North Sea seabirds: responses to fisheries and changing climate

Kate Searle, Francis Daunt, Sarah Burthe, Mark Newell,
Mike Harris & Sarah Wanless
(and many others)

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Talk Structure

- North Sea seabird community
- Indirect climate effects through changes in lower trophic levels
- Direct climate effects acting on seabirds
- Fisheries and climate change
- Summary

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Background: UK seabird conservation challenges

- Declines in last three decades
- 6/25 UK's Red listed
- Multiple impacts, non-linear and potential additive effects:
  - Climate – significant increase in SST
  - Fisheries – one of most heavily fished regions in the world
    - includes fishery of forage fish
  - Offshore renewable energy – undergoing large expansion
  - pollutants

Species	2000-2015
Fulmar	-31%
Shag	-34%
Arctic skua	-64%
Kittiwake	-44%
Little tern	-18%
Common tern	-10%


Disaster at sea: global warming hits UK birds

45 years of research in the North Sea

Isle of May long-term study

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Process-based research

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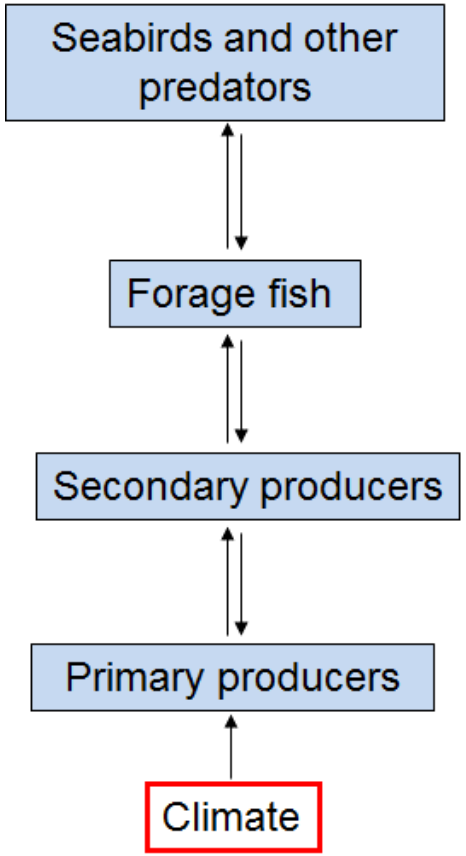
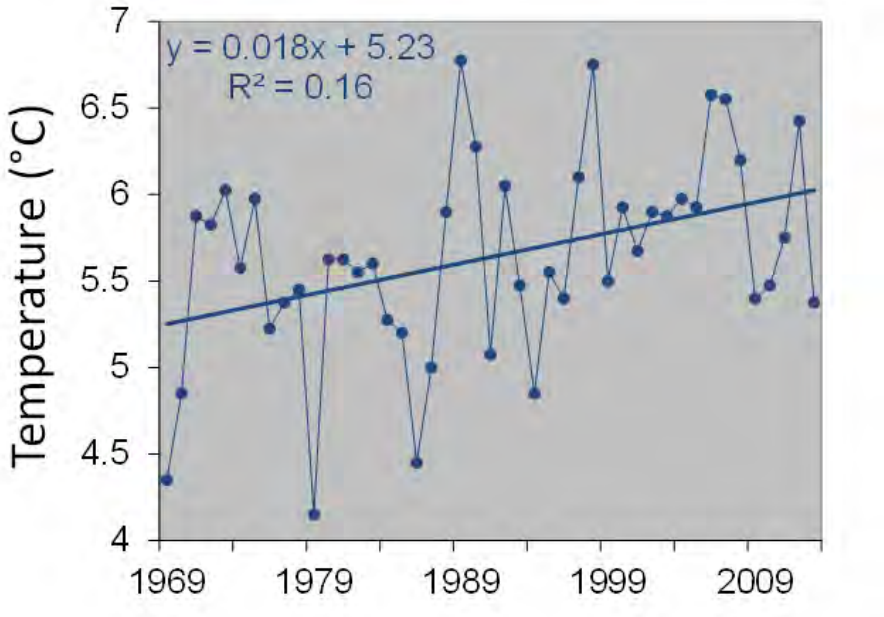
Climate Change: Indirect Effects Operating via food webs

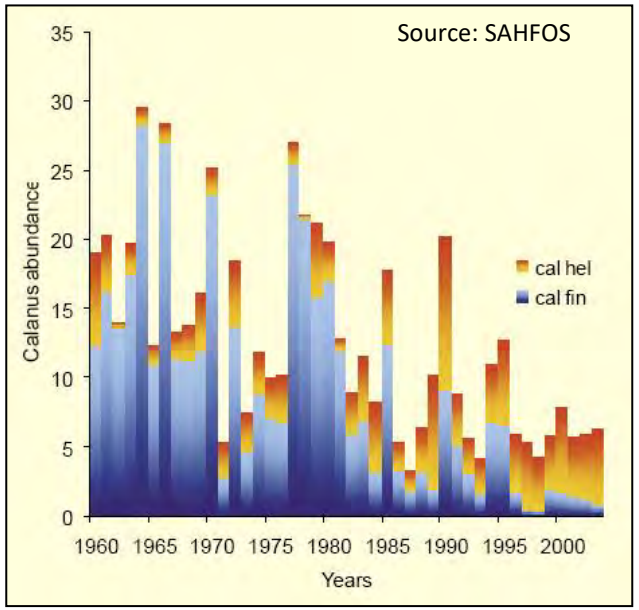


North Sea: mean changes

Temperature



Zooplankton



PAST CHANGE: North Sea plankton has shifted northwards as a result of the northward movement of a critical thermal boundary, along with widespread northward range shifts of fish species linked to increasing temperatures

FUTURE CHANGE: SST in NW North Sea expected to rise by 1.5 - 3.0 ^{o}C by late 21st C

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Climate: indirect effects via the food web

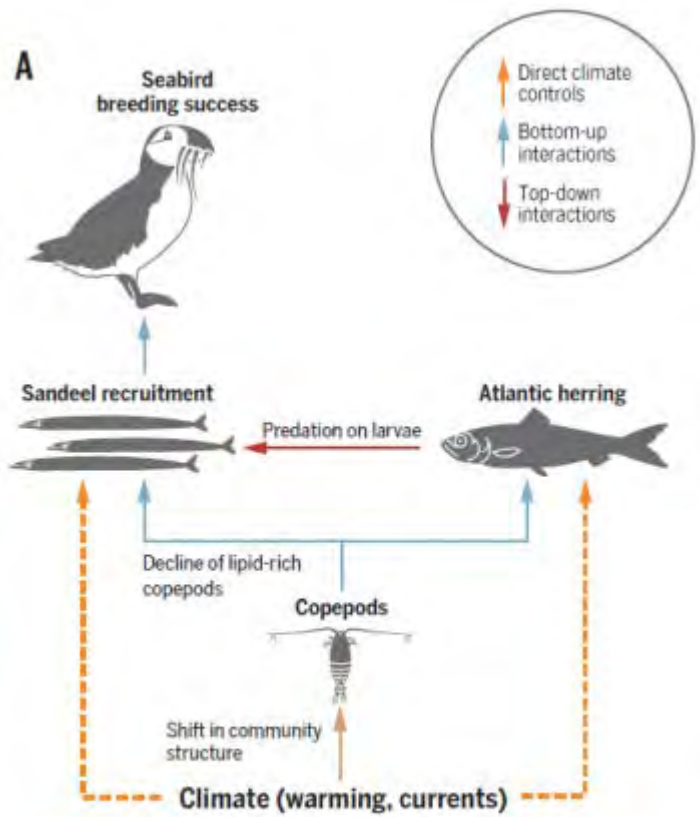
Types of Evidence:

1. Links to oceanography

2. Links to zooplankton

3. Links to forage fish

4. Trophic mismatch?



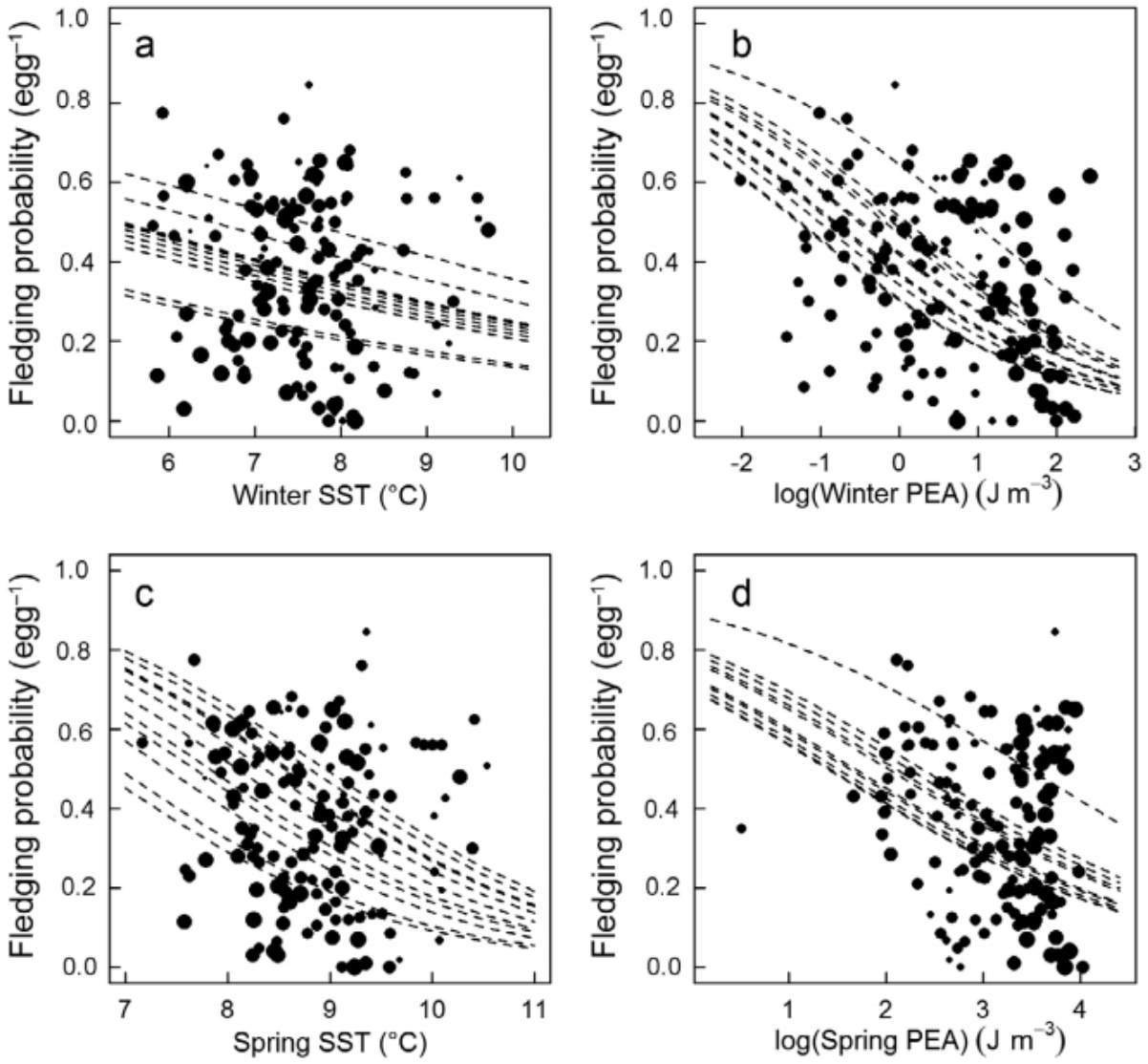
Sydeman et al (2015) Science

Links to oceanography

Temperature and oceanic stratification affect breeding success in North Sea kittiwakes

- Stratification: density differences between deep and shallow waters – nutrient availability and light
- GPS tracking and colony-specific data – better reflection of observed habitat use
- Stronger stratification before breeding and higher SSTs during breeding season ↓productivity
- Future climate projections indicate potential for decline of 21 to 43% by end of century
  - Warming SST and stronger and earlier stratification

Breeding success



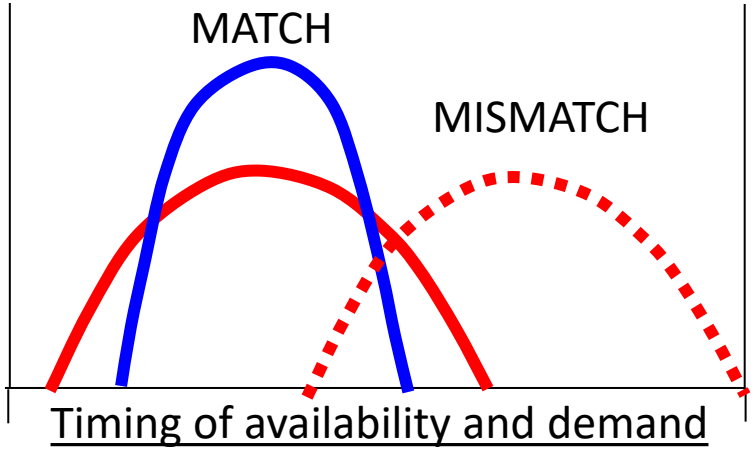
Carroll et al (2015)

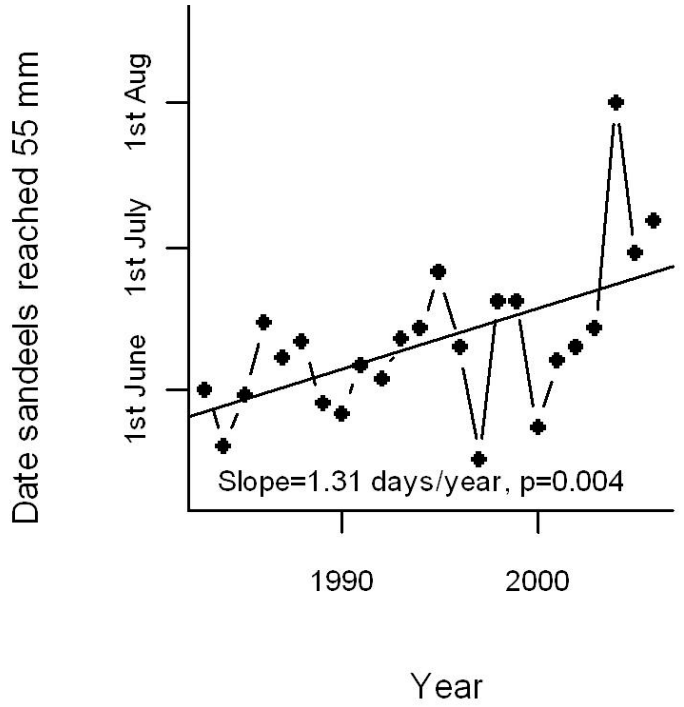
Trophic mismatch in the North Sea

Not just abundance of prey…

Marine systems are vulnerable to trophic mismatch due to highly seasonal pulses of productivity affecting fitness of higher trophic levels

- 4 levels of North Sea food web over 24 years when SST increased significantly (1.3^0C)
- Date at which sandeels achieved a given length became significantly later





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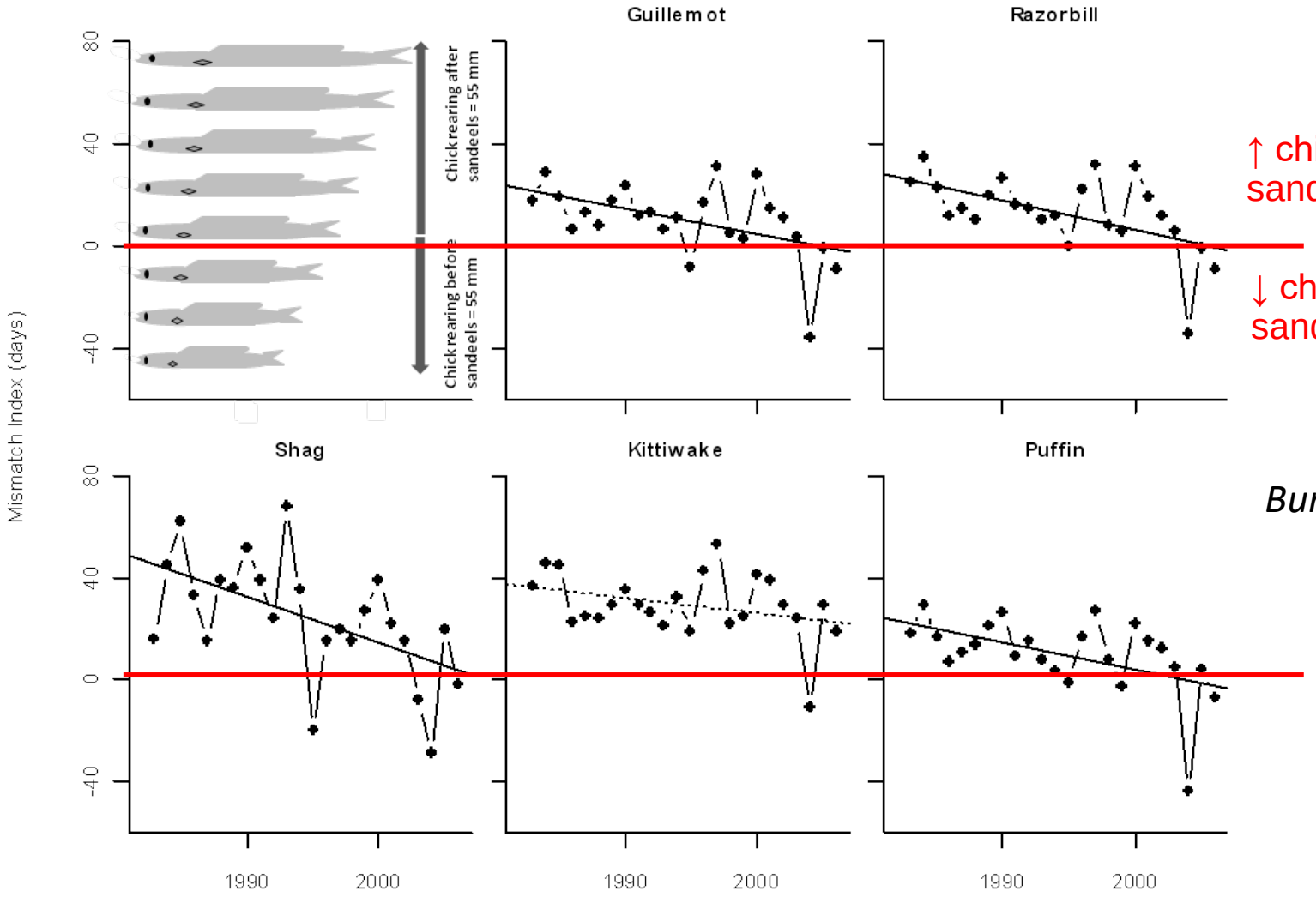
Burthe et al. (2012) MEPS

