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Zooplankton community variability and resilience on the northwest Atlantic shelves

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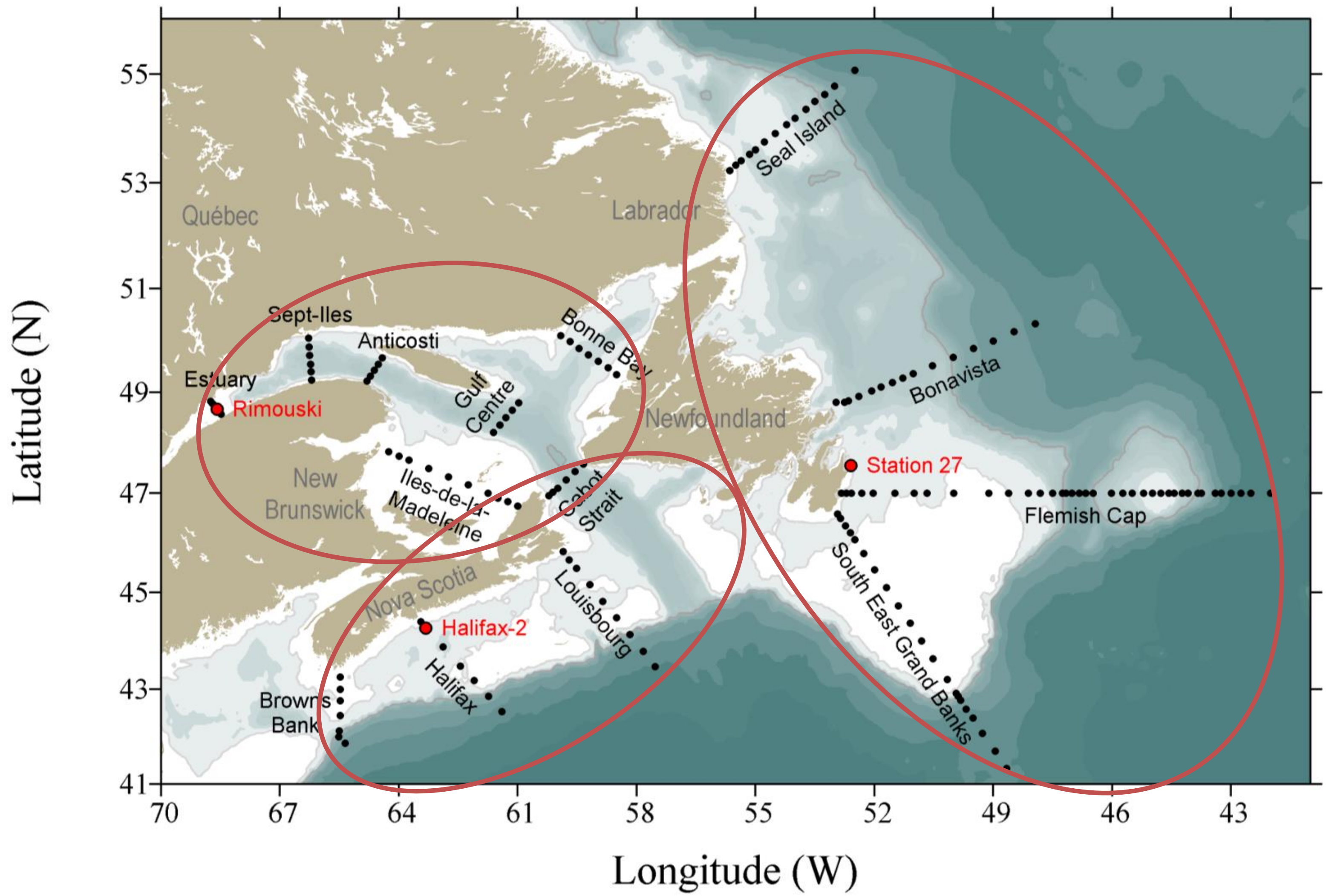
Canada

