A multi-scale view of the ocean along a 3,000 km Atlantic salmon post-smolt migration corridor

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THE MISSING SALMON ALLIANCE

Game & Wildlife CONSERVATION TRUST | ANGLING TRUST | Fisheries Management Scotland | The Rivers Trust

ATLANTIC SALMON TRUST

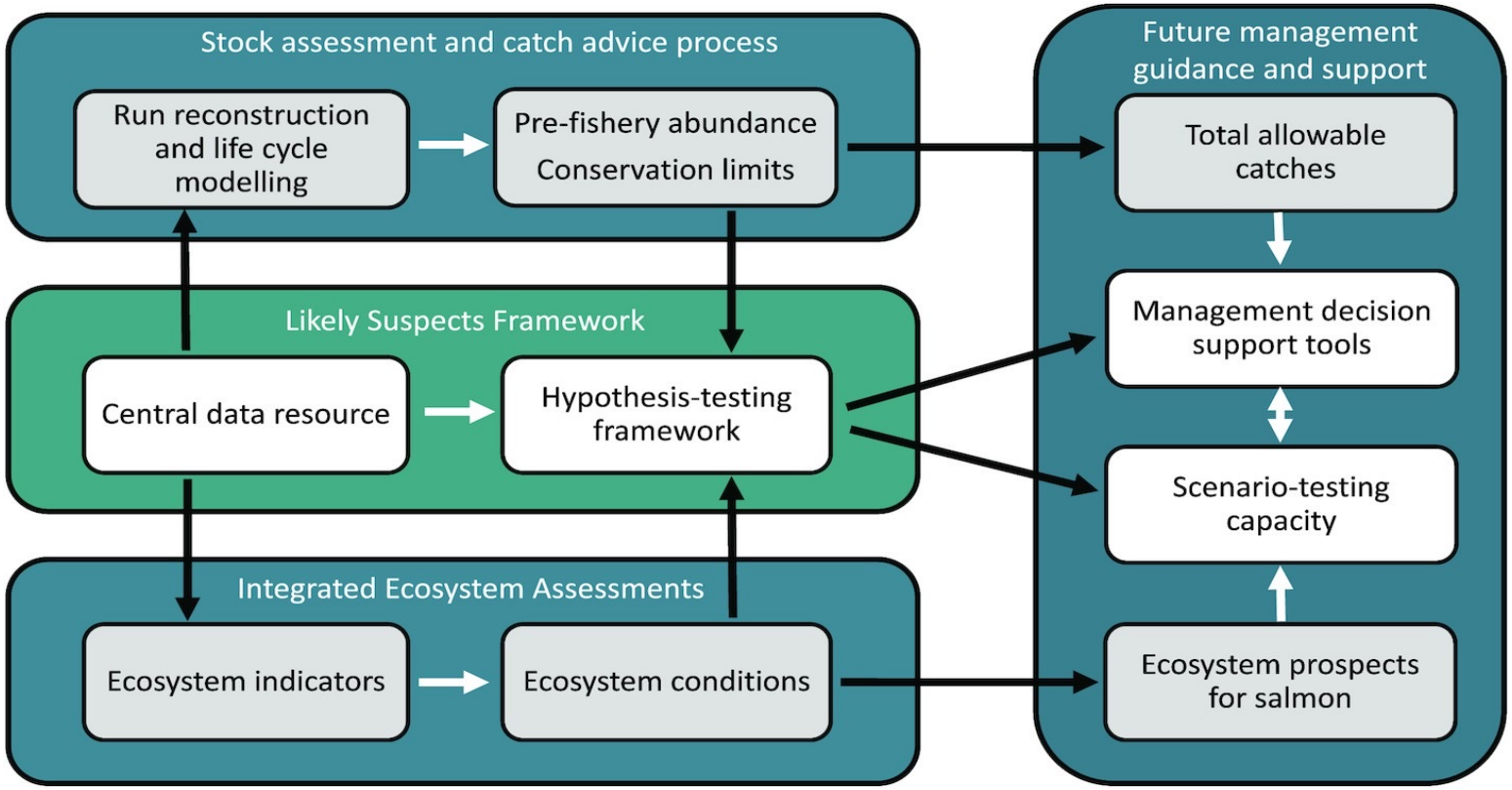
University of Strathclyde Glasgow

A Likely Suspects Framework case study

LSF Work Package 4:

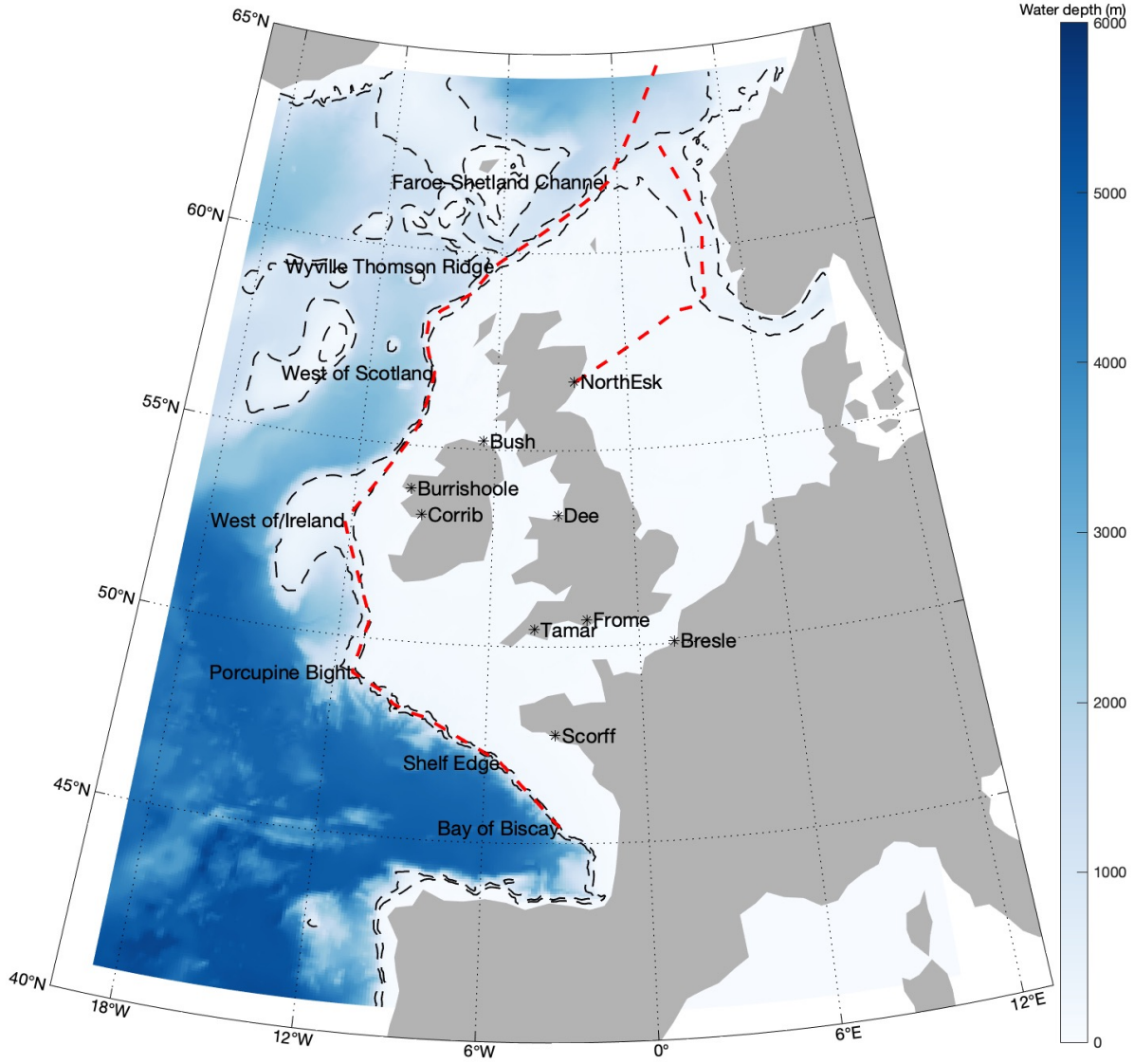
Using **freshwater** and **marine** data to develop **indicators** for marine mortality during **early marine** phase.

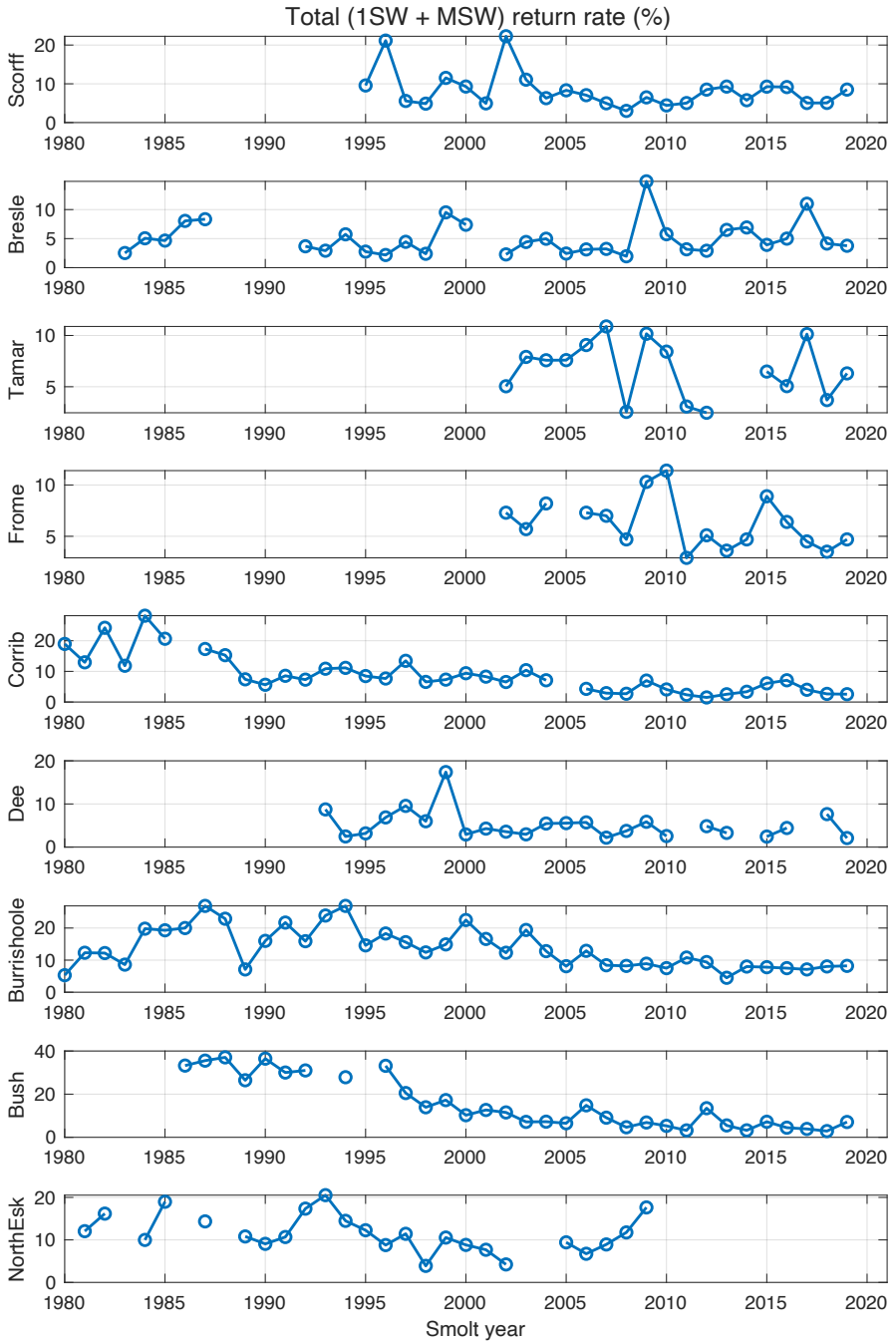
First part: **prey availability**.



