Vocational Aqualabs

# Vocational Aqualabs - Vocational Generic Skills for Researchers

## Experimental Design

### Introduction to multivariate analysis

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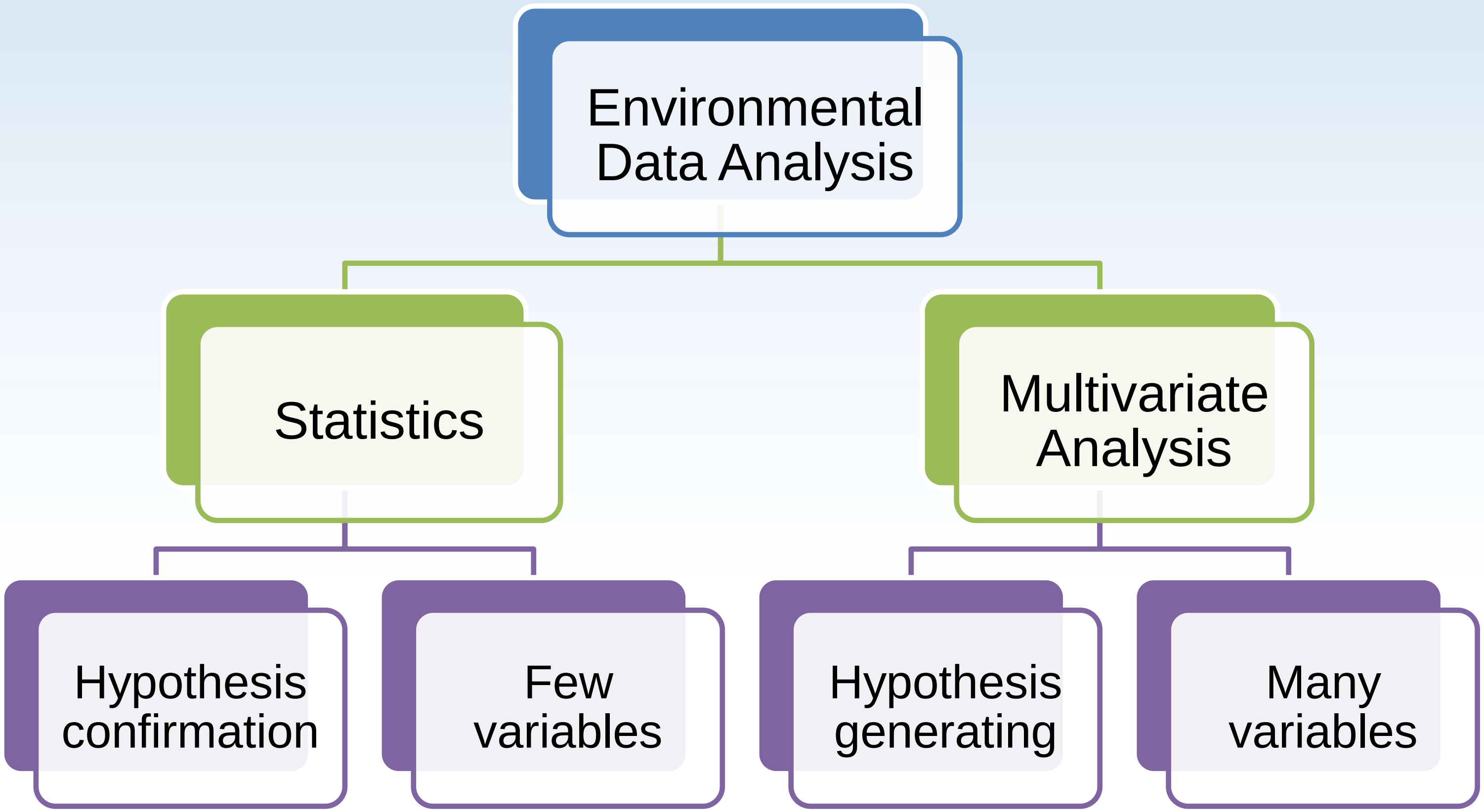
# Multivariate analysis

- Community level data is important for interpretation of ecological effects from properly constructed field studies (see unit 4), though can be used for a variety of lab-derived multivariate datasets
- Community level data is multivariate (many variables) as each sample site is described by the abundances of a number of species or environmental factors
- **What is Multivariate Analysis?**
- **Why use it for analysing environmental data?**
- **What are the main techniques of MVA?**

# Multivariate analysis

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# Multivariate analysis

**There are three main advantages of using MVA**

1. user appreciates the problem and foresees data type, sampling design and analysis method
2. there is a consistency of implementation
3. detects smaller differences and more subtle changes in community structure

