

Marine ecosystem conservation: indicators and indices

Marco Abbiati

Marine Biology
and
Environmental Sciences
University of Bologna –
Ravenna Campus

marco.abbiati@unibo.it

Fare i conti
con l'ambiente
Rifiuti acqua energia
Ravenna
25/26/27
settembre 2013



Outline of the talk

- The challenges posed by the EU directives
- Classifying complexity
- Impact of WFD and MSFD on research
- Replication in time and space
- Why are there so many indices
- Management perspectives



The key statement in the Water Framework Directive (2000/60/EC) and Marine Strategy Framework Directive (2008/56/EC) is

good ecological status of water ecosystems

This is a simple and apparently clear sentence, but it poses a major challenge to the scientific community: how to define the status of an ecosystems?

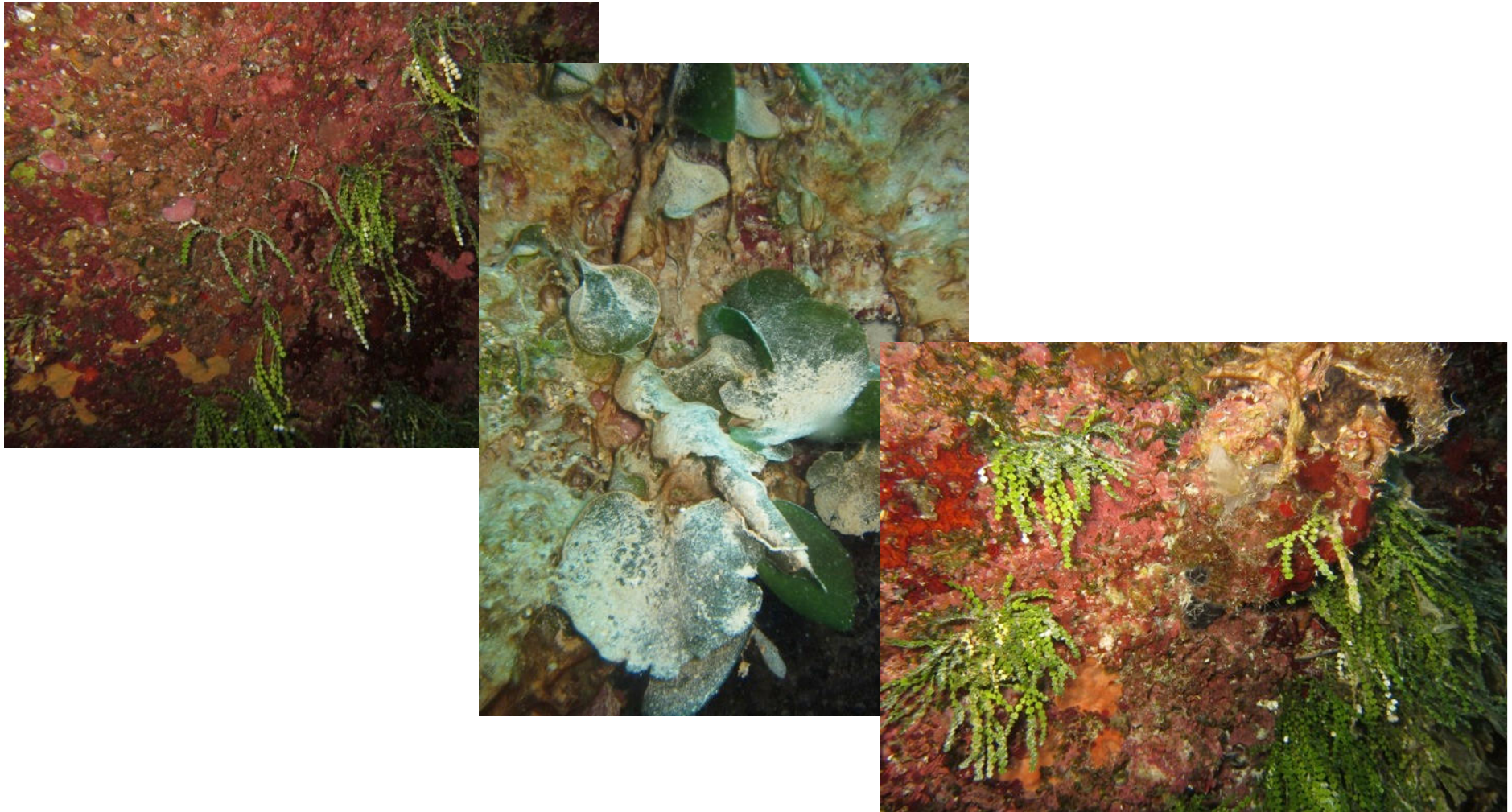
Complexity of natural systems

Most research on aquatic ecosystems in the last decades focussed on complexity, 6 major dimensions of complexity have been defined:

