DEVOTES
www.devotes-project.eu
Development of innovative tools for understanding marine biodiversity and assessing good environmental status

Long-term trends in the biomass of commercial fish in the North Sea
fishing impacts, predator-prey interactions and temperature change

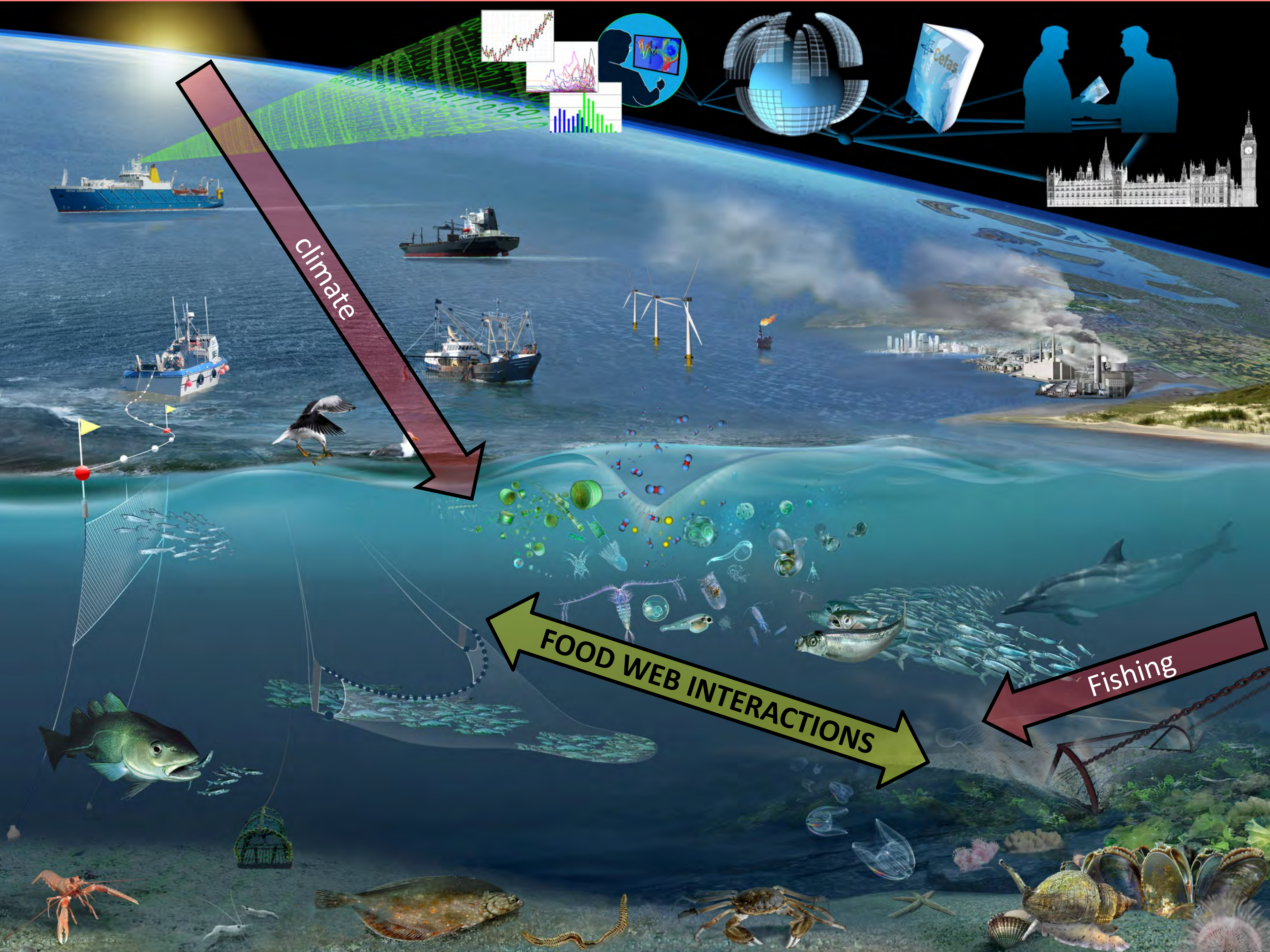
S10 Forecasting climate change impacts on fish populations and fisheries
Thursday 26th March 2015

Christopher Lynam
Pierre Helaouet
Christian Möllmann
Marcos Llope
Roddy Mavor
Georgia Bayliss-Brown
Nils-Christian Stenseth

Centre for Environment Fisheries & Aquaculture Science
fizzyfish

PICES Symposium on 'Effects of climate change on the world's oceans'

SEVENTH FRAMEWORK PROGRAMME



climate
FOOD WEB INTERACTIONS
Fishing

Motivation

"*Forecasting climate change impacts on fish populations & fisheries*"

Requires a strong understanding about the dynamics of the system

Why?

- To give strategic advice on potential response of the system to pressure (climate, fishing, …)
- Evaluate potential management strategies
- Explore trade-offs and sensitivities

How ?

- Modelling – which can take a number of forms

Statistical approach

Empirical - data driven combined with expert guidance

Use evidence to determine key signals in the data and capture the temporal dynamics of the system

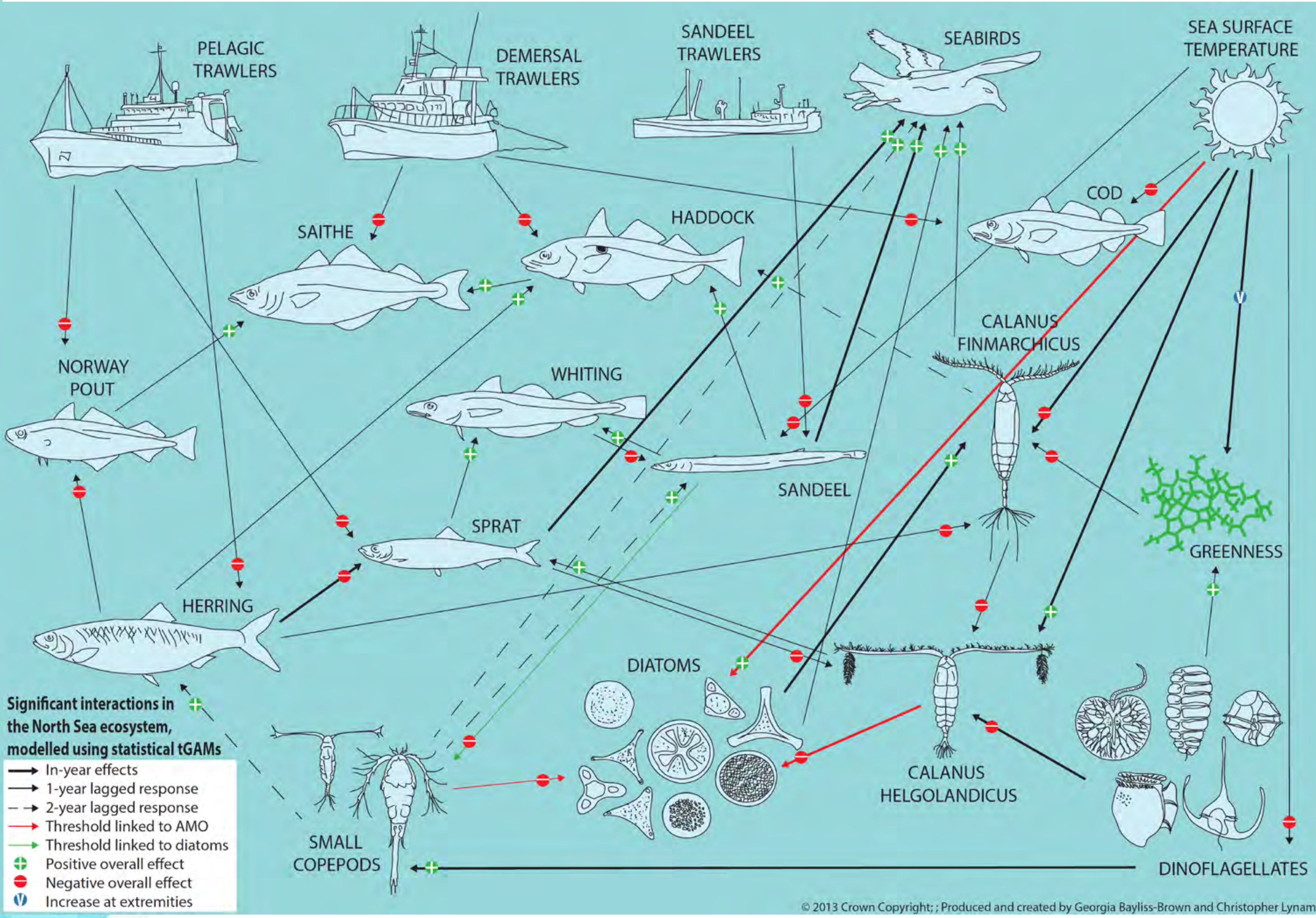
- Bottom-up control (driven by temperature)
- Top-down control (fishing pressure down)

