# 60 years of plankton community in the northern North Atlantic Ocean

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Est. 1884
Incorporated by
Royal Charter

Est. 1931

the CPR survey at www.mba.ac.uk/fellows/cpr-survey

the MBA at www.mba.ac.uk/membership/join/

# Community analysis with 60 years of planktonic data

**Dataset selection: when, where, whom**

- The impact of sampling effort *(if enough time…)*

**The dynamic in time**

- Method (dbMEM)

**Building communities and monitoring them**

- Method (PCA)

**The Community Stability Index (CSI)**

# Dataset selection:

*“When, where, whom”*

Est. 1884
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Est. 1931

# Community analysis with 60 years of planktonic data

*when, where, whom*

**Target time period with constant methodology (January 1958 to December 2017)**

60 years of data: Time series of 720 months (maximum)

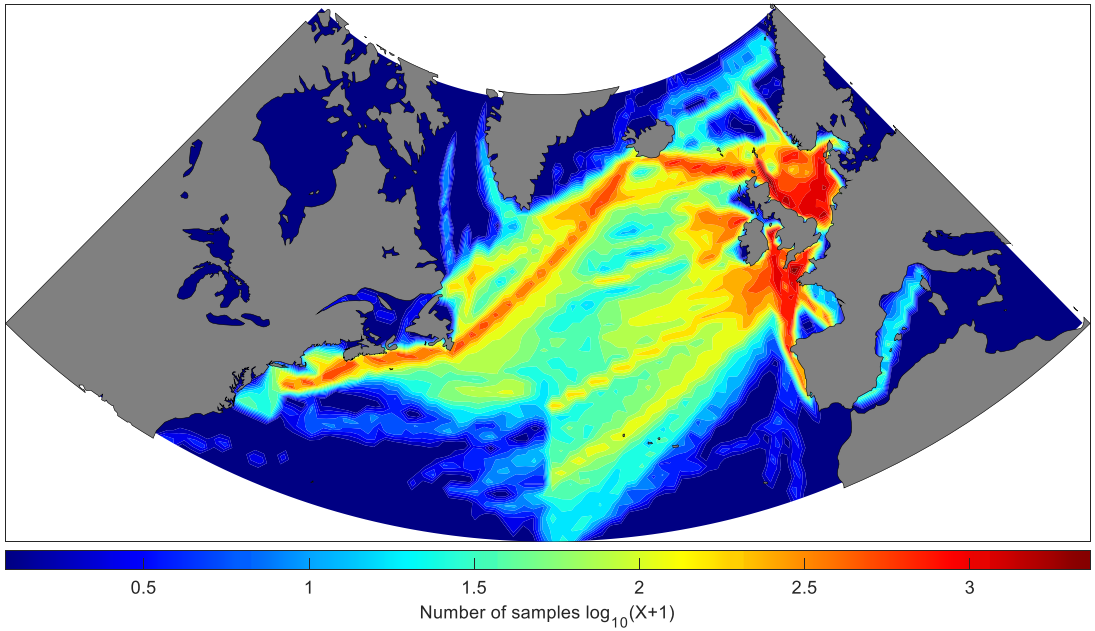
- ≈ 260 000 samples
- ≈ 400 zooplanktonic taxa
- ≈ 250 phytoplanktonic taxa

https://data.cprsurvey.org/datacatalog/

# Community analysis with 60 years of planktonic data

*when, where, whom*

## North Atlantic Ocean




the sampling effort is not homogenous in space …

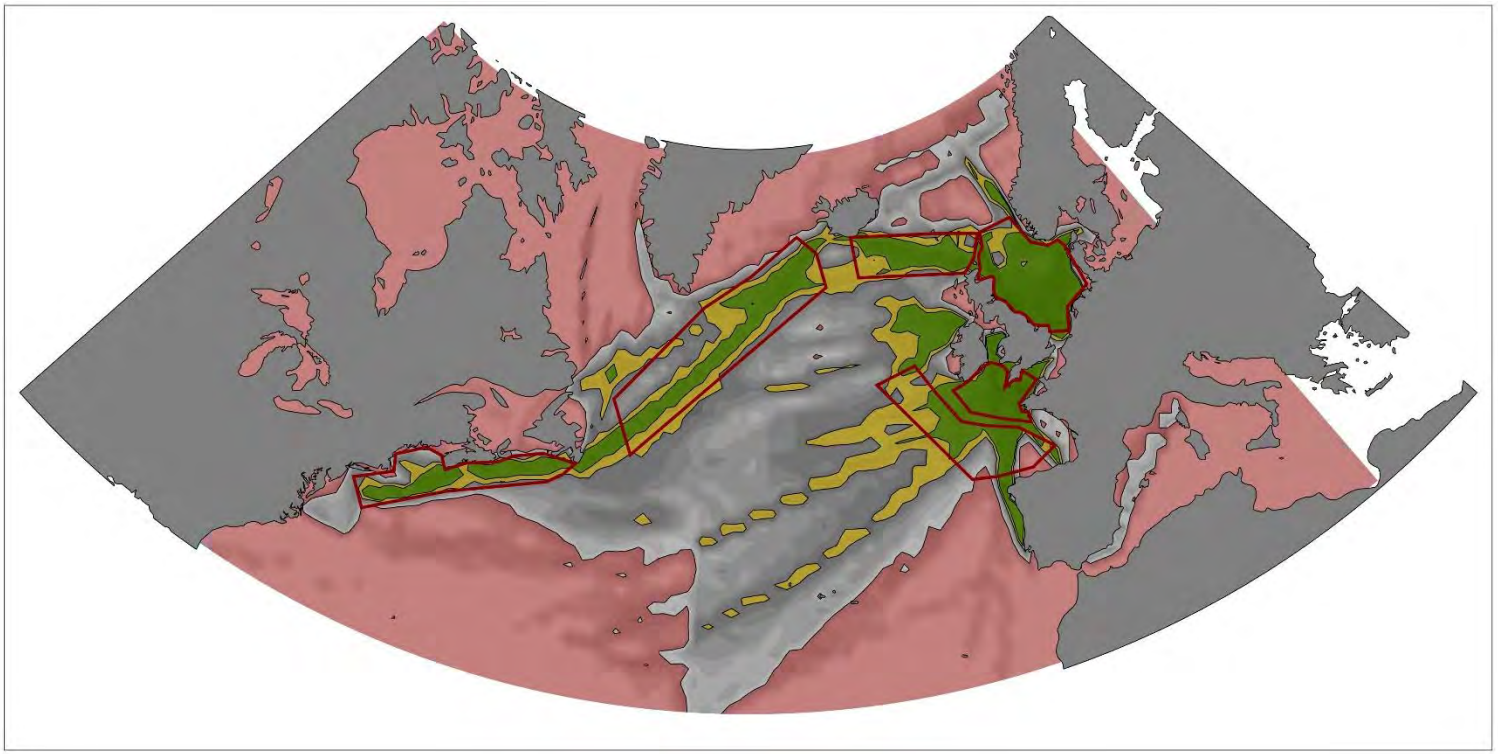
…nor in time

… and this has an impact

# Community analysis with 60 years of planktonic data

*when, where, whom*

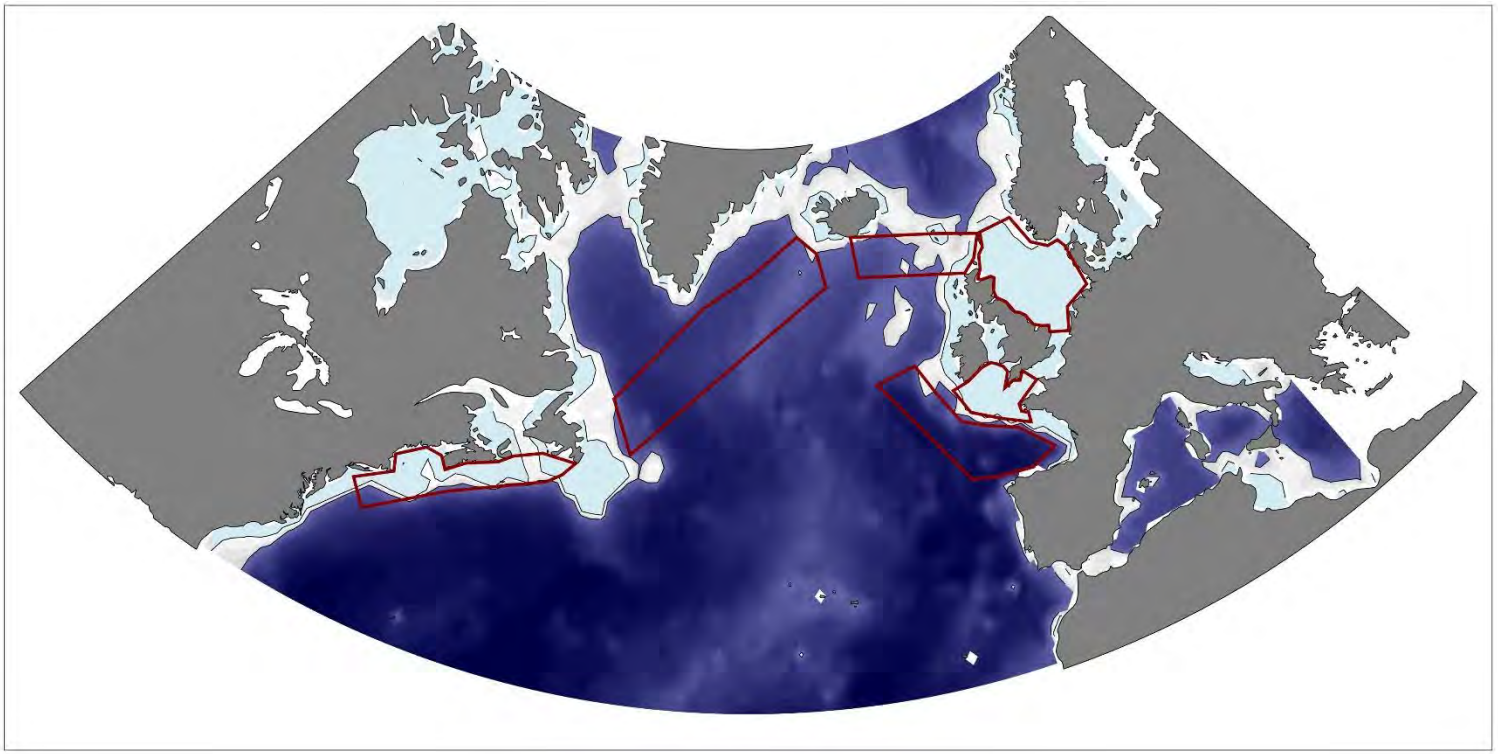
*Target most sampled areas*



# Community analysis with 60 years of planktonic data

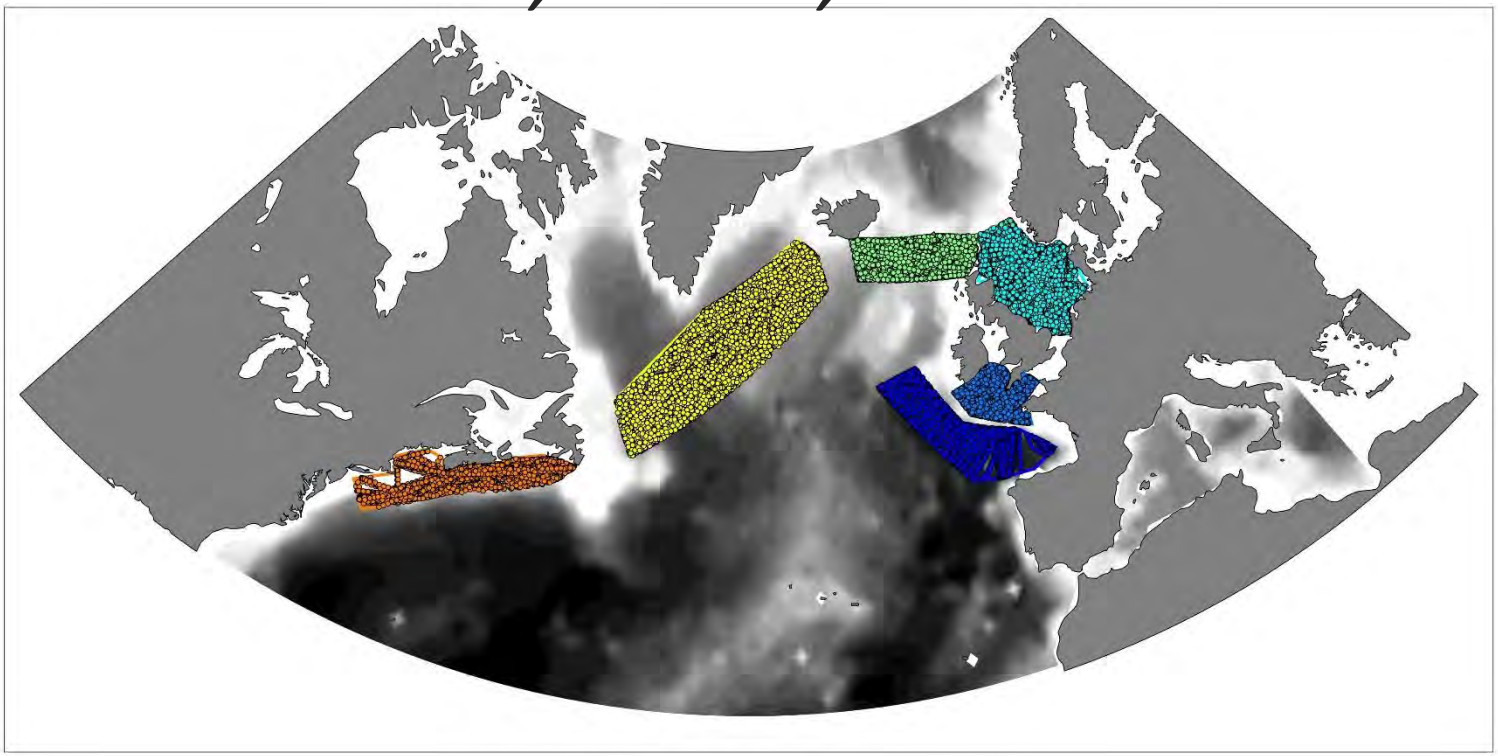
*when, where, whom*

*Target representative areas*



# Community analysis with 60 years of planktonic data

*when, where, whom*



- Area 1: Oceanic: Bay of Biscay: 13689 s.
- Area 2: Neritic: Celtic Sea: 20650 s.
- Area 3: Neritic: North Sea: 60124 s.
- Area 4: Oceanic: SW Island : 19152 s.
- Area 5: Oceanic: S Greenland: 28521 s.
- Area 6: Neritic: E Canada: 13721 s.

# Community analysis with 60 years of planktonic data

*when, where, whom …*

**For each area, all taxa that have a frequency of occurrence > 1%**
**(i.e. present at least once every 100 samples)**

# Community analysis with 60 years of planktonic data

*when, where, whom …* *what?*

**How to characterise the joined dynamic of planktonic taxa?**

**Is it dynamic or dynamics?**

Inter-annual dynamic (long-term)?

Intra-annual dynamic (seasonality)?