- spatial
- temporal
- structural
- process
- behavioral
- geometric

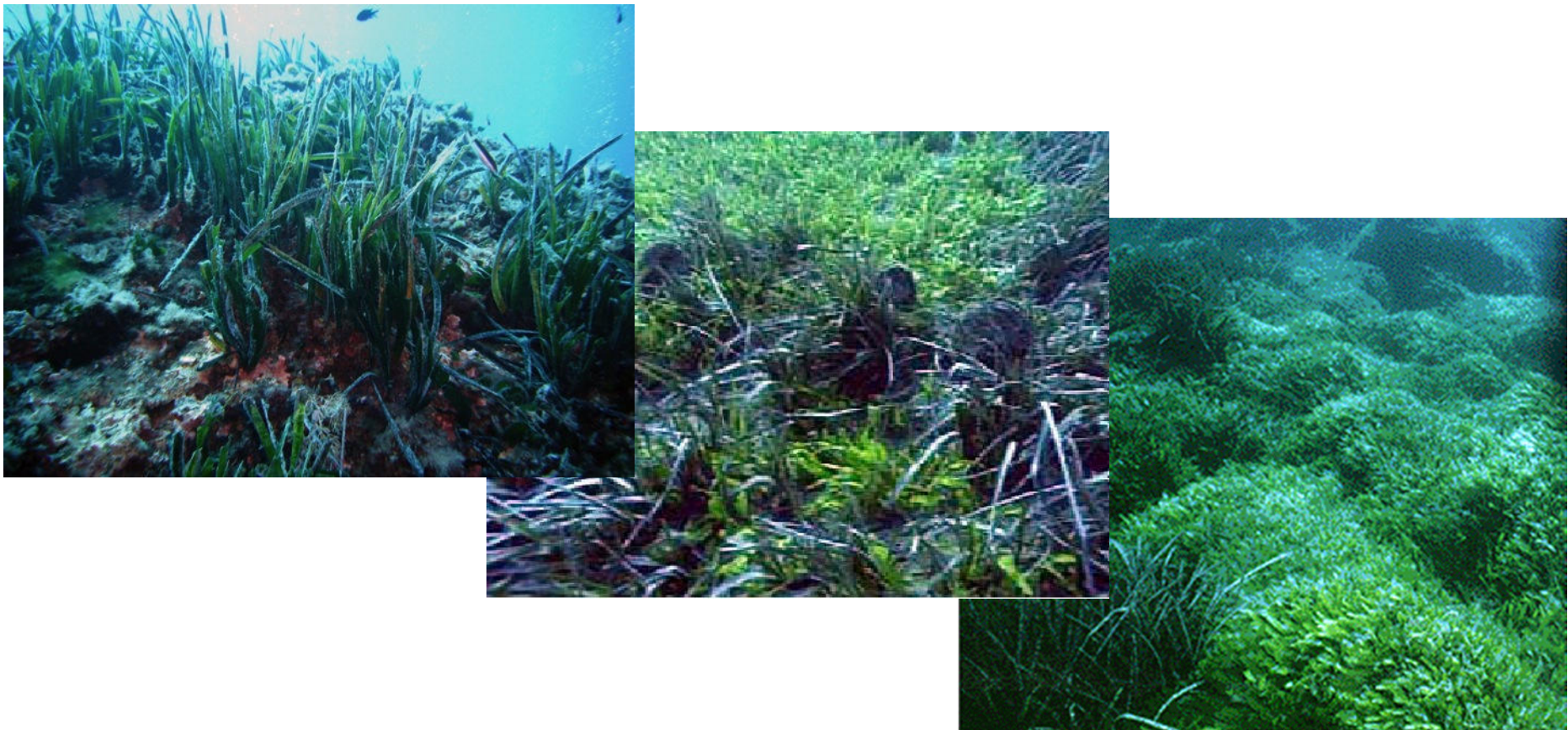
Spatial complexity

- It is visible in patterns of species distribution and abundance



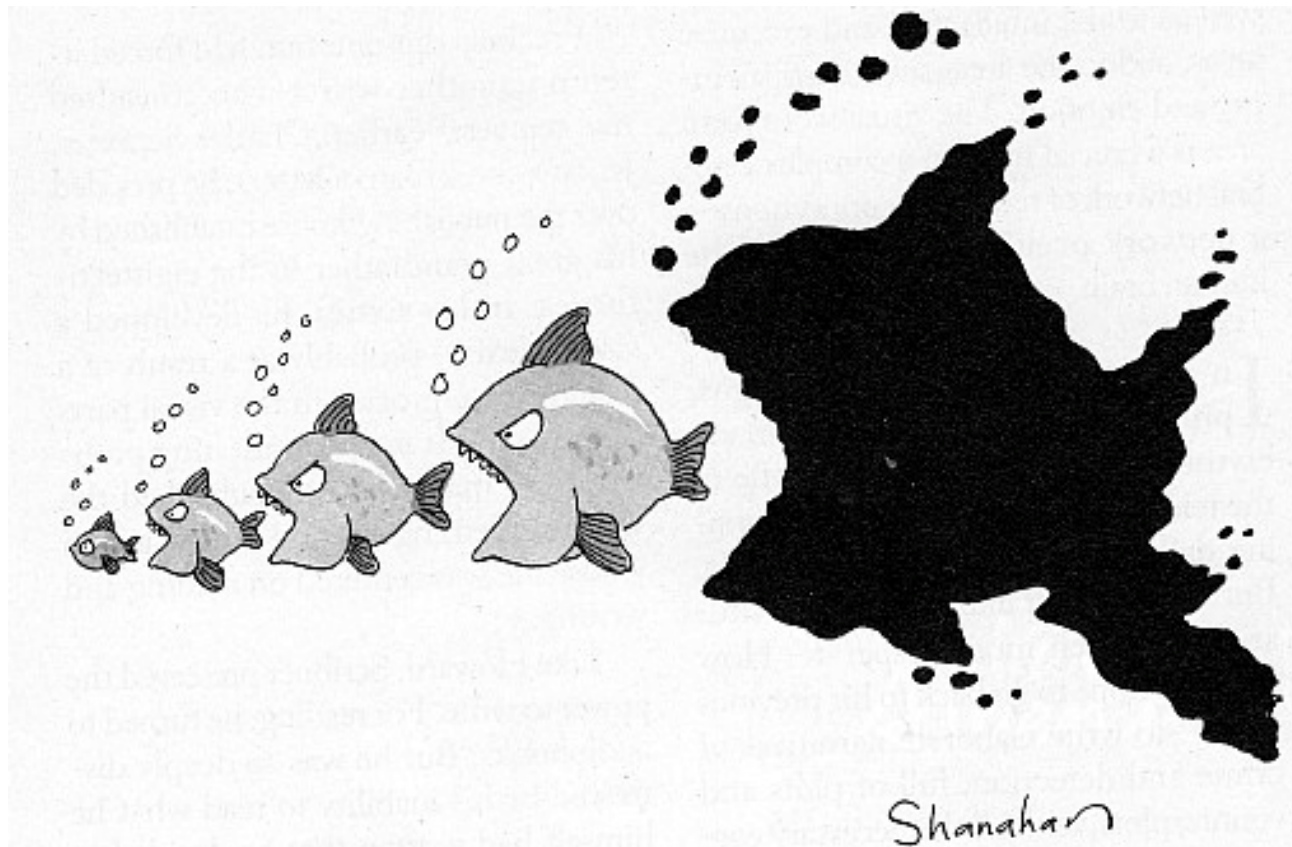
Temporal complexity

Arises from population dynamics, effects of fluctuating climate and weather; extinctions, invasions, metapopulation dynamics



