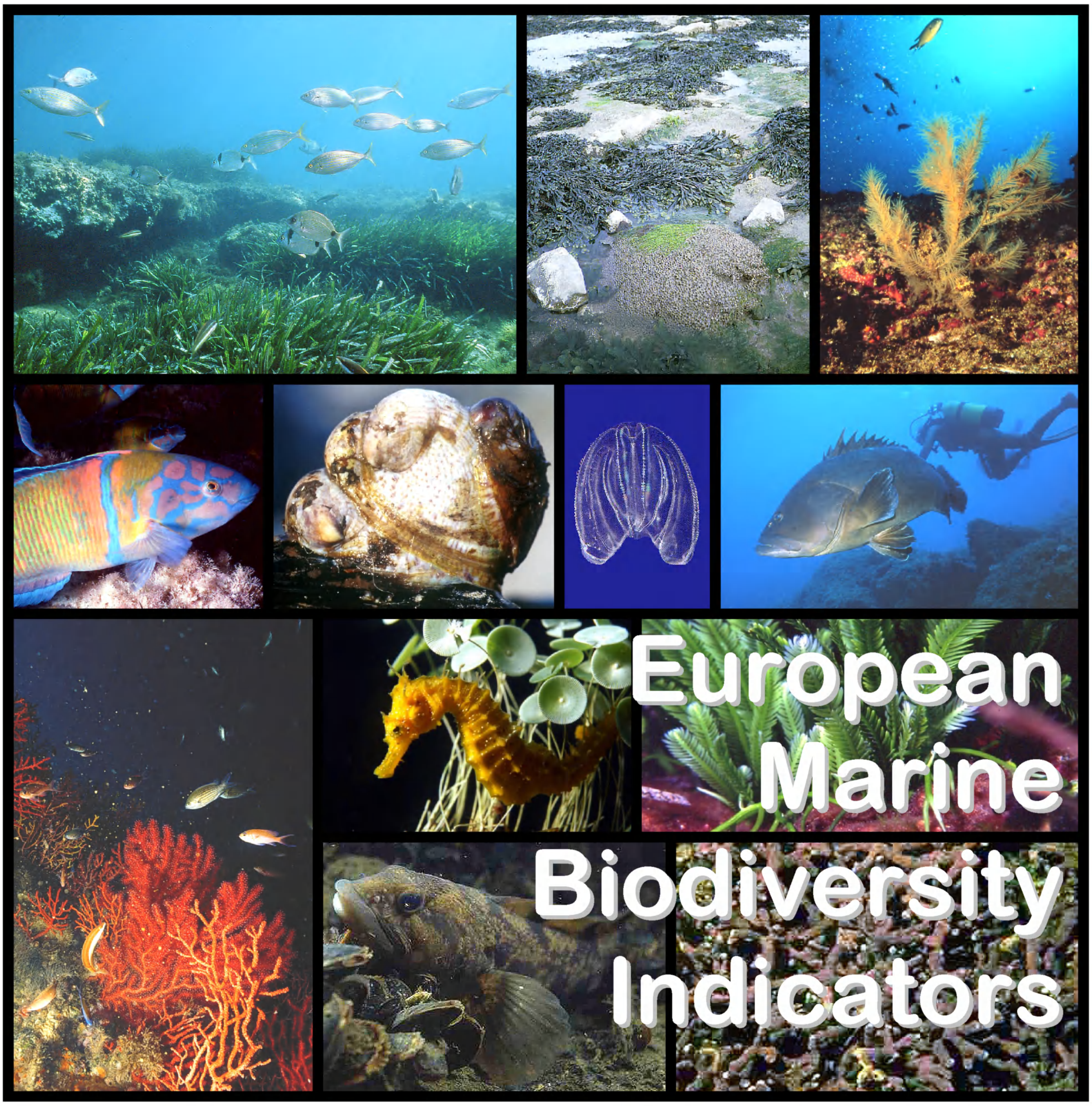
BIOMARE
Implementation and networking of large-scale long-term
Marine Biodiversity research in Europe



European Marine Biodiversity Indicators

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Report of the European Concerted Action : BIOMARE
Implementation and Networking of large scale, long term Marine Biodiversity Research in Europe

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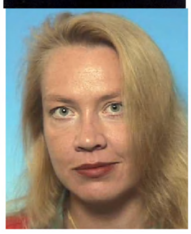

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Foreword

In the past few years marine biodiversity has risen from relative obscurity to become an important issue in European policy and science. The reasons are obvious. Species in general are disappearing at a rate never observed since life began on earth. The extinction crisis ranks with global climate change as the greatest threat to the integrity of the biosphere in the 21st century. The seas are no exception and human pressure is changing the diversity of life in coastal waters, the shelves and even the deep sea rapidly and on a global scale.

Species extinction is not just an aesthetic or moral problem. Marine organisms play a crucial role in almost all biogeochemical processes that sustain the biosphere, and provide a variety of products (goods) and functions (services), which are essential to mankind's well being, including the production of food and natural substances, the assimilation of waste, the remineralisation of organic matter and the regulation of the world's climate.

Knowledge about the patterns and changes of marine biodiversity in Europe and the role of marine biodiversity in ecosystem functioning is scattered and imprecise. The scale of the research efforts needed to obtain adequate knowledge for exploration, conservation and restoration of marine biodiversity demands European-scale collaboration. This was at the basis of the BIOMARE project. BIOMARE (Implementation and Networking of large-scale long-term Marine Biodiversity research in Europe) was a Concerted Action sponsored by the EC with the participation of 21 marine laboratories, members of the European Network of Marine Research Station MARS.

The objectives were to achieve a European consensus on the selection and implementation of 1) a network of Reference Sites, 2) internationally agreed standardised and normalised measures and indicators for (the degree of) biodiversity and 3) facilities for capacity building, dissemination and networking of marine biodiversity research. Through the International Biodiversity Observation Year IBOY, DIVERSITAS and the Census of Marine Life CoML, three global initiatives, BIOMARE has attracted attention worldwide as a major effort to coordinate biodiversity research at the European scale and beyond.

The results of BIOMARE have been published in two books and a permanent web site will be maintained by the MARS network. The first book describes the 100 European Marine Biodiversity Research Sites that provide the geographical skeleton for the implementation of long-term and large-scale research in Europe. Of these sites twelve are Reference Sites where conditions are as near to pristine as one can hope for in European waters. The Reference Sites as well as the Focal Sites in impacted areas should form the basis for future intensive surveys to assess the status and long-term development of marine biodiversity in Europe. Most of these sites are close to marine institutes, which can provide the infrastructure required for monitoring, explorative and experimental work.

The second book on biodiversity indicators presents a state of the art of the E.U. politics on biodiversity indicators, a strategy to choose indicators and to monitor biodiversity within the framework of the BIOMARE EMBRS and a catalogue of indicators that are used or recommended and for which at least some consensus on their utility exists. Such indicators are required to translate very complex biological structures and processes into more simple parameters and concepts that can be understood by non-scientists. The challenge was to construct a scientifically solid system that still is useful to the interested scientist, the CZM manager and the public alike. This book sets a first step but much work remains to be done.

Now that the foundations have been laid, it is our hope that marine biodiversity research in Europe will take advantage of the results from BIOMARE and the commitment of the scientists and institutes that supported it. Organization at the European level and partnerships within the European Research Area will be necessary if the marine community is to cope with one of the major challenges that will face it in the rapidly changing political and societal environment in Europe and worldwide.

Carlo Heip and Herman Hummel
NIOO, General Co-ordinators

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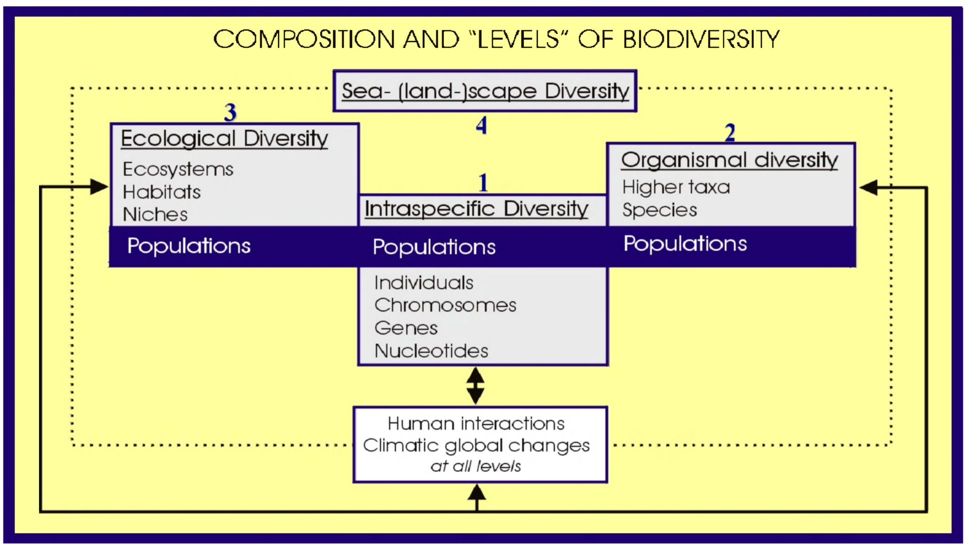
Background: Which biodiversity?

The term biodiversity has multiple meanings depending on the biological scale to which it is applied. Most commonly, biological diversity refers to the full range of species on Earth, including single-celled organisms such as bacteria, viruses, and protista, as well as multicellular organisms such as plants, animals, and fungi. On a finer scale of organisation, biological diversity includes the genetic variation within species, both among geographically separated populations and among individuals within single populations. On a wider scale, biological diversity includes variations in the biological communities in which species live, the ecosystems in which communities exist, and the interactions among these levels.

Ecosystem diversity (at least in the sea) and genetic diversity are less readily understood by decision makers and the public, but are not less important than species diversity. The continued survival of species and natural communities require the preservation of biodiversity at all of these levels. This is included in the definition given in the text of the Convention on Biological Diversity (Rio de Janeiro, 1992): "*Biological Diversity is the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*" [Article 2] (ISCBD, 1994)[1].

Given these various scales of biodiversity, the biological diversity of an area is conveniently described at three levels (*Figure below*): (**1**) **Infra-specific (genetic) diversity** is the variation within a population and among populations of a plant or animal species. The genetic makeup of a species is variable between populations of a species within its geographic range. Loss of a population results in a loss of genetic diversity for that species and a reduction of total biological diversity for the region. This unique genetic information cannot be reclaimed. This level of biodiversity is critical in order for a species to adapt to changing conditions and to continue to evolve in the most advantageous direction for that species. (**2**) **Organismal (species) diversity** is the total number and abundance of plant and animal species in an area. (**3**) The third level concerns the variety of **natural communities or ecosystems** within an area. These communities may be representative of or even endemic to the area. It is within these ecosystems that all life dwells.



Composition and levels of biodiversity. Biodiversity is conveniently described at three levels: infra-specific diversity, organismal diversity, and community or ecosystem diversity. A fourth level, the sea- (land-)scape diversity, takes into account global climatic changes and human activity impacts. It also integrates the type, condition, pattern, and connectivity of natural communities or ecosystems. (after Féral, 2002)[2].

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1 ISCBD (Interim Secretariat of the Convention on Biological Diversity), 1994. Convention on Biological Diver-sity:Text and Annexes (UNEP/CBD/94/1). United Nations Environment Programme, Geneva.

2 Féral J.-P. 2002 - How useful are the genetic markers in attempts to understand and manage marine biodiversity? J. Exp. Mar. Biol. Ecol. 268: 121–145

Biodiversity also covers a complex set of relationships within and between these different levels of organisation, including human action, and their respective origins in space and time. All the components overlap. And (**4**), a fourth level, the **sea- (land-)scape diversity**, integrates the type, condition, pattern, and connectivity of natural communities or ecosystems. Fragmentation of landscapes, loss of connections and loss of natural communities all result in a loss of biological diversity for a region. Humans and the results of their activities are integral parts of most landscapes.

Biodiversity is dynamic in its nature. Species and their populations are in continuous evolutionary change. The present-day diversity is the result of the combined effects of speciation and extinction. To understand biodiversity, it is thus necessary to investigate the underlying (genetic) processes involved. Genetics seeks to understand the heritable basis of variation and evolutionary change at all levels. The potential of a species to respond to novel environments and to disturbances caused by human activities depends on the extent of diversity and the kind of diversity that is available. Genetic differences among individuals within a species provide the foundation for diversity among species and ultimately the foundation for the diversity among ecosystems. Genetic diversity (i.e. infra-specific diversity) determines the ecological and evolutionary potential of species.

Marine biodiversity threats

As on the rest of the Earth, the composition and structure of the fauna, flora and habitats of the oceans change under natural or anthropogenic pressures. The latter is the reason for the deterioration of many environments, from the coast to deep sea; over the last 50 years the rate and extent of this deterioration has been unprecedented, as were the consequences on biological diversity. Among the causes of loss and degradation of biodiversity are:

Direct threats:

- Fragmenting and loss of natural habitats
- Overexploiting of certain species
- Biological Invasions, consequence to human activity
- Pollution [atmospheric fallout, pollution brought down by rivers, emissions, sea-farming (uneaten artificial aliments, antibiotics), hydrocarbons, antifouling paint, hot water, pesticides, detergents, heavy metals, radionuclides, waste, viruses and bacteria (waste water), silting, pleasure sailing (unauthorised anchorage)]
- Climatic changes

Indirect threats:

- Development of rivers and the coastline (valorising and occupying coasts for industrial, tourist and residential purposes)
- Increase of human population and concomitant exploiting of resources
- Disturbance linked to leisure activities
- Destruction of the sedimentary systems through mining exploitation
- Difficulty or impossibility of economic growth in certain countries
- Catches (fishing, gathering) mostly of wild stock
- Non-recognition or under assessment of marine diversity and natural resources in economic terms Weakness of legal systems and institutions
- Absence of adequate scientific knowledge and ineffective transmission of information

What is a (biodiversity) indicator?

An indicator consists of data selected from a larger statistical whole, and possesses particular significance and representativeness. Indicators thus condense information, and simplify the often-complex environmental phenomena, thus becoming precious **communication tools** between science and politics. Thus they must be envisaged in the context of information flow (scientific research, environmental management, decision making or public awareness).

In ecological sciences, a “good” indicator” is often an organism or a group of organisms which, by reference to biochemical, cytological, physiological, ethological or ecological variables, allows in a practical and safe way to characterize the state of an ecosystem or an eco-complex and to highlight as early as possible their natural or caused modification. Because organisms are subject to a variety of stressors in their environment, multiple measures of health are needed to help to identify and separate the

effects of man-induced stressors (e.g. contaminants) from the **effects of natural stressors**, at different scales (e.g. food and habitat availability, climatic changes).

When used by ecologists, conservation biologists and natural resource managers in the context of biological diversity, it generally refers to the **environmental attributes**, often of species or groups of species, which can be sampled and whose change in time and space would reflect a change of biological diversity as a whole. Therefore, indicators are measurable substitutes for the larger measurements of biological diversity. They are **monitoring tools** used because it is impossible to monitor biological diversity in its entirety, even in a restricted sector. From the point of view of decision-making, indicators constitute quantitative measurements, which imply a unit of measurement (distance from an **operational objective**, **baselines** permitting changes to be measured against a certain date or a certain state, **thresholds**, which are used as early warning systems, **targets**, which reflect tangible performance objectives, etc.) from which one can measure certain aspects of what is yielded by a policy of public interest. In this capacity they differ from statistics (raw data), because they present information in a context, which gives it significance for a wider public, not only for experts.

Criteria for biodiversity indicators

Key criteria for establishing a feasible and effective universal core set of biodiversity indicators have been proposed, among others, by UNEP (1999)[3] and were summarized by EEA (2002)[4] as follow:

- be easy to understand and policy-relevant;
- provide factual, quantitative information;
- be normative (possibility to compare to a baseline situation);
- be scientifically sound and statistically valid;
- be responsive to change in time/space;
- be technically feasible and cost-efficient to use within acceptable limits (in terms of data collection);
- be usable for scenarios for future projections;
- allow comparison between member states;
- allow aggregation at national and multinational level;
- take into account country-specific biodiversity;
- be user-driven.

They should also address the question of baselines for measurement (in light of the fact that application of a pre-industrial baseline may often be problematic). ***Indicators proposed in the following sections of the present booklet do not all meet these criteria that however, should actually be applied in a next step towards defining a core set of biodiversity indicators***.

The major policy questions to be answered and for which indicators can provide useful tools are derived from the main objectives of twelve biodiversity-related global and European policy instruments listed by EEA (2002)[4].

Target groups for biodiversity indicators

The target group for biodiversity indicators in Europe consists of two parties: those providing the data on the indicators (research institutes, non-governmental organizations, volunteers and/or government agencies[5]) and those making policy decisions on the basis of the message expressed by the indicators (European Council of Environment Ministers; European Commission (especially Directorates - General Environment, Agriculture, Energy and Transport, Fisheries, Regional Policy and Research and the Joint Research Centre); National governments of the EU member states).

Pressure-State-Response (PSR) model

Different models have been proposed to help in structuring thoughts on indicators. They have all their limitations in terms of interpretation and the classification of indicators depends on the sector or issue under view.

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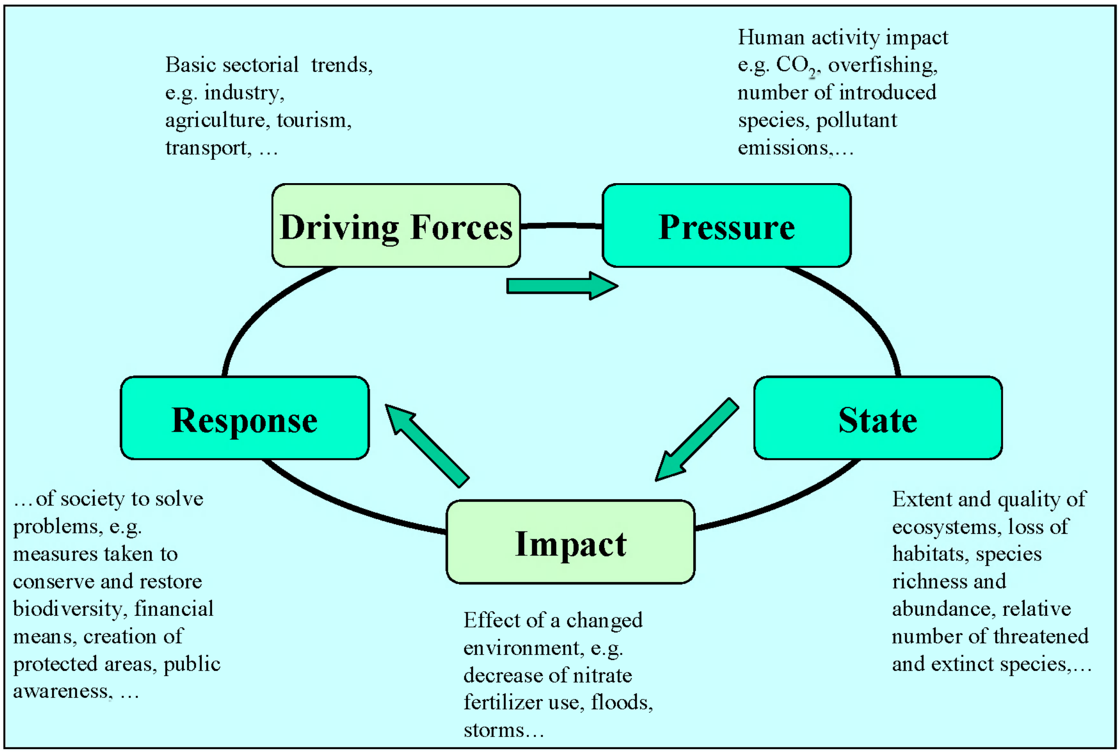
[3] UNEP (1999) Development of indicators of biological diversity. UNEP/CBD/SBSTTA/5/12 – Montreal, Subsidiary Body on Scientific, Technical and Technological Advice (http://www.biodiv.org/doc/meetings/sbstta/sbstta-05/official/sbstta-05-12-en.doc)

[4] EEA 2002 An inventory of biodiversity indicators in Europe, Copenhagen, European Environment Agency.

[5] EEA European Environment Agency and its European Topic Centre on Nature Protection and Biodiversity; EIONET National Reference Centres on biodiversity; International NGOs: ICES, CIESM, UNESCO, UNEP

The PSR model is based on the concept of causality: human activities exert pressures on the environment and change its quality and quantity of natural resources (“state”). Society responds to these changes through environmental, general economic and sectoral (“societal”) responses. The PSR framework was initially proposed by Friend and Rapport (1979)[6] for the purpose of analyzing the interactions between environmental pressures, the state of the environment and environmental responses.



Some organisations prefer variants of the PSR model. For example, the UN Commission for Sustainable Development (UN CSD) bases its indicator set on the Driving force-State-Response model (DSR) model, where the term “Driving Forces” is used synonimous for “Pressure” and which allows a better inclusion of non-environmental variables. For compatibility reasons to the DSR model the indicator community has formulated the Driving forces – Pressure – State – Impact - Response (DPSIR) model, which includes the PSR model as special case. This later appeared sufficient for practical biodiversity purposes.

Key questions concerning biodiversity indicators

A preliminary step toward developing a core set of biodiversity indicators is to identify the key questions that indicators can help to answer for policy makers. The questions must at least be national oriented and related to the status of biological diversity components and the pressures leading to biodiversity loss.

Pressure indicators (e.g. loss of habitat, fishing effort, number of species introduction, frequentation rates of natural habitat, pollutant emissions):

- What are the most important direct and indirect threats to biodiversity?
- Are these primary threats to biodiversity stable, declining or worsening?
- What are the linkages between these primary threats and changes in biodiversity status?
- What driving forces impact on biodiversity?
- What is the level of the main pressures on biodiversity?

State indicators (e.g. extent of ecosystems, quality of ecosystems, relative number of threatened and extinct species):

- What is the conservation status of Europe’s biodiversity?

6 Friend, A and D. Rapport (1979) Towards a Comprehensive Framework for Environment Statistics: A Stress-Response Approach. Statistics Canada, Ottawa, Canada.

- What are the major trends in the status of biological diversity (genes, species and ecosystems)?
- Are conditions stable, improving or deteriorating?
- What is the state of knowledge of biological diversity?

Response indicators (*see below*):
- Has the situation been corrected?
- What measures are taken to conserve or restore biodiversity?
- Are these measures effective in reaching the objectives?
- Are biodiversity conservation measures integrated into other sectors of society?
- Is use of biodiversity components carried out in a sustainable way?
- What is the status of awareness and participation of the public and policymakers?
- What is the status of information availability and understanding of biodiversity?
- Are financial means available for biodiversity conservation and how are they spent?
- Are pressures on biodiversity or causes for biodiversity loss being tackled?

E.U. state of the art of marine biodiversity indicators

In the framework of TEPI "Towards Environmental Pressure Indicators", by EUROSTAT, a list of ten policy fields was developed on the basis of the "themes" of the Fifth Environmental Action Programme: Air Pollution, Climate Change, Loss of Biodiversity, Marine Environment & Coastal Zones, Ozone Layer Depletion, Resource Depletion, Dispersion of Toxic Substances, Urban Environmental Problems, Waste, Water Pollution & Water Resources.

Six targeted economic sectors representing the societal actora of sustainable development were chosen for each theme. Those of *Marine Environment & Coastal Zones* are: Eutrophication, Overfishing, Development along shore, Priority habitat loss, Discharges of heavy metals, Oil pollution at coast and at seas. *Marine Environment & Coastal Zones* theme may overlap with *Loss of Biodiversity* (e.g. Protection area loss or damage, Wetland loss through drainage, Agriculture intensity) and major threats to the sea come from inland *Water Pollution.* It is clear that marine biodiversity per se and the negative ecological, economical and societal consequences are not actually considered.

EEA (2002) gave an inventory of biodiversity indicators in Europe. It gathered a large amount of information on biodiversity-related indicators and their use in Europe and globally. Almost nothing concerns marine biodiversity. EEA report recommended, given the need for further scientific research and testing, a two-way approach: (1) select some indicators that can be used in the short term (even when imperfect) and (2) meanwhile continue developing or fine-tuning other indicators for long-term use.

BIOMARE' bioindicator Workpackage

One of the operational objectives of the *Jakarta Mandate*[7] was the application of the precautionary approach to biodiversity impact and also to develop guidelines for ecosystem evaluation and assessment, paying attention to the need to identify and select indicators. BIOMARE Workpackage 2 (WP2) objectives fit with this. These were to inventory, list and select a number of biodiversity indicators used or proposed by involved European laboratories. As a result of the analysis of the involved marine institutes, we give in this booklet a state of the art of indicators to be used in a long-term, large-scale survey of marine biodiversity throughout Europe. Research programmes on the processes of marine biodiversity changes can then be developed in order to identify the main causes, the rate and extent of biodiversity change or loss and evaluate the benefit of the implementation of protective or corrective measures.

BIOMARE' European Marine Biodiversity Research Sites (EMBRS)

BIOMARE Workpackage 1 has established a network of marine coastal sites as the basis for long-term and large-scale marine biodiversity research in Europe. Among these EMBRS, a subset of **Reference Sites** has been selected where human activities or natural local perturbations do not affect biodiversity to any measurable degree, so that any future changes are likely to be dominated by natural factors. These sites have the potential to be used in future for studying large-scale effects on biodiversity, such as climate change. The remaining **Focal Sites** are impacted to varying degrees and by varying factors, and these can be used for studying more local effects on biodiversity. The entire net-

[7] Jakarta mandate on marine and coastal biological diversity, First meeting of experts, Jakarta, Indonesia, 7-10 March 1997.

work of EMBRS would be needed to address certain large scale issues such as the effects of climate change on range extensions of species (see Warwick *et al*. 2003)[8].

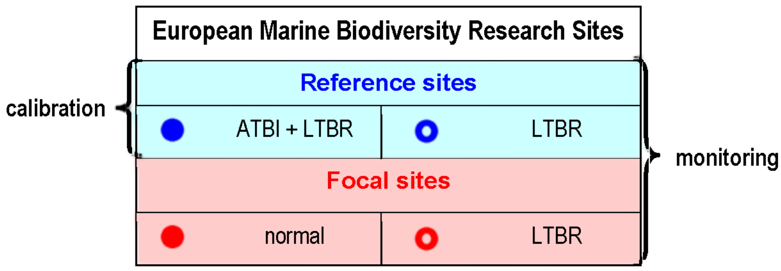
The Reference Sites have been further categorised as follows:

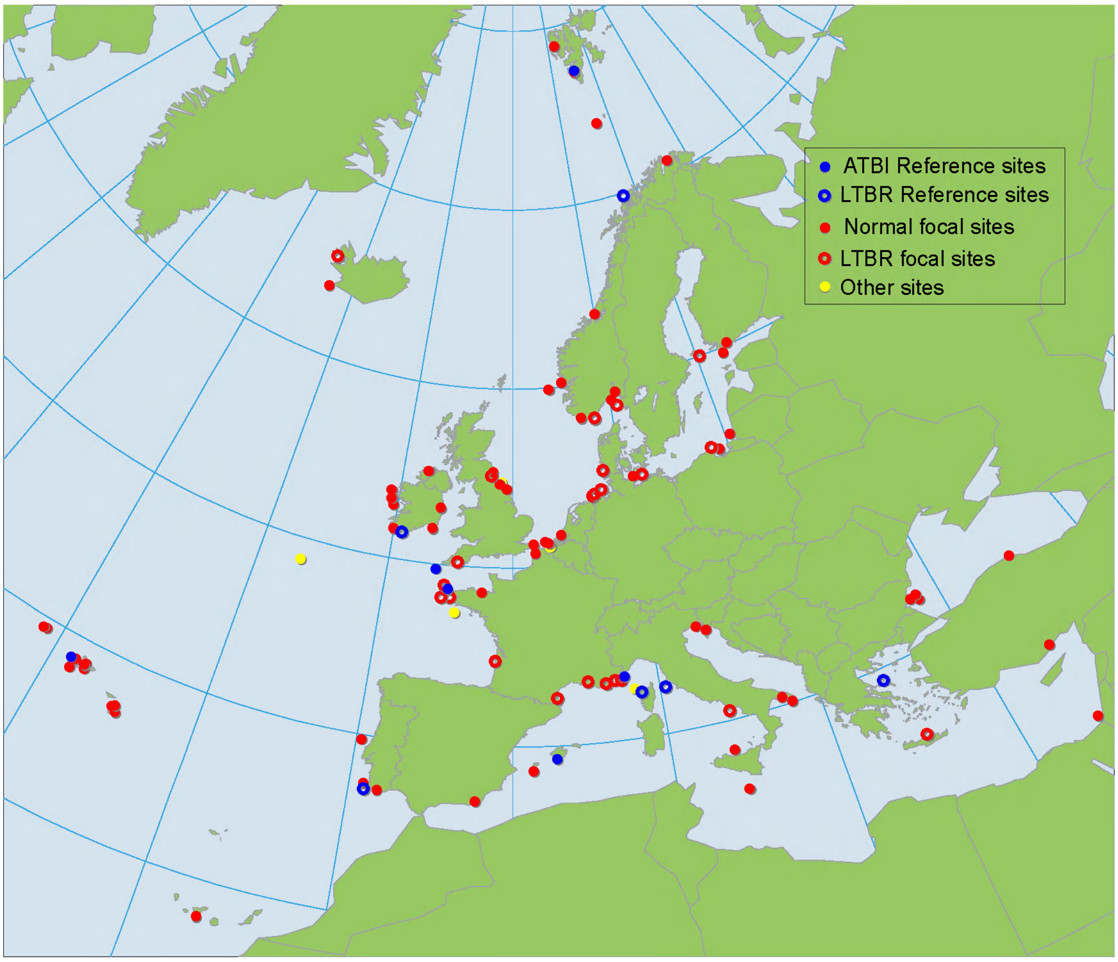
- **ATBI Sites.**

These are sites where inventories are already available for a large number of components of the biota, and where the production of an *All Taxon Biodiversity Inventory* (ATBI) is feasible. They are sites necessary to calibrate indicators and because they are protected against direct human impact, they are the reference for assessing and measuring climatic change effects.