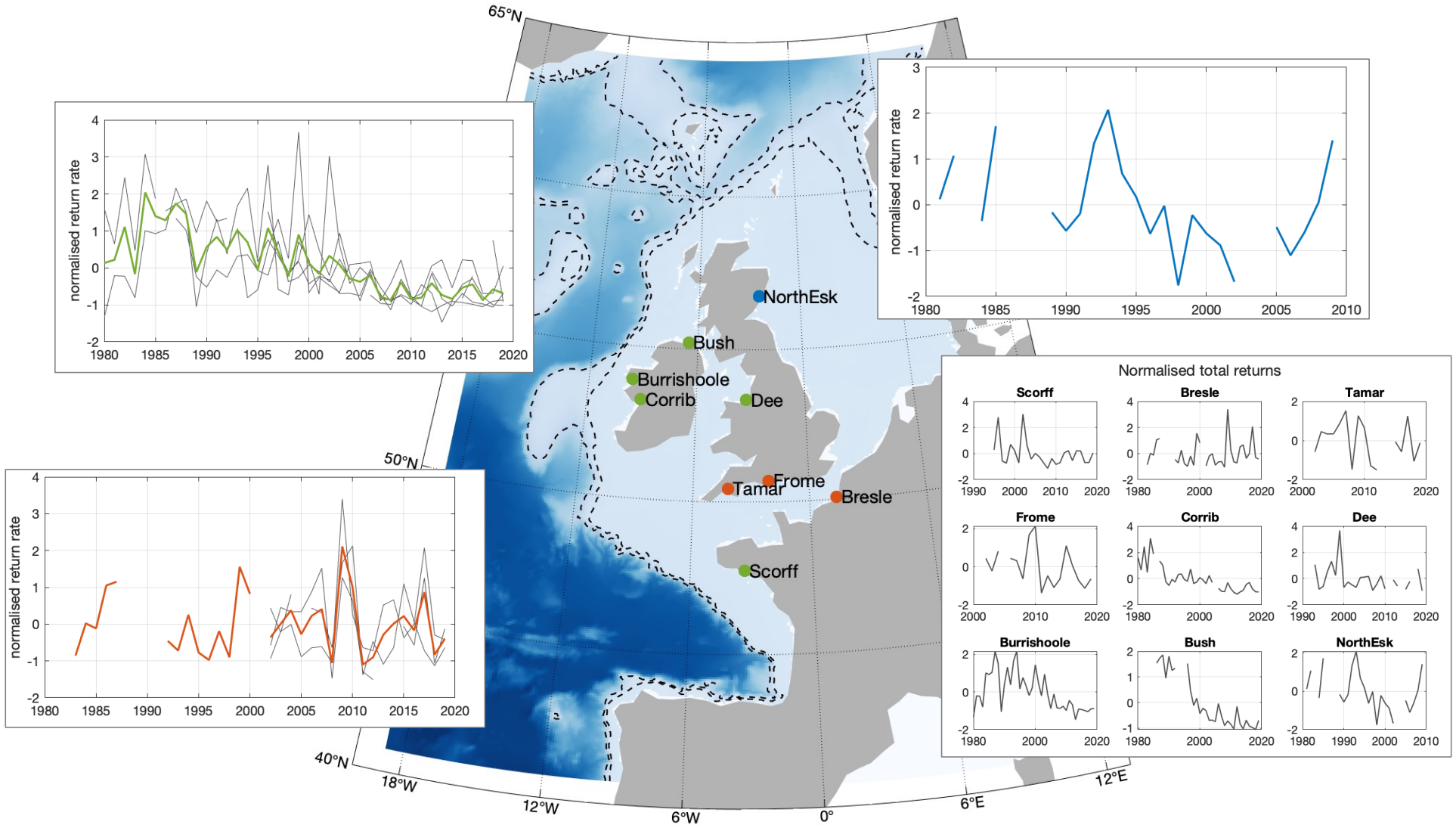
Bull *et al.*, 2022

Case study rivers

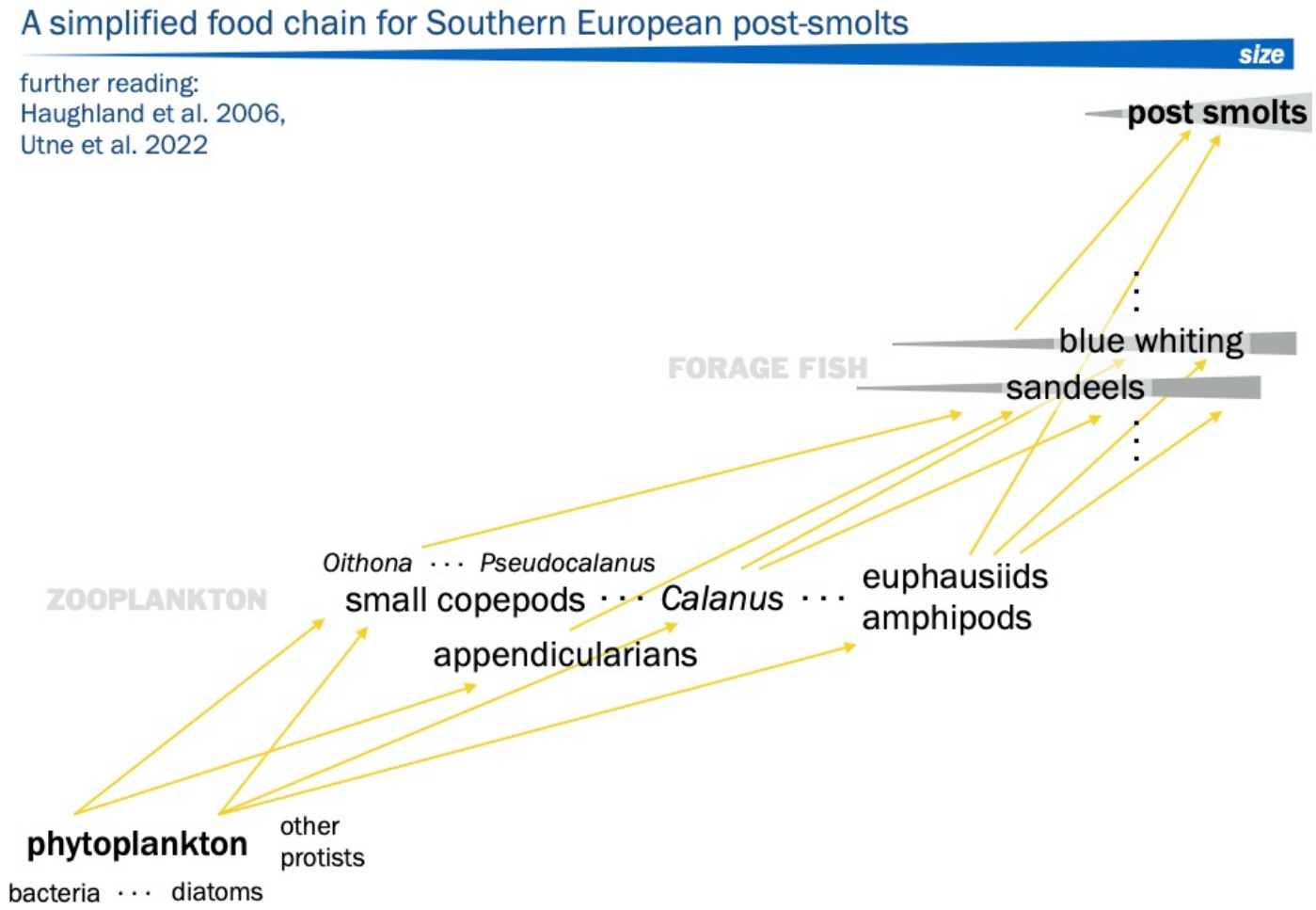




The rivers show synchrony in their returns



A post-smolt’s view of the marine environment: resolving the food web



