Detection and assessment of community changes in a trans-North Atlantic comparison of zooplankton time series

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ICES Working Group on Zooplankton Ecology (WGZE)

The ICES Working Group on Zooplankton Ecology monitors zooplankton sampling activities in the North Atlantic region and reviews new zooplankton sampling and analysis technologies.

Participants:

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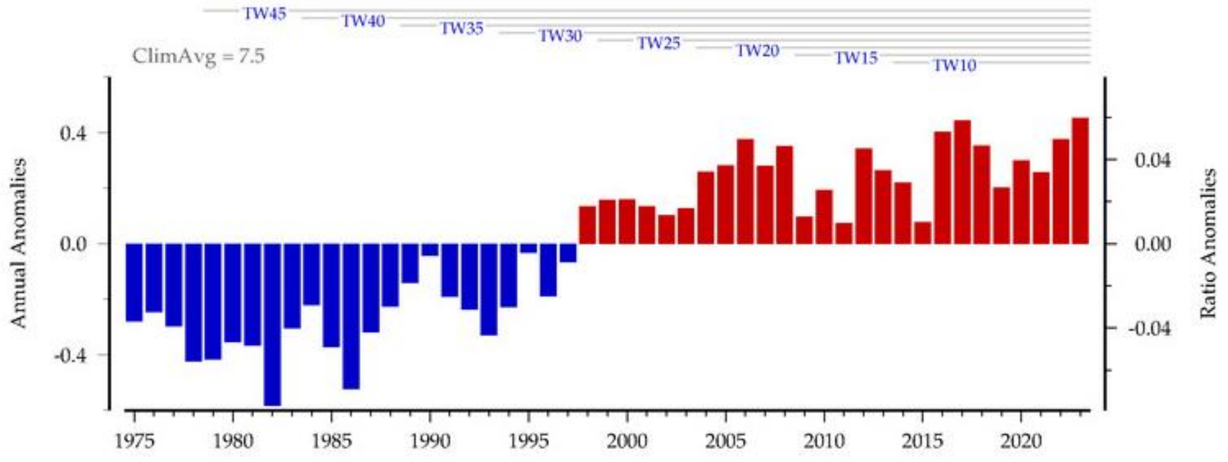
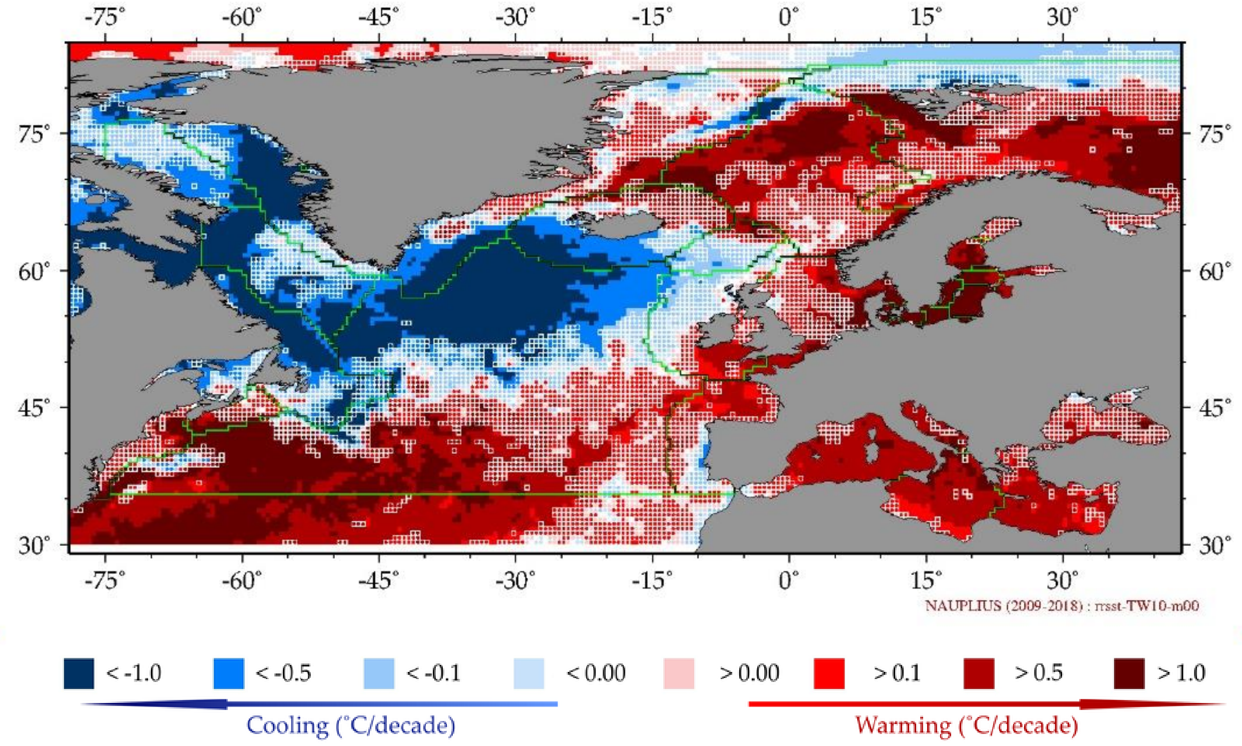
7th International Zooplankton Production Symposium, 20 March 2024

Climate change is driving changes in ocean conditions

1975-2023 North Atlantic
Sea Surface Temperature Anomalies



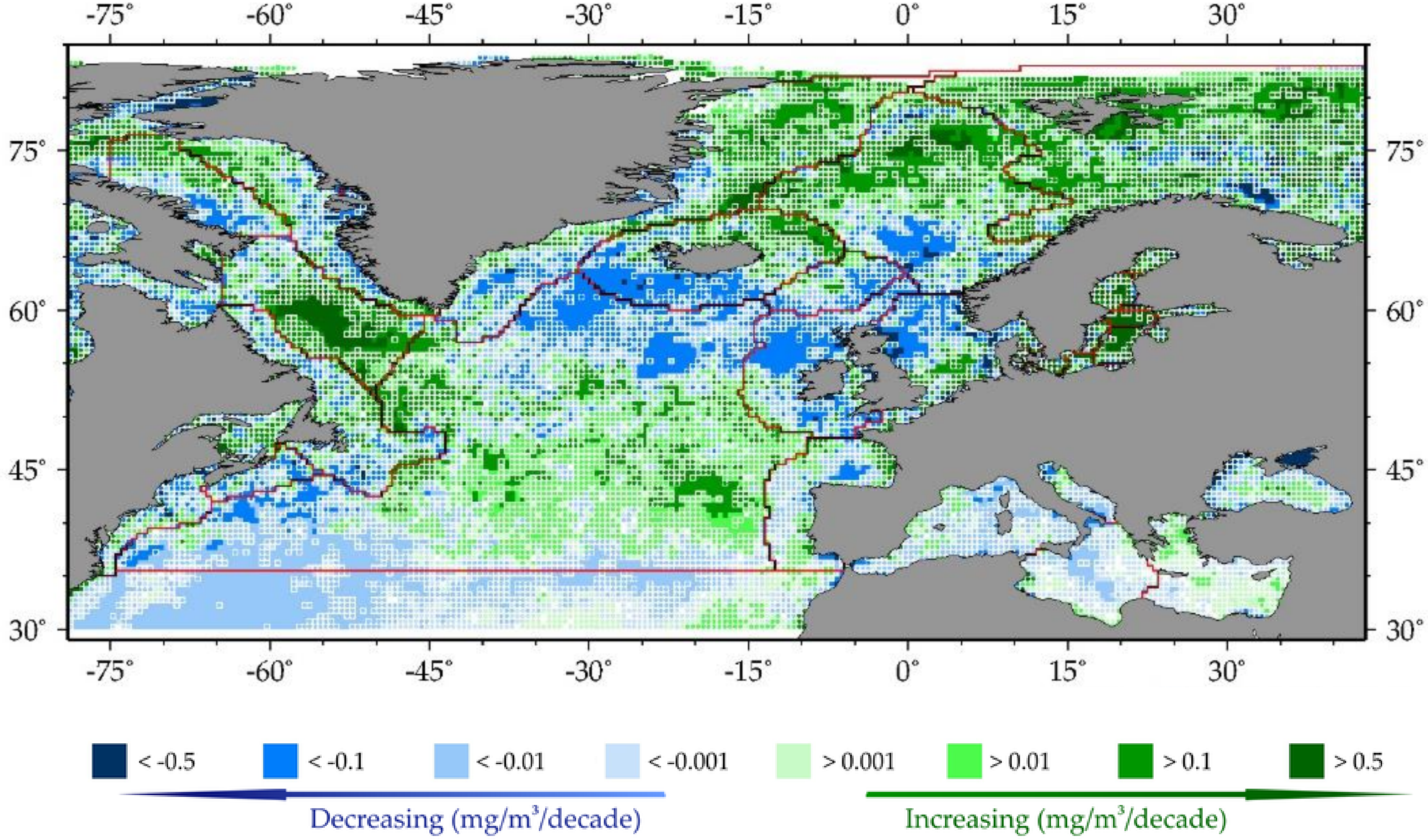
North Atlantic Sea Surface Temperature
10-year trends, 2010-2019



Data from Hadley Centre Sea Ice and Sea Surface Temperature data set (HadISST)