- **LTBR Sites.**

These are sites intended for Long-Term Biodiversity Research (LTBR) aiming at understanding the processes that govern the origin, maintenance and change of marine biodiversity, including human impacts. To this end, a number of Focal Sites centred on major well-established marine research laboratories in Europe have also been designated for this purpose. LTBR sites are managed by one or several committed institutes and in future may be the nodes of regional networks involving a number of satellite sites from the same region.





[8] WARWICK *et al.* 2003 - European Marine Biodiversity Research Sites

BIOMARE' Workpackage 2 process

A questionnaire was created and completed by the BIOMARE community, via the Internet (http://www.biomareweb.org) leading to an initial inventory of indicators and key-species. This inventory was then used as a start point for discussions during workshops. A number of points arose from these discussions. Most proposed indicators were essentially species, and were in fact indicators of "health" of the marine environment. Almost all propositions were deduced from a determinist view point (the same causes produce the same results), which is in fact neither well understood nor well documented. Moreover, none of the indicators [*i.e.* species] were actually in use on a long-term basis.

The analysis of the questionnaire also showed that, as already described some years ago[9], no "operational" indicator or set of indicators concerning marine and coastal biodiversity is currently available on either a regional or a European scale. We also noticed that none of the endangered species, ranging from plants to cetaceans, listed in the Berne Convention[10] or the OSPAR Convention[11], for example, was being monitored in a coherent way. The questionnaire results also showed that inventories and different actions such as the compiling of databases or studies on stocks were under way, but that:

- there was no standardised sampling plan,
- time and space scales were all different,
- the taxonomical skill involved in various projects also differed greatly.

BIOMARE' rationale for marine biodiversity monitoring

One of the main tasks of BIOMARE' WP2 was therefore to define strategies to choose indicators and to use them in the framework of a monitoring strategy. For society, using biodiversity indicators contributes to the objective to maintain within acceptable bounds, including for economical reasons, the following:

- The diversity of ecosystem types
- Species diversity
- Genetic variability within species
- Productivity of directly-impacted species
- Productivity of ecologically-dependent species
- Ecosystem structure and function
- Water quality (linked to e.g. mariculture, fisheries, recreation).

The purpose of monitoring biodiversity is thus to rationally conserve and sustainably use its resources. The aim is to understand how biodiversity changes through time, both now and in the past. To achieve this both inventory and monitoring are necessary. Inventory work establishes a baseline distribution of biodiversity for particular places at particular times. Monitoring addresses the issue of change or lack of change (depending on space and time scales) of biodiversity through time at particular places. In fact changes in biodiversity occur through time in all communities and ecosystems. Some of these changes result from natural factors and others from human disturbances. The goal of a monitoring programme is to document natural patterns of change or lack of change in order to establish a baseline for understanding the impact of natural disturbance on species composition and abundance in communities and ecosystems. Once this baseline is established it can be used to detect changes in biodiversity that result from human disturbance. Thus we are going to distinguish what to monitor and how to monitor in the different types of BIOMARE European marine biodiversity research sites.

An ideal core network of sites for monitoring changes in biodiversity would cover a selection of critical ecosystems. Areas such as those that are being subject to degradation through human activities, transition zones, sites which have been intensively studied and have well established species lists, coupled with meteorological and ecological data sets and sites, which are aligned along gradients such as longitude, latitude, salinity and other appropriate gradient could be used. In many ways, such a core network of sites could be built upon existing protected areas such as national parks.

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9 HEIP C. *et al.* (eds.) 1997. An inventory of marine biodiversity research projects in the EU/EEA member states.CEC/MAST and EERO, publ. MARS, NIOO, Yerseke. FERAL J.-P. 1999 . Indicators of marine and coastal biodiversity of the Mediterranean Sea UNEP(OCA)/MED WG.154/Inf.4

10 Site of the Bern convention: http://www.nature.coe.int/english/cadres/berne.htm
The text of the Bern Convention is on-line at: http://www.ecnc.nl/doc/europe/legislat/bernconv.html

11 Site of the OSPAR convention: http://www.ospar.org/
The text of the OSPAR convention is on-line at: http://www.ospar.org/eng/html/convention/welcome.htm

To efficiently use biodiversity indicators, BIOMARE WP1 and WP2 recommend selecting sampling sites along a **natural gradient of a single major environmental variable**, but within a single **region that is homogeneous in species pool and history**. To understand changes at a European scale implies the use of **transects in different regions and seas as replicates to test hypotheses** regarding the response of taxa and functional group richness to resource availability and disturbance. It is also necessary to select transects from areas **with high and low numbers of species** in the regional species pool. (*cf.* Solbrig 1991)[12]. It will also be necessary to nest replicate areas within regions to disentangle broader scale change from more localised fluctuations.

BIOMARE' proposal for a marine biodiversity monitoring strategy

1. Framework

1.1. Detecting changes of biodiversity in space and time

Detecting SPATIAL changes	
By what means and where	Objectives / Results
Direct assessment of biodiversity in limited protected areas (ATBI sites)	Give an idea of the European "unimpacted" biodiversity, solely threatened by natural perturbations
Indirect or selective assessment of biodiversity (in ATBI sites and particular LTBR sites)	Limits of distribution of species
	Compare biodiversity (at genetic, species, community and seascape levels) under different conditions (natural or anthropogenic stressors)
	Assess biodiversity along gradients

Detecting spatial changes in addition to those due to natural variability (ATBI as reference to compare to other sites), this primarily represents an inventory, which will be used as a baseline of biodiversity with respect to place and time.

Detecting TEMPORAL changes	
By what means and where	Objectives / Results
In "unimpacted" LTBR sites (using bioindicators of biodiversity or surrogates)	Assess impact of global changes, such as climate, on biodiversity
	Detect "natural" genetic variations
	Assess "natural" dynamics of communities and target populations
In protected areas, selective assessment of biodiversity	(Positive) impact of protected areas on biodiversity
In impacted sites (Focal sites) using bioindicators calibrated in ATBI sites	Long and short-term impact of anthropogenic stressors combined with global change on biodiversity via dynamics of communities and target populations.
	Detect the threshold of stress that an ecosystem can support before biodiversity changes.

Detecting temporal changes in addition to those due to natural variability (especially LTBR sites) and attribute changes to their causes, this monitoring programme will track changes in biodiversity over time. The following step is to attribute these changes to their causes by testing hypotheses and empirical models.

1.2 Monitoring scales

1.2.a Biodiversity at all levels of biological integration

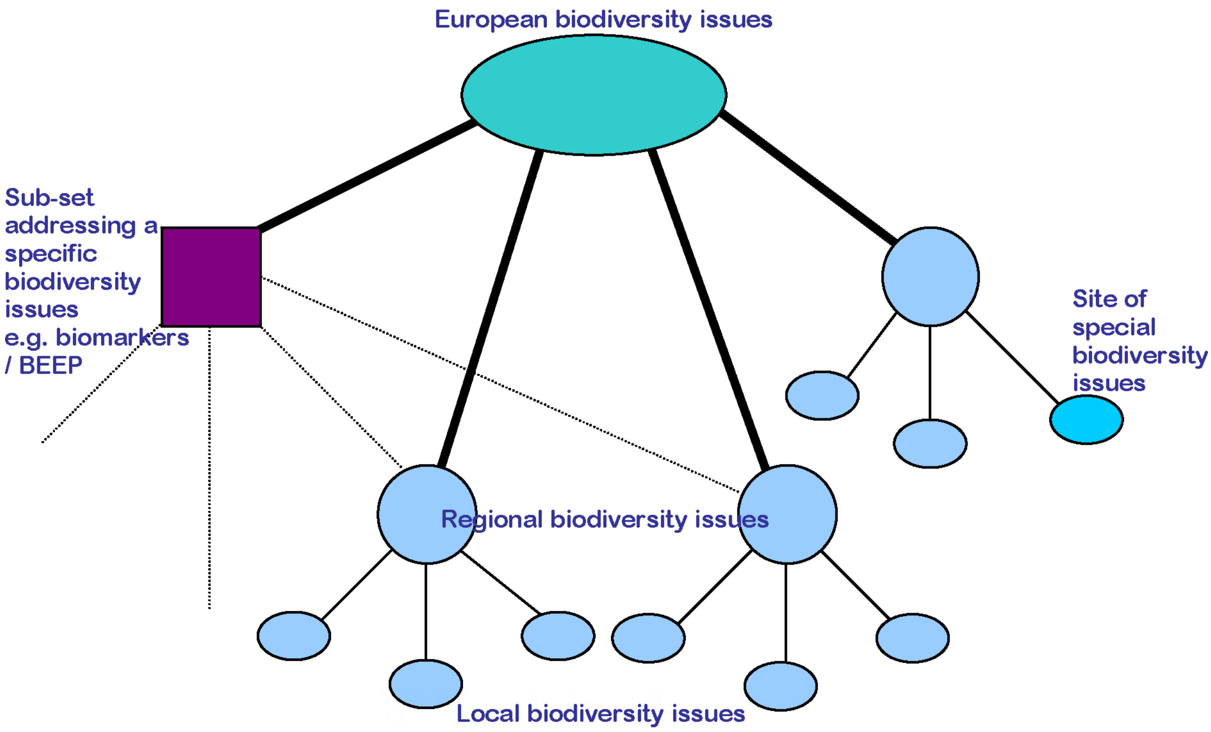
The task is to measure marine biodiversity changes on various biological spatial and temporal scales (from single samples to regional and global scales), identify the threats of marine biodiversity, and assess the consequences. To do so, multiscale and multidisciplinary approaches are necessary for a good assessment of marine biodiversity. Biodiversity must be therefore considered at its different levels: Genetic diversity, Organismal (species) diversity, Community or ecosystem diversity, Seascape diversity.

[12] Solbrig O.T. (ed) 1991. From gene to ecosystems: a research agenda for biodiversity. 124 pages. Published by IUBS, Paris

A baseline of biodiversity at these four levels should be made (if it does not already exist) at the ATBI sites.

1.2.b Geographic scales

At every site people are obviously working first at local level. The information obtained at that level could then also be relevant at a regional or Pan-European level. This means that the assessment and survey tools used must be at least partially Pan-European, to allow comparison of biodiversity and its



evolution on a large geographical scale. Information resulting from the survey of species indicators may not be directly comparable at a European level, but biodiversity trends (resulting from these indicators) are.

The first level is a sampling unit constituted by the habitat. As biodiversity measurements are surface-area dependent, sampling units must be calibrated and standardized for each habitat. Generally one site includes several habitats. Certain sites such as the ATBI sites (and some LTBR sites) have the whole panel of habitats considered in BIOMARE. In others, such as sites directly impacted by human activity, only one habitat of special interest may be monitored.

An initial information and research network creating an independent unit and developed at a regional or sub-regional level may subsequently be incorporated into an inter-regional European network. Different network subsets can be determined, and at the same time address large scale and long-term biodiversity issues. In the future, closer relations with networks addressing specific problematic targets concerning BIOMARE should be established.

Possible sub-set networks:

- Based on very specific problems (which can only be treated by a limited number of laboratories):
    - Biomarkers
    - Genetic diversity
    - Invasive species
    - Deep sea biodiversity
    - Particular ecosystems (estuaries, delta zones, caves…)
    - Climate change

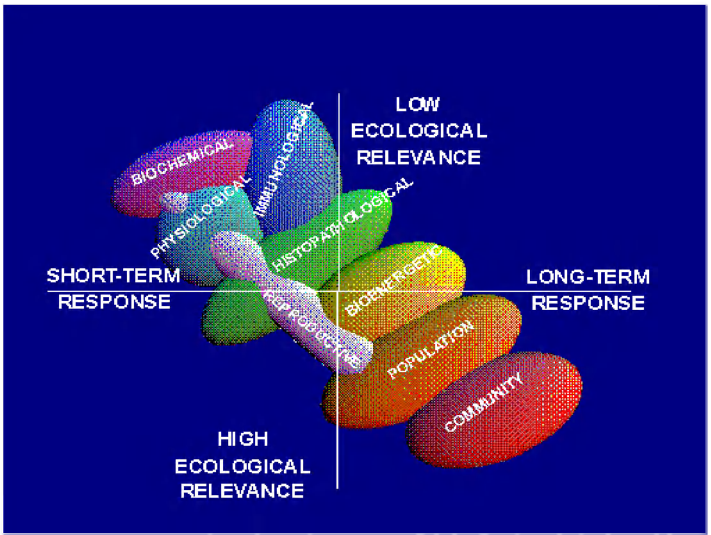
- Based on regional collaboration treating biodiversity in a more general way but delivered at different sites
    - Set of ATBI, LTER and focal sites depending on a eco-region
    - Set of sites depending on a country

1.2.c Time scale

The assessment of biodiversity on a European level through the ATBI sites should be done only once, at the beginning of any monitoring programme. The evolution and changes in biodiversity (other than natural) are to be followed through an appropriate time period. This will give a spatial reference with detailed information on the biodiversity of the different regions.
At reference sites, human impact is assumed as being virtually absent except through global changes. These global phenomena have an impact on biodiversity on a long-term scale and therefore should be monitored less often but for a longer period (10-15 years or more).
At focal sites, changes in biodiversity can be linked more directly to human impact associated with global changes. The survey of biodiversity changes in such sites should be more frequent but monitored on a shorter term.

1.3 Different types of indicators

The purpose of BIOMARE was to produce an inventory and evaluate indicators of biodiversity. However, as such indicators are not sufficient by themselves, they must be used together with other indicators to give a more total evaluation of the ecological risk. In particular, such combined indicators need to be able to give an early warning of an adverse change for the environment. For the protection of biodiversity, indicators which react quickly, at a cellular or sub-cellular or biochemical level, even at low ecological relevance, such as biomarkers are required. Policy decisions must take this point into account.



www.esd.ornl.gov/programs/bioindicators/whatare.htm

Among the different types of indicators (see above) BIOMARE WP 2 has mostly defined state indicators:

- Bioindicators of biodiversity at three levels (within a population, within a community/habitat, within a multi-unit site)
- Bioindicators of environmental health having a direct link with biodiversity at the three levels

Use and response indicators, were considered as they stand in the literature. We only give some examples below. Depending of the context and of the target, an indicator suggested in a given category can also be indicator in another one (state, pressure or response indicators). A closer link should be established between BIOMARE and national and international policies when the network reaches a functional state.

Use indicators
These are goods and services provided by ecosystems:

- Fishery catches: concurrency of rare species in the nets, note changes in size of catches;
- CPUEs (estimation from sets of landings by all boats over a month);
- Production of bioactive substances for medical use;
- Ecotourism development;
- Divers: observations are collected in certain Atlantic and Mediterranean sites.

Example of decision tree used to chose biodiversity indicators

Define the time and spatial scales of monitoring

A. Define the time-scale

Short-term	Long-term
Direct effect	Long term effect
↓	↓
T.1. Rapid assessment 1 time	T.2. (rapid) Assessment x times

S. Define the spatial scale

S.1 Pan-European	S.2. Regional	S.3. Station
	10-20 miles around fixed point	

Chose the Reference Point(s)

The operational objective, indicator, performance or response measure and reference point form a package whose each element is essential to properly define and interpret an indicator

T.2. Long term (rapid) Assessment x times

S.2. Regional

- Collect the baselines (databases on monitoring / historic data)

- Select biodiversity indicators:
  - B.1.1.2.b (rare/endemic ratio)
  - B.2.x.x.
  - B.5.x.x.

- Statistically test with the baseline data which of the above factors are good indicators of (changes in) biodiversity at the temporal and spatial scale chosen.
Beside biodiversity indicators, this evaluation may give an idea of the scale and rate of change

- For a prediction (prognosis) perform the proper modelling

Chose the indicator(s), regarding key issues (managers) or specific questions (scientists)

How do I collect the required information? Who did this type of work before? Who can do this work now?

B. Biodiversity indicators

B.1. Level of organization

- b.1.1. (presence of) taxa
- b.1.2. Key species
- b.1.3. Functional groups
- b.1.4. Phylogenetic groups
- b.1.5. Biogeographic groups
- b.1.8. Population dynamics
- b.1.9. Community indices (Biomass / species / abundance ratio)

B.2. Biomarkers

- b.2.1.
- b.2.2.

B.3. Genetic diversity

- b.3.1. Heterozygosity
- b.3.2. Average nr. alleles
- b.3.x. ...

B.4. Habitat diversity

- b.4.1. Number of biotopes per km^2
- b.4.2. ...

Chose the pertinent level of biological integration

Species are the most practical and widely applicable measure of biodiversity to date. However, trophic level balance or habitat complexity may fit better to operational objective *e.g.* for conservation purposes as well as (effective) population size, age structure, genetic variance or inbreeding coefficient.

B.1. Biodiversity indicators : detailed description of Level of organization

B.1.1. Taxa	B.1.2. Keyspecies (sentinel species)	B.1.3. Functional groups
B.1.1.1. Seals B.1.1.2. Fish B.1.1.3. Bivalves B.1.1.4. Nematodes B.1.1.x. ...	B.1.2.1. Dominant species (more than 20 % in numbers or biomass) B.1.2.2. Endemic sp. a. Level of endemism b. Rare/endemic taxa B.1.2.3. Invading taxa B.1.2.4. Charismatic sp. B.1.2.5. Biotope building B.1.2.x ...	B.1.3.1. Suspension feeders B.1.3.2. ... B.1.3.3. Predators B.1.3.4. ... B.1.3.5. Taxa indicating environmental conditions B.1.3.x. ...

Examples of some indicators used by MAP:
- Fishing production per broad species groups
- Number & average power of fishing boats
- Production of aquaculture
- Threatened species
- Share of fishing fleet using barge

Some information given by the FAO for each country:
- Fish for direct human consumption
- Number of vessels
- General evolution of fishing capacity
- Economic role of the fishing industry

Response indicators
These indicate the actions undertaken to solve an environmental problem:

Examples used in the French legislation:
- Protected areas as a percentage of total area (indicator 18.1/FR)
- Cumulative growth of the Conservatoire du Littoral's acquisitions (indicator 18.2/FR)
- Share of the ZNIEFFs belonging to a protected area (indicator 18.4/FR)

Examples of response indicators used by MAP:
- Total expenditure on protected areas management

Examples of response indicators selected by the EEA:
- Waste water treatment per country
- Development with time

2. Strategy of long term, large scale biodiversity monitoring

The BIOMARE sites (EMBRS) are located across Europe and are situated in different environmental conditions. They are also subject to varying degrees of human impact. They therefore do not have the same potential for marine biodiversity research and thus are classed into different categories, which different research objectives.

All sites are **European Marine Biodiversity Research Sites** that consist of:
- EMB Reference Sites (evaluated by an independent committee)
- EMB Focal Sites (only a few have been evaluated by an independent committee).

General strategies for long-term biodiversity research for both categories are proposed in this document. If these strategies are considered at a regional scale, the indicators to use may be indicated more precisely.

2.1 BIOMARE reference sites

These sites are the least influenced by human activities and two main research objectives have been identified:
- All Taxa Biodiversity Inventory (ATBI). This program concerns only a limited number of Reference sites, particularly those that are islands. These sites will serve as geographic reference locations, representing a baseline of biodiversity in Europe. All ATBI sites are also LTBR.
- Long Term Biodiversity Research (LTBR). This program concerns all the Reference sites and a few evaluated Focal sites. The purpose of these sites is to give a reference of biodiversity over time.

2.1.a ATBI sites

ATBI (Reference in space)	**Frequency**	**Scale at which a same method may be used**
Biodiversity Inventory using, if necessary, molecular biology: genetics and environmental genomics	Once Updated if required	European
Rapid Assessment Methods and indicators (indexes, indices and other methods) to be calibrated	Once	Regional or European
Biological markers: calibrated and validated (or not) for biodiversity	Once	European

2.1.b LTBR sites

Long Term Biodiversity Research (Reference in time)	**Frequency**	**Scale at which a same method may be used**
Environmental parameters: *Water temperature, salinity, [PCO2/O2] Redox potential, turbidity, current/ wave action, nutrients (link with national programs), sediment grain-size, meteorological parameters (link with meteorological stations)*	Continuous	European
Habitat cartography (using remote observation)	Once and possibly updated every ten years	European
Survey of target species used as bioindicators: Population dynamics and genetic diversity	Abundance: depending on the species Dynamics: Once over a five year period Genetics: once	Regional or sub-regional
Structure and dynamics of certain communities	Once over a ten year period	Regional
Replicates of calibration of RAM and indicators (if necessary in some sites)	Once	Regional or European

2.2. BIOMARE focal sites

These sites are directly impacted by human activities and biodiversity is influenced by both anthropogenic impacts and natural stresses such as climate change. A simple assessment of biodiversity in these sites is not meaningful as it changes rapidly as ecosystems constantly adapt to the changing environmental conditions. Biodiversity must therefore be surveyed in a dynamic way. A baseline study of biodiversity, using rapid assessment techniques, should be followed by periodic assessments.
The biodiversity of ecosystems may rapidly change over time with the loss, replacement or addition of species. Research at these sites should be able to determine the impact of the different stressors on biodiversity.

2.2.a LTBR Focal sites

A certain number of important marine stations throughout Europe have a long history of biodiversity research and excellent facilities to carry it out but are situated in somewhat impacted sites. These sites are characterised as focal sites. They have very clear research objectives and the same monitoring strategy as Reference LTBR sites (*see above*) should be applied.

2.2.b Other Focal sites

Focal sites	Frequency	Scale at which a same method may be used
Habitat cartography	Once and updated for certain habitats	European
Measures of pollutants	Yearly	Local
Population dynamics studies of target species suitable as bio-indicators of anthropogenic impacts	Abundance: frequent depending on the species Dynamics: once on a period of five years.	Regional or sub-regional
Biological markers	See with BEEP	European
Assessments of biodiversity using methods used for the Reference sites	Once every two years	European method adapted to regional specificities.

3. Selected methods and indices linked to biodiversity

Biodiversity is dependent on its environment. Therefore large scale, long-term biodiversity research should include biodiversity assessments from different environmental conditions as well as surveys of possible or actual changes in biodiversity. Consequently changes in the environment due to human impact and measured by bioindicators, can reflect actual changes in biodiversity and predict future ones.

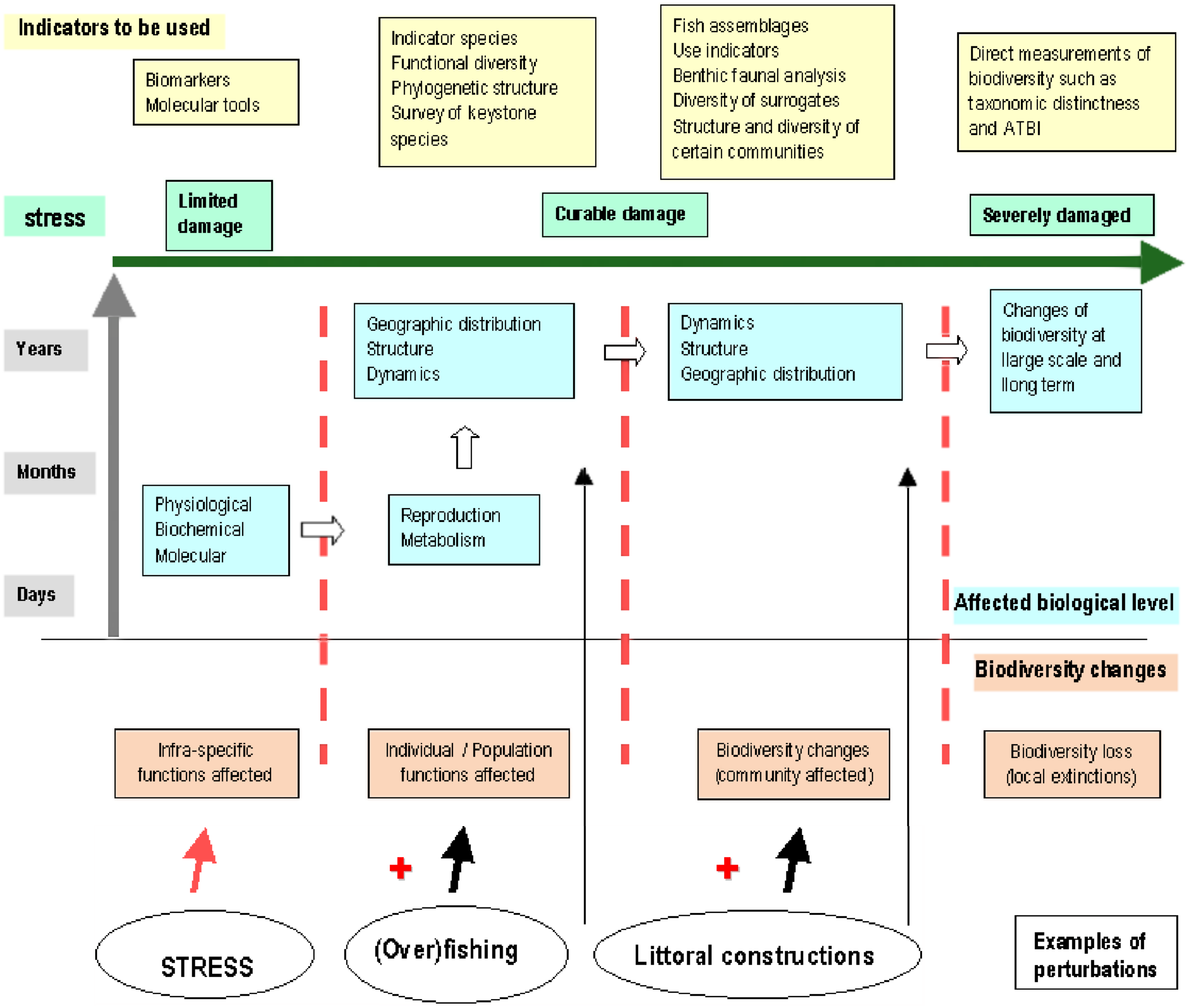
The methods of assessment and indices in this document have been proposed by the institutes participating in BIOMARE. They do not all have standardized protocols. One of the main goals for the future should be to clearly test and standardize the protocols of the indicators.

3.1. Indicators and methods for biodiversity assessment

A complete assessment of biodiversity is time consuming, requires specialists and is expensive. Therefore an All Taxa Biodiversity Inventory can only be made at a restricted number of sites and cannot be repeated often. ATBIs can only be compared geographically and give a reference in time (threshold). Consequently, other ways of estimating and surveying biodiversity geographically and temporally must be used.

3.1.a Indicators of biodiversity

Organismal diversity can be measured in a number of ways, and is usually expressed as some measure of species richness (the number of species), by more sophisticated index such as Shannon Diversity) or the taxonomic spread of species (e.g. taxonomic distinctness, phylogenetic structure). It



Types of indicators and level of biodiversity affected by different type of perturbations: Effects on populations, communities and ecosystems have a high ecological relevance but cannot be used to give an early warning of human pressures on biodiversity. Biodiversity loss may manifest itself long after biochemical dysfunction, physiological anomalies, growth or reproduction impairments have occurred.

It is almost impossible to measure biodiversity across the whole spectrum of organisms present so surrogates, or substitute measures for the total biodiversity are used. Such measures include some component or attribute of the biota that is relatively easy to determine, and which is correlated with overall biodiversity. Such surrogates include the diversity of a selected higher taxon or taxa (e.g. fish), the diversity of higher taxa (e.g. families or phyla), recording conspicuous species by visual methods, death assemblages (e.g. of molluscs), or the gut contents of key predators. The diversity of the surrogate may be assessed either as species diversity (most measures of which, especially the number of species, are sample size or sampling effort dependent) or as the taxonomic spread (taxonomic distinctness is independent of sample size and effort). Other aspects of diversity such as functional diversity (e.g. trophic) or genetic diversity of key species (heterozygosity, allele frequency, population size, inbreeding) may also be used as surrogates.

3.1.b Analysis methods

Examples of frequently used methods for measuring and remotely observing biodiversity in marine biodiversity assessment are given below. This list is not exhaustive, but shows how important remote observation is becoming. These non-destructive methods allow data collection in a standard way, which can be applied across Europe. The data generated may then be used in different layers of a GIS (see below).

3.2 Indicators and methods of environmental health related to biodiversity

The most commonly used bioindicators are those of environmental health. Of these, only a few are appropriate for our purpose. These will not give us an assessment of biodiversity but an indication of:

- Biodiversity changes in time (due to changes in the environment)
- Human impact on biodiversity

Bioindicators of environmental health may be classified by levels:

- Organism level

This consists of monitoring species that are sensitive to environmental conditions and that are most often essential in an ecosystem (see following section 5: “Using species as bioindicators of biodiversity”.

- Community level

Multispecies indicators:

  - The log normal distribution
  - Caswell’s neutral model
  - Coefficient of pollution
  - Ratios between pollution sensitive and insensitive taxa
  - Phylum level meta-analysis
  - Abundance/biomass comparison (ABC) plots
- Infra-specific level [Biological markers (early warning of threat)]:
  - Genotoxicity
  - Stress proteins (general indicator of health)
  - Secondary metabolites production (state indicator / invertebrates chemical defences)
  - Biomarkers of endocrine disruption such as imposex on gastropods
  - Reproduction success (may indicate some effects at the population level), fertility

3.2.a Biotic indicators of environmental state

These are multi-species indicators of environmental stress that depend on various taxa within an assemblage reacting differently from each other in a predictable way. The change in composition or structure of the assemblage can then be used as a stress response. In some cases the changed structure is compared to a theoretical expectation of what that structure should be in unperturbed conditions (e.g. a log normal distribution, Caswell’s neutral model). In other cases the change in composition is compared with empirically derived standards (e.g. coefficient of pollution, ratios between pollution sensitive and pollution tolerant taxa, phylum-level meta-analysis, infaunal trophic index (ITI), biotic index or biotic coefficient). In the case of abundance/biomass comparison (ABC) plots, one structural attribute of the same assemblage is contrasted with another.