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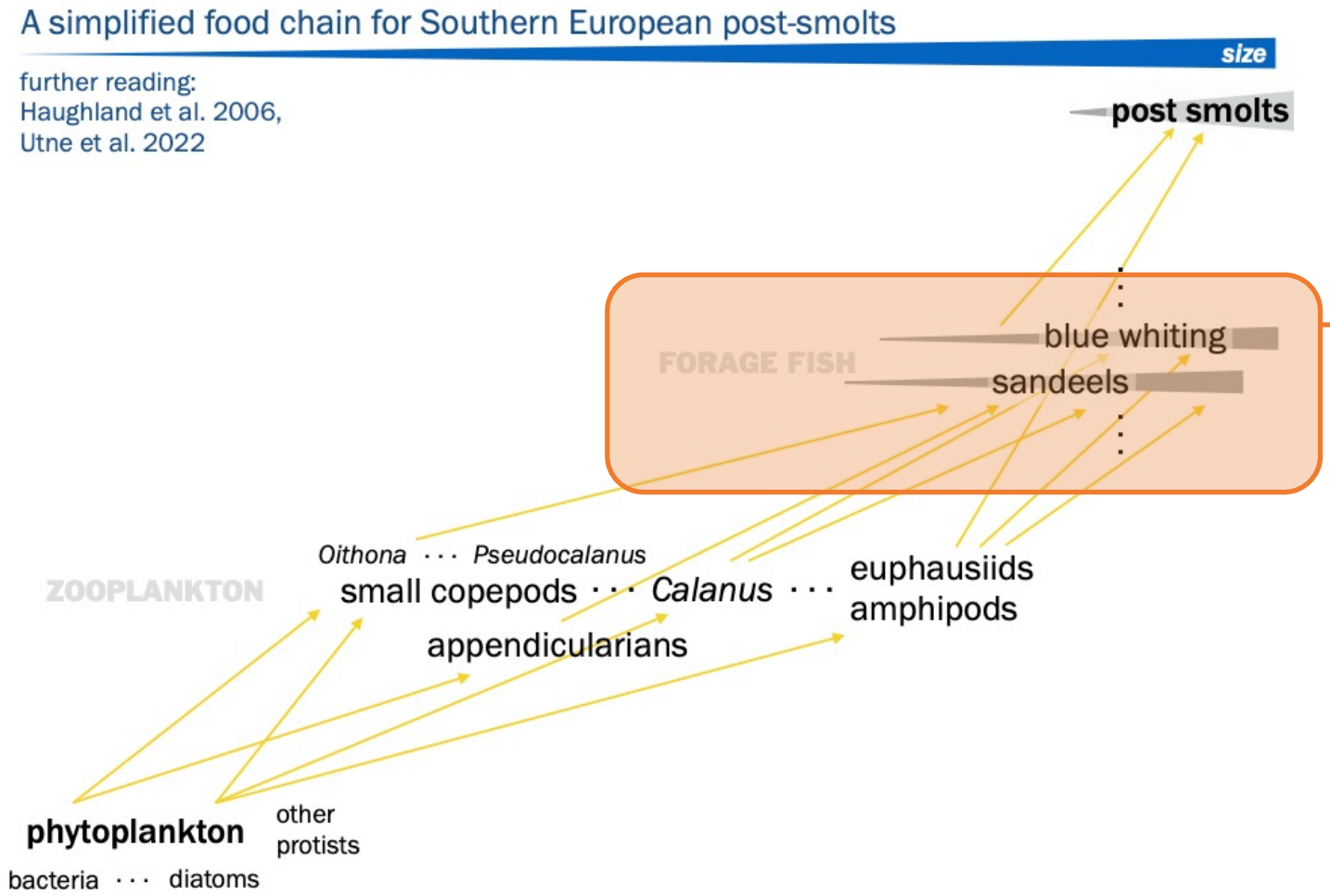
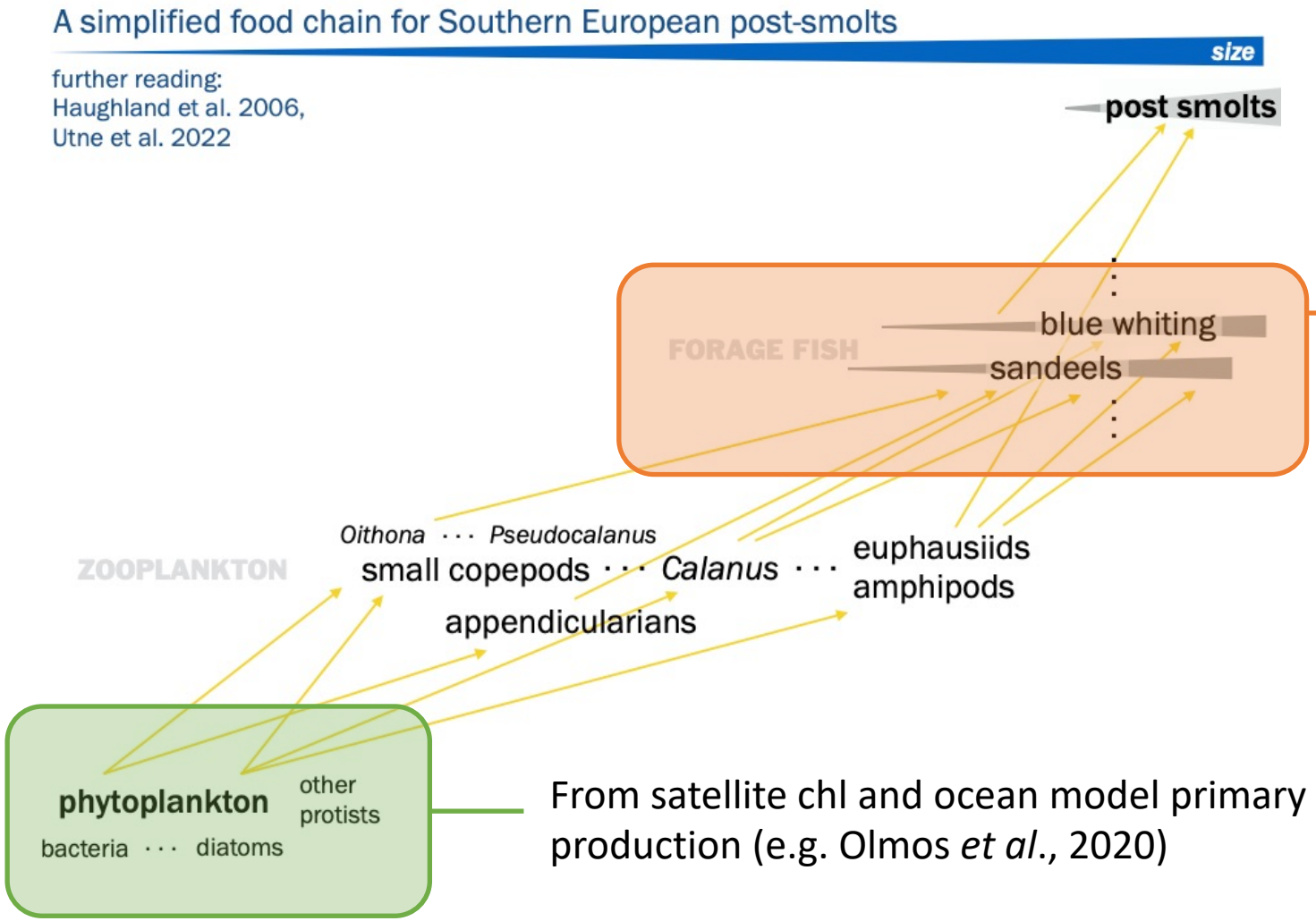


Little data. Assessments give SSB and R, not larvae eaten by post-smolts.

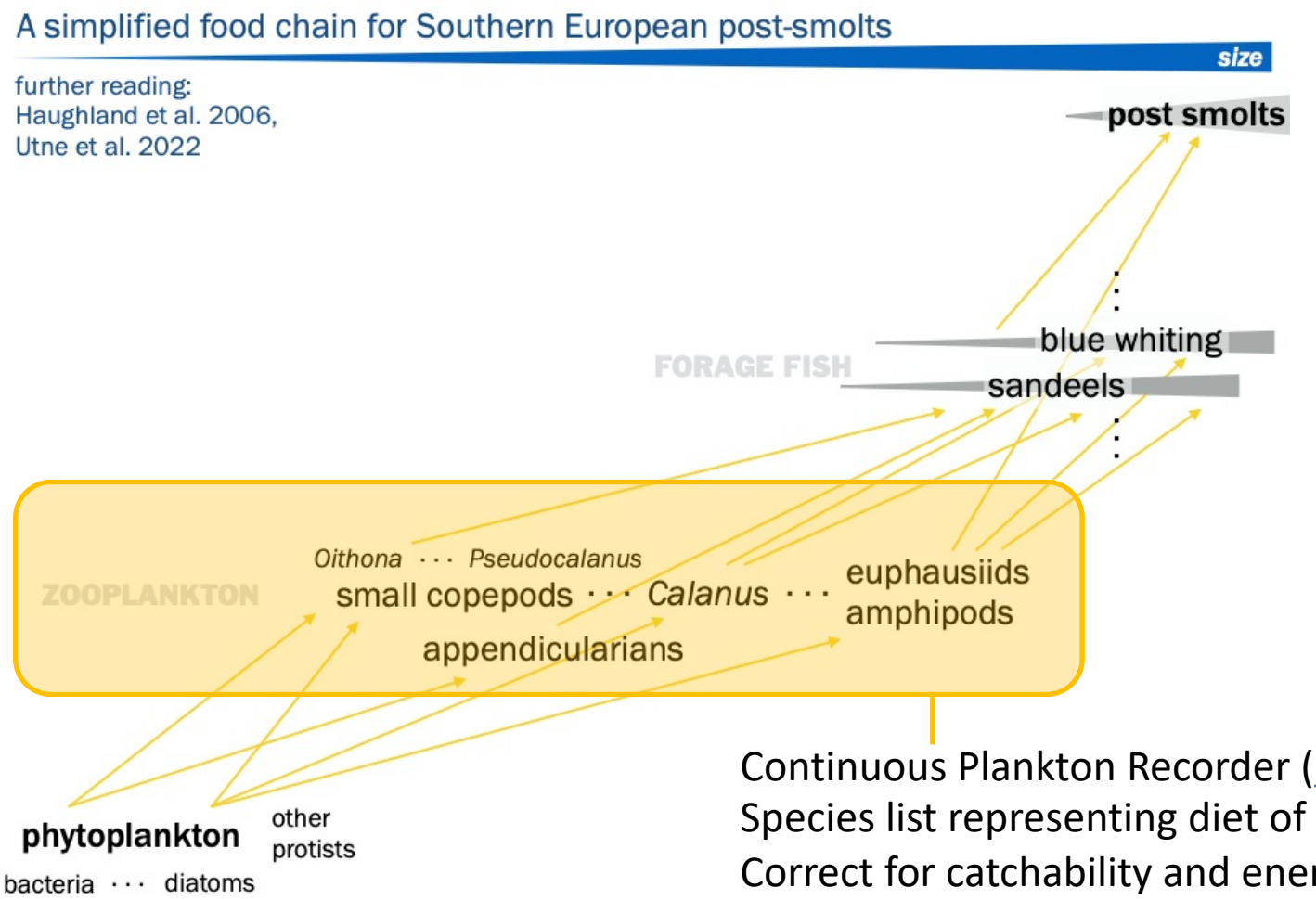
A post-smolt's view of the marine environment: resolving the food web