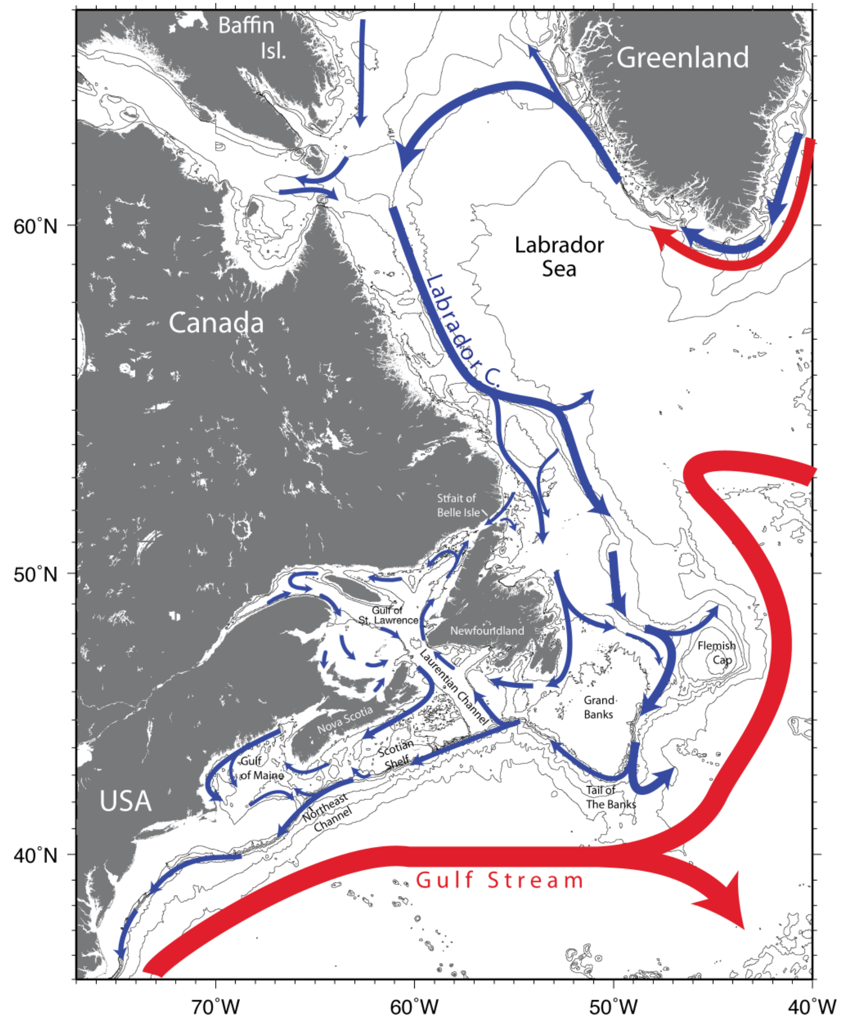
Atlantic Zone Monitoring Program



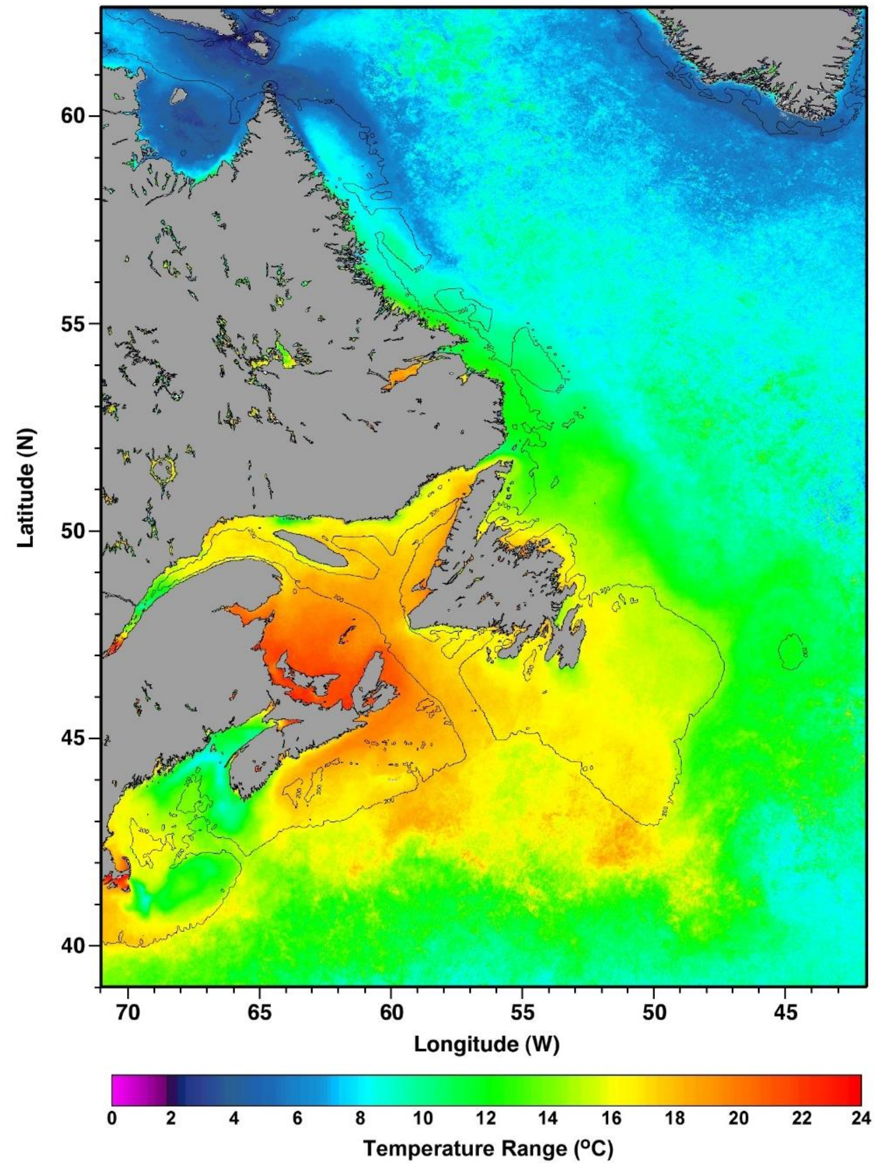
- High frequency timeseries stations
  ~2 times per month since 1999
- Sections
  2-3 times per year since 1999