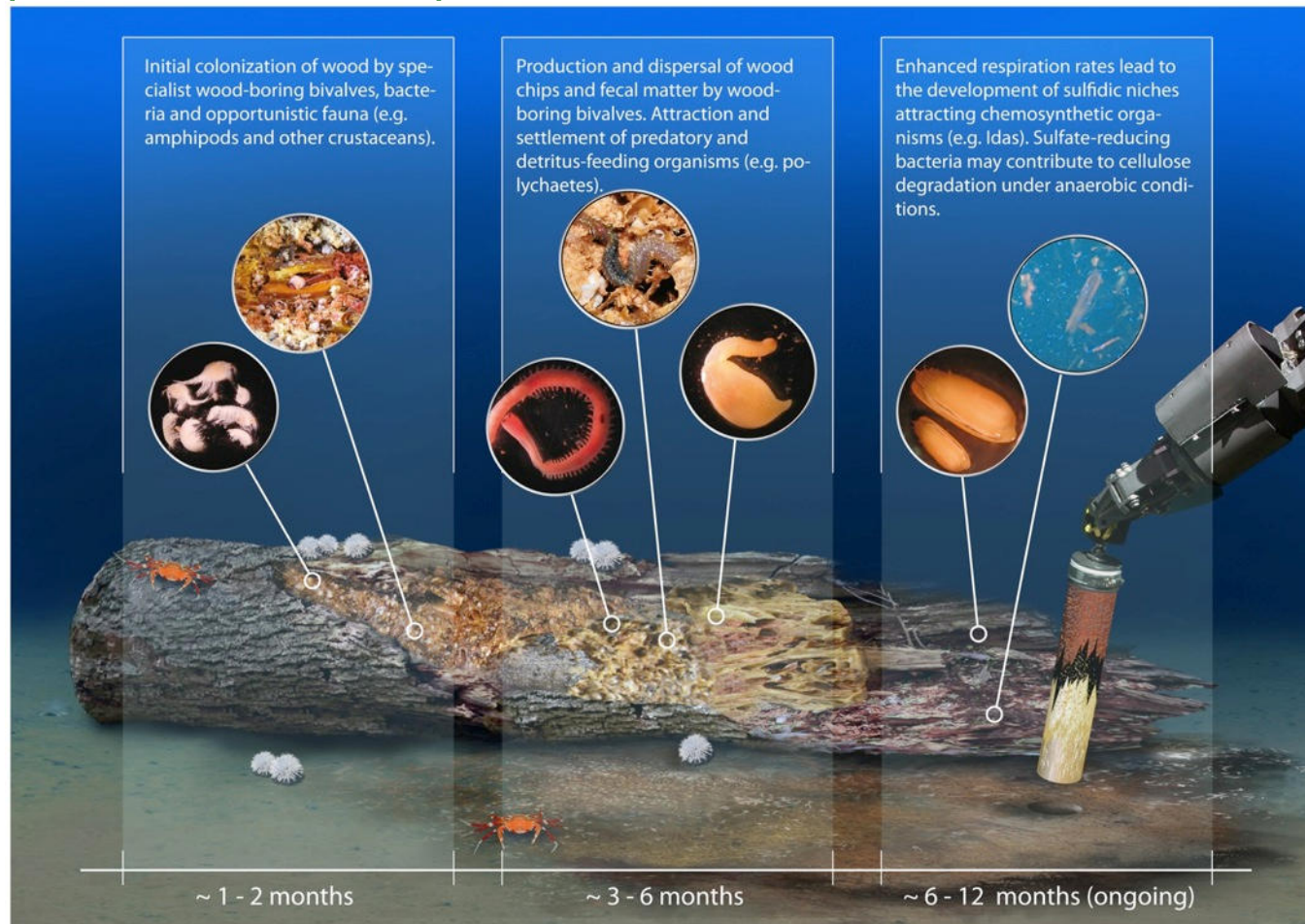
Structural complexity

Refers to relationships within an ecosystem: food web structure, community composition, networks of competition, and facilitation



Process complexity

Processes which contain many steps or components, primary production, decomposition, and succession



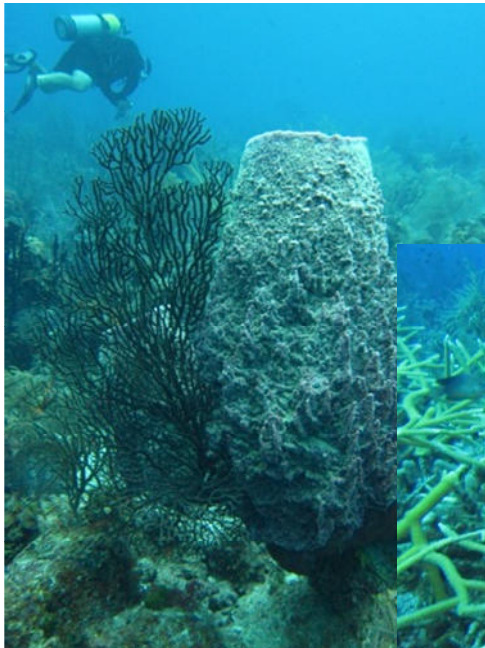
Behavioral complexity

Living organisms exhibit behaviors: sessile species adapt their growth form, predators become more adept at catching prey as they gain experience.



Geometric complexity

Algal canopy vs. individual algae, ecosystem engineers, habitat forming species, reef building taxa.



What managers and policy makers would like?

Complex features of an ecosystems to be summarised in a single number: the Ecological Indicator or Index

Which is supposed to:

- reflect the complexity
- define the quality
- allow an easy ranking
- detect changes

From natural history to hypothesis testing

The 'expert judgement' has long been used as the major criterion to assess environmental quality

In the early 20th century quantitative ecology has been promoted as a tool to quantify community structure

The first experimental studies in marine ecology have been carried out in the middle 60s