Requires a lot of data

- Long time-series data (1964-2010)
  - Sea surface temperature (Hadley centre plus AMO)
  - Phytoplankton abundance (SAHFOS)
  - Zooplankton abundance (SAHFOS)
  - Fish stock biomass and fishing mortality (ICES)
  - Marine bird breeding success (JNCC, 1989-2010)

- Statistical modelling:
  - Generalised Additive Model (GAM)
  - threshold-Generalised Additive Model (tGAM)
- Expert knowledge of the system

interaction web



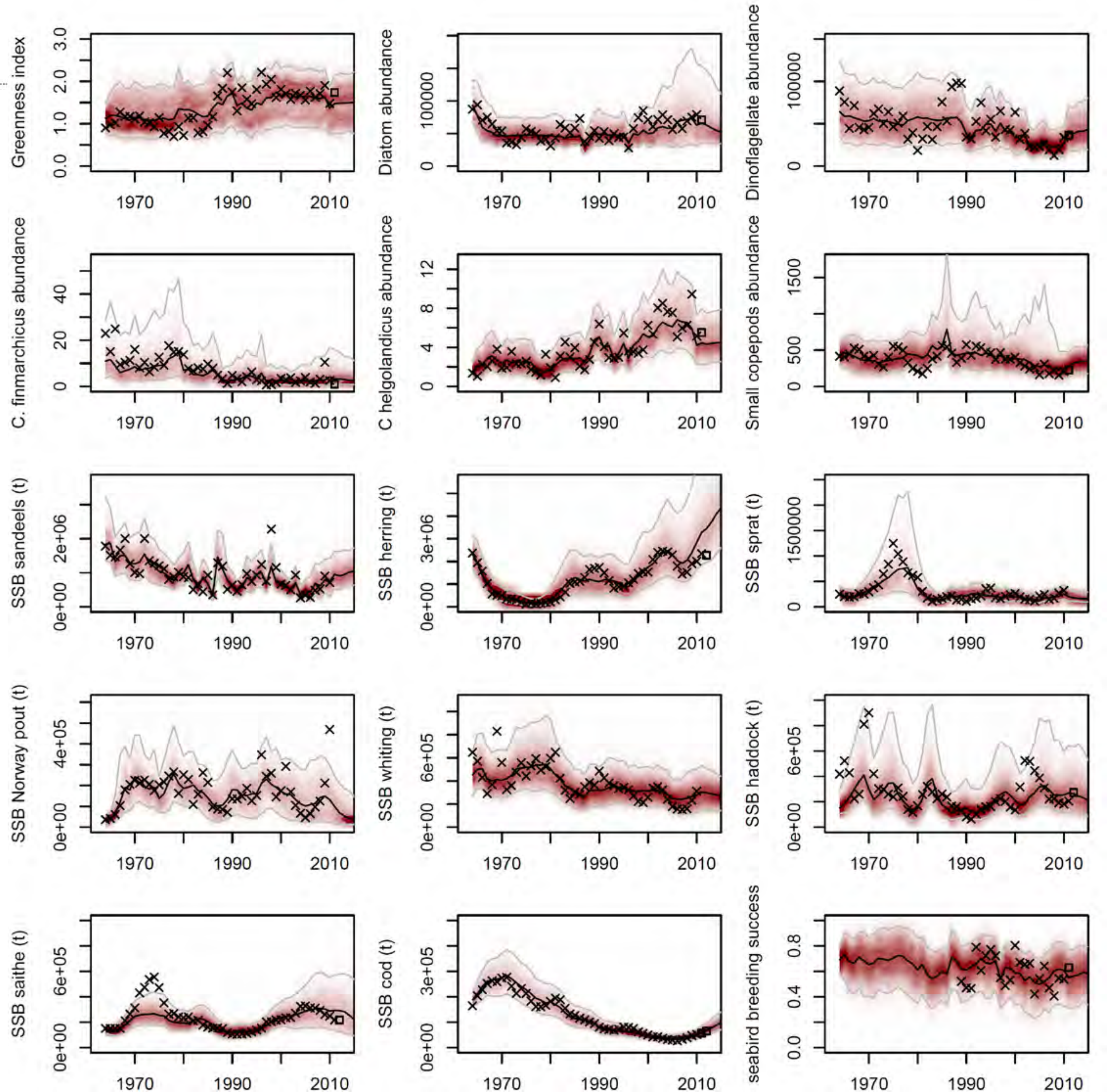
simulations

Recreated solely from initial conditions for plankton and fish in 1964

+ time-series of fishing mortality by stock

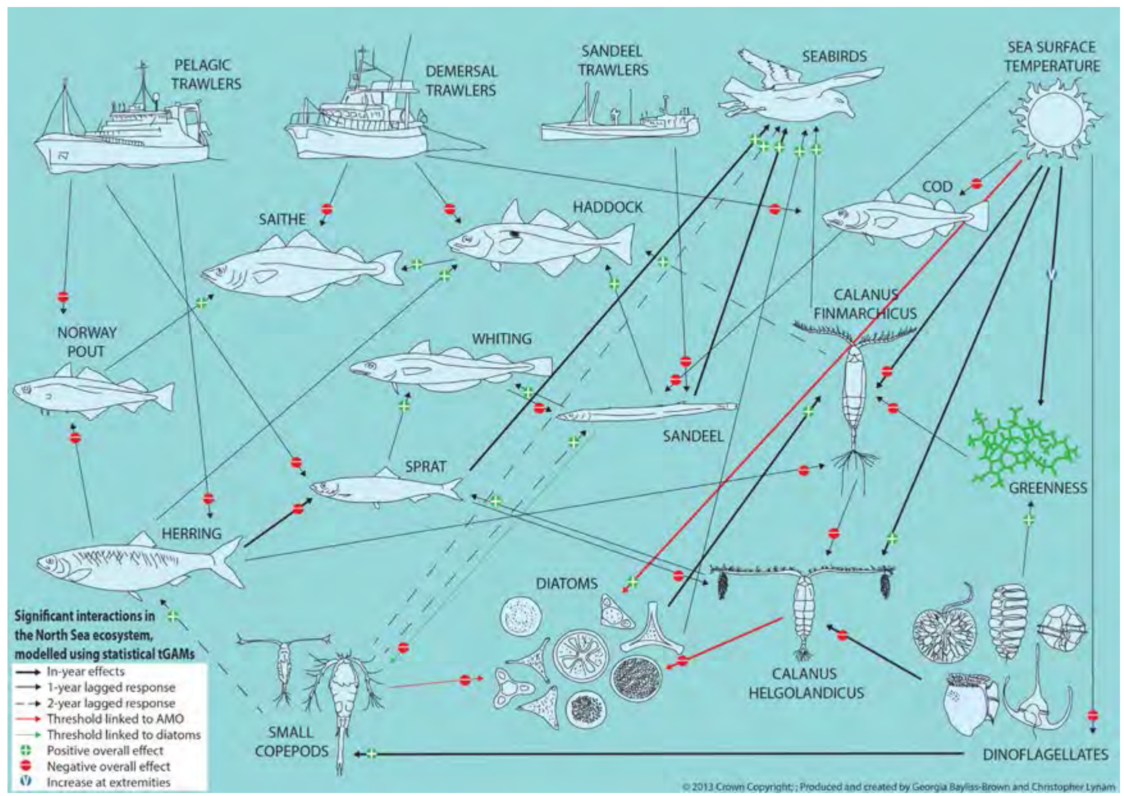
+ SST

+ AMO



How generate simulations non-mechanistically?

