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Climate responses of avian predators in a heavily exploited shelf sea:

Effects on trophic interactions and consequences for ecosystem control in the North Sea

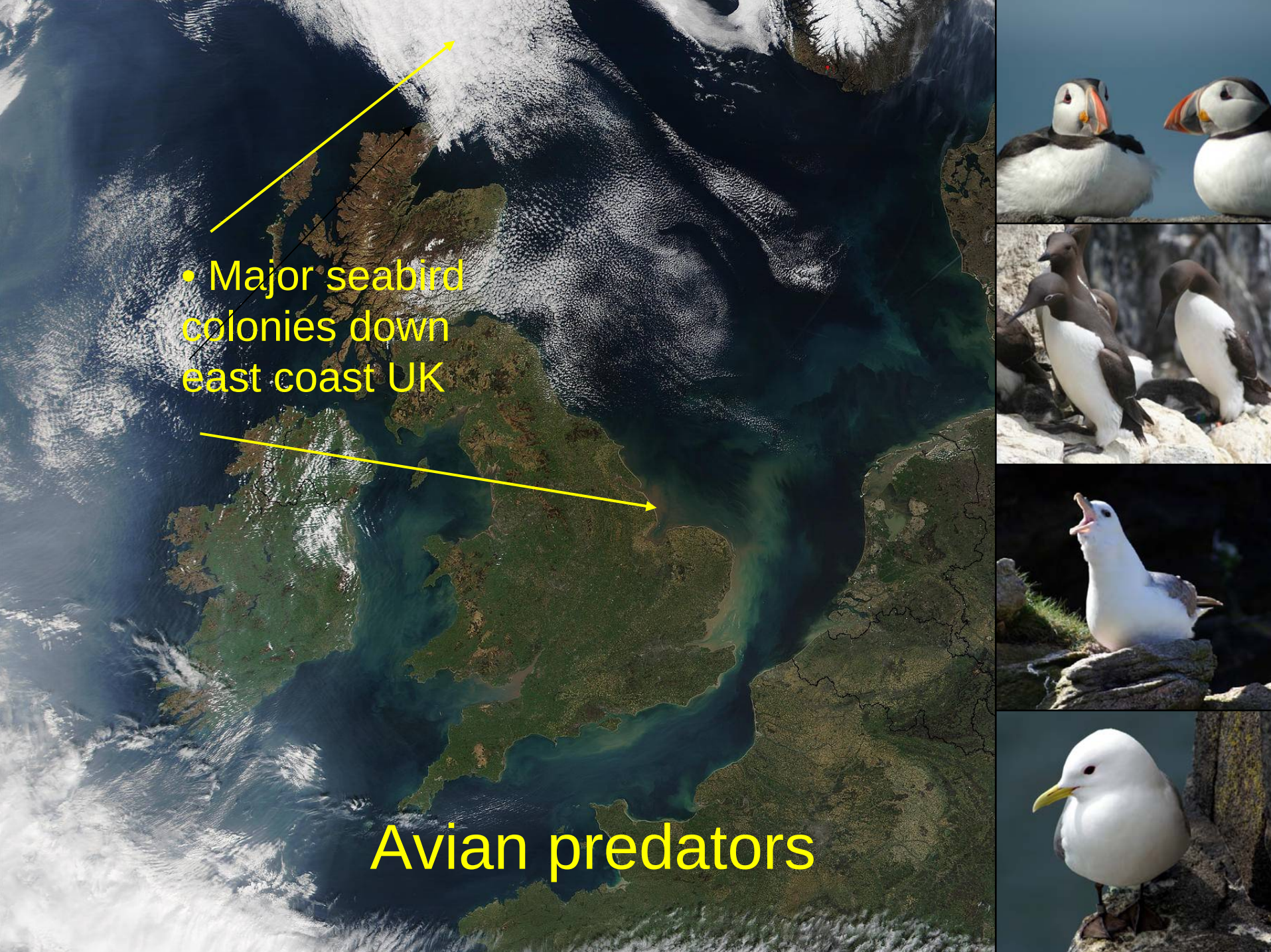
Sarah Wanless and Morten Frederiksen

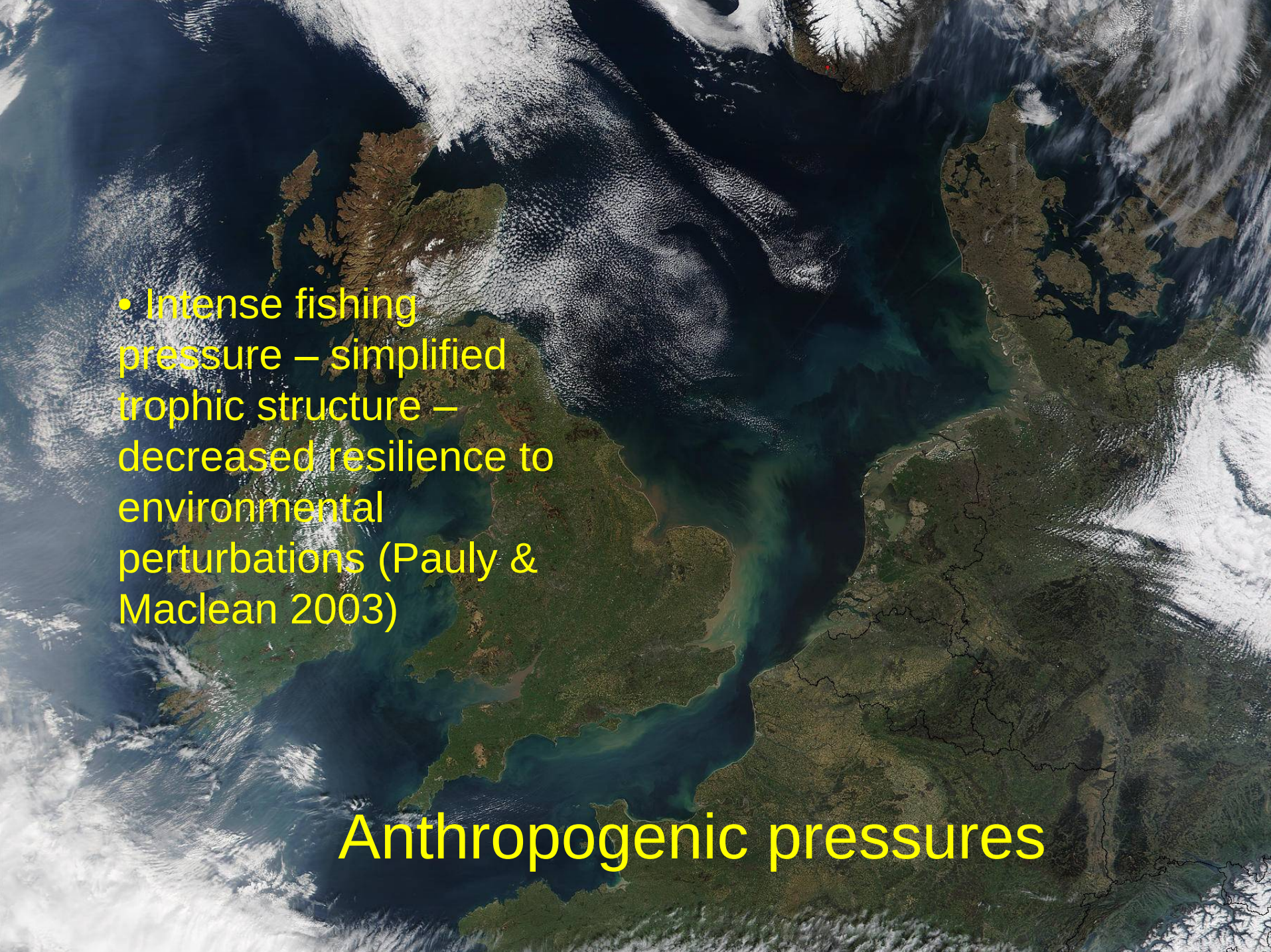
PICES XV, Yokohama, 12 Oct 2006




- Semi-enclosed, small, shallow shelf sea
- Tides - vertical and horizontal mixing and basic circulation pattern
- Highly seasonal - pronounced spring bloom
- Rising sea temperatures – 0.5^{o}C/decade winter and 1.5^{o}C/decade summer
- Changes in plankton community

North Sea ecosystem


• Major seabird colonies down east coast UK
Avian predators



- Intense fishing pressure – simplified trophic structure – decreased resilience to environmental perturbations (Pauly & Maclean 2003)

Anthropogenic pressures

Massive media hype

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Ecology » Fish stocks and sea bird numbers plummet as soaring water temperatures kill off vital plankton

North Sea faces collapse of its ecosystem

By Richard Sadler and Geoffrey Lean

The North Sea is undergoing "ecological meltdown" as a result of global warming, according to startling new research. Scientists say that they are witnessing "a collapse in the system", with devastating implications for fisheries and wildlife.

Record sea temperatures are killing off the plankton on which all life in the sea depends, because they underpin the entire marine food chain. Fish stocks and sea bird populations have slumped.

Scientists at the Sir Alistair Hardy Foundation for Ocean Science in Plymouth, which has been monitoring plankton in the North Sea for over 70 years, say that an unprecedented heating of the waters has driven the cold-water species of this microscopic but vital food hundreds of miles to the north. They have been replaced by smaller, warm-

dence of climate change on a large-scale ecosystem. We are likely to see even greater warming, with temperatures becoming more like those off the Atlantic coast of Spain or further south, bringing a complete change of ecology.

"Some of the colder-water fish species that people like to have with chips are at the southern limit of their range, and if the warming trend continues, cod are likely to become extinct in the North Sea in the next few decades."

This year stocks of young cod were at their lowest for 20

'We are seeing a collapse in the system. Catches of cod and salmon are down and we are getting smaller fish'

their expected recovery after severe cuts in fishing quotas. They say that continued warming will effect all forms of marine life, including seabirds and dolphins.

Research by the Royal Society for the Protection of Birds has established that seabird colonies off the Yorkshire coast and the

this year suffered th

breeding season sinc

began, with many

abandoning nesting

The society puts

a record slump in

which normally bre

millions, providing

diet for many sea

large fish. The eels

the plankton that

