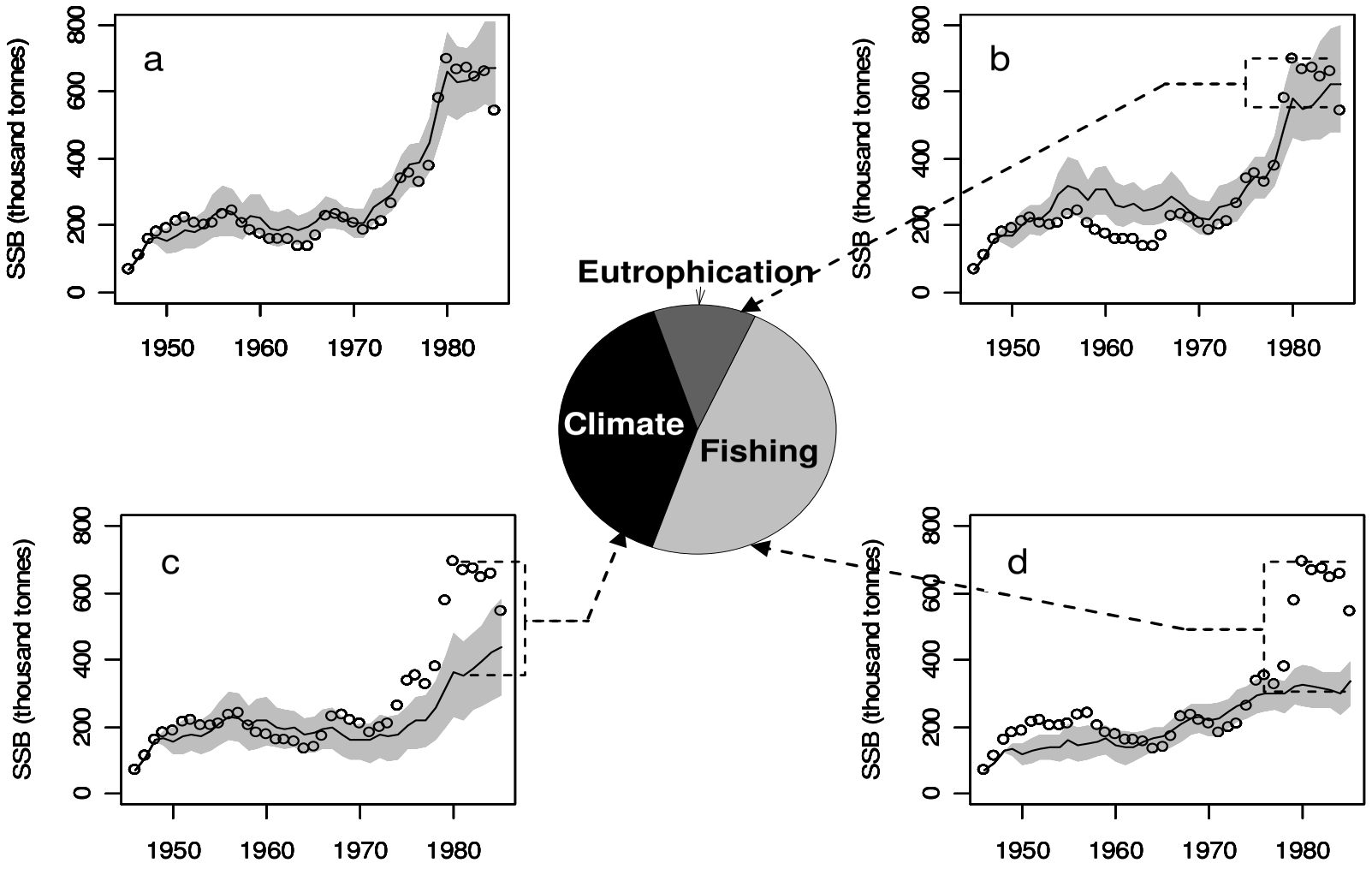
Bornholm Basin
Retention vs
Dispersion




**Model with SSB +T + Drift explains >70%**
**Recruitment variability in Baltic Sprat**
**(Baumann, Hinrichsen et al.)