Conserving biodiversity in a rapidly changing world:

Using long-term observations, in parallel experiments and modelling to measure and manage global environmental change and its interaction with regional and local impacts on biodiversity.

Prof Steve Hawkins

Director Marine Biological Association, UK (1999- Oct 2007)

Head of College Natural Sciences, Bangor University, UK (2007-)

THE MARINE BIOLOGICAL ASSOCIATION

Established 1884

BANGOR

marbef

Global Environmental Change

Climate:

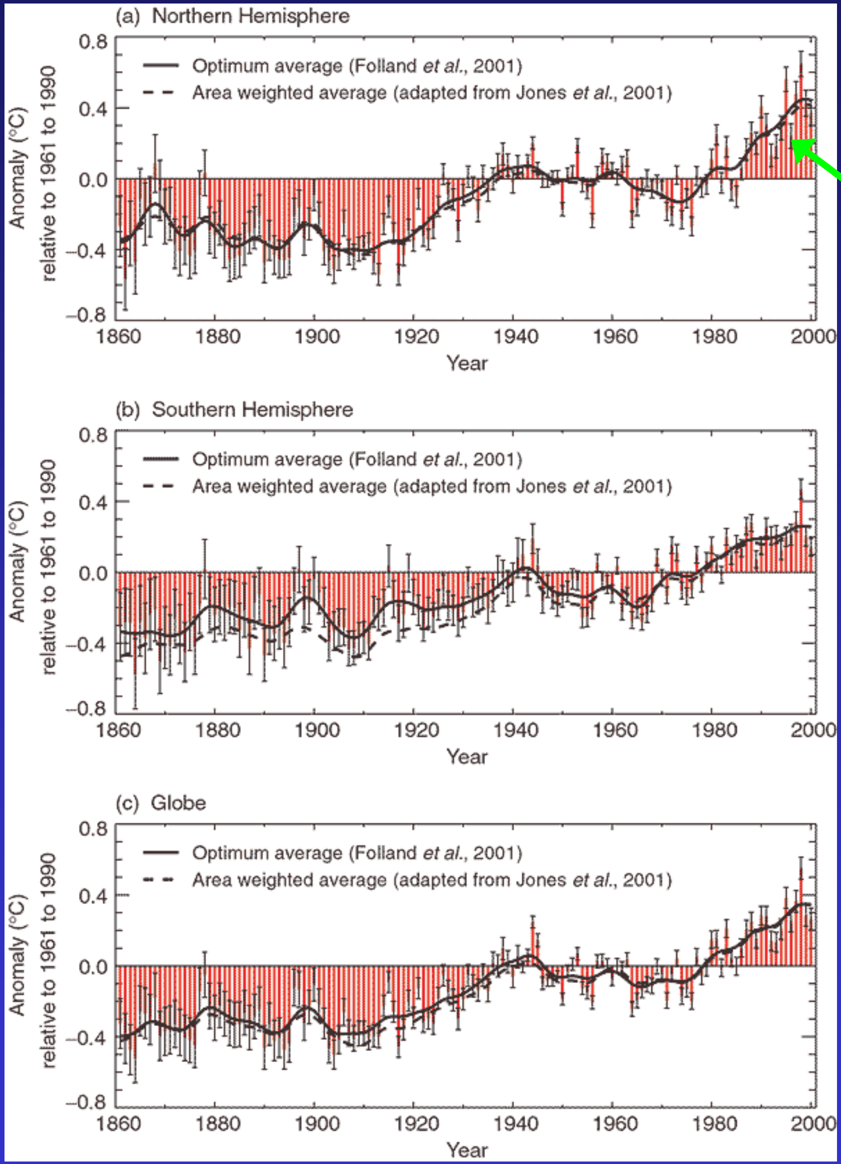
- Not just temperature
- But also storms, precipitation, frequency of extreme events, NAO index (more positive yrs)

(Reduced alkalinity a much longer-term problem)

Will influence biodiversity:

- Shifts in environmental gradients (desiccation, wave action, stratification, salinity etc)
- Changes in frequency of disturbance events
- Poleward migration of species
- Changes in assemblage composition & interactions (often via recruitment regimes)
- Greater likelihood of non-native invasions

Climate Change in the N.E. Atlantic



IPCC Climate Change 2001 The Scientific Basis

Particularly strong warming has occurred in the North Atlantic since the mid-1980s (35° to 65°N, 0° to 35°W)

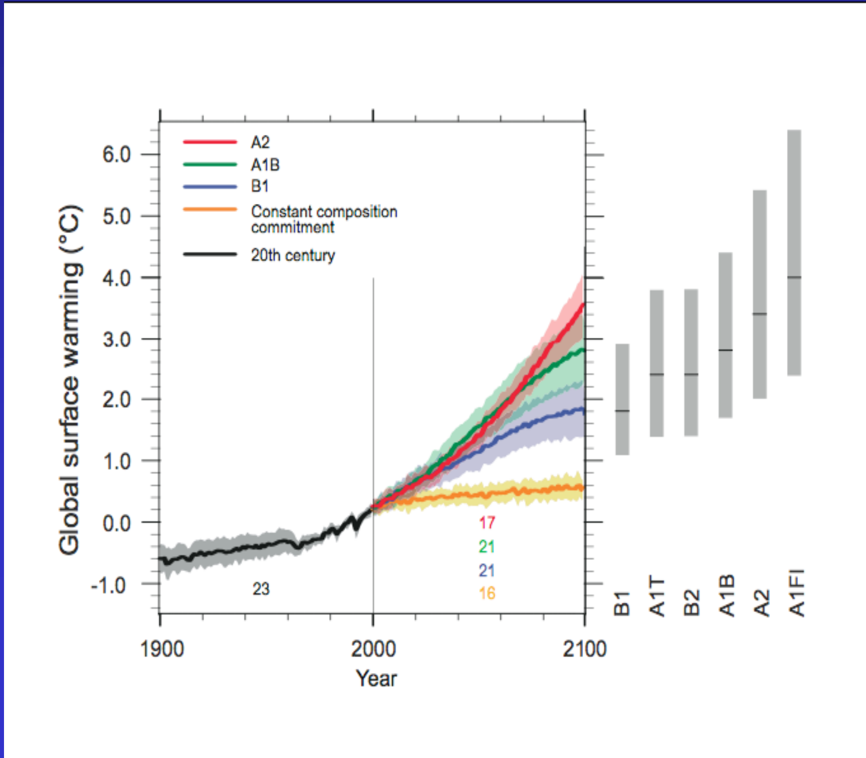
This is 2 x rate of any previous warming event on record, 0.5-1°C in last 20 years

← Exceeds global average

Physical changes in the marine environment

- Substantial fluctuations in sea temperature over the 20th C
- SST may be linked to solar activity (sunspots) (Southward 1980, Nature)
- Intensity of North Atlantic Oscillation
- Accelerating warming since 1980s
- Predicted warming scenarios of:

low 1.1-2.9 °C (B1)
high 2.4-6.4 °C (A1FI)
Over the next 100 years
(IPCC 2007)



Multi-model global averages of surface warming, IPCC 2007

Because of the inertia in earth climate system: we shall probably have to live with warming etc for the next 50 years or so (IPCC)

Therefore to conserve biodiversity we must concentrate on adaptation by managing the interactions of climate change with those things we can do something about:

i.e. fishing, pollution, habitat loss and modification, non-native species, implementation of mitigation measures

Outline of Talk

- Need to separate climate signal from natural noise
- Interactions of global change with regional & local scale impacts
- Examples of interactions: climate & fishing, climate & pollution, climate & habitat modification,
- Linking sustained observations with experimental process studies & modelling (rocky shores as a tractable sentinel system)
- The challenge of mitigation: long-term gain vs short term impacts (pain)???
- The science agenda: european scale, capability and research priorities

Long–term studies by the MBA with SAMS, PML, University of Porto*

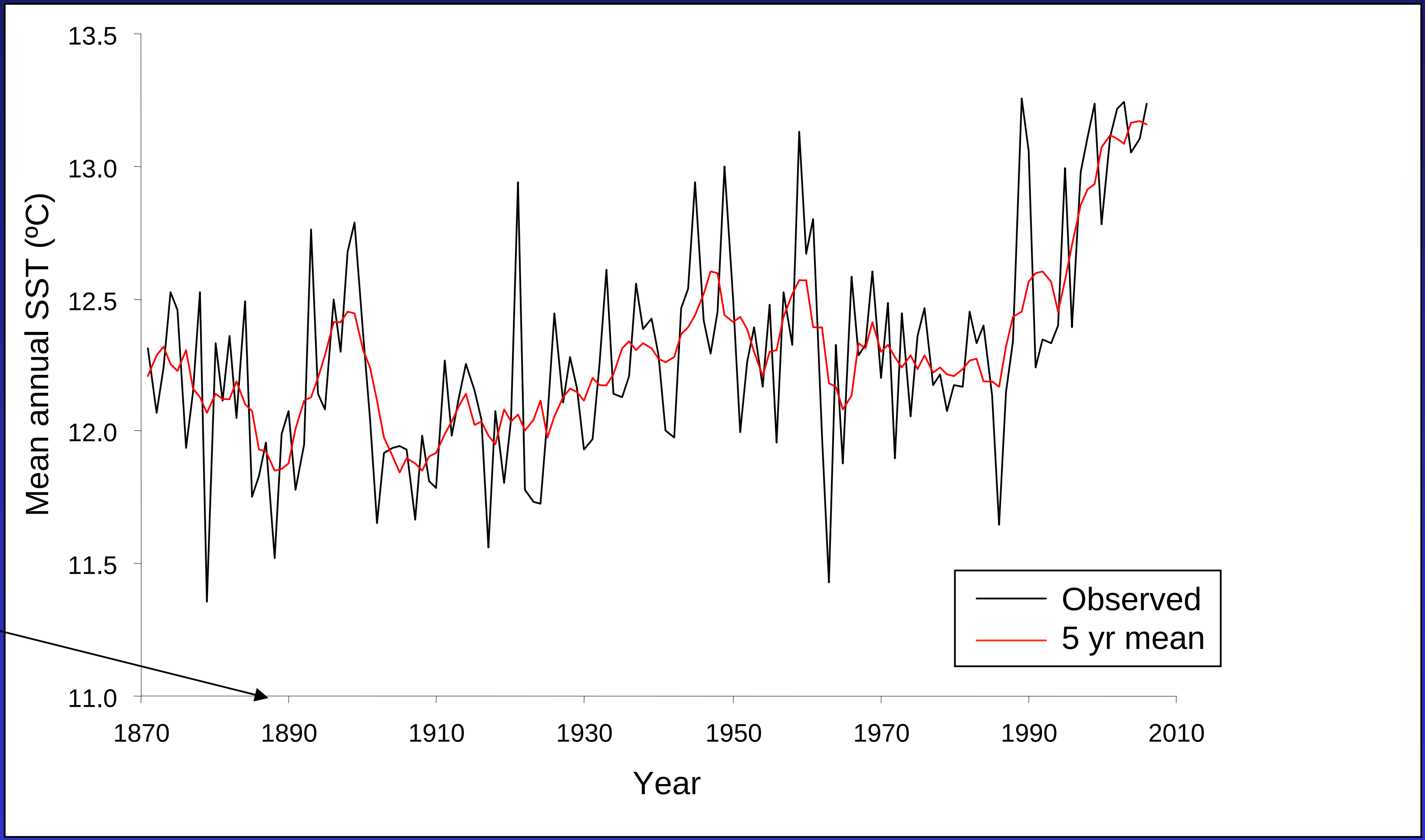
Steve Hawkins, Pippa Moore, David Sims, Martin Genner, Nova Mieszkowska, Mike Kendall, Fernando Lima*, Antonio Murias dos Santos*, Rebecca Leaper, Mike Burrows, Matt Frost, Paula Moschella, Elvira Poloczanska, Roger Herbert & ALAN SOUTHWARD

1888

2007

and previous generations of MBA staff

Mean annual sea surface temperature 1871-2006 off Plymouth (grid square 50–51° N, 04–05° W).



MBA lab founded

Data from the UK Meteorological Office Hadley Centre. Much of it collected by the MBA/PML

MBA Time Series: English Channel

To be Western Channel Observatory from 2007

PML/ MBA/SAHFOS as part of Oceans 2025

Temperature and Salinity	E1	1902-1987, 2002-
Nutrients	E1	1921-1987, 2002-
Phytoplankton	E1	1903-1987, 2002-
Primary production	E1	1964-1984
Zooplankton	E1, L5	1903-1987, 1995-1998,2002-
Planktonic larval fish	E1, L5	1924-1987, 1995-1998,2002-
Demersal fish	L4	1913-1986, 2001-2003,2005-
Intertidal organisms	various	1950-1998, 1997/2001-2005,-
Infaunal benthos (intermittent)	L4	1922-1950, 2003
Epifaunal benthos (intermittent)	L4	1899-1986, 2005-

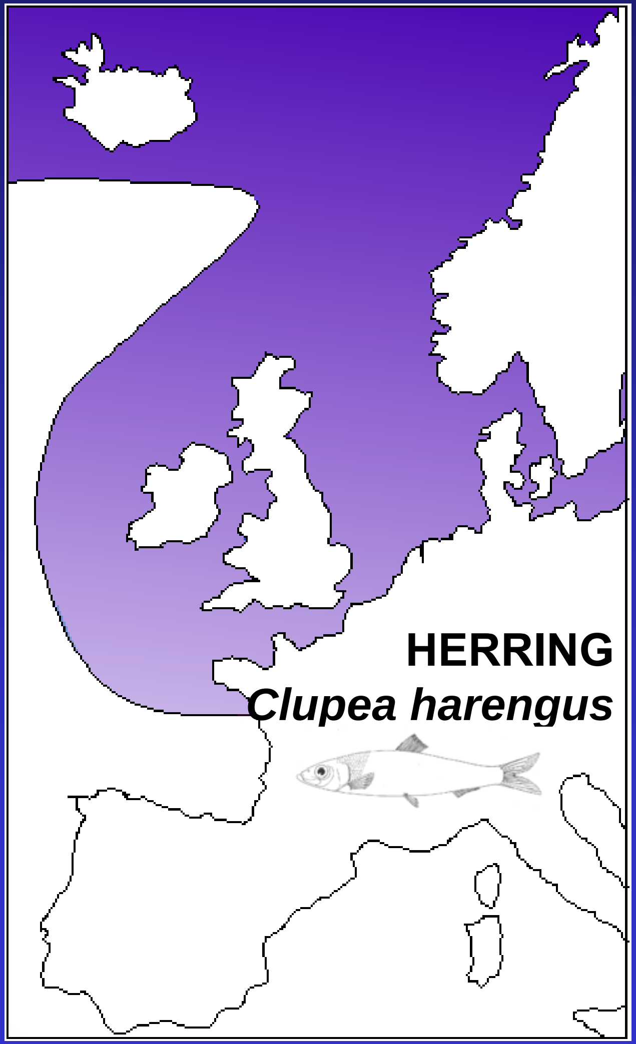
PML time series:plankton & hydrography at L4 since 1987

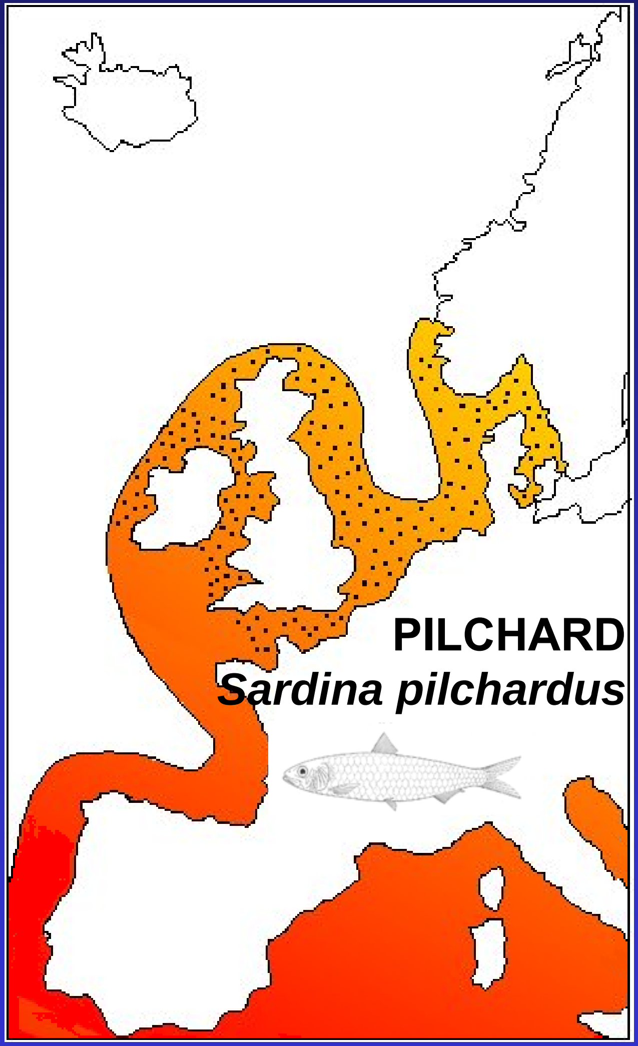
n.b. There are many gaps in these series,

