ICARUS
Irish Climate Analysis and Research Units

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Role of Sea surface temperature on growth of Mytilus sp. in Irish waters from 1992-2022

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Marine Institute
Foras na Mara

A4 Aigéin Aeráid Athrú Atlantagh

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Study Motivation

- Mussels are a corner stone species within the Irish marine environment
  - Habitat formation
  - Food web maintenance
  - Improve water quality by filtering
  - Commercial value E9.8 million 2022, E8.9million 2023
- Sensitive to environmental changes
  - Heatwaves
  - Pollution
  - Freshwater run off
  - Changing planktonic communities make up

Previous finding

- Reported declines in mussels in international (Petraitis & Dudgeon 2020) and Irish waters (Little et al 2024)
- Significant decline (-148 t yr-1) in wild mussel seed particularly since 2012 in Spanish waters (Padin et al 2024)
- Marine heatwaves have been shown to lead to mass mortality (Seuront at al., 2019)
- Irish waters shown to have decreased in temperature since peak in 2007 (McCarthy et al, 2023)

Petraitis, P.S. and Dudgeon, S.R. 2020. Declines over the last two decades of five intertidal invertebrate species in the western North Atlantic. *Communications Biology* 3(1). doi: 10.1038/s42003-020-01326-0.

Little, C., Trowbridge, C.D., Pilling, M., Williams, G.A., Morritt, D. and Stirling, P. 2024. Long-term fluctuations and recent decline of mussel populations in an Irish sea lough. *Journal of Molluscan Studies* 90(1). doi: 10.1093/mollus/eyae002.

Padin, X.A. et al. 2024. The declining availability of wild mussel seed for aquaculture in a coastal upwelling system. *Frontiers in Marine Science* 11. doi: 10.3389/fmars.2024.1375269.

Seuront, L., Nicastro, K.R., Zardi, G.I. and Goberville, E. 2019. Decreased thermal tolerance under recurrent heat stress conditions explains summer mass mortality of the blue mussel Mytilus edulis. *Scientific Reports* 9(1). doi: 10.1038/s41598-019-53580-w.

McCarthy, G. D., Caesar, L., Ulthaman, A., & Daly, E. (2023). *Physical Oceanography* in *Irish Ocean Climate and Ecosystem Status Report* (Eds: G. Nolan, C. Cusack, D. Fitzhenry). Marine Institute

Data available

- Data provided by the marine institute by Brendan McHugh
- Collected in accordance with environmental and food safety monitoring programs
- Data collected from intertidal, bed and suspended mussel samples
  - Shell length
  - Shell weight
  - Tissue/meat weight
  - Moisture content
  - Temperature
  - Date of collection

Data treatment

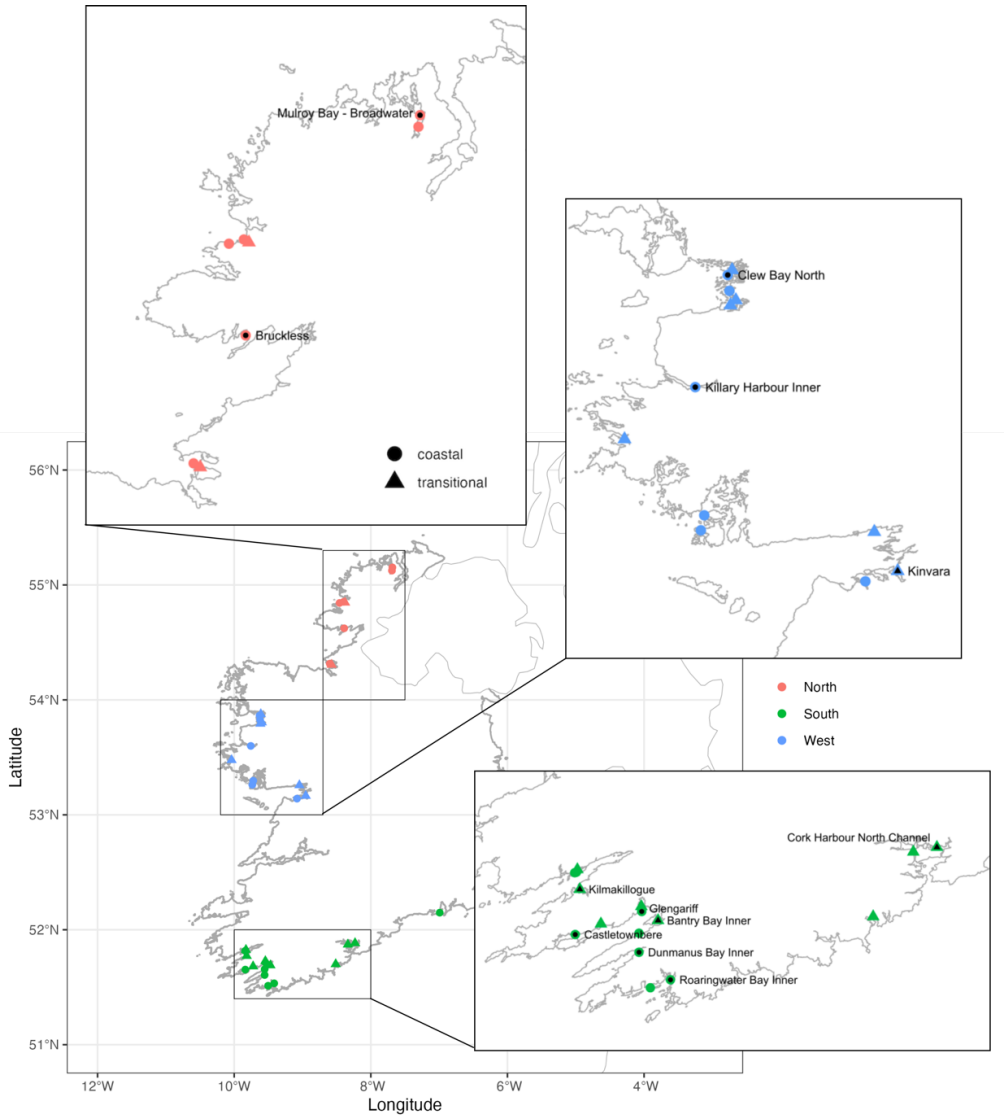
- Sampling locations and time of sampling were not consistent
- Mitigated by
    - Using only suspended cultures (ropes and trestles)
    - Using only Autumn samples only (Sep-Nov)
    - Subsampling to create data set where sampling occurred over timeframe of study