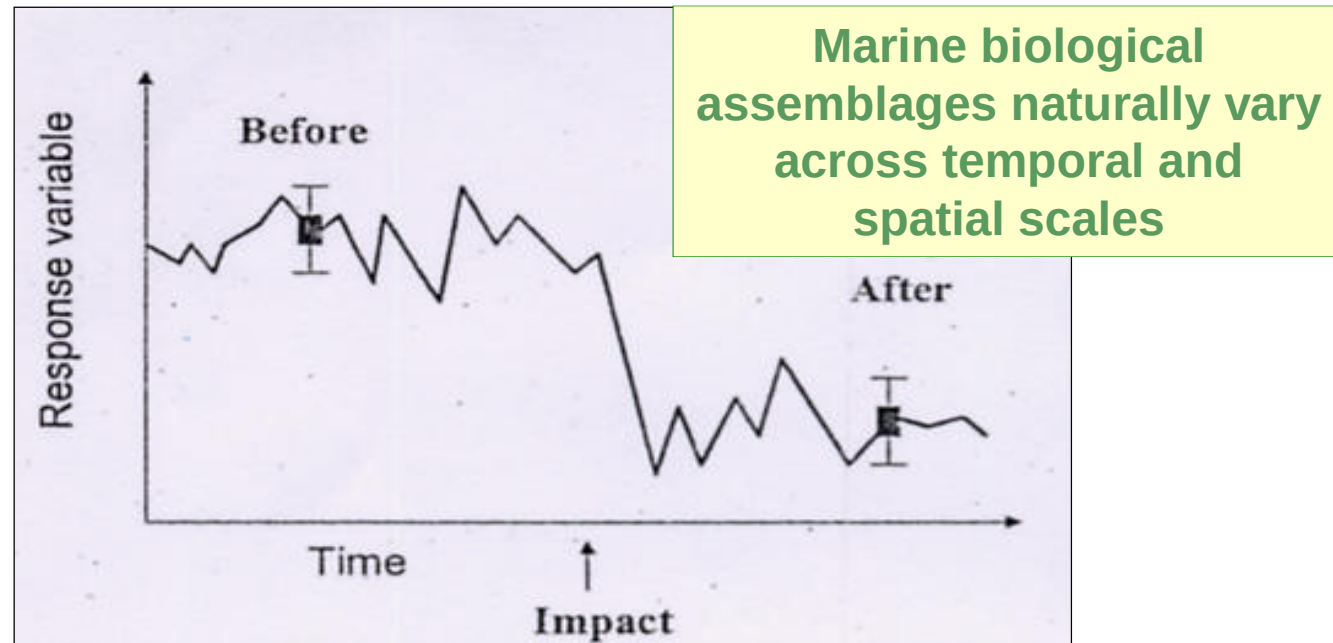
From natural history to hypothesis testing

And in the 90s experimental designs to test hypothesis on environmental changes and impacts have been developed; they require:

1. comparison with reference condition
2. replication in space
3. replication in time

Quality assessment in marine environment

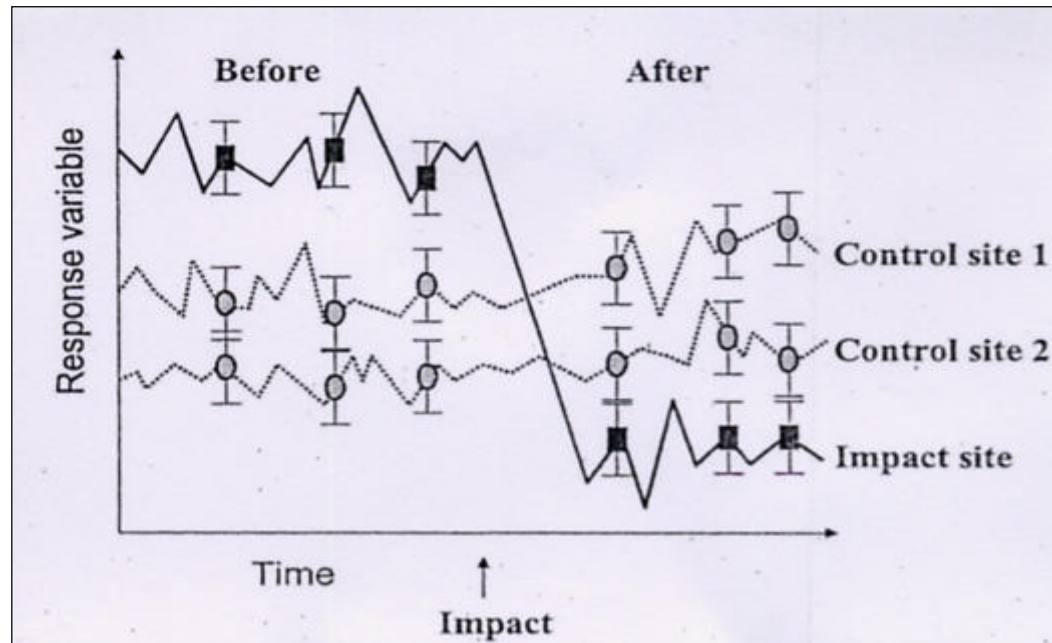
Impact is a perturbation causing the alteration of a response variable



Disturbances can be difficult to detect because they must be differentiated from a background of natural spatial and temporal variation

Quality assessment in marine environment

Comparative experimental design replicated in time and space



- These methodological constraints do apply to any study no matter the type of data analyses

Data matrix

- Analyses of benthic species assemblages, benthos.
- The information is scattered in the cells of a matrix species X samples