- Behind each arrow in the interaction web is a significant relationship modelled using either GAM/tGAM



Example – GAM fitting to the SSB of saithe

saithe in year z

~ *intercept*

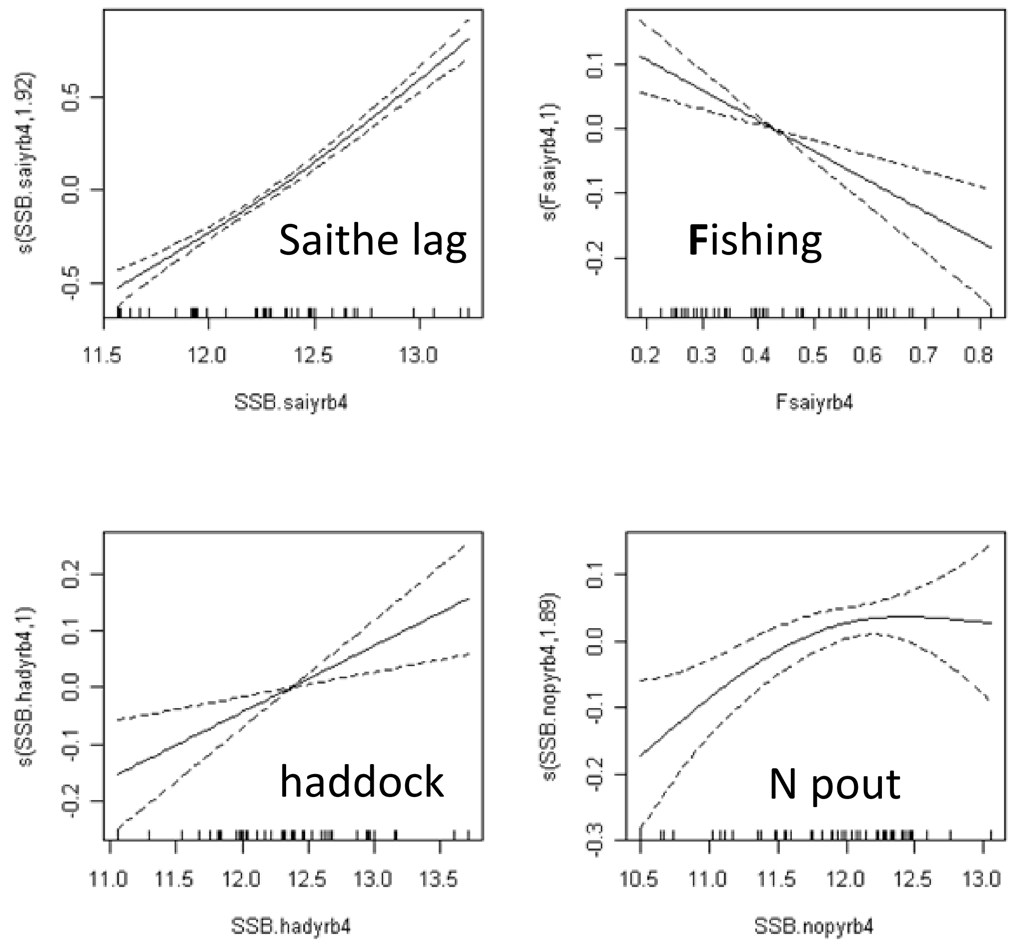
\+ s(Fishing mortality year z-1)

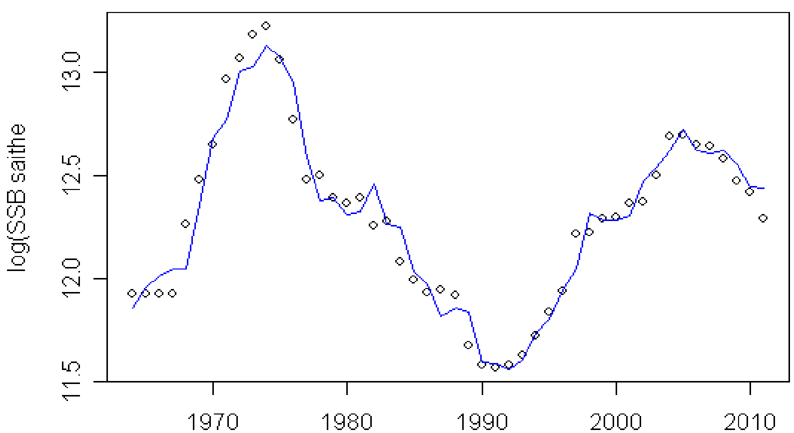
\+ s(saithe year z-1)

\+ s(haddock year z-1)

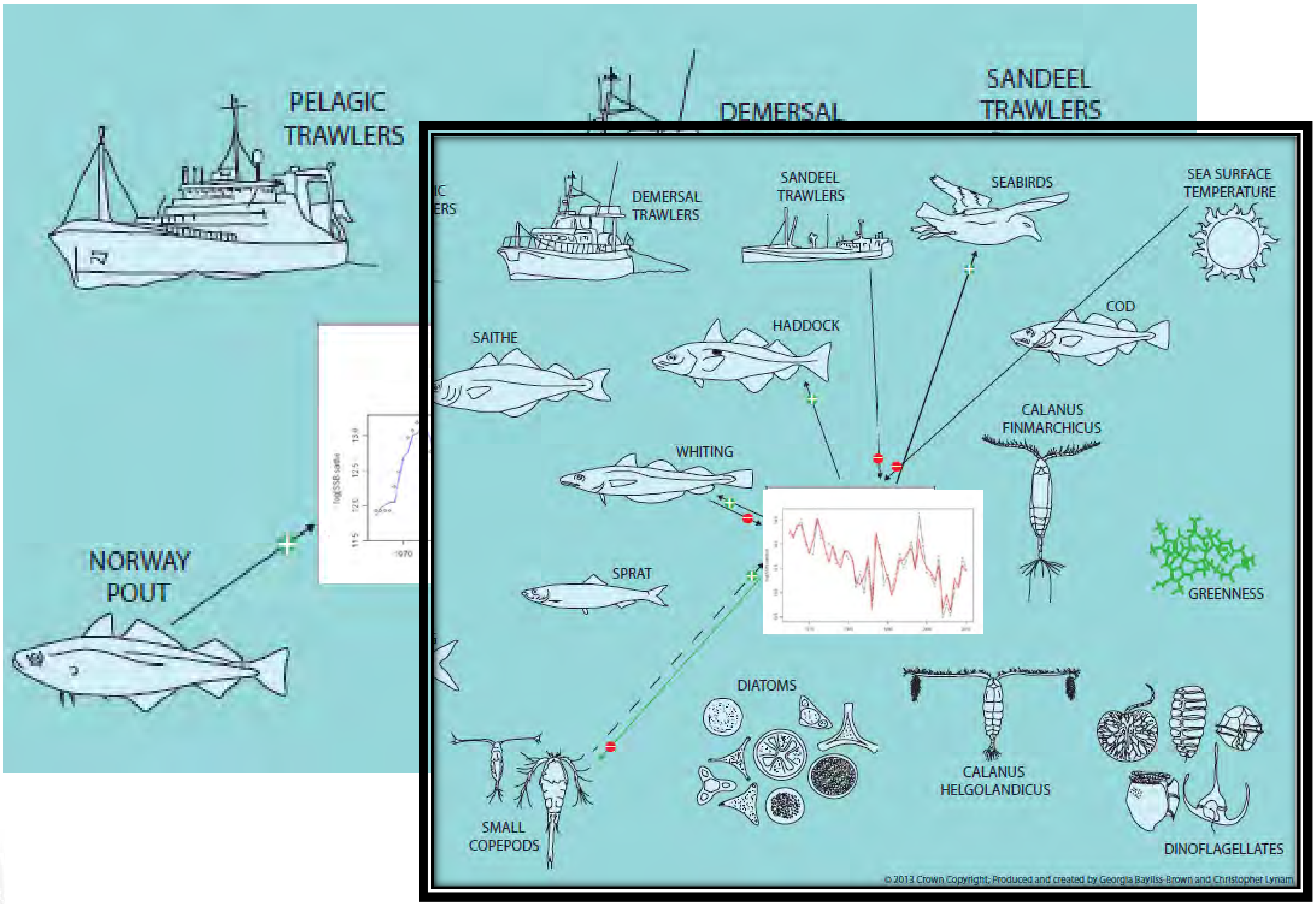
\+ s(N. pout year z-1)