Trophic mismatch in the North Sea

Mismatch index:
difference (days) between date of mid chick-rearing and date sandeels >55mm



↑ chick-rearing after sandeels=55mm

↓ chick-rearing after sandeels=55mm

Burthe et al. (2012) MEPS

- Seabirds delaying breeding: phenology became later, but insufficient to keep pace with changes in timing of sandeels
- Net decline in sandeel length and energy value at mid chick-rearing
- suggestive of trophic mismatch

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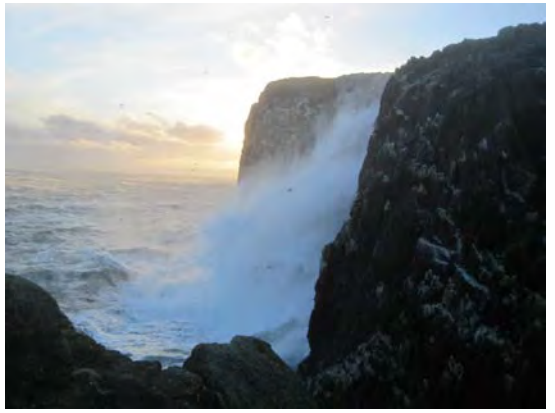
Climate Change: Direct Effects

Effects of extreme weather

- Tendency to focus on mean effects, not variability
- Direct effects of weather on seabirds is comparatively understudied – expectation has been that trophic effects may be more important
- Potentially important because can result in large scale mortality in a short period of time
- Many climate models are forecasting an increase in wind and extreme weather events (higher latitudes)
- Effects may be completely unrelated to food abundance



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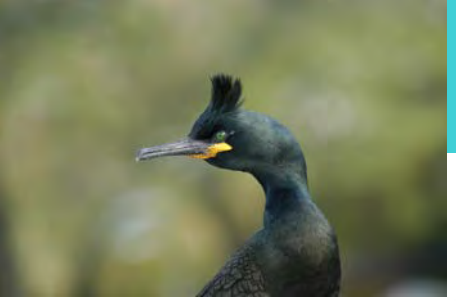
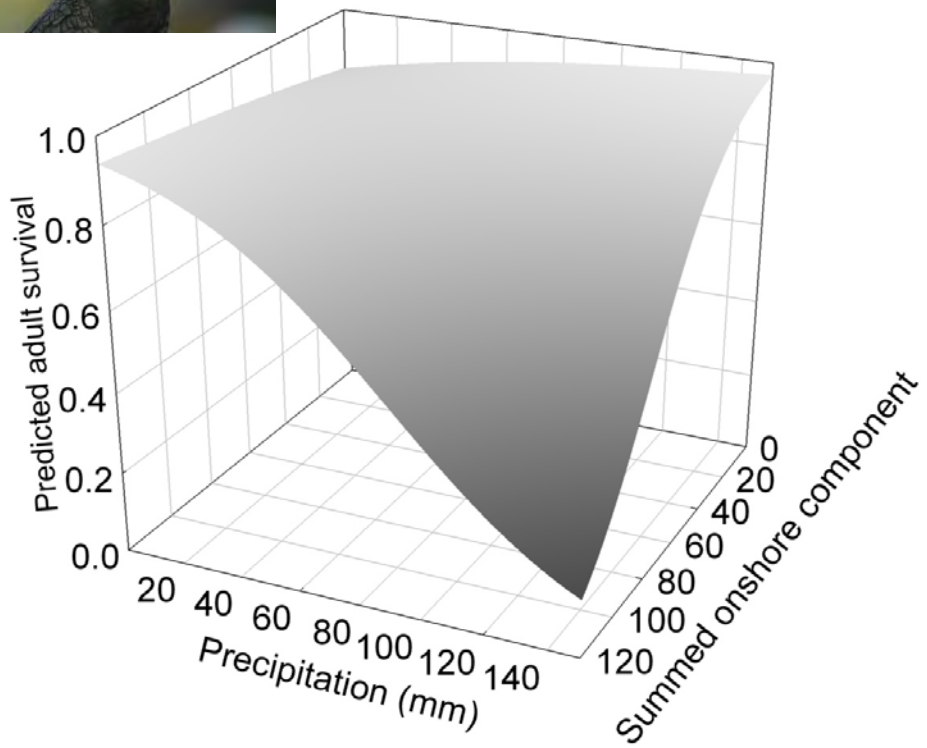
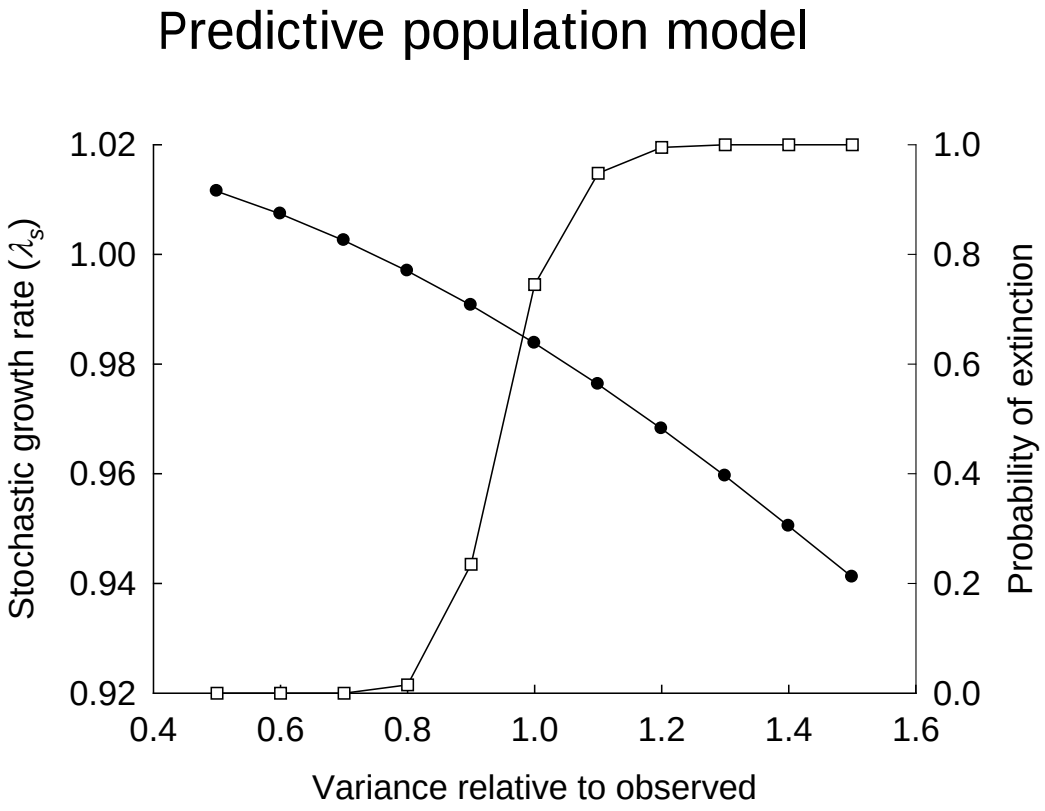
Climate: direct effects - winter weather