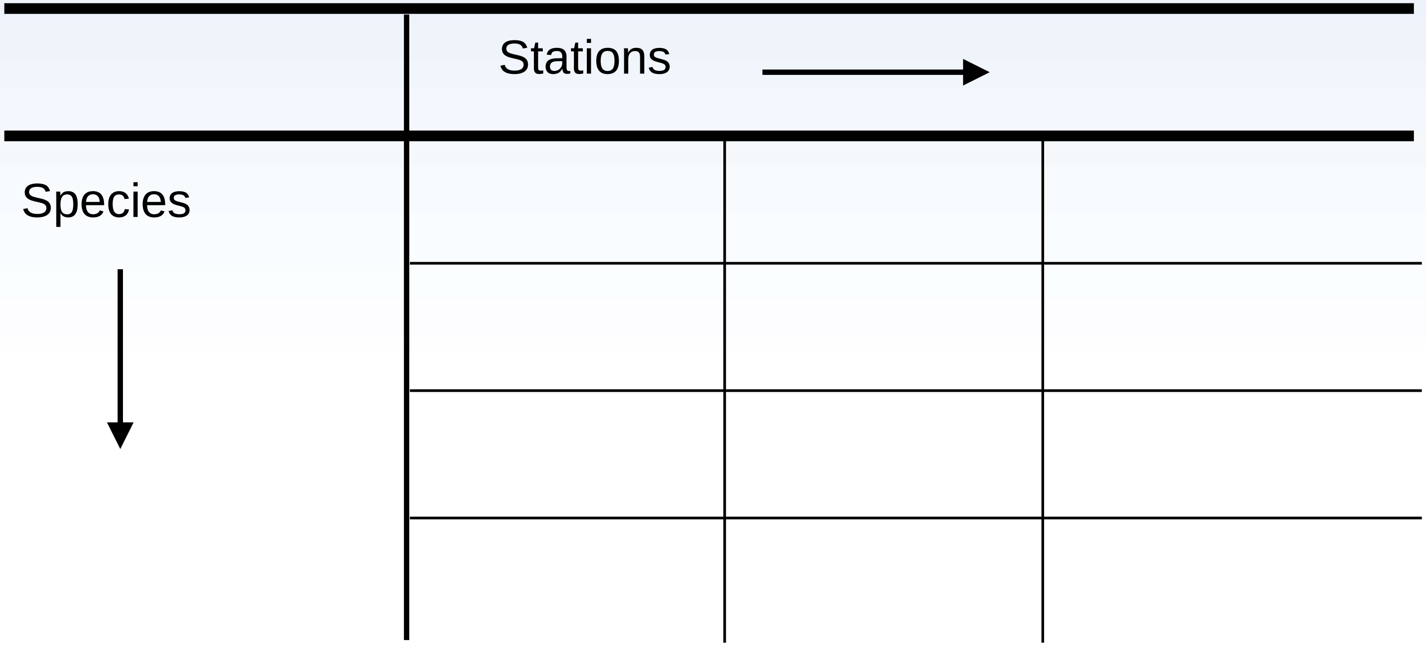
# Multivariate analysis – main types

- **Classification**
- **Ordination**

- **<u>Data input</u>**

# Multivariate analysis – data input

## Data matrix (two way table):



# Multivariate analysis - transformations

- **for MVA is primarily used to weight the data in order to even out the contribution made by all variables, e.g. species, environmental factors**
- **Commonly used transforms:**
  - square root (sq rt)
  - log transform (lg)
  - fourth root (4rt)
  - binary or presence/absence
- **Strength: sq rt < lg < 4rt < +/-**



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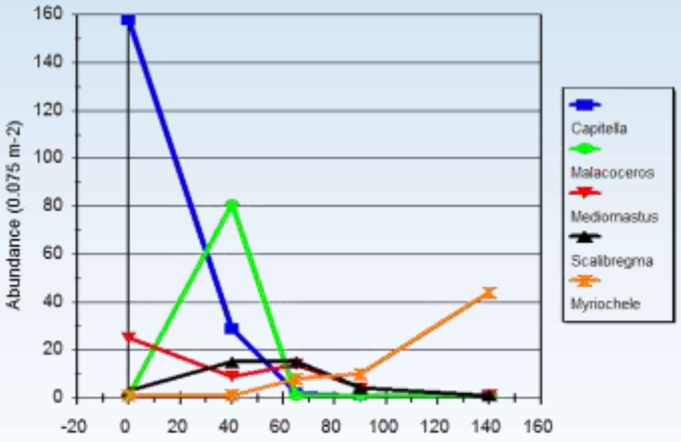
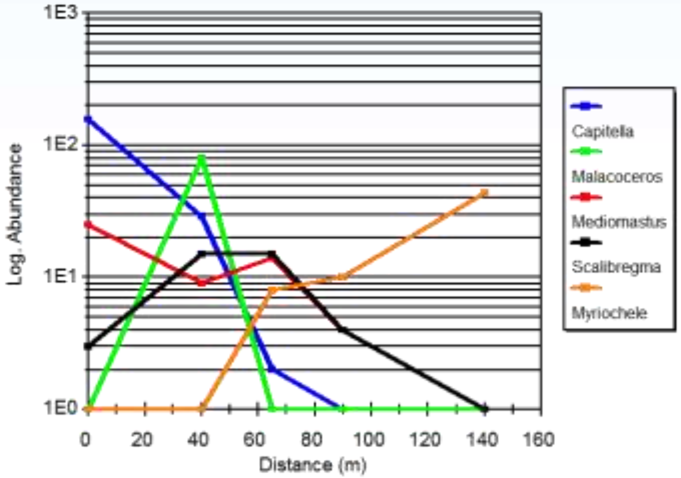
# Multivariate analysis - transformations

