

Acquisition, validation, quality control and access to biodiversity data -

Training course for less experienced users of data products

Spatial and temporal trends in marine biodiversity in Europe

Geographic gradients observed in Europe

Trends between physico-chemical data and biodiversity data

Which environmental factors explain geographic gradients most?

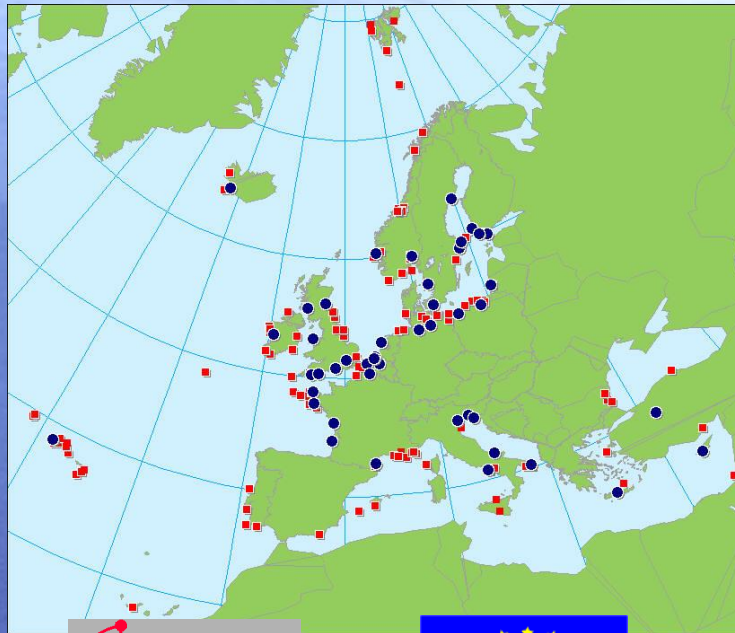
Herman Hummel & Matt Frost

Netherlands Institute for Sea Research, Yerseke, the Netherlands
Marine Biological Association, Plymouth, UK



From 2000 a range of projects composed overviews on geographic gradients of marine biodiversity along the European coastline. We will show results of the MARS initiated projects BIOMARE, MarBEF, BioCoMBE and EMBOS.

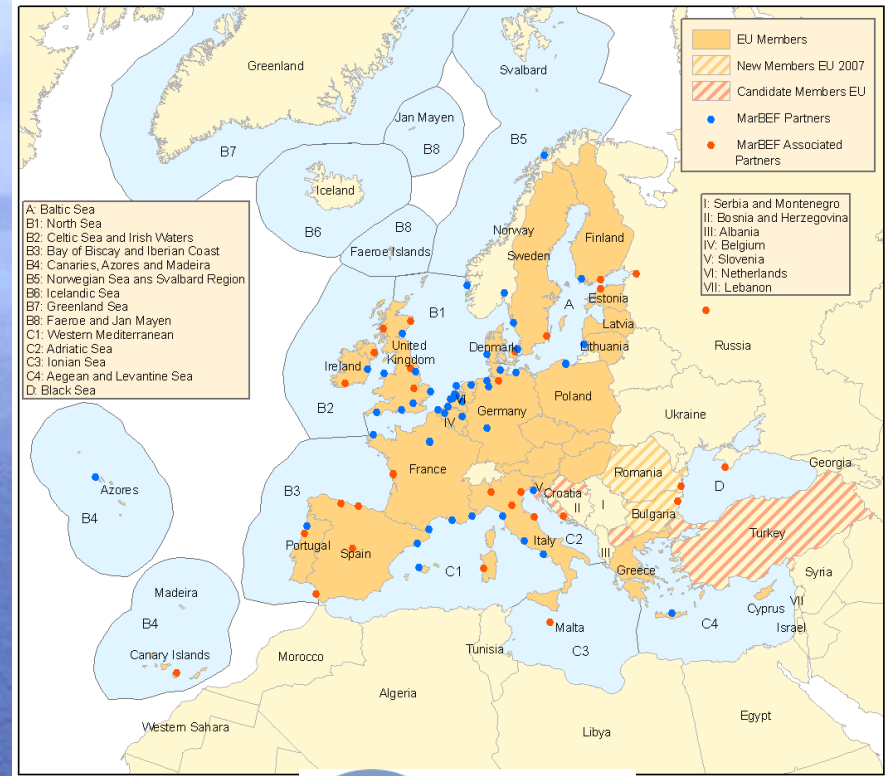
Firstly a couple of general trends (BIOMARE, MarBEF)
secondly some more detailed trends (BioCoMBE, EMBOS)



MARS
members
(blue dots)



BIOMARE
Reference / Focal
sites (red dots)



MarBEF datasets covering the European distribution patterns of species showed the relation of species diversity to factors as productivity, depth, survey area

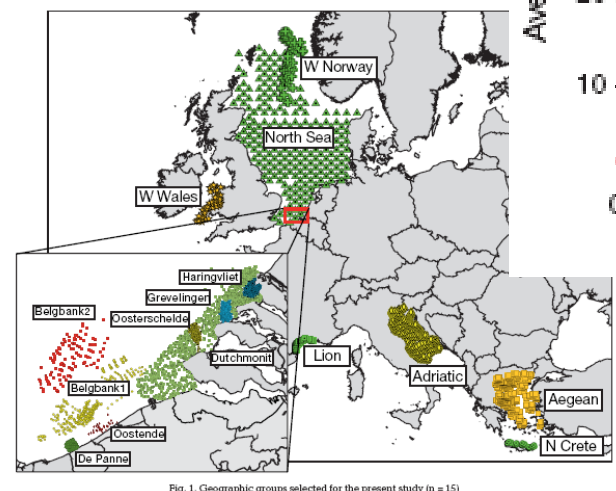
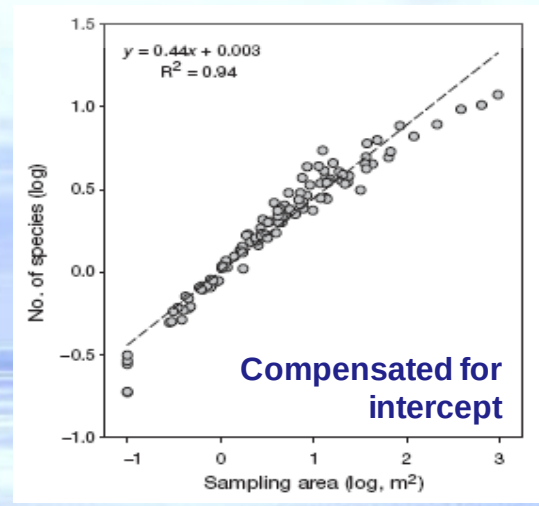
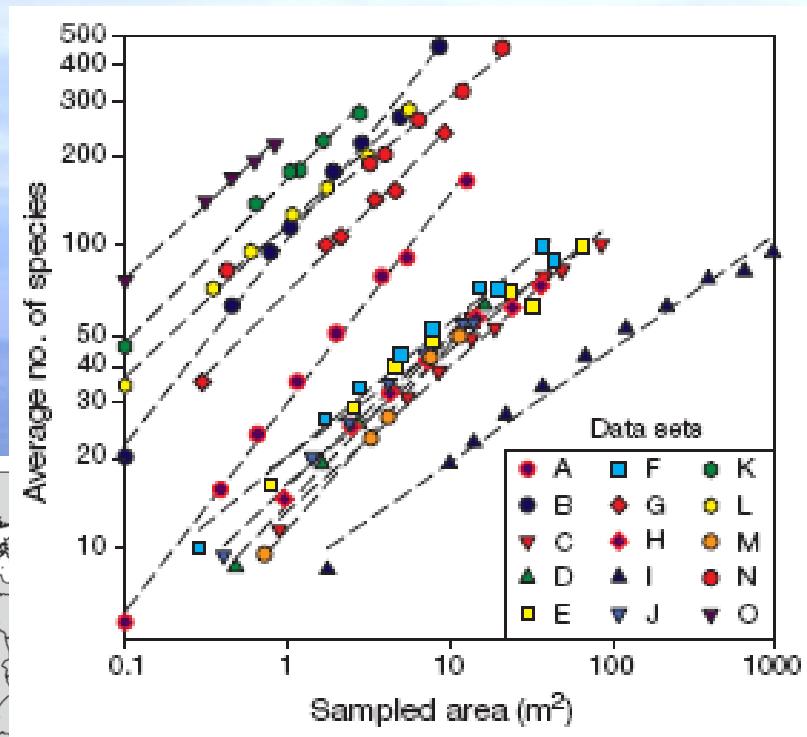
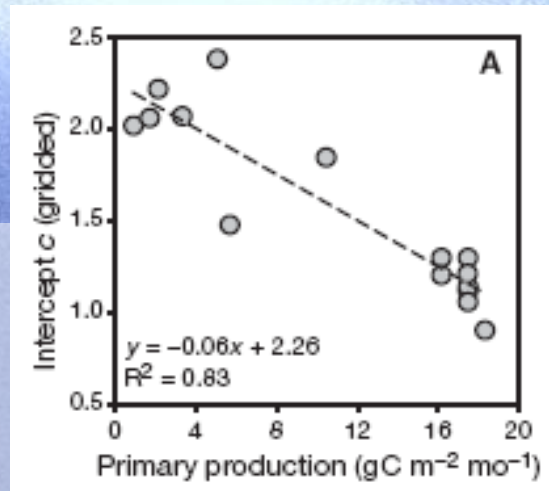


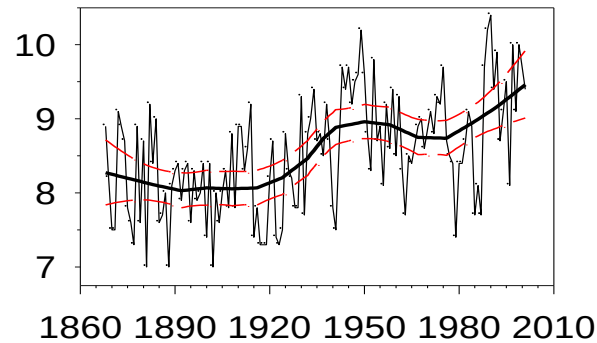
Fig. 1. Geographic groups selected for the present study (n = 15)

The species diversity was related negatively to primary production in an area, indicating that coastal areas are still eutrophicated



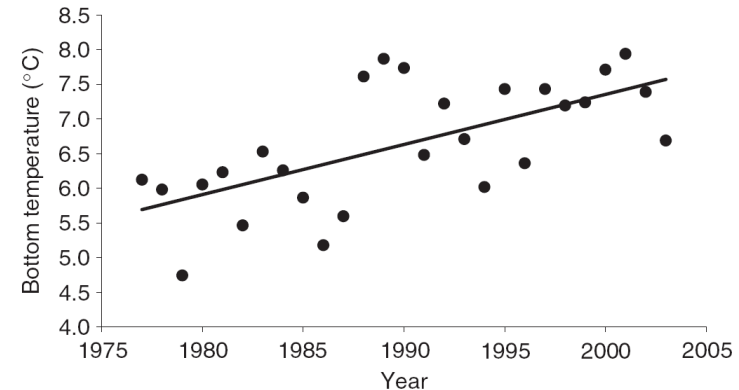
MarBEF actions covered also the **impact of Climate Change on marine biodiversity**

Torungen, Skagerrak



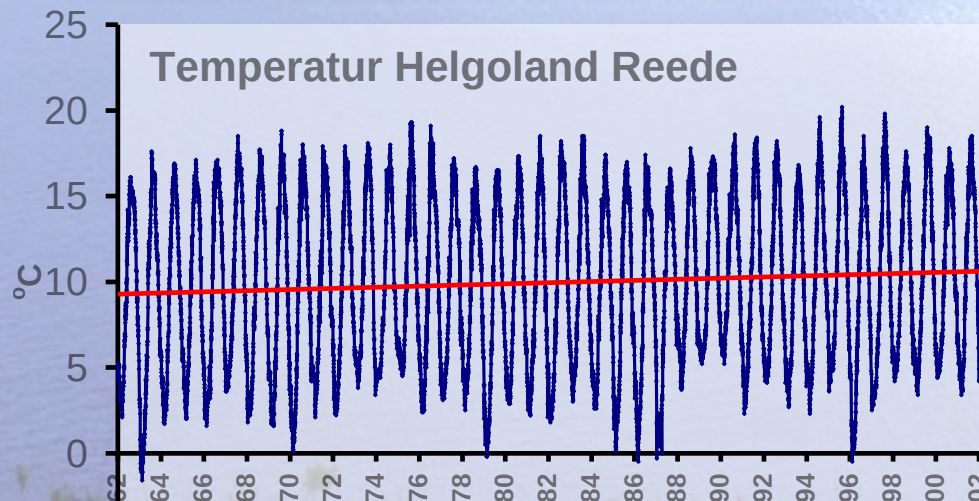
MacKenzie & Schiedek 2007
Global Change Biol.

Central North Sea



Hiddink & Ter Hofstede 2008
Global Change Biol. 14: 453-460

Temperatur Helgoland Reede

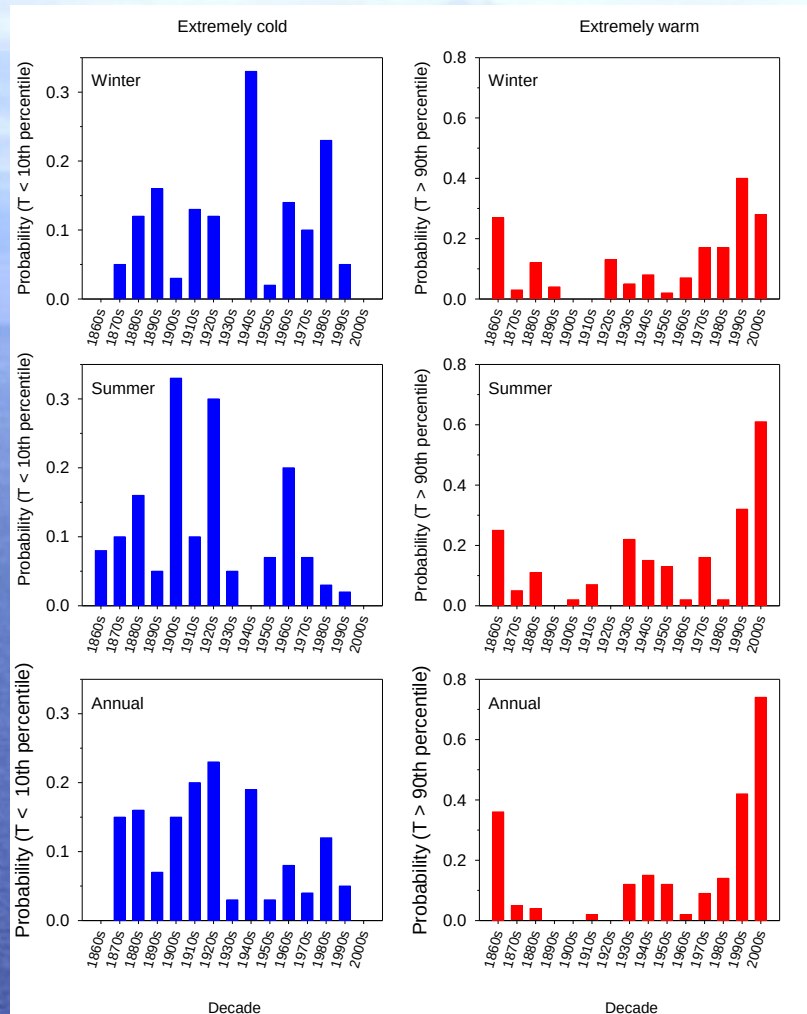


**Mean Temperature rise
1 to 1.5 °C since 1960**

Wiltshire & Manly, 2004
Helg. Mar. Res. 58: 269-273

Not only changes in average temperature but also changes in probability of Extremely Cold and Warm Years: 1860-2000

Extreme cold years becoming rarer

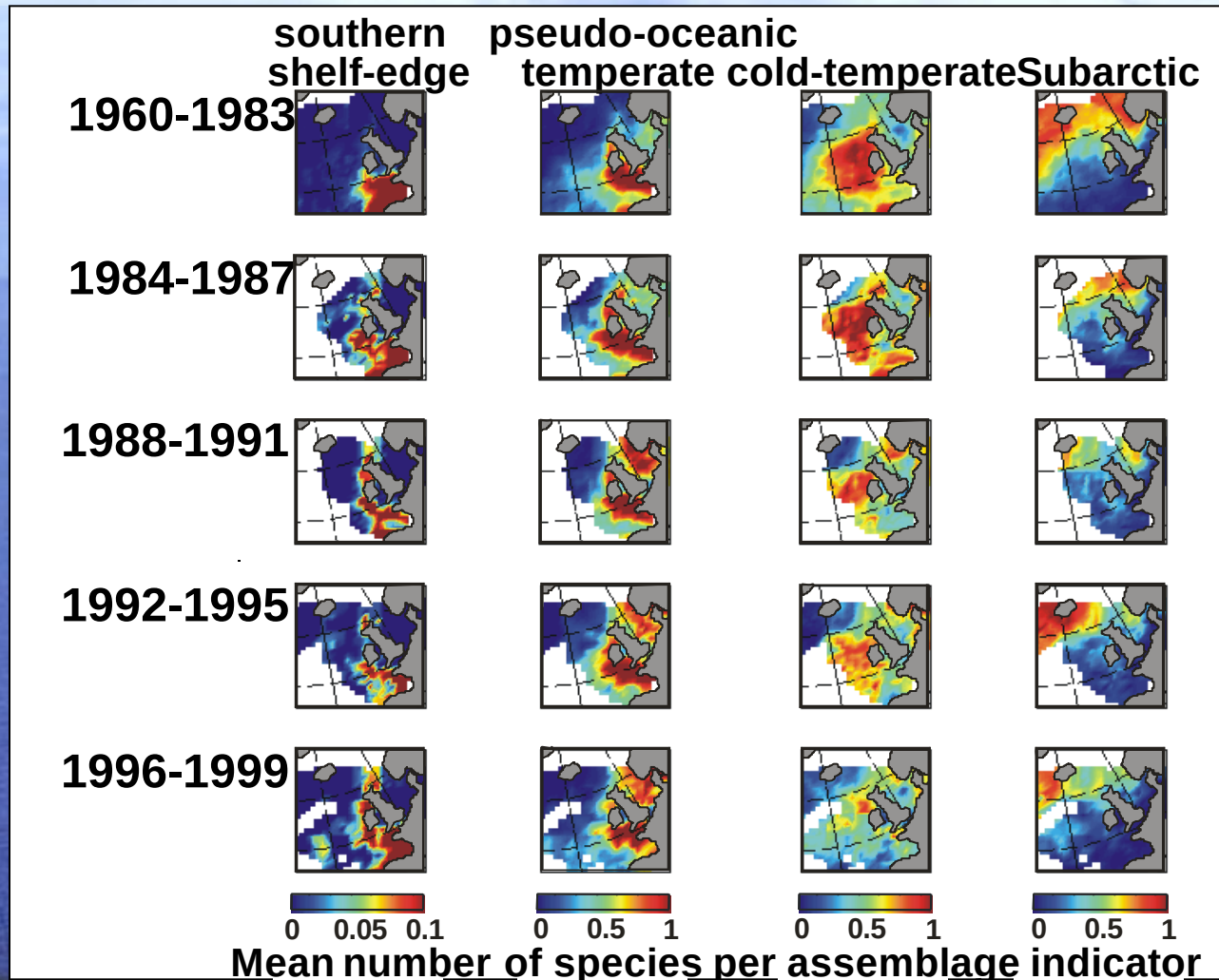


Extreme warm years becoming common

MacKenzie & Schiedek 2007
Global Change Biol.

An effect of Climate Change was also earlier noted in marine plankton species diversity (measured with the SAHFOS - Continuous Plankton Recorder Data).