- Weather more extreme in winter
- Most mortality of adults takes places in winter
- Adult survival is the main driver of seabird population size
- Very difficult to record mortality directly



Shags: winter effects of wind and rain on survival





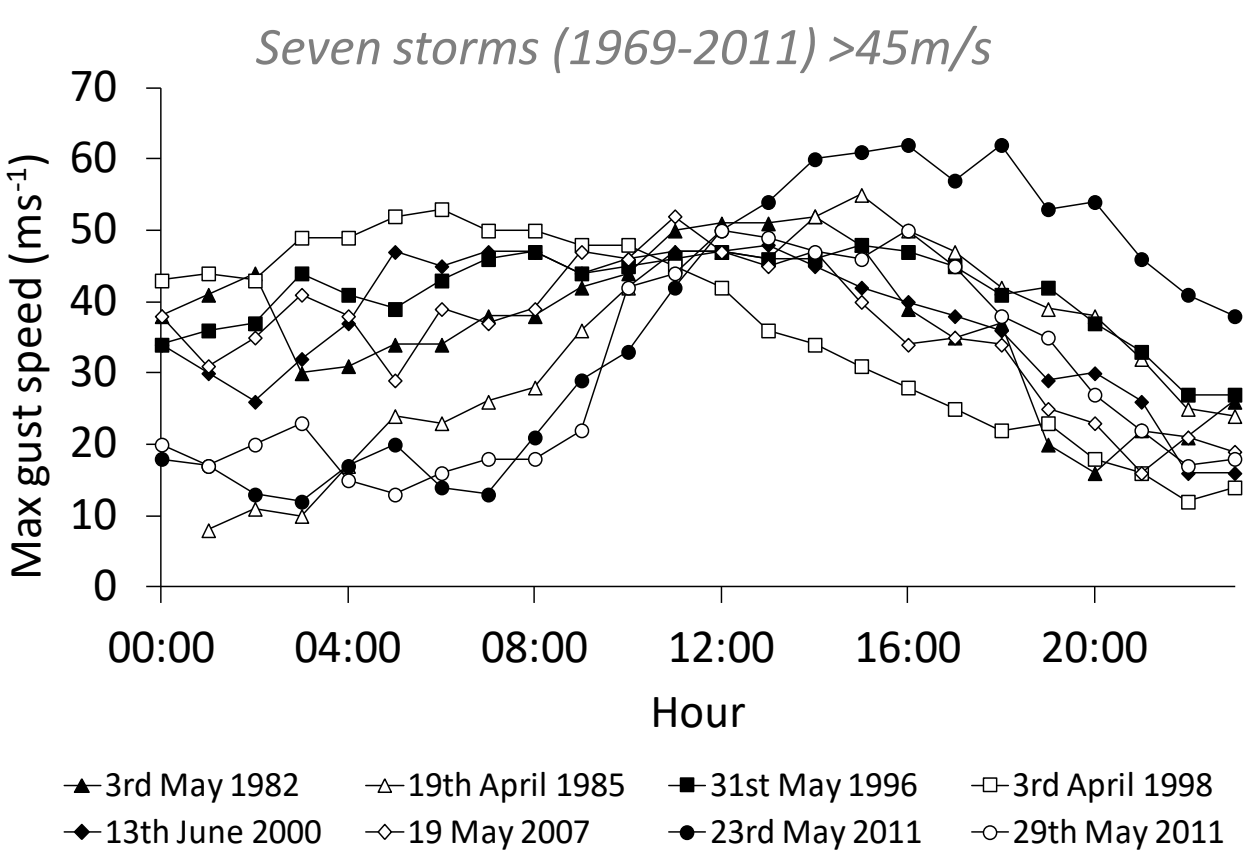
- Shags show much reduced survival during sustained windy conditions and rainfall
- Population model predicts that local extinction is likely if number of extreme events increases

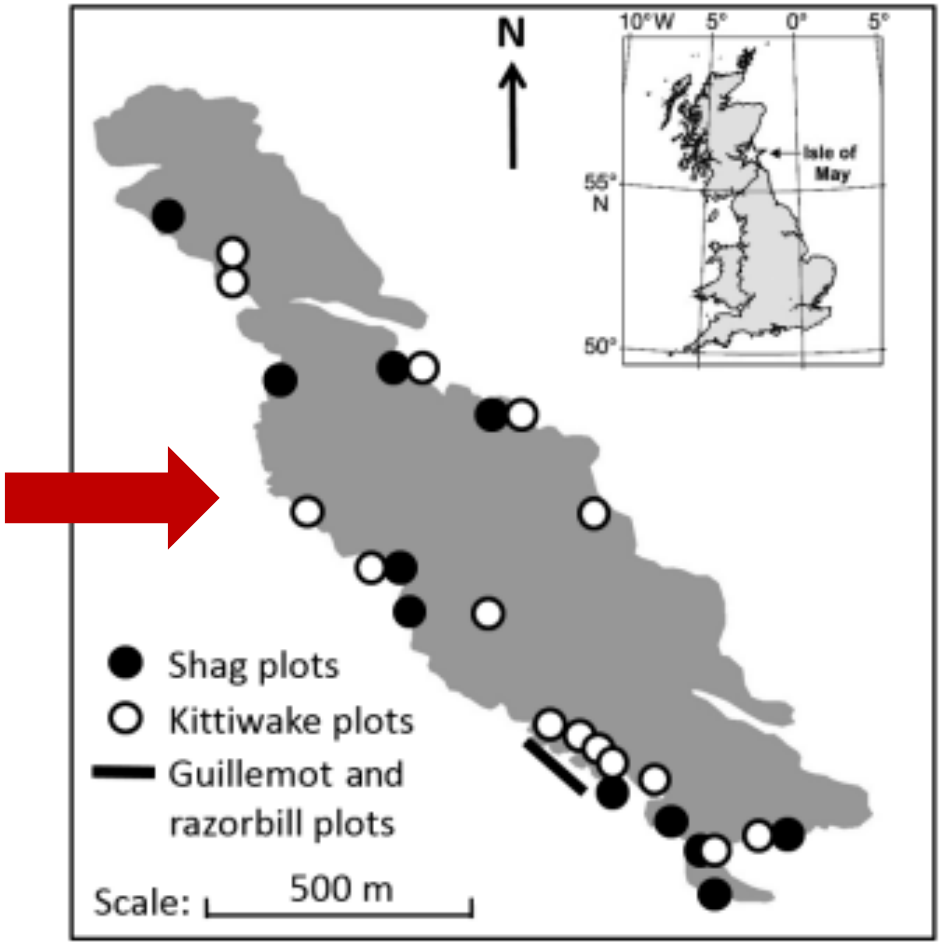
Frederiksen et al., Journal of Animal Ecology 2008

Summer storms

- Potential for widespread breeding failure
- Can be much shorter temporal scale
- Main effects likely to be:
  - rainfall: flooding and hypothermia
  - wind/swell: nests or chicks being blown or washed away
- Timing likely to be important (*possibility of re-lays*)

2011 Summer Storm: 4 species cliff nesters





- Strongest summer gale in 30 years
- Storm was forecast so all plots checked day before and day after
- Monitored thereafter, including re-lays

Newell et al. 2015

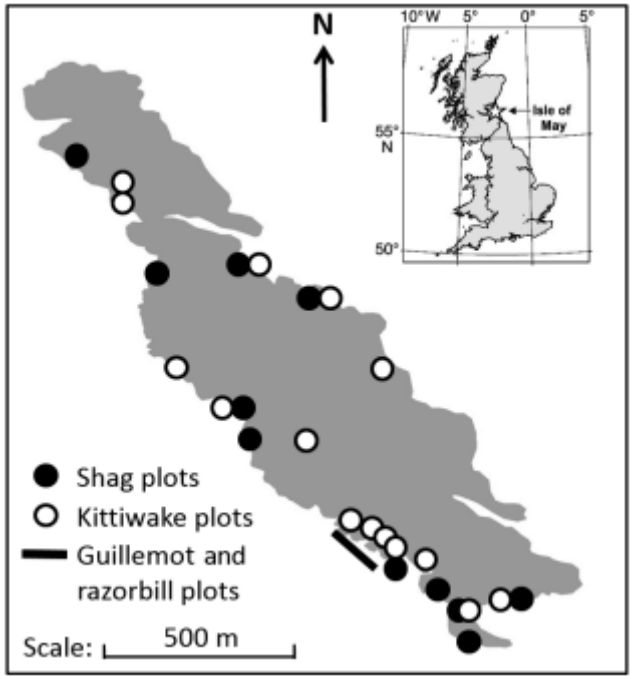
2011 storm: West vs East

- *Shags:*
  15.1% failed on W
  0% on E ($p = 0.06$)