\+ ε(0,1)

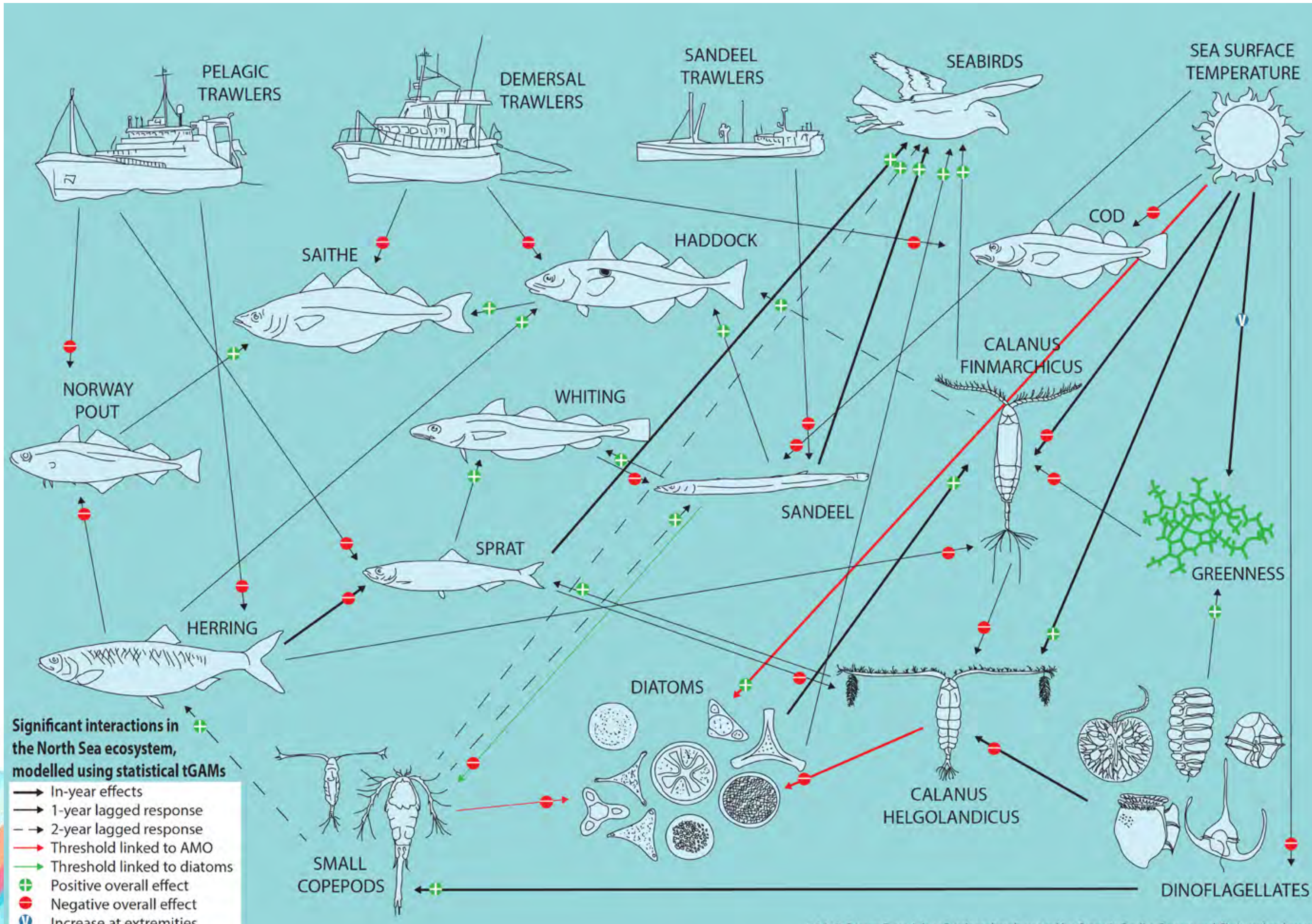




Repeat previous step separately for each component e.g. sandeels



How important are indirect effects/cascades?



Proportion of deviance explained by groups

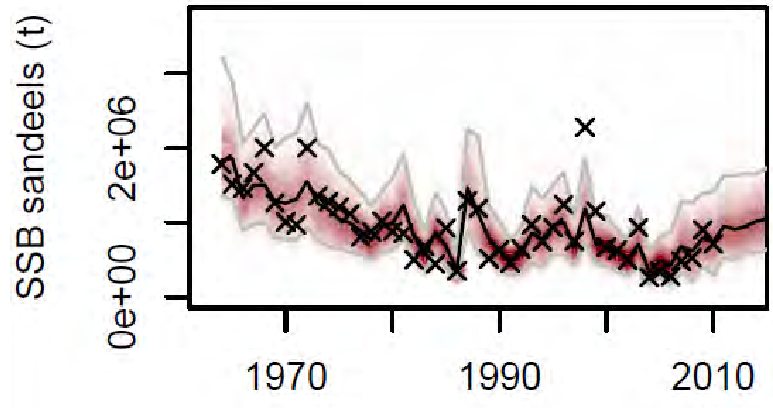
Bottom up

Top down

	Response variable	% deviance explained by regression and % split by groups in the model						
		All terms	Pop-lag	Climate (SST)	Phyto-plankton	Zoo-plankton	Fish species	Fishing mortality
	Greenness	81	**49**	29	**2**	-	-	-
	Diatoms	67	**42**	**11**	-	14	-	-
	Dinoflagellates	54	**29**	*25*	-	-	-	-
	C. helgolandicus	79	-	**28**	*10*	29	*12*	-
	C. finmarchicus	70	-	*22*	37	-	*11*	-
	Small copepods	79	**33**	-	**39**	-	*8*	-
Key species	Sandeel	87	**17**	*18*	-	11	*4*	*37*
Key species	Herring	97	**75**	-	-	**2**	-	*20*
	Sprat	87	**38**	-	-	**4**	*39*	*6*
	Norway pout	76	44	-	-	-	26	*6*
	Haddock	83	55	-	-	**4**	**15**	*10*
	Saithe	95	**55**	-	-	-	**28**	*12*
	Whiting	77	**41**	-	-	-	**36**	-
	Cod	99	**66**	*26*	-	-	-	*6*
	Seabirds	80	-	-	**7**	**51**	**22**	-