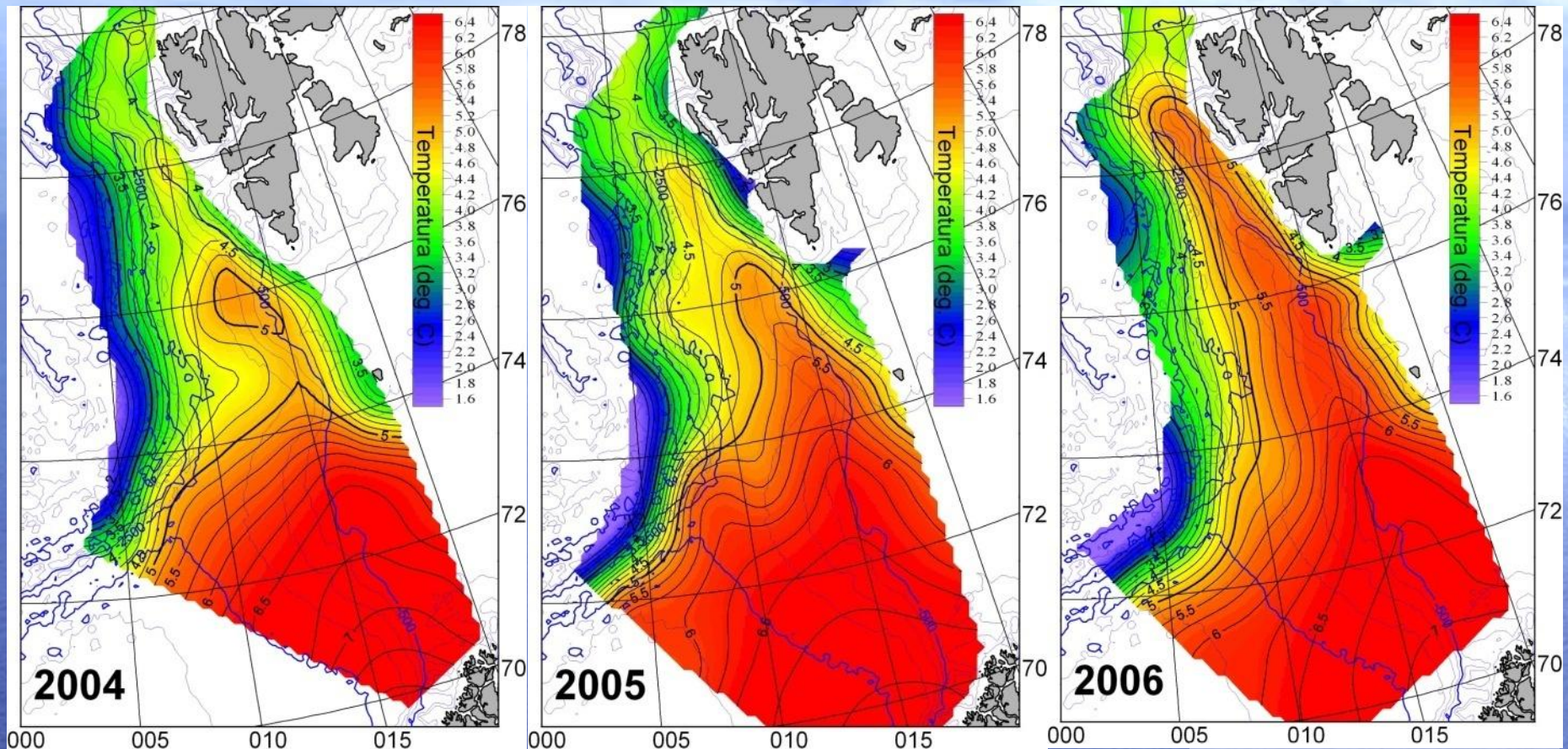
Long-term changes in four species assemblage indicators showed a poleward shift in the diversity of warm-water species associated with a decrease in the diversity of colder-water species



**Beaugrand et al.
(2002). Science.
296: 1692-1694**

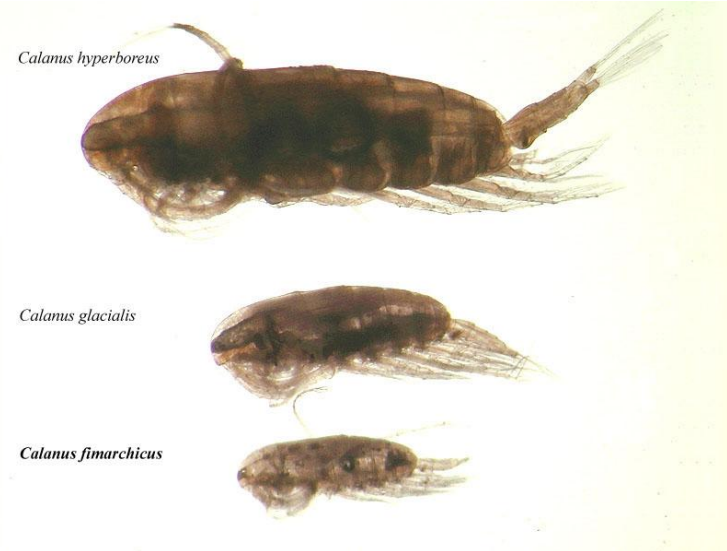
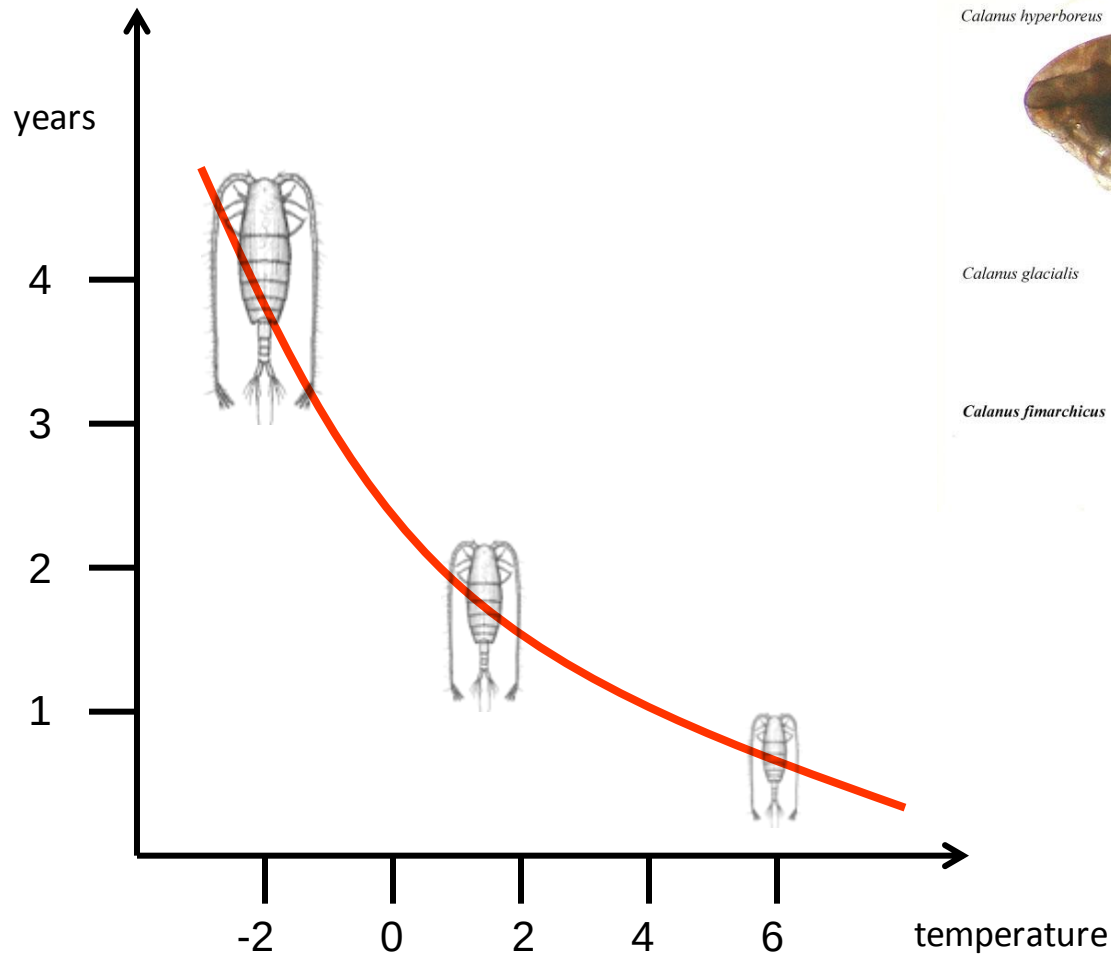
Similar trends and shifts were also found in the (sub)Arctic (just south of Spitsbergen)

Water temperatures in the Arctic are increasing



Walczowski et al. 2007

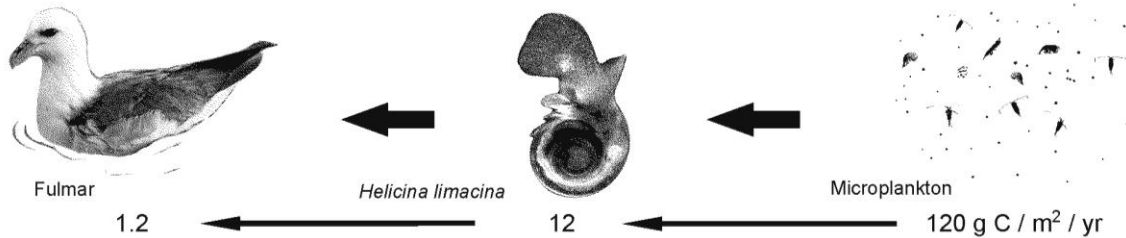
At higher temperatures more but smaller plankton species occur



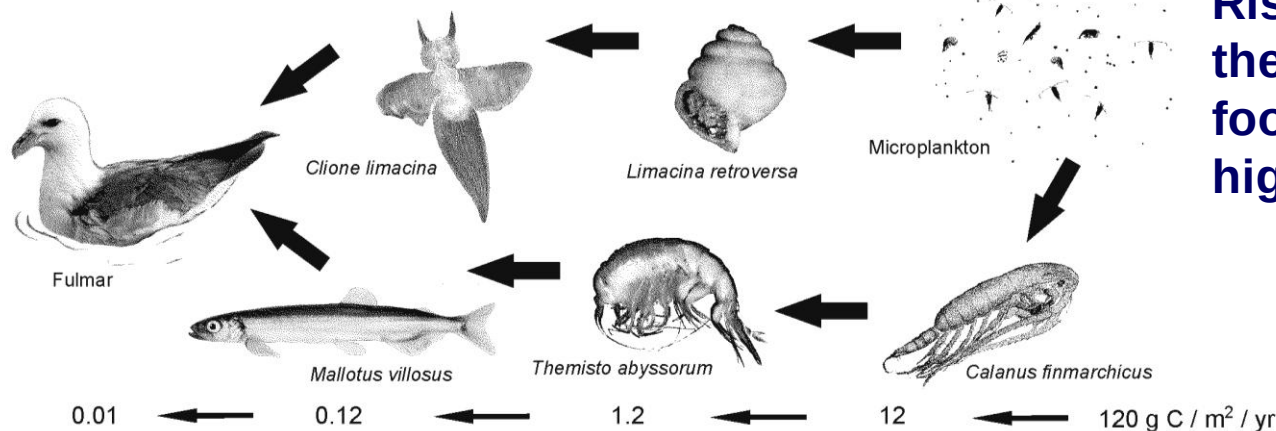
Higher temperatures thus coincide with more species , but also with

- 2) smaller plankton species,
- 3) longer trophic chain length,
- 4) lower carrying capacity for larger predators

ARCTIC



SUB-ARCTIC



Surprising conclusion:
Rising biodiversity in the Arctic may lead to food shortage for the higher trophic levels

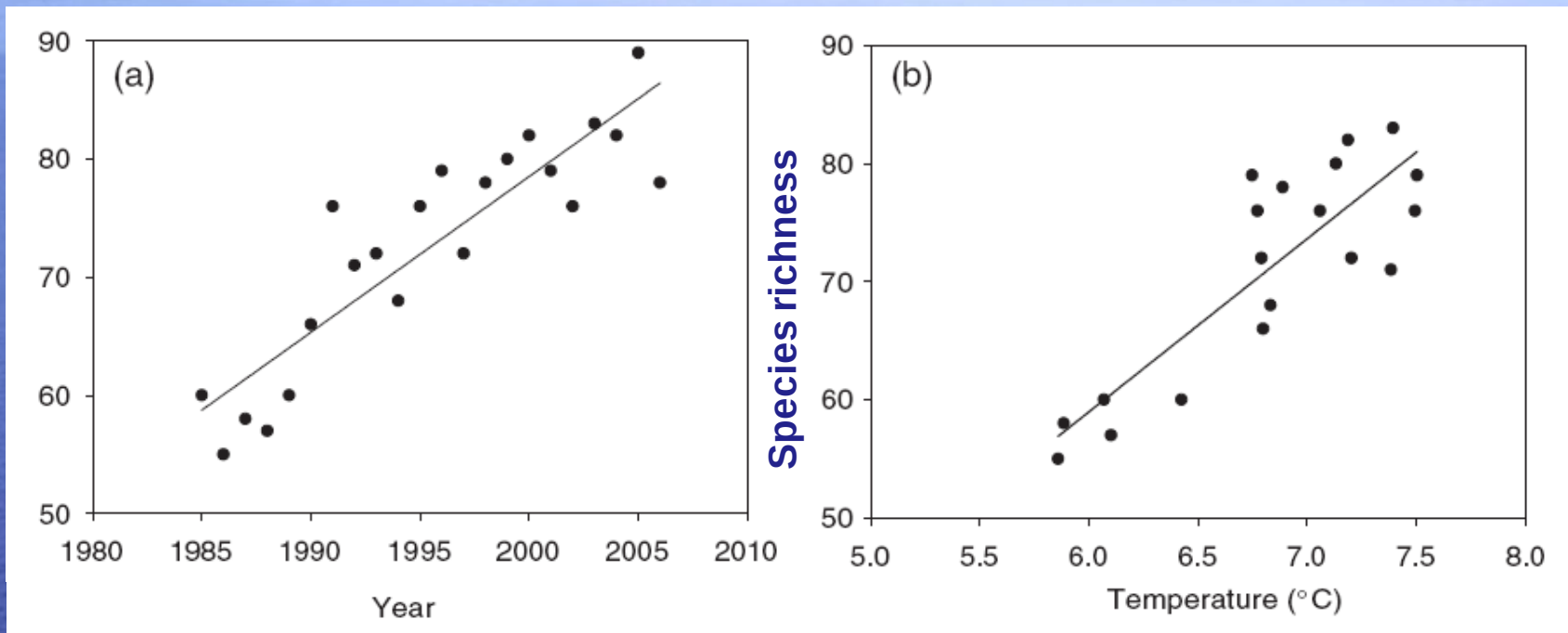
Thus, not the number, but the uniqueness of species diversity counts



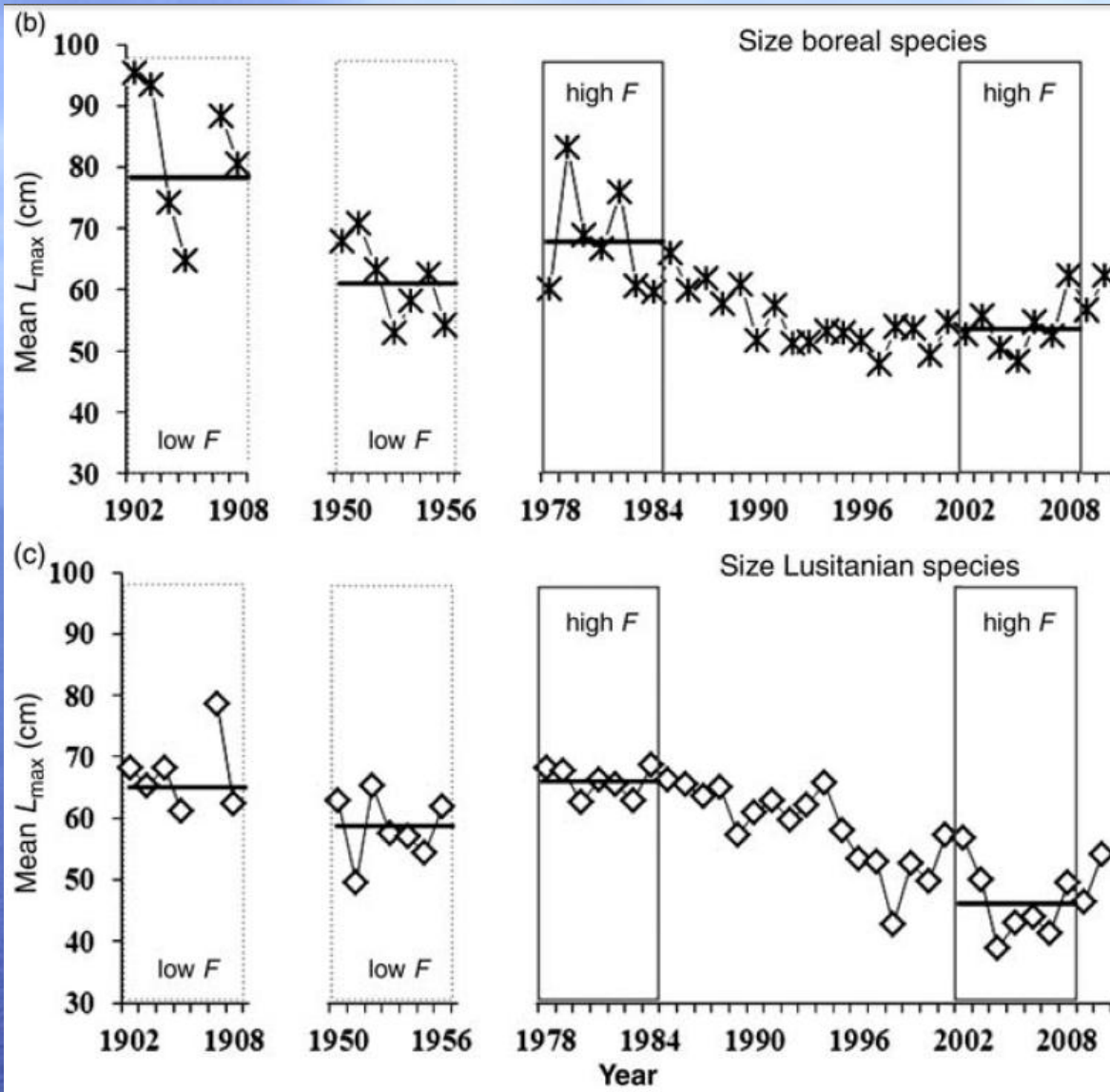
Little auks – change indicators

For fish species richness in the North Sea similar effects were found as in the Arctic, i.e. total species richness increased over time (and with an increase of temperature). Explanation is:

- number of small southern species increased
- large northern species decreased their range



Hiddink & van Hofstede, 2008
Glob. Ch. Biol. 14: 453



Since the

- number of small southern species increased
 - large northern species decreased their range
- the average length of the fish decreased



Large top predators can of course also disappear because of overexploitation.

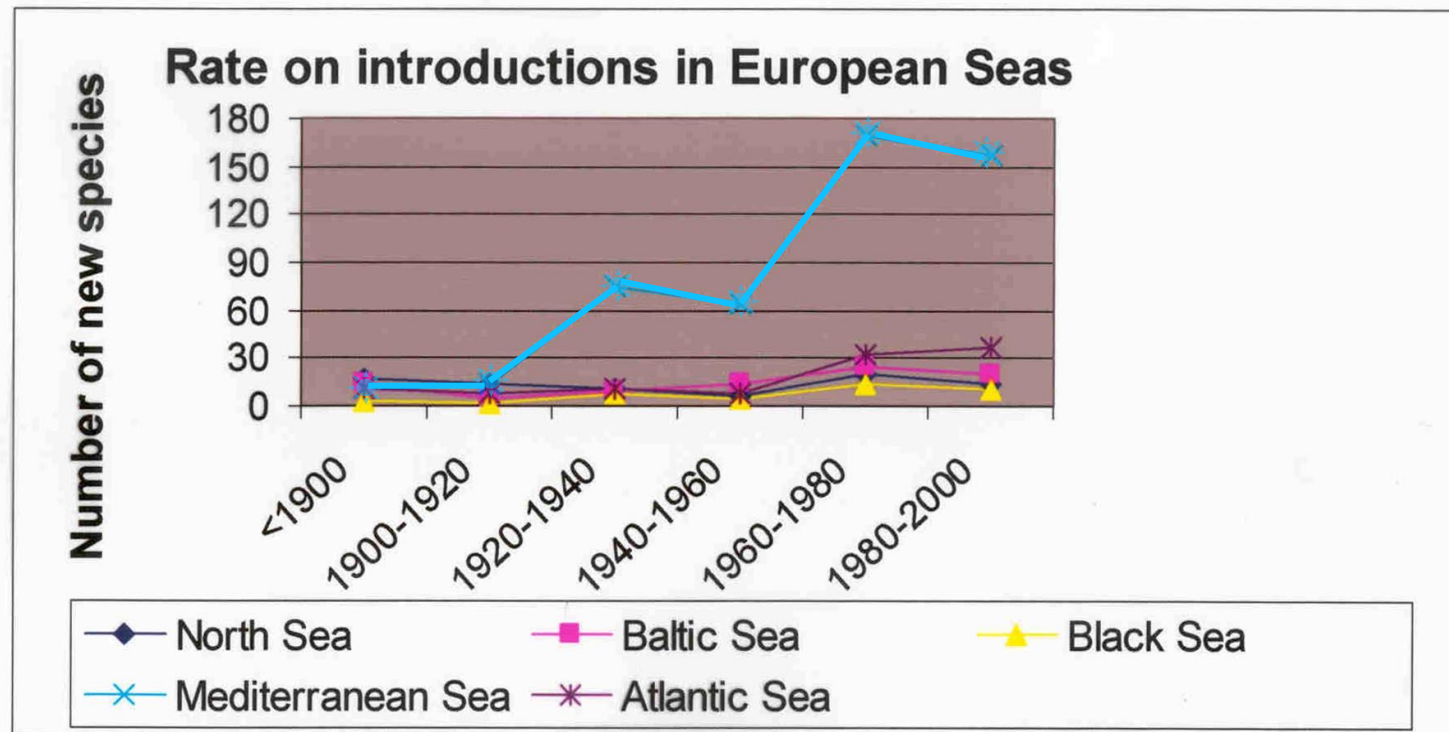
Example: Bluefin Tuna caught in the North Sea: UK 1933 (upper two), and Denmark (lower) 1946.

