Velocity and seasonal shift in climate:
Ecologically relevant indices for predicting changes in species distributions and phenology

Michael T. Burrows, Jorge García Molinos, Benjamin S. Halpern, Anthony J. Richardson, Pippa Moore, Elvira Poloczanska and David S. Schoeman
Rapid shifts in distributions of marine species

- NE Atlantic plankton
  - 1958-2005

- 1000km poleward over 40 years

Warm-water barnacles in the English Channel – 1964-2001 – *Balanus perforatus*

120km eastwards 33 km/decade

• North Sea fish
  – 1962-2001

• 0 to 120km/decade

Marine organisms are moving to higher latitudes consistent with warming trends (high confidence)

Poloczanska et al 2013 Nature Climate Change, IPCC WGII SPM
Velocity of Climate Change (VoCC)

How fast and in which direction are isotherms shifting?

Velocity = \frac{\text{Temperature trend}}{\text{Spatial gradient}} = \frac{\text{km/yr}}{\text{°C/km}}

1960-2009 surface temperatures


• Velocity is **fast**
  – where spatial gradients are shallow (Equator)
  – Where change in temperature is highest

• Velocity is **slow**
  – Where gradients are sharp
  – Where temperature change is least

• Velocity is **negative**
  – Where the oceans have cooled (Southern Ocean)
  – Indicates movement towards warmer regions

21.7 km/decade
Ocean median
- W Scotland
  - 20-50 km/decade
- North Sea
  - 200+ km/decade

Shallow gradient + faster warming = greater velocity
Does velocity predict observed shifts?

- **Yes,** for ocean observations with >10 years data
  
  - (n=139, P<0.001)
  
  - some species faster, some slower

Marine taxa track local climate velocities

128 million individuals across 360 marine taxa sampled from 1968-2011

Pinsky et al. 2013 Science
Projections from velocity of climate change

- String arrows together to give climate trajectories
- Projections from velocity of climate change
- Sources
- Divergence
- Corridors
- Non-moving
- Slow-moving
- Convergence
- Sinks
“Source”

• Not connected to warmer climate
  • where climate is warming
• No new climate migrants
• Diversity declines
Global patterns: **oceans**

**Sources** are arranged around the equator and on poleward-facing coasts

**Sinks** are mostly on equatorward-facing coasts
VoCC Trajectories used to shift distributions

...plus assumptions about upper thermal limits (Tmax + 1SD over 50 years)

and many species distributions (e.g. Aquamaps)

...to give projected change in species richness globally

García Molinos et al., unpublished
Metaanalysis: How fast is phenology shifting?

Spring advancement ocean: 4.4 days dec$^{-1}$
Spring advancement coastal: 7.3 days dec$^{-1}$

Spring advancement land: 2.3-2.8 days dec$^{-1}$

Parmesan and Yohe 2003 Nature
Parmesan 2007 GCB
Root et al 2003 Nature
Phenology change – an analogous predictor to VoCC?

• By how much should organisms change their seasonally timed activities to track changes in temperature?

• The change in arrival time of equal seasonal temperatures over longer periods (decades)
Perch in a UK lake

- Zooplankton prey getting earlier faster than larval perch
- Larvae get less food, reducing recruitment

Seasonal climate shifts

Seasonal shift = \frac{\text{Long–term temperature trend by month}}{\text{Seasonal rate of change in temperature}}

days/yr = \frac{\degree C/\text{year}}{\degree C/\text{day}}
Fig. S5.
Calculation of seasonal shift. Seasonal shift is the advance or delay in timing of seasonal arrival of fixed temperatures. If the rate of seasonal change in temperature is given by the slope of the grey line, then the seasonal shift, \( b \), is the temperature change \( (a, \text{ positive or negative}) \) divided by the slope.
April

- W Scotland  
  - 0.5-1 days/decade

- North Sea  
  - 5-10 days/decade
Does Seasonal climate shift (SCS) predict spring phenology change?

• **No**, in the ocean
• (n=57, P=>0.05)... But very significant taxon effects
Better validation data may help

- Like.....

Pinsky et al. 2013 Science

- phenology change versus spatially variable climate change
  - e.g. continuous plankton recorder
We need more phenology data from the ocean...

- UK Phenology network
  - 2 million records back to 1700

- Poloczanska et al 2013
  - 57 studies

First flowering timing index versus Central England Temperature

Thank you

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Anthony Richardson
Elvira Poloczanska