- *Kittiwakes:*
  15.6% failed on W
  1.9% on E ($p < 0.01$)

Net reduction annual productivity:

- RZ: ↓ 22.8% (lowest recorded)
- KW: ↓ 10.7%
- GU: ↓ 8.9%
- SH: ↓ 4.6%



Orientation and timing are critical in determining population level effects

Only partial compensation through re-laying (only some nests and lower success)

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Newell et al. 2015

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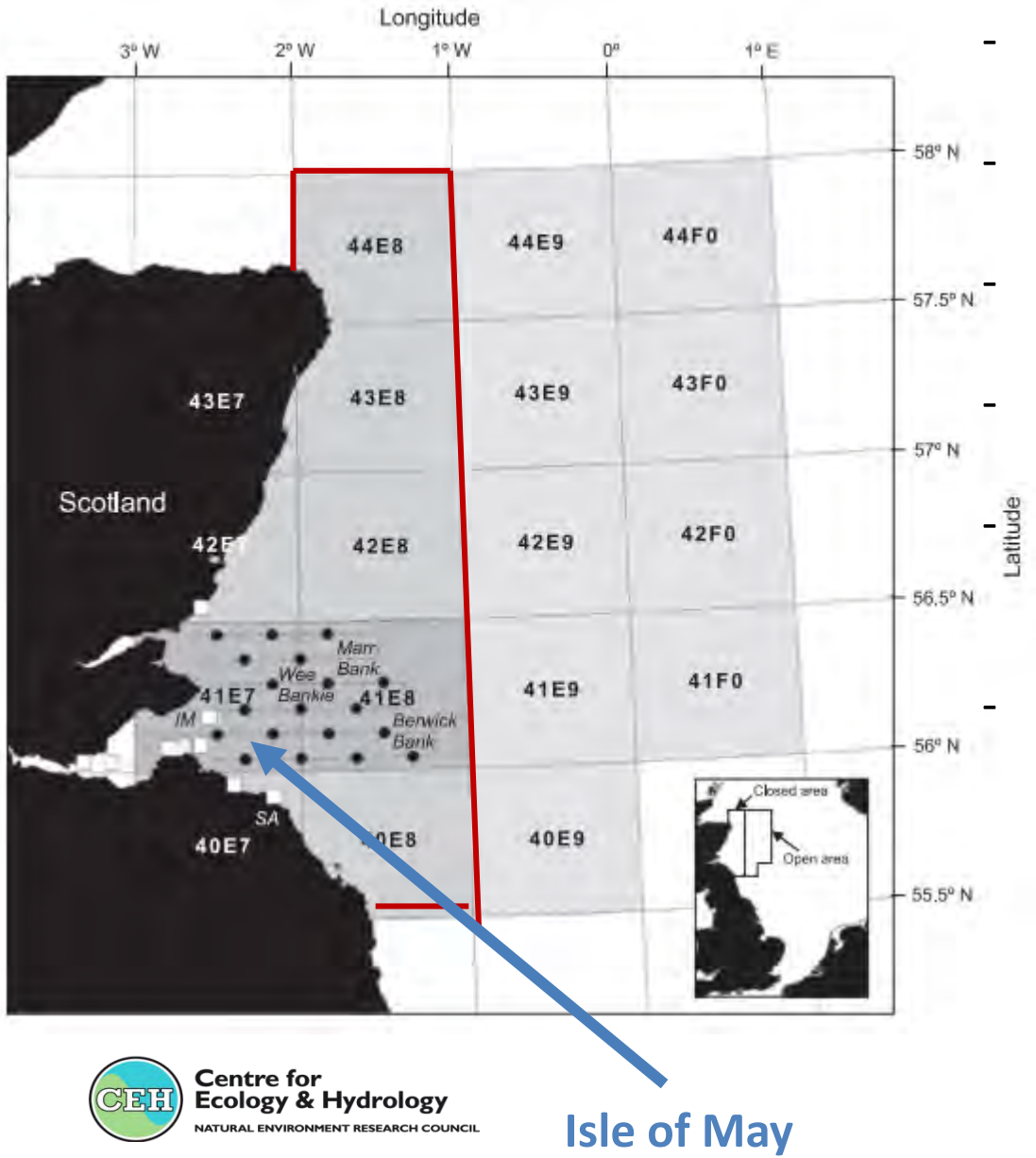
Fisheries and Climate Change

Forage fish fishery in North Sea



- Sandeel fishery started in 1950s
- became largest single-species fishery in region
- landings >1million t in some years
- Wee Bankie not exploited till 1990
- Late 1990s concern rose over several years of very poor breeding success kittiwakes
- Closed zone from 2000, so one of only a few examples where effects of a forage fish fishery can be related to seabird demography in a semi-experimental way…

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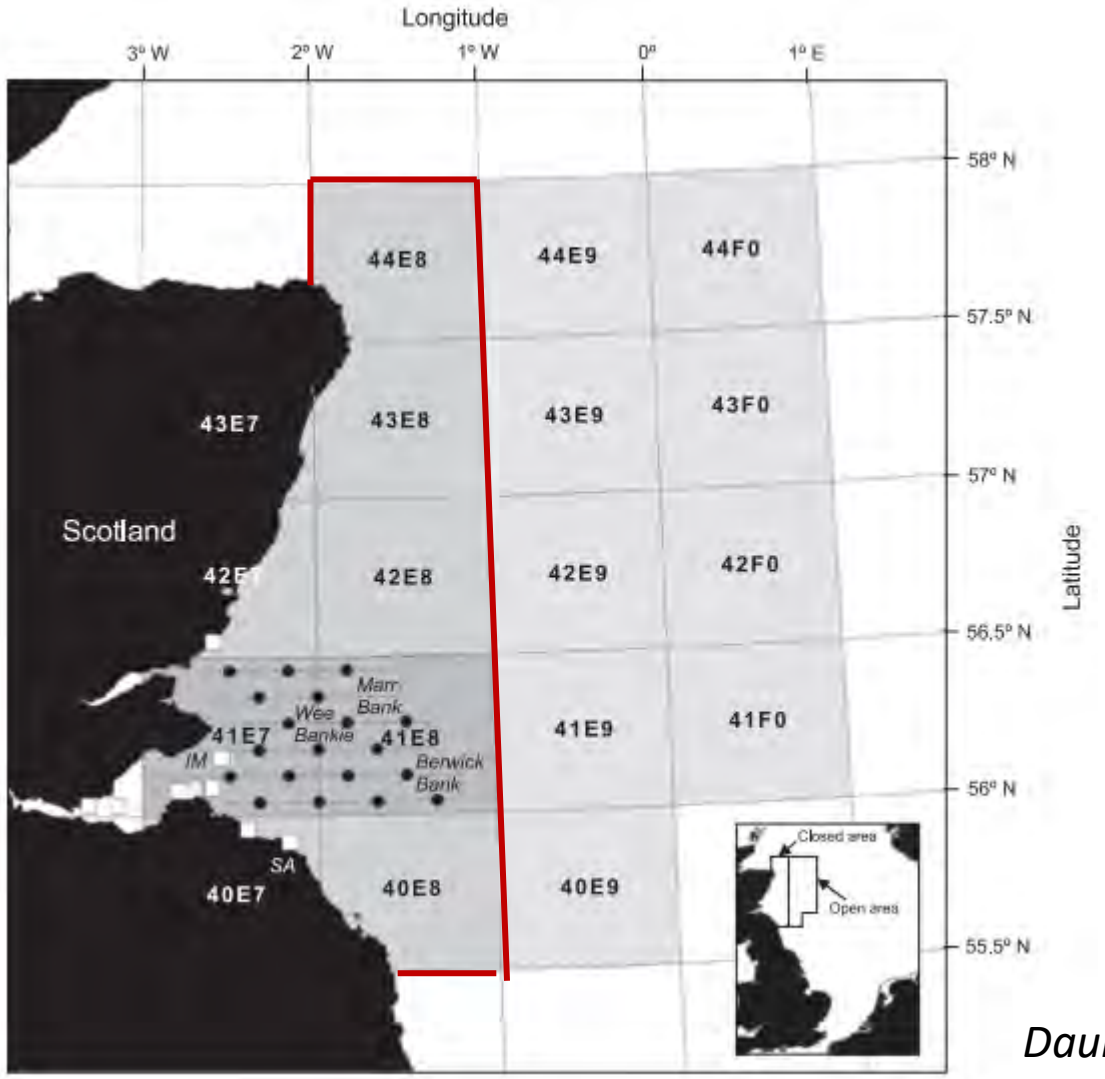
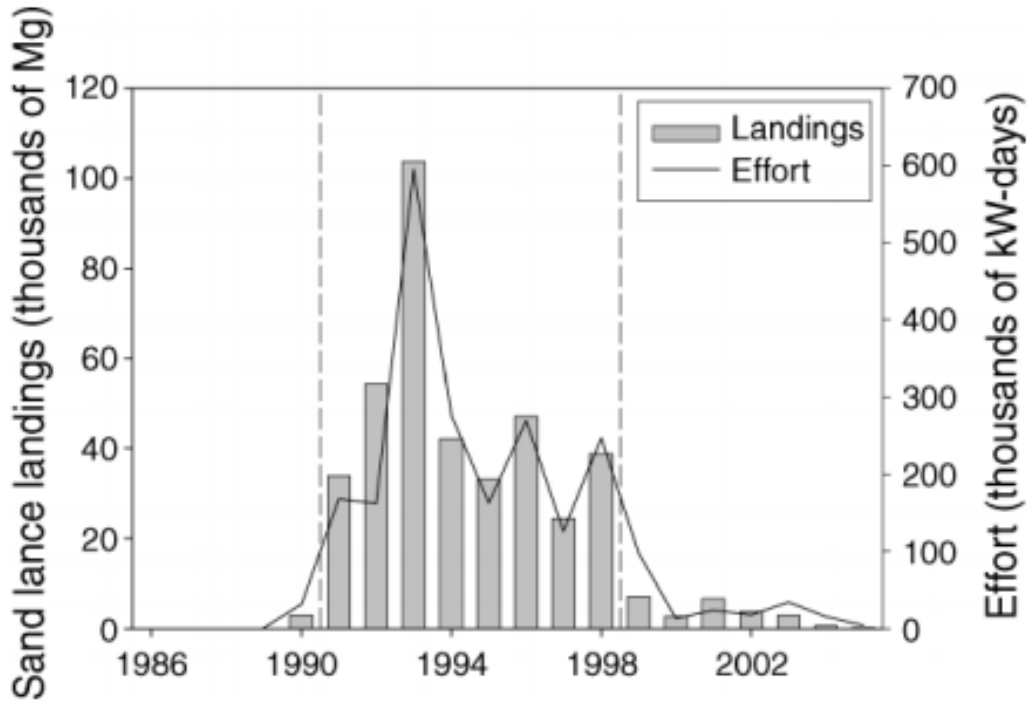
Isle of May