**How to disentangle those dynamics?**

Notion of multiscales analysis (dbMEM)

**How to synthesise the dynamic of all taxa?**

Notion of ordination in reduced space (PCA)

# The dynamic in time

*"Everything is related to everything else, but near things are more related to distant things"*

*(First law of geography from Tobler 1970)*

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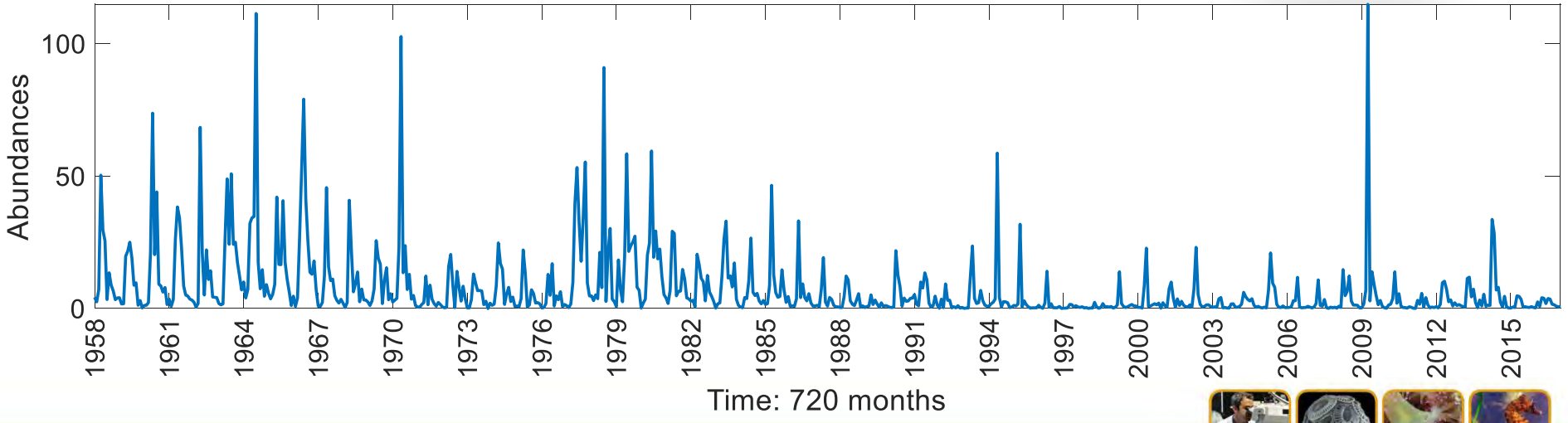
Est. 1931

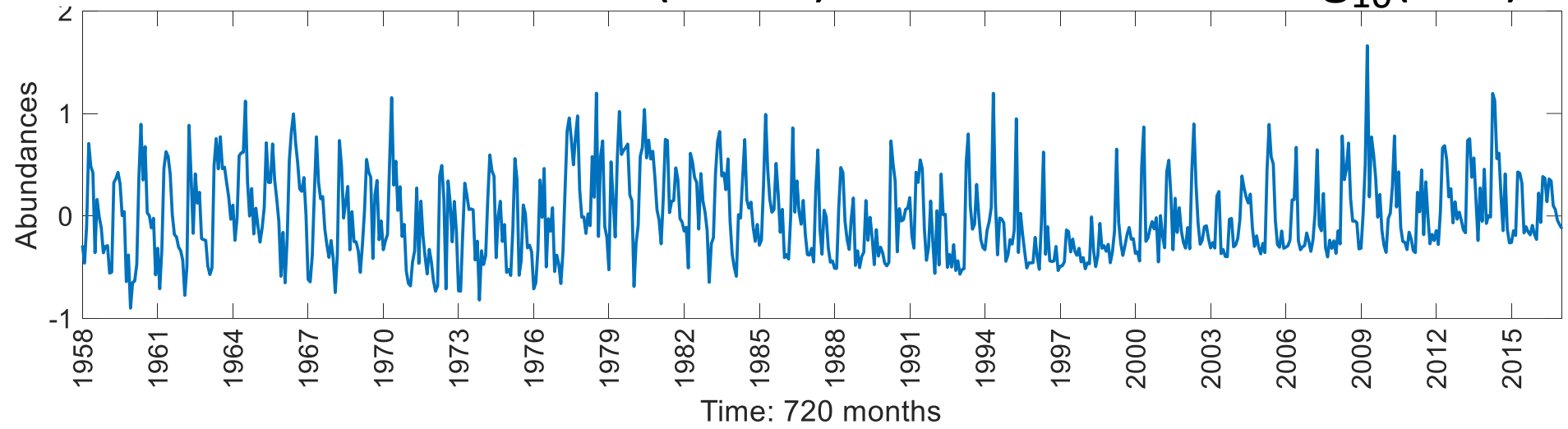
# Notion of multiscales analysis

Example in the North Sea with *Calanus finmarchicus*

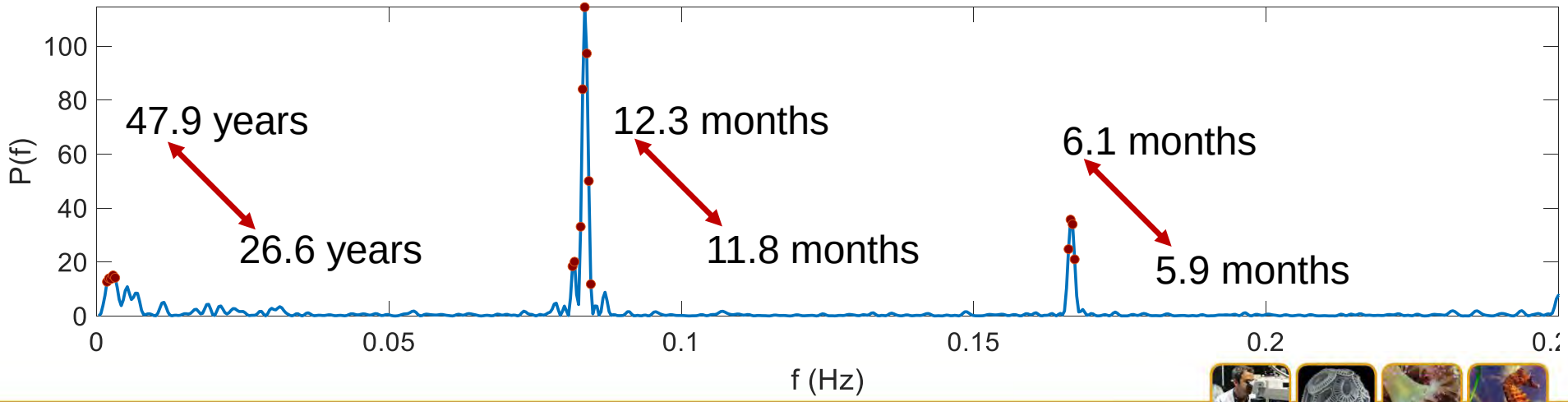



# Notion of multiscales analysis

## Time-series : Detrended (linear) and transformed $\log_{10}(X+1)$




## Lomb normalized periodogram

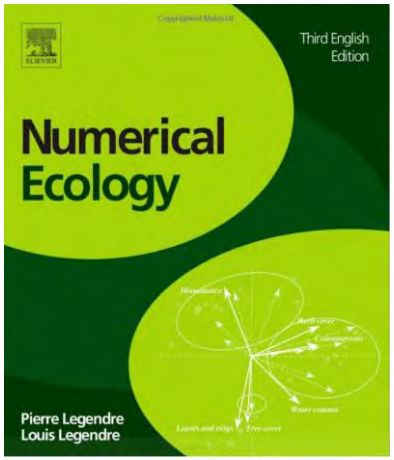



# Notion of multiscales analysis

**How to study the three signals?** **(long-term, seasonal and Infra-seasonal)**

**How to you separate signals?**
**(*Without butchering them…*)**

***The distance-based Moran's Eigenvector maps (dbMEM)***

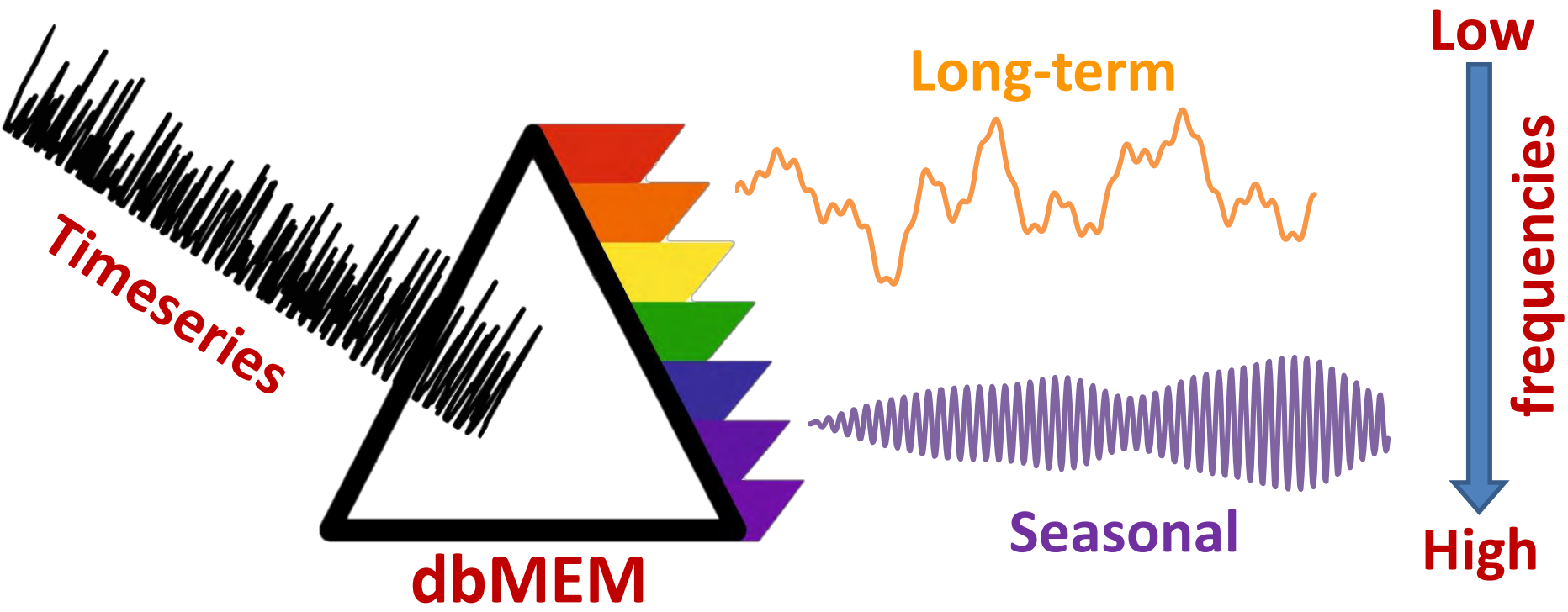



See Numerical Ecology, 3rd Ed, Legendre P. and Legendre L.

Available in R, "adespatial", by Stephane Dray

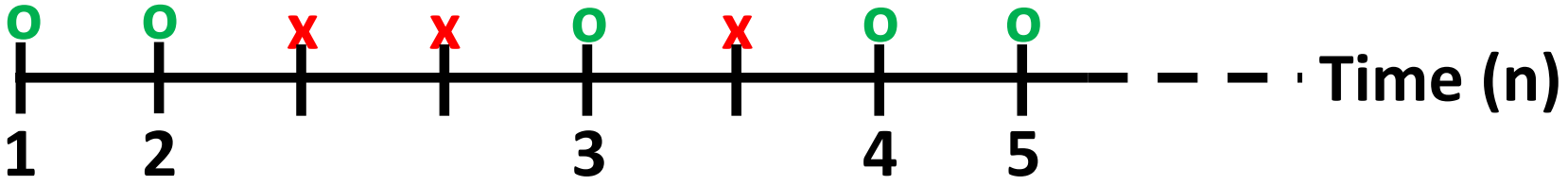
# dbMEM - Concept

What are the temporal scales of variation of the data?



# dbMEM - Method

**1 -** Compute a matrix of temporal distances (sampling effort)




**2 -** Distance matrix truncation (large values replaced)

**3 -** Diagonal replaced (by same threshold value)

**4 -** Principal Coordinate Analysis (PCoA)

Eigenanalysis produced n-1 eigenvalues ≠ 0 (eigenvectors)

some eigenvalues > 0 and some eigenvalues < 0

The temporal eigenfunctions (principal coordinates) model the multiscale relationships among the months.

Relationship represented by a scalogram

# dbMEM - Method

Some quick comments

- *The eigenvectors = called Moran's eigenvectors because they correspond to the Moran's Index of temporal correlation*
- *On regular sampling, half eigenvectors are > 0 and model positive temporal correlations*
- *Based on distance matrix, it allows for missing values*

**4 -** Temporal eigenvectors used as explanatory variables

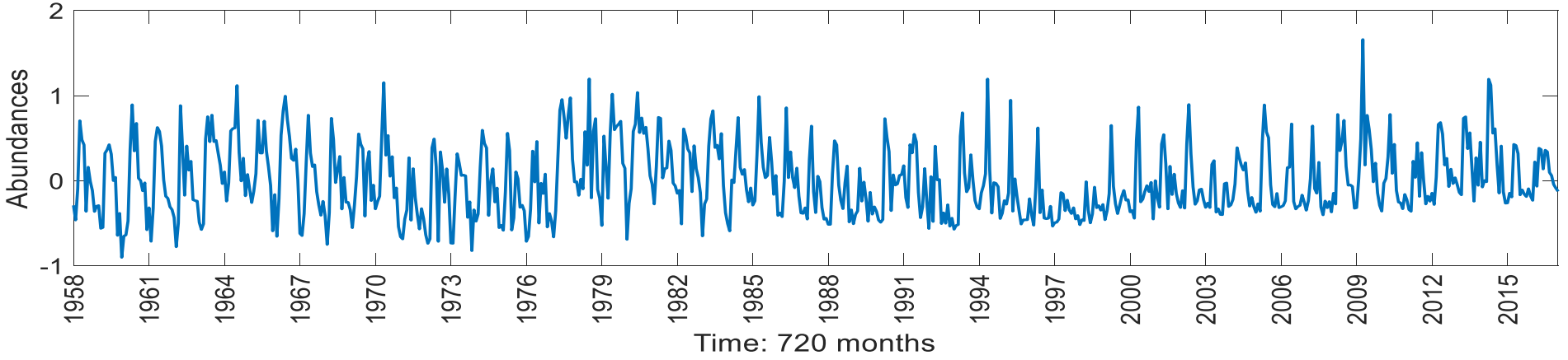
*Multi-regression of taxa timeseries using all eigenvectors > 0*