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warming waters.

The survey conce

kittiwakes, but oth

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RSPB said last w

years. The numbers of wild

Plankton
Microscopic
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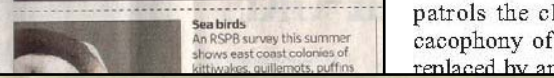


Sea birds
An RSPB survey this summer shows east coast colonies of kittiwakes, guillemots, puffins

NEWS OF THE WEEK

ECOLOGY

Reproductive Failure Threatens Bird Colonies on North Sea Coast

CAMBRIDGE, U.K.—Warden Deryk Shaw can't believe what he's not hearing as he patrols the cliffs of Fair Isle. The usual cacophony of 250,000 sea birds has been replaced by an eerie silence. That's because

they are now also succumbing is "causing everyone consternation," she says.

Experts say that the most likely causes for the decline in sand eels are past overfishing and rising sea temperatures. Previous re-

rch has linked rising temperatures to de-

eding kittiwakes have experienced a 30%
colonies since 1988.

Disaster at sea: global warming hits UK birds

By Michael McCarthy
Environment Editor

HUNDREDS OF thousands of Scottish seabirds have failed to breed this summer in a wildlife catastrophe which is being linked by scientists directly to global warming.

The massive unprecedented collapse of nesting attempts by several seabird species in Orkney and Shetland is likely to prove the first major impact of climate change on Britain.

In what could be a sub-plot from the recent disaster movie, *The Day After Tomorrow*, a rise in sea temperature is believed to have led to the mysterious disappearance of a key part of the marine food chain – the sandeel, the small fish whose great teeming shoals have hitherto sustained larger fish, marine mammals and seabirds in their millions.

In Orkney and Shetland, the sandeel stocks have been shrinking for several years, and this summer they have disappeared: the result for seabirds has been mass starvation. The figures for breeding failure, for Shetland in particular, almost defy belief.

More than 172,000 breeding pairs of guillemots were recorded in the islands in the last national census, Seabird 2000,

unprecedented in Europe." More than 6,800 pairs of great skuas were recorded in Shetland in the same census; this year they have produced a handful of chicks – perhaps fewer than 10 – while the arctic skuas (1,120 pairs in the census) have failed to produce any surviving young.

The 24,000 pairs of arctic terns, and the 16,700 pairs of Shetland kittiwakes – small gulls – have "probably suffered complete failure", said Mr Ellis.

In Orkney the picture is very similar, although detailed figures are not yet available. "It looks very bad," said the RSPB's warden on Orkney mainland, Andy Knight. "Very few of the birds have raised any chicks at all."

The counting and monitoring is still going on and the figures are by no means complete: it is likely that puffins, for example, will also have suffered massive breeding failure but because they nest deep in burrows, this is not immediately obvious.