**

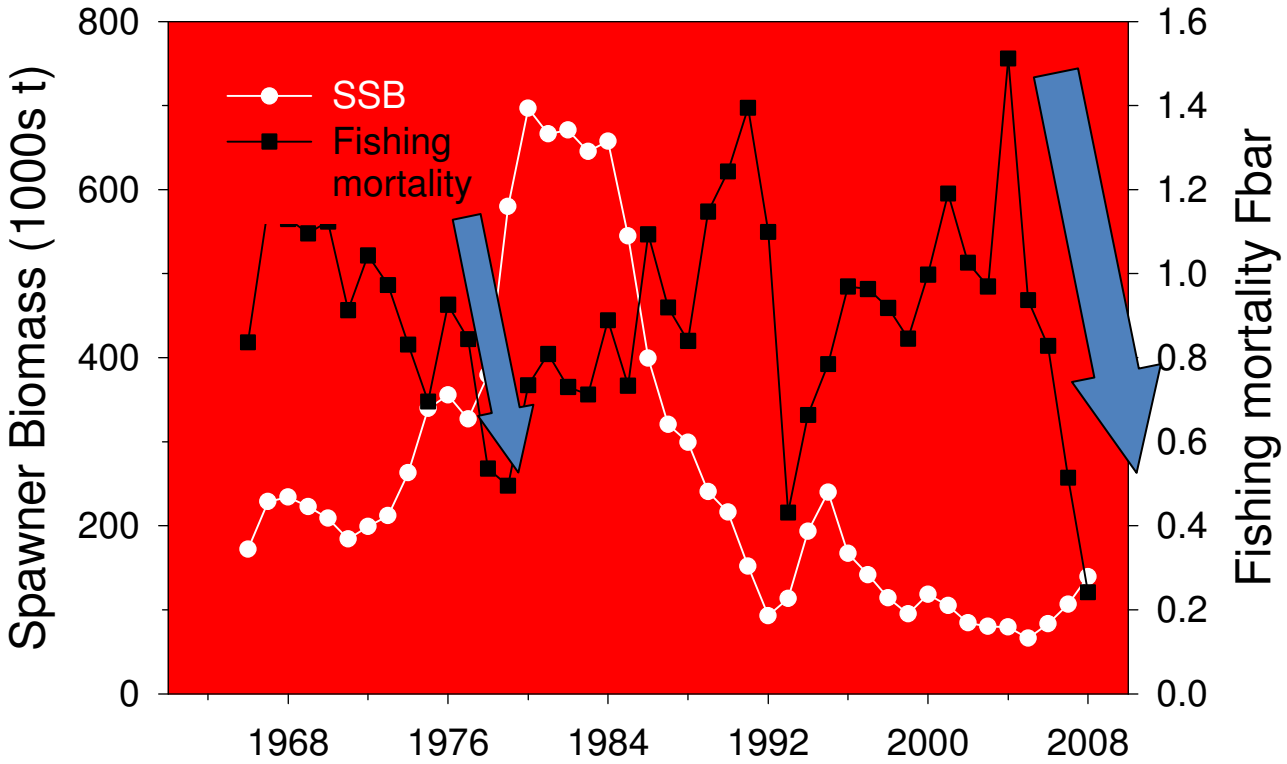


# Relative contributions of climate, fishing and eutrophication to the peak in cod biomass in the 1980s




Eero et al. (2009)