Climate change is driving changes in ocean conditions

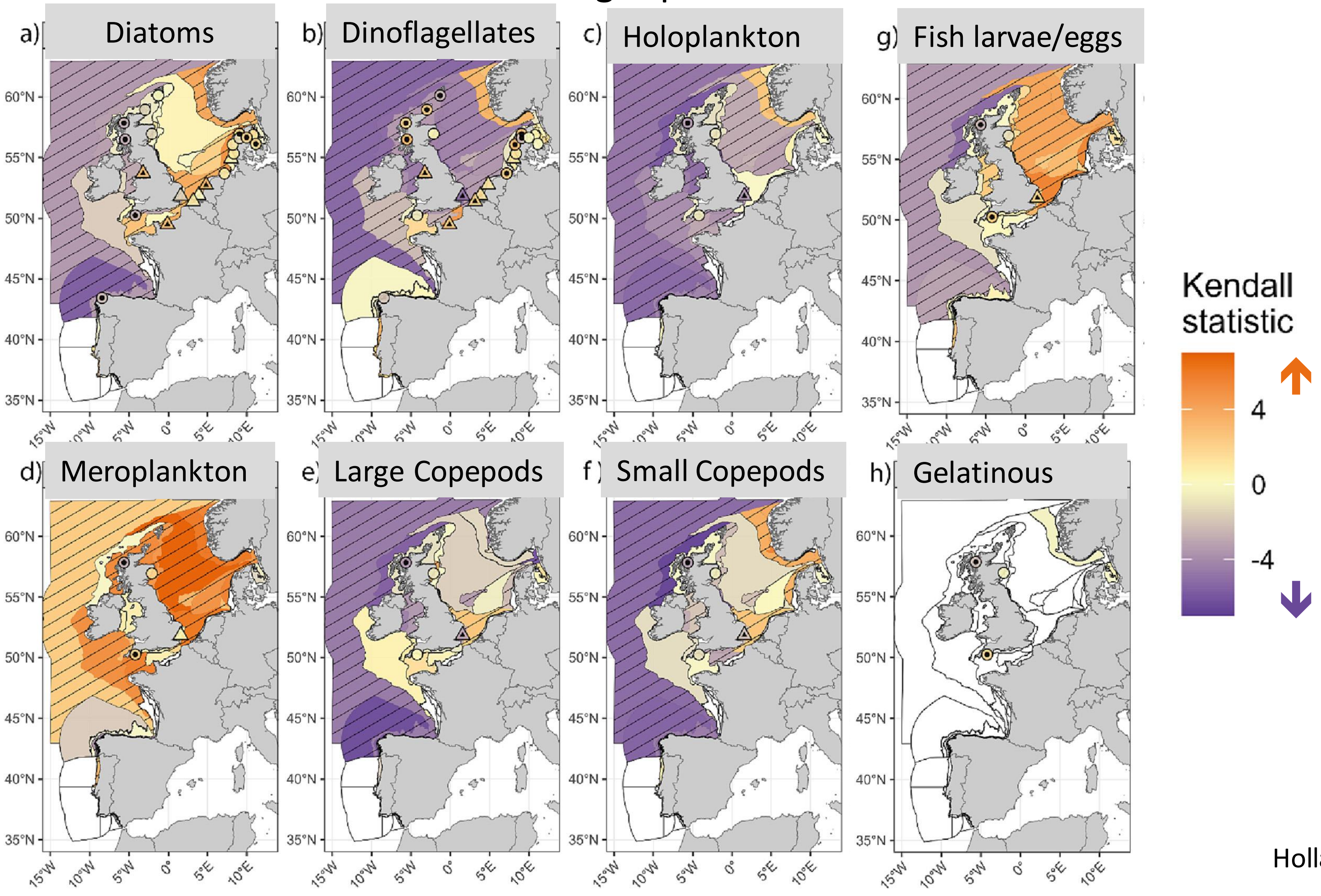
North Atlantic Sea Surface Chlorophyll
10-year trends, 2010-2019



Satellite Chlorophyll

Zooplankton are sensitive to ocean conditions

Kendall trend test for eight plankton life forms



Increasing

- Meroplankton
- North Sea Fish larvae/eggs
- North Sea coastal diatoms

Decreasing

- Holoplankton
- Dinoflagellates
- NE Atlantic copepods

Holland et al (2023) Sci Total Environ 898: 165505

Environmental drivers and zooplankton responses

Environment

- Increasing temperature
- Increasing stratification
- Changing nutrient dynamics
- Changing phytoplankton dynamics and community
- Changes in circulation
- Extreme events

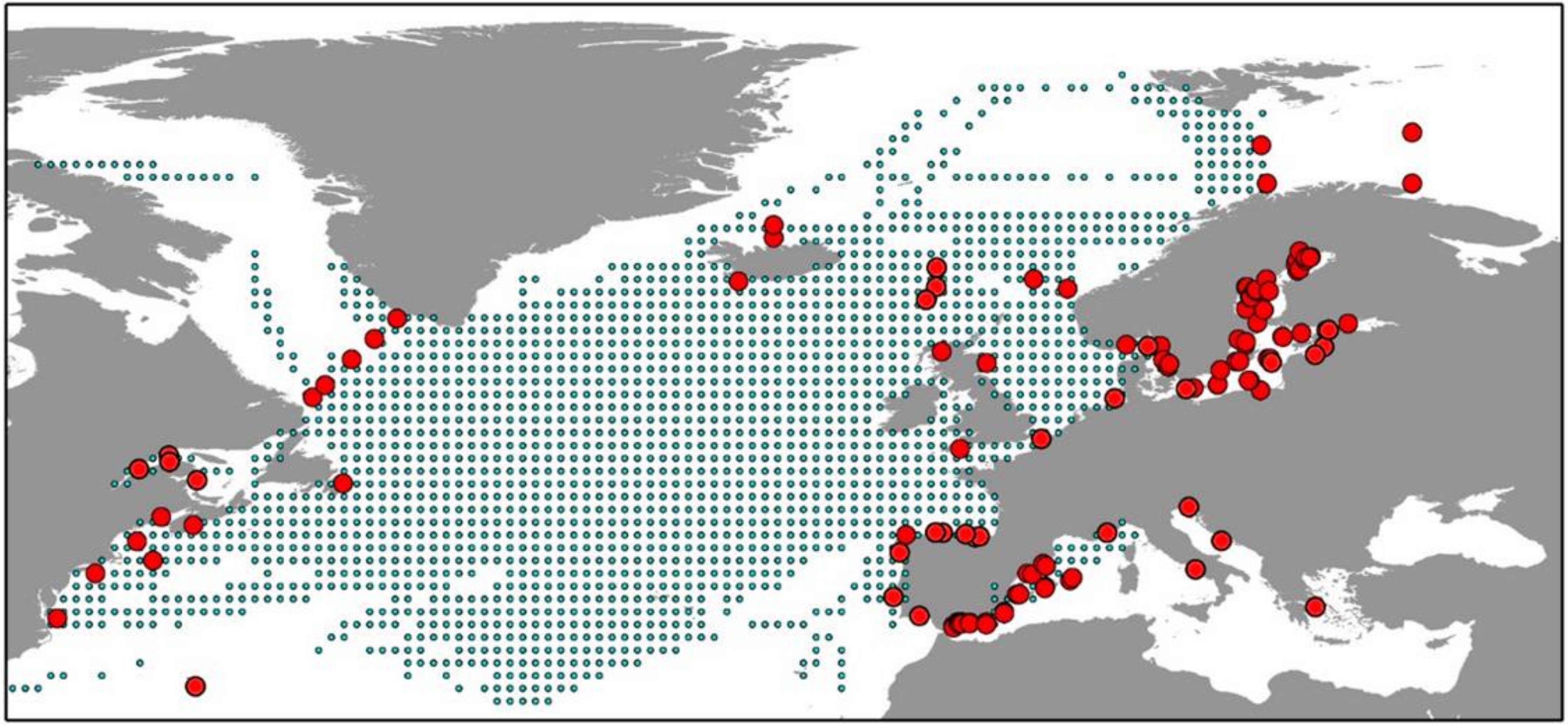
Zooplankton

Changes in
- Abundance
- Biomass
- Phenology
- Spatial distribution
- Community composition
- Community size structure
- Ecological interactions

Overarching question

What are the broad-scale patterns of zooplankton population and community change from regional to basin scale in the North Atlantic?

ICES Working Group on Zooplankton Ecology Time Series



- Continuous Plankton Recorder (CPR) range, 1° Lat. x 1° Lon. Grid
- Fixed site time series and gridded survey sites

Major Challenges - Sampling

Methodological differences across observing programs hinder comparison!

Year Start: 1974 – 1999

Frequency: 1x/yr; 4x/yr; 5x/yr; 12x/yr; 24x/yr; 52x/yr

Design: single station, sections, stratified random

Habitat: Nearshore to oceanic

Gear: WP2, CPR, 0.56 and 0.75 diameter ring net, bongo 0.5 m diameter, Apstein, CalCoFi, Hensen

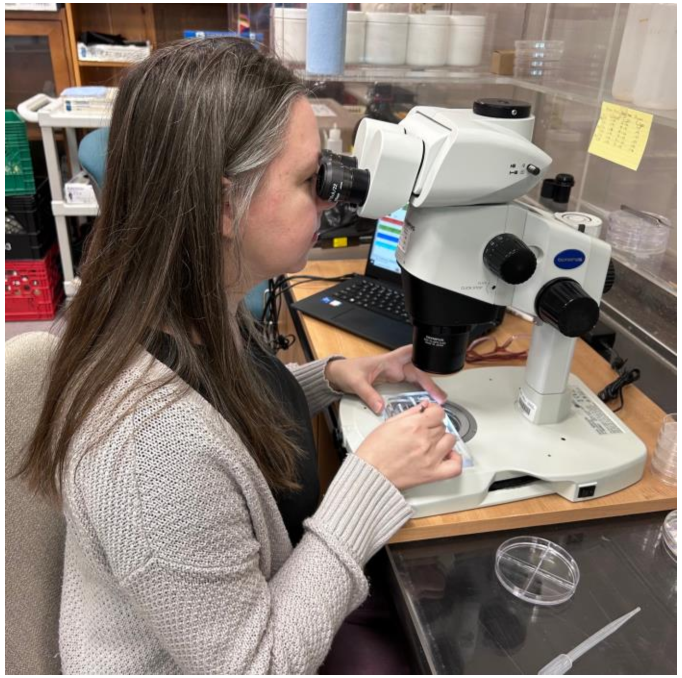
Mesh: 100, 180, 200, 333 µm

Max Sampling Depth: surface layer, 50 m, bottom – 10 m, stratified dependent on halocline, thermocline and anoxic bottom