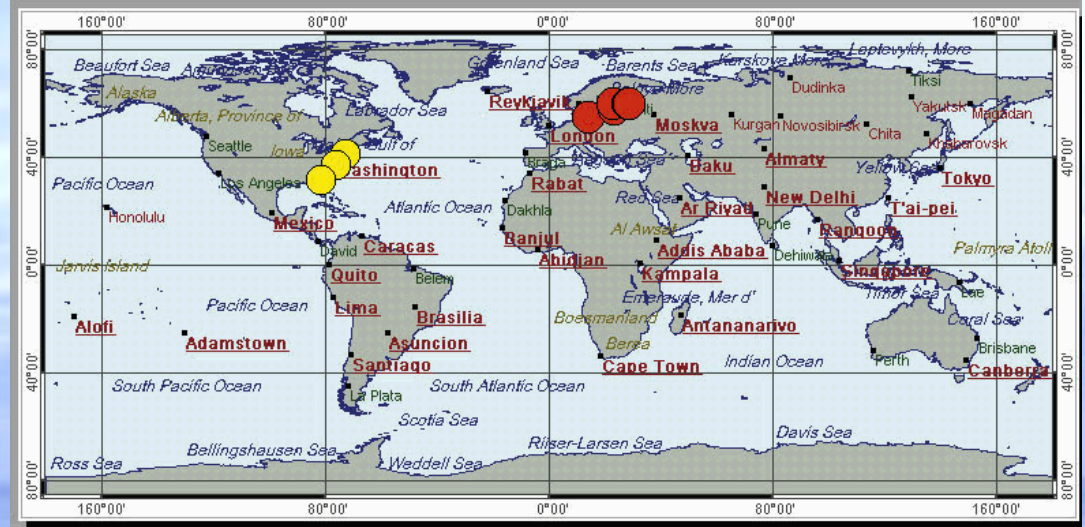
**The species has now disappeared completely.
(MacKenzie and Myers, 2007)**

Together with the changes due to Climate Change also the threat due to species introductions, i.e. invading (exotic) species, is strongly felt, e.g.

- *Marenzelleria* sp.
- *Caulerpa* in Mediterranean

Rate of Introduction of marine alien species





<http://www.zin.ru/projects/invasions/gaas/>



Photo: Johanna Stigzelius

***Marenzelleria* sp.
have taken over 80 %
of the biomass in
several lagoons in
the Baltic**

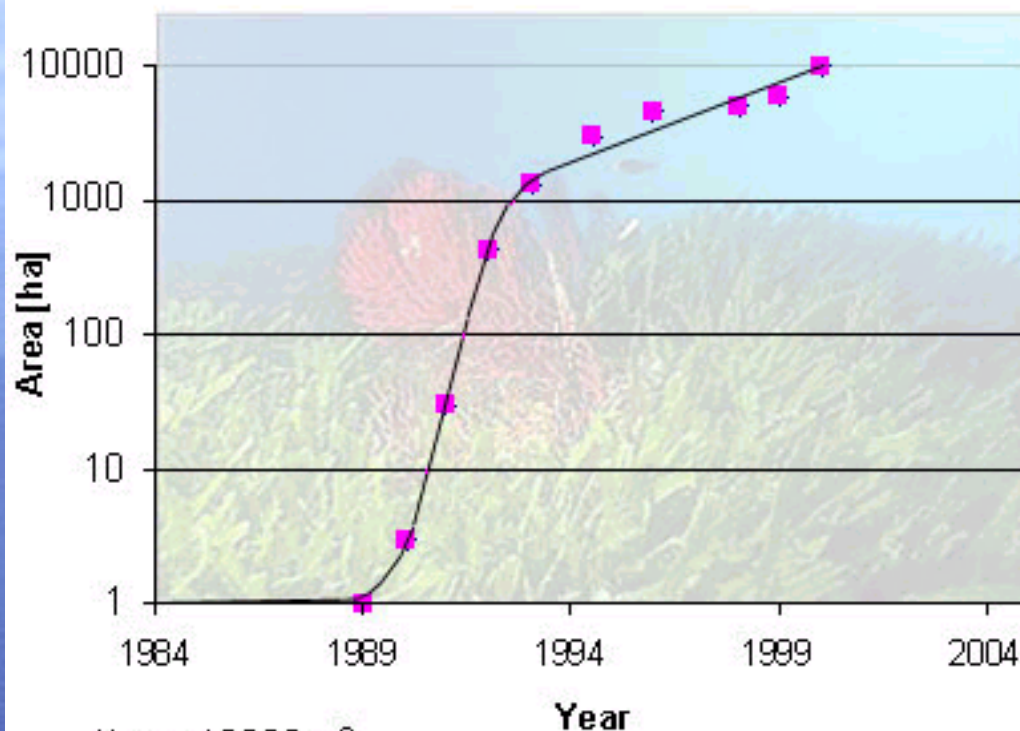


Caulerpa taxifolia

Believed to have escaped from museum in Monaco, now invading the Mediterranean

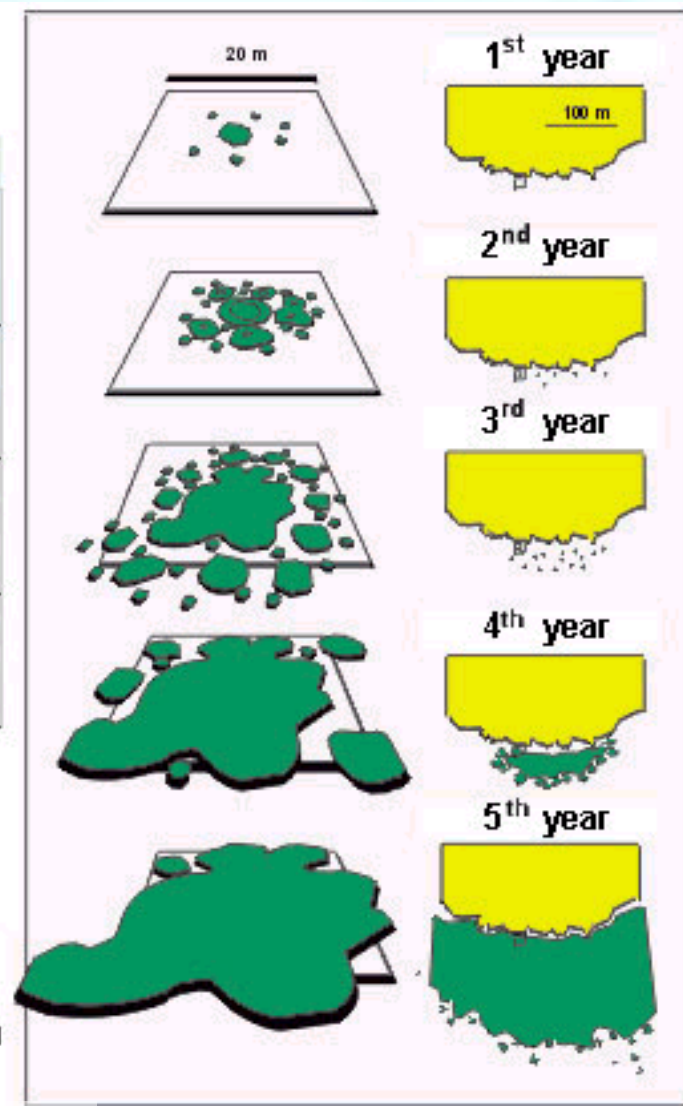


Sigmoidal growth of *C. taxifolia* (French Riviera)

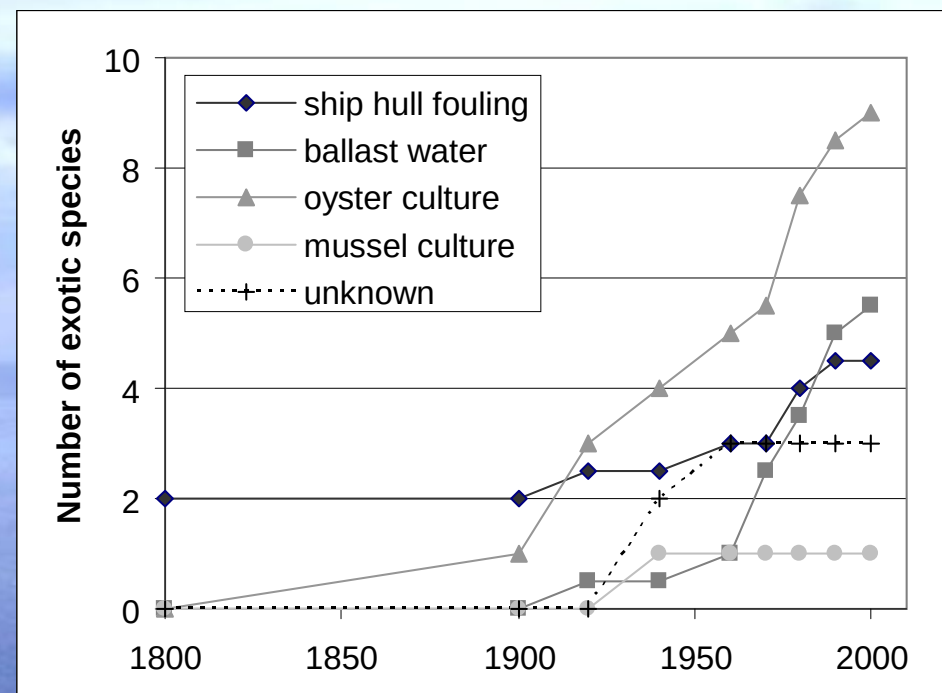
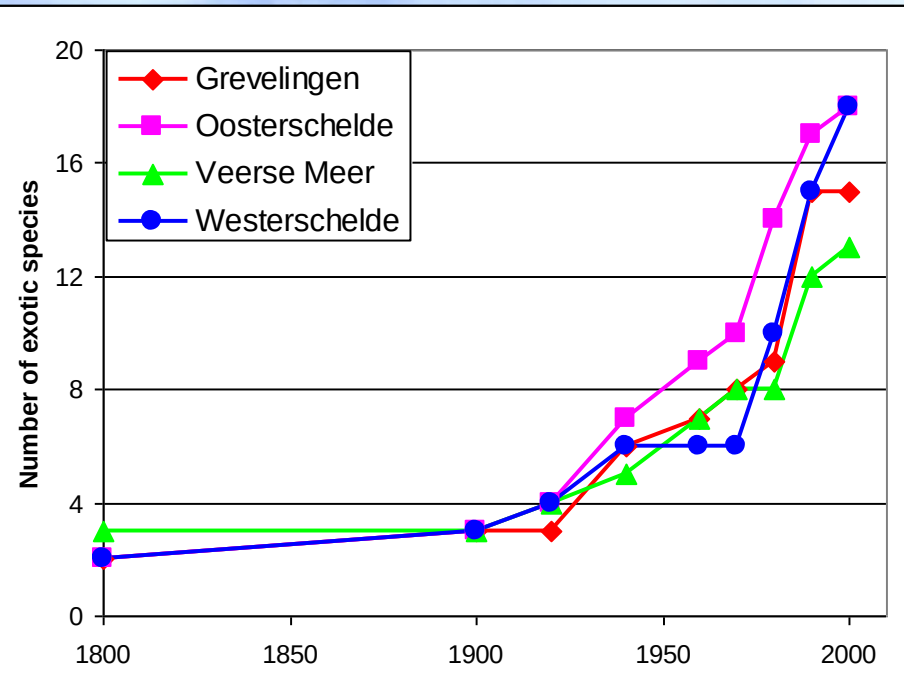


Expansion of an isolated patch of *C. taxifolia* at the French Riviera (Cap Martin)

Source: Dieval M.E.



Same pattern of arrival of exotic species in SW Netherlands



Increasing number of exotic species:

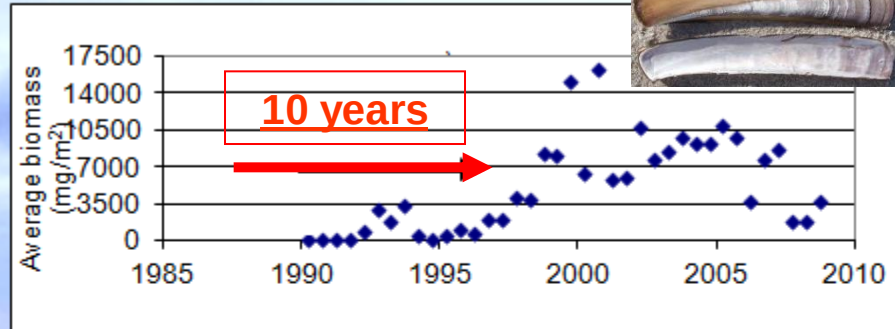
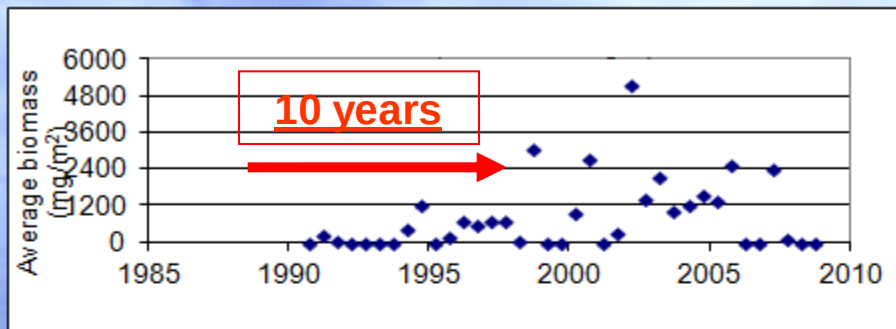
- Stronger increase since 40s-50s: due to aquacultural introductions (but also artefact because of intensification of research)
- From 60s-70s stronger impact of shipping
- During last 20 years appearance of about 1 exotic species per year

Patterns in population dynamics of exotic and endemic species: Molluscs

Grevelingen Oosterschelde

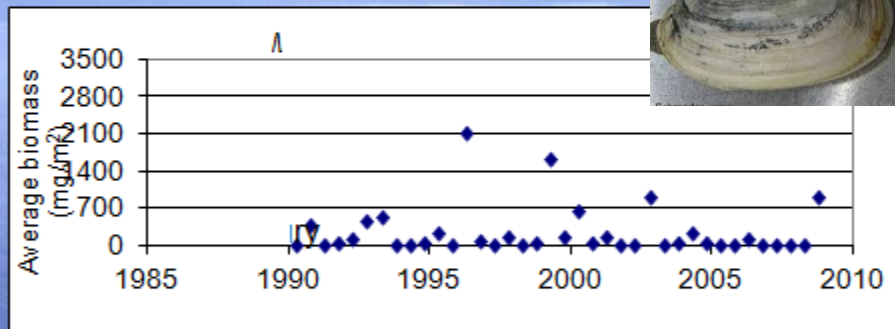
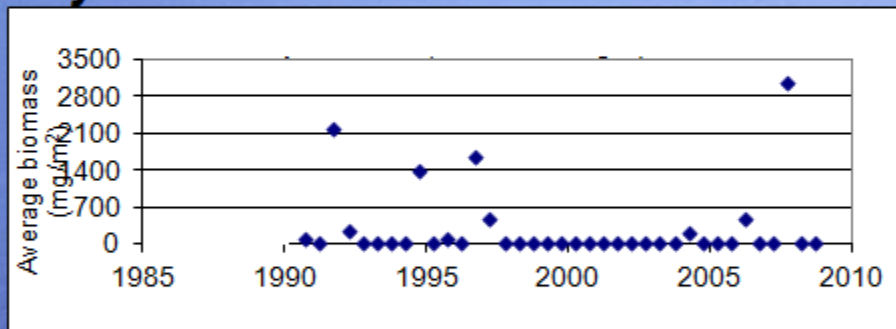
Ensis directus

Arrived in 1989



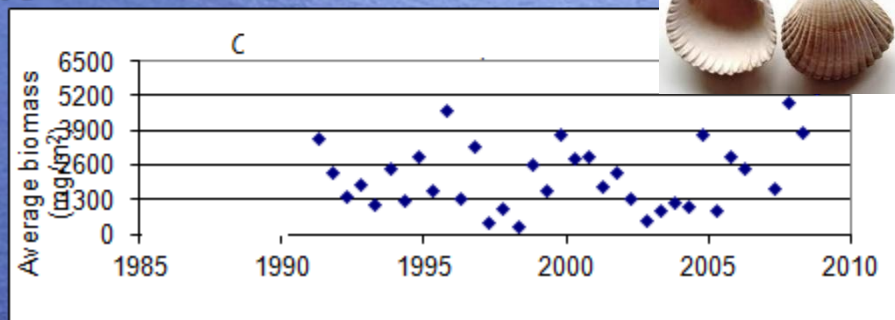
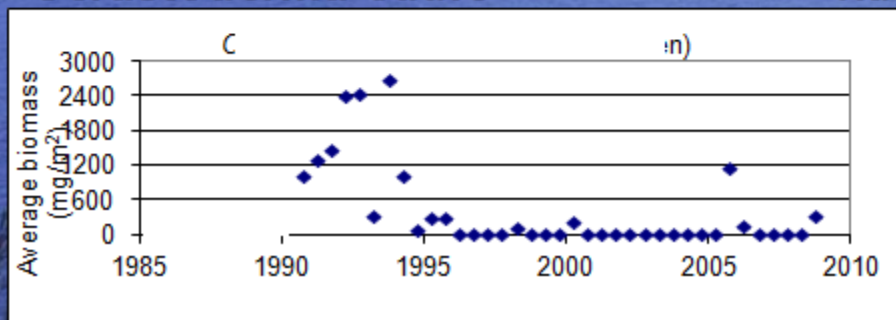
Mya arenaria

Arrived before 1800



Cerastoderma edule

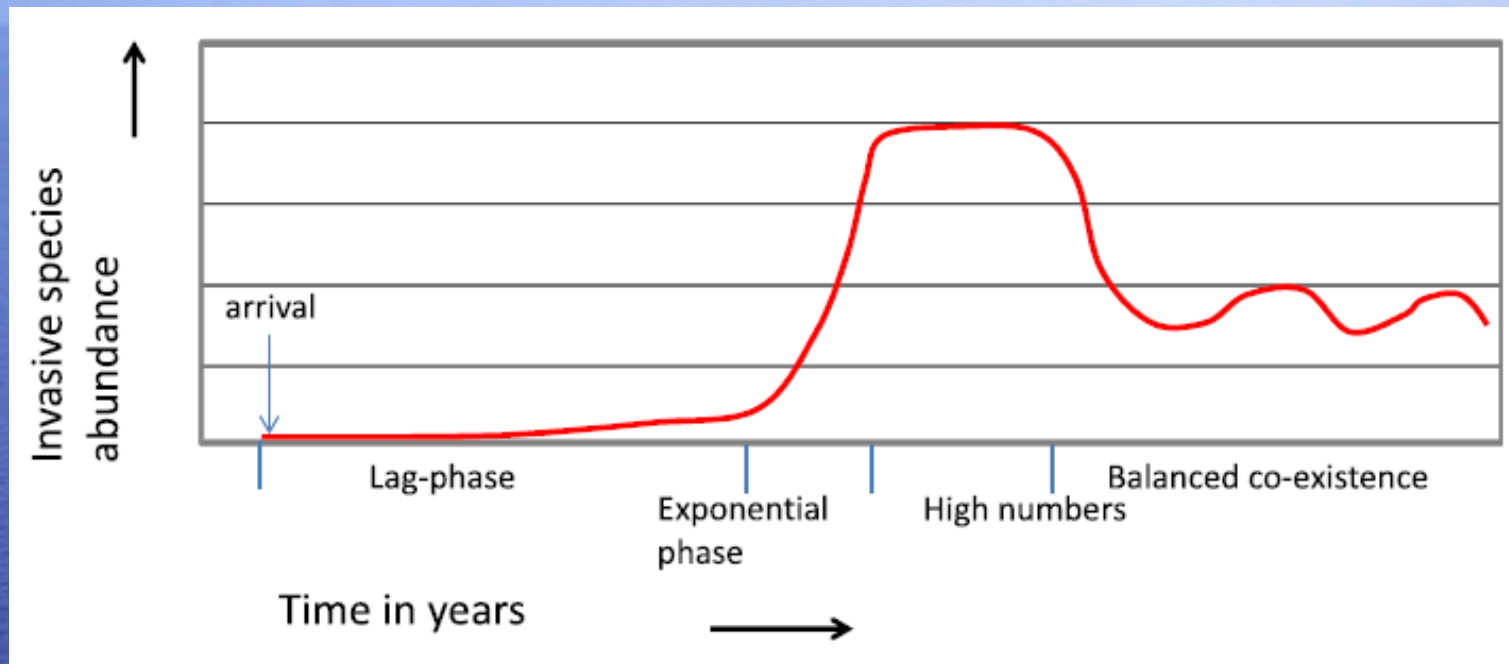
Native



From these patterns a conceptual pattern for the population development of invasive species could be derived. It shows:

- Lag phase
- Exponential phase
- Stable period with high numbers
- Decrease to balanced existence

From arrival to balanced existence lasts about 20 to 25 years.



