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?

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

**Central North Sea**

*MacKenzie & Schiedek 2007*  
*Global Change Biol.*

*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

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

Ter Hofstede & Rijnsdorp, 2011
ICES J. Mar. Sc. 68: 1189
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.
- *Marenzellaria* sp.
- *Caulerpa* in Mediterranean
Marenzelleria sp. have taken over 80% of the biomass in several lagoons in the Baltic.

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

Photo: Johanna Stigzelius
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.

http://www.sbg.ac.at/ipk/avstudio/pierofun/ct/caulerpa.htm
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**

**Ensis directus**
Arrived in 1989

Mya arenaria
Arrived before 1800

**Cerastoderma edule**
Native

10 years
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.

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 zoomacro-benthos (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 dm$^2$ total)  
  (EMBOS: 3 cores, 4 dm$^2$ 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
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
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)
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)
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.

**Figure 3.** Species diversity as a function of latitude for bryozoans and bivalves. The least-squares best fit is \( Y = -5.29X + 481.8; r = 0.51**; \( n = 41 \).
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
The distribution of major taxonomic groups is regionally connected. Especially for polychaetes.
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

Hummel et al. 2016. JMB (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)
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

Redrawn from Remane (1958)

Hummel et al. 2016. JMBA (acc.)
Densities and species diversity in relation to mud and organic matter content

Hummel et al. 2016. JMBA (acc.)
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

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- Polychaetes (high in North Sea & Atlantic) relate to mud content
- Major feeding types related to salinity, i.e. indirectly to Baltic and latitude

![Diagram with various ecological terms and their relationships]
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.