3.2.b Biological markers

Environmental stressors, either chemical, physical, or biological have both direct (affecting metabolic pathways) and indirect (changing food and habitat availability) effects on biota. Therefore, the assessment of environmental quality can be directly linked with the monitoring of indicators at all levels of biological organization (bioassessment evaluation). Three successive steps can be recognized for this procedure:

1. Determining which organisms have been exposed to the stressors;
2. Assessing of the level of the hazard and the effect of stressors on the organisms and populations;
3. Assessing the ecological risk in order to determine the ecological damage.

A subset of bioindicators, known as biomarkers or biological markers, is generally used to indicate exposure of biota to stressors at lower levels of biological integration (sub-cellular to organism).

A number of bioindicators used as assessment tools for the quality of the marine environment have been proposed as potential indicators for the assessment of the marine biodiversity, by members of the BEEP Project (Biological Effects of Environmental Pollution in marine ecosystems). Although no conclusive links between biomarkers and biodiversity have yet been established, the BIOMARE Consortium feels that future evaluation of this category of bioindicators as biodiversity-monitoring tools should be made and that their potential inter-calibration with the other biodiversity surrogates proposed in this booklet should be explored. Some of the criteria used for their selection (i.e. sensitivity, specificity, broad applicability, representativeness and low-cost), their potential use in providing an early warning of impending environmental damage, their potential to create links between stressors and effects, and their incorporation into ecological risk assessment, have been addressed..

Relevant levels of biodiversity changes

Levels of analysis	Genetic	Species	Assemblages (different taxonomic levels, community level, and other assemblages)	Habitat
Infra-specific	Genetic markers : • Heterozygosity • Allele frequency • Population size (N) • Effective population size (Ne) DNA probes	Biomarkers : • Acetylcholinesterase (AChE) inhibition • DNA adducts Genetic markers : • Heterozygosity • Allele frequency • Population size (N) • Effective population size (Ne) DNA probes		
Population	Genetic markers : • Heterozygosity • Allele frequency • Inbreeding coefficient DNA probes	*All the above, and:* Species indicators : *see below* Early indicators : • Reproduction success • Endocrine disruption • Embryo sex ratio	• Species indicators that are constituents of habitat • Species indicators that are keystone • Gut contents of key predators	• Species indicators that are habitat builders using remote sensing
Assemblages	Genetic markers : • Heterozygosity • Allele frequency DNA probes	*All the above, and:* Biotic indicators of environmental state: • The log normal distribution • Caswell's neutral model • Coefficient of pollution • Ratios between pollution sensitive and pollution insensitive taxa • Phylum level meta-analysis • Abundance/biomass comparison (ABC) plots • Infaunal Trophic Index • Biotic index & Biotic coefficient Biodiversity indices: • ATBI • Number of species • Fish Indice • Taxonomic distinctness • Death assemblages	*All the above, and:* Biodiversity indices: • Death assemblages • Measurement of functional diversity • Phylogenetic structure • Selected higher taxon or taxa • Recording conspicuous species by visual methods • Higher taxonomic diversity • Number of species • Taxonomic distinctness • ATBI	• Species indicators that are habitat builders using remote sensing
Habitat	Genetic markers : • Heterozygosity • Allele frequency DNA probes	*All the above*	*All the above, and:* • Remote sensing of habitat builders	• Remote sensing

BIOMARE marine biodiversity indicators classified in function of the monitored level of biodiversity

Indicators of biodiversity

Legend used for the indicators

State of validation	Not validated ★	Rarely validated ★★	Needs more ★★★	Validated ★★★★
Recommendation	Not recommended ★	Limited ★★	Usable with care ★★★	Recommended ★★★★

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Taxonomic distinctness**
Summary	These are measures of the taxonomic spread of species, rather than the numbers of species. They are independent of sample size and sampling effort, they can be used with simple non-quantitative species lists, and there are possibilities of testing for representativeness using permutation tests. Average taxonomic distinctness (AvTD) is a measure of the average degree to which species in an assemblage are related to each other. Variation in taxonomic distinctness (VarTD) is a measure of the degree to which certain taxa are over- or under-represented in samples. For both indices, a simple permutation test of the hypothesis that the species inventory has a taxonomic structure that is representative of the full biodiversity can be constructed. These measures are beginning to find application in broad scale geographical comparisons of biodiversity, in environmental impact assessment and in evaluation of surrogates for biodiversity estimation.
Geographic Scale	Sample to region
Targets	Broad-scale comparisons of diversity where the sampling effort, methodology etc have not been standardised.
Data needed	Simple non-quantitative species lists
Assessment of likely data availability	There is an enormous amount of data in the literature of this type, which by using more conventional species richness measures is not amenable to biodiversity analysis.
Costs involved	Cheap especially if surrogates can be used, e.g. death assemblages of molluscs washed up on sandy beaches.
Human resource required	Not much
Data generated	Real
Time Frame	Fast
Examples of implementation	Indices have been applied to data on nematodes, demersal fish, corals, macrobenthos, molluscs (see Warwick & Clarke 2001 for references)
Points FOR	Fast, cheap, accurate predictions, provides a manual for biodiversity managers, provides data compatible for collating information, applicable for all seas in Europe, data are directly comparable with other sites assessed by different methods.
Points AGAINST	None
Appraisals	
Literature	*See* Warwick, R.M. and Clarke, K.R. (2001). Practical measures of marine biodiversity based on relatedness of species. Oceanogr. Mar. Biol. An. Rev. 39: 207-231. for review of applications.
Remarks	
State of validation	★★★★
Recommendation	★★★★

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Fish Indices**
Summary	Measurement of the occurrence, frequency, species richness, abundance and demographic structure of two types of fish: type A, 16 large meso- and macro carnivores particularly threatened by spear fishing; Type B: two small territorial fishes particularly impacted by angling. Census is made visually by SCUBA diving along four permanent transects (4x125m) by site both in a protected area and outside the protected area
Geographic Scale	Local
Targets	A need to measure the positive impact of reserves, "reserve effect".
Data needed	Accurate quantitative data (abundance) on all species in the assemblages
Assessment of likely data availability	
Costs involved	
Human resource required	Low
Data generated	List of species and their abundance
Time Frame	One day, twice per season
Examples of implementation	Marseilles' region (Golfe du Lion)
Points FOR	
Points AGAINST	
Appraisals	
Literature	J.-G. Harmelin, F. Bachet & F. Garcia (1995). Mediterranean Marine Reserves: Fish Indices as Tests of Protection Efficiency. Marine Ecology. 16 (3): 233-250.
Remarks	The two sites need to be chosen in close vicinity in order to ensure having the same hydrological environment and to ensure easy accessibility within the same day period. The selection of the sites must be based on similarity in depth, slope, topographic complexity and bottom types. Diving equipment, boards with pre-written species lists are needed.
State of validation	
Recommendation	

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Phylogenetic structure**
Summary	Measures that reflect diversity at a hierarchy of taxonomic levels (phylum to species). Phylogenetic diversity (PD) is the total path length constituting a full phylogenetic (or taxonomic) tree (which is sample size dependent).
Geographic Scale	Sample to region
Targets	Broad-scale comparisons of diversity where the sampling effort, methodology etc have not been standardised.
Data needed	Simple non-quantitative species lists
Assessment of likely data availability	There is an enormous amount of data in the literature of this type, which by using more conventional species richness measures is not amenable to biodiversity analysis.
Costs involved	Cheap especially if surrogates can be used, e.g. death assemblages of molluscs washed up on sandy beaches.
Human resource required	Not much
Data generated	Real
Time Frame	Fast
Examples of implementation	PD used mainly for terrestrial biota.
Points FOR	More informative than species richness, as it reflects relatedness between species.
Points AGAINST	PD dependent on sample size or sampling effort, therefore not comparable between sites where these are not standardised.
Appraisals	
Literature	Warwick, R.M. and Clarke, K.R. 2001. Practical measures of marine biodiversity based on relatedness of species. Oceanogr. Mar. Biol. An. Rev. 339:207-231. Faith, D.P. 1994. Phylogenetic pattern and the quantification of organismal biodiversity. Philosophical Transactions of the Royal Society of London Series B, 345, 45-58.
Remarks	Use taxonomic distinctness instead.
State of validation	
Recommendation	

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Number of Species**
Summary	Simple concept, but notoriously sample-size dependent and therefore difficult to measure accurately. Of use in rigorously controlled studies examining components of biota.
Geographic Scale	Conceptually useful at all scales, but practically limited to smaller-scale studies, with rigorously controlled sampling regimes.
Targets	Local environmental impact assessment
Data needed	Assessed directly from samples.
Assessment of likely data availability	Except at small scales, most data are deficient.
Costs involved	Very high
Human resource required	As all taxa need to be identified to species, this requires enormous effort for anything other than small scale sampling of faunal components.
Data generated	Species number; derivative measures (e.g. H') if relative abundances can be assessed.
Time Frame	Short (environmental assessment) and long (ATBI).
Examples of implementation	Commonly presented for small-scale studies of components of fauna as a relative measure. Sometimes used for larger-scale studies but considered to be a poor measure of biodiversity if sampling effort is not controlled.
Points FOR	A 'pure' biodiversity measure, conceptually simple.
Points AGAINST	Scale dependent
Appraisals	See Warwick & Clarke, 2001 Practical measures of marine biodiversity based on relatedness of species. Oceanogr. Mar. Biol. An. Rev. 339:207-231
Literature	Vast literature, as number of species is widely considered to be synonymous with 'biodiversity', despite the practical difficulties of measuring it accurately.
Remarks	Size sample dependent.
State of validation	
Recommendation	

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Higher taxonomic diversity**
Summary	Individuals in samples are either identified directly to the target taxon (phylum, class, order …) or to the lowest practical taxonomic level and then aggregated to higher taxa. Indices are calculated from numbers of taxa and/or their relative abundances..
Geographic Scale	Sample to region.
Targets	Any study requiring comparison of biodiversity.
Data needed	Assessed directly from samples or aggregated from.
Assessment of likely data availability	ATBI calibration not available. Data to calculate indices widely available.
Costs involved	Relatively cheap once calibrated
Human resource required	Potentially, the higher the target taxon, the cheaper the indices are to calculate as the requirement for taxonomic expertise becomes less.
Data generated	Numbers (and relative abundances) of individuals in higher taxa.
Time Frame	Quick
Examples of implementation	Sometimes calculated (see Clarke and Warwick 2001 for examples) as a relative measure, but yet to be calibrated as a biodiversity measure.
Points FOR	Quicker than species identification, requiring less expertise.
Points AGAINST	As yet uncalibrated as a surrogate for overall biodiversity.
Appraisals	A simple concept that, if it can be calibrated, offers great potential. Many studies demonstrated that multivariate methods at higher taxonomic levels are similar to analyses conducted at the species level..
Literature	Heip, C., R.M. Warwick, M.R. Carr, R. Clarke, P.M.J.. Herman, R. Huys, N. Smol & K. Van Holsbeke. 1988. Analyses of community attributes: the benthic meiofauna of Langesund and Frierfjord, Norway. Mar.Ecol.Progr.Ser.46: 171-180. Warwick, R.M. 1993. Environmental impact studies on marine communities: pragmatical considerations. Aust. J. Ecol., 18: 63-80.
Remarks	Has been validated for environmental health, needs validation for biodiversity
State of validation	★★★
Recommendation	★★★

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Gut contents of key predators**
Summary	Uses the concept of predators as biodiversity collectors, i.e. their gut contents or faeces reflect the biodiversity of prey items available. Not yet tested or calibrated.
Geographic Scale	Local for species with high habitat fidelity, but more usually regional for wide-ranging predators.
Targets	Any study requiring comparative biodiversity data.
Data needed	None.
Assessment of likely data availability	Plenty of data for benthic fauna and predator gut contents available, but matching has not yet been done as far as we know.
Costs involved	Relatively cheap if predators are a by-product of other studies (e.g. fish census).
Human resource required	Taxonomic experience required to identify sub-optimal material.
Data generated	Biodiversity information on the range of prey that comprise the spectrum of the target species diet. .
Time Frame	Quick..
Examples of implementation	None to our knowledge
Points FOR	Avoids need for wide ranging samples from the area under study.
Points AGAINST	Not yet tested or calibrated at any sites.
Appraisals	None.
Literature	Plenty of papers on prey items of predators and prey communities in the field, but not calibrated as a biodiversity measure.
Remarks	Comparisons of demersal fish gut contents and benthic macrofauna are made by several fisheries institutes, e.g. Aberdeen, Tromso. Seal faeces analysed for fish otoliths at SMRU St. Andrews, UK.
State of validation	
Recommendation	

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Death assemblages**
Summary	Kidson (2001) compared the living and dead species composition of shell-bearing molluscs (gastropods and bivalves) in 85 studies of marine sedimentary habitats. She found that these 'time averaged' death assemblages retain a strong signal of the rank order of relative species abundances in the original living source community. In the context of regional biodiversity we also need to know whether death assemblages are spatially averaged as well as time averaged, i.e. is their composition representative of the regional living species pool from all habitats within the region, not just the habitat in which they were found?
Geographic Scale	Local to regional
Targets	Any study requiring comparative biodiversity data.
Data needed	Locations of appropriate collecting sites (e.g. accumulating sand-beaches).
Assessment of likely data availability	For molluscs, mostly in the grey literature and in the files of amateur conchologists. For foraminifera, a lot of geological papers.
Costs involved	Cheap
Human resource required	Sample collection easy, some identification skills needed.
Data generated	Species lists for animals with hard parts preserved in the death assemblage.
Time Frame	Collection of data instantaneous, but death assemblage may be integrated over a long period (maybe several decades). Can be used for fossil death assemblages to study long-term changes (geological time).
Examples of implementation	Warwick, R.M. & Light, J., 2002. Death assemblages of molluscs on St. Martin's Flats, Isles of Scilly: a surrogate for regional biodiversity? Biodiversity and Conservation. Warwick, R.M & Turk, S.M. 2002. Predicting climate-change effects on marine biodiversity: comparison of recent and fossil molluscan death-assemblages. J. mar biol. Ass. UK. (in press).
Points FOR	Quick, few resources for collection.
Points AGAINST	Depends on existence or not of dead shell transport barriers to collecting site.
Appraisals	
Literature	Warwick, R.M. & Light, J., 2002. Death assemblages of molluscs on St. Martin's Flats, Isles of Scilly: a surrogate for regional biodiversity? Biodiversity and Conservation
Remarks	Can also be used for paleoecology and climate research.
State of validation	★★★★
Recommendation	★★★★

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Measurement of functional diversity**
Summary	Must identify to species level and apply knowledge of functional roles to classifying species - for plants by morphology, for animals either by trophic or engineering activities (depending on the function of interest). Can classify broadly (e.g. predators, herbivores, etc) or more finely (e.g. shredders, grazers, etc.). Physiological performance and survival, i.e. capacity of persistence in an ecosystem are determined in model- or indicator-organisms in response to environmental changes such as temperature, eutrophication or UV-radiation.
Geographic Scale	Local to regional. Pan European comparisons aimed at environmental gradients, e.g. latitudinal/climatic, salinity, trophic environment, pollution.
Targets	Aimed to reflect diversity in terms of functional roles to emphasise functional relationships and changes in functionality of system rather than its taxonomic structure. Under this term, functionality of species regards adaptive strategies with respect to environmental changes is also investigated. Environmental managers concerned with sustaining ecosystem function. EIA. Scientific interest.
Data needed	Full species list and knowledge of functional roles. Experimental, on physiological performance.
Assessment of likely data availability	Available in the literature. Flora easier to classify than fauna. Physiological data in literature, partly not well enough ecologically oriented.
Costs involved	Initially expensive in terms of labour - collecting samples. Experimentation, analysis needs specialised equipment.
Human resource required	Initially need expertise on identification and general biology/life history (ethology, physiology, biochemistry, anatomy, and ecosystem).
Data generated	Proportions of functional groups and predictions of ecosystem functional integrity.
Time Frame	Initially time-consuming but subsequently fast, on comparative basis.
Examples of implementation	Hilly in Brittany on rocky shore fauna. M. Tobin on Yorkshire coast flora on rocky shores. F. Buchholz on climatic gradients in pelagic systems.
Points FOR	Makes connection between diversity and ecosystem functioning / 'goods and services'. Powerful tool to integrate scientific knowledge into measures relevant to management.
Points AGAINST	Lack of information for assigning functional roles. Subjectivity in assigning functional roles. Possibility of different levels of classification. Multi-factorial analysis difficult. Technique under development.
Appraisals	Scientific basis reasonably well established, but application to biodiversity assessment / management not yet appraised.
Literature	Buchholz, F; David, P; Matthews, J; Mayzaud, P; Patarnello, (1998) Impact of a climatic gradient on the physiological ecology of a pelagic crustacean (PEP) Third European Marine Science and Technology Conference (MAST Conference), Lisbon, 23-27 May 1998: Project Synopses Vol. 1: Marine Systems. pp. 39-47. Steneck, RS; Dethier, MN, (1994) A functional group approach to the structure of algal-dominated communities Oikos, 69 (3): 476-498
Remarks	
State of validation	★★
Recommendation	★★★

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Selected higher taxon or taxa**
Summary	Uses one or a subset of taxonomic groups (e.g. Terebellidae, Malacostraca, sea birds, mammals) to represent total biodiversity.
Geographic Scale	Comparisons possible at all scales
Targets	Biodiversity assessment, environmental management. Aims to concentrate efforts on a tractable taxon with well-known taxonomy / easy sampling. Well-established technique in terrestrial literature.
Data needed	Quantitative or semi-quantitative data on selected taxonomic group(s)
Assessment of likely data availability	Many existing data sets
Costs involved	Cost-effective
Human resource required	Need initial expertise, but can cheaply train non-specialists due to restricted focus
Data generated	Detailed data on focal group, considered to represent all
Time Frame	Much faster than full survey
Examples of implementation	Many terrestrial examples. Marine examples include Terebellidae, Ostracoda, Pericaridae, sea birds and mammals.
Points FOR	Quick, cheap, informative, can also link with functional approach. If well-calibrated can be very powerful
Points AGAINST	Needs to be calibrated in each new context.
Appraisals	Plenty in terrestrial literature, e.g. Oliver and Beattie, 1996. Some in marine, but needs further testing.
Literature	Oliver and Beattie, 1996; Hull 1998, 1999
Remarks	Can also use ratios of different taxa, e.g. Bellan. As an indicator of total biodiversity still needs to be validated.
State of validation	★★
Recommendation	★★★

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Recording conspicuous species by visual methods**
Summary	Use relatively superficial survey to record only the conspicuous species (e.g. cover of fucoids algae, mussels, sponges, etc.).
Geographic Scale	Sample to region
Targets	Originated in diver-based surveys to make optimal use of limited sampling time by focussing on large, easily seen and recognised taxa. Frequent, low intensity surveys as part of extensive long-term research/ monitoring. Also suited to inaccessible habitats / photographic surveys.
Data needed	Ideally some knowledge of relationship between conspicuous and cryptic diversity.
Assessment of likely data availability	
Costs involved	Cheap
Human resource required	Once the programme has been designed, data can be collected by relatively unskilled researchers. Suitable for community group involvement in monitoring.
Data generated	
Time Frame	Fast
Examples of implementation	Large species such as *Pinna nobilis* in *Posidonia* beds.
Points FOR	Very quick and cheap so able to study many sites at high frequency
Points AGAINST	Crude - may not be representative of variation in cryptic fauna - needs calibration.
Appraisals	Report to JNCC - John Moore Plymouth Sound monitoring survey
Literature	
Remarks	
State of validation	★★★
Recommendation	★★★

Tool Class	**Bioindicator**
Tool Type	**Biodiversity**
Name	**Genetic markers**
Summary	Genetic diversity is measured by analysing isoenzyme or DNA allelopatterns. Indicates the variety in genes within and between species. It is generally considered that higher heterozygosity is related with better performance of organisms/species, low heterozygosity is related with loss in diversity and loss of capability to cope with stress.
Geographic Scale	Local to pan European
Targets	key species
Data needed	Frequency of alleles for 7 polymorphic isoenzymes or DNA tracers in 30 to 40 specimens per population
Assessment of likely data availability	Many studies on key species available
Costs involved	Per population 200 Euro
Human resource required	Skilled technician
Data generated	Powerful comparison between (spatial and temporal differences in) level of genetic diversity between populations
Time Frame	One day per population
Examples of implementation	Hummel, H., C. Amiard-Triquet, G. Bachelet, M. Desprez, J. Marchand, B. Sylvand, J.C. Amiard, H. Rybarczyk, R.H. Bogaards and L. de Wolf, 1997. Comparison of ecophysiological, biochemical and genetic traits in the estuarine bivalve Macoma balthica from areas between the Netherlands and its southern limits (Gironde): Geographic clines parallel effects of starvation and copper exposure. L.E. Hawkins & S. Hutchinson (ed.). Proceeding 30th EMBS. University of Southampton, pp 15-20
Points FOR	Accurate indication of genetic diversity, and on changes in diversity. Monitoring of invasive taxa and of aquaculture escapees. **Biodiversity assessment of very small sized organisms** (e.g. bacteria, nanoplankton, …)
Points AGAINST	At wide scale studies time consuming, and costly in case DNA tracers are used
Appraisals	Scientific basis well established
Literature	LANDE, R., 1988. Genetics and demography in biological conservation. Science 241, 1455-1460. BEAUMONT, A.R. (Ed.), 1994. Genetics and Evolution of Aquatic Organisms. Chapman & Hall, London. Moritz, C., 1994. Applications of mitochondrial DNA analysis in conservation: a critical review. Mol. Ecol. 3,401-411. RAYMOND, M., VÄÄNTÖ , R.L., THOMAS, F., ROUSSET, F., DE MEEÜS, T., RENAUD, F., 1997. Heterozygote deficiency in the mussel Mytilus edulis species complex revisited. Mar. Ecol.: Prog. Ser. 156, 225-237. AVISE, J.C., 1998. Conservation genetics in the marine realm. J. Hered. 89, 377-382. CARVALHO, G.R., 1998. Advances in molecular ecology NATO Sciences Series. Serie A: Life Sciences, vol. 306.IOS Press, Amsterdam. DAVID, P., 1998. Heterozygosity-fitness correlations: new perspectives on old problems. Heredity 80, 531-537. HOLLAND BS (2000) Genetics of marine bioinvasions. Hydrobiologia 420: 63-71. HUMMEL, H., F. COLUCCI, R.H. BOGAARDS & P. STRELKOV, 2001. Genetic traits in the bivalve Mytilus from Europe, with an emphasis on Arctic populations. Polar Biol. 24: 44-52. FÉRAL J.-P. 2002 - How useful are the genetic markers in attempts to understand and manage marine biodiversity. J. Exp. Mar. Biol. Ecol. 268: 121-145
Remarks	Powerful at all biological integration levels
State of validation	
Recommendation	

Analysis methods

Legend used for the indicators

State of validation	Not validated	Rarely validated	Needs more	Validated
Recommendation	Not recommended	Limited	Usable with care	Recommended

Tool Class	**Method**
Tool Type	**Remote observation**
Name	**Aerial photography**
Summary	Intertidal resource mapping using aerial photographs. Shore mapping aims to create maps showing the distribution of biotopes and habitats along with associated information, such as the occurrence of rare species, details of habitat, etc. Biotopes located on the shore are matched to features shown on recent colour aerial photographs (corrected to allow an Ordnance Survey grid overlay) or through the use of cliff top or transect photography.
Geographic Scale	Pan-European
Targets	Cliff top and transect photography is used for mapping algal communities in the intertidal and littoral areas. Biotope mapping for Environmental Impact Assessment. To develop replicable ground sampling techniques suitable for use in a long-term. Attributes measurable by shore mapping: • distribution of individual or groups of biotopes, biotope complexes and life forms present in an area • extent of individual or groups of biotopes, biotope complexes and life forms present in an area • diversity of biotopes present in an area • other attributes attached to polygons in the form of target notes, such as species information, condition of biotopes (Bunker and Bunker 1998) and sensitivity (Cooke and McMath 2000) Although not essential, the use of GIS, especially when linked to a database, greatly facilitates measuring of various attributes of shore mapping.
Conditions needed for application	Low tide and a suitable platform, conditions and/or availability of aerial photography.
Material requested	Clipboard, scanned aerial photographs, maps (enlarged if necessary), field notebook for recording biotopes, target notes and shore profiles, recording forms , collecting equipment for voucher specimens, camera, compass and hand-held differential GPS, basic safety equipment including mobile phone, VHF radio, personal protective clothing, first aid kit, life jacket, tide tables, etc
Assessment of likely data availability	Aerial photography is widely available although can be expensive. Low tide photography is less available and may need to be specifically taken
Costs involved	Low for data collection if taking cliff top photography or
Human resource required	Two people including one person knowing how to take photos.
Data generated	The images are downloaded to a computer and layered and merged using a graphics processor to produce a set of mosaic view images which can be used for a GIS. Images perspective is corrected using SigmaScan. Once the images have been merged and stretched, the resulting mosaïc image is rectified to produce an overhead image of the site. End products by necessity depend on study requirements. It is important to ensure that the GIS and associated database can be interrogated for required information prior to entering data. Commonly required products include printouts of biotope maps, together with data tables of associated information (e.g. target notes) and a written discussion. For monitoring purposes, precise details of the methodology will be required for future surveys. Electronic copies of the maps, database, etc. are perhaps the most important data products.
Time Frame	Rapid (1-2 days) depending on area to be covered
Examples of implementation	Flamborough Head (England).East coast of Ireland (www.ecoserve.ie/projects/sensmap).UK coastline
Points FOR	Non-destructive, can provide information for large and small areas, Provides pictures easier to interpret by anybody and can be more effective than data when explaining features to non-specialists, Can be carried out by non-biologists (e.g. local staff or volunteers), Cheap and quick, images are permanent (if stored properly) and can be interpreted at a later date. Gives an overview of the dominant assemblages and the range of habitats present. The maps can show the overall distribution of biotopes over large areas of shoreline and can be invaluable for developing resource management and monitoring strategies. The maps can highlight and help quantify large-scale changes in biotope distribution. Aerial photograph interpretation is a tried and tested technique. Data stored in a GIS are more flexible and can be interrogated in a number of ways. Entering field data directly to a PC has several advantages. As well as being quick, it cuts out sources of error, which can be created by in-between paper stages.