A couple of more detailed studies on marine biodiversity at different organisational level, the geographic gradients observed in Europe, and trends between physico-chemical data

**The question in the two projects BIOCOMBE and EMBOS was:
Can we observe patterns of (variation in) marine biodiversity in Europe
by combining information from a large-scale range of marine stations**

To this end we measured :

- The diversity of benthos**
- in the intertidal or upper subtidal zone**
- in spring and/or autumn**
- together with several abiotic factors in water and substrate**

**In this presentation focus on soft sediment zoomacrofauna
(benthic animals larger than 1 mm)**

**In Biocombe we analysed diversity at genetic, ecophysiological and
community level, in EMBOS at species and community level**

For BIOCOMBE (2004-2007)

- along the European coast: >16 stations from Italy to the north of Sweden
- describing (gradients in) distribution and diversity of species (races/ecotypes)
- seasonal surveys, exposure experiments and field translocations



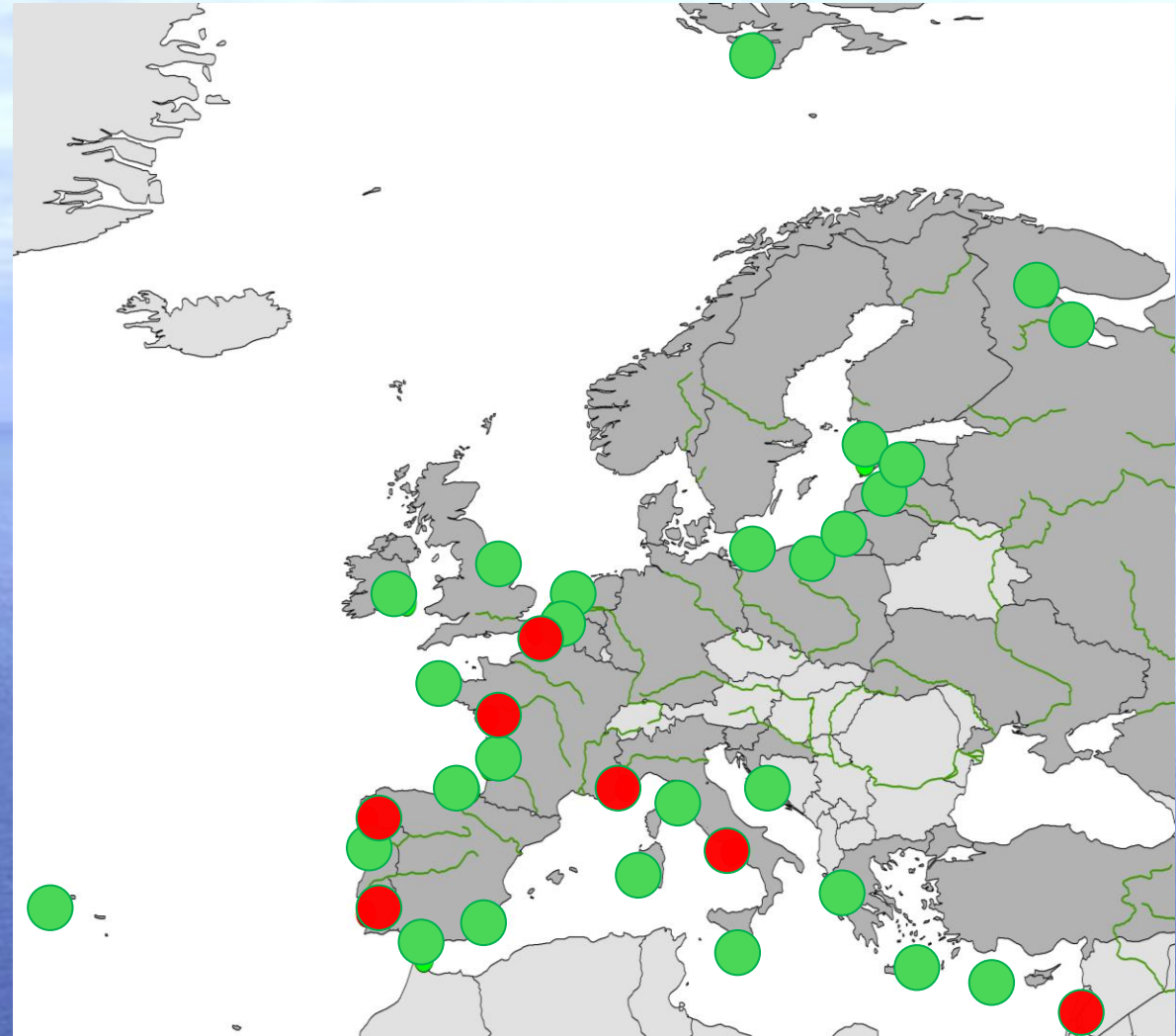
Species / Community diversity

- **Macrozoobenthos: 0.5 mm sieve**
(Biocombe: 10 cores, 4 dm² total)
(EMBOS: 3 cores, 4 dm² total)
- LWL or upper subtidal
- **Spring (Biocombe: also autumn)**
- **Water (S, T; Biocombe also C,N)**
- **Sediment (granulometry, C, N)**



The EMBOS Pilot Project (2011-2015), following harmonised methods, is carried out with observations at 34 stations on:

- Hard-substrate
- Soft-substrata
- Pelagic



Genetic diversity

- two key species (mussel and clam) in Europe

We used different markers for genetic diversity:

- **Morphological markers (shells):**
NMNH Leiden

- **Allozymes:**

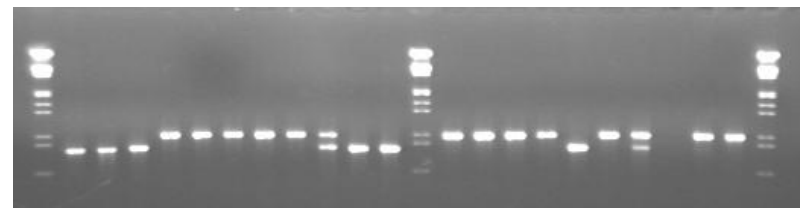
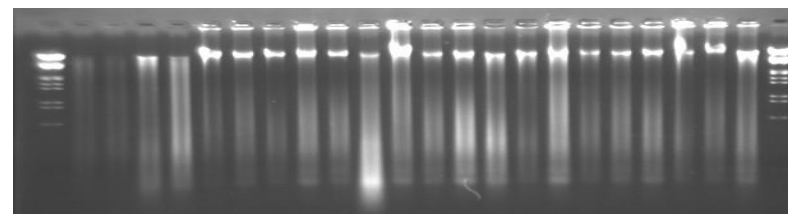
Netherlands Institute for Sea Research;
University of Gdansk

- **mtDNA markers (COI, D-loop):**

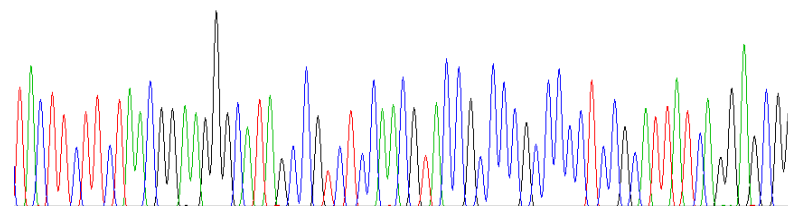
Polish Academy of Sciences;
University of La Rochelle

- **Nuclear (& hypervariable) markers (ITS, AFLP, EFbis, Me 15-16)**

Radboud University Nijmegen;
University of La Rochelle



T A C T T C T T C T A A C G G A A G G C A T A C C G T T C C A A C G T A C C C C C C C C C C C T C C G A T T A T C A G G A G C C G



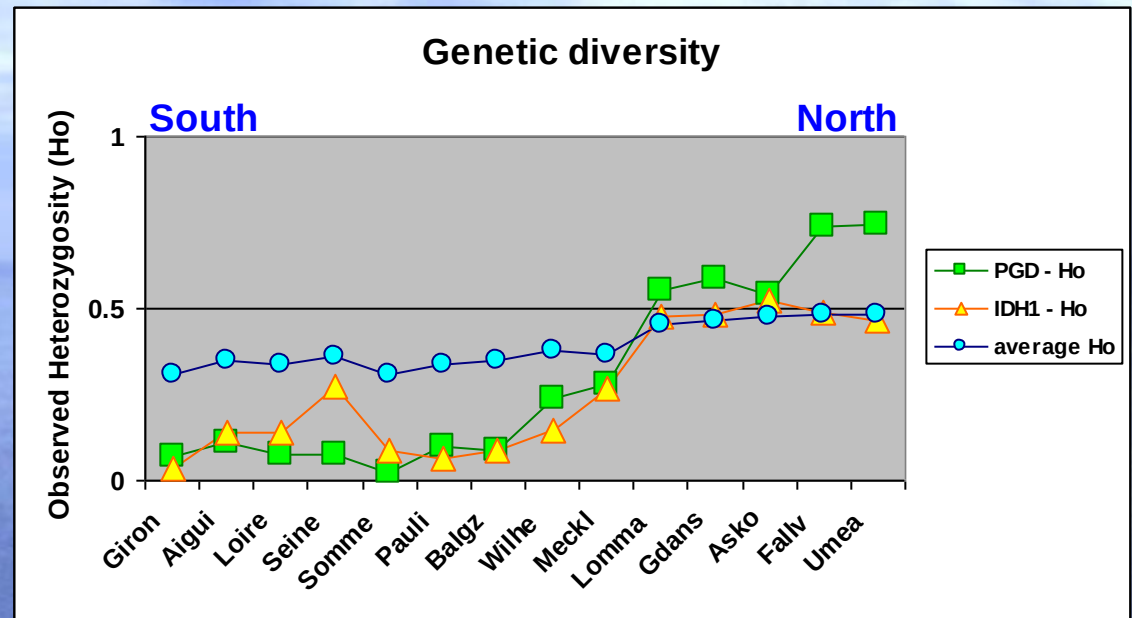
CFVVVLCV CVLVLLGILLdGICVIVGCLLCLLVG ClddIVGVLLIFVGV VGL CC
B9TJS : C L V V V L C V C C V L V L L L G C L L V G C L L V V C L C C C L V C V L L L L V C V C V C L C C : 22
26TJS : C L V V V L C V C C V L V L L L G C L L V G C L L V V C L C C C L V C V L L L L V C V C V C L C C : 22
V203 : C L V V V L C V C C V L V L L L G C L L V G C L L V V C C C C C L V C V L L L L V C V C V C L C C : 22
V3096 : C C V V V L C V C C V L V L L L G C L L V G C L L V V C C C C C L V C V L L L L V C V C V C L C C : 22
V3096 : C L V V V L C V C C V L V L L L G C L L V G C L L V V C L C V V L V C V L L L L V C V C V C L C C : 22
Me211 : C L V V V L C V C C V L V L L L G C L L V G C L L V V C L C C C L V C V L L L L V C V C V C L C C : 20
B7932 : C L V V V L C V C C V L V L L L G C L L V G C L L V V C L C C C L V C V L L L L V C V C V C L C C : 22

* 50 * 10 *

Genetic diversity of *Macoma balthica* along the European coast

Genetic diversity (heterozygosity) for the isoenzymes with significant differentiation

Higher diversity in the north, i.e. in Baltic populations

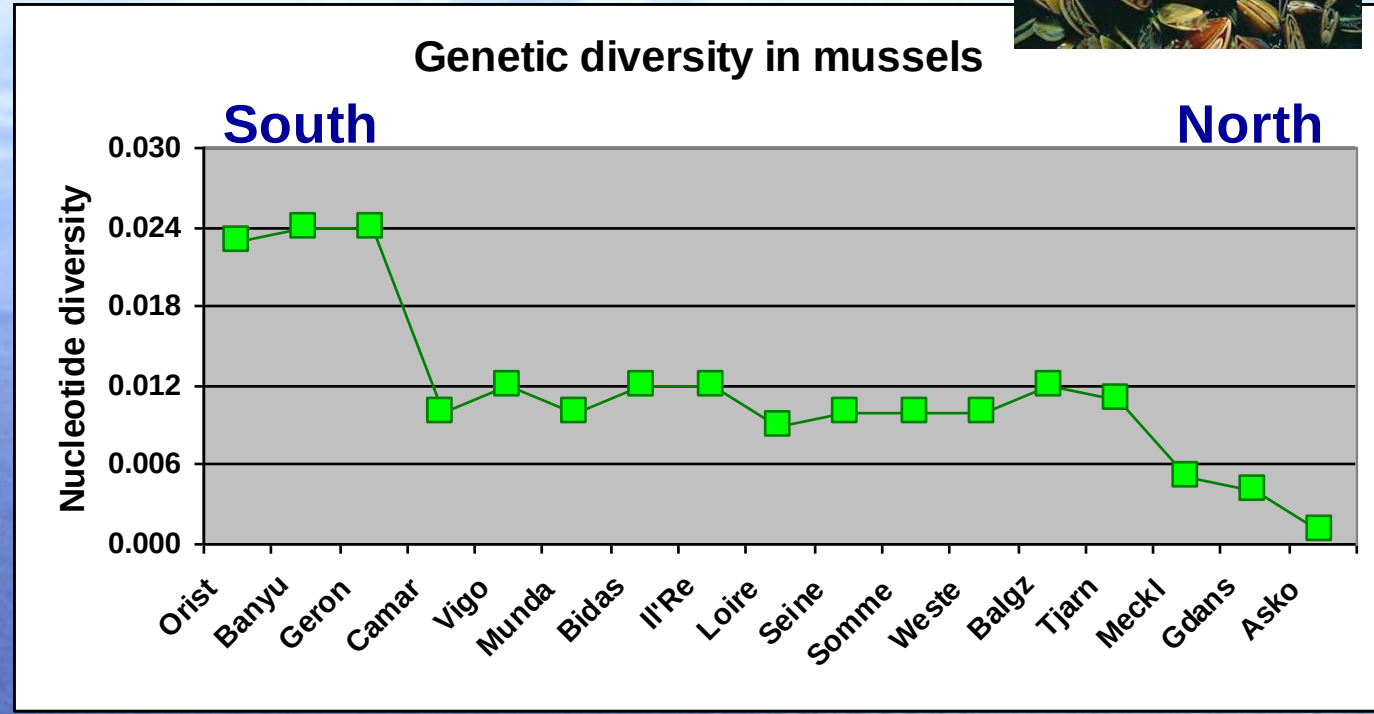


Biscay | Engl Ch | North Sea | Baltic





Genetic diversity in mussels



Med | Biscay | Engl Ch | North Sea | Baltic

MtDNA D-loop

Nucleotide diversity in *Mytilus*

In contrast to clams a much lower diversity in Baltic

Geological history and selection are of strong influence

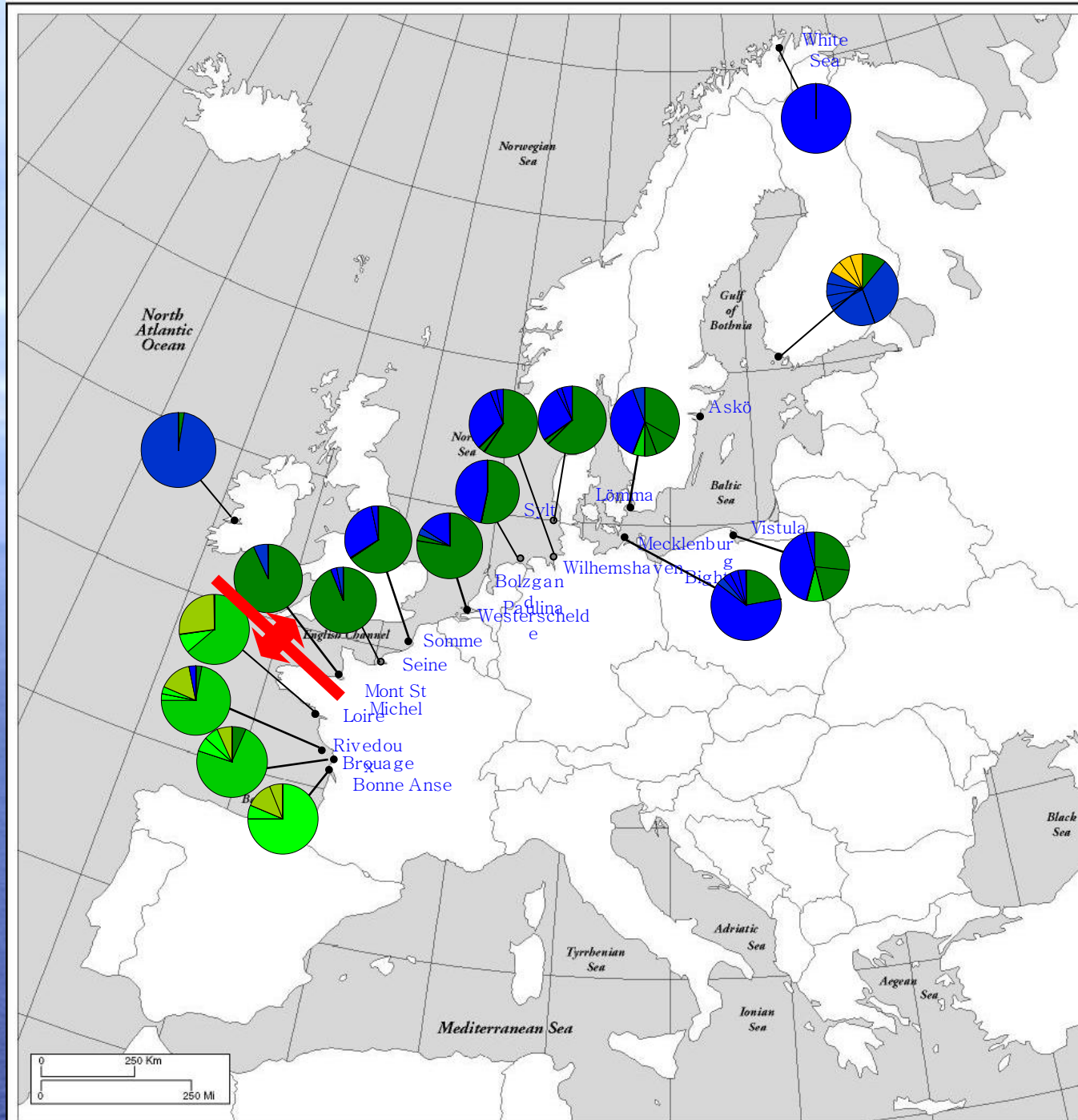


Macoma balthica

Analyses of
MtDNA (COI)
shows:

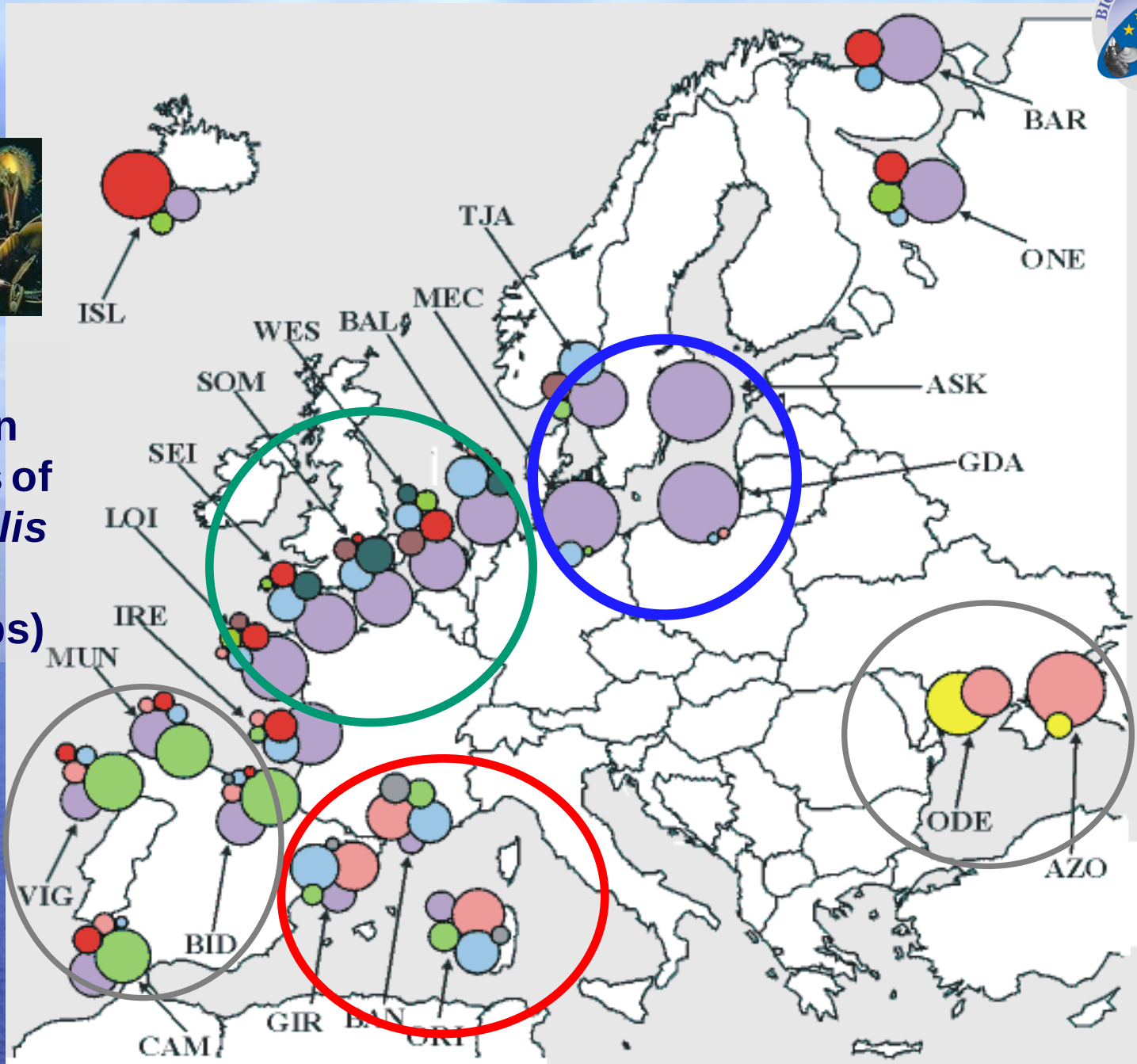
- Additional haplotype in Bay of Biscay, that does not enter North Sea

- Atlantic variant (dark green) enters southern Baltic

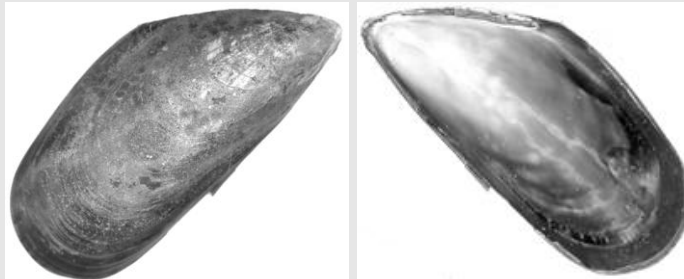




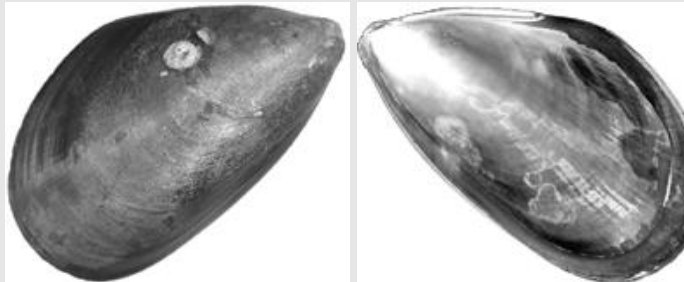
**Genetic
diversity in
populations of
Mytilus edulis
(Mt-DNA
haplogroups)**



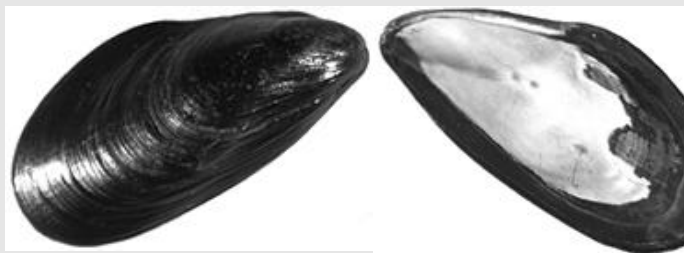
Mussels of the *Mytilus* complex are morphologically not easy to separate



Mytilus edulis
L., 1758



Mytilus galloprovincialis
Lamarck, 1819

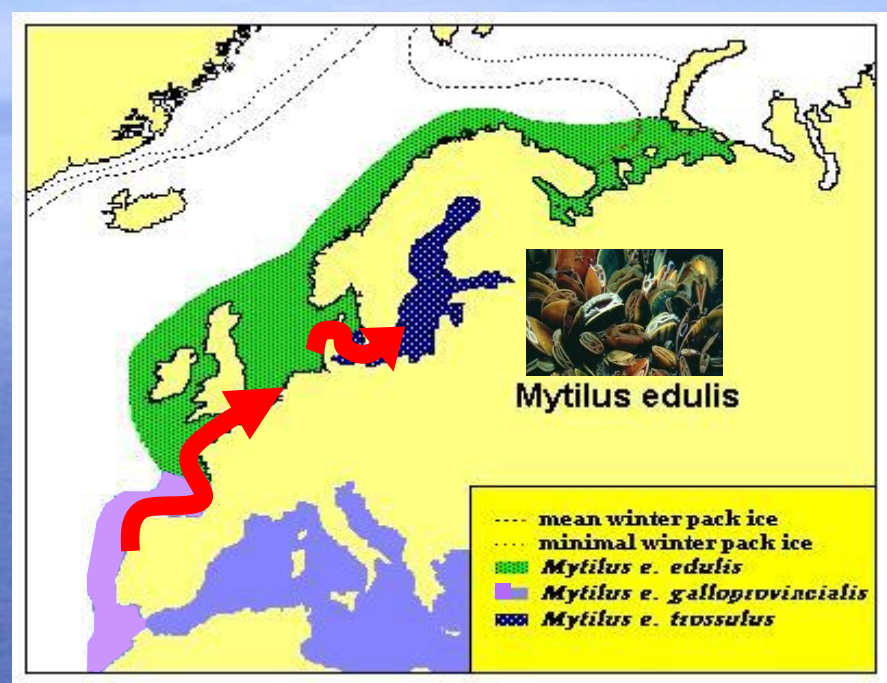
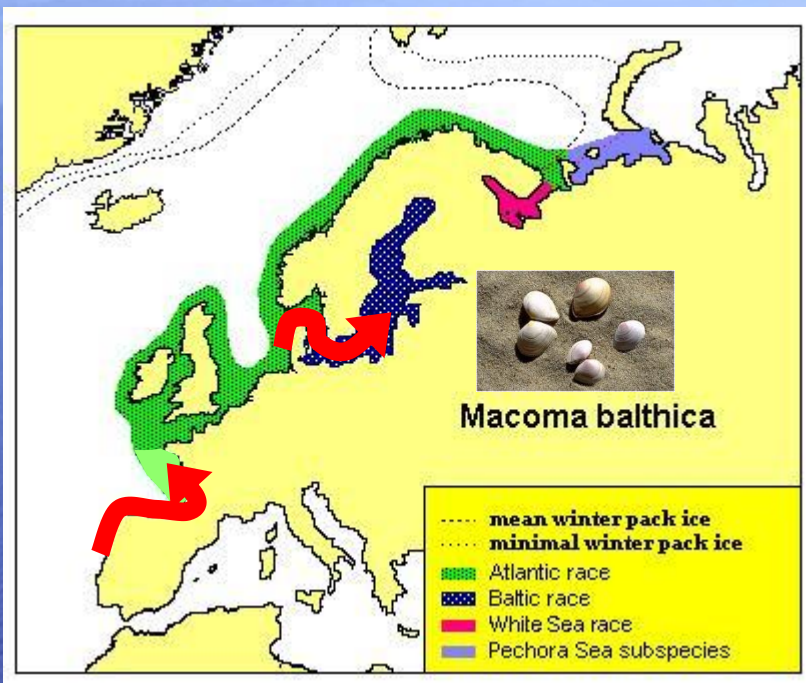


Mytilus trossulus
Gould, 1850

Wesselingh, 2003

Analyses of genetic diversity traits and historical records (from literature) indicate shift/changes of species/races along the European coast for both species groups. Mainly apparent around two locations:

- Bay of Biscay
- Kattegat (entrance Baltic)



Ecophysiological / adaptation diversity

We used several indicators for ecophysiological diversity:

- **Biochemical composition:**

(FAA, lipid, glycogen)

University of Gdansk;

Institut für Ostseeforschung Warnemünde

- **Weight index:**

University of Gdansk

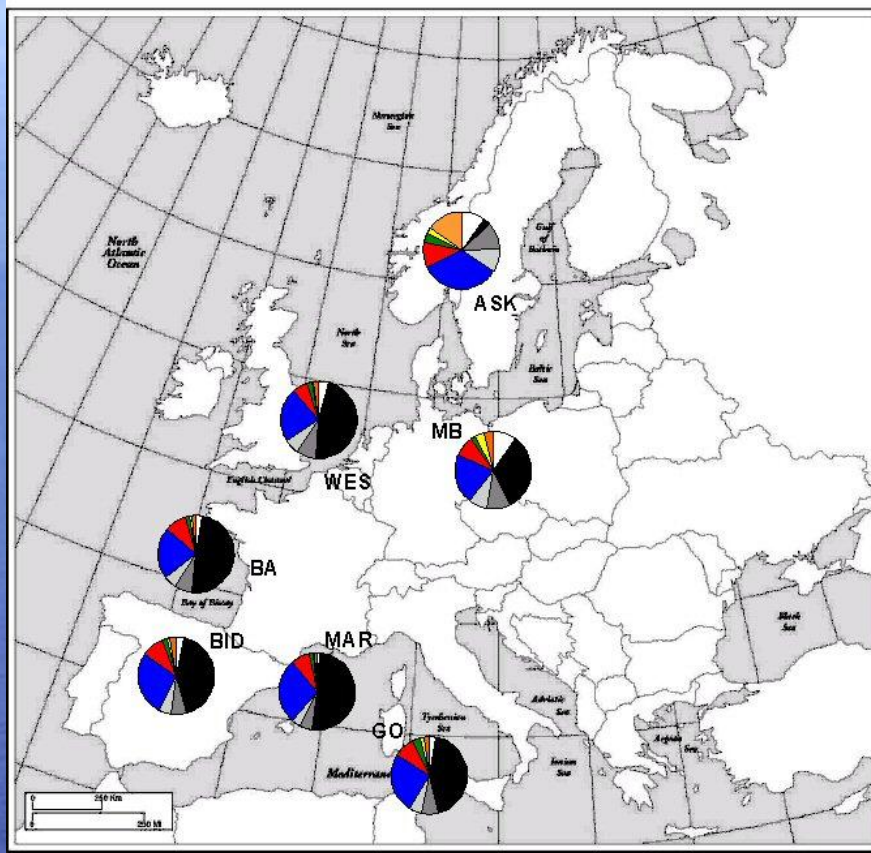
- **Respiration:**

Netherlands Institute for Sea Research

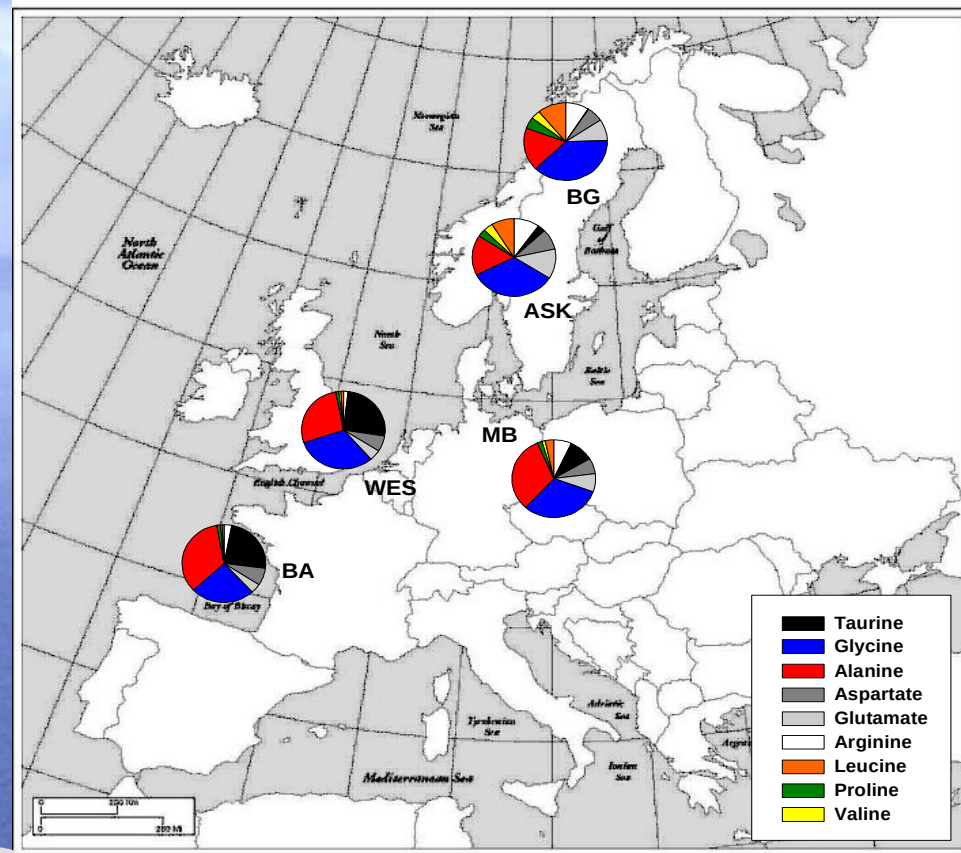


Free amino acids: Composition

Composition in Baltic strongly different from other areas
(in Baltic proper in animals no taurine, yet more leucine and proline)



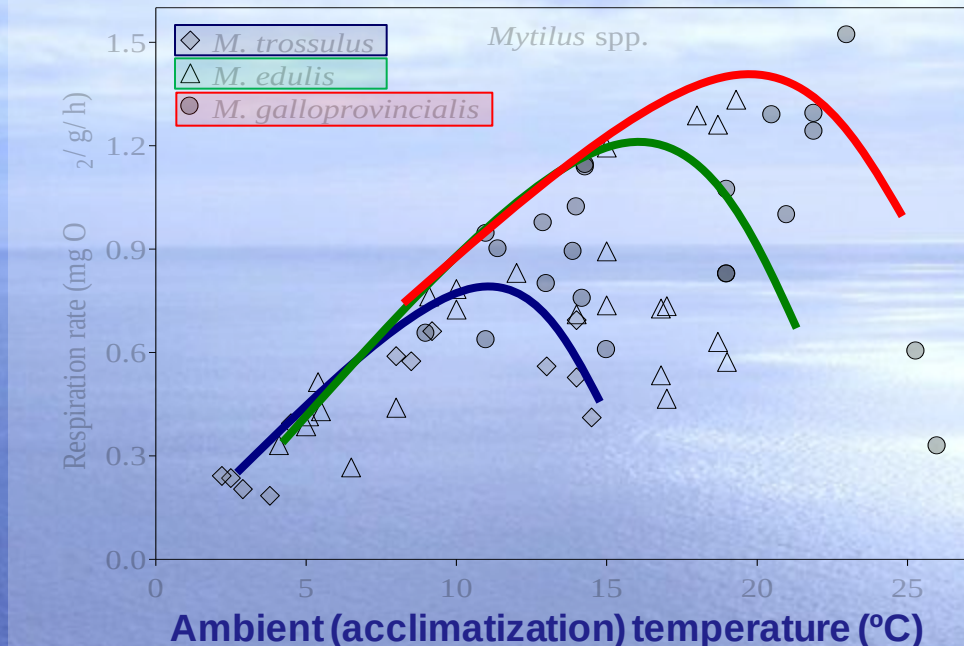
Mytilus
spp.



Macoma
balthica

Respiration rate (for *Mytilus* sp) : Clear differences between genetic groups

- Increase of the maximum respiration rate with ambient temperature
- Above 12 °C down-regulation because of dependency on other factors, e.g. food



If Climate Change continues the North-eastward shift of ecotypes/species along the European coastline will continue, having an effect on the performance of populations

This is important for aquaculture. At temperatures below 12 °C the potential growth of cultured mussels is more limited by low temperature than by food availability – a higher food supply will be less effective. At higher temperatures an increasing food supply may result in proportionally higher growth rates.