Northwest Atlantic shelf system

NW Atlantic circulation

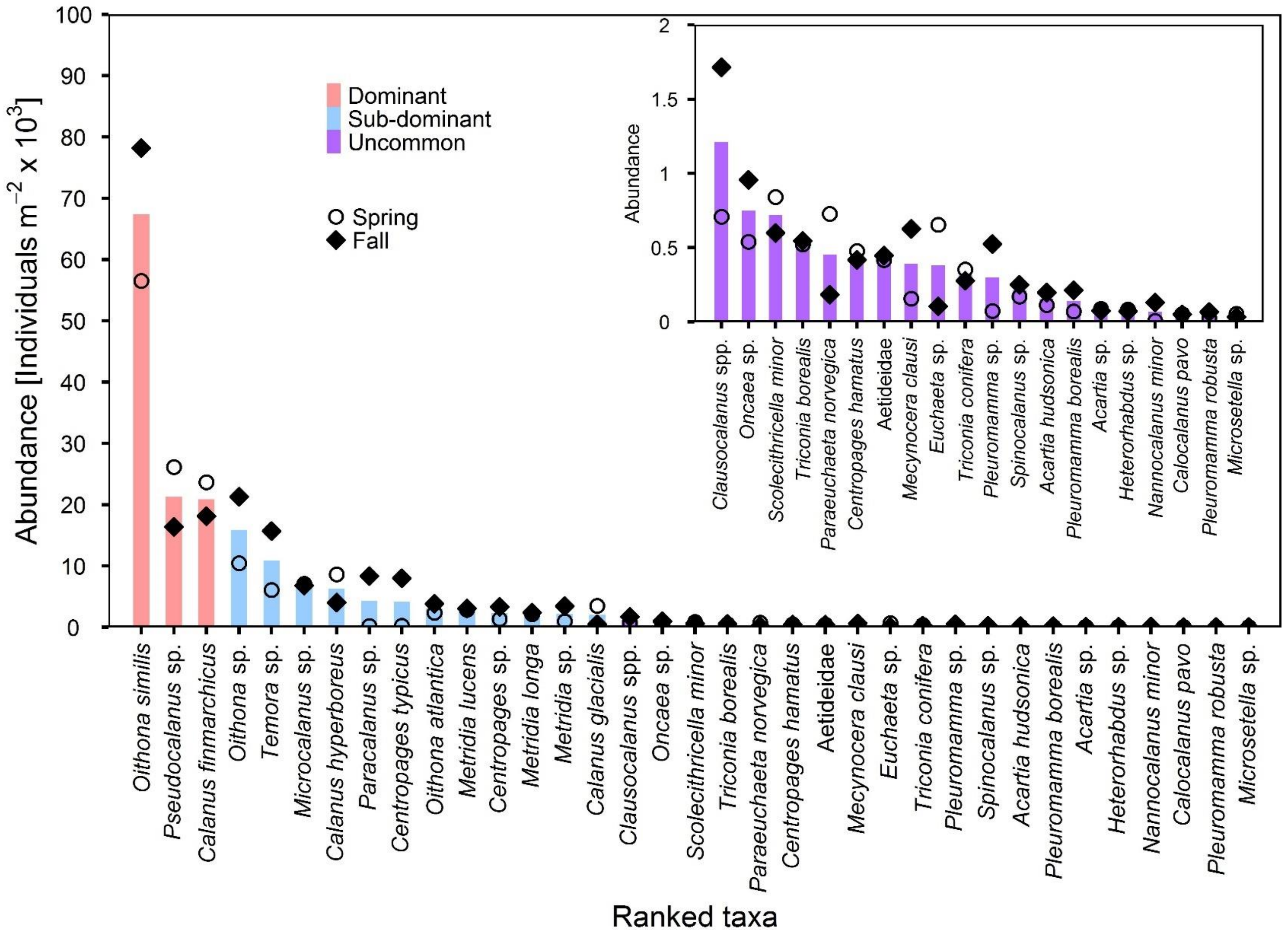


Annual range of surface temperature



Fratantoni & MacCartney (2010) Deep-Sea Res. 57: 258-283; **Hannah et al.** (2001) J. Phys. Oceangr. 31: 591-615; **Drinkwater & Gilbert** (2004) J. NW Atl. Fish. Org. 34: 85-101.