Gear changes: flow meter, Hensen to WP2, mesh size

Major Challenges – Sample Analysis

Subsampling: Typically, a minimum of 100-200 required



Typical Target Taxonomic Level:

In many cases,

- adult copepods are ID'd to species
- subadults copepods are ID'd to genus
- morphologically similar small copepods may be ID'd only to genus (e.g., *Pseudocalanus*, *Paracalanus*, *Oithona*)
- non-copepods ID'd to higher level

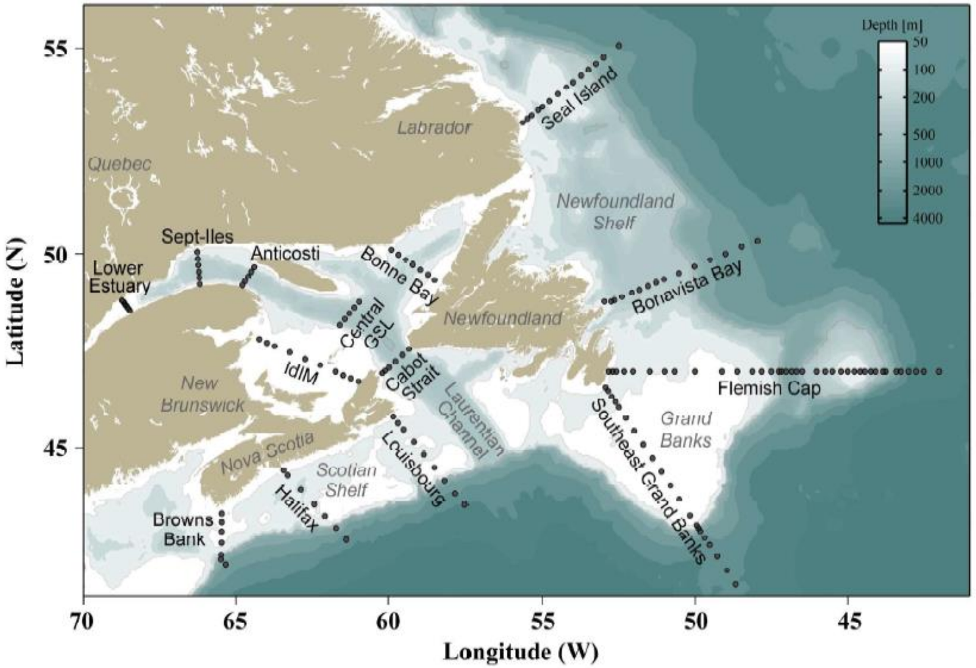
Approach

Comparing disparate datasets – look at relative changes within each time series

- SCOR WG125 “Global Comparisons of Zooplankton Time Series” (circa 2004)
- “*While you may not be able to quantitatively compare time series with different methods/gear, you can compare **relative change** and **direction of change** between these time series*.”
- Relative change comparisons are possible *if* the individual time series methods remained consistent within the individual time series itself.

Rank abundance of northwest Atlantic shelf copepods

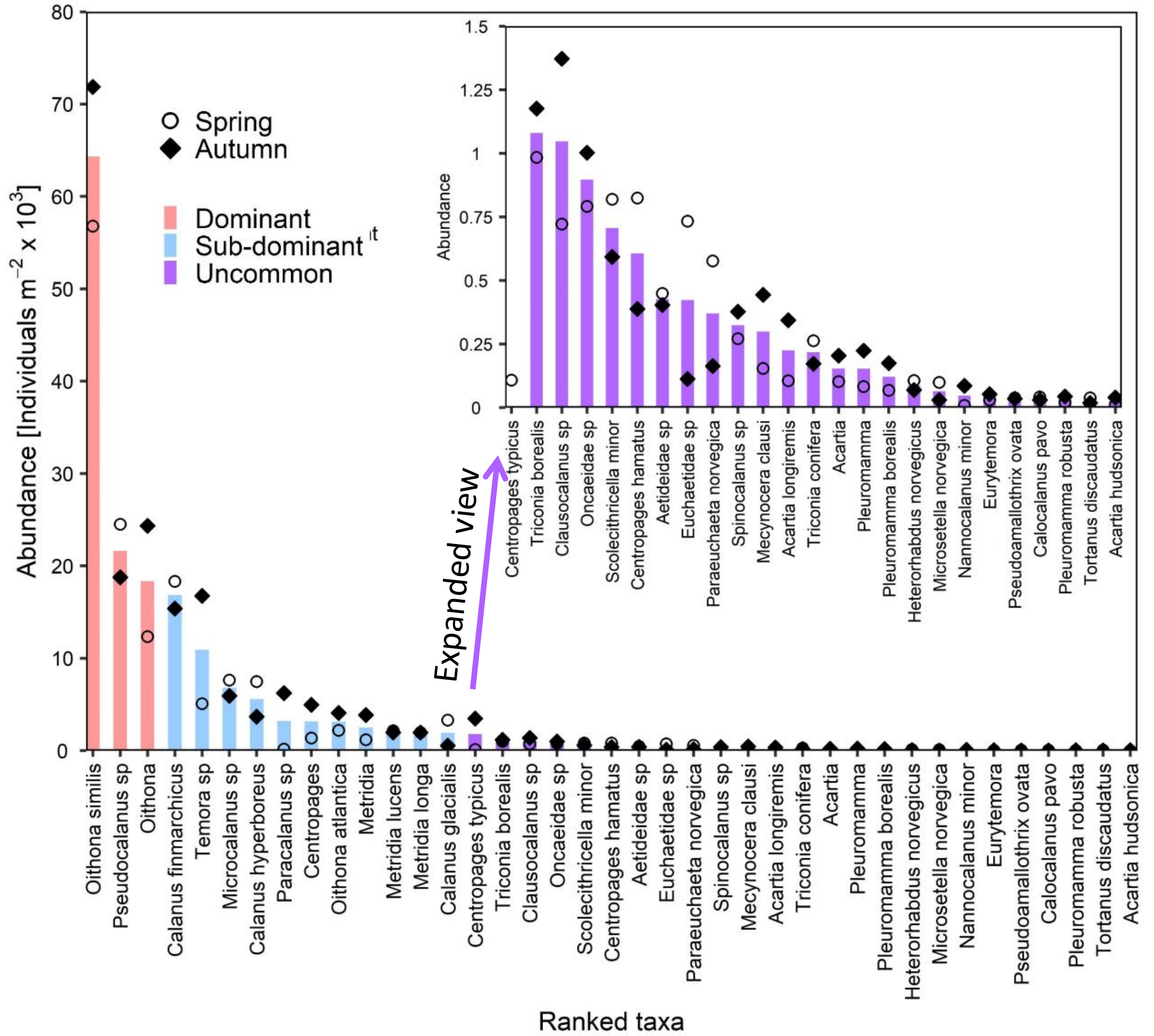
DFO Atlantic Zone Monitoring Program
Northwest Atlantic Shelf Zooplankton Atlas
1999-2020



Johnson, Casault, Plourde, Pepin (*in prep*)

Copepods were divided into dominant, subdominant, uncommon, and rare groups based on occurrence and cumulative abundance thresholds