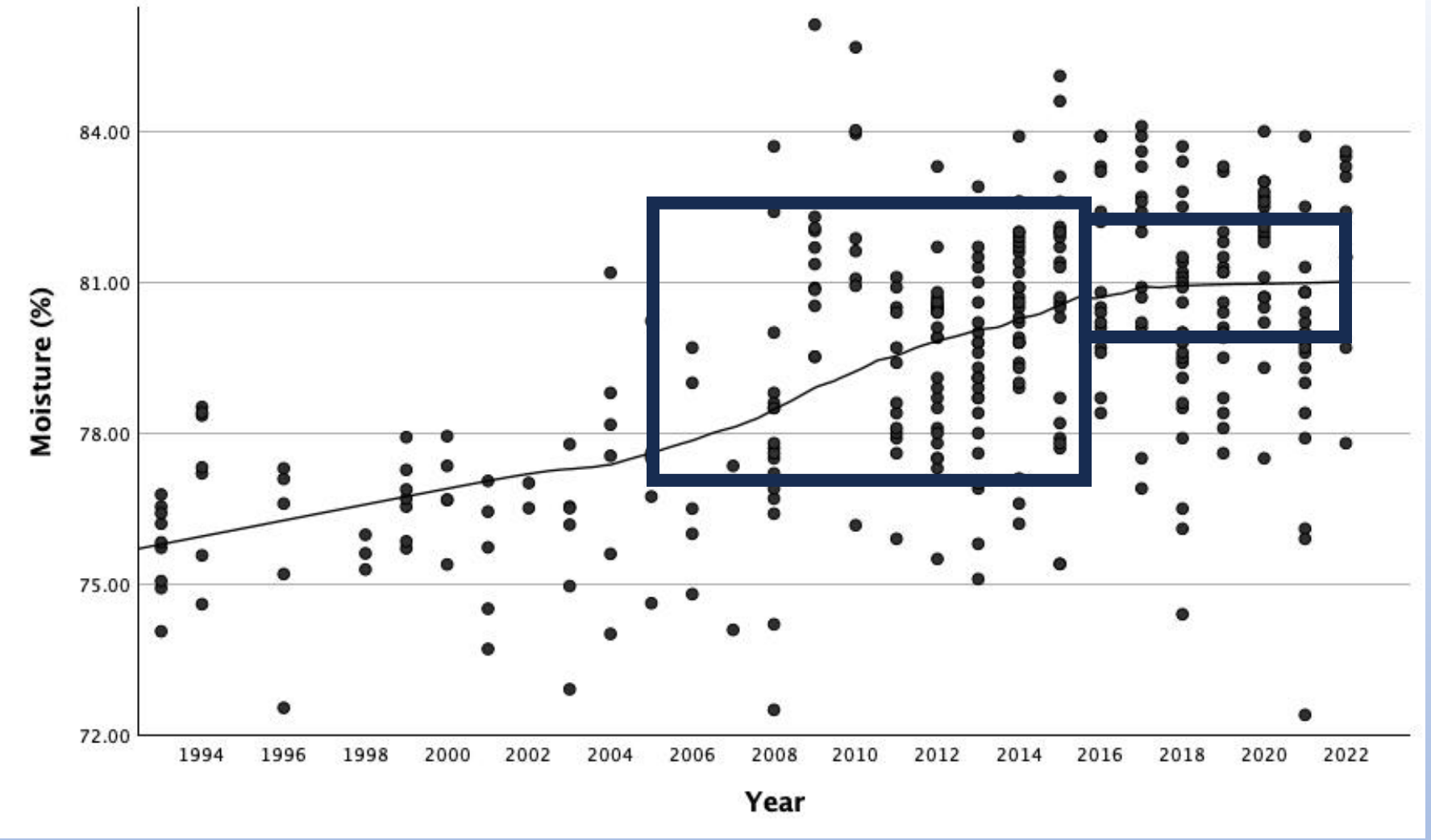
- Shell weight and tissue weight divided by length of the samples to provide weight per mm in length.
- Temperature data was too low resolution leading to satellite derived sea surface temperatures were employed

Data collection locations for suspended mussel samples

- Named points represent locations included in the subset of data. Coloured markers represent red north samples, blue west and green south.