Conclusions on Ecophysiological and genetic diversity:

Several ecophysiological diversity (performance) indicators, particularly respiration rates, show differentiation between groups (ecotypes) of mussels and clams

>>>

Patterns of ecophysiological diversity coincide with those of genetic diversity

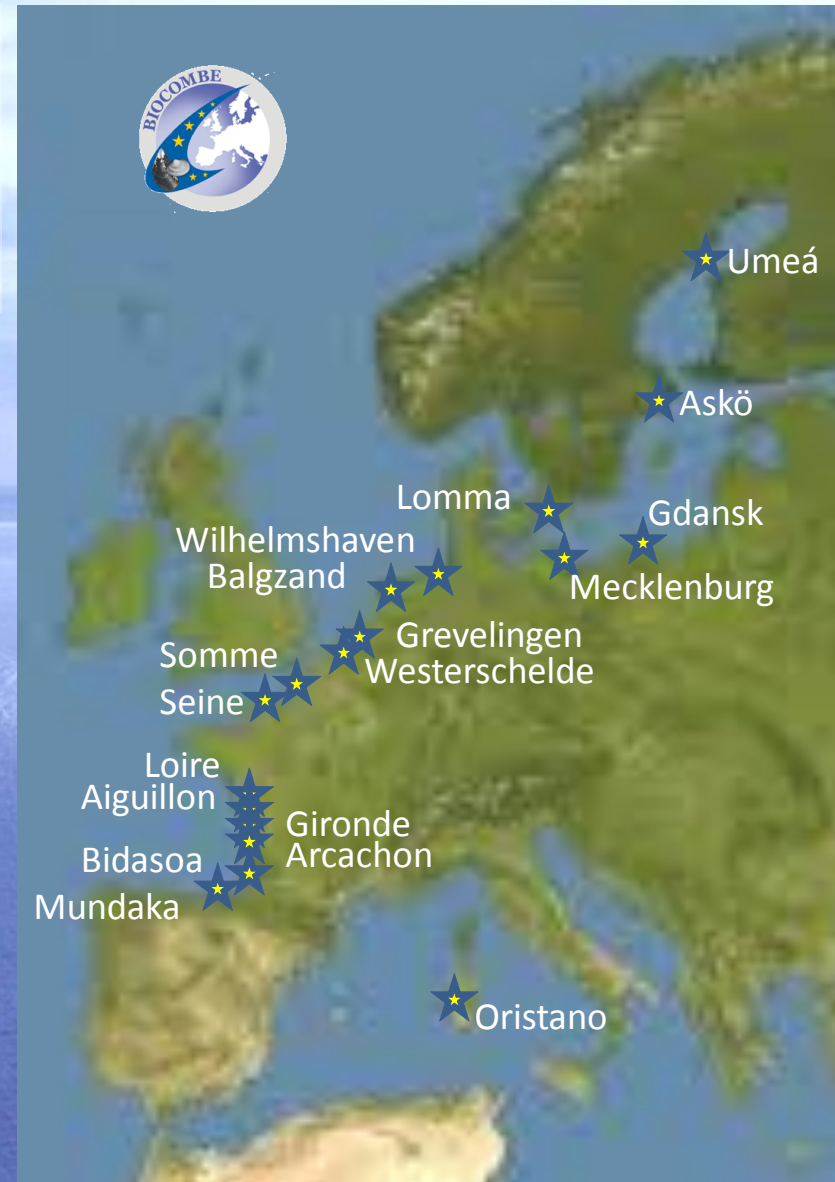
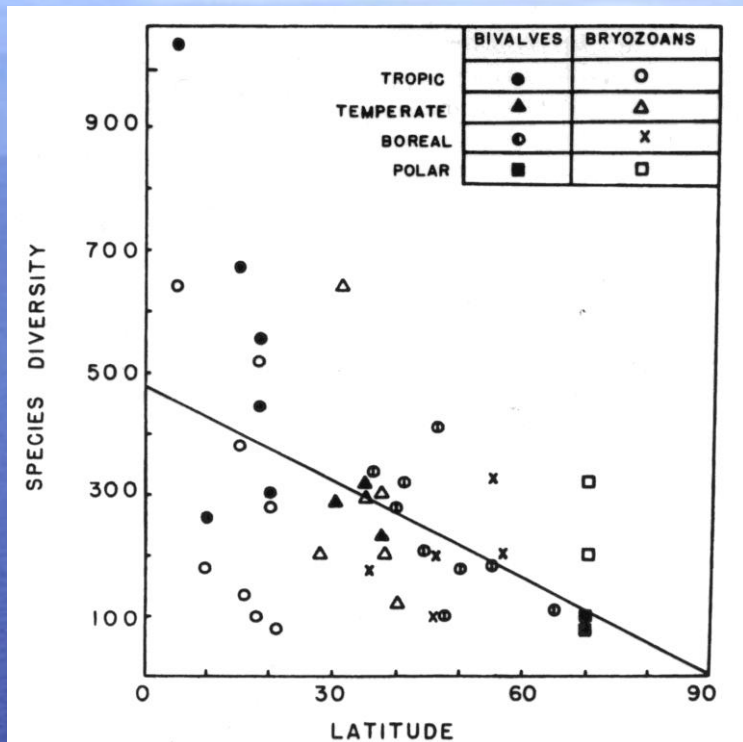
Level and amplitude of variation for ecophysiological indicators are primarily determined by T, S, food

Because of the increase of temperature with a speed of 1.4 per 40 year, the observed northward range shifts of mussels will continue with further warming
- we prospect this happens at an average speed of approx. 100 km in 10 years

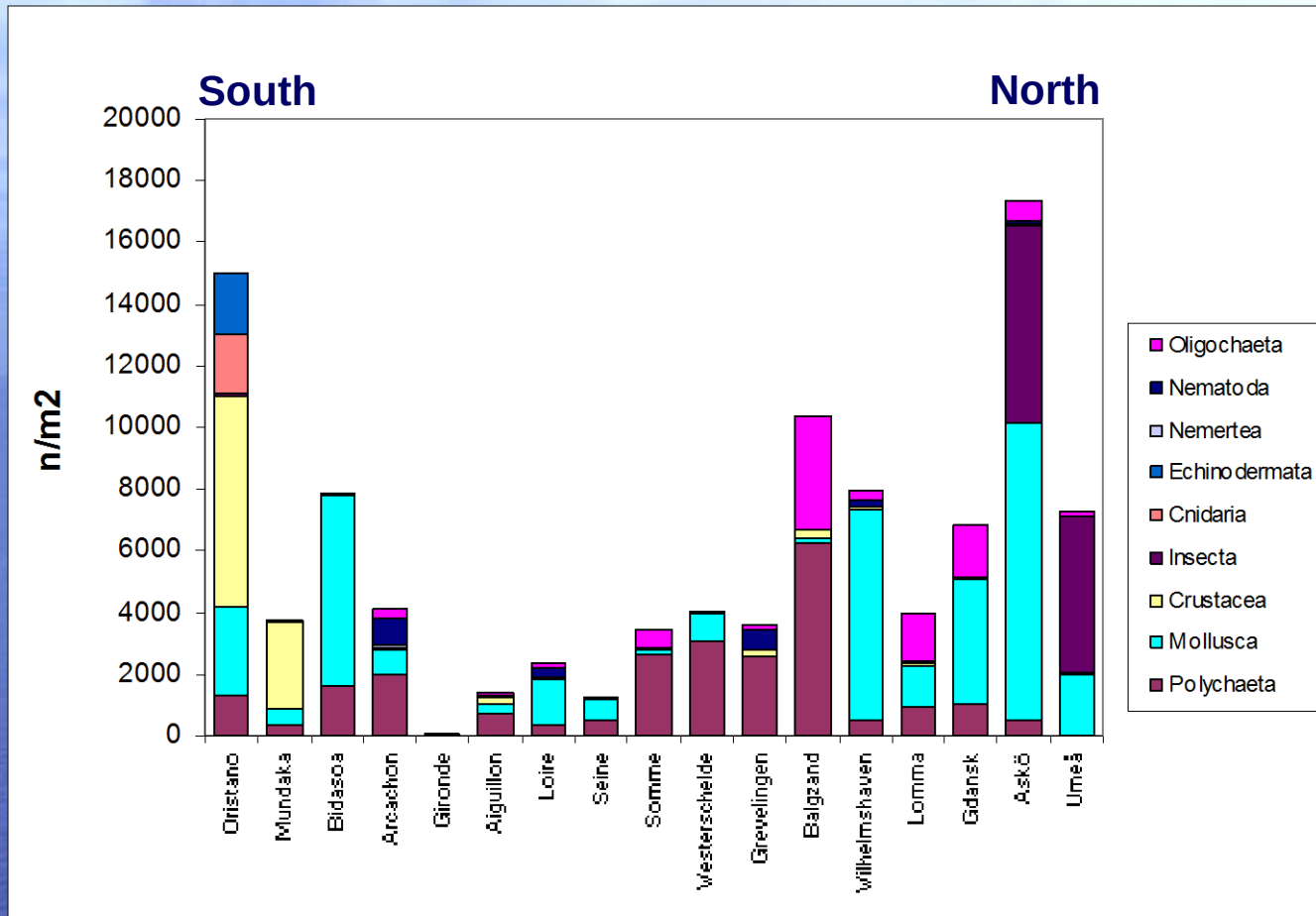
The genetic divergent group of *M. balthica* in the Bay of Biscay, with a low genetic diversity, will disappear from the Bay of Biscay with further climatic changes - we prospect this to happen within 50 to 100 years from now.

Species / Community diversity

The classical theory indicated that there is a decreasing diversity at increasing latitude. In BIOCOMBE and EMBOS we tested this.



Biocombe: Distribution of major taxonomic groups along European coast **2005 (densities; n/m2, spring)**



**No linear relation
between numbers
and latitude**

**Higher numbers:
- in Mediterranean,
North Sea, Baltic**



crustaceans

polych

polychaetes

insects

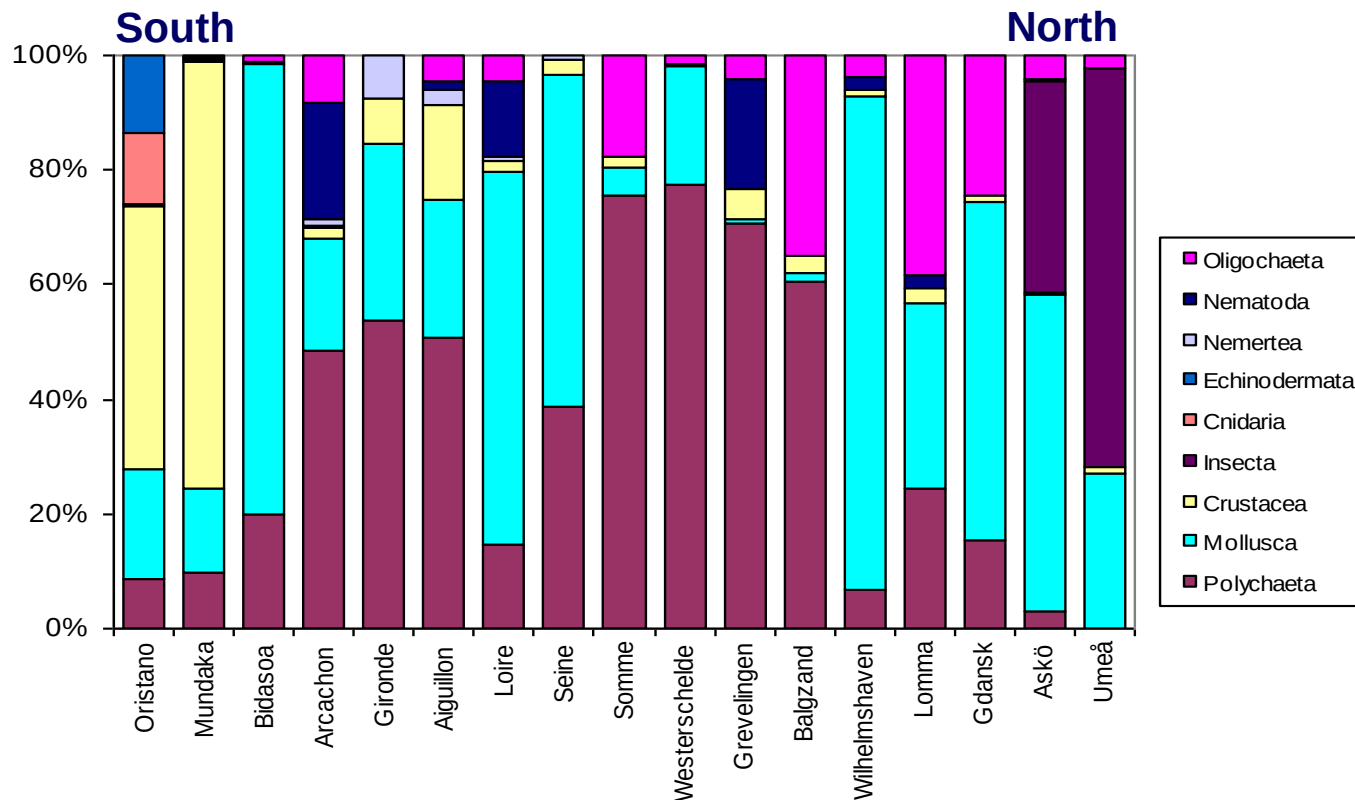


m

mollusks



Biocombe: Relative distribution of major taxonomic groups along Europe (based on numbers)



The distribution of major taxonomic groups is regionally connected.

Especially for polychaetes

crustaceans

polychaetes

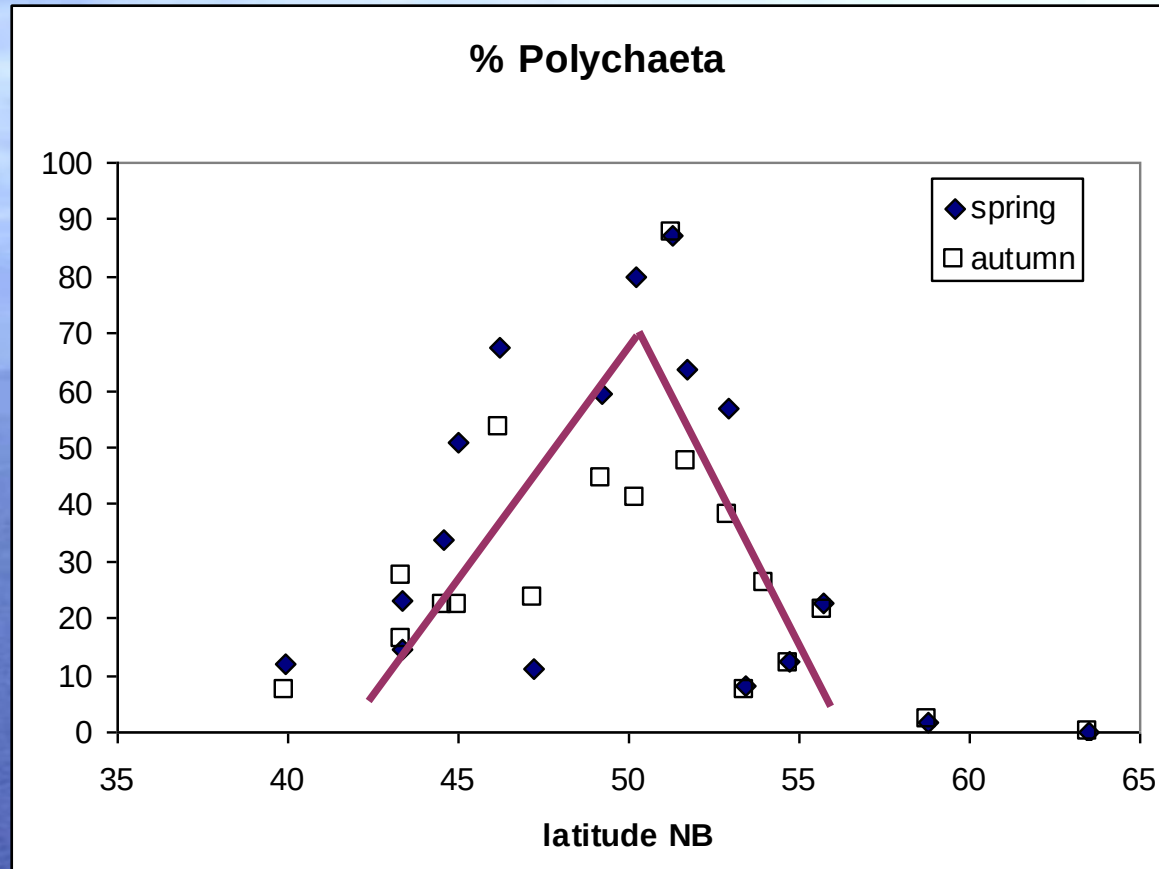
insects

mollusks

mollusks

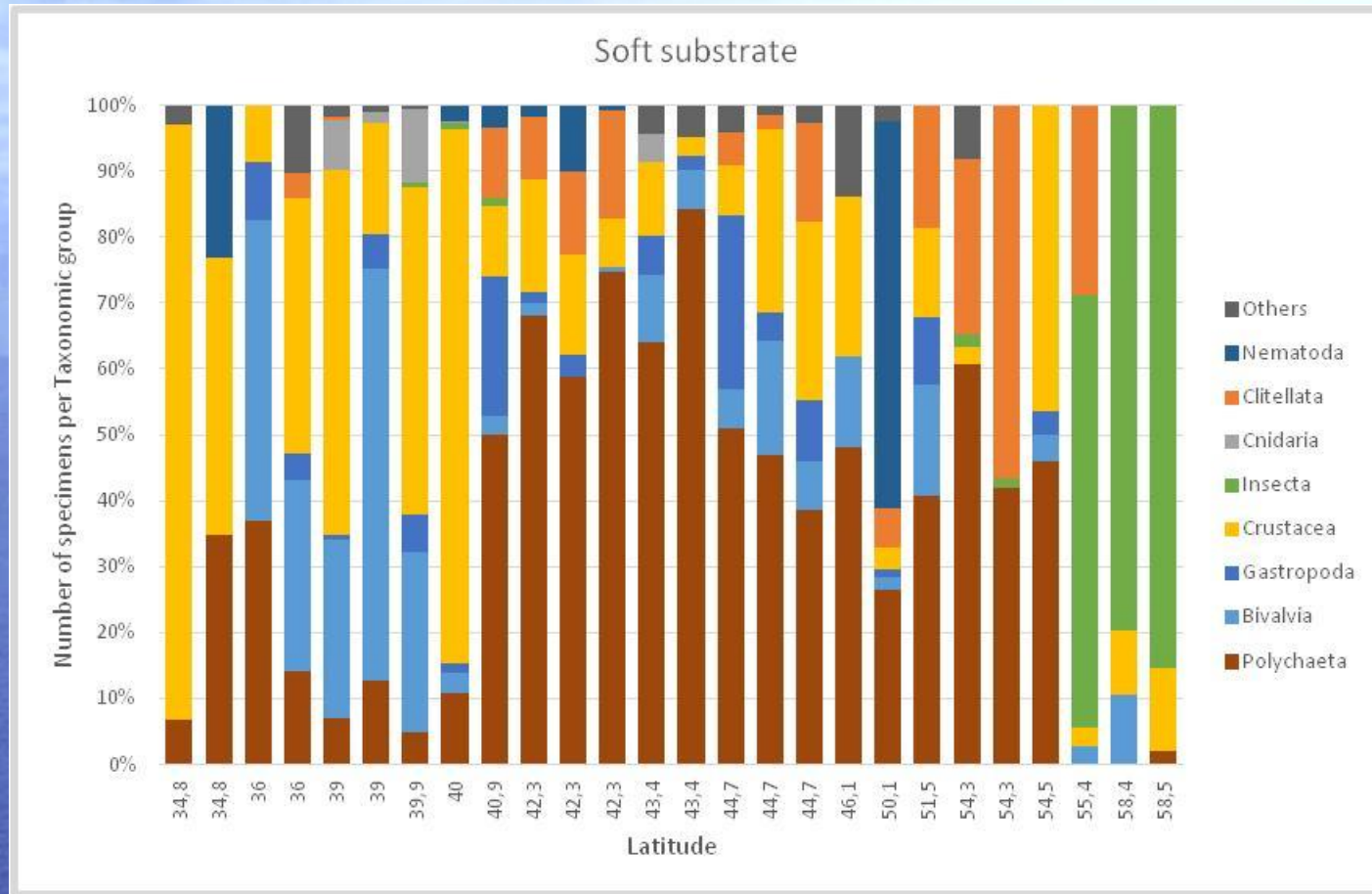


Relation % polychaetes and latitude



Relation % polychaetes is in fact dependent on environmental factors (see slide 47)

