Warmer winters and shifting spawning phenology in sole

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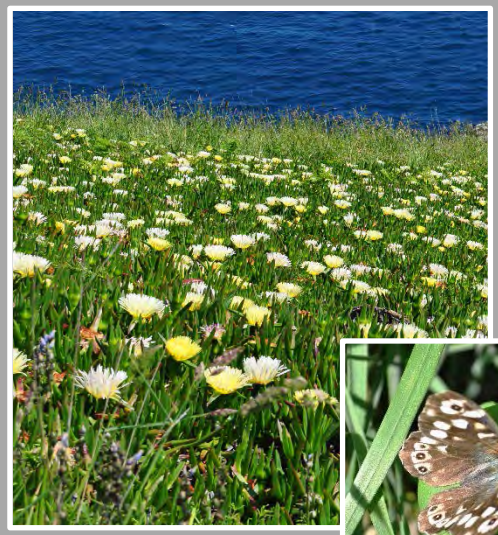
Phenology in the marine: the need to know more

- So far, climate change research on marine fish has focussed on changes in productivity and distribution
- Far less attention to changes in *phenology* – why?
  - Terrestrial: easy to monitor continuously, obtain flowering times, breeding dates, eclosion times, etc.
  - Marine: ship-based surveys once or few times a year, not year-round but 'snapshots' – difficult to measure seasonal timing marine organisms
  - Need for methodologies based on *routine data* monitored *year-round*