But the astonishing scale of what has taken place is already clear – and the link to climate change is being openly made by scientists. It is believed that the microscopic plankton on which tiny sandeel larvae feed are moving northwards as the sea water warms, leaving the baby

North Sea pelagic food web

'Wasp-waist' trophic structure

Top predators (seabirds, seals, cetaceans, fish)

Industrial fishery

Forage fish (sandeels)

Secondary producers (copepods, gammarids, echinoderms, decapods)

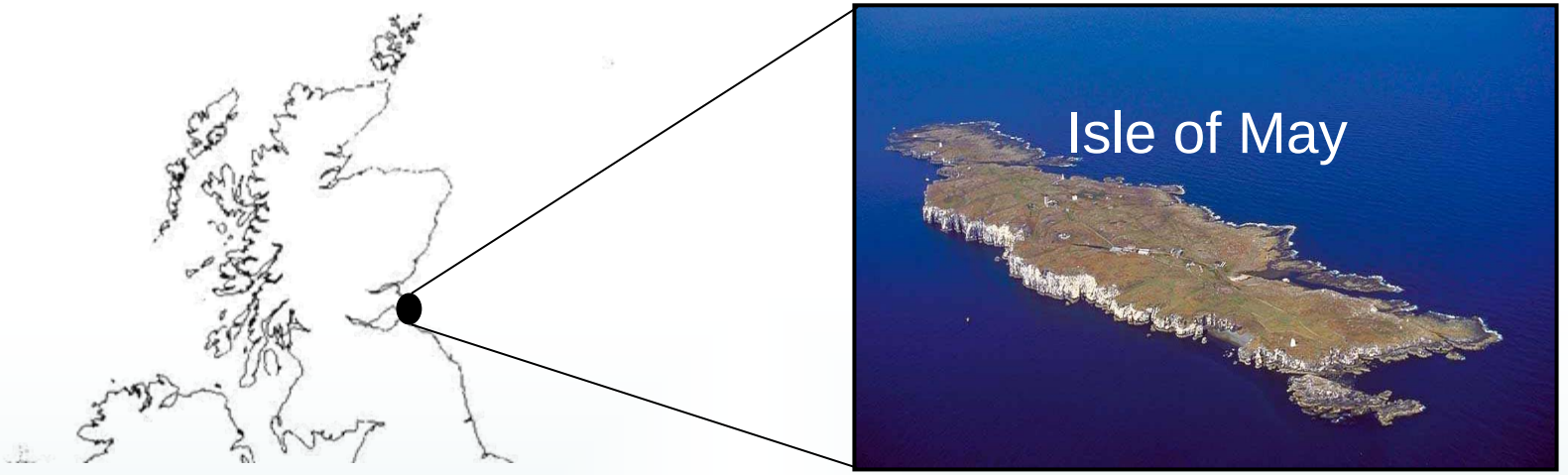
Primary producers (dinoflagellates, diatoms)

Species diversity

Sandeels and climate

- Cold water species
- Recruitment lower when sea temperature higher (Arnott & Ruxton 2002)
- Predict higher temperatures will have a negative effect on seabird performance

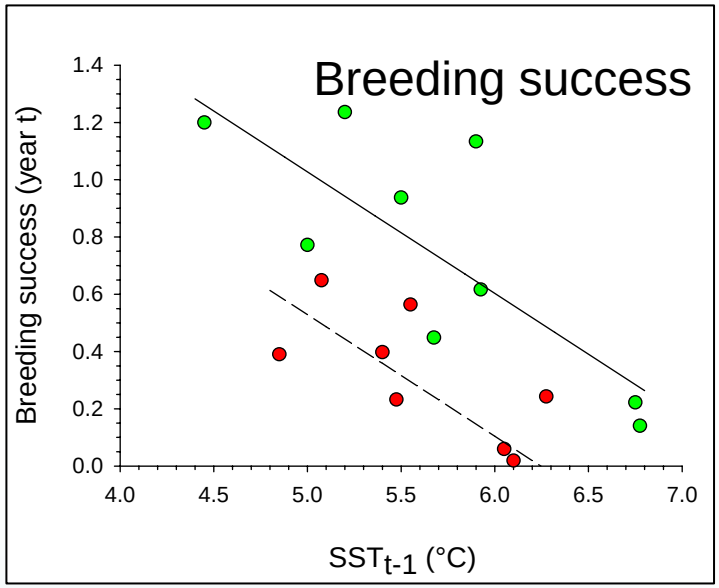
Isle of May long-term studies

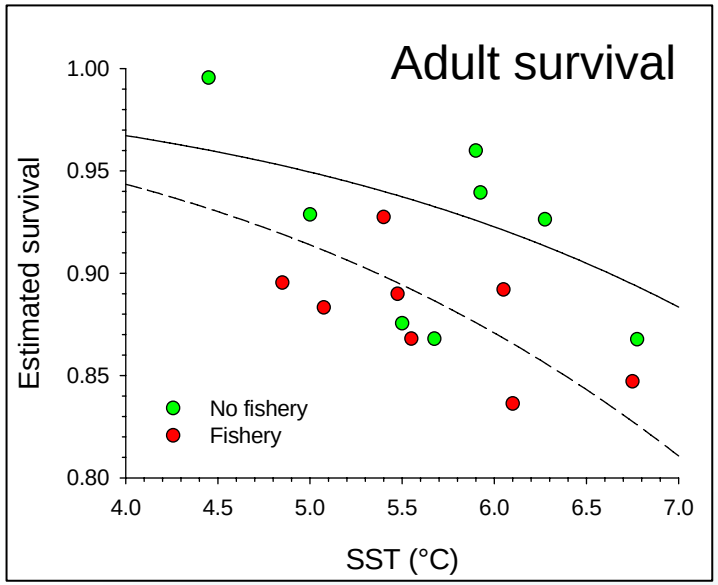


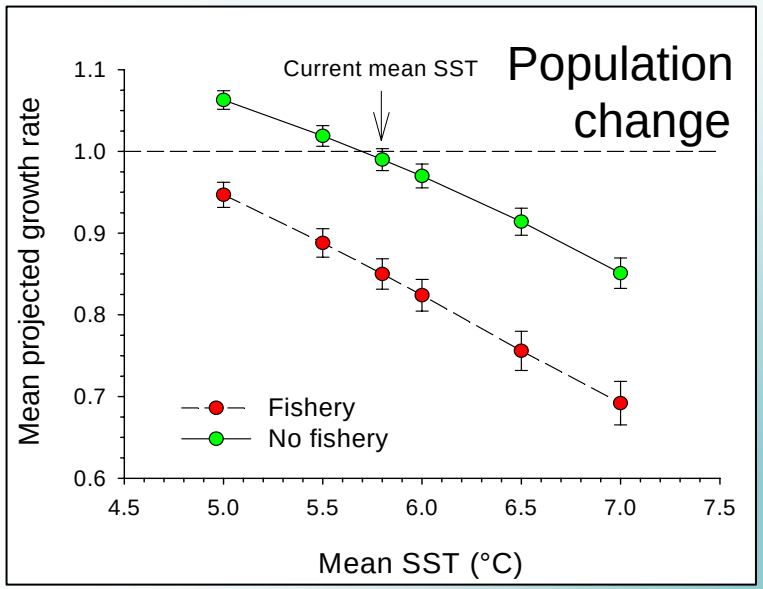
- 20 - 30 years data on:
- Demography (breeding success and survival)
- Phenology
- Diet