- **log transformation**
  - downweights abundant species
  - increases importance of rare species
- **log(x + 1)**
  - 1000 ind  > 3.0004
  - 100 ind  > 2.0043
  - 10 ind  > 1.0413
  - 1 ind > 0.3010



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# Multivariate analysis – main types

- <u>Classification</u>
- Ordination



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# Multivariate analysis - classification

- **Groups similar entities together in clusters or groups**

- **Two basic kinds:**
  - Non-hierarchical classification, e.g. twoway table
  - Hierarchical classification, e.g. cluster analysis

# Multivariate analysis - classification

- simple ordering or species and stations so their occurrences give a patterned structure along the gradient
- good for large data sets
- done “by eye” or by computer

Table 1.3. *German meadow samples arranged by the Braun-Blanquet method*

| | Sample* | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | B | B | B | B | B | B | B | G | G | G | G | G | G | C | O | C | C | C | C | C | C | C | C | C |
| Species | 4 | 10 | 1 | 9 | 15 | 3 | 24 | 2 | 16 | 18 | 12 | 20 | 5 | 22 | 23 | 19 | 13 | 17 | 6 | 11 | 8 | 21 | 25 | 14 | 7 |
| *Ia* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Bromus erectus* | 9 | 7 | 8 | 8 | 8 | 8 | 6 | | | | | | | | | | | | | | | | | | |
| *Scabiosa columbaria* | 2 | 1 | 1 | | 1 | | | 3 | | | | | | | | | | | | | | | | | |
| *Thymus serpyllum* | 1 | 3 | 2 | | | 1 | | 1 | | | | | | | | | | | | | | | | | |
| *Salvia pratensis* | | 5 | | 3 | 2 | 4 | 4 | | | | | | | | | | | | | | | | | | |
| *Koelria pyramidata* | 3 | 4 | 4 | 4 | | | | | | | | | | | | | | | | | | | | | |
| *Festuca ovina* | | 3 | 3 | 2 | | | | 2 | | | | | | | | | | | | | | | | | |
| *Ib* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Campanula glomerata* | 2 | | 1 | 2 | | 2 | 1 | | 1 | | 2 | | | | | | | | | | | | | | |
| *Viola hirta* | | 4 | | 3 | 1 | 1 | 1 | | | 1 | | | | | | | | | | | | | | | |
| *Briza media* | | 2 | 2 | 3 | | | | 2 | 3 | | | | | | | | | | | | | | | | |
| *Linum catharticum* | 1 | | 1 | 1 | | 1 | | | 1 | | | | | | | | | | | | | | | | |
| *IIb* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Geum rivale* | | | | | | | | | 2 | 1 | 1 | 1 | | 1 | | 2 | 1 | 1 | 3 | 4 | 5 | 2 | 1 | | 2 |
| *Holcus lanatus* | | | | | | | | | | | | | 2 | | 1 | 1 | 2 | 3 | 2 | 3 | 3 | 3 | 6 | 3 | 2 |
| *Melandrium diurnum* | | | | | | | | | 2 | | 1 | | | 1 | | 1 | 1 | 1 | 3 | | | 1 | 4 | 2 | 2 |
| *Alopecurus pratensis* | | | | | | | | | | 3 | | | 3 | 6 | | | 4 | | 5 | 5 | 6 | 6 | 2 | | |
| *Lysimachia nummularia* | | | | | | | | | | | 1 | 1 | | | | | | 1 | 1 | 1 | 2 | 1 | 1 | | |
| *Lychnis flos-cuculi* | | | | | | | | | 2 | | | | | | | 1 | | 1 | | 1 | 1 | 1 | 1 | | |
| *Glechoma hederacea* | | | | | | | | | | | 1 | | 1 | 1 | | | | | | 1 | 1 | | | | 1 |
| *IIa* | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cirsium oleraceum* | | | | | | | | | | | | 1 | 1 | 1 | 2 | 1 | 1 | 3 | 6 | 4 | 7 | 3 | 4 | 7 | 7 |
| *Deschampsia caespitosa* | | | | | | | | | | | | | | | | 3 | | 6 | | 7 | 3 | 5 | | 2 | 6 |
| *Angelica sylvestris* | | | | | | | | | | | | | | | 2 | | 1 | | 2 | | | | 1 | 2 | 3 |
| *Carex acutiformis* | | | | | | | | | | | | | | | | 3 | | | | 4 | | 2 | 3 | | 6 |
| *Filipendula ulmaria* | | | | | | | | | | | | | | | | | 1 | | 4 | | 3 | | | 1 | |
| *Pimpinella magna* | | | | | | | | | | | | | | | | | 2 | 1 | | | | 2 | | | 1 |
| *Polygonum bistorta* | | | | | | | | | | | 1 | | | | | 2 | | | | | | | 4 | | 2 |
| *Arrhenatherum elatius* | 3 | 5 | 1 | 5 | 6 | 3 | 7 | 2 | 6 | 7 | 6 | 7 | 4 | 7 | 7 | 7 | 6 | 6 | 4 | 6 | 6 | 7 | 8 | 6 | 4 |
| *Poa pratensis* | 5 | 5 | 4 | 6 | 6 | 6 | 7 | 9 | 6 | 6 | 7 | 5 | 4 | 6 | 6 | 2 | 3 | 5 | 2 | 5 | 4 | 2 | 6 | 5 | 5 |
| *Crepis biennis* | 1 | 5 | 2 | 3 | 2 | 4 | 5 | 1 | 2 | | 4 | 4 | 1 | 2 | 2 | 1 | 2 | 2 | 4 | 1 | 2 | 1 | | 3 | 3 |