Building simulations

submodels (regressions) should be linked sufficiently to form a web



- Starting from the initial conditions 1964
- use F, SST and AMO values to predict 1965 values
  - include noise from residuals from GAMS/tGAMS (resampling)
- For the next time step (1966), use set of predictions from above plus new F, SST and AMO values ….
- Repeat for length of drivers

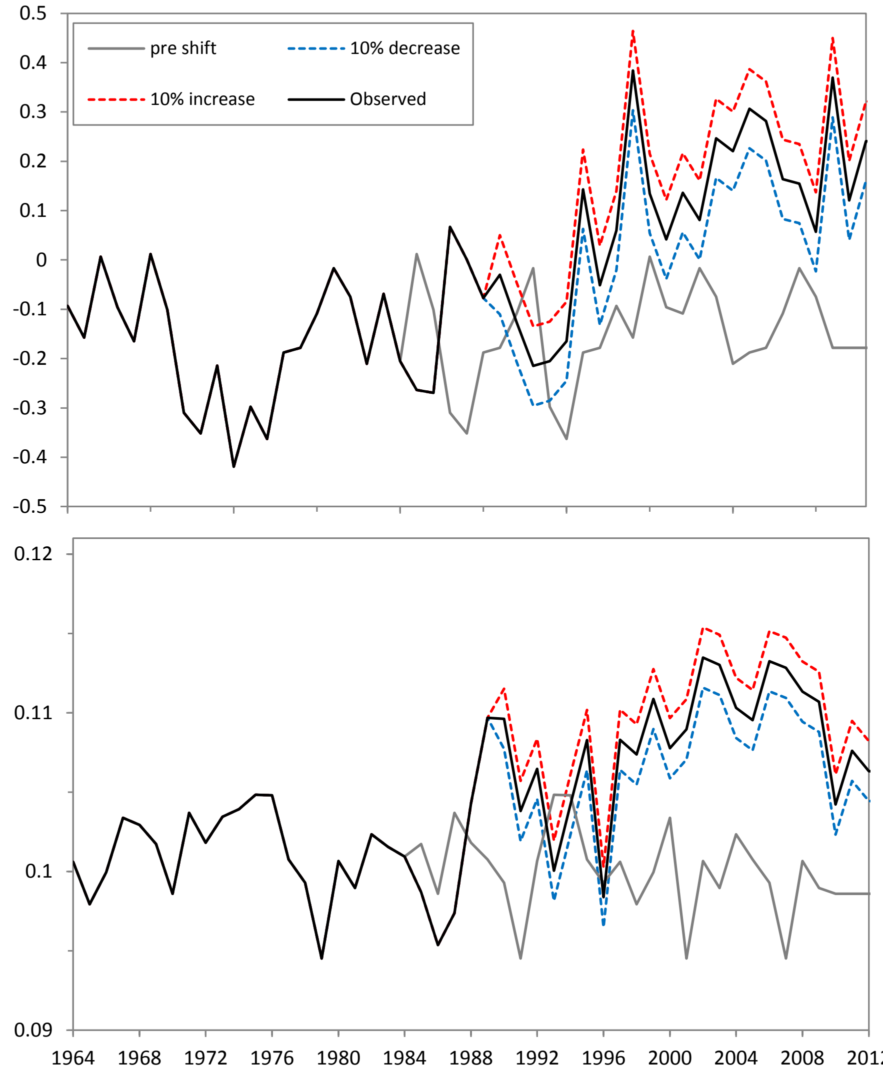
  (observed data / scenario)

saithe in year z
~ *intercept*
\+ s(Fishing mortality year z-1)
\+ s(saithe year z-1)
\+ s(haddock year z-1)
\+ s(N. pout year z-1)
\+ ε(0,1)

Temperature scenarios to explore

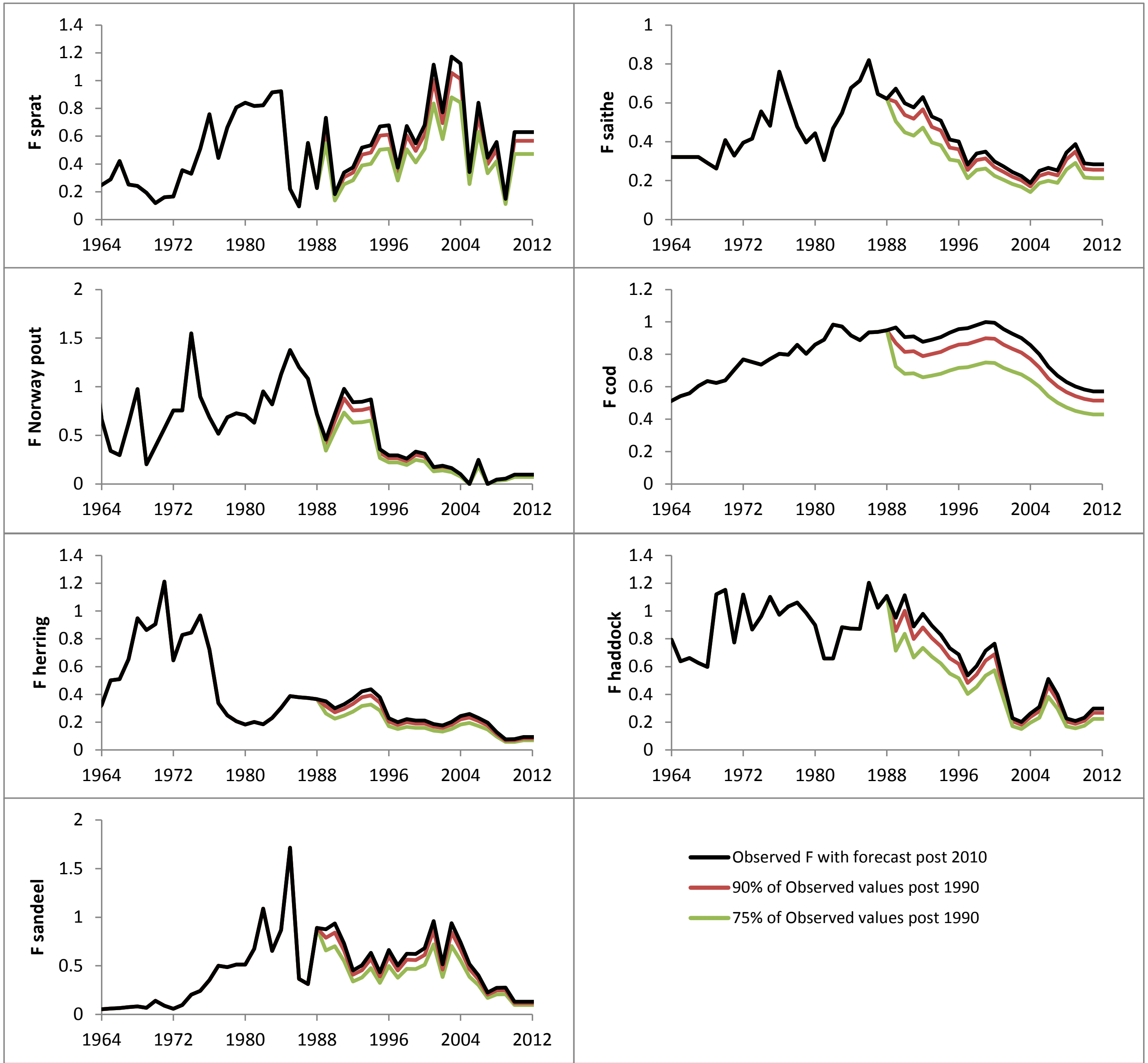
Atlantic Multi-decadal Oscillation anomalies