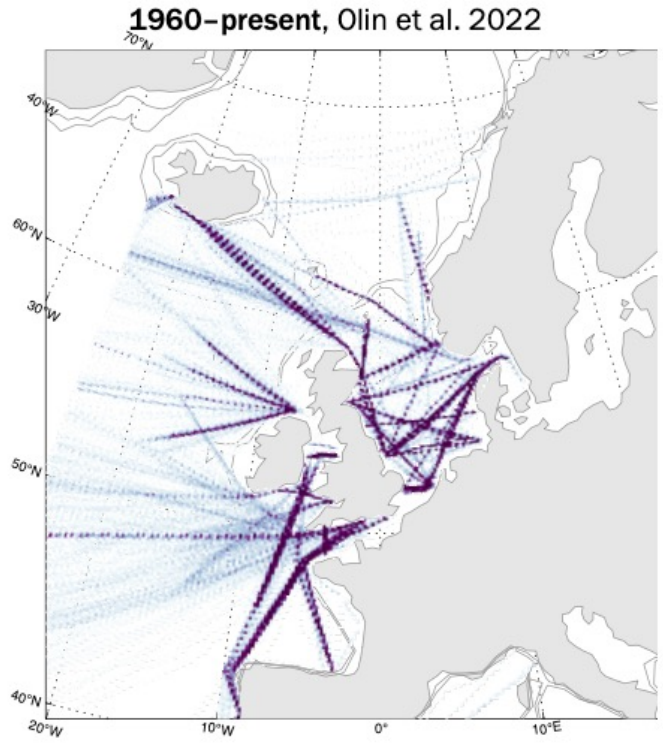


Little data on forage fish prey. Assessments give SSB and R, not larvae eaten by post-smolts.

From satellite chl and ocean model primary production (e.g. Olmos *et al.*, 2020)

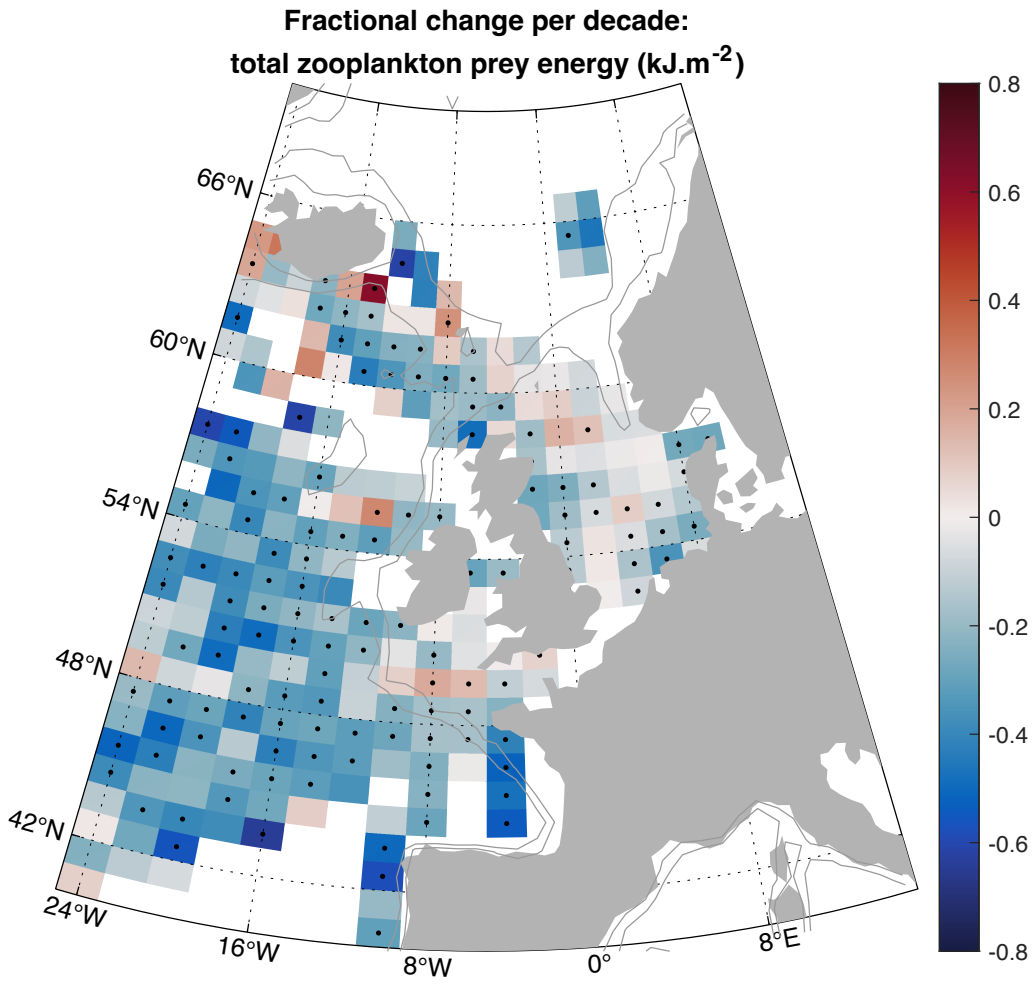
A post-smolt's view of the marine environment: resolving the food web





Continuous Plankton Recorder (https://www.cprsurvey.org):
Species list representing diet of forage fish larvae.
Correct for catchability and energy content (Olin *et al.*, 2022).
=> zooplankton prey energy.

Zooplankton prey energy has declined over large parts of the NE Atlantic



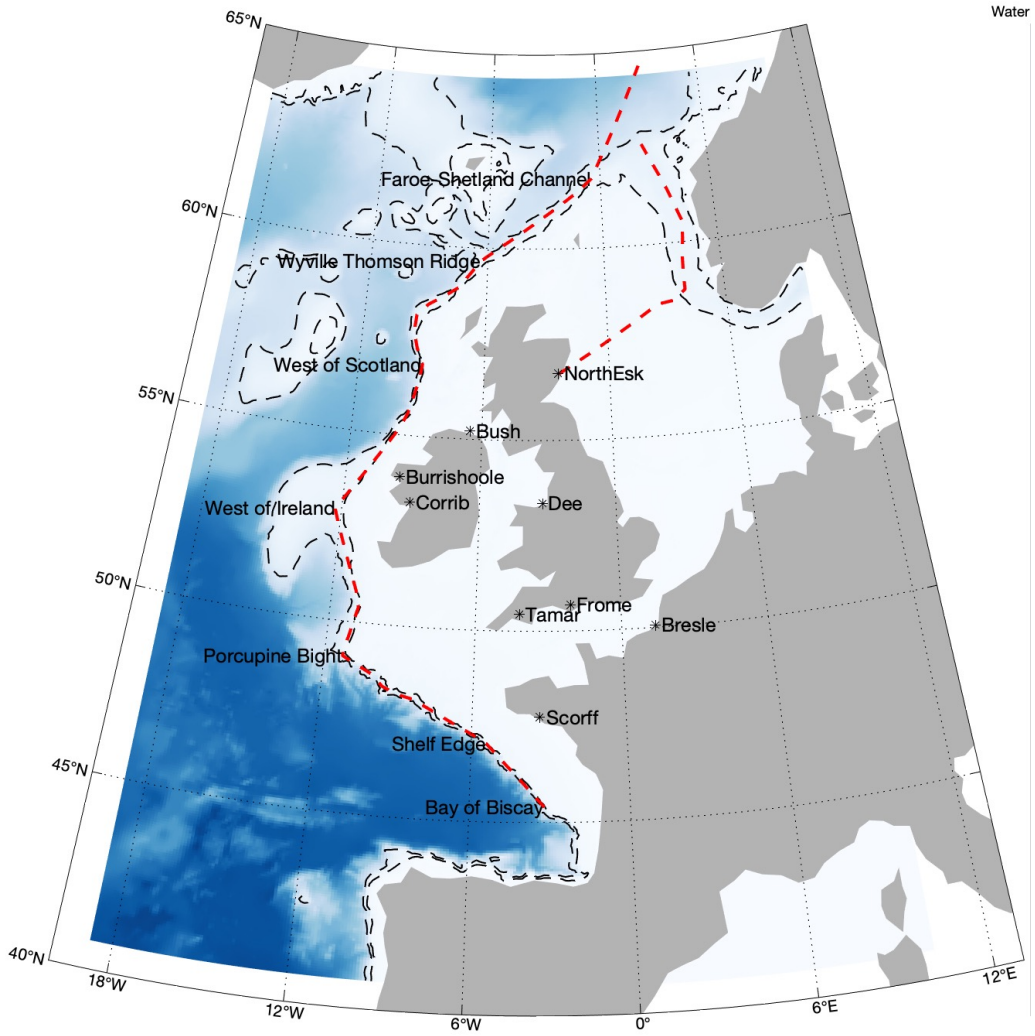
Larger spatial context of change.