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# Multivariate analysis - classification

- groups similar entities together into classes in a hierarchical manner
- single analysis may be viewed on several levels, e.g. general / detailed
- relationships are expressed among the entities classified
- poor for large datasets, good for smaller datasets
- two types:
    - **Monothetic divisive** *(all samples in a single cluster then progressively divide into smaller ones)*
    - **Polythetic agglomerative** *(each sample in a single cluster then agglomerate these into larger and larger clusters)*

# Multivariate analysis – assoc. matrix

- comparison of sample pairs or species pairs
- many different techniques, e.g. percentage similarity

PERCENT SIMILARITY

| | MID | A0 | A15 | A30 | A50 | A75 |
|---|---|---|---|---|---|---|
| MID | 100 | 75.794 | 52.241 | 17.121 | 2.006 | 4.839 |
| A0 | 75.794 | 100 | 60.171 | 20.701 | 0 | 0 |
| A15 | 52.241 | 60.171 | 100 | 43.164 | 17.844 | 24.758 |
| A30 | 17.121 | 20.701 | 43.164 | 100.000 | 54.561 | 57.640 |
| A50 | 2.006 | 0 | 17.844 | 54.561 | 100 | 49.979 |
| A75 | 4.839 | 0 | 24.758 | 57.640 | 49.979 | 100 |
| A100 | 1.956 | 0 | 20.994 | 49.447 | 65.520 | 56.377 |
| B0 | 73.289 | 73.947 | 49.904 | 20.060 | 0 | 4.901 |
| B15 | 16.673 | 14.291 | 36.491 | 68.575 | 53.796 | 56.250 |
| B30 | 2.139 | 0 | 21.585 | 53.373 | 61.295 | 55.675 |
| C0 | 75.601 | 74.378 | 46.425 | 17.878 | 1.993 | 0 |
| C15 | 40.886 | 48.576 | 59.823 | 45.219 | 21.957 | 27.091 |
| C30 | 27.396 | 32.810 | 53.496 | 64.443 | 37.842 | 45.030 |
| C50 | 16.729 | 15.864 | 35.951 | 69.550 | 56.097 | 59.998 |
| C75 | 11.721 | 11.107 | 28.022 | 67.388 | 58.387 | 48.990 |
| C100 | 1.545 | 0 | 17.747 | 56.802 | 63.073 | 52.641 |
| D0 | 79.475 | 73.622 | 47.078 | 21.461 | 1.979 | 7.139 |
| D15 | 17.582 | 14.976 | 37.532 | 62.970 | 7.407 | 59.444 |
| D30 | 2.052 | 2.024 | 26.919 | 62.486 | 62.275 | 61.908 |
| REF2 | 4.729 | 2.328 | 27.201 | 52.518 | 56.907 | 51.905 |
| REF3 | 4.417 | 0 | 23.599 | 53.562 | 54.597 | 64.218 |