Defra funded restarts in red

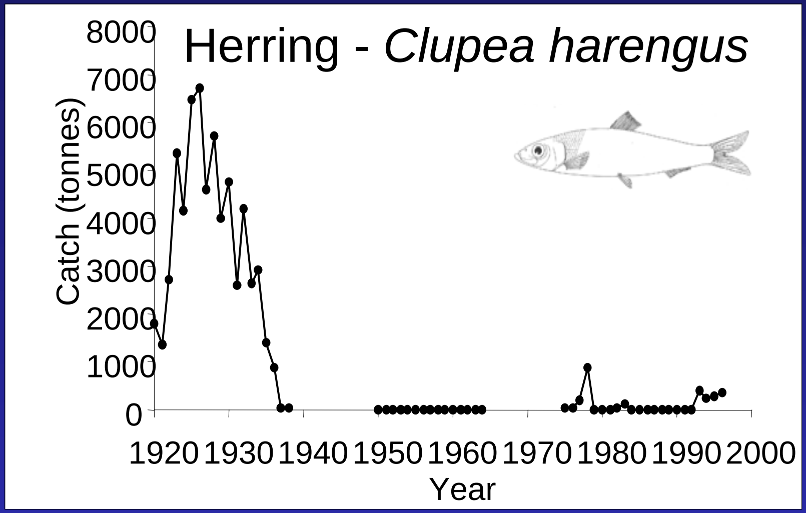
Reviewed in Southward et al., Adv. Mar. Biol. 47:1-105, 2005

Pelagic fish species



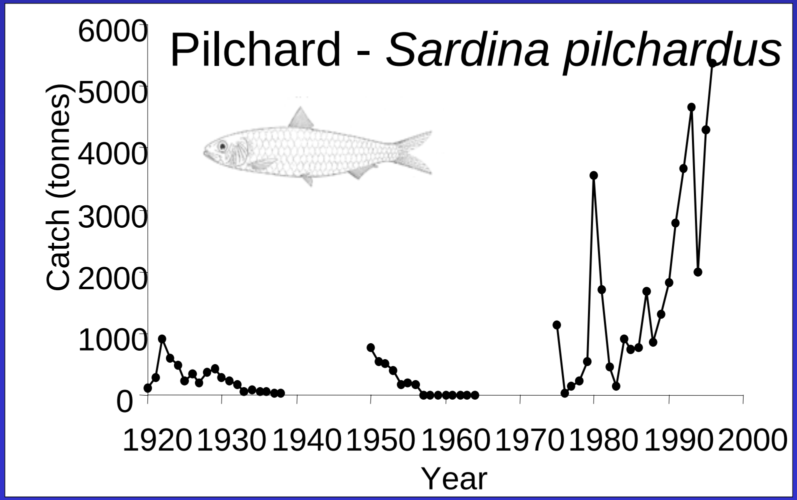


Landings of pelagic fish at Plymouth



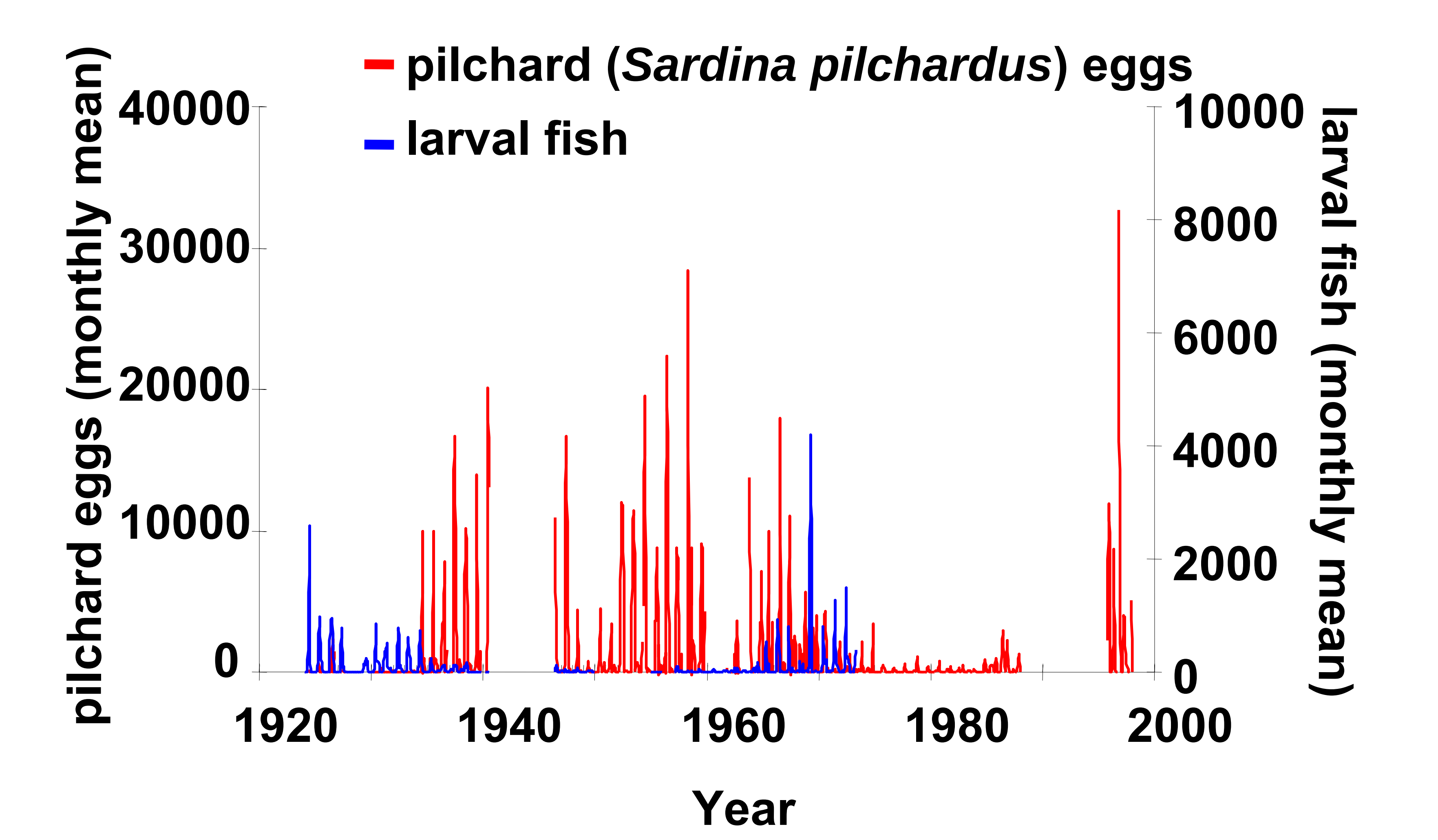
Data source: UK Government records

Sutton Harbour, Plymouth, 1925

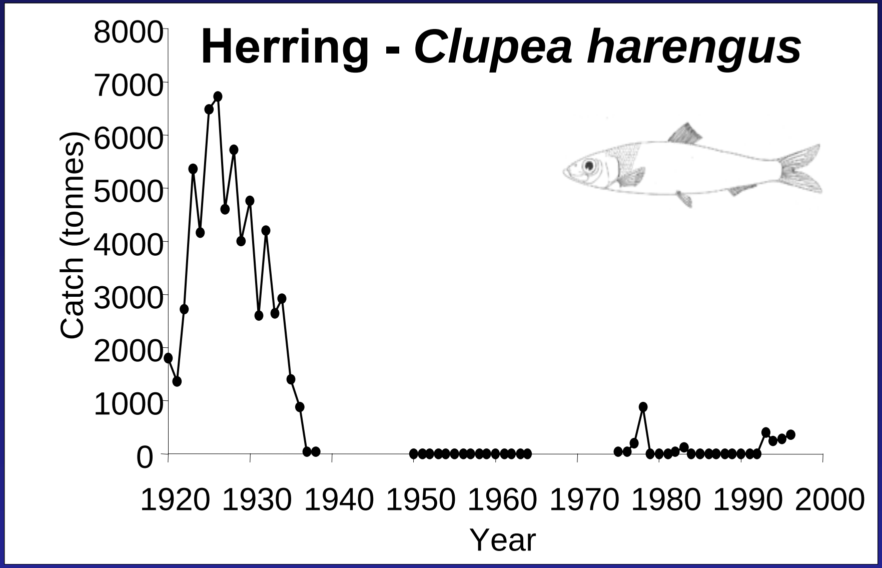


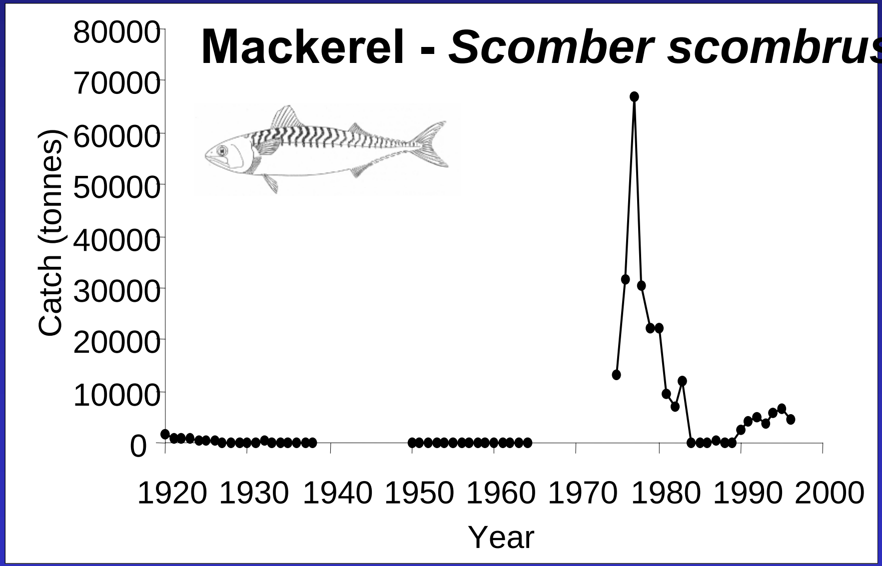
Such fluctuations have occurred since 13th century (Southward et al 1988 JMBA)

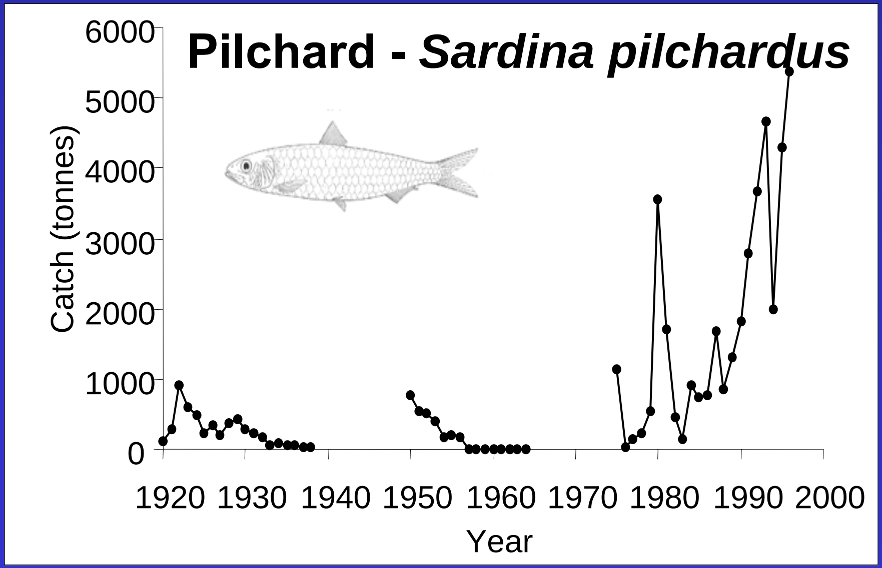
Pilchard eggs and non-clupeid larvae



Landings of pelagic fish at Plymouth







Data source: MAFF, Hawkins et al. STOTEN 2003

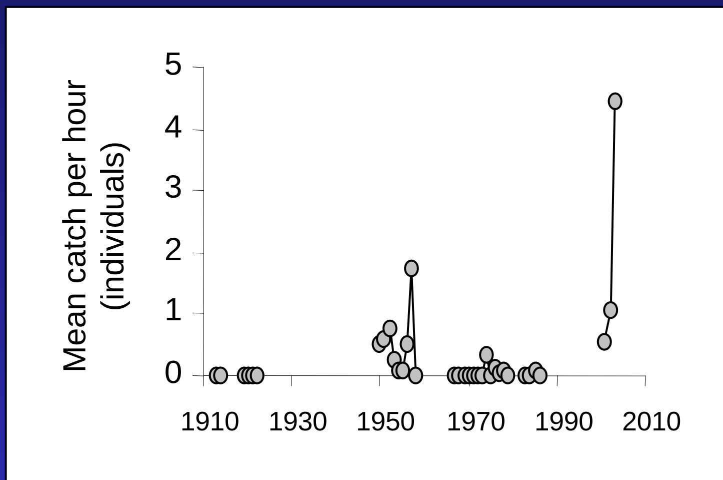
MBA Trawls: fewer large fish species in catches due to fishing

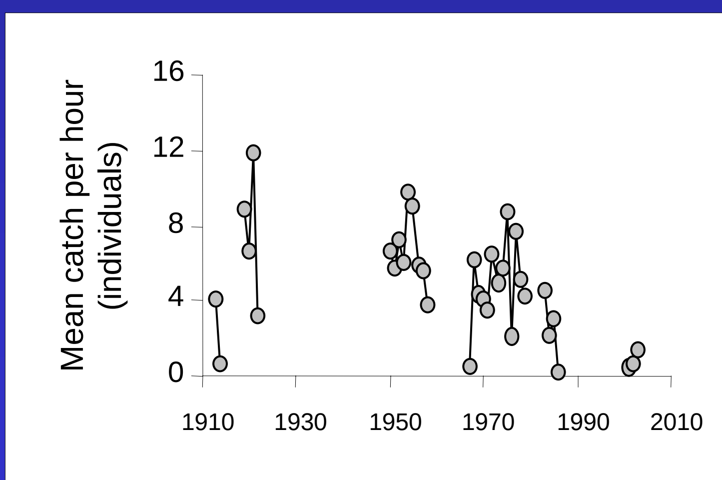
October 1963

November 2001

Sharpest declines seen in large species: skate & ray, brill, conger eel

Plymouth inshore demersal fisheries



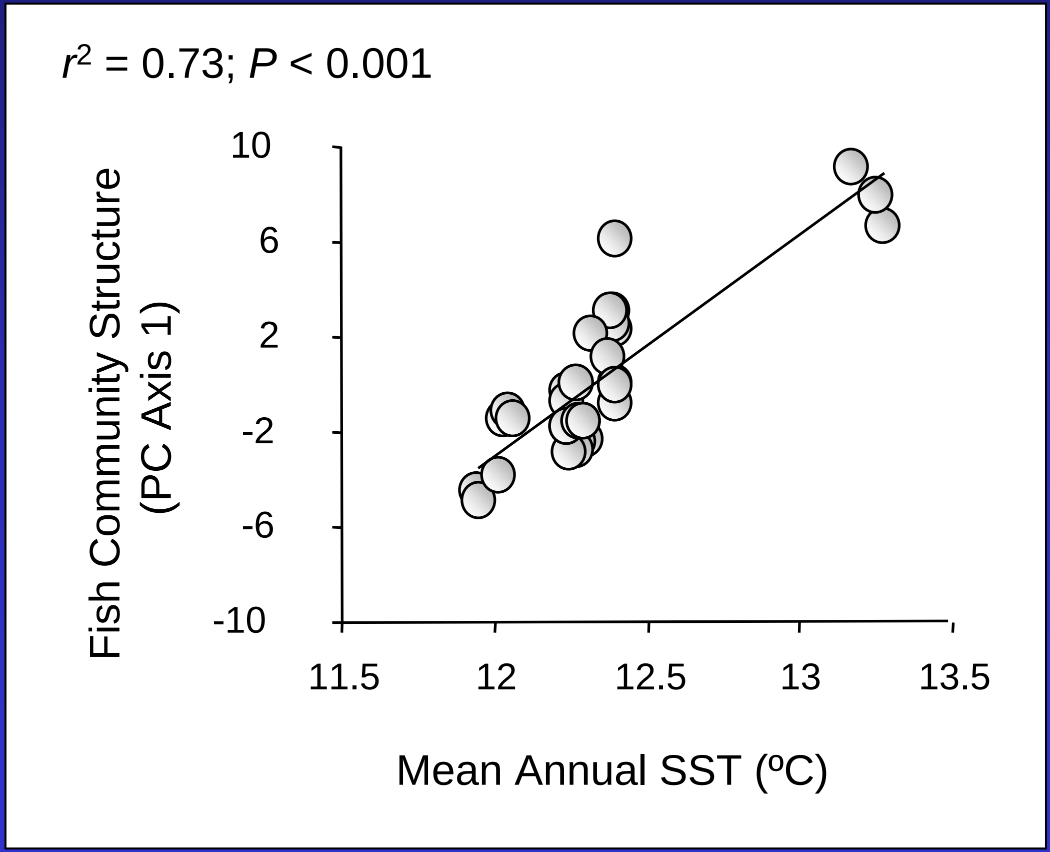


Genner et al., unpublished

Climate driven : warm water Breams (Family Sparidae)