Points AGAINST	Does not provide any reliable quantitative data. The colour maps produced on a GIS can appear impressive, but their accuracy together with the biotope boundaries must always be scrutinised. Many shore species and communities occur along a continuum and therefore biotope boundaries are often artificial and subjective. Mapping biotopes with strict adherence to a national classification (Connor et al. 1997) may not take account of regional characteristics. So it is essential that proper local descriptions are prepared. Small features or species of interest may be overlooked where a large area is being studied. For example, intertidal Zostera plants may virtually disappear from sediment flats due to winter dieback and grazing by wildfowl (Perrins and Bunker 1998) and the low density may be missed by ground validation. It is difficult to represent the quality of a biotope. The importance of target notes and quantitative studies associated with mapped biotopes is stressed. An important biotope may not be a mappable unit resolved by the aerial photograph. Photographs may not be taken at the same time as the survey, particularly at low water. However, it is important to use recent aerial photographs. On sediment shores, features can shift over short time scales (between tides in some cases) and this will affect the accuracy of maps produced (see discussion in Perrins and Bunker 1998). The aerial photographs available to a study may not be of high enough resolution or quality for shore mapping.
Literature	Moore, J 2000. Fixed viewpoint photography. Procedural Guideline 1-2, Marine Monitoring Handbook. Moore, J J, Taylor, P & Hiscock, K. (1995) Rocky shores monitoring programme (Sullom Voe, Shetland). Proceedings of the Royal Society of Edinburgh, 103B, 181-200. Bunker, F St P D and Bunker, A (1997) Biotope studies on selected rocky shores of South Pembrokeshire following the Sea Empress Oil Spill. Unpublished report to the Countryside Council for Wales, Bangor. Bunker, F S t P D and Foster-Smith, R L (1996) Field Guide for Phase I Seashore Mapping. BioMar. Connor, D W, Brazier, D P, Hill, T O and Northen, K O (1997) Marine Nature Conservation Review: marine biotope classification for Britain and Ireland. Volume 1. Littoral biotopes. Version 97.06. JNCC Report, No. 249. Joint Nature Conservation Committee, Peterborough. Cooke, A and McMath, A (1998) SENSMAP: Development of a protocol for assessing and mapping the sensitivity of marine species and benthos to maritime activities. Working draft, CCW marine report: 98/6/1. Countryside Council for Wales, Bangor. English Nature (1999) UK Biodiversity Group, Tranche II Action Plans, Volume II – terrestrial and freshwater habitats. English Nature, Peterborough. Wyn (2000). Perrins and Bunker (1997). Emblow, C. S., Costello, M. J. & Wyn, G. 1998. Methods for mapping seashore and seabed biotopes in Wales and Ireland - INTERREG SensMap project. In: Emergency response planning: saving the environment: 51-58.
Remarks	Proper planning of fieldwork is essential for efficient use of the limited time the whole shore is uncovered. As a guide, effective shore mapping work can be carried out for a maximum of 4 hours (2 hours either side of low water) in any period of one low water. Fieldwork should only be carried out during the two to three days either side of spring tides.
State of validation	★★★★
Recommendation	★★★ (★★★★ for habitat diversity)

Tool Class	**Method**
Tool Type	**Remote observation**
Name	**Satellite imagery**
Summary	Colour image analysis in determined wavelengths of the Ocean surface allows for the analysis of pigment diversity. This can act as an indicator of plankton diversity and abundance.
Geographic Scale	Pan-European
Targets	Plankton, chlorophyll, long term, sea surface. Pelagic area.
Conditions needed for application	No cloud cover.
Material requested	Satellite information, ground station and workstation.
Assessment of likely data availability	
Costs involved	Expensive
Human resource required	
Data generated	Images with ocean colour patterns
Time Frame	After establishing a routine the information is almost on-line.
Examples of implementation	Used widely for the ocean.
Points FOR	It allows for the long term monitoring of large areas.
Points AGAINST	Low resolution requires proper calibration, high tech solution required.
Literature	
Remarks	Biodiversity indicator value not tested yet in DOP, only as productivity indicator.
State of validation	★★★
Recommendation	★★

Tool Class	**Method**
Tool Type	**Remote observation**
Name	**Acoustic ground discrimination systems (RoxAnn, QTC, Echoplus)**
Summary	AGDS is an electronic signal processing system connected to the transducer of a conventional echo-sounder in parallel with the existing display. The system functions by processing the echoes returned from the sea bed to derive values for the physical nature of the sea floor [RoxAnn calculates 'roughness' (ie. topographic irregularity) and 'hardness' (ie. substratum type, rock/sand/mud etc.)]. By plotting these functions against each other and integrating this information with values for water depth, a detailed map of the distribution of substratum types in a survey area can be produced. Extensive ground validation is required to link substrata with biological assemblages
Geographic Scale	Pan-European
Targets	Community descriptor, Biogeography for littoral and intertidal zones of all habitats.
Conditions needed for application	Relatively calm sea state; high turbidity may affect system.
Material requested	Suitable vessel
Costs involved	Expensive
Data generated	Georeferenced point data of seabed characteristics. Data can be interpolated to create a continuous coverage
Time Frame	
Examples of implementation	It has been used in surveys of several candidate SACs, including Strangford Lough (Magorrian et al., 1995), Loch nam Madadh (Entec, 1996), the Sound of Arisaig (Davies et al., 1996) and the Berwickshire/North Northumberland Coast (Foster-Smith et al., 1996). In all of these areas, sedimentary biotopes with sea pens and burrowing megafauna were identified and mapped. This aspect of marine technology is evolving rapidly, and other comparable acoustic systems will
Points FOR	The great advantage of AGDS is that information on substratum types over wide expanses of sea floor (ie. on a scale of tens of kilometres) can be gathered very rapidly, in far less time than it would take to collect and analyse grab samples over such an area (Sotheran et al., 1997; Greenstreet et al., 1997). In addition, the system is sensitive not only to the physical characteristics of the substratum, but also to certain biotic characteristics such as the presence of organisms projecting above the sea bed, or to the presence of large burrows in the sediment. The technique therefore clearly has enormous potential for rapid mapping of marine biotopes. No depth (within coastal waters) or time limitations. Allows substrata to be mapped rapidly over large areas. Water turbidity unimportant
Points AGAINST	RoxAnn™ data cannot be used in isolation. The substratum types distinguished by the system in its present form must be 'ground-truthed', ie. checked by analysis of grab samples, diver survey or photographic observations. In some cases the system distinguishes more sediment 'types' than can be recognized by traditional particle size analysis (Greenstreet et al., 1997). Although broad biotope categories can be identified, their precise species composition must still be determined by other means. Equipment needs a hard boat to operate. May be unable to access very shallow waters or enclosed inlets. Equipment very expensive. Results need to be 'ground-truthed' by other methods (eg. grab sampling, towed video). Does not provide details of biological community composition or species abundance. Not able to collect benthic samples
Literature	Brown et al - CEFAS report Chivers, R C, Emerson, N, and Burns, D R (1990) New acoustic processing for underway surveying. Hydrographic Journal, 56, 9–17. Collins, W, Gregory, R and Anderson, J (1996) A digital approach to seabed classification. Sea Technology, 37, 83–87. Davies J., Foster-Smith, R Sea Technology Sotheran, I S, Foster-Smith, R L and Davies, J (1997) Mapping of marine benthic habitats using image processing techniques within a raster-based geographic information system. Estuarine, Coastal and Shelf Science, 44 (Supplement A), 25–31.
Remarks	Doubtless become available in the near future.
State of validation	★★
Recommendation	★★★ (for habitat diversity & conspicuous species)

Tool Class	**Method**
Tool Type	**Remote observation**
Name	**Remotely-operated vehicles (ROVs)**
Summary	ROVs are video camera systems mounted in a compact submersible vehicle whose movements are controlled by a surface operator via an umbilical cable (Auster, 1993). The capacities of ROVs are in some respects intermediate between those of SCUBA diving and towed video. Operations are free from the depth and time constraints imposed on human divers, but have a radius of operation defined by the length of the umbilical cable. Surveying outside this radius is achieved by moving the support vessel. An ROV has the advantage over towed video of being able to hover over a selected point or 'retrace its steps', allowing the operator to closely examine a feature of interest. However, quantification of features on the sea bed is more difficult than from a towed video recording, as an ROV does not always remain at a fixed distance from the substratum, and the field of view may therefore change. Because the movements of the ROV are controlled by the surface operator, surveys using this method are by nature more selective than video transects, and so may not give a representative view of the sea floor characters. Some models of ROV have mechanical 'arms' controlled by the surface operator and so have the capacity to take benthic samples.
Geographic Scale	Pan-European
Targets	Mapping underwater biotops, sea bed features, short term, Taxonomic inventories, Rare endemic species, Invasive taxa, emblematic species, community descriptor, biogeography, broad community indices. Adapted to all habitats.
Conditions needed for application	No turbidity
Material requested	Hard boat, ROV and connections
Assessment of likely data availability	
Costs involved	Expensive
Data generated	Video images
Time Frame	Rapid (1-2 days)
Examples of implementation	No published examples. Widely used in the offshore oil and gas industry
Points FOR	No time constraints. Depth range limited by length of umbilical but most models can access depths likely to be encountered in UK coastal waters Able to cover wide areas (relative to capacity of human divers) Mobility allows close-up examination of sea bed Give much information on sea bed topography and burrow types present Deployment areas less restricted than towed video. Can be used over mixed substrata or in areas with submarine obstructions Some models able to collect benthic samples
Points AGAINST	Taxonomic resolution is limited to generally large conspicuous species. Equipment needs a hard boat to operate. May be unable to access very shallow waters or enclosed inlets. Opperating in deep environments is difficult because of the long umbilical line, especially in very hydrodinamical areas. Equipment very expensive. Precise quantification of sea bed features difficult due to changes in field of view. Effectiveness can be limited by water turbidity (the ROV motors themselves may disturb the bottom sediments). Provide only limited information on smaller sediment fauna. Sampling of sea floor features is non-random
Literature	
Remarks	Video images provide a permanent data source that can be re-analysed at a later time.
State of validation	
Recommendation	

Tool Class	**Method**
Tool Type	**Remote observation**
Name	**Sea-bed habitat mapping using side-scan sonar**
Summary	Sidescan sonar has been defined as an acoustic imaging device used to provide wide-area, high-resolution pictures of the seabed. The system typically consists of an underwater transducer connected via a cable to a shipboard recording device. In basic operation, the sidescan sonar recorder charges capacitors in the tow fish through the cable. On command from the recorder the stored power is discharged through the transducers, which in turn emit the acoustic signal. The emitting lobe of sonar energy (narrow in azimuth) has a beam geometry that insonifies a wide swath of the seabed particularly when operated at relatively low frequencies, e.g. <100kHz. Then over a very short period of time (from a few milliseconds up to one second) the returning echoes from the seafloor are received by the transducers, amplified on a time-varied gain curve and then transmitted up to the recording unit. Modern high (generally dual) frequency digital sidescan sonar devices offer very high resolution images of the seabed that can detect objects in the order of tens of centimetres at a range of up to 100m either side of the towfish (total swath width 200m), although the precise accuracy will depend on a number of factors.
Geographic Scale	Pan-European
Targets	Mapping of sea-bed on large areas down to more than 100m of all habitats.
Conditions needed for application	Relatively calm conditions with little water movement
Material requested	One boat plus a side-scan.
Human resource required	One operator for the side scan; experienced interpreters required for analysis
Data generated	From thermal records a seabed feature and/or sediment distribution plan is typically produced. These should be annotated with information on the dimensions of targets such as sand waves. This may be augmented by images showing features of interest that have been scanned in to a computer and added to the plan(s). Typical output from digitally collected data may include the following: Mosaic of data annotated with features of interest, supplied as both a paper chart and in digital format correct for insertion into a GIS system (GeoTiff files). Magnified and enhanced images of particular features of interest supplied both in paper and GIS compatible format. Plan of sediment type distribution supplied as a hard copy chart and in GIS compatible digital format.
Examples of implementation	Port-Cros, Azores; widely used in offshore exploration industry, military and by national geological surveys - geological sediment maps often based on sidescan sonar. AFEN project for West of Shetland
Points FOR	Due to the relatively large swath produced by sidescan at lower frequencies it is possible to cover relatively large areas of the seabed in a relatively short period of time. An almost photorealistic picture of the seabed can be generated as individual survey tracks are mosaiced together and like a photograph the raw acoustic data 'speaks for itself', which is why sidescan sonars are sometimes referred to as self-calibrating The quality of the data are not affected by changes in the depth of water since the sonar fish is towed at a fixed height above the seabed at all times. As it is very sensitive to disturbances in the water column, it is also used for hydrothermal vent detection in shallow areas.
Points AGAINST	The system only resolves the physical habitat except for biological assemblages with high sonar reflectivity - biogenic reefs such as mussel beds. The grey-scale (or signal amplitude) between swaths covering the same area of seabed is often noticeably different, particularly when the orientation of the sonar to the target feature varies., Large amounts of data are typically generated. The size of the data files also necessitates powerful computers. In extremely high slopes or topographycally complex areas the data is very complex to analyse. Difficult to resolve some habitat types - expert interpretation is required.
Literature	Reports of the AFEN project, west Shetland (links from SOC and GeoTek web sites). Kenny, A et al. (2000) An overview of seabed mapping technologies in the context of marine habitat classification. ICES Annual Science Conference September 2000: Theme session on classification and mapping of marine habitats. Paper CM 2000/T:10. UK Marine SACs Project. (2001) Marine Monitoring Handbook 1-4.
Remarks	A useful technique for giving and overview of a large area but the resolution is limited to physical habitat. Images require expert identification and ground validation
State of validation	★★★★
Recommendation	★★★ (★★★★ for habitat diversity)

Tool Class	**Method**
Tool Type	**Remote observation**
Name	**Sediment Profile Imagery**
Summary	Sediment Profile Imagery, or SPI, is an innovative and cost-efficient method of surveying and/or monitoring marine aquatic environments with a view to establishing the environmental status of these habitats or as part of a site inventory study. SPI is based on single lens reflex (SLR) camera photography and computer-based image analysis which greatly accelerates the data acquisition.
Geographic Scale	Pan-European
Targets	To identify different seabed types and redox status (in relation to organic enrichment gradients)To identify sediment type and bed forms. To identify habitat quality (in relation to physical disturbance and deoxygen-tion).
Material requested	Sediment profile camera: This can be diver held or remotely operated on a frame lowered from a boat .Ideally, the surface of the sediment should also be photographed using a separate camera (by the diver)or a camera mounted on the remotely-operated frame before it touches the seabed. .Survey vessel: A vessel with lifting equipment is required, preferably an A-frame at the stern, with suitable winch gear.
Human resource required	Full diving team if diver operated and an appropriate boat and crew.
Data generated	Photographs are analysed to extract the depth of penetration, redox discontinuity level and voids(number and size of vesicles, presence and absences). Improved interpretation of photographs can be obtained by using computerised image analysis (digitisation and enhancement). The exact analyses will depend on the type of information required. More detailed descriptions are presented athttp://www.aquafact.ie/SPI2.html and http://www.courses.vcu.edu/ENG-esh/diaz/diaz_services.htm.
Time Frame	Field: About 30 stations a day from a boat. A diver could sample 10 stations with 3 images at each, along a transect. Laboratory: Each enhanced image takes approximately 5 minutes to analyse.
Examples of im-plementation	
Points FOR	Rapid deployment whether by diver or boat. Permanent images of the sea bed profile. No physical sample analysis required. Turn-around to report very rapid
Points AGAINST	Only works on mud or muddy sand sediments without subsurface obstructions. Samples not available for identification of fauna or sediment particle size (ground truthing or quantitative analysis).Sediment may smear on faceplate and make interpretation difficult. Equipment may flood
Appraisals	
Literature	Information taken in the Marine Monitoring Handbook, Procedural Guideline No.2-2, SPI. Germano, J D (1983) High resolution sediment profiling with REMOTS camera system. Sea Technology 24(12),35–41. Grizzle, R E and Penniman, C A (1991) Effects of organic enrichment on estuarine macrofaunal benthos: a comparison of sediment profile imaging and traditional methods. Marine Ecology Progress Series, 74, 249–262. Nilsson, H C and Rosenberg, R (1997) Benthic habitat quality assessment of an oxygen stressed fjord by surface and sediment profile images. Journal of Marine Systems, 11, 249–264. O'Connor, B D S, Costelloe, J, Keegan, B F and Rhoads, D C (1989) The use of REMOTS technology in monitoring coastal enrichment resulting from mariculture. Marine Pollution Bulletin, 20(8), 384–390. Rhoads, D C and Germano, J D (1982) Characterisation of organism-sediment relations using sediment profile imaging: an efficient method of remote ecological monitoring of the seafloor (REMOTS system). Marine Ecology Progress Series, 8, 115–128. Rumohr, H and Schomann, H (1992) REMOTS sediment profiles around an exploratory drilling rig in the southern North Sea. Marine Ecology Progress Series, 91, 303–311.
Remarks	
State of validation	★★★★
Recommendation	★★★

Tool Class	**Method**
Tool Type	**Remote observation**
Name	**Assessment of cetaceans using hydrophones**
Summary	One of the greatest problems in assessing cetacean populations is the difficulty in finding the animals, either because of poor sea conditions, species behaviour or both. Sound travels better through water than air and at least most, if not all, cetaceans rely on acoustics both for communication and detection of cues from their environment. As most species vocalise frequently, researchers have been developing acoustic methods for cetacean detection, with several advantages. Acoustic methods can be used both during day and nigh time, at most weather conditions and can detect animals that are not at the surface and thus unavailable to sighting methods. With the development of more powerful computers that enable the acquisition and analysis of large quantities of acoustic information, the use of these techniques have become generalized and the relation between efficiency and costs have increased significantly.
Geographic Scale	Regional
Targets	Cetaceans, up to 5000 meters, from coastal to pelagic
Conditions needed for application	Vessel with accommodation for crew and two or more researchers, acquisition and analysis equipment and software, specialised researchers for data acquisition and analysis.
Material requested	Four elements towed hydrophone array; DAT Recorder; Computer for sound analysis; Specialised software;
Data needed	Vocalisations and echolocation sounds.
Assessment of likely data availability	As explained above, cetaceans heavily rely on sound to interact with their environment, and thus sounds are normally associated with their presence, making this an highly efficient method.
Costs involved	EURO 50000 / year
Human resource involved	4 (one operator; one data annalist; two crew members)
Data generated	Distribution plots, relative and/or total abundance; movement plots; 3D positioning; spectrograms enabling stock or population identification;
Time Frame	5 days/month. Data can cover from days to years
Examples of implementation	Stock assessment of cetaceans in Antarctica, Europe and America. Ecology and behaviour studies by several research teams.
Points FOR	Highly effective with relatively low costs.
Points AGAINST	Not known
Appraisals	
Literature	Buckland, S. T. (1996) The potential role of acoustic surveys in estimating the abundance of cetacean populations. In: *Reports of the Cetacean Acoustic Assessment Workshop, 1996, Hobart, Tasmania.*.Thomas, J. A., Fisher, S. R., Ferm, L. M., Holt, R. S. (1986) Acoustic detection of cetaceans using a towed array of hydrophones. *Report of the International Whaling Commission* (special issue 8), 139-148. Pavan, G. Borsani, J. F. (1997) Bioacoustic research on cetaceans in the Mediterranean Sea. *Maine and Freshwater Behaviour and Physiology*, 30, 99-123. Gordon, J., Gillespie, D., Chappell, O., Hiby, L. (1998) Potential uses of automated passive acoustic techniques to determine porpoise distribution and abundance in the Baltic Sea. In: *5th meeting of the Advisory Committee of ASCOBANS, Hel, Poland.* Evans, P. G., Raga, J. A. *eds.* (2001) *Marine Mammals Biology and Conservation.*. Kluwer Academic/Plenum Publishers, London, 630 pp.
Remarks	
State of validation	★★★★
Recommendation	★★★★

Tool Class	**Method**
Tool Type	**Remote observation**
Name	**Assessment of fish using echo sounding**
Summary	Echo sounding / Echo integration has been used as a tool for unselectively and remotely sample a large fraction of aquatic ecosystems. In fisheries it as been mostly used for studies of abundance/density, spatial distribution and behaviour of selected pelagic finfish species. It is one of the few techniques that is able to perform direct observation and quantitative measurements on fish *in situ*..
Geographic Scale	Regional
Targets	Usually pelagic species, up to 500m depths, but it can go deeper using lowered transducer methods
Conditions needed for application	For stock assessment it is required knowledge of the target strength to length relationship and adequate capability of biological sampling. Relatively calm sea-state. Operation under relatively bad weather conditions, or for looking at greater depths, require a towed body.
Material requested	Echo sounder, echo integrator, towed body, software for signal acquisition/processing and adequate biological sampling gears
Data needed	
Assessment of likely data availability	
Costs involved	5000 € / year
Human resource involved	4 (1 sonar operator, 1 data annalist, 2 crew)
Data generated	The typical output consists in echograms that can be analysed visually or processed
Time Frame	Hours
Examples of implementation	See above. Used for the stock assessment of several exploited finfish species in the Atlantic (e.g. herring, capelin, blue whiting, sardine, pollock, redfish, etc.) and in the Pacific
Points FOR	Quick covering/monitoring of large areas
Points AGAINST	Several sources of uncertainty related with the Target Strength values *in situ* and with fish behaviour
Appraisals	
Literature	Anonymous - ICES Fisheries Technology Committee, reports of the Working Group on Fisheries Acoustics Science and Technology.Johannesson, K. A. and R. B. Mitson (1983) – Fisheries acoustics: a practical manual for aquatic biomass estimation. FAO Fish. Tech. Pap., (240):249p.
Remarks	
State of validation	★★★★
Recommendation	★★★

Tool Class	**Method**
Tool Type	**Remote observation**
Name	**Assessment of mammals using echo sounding**
Summary	Echo sounding has been used to study behavior of marine mammals by some authors. Tracking of dives using sonars has been used to study the diving behaviour of individuals, for some species of odontocete and mysticete whales. Zimmer and others have used passive sonar to determine the diving behavior of a sperm whale (*Physeter macrocephalus*). Two sperm whales tagged with acoustic transponder tags were tracked by sonar by Watkins and others and Hooker calculated the maximum depth of diving of bottlenose whales in the Gully using both attached time-depth recorder/VHF radio tags and sonar. Ridoux and others tested the use of a multibeam sonar for fine-scale studies of the foraging activity of bottlenose dolphins. Echo sounding can also be used to study associations between cetaceans and fishes, giving indirect data on possible prey.
Geographic Scale	Pan-european
Targets	Cetacean diving behaviour
Conditions needed for application	Calm sea
Material requested	Echo sounder and boat
Data needed	
Assessment of likely data availability	
Costs involved	5000 EUR / year
Human resource involved	4 (1 sonar operator, 1 data annalist, 2 crew)
Data generated	Graphics of time-depth dives of cetaceans, as well as association with fish schools.
Time Frame	Hours
Examples of implementation	As explained above
Points FOR	The use of tags to study diving behaviour of cetaceans is effective but very expensive, thus making that most works are done with few animals. Sonar technology is cheaper, being possible the use of the same equipment with unlimited number of animals and time. On the other hand, tags do not give information on the presence of other organisms, like possible preys or individuals of the same species, which is possible to obtain with sonar.
Points AGAINST	**Most Highly Negative Effects:** Cetaceans are heavily dependent on sound and depending on the frequency and/or energies used the behaviour of the subjects may be changed. **High energies at given frequencies are believed to cause acoustic trauma in some cetacean species.**
Appraisals	
Literature	Hooker, Sascha K. Resource and habitat use of northern bottlenose whales in the Gully: ecology, diving and ranging behaviour [Ph.D. dissertation]. Halifax, Nova Scotia: Dalhousie University; 1999, 211 pp. Ridoux, Vincent; Guinet, Christophe; Liret, Céline; Creton, Pol; Steenstrup, Resen, and Beauplet, Gwenaël. A video sonar as a new tool to study marine mammals in the wild: measurements of dolphin swimming speed. Marine Mammal Science. 1997; 13(2):196-206. ISSN: 0824-0469. Watkins, William A.; Daher, Mary Ann; Fristrup, Kurt M.; Howald, Terrance J., and di Sciara, Giuseppe Notarbartolo. Sperm whales tagged with transponders and tracked underwater by sonar. Marine Mammal Science. 1993; 9(1):55-67. ISSN: 0824-0469.
Remarks	
State of validation	★★
Recommendation	★

Tool Class	**Method**
Tool Type	**Biodiversity**
Name	**Soft-bottom macrobenthic fauna: sampling and sample processing**
Summary	Soft bottom sediments sampled using standard methods and sampling areas. Fauna captured is identified, either quantitatively (all individuals in all taxa counted) or semi-quantitatively (all or selected taxa identified and relative abundances e.g. on 4-point scale). Resulting faunal lists analysed in terms of distribution, abundances, diversity patterns etc. and interpreted using expert knowledge of what the observed patterns tell about the environment. Can be done statistically or intuitively, depending on objectives.
Geographic Scale	Sample to Region
Targets	Standardised sampling and sample processing provides the data needed for further benthic faunal analyses or ATBI. Target: research and environmental management.
Data needed	Station positions and taxon inventories if previous survey carried out in area. Not needed for "first-time" investigations.
Assessment of likely data availability	Possible existing data from previous surveys.
Costs involved	Cheap to expensive, depending on level of detail required.
Human resource required	Needs benthic faunal expert to make identifications and assessments. Skills easily taught at low level of resolution, increasing skills required with increasing taxonomic resolution.
Data generated	Inventory (quantitative or semi-quantitative eg. abundance classes) of all or selected benthic fauna in samples, at chosen level of detail.
Time Frame	Fast (same-day results) to labour intensive (weeks) depending on level of detail.
Examples of implementation	Widely implemented in Norway for aquaculture impact monitoring, also municipal effluents etc. Over a set "threshold" level of impact, a fully quantitative survey is required by the authorities.
Points FOR	Sensitive method for biodiversity research and management; large variety of uses for environmental status assessment and long-term monitoring. Produces valuable specimen collections for taxonomic research (depending on financial scope and priorities).
Points AGAINST	Integration of data sets produced by different institutes depends on standardised methodology being used. Identifications need standardised by ring testing; not all countries participate in this.
Appraisals	Method is applicable from shallow waters to deep sea; limiting factor is equipment.
Literature	ISO 16665 (TC 147/SC5/WG11, currently DIS, final release 2003). Also technical and scientific references therein
Remarks	Method is dependent on standardised methodology; applies both to quantitative and semi-quantitative approaches. Among the earliest European soft-bottom macrofaunal studies are Petersen (1914). Utility of the method as a tool outlined in Pearson & Rosenberg (1978), validated and refined in numerous publications since then.
State of validation	★★★★
Recommendation	★★★

Tool Class	**Method**
Tool Type	**Biodiversity**
Name	**Hard-bottom benthic fauna: sampling and sample processing**
Summary	Hard bottom organisms either sampled by destructive methods (suction sampling or scraping) or non-destructively assessed by still or video photography or diver censes (transect or fixed stations). Sampled organisms processed as for soft-bottom. Images quantified as far as possible (organisms identified and % area covered analysed, often via. digital recognition). Resulting faunal lists analysed in terms of distribution, abundances, diversity patterns etc. and interpreted using expert knowledge of what the observed patterns tell about the environment.
Geographic Scale	Sample to Region
Targets	Environmental management, biodiversity status assessment and mapping, also data input for taxonomic distinctness method.
Data needed	Station positions and taxon inventories if previous survey carried out in area. Photographic material and census data.
Assessment of likely data availability	Possible existing data from previous surveys.
Costs involved	Cheap to expensive, depending on level of detail required and method in use. Main costs in diver and equipment fees. Analysis of photographic material is usually cheaper than analysis of samples taken by quadrate sampling
Human resource required	Needs benthic faunal expert to make identifications and assessments. Skills easily taught at low level of resolution, increasing skills required with increasing taxonomic resolution. 3 divers with required certificates or remote equipment with operator is needed as a minimum.
Data generated	Semi-quantitative or qualitative list of in-situ determined benthic taxa. Also relative abundance (eg. on 4-point scale). If quadrate sampling quantitative analysis is possible.
Time Frame	Fast for general lists, longer time scale for digital work or sample identification in the laboratory.
Examples of implementation	Sampling and analyses on rocky shores, underwater slopes or vertical cliffs (transect along faunal succession gradients). Used for mapping and detection of change. Implemented in Norway for municipal and industrial effluents etc. (in combination with soft bottom macrobenthic fauna analyses).
Points FOR	Quick, "photogenic" (eg organisms often highly visible). Method for biodiversity research and management; used for environmental status assessment and long-term monitoring. Produces valuable specimen collections for taxonomic research (from destructive samples).
Points AGAINST	Limited by diving resources or availability of remote equipment. Ring testing and standardisation of methods should be done.
Appraisals	Method covers only top-layer organisms and if photographic method or diver census is used it is limited to those species that are easily visible. Details depend widely on quality of equipment (photographic resolution etc.) or expertise of personnel (the latter counts also for destructive sampling).
Literature	NS 9424, 2002 (going to be published in English in the near future); JNCC Marine Monitoring Handbook, 2001
Remarks	Method is dependent on standardised methodology; applies both to quantitative and semi-quantitative approaches.
State of validation	★★★★
Recommendation	★★★

Tool Class	**Method**
Tool Type	**Biodiversity**
Name	**Epibenthic sampling using dredges or trawls**
Summary	Epibenthic organisms are collected by a trawl or dredge. Data are recorded for a standard distance over the seabed.
Geographic Scale	Local to region
Targets	Comparison of spatial and temporal changes in diversity
Data needed	Simple quantitative species lists
Assessment of likely data availability	Detailed studies have been made in Westerschelde estuary by Ghent University and NIOO-CEME
Costs involved	Costs of ships and gear
Human resource required	Several fte per location
Data generated	Relationships of (functional) groups and taxa of epibenthos. Changes reflect impact of salinity and temperature
Time Frame	Days to months
Examples of implementation	Westerschelde , Scottish and Belgian coast
Points FOR	Easy to handle; link with fish research
Points AGAINST	Cost intensive
Appraisals	
Literature	Attrill & Thomas 1996. Long term distribution patterns of mobile estuarine invertebrates in relation to hydrological parameters. MEPS 143 : 25-36. Holme & MacIntyre. Beijst et al 2002. Factors influencing the spatial variation in fish and macrocrustacean communities in the surf zone of sandy beaches in Belgium. JMBA 82 : 181-187. Gibson et al 1993. Seasonal and annual variations in abundance and species composition of fish and macrocrustacean communities on a Scottisch sandy beach. MEPS 98 :89-105. Oyugi 1999. Diversity, abundance and community structure of benthic ichthyofauna and crustaceans in the North Sea. MSc thesis, University Hent.
Remarks	
State of validation	
Recommendation	

Biotic indicators of environment state

Legend used for the indicators

State of validation	Not validated ★	Rarely validated ★★	Needs more ★★★	Validated ★★★★
Recommendation	Not recommended ★	Limited ★★	Usable with care ★★★	Recommended ★★★★

Tool Class	**Bioindicator**
Tool Type	**Environmental state**
Name	**The log normal distribution**
Summary	Unimpacted communities have a log normal distribution of the numbers of individuals among species, so that cumulative percentage of species abundance on a probability scale plotted against geometric abundance classes produces a linear plot. Deviation from this in the form of a break or breaks in the line is considered to characterise perturbation.
Geographic Scale	Local
Targets	Local environmental impact assessment.
Data needed	Accurate quantitative data (abundances) on all species in the assemblage.
Assessment of likely data availability	A lot of data available in environmental impact reports ('grey' literature).
Costs involved	Labour intensive, requiring high taxonomic skills. Therefore relatively expensive
Human resource required	Extensive
Data generated	Data generated are real, but the model with which they are compared is hypothetical.
Time Frame	Takes a long time to get the necessary data (sample sorting labour- intensive).
Examples of implementation	Most applications are for macrobenthos of soft sediments.
Points FOR	Simple in concept. No sophisticated computing involved.
Points AGAINST	Undisturbed benthic communities not observed to be obviously log normal. Subjective methods used to discriminate between linear and non-linear plots. May only be applicable to organic enrichment, not for example effects of toxic metals.
Appraisals	
Literature	For review of arguments for and against see review in: Warwick, R.M. 1993. Environmental impact studies on marine communities: pragmatical considerations. Aust J. Ecol. 18: 63-80. Gray, J.S. 1981. Detecting pollution induced changes in communities using the log-normal distribution of individuals among species. Mar. Poll. Bull. 12: 173-176.
Remarks	Not appropriate for heterogeneous assemblages without further validation. Has been used for soft bottom benthos.
State of validation	★★★★
Recommendation	★★

Tool Class	Bioindicator
Tool Type	Environmental state
Name	**Caswell's neutral model**
Summary	Observed Shannon diversity (H') is compared with the theoretical diversity (EH') for a sample with the same number of species and individuals, assuming certain assembly rules (random births, deaths, immigrations, emigrations) and the absence in interactions between species. A deviation statistic V is calculated by subtracting EH' from H' and dividing by the standard error of EH'. When V=0 the sample is considered to be derived from a neutral assemblage. When V is negative this implies excessive dominance, which is likely to result from perturbations of various kinds.
Geographic Scale	Local
Targets	Local environmental impact assessment.
Data needed	Accurate quantitative data (abundances) on all species in the assemblage.
Assessment of likely data availability	A lot of data available in environmental impact reports ('grey' literature).
Costs involved	Labour intensive, requiring high taxonomic skills. Therefore relatively expensive.
Human resource required	Extensive
Data generated	Data generated are real, but the model with which they are compared is hypothetical
Time Frame	Takes a long time to get the necessary data (sample sorting labour- intensive).
Examples of implementation	Most applications are for macrobenthos of soft sediments or free living marine nematode assemblages. Implemented in the PRIMER software package
Points FOR	Simple in concept. No sophisticated computing involved.
Points AGAINST	Only influenced by evenness component of diversity (not species richness).
Appraisals	Performance not well tested (performed badly on a well defined pollution gradient, see Warwick, R.M. 1993. Environmental impact studies on marine communities: pragmatical considerations. Aust J. Ecol. 18: 63-80.).
Literature	The computer program by Goldman & Lambshead is useful: Goldman, N. & Lambshead, P.J.D. 1989. Optimization of the Ewens/Caswell neutral model program for community diversity analysis. Mar. Ecol. Prog. Ser. 50: 255-261. Caswell, H. 1976. Community structure: a neutral model analysis. Ecol. Monogr. 46: 327-354
Remarks	Not appropriate for heterogeneous assemblages without further validation. Has been used for soft bottom benthos.
State of validation	
Recommendation	

Tool Class	**Bioindicator**
Tool Type	**Environmental state**
Name	**Coefficient of pollution**
Summary	Empirical relationships are established between the number of individuals and species and the variables of water depth and sediment granulometry in unpolluted macrobenthic communities, which is described by a single index. The index is calculated from a series of empirically derived integrated equations and makes a comparison of the observed numbers of individuals and species present with the theoretical prediction for a given sediment type and water depth.
Geographic Scale	Local
Targets	Local environmental impact assessment.
Data needed	Accurate quantitative data (abundances) on all species in the assemblage.
Assessment of likely data availability	A lot of data available in environmental impact reports ('grey' literature).
Costs involved	Labour intensive, requiring high taxonomic skills. Therefore relatively expensive.
Human resource required	Extensive
Data generated	Data generated are real, but the model with which they are compared is empirically derived for a specific region.
Time Frame	Takes a long time to get the necessary data (sample sorting labour-intensive).
Examples of implementation	Soft sediment macrobenthos only.
Points FOR	Simple in concept. No sophisticated computing involved.
Points AGAINST	New equations should be derived for each region under study: empirical relationships derived for the Mediterranean will not have global applicability.
Appraisals	Performed badly on a well defined pollution gradient, see Warwick, R.M. 1993. Environmental impact studies on marine communities: pragmatical considerations. Aust J. Ecol. 18: 63-80.
Literature	References to both the Mediterranean and Californian studies can be found in the above paper. Satsmadjis, J. 1982. Analysis of benthic data and the measurement of pollution. Rev. Int. Oceanogr. Med. 66-67: 103-107
Remarks	
State of validation	
Recommendation	

Tool Class

Bioindicator

Tool Type

Environmental state

Name

Ratios between pollution sensitive and pollution insensitive taxa

Summary

Simple ratios are established between taxa regarded as pollution sensitive and those considered insensitive. Examples include the infaunal trophic index of Word (1979) for macrobenthic trophic groups, the ratio between sensitive and insensitive polychaete species of Bellan (1979) and the nematode/copepod ratio of Raffaelli & Mason (1981).