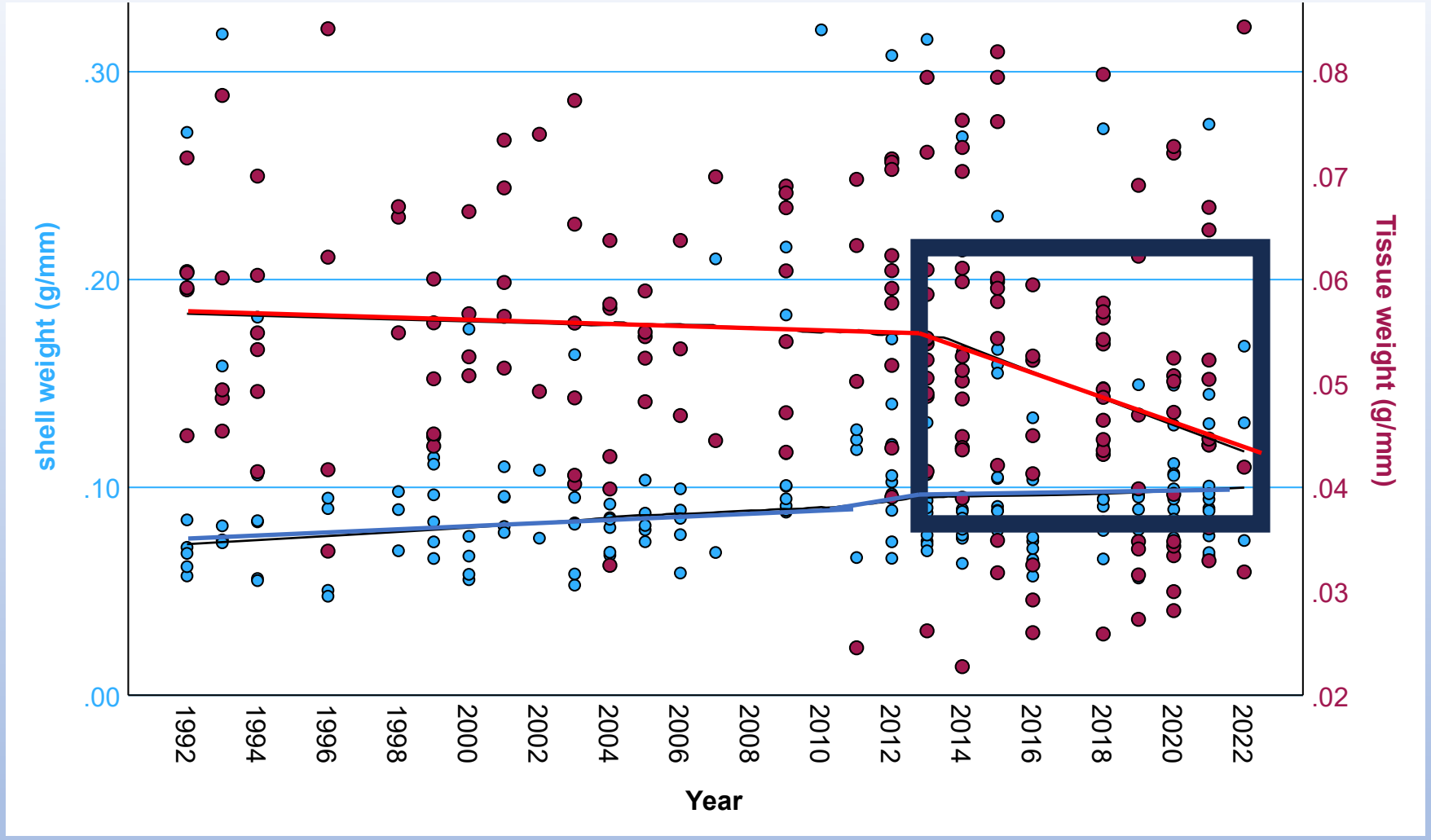
- No samples were included from the east as these did not contain any suspended samples





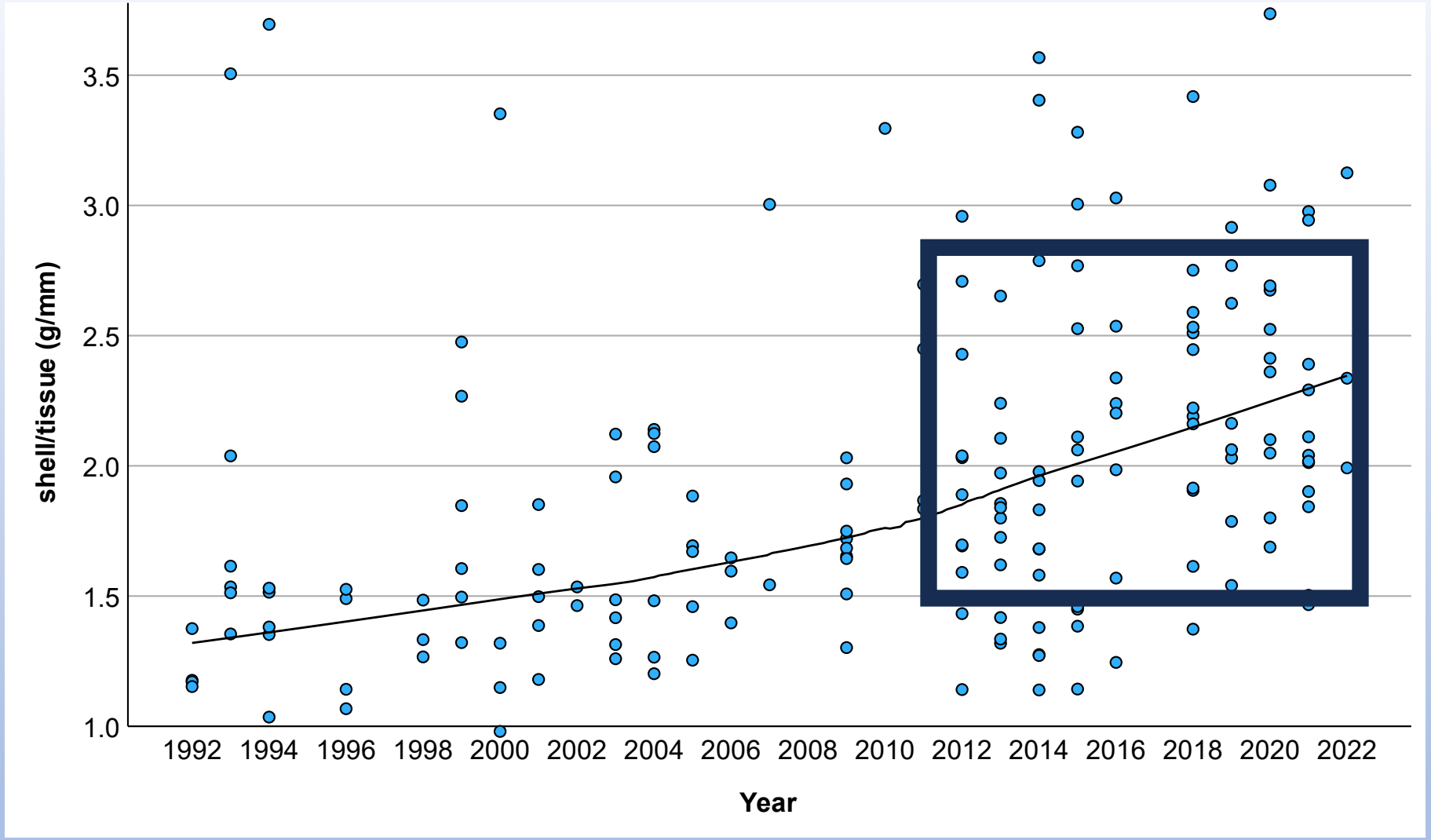
Moisture trends over the time period of 1992 – 2022

