Patterns and food web consequences of phenological change in marine, freshwater and terrestrial ecosystems

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Overview

What is trophic mismatch?

Why is this important?

Ecological conditions that promote mismatching effects

A large-scale “signature” of trophic mismatch?

Future directions
The species-specific nature of phenological change


Fig. 2  Changes in timing of spring events in days/decade\(^{-1}\) for individual species grouped by taxonomy or functional type for the combined dataset. Each bar represents a separate, independent species. Negative values indicate advancement (earlier phenology through time) while positive values indicate delay (later phenology through time).
The population-specific nature of phenology


- Populations differ in phenology

Source: www.seabird.org
What is trophic mismatch?
The match-mismatch hypothesis

Match-mismatch research

- Web of knowledge search ("trophic mismatch", "match mismatch")
- 158 papers
Why is this important?
Terrestrial

Marine

• Watanuki (2009)
  MEPS 393: 259-271

© Rich Lindie, Source: www.birdskorea.org

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Freshwater

Ecological conditions that promote mismatching effects
Species respond to different drivers

- Winder & Schindler (2004) - Temperature effects
- Post & Forchhammer (2008) - Photoperiod
Species respond to the same driver (at different times or locations)


Dan Parsons Source: http://www.flickr.com
Species responses are constrained


Mark Newell, CEH
Species responses are constrained

• Both (2010) Current Biology **20**: 243-248

• Migrant species are influenced by conditions on their wintering grounds and migration route

Source: www.djsphotography.co.uk
Seasonality of resource supply

A large-scale “signature” of trophic mismatch?
Cross system studies

- Assembled published studies
- 8/11: differing rates of change among trophic levels
A large-scale “signal” of potential trophic mismatching?

Trophic level asynchrony in rates of phenological change for marine, freshwater and terrestrial environments

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Meta-analyses of changing phenology

- Give mean (and variability) of rates of change across taxa, **but:**

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**Fig. 2** Changes in timing of spring events in days·decade$^{-1}$ for individual species grouped by taxonomy or functional type for the combined dataset. Each bar represents a separate, independent species. Negative values indicate advancement (earlier phenology through time) while positive values indicate delay (later phenology through time).
Meta-analyses of changing phenology

• Under-representation of freshwater and marine taxa

28,586 significant biological changes in terrestrial systems but only 85 from marine and freshwater systems

*IPCC Fourth Assessment report (2007)*

**Fig. 2** Changes in timing of spring events in days/decade$^{-1}$ for individual species grouped by taxonomy or functional type for the combined dataset. Each bar represents a separate, independent species. Negative values indicate advancement (earlier phenology through time) while positive values indicate delay (later phenology through time).
Meta-analyses of changing phenology

- Variable time periods among taxa – rates of change differ over time

Root et al (2003): 10-54 years

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Meta-analyses of changing phenology

- Positive publication bias

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The phenological dataset

- Marine and freshwater plankton – start of growth period
- Freshwater fish – spawning dates
- Marine and terrestrial birds – first and median egg dates
- Aphids, moths, butterflies – first and peak dates
- Mammals – first and median birth dates
- Pollen production – median dates
- Terrestrial plants – first leaf, flowering dates
- Amphibians – first spawning
UK warming 1976-2005

- Temperature increase across all major habitats, especially post-1980s
UK phenology 1976-2005

- Over 700 taxa and over 25,000 trends analysed
- Spring and summer events
- ~80% of all trends were towards earlier seasonal timing
- Advanced timing for primary producers, invertebrates & vertebrates
UK phenology 1976-2005

- Mean trend: 3.9 d decade\(^{-1}\) earlier
- Fastest change for leafing, flowering, fruiting in terrestrial plants (5.8 d decade\(^{-1}\) )
- Slowest change for phytoplankton growth (2.3 d decade\(^{-1}\) )
Mixed effects modelling: decades and environments

- Mean rates of change do not differ among environments over 30 year period

- Similar decadal acceleration of phenological advance across environments
Mixed effects modelling: trophic level

- Mean rates of change differ significantly with trophic level over 30 year period

- Significant decade x trophic level interaction: secondary consumers show less decadal acceleration

- Result: mean rates of change over 30 years are slowest for secondary consumers
Future directions
Resource abundance and seasonality


- Overall prey abundance and mismatching both affect reproductive success
Resource abundance and seasonality


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Resource abundance and seasonality


- Overall prey abundance and mismatching both affect reproductive success
Ecosystem context


- Phenological change under selection due to interactions with food and predators

Species ontogeny


- Søreide et al (2010) GCB Online early
Freshwaters


- Timing of *Asterionella formosa* blooms can be affected by warming **and** nutrient supply – not just climate
Mismatching in plankton communities?

- Timing is a function of population growth
- Food availability affects clutch size/growth
- Temperature affects development rates for eggs, juveniles, adults
- Would expect changes in food availability and temperature to affect time of population growth
Summary

• Phenological changes vary among species - this might affect species interactions and impact upon reproductive success

• Differences in driving variables or times/locations of their influence are important

• Some species are constrained in their ability to respond to lower trophic levels

• In the UK, there is evidence of large-scale systematic differences in rates of change among trophic levels

• Future studies should address the interaction between phenology and prey availability, the wider ecosystem context and ontogenetic issues

• More freshwater studies!