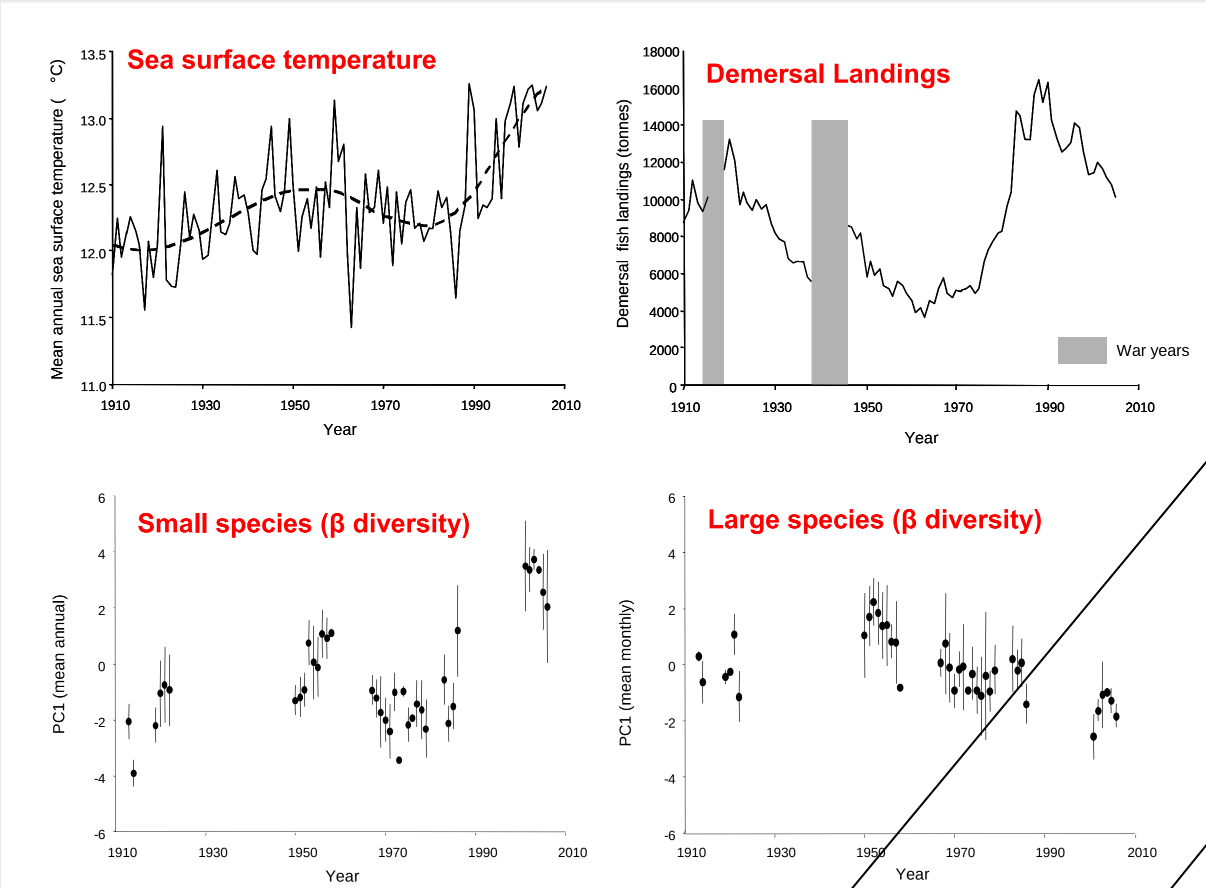
Fishing driven: low fecundity Rays (Family Rajidae)

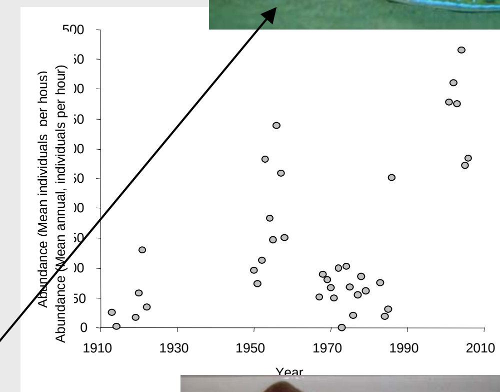
PC1, an index of community-level change, correlates with sea temperature

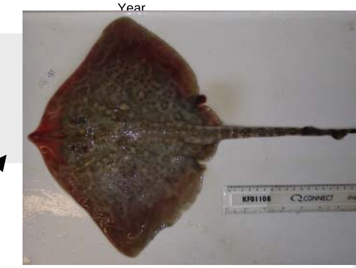


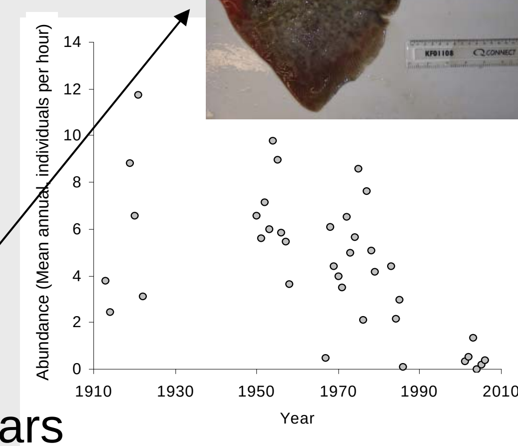
Genner *et al.* (2004) *Proc. R. Soc. London B*

English Channel fish diversity









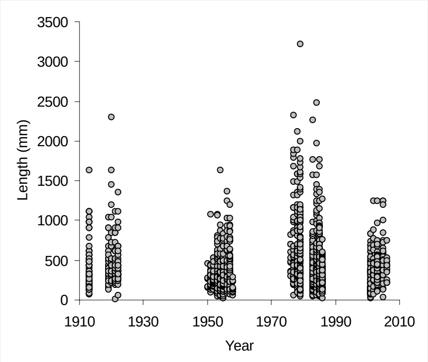
Small species – follow climate change

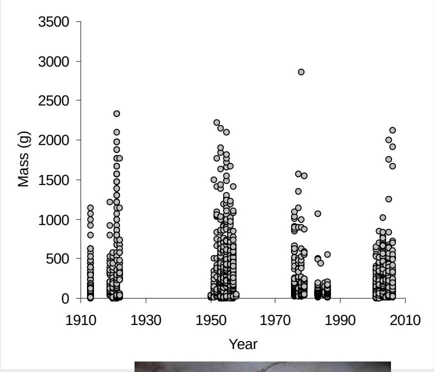
Large species - abundance declines over the last 50 years

Co-funded by DEFRA (projects MF0727 and MF0730; 2000-2003)

English Channel fish sizes 1913-2006

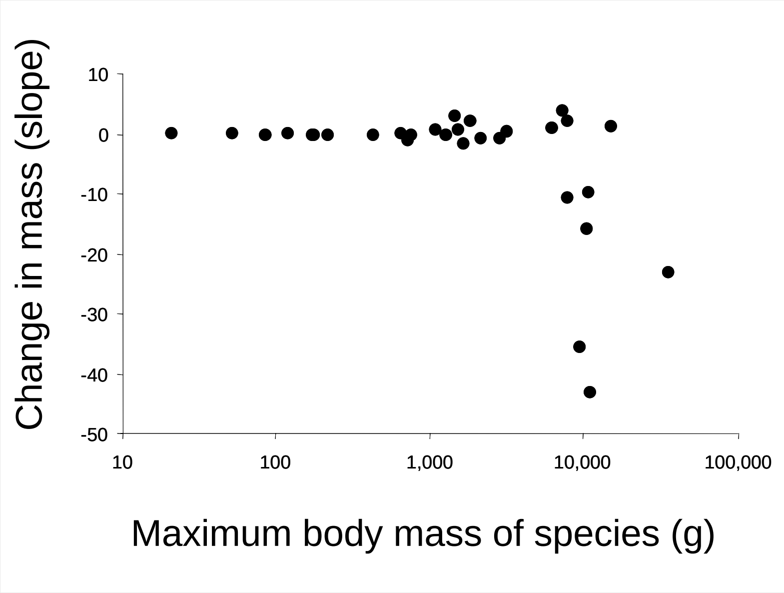
Plaice



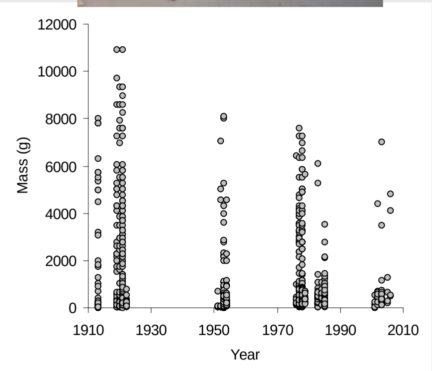


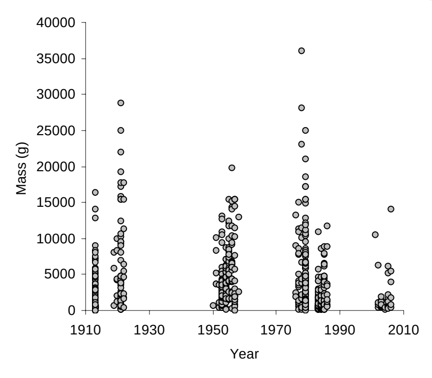
John Dory

Small and medium species – no change
Large species – fewer large individuals

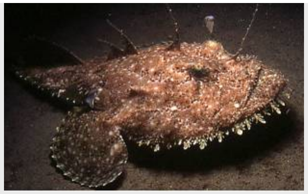


Rays





Monkfish



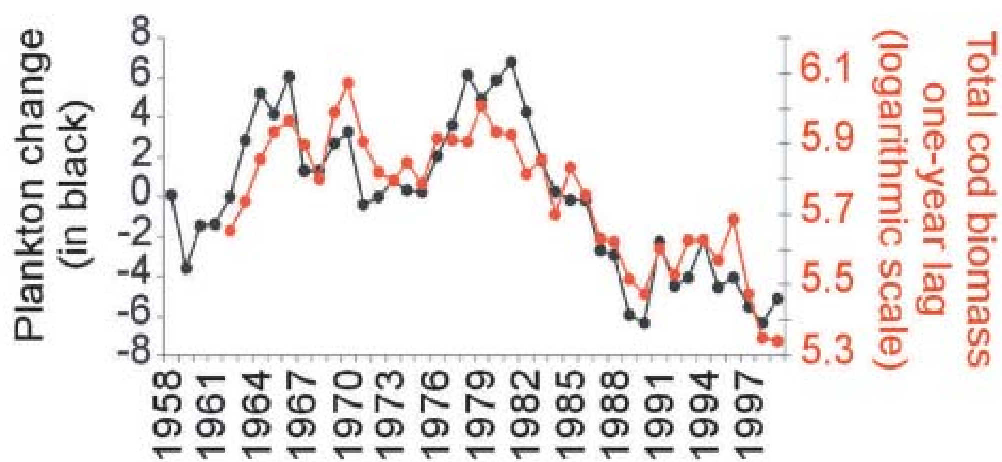
Trophic interactions in the North Sea

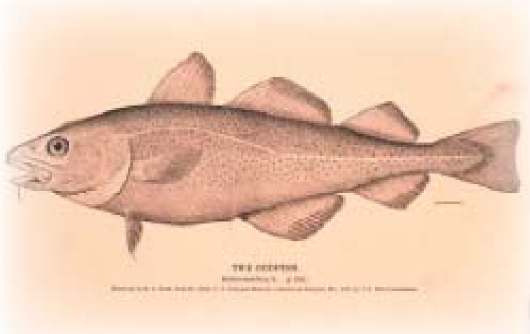
CPR -SAHFOS data

Plankton, cod and climate change

Cod larval survival and climate

In addition to overfishing, fluctuations in the plankton recorded by the CPR survey has shown that changes in the plankton have resulted in poorer cod recruitment in the North Sea. Survival of larval cod is dependant on plankton abundance, the mean size of plankton and their seasonal timing.





Beaugrand et al. (2003). Nature, 426: 661-664

Warming worsens the effects of overfishing, Brander ICES

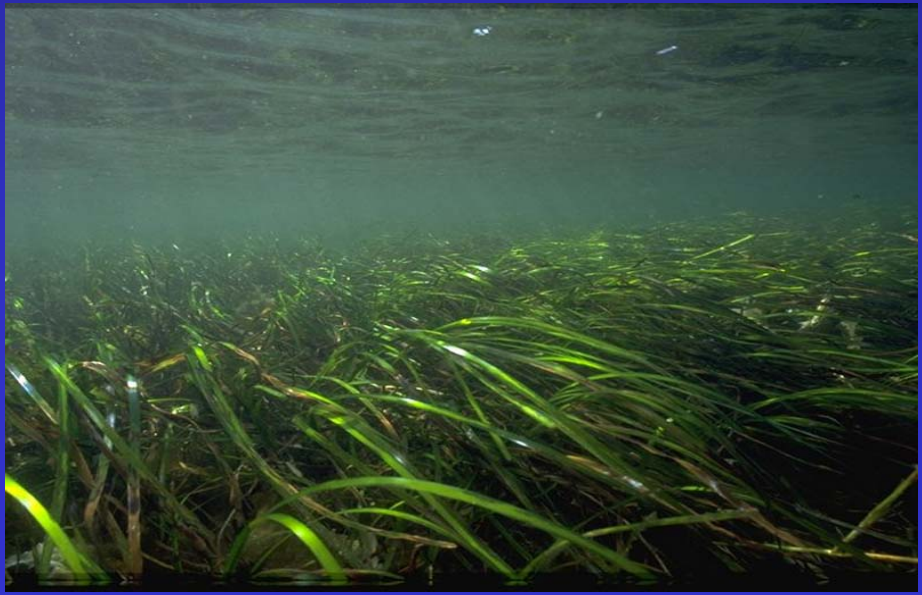
Continuous Plankton Recorder survey

Interaction of climate change and pollution: warming seas worsen impacts of increased nutrients

E.g. German Bight, Skagerrak in 1980s, Adriatic

- Algal blooms.
- Oxygen depletion.
- Death of fish and invertebrates such as brittlestars & clams.

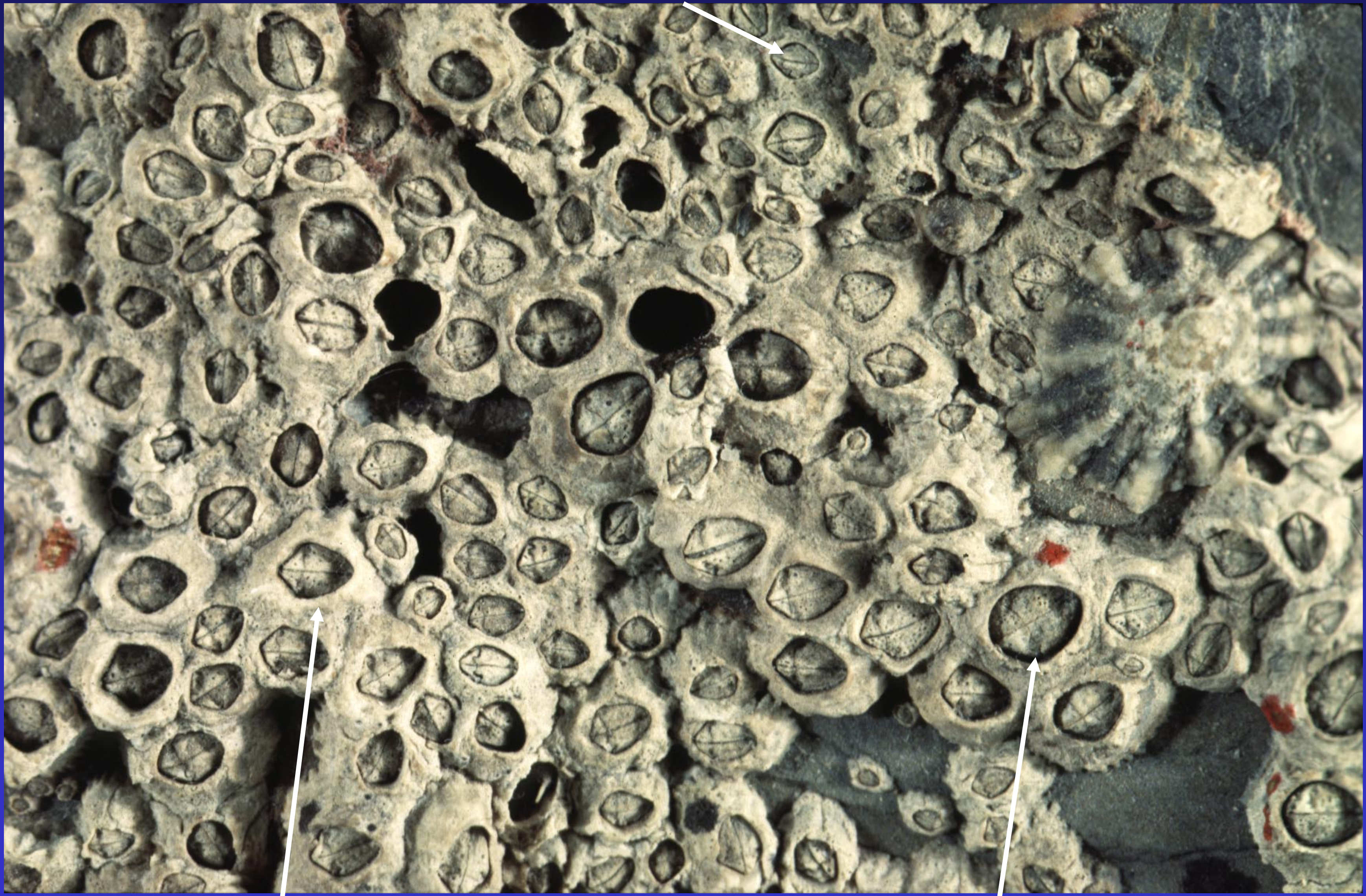
Decline of seagrass beds?



Agent in sea fan deaths?