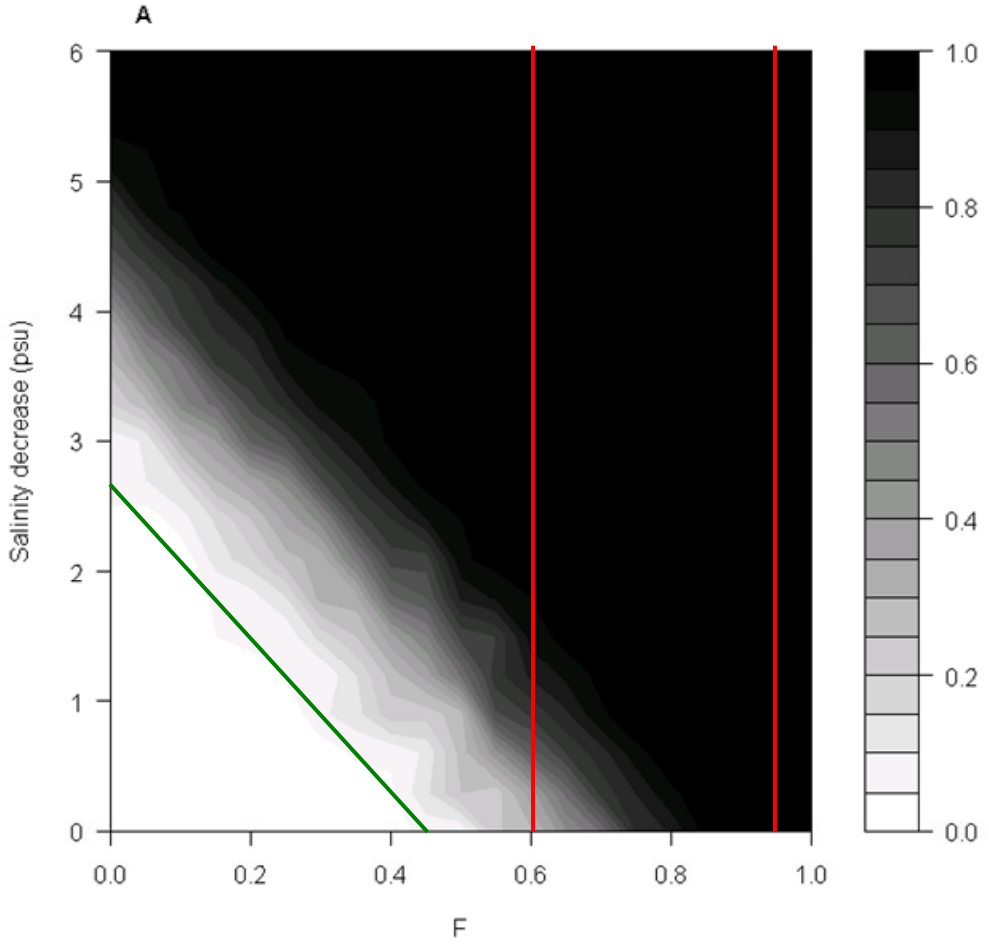
Fishing mortality has decreased:




ICES 2009

# Recovery potential of Baltic cod

-1000 simulations for every combination of salinity and fishing mortality (F)
Probability of "collapse" = % of simulations where SSB<160 000 t ($B_{lim}$).




(Lindegren et al. in prep.)

- Reference points: $F_{pa}$ (0.6) and $F_{lim}$ (0.96) not "precautionary" enough.
- EC recovery plan: target reference point F=0.3.
- We should adjust F according to climate conditions and species interactions

# Conclusions

Climate and fishing are both important for the population development of the Baltic cod and sprat stocks

Good environment and low to moderate fishing intensity have to occur **simultaneously** for good productivity

# **F**orage fish inter**ACT**ion**S**

*To what degree does the strength of the impact of forage fish on the Baltic Sea food web differ between sub-systems and how do these regional differences influence advice on ecosystem-based management?*

*How important are density-dependent feedback loops between forage fish, their prey and predators and how do these influence ecosystem stability?*

*What are the economic costs and benefits (for fisheries and other ecosystem services) of changes in the management of Baltic Sea forage fish, taking into account interactions with top predators (cod and seals) and climate induced ecosystem changes?*