- **Moisture is seen as an indicator of health with increased levels indicative of lower condition**
- **Moisture increases from 76 % to 81 % with the period between 2006 and 2016 showing the largest transition**
- **Moisture changes were observed in all geographic locations within the study**
- **New ‘normal’ seems to have occurred**



Shell weight and tissue weight per mm of mussels in Irish water of 1992 – 2022

- **Shell weight increased from 0.075 g/mm to around 0.1 g/mm (33%)**
- **Tissue weight decreased overtime with a decline of 25 % from 2012 onwards**

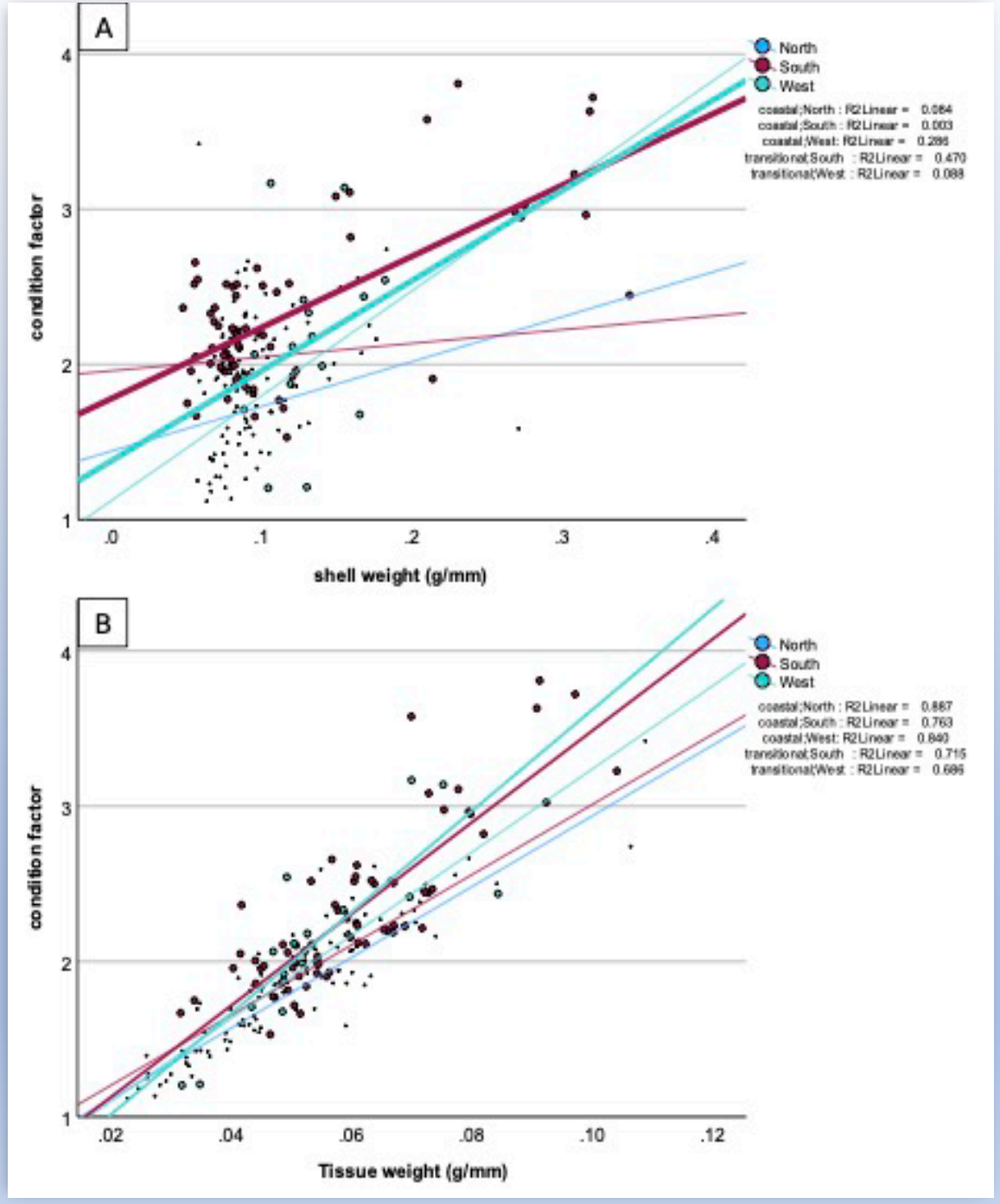


- **<u>Shell/tissue of mussels in Irish water of 1992 – 2022</u>**
- **Increase in shell and decrease in tissue lead to a sharp increase in shell:tissue**

- Condition factor= $100*W/L^3$

- W= total weight (mean shell weight + mean tissue weight)
- L = length of the shell

Tissue weight more influential than shell in the determination of the overall condition of the animals



Biometric results overview

Moisture increases over time – with very abrupt increase 2006-2016

Leading to a new higher level of ‘normal’