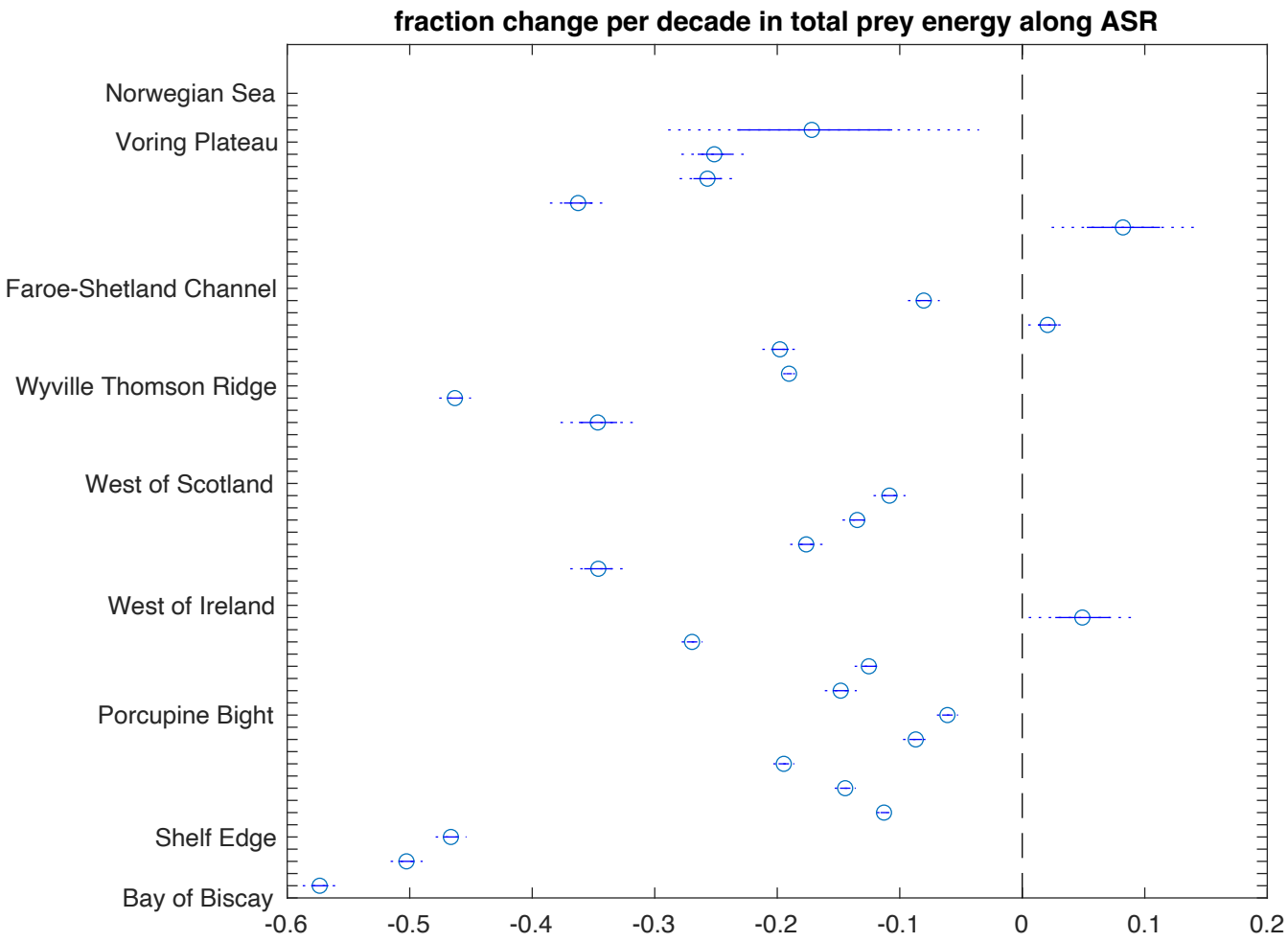
Note: Trend only calculated where there are 40+ years of CPR data including pre-1980 and post-2000.

Trend is *m*, where $\log_{10}(\text{energy}+1) \sim \boldsymbol{m} * \text{year} + c$

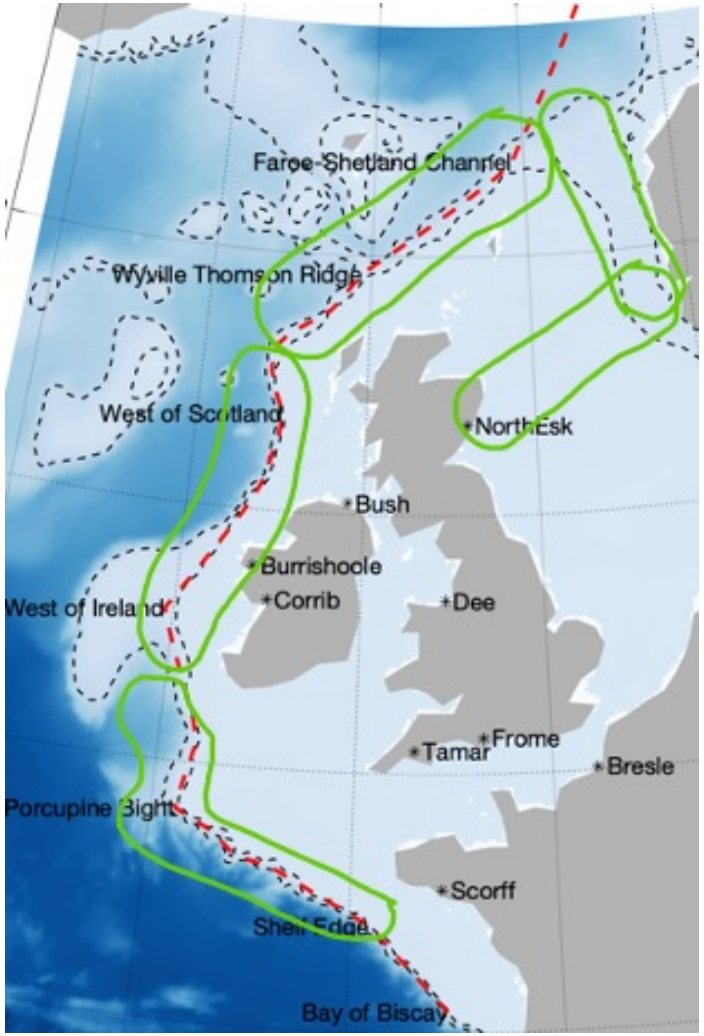
· indicates $p<0.05$

Zooplankton energy has declined in salmon post-smolt migration space-time domains

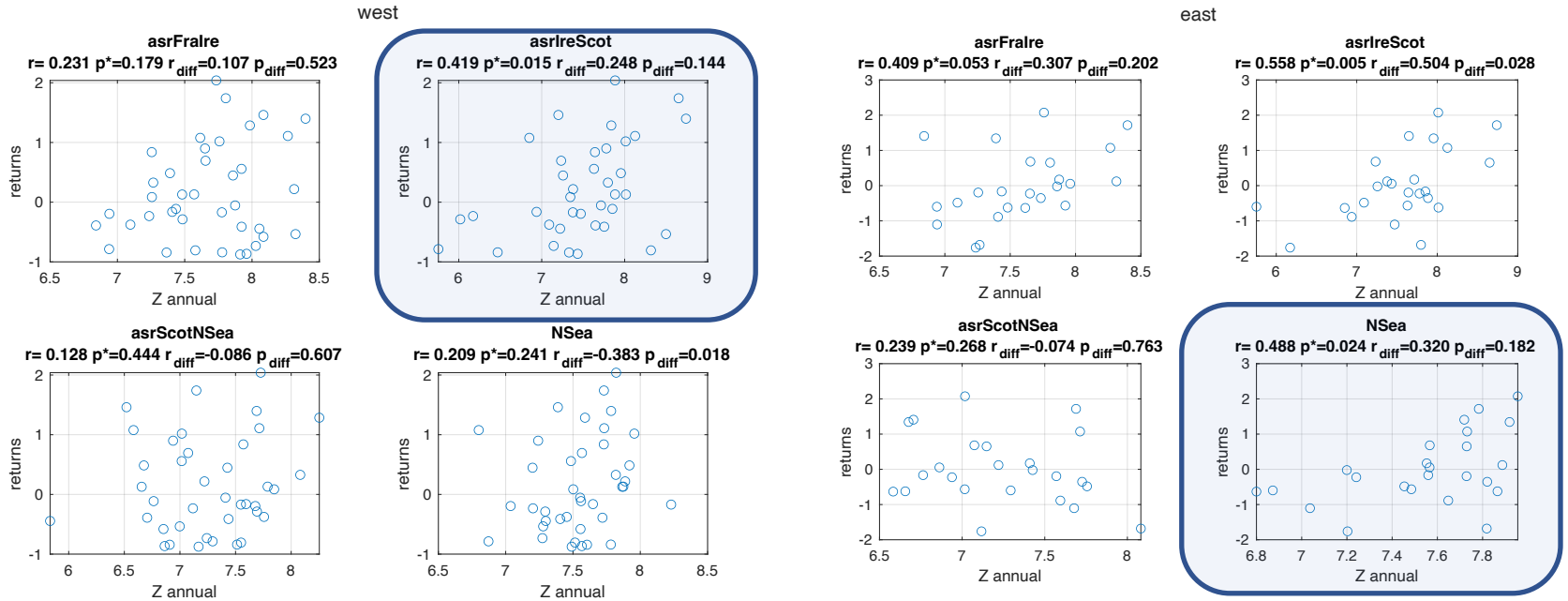




Zooplankton prey energy *during migration* is correlated with salmon returns

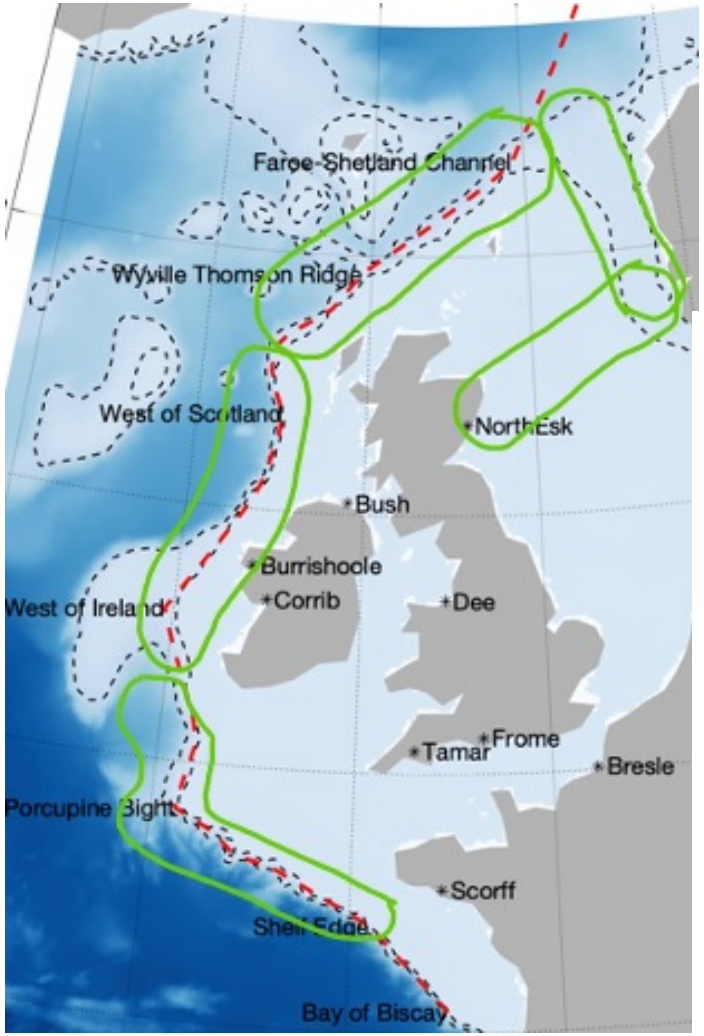


- **West cluster** returns strongly correlated with Z energy **west of UK and Ireland**.
- **East cluster** returns strongly correlated with Z energy along **North Sea route**.