Taxa	1a1	1a2	1a3	1c1	1c2	1c3
Actiniaria n.i.	1	0	2	0	0	0
Cnidari n.i.	0	0	0	0	0	0
Nemertea	0	0	0	0	0	0
Haminoea navicula	0	0	0	0	0	0
Hydrobia ventrosa	0	4	1	0	0	0
Cyclope neritea	0	0	0	0	0	0
Nassarius reticulatus	1	1	2	0	0	0
Bittium reticulatum	0	0	0	0	0	0
Anadara inaequalis	1	0	0	0	0	0
Anadara demiri	1	0	4	0	0	0
Musculista senhousia	0	0	0	0	0	0
Mytilus galloprovincialis	0	0	1	0	0	0
Abra nitida	0	1	0	0	0	0
Elasmobranchia	0	1	1	0	0	0
Phylloporo mucosa	0	0	0	0	0	0
Pilargidae n.i.	0	0	0	0	0	0
Murphyella sanguinea	0	0	0	0	0	0
Murphyella fallax	0	0	0	0	0	0
Lumbrineris tetraura	0	0	0	0	0	0
Carophorus furcatus	0	1	0	0	0	0
Spinidae n.i.	0	1	0	0	0	0
Polydora ciliata	1	0	1	7	4	3
Pseudopolydora cfr. paucibranchiata	2	0	0	0	0	0
Prionospio cirrifera	45	6	4	15	28	91
Streblospio shrubsolei	5	4	0	18	6	19
Malacocephalus cfr. fuliginosus	0	0	0	0	0	0
Spio decausis	3	5	0	3	16	24
Cirratulidae tentaculata	1	3	4	8	2	6
Capitella capitata	12	24	10	29	38	85
Heteromastus filiformis	9	8	6	3	4	3
Hydrobia dianthus	8	0	9	0	0	0
Paraloceros sp.	0	0	1	0	0	0
Danua pagenstecheri	0	0	0	0	0	0
Sabellaria alcocki	0	0	41	0	0	0
Pectinaria korei	0	0	0	0	0	0
Oligochaeta spp.	18	4	6	93	154	232
Idotea balthica	0	0	0	0	0	0
Lekanesphaera hookeri	0	0	0	0	0	0
Amphipoda n.i.	0	0	0	0	0	0
Ampelisca sp.	0	0	0	2	2	1
Microdeutopus gryllotalpa	3	1	2	25	4	28
Corophium insidiosum	4	1	0	12	4	17
Corophium acherusicum	2	0	0	0	0	0
Erichthonius punctatus	0	0	0	0	0	0
Gammarus aequicauda	0	0	0	0	0	0
Gammarus cfr. insensibilis	0	0	0	0	0	0
Gammarus spp. (juveniles)	0	0	0	0	0	0
Orchestoidea	0	0	0	0	0	0
Caprellia laportensis	0	0	0	1	1	0
Brachydeutopus gemmellari	0	0	0	0	0	0
Amphipolis sp.	0	1	0	0	0	0
Ophiuroidea n.i.	0	0	0	0	0	0
Chironomus salinarum	0	0	0	1	8	11
Diptera n.i.	0	0	0	0	0	0
Plantopoda n.i.	0	0	0	0	0	0
Mollusca n.i.	0	0	0	0	0	0
Aspidacea n.i.	0	0	0	0	0	0
Phoronis sp.	1	0	1	1	0	0

Human need to 'classify' objects

- Diversity, equitability, evenness, species richness ... are the traditional indices developed in the 50's to study benthic communities and to classify/compare assemblages
- WFD imposed the development of a new type of indices, that take into account species biology and ecology e.g.
 1. Water quality index for Catalunya wetlands (QUALES)
 2. Swan Wetlands Aquatic Macroinvertebrate Pollution Sensitivity (SWAMPS)
 3. Weighted Biotic Index (WBI)
 4. Ecofunctional Quality Index (EQI)
 5. AZTI' Marine Biotic Index (AMBI)
 6. The BENTIX biotic index
 7. Benthic Response Index (BRI)

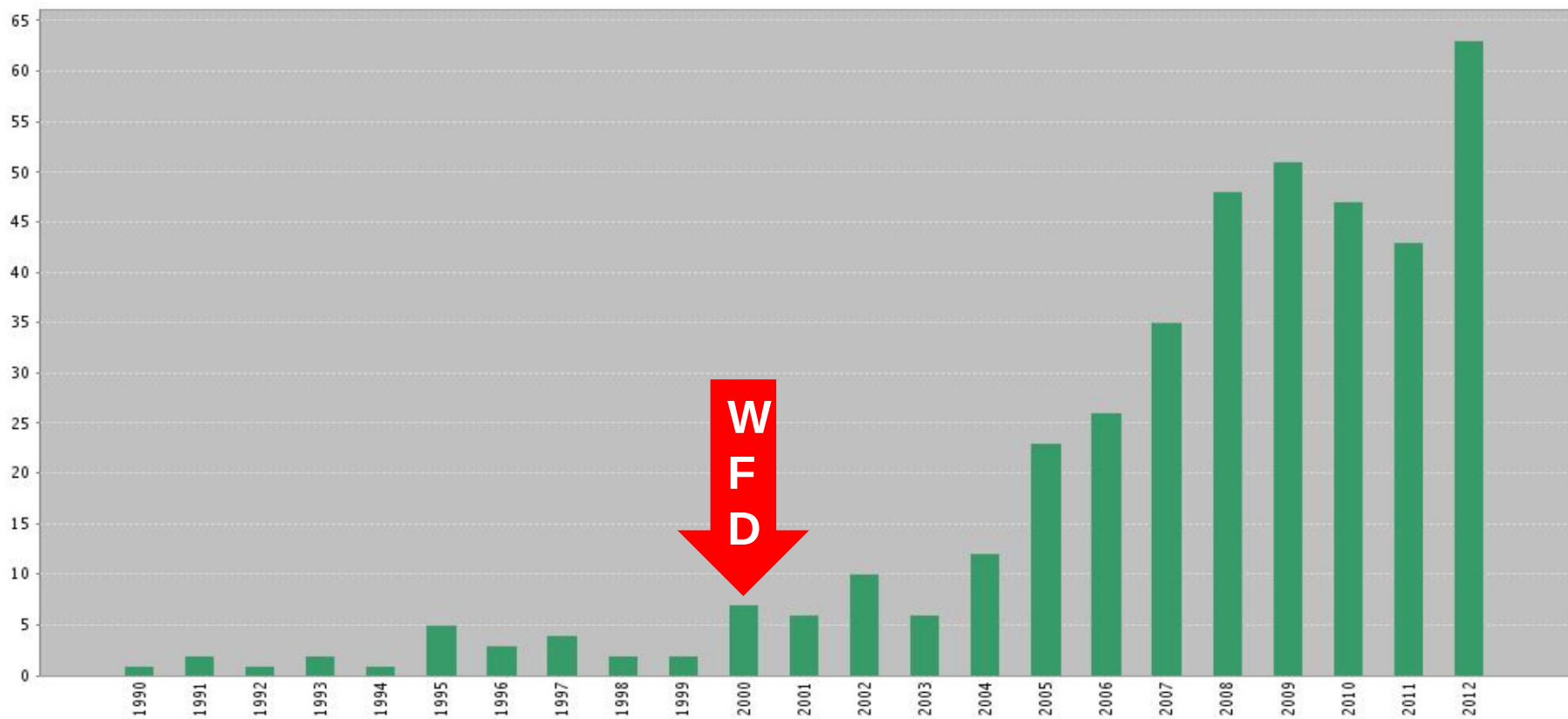
... and more ...