*Multi-regression with forward selection (AIC or BIC)*

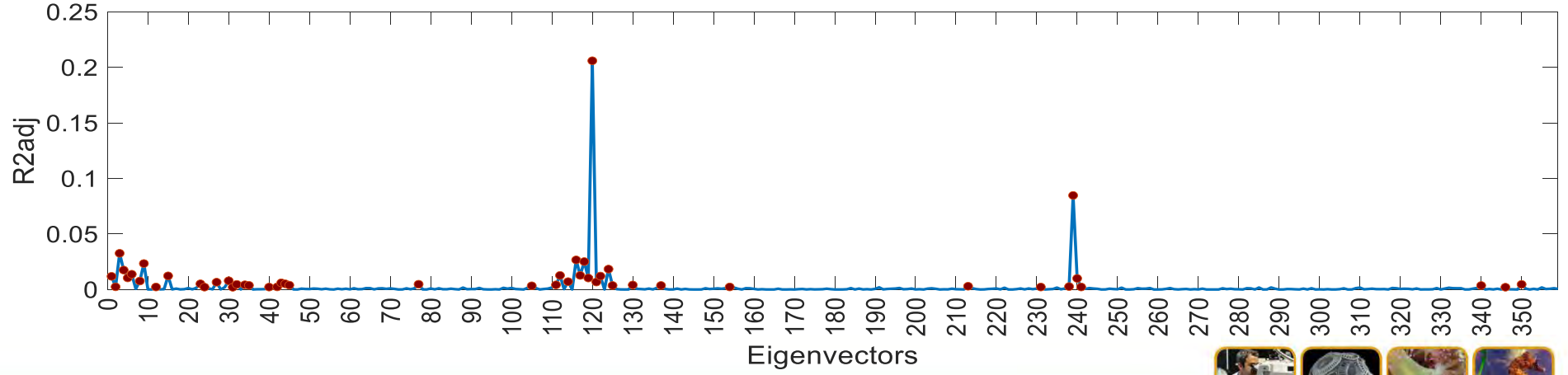
**Multiregression model using subset of Eigenvectors**