- Local sandeel fishery operating 1990 – 1999
- Closed since 2000 because of concern about effects on predators

Climate and fishery effects





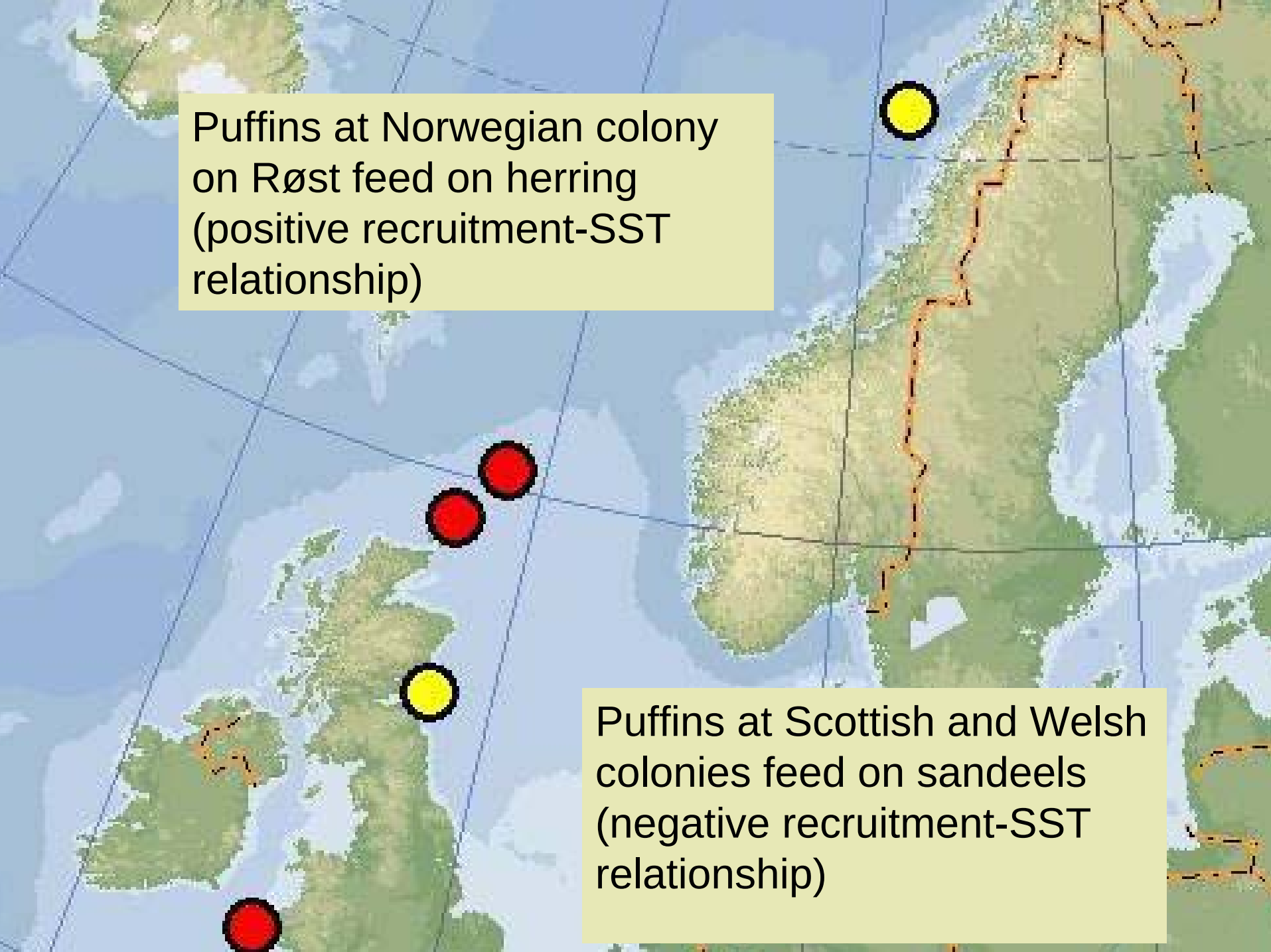


Frederiksen et al (2004)

Regional variation in climate responses

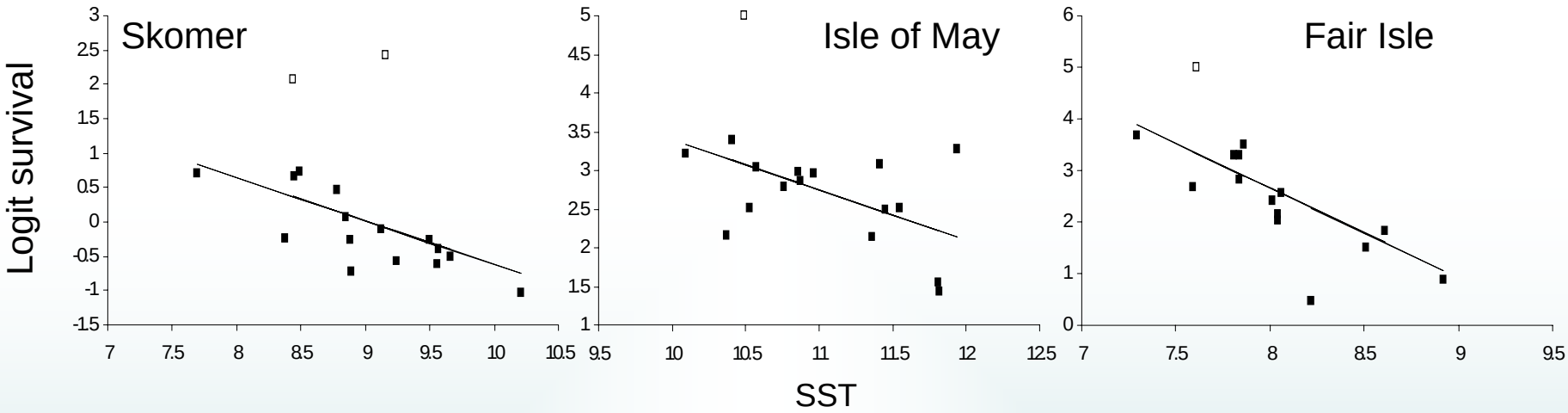
- Comparative approach use information from across breeding range
- Diet of birds varies among colonies
- Recruitment – temperature response differs between prey species