8. Multimetrix Benthic Indices of Biotic Integrity (B-IBI family)
9. Chesapeake Bay Benthic Index of Biotic Integrity
10. Carolinian Benthic Index of Biotic Integrity
11. Benthic Index of Estuarine Condition for the Virginian Biogeographic Province
8. Eaton's biocriteria for North Carolina Estuarine Waters
9. Multimetrix benthic assessment in San Francisco Estuary
10. Fuzzy INdex of Ecosystem integrity (FINE)
11. Index of Size Distribution (ISD)
12. Ecological Evaluation Index (EEI)
13. Rhodophyceae/Chlorophyceae (R/C) and Chlorophyceae/Phaeophyceae (C/P)
14. ...

Popularity of indices in scientific literature

- Scientists discovered the indices following the WFD (355 records – ISI Web of Science)
- This is an extraordinary example about how politics can drive science!

22/09/13 20:22

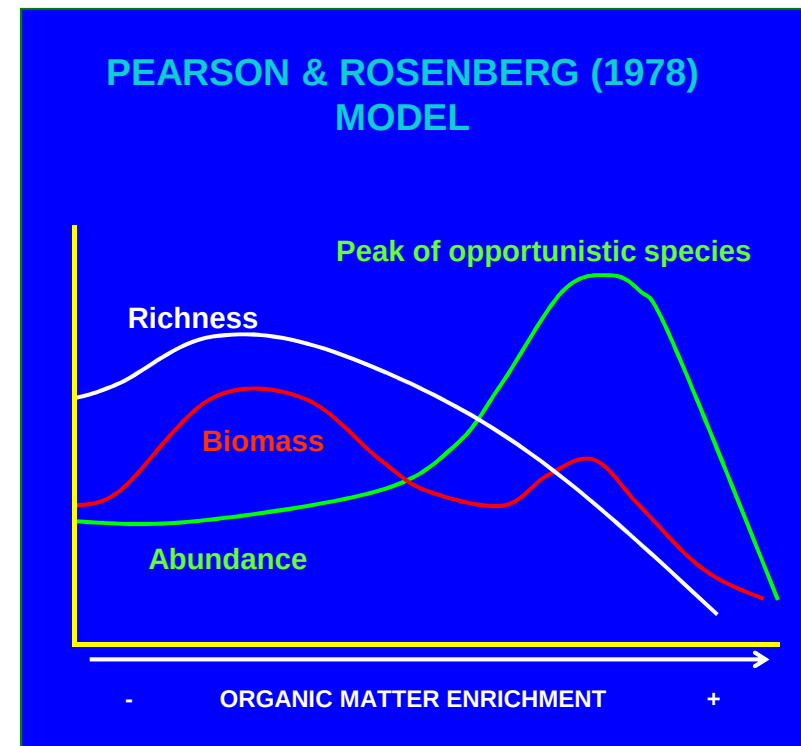


Popularity of indices in scientific literature

- Many papers are dealing with the development of biotic indexes
- Many papers are dealing with the application and testing of indices in different habitats
- Few paper are comparing the results provided by different indices using the same data set, (but see Diaz et al 2004)
- Often indices are validated by the 'expert judgement'

What is the rationale of the biotic indices?

- To calculate an index, species are usually classified in (5) groups from sensitive to opportunistic, reflecting the traditional classification of the r versus K strategies.



An example from AMBI

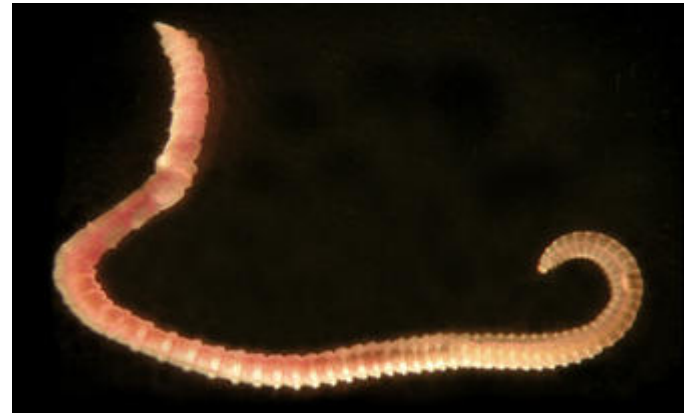
Borja, A., J. Franco, V. Pérez, 2000. *Marine Pollution Bulletin*, 40(12): 1100-1114.

- **Group I: Species very sensitive to disturbance**, present under unpolluted conditions (initial state): specialist carnivores, some deposit-feeding tubicolous polychaetes.
- **Group II: Species indifferent to disturbance**, present in low densities, non-significant variations with time (from initial state, to slight unbalance), suspension feeders, less selective carnivores, scavengers.
- **Group III: Species tolerant to excess organic matter** enrichment. They occur under normal conditions, but are stimulated by organic enrichment (slight unbalance situations), surface deposit-feeding species, as tubicolous spionids.
- **Group IV: Second-order opportunistic species** (slight to pronounced unbalanced situations). Mainly small sized polychaetes: subsurface deposit-feeders, such as cirratulids.
- **Group V: First-order opportunistic species** (pronounced unbalanced situations). These are deposit-feeders, which proliferate in reduced sediments.

How can we assess species tolerance?

The role of 'indicator' has been attributed to many species:

- *Capitella capitata* – opportunistic species
- *Hydrobia ventrosa* – sensitive species



Criticality 1 - Do species really indicate what we assume they indicate

- Very few experimental evidences on species life cycle and tolerance to pollutants; classification is based on descriptive correlative studies
- The ecological weight given to each species is often arbitrary
- Taxonomy is a hard job, and classification not always reflects the real name of the species

These aspects are the main critical points in input for the index calculation

Criticality 2 - Biogeography and quality assessment

- Due to the lack of studies, often similar ecological features are attributed to co-generic species worldwide
- Species assemblages differ among biogeographic areas - many indices are site specific: an index works better for the habitat/geographic region where it has been developed
- As a consequence the literature has been populated with extended families of analogous region-specific indices