# Multivariate analysis – sorting methods

- **Agglomeration procedures**

- **e.g.**

  **Nearest neighbour**

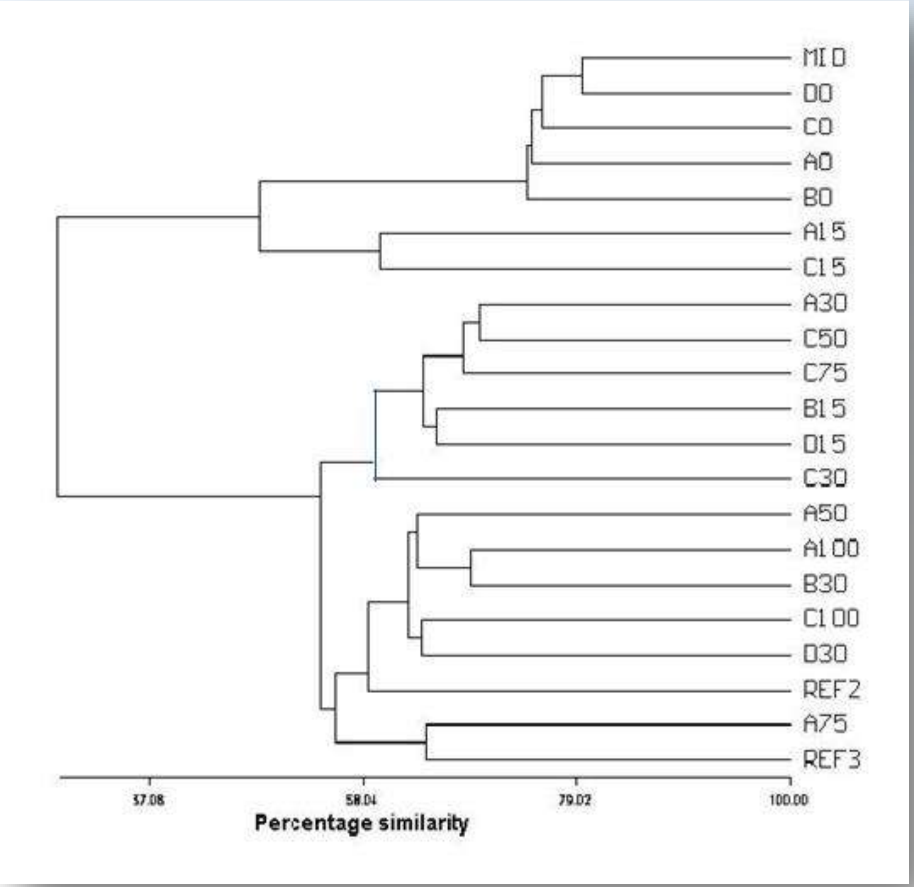
  (lowest similarity measure)

  **Furthest neighbour**

  (highest similarity measure)

  **UPGMA**

  (average similarity measure)



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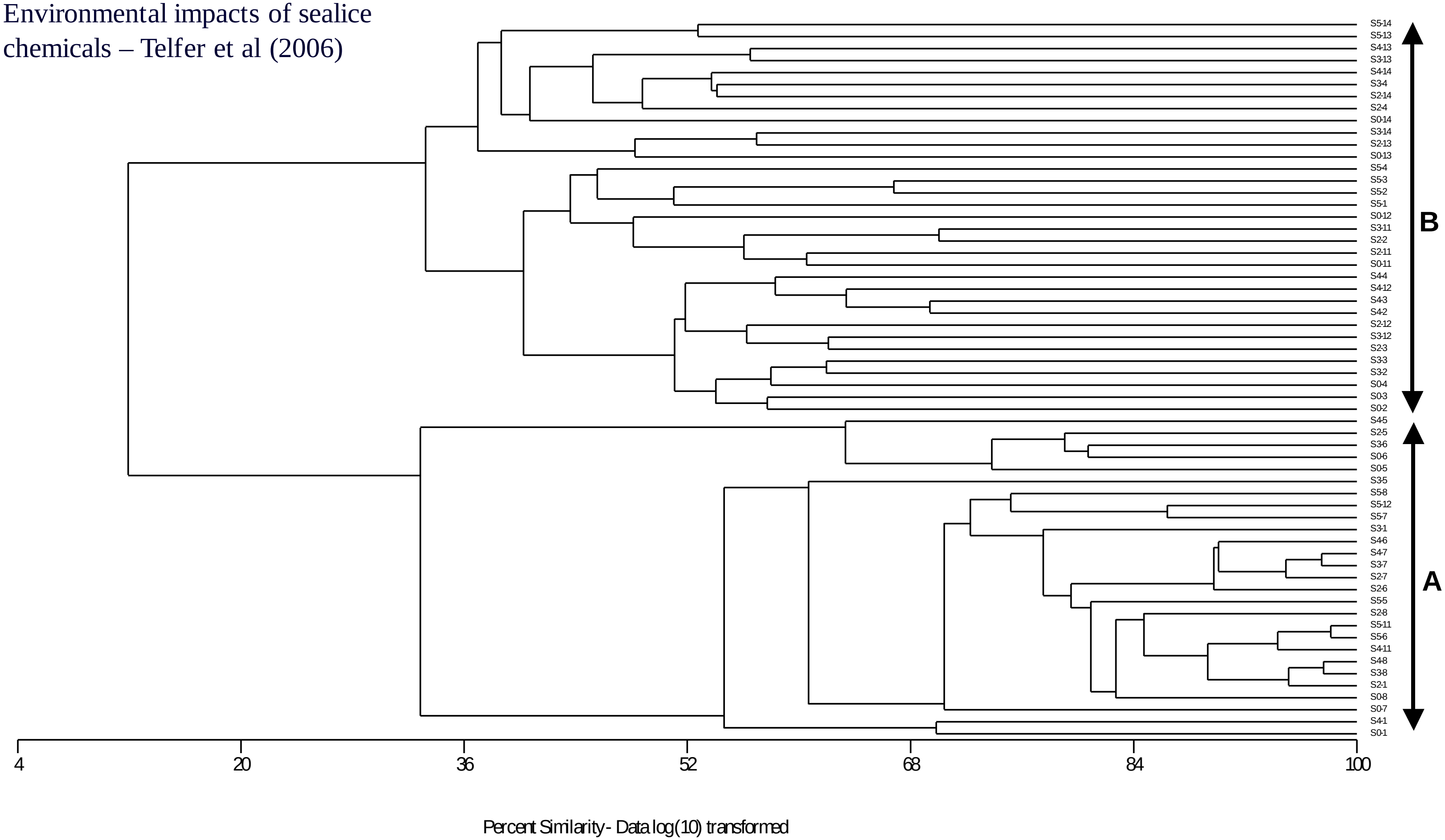
# Multivariate analysis – dendrogram