Reduction in tissue/meat content in particularly since 2012

Shell weight increased slightly

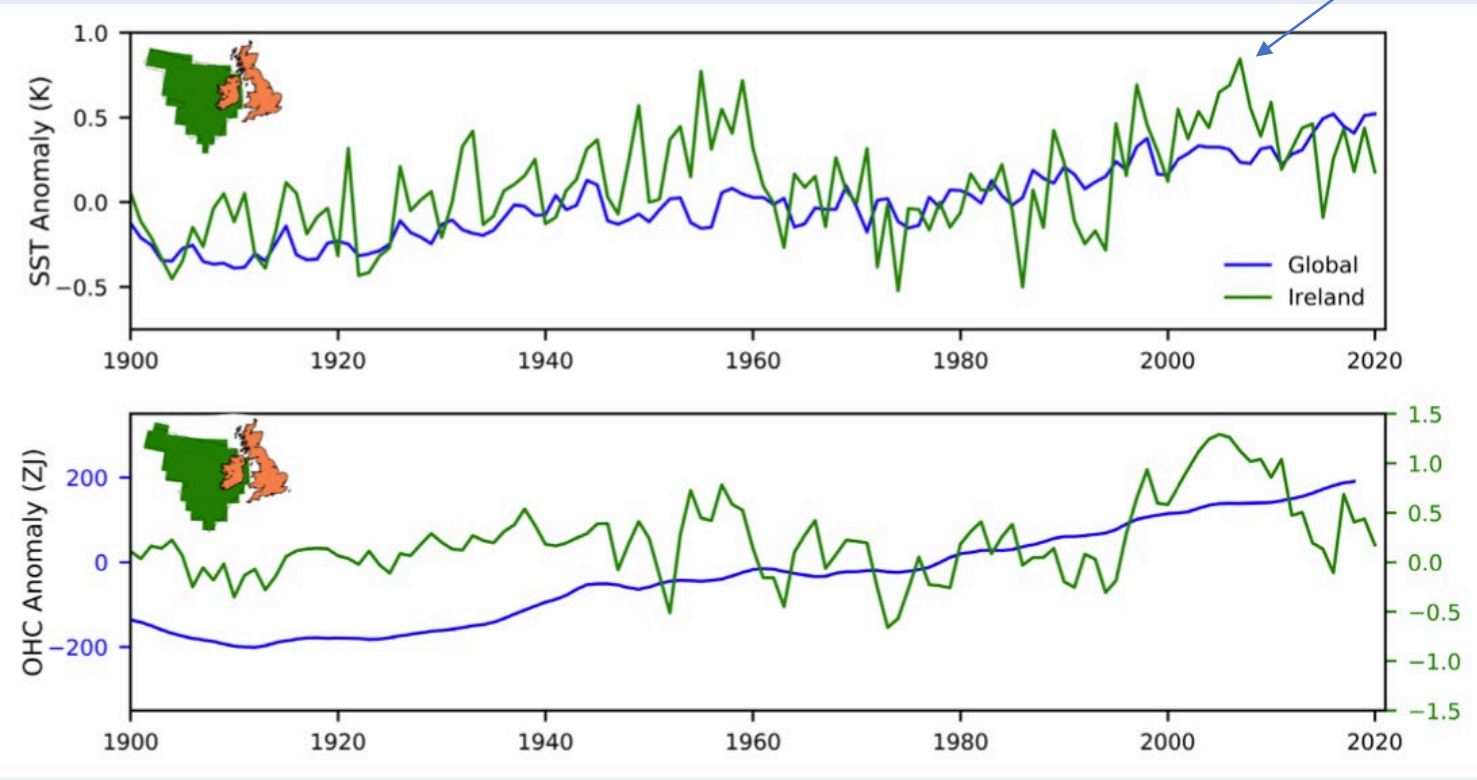
Shell/meat content almost doubles over the 30 year time period indicating a loss of meat content

Tissue /meat has more influence on the condition factor than shell despite being equally weighted in the calculation