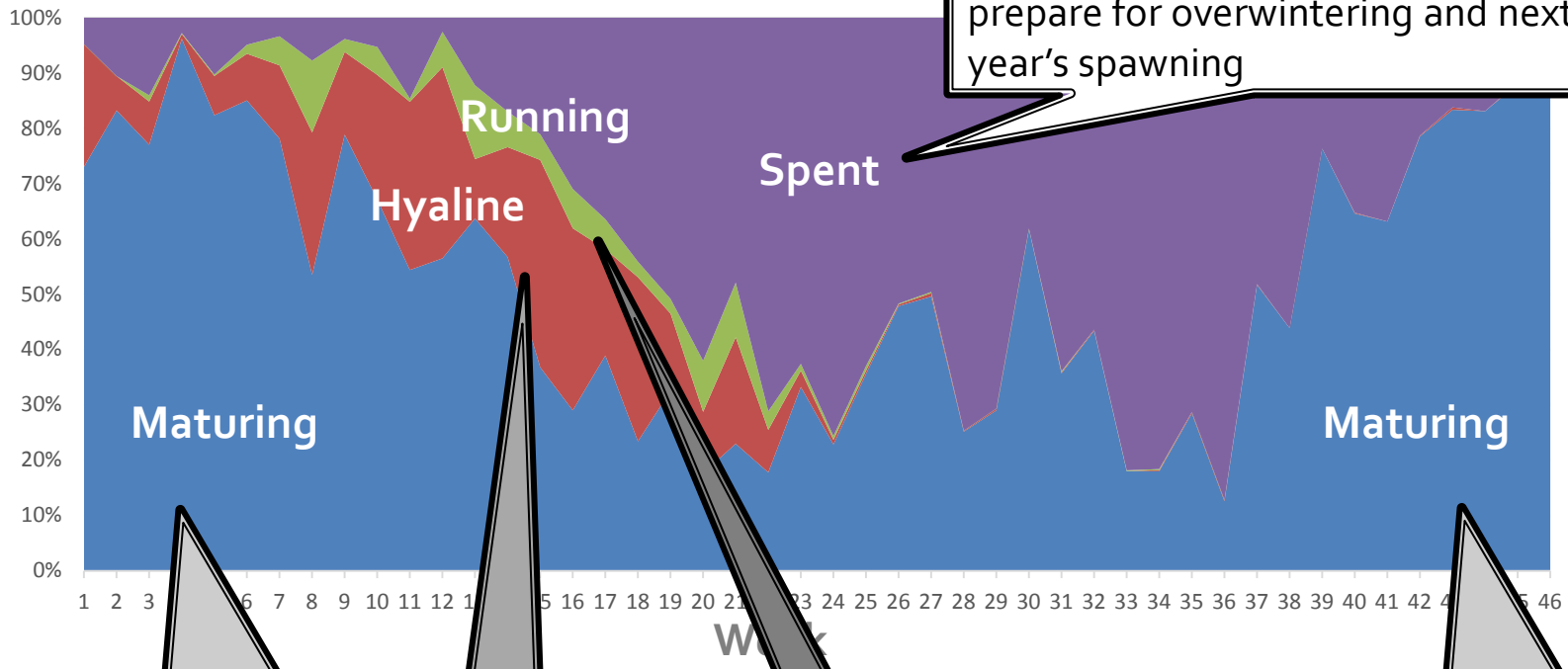


Market sampling data

- Year-round, market sampling staff go to fishing ports around the world and sample the catches of fish landed by fishing vessels
- They record fish size, age, sex, and maturity status – crucial data for fish stock assessments
- *Maturity data* also contain valuable information on phenology

John Gulland, famous Cefas fisheries scientist, records while a colleague measures fish, at Lowestoft fish market

Maturity – the annual cycle



Fish resume feeding to recover and prepare for overwintering and next year's spawning

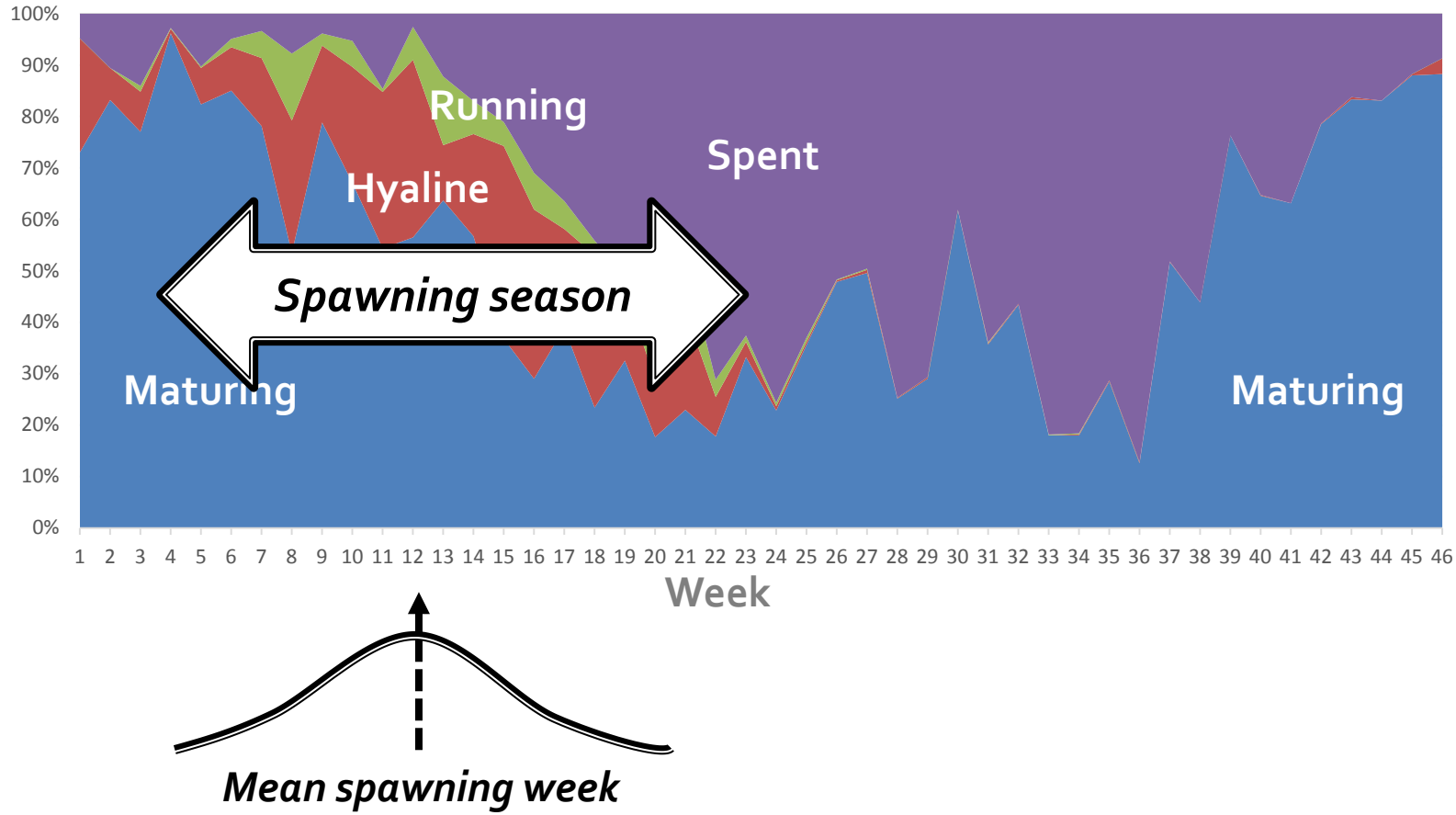
Fish ripening gonads in preparation of spawning