Photo Akinori Takahashi

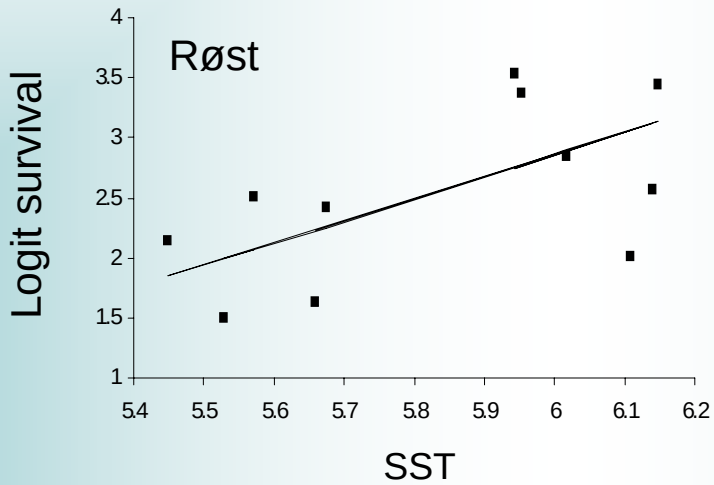

Puffins at Norwegian colony on Røst feed on herring (positive recruitment-SST relationship)
Puffins at Scottish and Welsh colonies feed on sandeels (negative recruitment-SST relationship)

Puffin survival and climate

Sandeel-dependent colonies – negative relationships



Herring-dependent colony – positive relationship



- Relationships with SST in line with those expected from temperature dependent recruitment of prey

Harris et al. (2005)

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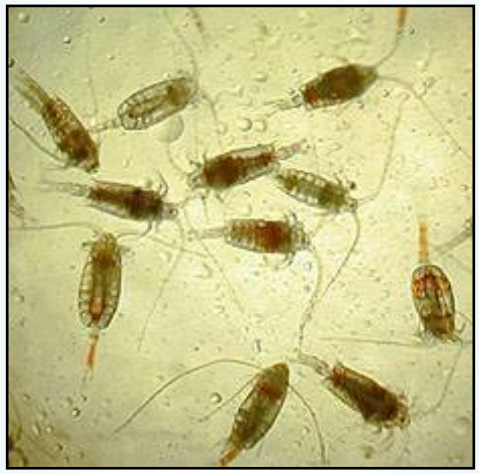
Multi-trophic interactions

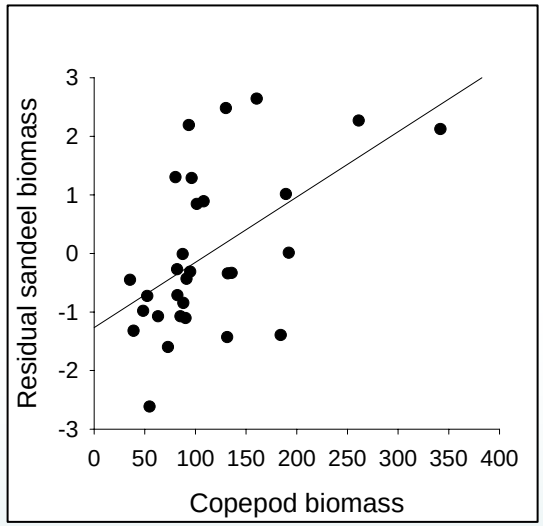
- Long term data on plankton abundance and biomass of larval sandeels from Continuous Plankton Recorder (CPR)

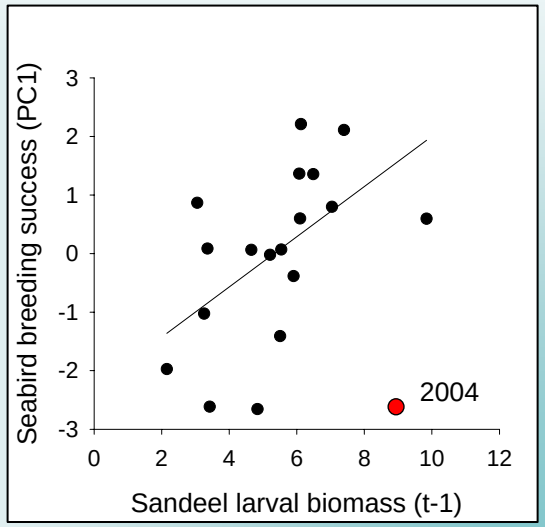


- Long term data on seabird productivity and sandeel size from Isle of May

Trophic interactions

- Positive correlations between larval sandeel biomass and planktonic prey
- Positive correlations between seabird productivity (5 species) and larval sandeel abundance with a 1-year lag
- Consistent with bottom-up control BUT doesn't explain poor performance in 2004