Annual-scale NW Atlantic Copepod Rank Abundance



Mixed taxonomic resolution representing all copepod taxa > 200 µm

Rank biomass of northwest Atlantic shelf copepods

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Northwest Atlantic Shelf Zooplankton Atlas
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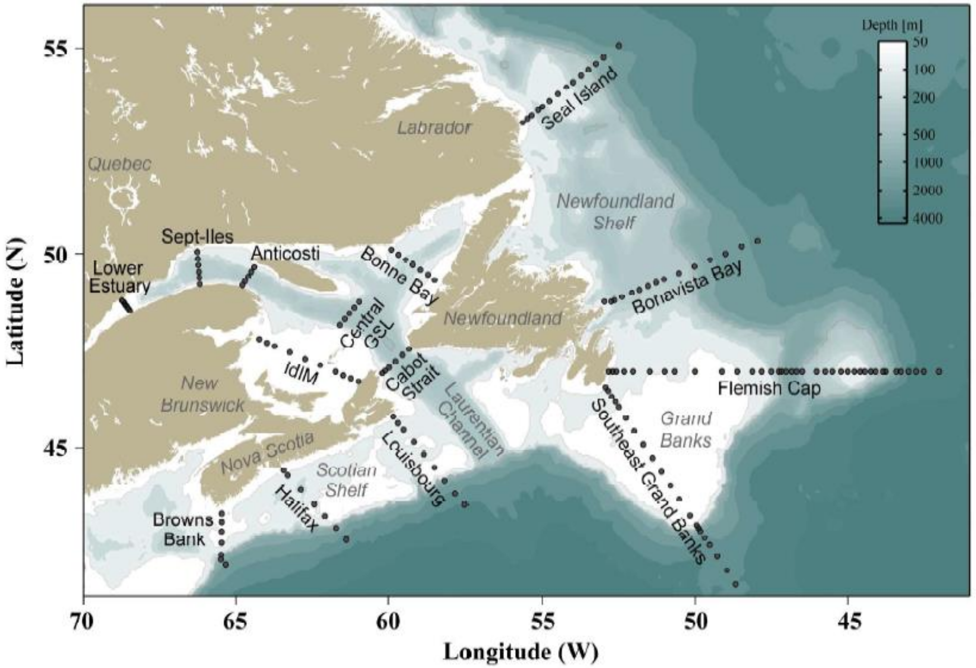
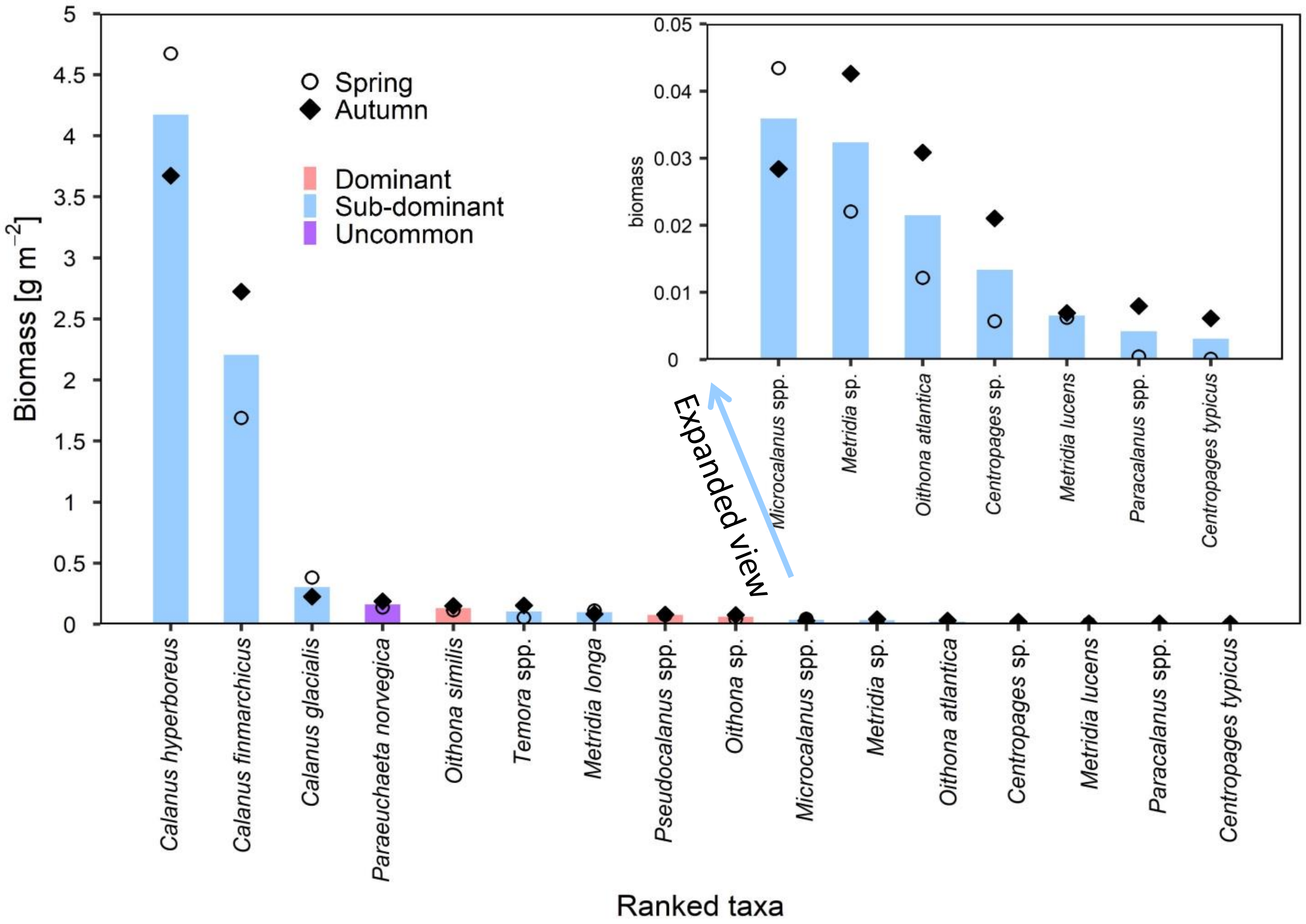


Johnson, Casault, Plourde, Pepin (*in prep*)

Annual-scale NW Atlantic Copepod Rank Biomass



Mixed taxonomic resolution representing all copepod taxa > 200 µm

Specific Objectives of the Study

- Compare dominant taxa across time series
  -Dominance across habitats and large-scale environmental gradients
- Characterize changes in dominant taxa through time
  -Annual, interannual, interdecadal time-scales
- Examine different aspects of community change, e.g.,
  Changes in…
  -The copepod community, ranked by abundance
  -The copepod community, ranked by biomass
  -Relative abundance of non-copepods and copepods
  -Non-copepod groups ranked by abundance
  -Functional groups
- Relationships with environmental changes

Methods – Data Compilation

- Zooplankton data from participating time series were compiled in a WGZE Collaboration Space
- A “data set” is defined as data from an individual time series or survey program **collected using the same method**
- Data were contributed at their original taxonomic resolution
- Taxonomic names were updated using the World Register of Marine Species (WoRMS)

Time series compiled to date

Canada	Atlantic Zone Monitoring Program – Scotian Shelf, E. Gulf of Maine
Finland	Northern Baltic
Germany	North Sea – Helgoland Roads
Iceland	Siglunes, Selvogsbanki transects
Italy	LTER-MC
North Atlantic	Continuous Plankton Recorder
Norway	Barents Sea – Fugløya-Bjørnøya transect
	Norwegian Sea – Svinøy transect
	Northern Skagerrak – Arendal St2
	North Sea – Utsira-Startpoint, Hanstholm-Aberdeen
	West Spitsbergen Current
Poland	Baltic Sea – P1,P5,P40,P140
Spain	A Coruña – RADIALES
	Bilbao – B35
	Urdaibai – U35
Sweden	Baltic Sea – SHARK
UK	North Sea – Stonehaven
	Scotland Western Isles – Loch Ewe
	English Channel – L4
US	EcoMon – Gulf of Maine

Methods – Group taxa

- The current data sets range from 90 – 500+ unique taxa identifications ranging from species to phylum – Simplified example at right is representative
- To compare data at the same taxonomic resolution, taxa in each data set are grouped at a level specific to the requirements of the analysis
- Analyses requiring high taxonomic resolution may focus on subsets of data (e.g., copepods only)

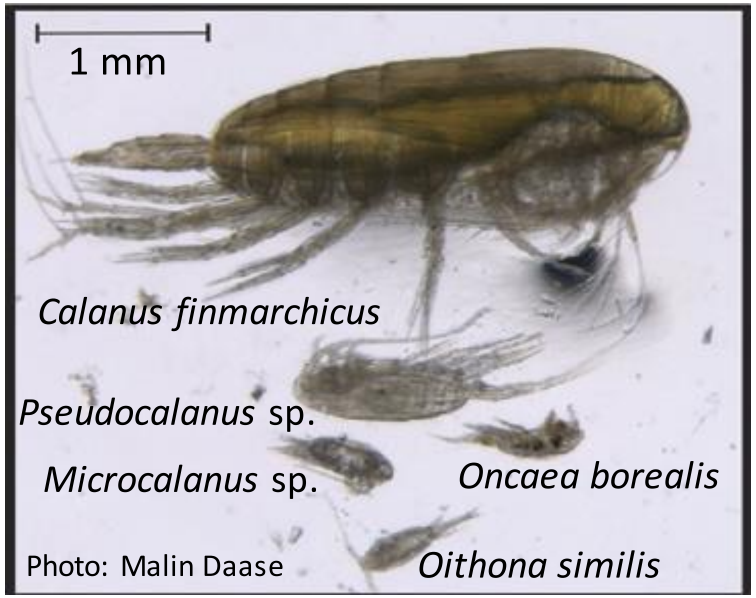
Calanus finmarchicus (species)
Calanus helgolandicus (species)
Calanus hyperboreus (species)
Pseudocalanus sp. (genus)
Clausocalanus sp. (genus)
Oithona similis (species)
Oithona other than similis (~genus)
Amphipods (order)
Decapoda larvae (order)
Barnacle cypris (subclass)
Echinopluteus larvae (phylum)
Sagitta species-1 (species)
Sagitta species-2 (species)

Methods – Aggregated Cumulative Minimum Level analysis

<table>
<thead>
<tr><th>F00</th><th>F01</th><th>F02</th><th>F03</th><th>F04</th><th>F05</th></tr>
<tr><th>original identifications (mixed)</th><th>"Genus+"</th><th>"Family+"</th><th>"Order+"</th><th>"Class+"</th><th>"Phylum+"</th></tr>
</thead>
<tbody>
<tr><td>Calanus finmarchicus (species)</td><td rowspan="3">Calanus (genus)</td><td rowspan="3">Calanidae (family)</td><td rowspan="5">Calanoida (order)</td><td rowspan="7">Copepoda (class)</td><td rowspan="10">Arthropoda (phylum)</td></tr>
<tr><td>Calanus helgolandicus (species)</td></tr>
<tr><td>Calanus hyperboreus (species)</td></tr>
<tr><td>Pseudocalanus sp. (genus)</td><td>Pseudocalanus (genus)</td><td rowspan="2">Clausocalanidae (family)</td></tr>
<tr><td>Clausocalanus sp. (genus)</td><td>Clausocalanus (genus)</td></tr>
<tr><td>Oithona similis (species)</td><td rowspan="2">Oithona (genus)</td><td rowspan="2">Oithonidae (family)</td><td rowspan="2">Cyclopoida (order)</td></tr>
<tr><td>Oithona other than similis (~genus)</td></tr>
<tr><td>Amphipods (order)</td><td>Amphipods (order)</td><td>Amphipods (order)</td><td>Amphipoda (order)</td><td rowspan="2">Malacostraca (class)</td></tr>
<tr><td>Decapoda larvae (order)</td><td>Decapoda larvae (order)</td><td>Decapoda larvae (order)</td><td>Decapoda (order)</td></tr>
<tr><td>Barnacle cypris (subclass)</td><td>Barnacle cypris (subclass)</td><td>Barnacle cypris (subclass)</td><td>Barnacle cypris (subclass)</td><td>Thecostraca (class)</td></tr>
<tr><td>Echinopluteus larvae (phylum)</td><td>Echinopluteus larvae (phylum)</td><td>Echinopluteus larvae (phylum)</td><td>Echinopluteus larvae (phylum)</td><td>Echinopluteus larvae (phylum)</td><td>Echinodermata (phylum)</td></tr>
<tr><td>Sagitta species-1 (species)</td><td rowspan="2">Sagitta (genus)</td><td rowspan="2">Sagittidae (family)</td><td rowspan="2">Aphramorphora (order)</td><td rowspan="2">Sagittodea (class)</td><td rowspan="2">Chaetognatha (phylum)</td></tr>
<tr><td>Sagitta species-2 (species)</td></tr>
</tbody>
</table>