Geographic Scale

Sample to Region

Targets

Environmental impact assessment.

Data needed

Varies depending on taxa used, but samples could be analysed at a very coarse level of taxonomic discrimination e.g. divided into trophic groups, or identified to higher taxon (nematodes and copepods).

Assessment of likely data availability

A lot of data available in environmental impact reports ('grey' literature).

Costs involved

Relatively cheap

Human resource required

Low

Data generated

Real

Time Frame

Fast (sample sorting not labour-intensive).

Examples of implementation

Cortiou, Golfe de Fos, Vieux Port of Marseille, France

Points FOR

Simple in concept. No sophisticated computing involved.

Points AGAINST

All methods suffer from difficulties of interpretation. We don't know what the ratios should be for unperturbed communities, at least not outside the immediate geographical area and environmental conditions for which the training data were obtained. The infaunal trophic index is strongly modified by changes in current speed/sediment type and water depth, the polychaete species identified by Bellan as pollution indicators have a restricted distribution, and the nematode/copepod ratio behaves unpredictably with different kinds of pollution.

Appraisals

Literature

Bellan, G. 1979. Annelides polychetes des substrats solides de trois millieux pollues sur la cotes de provencce (France): Cortiou, Golfe de Fos, Vieux Port de Marseille. Tethys 9: 267-277. Raffaelli, D.G. & Mason, C.F. 1981. Pollution monitoring with the meiofauna, usiong the ratio of nematodes to copepods. Mar. Poll. Bull. 12: 158-163. Word, J.Q. 1979. The infaunal trophic index. 5th Calif. Coast. Wat. Res. Proj. Annu. Rep., El Segundo, 19-39.

Remarks

State of validation

Recommendation

Tool Class	**Bioindicator**
Tool Type	**Environmental state**
Name	**Phylum level meta-analysis**
Summary	Phyletic composition of marine macrobenthic communities is unaffected by sediment type and water depth, but modified by perturbations of various kinds. Mutivariate analysis (non-metric MDS) of combined data from a range of impacted and non-impacted locations for the NE Atlantic shows that the long axis of the 2-dimensional configuration corresponds to the level of pollution. Combined abundance (A) and biomass (B) data are used in the form (B/A)0.73 ´ A to approximate relative production of each phylum. New data are combined with these training data and the MDS rerun; the position of the new sites in the configuration indicates the disturbance level.
Geographic Scale	Sample to Region
Targets	Environmental impact assessment.
Data needed	Both abundance and biomass data for each phylum
Assessment of likely data availability	A lot of data available in environmental impact reports, but many have abundance only (not biomass).
Costs involved	Relatively cheap
Human resource required	Low
Data generated	Real
Time Frame	Fast (sample sorting not labour-intensive since only required to phylum level).
Examples of implementation	Used in the tropics (Trinidad) and Southern Africa as well as NE Atlantic, using the same training data set.
Points FOR	Identification of organisms required to phylum level only, so skilled taxonomists not required. All types of pollution and disturbance so far tested act in the same way.
Points AGAINST	Biomass data for each phylum also required (often not available)
Appraisals	Used in the tropics (Trinidad) and Southern Africa as well as NE Atlantic, using the same training data set.
Literature	Warwick, R.M. & Clarke, K.R. 1993. Comparing the severity of disturbance: a meta-analysis of marine macrobenthic community data. Mar. Ecol. Prog. Ser. 92: 221-231..
Remarks	
State of validation	
Recommendation	

Tool Class	Bioindicator
Tool Type	Environmental state
Name	**Abundance/biomass comparison (ABC) plots**
Summary	Unperturbed communities are dominated by K-selected species with large body size and long lifespan; perturbed communities by r-selected opportunists with small body size and short lifespan. In combined plots, the k-dominance curve for biomass lies above that for abundance throughout its length in undisturbed conditions, the reverse is true for gross perturbation, and the two curves closely coincide for moderate perturbation. W-statistic (Clarke 1990) measures area between the two curves; positive value if biomass above abundance, negative if the reverse. Works at family level as well as species level of taxonomic resolution. Ref: Clarke, K.R. 1990. Comparisons of dominance curves. J. exp. Mar. Biol. Ecol. 138: 143-157.
Geographic Scale	Local
Targets	Environmental impact assessment.
Data needed	Both abundance and biomass data for each species or family.
Assessment of likely data availability	A lot of data available in environmental impact reports, but many have abundance only (not biomass).
Costs involved	Relatively cheap if family level identification applied.
Human resource required	Moderate
Data generated	Real
Time Frame	Moderate (sample sorting not so labour-intensive if identifications to family rather than species level).
Examples of implementation	Many examples for macrobenthos. Also seems to work for fish.
Points FOR	Conceptual model on which it is based depends on a number of clearly definable and testable hypotheses (See: McManus, J.W. & Pauly, D. 1990. Measuring ecological stress: variations on a theme by R.M. Warwick. Mar. Biol. 106: 305-308).
Points AGAINST	Biomass data for each species or family also required (often not available).. Settlement of large numbers of small individuals from the plankton may give false impression of disturbance (elevation of k-dominance curves over-dependent on the abundance of the first ranked species). This can be overcome by use of partial dominance curves (Clarke 1990), and intelligent biological interpretation (Warwick & Clarke 1994) Refs: Clarke, K.R. 1990. Comparisons of dominance curves. J. exp. Mar. Biol. Ecol. 138: 143-157. Warwick, R.M. and Clarke, K.R. 1994. Relearning the ABC: taxonomic changes and abundance/biomass relationships in disturbed benthic communities. Mar. Biol., 118: 739-744.
Appraisals	Many examples for macrobenthos. Also seems to work for fish.
Literature	See sections 2, 3, 14 & 15. McManus, J.W. & Pauly, D. 1990. Measuring ecological stress: variations on a theme by R.M. Warwick. Mar. Biol. 106: 305-308). Clarke, K.R. 1990. Comparisons of dominance curves. J. exp. Mar. Biol. Ecol. 138: 143-157. Warwick, R.M. & Clarke, K.R. 1994. Relearning the ABC): taxonomic changes and abundance/biomass relationships in disturbed benthic communities. Mar. Biol., 118: 739-744. Warwick, R.M. 1986. A new method for detecting pollution effects on marine macrobenthic communities. Mar. Biol. 92: 557-562. Warwick, R.M. 1986. A new method for detecting pollution effects on marine macrobenthic communities. Mar. Biol. 92: 557-562
Remarks	
State of validation	★★★★
Recommendation	★★★★

Tool Class	Bioindicator
Tool Type	Environmental state
Name	**Infaunal Trophic Index**
Summary	The ITI was developed as an aid to identify changed and degraded environmental conditions as a result of organic pollution. The index involves allocating species into one of four groups based on the type of food consumed and the origin of the food. It is based on the principle that the dominant feeding types change along a gradient of increasing organic enrichment. That is, species feeding at the interface of the sediment and water (such as suspension feeders) occur in areas of low organic enrichment whereas species, which are predominantly deposit feeders, occur in areas of high organic enrichment.
Geographic Scale	Local to regional
Targets	Environmental impact assessment.
Data needed	
Assessment of likely data availability	
Costs involved	Labour intensive, requiring high taxonomic skills. Therefore relatively expensive.
Human resource required	Low for analysis
Data generated	Index
Time Frame	
Examples of implementation	
Points FOR	The ITI was designed for use in coastal waters with organic contamination only. Relatively simple to calculate
Points AGAINST	Feeders and the low number of taxa generally prevent this being of use in transitional waters. ITI is modified strongly by changes in water depth and current speed/sediment type [Warwick, R. M. (1993) Environmental impact studies on marine communities: Pragmatical considerations. Australian Journal of Ecology 18, 63-80]Many species are not yet allocated to an ecological group.
Appraisals	Bascom, W. (1982) The effects of waste disposal on the coastal waters of southern California. Env Sci & Tec. 16, 226-236
Literature	Codling, I. D. & Ashley, S. J. (1994). Investigations into the development of a biotic index to assess the pollution status of macrobenthic communities in the marine intertidal. Final report to SNIFFER. SR 3755. WRc plc, UK. Word, J. Q. (1979) The Infaunal Trophic Index. Sth Calif. Coast. Wat. Res. Proj. Annu. Rep., El Segundo, California. 19-39. Word, J. Q. (1980) Classification of benthic invertebrates into Infaunal Trophic Index feeding groups. In: Coastal Water Research Project Biennial Report 1979-1980. SCCWRP, Long Beach, California, USA, pp 103-121
Remarks	Not fully tested but currently being evaluated in UK in relation to the Water Framework Directive. Useful in study of eutrophication gradients.
State of validation	
Recommendation	

Tool Class	Bioindicator
Tool Type	Environmental state
Name	**Biotic index & Biotic coefficient**
Summary	The index classifies species in to 5 groups according to their sensitivity to an increasing organic gradient. Index values are derived from an assessment of the relative abundance of the five groups of species aided by a distribution model.
Geographic Scale	Local to regional
Targets	Environmental impact assessment.
Data needed	Accurate quantitative data (abundance) on all species in the assemblage
Assessment of likely data availability	
Costs involved	Labour intensive, requiring high taxonomic skills. Therefore relatively expensive.
Human resource required	Low for analysis
Data generated	Index
Time Frame	
Examples of implementation	
Points FOR	Validation of the model shows different anthropogenic influences can be detected e.g. dredging, engineering works, sewerage plants and the dumping of polluted waters. It is relatively simple and can be applied to other European coastal areas. In fact many of the species found in the North Sea and the Mediterranean are included with over 900 taxa being identified.
Points AGAINST	A degree of taxonomic skill is required with the same cost implications as the univariate measures discussed previously. There is overlap in the groupings. Many species are not yet allocated to an ecological group.
Appraisals	
Literature	BORJA, A.; J. FRANCO & V. PÉREZ, 2000. A marine biotic index to establish the ecological quality of soft bottom benthos within European estuarine and coastal environments Marine Pollution Bulletin 40(12): 1100-1114
Remarks	Not fully tested but currently being evaluated in UK in relation to the Water Framework Directive.
State of validation	
Recommendation	

Biological markers

Legend used for the indicators

State of validation	Not validated ★	Rarely validated ★★	Needs more ★★★	Validated ★★★★
Recommendation	Not recommended ★	Limited ★★	Usable with care ★★★	Recommended ★★★★

Tool Class	**Biomarker**
Tool Type	**Environmental state**
Name	**Acetylcholinesterase (AChE) inhibition**
Origin	BEEP program
Summary	AChE activity is inhibited in the presence of neurotoxic chemicals. When pesticides are in combination with other chemicals such as metals (for instance copper and lindane), inhibition of AChE was observed in the clam Ruditapes decussatus (Hamza-Chaffai et al., 1998). In the same way, tests performed on the copepod Tigriopus brevicornis (Crustacea, Copepoda) showed that at the sublethal level, the presence of arsenic, copper or cadmium seemed to enhance the inhibitory effects of organophosphorous compounds and carbamates (Forget et al., 1999). In the bay of Agadir (Morocco) Najimi et al. (1997) measured AChE activity both in the African mussel Perna perna and in Mytilus galloprovincialis, AChE presented a more significant response in the polluted site (Anza) as compared to the reference site (Cap Ghir). Acetylcholinesterase activity is measured through the enzymatic reaction in the fraction obtained after centrifugation at 20.000 using acethylthiocholine iodide as substrate (Burgeot et al., 2001)
Geographic Scale	European
Targets	Neurotoxicity of common pesticides (carbamate and organosphosphorous compounds) but also of metals (Najimi et al., 1997). Marker of effect: The inhibition of AChE by neurotoxicants may have consequences on behaviours which are important in life cycles: research of food, research of sexual partner, care of young, inducing potential threat at the population level. Target species: fish, crab, annelids, bivalves
Costs involved	Low
Human resource involved	Many labs in Europe
Human resource required	Low
Points FOR	Early warning system
Points AGAINST	The link with changes in biodiversity is not direct
Appraisals	
Literature	Burgeot T., Bocquené G., His E., Vincent F., Geffard O., Beiras R., Quiniou F., Goraguer H., Galgani F. (2001) Procedures for cholinesterase determination in fish and mussel. In: Biomarkers in marine organisms: a practical approach. Garrigues Ph., Barth H., Walker C.H., Narbonne J.F., eds., Elsevier Science, Amsterdam. Technical Annex (Chapter 7).
Remarks	Subject to intercalibration exercise in BEQUALM Programme
State of validation	Only validated for environmental state.
Recommendation	

Tool Class	**Biomarker**
Tool Type	**Environmental state**
Name	**DNA adducts**
Origin	BEEP program
Summary	The DNA, a biological macromolecule that is present in all cells, is the holder of the genetic patrimony. Its structure is complex and may be modified by both physical and chemical agents known as "genotoxic". Due to its functional role, the DNA integrity is indispensable to the survival of cells and organisms. Genotoxic disturbances in germinal cells are particularly important due to the transferability of such new characteristics to the progeny. Some of them, particularly if they are limited to a small fraction of the population, may be rapidly eliminated due to embryo mortality, whereas neutral genetic changes can be perennialized, inducing changes in the relationships which other species in the community (Rether et al., 1997).
Geographic Scale	European
Targets	Marker of effect. Index of genotoxic effects, Predictor of pathology. Target species: fish, crab, bivalves
Costs involved	High
Human resource involved	Many labs in Europe
Human resource required	Good skill
Points FOR	Early warning system
Points AGAINST	DNA repair can intervene as well as ecological compensation
Appraisals	
Literature	Venier P. (2001) Detection of bulky aromatic DNA adducts by ^{32}P-postlabelling. In: Biomarkers in marine organisms: a practical approach. Garrigues Ph., Barth H., Walker C.H., Narbonne J.F., eds., Elsevier Science, Amsterdam. Technical Annex (Chapter 4).
Remarks	Subject to intercalibration exercise in BEQUALM Programme
State of validation	★ Only validated for environmental state.
Recommendation	★★

Tool Class	**Biological marker**
Tool Type	**Environmental state**
Name	**Endocrine disruption: Imposex in gastropods, Intersex in crustaceans, Histology of gonads**
Origin	BEEP program
Summary	In the past few years, numerous effects of endocrine disrupting chemicals on wildlife have emerged including changes in the sex of fishes, reproductive failure in birds and abnormalities in the reproductive organs of reptiles and mammals (Depledge et al. 1999). Examples of endocrine disruption in marine invertebrates have also been found, including imposex in gastropods exposed to organotin compounds, and intersex in crustaceans and fish particularly when they are exposed to sewage discharges. Numerous observations have been reported in european coastal areas. In the Fal estuary (Cornwall, UK) where the incidence of imposex in the dogwhelk *Nucella lapillus* was nearly 100%, populations have declined dramatically (Bryan et al., 1987).
Geographic Scale	European
Targets	Marker of effect: Reproduction disturbances. Target species: gasteropods, crustaceans, fish
Costs involved	Low
Human resource involved	Many labs in Europe
Human resource required	Medium
Points FOR	Strong link with potential changes in biodiversity
Points AGAINST	Not a real early warning system
Appraisals	
Literature	Depledge, M. H., Billinghurst, Z. (1999) Ecological Significance of Endocrine Disruption in Marine Invertebrates, Marine Pollution Bulletin, Volume 39, Issues 1-9, January 1999, Pages 32-38. Bryan GW, Gibbs PE, Hummerstone LG, Burt GR (1987) Copper, zinc and organotin as long-term factors governing the distribution of organisms in the Fal estuary, Estuaries, Volume 10, Pages 208-219
Remarks	imposex on gasteropods: Subject to intercalibration exercise in BEQUALM Programme
State of validation	Only validated for environmental state.
Recommendation	

Tool Class	**Biological marker**
Tool Type	**Environmental state**
Name	**Embryo sex ratio**
Origin	BEEP program
Summary	Disturbances registered at this level are considered as a warning system for highly probable failure in re-production on the medium- term
Geographic Scale	North Atlantic and Baltic Sea
Targets	Marker of effect: Embryo development and survival in eelpout viviparous fish. Target species: Fish (*Zoarces viviparus*, eelpout)
Costs involved	Low
Human resource involved	
Human resource required	Low
Points FOR	Strong link with potential changes in biodiversity
Points AGAINST	Not a real early warning system
Appraisals	
Literature	
Remarks	Subject to intercalibration exercise in BEQUALM Programme
Choice	
State of validation	★ Only validated for environmental state.
Recommendation	★★

Tool Class	**Biological marker**
Tool Type	**Environmental state**
Name	**Reproductive success**
Origin	BEEP program
Summary	The reproductive success may be affected by a wide range of chemicals. It affects directly the ability of a population to be present or not in a more or less impacted environment.
Geographic Scale	North Atlantic and Baltic Sea
Targets	Marker of effect: Measures reproductive output and survival of eggs and fry in relation to contaminants. Target species: Fish
Costs involved	Low
Human resource involved	
Human resource required	Low
Points FOR	Strong link with potential changes in biodiversity
Points AGAINST	Not a real early warning system
Appraisals	
Literature	
Remarks	
Choice	
State of validation	Only validated for environmental state
Recommendation	

WP2 tool list

Tool Class	Tool type	Name	Page
Bioindicator	Biodiversity measure	Taxonomic distinctness	27
Bioindicator	Biodiversity measure	Fish Indices	28
Bioindicator	Biodiversity measure	Phylogenetic structure	29
Bioindicator	Biodiversity measure	Number of Species	30
Bioindicator	Biodiversity measure	Higher taxonomic diversity	31
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Bioindicator	Biodiversity measure	Death assemblages	33
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Bioindicator	Biodiversity measure	Selected higher taxon or taxa.	35
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Method	Biodiversity measure	Soft-bottom macrobenthic fauna: sampling and sample processing	51
Method	Biodiversity measure	Hard-bottom benthic fauna: sampling and sample processing	52
Method	Biodiversity measure	Epibenthic sampling using dredges or trawls	53
Bioindicator	Environmental state	The log normal distribution	57
Bioindicator	Environmental state	Caswell's neutral model	58
Bioindicator	Environmental state	Coefficient of pollution	59
Bioindicator	Environmental state	Ratios between pollution sensitive and pollution insensitive taxa.	60
Bioindicator	Environmental state	Phylum level meta-analysis	61
Bioindicator	Environmental state	Abundance/biomass comparison (ABC) plots	62
Bioindicator	Environmental state	Infaunal Trophic Index (ITI)	63
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Biomarker	Environmental state	Acetylcholinesterase (AChE) inhibition	67
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Method	Remote observation	Aerial photography	41
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Method	Remote observation	Acoustic ground discrimination systems (RoxAnn, QTC, Echoplus)	44
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Method	Remote observation	Assessment of cetaceans using hydrophones	48
Method	Remote observation	Assessment of fish using echo sounding	49
Method	Remote observation	Assessment of mammals using echo sounding	50

Using species as indicators of biodiversity

The very concept of single species as indicator of biodiversity was the object of very significant debates in the community of BIOMARE.These debates are still not finished. It is very difficult to find species that are able to be state indicators of biodiversity or of its evolution (increase, stationary state or decrease or loss). There is indeed no current work that unequivocally allows us to choose a species for which the presence, the absence or the variation of abundance represents fluctuations of the whole diversity at a given place, and consequently can be used as a biodiversity indicator. Another difficulty is that such a species must be easily and reliably recognizable, without the expert assistance of a specialist, a concept that is not always understood by such specialists. These are the reasons why the following suggested choice is certainly not a final list. It is more the current inventory. Except for the categories "habitat builders", certain " keystone species" and certain "invasive species", it is clear that this list will need to be modified by additions and perhaps by deletions. Moreover, a number of taxa were not definitively recommended, but proposed to be tested and it is thus not sure that they will remain. Certain species were not included because of their redundancy or by the lack of published or otherwise contributed information. The choice was also to invasive species. The objective of BIOMARE was not to make a list of these species[13], but to choose those taxa that were considered to pose the most significant threat to biodiversity bearing in mind that only a minimum of information has been provided to us.

These species, like the indicators described previously, will be accessible in a data base published on Internet and managed by MARS. This base is conceived as a dynamic tool and it will be updated as information arriving to *indicators@biomareweb.org* is evaluated by the MARS scientific committee or an *ad hoc* committee to be created

For a species to be considered as an indicator, there has to be a correlation between its occurrence and the diversity of the various taxa present. We presently know that this correlation may be very low for modifications to biodiversity resulting from natural disturbance or anthropogenic stress. It is thus obvious that if research has to focus on indicator taxa, it is essential to consider the associated ecological processes in order to establish the theoretical principles underlying the correlation correlation between diversity and the indicator taxon. Moreover, indicator species are present in the environment even when the conditions they are thought to indicate are absent (or not yet present), so one must always go further than a simple presence/absence information. Another point is that the abundance of a species may not be the result of a single factor but of many, giving rise to a general problem of interpretation and research into the origin of the disturbance. It is thus **necessary to be able to experimentally manipulate diversity**. It is also important to emphasise on the fact that certain species thought to be indicators have been shown to be complexes of species. Depending on the target of the indicator, this may necessitate a local calibration because of the possible existence of non-homogeneous physiologies in different species. Therefore, the unique way is to standardise protocols and intercalibrate methods. No indicator by itself can allow biodiversity to be reported, a *fortiori* changes in biodiversity. Anyone indicator can give an incorrect response at one certain moment, but all the indicators of a correctly chosen “multi-indicator grid” cannot be wrong together. The setting up of a set of indicators that are pertinent from a scientific and political point of view, and are in harmony at international level, is thus an important stake to be able to measure in the best possible way the progress of societies along the road to sustainable development.

The presence and good health of a certain number of species, and therefore biodiversity, in a given site depends on:

1. availability of habitat and reproduction sites,
2. availability of food or energy,
3. available niche in an ecosystem,
4. the state of the environment.

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[13] A number of articles, reviews and books have been written on marine bioinvasions. There are also quite an important numbers of web sites dedicated to this field. Among them, we suggest:
Leppäkoski, Erkki, Stephan Gollasch and Sergej Olenin (eds). *Aquatic Invasive Species of Europe - Distribution, Impacts and Management.* Kluwer Academic Publishers, Dordrecht, Boston, London, 2002.
Mediterranean: http://www.ciesm.org/atlas/
British Isles: http://www.jncc.gov.uk/marine/non_native/default.htm
Baltic Sea: http://www.ku.lt/nemo/mainnemo.htm

In consequence, species that are habitat structuring species, keystone species, invasive species and species closely related to the environmental state, may give important information on the evolution of biodiversity. This type of indicator is to be considered on a rather short-term survey.

A species rarely covers a very large scale (European). However, the survey of species having the same status in ecosystem functioning, or species of the same genus, may reflect an identical trend of biodiversity evolution. However, this implies a survey of identical parameters and the use of the same methods on different species. This stresses the importance of inter-calibration of sampling and analysis methods.

It must be kept in mind that it is not a single European species to survey, but potentially a group of species that can give information on the biodiversity of a region. The common results of regional trends may give an indication on global changes affecting the European coastal area. Therefore the listed species are classified by functional status. Because of the research necessary to validate a species as a biodiversity indicator, there are only a few that are effectively used as such with a precise protocol. Nevertheless, the institutes that participated to BIOMARE propose some species as bioindicators (those that seem closely related to biodiversity) to be tested (and possibly validated) in future networks. Because of the diversity (geographically, physically, and by the level of human impact) of the BIOMARE sites, these are ideal to validate bioindicators.

The species adopted as [potential] biodiversity indicators by BIOMARE have been classified as shown in the next table:

Concerns	Features	Validation
Species that are habitats	• Keystone[14] habitat builders	Good but need more
Species that are essential in a community or an ecosystem by their functional importance (other than habitat builders)	• Other keystone[14] species: o Trophic role o Are part of a habitat o Engineer species	Good but need more
Species which dynamics is often not well known in a specific environment	• Invasive species[15]	Need more
Species which dynamics may rapidly change in a specific site or region	• Geographically range changing species • Pioneer species	Rarely or never validated
Species endangered because of their limited distribution or number, or species under direct mankind impact. These are often species under protection.	• Charismatic / Patrimonial • Commercial • Endemic • Rare	Rarely or never validated

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[14] species whose removal from an ecosystem would result in significant changes in the frequencies or interactions of the remaining species (EPBRS suggested definition)

[15] **Invasion** (= biological invasion): the event in which a population is moved beyond its natural range or natural zone of potential dispersal through human-mediated transport. Invasions are distinct from colonisations, which are often viewed as natural range expansions.
Invasive species: a species that contains populations that invade. Invasive species typically refer to introduced species that cause **negative impacts** on the environment, human activities, or human health. Among species that are introduced, only a very a small proportion become established and then invasive.
Eunmi Lee C. 2002 Evolutionary genetics of invasive species. TREE 17: 386-391

Tracing the history of introduced species using molecular techniques can help to identify the source of an invasion, which, in turn, can aid predictions about the impacts of the invasion, the prevention of further invasions, as well as permitting the estimation of the size of the founding population and providing information about post-invasion population dynamics.
Grosholz E. 2002 Ecological and evolutionary consequences of coastal invasions. TREE 17: 22-27

Keystone habitat builders

Why?	Their evolution will change a habitat on which a lot of species (some tens or hundreds) depend. The morphology of a site can change by the local disappearance of these species. This may induce changes in physical parameters (such as hydrology) and therefore in the environment of a site. Decrease of such structuring species leads directly to a decrease of biodiversity. Habitat biodiversity is directly implied. Structuring species are probably the most advanced and generalized species bioindicators in terms of methodology.
Which are they?	Species that are a habitat in themselves (mainly phanerogames and macroalgae).
What should be monitored?	Dynamics of the population at the scale of the site and region (health, reproduction or expansion rate, bathymetric distribution). Genetic parameters. Evolution in time and in space.
Where?	In protected unimpacted sites in order to have a reference state (evolution in space) and survey effects of global change. In sites impacted by a specific stressor(s). Along a salinity or temperature gradient. At the limits of distribution area of chosen species. In transitional zones.
Economic importance	Protection of beaches against wave action, commercial species habitat or nurseries.