10 years later same result with EMBOS: Distribution of diversity along European coast



crustaceans

polychaetes

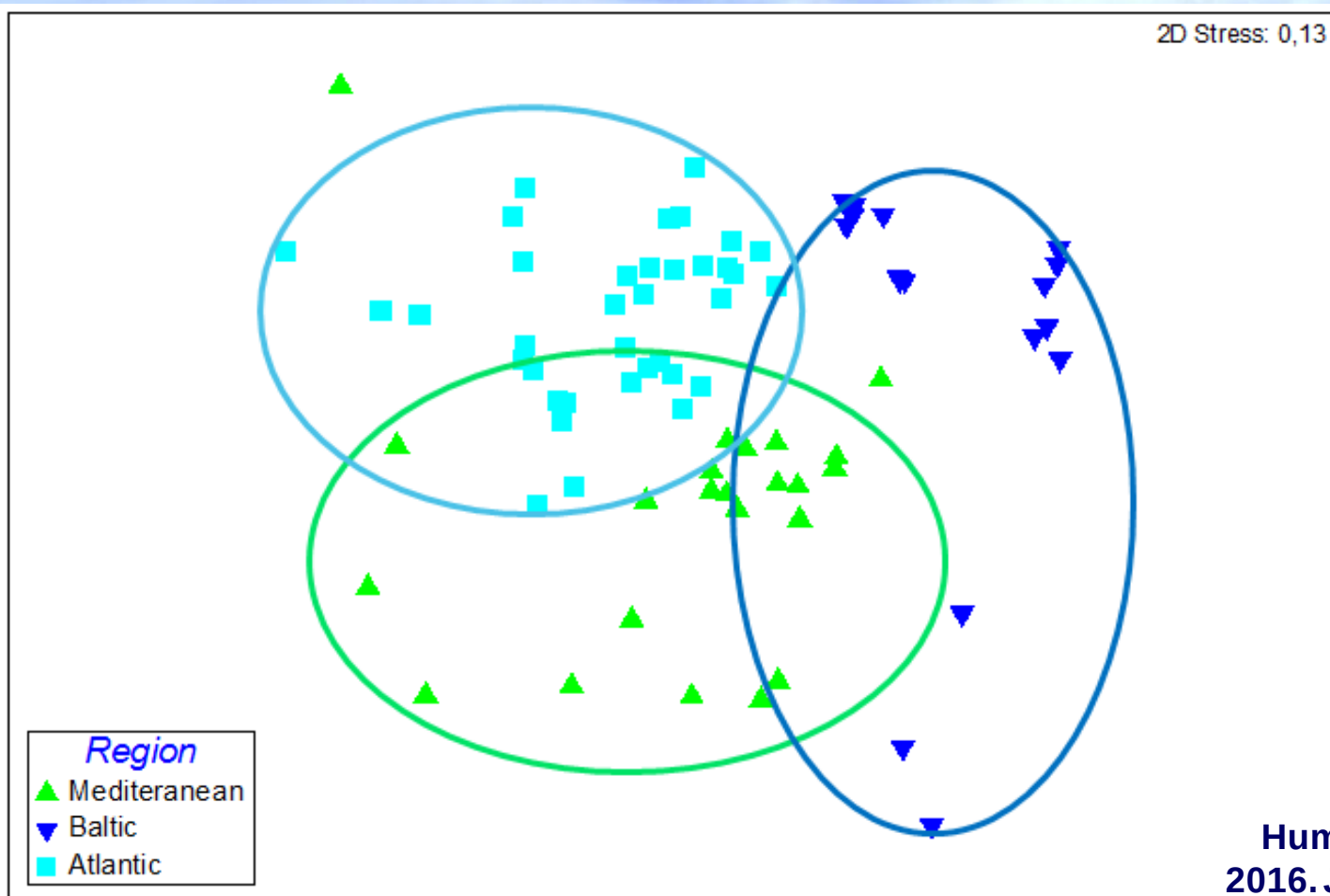
insects

mollusks

mollusks

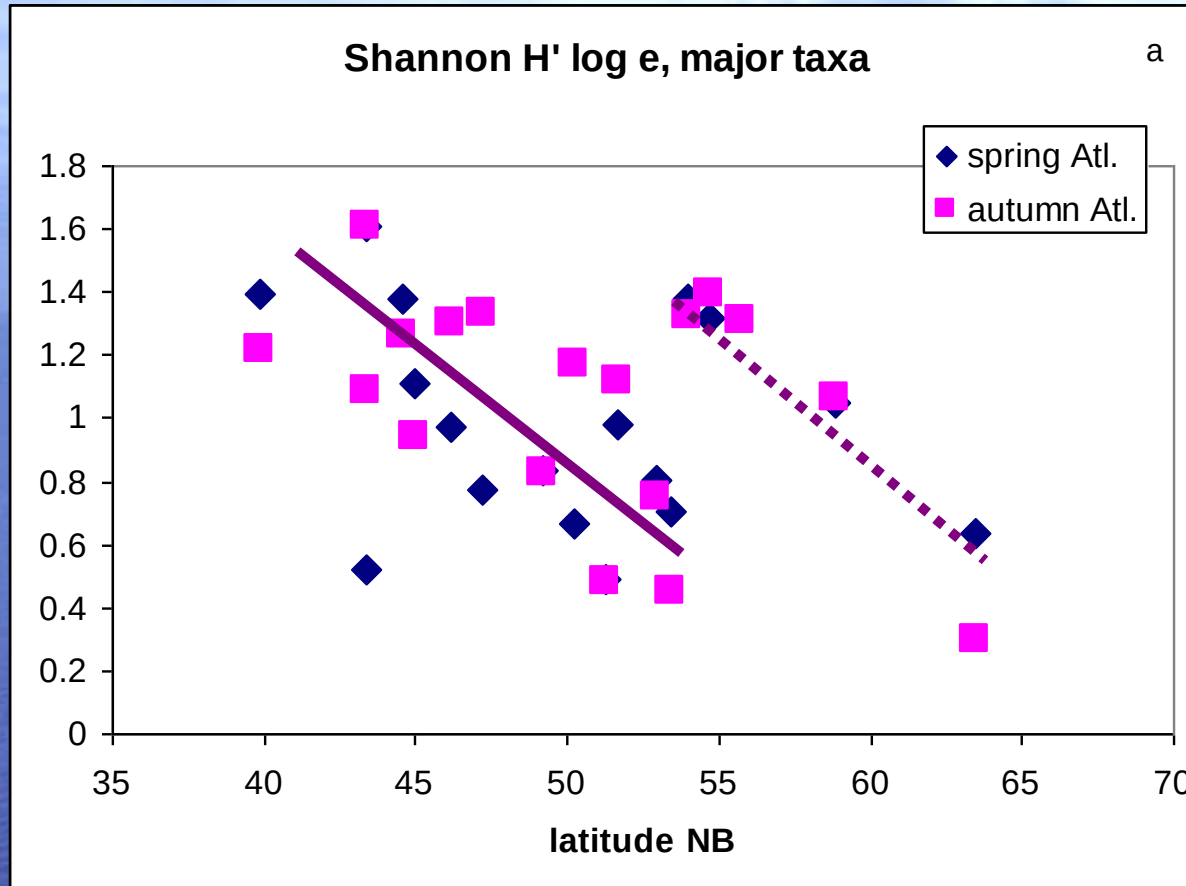
Humme et al.
2016. JMBA (acc.)

The differentiation in species composition divides the studied European population in 3 major clusters (= regions)
 (MDS on species diversity; square root transition of densities)
 (3 replicates per plot; 3 plots per station;; Bray Curtis similarities)



Humme et al.
 2016. JMBA (acc.)

Biocombe: Distribution of diversity along European coast

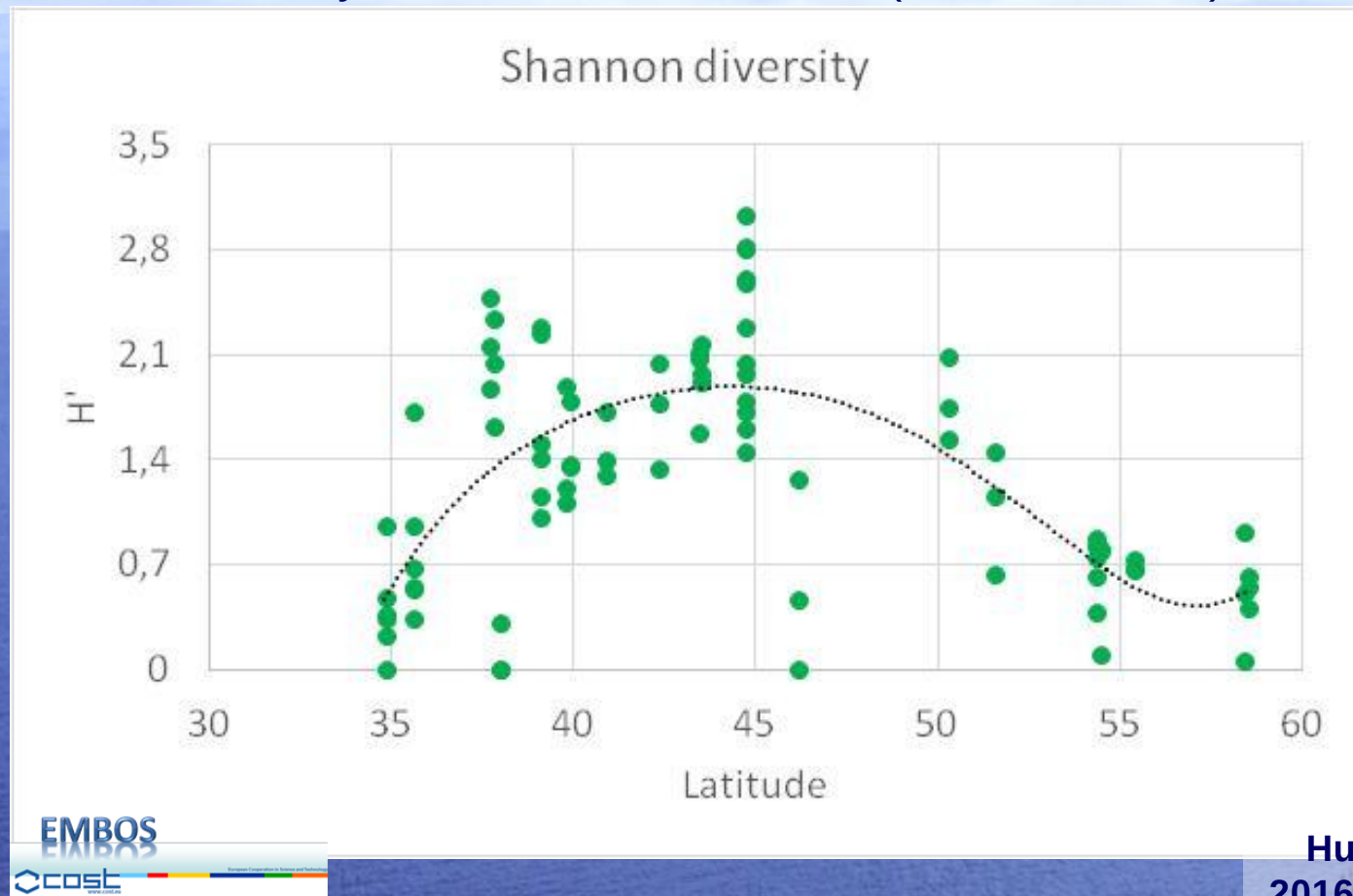


Species diversity seems to be in the benthic communities equal and equally variable at all latitudes

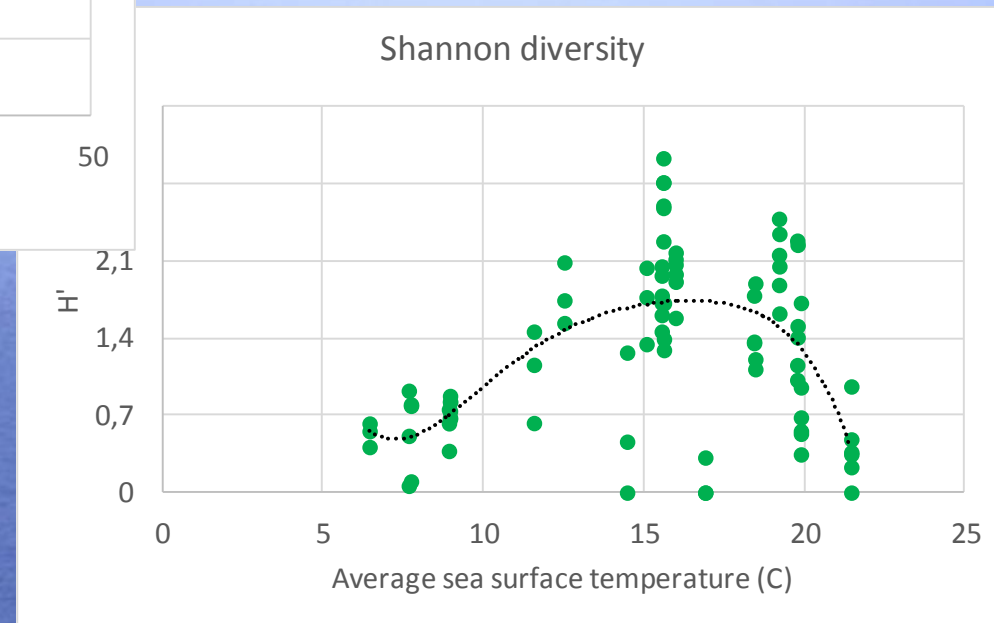
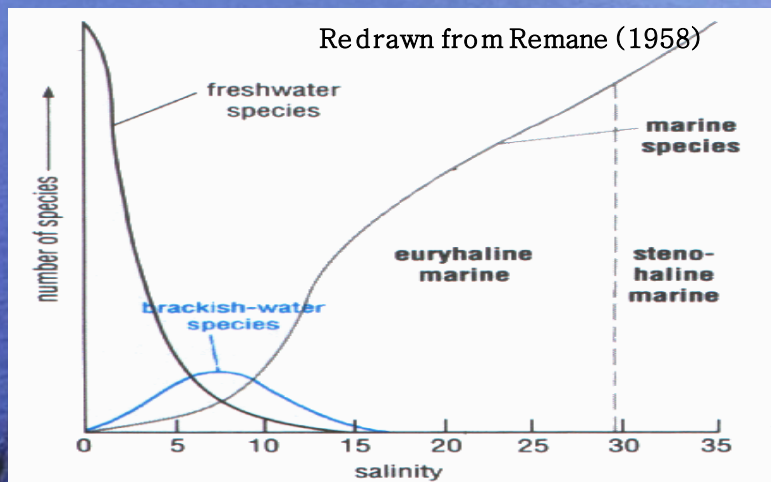
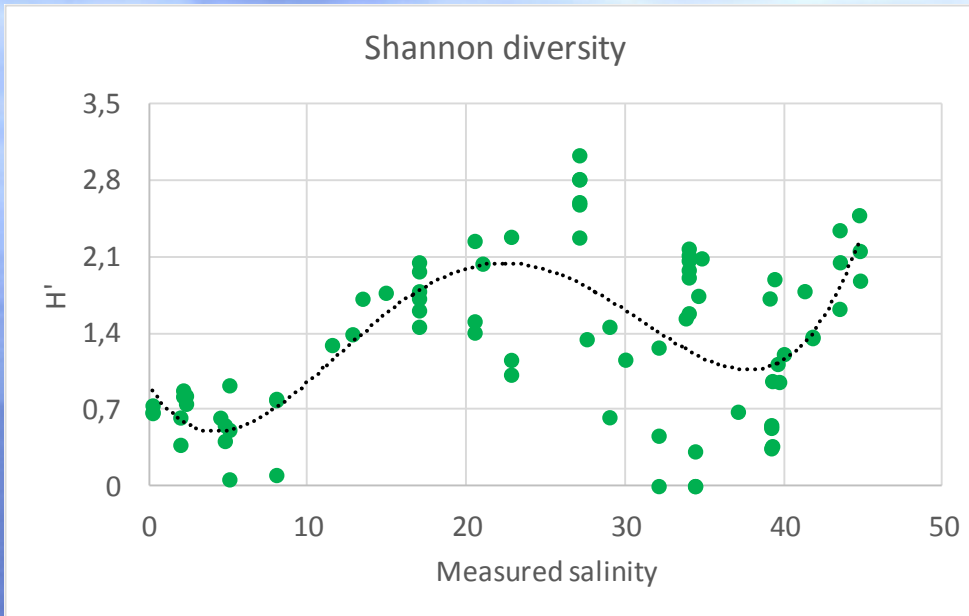
Yet,
different picture if we separate Baltic stations from other European stations

In EMBOS slightly different distribution of diversity with latitude along European coast

In EMBOS we were able to relate this changing level of biodiversity to environmental factors (see next slides)

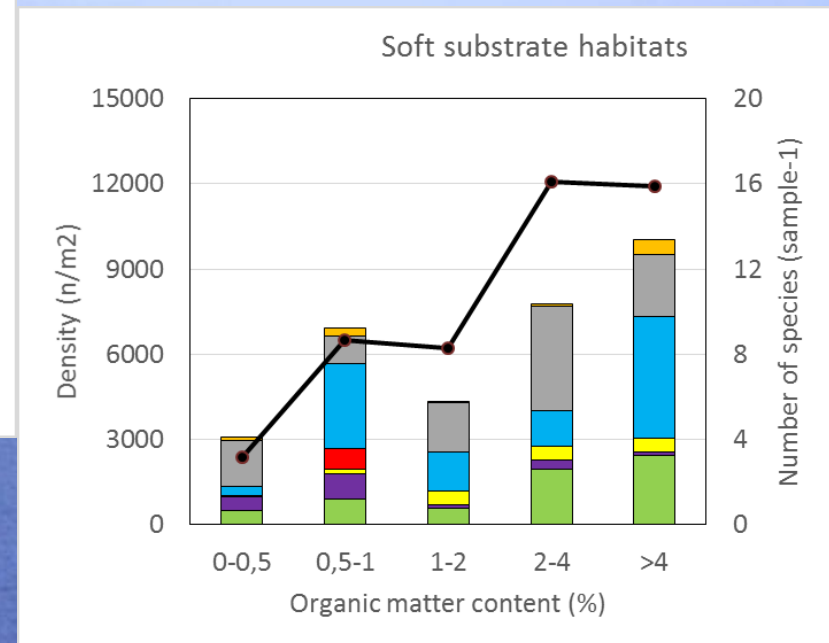
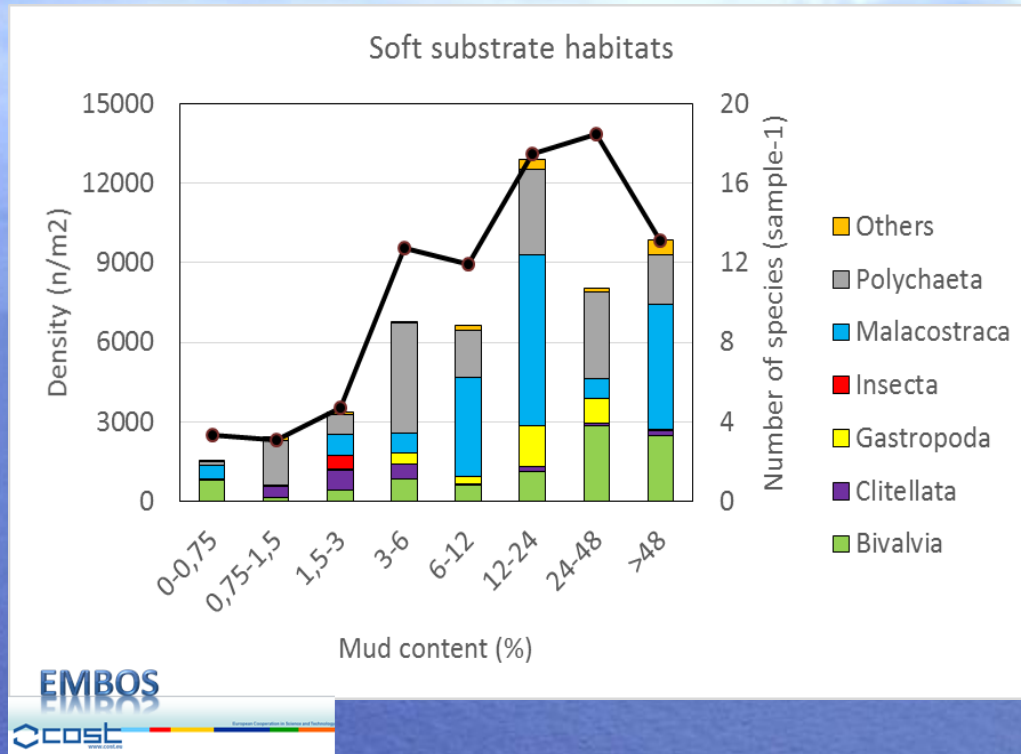


Species diversity in relation to salinity and temperature



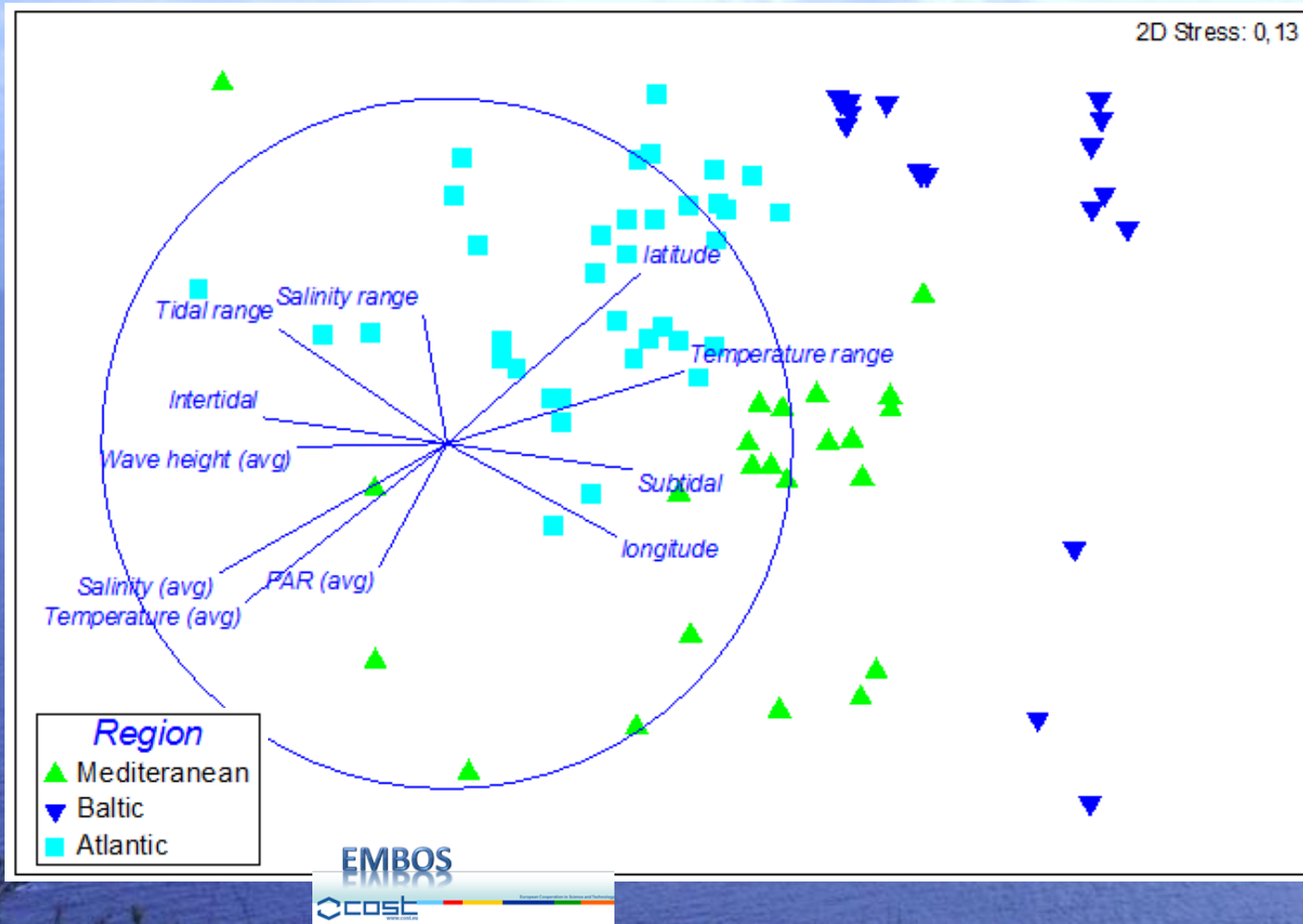
Humme et al.
2016. JMBA (acc.)