As moisture increased condition decreases

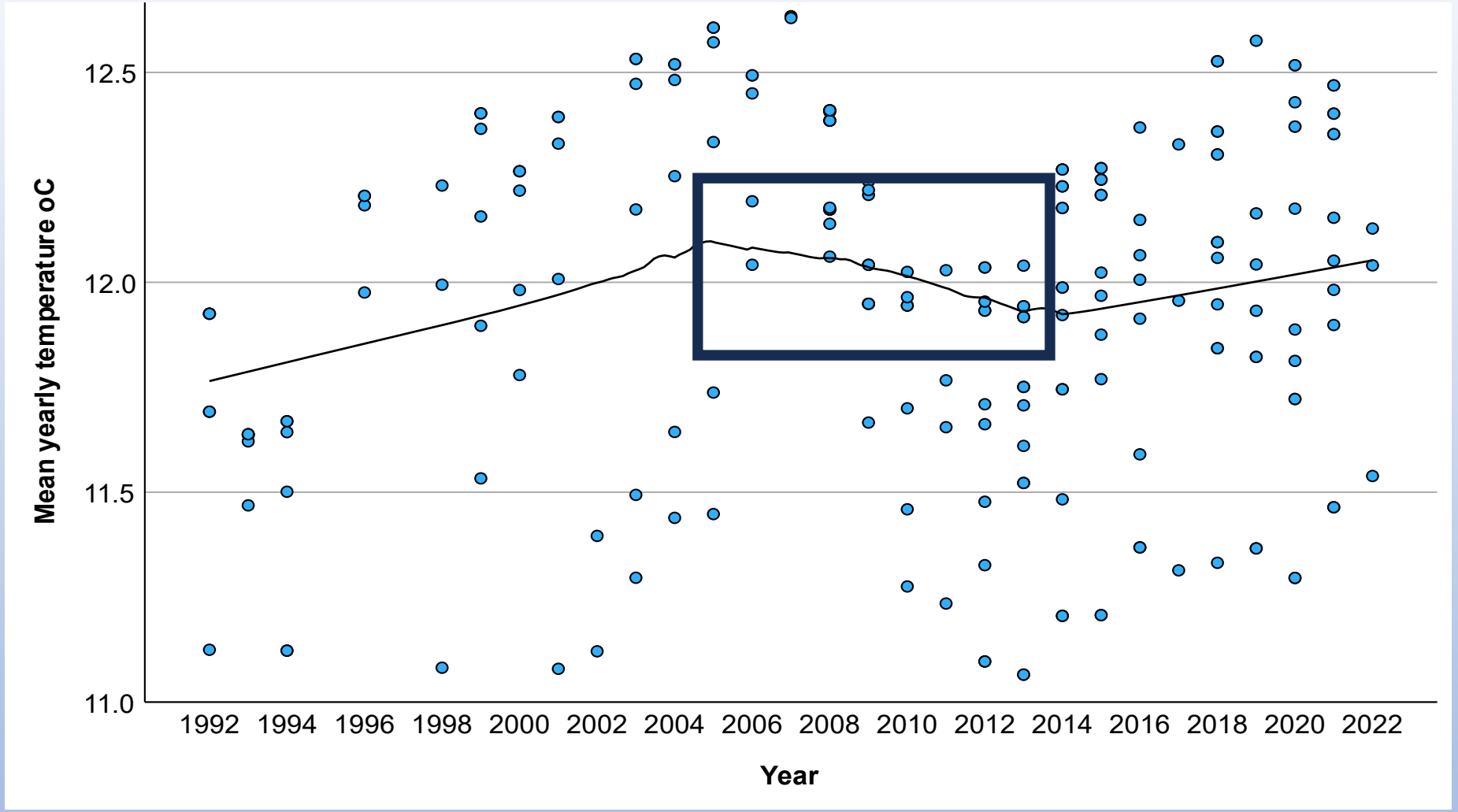
Warming in Irish Waters

decadal peak in 2007



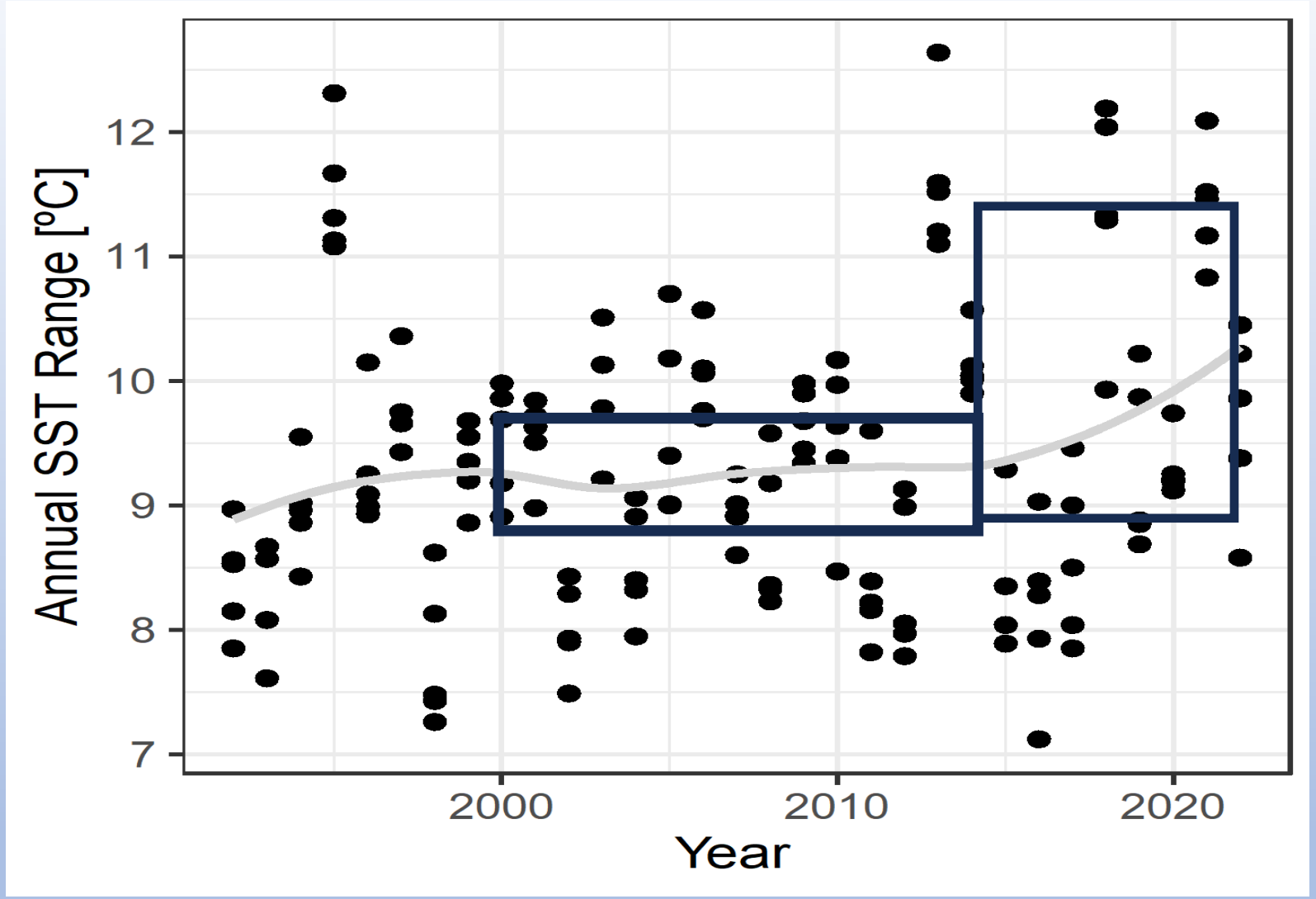
Irish waters warmed strongly from the 1980s to the mid-2000s, with the highest annual sea surface temperatures recorded in 2007 at over 0.8 °C above the 1960–1990 average. Recent years have seen a cooling trend of over -0.3 °C/decade, linked by some to a decline in the AMOC.