Fish are spawn-ready – eggs fully ripened

Fish are in process of spawning

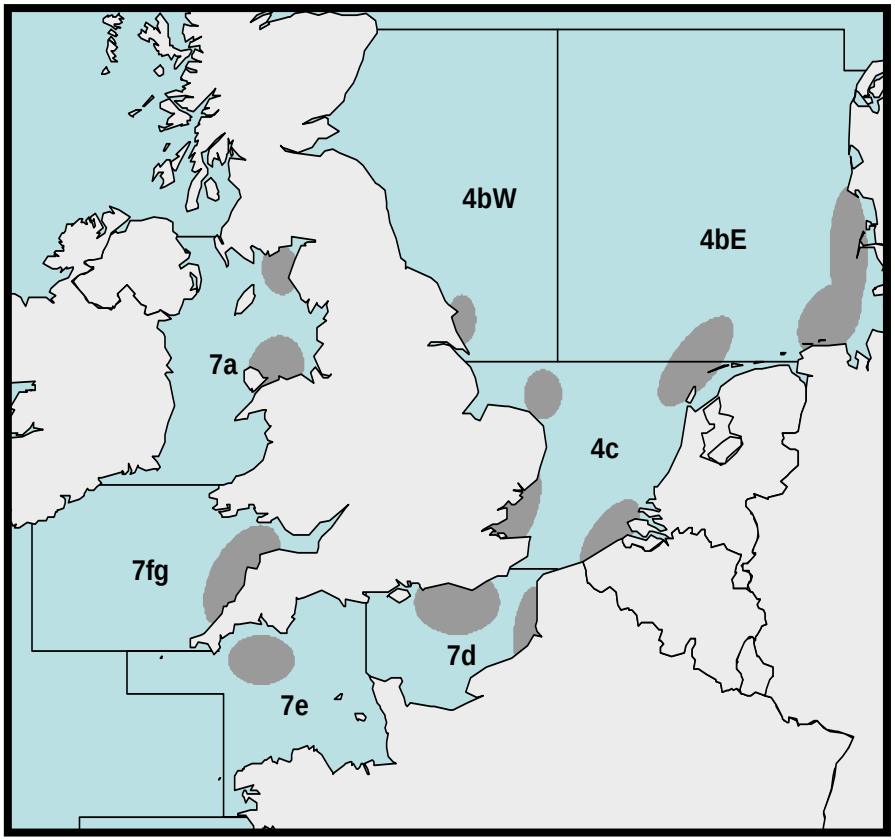
Fish ripening gonads in preparation of spawning

From weekly maturity data to spawning phenology



The case study

- Sole *Solea solea* – of high value to the fisheries of 6 NW European countries
- 7 study populations, ranging from…
  - Late-spawning, northern populations
  - To early-spawning, southern populations
- East-west gradient
  - More seasonal in shallower, eastern sites