Methods – Copepod Biomass estimate

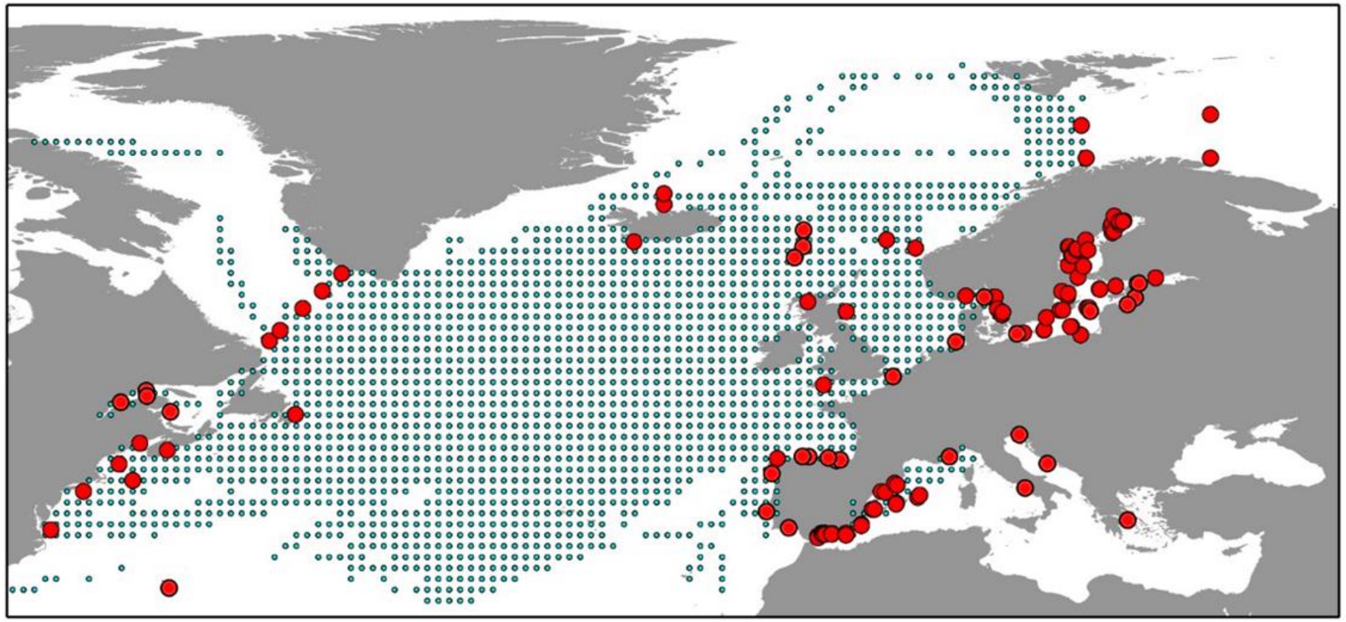
- Approach: Rough estimates of biomass, ignoring intraspecific variability
  "comparing grapes to watermelons"
- Compile total length (TL) for each species (adults) from WoRMS
- Convert TL to Individual Dry Weight (IDW) with a "generic" copepod equation
  (Mizdalski 1988 Ber. Polarforsch 55:1-72)
- Method can be updated with species-specific length to IDW equations in the future
- Estimate total biomass for each species as IDW*Abundance



Methods – Spatio-temporal averaging

- For broadscale sampling programs, combine data in 1° x 1° Latitude/ Longitude grid cells
- Combine data in year-month averages for each grid cell

North Atlantic domain with 1° x 1° grid cell figure

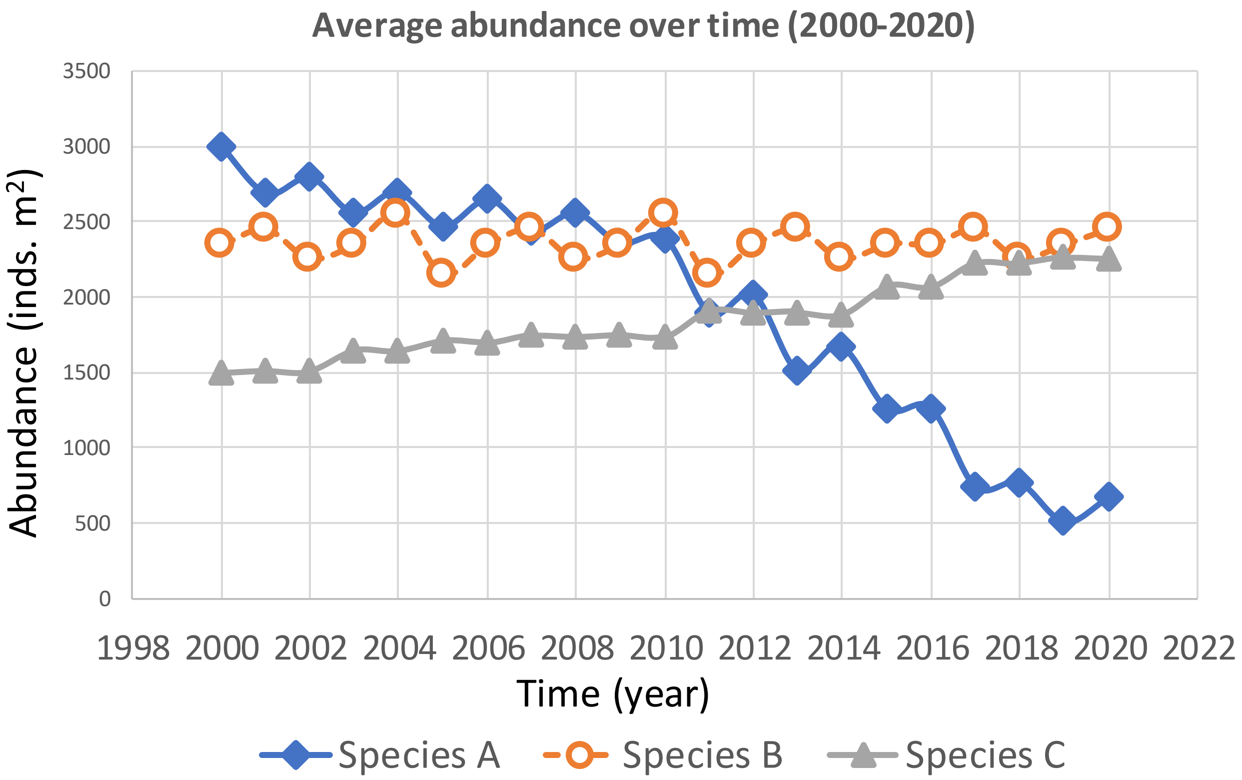


Methods – Ranking

- Create grid cell ranking and trend statistics for each data set and taxon
- Each grid cell and data sets within are analyzed separately.
  E.g., the CPR will be present in many grid cells. “L4” will be present in only one grid cell. Transects will show up in multiple grid cells.

Each taxon

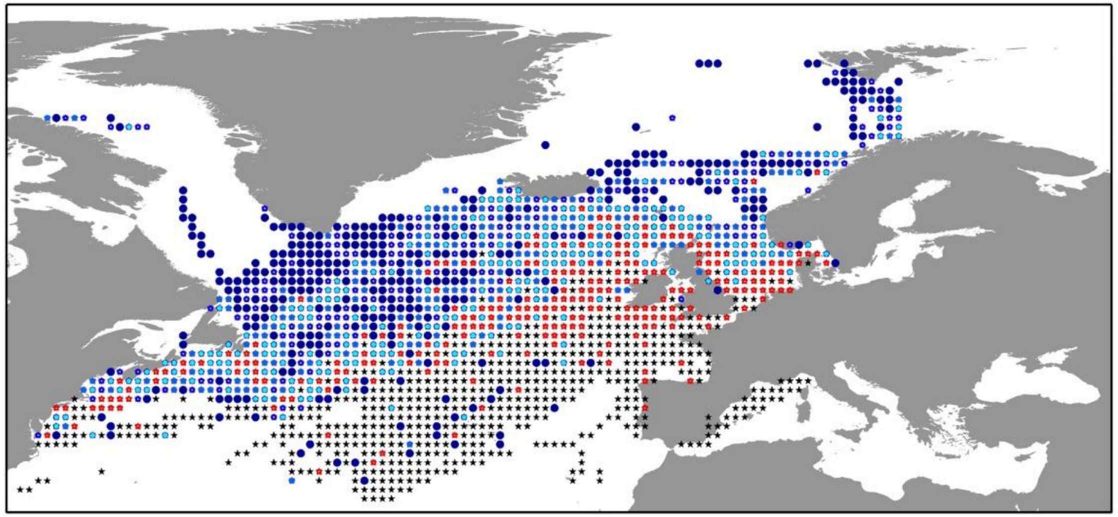
- Can be processed separately, to create a species abundance or biomass trend over time
- Can be compared to all taxa (per grid cell per data set per year per month) to create a time series of “relative ranking” for that species
- Changes (trends) in abundance may contrast changes in rank
  (e.g., flat abundance trend can hide increasing dominance/ranking, as for Species B)

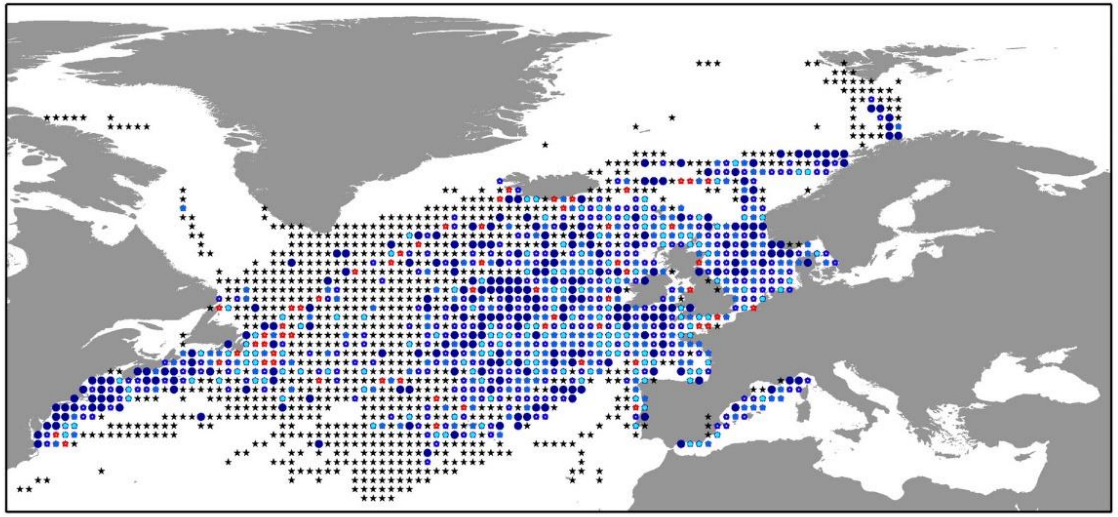


Spatial maps of species rank – N. Atlantic scale

Gridded maps indicate spatial patterns in species rank. Distribution often can be related to species preferences (e.g., warmer/cooler temperatures, coastal/shelf vs. open ocean, etc.)