Environmental impacts of sealice chemicals – Telfer et al (2006)



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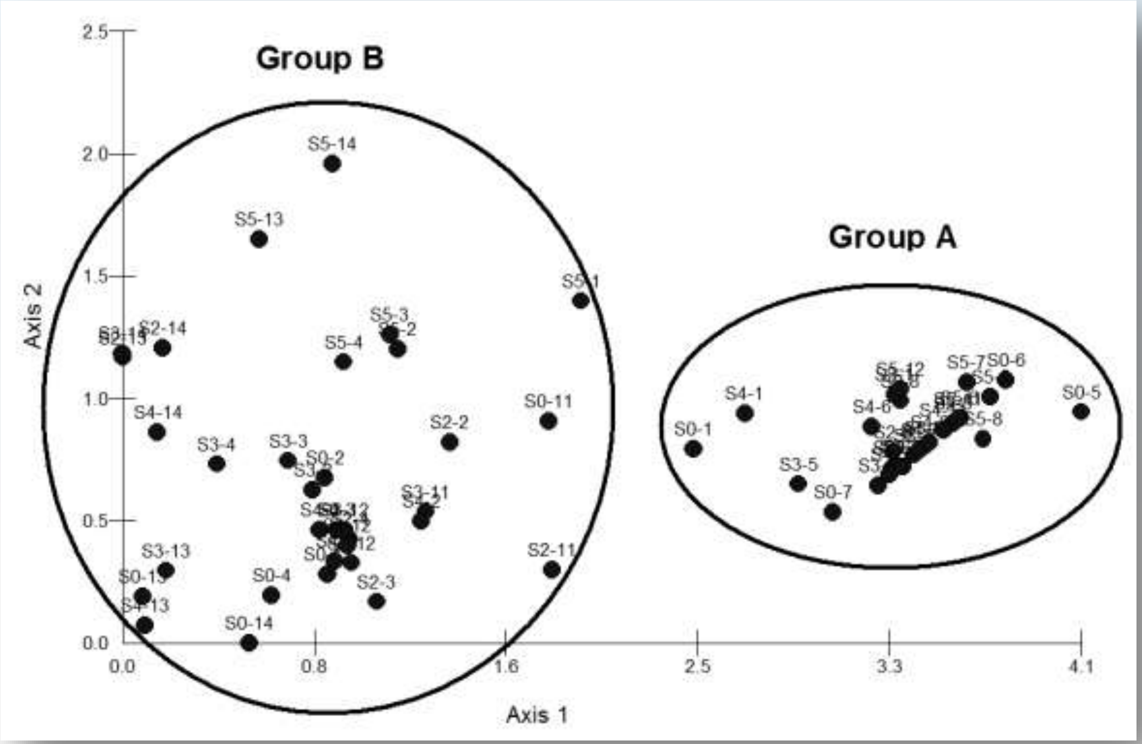
# Multivariate analysis – main types