Other keystone species

Why?	Biodiversity depends on functional systems that may be modified by changes in the population of one or a group of key-species. These species being tightly linked to a good development of an ecosystem, their survey will give indications on the state and evolution of biodiversity.
Which are they?	Species with a functional importance. These species have a major role in the proper functioning of a given ecosystem (major impact on community metabolic processes such as e.g. primary production, remineralisation, bioturbation, predation) or habitat (demersed part of a species or erected species). Species that participate in equilibrium of a habitat mainly those that can modify the substrate (engineer species). Pelagic species that are the functional link between benthic and pelagic systems: key zooplankton grazers that provide trophic links to pelagic fishes and act as gateways for the faecal export of organic matter to the ocean floor, phytoplankton that is the origin of massive amount of vegetal matter which fuels benthic productivity
What should be monitored?	Exact function of the species and links existing in the ecosystem especially if the environmental parameters change. Dynamics of the population. Possible modelling could perhaps be used.
Where?	In protected unimpacted sites in order to have a reference state and survey the impact of Global change. In impacted sites where there is already a strategy of survey of the species. In sites where biodiversity is especially fragile. In transitional zones.
Economic importance	They have an obvious economic importance but that is still to be evaluated

Invasive species

Why?	Invasive species evolve in an environment that is not their original one. Therefore they are intrusive in an ecosystem where they are going to take a place that is or is not occupied. There will either be a replacement (partial or complete) of a species or a new species in a functional system. The dynamics and impact of this new species in the ecosystem is often unpredictable and may be disastrous. The population dynamics of certain invasive species are actually known to be a threat to local biodiversity. Others must be surveyed because they might become a threat to biodiversity.
Which are they?	Species introduced by different ways (ballast water, fouling, boats, escapees from aquaculture, etc.).
What should be monitored?	Geographic evolution. Dynamics of the species (reproduction or expansion rate). Genetics and molecular indicators.
Where?	Not all sites are strategic to survey invasive species. Two cases: A species well known and already installed in a region has to be followed in the impacted sites and the limits of distribution of the species. For the other species strategic sites such as transitional zones, big harbours and areas where aquaculture is important must be surveyed.
Economic importance	The impact of such species may be of great economical importance either positive or negative.

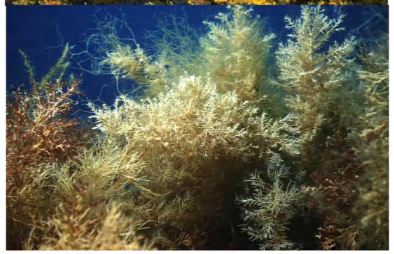
Range changing species

Why?	The environmental conditions at the limit of distribution of a species may changes (temperature, salinity) and become favourable or not to the species. In consequence, the area of distribution expands or diminishes. Environmental conditions may change in part of the area of distribution of a species and create conditions where the species may proliferate to the detriment of others. This concerns all species of a given area. However, only species whose distribution range do not cover the totality of the considered area may be useful as indicators.
Which are they?	These species are expansive in space or in number. They are: • geographically range changing species • pioneers species.
What should be monitored?	Variations of the limit of distribution and dynamics of geographically range changing species. Abundance and dynamics of the populations of pioneers (may be linked to pollution events).
Where?	At the limits of distribution for the range changing species. In sites impacted by organic matter or pollutant(s). Along a gradient (salinity, temperature)
Economic importance	Potentially important e.g. if these species become invaders

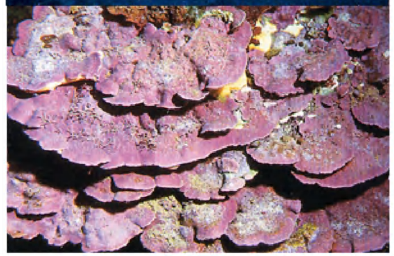
Other possible species indicators

Why?	Biodiversity does not generally depend on these species. But these species that are often endangered because of their limited distribution or number may give a good image of future evolution in time of biodiversity in a given site. Some may be endangered either because their habitat is disappearing or because environmental conditions are changing. A species may become rare in a certain habitat only. They are also a good indicator (charismatic, rare and endemic) of the efficiency of protective measures (response indicator). They are often directly or indirectly under exploitation and fishing pressure. These species may have a tourist importance and commercial species have of course an economical importance.
Which are they?	They are: 1. charismatic / patrimonial (social and cultural value) 2. commercial 3. endemic 4. rare They are generally species limited to a site or a region.
What should be monitored?	Mainly abundance in all areas covered by these species and recolonization (population dynamics) in protected areas. The causes of the limited population of these species.
Where?	In all BIOMARE sites covered by these species.
Economic importance	These species often have an emblematic importance except for the commercial species. The latter are of great economical importance in certain countries or regions.

Species indicators: keystone habitat builders

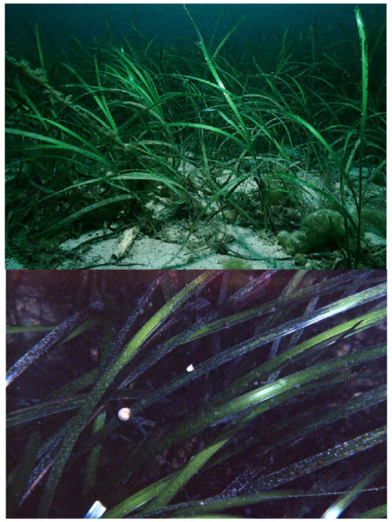


Phylum/Class	*Fucophyceae*	Fucophyceae
Genus	*Cystoseira*	*Fucus*
Species	***C. mediterranea, C. amentacea, C. tamariscifolia complexe***.	***Fucus* spp**
State of validation	Validated	To be tested
Photo legend / credit	Top: Photo: J. Templado Bottom: P. Francour/LEML	*Fucus vesiculosus*, Photo : N. Nappu Fucus serratus, Photo: C. Emblow/EcoServe
Feature 1	Keystone: Habitat builder	Keystone: Habitat builder
Feature 2	Range changing	
Stressor 1	Littoral management & OM enrichment, eutrophication & Contaminants	Various stressors
Stressor 2	Temperature change	
Habitat	Hard substrate littoral & subtidal	Hard substrate littoral & subtidal
Geographic distri-bution	Mediterranean & Atlantic	Europe
Shallowest depth	0	0
Deepest depth	-1	-20
Institute using this species	IMEDEA, COM	AWI , IOPAS , IECS and GEMEL , RUG-SMB
Life span	50 years	
Identification	Morphological (need of a specialist)	Morphological (need of a specialist)
Changes observed	Decrease of the number	
Literature	BALLESTEROS, E. (1988). Estructura y dinámica de la comunidad de Cystoseira mediterranea Sauvageau en el Mediterráneo noroccidental. Investig. Pesq. Cystseira spp.: BALLESTEROS, E., SALA, E., GARRABOU, J. & ZABALA, M. (1998). Community structure and frond size distribution of a deep water stand of *Cystoseira spinosa* (Phaeophyta) in the Northwestern Mediterranean. Eur. J. Phycol., 33: 121-128. MONTESANTO, B. & PANAYOTIDIS, P. (2000). The *Cystoseira* spp. from the Aegean Sea (north-east Mediterranean). J. Mar. Biol. Ass. U.K., 80:357-358.	KANGAS, P. (1978). On the quantity of meiofauna among the epiphytes of *Fucus vesiculosus* in the Askö area, northern Baltic Sea. Contributions from Askö Laboratory Vol. 24 Pp. 1-30. KAUTSKY, H., KAUTSKY, L., KAUTSKY, N., KAUTSKY, U., LINDBLAD, C., (1992). Studies on the *Fucus vesiculosus* community in the Baltic Sea. Phycological studies of Nordic coastal waters: a festschrift dedicated to Prof. Mats Waern on his 80th birthday, ISBN 91-7210-078-8: eds. I. Wallentinus, P. Snoeijs. (Acta phytogeographica Suecica, ISSN 0084-5914; 78). Pp. 33-48. ENGQVIST, R. (2001). Grazing in macroalgae communities of the Baltic Sea. Dept. of Systems Ecology, Stockholm University, Stockholm
Remarks		Positively correlated to biodiversity because of increase of habitat complexity. Primary coverage percentage should be surveyed

Phylum/Class	Fucophyceae	 	Rhodophyceae	 
Genus	*Laminaria*		*Lithophyllum*	
Species	***Laminaria digitata***		***Lithophyllum byssoides***	
State of validation	Validated		validated	
Photo legend / credit	Top: *L. saccharina*, Photo: J-P. Ducrotoy Bottom: *L. digitata*, Photo: J-P. Ducrotoy		Top. *L. byssoides* Trottoir Photo: A. Meinesz Bottom. *Lithophyllum cabiochae* Photo: A. Meinesz	
Feature 1	Keystone: Habitat builder		Keystone: Habitat builder	
Feature 2			Keystone: Engineer	
Habitat			Hard substrate-subtidal	
Geographic distribution	Baltic & Atlantic		Mediterranean	
Institute using this species	AWI , IOPAS		COM	
Identification	Morphological (need of a specialist)		Morphological (need of a specialist)	
Alternative species	***Laminaria saccharina***		*Lithophyllum cabiochae, Mesophyllum alterans (main components of coralligen)*	
Literature	L'HARDY, J.-P. (1962). Observations sur le peuplement épiphyte des lames de *Laminaria saccharina* (Linné) Lamouroux en Baie de Morlaix (Finistère). Cahiers de Biologie Marine, 3: 115-127.BURROWS, E.M. & PYBUS, C. (1971). *Laminaria saccharina* and marine pollution in north-east England. Mar. Pol. Bull., 2: 53-56. CONOLLY, N.J. & DREW, E.A. (1985). Physiology of *Laminaria* III. Effect of a coastal eutrophication gradient on seasonal patterns of growth and tissue composition in *L. digitata* Lamour. and *L. saccharina* (L.) Lamour. Mar. Ecol., 6: 181-195.AXELSSON, B., AXELSSON, L. (1987).Rapid and reliable method to quantify environmental effects on *Laminaria* based on measurements of ion leakage. Botanica marina, ISSN 0006-8055 Vol. 30, 1. Pp. 55-61.		FORD, H., HARDY, F. G. & EDYVEAN, R.G.J. (1983). Population biology of the crustose red alga *Lithophyllum incrustans* Phil. Three populations on the east coast of Britain. Biol. J. Lin. Soc., 19: 211-220. LABOREL, J. MORHANGE, C. LABOREL-DEGUEN, F. & LE CAMPION, J. (1993). Les bioconstructions à *Lithophyllum lichenoides*, indicatrices des variations du niveau de la mer. Revue d'Archéométrie, 17: 27-30..	
Remarks	As a structuring species and habitat builder kelp is providing space for number of other species. Kelps' density and species richness is positively related to overall species and habitat diversity http://www.algaebase.org/		*Lithophyllum lichenoides* is a synomym of *L. byssoides*. It is the main component of the "trottoir". It is indicator of sea level variations http://www.algaebase.org/	

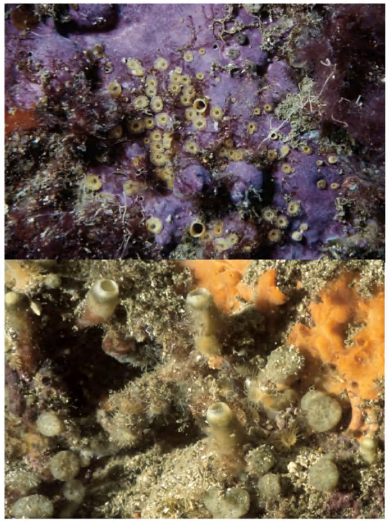
Phylum/Class	Rhodophyceae	Magnoliophyceae
Genus	*Lithothamnion*	*Posidonia*
Species	***Lithothamnion corallioides***	***Posidonia oceanica***
State of validation	Validated	Validated
Photo legend / credit	Top, *Lithothamnion corallioides* (Mearl) Bottom, *Phymatolithon calcareum (Mearl)* Photos: M. Verlaque	COM-Station Marine d'Endoume, Photo : T. Perez
Feature 1	Keystone: Habitat builder	Keystone: Habitat builder
Feature 2		Range changing
Stressor 1	Various stressors	Various stressors
Stressor 2		Temperature change. Effect of urbanization: ratio [*Cymodocea*] / [*Posidonia*] (varies from 0;8 in urbanized areas to 0,3 in less artificialized waters)
Habitat	Hard substrate-subtidal	Hard substrate-subtidal & Sandy sediment-subtidal
Geographic distribution	Europe	Mediterranean
Shallowest depth	-5	0
Deepest depth	-50	-50
Institute using this species	AWI, COM	COM, IMEDEA, GIS Posidonies
Life span		More than 100 years
Identification		Morphological (easily recognizable)
Changes observed		Decrease of the number & Changes in the bathymetric distribution
Alternative species	*Phymatolithon calcareum*	
Literature	CABIOCH, J., 1969. Les fonds de maerl de la baie de Morlaix et leur peuplement végétal. Cah. Biol. Mar., 10, 139-161. ADEY, W.H. (1970). The crustose corallines of the northwestern North Atlantic, including *Lithothamnion lemoineae* n. sp. J. Phyco., 6: 225-229. BRIAND, X. (1991). Seaweed harvesting in Europe. In Guiry, M.D. & Blunden, G. (eds), Seaweed Resources in Europe, pp. 259-308. Wiley, Chichester. O'CONNOR, B., MCGRATH, D., KONNECKER, G. & KEEGAN, B.F. (1993). Benthic macrofaunal assemblages of Greater Galway Bay. Biology Environm., 93B: 127-136. GRALL, J. & GLEMAREC, M. (1997). Biodiversité des fonds de maerl en Bretagne: approche fonctionnelle et impacts anthropiques. Vie Milieu, 47: 339-349. HALL-SPENCER, J.M., 1998. Conservation issues relating to maerl beds as habitats for molluscs. J. Conchology Special Pub., 2, 271-286. BIOMAERL team, 1999. Biomaerl: maerl biodiversity; functional structure and anthropogenic impacts. EC Contract no. MAS3-CT95-0020, 973 pp.. GRAVE De, S. & WHITAKER, A., 1999. Benthic community re-adjustment following dredging of a muddy-maerl matrix. Marine Pollution Bulletin, 38, 102-8	ASTIER J.M., (1984) GIS Posidonie publ., 1: 255-259. PERGENT G., et al. 1995. Utilisation de l'herbier à *Posidonia oceanica* comme indicateur biologique de la qualité du milieu littoral en Méditerranée: Etat des connaissances. Mésogée, 54:3-27. BOUDOURESQUE C.F. et al. (1990). Le Réseau de surveillance des herbiers de Posidonies mis en place en région Provence-Alpes-Côte d'Azur. Rapp. Comm. miss.internation. Mer Médit., 32 (1):11. CECCHERELLI, G. & CINELLI, F. (1999). Effects of *Posidonia oceanica* canopy on *Caulerpa taxifolia* size in a north-western Mediterranean bay. JEMBE 240:19-36. PIAZZI, L., ACUNTO, S. & CINELLI, F. (2000). Mapping of *Posidonia oceanica* beds around Elba Island (western Mediterranean) with integration of direct and indirect methods. Oceanol. Acta 23:339-346. BOUDOURESQUE C.F. et al. (2002). Monitoring methods for *Posidonia oceanica* sea-grass meadows in Provence and the French Riviera. [in press]. MEINEZ A. et al., 1991 Mar. Pollut. Bull., 23:343-347.
Remarks	http://www.algaebase.org/	http://www.com.univ-mrs.fr/gisposi/ http://www.algaebase.org/

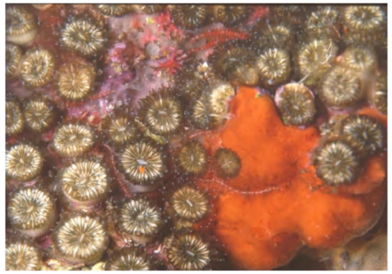
Phylum/Class	Magnoliophyceae	Magnoliophyceae
Genus	*Ruppia*	*Spartina*
Species		
State of validation	Validated	Validated
Photo legend / credit	Top: *Ruppia maritima*. Photo: T. Makovec, Gulf of Trieste 	Photo: J-P Ducrotoy 
Feature 1	Keystone: Habitat builder	Keystone: Habitat builder
Feature 2		Invading
Stressor 1	Various stressors	Various stressors
Habitat	Soft muddy sediment-littoral	Soft muddy sediment-littoral
Geographic distribution	Baltic	Mediterranean & Atlantic
Shallowest depth	0	
Deepest depth	-5	
Institute using this species	AAU	RUG-SMB , AWI, IECS and GEMEL
Identification	Morphological (need of a specialist)	Morphological (easily recognizable)
Literature	VERHOEVEN, J.T.A., The ecology of *Ruppia*-dominated communities in western Europe. I. (1979). Distribution of *Ruppia* representatives in relation to their autecology. Aquat. Bot., 6,197-268. II. (1980a) Synecological classification. Structure and dynamics of the macroflora and macrofaunal communities. Aquatic Botany, 8, 1-85. III. (1980b) Aspects of production, consumption and decomposition. Aquatic Botany, 8, 209-253. BOSTRÖM, C., BONSDORFF, E. (1999). Faunal recruitment to sea-grass beds - testing the importance of habitat complexity on zoobenthic colonization. 34th European Marine Biology Symposium, Program and Abstarcts. BOSTRÖM, C., BONSDORFF, E. (2000). Zoobenthic community establishment and habitat complexity - the importance of sea-grass shoot-density, morphology and physical disturbance for faunal recruitment. Mar. Ecol. Prog. Ser Vol. 205. Pp. 123-138	HUBBARD, J.C.E. 1965. *Spartina* marshes in southern England. VI. Pattern of invasion in Poole Harbour. Journal of Ecology 53:799-813. MARCHANT, C.J. 1967. Evolution of *Spartina* (Gramineae). I. The history and morphology of the genus in Britain. Journal of the Linnean Society (Botany), 60: 1-24. GRAY, A.J., D.F. MARSHALL, AND A.F. RAYBOULD. 1991. A century of evolution in *Spartina anglica*. Advances in Ecological Research 21:1-62. THOMPSON, J.D. 1991. The biology of an invasive plant: What makes *Spartina anglica* so successful? BioScience 41:393-401.
Remarks	http://www.marlin.ac.uk/index2.htm?demo/Rupmar.htm http://www.algaebase.org/	The smooth cord-grass *Spartina alterniflora* was introduced from the east coast of North America to England at the end of the 19th century and was first found on mudflats. Its subsequent crossing with the native small cord-grass *S. maritima* resulted in the appearance of a fertile amphidiploid, the common cord-grass *S. anglica* (and in the sterile hybrid *S. townsendii* which preceded it). It is thought that *Spartina alterniflora* was originally introduced in ships' ballast water. It spreads by clonal growth, often forming extensive meadows. *S. anglica* was extensively planted throughout Britain to stablise soft sediments. http://www.univ-lehavre.fr/cybernat/pages/spartown.htm http://www.wapms.org/plants/spartina.html



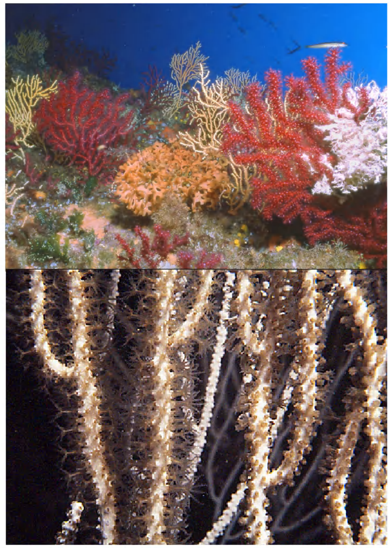
Phylum/Class	Magnoliophyceae
Genus	*Zostera*
Species	***Zostera marina***
State of validation	Validated
Photo legend / credit	Top: Broadhaven Ireland. Photo: B.E. Picton ©BioMar project TCD Bottom Galway Bay Irlande, Photo: J.P. Féral
Feature 1	Keystone: Habitat builder
Stressor 1	Littoral management & OM enrichment, eutrophication & Contaminants
Stressor 2	Various stressors
Habitat	Sea-grass bed
Geographic distri-bution	Europe
Shallowest depth	0
Deepest depth	-50
Institute using this species	IOPAS , AAU , AWI
Identification	Morphological (easily recognizable)
Changes observed	Disappearance of the species
Literature	DENNISON, W.C., ORTH, R.J., MOORE, K.A., STEVENSON, J.C., CARTER, V., KOLLAR, S., BERGSTROM, P.W. & BATIUK, R. (1993). Assessing water quality with submersed aquatic vegetation. Bioscience, 43: 86-91. DEN HARTOG, C. (1994). Suffocation of a littoral *Zostera* bed by *Enteromorpha radiata*. Aquatic Botany, 47: 21-28. BOSTRÖM, C. & BONSDORFF E. 1997. Community structure and spatial variation of benthic invertebrates associated with Zostera marina (L.) beds in SW Finland. - (J. Sea Res. 37: 153-166). REUSCH, T. B. H., STAM, W. T. & J. L. OLSEN (1999). Microsatellite loci in eelgrass *Zostera marina* reveal marked polymorphism within and among populations. Mol. Ecol. 8: 317-322. http://www.marlin.ac.uk/index2.htm?demo/Zosmar.htm http://www.algaebase.org/
Remarks	Vulnerable species for number of stressors, its presence ensures increased biodiversity. The genetic structure is studied through Europe to trace gene flow and "stability"

Species indicators: other keystone species





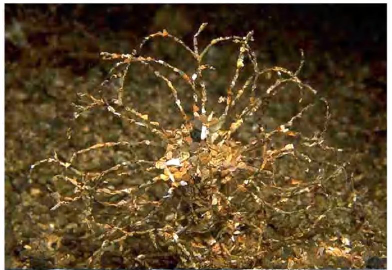
Phylum/Class	Porifera	Cnidaria
Genus	*Cliona*	*Cladocora*
Species	***Cliona celata***	***Cladocora caespitose***
State of validation	Being validated	To be validated
Photo legend / credit	Top: *Cliona celata*, Station marine d'Endoume. Photo:J. Vacelet, Riou Archipelago, 15 m Bottom: *Cliona viridis*, Station Marine Endoume. Photo: J. Vacelet Marseille (Maire island) 12 m	Photo: D. Luquet.
Feature 1	Keystone: Engineer	Keystone: Engineer
Feature 2		Charismatic
Stressor 1	OM enrichment, eutrophication	Littoral management & OM enrichment, eutrophication & Contaminants
Stressor 2		Various stressors
Habitat	Hard substrate littoral & subtidal	Hard substrate-subtidal
Geographic distribution	Europe	Mediterranean
Shallowest depth	-5	0
Deepest depth	-10	-30
Institute using this species	COM	IMEDEA
Life span	Morphological (need of a specialist)	15 years
Identification	Increase of the number	Morphological (easily recognizable)
Changes observed	*C. viridis, C. deletrix, C. inconstans*	Decrease of the number & Changes in the geographic distribution
Literature	ROSELL, D., 1993. Effects of reproduction in *Cliona viridis* (Hadromerida) on zooxanthellae. Sci. Mar., 57, 405-413. CARBALLO J.L. NARANJO SA & GARCÍA-GÓMEZ JC 1996 Use of marine sponges as stress indicators in marine ecosystems at Algeciras Bay (southern Iberian Peninsula). MEPS 135: 109-122. ROSELL D & M-J. URIZ 2002 Excavating and endolithic sponge species (Porifera) from the Mediterranean: species descriptions and identification key. Organisms Diversity & Evolution 2(1): 55-86.	AGUIRRE, J. & JIMENEZ, A.P. (1998). Fossil analogues of present-day *Cladocora caespitosa* coral banks: sedimentary setting, dwelling community, and taphonomy (Late Pliocene, W Mediterranean). PEIRANO, A., MORRI, C. Y BIANCHI, C.N. (1999). Skeleton and density pattern of the temperate, zooxanthellate scleractinian *Cladocora caespitosa* from the Ligurian Sea (NW Mediterranean). Mar. Ecol. Prog. Ser., 185: 195-201. MORRI, C., PEIRANO, A., BIANCHI, C.N. Y RODOLFO-METALPA, R.(2000). *Cladocora caespitosa*: a colonial zooxanthellate Mediterranean coral showing constructional ability. Reef Encounter, 27: 22-25.
Remarks		



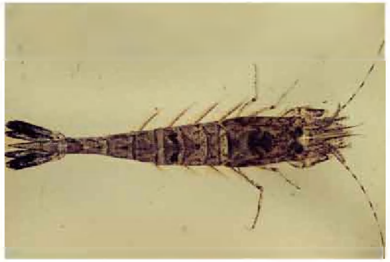
Phylum/Class	Cnidaria	Cnidaria
Order/Genus	Antipatharia	*Paramuricea*
Species		***Paramuricea clavata***
State of validation	To be tested	Being validated
Photo legend / credit	*Antipathes wollastoni Imag* DOP Photo:F Cardigos	*Paramuricea clavata*, Station Marine d'Endoume, Coraligenous habitat. Photo: J.-G. Harmelin Bottom *Eunicella verrucosa*, Banyuls. Photo J.P. Féral
Feature 1	Demersed part or erected species	Demersed part or erected species
Feature 2		Range changing
Stressor 1	Littoral management & OM enrichment, eutrophication & Contaminants	Various stressors
Stressor 2	Exploitation, fishing	
Habitat	Hard substrate-subtidal	Hard substrate-subtidal
Geographic distribution	Mediterranean & Atlantic	Mediterranean
Shallowest depth	-20	-20
Deepest depth	-300	-100
Institute using this species	DOP/Univ.	COM
Identification	Morphological (easily recognizable)	Morphological (easily recognizable)
Changes observed	Decrease of the number	Morphological changes of individuals
Alternative species		*Corallium rubrum; Eunicella cavolinii; Eunicella singularis, Lophogorgia ceratophyta*
Literature		PEREZ, T.,GARRABOU, J.,SARTORETTO, S., HARMELIN, J.G.,FRANCOUR, P.,& VACELET, J. (2000).Mortalité massive d'invertébrés marins:un événement sans précédent en Méditerranée nord-occidentale (Mass mortality of marine invertebrates: an unprecedented event in the NW Mediterranean).C.R.Acad.Sci. Paris,III 323,853-865. CERRANO,C.,BAVESTRELLO,G.,BIANCHI,C.N., CATTANEO-VIETTI,R.,BAVA,S., MORGANTI,C.,MORRI,C.,PICCO,P., SARA, G., SCHIAPARELLI, S., SICCARDI, A. & SPONGA, F.(2000).A Catastrophic Mass-mortality Episode of Gorgonians and Other Organisms in the Ligurian Sea (North-western Mediterranean),Summer 1999.*Ecology Letters 3*,284-293. ROMANO, J.C., BENSOUSSAN, N.,YOUNES, W.A.N., & ARLHAC, D.(2000).Anomalies thermiques dans les eaux du golfe de Marseille durant l'été 1999.Une d'invertébrés fixés. C.R.Acad.Sci.Paris, III 323,415-427. GARRABOU,J.,PEREZ,T.,SARTORETTO,S.,& HARMELIN,J.G.(2001).Mass mortality event in red coral (*Corallium rubrum*, Cnidaria,Anthozoa,Octocorallia) population in the Provence region (France,NW Mediterranean).MEPS.*217*, 263-272.
Remarks	Not yet tested	

Phylum/Class	Mollusca	Mollusca
Genus	*Dendropoma*	*Hydrobia*
Species	***Dendropoma petraeum***	***Hydrobia ulvae***
State of validation	Validated	Validated
Photo legend / credit	Top. Photo: J. Templado bottom. Photo: B. Galil, close-up	*Hydrobia sp.* Photo: J-P Ducrotoy
Feature 1	Keystone: Engineer	Keystone: Engineer
Feature 2	Rare	
Stressor 1	Littoral management & OM enrichment, eutrophication & Contaminants	Various stressors
Stressor 2	Temperature change	
Habitat	Hard substrate-littoral	Soft muddy sediment littoral
Geographic distribution	Mediterranean	Europe
Shallowest depth	0	0
Deepest depth	-5	-5
Institute using this species	IMEDEA, IOLR	AWI
Life span	15 years	
Identification	Morphological (easily recognizable)	
Changes observed	Decrease of the number	
Literature	SAFRIEL, U.N. (1975). The role of vermetid gastropods in the formation of Mediterranean and Atlantic reefs. Oecologia, 20: 85-101. LABOREL, J. (1987). Marine biogenic constructions in the Mediterranean. Sci. Rep. Port-Cross Natl. Park, Fr., 13: 97-126. CALVO, M., TEMPLADO, J. & PENCHASZADEH, P. (1998). Reproductive biology of the gregarious Mediterranean vermetid gastropod *Dendropoma petraeum*. J. Mar. Biol. Ass. U. K., 78: 525-549.	TOURNIE, T., AND H. EL MEDNAOUI. 1986 Metal-Complexing Agents Released into the Marine Environment by the Deposit Feeder Hydrobia ulvae (Gastropoda: Prosobranchia). MEPS 34:251-259. JENSEN K. T. & K. N. MOURITSEN 1992 Mass mortality in two common soft-bottom invertebrates, *Hydrobia ulvae* and *Corophium volutator* - the possible role of trematodes. Helgoländer Meeresunters. 46: 329-339. CHANDRASEKARA, W.U. & FRID, C.L.J. (1998) A laboratory assessment of the survival and vertical movement of two epibenthic gastropod species, *Hydrobia ulvae* (Pennant) and *Littorina littorea* (Linnaeus), after burial in sediment. JEMBE 221: 191-207. J. I. SAIZ-SALINAS &J. URKIAGA-ALBERDI 1999 Use of faunal indicators for assessing the impact of a port enlargement near Bilbao (Spain). *Environmental Monitoring and Assessment* 56: 305–330. Blanchard GF, Guarini JM, Provot L, Richard P, Sauriau PG (2000) Measurement of ingestion rate of Hydrobia ulvae (Pennant) on intertidal epipelic microalgae: the effect of mud snail density. J. Exp. Mar. Ecol. 255:247-260. HAUBOIS, A.-G.; GUARINI, J.-M.; RICHARD, P.; BLANCHARD, G.F.; SAURIAU, P.G. (2002). Spatio–temporal differentiation in the population structure of Hydrobia ulvae on an intertidal mudflat (Marennes-Oléron Bay, France). J. Mar. Biol. Ass. U.K. 82(4): 605-614. Scot E. Hagerthey*, Emma C. Defew**, David M. Paterson (2002) Influence of *Corophium volutator* and *Hydrobia ulvae* on intertidal benthic diatom assemblages under different nutrient and temperature regimes. MEPS 245:47-59
Remarks	Indicator of sea level changes.	