- South cluster returns not correlated with Z energy in any part of the migration route.

Zooplankton prey energy *during migration* is correlated with salmon returns



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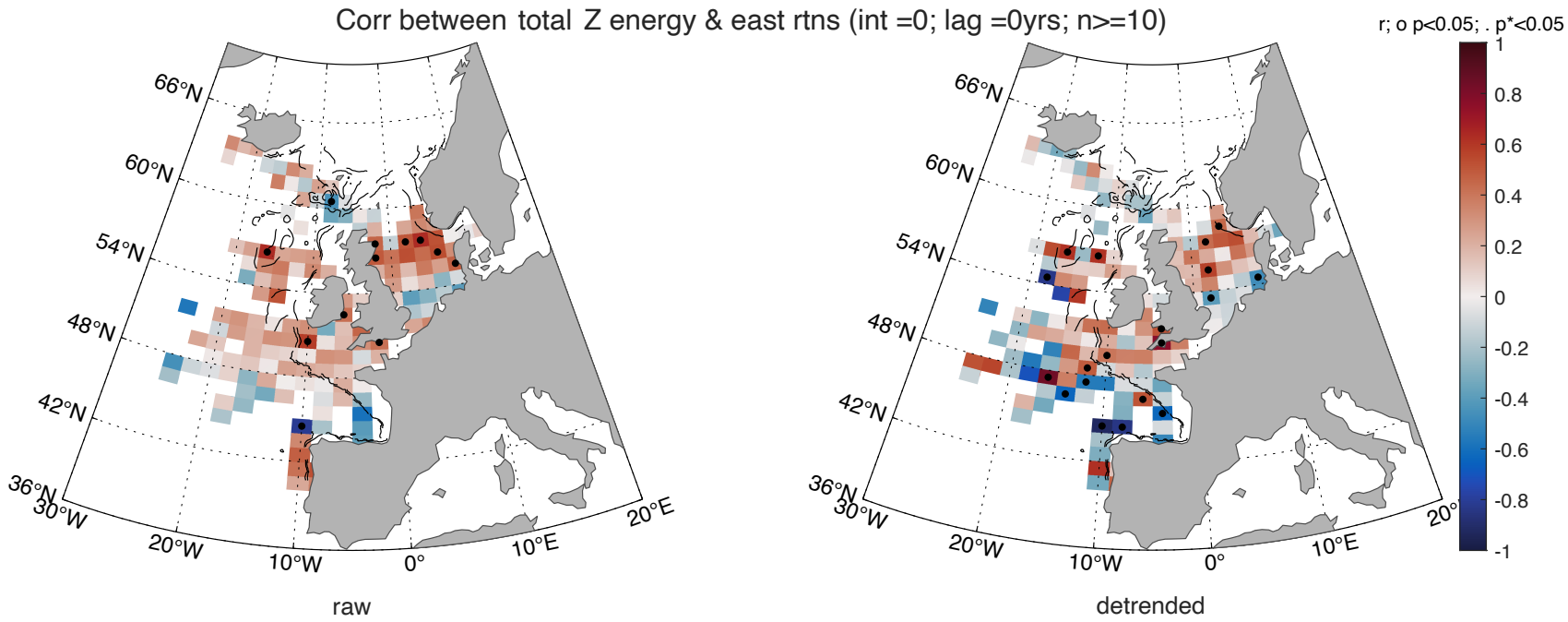
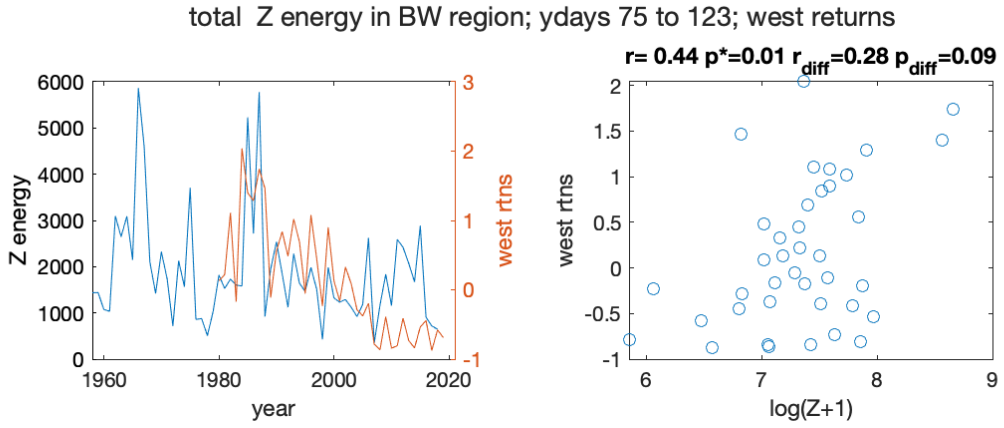
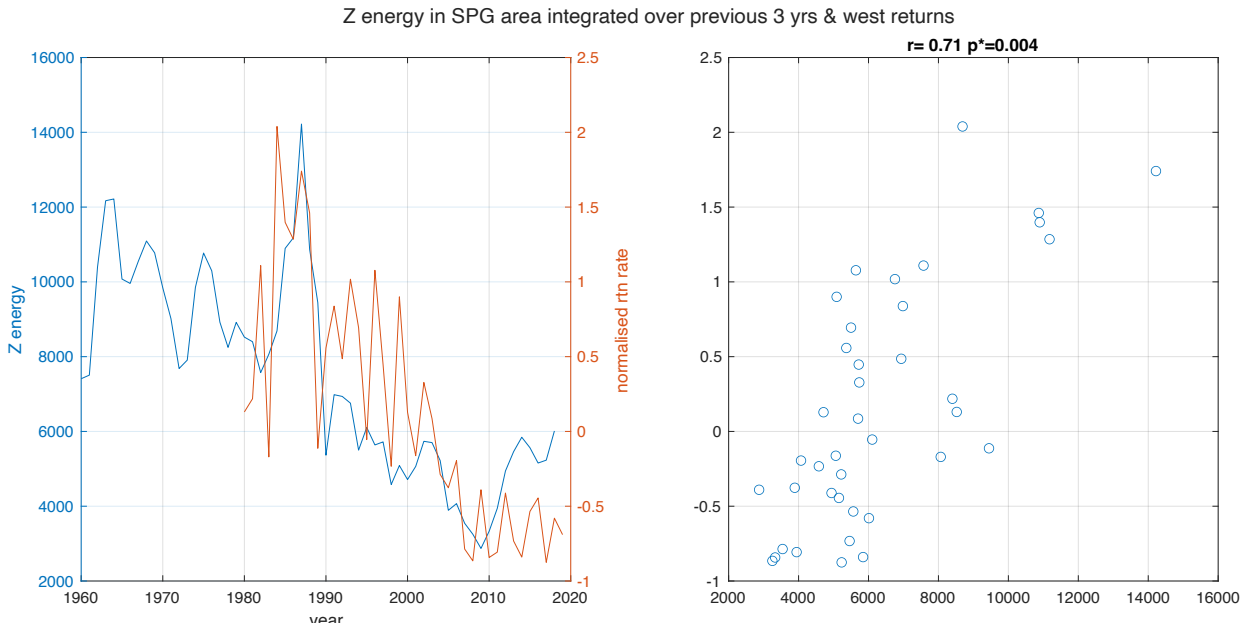


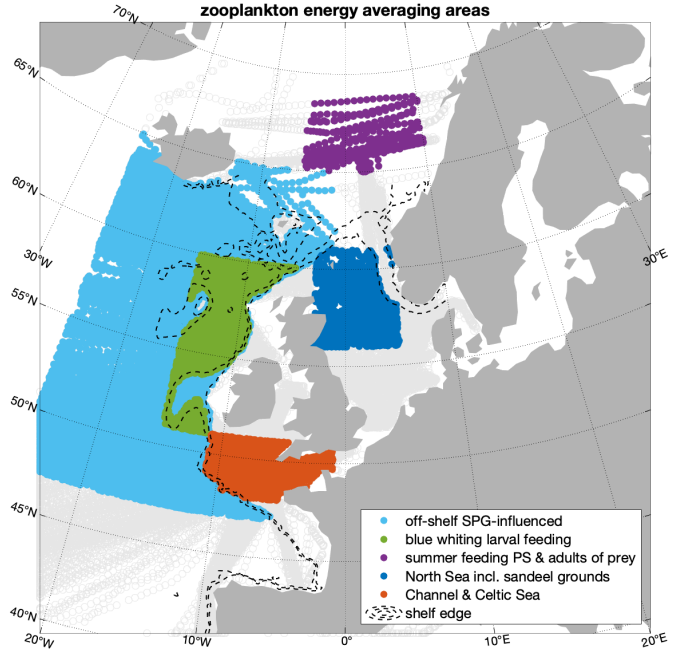
Ecosystem-integrated zooplankton prey energy is correlated with salmon returns



West returns significantly correlated with Z energy:

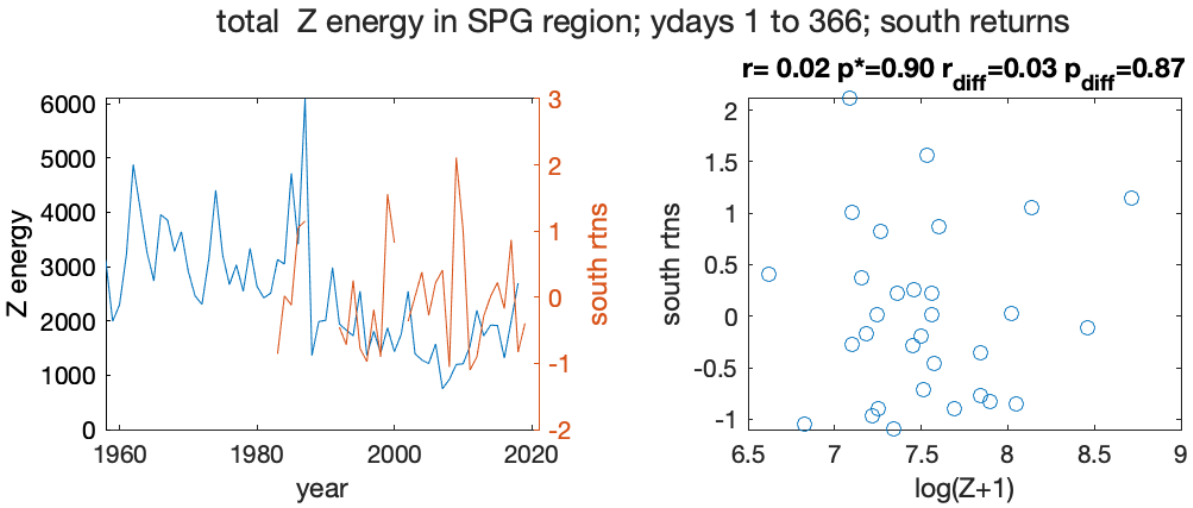
- in blue whiting spawning region during migration
- in wider offshore sub-polar gyre influenced region integrated over several years.