# dbMEM - Example - Scalogram

## Timeseries: Detrended and log10(X+1)

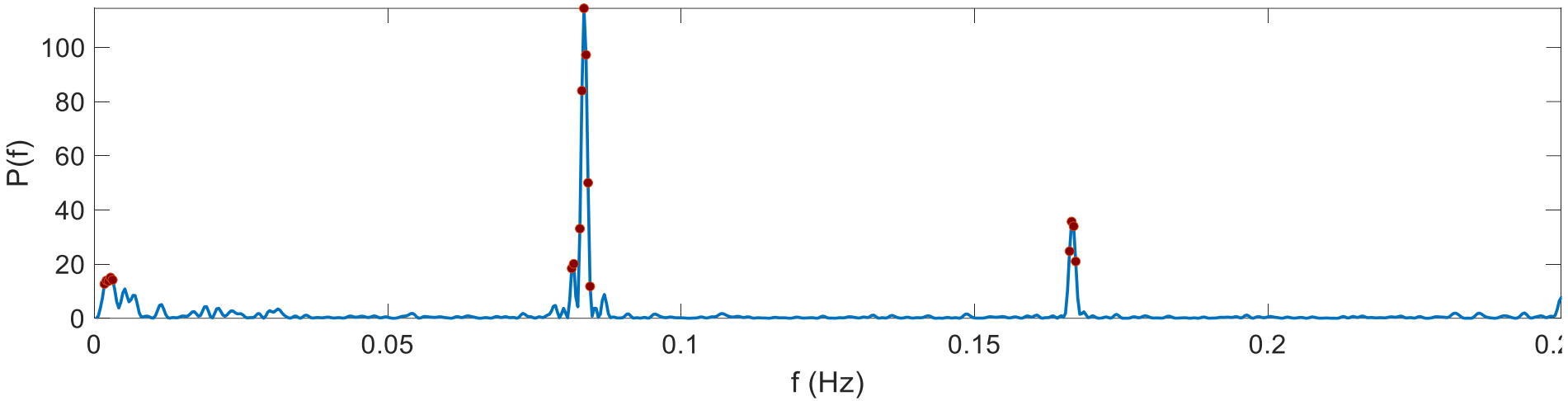



## Scalogram: Eigenvectors Versus Variance explained ($R^2$adj)

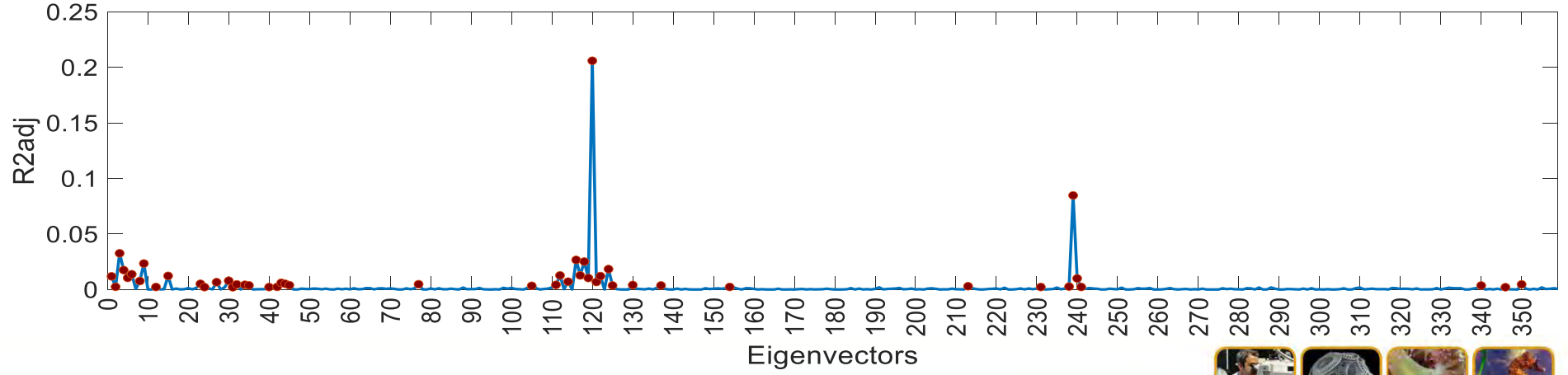



# dbMEM - Example - Scalogram

## Lomb normalized periodogram

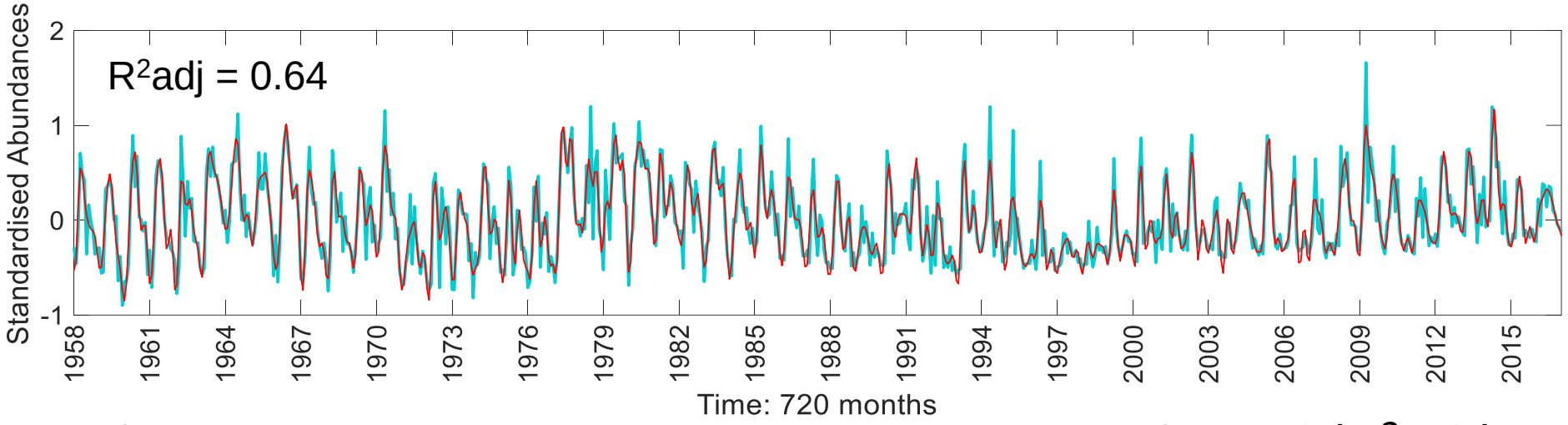



## Scalogram: Eigenvectors Versus Variance explained ($R^2$adj)

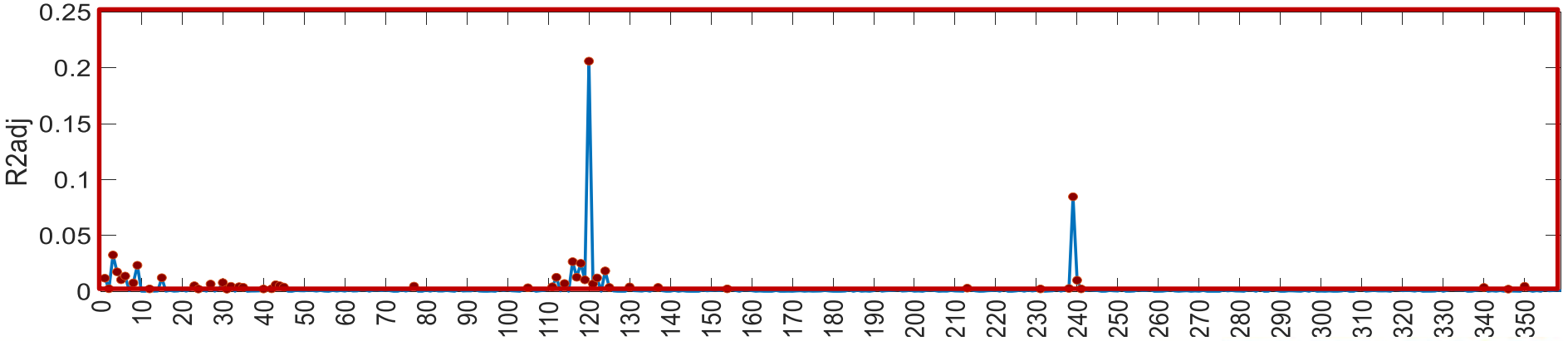



# dbMEM – Example - Multiregression

## Model using all significant positive eigenvectors (AS model)

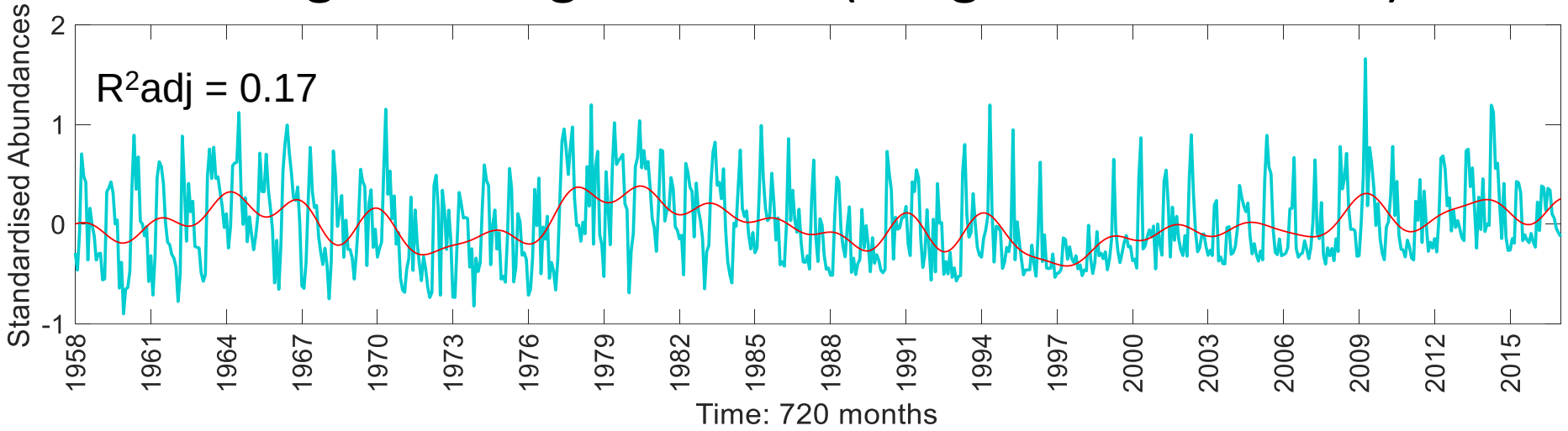



## Scalogram: Eigenvectors Versus Variance explained ($R^2$adj)

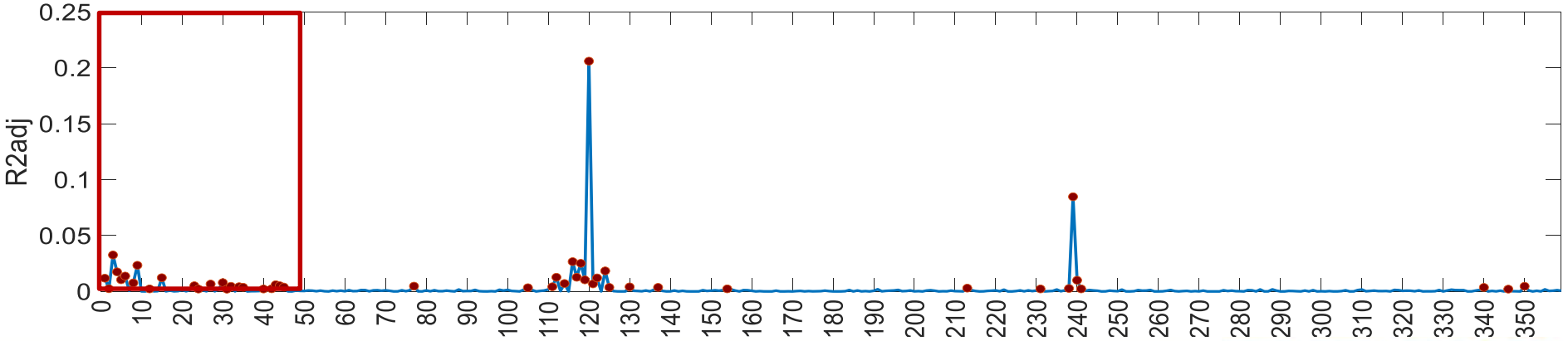



# dbMEM - Example - Multiregression

## Model using some eigenvectors (Long-term: LS model)

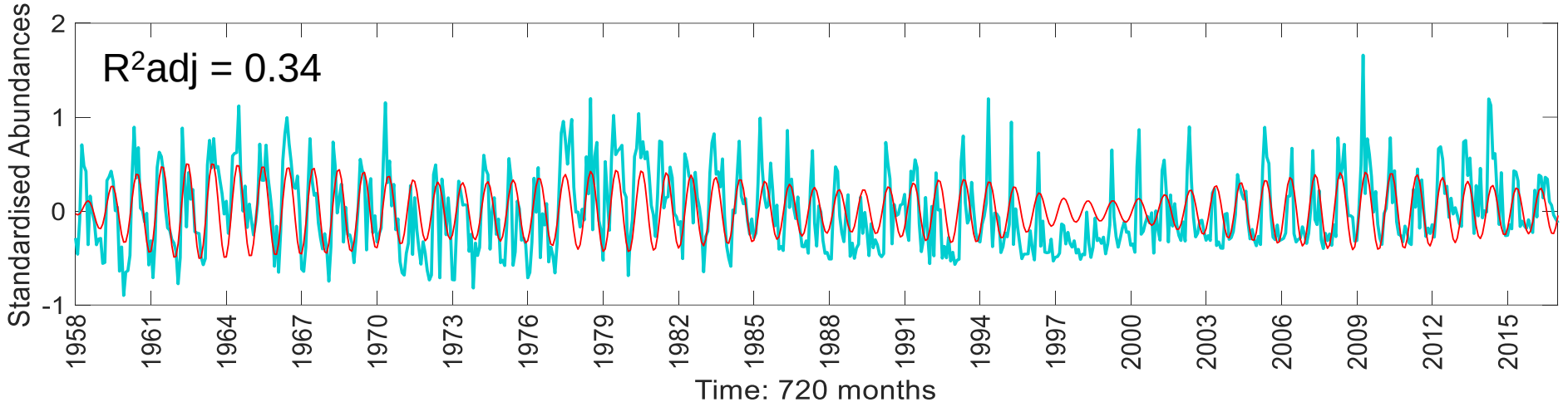



## Scalogram: Eigenvectors Versus Variance explained ($R^2adj$)

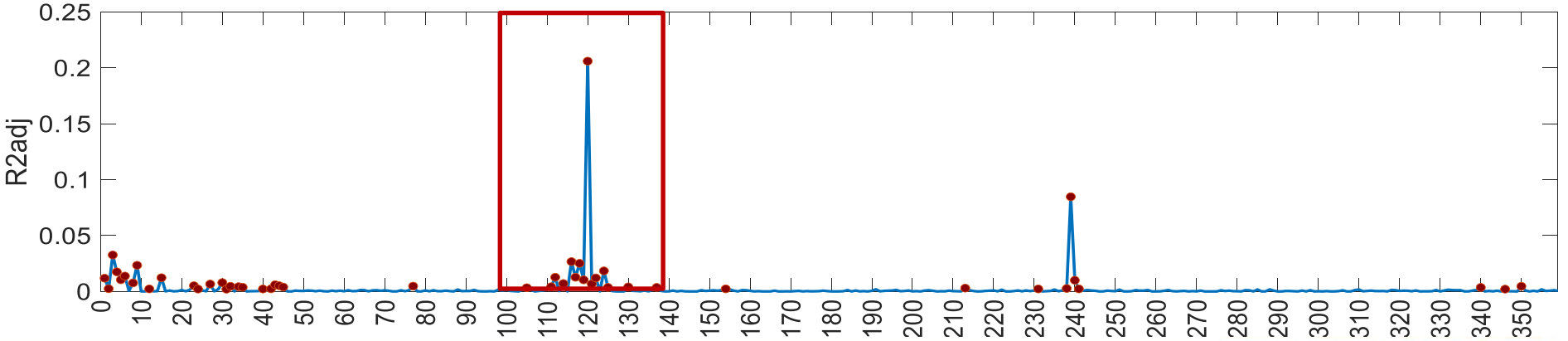



# dbMEM - Example - Multiregression

## Model using some eigenvectors (Seasonal: SS model)

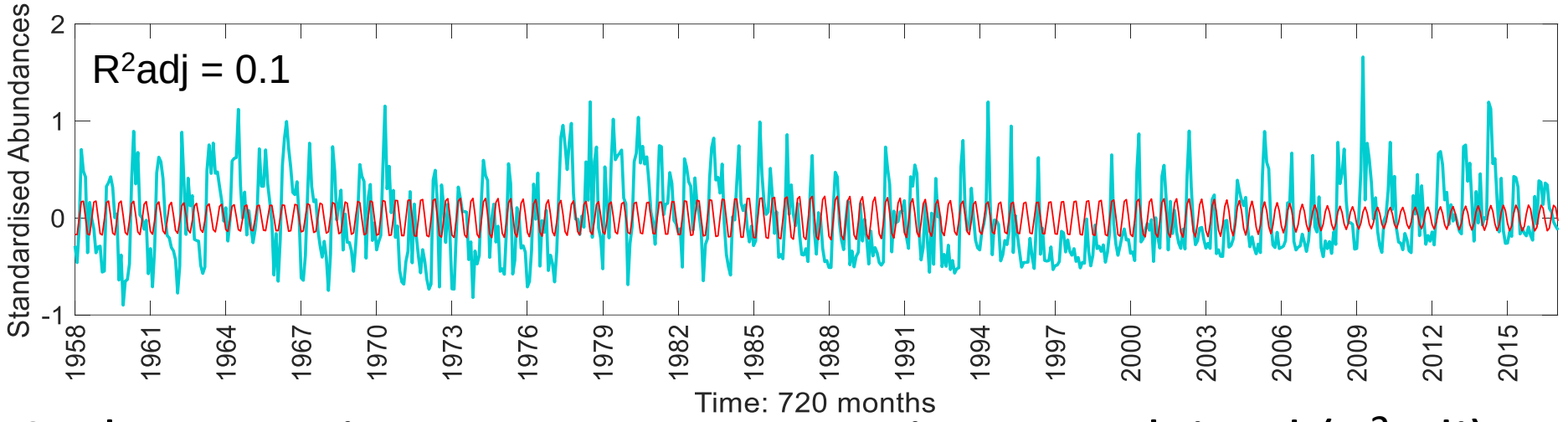



## Scalogram: Eigenvectors Versus Variance explained ($R^2adj$)

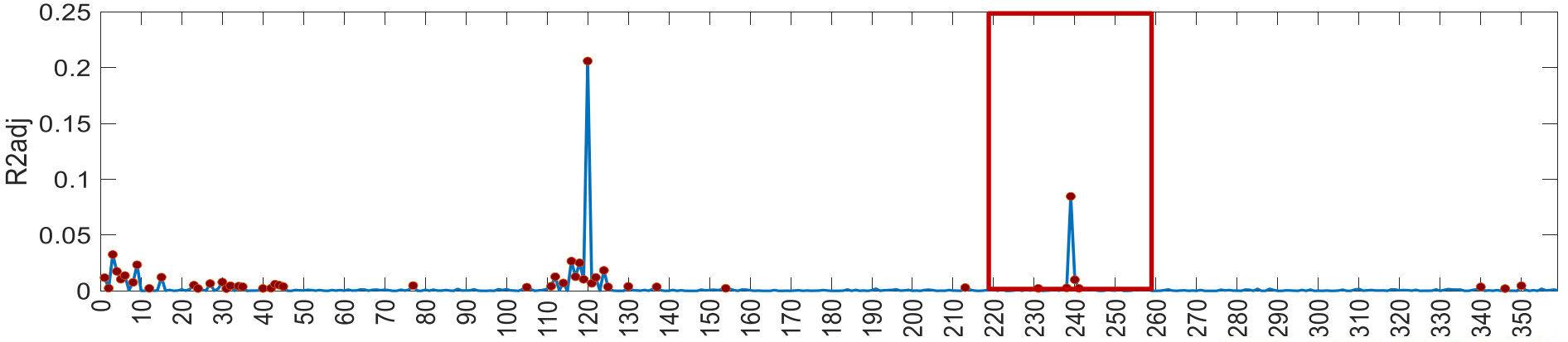



# dbMEM - Example - Multiregression

## Model using some eigenvectors (Infra-Seasonal: IS model)




## Scalogram: Eigenvectors Versus Variance explained ($R^2adj$)




# dbMEM - Synthesis

*Per Area, an average of 33 Zooplankton taxa and 27 phytoplankton were modelled*

*For each area, each selected taxa is modelled 4 times:*

*Using All Scales (AS model)*

*Using Large Scales (LS model)*

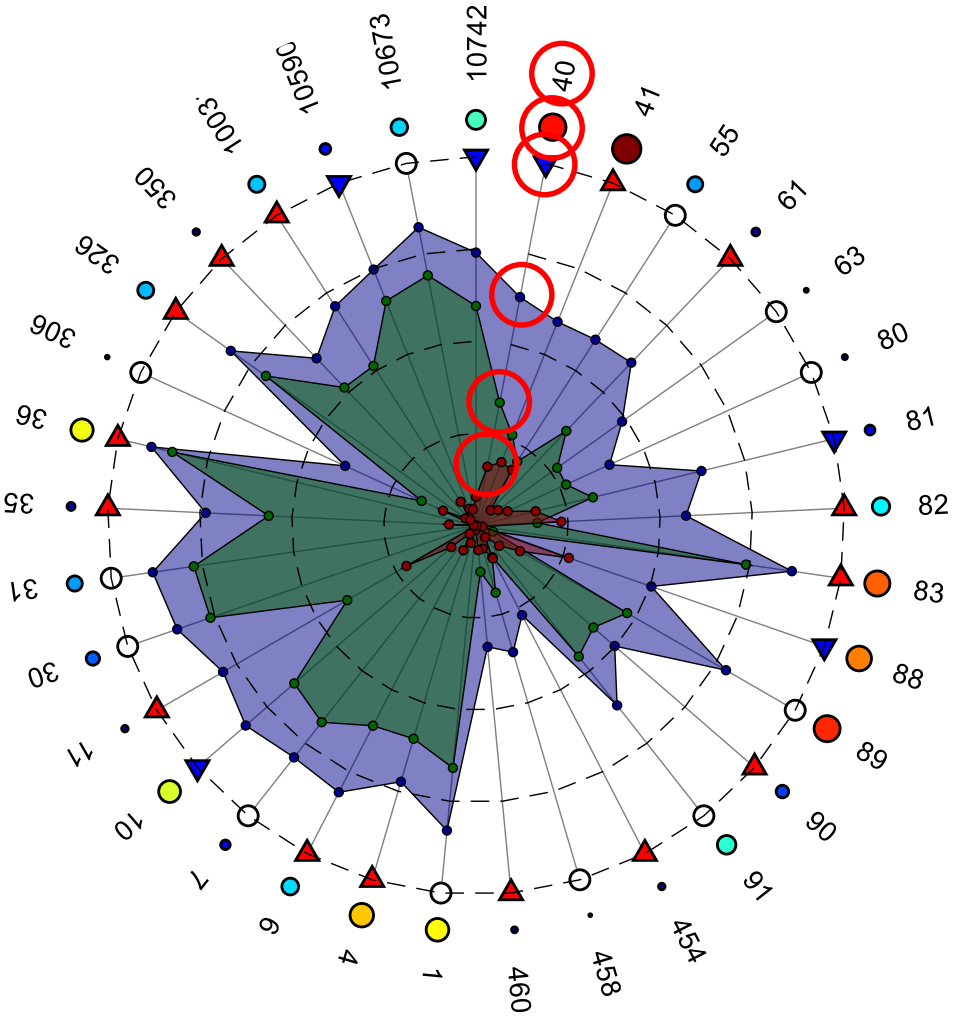
*Using Seasonal Scales (SS model)*

*Using Infra-seasonal Scales (IS model)*

*A lot of models….*

# dbMEM - Synthesis

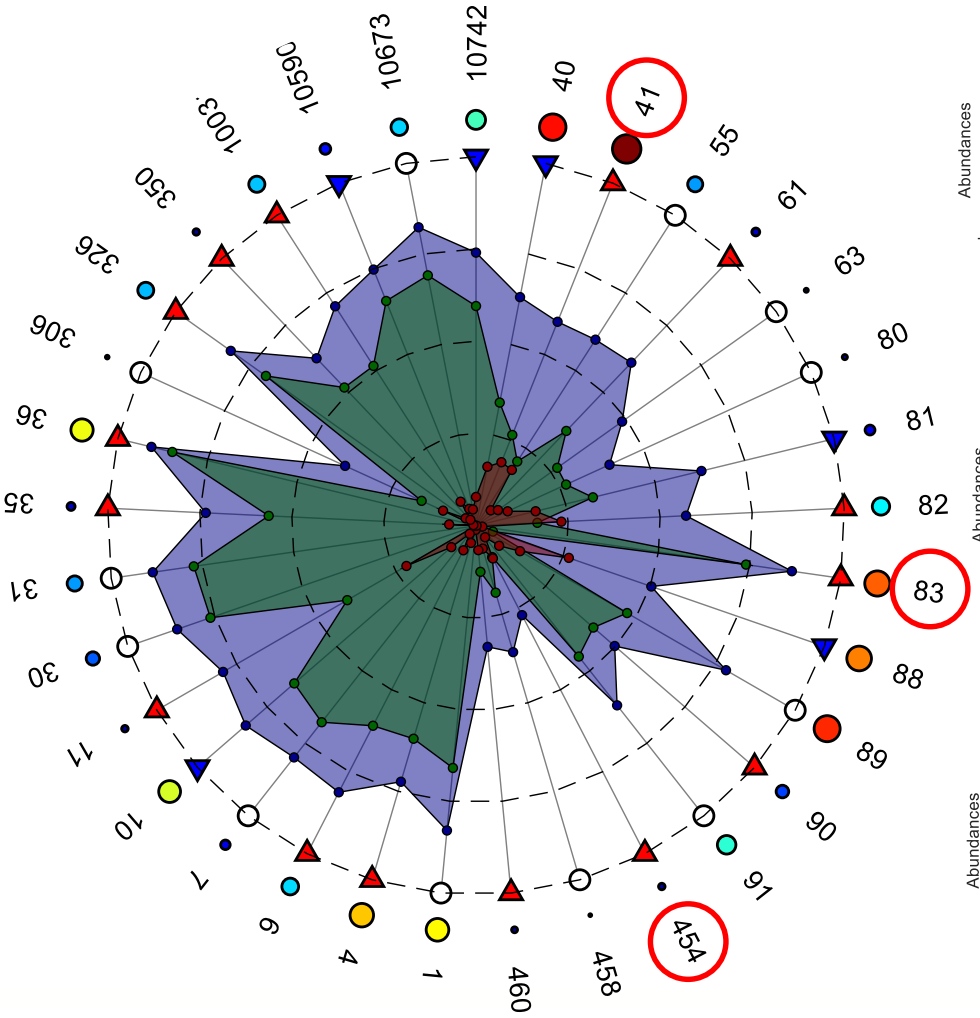
## Model results: North Sea zooplankton



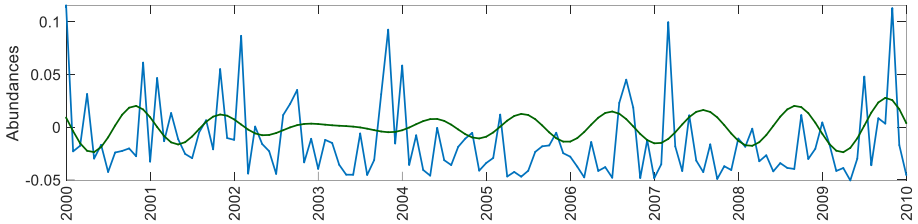

| ID | Name | Linear trend | R2adj | As model | LS model | SS model |
|---|---|---|---|---|---|---|
| 40 | 'Calanus finmarchicus' | -0.000981 | 0.196226 | 0.630968 | 0.16293 | 0.339909 |
| 41 | 'Calanus helgolandicus' | 0.0006961 | 0.188793 | 0.59537 | 0.1854 | 0.264933 |
| 55 | 'Metridia lucens' | NaN | NaN | 0.599386 | 0.179795 | 0.207012 |
| 61 | 'Candacia armata' | 7.91E-05 | 0.096735 | 0.610654 | 0.057792 | 0.354949 |
| 63 | 'Labidocera wollastoni' | NaN | NaN | 0.486554 | 0.073149 | 0.270483 |
| 80 | 'Tomopteris spp.' | NaN | NaN | 0.398159 | 0.094325 | 0.268601 |
| 81 | 'Gammaridea' | -8.64E-05 | 0.027483 | 0.629351 | 0.166413 | 0.326414 |
| 82 | 'Hyperiidea (Total)' | 9.47E-05 | 0.018976 | 0.570491 | 0.231904 | 0.166512 |
| 83 | 'Decapoda larvae (Total)' | 0.00036 | 0.036349 | 0.865806 | 0.017211 | 0.740144 |
| 88 | 'Euphausiacea Total' | -0.000495 | 0.176496 | 0.503362 | 0.266443 | 0.048398 |
| 89 | 'Chaetognatha eyecount' | NaN | NaN | 0.783141 | 0.137834 | 0.473323 |