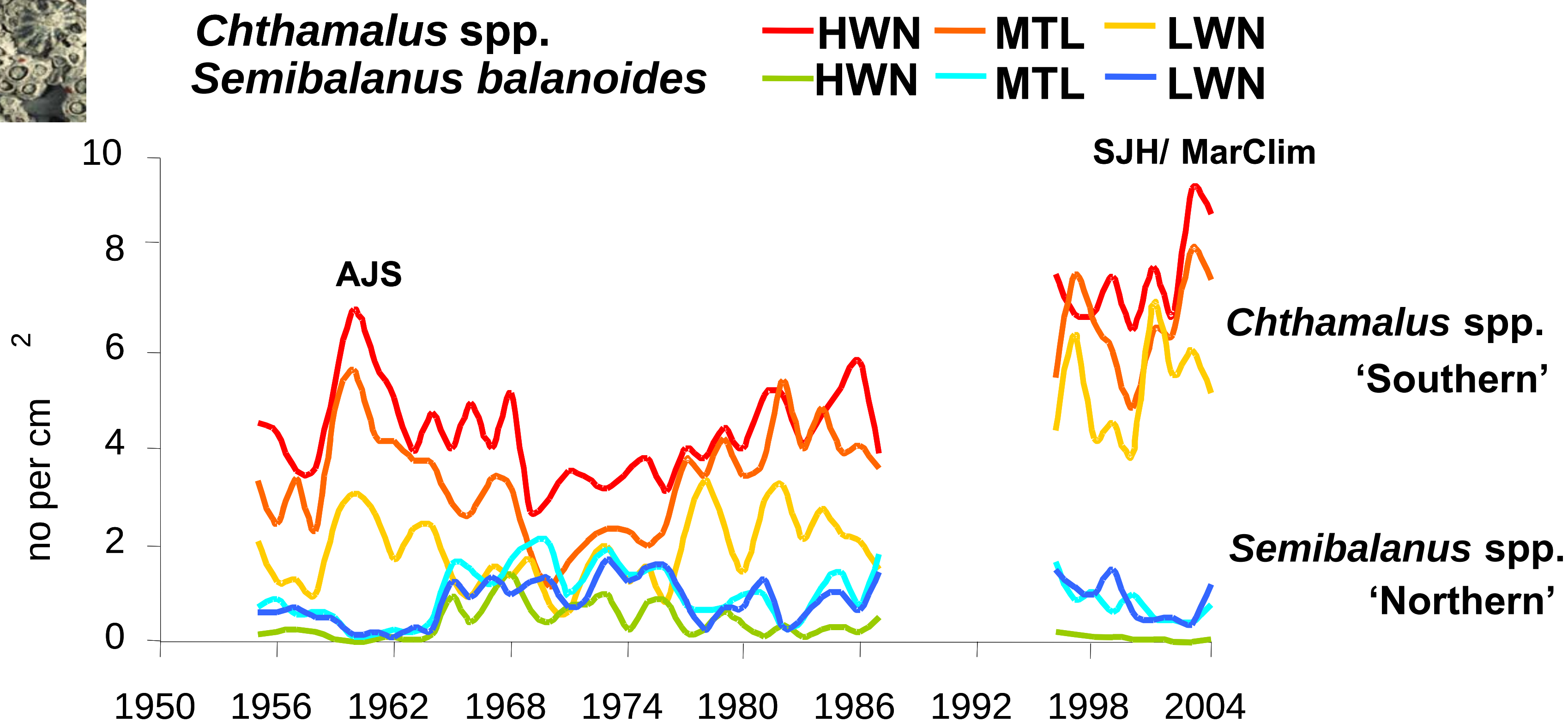
Linking sustained observations, experiments and modelling for better prediction – using the intertidal as a tractable system

Semibalanus balanoides (northern species)



Chthamalus montagui *Chthamalus stellatus*
(southern species)

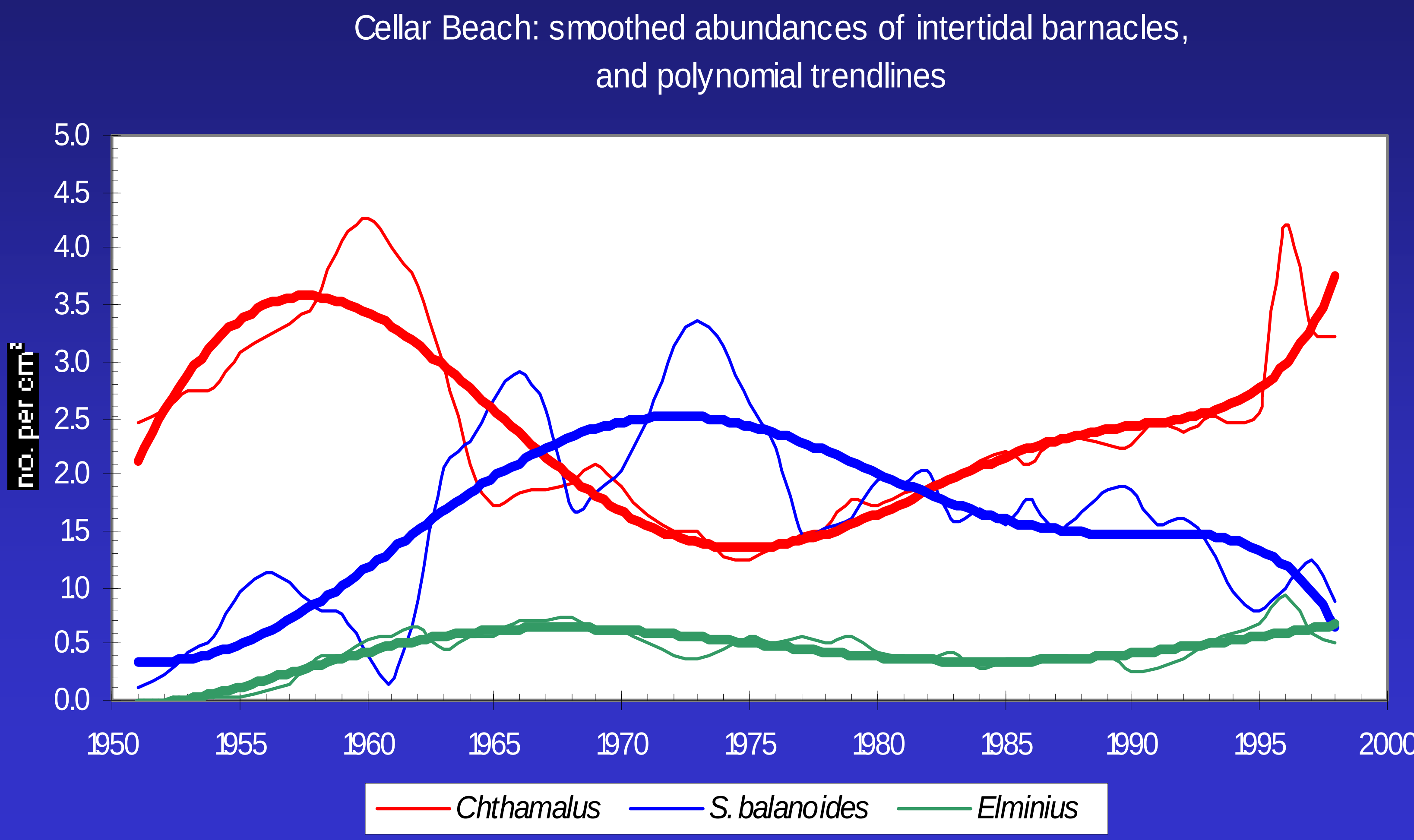
MBA time series: abundance of barnacles in S.W. England (8 sites south coast)



1997-2003 NERC small grant

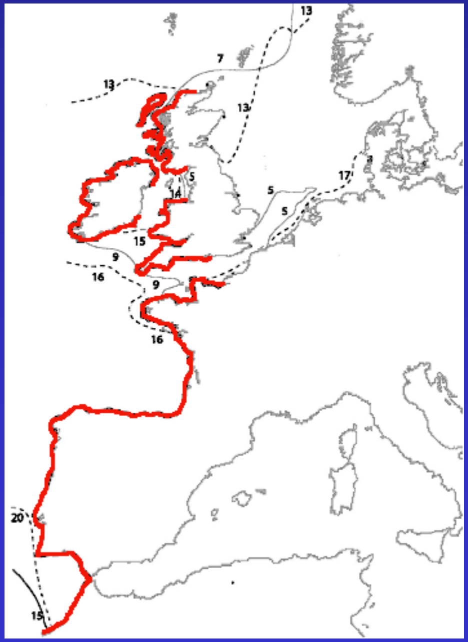
Southward (1967, 1980, 1991) then Hawkins unpub

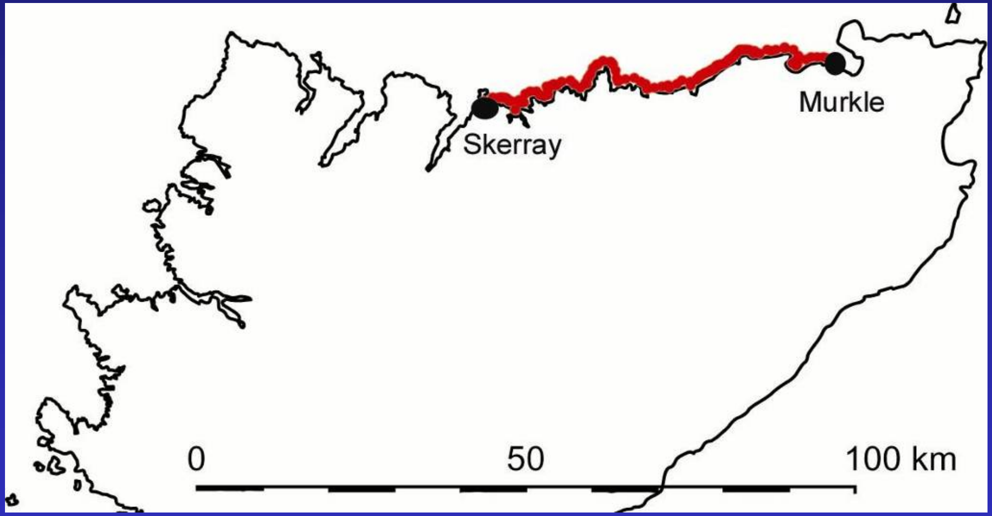
Barnacle Time Series: Cellar Beach, S.W. England



Southward, 1991, JMBA

Example of changes in the distribution of a intertidal species in Northern Scotland (spring 2002)

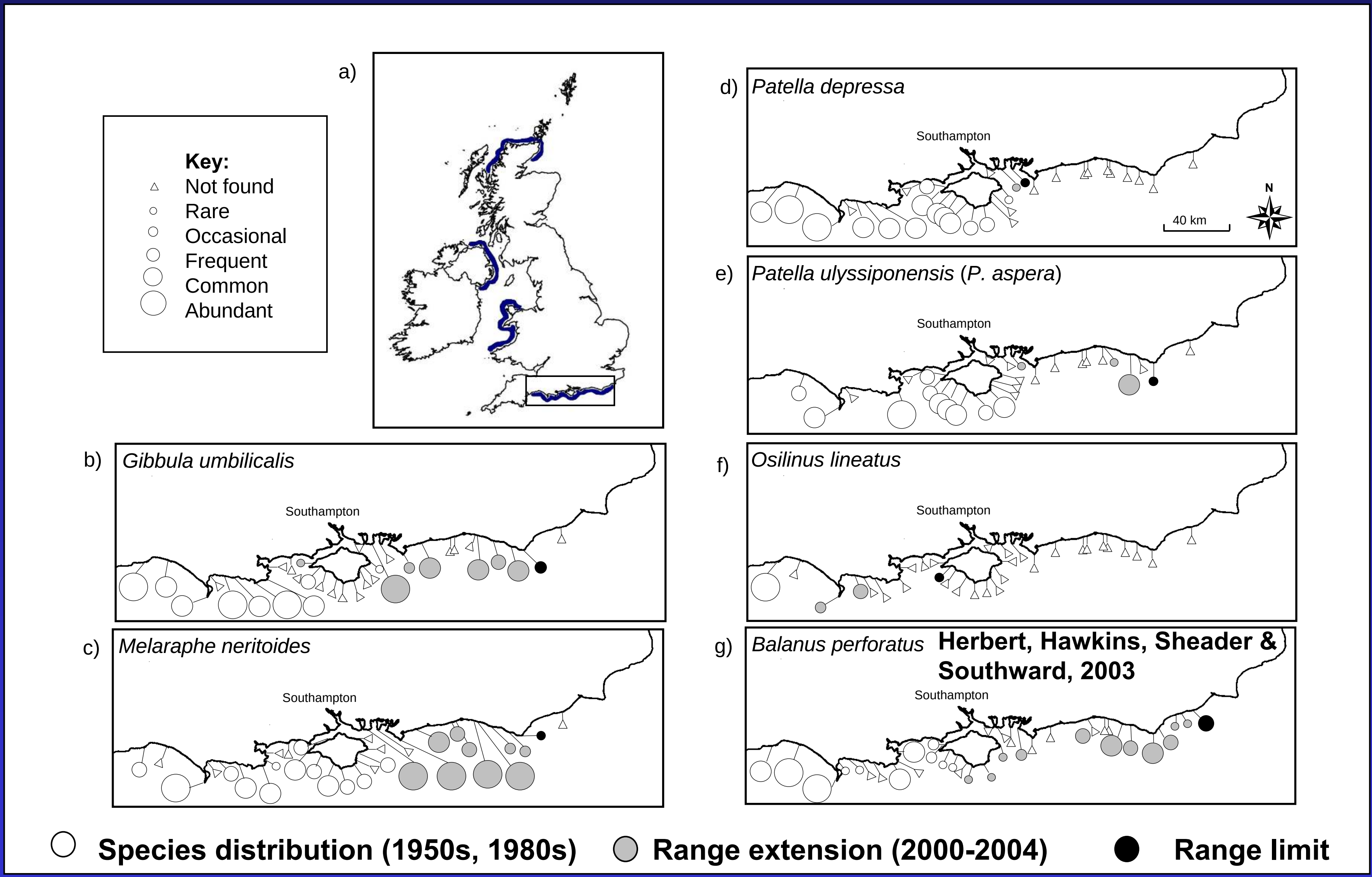




- **northern range extension of ~70km in North Scotland since 1986 (Miezskowska, unpub)**

Top shell – *Gibbula umbilicalis*

Range of distribution of intertidal species in the English Channel (summer 2004)



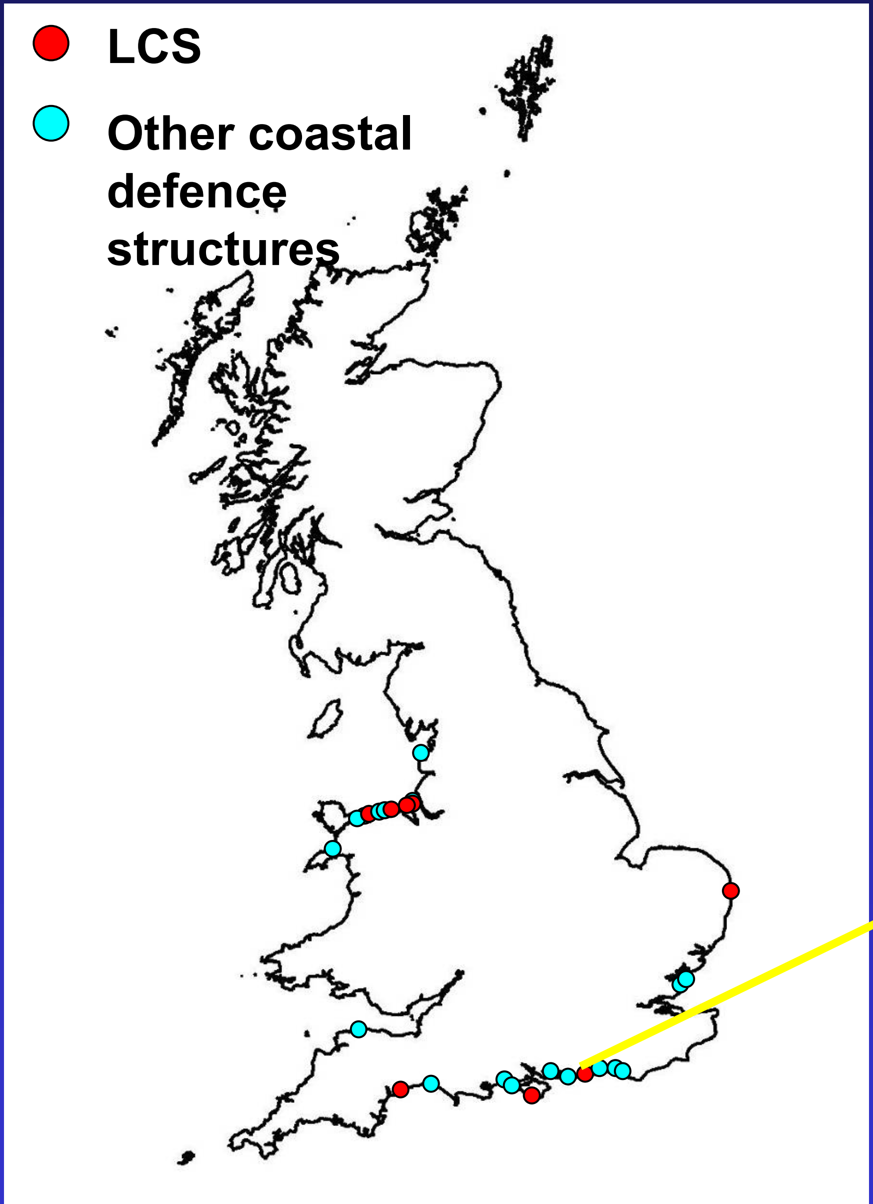
Hawkins, Moschella new data, 2004

DELOS: Environmentally sensitive design of low crested, coastal defence structures