Northwest Atlantic copepods rank abundance

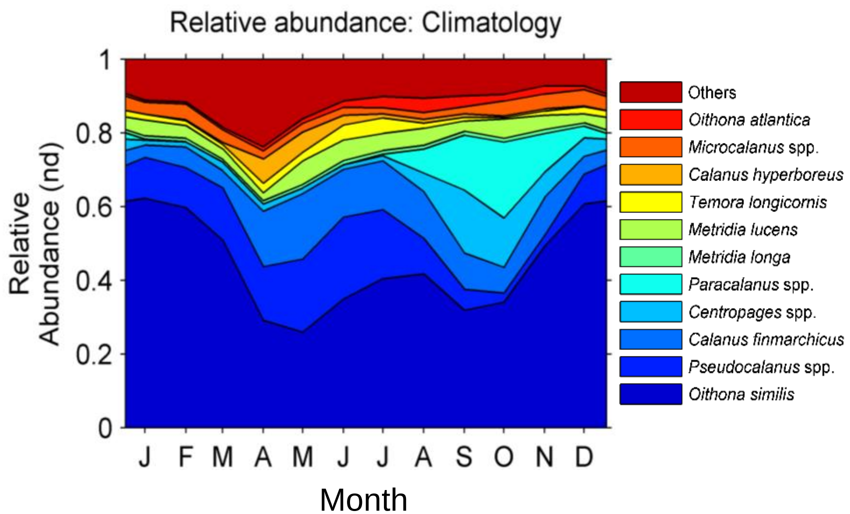


99 copepod taxa observed in total by AZMP
64 rare copepod taxa not shown

Johnson, Pepin, Casault, Harvey (in prep.) NW Atlantic zooplankton atlas

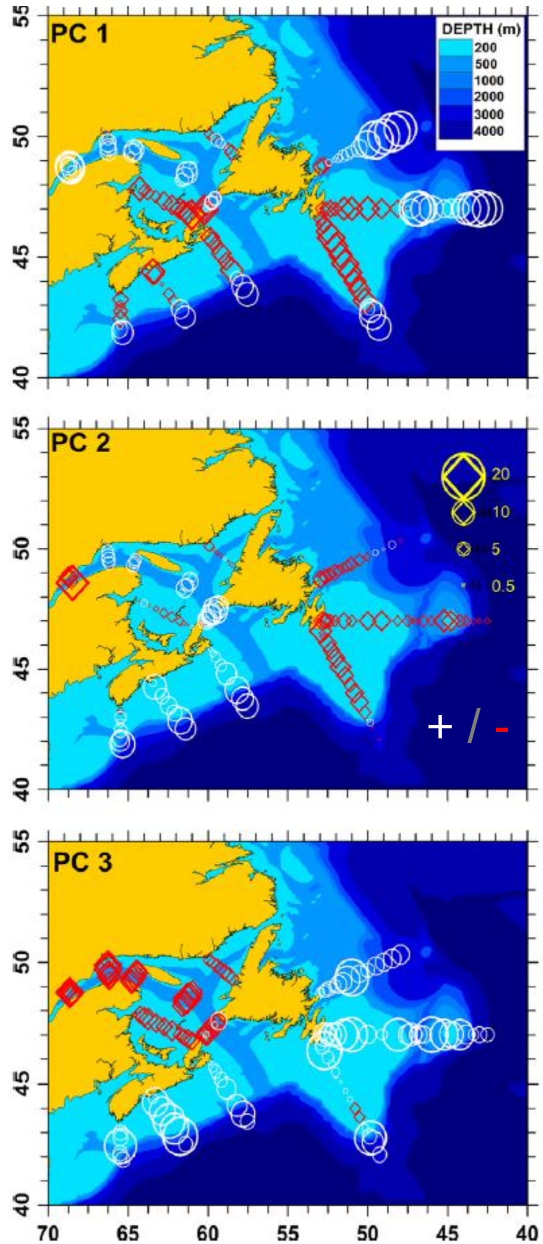
Recurring annual and spatial community pattern is characteristic of the NW Atlantic shelf system, despite strong annual environmental variability and advection