Annual Average Rank of Taxa Observed with CPR, 1950-2019



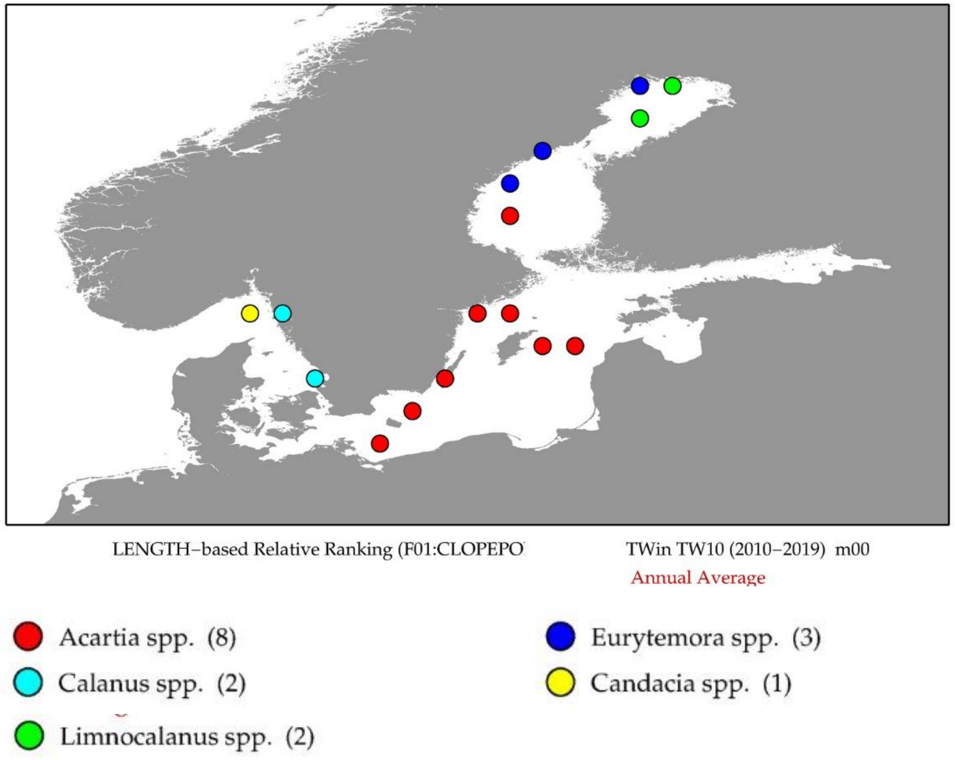


Rank–01 Rank–02 Rank–03 Top–05 Top–10 ☆ *outside of Top–10*

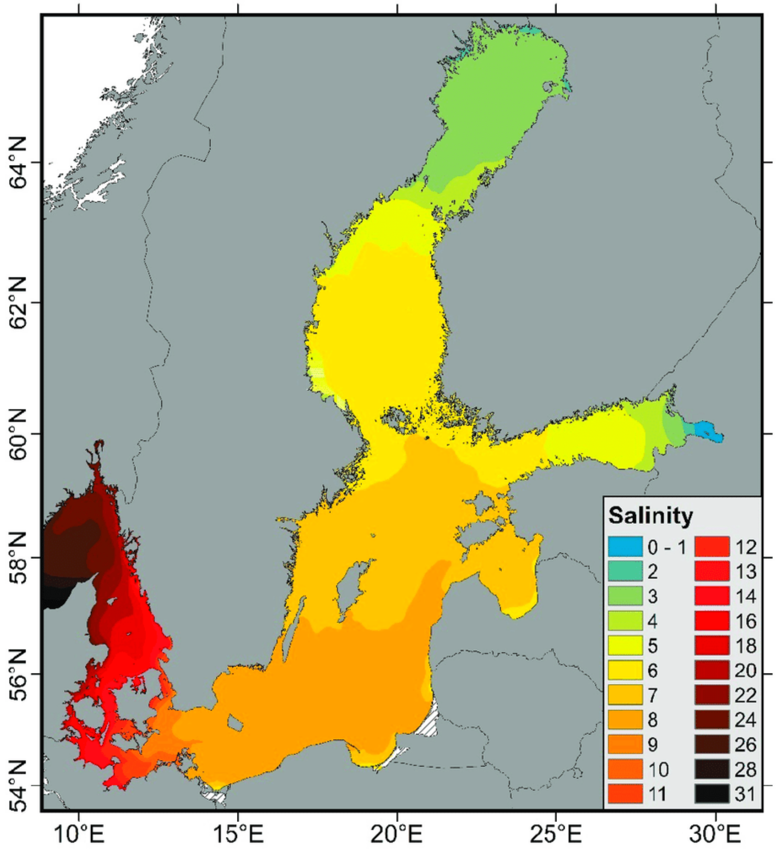
Spatial maps of dominant species – Baltic Sea