EU Framework Programme V, 2001-2004, EVK3-2000-22038

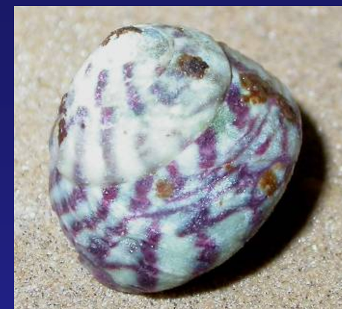
DELOS

Broad-scale modification of coastline



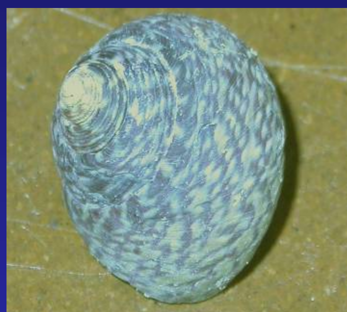
Elmer defence scheme

Range extensions of southern species



Gibbula umbilicalis

Purple topshell

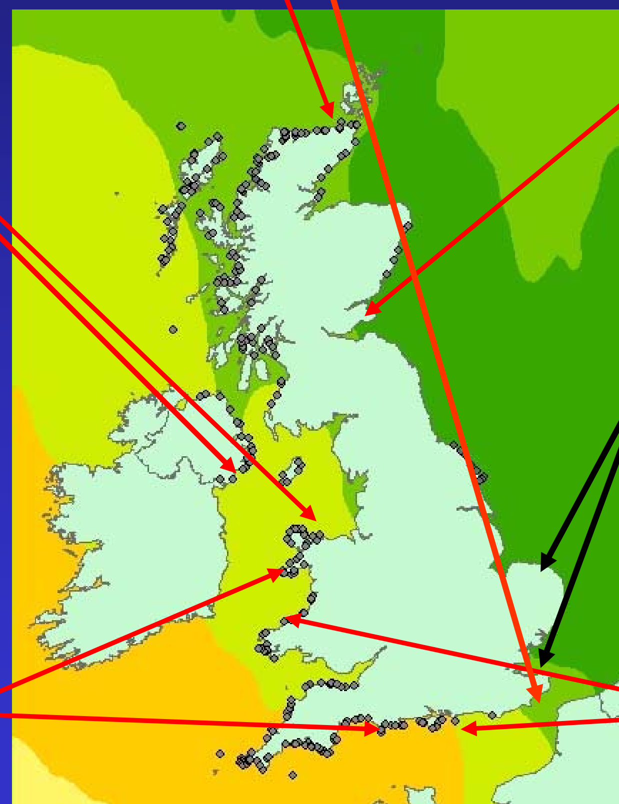


Osilinus lineatus

Toothed topshell

Chthamalus montagui

Stellate barnacle



Melaraphe neritoides

Small periwinkle

Bifurcaria bifurcata

Brown alga

Balanus perforatus

Acorn barnacle

Decreases in abundance and retreats of northern species

Tectura testudinalis

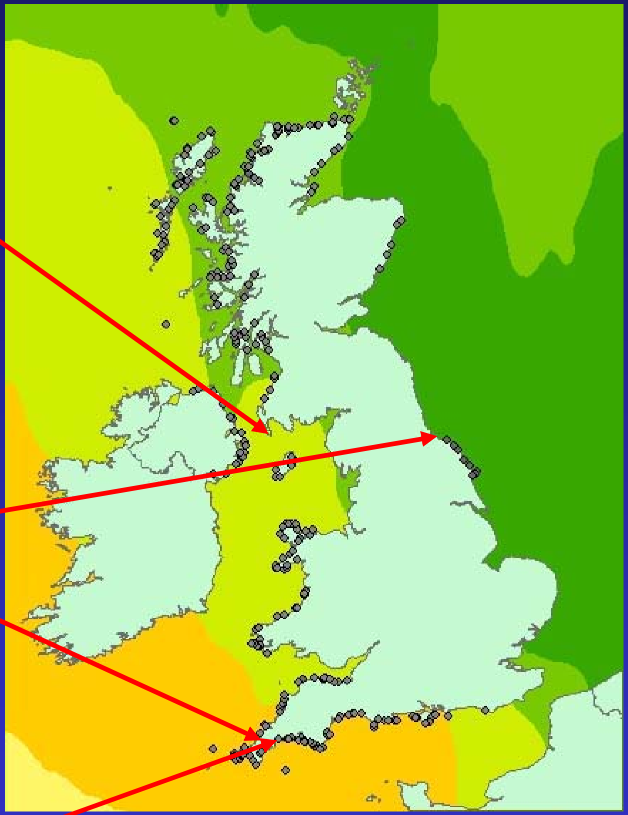
Tortoiseshell limpet

Alaria esculenta

Brown alga

Semibalanus balanoides

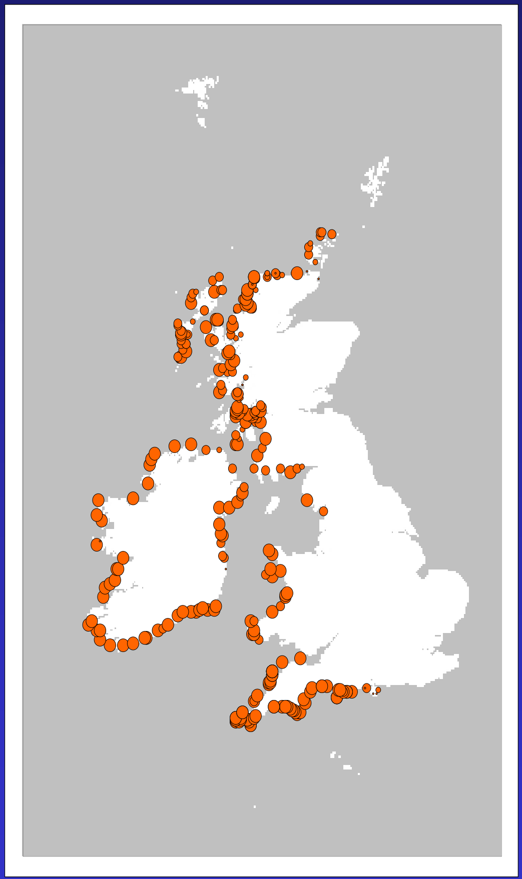
Acorn barnacle

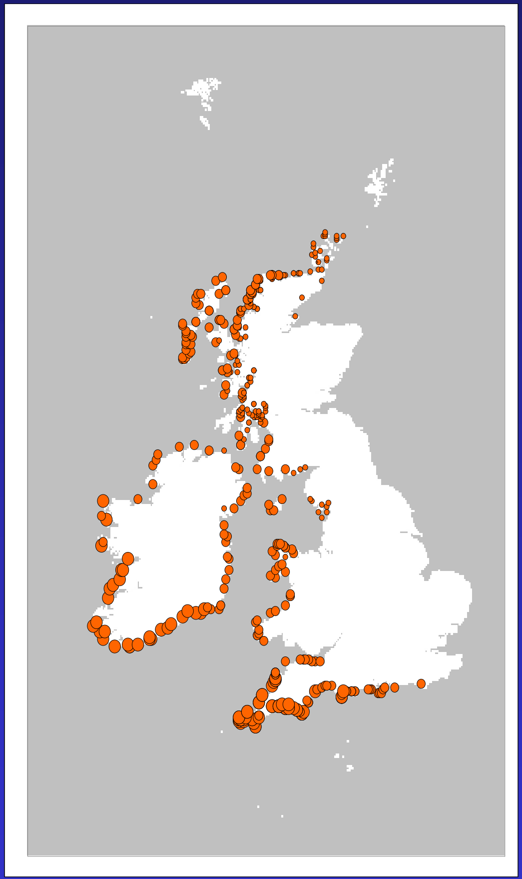


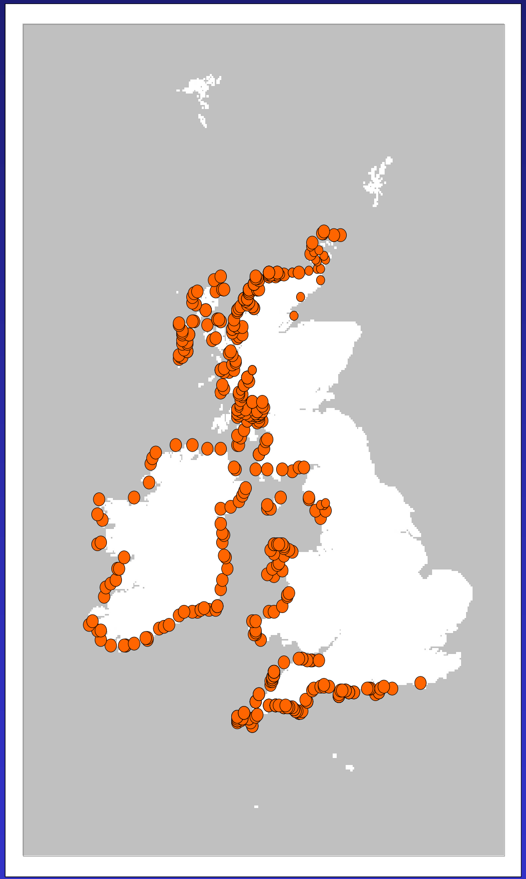
Chthamalus montagui

Model Output

Marclim Survey Data | **Present Climate** | **2°C rise SST**



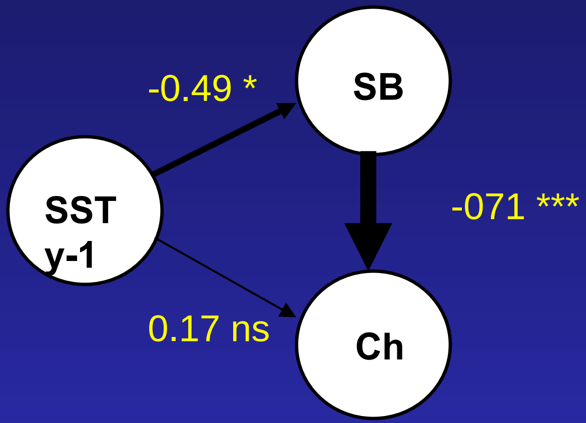




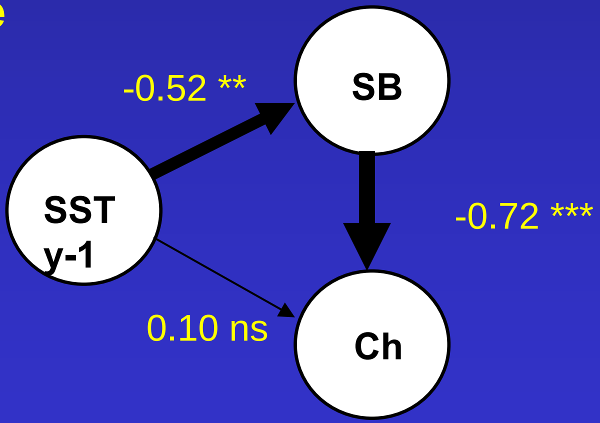
Key: abundant, common, frequent, occasional, rare

Is climate acting on each species directly or is climatic influence mediated by the presence of a competitor?

High Shore



Mid Shore



Causal Path Analysis

- SST the previous June directly influencing adult *S. balanoides* abundance only
- *S. balanoides* abundance influences adult Chthamalid abundance
- The influence of climate on Chthamalids is mediated by the presence of *S. balanoides*, the dominant competitor, in SW England

Model Output

Barnacle recruitment driven by SST

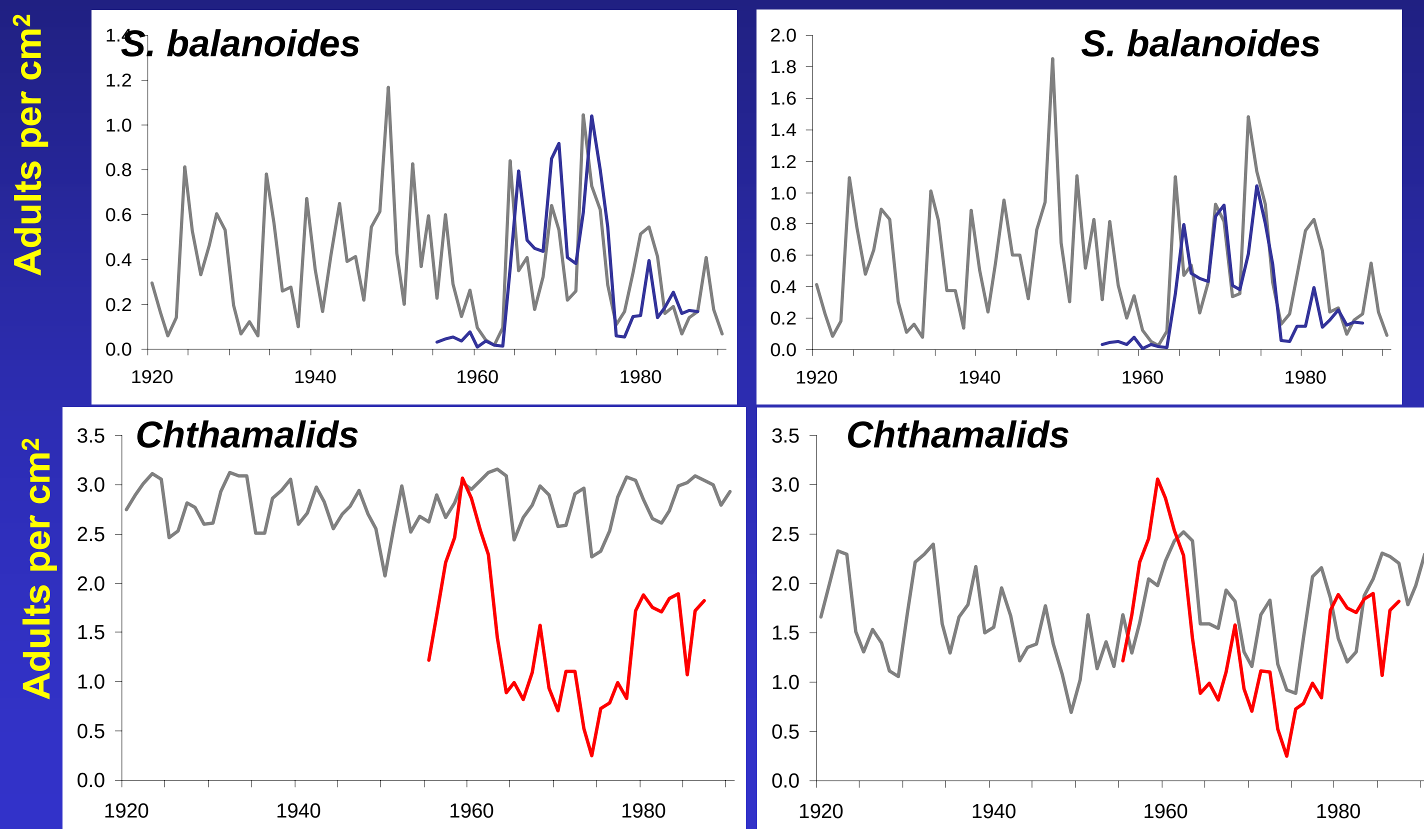
***S. balanoides* recruitment driven by SST**