Local indices

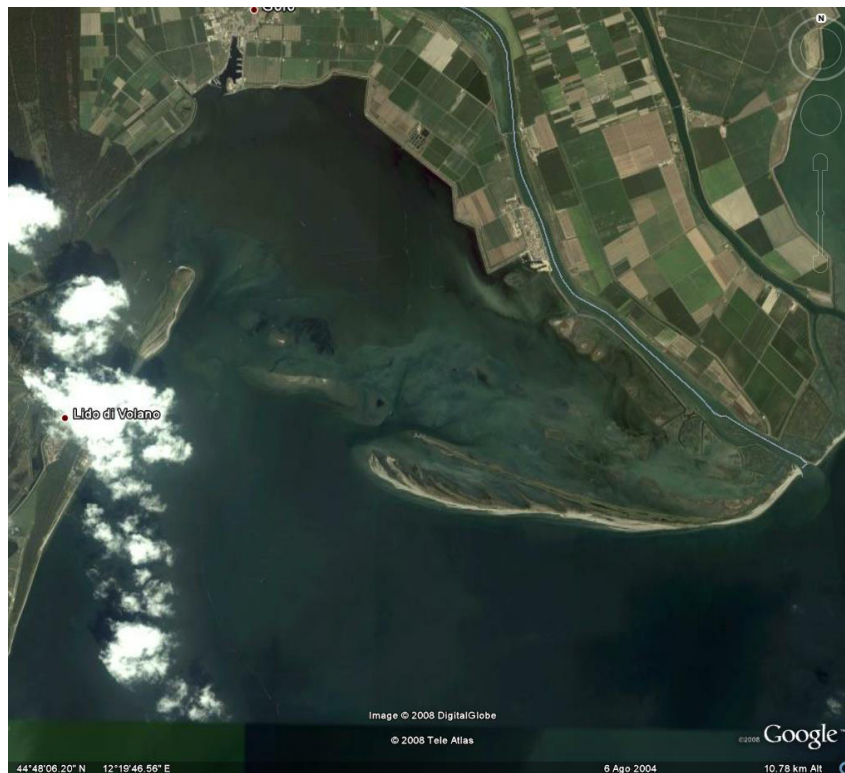
1. Water quality index for **Catalunya** wetlands (QUALES)
2. **Swan Wetlands** Aquatic Macroinvertebrate Pollution Sensitivity (SWAMPS)
3. Weighted Biotic Index (WBI)
4. Ecofunctional Quality Index (EQI)
5. AZTI' Marine Biotic Index (AMBI)
6. The BENTIX biotic index
7. Benthic Response Index (BRI)
8. Multimetric Benthic Indices of Biotic Integrity (B-IBI family)
9. **Chesapeake Bay** Benthic Index of Biotic Integrity
10. **Carolinian** Benthic Index of Biotic Integrity
11. Benthic Index of Estuarine Condition for the **Virginian**

Biogeographic Province

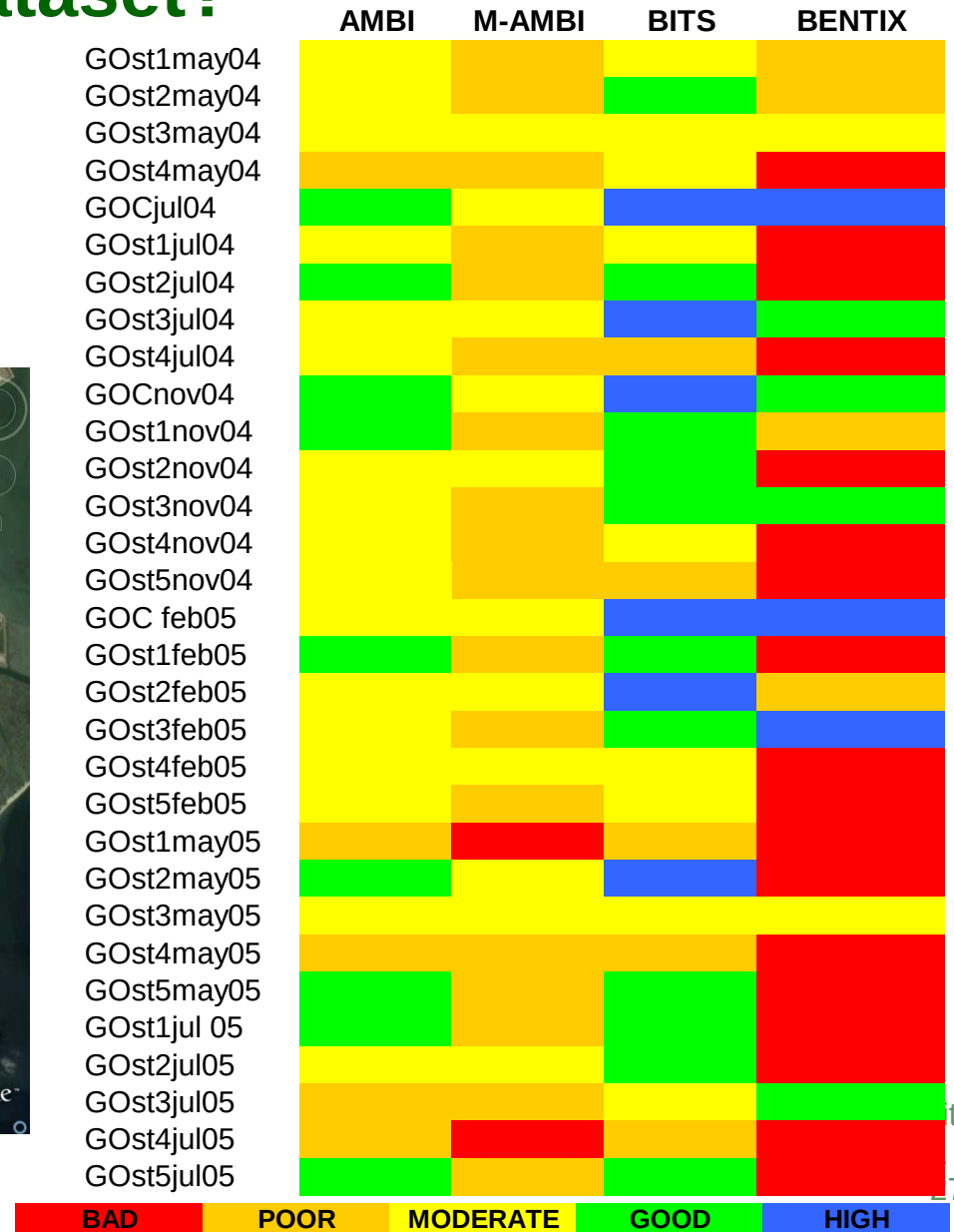
8. Eaton's biocriteria for **North Carolina Estuarine** Waters
9. Multimetric benthic assessment in **San Francisco Estuary**
10. Fuzzy INdex of Ecosystem integrity (FINE)
11. Index of Size Distribution (ISD)
12. Ecological Evaluation Index (EEI)
13. Rhodophyceae/Chlorophyceae (R/C) and Chlorophyceae/Phaeophyceae (C/P)

Do these indices provide consistent results on the same dataset?