Phylum/Class	Mollusca	Mollusca
Genus	*Cerastoderma*	*Mytilus*
Species	***Cerastoderma edule / C.glaucum*** complex	***Mytilus edulis/ M. galloprovincialis/ M. trossulus*** complex
State of validation	Validated	Validated
Photo legend / credit	Top *Cerastoderma edule*. Photo: NIOO-CEME Bottom *Cerastoderma glaucum* Photo: R. Hamblett	*Mytilus trossulus*. Photo : N. Nappu - Baltic Sea *Mytilus edulis*. Photo K. Hiscock
Feature 1	Keystone: Engineer	Keystone: Engineer
Feature 2		Range changing
Stressor 1	Various stressors	Temperature change
Habitat	Sandy sediment littoral & subtidal	Hard substrate-littoral
Geographic distribution	Europe	Europe
Shallowest depth	0	0
Deepest depth	-100	-50
Institute using this species	NIOO-CEME	IOPAS, NIOO-CEME, COM
Identification	Morphological (need a specialist)	Genetics. Identification by Isoenzyme electrophoresis or DNA analysis.
Changes observed		Changes in the geographic distribution
Alternative species		*Macoma balthica*
Literature	Wilson JG (1993) Climate change and the future for the cockle *Cerastoderma edule* in Dublin Bay , an exercise in prediction modelling. 2 Occasional Publication of the Irish Biogeographical Society, 141-149. PRICE, G.D. & PEARCE, N.J.G. (1997) Biomonitering of pollution by *Cerastoderma edule* from the British Isles: A Laser ablation ICP-MS study. *Marine Pollution Bulletin*, 34, 1025-1031. JOHNSTONE, I & NORRIS, K 2000 The influence of sediment type on the aggregative response of oyster-catchers, *Haematopus ostralegus*, searching for cockles, *Cerastoderma edule*. *Oikos* 89: 146-154. STRASSER M. 2000 Recolonization Patterns of Benthic Fauna in the Intertidal Wadden Sea after the Severe Winter of 1995/96. Wadden Sea Newsletter - No. 1: 9-11	MCGRORTY S, GOSS-CUSTARD JD 1995 Population dynamics of *Mytilus edulis* along environmental gradients: density-dependent changes in adult mussel numbers MEPS 129:197-213. RAYMOND M, VÄÄNTÖ RL, THOMAS F, ROUSSET F, DE MEEÛS T, RENAUD F 2001 Heterozygote deficiency in the mussel *Mytilus edulis* species complex revisited. MEPS 156:225-237. DAGUIN C., BONHOMME F. & BORSA P. 2001 The zone of sympatry and hybridization of *Mytilus edulis* and *M. galloprovincialis*, as described by intron length polymorphism at locus *mac-1*. Heredity 86: 342-354. HUMMEL, H., F. COLUCCI, R.H. BOGAARDS & P. STRELKOV, 2001. Genetic traits in the bivalve *Mytilus* from Europe, with an emphasis on Arctic populations. Polar Biol. 24: 44-52. BIERNE N, DAVID P, LANGLADE A, BONHOMME F 2002 Can habitat specialisation maintain a mosaic hybrid zone in marine bivalves? MEPS 245:157-170.
Remarks		*Mytilus edulis*: Atlantic, north of SW France, and Baerents Sea (subarctic), *Mytilus galloprovincialis*: Mediterranean and Atlantic south of Great Britain; *Mytilus trossulus*: Baltic. With the warming of sea water, the Mediterranean ecotype invaded the southern European countries along the coast of Europe (Portugal, Spain, France, Southern Great Britain), and is now invading the Netherlands and Germany. The Atlantic ecotype is withdrawing to the north. The Atlantic ecotype (*M. edulis*) is reclaiming subarctic areas with ongoing warming.

Phylum/Class	Annelida	 	Crustacea	 
Genus	*Lanice*		*Idotea*	
Species	***Lanice conchilega***			
State of validation	Being validated		Validated	
Photo legend / credit	Top: *Lanice conchilega* Photo B. Picton Bottom: *Sabellaria alveolata.* Photo K. Hiscok		Top: *Idotea baltica*. GEMEL. Photo: J-P Ducrotoy Bottom: *Idotea emarginata*. Photo: Lars Gutow	
Feature 1	Keystone: Engineer		Keystone: Engineer	
Feature 2				
Stressor 1	Various stressors		Various stressors	
Stressor 2				
Habitat	Sandy sediment littoral & subtidal		Hard substrate littoral & subtidal	
Geographic distri-bution	Mediterranean & Atlantic		Europe	
Shallowest depth	0		0	
Deepest depth	-40		-20	
Institute using this species	RUG-SMB, AWI , IECS, GEMEL		AWI	
Life span				
Identification	Morphological (need of a specialist)			
Changes observed				
Alternative species	Tube building Maldanids, *Sabellaria, Marenzelleria*			
Literature	GRUET, Y. 1986. Spatio-temporal changes of sabellarian reefs built by the sedentary polychaete *Sabellaria alveolata* (Linne), P.s.z.n. I: Marine Ecology, 7, 303-319. ZETTLER M.L. 1996. Successful establishment of the spionid polyohaete, *Marenzelleria viridis* (Verrill, 1873), in the Darss-Zingst estuary (southern Baltic) and its influence on the indigenous macrozoobenthos. Arch. Fish. Mar. Res., 43 (3): 273-284. ZÜHLKE R. 2001 Polychaete tubes create ephemeral community patterns: *Lanice conchilega* (Pallas, 1766) associations studied over six years. J. Sea Res. 46: 261-272. ZUHLKE, R.; BLOME, D.; VAN BERNEM, K. H. & DITTMANN, S. (1998). Effects of the tube-building polychaete *Lanice conchilega* (Pallas) on benthic macrofauna and nematodes in an intertidal sandflat. Senckenbergia maritima, 29:131-138. CALLAWAY R. 2003 Long-term effects of imitation polychaete tubes on benthic fauna: they anchor *Mytilus edulis* (L.) banks JEMBE 283: 115-132.		FRANKE, H.-D.,JANKE, M.(1998). Mechanisms and consequences of intra- and interspecific interference competition in *Idotea baltica* (Pallas) and *Idotea emarginata* (Fabricius) (Crustacea: Isopoda): A laboratory study of possible proximate causes of habitat segregation, JEMBE, 227, 1-21. FRANKE, H.-D. GUTOW, L. JANKE, M.(1999). The recent arrival of the oceanic isopod *Idotea metallica* Bosc off Helgoland (German Bight, North Sea): an indication of a warming trend in the North Sea? Helgoland marine research, 52, 347-357. GUTOW, L., FRANKE, H.-D.(2003). Metapopulation structure of the marine isopod *Idotea metallica* - a species associated with drifting habitat patches, Helgoland Marine Research, 56: 259-264.	
Remarks	Density and number of patches positively correlated with (benthic) diversity through increasing habitat complexity. Density, number of patches, coverage percentage should be surveyed by grab/core samples, high resolution acoustic remote sensing (e.g. side scan sonar)			

Phylum/Class	Crustacea / Cirripeda	Crustacea
Genus		*Gammarus*
Species		***Gammarus oceanicus / G. setosus***
State of validation	To be validated	Validated
Photo legend / credit	*Megabalanus azoricus*: *Imag* DOP Photo: RS Santos Bottom *Balanus perforatus* Roscoff Photo J.P. Féral	*Gammarus setosus*. Photo: J-M Weslawski
Feature 1	Keystone: Engineer	Keystone: Engineer
Feature 2		Range changing
Stressor 1	Various stressors	Temperature change
Habitat	Hard substrate littoral & subtidal	Hard substrate-littoral
Geographic distri-bution	Europe	Mid & North Atlantic, Baltic, Arctic
Shallowest depth	0	0
Deepest depth	-200	-20
Institute using this species	SCCS	IOPAS
Life span		5 years
Identification		Morphological (need of a specialist)
Changes observed		Changes in the geographic distribution
Literature		THOMAS, J.D. 1993 Biological monitoring and tropical biodiversity in marine environments: a critique with recommendations, and comments on the use of amphipods as bioindicators. J. Nat. His. 27: 795-806. WESLAWSKI J.M. 1994. *Gammarus* (Crustacea, Amphipoda) from Svalbard and Franz Josef Land. Distribution and density. - *Sarsia* 79:145-150. LAWRENCE A. & C. POULTER 1996 The potential role of the estuarine amphipod *Gammarus duebeni* in sub-lethal ecotoxicology testing. Water Sci. Technol. 34: 93-100.
Remarks		Occurrence of those species shows the division between Artic and Atlantic water mass in Svalbard



Phylum/Class	Crustacea	Crustacea
Genus	*Crangon*	*Oithona*
Species	***Crangon crangon***	***Oithona nana***
State of validation	Being validated	To be tested
Photo legend / credit	*Crangon* sp. Sigean lagoon, Mediterranean, Photo: J. Leccmte	Top *Oithona* sp Photo C. Razouls/OOB Bottom *Pontella* sp Photo J. Lecomte/OOB
Feature 1	Keystone: Trophic role	Keystone: Trophic role
Stressor 1	Various stressors	OM enrichment, eutrophication
Stressor 2		Contaminants
Habitat	Sandy sediment littoral & subtidal	Pelagic
Geographic distribution	Baltic & Atlantic	Black Sea
Shallowest depth	0	
Deepest depth	-50	
Institute using this species	AAU , AWI , IOPAS , GEMEL	IMS
Identification	Morphological (easily recognizable)	Disappearance of the species
Alternative species		*Pontella mediterranea*
Literature	HENDERSON (1987). On the population biology of the common shrimp *Crangon crangon* in the Severn estuary and Bristol Channel. J. Mar. Biol. UK. 67, 825-847. HENDERSON, SEABY & MARSH (1990). The population zoo geography of the common shrimp (*Crangon crangon*) in British waters. J. Mar. Biol. UK. 70, 89-97. SMITH V.J. & JOHNSTON P.A. 1992 Differential haemotoxic effect of PCB congeners in the common shrimp, *Crangon crangon*. Comp Biochem Physiol 101C: 1-649. NORKKO, A. 1998. The impacts of loose-lying mats and predation by the brown shrimp *Crangon crangon* (L.) on infaunal prey dispersal and survival. JEMBE *221*, 99-116. CHUL-WOONG OH, RICHARD G. HARTNOLL*, RICHARD D. M. NASH 2001. Feeding ecology of the common shrimp *Crangon crangon* in Port Erin Bay, Isle of Man, Irish Sea MEPS 214:211-223. BEYST B. K.HOSTENS & J. MEES 2001 Factors influencing fish and macrocrustacean communities in the surf zone of sandy beaches in Belgium: temporal variation. J. Sea Res. 46: 281-294. LSHAW C., L.C. NEWTONA, I. WEIRB & D.J. BIRDA 2002 Concentrations of Cd, Zn and Cu in sediments and brown shrimp (*Crangon crangon* L.) from the Severn Estuary and Bristol Channel, UK. Mar. Env. Res. 54: 331-334. JEFFERY S. & A. REVILL 2002 The vertical distribution of southern North Sea *Crangon crangon* (brown shrimp) in relation to towed fishing gears as influenced by water temperature. Fisheries Res. 55: 319-323. http://www.europarl.eu.int/stoa/publi/98-17-01/chap2_en.htm	KOVALEV, A.V., GUBANOVA, A.D., (1995). Long-term dynamics of the Sevastopol Bay zooplankton of the shelf zone of the Azov-Black Sea Basin. NAS of Ukraine, MHI, Sevastopol, 96-99 (in Russian). PORUMB, F., (1992). Evolution du zooplankton des eaux du plateau continental Roumain de la mer Noire au cours de trois decennies. Rap. proc.- verb. Reun. Comm. Int. explor. Sci. Mediterr. Monaco, 33, 266. ZAGORODNYAYA, YU.A., SKRYABIN, V.A., (1995). Current trends in the zooplankton evolution in the Black Sea coastal areas of the shelf zone of the Azov-Black Sea Basin. NAS of Ukraine, MHI, Sevastopol, pp. 87-95 (in Russian). KONSULOV, A., KAMBURSKA, L., 1997. Sensitivity to anthropogenic factors of the plankton fauna adjacent to the Bulgarian coast of the Black Sea. In: Sensitivity to Change: Black Sea, Baltic Sea and North Sea, E. Ozsoy and A. Mikaelyan (eds.), Kluwer Acad. Publ., pp.95-104. KONSULOV, A., KAMBURSKA, L., (1998). Black Sea zooplankton structural dynamic and variability off the Bulgarian Black Sea coast during 1991-1995. In: NATO TU-Black Sea Project: Ecosystem Modeling as a Management Tool for the Black Sea, Symposium on Scientific Results, L. IVANOV & T. OGUZ (eds.), Kluwer Academic Publishers, pp.281-292. Kovalev, A.V., Bingel, F., Kideys, A.E., Niermann, U., Skryabin, V.A., Uysal, Z., Zagorodnyaya, Yu.A., 1999. The Black Sea zooplankton: history of investigations, composition, and spatial/temporal distribution. Turkish J. of Zoology 23: 195-209
Remarks	Crustacean vulnerable for pollution, important as food item for top predators and opportunistic feeder, its presence is positively related to species diversity in the area.	

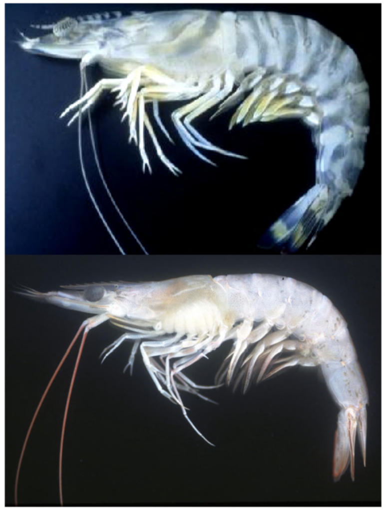
Phylum/Class	Echinodermata		Pisces	
Genus	*Amphiura*		*Zoarces*	
Species	***Amphiura filiformis***		***Zoarces viviparous***	
State of validation	Validated		Validated	
Photo legend / credit	*Amphiura fifliformis* arms emerging from muddy sand with an *Arenicola marina* cast. Photo: B.E. Picton ©BioMar project TCD:		Top: Photo: Falk Wieland www.unterwassefoto-und-story.de	
Feature 1	Keystone: Engineer		Keystone: Trophic role	
Feature 2	Keystone: Trophic role			
Stressor 1	OM enrichment, eutrophication		Various stressors	
Habitat	Soft muddy sediment-subtidal		Hard substrate-subtidal	
Geographic distri-bution	Baltic & Atlantic		Baltic & Atlantic	
Shallowest depth	-10			
Deepest depth	>1000			
Institute using this species	AN/UNIS, most environmental consultancies		MEI , AAU	
Identification	Morphological (need of a specialist)		Morphological (need of a specialist)	
Changes observed	Decrease of the number			
Literature	PEARSON, T.H. & R. ROSENBERG (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. – Oceanogr. Mar. Biol. Ann. Rev. 16: 229-331. O'CONNOR, B., BOWMER, T. & GREHAN, A., 1983. Long-term assessment of the population dynamics of *Amphiura filiformis* (Echinodermata: Ophiuroidea) in Galway Bay (west coast of Ireland). *Marine Biology*, 75: 279-286. FIELER, R., M.J. GREENACRE & T.H. PEARSON (1994). Evaluation and development of statistical methods. - Akvaplan-niva report 92.347.01.03: 71pp + appendix. OLSGARD, F., AND GRAY, J.S. 1995. A comprehensive analysis of the effects of offshore oil and gas exploration and production on the benthic communities of the Norwegian continental shelf. MEPS 122: 277–306. LO L., JONSSON P.R., SKÖLD M. & KARLSSON Ö. 1996 Passive suspension feeding in *Amphiura filiformis* (Echinodermata: Ophiuroidea): feeding behaviour in flume flow and potential feeding rate of field populations. MEPS 139: 143-155. ROSENBERG, R., NILSSON, H.C., HOLLERTZ, K. & HELLMAN, B., 1997. Density-dependent migration in an *Amphiura filiformis* (Amphiuridae, Echinodermata) infaunal population. *Marine Ecology Progress Series*, 159: 121-131. GUNNARSSON J. S., SKOLD M. 1999 Accumulation of polychlorinated biphenyls by the infaunal brittle stars *Amphiura filiformis* and A. chiajei: effects of eutrophication and selective feeding. MEPS 186: 173-185.		FRYDENBERG, O., GYLDENHOLM, A. O., HJORTH, J. P., & V. SIMONSEN. 1973. Genetics of *Zoarces* populations III. Geographic variations in the esterase polymorphism Est III. Hereditas 73: 233-38. HJORTH, J.P. & V. SIMONSEN. 1975. VIII. polymorphic loci Hbl and EstIII. Hereditas 81: 173-184. CHRISTIANSEN, F.B., FRYDENBERG, O., HJORTH, JP., SIMONSEN.V 1976. IX. Three phosphoglucomutase loci. Hereditas 83: 245-256. ESSINK, K. 1985. Monitoring of mercury pollution in dutch coastal waters by means of the teleostean fish *Zoarces viviparus*. Neth. J. Sea Res. 19 (2): 177-182. MATHIESON, S., GEORG, S.G., & D.S. MCLUSKY. 1996. Temporal variation of total mercury concentrations and burdens in the liver of eelpout *Zoarces viviparus* from the Forth estuary, Scotland: implications for mercury biomonitoring. MEPS. 138: 41-49. SCHLADOT, J.D., BACKHAUS, F., OSTAPCZUK., P., & H. EMONS. 1997. Eel-pout (*Zoarces viviparus* L.) as a marine bioindicator. Chemosphere 34: 2133-2142. OJAVEER, H., LANKOV, A., (1997), Adaptation of eel-pout *Zoarces viviparus* (L.) to spatially changing environment on the coastal slope of the Gulf of Riga (Baltic Sea), ICES C.M. 1997/EE: 03.	
Remarks	This indicator is very reliable in fine sandy sediments and is especially used in monitoring of petroleum activities in the Northern North Sea / Norwegian Sea. Note: in deeper sediments, and/or those dominated by mud/pelite, *Amphiura filiformis* is replaced by other types of brittle stars. Presence of *Amphiura filiformis* in the areas usually correlates with non-enriched environments with a high biodiversity. There are no protocols specifically for the use of *Amphiura filiformis* as an indicator. Quantitative analyses should be carried out according to international guidelines for macrofaunal sampling and analyses.		The viviparous blenny (*Zoarces viviparus* (L.)) is considered as an indicator of biological effects of harmful substances. ICES C.M. 1985/E:19/sess. (cf. JACOBSSON, A., NEUMAN, E., OLSSON, M.,(1993), Viviparous blenny as an indicator of effects of toxic substances. Fiskeri. Kustlab., Öregrund, 22 p., ISSN 1102-5670.)	

Phylum/Class	Chlorophyceae	Chlorophyceae
Genus	*Caulerpa*	*Enteromorpha*
Species	***Caulerpa prolifera***	
State of validation	Validated	To be validated
Photo legend / credit	Photo: A. Meineisz/LEML	*Enteromorpha* sp.Photo: M. Verlaque/COM herbarium
Feature 1	Keystone: Engineer	Keystone: Engineer
Feature 2	Range changing	
Stressor 1	Littoral management	Various stressors
Stressor 2	Temperature change	
Habitat	Soft muddy sediment-subtidal	Sandy sediment littoral & subtidal
Geographic distribution	Mediterranean & Atlantic	Baltic & Atlantic & Mediterranean
Shallowest depth	0	0
Deepest depth	-50	-5
Institute using this species	IMEDEA	AWI, IECS, GEMEL
Life span	50 years	
Identification	Morphological (easily recognizable)	Morphological (need of a specialist)
Changes observed	Changes in the geographic distribution	
Literature	TERRADOS J, ROS JD (1992) The influence of temperature on seasonal variation of *Caulerpa prolifera* (Forsskal) Lamouroux photosynthesis and respiration. Journal of Experimental Marine Biology and Ecology 162:199-212. TERRADOS J, ROS JD (1995) Temporal variation of the biomass and structure of *Caulerpa prolifera* (Forsskal) Lamouroux meadows in the Mar Menor lagoon (SE Spain). Scientia Marina 59:49-56. TERRADOS J, LÓPEZ-JIMÉNEZ JA (1996) Fatty acid composition and chilling resistance in the green alga *Caulerpa prolifera* (Forsskal) Lamouroux (Chlorophyta, Caulerpales). Biochemistry and Molecular Biology International 39:863-869	MULLER, M., SCHIRMER, M. AND KETTLER, J. 1993. Use of *Enteromorpha intestinalis* (Chlorophyceae) for active biomonitoring of heavy metals in the Weser estuary. Netherlands Journal of Aquatic Ecology, 27 (2-4), 189-196. LESKINEN, E. & PAMILO, P. 1997: Evolution of the ITS sequences of ribosomal DNA in *Enteromorpha* (Chlorophyceae). Hereditas 126: 17–23. FONG, P. BOYER, K.E. & ZEDLER, J.B. (1998). Developing an indicator of nutrient enrichment in coastal estuaries and lagoons using tissue nitrogen content of the opportunistic alga, *Enteromorpha intestinalis* (L. Link). JEMBE, 231: 63-79. BLOMSTER, J., MAGGS, C.A. & STANHOPE, M.J., 1998. Molecular and morphological analysis of *Enteromorpha intestinalis* and *Enteromorpha compressa* (Chlorophyta) in the British Isles. Journal of Phycology, 34, 319-340. KAMER K, FONG P. 2000 A fluctuating salinity regime mitigates the negative effects of reduced salinity on the estuarine macroalga, Enteromorpha intestinalis (L.) link. 254: 53-69.

Species indicators: Invasive species

Phylum/Class	Ctenophora	Mollusca
Genus	*Mnemiopsis*	*Brachidontes*
Species	***Mnemiopsis leidyi***	***Brachidontes pharaonis***
State of validation	Validated	Validated
Photo legend / credit	*Mnemiopsis leidyi*. Photo: T. Shiganova	*B. pharaonis* Photo: Bella Galil
Feature 1	Invading	Range changing
Feature 2	Keystone: Trophic role	Invading
Stressor	Various stressors	
Habitat	Pelagic	Hard substrate littoral & Sandy sediment littoral
Geographic distribution	Black Sea, Mediterranean, western Atlantic	Europe
Shallowest depth	0 m	
Deepest depth	120 m	
Institute using this species	Faculty of Fishery, Sinop, Turkey; IMS	IOLR, COM, CIESM
Life span	Possibly maximum 1 year	
Identification	Morphological (need of a specialist)	Morphological (easily recognizable)
Changes observed	Increase, proliferation and after disappearance	Increase of the number
Alternative species	*M. mccradyi*	Bivalvia: *Pinctada radiata* (fouling species), *Mya arenaria* in lagoons and closed seas, *Chama pacifica* in ports especially Gastropod:
Literature	KIDEYŞ A. E. (1994). Recent dramatic changes in the Black Sea ecosystem: The reason for the sharp decrease in Turkish anchovy fisheries. J. Mar. Systems 5: 171-181. GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) (1997). Opportunistic settlers and the problem of the ctenophore *Mnemiopsis leidyi* invasion in the Black sea. Rep. Stud. GESAMP, 58: 84p. IVANOV PI, AM KAMAKIM, VB USHIVTZEV, T. SHIGANOVA, O. ZHUKOVA, N. ALADIN, SI WILSON, GR HARBISON, HJ DUMONT (2000). Invasion of Caspian Sea by the comb jellyfish *Mnemiopsis leidyi* (Ctenophora). Biol. Inv. 2: 255-258. KIDEYS A.E. & MEHDI MOGHIM 2002. Distribution of the alien ctenophore *Mnemiopsis leidyi* in the Caspian Sea in August 2001. Submitted to Mar. Biol. KIDEYS A. E. (2002). The comb jelly *Mnemiopsis leidyi* in the Black Sea. In: Invasive Aquatic Species of Europe - Distributions, Impacts and Management, E. Leppäkoski, S. Olenin and S. Gollasch (Eds), Kluwer Acad. Publ., Dordrecht, NL, pp. 56-61. http://gesamp.imo.org/no58/executive.htm	ARCIDIACONO & DI GERONIMO, I.(1976). Studio biometrico di alcuni campioni di Brachiodontes variabilis (Krauss). Conchiglie 12:61-74. ICES, (1999). Report of the working group on transfers of marine organisms, ICES CM 1999/ACME 1: ref. E+F, 57 pp. SAFRIEL, I., (1977). Parameters of population growth of *Cerithium* (Mollusca, Gastropoda) species in a colonizing system. Screening species for its presence may be used to identify those, which are potential colonizers. Isr. J. Zool. 26(3-4): 257-258. DI NATALE, A., (1982). Extra-Mediterranean species of Mollusca along the southern Italian coasts. Proc. 7th international Malacological congress. Malacologia 22 (1-2): 571-580. ZIBROWIUS H. (1992). Ongoing modification of the Mediterranean marine fauna and flora by the establishment of exotic species. Bulletion du Musee d'Histoire Naturelle de Marseille 51:83-107. RICORDI, F. (1993). Segnelazione di Pinctada radiata (Leach, 1814) per il Tirreno meridionale. Notizario S.I.M. 11:41-42. SABELLI, B. (1969). Ritrovamenti malacologici a Pantellaria e nei banchi de Pesca tunisini. Conchiglie 5:8. GALIL, B.S. & ZENETOS, A., (2002). A sea-change - exotics in the eastern Mediterranean Sea. In: Leppakoski, E., S. gollasch, S. Olenin (eds). Invasive Aquatic species of Europe. Kluwer, the Netherlands pp. 325-336.
Remarks	This species had a negative impact on the most dominant fish of the Black Sea, the anchovy *Engraulis encrasicolus*, through competion for the edible zooplankton as well as consumption anchovy eggs and larvae in the Black Sea. Predatory ctenophore *Beroe ovata* is very effective on this species.	http://www.ciesm.org/atlas/Brachidontespharaonis.html http://www.ciesm.org/atlas/Cerithiumscabridum.html

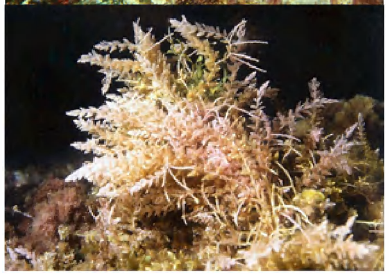
Phylum/Class	Mollusca	Mollusca
Genus	*Crepidula*	*Mya*
Species	***Crepidula fornicata***	***Mya arenaria***
State of validation	Validated	Validated
Photo legend / credit	Top, Photo: D. Thieltges (AWI) Bottom, Saint Brieuc Bay, Brittany, Photo: IFREMER	Top: Etang de Berre, Mediterranean coast, France Bottom detail. Photos: H. Zybrowius.
Feature 1	Invading	Invading
Habitat	Sandy sediment littoral & sub-tidal	Soft muddy sediment littoral
Geographic distribution	Mediterranean & Atlantic	Atlantic, Mediterranean & Black Sea
Shallowest depth	0	
Deepest depth	-30	
Institute using this species	IFREMER, JNCC, CIESM	JNCC, CIESM
Life span		15 years
Identification	Morphological (easily recognizable)	Morphological (easily recognizable)
Changes observed	Proliferation	Increase of the number
Alternative species		*Dreissena polymorpha*
Literature	LOOSANOFF, V.L. (1955). The European oyster in American waters. *Science, 121* (3135): 110-121. BARNES, R.S.K., COUGHLAN, J., & HOLMES, N.J. (1973). A preliminary survey of the macroscopic bottom fauna of the Solent, with particular reference to *Crepidula fornicata* and *Ostrea edulis*. *Proceedings of the Malac. Soc., 40*: 253-275. FRANKLIN, A. (1974). *The destruction of the oyster pest* Crepidula fornicata *by brine-dipping*. Fisheries Laboratory, Ministry of Agriculture Fisheries and Food, Lowestoft. ZIBROWIUS H., (1992). Ongoing modifications of the Mediterranean marine fauna and flora by the establishment of exotic species. *Mesogée*, 51: 83-107. CROUCH, W. (1894). On the occurrence of *Crepidula fornicata* (L.) off the coast of Essex. *Essex Naturalist*, *8*: 36-38. SMITH, S. (1995). *Crepidula fornicata* (L., 1758) (Mollusca: Gastropoda) at Tenby, south west Wales. *Porcupine Newsletter*, *6*: 82. BLANCHARD, M., 1997. Spread of the slipper limpet *Crepidula fornicata* (L.1758) in Europe. Current state and consequences. Sci. Mar., 61, Suppl 9, 109-118. De MONTAUDOUIN, X., ANDEMARD, C. & LABOURG, P-J., 1999. Does the slipper limpet (*Crepidula fornicata* L.) impair oyster growth and zoobenthos diversity ? A revisited hypothesis. JEMBE, 235, 105-124. De MONTAUDOUIN, X. & SAURIAU, P.G., 1999. The proliferating Gastropoda *Crepidula fornicata* may stimulate macrozoobenthic diversity. JMBA UK, 79, 1069-1077. De Montaudouin, X., Labarraque, D, Giraud, K. & Bachelet, G., 2001. Why does the introduced gastropod Crepidula fornicata fail to invade Arcachon Bay (France) ? JMBA UK, 81, 97-104. http://www.ciesm.org/atlas/CrepidulForni.html, http://www.marlin.ac.uk/	FOSTER, R.W. (1946). The genus *Mya* in the western Atlantic. Johnsonia, 2: 20. POUTIERS J.M. 1987. Bivalves. pp. 369-514. In : Fiches FAO d'identification des espèces pour les besoins de la pêche. Méditerranée et Mer Noire. Zone de pêche 37. Révision 1, vol. 1. FAO, Rome. HAYWARD, P.J., & RYLAND, J.S. eds. 1990. The marine fauna of the British Isles and north-west Europe. 2 vols. Oxford, Clarendon Press. SEAWARD, D.R. (1990). Distribution of the marine molluscs of north west Europe. Peterborough, Nature Conservancy Council, for Conchological Society of Great Britain and Ireland. PETERSEN, K.S., RASMUSSEN, K.L., HEINEMELER, J., & RUD, N. (1992). Clams before Columbus? Nature, 359: 679. STRASSER, M. 1999 *Mya arenaria* - an ancient invader of the North Sea coast Helgoländer Meeresuntersuchungen, 52, 309-324 http://www.ciesm.org/atlas/Myaarenaria.html, http://fwie.fw.vt.edu/WWW/macsis/lists/M060160.htm http://www.sea.ee/Sektorid/merebioloogia/MASE/Benthic_invertebrates.htm http://www.marlin.ac.uk/
Remarks	Introduced with oyster farming, it is considered a pest on commercial oyster beds, competing for space and food, while depositing mud on them and the mud rendering the substratum unsuitable for the settlement of spat. Limited to lagoons were there is farming in the Mediterranean.	"Ancient" invader of European Atlantic coasts (1245). Firstly signalled in Mediterranean in 1987.