Interference competition between juvenile *S. balanoides* and Chthamalids

Historical abundance *S. balanoides*

Model output

Historical abundance chthamalids



Hyp.1 Temperature driven

Hyp.3 Temp. & competition

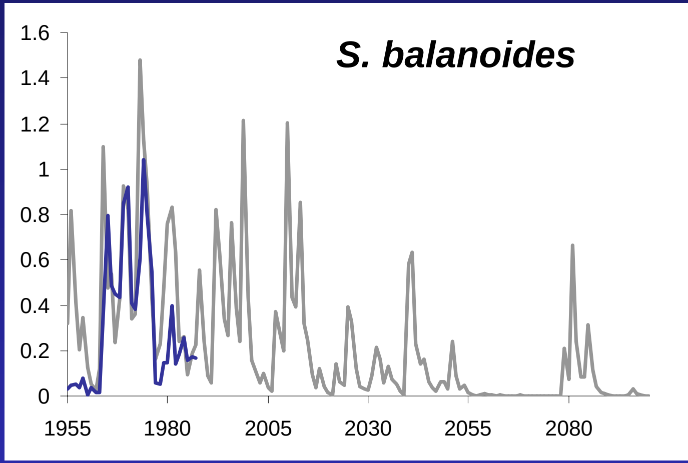
Model output Hypothesis 3: 1955 - 2100

Historical abundance *S. balanoides*

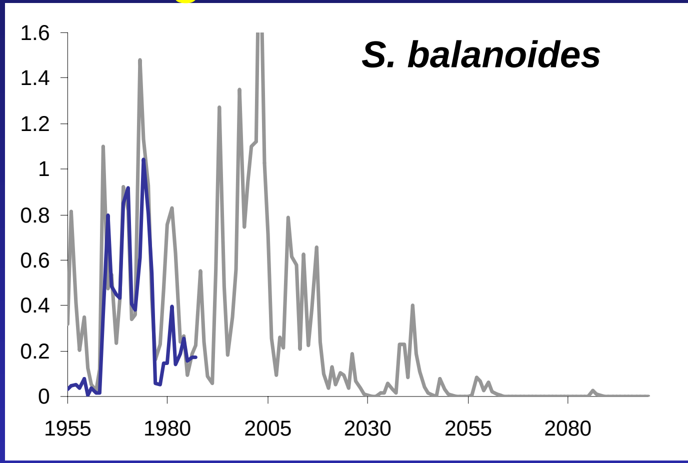
Model output

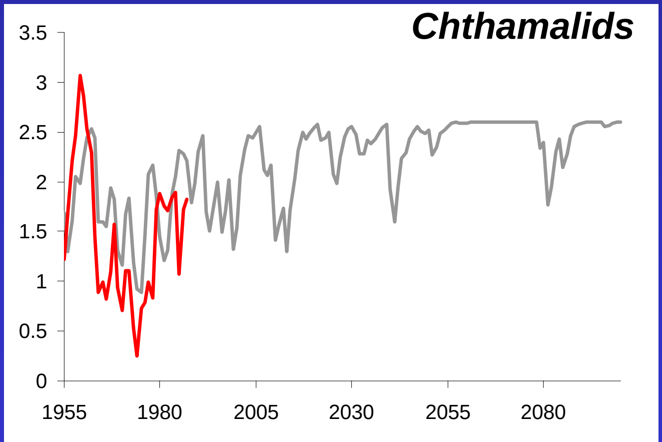
Historical abundance chthamalids

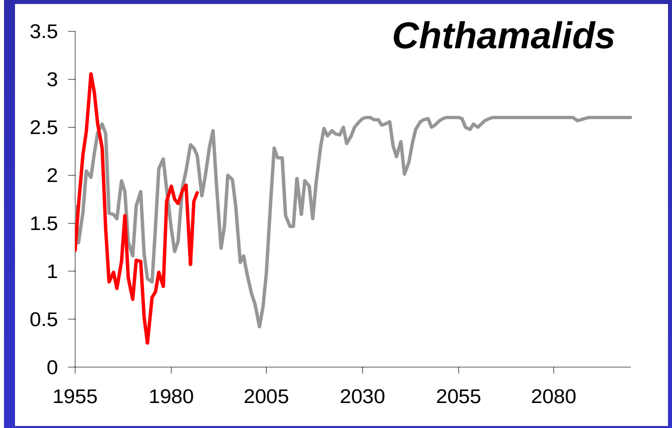
Low emissions



High emissions







Interaction of global change and habitat modification and loss

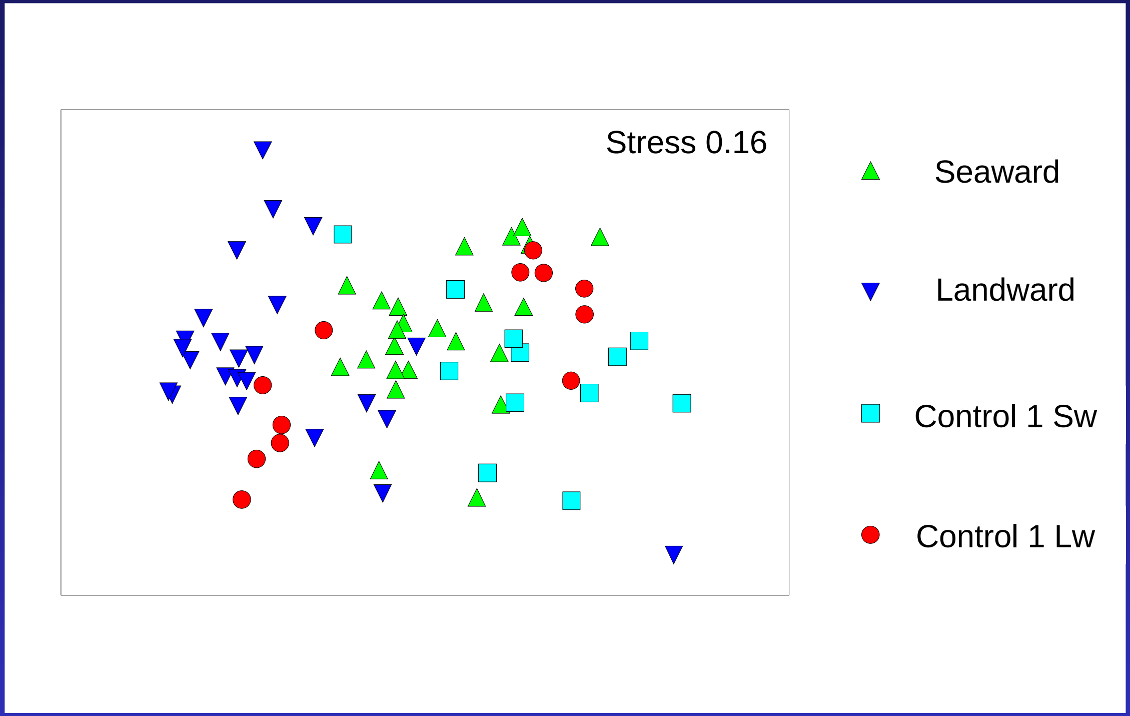
See Airoldi & Beck, 2007, Oceanography and Marine Biology Annual Review

Liverpool (English West Coast)

- Tidal range: 10 m (mean spring tide)
- Sheltered shore
- Fine sand

Elmer

Multivariate analysis. Results 1. - Control 1 (150m)



Nested ANOSIM:
Variability within location: R = 0.58

Differences between locations:
seaward versus landward: R = 0.63
seaward versus controls 1: R = 0.22-0.29
landward versus controls 1: R = 0.25-0.86
control 1 Sw versus control 1 Lw = n.s.

Climate change and non-native species

Both an example of global change?

Globalization

Harbour wall - Nelson, N.Z.

Elminius and *Mytilus*

S. Indopacific

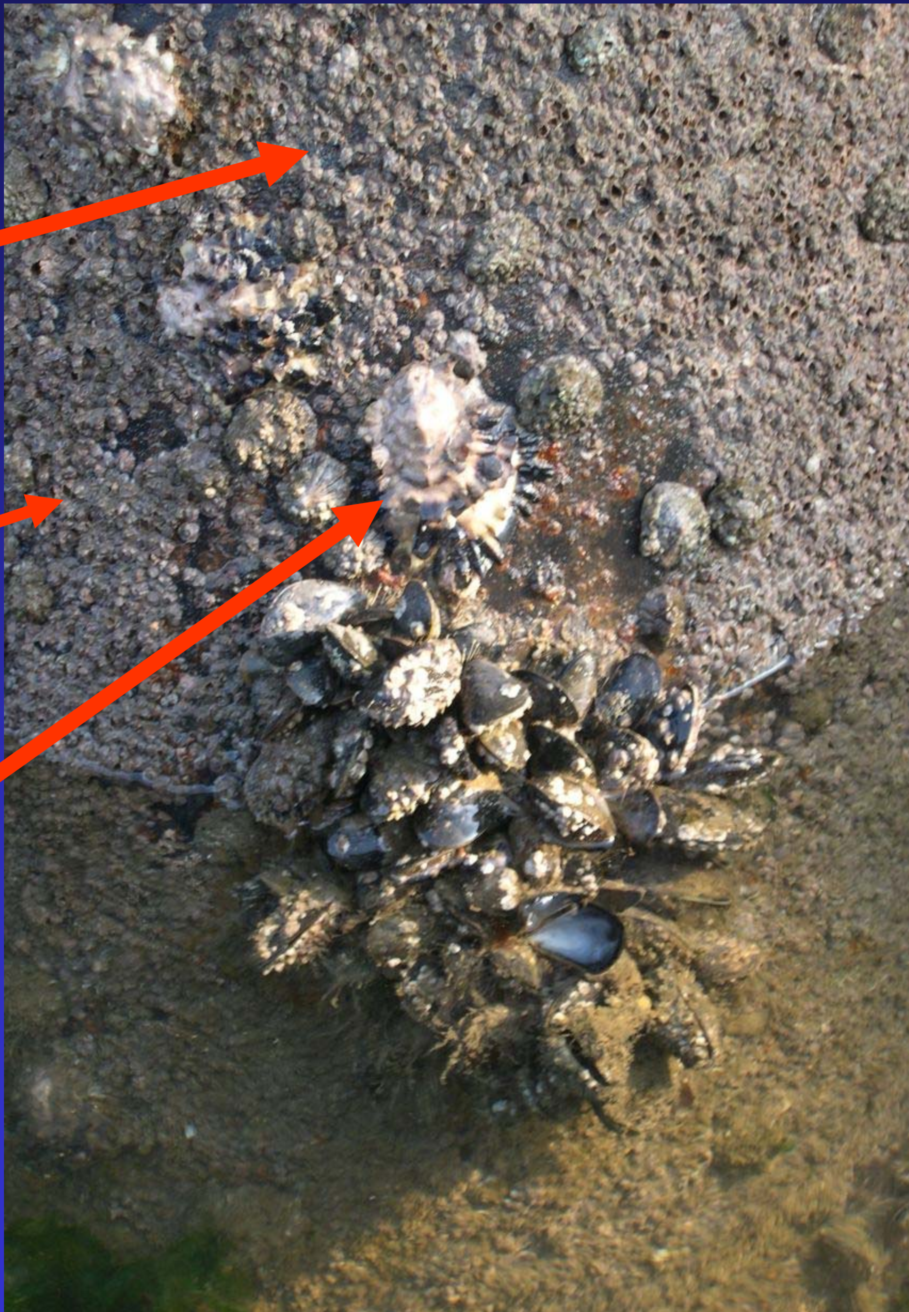
Breakwater - Liverpool, U.K.

Mytilus and *Elminius*

N. Pacific & Atlantic

Homogenisation

What will have most effect on ecosystem functioning?



Climate driven change in barnacle assemblage composition

or

Adding *Elminius*
(last 40 yrs)

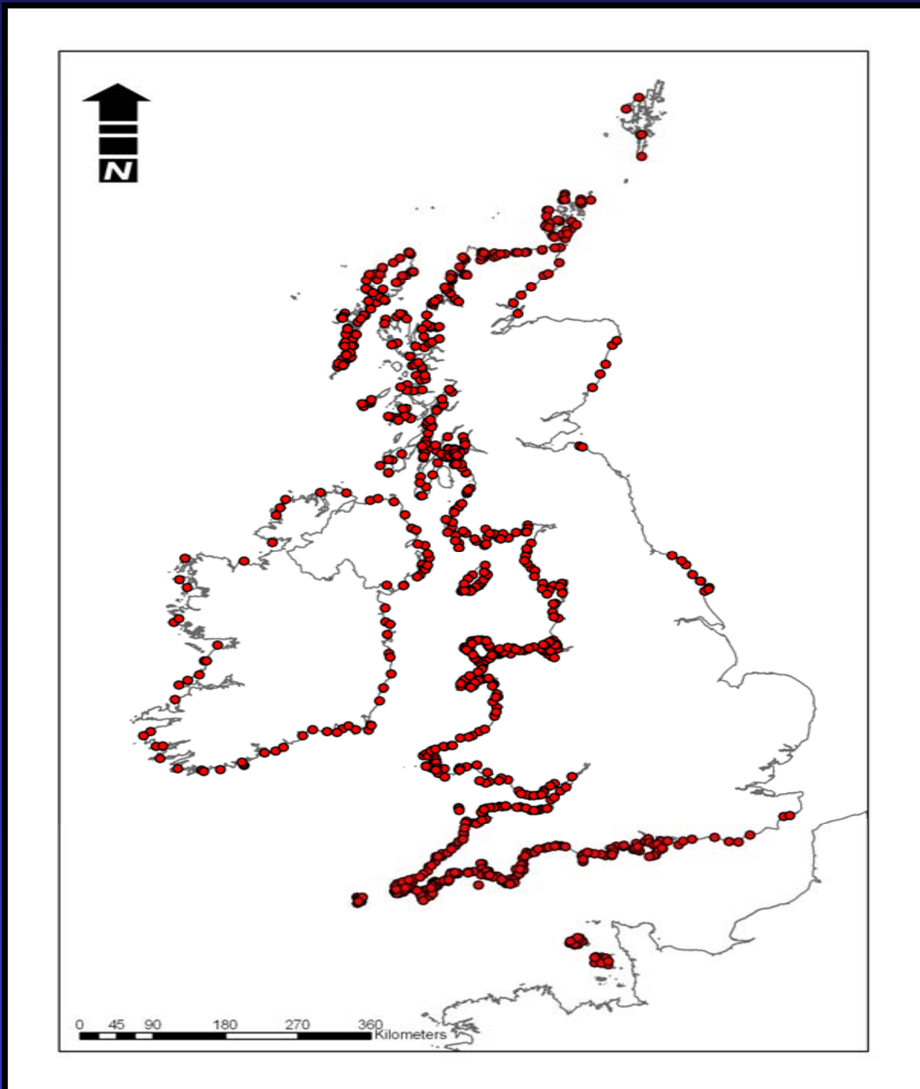
or

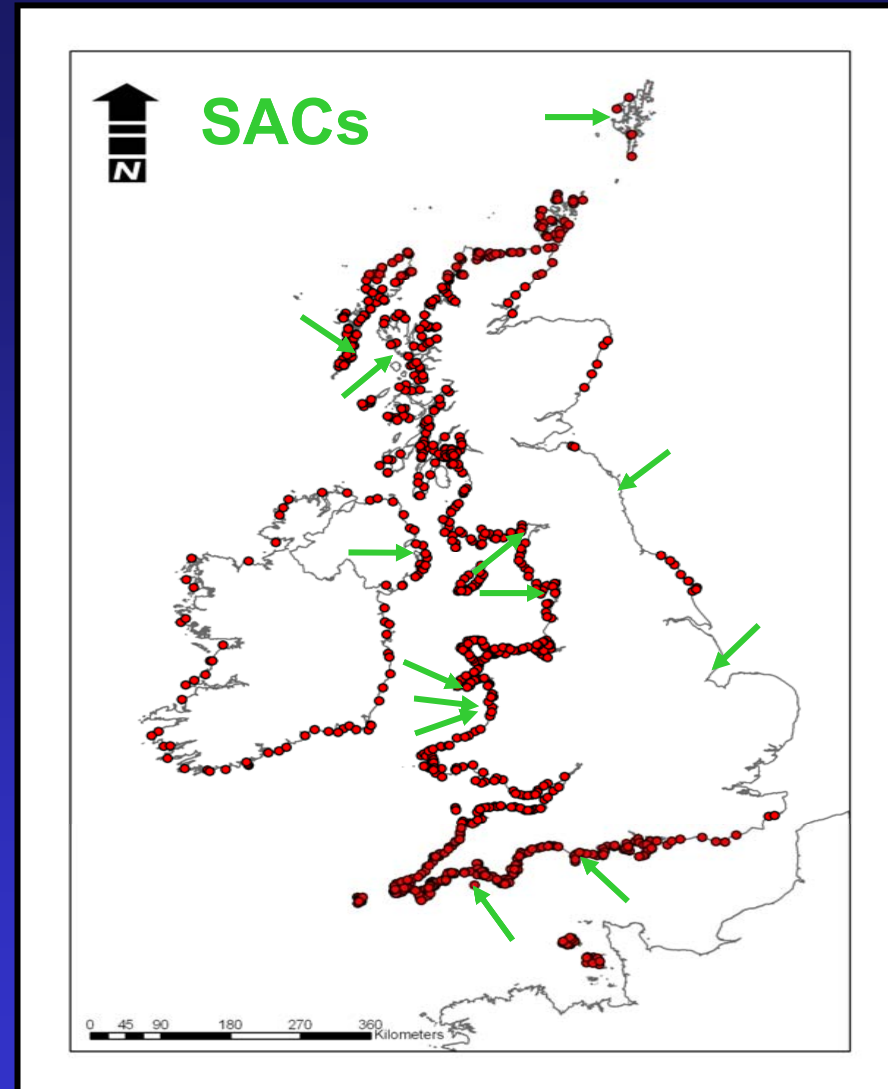
Adding *Crassostrea*
(last 5 yrs facilitated by warming)

Climate impacts → Quantitative: but biodiversity change generally gradual with additions and losses within functional groups