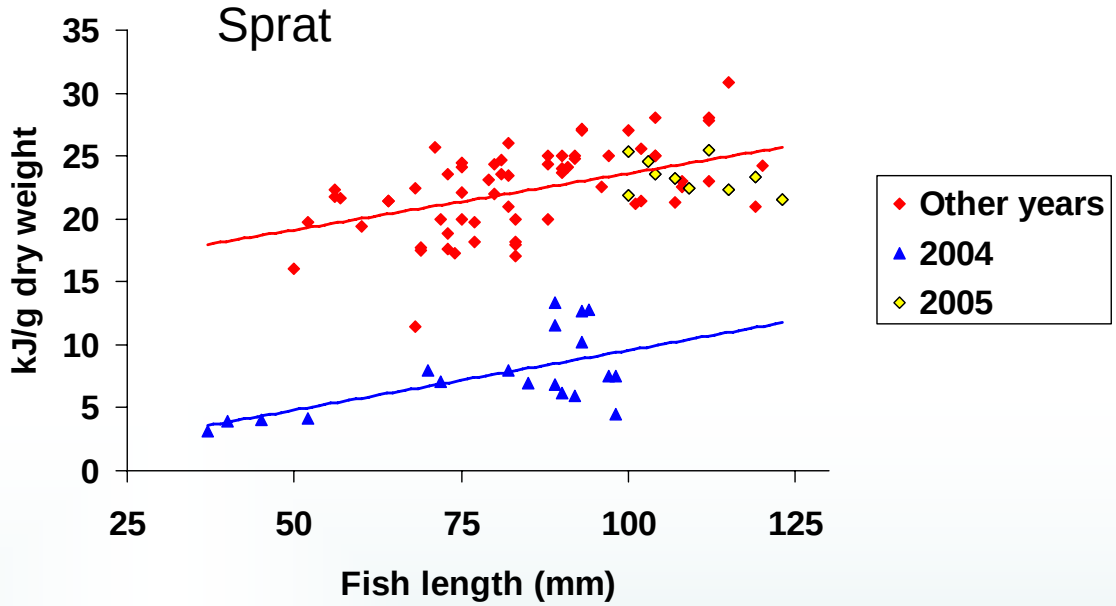


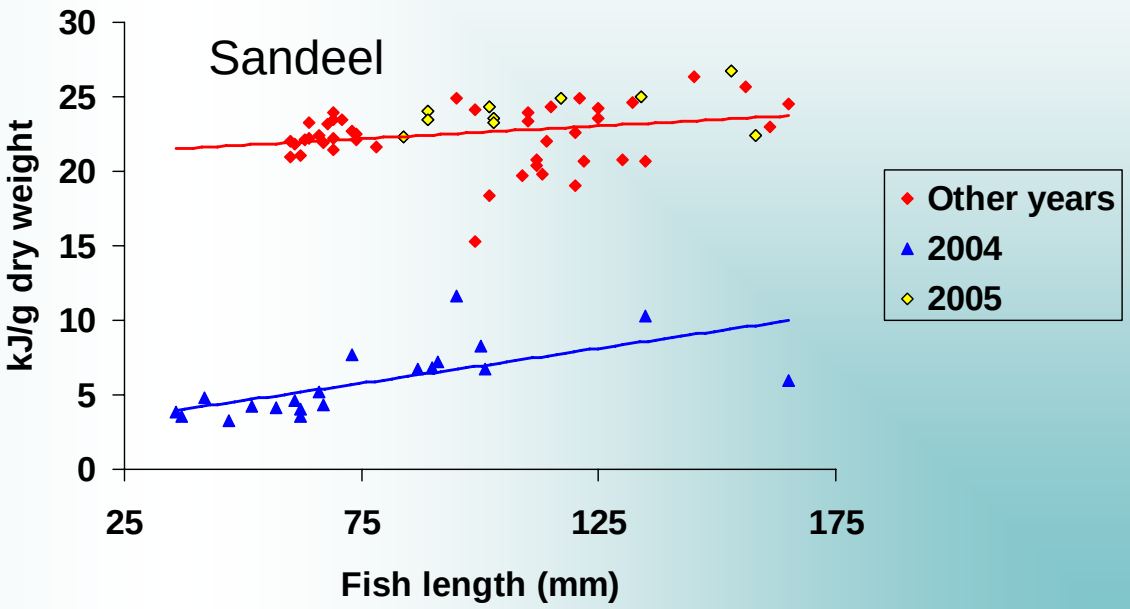
Frederiksen et al (2006)

Body condition of prey

- Energy value greatly reduced in 2004
- Indicative of problems lower down the food chain

Wanless et al. (2005, updated)