Halifax-2 copepod community



Johnson et al. 2015

Zooplankton principle component analysis



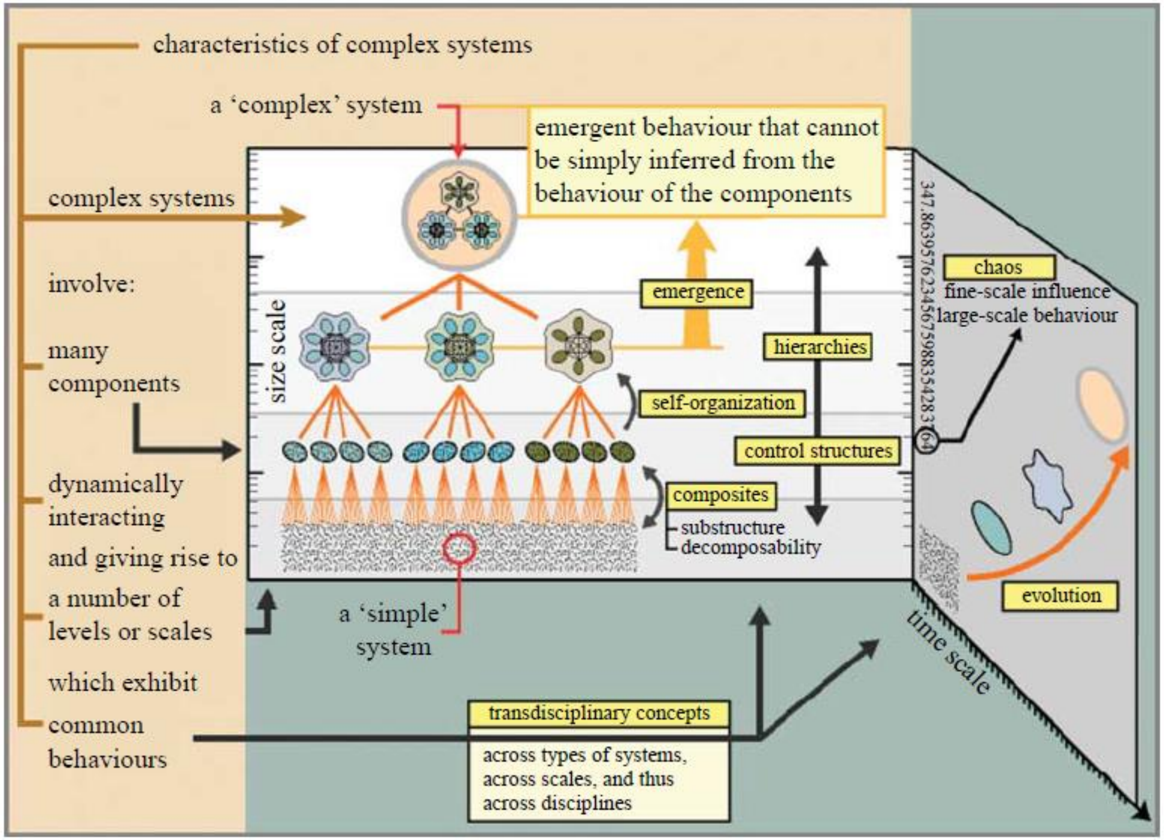
Pepin et al. 2015

Zooplankton community as a Complex Adaptive System

Characteristics

- Sustained diversity and individuality of components
- Localized interaction among components
- An autonomous process that selects from among the components

Levin, 1998; Leibold & Norberg , 2004



Slingo et al. 2009 after Marshall Clemens

Emergent pattern is one of the properties of CAS

Objective

Characterize emergent pattern in copepod community

Approach

- Identify community variation associated with “repeatable” features – day of year, latitude, depth
- Evaluate the influence of annual-scale environmental drivers on residual community variability
- Consider high frequency and broad-scale survey data together
- Here: Evaluate community variability on the Scotian Shelf
  Later: Compare pattern among the three regions