Direct evidence of forage fish fisheries impacts:

Quasi-experimental set up (BACI) with Wee Bankie closed area NW North sea:

Multiple colonies and species





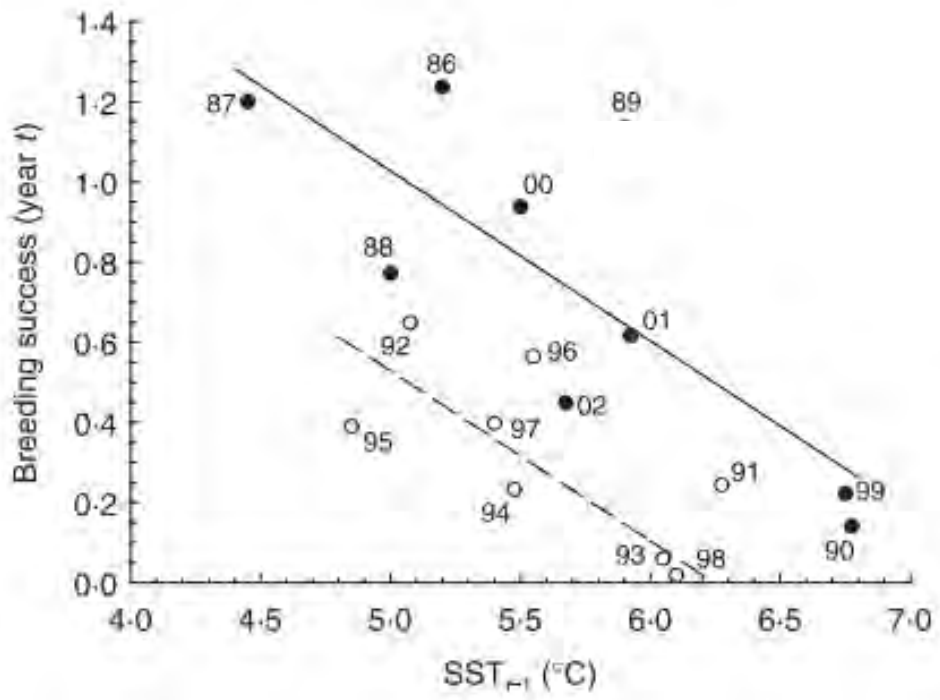
Daunt et al; Frederiksen et al (2008)