Hypotheses

1. Winter sea temperatures in sole habitats have risen significantly in the past 40 years

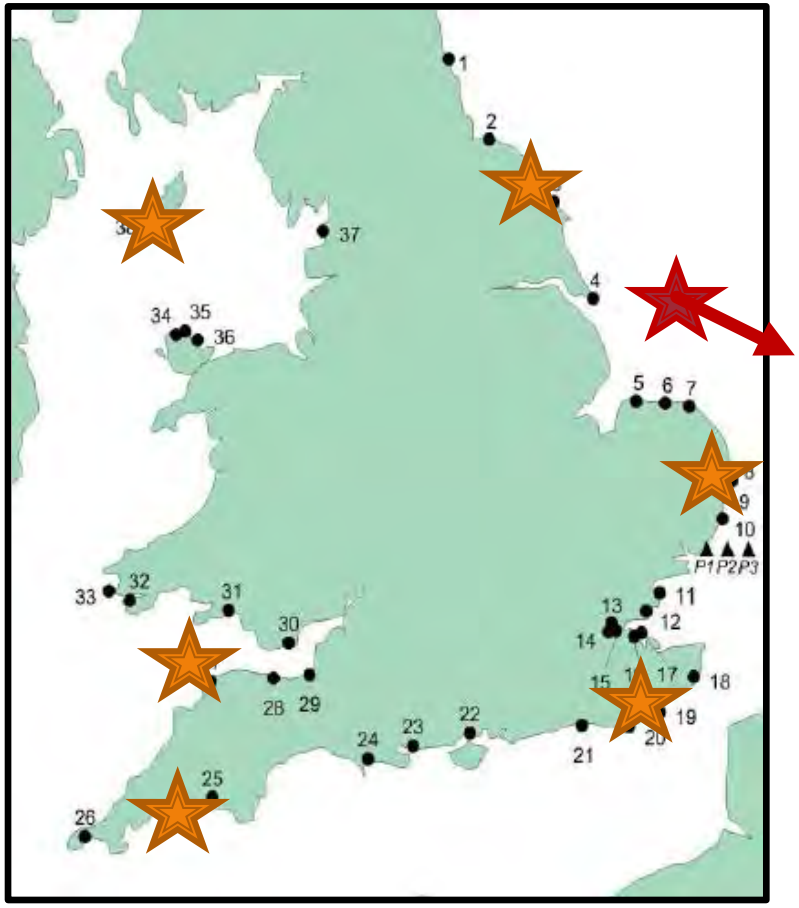
2. There have been significant shifts in the peak spawning dates of sole