Population explosion of snake pipefish *(Entelurus aequoreus)*

Since 2003 massive increase in snake pipefish records from:-

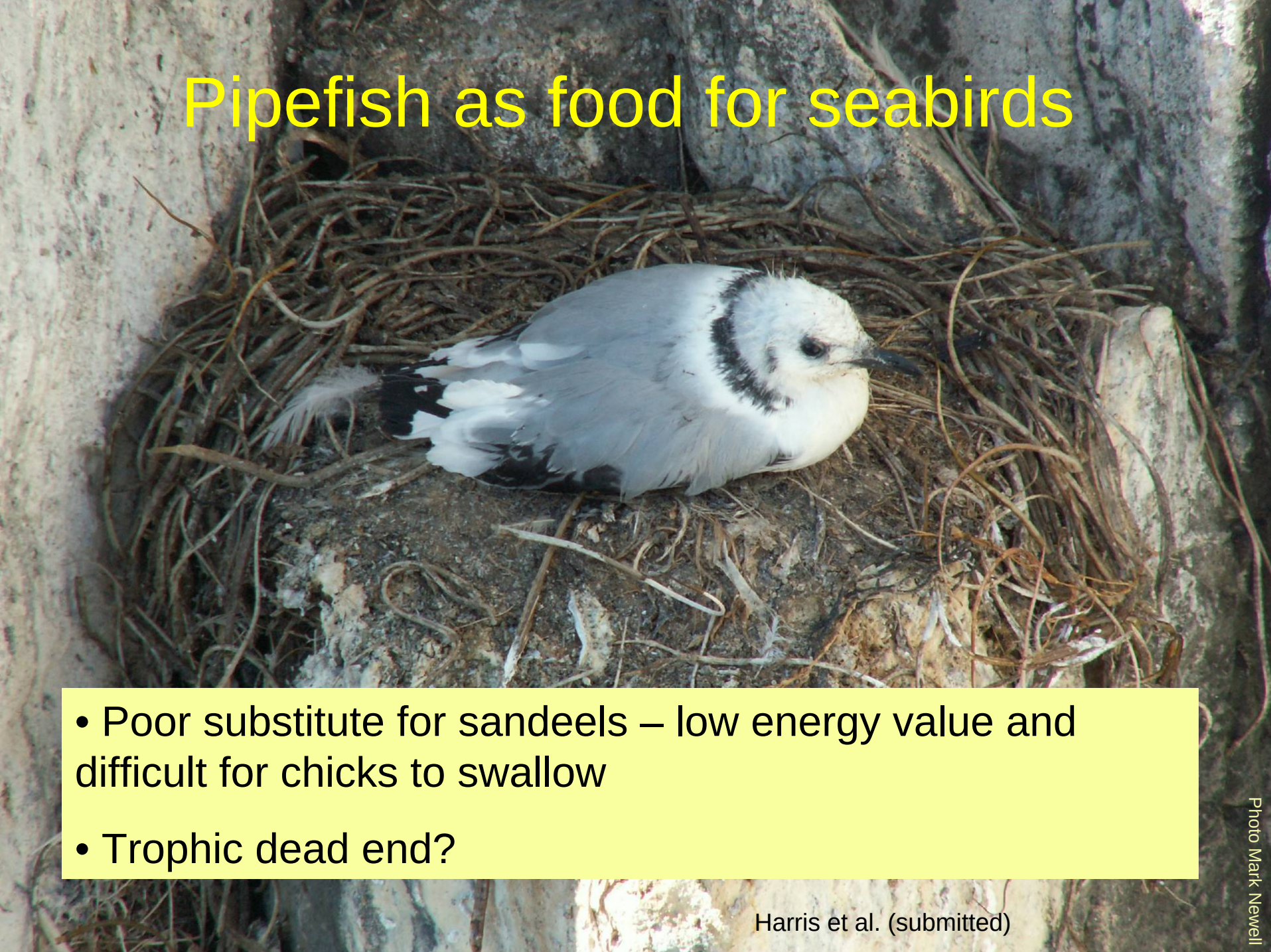
- Fish surveys in northeast Atlantic

- Seabird diet monitoring at colonies in UK and Norway

Status changed from rare to very abundant

Harris et al. (submitted)

Pipefish as food for seabirds



- Poor substitute for sandeels – low energy value and difficult for chicks to swallow
- Trophic dead end?

Harris et al. (submitted)

Photo Mark Newell

Phenology and climate change

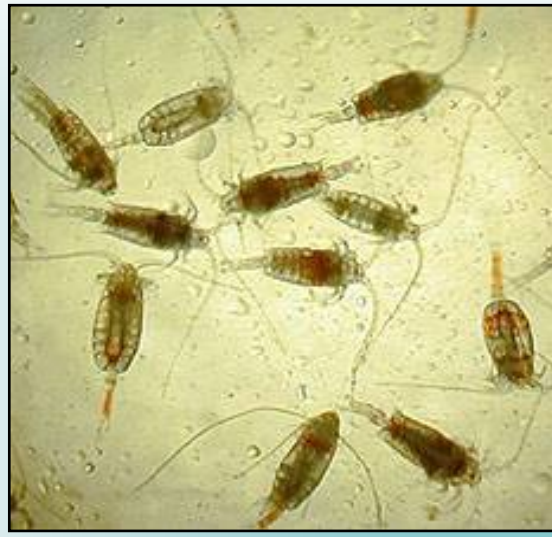
- Extensive evidence of climate-induced changes in phenology

- Do these match environmental change?

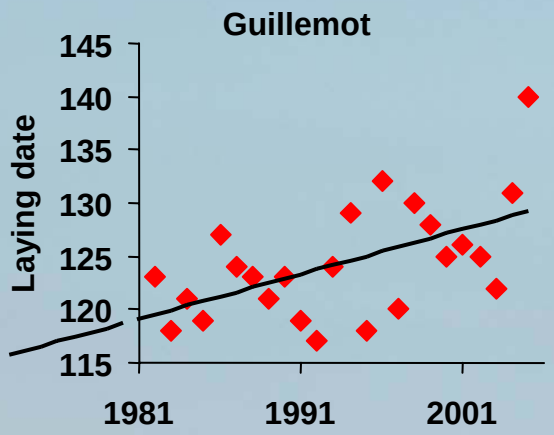
Photo Anke Addy

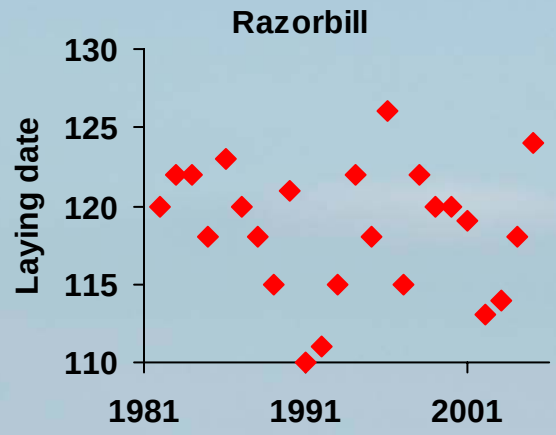
Phenology and the North Sea

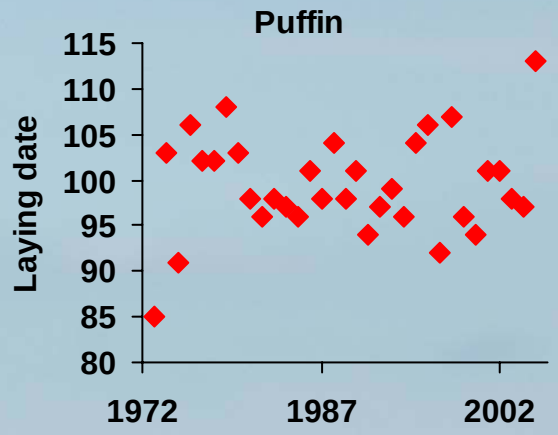
- Spring sea temperature risen by 0.05^{o}C/year (Hadley Centre)
- No trend in seasonal peak of phytoplankton (diatoms) (Edwards & Richardson 2004)
- Seasonal peak of decapod larvae 4 – 5 weeks earlier (Edwards et al 2006)
- BUT also shift from cold-water, early peaking copepod *(Calanus finmarchicus)* to warm-water, later peaking species *(C. helgolandicus)* (Edwards et al 2006)