North Sea SST anomalies



shift 1984 - 1990

Fishing scenarios to explore

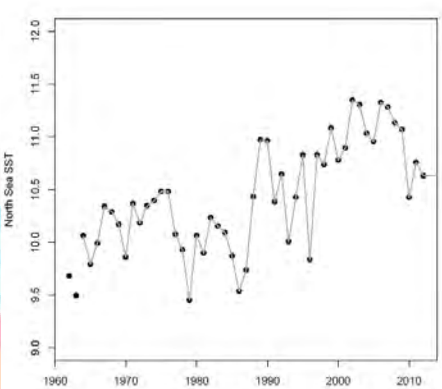


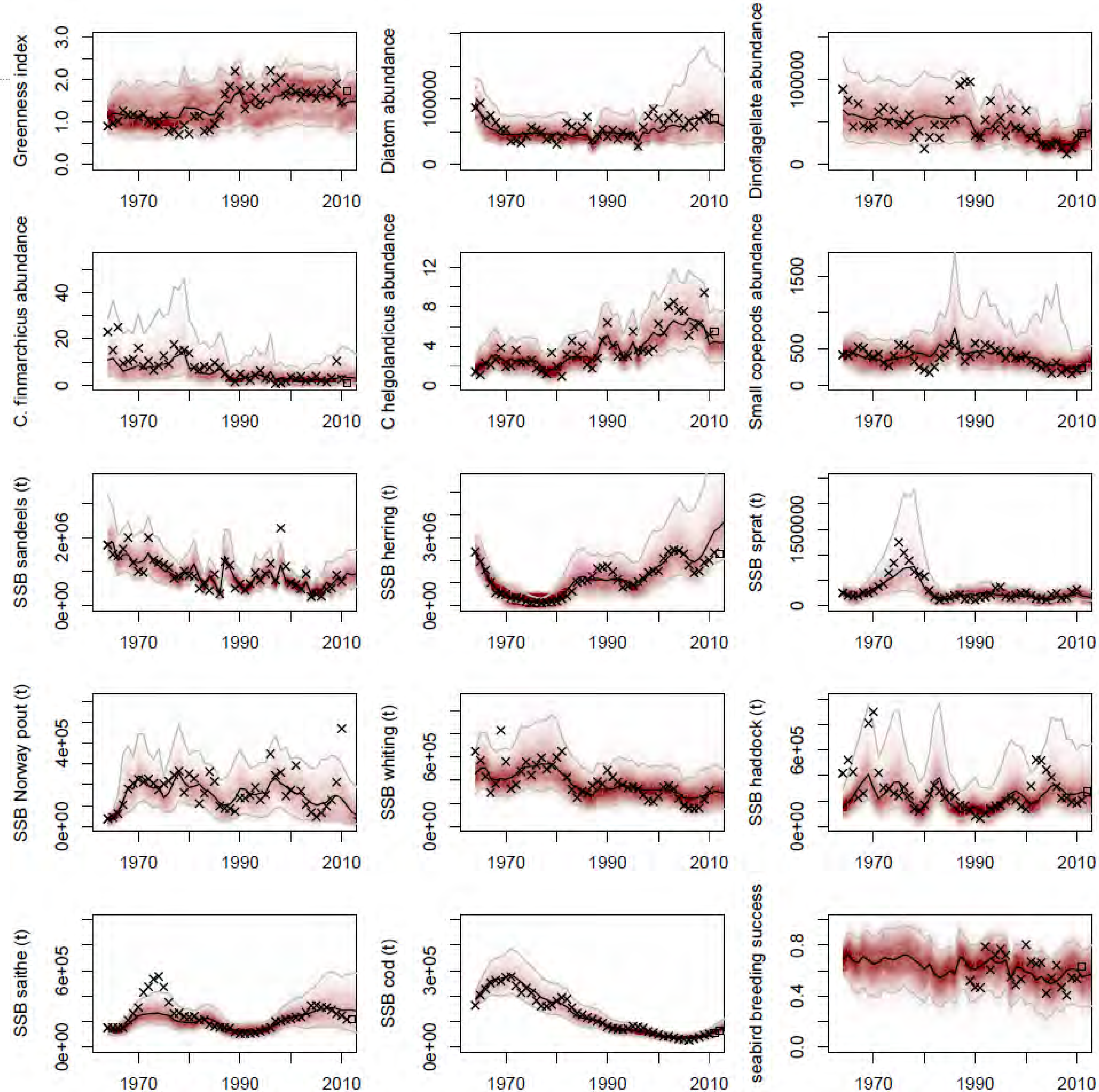
Simulations

Recreated solely from initial conditions for plankton and fish in 1964

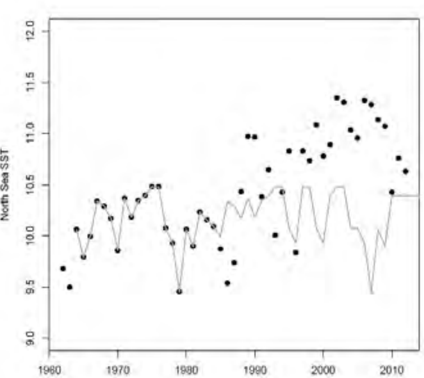
+ time-series of F

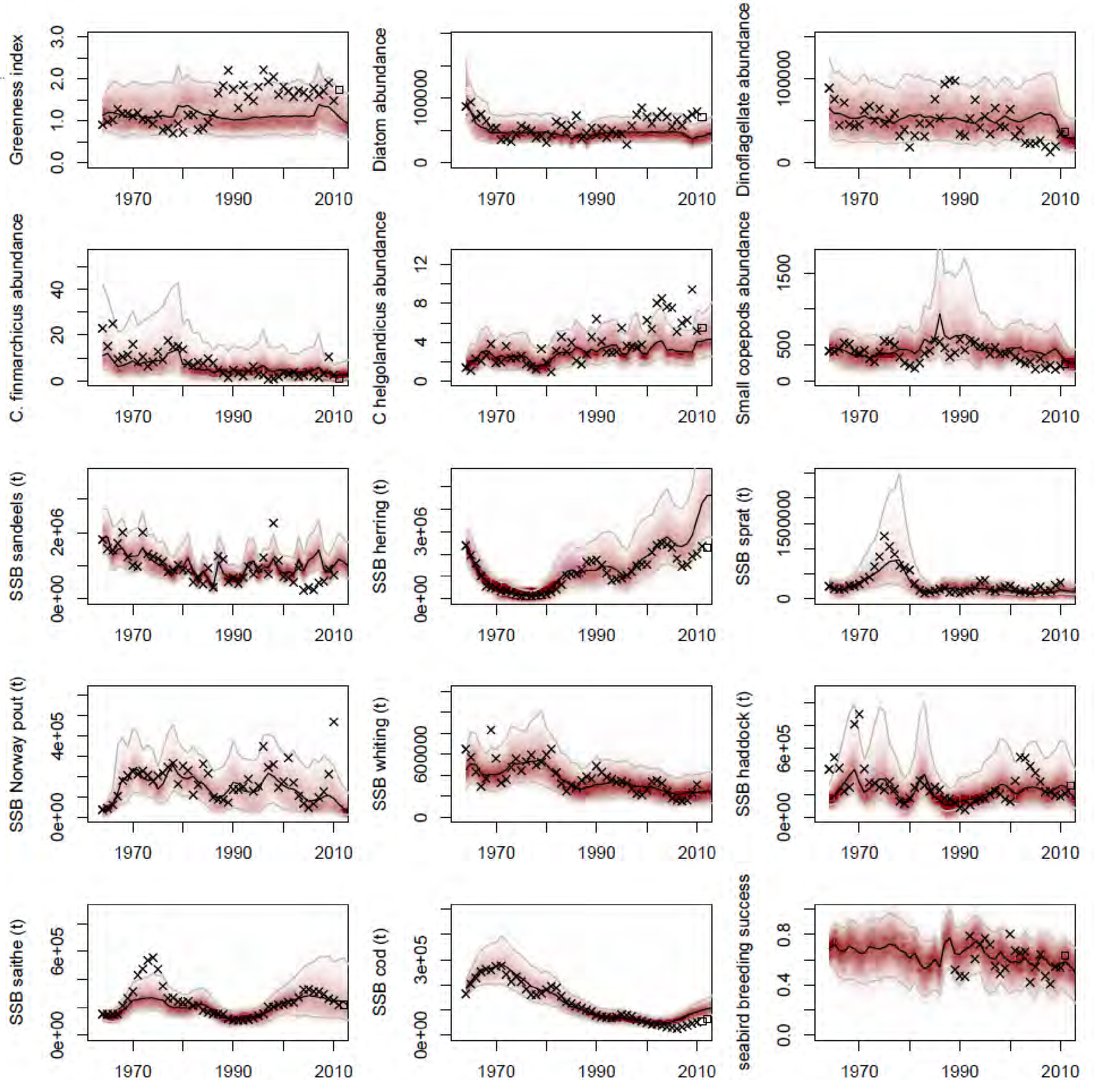
+ SST + AMO



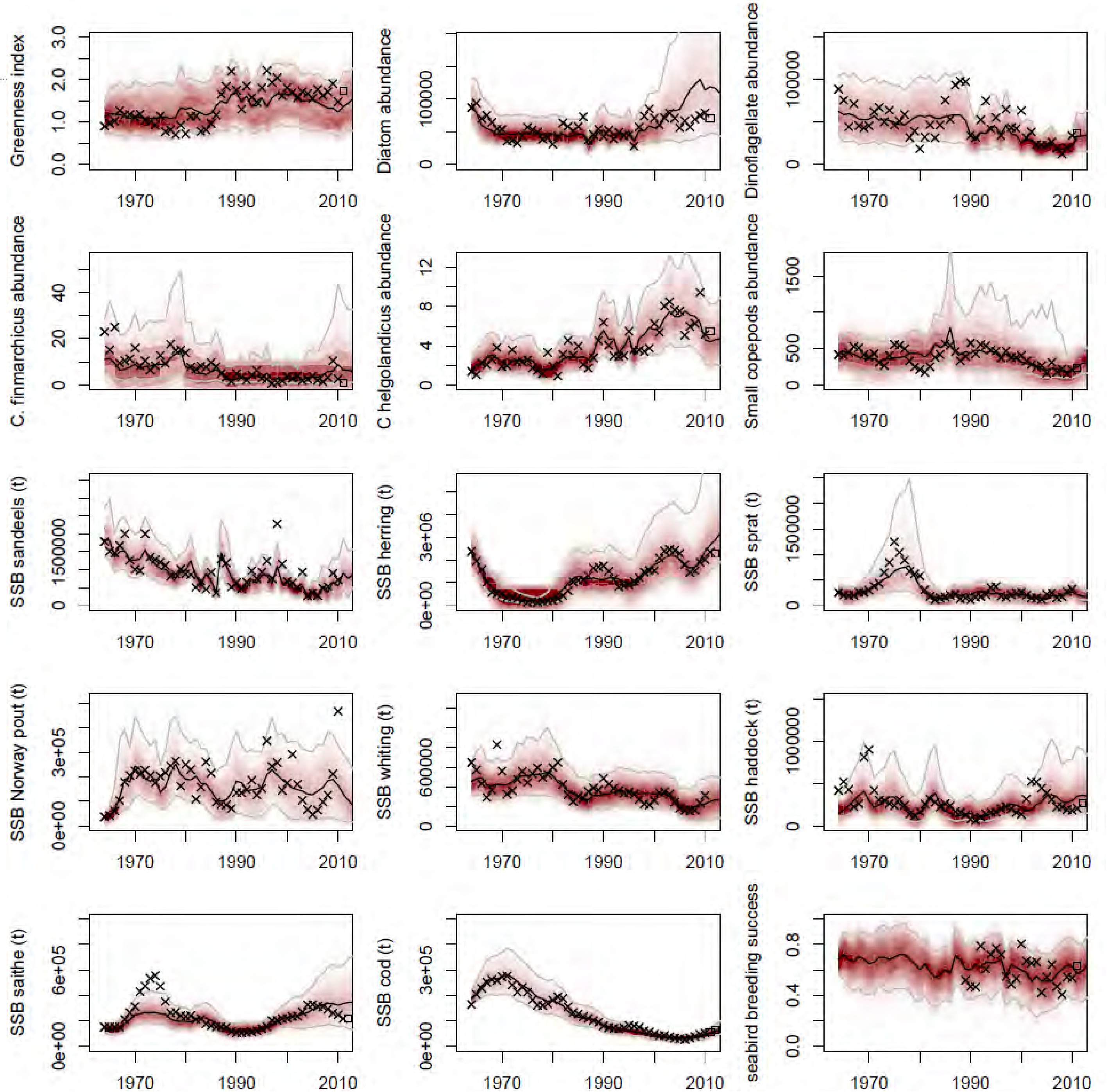


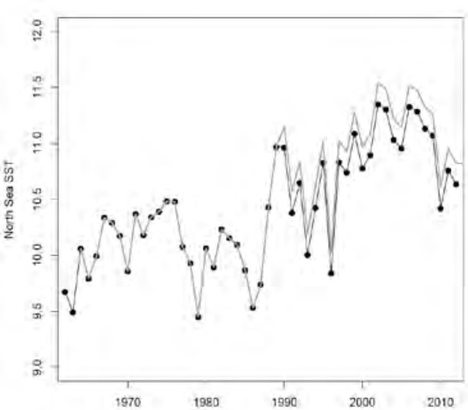
Simulation without SST rise since 1984





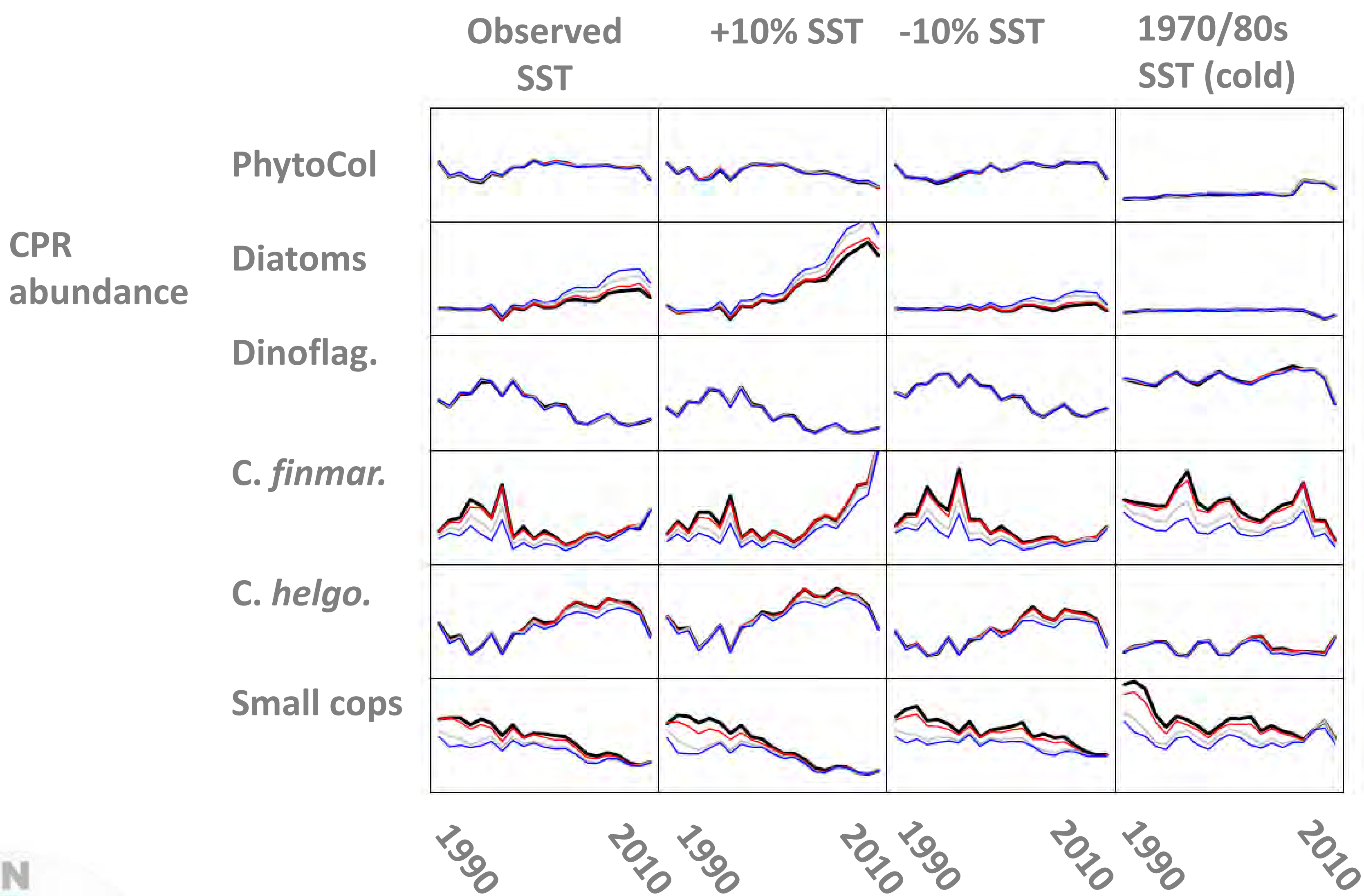
Simulation with 10% SST rise (1990 on)





Some effect of climate, but fishing has been such a strong effect that it has masked the full impact on the North Sea system

What would happen if we reduced fishing? More sensitive to climate?