- **Classification**
- **Ordination**

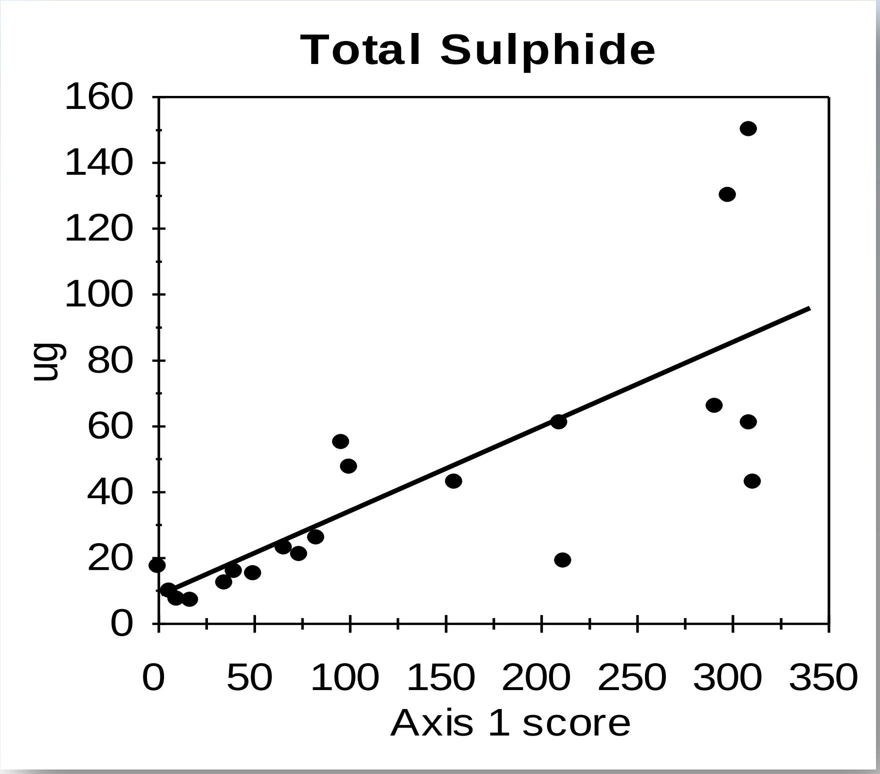
# Multivariate analysis - ordination

- represents samples and species relationships in a low dimensional space
- plot where similar samples/species situated near to each other
- arrangement of samples or species related to environmental factors
  - graphically
  - statistically




Environmental impacts of sealice chemicals – Telfer et al (2006)

# Multivariate analysis - ordination




*Graph - Regression analysis*

Regression analysis

# Multivariate analysis - ordination

Spearman Rank Correlation

| Variable | Axis 1 | Axis 2 | n |
|---|---|---|---|
| Carbon | 0.513* | 0.428 | 20 * |
| Total S | 0.847** | 0.288 | 20 |
| Free S | 0.764** | 0.185 | 19 |