Trends in seabird breeding phenology

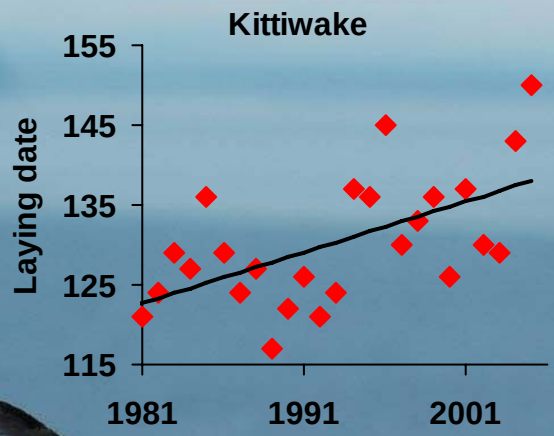






Guillemot – 4.6 d/decade

Kittiwake – 7.1 d/decade



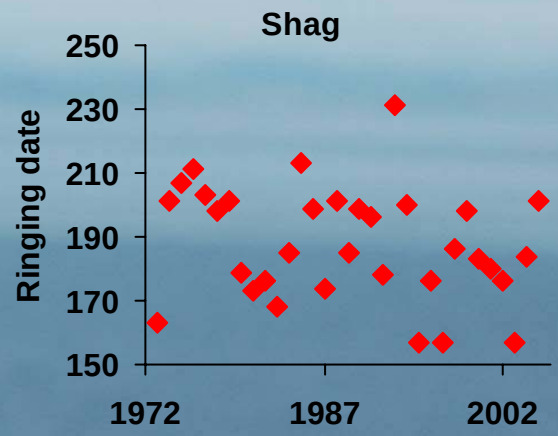


Photo Akinori Takahashi

Phenology of North Sea sandeels

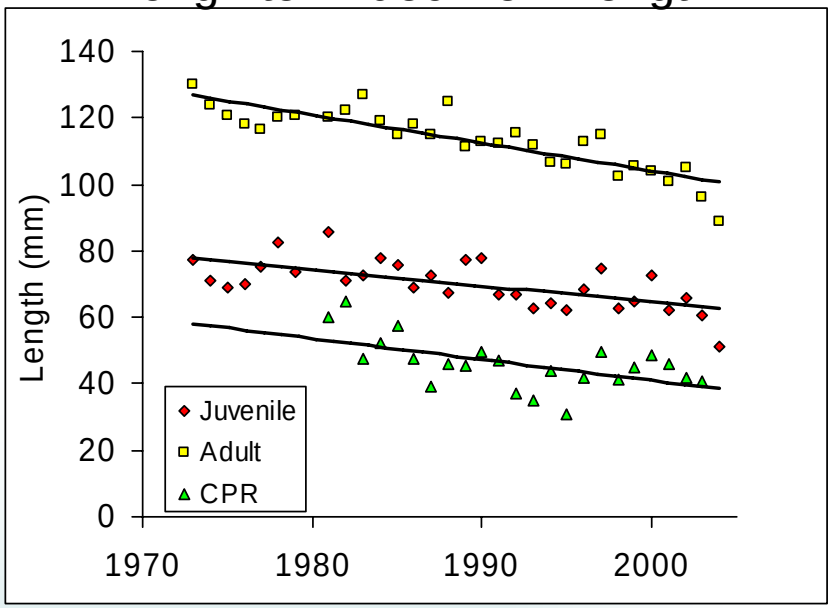
- Closely associated with sandy substrates
- Winter spawning
- Adults active in water column April – June
- Larval fish metamorphose May, feed until late summer
- No direct data on phenology

Indirect measures of sandeel phenology

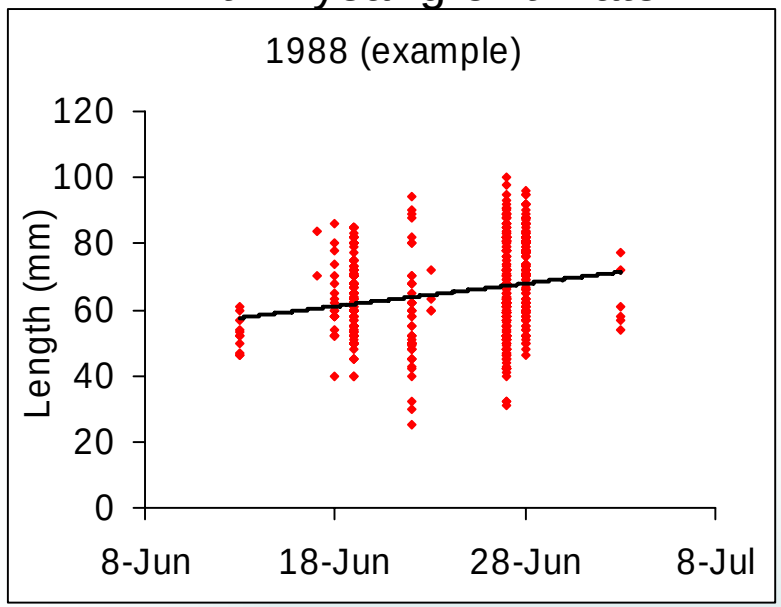
- Sampling of fish brought in by puffins, mid May – early August for 30 years
- 0 group length at 1 July, 1 group length at 1 June
- Larval sandeel lengths in CPR

Index of sandeel phenology

Long –term decline in length

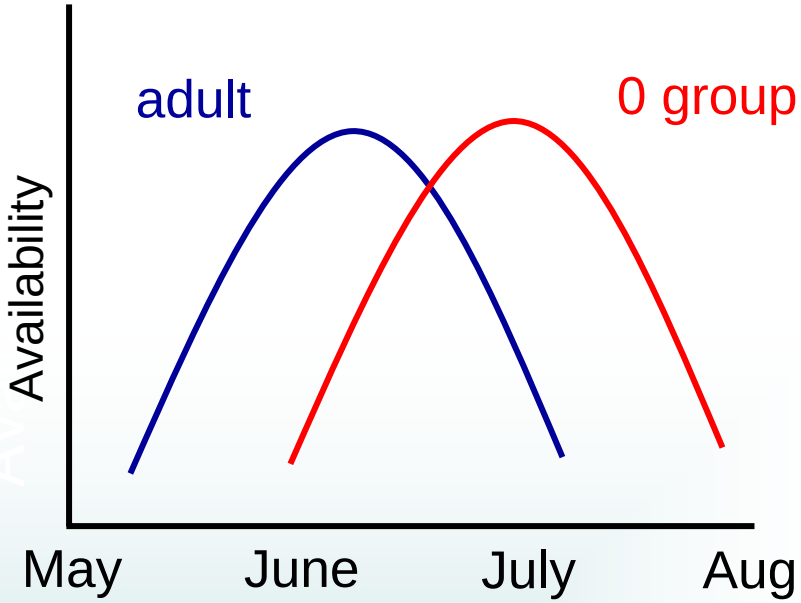


Within-year growth rate



- Average annual decline in length (0.37mm/yr)
- Average within-year growth rate (0.409 mm/d)
- Date a given size reached delayed by 9 d/decade (0.37/0.409*10)
- Approach does not separate phenology and growth rate
- Kittiwake tracking changes but effects less clear for other species

Sandeel – seasonal availability



Climate-induced mismatch might occur if:

- Sandeels miss the peak in plankton availability if they emerge at the wrong time
- Seabirds miss the sandeel peak if they breed too early or late

Summary

- North Sea seabirds currently dependent on a cold water species (lesser sandeel) and warmer winters associated with poorer performance

- 2004 exceptionally bad breeding season. Evidence of major hydrobiological change

- Contrasting patterns of phenological change across functional groups. Classic conditions for climate change induced trophic mismatching

Photo Akinori Takahashi