In this Baltic Sea example, the distributions are associated with salinity

Rank of Copepod Genera, 2010-2019,
Sweden SHARK monitoring program

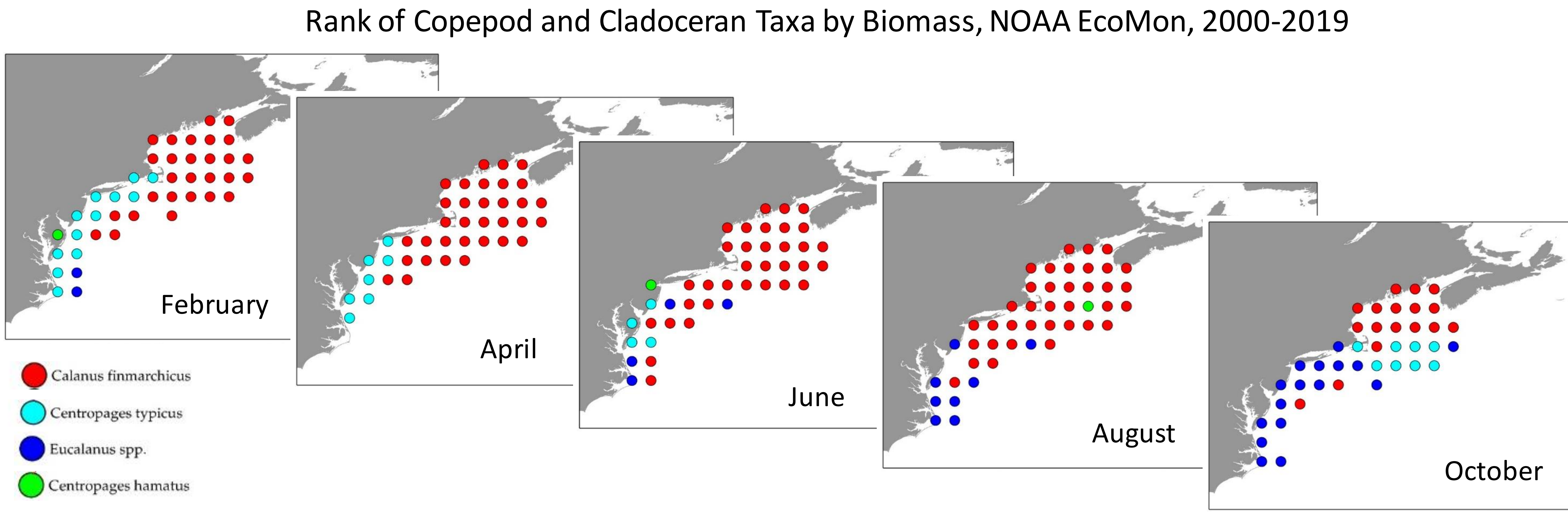


Sea Surface Salinity
Five-year average, 2015-2019



Jespers et al (2021) Diversity 13(2): 57

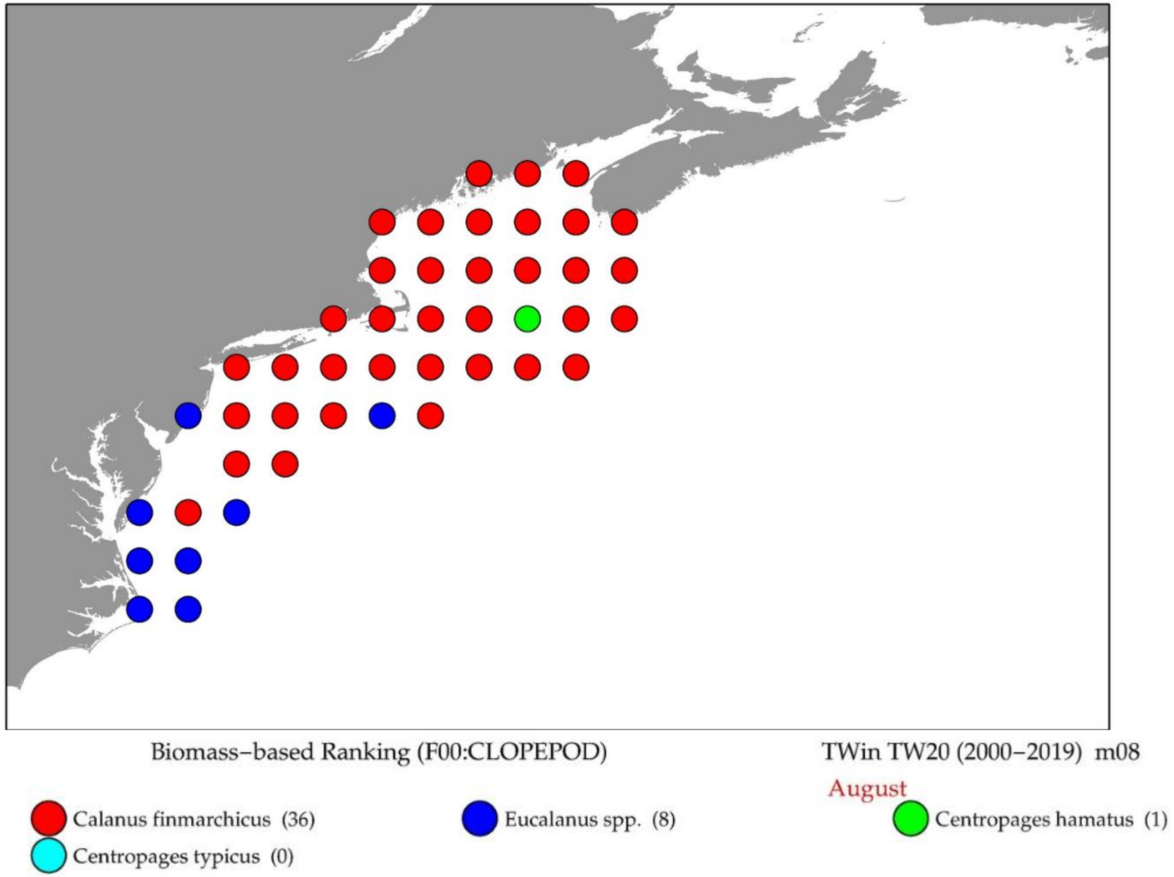
Seasonal changes in dominance and distribution



Biomass ranking across multiple sites indicates seasonal community changes and and spatial coherence in the biomass-dominant species.

Biomass- vs. abundance-based dominance patterns

Rank of Copepod and Cladoceran Taxa by Biomass
NOAA EcoMon, 2000-2019 (August)



Rank of Copepod and Cladoceran Taxa by Abundance
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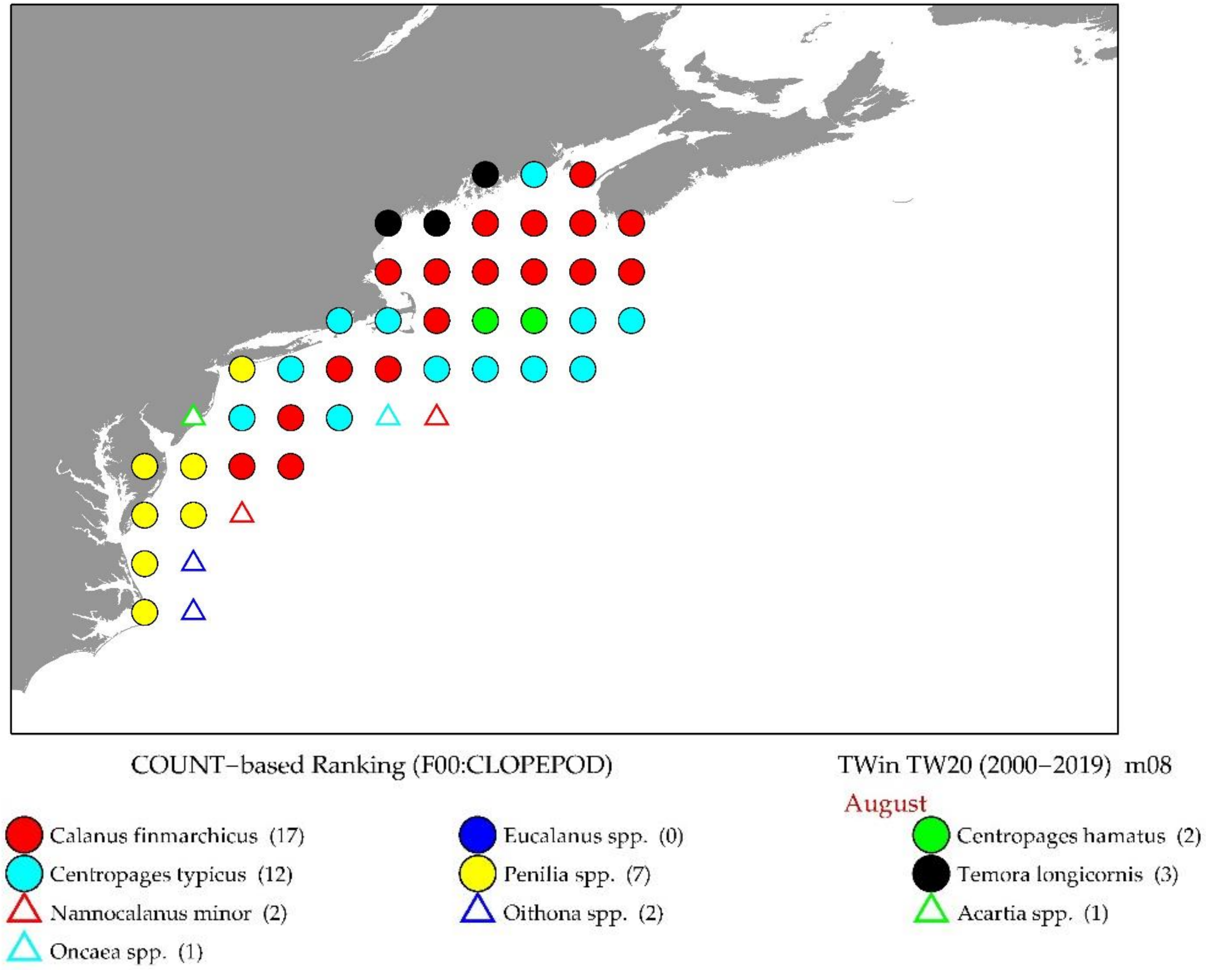
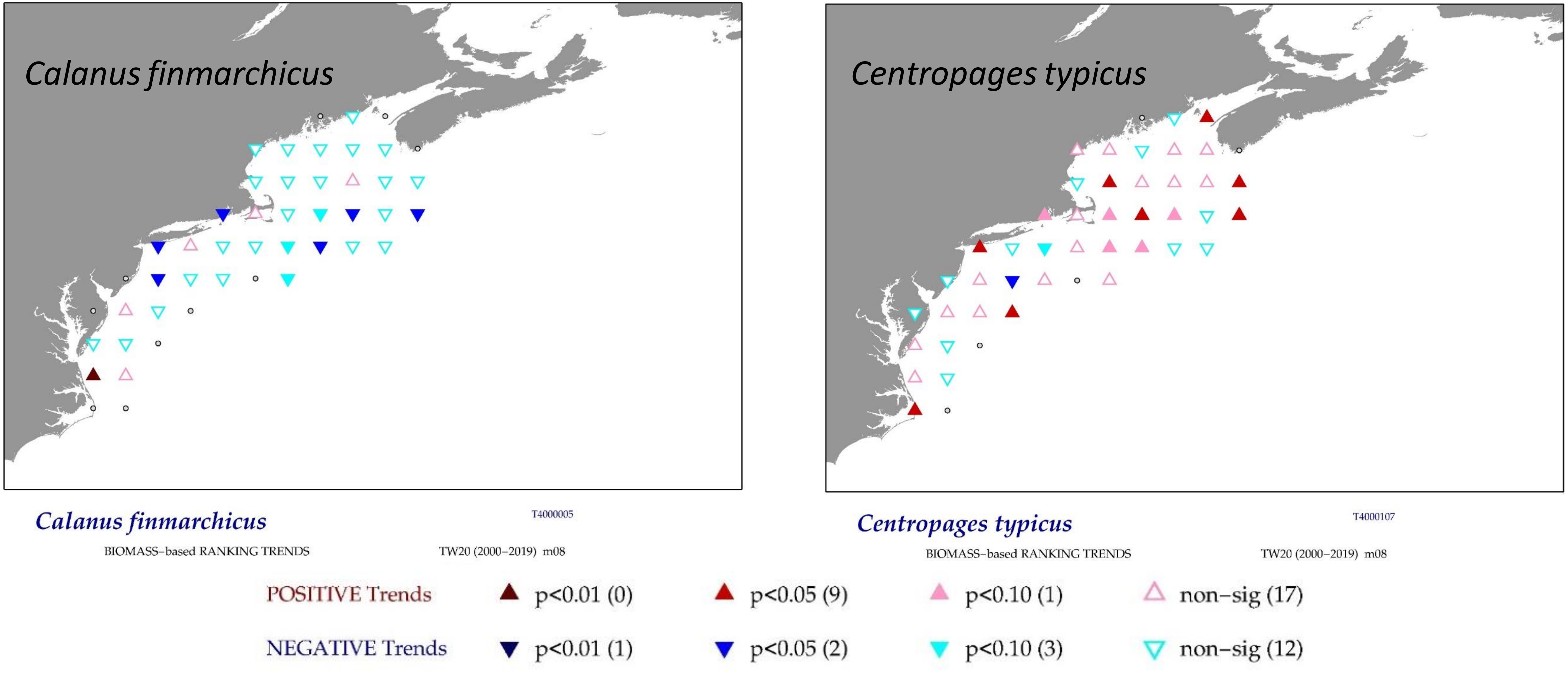


Biomass-based ranking (left map) tells a different (and simpler) story from abundance-based ranking (right map)