Densities and species diversity in relation to mud and organic matter content

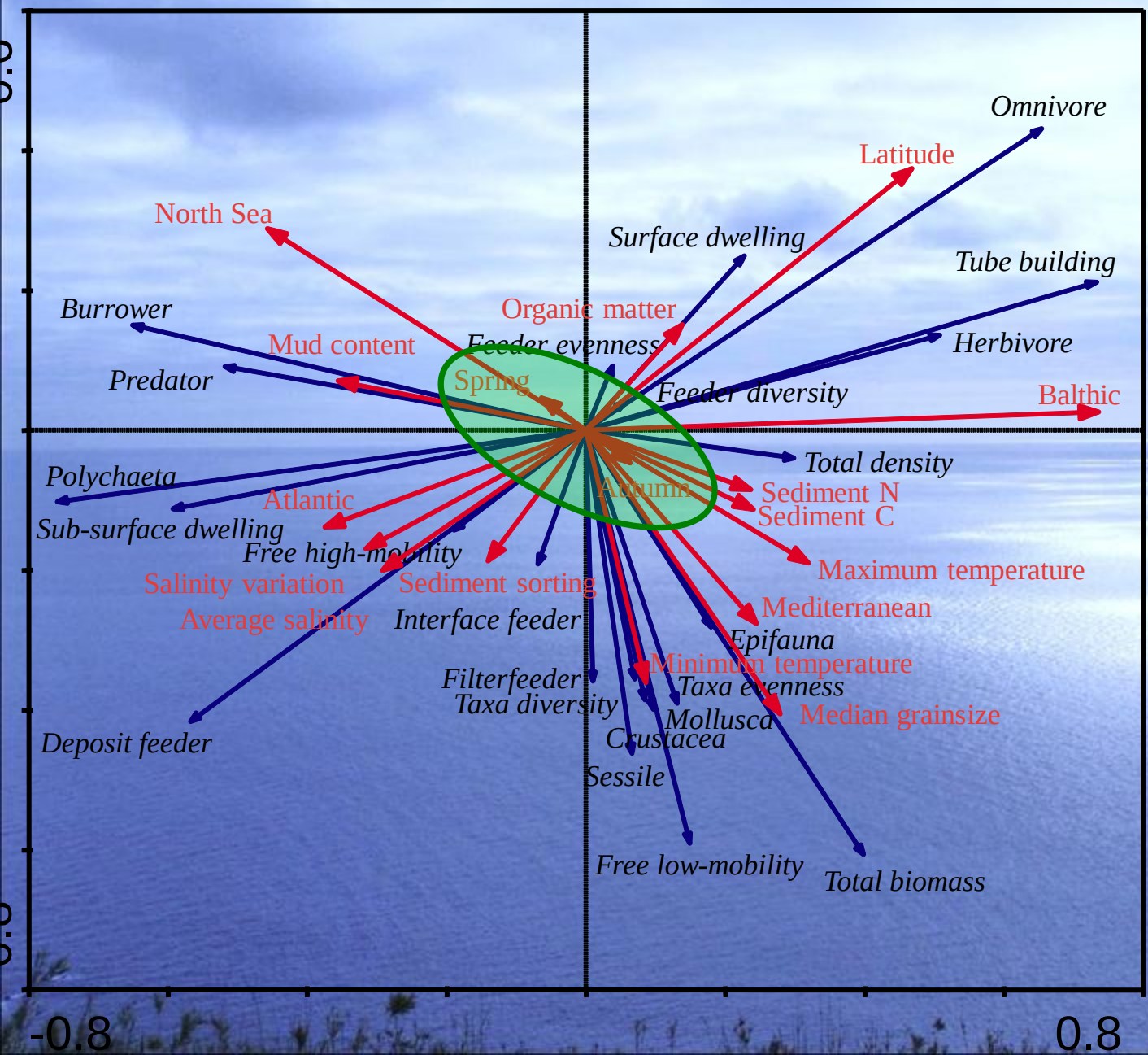


Hummelet al.
2016. JMBA (acc.)

MDS on species diversity (square root transition of densities) PCA on environmental variables

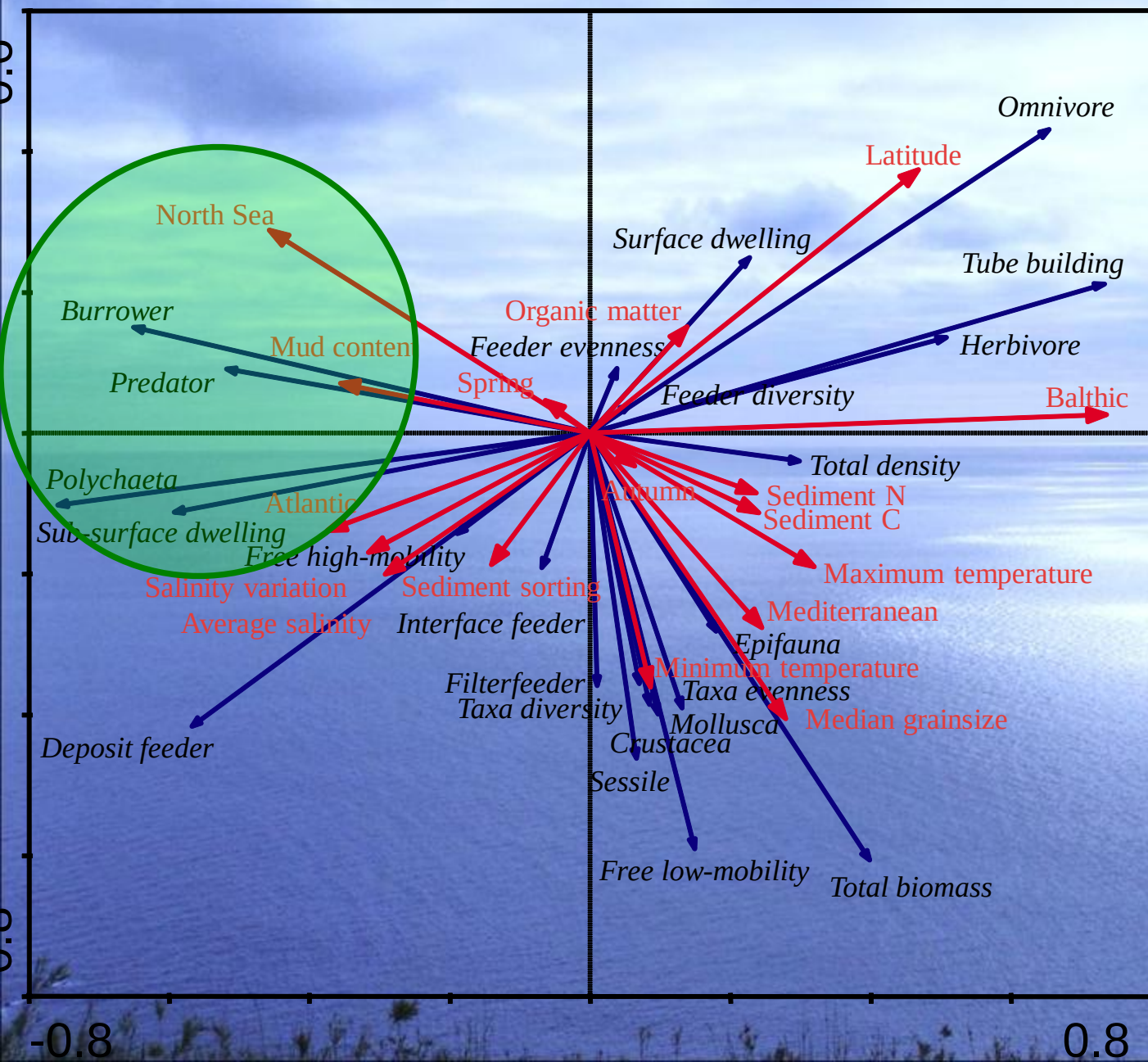


Latitude is related to the changes in salinity and temperature, and therefore we find nice correlations with all these factors



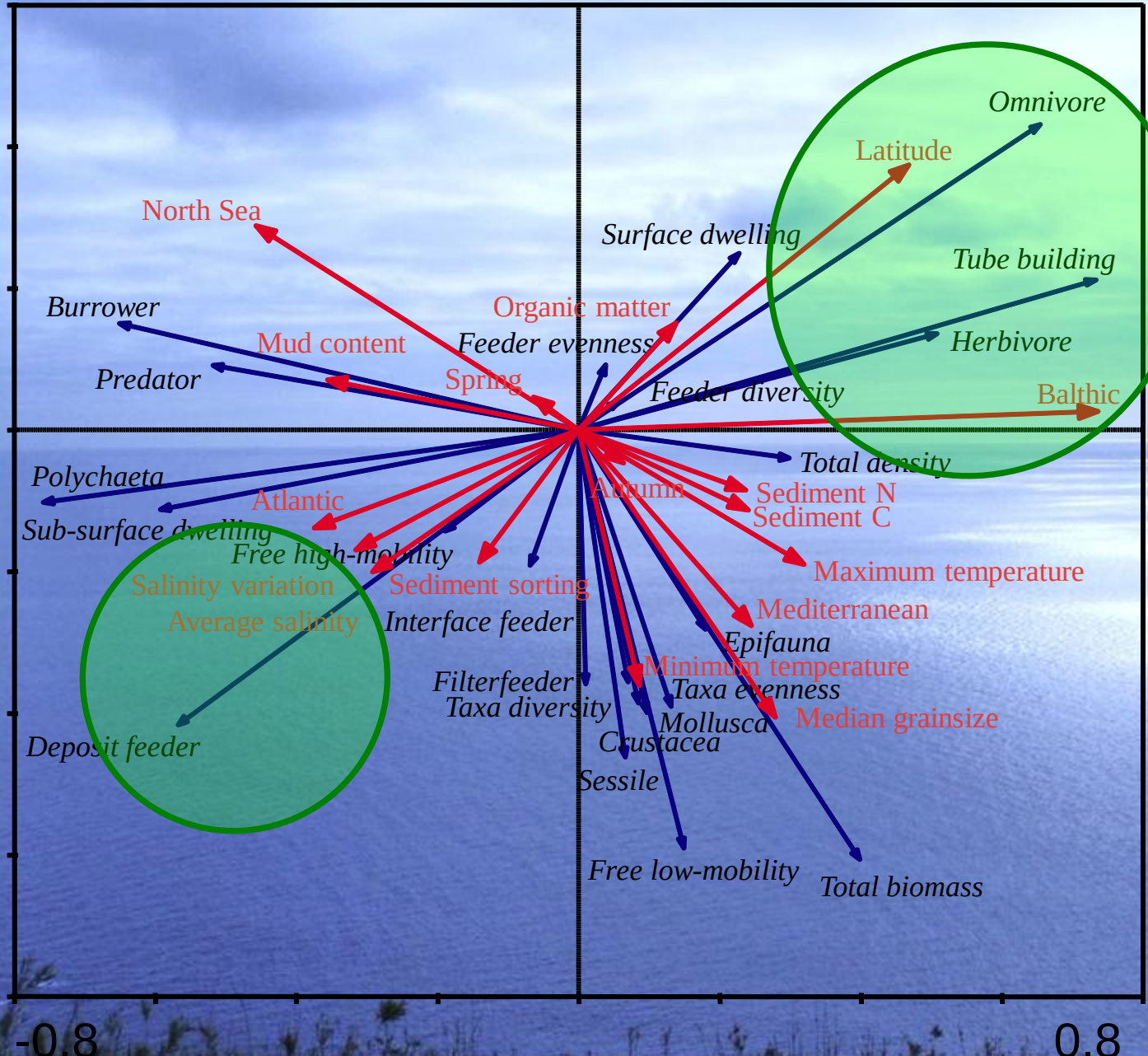
Redundancy Analysis (RDA) to unravel patterns in the various relations and variance

- No difference between seasons



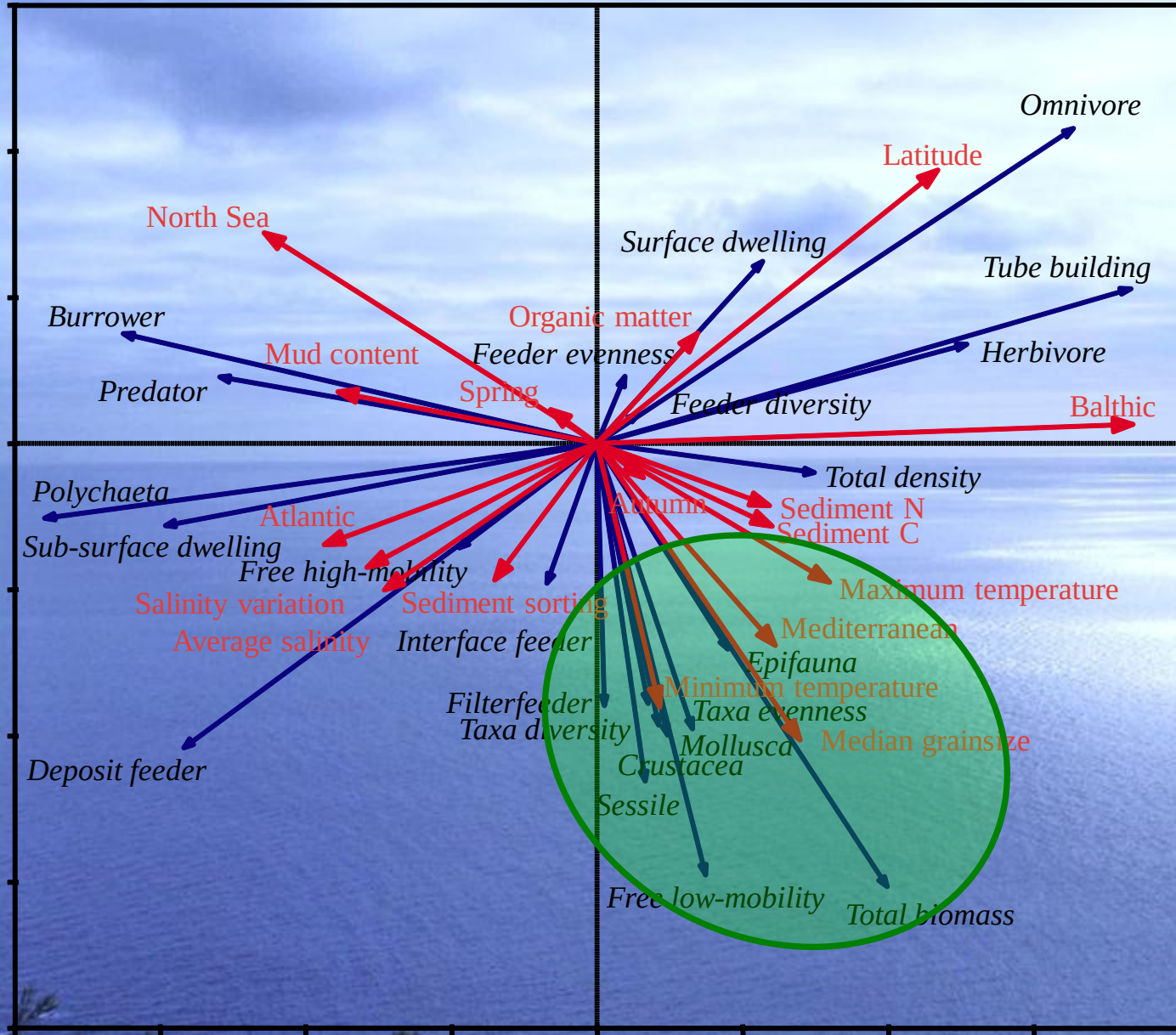
Redundancy Analysis (RDA) to unravel patterns in the various relations and variance

- No difference between seasons
- Polychaetes (high in North Sea & Atlantic) relate to mud content



Redundancy Analysis (RDA) to unravel patterns in the various relations and variance

- No difference between seasons
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- Major feeding types related to salinity, i.e indirectly to Baltic and latitude



Redundancy Analysis (RDA) to unravel patterns in the various relations and variance

- No difference between seasons
- **Polychaetes** (high in North Sea & Atlantic) relate to mud content
- **Major feeding types** related to salinity, i.e indirectly to Baltic and latitude
- **Taxa diversity and biomass** related to **temperature** (high in Mediterranean) and **grainsize**, and thereby to sessile filter-feeding Molluscs and low mobile Crustaceans in the epifauna

Conclusions on species / community diversity

- **Species diversity has no (simple linear) relationship with latitude**
- **Taxonomic diversity** (and other diversity indicators as e.g. feeding type), **can be related to environmental factors** (T, S, mud content, grain size)
- **Diversity has no relation with numbers (densities) of benthic animals**
- **Latitudinal trends (in diversity and biomass) and regional differences are result of including areas like Baltic with typical salinity clines and taxa (insects) and Mediterranean with higher temperatures (and crustaceans)**
Trends with latitude and regional differences are indirect and can be atypical.

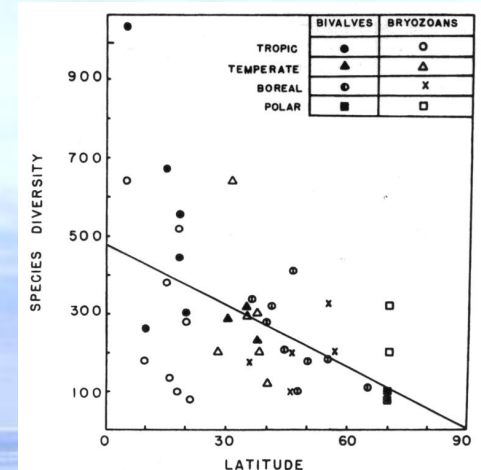


Figure 3. Species diversity as a function of latitude for bryozoa and bivalves. The least-squares best fit is $Y = -5.29X + 481.8$; $r = 0.51^{**}$; $n = 41$.



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