| 90 | 'Fish eggs (Total)' | 0.0001424 | 0.041961 | 0.497794 | 0.082937 | 0.421352 |
| 91 | 'Fish larvae' | NaN | NaN | 0.619208 | 0.039599 | 0.451033 |
| 454 | 'Cumacea' | 7.56E-05 | 0.081331 | 0.27261 | 0.0997 | 0.09557 |
| 458 | 'Mysidacea' | NaN | NaN | 0.357028 | 0.064639 | 0.189019 |
| 460 | 'Echinoderm post larvae' | 8.66E-05 | 0.055199 | 0.329753 | 0.066517 | 0.12556 |
| 1 | 'Calanus I-IV' | NaN | NaN | 0.829726 | 0.011195 | 0.659402 |
| 4 | 'Temora longicornis' | 0.0005905 | 0.041723 | 0.72313 | 0.048592 | 0.601644 |
| 6 | 'Centropages typicus' | 0.0011567 | 0.122071 | 0.812716 | 0.07492 | 0.609835 |
| 7 | 'Centropages hamatus' | NaN | NaN | 0.798762 | 0.027821 | 0.677465 |
| 10 | 'Oithona spp.' | -0.000914 | 0.118204 | 0.826813 | 0.088588 | 0.652497 |
| 11 | 'Corycaeus spp.' | 0.0005446 | 0.061339 | 0.792484 | 0.218027 | 0.403403 |
| 30 | 'Podon spp.' | NaN | NaN | 0.858051 | 0.001106 | 0.762493 |
| 31 | 'Evadne spp.' | NaN | NaN | 0.886122 | -0.00146 | 0.773644 |
| 35 | 'Cyphonautes' | 0.0003236 | 0.021524 | 0.734255 | 0.073002 | 0.56318 |
| 36 | 'Echinoderm larvae' | 0.0009124 | 0.025637 | 0.906241 | 0.007341 | 0.848038 |
| 306 | 'Harpacticoida Total Traverse' | NaN | NaN | 0.390505 | 0.098305 | 0.162297 |
| 326 | 'Copepod nauplii' | 0.0004473 | 0.026546 | 0.816888 | 0.034655 | 0.69985 |
| 350 | 'Cirripede larvae (Total)' | 0.0003506 | 0.02309 | 0.627052 | 0.022196 | 0.517587 |
| 10031 | 'Appendicularia' | 0.0007937 | 0.09438 | 0.70692 | 0.077408 | 0.514816 |
| 10590 | 'Bivalvia larvae' | -0.000712 | 0.046938 | 0.747811 | 0.049357 | 0.65609 |
| 10673 | 'Thecosomata (North Atlantic)' | NaN | NaN | 0.823758 | 0.044899 | 0.690965 |
| 10742 | 'Pseudocalanus spp. adult Total' | -0.000519 | 0.034494 | 0.740177 | 0.078091 | 0.595414 |

# dbMEM – Synthesis

## AS Model (all scales) results: North Sea zooplankton

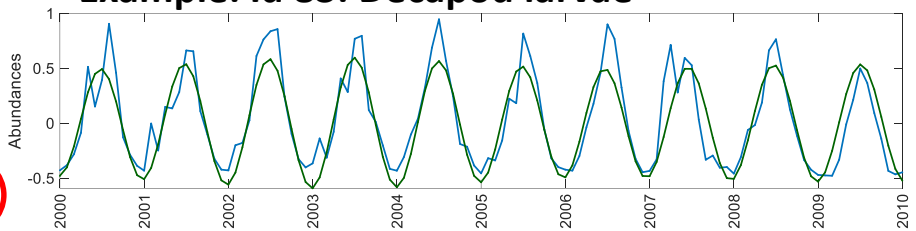



**Example: Id 454: Cumacea**



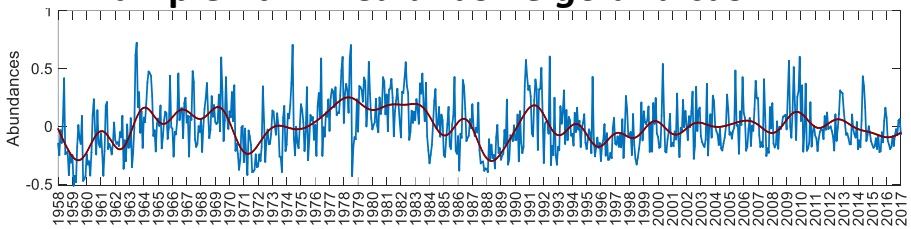

**Weak model: because stochasticity**

**Example: Id 83: Decapod larvae**




**Strong model: clean seasonality**

**Example: Id 41: *Calanus helgolandicus***




**Strong model: clear longterm signal**

# The community analysis

*Ordination in reduced space*

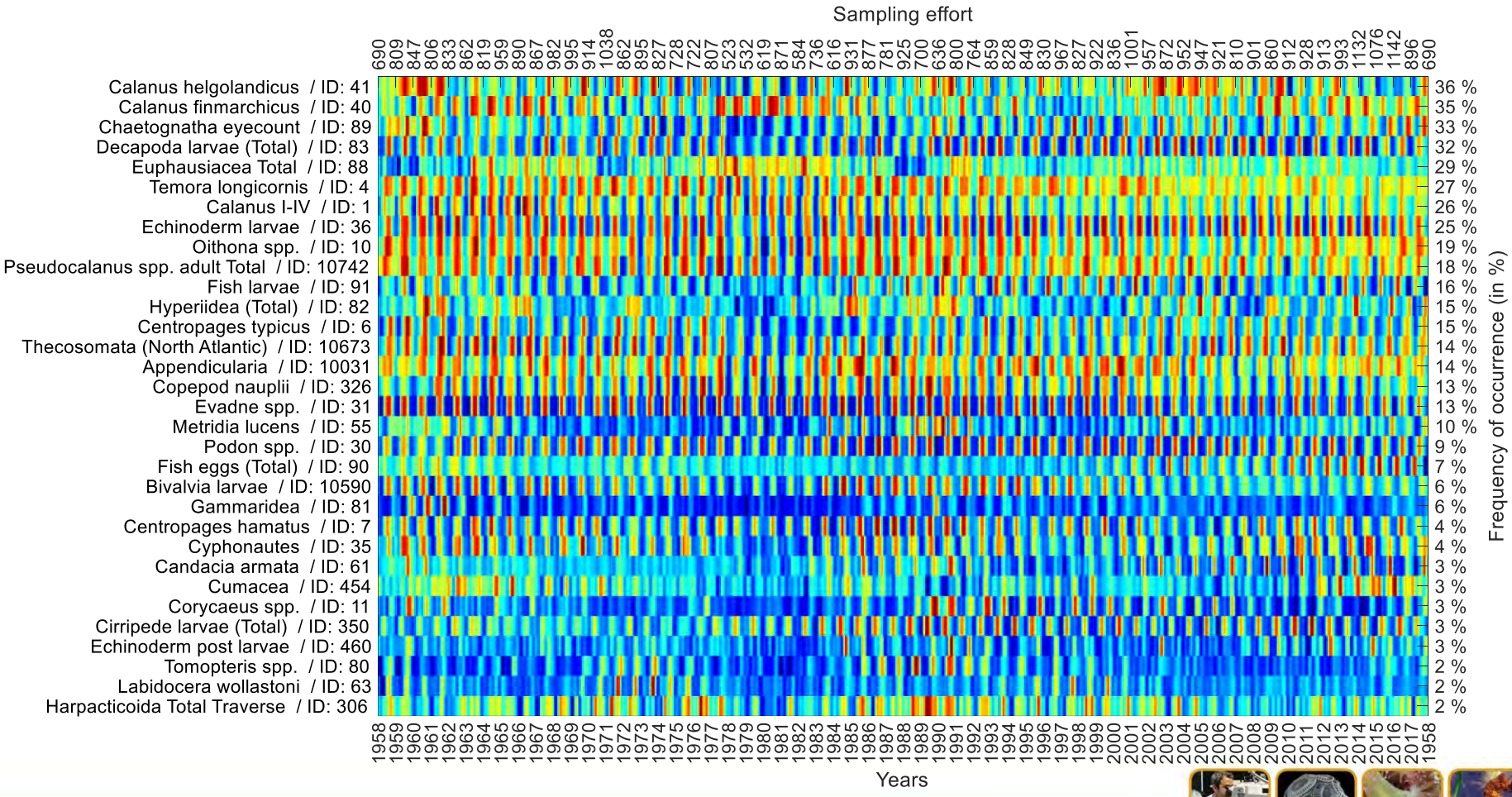
Est. 1884
Incorporated by
Royal Charter

Est. 1931

# The community analysis

## How to characterise the joined dynamic of planktonic taxa?

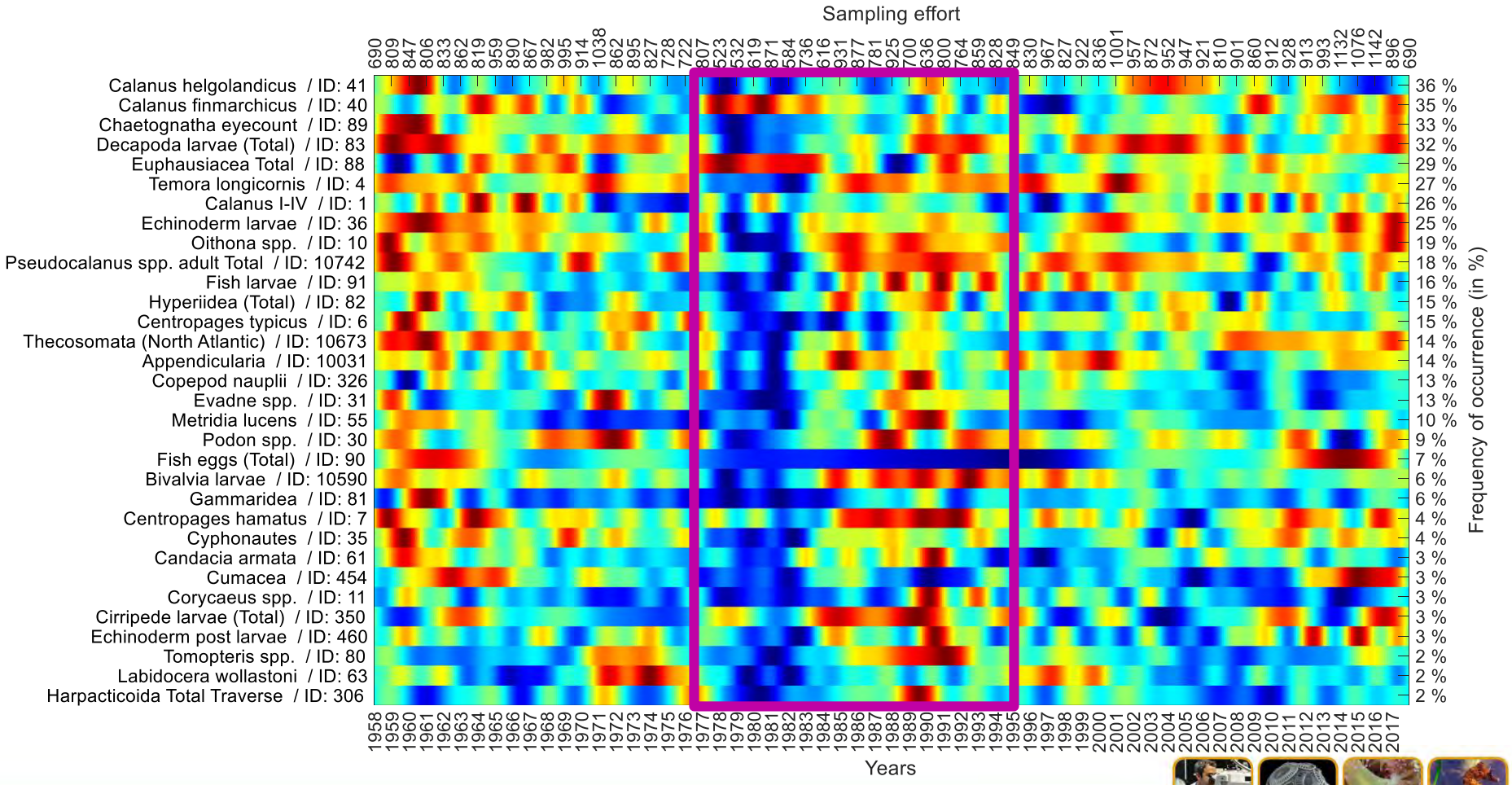
### All Raw timeseries: dynamic too complex to describe




# The community analysis

## How to characterise the joined dynamic of planktonic taxa?

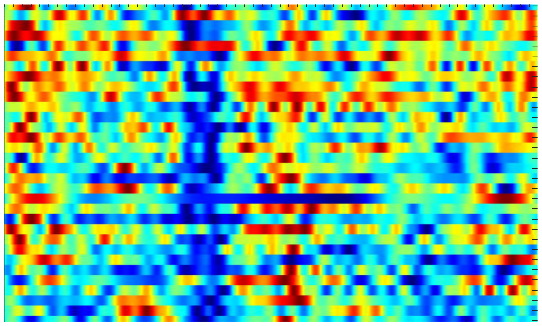
## All LS timeseries: long-term dynamic is (much) clearer



# The community analysis

How to characterise the joined dynamic of planktonic taxa?