McCarthy, G. D., Caesar, L., Ulthaman, A., & Daly, E. (2023). *Physical Oceanography* in *Irish Ocean Climate and Ecosystem Status Report* (Eds: G. Nolan, C. Cusack, D. Fitzhenry). Marine Institute



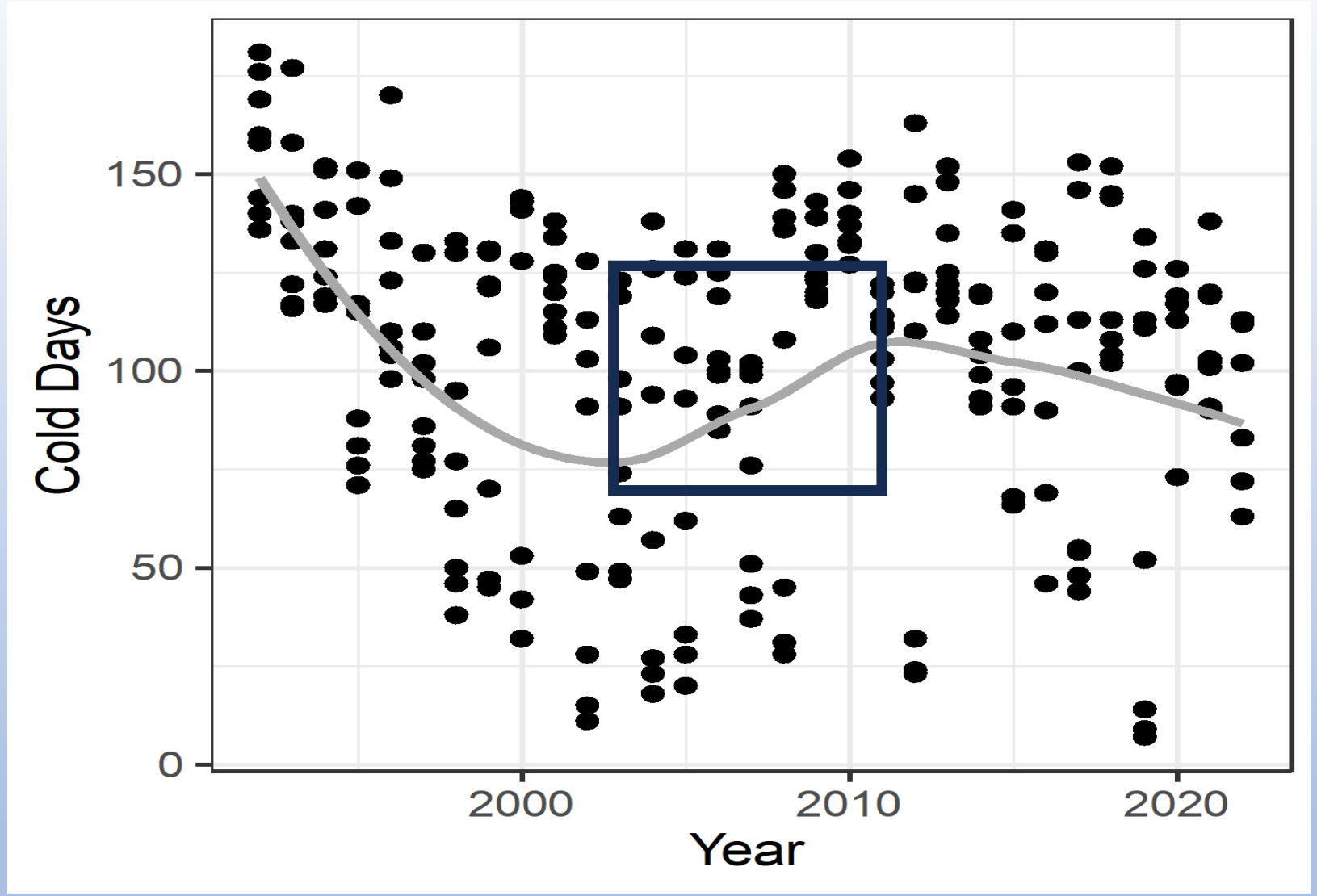
Mean sea surface temperature from each station in the suspended Mussel culture subsample locations in Ireland 1992-2022

- Temperatures peaked followed by decline and a second increase



Yearly SST Range from 1992-2022

- Temperature Range calculated as difference between maximum temperature in a year and the minimum
- Range fairly consistent until around 2015 despite general temperature changes
- Increase in the range driven by increase in max summer temp



Number of cold days in sample stations per year

- Cold day defined as SST under 10 degrees Celsius
- Number cold days increases during 2002-2012
- Number cold days currently decreasing

Temperature results overview

Global sea surface temperature seen to increase over-time but Ireland has been noted as cooling 0.3 degrees decade since 2007

Station sst data indicates a cooling event 2004-2014 followed by warming

Increase cold days 2004-2011, but no increase in the SST ranges suggesting cold conditions all year.