3. Shifts in peak spawning are related to trends and interannual variability in winter sea temperatures

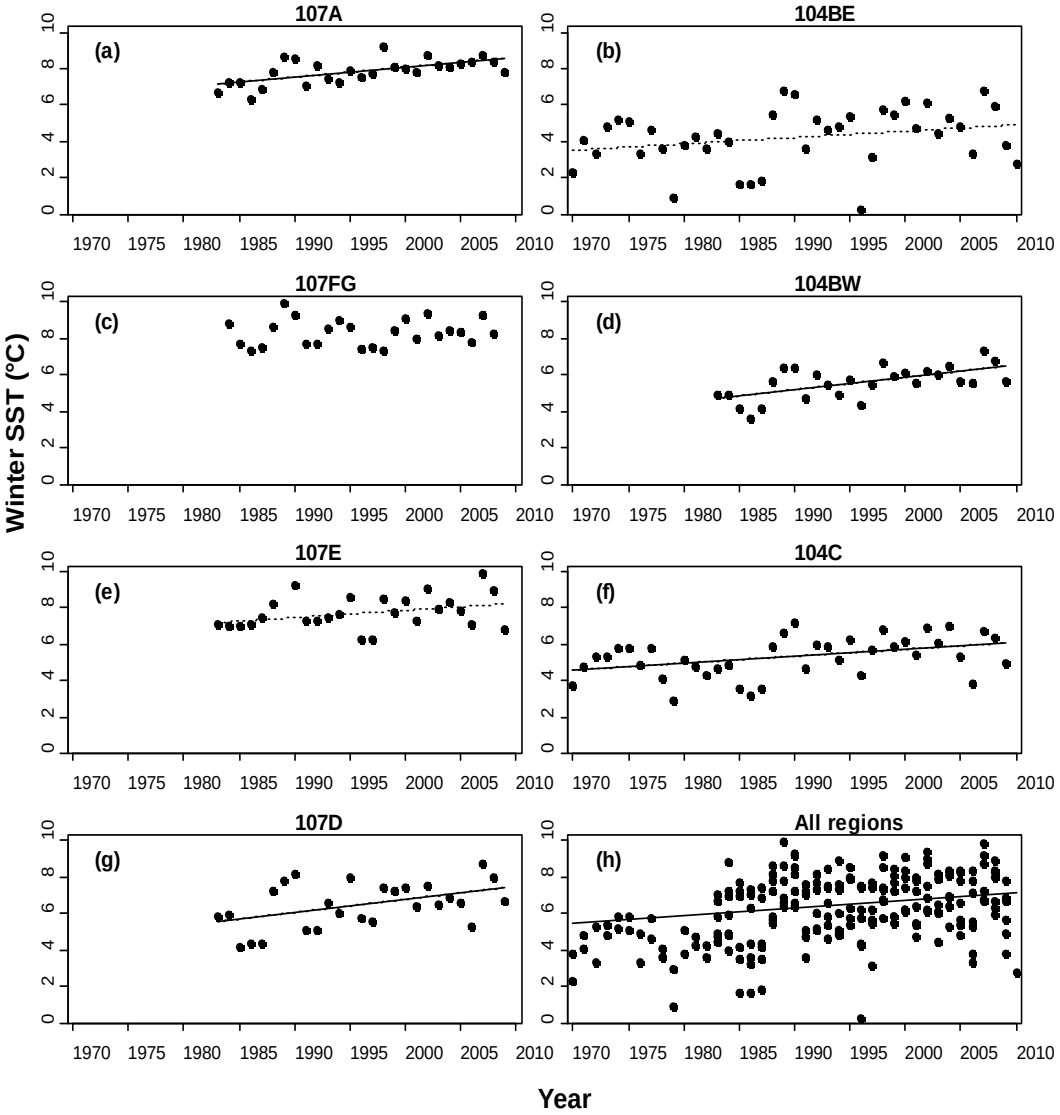
The data

- Sole spawning – market sampling data from England and Netherlands

- Winter temperature (January–March):
  - from Cefas Coastal Temperature Network
  - NIOZ (NL) Marsdiep time series