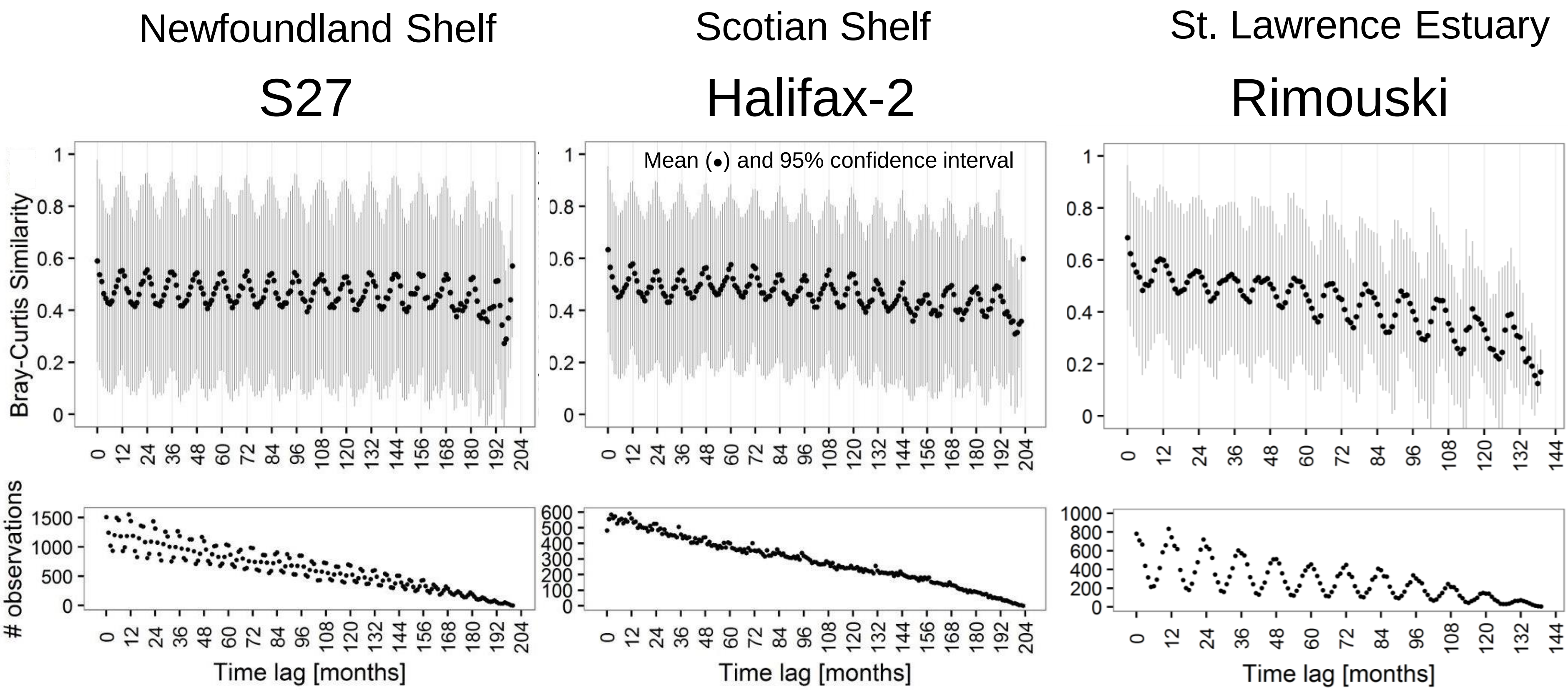
Methodology

- Temporal pattern of community variability
  - Bray-Curtis Pseudo-Autocorrelation (Cram et al. 2014)
  - Redundancy analysis (RDA) on Hellinger transformed abundance (R Core Group, 2015; Oksanen et al. 2013)
  - *dominant and subdominant copepods at high frequency timeseries stations*

- Annually and spatially repeatable variability
  - RDA with transformed day of year, latitude, and depth as constraints
  - *regional broad-scale survey and HF timeseries station*

- Influence of annual environmental drivers and residual community variability
  - partial RDA on residual copepod community variability with annual-scale metrics as constraints
  - *regional broad-scale survey and HF timeseries station*

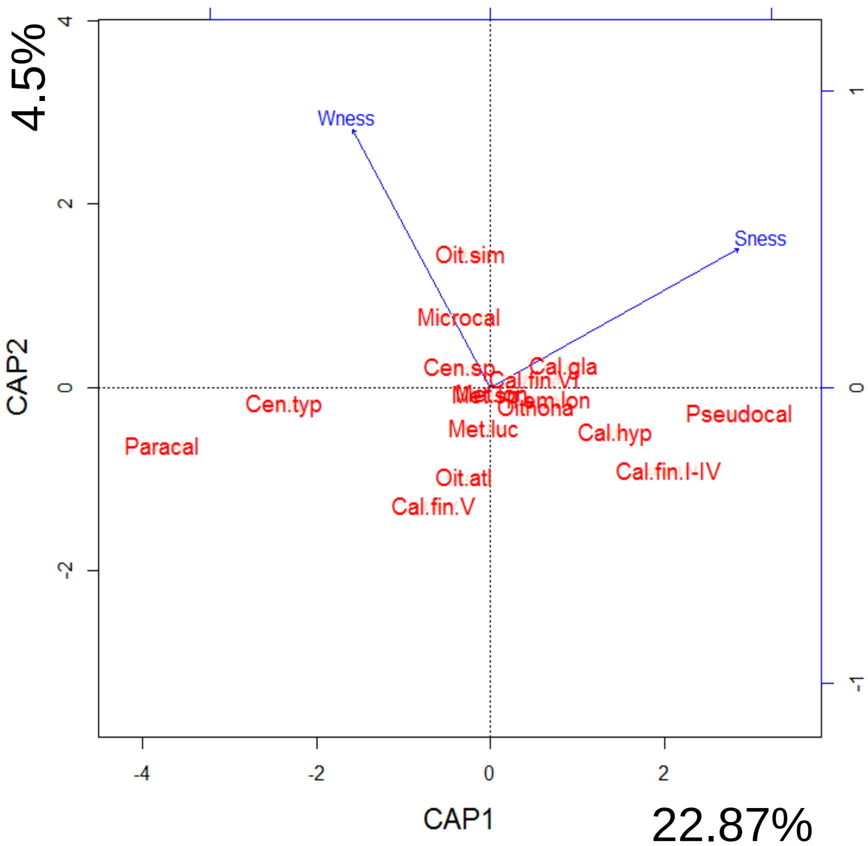
Temporal community variability at timeseries stations



- Peaks in similarity at annual period lags at all stations
- Mean low similarity also relatively high
- Decline in community similarity lowest at S27, highest at Rimouski

Annual community variability at Halifax-2

Redundancy Analysis:
Copepod community variability constrained by transformed Day of Year



	Inertia	Proportion
Total	76.19	1.0000
Constrained	20.82	0.2733
Unconstrained	55.37	0.7267