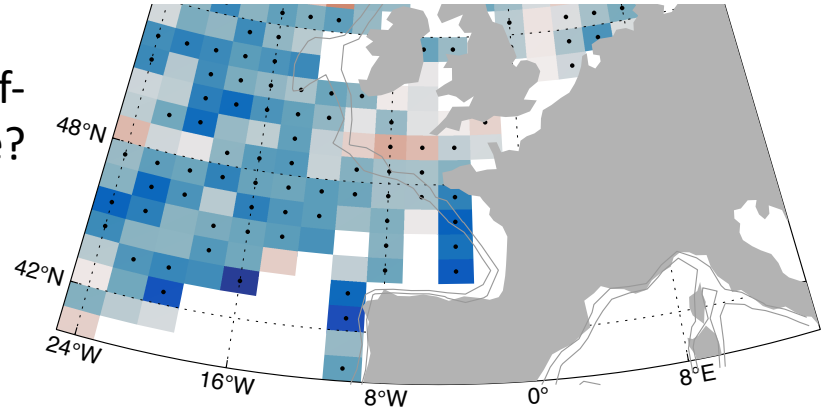


And some negative results…

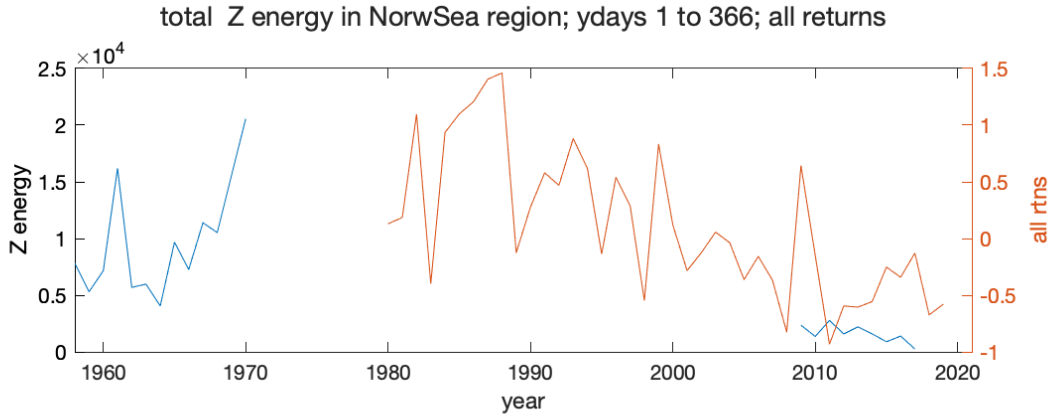
South returns not significantly correlated with any version of Z energy. Why not?



On-shelf vs. off-shelf influence?



Low time series overlap in **Norwegian Sea**. Shared feeding area. Critical data gap!



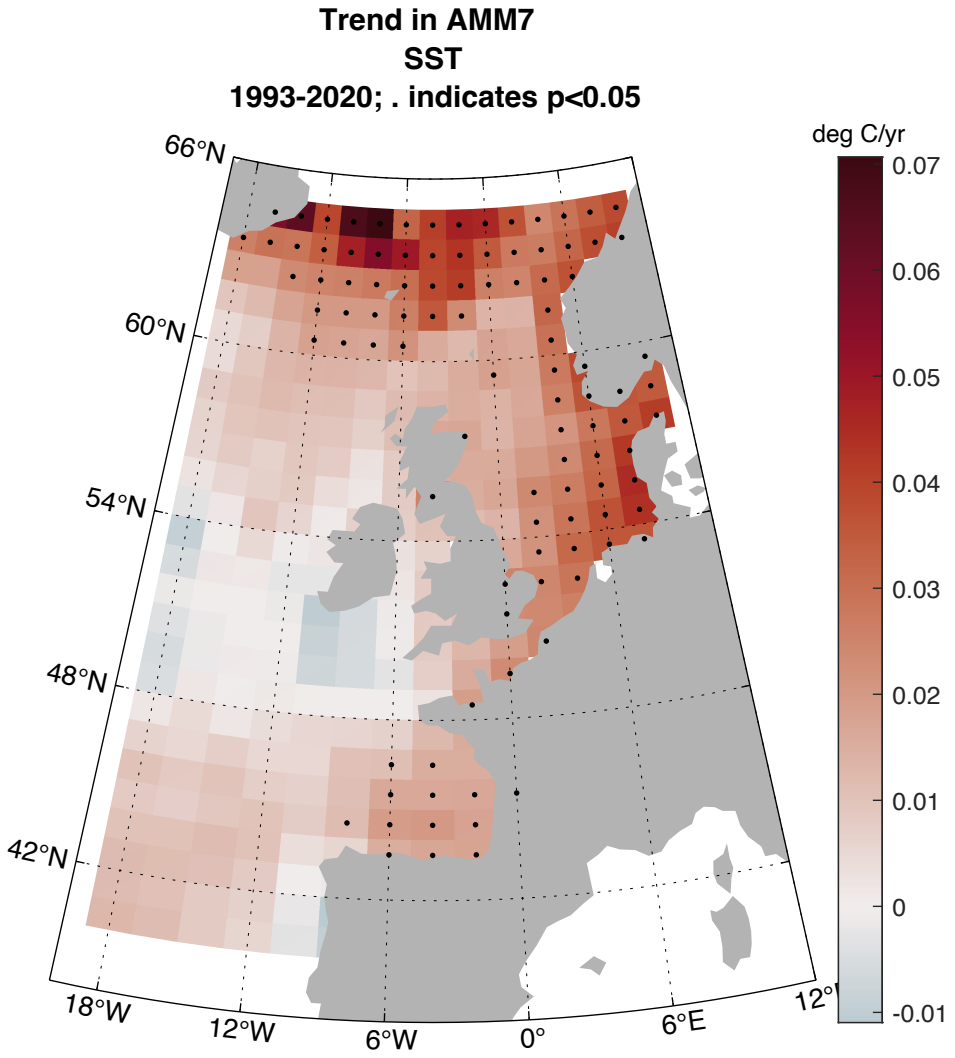
The challenge - what explains variability and trends in zooplankton energy?

For example:

- SST has increased
- (but not along most of migration route)

Use of ocean model hindcast AMM7 NEMO-ERSEM:

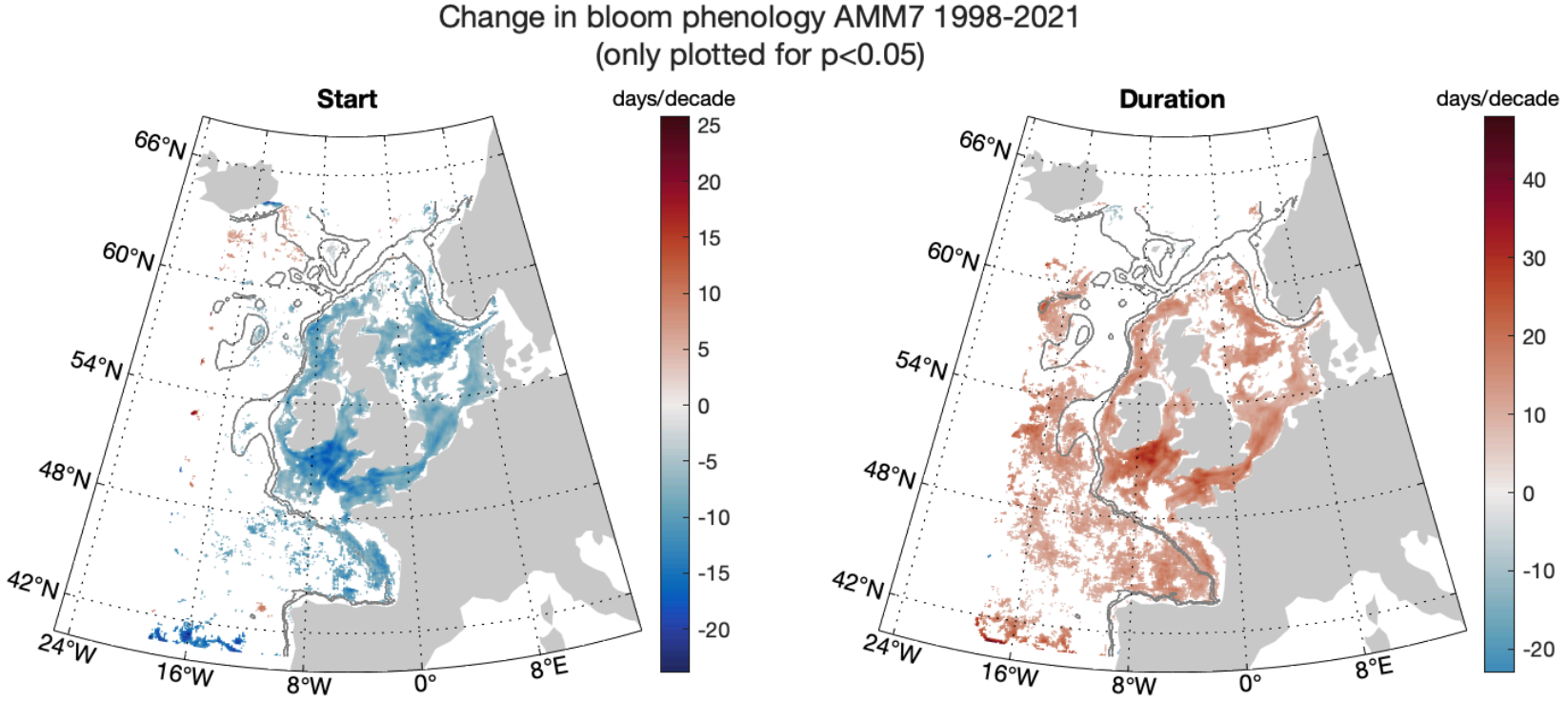
- Physical - biogeochemical
- ~7 km resolution
- Hosted by Copernicus (CMEMS)
- 1993-2021



The challenge - what explains variability and trends in zooplankton energy?