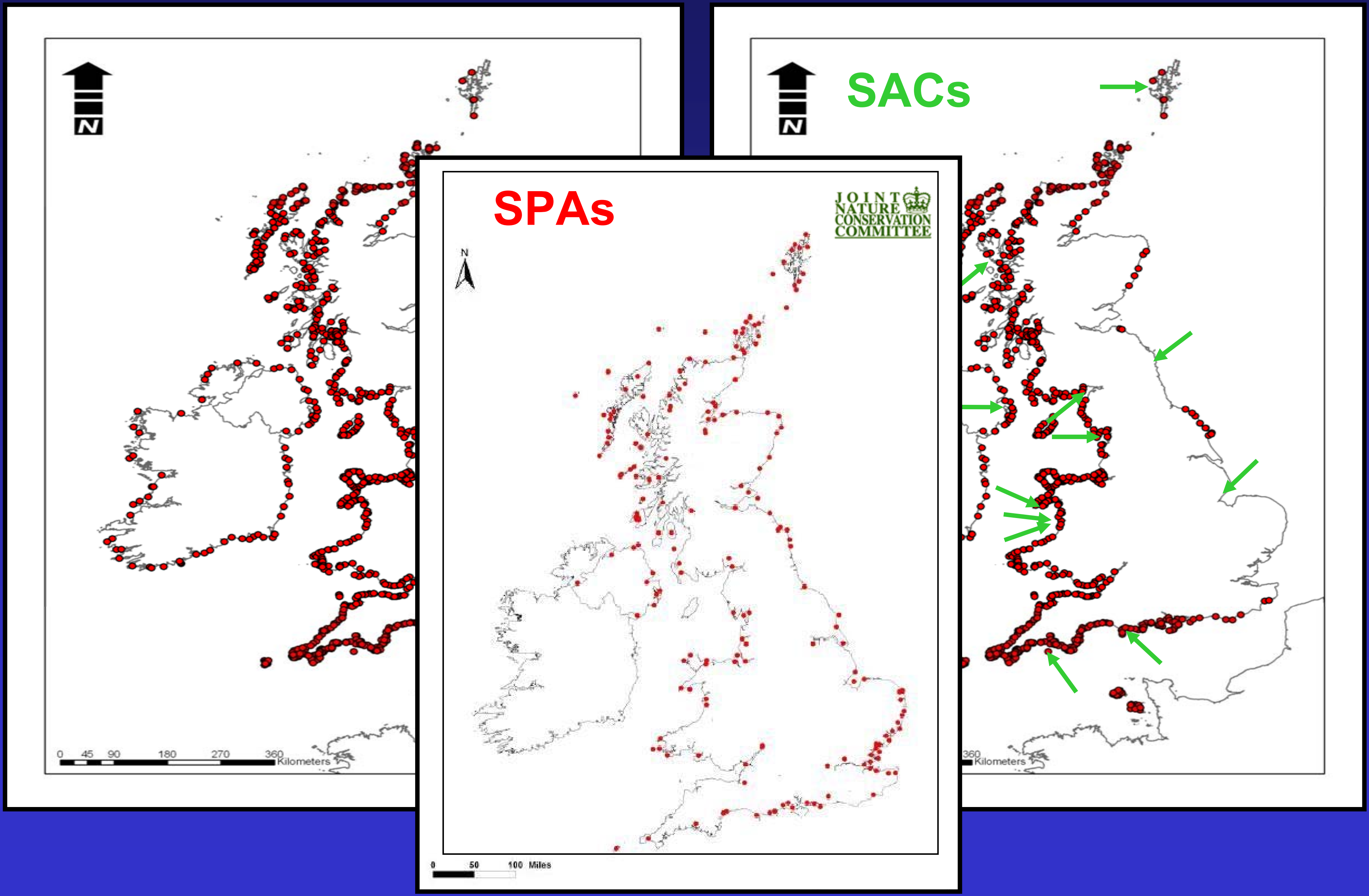
Non-native introductions → Qualitative: and can be abrupt depending on invasion dynamics additions – sometimes losses.
New functional groups

MarClim broad scale sampling in the UK





MarClim broad scale sampling in the UK



MBA Time Series: English Channel

To be Western Channel Observatory from 2007

PML/ MBA/SAHFOS as part of Oceans 2025

Temperature and Salinity	E1	1902-1987, 2002-
Nutrients	E1	1921-1987, 2002-
Phytoplankton	E1	1903-1987, 2002-
Primary production	E1	1964-1984
Zooplankton	E1, L5	1903-1987, 1995-1998,2002-
Planktonic larval fish	E1, L5	1924-1987, 1995-1998,2002-
Demersal fish	L4	1913-1986, 2001-2003,2005-
Intertidal organisms	various	1950-1998, 1997/2001-2005,-
Infaunal benthos (intermittent)	L4	1922-1950, 2003
Epifaunal benthos (intermittent)	L4	1899-1986, 2005-

PML time series:plankton & hydrography at L4 since 1987

n.b. There are many gaps in these series,

Defra & Agg. levy funded restarts in red

Reviewed in Southward et al., Adv. Mar. Biol. 47:1-105, 2005

Marine Environmental Change Network MECN

Hosted by The Marine Biological Association of the UK

Funded by:

DEFRA
Department for Environment, Food & Rural Affairs

MECN NETWORK

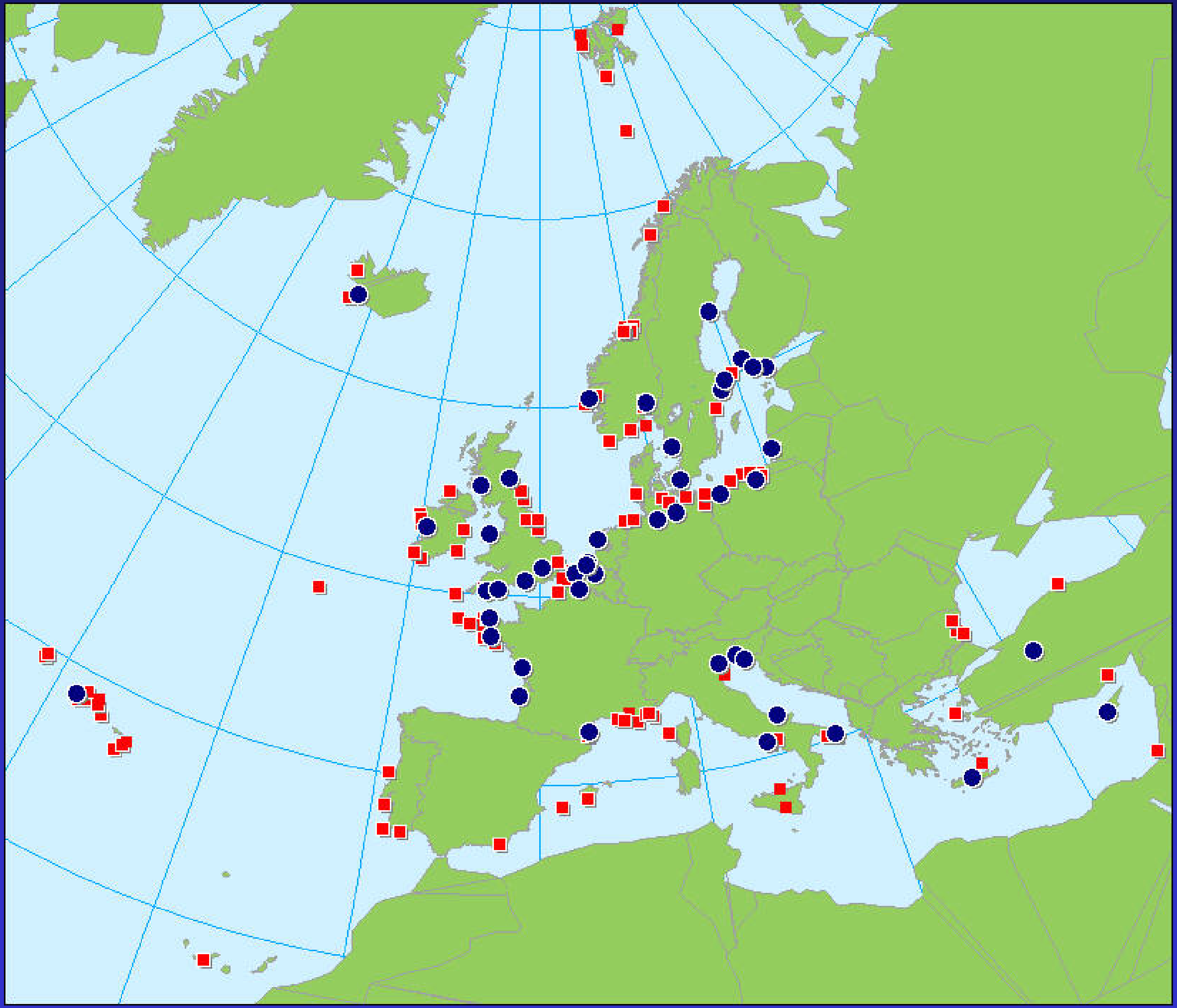
19 Partners:

MBA	DEFRA*
SAHFOS	PEML
PML	Dove ML
SAMS	SOS Bangor
POL	DARD
NOC	CEFAS
SMRU	FRS
	JNCC*
	BODC*
	Met Office
	EA*
	SE*

The NoE builds on previous/existing actions by MARS, BIOMARE and MARBENA

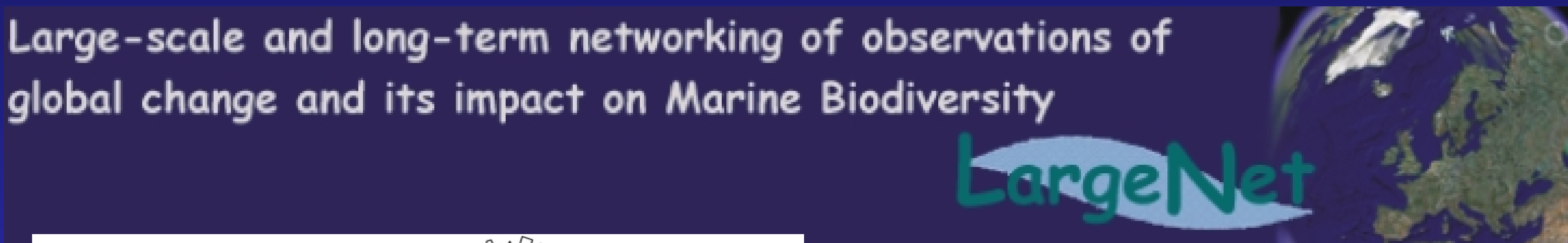
MARS members
(blue dots)

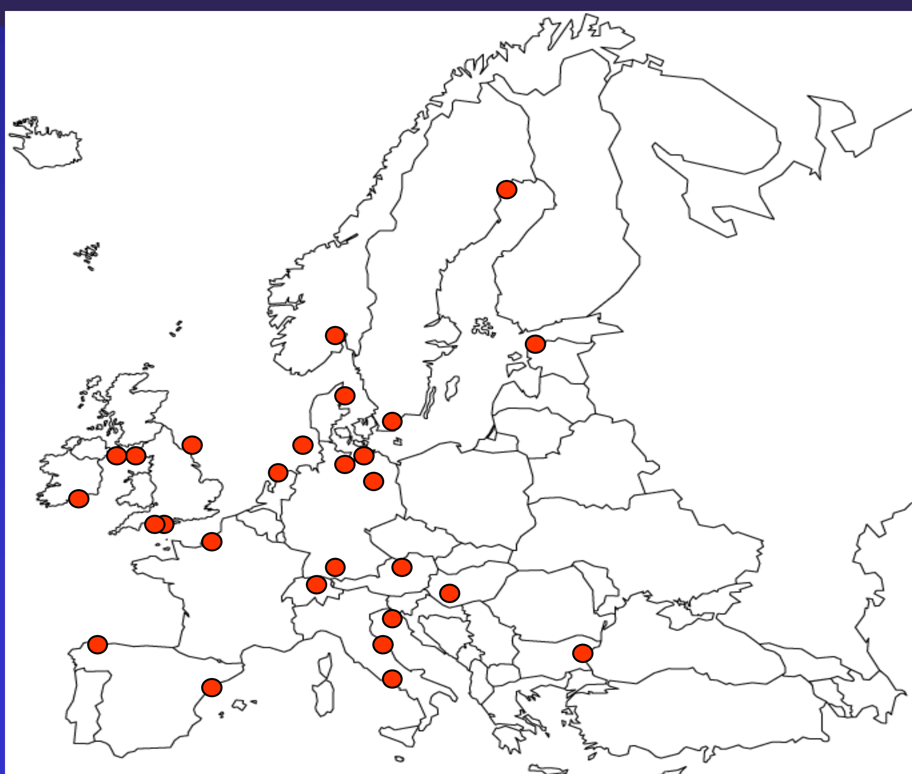
BIOMARE
Reference and Focal sites
(red dots)



Observatory benefits

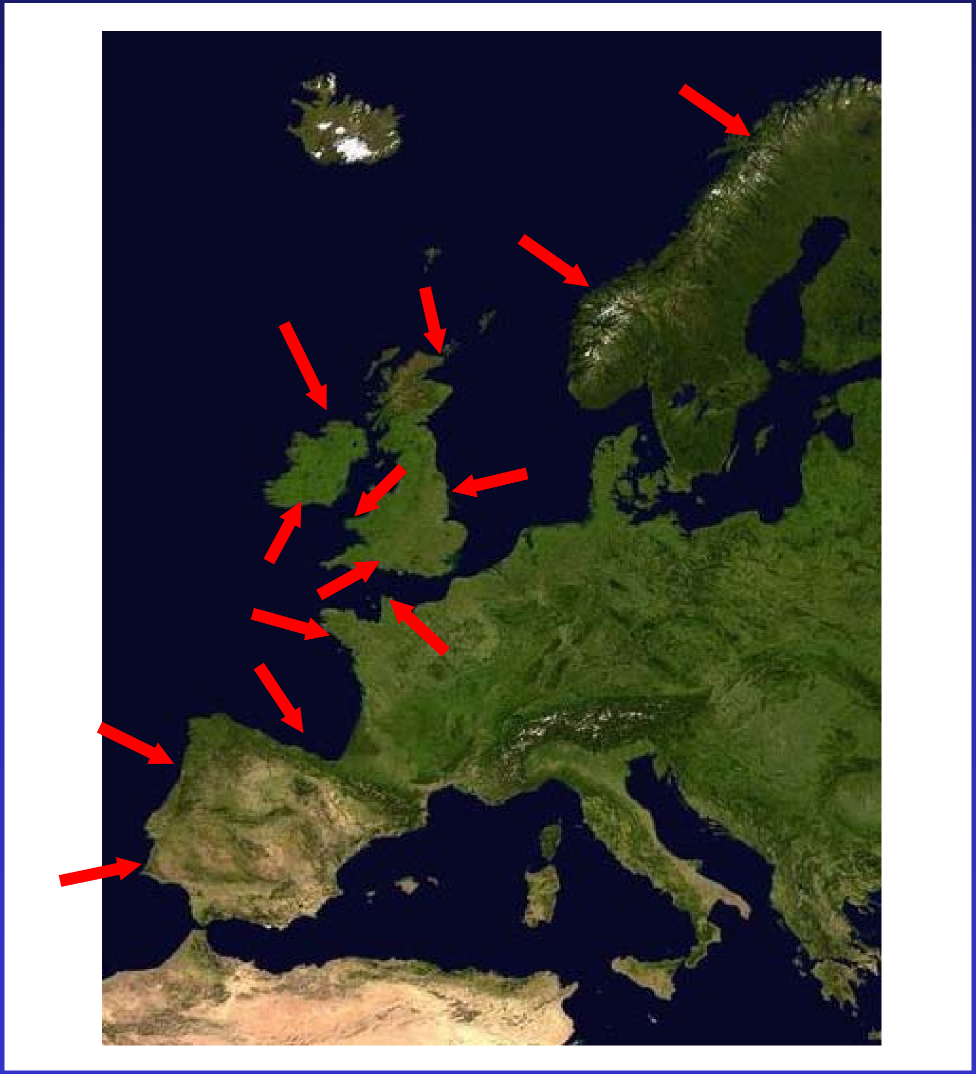
- synthesis of data beyond WEC (continued)
  - European (MarBEF): Largenet





e.g. Long-term pelagic stations in Europe. (Source: Karen Wiltshire, MECN Workshop, DEC 2005)

Boundary Zones

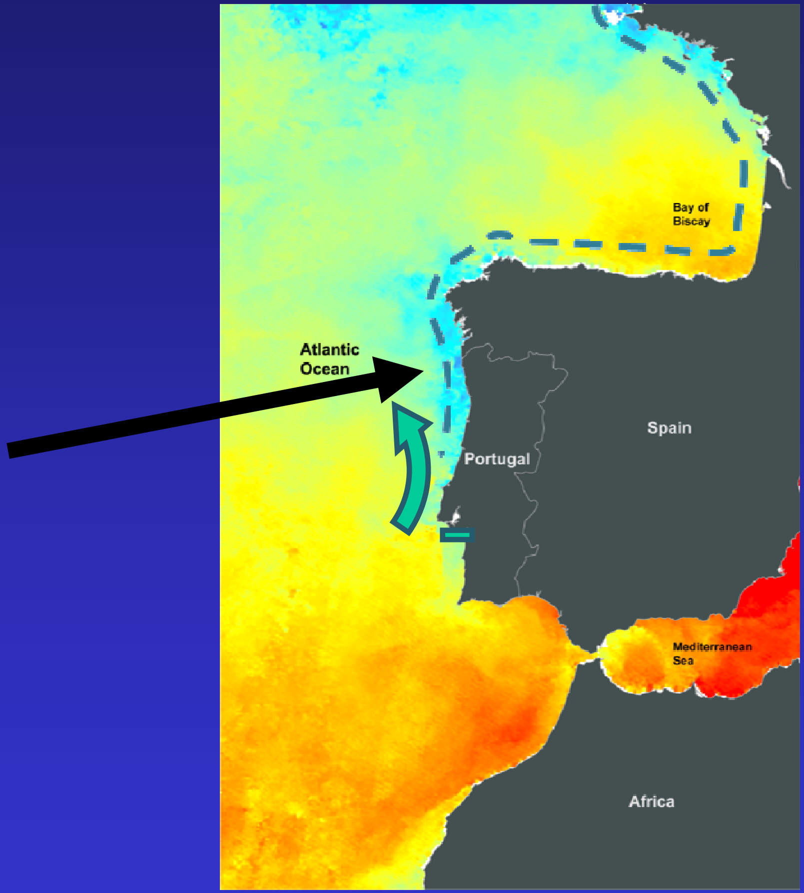


MARBEF network: simple rocky shore monitoring as part of LargeNet in key transitional zones?

Process studies as part of FP 7?