All LS timeseries: long-term dynamic is (much) clearer



**Principal Component Analysis**

**(PCA)**

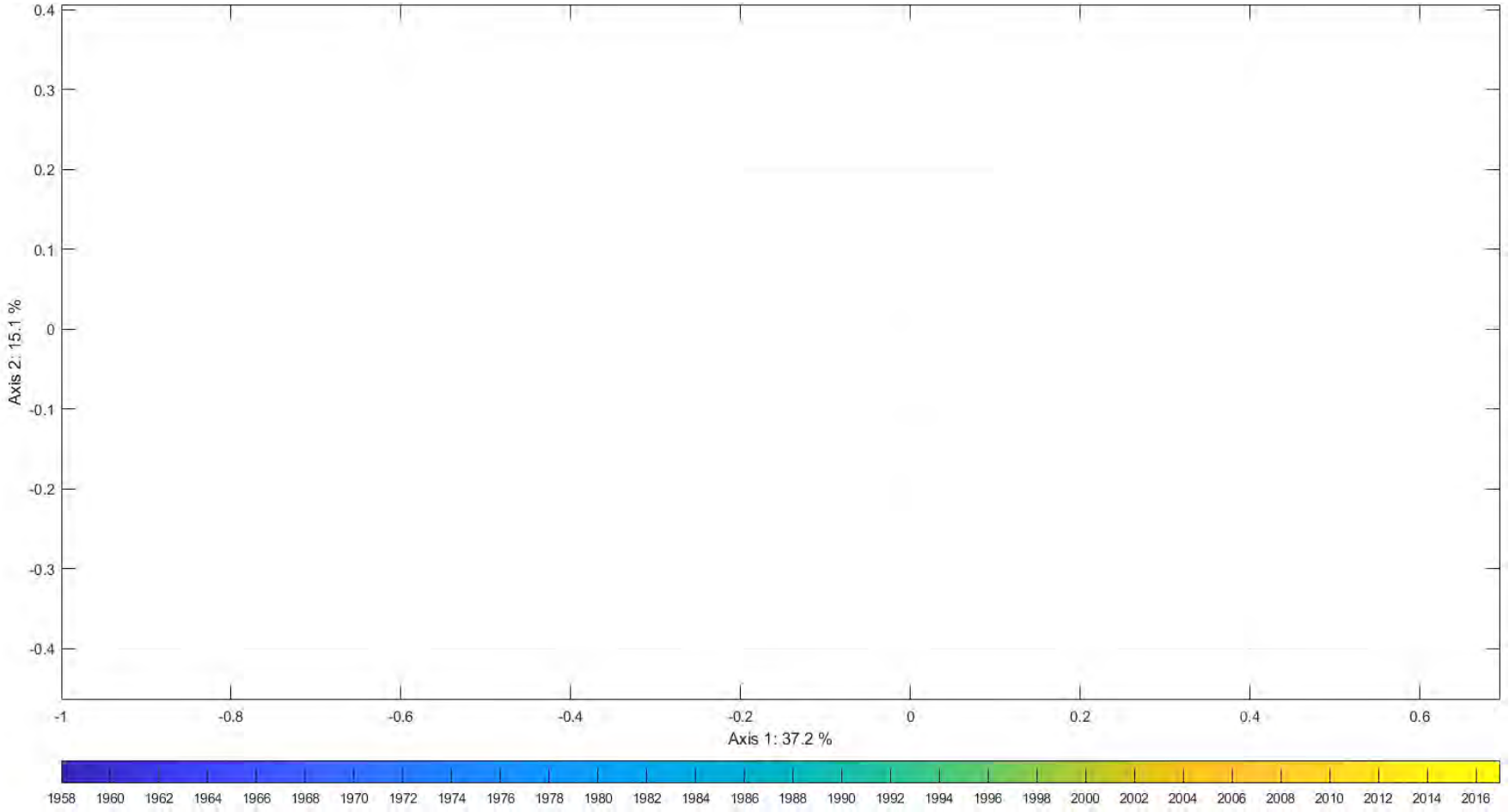
**Reduce a multidimensional array in 2D**

*Knowing how much variance is contained in each PC*

*Knowing which taxa contribute to each PC*

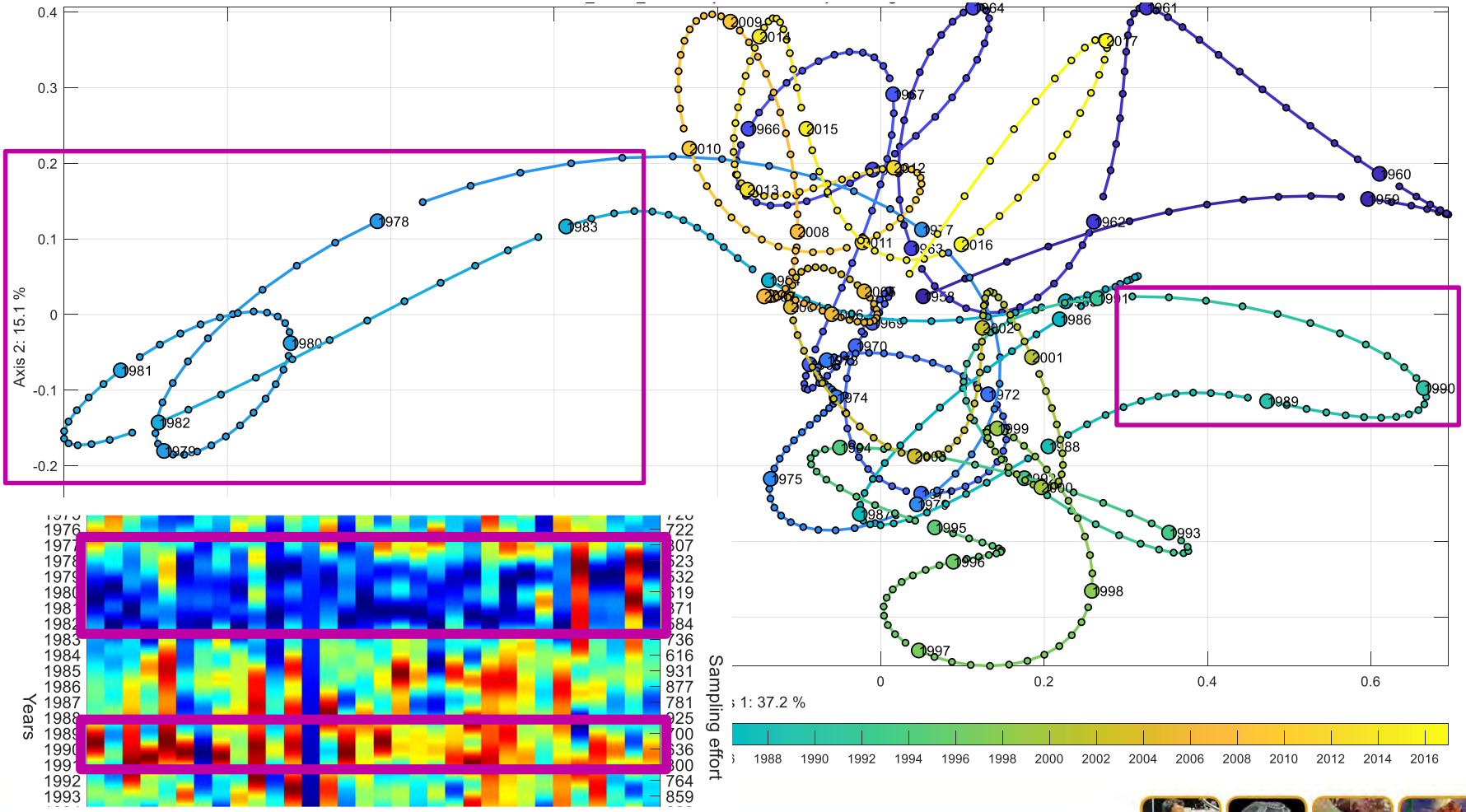
# The community analysis

## The long-term dynamic of zooplankton (33) in the North Sea



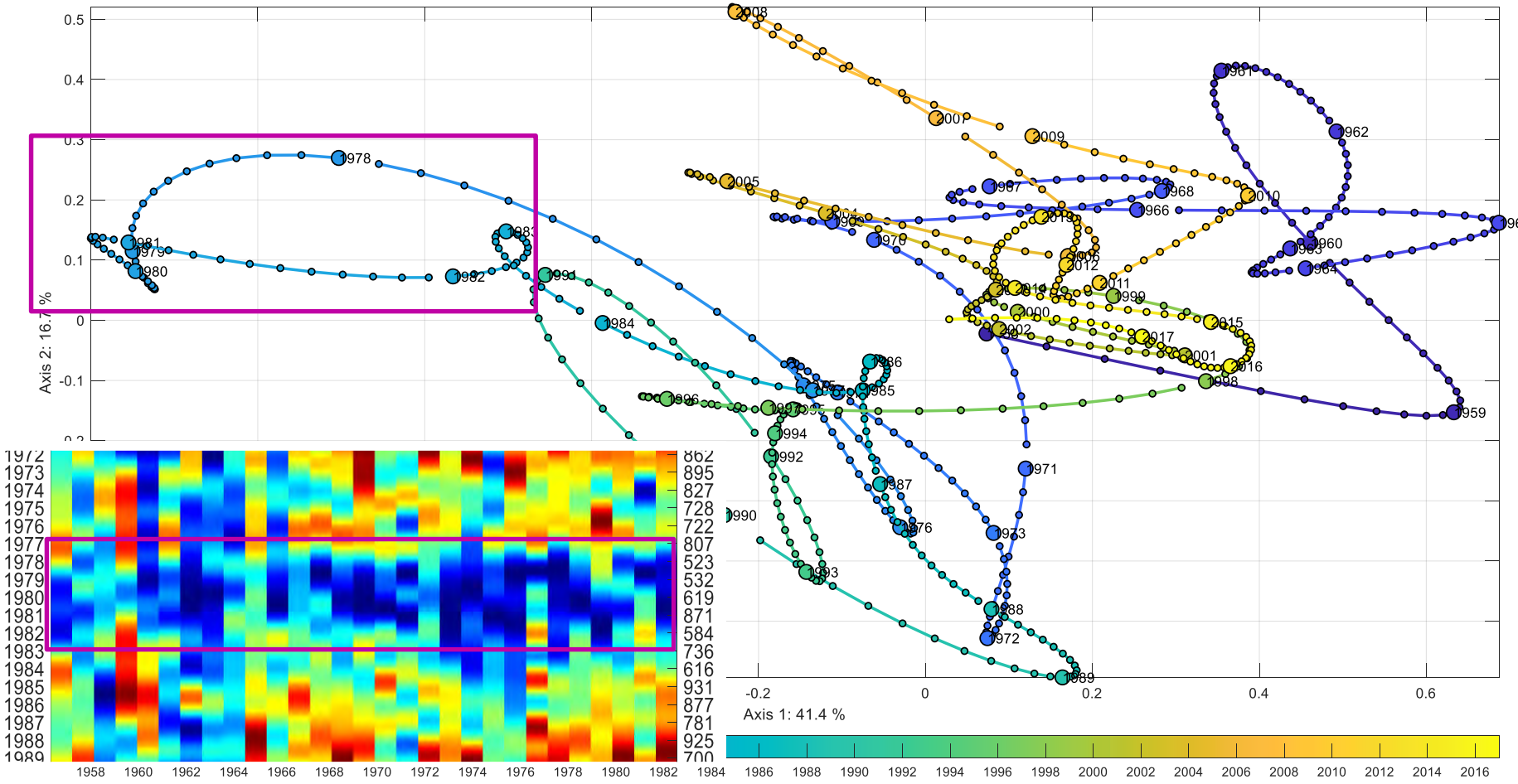
# The community analysis

## The log-term dynamic of zooplankton (33) in the North Sea



# The community analysis

## The long-term dynamic of phyto- (30) in the North Sea



# The community analysis

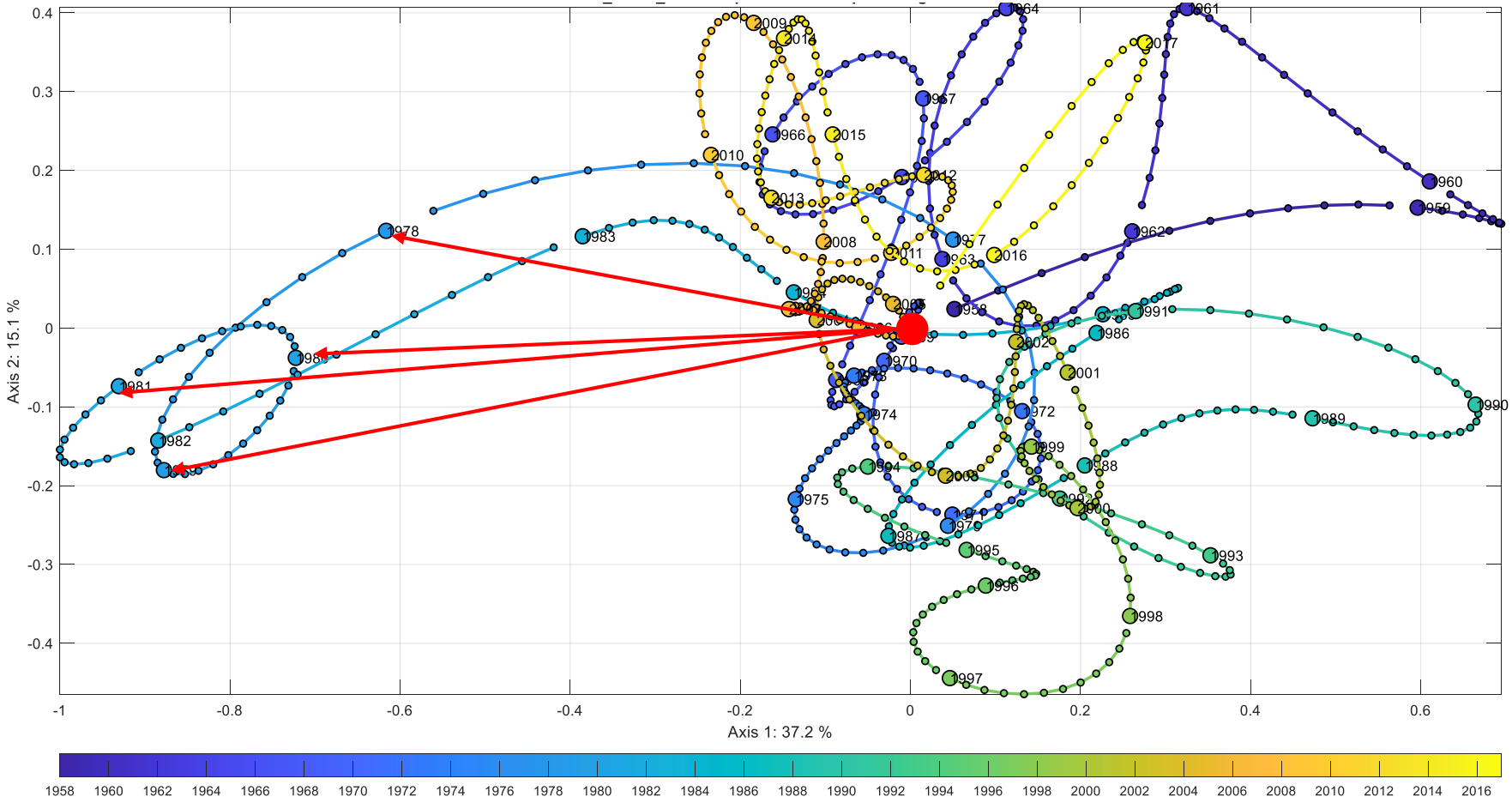
*The Community Stability Index (CSI)*

Est. 1884
Incorporated by
Royal Charter

Est. 1931

# The Community Stability Index (CSI)

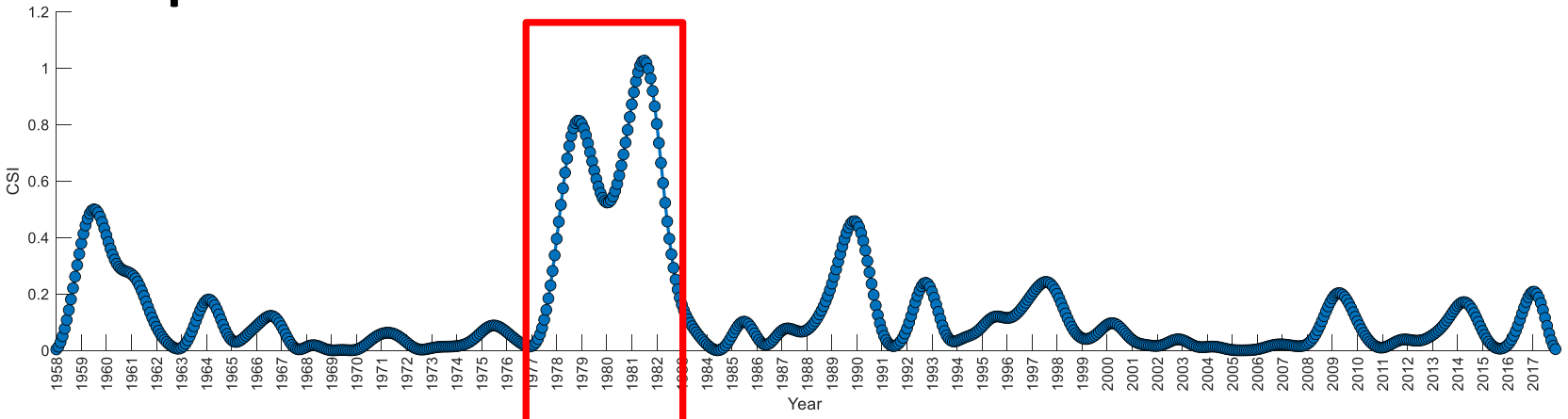
## The log-term dynamic of zooplankton (33) in the North Sea