Trends in dominance over time

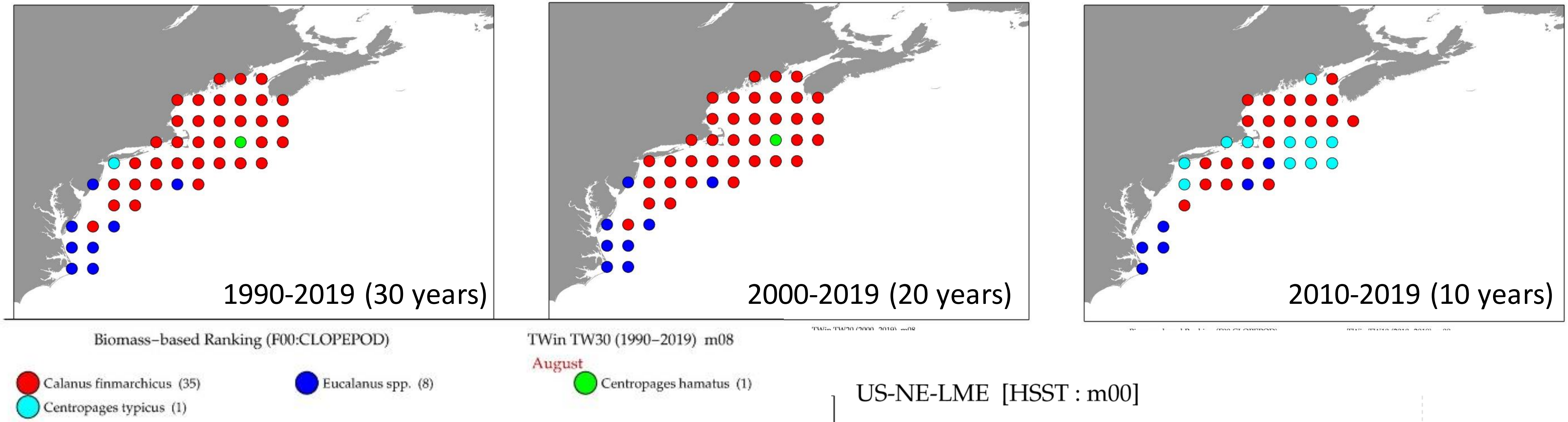
Trends in Biomass-based Rank, NOAA EcoMon, 2000-2019 (August)

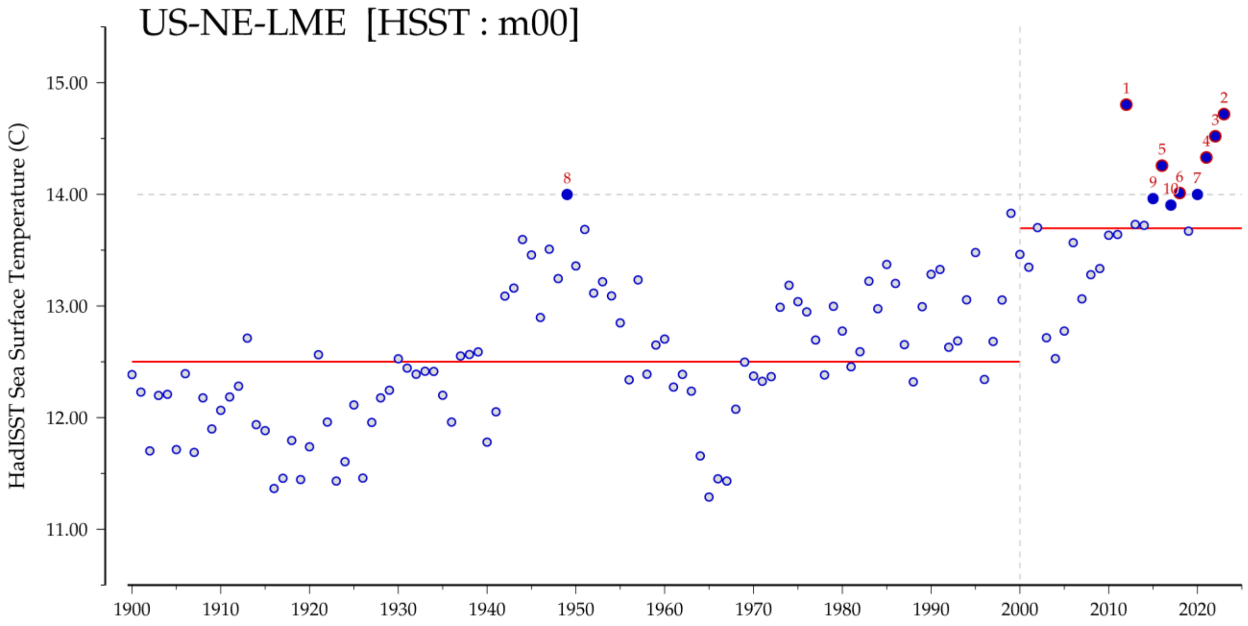


Trends in ranking

Changes in dominance over time

Rank of Copepod and Cladoceran Taxa by Biomass, NOAA EcoMon (August)





- Biomass dominance pattern appeared to be fairly stable up until recently
- This change is associated with extreme warming in the 2010s in the region

Summary / Next steps

- Collaboration space and visualization tools were created to compile and process diverse time series data
- Preliminary analyses provide a proof of concept for exploring large scale patterns of zooplankton community changes
- Near-term next steps

  -Review of time series products in each region

  -Identify optimal taxonomic grouping levels for comparisons across time series

Next steps

- Longer–term

  -Combine time series to map regional- and basin-scale patterns of zooplankton population and community change across the North Atlantic

- Examine diverse perspectives of community change

  -Relative abundance of non-copepods and copepods

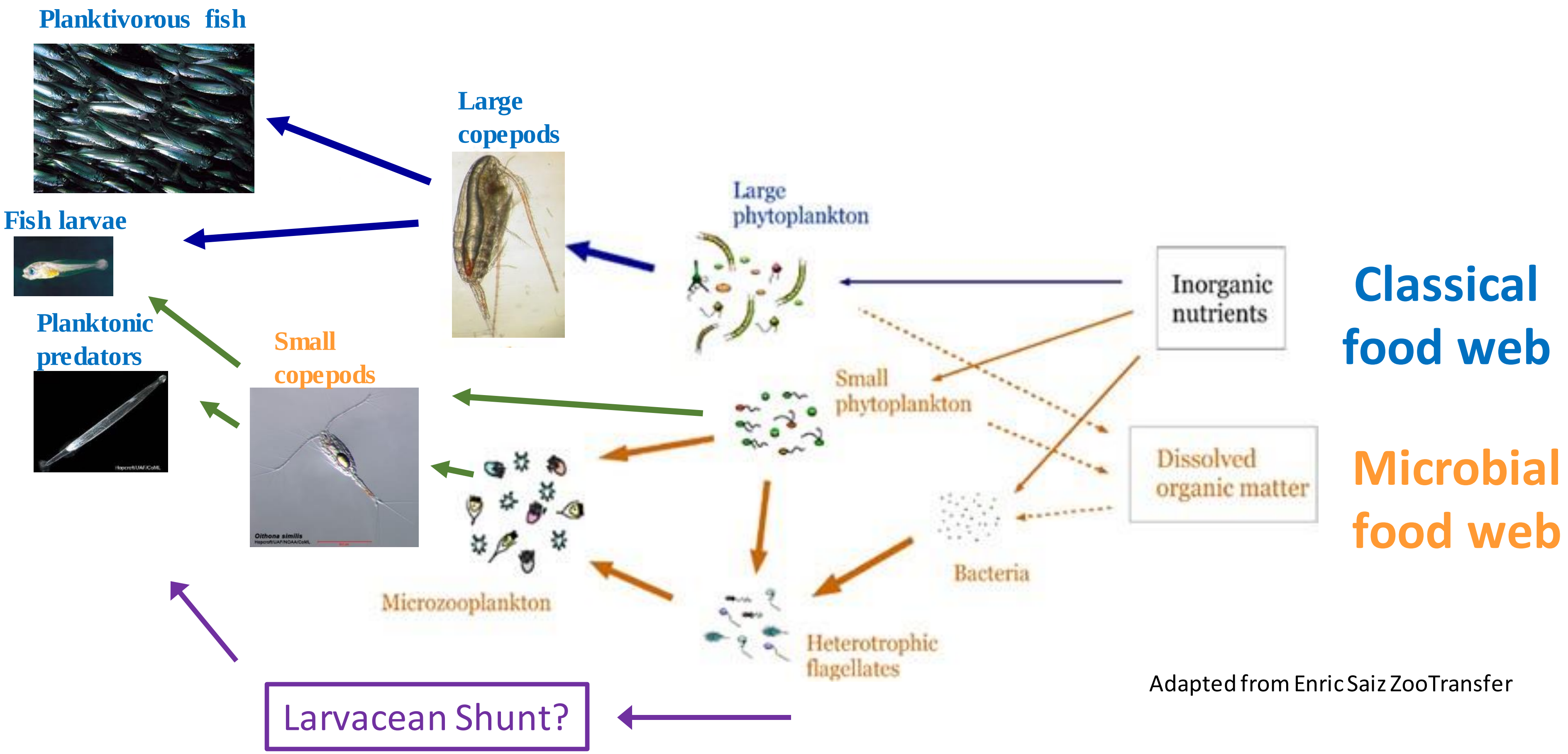
  -Non-copepod groups ranked by abundance

  -Functional groups

  -Relationships with environmental changes

Significance of community changes

- Phytoplankton and zooplankton community composition and abundance influence the pathways and efficiency of energy flow through the ecosystem
- In a rapidly changing ocean, monitoring and understanding how lower trophic level communities are changing is critical for sustainable management of marine resources



Adapted from Enric Saiz ZooTransfer

Acknowledgements

- ICES and WGZE co-chairs and participants for supporting and coordinating the analysis (WGZE ToR B)
- The institutes, staff, and officers and crew of vessels who all support our monitoring programs
- Our organizations for supporting our involvement with ICES WGZE
- PICES travel support allowing CLJ to attend the 7th IZPS