Climate: additive effects with fisheries

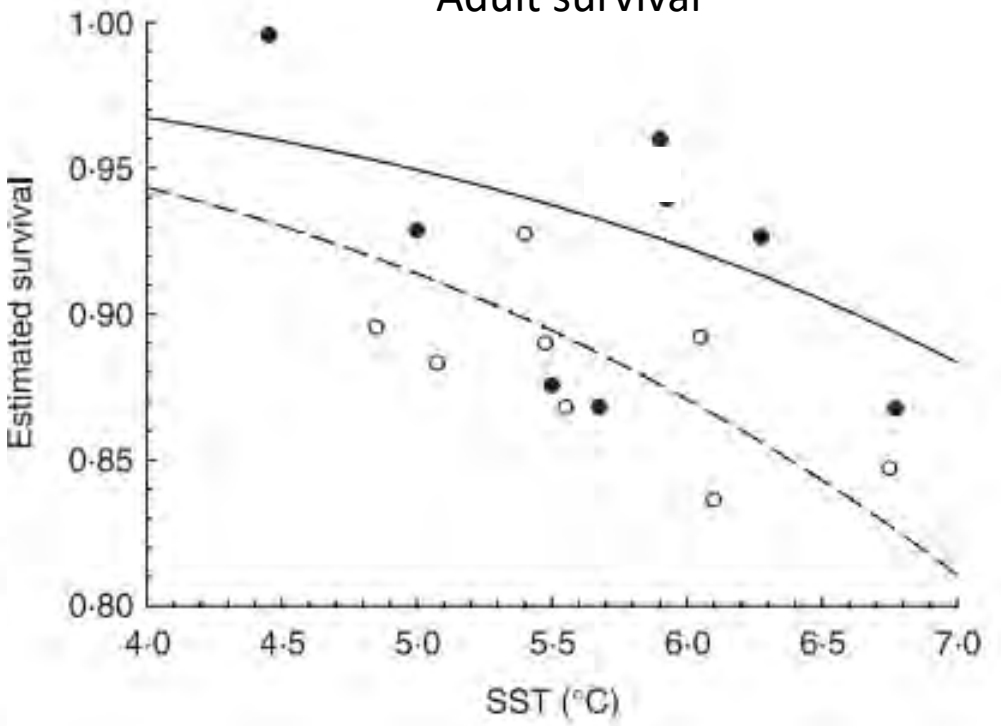
Black/solid = before fishery

White/dotted = during fishery

Breeding success



Adult survival

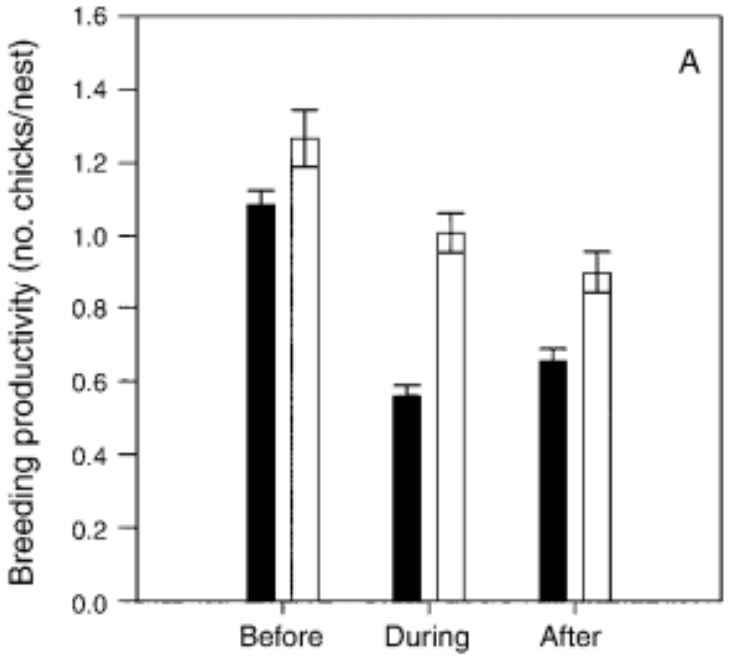


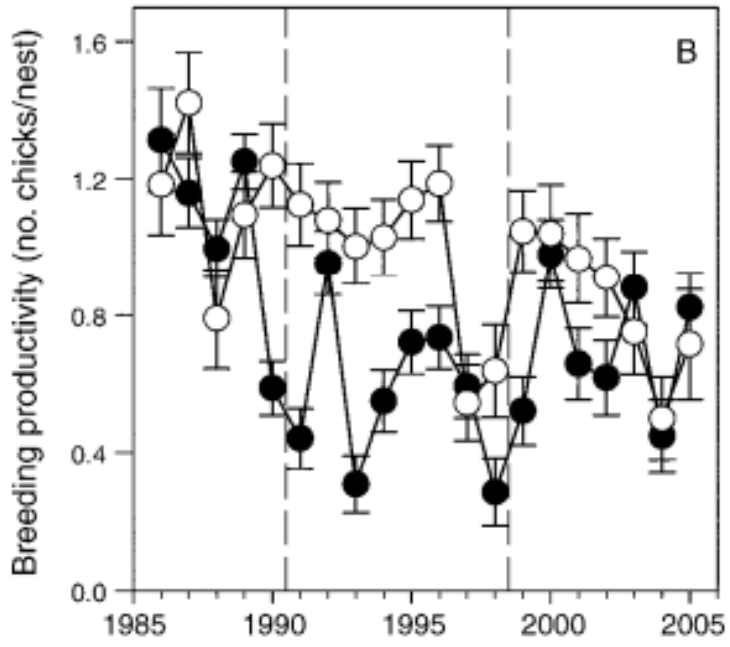
TEMPERATURE

- Before/During/After fishery study on the Isle of May
- Breeding success of kittiwakes depressed when winter SST higher (1 yr lag)
- Additive negative effect of fishery

Frederiksen et al. (2004); Frederiksen (2014)

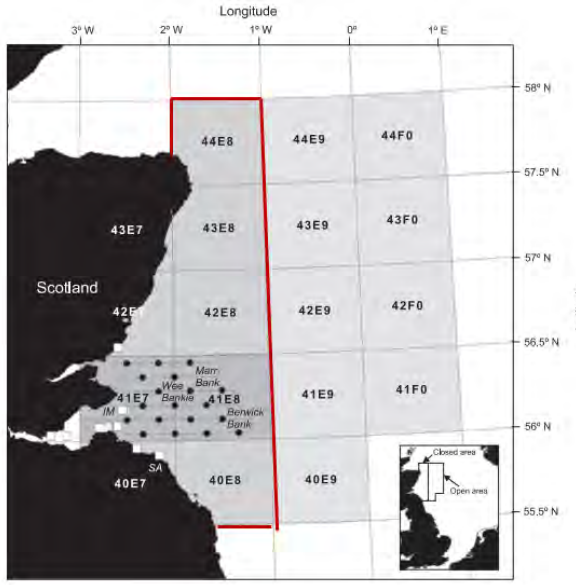
Direct evidence of forage fish fisheries impacts:





Closure area: solid/black

Control area: open/white



Breeding Success in closure zone relative to control zone – declined when fishery was open and recovered when fishery closed, but insufficient to halt decline

Strong regional effect:

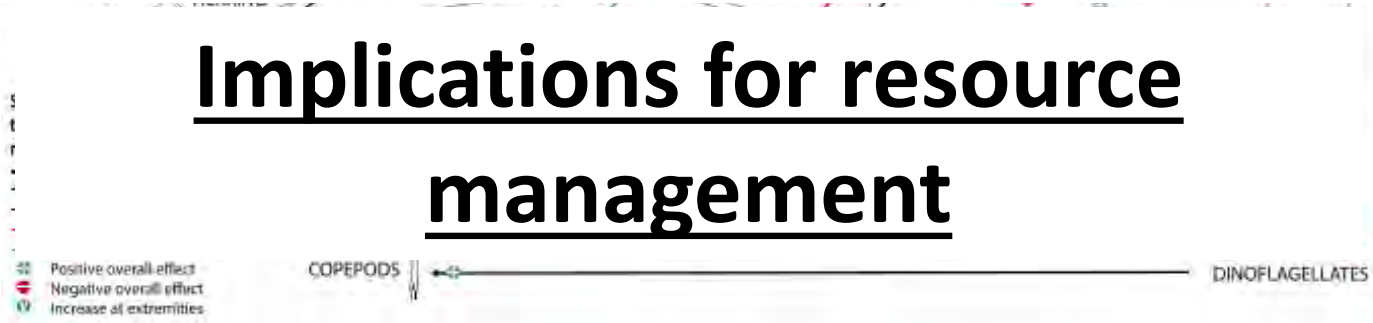
- relationship between breeding success, fishery and SST similar for all 7 kittiwake colonies in closure zone

Ecosystem Regulation: bottom-up or top-down?

Bottom up: amount of primary production regulated by nutrient or climatic control → determines abundance of higher trophic levels

Top down: predation by higher trophic levels regulates lower trophic levels

Implications for resource management



Lynam et al 2017

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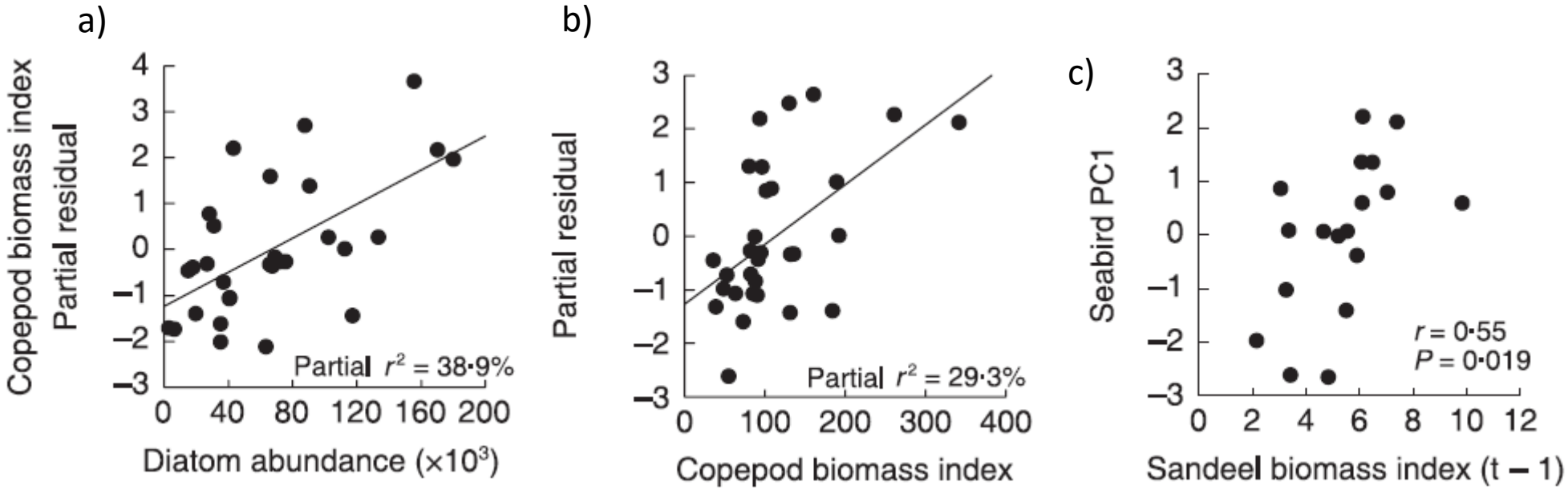
North Sea: bottom-up processes

a) Diatom vs copepods
b) Copepods vs sandeels
c) Sandeels vs seabirds



- Consistent with bottom-up ecosystem regulation

- Coupled with SST indicates importance of climate-driven effects in plankton communities affecting top predators through dynamics of mid-trophic level fish