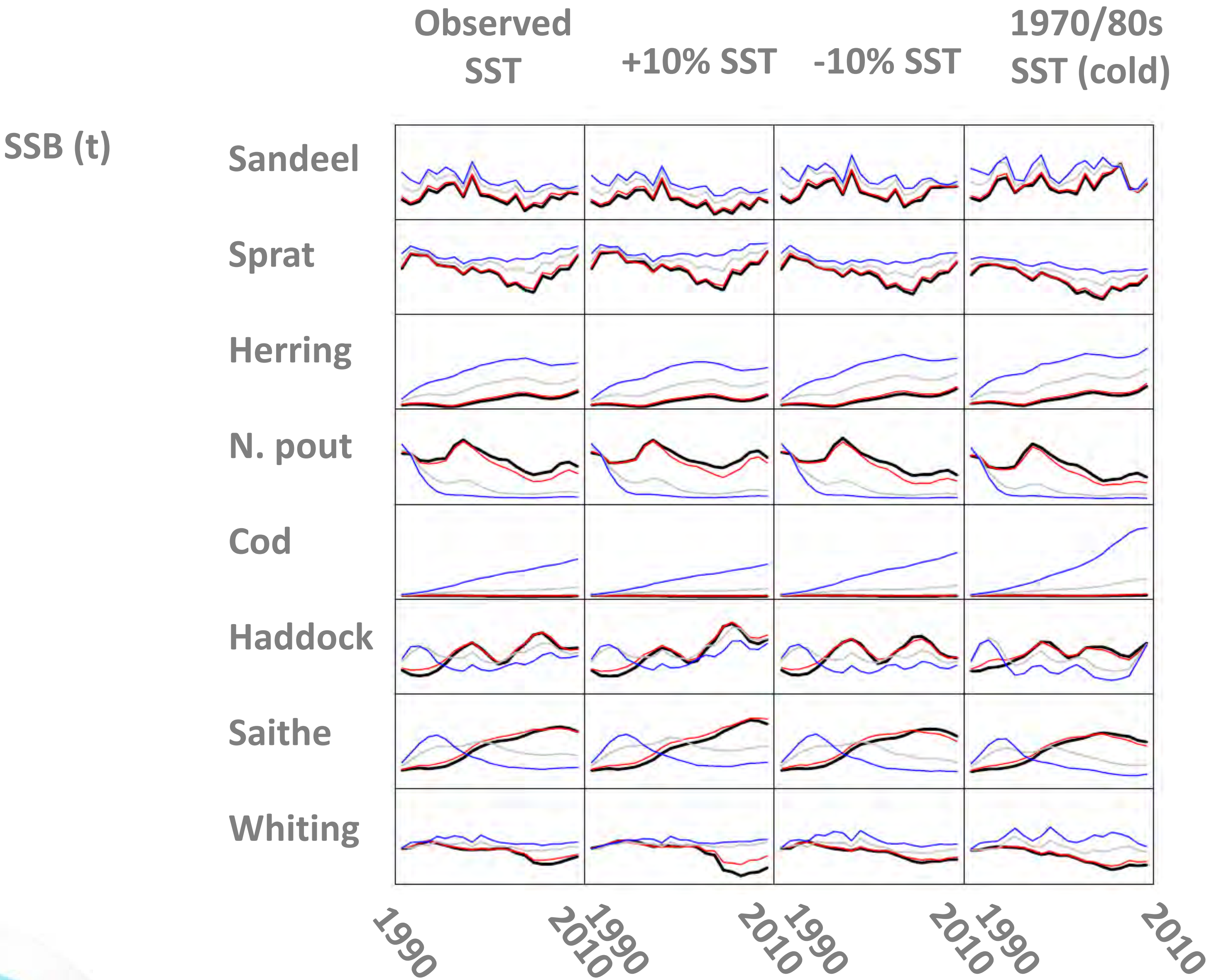


Blue: 80% reduction in F
Red: 10% decrease in F
Grey: 50% decrease in F
Black: observed F

- Diatoms benefit in warm temperatures
- *C. helgolandicus* benefit from warm temperatures
- *C. finmarchicus* benefit from warm *if* diatoms increase

- Dinoflagellates decline when warm, increase with cold
- *C. finmarchicus* benefit during cold temperatures
- Small copepods (*Acartia, Temora, Para-pseudocalanus*) benefit from cold

- Zooplankton decline as fishing pressure lowered
- Diatoms increase as fishing pressure lowered if warm



Blue: 80% reduction in F

Red: 10% decrease in F

Grey: 50% decrease in F

Black: observed F

Cold preference

- Dinoflagellates
- Sandeel
- Herring
- Cod

Warm preference

- Diatoms
- *C. helgolandicus*
- Sprat, Norway pout, saithe

Key interactions during warm period

- *C. finmarchicus* benefit *if* diatoms increase
- Haddock benefit when both diatoms and *C. finmarchicus* do
- Whiting – mixed response – decrease if sandeel decrease (greater than sprat increase)

DEVOTES

www.devotes-project.eu

Development of innovative tools for understanding marine biodiversity and assessing good environmental status

Grant agreement nº 308392

SEVENTH FRAMEWORK PROGRAMME

Project co-funded by the European Commission within the Seventh Framework Programme (2007-2013)

---

www.devotes-project.eu

fizzyfish

Centre for Environment Fisheries & Aquaculture Science

'Effects of climate change on the world's oceans' Santos City, Brazil, 23-27 March 2015

S10 Forecasting climate change impacts on fish populations and fisheries