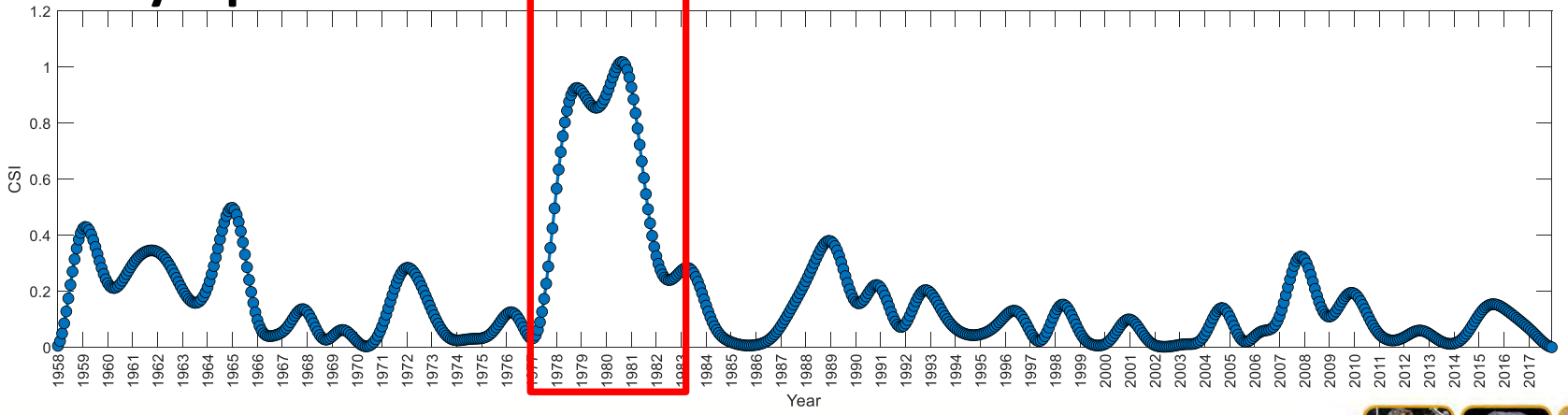
# The Community Stability Index (CSI)

From the PCA, distance to centroid for each month

## Zooplankton in the North Sea

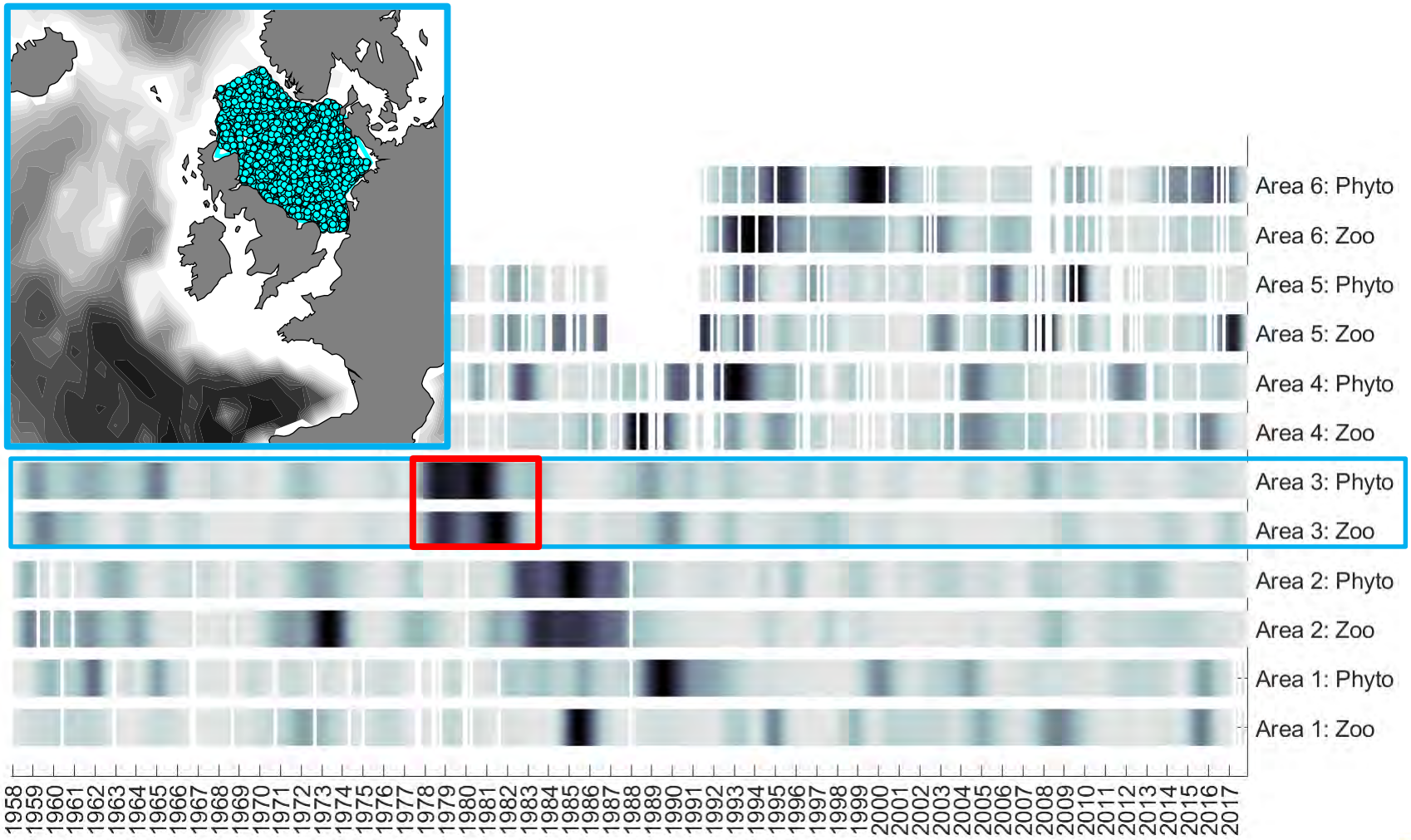



## Phytoplankton in the North Sea



# The Community Stability Index (CSI)

## Long-term CSI: Zoo- + Phyto- plankton, all areas



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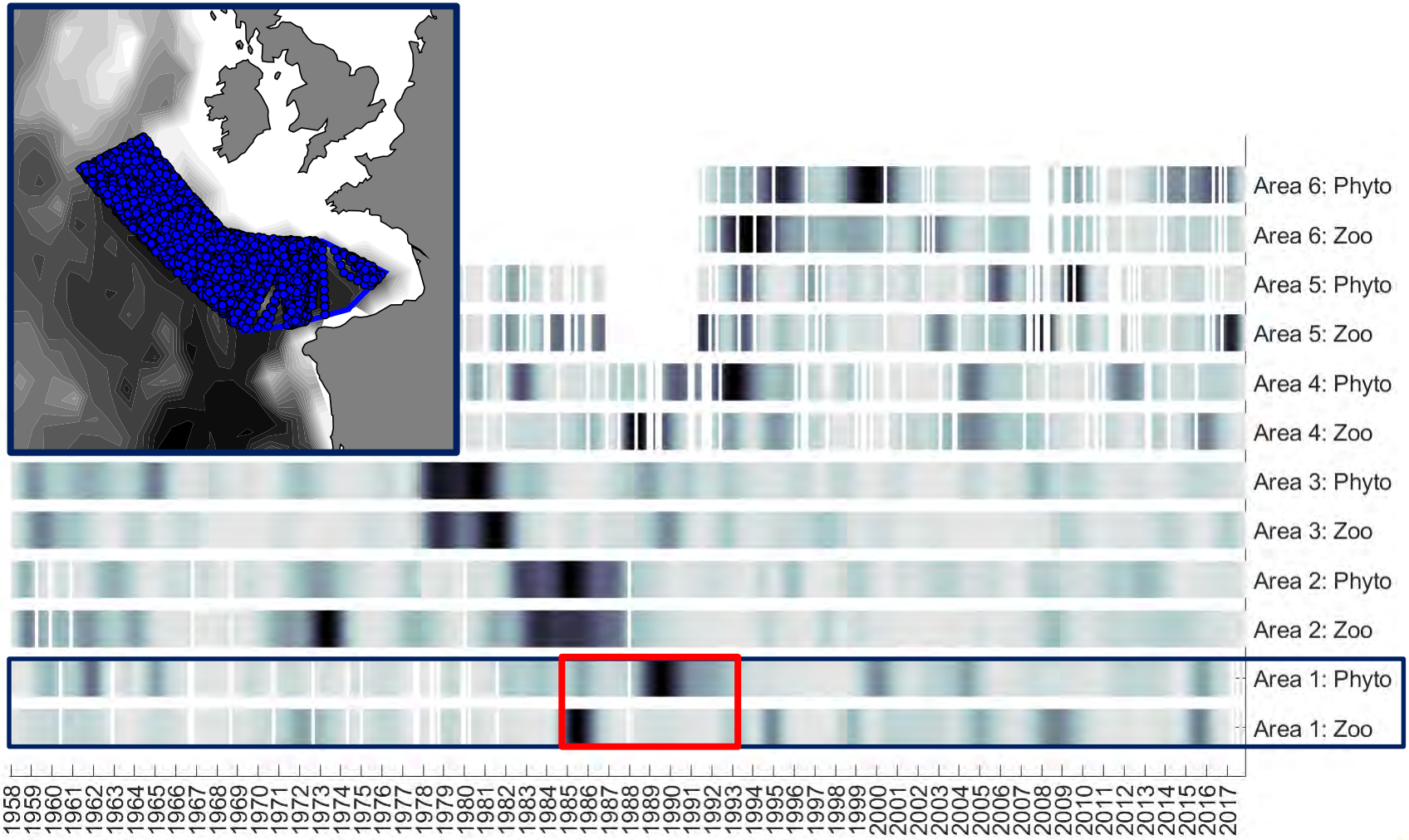

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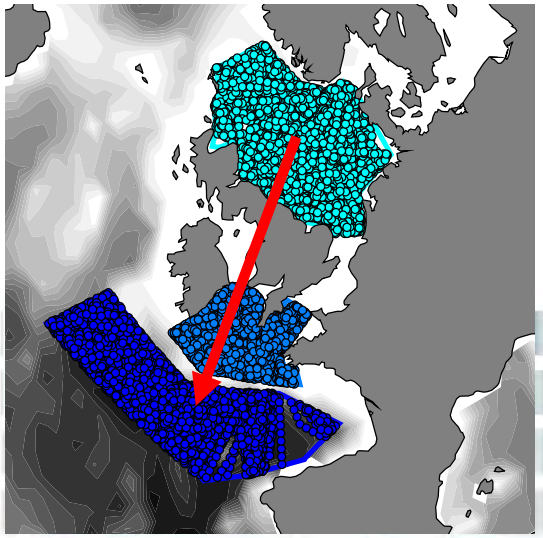