Northern Portugal a critical boundary zone

Iberian upwelling zone



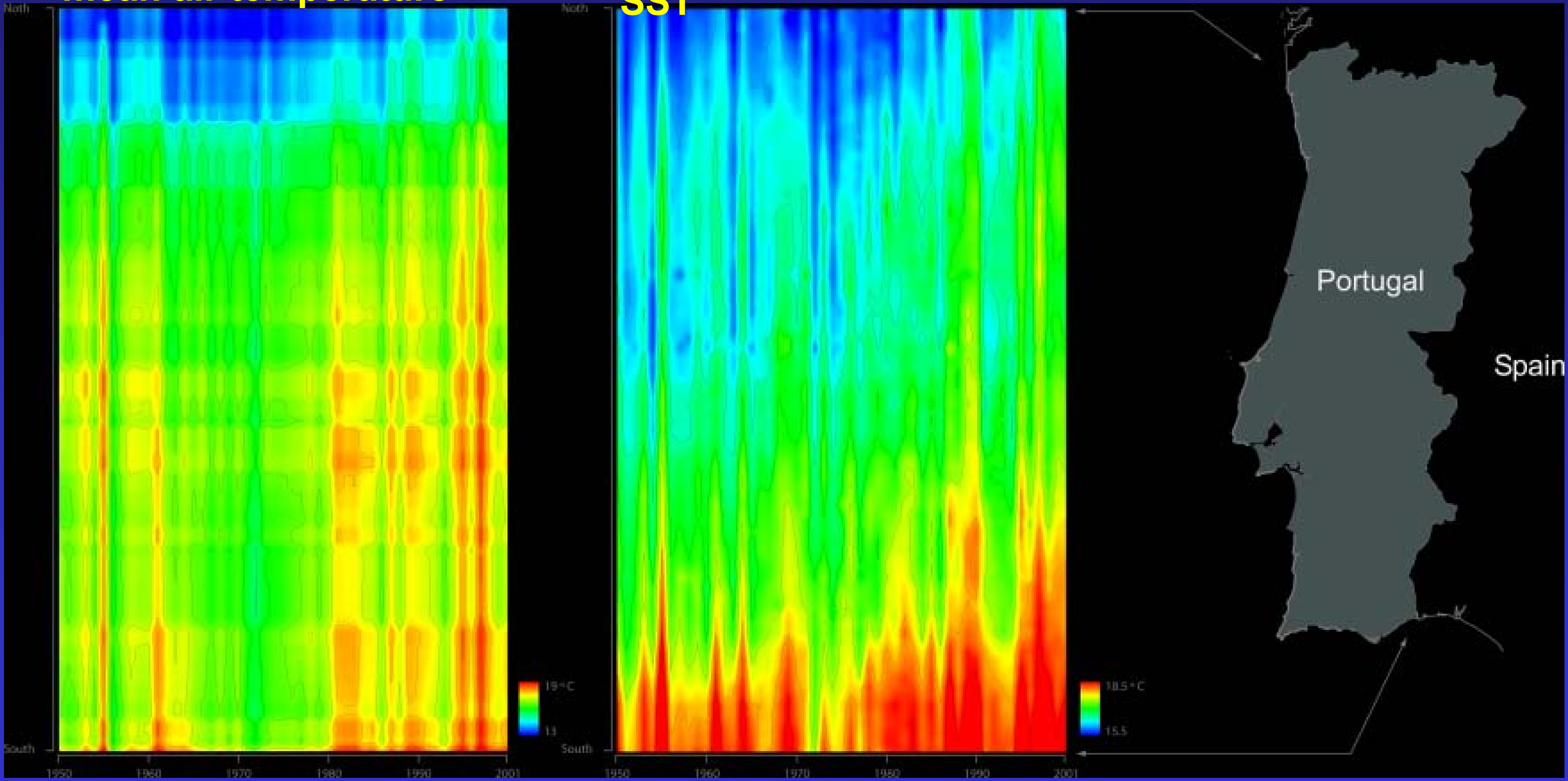
Fernando P. Lima, Pedro A. Ribeiro, Nuno Queiroz, Stephen J. Hawkins and António M. Santos. (In press) Do distributional shifts of northern and southern species of algae match the warming pattern? Global Change Biology. doi: 10.1111/j.1365-2486.2007.01451.x

Processes driving temporal changes

Temperature trends (1950-2001)

Tyndall Centre yearly mean air temperature

ICOADS Monthly mean SST



Changes in the North Portugal

Past and current distribution of *Patella rustica*(lusitanica)

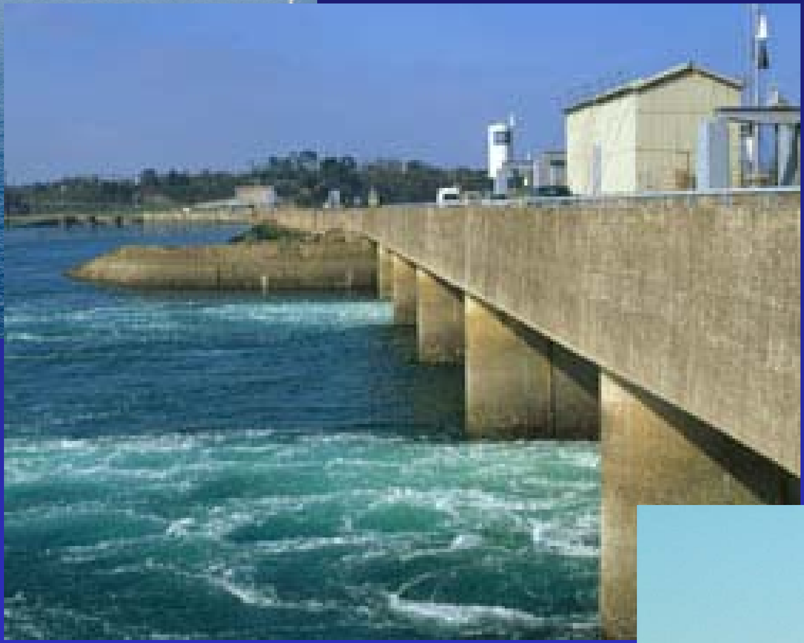
Observed in 1950s

Observed in 2001-06

Fernando P. Lima, Raquel Xavier, Pedro A. Ribeiro, Nuno Queiroz, Pedro Tarroso, Stephen J. Hawkins and António M. Santos. (2007) Modelling past and present geographical distribution of the marine gastropod Patella rustica as a tool for exploring responses to environmental change. Global Change Biology, 13: 2065–2077

Long-term mitigation gain versus short term pain??

Off-shore wind-farm off Denmark



Tidal barrage at La Rance, France

World's first wave farm nr Povoa de Varzim, Portugal. World's first wave energy test facility north coast Cornwall, UK

Research agenda

- Long-term and broad-scale sustained observations
- Process studies using experimental approach
- Targeted research on interactions
- Modelling for forecast and prediction
- Tractable well studied systems (such as rocky shores….)

Peer Reviewed Publications:

*Herbert, R.J.H., Southward, A.J., Sheader, M. & Hawkins, S.J., 2007. Journal of the Marine Biological Association of the UK 87: 487-499.

*Mieszkowska, N., Hawkins, S.J., Burrows, M.T. & Kendall, M.A., 2007. Journal of the Marine Biological Association of the UK, 87: 5379/1-9.

*Moore, P., Hawkins, S.J., & Thompson, R.C., 2007. Marine Ecology Progress Series, 334: 11-19.

*Moore, P., Hawkins, S.J. & Thompson, R.C., 2007. Journal of Experimental Marine Biology and Ecology, 344: 170-180.

*Lima, F.P., Ribeiro, P.A., Querioz, N., Xavier, R., Tarroso, P., Hawkins, S.J. & Santos, A.M., 2007. Global Change Biology, in press.

*Mieszkowska, N., M.A. Kendall, S.J. Hawkins, R. Leaper, P. Williamson, N.J. Hardman-Mountford & A.J. Southward, 2006. Hydrobiologia 555: 241-251.

*Lima, F.P., Queiroz, N., Ribeiro, P.A., Hawkins, S.J. & Santos, A.M. 2006. Journal of Biogeography 33: 812-822.

*Helmuth, B., Mieszkowska, N., Moore, P. & Hawkins, S.J., 2006. Annual Review of Ecology Systematics and Evolution 37: 373-404.

*Lima, F.P., Queiroz, N., Ribeiro, P.A., Hawkins, S.J., Santos, A.M., 2006. Journal of Biogeography 33, 812-822.

Simkanin,C., Power, A-M., Myers, A., McGrath, D., Southward, A.J., Mieszkowska, N., Leaper, R. & O'Riordan, R., 2005. Journal of the Marine Biological Association of the U.K. 85: 1329-1340.Hiscock, K., Southward, A.J., Tittley, I. & Hawkins, S.J. 2004. Aquatic Conservation 14: 333-362.

*Hardman-Mountford, N.J., Allen, J.I., Frost, M.T., Hawkins, S.J., Kendall, M.A., Mieszkowska, N., Richardson, K.A. & Somerfield, P.J. 2005. Marine Pollution Bulletin 50: 1463-1471.

*Southward, A.J., Langmead, O., Hardman-Mountford, N.J., Aiken, J., Boalch, G.T., Dando, P.R., Genner, M.J., Joint, I., Kendall, M.A., Halliday, N.C., Harris, R.P., Leaper, R., Mieszkowska, N., Pingree, R.D., Richardson, A.J., Sims, D.W., Smith, T., Walne, A.W. & Hawkins, S.J. 2005. Advances in Marine Biology 47: 1-105.

Svensson, C-J., Jenkins, S.R., Hawkins, S.J., Aberg, P.A., 2005. Oecologia 142: 117-126.

*Kendall, M.A., Hawkins, S.J., Burrows, M.T. & Southward, A.J. 2004. Ibis (Special Edition) 146: 40-47.

*Genner, M.J., Sims, D.W., Wearmouth, V.J., Southall, E.J., Southward, A.J., Henderson, P.A., Hawkins, S.J., 2004. Proceedings of the Royal Society of London, Biological Sciences 271: 655-661.

*Sims, D.W., Wearmouth, V.J., Genner, M.J., Southward, A.J., Hawkins, S.J., 2004. Journal of Animal Ecology 73: 333-341.

*Hawkins, SJ, Southward, A.J. & Genner M.J. 2003. Science of the Total Environment, 310: 245-56.

*Herbert, R.J.H., Hawkins, S.J., Sheader, M. & Southward, A.J. 2003. Journal of the Marine Biological Association of the UK, 83: 73-82.

*Thompson R.C., Crowe, T.P, & Hawkins, S.J. 2002. Environmental Conservation. 29(2): 168-191.

*Burrows, M.T., Moore, J., & James, B. 2002. Marine Ecology Progress Series 240: 39-48

*Sims, D.W., Genner, M.J., Southward, A.J., Hawkins, S.J., 2001. Proceedings of the Royal Society of London Series B 268: 2607-2611.

Selected Government, NGO reports, knowledge transfer, public understanding reports & theses:

Hawkins, S.J., Mieszkowska, N., Burrows, M.T., Genner, M.J., Kendall. M.A., Leaper, R., Poloczanska, E., Sims, D., Thompson, R.C. & Southward, A.J., 2007. Long- term changes in marine biodiversity in relation to climate, measured using rocky shore indicators. Proceedings of the 24th Conference of the IEEM: 83-91.

Mieszkowska, N., Moore, P., Burrows, M.T. & Hawkins, S.J., 2007. Effects of climate change on intertidal species. MCCIP Annual Report.

Mieszkowska, N., Sims, D. & Hawkins, S.J., 2007. Fishing, climate change and North East Atlantic cod stocks. Commissioned scientific report for World Wildlife Fund.

Mieszkowska, N., Leaper, R., Hill, J., Southward, A.J. & Hawkins, S.J., 2007. The effects of climate change on intertidal species. Book Section. Predicting the Effects of Climate Change on Guernsey.

Mieszkowska, N. & Hawkins, S.J., 2007. Marine Biodiversity and Climate Change in the British Isles. Marine Climate Change Impacts Partnership News.

Hawkins, S.J., Mieszkowska, N., Burrows, M.T., Genner, M.J., Kendall. M.A., Leaper, R., Poloczanska, E., Sims, D., Thompson, R.C. & Southward, A.J., 2007. Long- term changes in marine biodiversity in relation to climate, measured using rocky shore indicators. Proceedings of the 24th Conference of the Institute of Ecology and Environmental Management: 83-91.

Moore, P., Hawkins, S.J., Hiscock, K. & Southward, A.J. 2006. A Sea of Change. The Edge – The magazine of CoastNET.

Hawkins, S.J., 2006. Effects of climate change on intertidal species. MCCIP Annual Report.

Laffoley, D., Baxter, J., O'Sullivan, G., Greenaway, B., Colley, M., Naylor, L. & Hamer, J. 2005 The MarClim Project: Key messages for decision makers and policy advisors, and recommendations for future administrative arrangements and management measures. *English Nature Research Reports*, No. 671.

Mieszkowska, N. 2005. Changes in the biogeographic distribution of the trochid gastropods *Osilinus lineatus* (da Costa) and *Gibbula umbilicalis* (da Costa) in response to global climate change: range dynamics and physiological mechanisms. Ph.D. Thesis, University of Plymouth. p146

Hawkins, S.J., Mieszkowska, N., Leaper, R., Frost, M. T., Moore, P.J. & Kendall, M. A., 2005. Climate change: a network for observations by European Marine Stations. MARS Newsletter Winter 2005.

Moore, P.J. 2005. The role of biological interactions in modifying the effects of climate change on intertidal assemblages. Ph.D. Thesis, University of Plymouth. p126

Vance, T. 2004. Loss of the northern species *Alaria esculenta* from Southwest Britain and the implications for macroalgal succession. MRES Thesis, University of Plymouth.

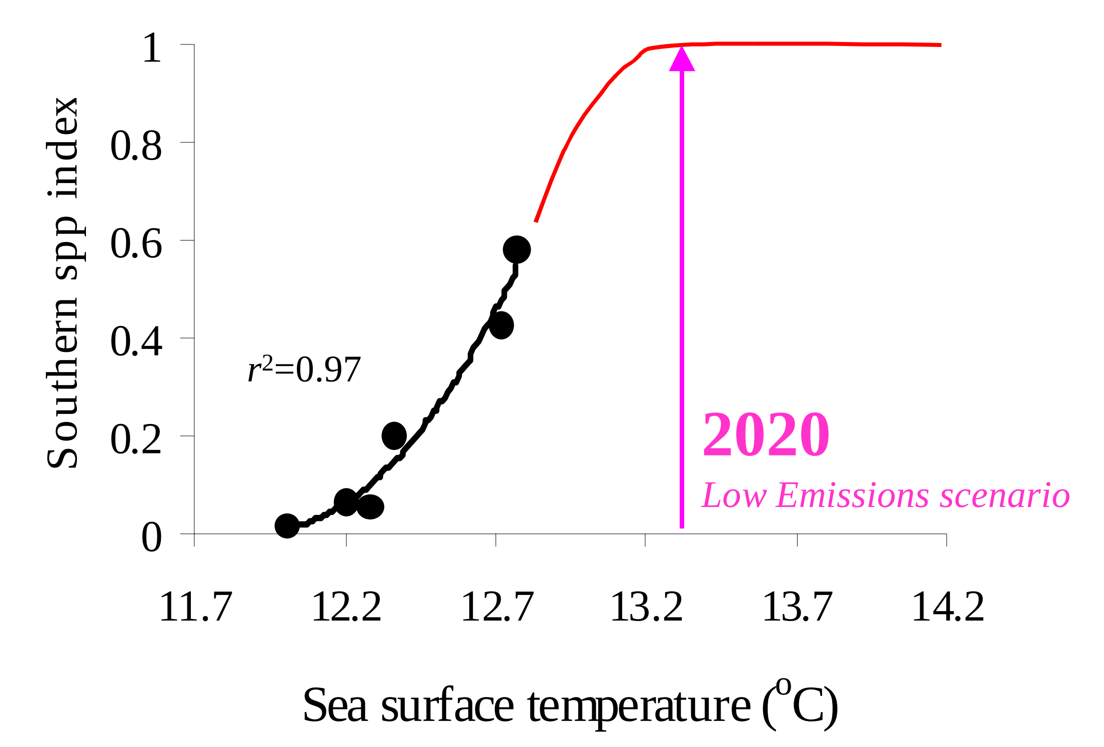
Frost, M. T., Leaper, R., Mieszkowska, N., Moschella, P., Murua, J., Smyth, C. & Hawkins, S. J. 2004. Recovery of a Biodiversity Action Plan species in northwest England: possible role of climate change, artificial habitat and water quality amelioration. Occasional Publication of the MBA No.16: 1-55.

Cannell, M., Brown, T., Sparks, T., Marsh, T., Parr, T., George, G., Palutikof, J., Lister, D., Dockerty, T. & Leaper, R. 2003. Review of UK Climate Change Indicators. DEFRA Contract Report No. *EPG 1/1/158.*

Mieszkowska, N., 2003. *Osilinus lineatus*. Thick top shell. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom.

Kendall, M. A. 2002. MarClim – Marine Biodiversity and Climate Change. *Report to BIOMARE Newsletter*, p10, Autumn 2002 Issue.

Using non-commercial southern species as indicators of climate change



Sims et al., unpublished data

'Standard Haul' data (1913-2002): **The southern species index is the mean sum frequency of occurrence for 7 southern (*Lusitanian*) species with a logistic fit (black line).**

Using a sigmoidal model (black + red lines) we predict that by 2020 (under a Low Emissions scenario; HadRM3) these southern species will occur in nearly every trawl compared with the current rate of 45-60 % occurrence.