Permutation test

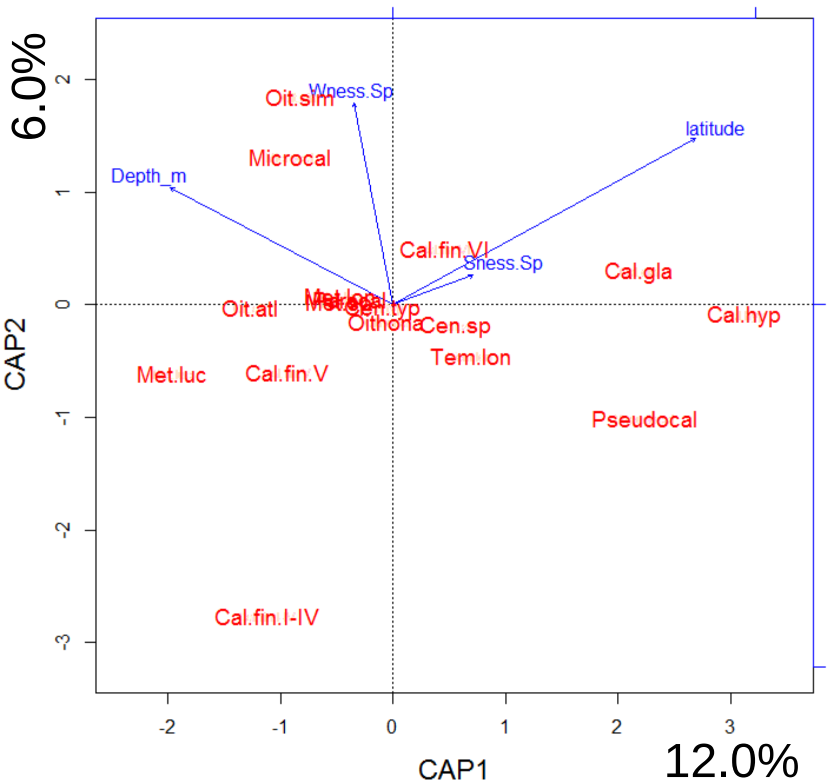
	Df	Var	F	p
Wness	1	6.77	41.59	0.005
Sness	1	14.05	86.26	0.005
Residual	340	55.37		

Day of Year transformation:
Winterness = cos(2*pi*DoY/365)
Springness = sin(2*pi*DoY/365)

Transformed DoY accounts for 27.3% of community variation at Scotian Shelf timeseries station

Recurring community variability (Scotian Shelf, spring)

Redundancy Analysis:
Copepod community variability constrained by transformed Day of Year



	Inertia	Proportion
Total	106.59	1.0000
Constrained	24.40	0.2289
Unconstrained	82.19	0.7711

Permutation test

	Df	Var	F	p
Wness	1	3.31	23.97	0.005
Sness	1	4.87	35.29	0.005
Latitude	1	10.28	74.43	0.005
Depth	1	5.93	42.94	0.005
Residual	595	82.19		

CAP1	CAP2	CAP3	CAP4
12.0%	6.0%	3.3%	1.6%

Latitude, depth, and transformed DoY account for 22.9% of community variation in spring

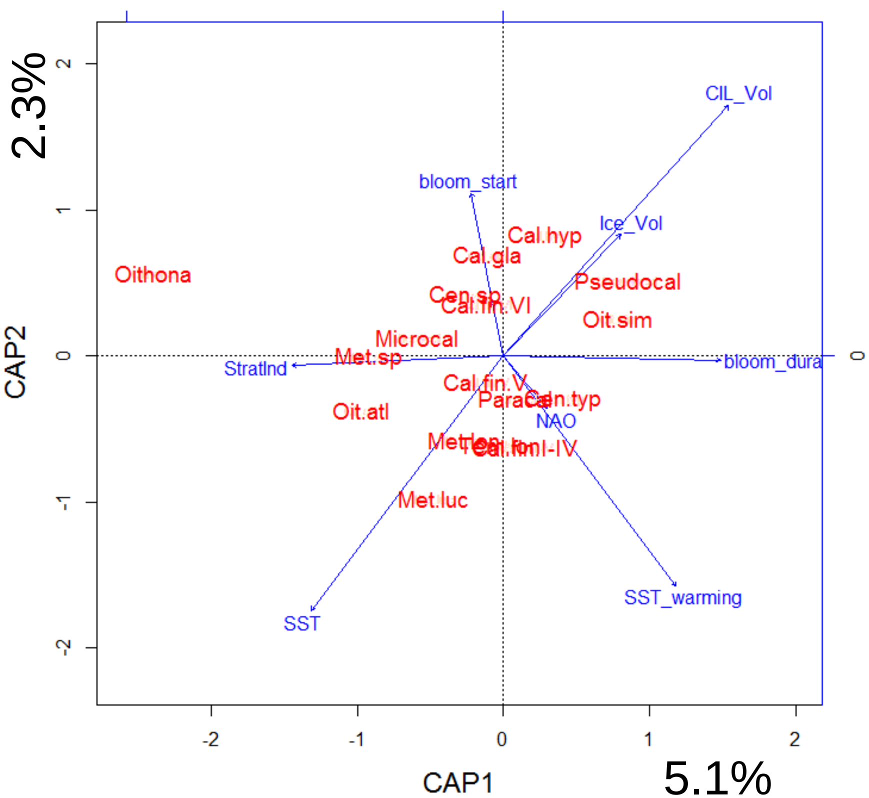
Annual Scale Metrics

Metric	Description
NAO	Winter North Atlantic Oscillation index
SST	Annual mean Sea Surface Temperature (SST)
SST_warming	Rate of SST warming (March to May)
Stratification_Ind	Annual mean 0-50 m density difference
Ice_volume	Ice volume in Gulf of St. Lawrence
CIL_volume	Cold Intermediate Layer (< 4 °C) volume
Bloom_duration	Spring bloom duration (satellite, Gaussian fit)
Bloom_start	Spring bloom initiation day (satellite, Gaussian fit)

Region: Scotian Shelf

Influence of annual-scale environmental variation

Partial Redundancy Analysis:
Residual copepod community variability constrained by annual metrics



Partial RDA based on annual metrics explained an additional 8.6% of the variance; all 8 metrics had a significant influence.