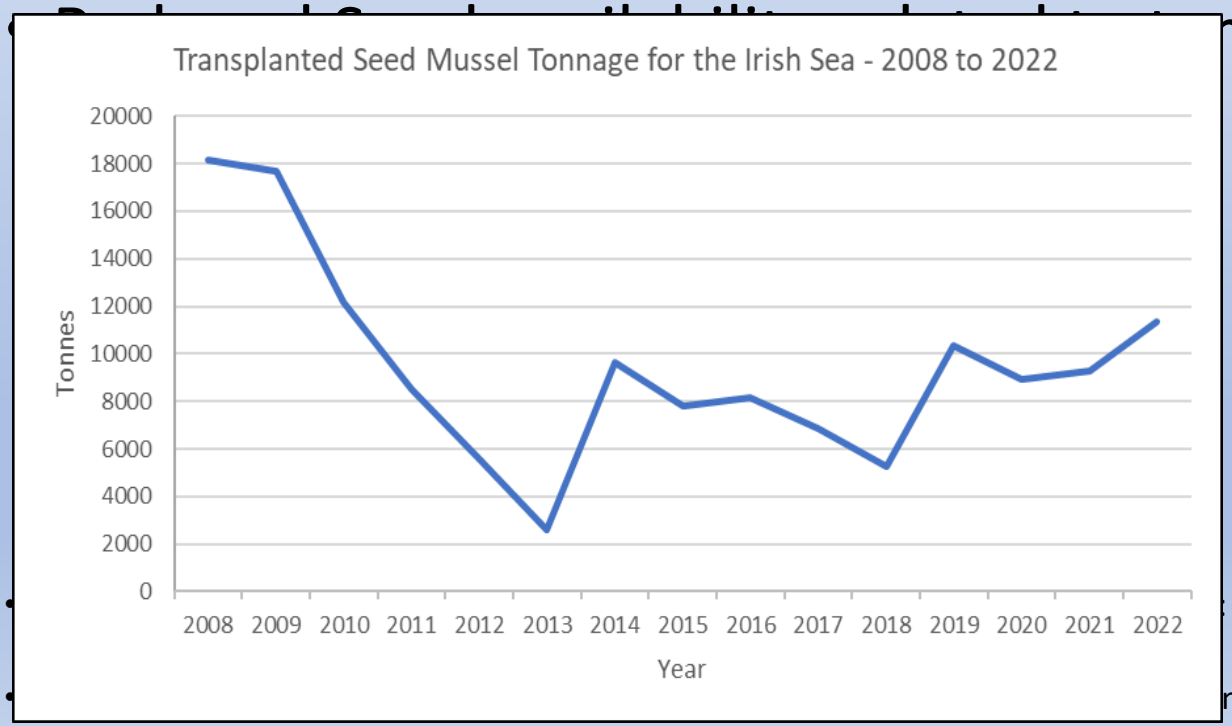
SST range fairly constant, until around 2012 when the range begins to steadily increase, driven by warmer summer conditions.

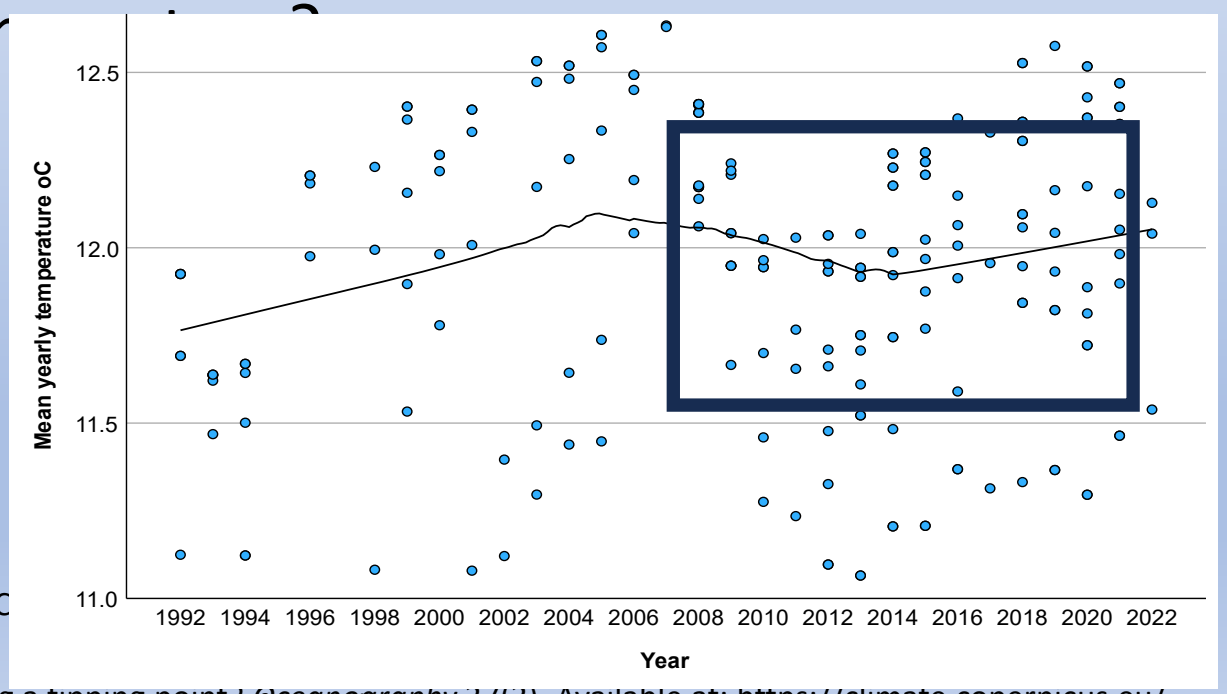
Temperature impacts on mussels?

- The reduced sea surface temperature and increase number of cold days suggesting overall cooler conditions during this time, coincides with the marked increase in moisture and reduced condition
- Increase in the range of temperatures driven by recent warmer summers appears to coincide with reduced tissue content and increased shell:tissue following on from the cooler event and increase in moisture
- The relationship with temperature whilst apparent is not straight forward and is likely influenced by other factors such as seed availability, food availability, pH, fresh water input, disease ect

Things to consider

- Possible changes in current in Irish waters driven by AMOC change(Caeser at al 2021, Rahmstorf, 2024)
- Potential changes in food availability and type leading to changes in growth and successful recruitment?
- Potential chemical changes due to freshwater input ect





ng a tipping point? *Oceanography* 37(3). Available at: https://climate.copernicus.eu/.
Southeast coast of Ireland/2024
PhD thesis for Nicolas Chopin.

Future work?

- Extend the study to include the most recent mussel data
- Incorporate chlorophyll and plankton data to assess for relationships
- Incorporate data on seed availability
- Targeted sampling and insitu continuous pH and temperature monitoring
- Extend sampling locations to include bed mussels
- Consider incorporation of weather data where possible

Conclusions

Mussel health in Ireland has shown signs of decline in the past 30 years with reduced tissue , condition and seed production in all geographical locations studied in Ireland

Changes in SST appear to be reflected in changes in mussel health

Further work needed to assess impacts of other variables on mussel health