* correlation at $p<0.05$

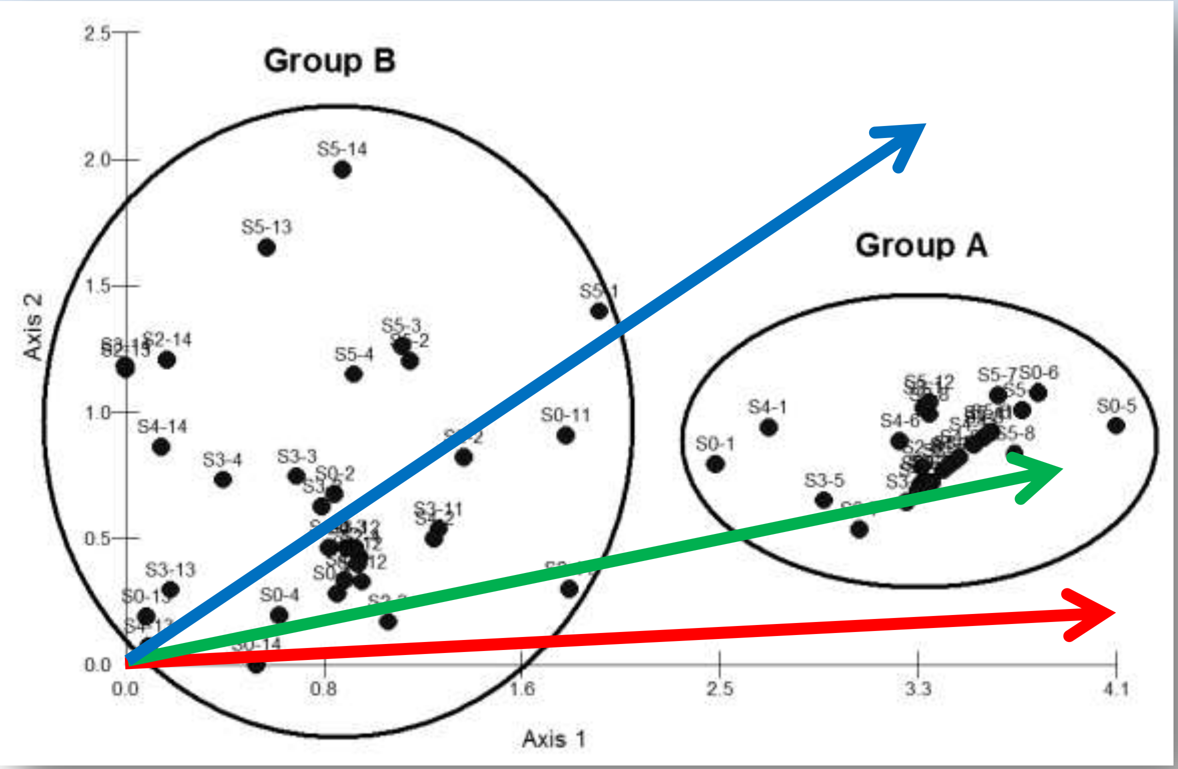
** correlation at $p<0.01$

n represents the number of stations used for the correlation as the chemical parameters were not done at all stations

$$r_s = 1 - \frac{6\sum d^2}{n(n^2 - 1)}$$

# Multivariate analysis - ordination

- The real relationship between the environmental factors and the positions of the sampling stations would be:



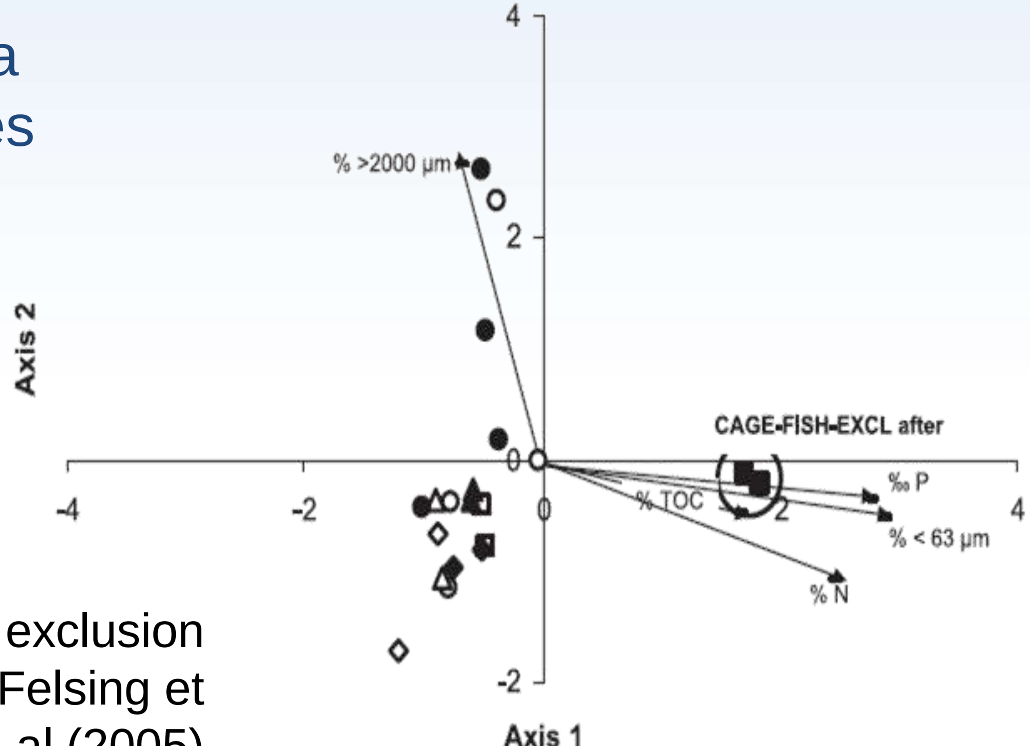

Free Sulphide

Total Sulphide

Total Carbon

# Multivariate analysis - ordination

- **Canonical Correspondence Analysis**
- ordinates both species data and environmental variables
- based on DECORANA
- gives the actual axis directions




Fish exclusion experiments – Felsing et al (2005)

# Multivariate analysis – useful refs

**Greig-Smith, P.** (1982) *Quantitative plant ecology. Third edition.* Studies in Ecology Volume 9. Blackwell Scientific Publications, Oxford.

**Gauch, H.G.** (1982) *Multivariate analysis in community ecology.* Cambridge Studies in Ecology. Cambridge University Press. Cambridge.

**Kent, M & Coker, P** (1994) *Vegetation description and analysis. A practical approach*. John Wiley & Sons, Chichester. 363pp.



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# Thank you

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