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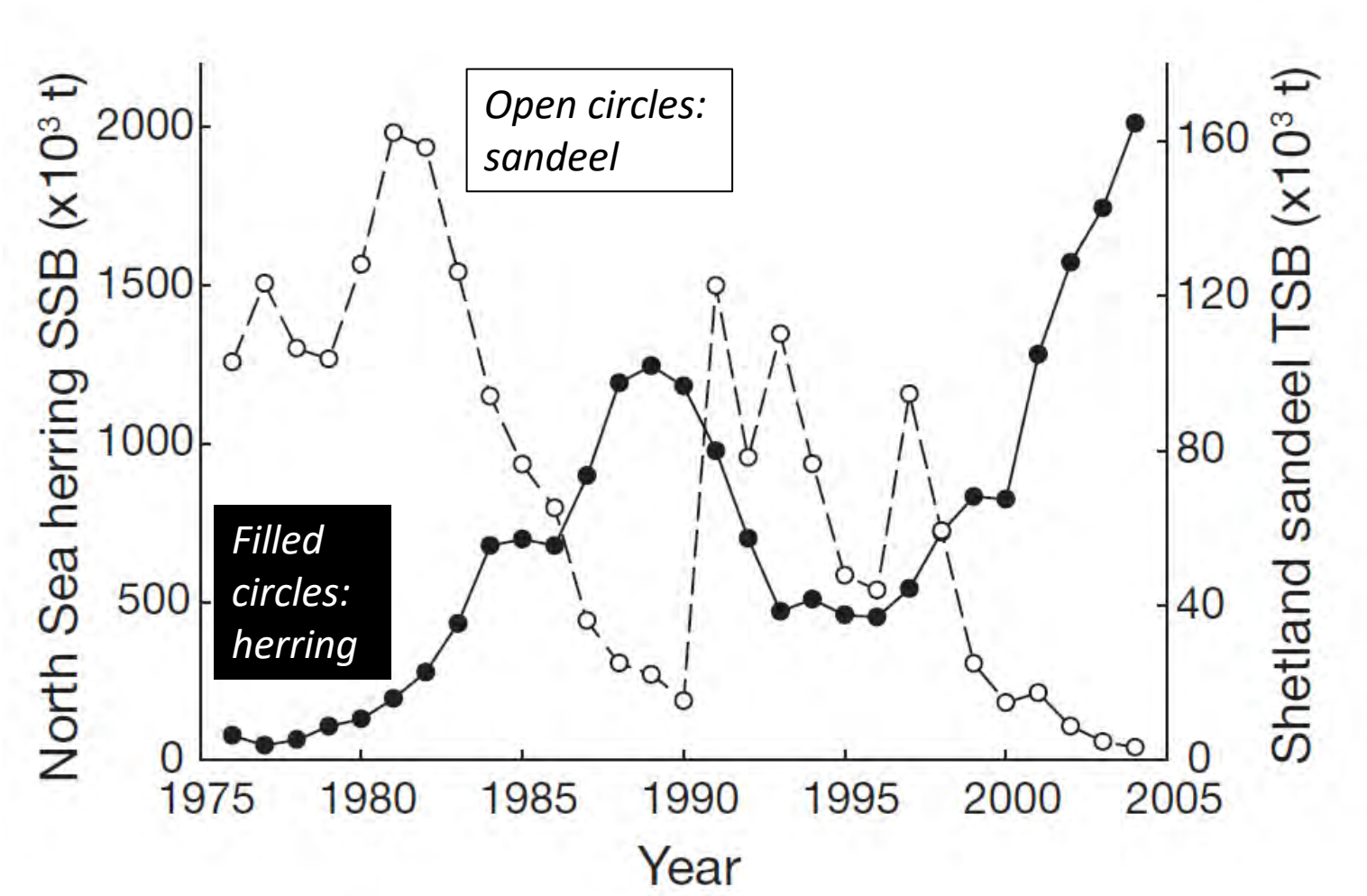
Frederiksen et al., Journal of Animal Ecology 2006

Trophic interactions in Shetland: top-down control by herring



Herring reduced dramatically by over-fishing in 1960s

Herring spawning stock increased from 100,000t (1970s) to 2 million t (2004)

Shetland: record high abundance of herring coincided with record low abundance of sandeels

Suggests top down pressure by herring on sandeels

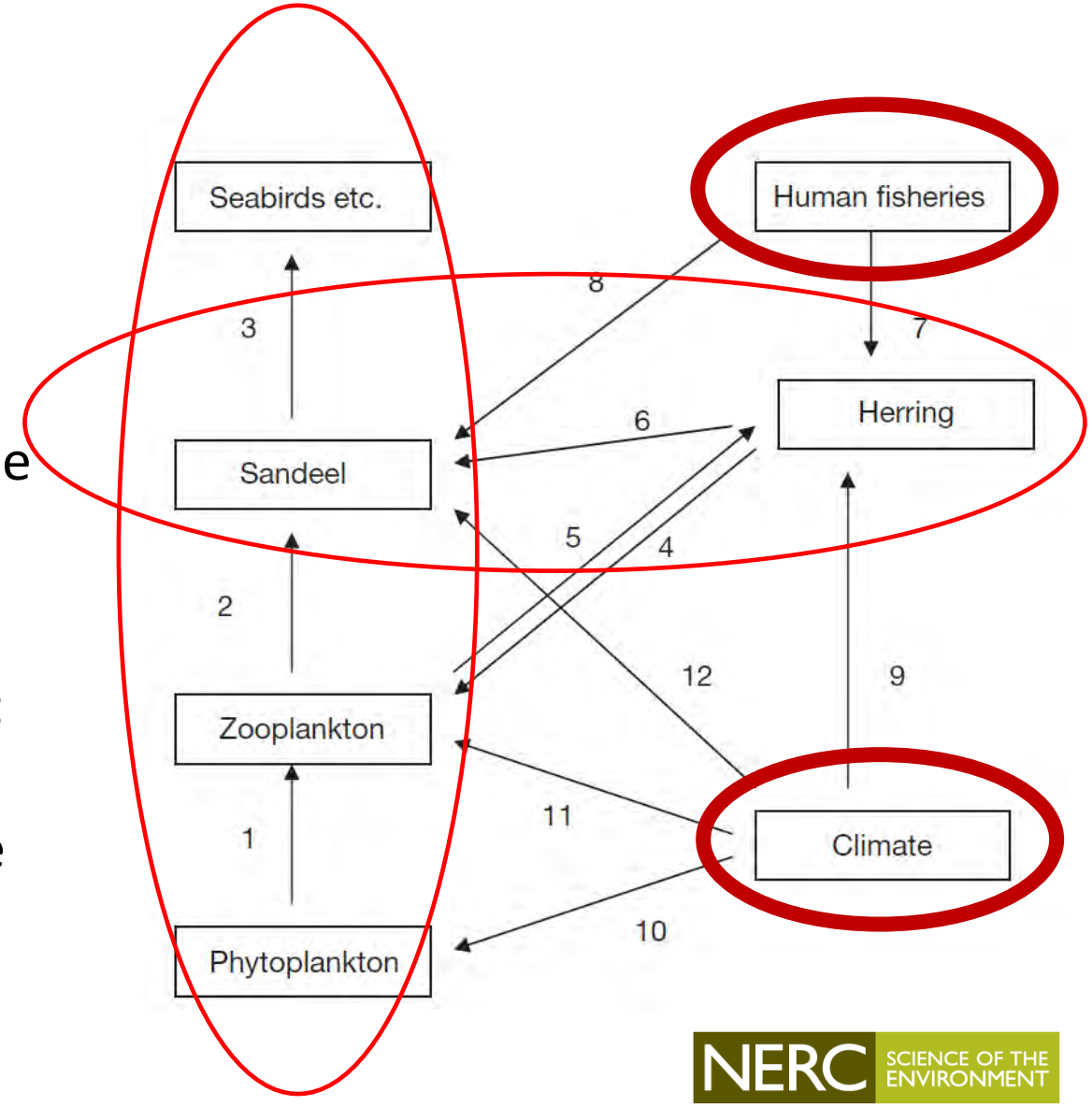
Frederiksen et al. (2007) Marine Ecology Progress Series

North Sea food web: summary

- Evidence of bottom up and top down
- Emergence of complex patterns of control

- Important to understand linkages, but also to recognise complexity of the system
  - Shifts in species distribution and abundance across trophic levels

- Ecosystem approach to fisheries management: critical to understand spatial and temporal within-system variation in importance of these 2 types of control



Frederiksen et al 2007, Lynam et al 2017

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Summary

- Bottom up versus top down regulation - need for cross trophic level analyses, scale-dependence of effects

- The direct effects of extreme weather on seabirds is understudied but potentially important
- Range shifting – improve predictions, develop early warning indicators, understand formation of new colonies

- Climate and fisheries effects can be additive and severe

- Cumulative impacts

Summary

- <u>Knowledge gaps</u>

  - Population regulatory processes and environmental change (poster)
  - Behavioural and phenotypic plasticity, adaptation, heritability
  - Dispersal and social component of colony formation
  - Diet and prey switching
  - Disease, parasites and pathogens
  - Functional and numerical responses of seabirds to prey availability
  - Marine ecosystem models and ensemble modelling

- Improved cooperation between diverse research organisations

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Acknowledgements

- Morten Frederiksen
- Sue Lewis
- Maria Bogdanova
- Rich Howells
- Carrie Gunn
- Students
- volunteers
- Adam Butler (BioSS)
- Ewan Wakefield (Uni Glasgow)
- James Waggitt (Uni Bangor)
- Peter Evans (Seawatch Foundation)
- Simon Greenstreet (MSS)
- Peter Wright (MSS)
- David Johns (SAHFOS)

JNCC, NERC, EU, SNH and ASAB for funding