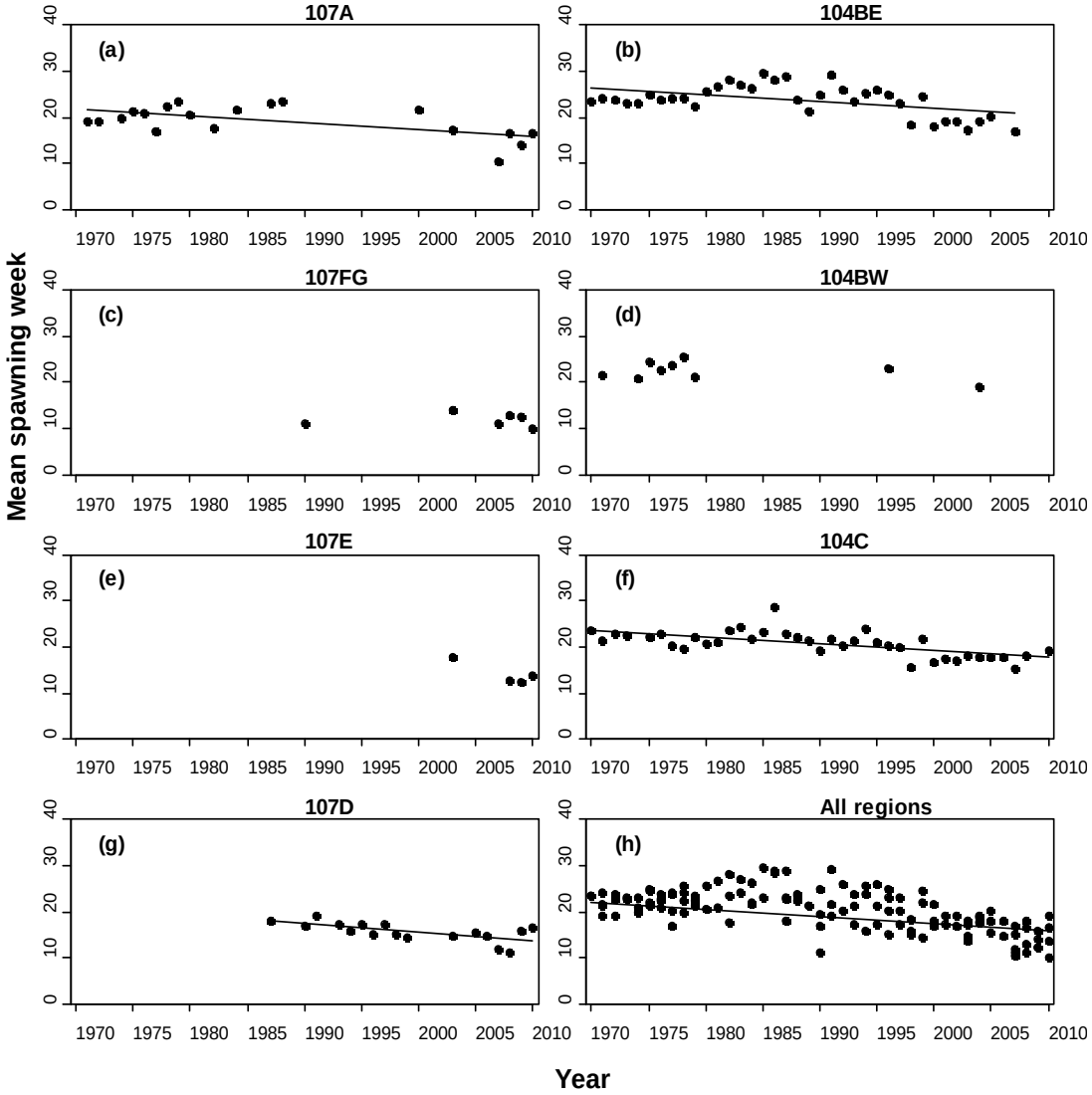


1. Winter sea temperatures in sole habitats have risen significantly in the past 40 years



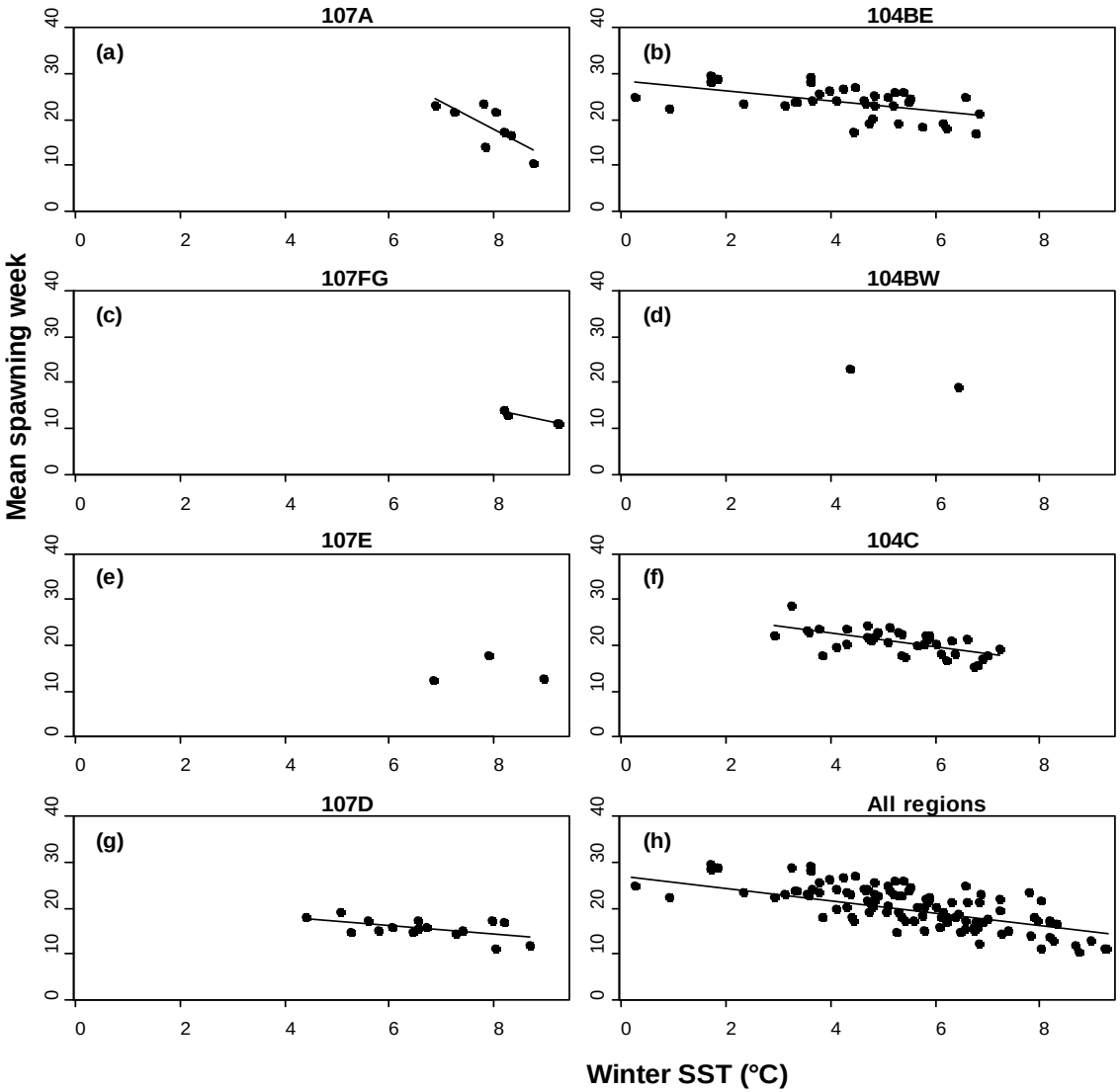
- 4 out of 7 regions showed significant temperature rises
- Linear mixed effects models showed a difference between regions
- And an increase the equivalent of 1°C in 23 years

2. There have been significant shifts in the peak spawning dates of sole



- 4 out of 7 regions showed significant trend for earlier spawning
- Linear mixed effects models showed an overall shift from week 22 to week 16
- An advancement of a day per year