**Propagation of instability?**




# The community analysis

*The Community Stability Index (CSI)*

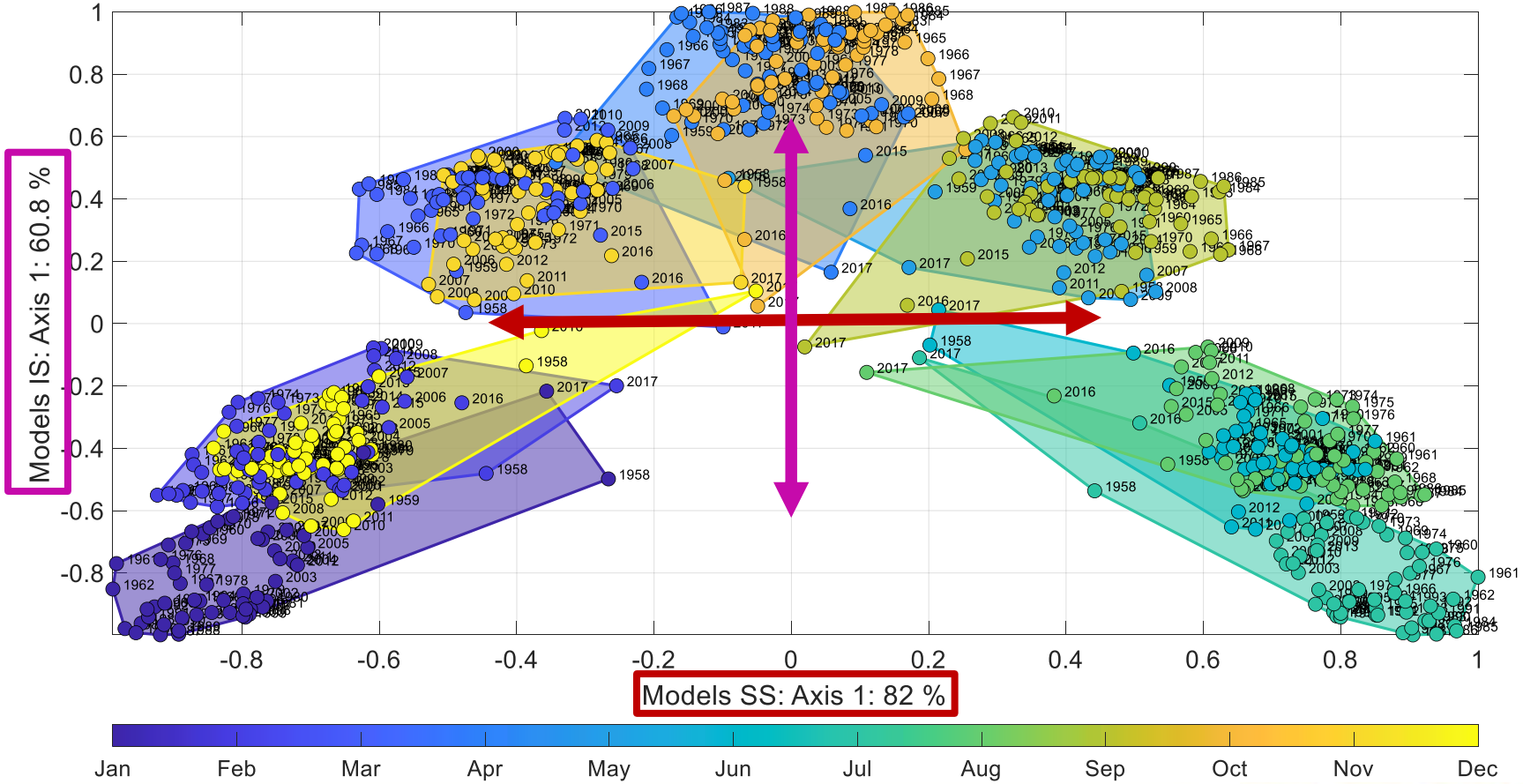
*"Seasonal CSI"*

Est. 1884
Incorporated by
Royal Charter

Est. 1931

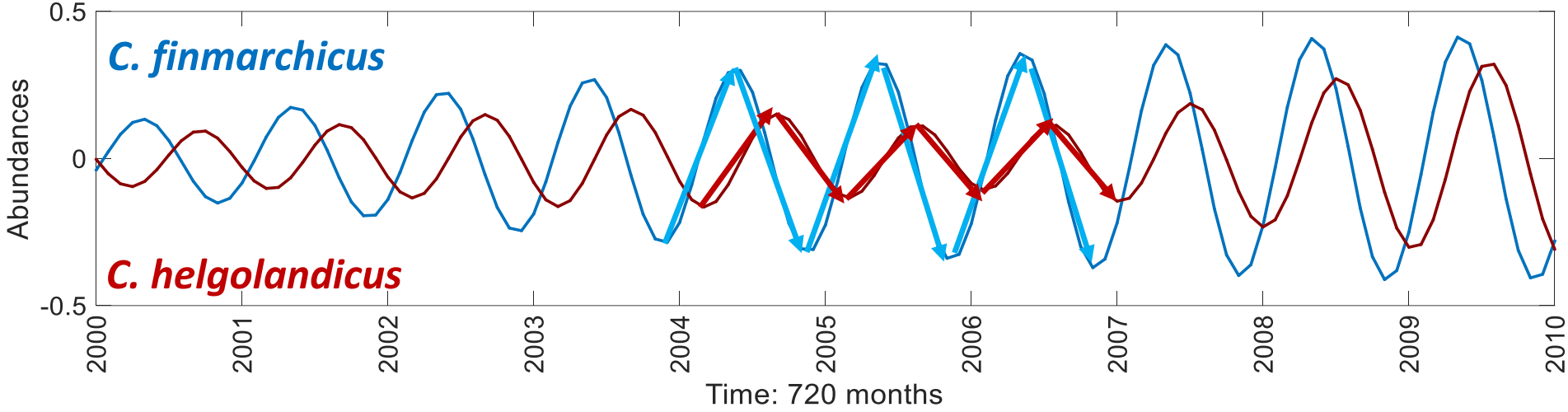
# The community analysis: Seasonality

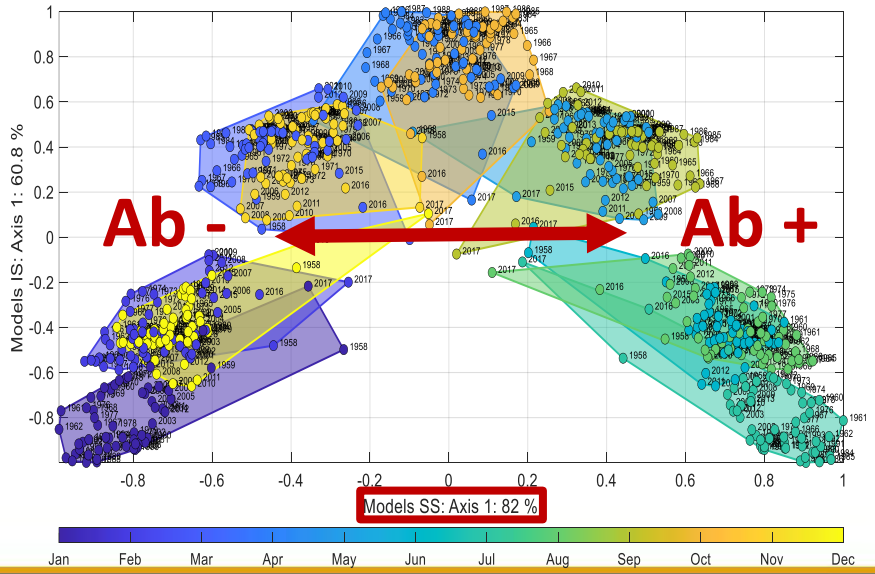
## The seasonal dynamic of phytoplankton (30) in the NS



# The community analysis: Seasonality

## The information in axis 1



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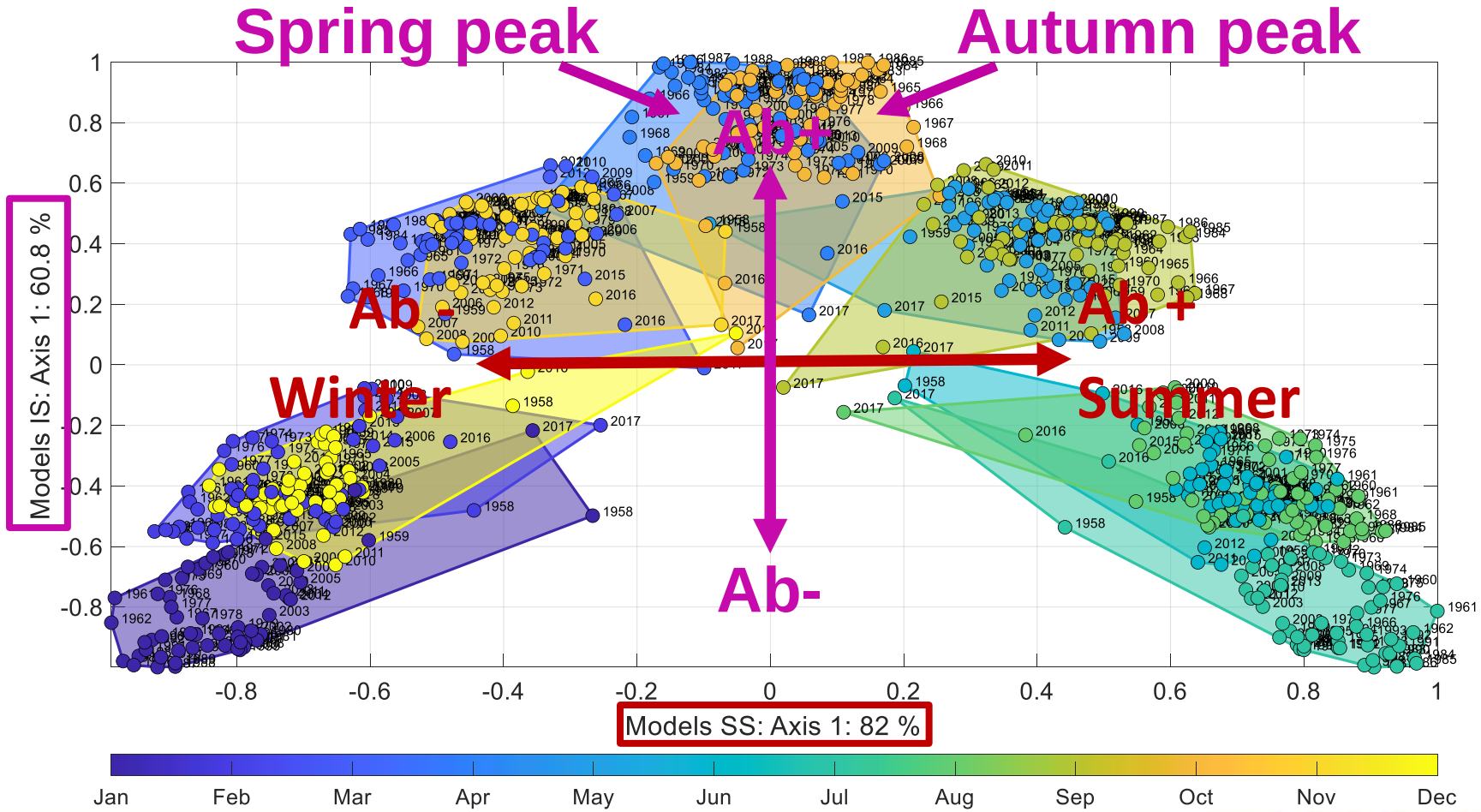

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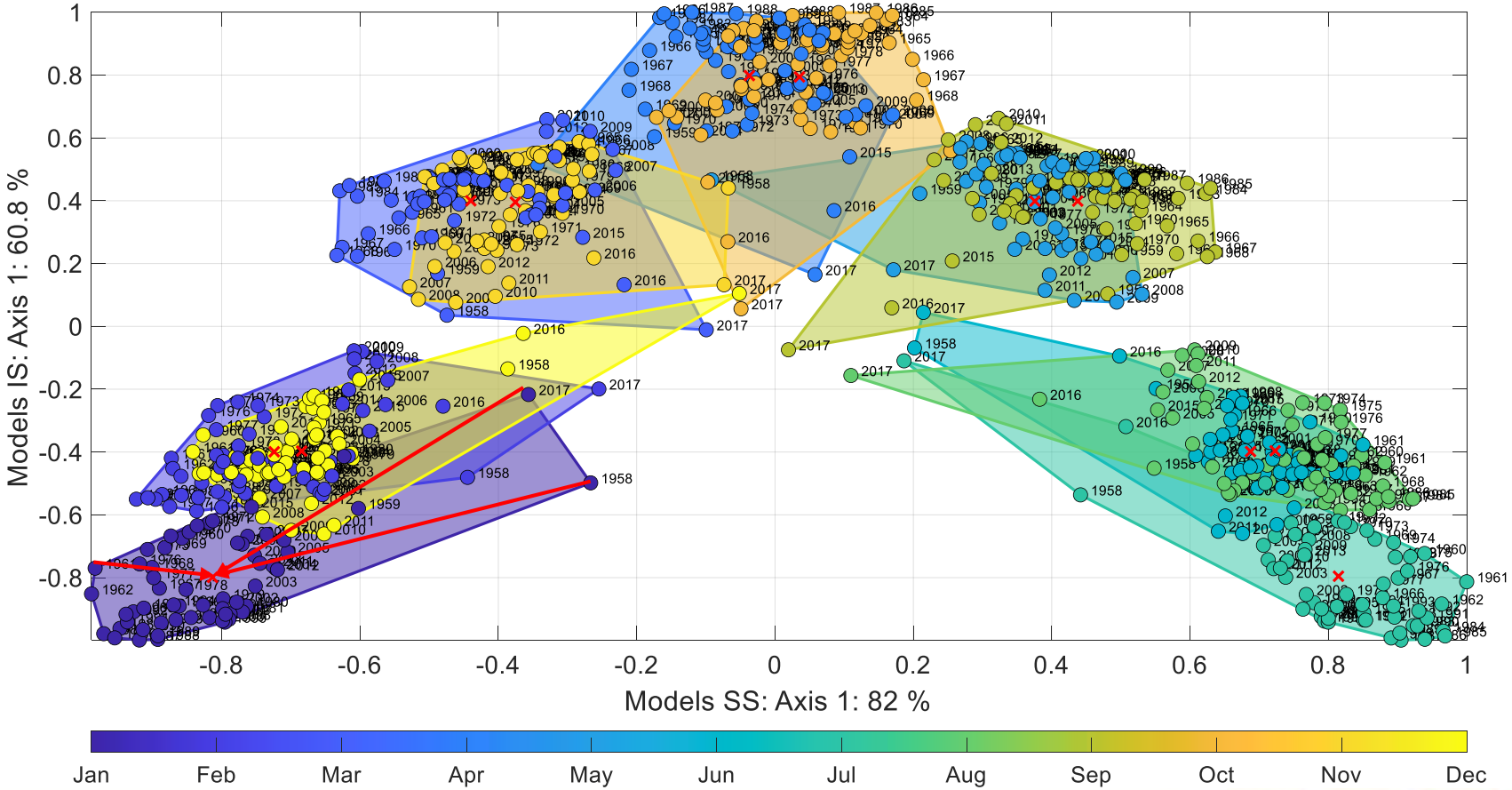
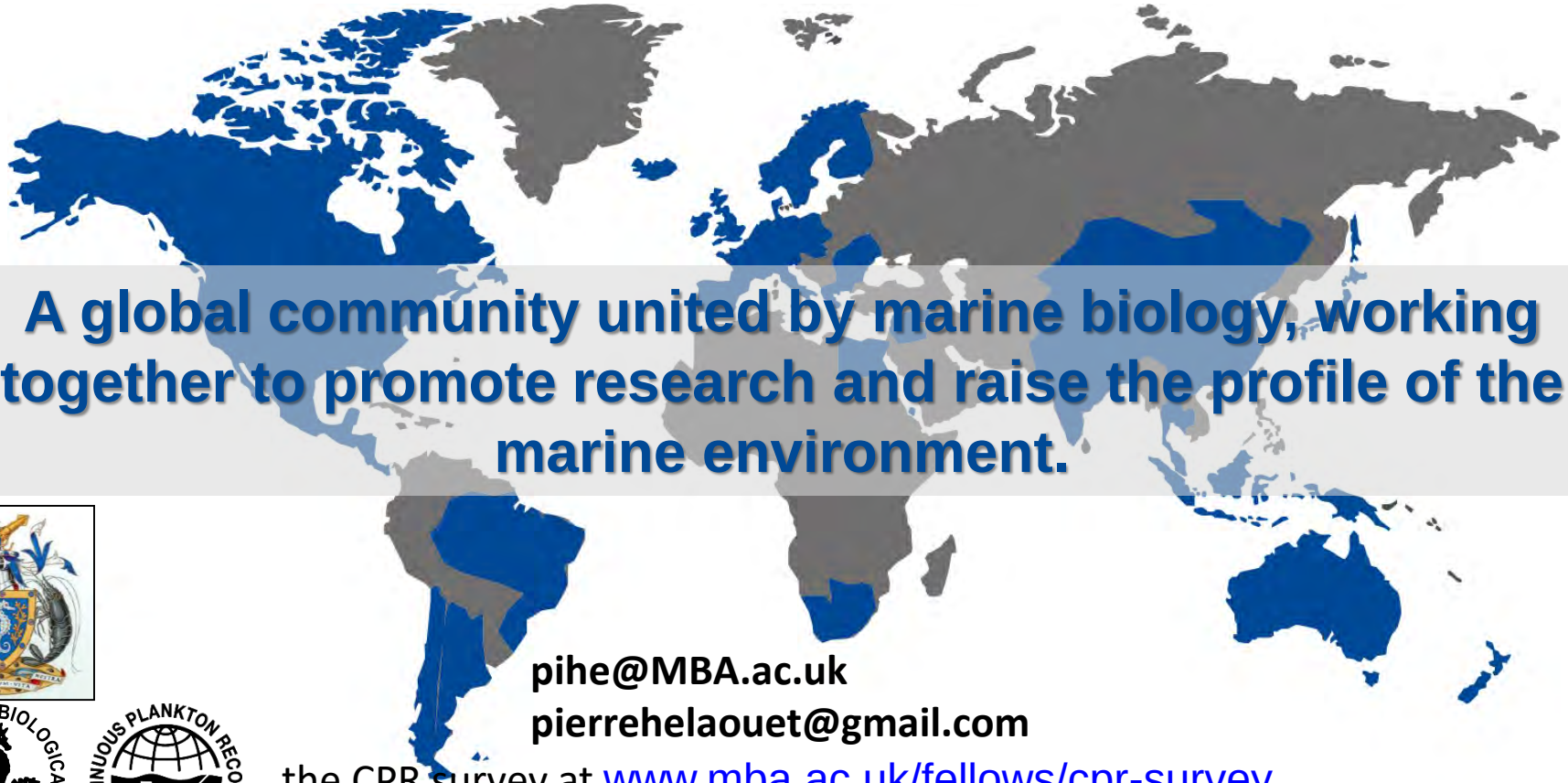


# The community analysis

Explain all patterns …

# The Marine Biological Association U.K.

**1700+ Members** **6 Continents** **40+ Countries**



**A global community united by marine biology, working together to promote research and raise the profile of the marine environment.**

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the CPR survey at www.mba.ac.uk/fellows/cpr-survey

the MBA at www.mba.ac.uk/membership/join/

THE MARINE BIOLOGICAL ASSOCIATION

Est. 1884
Incorporated by
Royal Charter

CONTINUOUS PLANKTON RECORDER SURVEY

Est. 1931