For example:

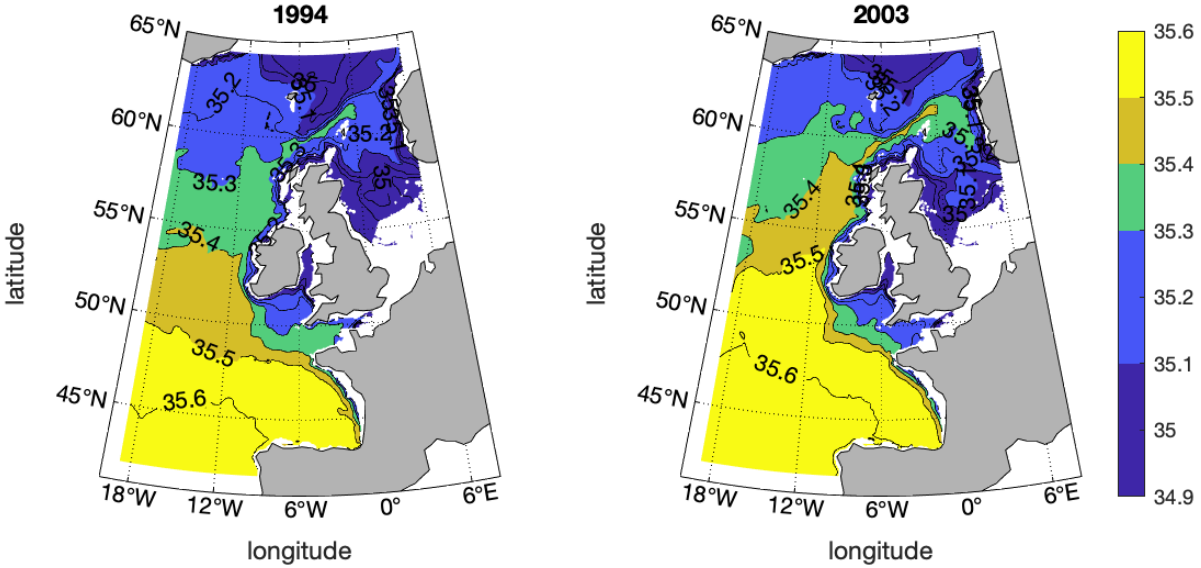
- The spring phytoplankton bloom has got earlier and longer
- Summer chl has declined and phytoplankton community size composition may be shifting (e.g. Schmidt *et al*., 2020)

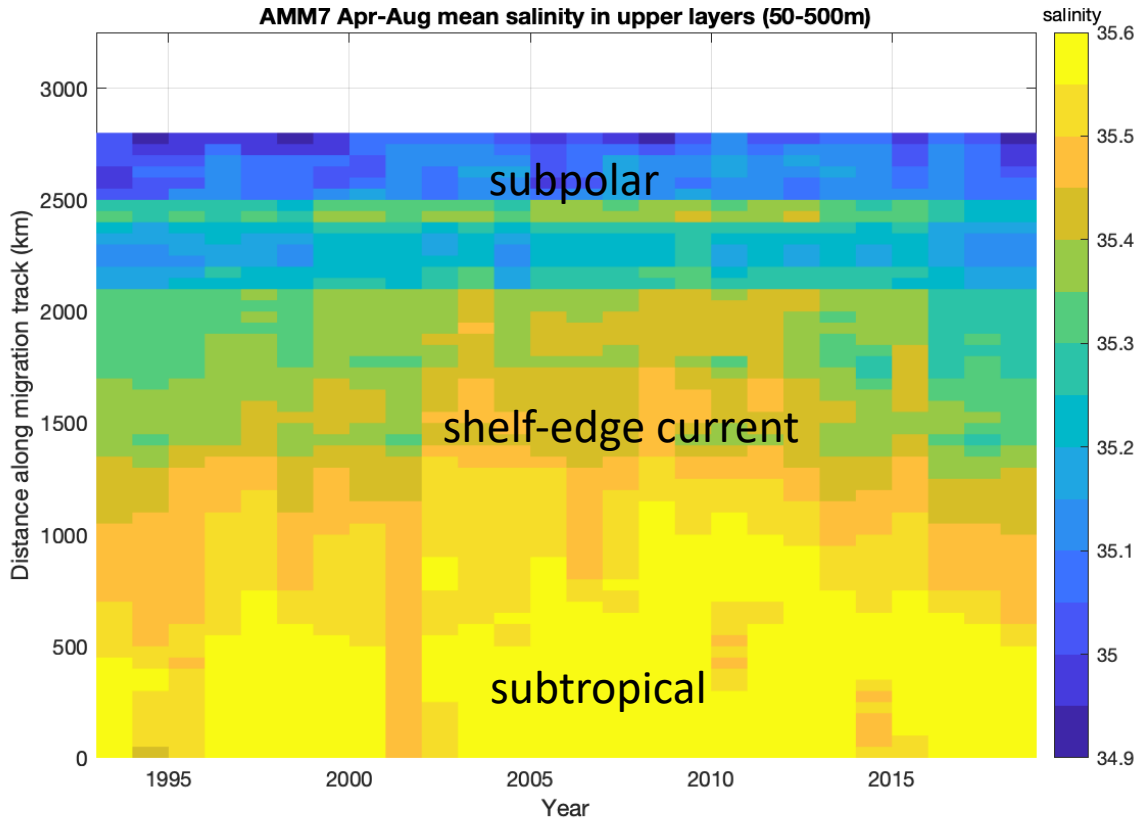


The challenge - what explains variability and trends in zooplankton energy?

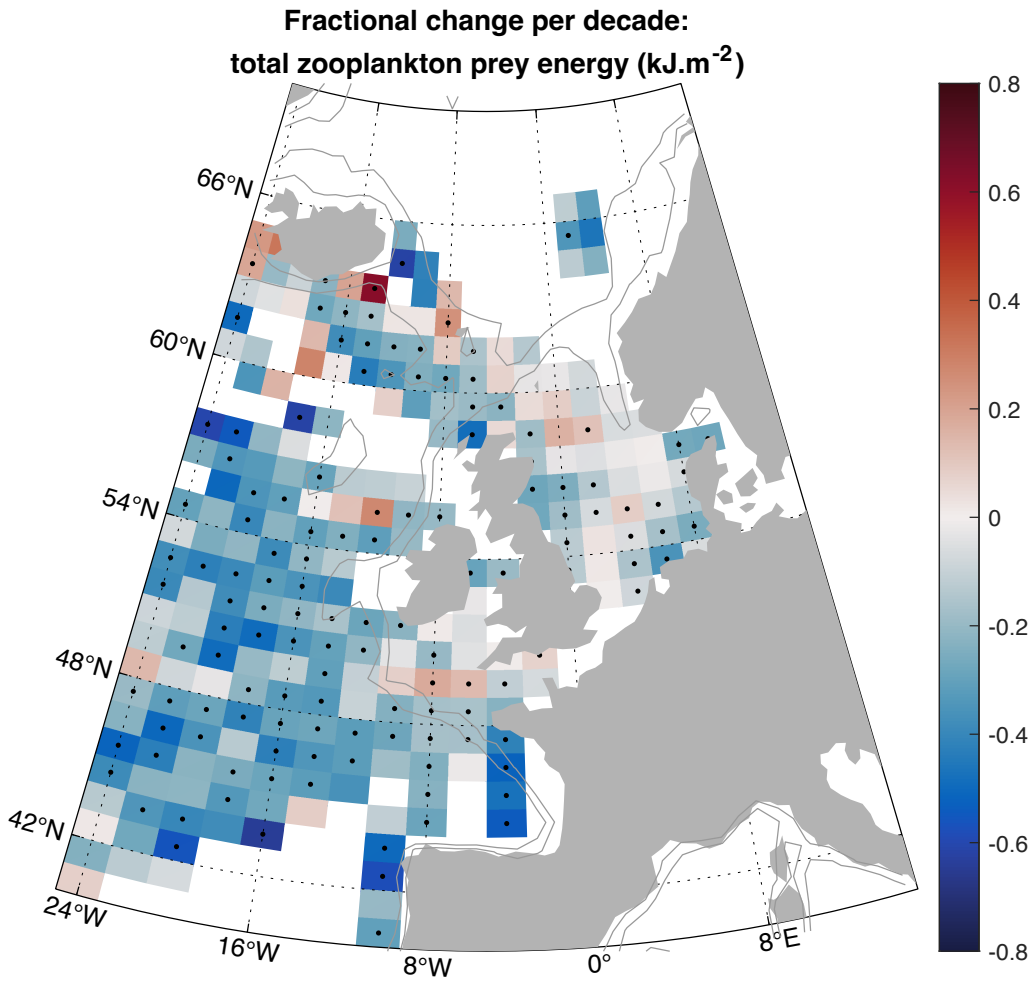
For example:

- Shifting influences of water masses and associated zooplankton assemblages





Conclusion: zooplankton prey energy could be a powerful indicator of changes in salmon returns



Making predictions:

Can we develop a practical forecasting ability on year-to-year timescale and under climate-scenario projections?

Thank you for listening!

The Likely Suspects Framework is a **Missing Salmon Alliance** project (https://missingsalmonalliance.org).

Thank you to these organisations for smolt run timing and returns data:

Agri-Food and Biosciences Institute; Irish Marine Institute; Inland Fisheries Ireland; Environment Agency; Marine Scotland Science; Cefas; Natural Resources Wales; Game and Wildlife Trust; National Research Institute for Agriculture; Food and Environment France.

Thank you to David Johns for CPR data.

References:
Bull *et al*. (2022). The likely suspects framework: the need for a life cycle approach for managing Atlantic salmon (Salmo salar) stocks across multiple scales. ICES Journal of Marine Science 79(5):1445–1456
Olmos *et al*. (2019). Spatial synchrony in the response of a long range migratory species (*Salmo salar*) to climate change in the North Atlantic Ocean. Global Change Biology 26:1319-1337
Olin *et al*. (2022). Spatio-temporal variation in food conditions for lesser sandeels: species and community trait patterns from the Continuous Plankton Recorder in the north-east Atlantic. ICES Journal of Marine Science, 79(5):1649–1661

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