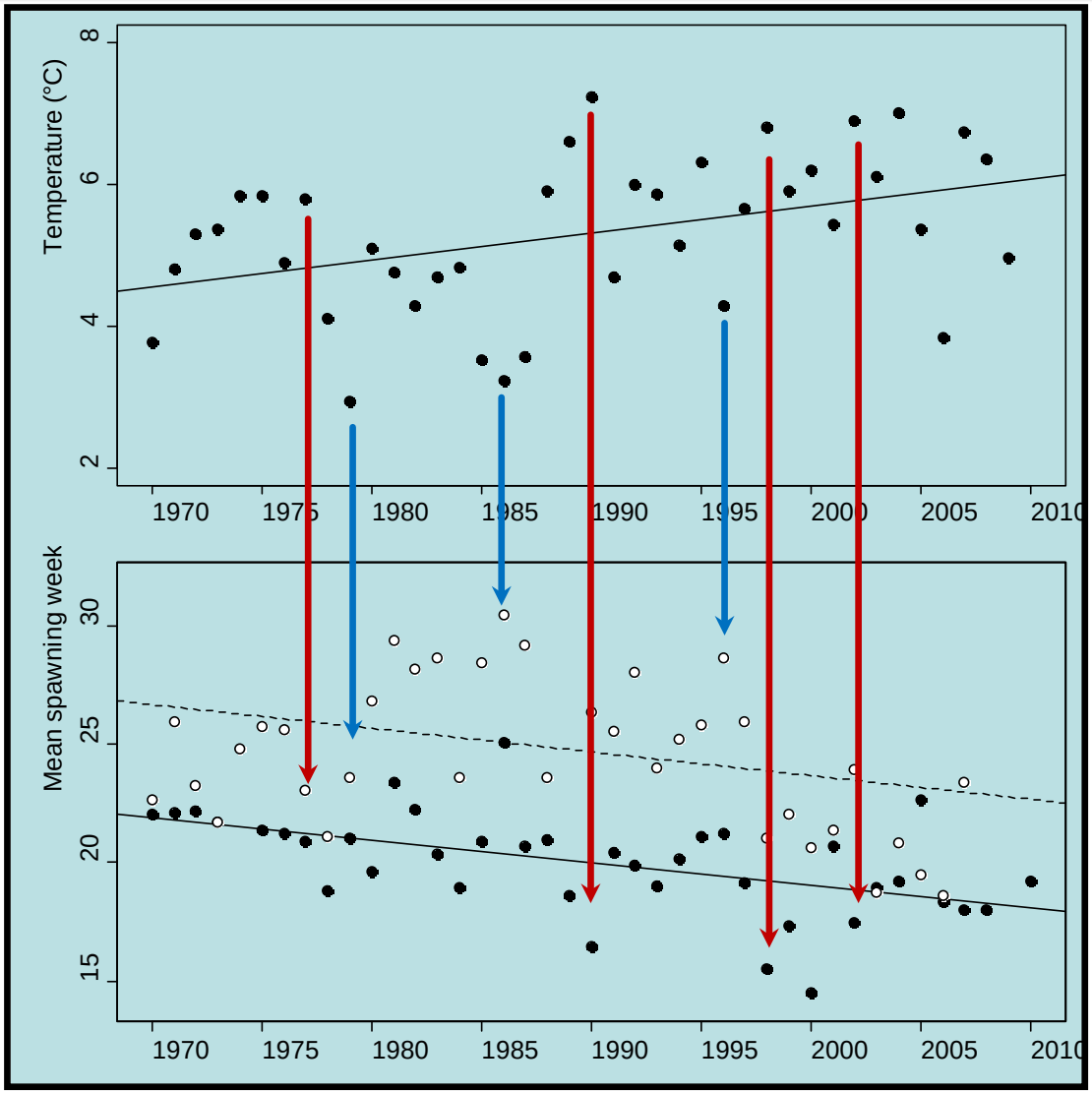
3. Shifts in peak spawning are related to trends and interannual variability in winter sea temperatures



- Stocks inhabiting warmer waters generally have earlier spawning
- Spawning advances by 1.14 weeks for every 1°C rise
- Regions vary in their response

Short- and long-term impact on spawning

- Long-term temperature trend resulting in multidecadal shift towards spawning
- Single cold/warm winters causing sole to spawn later/earlier in the following spring



Implications

- Strong evidence that sole spawning phenology is ***advancing*** in response to climate change
- Earlier spawning ***might*** be beneficial: earlier hatching allows larvae more time to feed and develop
- …But might also lead to a ***mismatch*** between hatching and peak planktonic prey availability – with risk of starvation for larvae
  - Historically, ***cold winters*** often linked with strong recruitment in sole!
- …And may also have implications for fisheries in relation to spawning stock protection and seasonal area closures

Perspectives

- Sole are only one out of many key fish species, where climate change is likely impacting the phenology of reproduction
  - Flounder, mackerel, cod, herring, salmon…
- **Multidecadal, year-round market sampling data are an under-utilised data source for phenology studies on fish**
- We encourage the use of such data to understand the short- and long-term phenological responses to climate change in fish populations globally