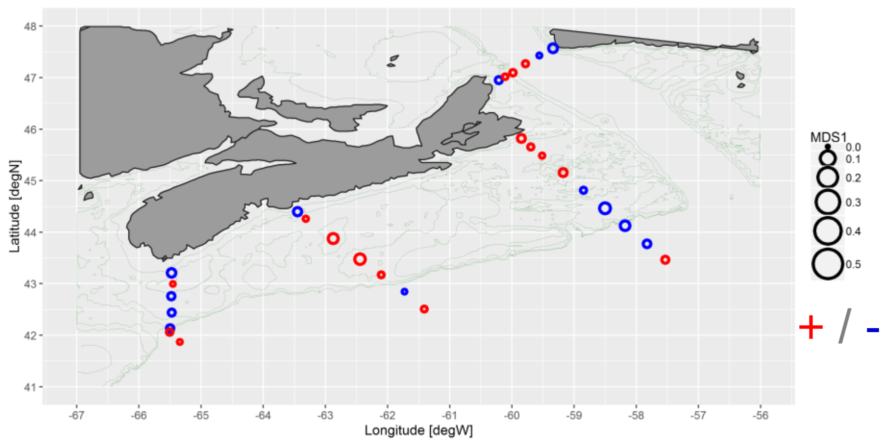
	Inertia	Proportion
Total	106.59	1.0000
Conditional	24.40	0.2289
Constrained	9.21	0.0864
Unconstrained	72.97	0.6847

Permutation test

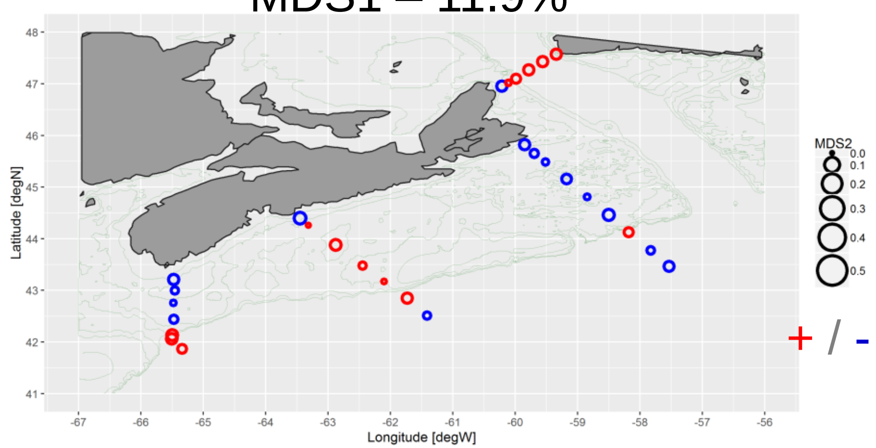
	Df	Var	F	p
SST	1	2.28	18.33	0.005
SST_warming	1	1.89	15.19	0.005
Stratification_Ind	1	1.22	9.80	0.005
Bloom_duration	1	1.10	8.82	0.005
NAO	1	0.80	6.45	0.005
Bloom_start	1	0.66	5.31	0.005
Ice_volume	1	0.64	5.18	0.005
CIL_volume	1	0.63	5.03	0.005
Residual	595	72.97		

Residual variability has coherent mesoscale structure

MDS1 – 12.3%



MDS1 – 11.9%



MDS3	MDS4	MDS5	MDS6	…
7.8%	6.8%	5.1%	4.3%	…

Conclusions

- Annual variability is a dominant timescale of community variability, and day of year explained substantial (27.3%) community variance at Halifax-2.
- Both spatio-temporal and interannual metrics had highly significant effects on community composition on the Scotian Shelf; spatio-temporal metrics explained about 2.5 X as much variance as interannual metrics.
- In spatio-temporal RDA, latitude and depth provided good separation between colder water community members (*C. hyperboreus, C. glacialis, Pseudocalanus*) and warmer, deeper species (*O. atlantica, M. lucens*); features of seasonal succession appeared on second RDA axis.
- Local physical metrics explain more variance than other annual metrics.
- Higher SST and faster warming are associated with warmer water taxa (*M. lucens, Paracalanus, Temora*); Colder winter and later bloom onset favoured colder water species (*C. hyperboreus, C. glacialis, Pseudocalanus*); Higher stratification and shorter bloom duration was associated with deeper and off-shelf species (*O. atlantica, Microcalanus, Metridia*)
- Approach will next be used to compare community responses among regions

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