An example: the Adriatic wetland of Goro



>Rave
nna
25/26/27
settembre 2013



An example from south eastern EU



Comparing environmental qualities

	H'	AMBI	BENTIX
ALIMINI	poor	good	poor
BAIONA	moderate	poor	poor
CESINE	poor	good	poor
GUACETO	poor	good	good
KARAVASTA	moderate	good	moderate
PATOK	moderate	good	poor
SINOE	poor	poor	poor
VARNA	poor	good	poor

Validation of the indices

Biotic indices are a powerful tool for the management of coastal areas, however, several steps need to be further implemented.

Defining standard reference condition is a priority

Indices need to be validated on independent data sets, setting a priori correct classification criteria

Intercalibration of the within the eco-regions to set the boundaries between the Ecological Status classes

Subjective expert judgment should be reduced to the minimum

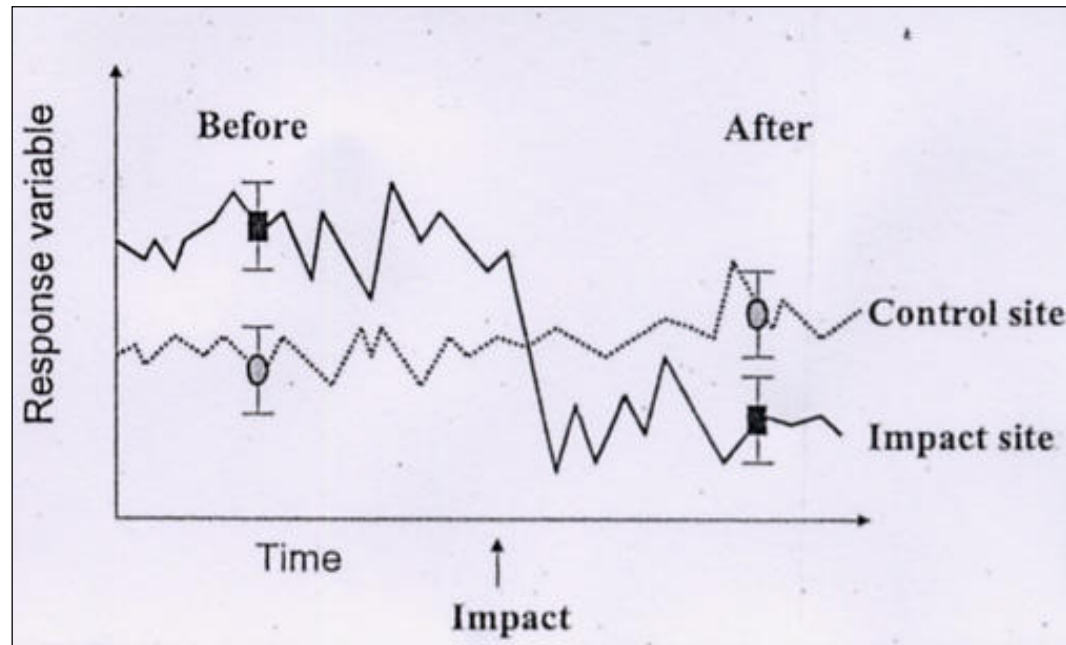
Towards Marine Spatial Planning

- Marine Spatial Planning appears to be promising tools for the management and conservation of coastal habitat and resources
- A fully integrated marine classification scheme resolving habitat mapping and ecosystem integrity is needed
- Selected indices for assessing organism-substrate relationships based on validated ecological principles have to be implemented

Thank you for your attention

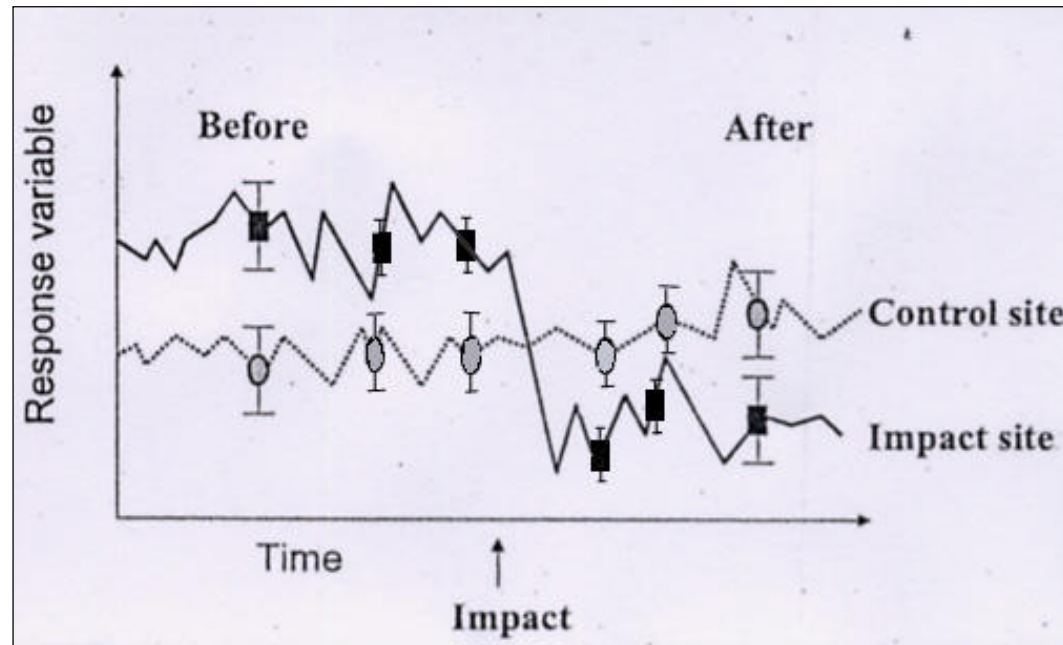
Quality assessment in marine environment

Quality can only be defined in comparative studies



Quality assessment in marine environment

Comparison requires replication in time of the data collection



Most biotic indices refer to the benthic assemblages

Advantages of using benthic assemblages:

- real affection to biota (species-community level)
- global indicator of pollution (decades of research)
- integrated information through time
- short life-span species: fast recovery
- easy-work ecosystem component

Disadvantages :

- taxonomists are needed
- high economic cost
- slow delivery of results