Phylum/Class	Crustacea	Echinodermata / Holothurioidea
Genus	*Marsupenaeus*	*Synaptula*
Species	***Marsupenaeus japonicus***	***Synaptula reciprocans***
State of validation	Validated	Validated
Photo legend / credit	*Marsupenaeus japonicus* (top) & *Metapenaeus monoceros* (bottom). photos: Bella Galil	Photo: Bülent Cihangir (top), specimen of Red Sea, Aqaba, J.-P. Féral (bottom)
Feature 1	Range changing	Invading
Feature 2	Invading	
Stressor		Various stressors
Habitat	Hard substrate littoral & sub-tidal	Soft and hard substrate-subtidal
Geographic distribution	Europe	Eastern Mediterranean, from Egypt to Aegean Sea
Shallowest depth		Less than 1 m
Deepest depth		10 m
Institute using this species	IOLR, CIESM	
Life span		
Identification	Morphological (easily recognizable)	Morphological, conspicuous species very easy to follow
Changes observed	Increase of the number	
Alternative species	*Metapenaeus monoceros,*	
Literature	HOLTHUIS, L.B. (1987). Crevettes. pp. 189-192. In: Fischer, W., L. BAUCHOT, and M. SCHNEIDER (eds pêche 37. vol. 1. Végétaux et invertébrés. Rome. GALIL, B.S., 2000. A sea under siege – alien species in	CHERBONNIER G., 1986. Holothuries de la Méditerranée et du nord de la mer Rouge. Bull. Mus. nat. Hist. nat., (Ser. 4) 8: 43-46. MORTENSEN T., 1926. Zoological results of the Cambridge expedition to the Suez Canal, 1924. 6. Report on the echinoderms. Transactions of the zoological society of London, 22 (6): 117-131, fig. 11-13. ZIBROWIUS H., 1992. Ongoing modification of the Mediterranean fauna and flora by the establishment of exotic species. Mésogée, 51: 83-107. ZAITSEV Y., ÖZTÜRK B. (ed.), 2001. Exotic species in the Aegean, Marmara, Black, Azov and Caspian Seas. Turkish Marine Research Foundation, Publication no.8, 267 p.
Remarks	Thermophilic invasives via Suez Canal, mariculture release or shipping. http://www.ciesm.org/atlas/Marsupenaeusjaponicus.html http://www.ciesm.org/atlas/Metapenaeusmonoceros.html	Lessepsian species, observed in 1944 in the lake Timsah, Suez Canal (Tortonese), off Kos Island in 1973 (Féral), off Simy and Kalimnos Islands, Aegean Sea 1995 (Fourt), all along the Turkish south coast in 1996 (Jaubert)

Phylum/Class	Pisces
Genus	***Siganus***
Species	*Sigalus luridus*
State of validation	Validated
Photo legend / credit	Top left: *Stephanolepsis diaspros* Photo J.G. Harmelin. (Lebanon coast, off Tripoli) Top right: *Siganus rivulatus* Photo B. Galil. Bottom left: *Saurida undosquamis* Photo J.G. Harmelin (Lebanon coast, Saïda). Bottom right: *Siganus luridus* Photo J.G. Harmelin (Lebanon coast, off Tripoli)
Feature 1	Range changing
Habitat	Pelagic
Geographic distribution	Europe
Shallowest depth	-30
Deepest depth	-100
Institute using this species	IOLR, CIESM
Identification	Morphological (easily recognizable)
Changes observed	Increase of the number
Alternative species	*Saurida undosquamis, Parexocoetus mento, Siganus rivulatus, Stephanolepis diaspros*
Literature	OREN, O.H., (1957). Changes in the temperature of the eastern Mediterranean Sea in relation to the catch of the Israel trawl fishery during the years 1954/55 and 1955/56. Bulletin de L'Institut Oceanographique (Monaco) 1102:1-12. BEN YAMI, M & GLASER, T. (1974). The invasion of *Saurida undosquamis* (Richardson) into the Levant Basin – an example of biological effect of interoceanic canal. Fishery Bulletin, 72:359-373. LUNDBERG, B. (1989). Food habits of *Siganus rivulatus*, a Lessepsian migrant, as adapted to algal resources at the coast of Israel. In: E. Spanier, Y. Steinberger & M. Luria (Eds.), Environmental Quality and Ecosystem Stability. ISEEQS Pub. Jerusalem, IV-B: 113-124. PAPACONSTANTINOU, (1990). The spreading of lessepsian fish migrants into the Aegean Sea (Greece). Scientia Marina 54(4):313-316. BRUUN, A.F. 1935. Parexocoetus, a Red Sea flying fish in the Mediterranean. Nature, 136:553. GOLANI, D. (1993). The biology of the Red Sea migrant, *Saurida undosquamis*, in the Mediterranean and comparison with the indigenous confamilial Synodus saurus (Teleosti: Synodontidae). Hydrobiologia, 271:109-117. LUNDBERG, B. and D. GOLANI, (1995). Diet Adaptations of Lessepsian Migrant Rabbitfishes, *Siganus luridus* and *S. rivulatus*, to the Algal Resources of the Mediterranean Coast of Israel. Marine Ecology. 16(1):73-89. LUNDBERG B., PAYIATAS G. & M. ARGYROU. (1999). Notes on the diet of the Lessepsian migrant herbivorous fishes, *Siganus luridus* and *S. rivulatus*, in Cyprus. Isr. J. of Zool. 45:127-134. ZAITSEV, Y. & B. OZTURK, 2001. Exotic species in the Aegean, Marmara, Black, Azov and Caspian Seas. Turkish Marine research Foundation, 267 pp. DULCIC, J., L. LIPEJ, B. GREBEC, (2002). Changes in the Adriatic fish species composition. In: B. Ozturk & N. Basusta (eds). Workshop of lessepsian migration. Turkish Marine research Foundation. pp. 10-21. http://www.ciesm.org/atlas/Sauridaundosquamis.html, http://www.ciesm.org/atlas/Siganusluridus.html, http://www.ciesm.org/atlas/Siganusrivulatus.html,
Remarks	These thermophilic lessepsian species manly enter the Mediterranean through the Suez Canal.

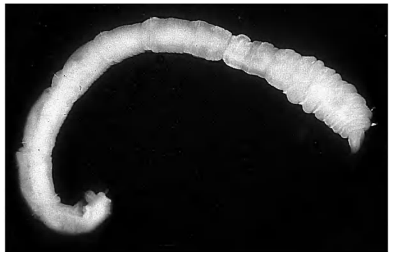
Phylum/Class	Chlorophyceae	Chlorophyceae
		
Genus	*Caulerpa*	*Caulerpa*
Species	***Caulerpa racemosa***	***Caulerpa taxifolia***
State of validation	Validated	Validated
Photo legend / credit	Photo: S. Ruitton/GIS Posidonie	Photo: D. Luquet
Feature 1	Invading	Invading
Habitat	Soft muddy sediment-subtidal	Soft muddy sediment-subtidal
Geographic distribution	Mediterranean	Mediterranean
Shallowest depth	0	0
Deepest depth	-50	-50
Institute using this species	IMEDEA, COM, LELM, GIS Pösidonie	IMEDEA; COM, LELM, GIS Posidonie
Identification	Morphological (easily recognizable)	Morphological (easily recognizable)
Changes observed	Proliferation	Proliferation
Literature	PIAZZI, L., BALESTRI, E., & CINELLI, F. (1994). Presence of *Caulerpa racemosa* in the Northwestern Mediterranean. Cryptogamie Algol. , 15: 183-189. PIAZZI, L., CECCHERELLI, G., & CINELLI, F. (2001). Threat to macroalgal diversity: effects of the introduced green alga *Caulerpa racemosa* in the Mediterranean. Marine Ecology Progress Series, 210: 149-159. RELINI, G., RELINI, M., TORCHIA, G. 2000. The role of fishing gear in the spreading of allochthonous species: the case of *Caulerpa taxifolia* in the Ligurian Sea. Ices Journal Of Marine Science, 1421-1427. VERLAQUE, M; BOUDOURESQUE, CF; MEINESZ, A; GRAVEZ, V. 2000. The *Caulerpa racemosa* Complex (Caulerpales, Ulvophyceae) in the Mediterranean Sea AU: SO: Botanica Marina, 43, 1, 49-68. DURAND, C; MANUEL, M; BOUDOURESQUE, CF; MEINESZ, A; VERLAQUE, M; LE PARCO, Y. 2002. Molecular data suggest a hybrid origin for the invasive *Caulerpa racemosa* (Caulerpales, Chlorophyta) in the Mediterranean Sea. Journal of Evolutionary Biology,15,1, 122-133. **http://www.caulerpa.org/**	VERLAQUE M., 1994. Inventaire des plantes introduites en Méditerranée : origines et répercussions sur l'environnement et les activités humaines. *Oceanologica Acta*, Fr., 17 (1) : 1-23. DE VILLELE, X. & VELARQUE, M. (1995). Changes and degradation in a *Posidonia oceanica* bed invaded by the introduced tropical alga *Caulerpa taxifolia* in the North Western Mediterranean. Botanica Marina, 38: 79-87. BELLAN-SANTINI D., ARNAUD P.M., BELLAN G., VERLAQUE M., 1996. The influence of the introduced tropical alga *Caulerpa taxifolia*, on the biodiversity of the Mediterranean marine biota. J. mar. biol. Ass. U.K., 76 : 235-237. HILL D., COQUILLARD P., VAUGELAS J. de, MEINESZ A., 1998. An algorithmic model for invasive species : application to *Caulerpa taxifolia* (Vahl) C. Agardh development in the North-Western Mediterranean Sea. *Ecological modelling*, 100 : 251-265. JOUSSON O., PAWLOWSKI J., ZANINETTI L., MEINESZ A., BOUDOURESQUE C.F., 1998. Molecular evidence for the aquarium origin of the green alga *Caulerpa taxifolia* introduced to the Mediterranean Sea. *Mar. Ecol. Progr. Ser.*, 172 : 275-280. AUSSEM, A., HILL, D. 2000. Neural network metamodelling for the prediction of *Caulerpa taxifolia* development in the Mediterranean Sea. Neurocomputing, 30, 71-78. MEUSNIER, I., J. L. OLSEN, W. T. STAM, C. DESTOMBE & M. VALERO, 2001 Phylogenetic analyses of *Caulerpa taxifolia* (Chlorophyta) and of its associated bacterial microflora provides clues to the origin of the Mediterranean introduction. Molecular Ecology. 10 : 931-946. MEUSNIER I, VALERO M., DESTOMBE C., GODE C., BONHOMME F., STAM W.T., OLSEN J.L., Sous-presse. PCR-SSCP analyses of nuclear and chloroplast DNA provide evidence for recombination, multiple introductions and nascient speciation in the *Caulerpa taxifolia* complex. Molecular Ecology **http://www.caulerpa.org/**



Phylum/Class	Rhodophyceae	Rhodophyceae / Fucophyceae
Genus	*Asparagopsis*	*Womersleyella*
Species	***Asparagopsis armata***	***Womersleyella setacea***
State of validation	Validated	Validated
Photo legend / credit	Top: *Imag*DOP, Photo: P Wirtz Bottom: A female gametophyte, Photo: A. Meinesz	Top : *Womersteyella setacea*, Photo: M. Verlaque Bottom: *Stypopodium schimperi*, Photo: M. Verlaque
Feature 1	Invading	Invading
Habitat	Hard substrate-subtidal	Hard substrate-subtidal
Geographic distribution	Western Mediterranean	Mediterranean
Shallowest depth	0	0
Deepest depth	-20	-50
Institute using this species	COM	COM
Identification	Morphological (easily recognizable)	Morphological (need of a specialist)
Changes observed	Proliferation	Proliferation
Alternative species	*Acrothamnion preissii*	*Stypopodium schimperi, Acrothamnion preissii*
Literature	SALA, E., and BOUDOURESQUE, C.F. (1997). The role of fishes in the organisation of a Mediterranean sublittoral community. I: algal communities. Journal of Experimental Marine Biology and Ecology 212, 25-44. BOUDOURESQUE C.F., and VERLAQUE M., (2002). Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes. Marine Pollution Bulletin 44, 32-38.	PIAZZI L. & F. CINELLI 2001 Distribution and Dominance of Two Introduced Turf-forming Macroalgae on the Coast of Tuscany, Italy, Northwestern Mediterranean Sea in Relation to Different Habitats and Sedimentation. Bot. Mar. 44: 509–520. BOUDOURESQUE C.F., and VERLAQUE M., (2002). Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes. Marine Pollution Bulletin 44, 32-38. M. SANSÓN, J. REYES, J. AFONSO-CARRILLO AND E. MUÑOZ 2002 Sublittoral and Deep-Water Red and Brown Algae New from the Canary Islands. Bot. Mar. 45: 35–49
Remarks	Strong chemical defences against herbivores.	Overgrowing and carpeting native species and stands.

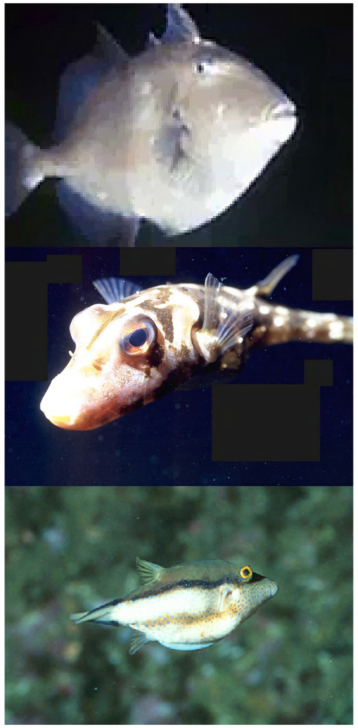
Species indicators: Geographically range changing species and pioneer species

	Macoma balthica	Patella vulgata
Phylum/Class	Mollusca	Mollusca
Genus	*Macoma*	*Patella*
Species	***Macoma balthica***	***Patella vulgata***
State of validation	Validated	Being validated
Photo legend / credit	Photo: H. Hummel 	Yorkshire Coast (England). Photo: J-P Ducrotoy 
Feature 1	Range changing	Range changing
Feature 2	Keystone: Engineer	Keystone: Trophic
Stressor 1	Temperature change	Temperature change
Stressor 2	Various stressors	
Habitat	Soft muddy sediment littoral & subtidal	Hard substrate-littoral
Geographic distribution	Mid & North Atlantic, Baltic, Arctic	Europe
Shallowest depth	0	
Deepest depth	-100	
Institute using this species	AWI , CORPI , NIOO-CEME , IOPAS , GEMEL , AAU	IECS, GEMEL
Life span	25 years	15 years
Identification	Morphological (easily recognizable)	Morphological (easily recognizable)
Changes observed	Increase, proliferation and after disappearance	Changes in the geographic distribution
Alternate species	*Mytilus edulis* complex	
Literature	HUMMEL, BOGAARDS, AMIARD-TRIQUET, BACHELET, DESPREZ, MARCHAND, RYBARCZYK, SYLVAND, DE WIT & DE WOLF 1997 Comparison of ecophysiological, biochemical and genetic traits in the estuarine bivalve *Macoma balthica* from areas between the Netherlands and its southern limits (Gironde): Geographic clines parallel effects of starvation and copper exposure HAWKINS & HUTCHINSON (ed.). Proc 30th EMBS: 15-20. HUMMEL, BOGAARDS, BEK, POLISHCHUK, AMIARD-TRIQUET, BACHELET, DESPREZ, STRELKOV, SUKHOTIN, NAUMOV, DAHLE, DENISENKO, GANTSEVICH, SOKOLOV & DE WOLF 1997 Sensitivity to stress in the bivalve *Macoma balthica* from the most northern (Arctic) to the most southern (French) populations: low sensitivity in Arctic populations because of genetic adaptations? Hydrobiologia 355: 127-138. HUMMEL, BOGAARDS, BEK, POLISHCHUK, SOKOLOV, AMIARD-TRIQUET, BACHELET, DESPREZ, NAUMOV, STRELKOV, DAHLE, DENISENKO, GANTSEVICH & DE WOLF 1998. Growth in the bivalve *Macoma balthica* from its northern to its southern distribution limit: a discontinuity in North-Europe because of genetic adaptations in Arctic populations? Comp. Biochem. Physiol. 120A: 133-141. HUMMEL, BOGAARDS, BACHELET, CARON, SOLA & AMIARD-TRIQUET 2000 The respiratory performance and survival of the bivalve *Macoma balthica* at the southern limit of its distribution area: a translocation experiment JEMBE 251: 85-102. HUMMEL, SOKOLOWSKI, BOGAARDS & M. WOLOWICZ 2000 Ecophysiological and genetic traits of the Baltic clam *Macoma balthica* in the Baltic: Differences between populations in the Gdansk Bay due to acclimatization or genetic adaptation? Internat. Rev. Hydrobiol. 85: 621-637.)	LEWIS, J.R. & BOWMAN, R.S., (1975). Local habitat-induced variations in the population dynamics of *Patella vulgata* L. Journal of Experimental Marine Biology and Ecology, 17, 165-203. HAWKINS, S.J., SOUTHWARD, A.J. & BARRETT, R.L., (1983). Population structure of *Patella vulgata* (L.) during succession on rocky shores in southwest England. Oceanolgica Acta, Special Volume, 103-107.
Remarks		Population dynamics to be used as an indicator of climate change at limit of distribution

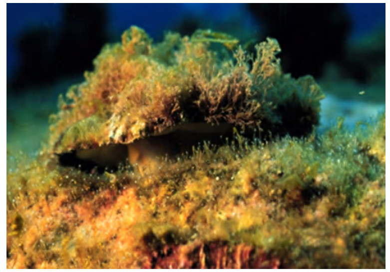


Phylum/Class	Annelida	Crustacea
Genus	*Capitella*	*Calanus*
Species	***Capitella capitata***	***Calanus glacialis***
State of validation	Validated	Being validated
Photo legend / credit	Capitella capitata. Photo: S. Degraer	*Calanus finmarchicus* (left) & *C. glacialis*. Photo: J.M. Weslawski
Feature 1	Pioneer	Range changing
Stressor 1	OM enrichment, eutrophication	Temperature change
Habitat	Soft muddy sediment-subtidal	Pelagic
Geographic distribution	Europe	Europe
Shallowest depth	-5	0
Deepest depth	>500	-200
Institute using this species	AN/UNIS, most environmental consultancies; IMBC	AWI, IOPAS
Life span	1 year	5 years
Identification	Morphological (need of a specialist) and/or genetics	Morphological (need of a specialist)
Changes observed	Increase, proliferation and after disappearance	Changes in the geographic distribution
Alternative species	*Chaetozone setosa, Spiochaetopterus typicus* and other annelids	*C.helgolandicus, C. finmarchicus, C. hyperboreus*
Literature	PEARSON, T.H. & R. ROSENBERG (1978). Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. - Oceanography and Marine Biology Annual Review 16: 229-331. FIELER, R., M.J. GREENACRE & T.H. PEARSON (1994). Evaluation and development of statistical methods. - Akvaplan-niva report 92.347.01.03: 71pp + appendix.	
Remarks	Occurrence of different functional types of annelids is related to the quality of the environment – and indirectly to the diversity of benthic fauna. The key species abundance should be monitored, associated species lists are needed for the studied locality; This indicator is validated for marine soft-bottom sediments. The presence of large numbers of *Capitella capitata* (for example in response to organic enrichment) generally occurs at the expense of other taxa. In extreme cases *C. capitata* occurs either alone or with a very few other taxa (often the polychaetes *Malacoceros fuliginosus* and/or *Chaetozone setosa*). This contrasts with a «normal» community comprising many taxa, often more than 100. A high abundance of *C. capitata* therefore indicates a reduced biodiversity. This also indicates reduced environmental health (note: not always of anthropogenic disturbance - organic enrichment or hypoxia can also occur naturally in certain areas). There are several taxa within *C. capitata*, as revealed by genetic studies. These may also be recognised morphologically by an expert. For the purposes of indicating environmental health or biodiversity in organically enriched areas, identification to the level of *C. capitata* is adequate. There are no methodology protocols specifically for the use of *C. capitata* as an indicator. Quantitative analyses should be carried out according to international guidelines for macrofaunal sampling and analyses	Species richness indicator. Sequence of sibling *Calanus* species from temperate *C. helgolandicus*, boreal- *C.finmarchicus* to Arctic *C. glacialis* and deep water *C. hyperboreus* indicates zooplankton assemblages connected with specific water masses and specific levels of diversity (e.g. Atlantic water plankton assemblage is more diverse compared to arctic water) mass assemblage). The species composition, abundance, should be assessed with the use of standard mesozooplankton nets of 200um mesh size (WP-2 net, Multinet etc).

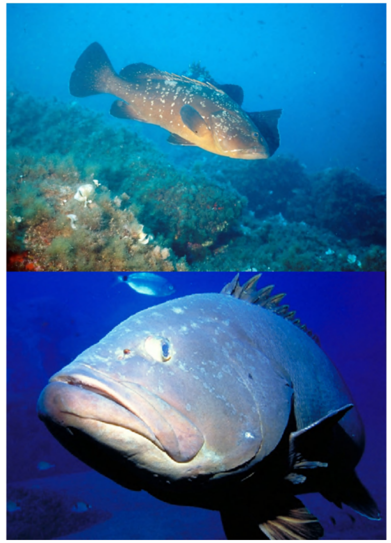
Phylum/Class	Pisces
Genus	*Balistes*
Species	***Balistes carolinensis***
State of validation	Being validated
Photo legend / credit	From top to bottom: *Baliste carolinesis* Photo : D. Luquet; *Sphoeroides marmoratus Imag*DOP Photo : F Cardigos; *Canthigaster rostrata Imag*DOP Photo : J Fontes
Feature 1	Range changing
Stressor 1	Temperature change
Habitat	Pelagic & Hard substrate-subtidal & Sandy sediment-subtidal
Geographic distribution	Mediterranean & Atlantic
Shallowest depth	0
Deepest depth	-100
Institute using this species	DOP/Univ.
Life span	15 years
Identification	Morphological (easily recognizable)
Changes observed	Increase of the number & Changes in the geographic distribution
Alternative species	*Halobatrachus didactylus*, *Sphoeroides marmoratus*, *Canthigaster rostrata* *Thalasscma pavo* (Mediterranean)
Literature	ROBINS, C.R. AND G.C. RAY. (1986) A field guide to Atlantic coast fishes of North America. Houghton Mifflin Company, Boston, U.S.A. 354 p. BAUCHOT, M.-L. (1987). SHIPP, R.L. 1990. Tetraodontidae. p. 1069-1072. In J.C. Quero, J.C. Hureau, C. Karrer, A. Post and L. Saldanha (eds.) Check-list of the fishes of the eastern tropical Atlantic (CLOFETA). JNICT, Lisbon; SEI, Paris; and UNESCO, Paris. Vol. 2.
Remarks	Range changing



Species indicators: Others

Phylum/Class	Mollusca 	Mollusca 
Genus	*Pinna*	*Patella*
Species	***Pinna nobilis***	***Patella aspera***
State of validation	Validated	Validated
Photo legend / credit	Photo: D. Luquet	*Imag*DOP. Photo: RS Santos -
Feature 1	Charismatic	Commercial
Feature 2	Rare	Rare
Stressor 1	Littoral management & OM enrichment, eutrophication & Contaminants	Exploitation, fishing
Habitat	Sea-grass beds	Hard substrate littoral & subtidal
Geographic distri-bution	Mediterranean	Mid Atlantic
Shallowest depth	0	0
Deepest depth	-50	-10
Institute using this species	IMEDEA	DOP/Univ.
Life span	25 years	5 years
Identification	Morphological (easily recognizable)	Morphological (easily recognizable)
Changes observed	Disappearance of the species	Decrease of the number
Alternative species	*Patella ferrugina*	
Literature	BUTLER (A.), VICENTE (N.), DE GAULEJAC (B.) 1993 Ecology of the pterioid bivalves *Pinna bicolor* Gmelin and *Pinna nobilis* L.. Marine Life 3 (1-2), p.37-46. RICHARDSON, C.A., KENNEDY, H., DUARTE, C.M., KENNEDY, P. & PROUD, S.V. (1999). Age and growth of the fan mussel *Pinna nobilis* from south-east Spanish Mediterranean sea-grass (*Posidonia oceanica*) meadows. Marine Biology, 133: 205-212. KENNEDY, H., RICHARDSON, C.A., DUARTE, C.M. & KENNEDY, D.P. (2001). Oxygen and carcon stable isotopic profiles of the fan mussel, *Pinna nobilis*, and reconstruction of sea surface temperatures in the Mediterranean. Marine Biology, 139: 1115-1124.	WEBER, L. I., J. P. THORPE, R. S. SANTOS & S. J. HAWKINS (1998). Identification of stocks of the exploited limpets *Patella aspera* and *P. candei* al Madeira archipelago by allozyme electrophoresis. Journal of Shellfish Research, 17 (4): 945-953.
Remarks	http://pinnanobilis.free.fr/	

	Homarus gammarus	*Cetorhinus maximus*
Phylum/Class	Crustacea	Chordata / Elasmobranchii
Genus	*Homarus*	*Cetorhinus*
Species	***Homarus gammarus***	***Cetorhinus maximus***
State of validation	Being validated	Being validated
Photo legend / credit	Photo: D. Luquet	Gulf of Trieste. Photo: L. Lipej
Feature 1	Charismatic	Charismatic
Stressor 1	Various stressors	Various stressors
Habitat	Hard substrate-littoral	Pelagic
Geographic distribution	Europe	Europe
Shallowest depth	0	
Deepest depth	-30	
Institute using this species	AWI	
Life span	50 years	
Identification	Morphological (easily recognizable)	Morphological (easily recognizable)
Changes observed	Decrease of the number	Decrease of the number
Literature	BANNISTER, R.C.A., J.T. ADDISON, AND S.R.J. LOVEWELL. 1994. Growth, movement, recapture rate and survival of hatchery-reared lobsters (*Homarus gammarus* Linnaeus, 1758) released into the wild on the English east coast. Crustaceana 67: 156-172. UGLEM, I., & S. GRIMSEN. 1995. Tag retention and survival of juvenile lobsters, *Homarus gammarus* (L.), marked with coded wire tags. Aquaculture Research 26:837-841. AGNALT, A.-L., VAN DER MEEREN, G.I., JØRSTAD, K.E., NÆSS, H., FARESTVEIT, E., NØSTVOLD, E., T. SVÅSAND, T., KORSØEN, E., & YDSTEBØ L. 1999. Stock enhancement of European lobster (*Homarus gammarus*); a large-scale experiment off south-western Norway (Kvitsøy). In: Stock Enhancement and Sea Ranching (eds.: B.R. Howell, E.Moksness & T. Svåsand), Fishing News Books, Oxford, UK, pp. 401-419. JØRSTAD, K.E. & FARESTVEIT, E. 1999. Population genetic structure of lobster (*Homarus gammarus*) in Norway and implications for enhancement and ranching operation. Aquaculture, 173: 447-457. ULRICH, I., MÜLLER, J., SCHÜTT, C., BUCHHOLZ, F. (2001). A study of population genetics in the European lobster, *Homarus gammarus* (Decapoda, Nephropidae), Crustaceana, 74, 825-837.	HALLACHER, L.E., 1977 On the feeding behavior of the basking shark, *Cetorhinus maximus*. Env. Biol. Fish. 2(3):297-298. PRIEDE, I.G., 1984 A basking shark (*Cetorhinus maximus*) tracked by satellite together with simultaneous remote sensing. Fish. Res. 2:201-216.
Remarks		IUCN Red List (http://www.redlist.org/), Appendix II of CITES http://www.fishbase.org/Summary/SpeciesSummary.cfm?genusname=Cetorhinus&speciesname=maximus http://www.ukbap.org.uk/asp/UKPlans.asp?UKListID=203



Phylum/Class	Chordata / Osteichtyes	Pisces / Osteichtyes
Genus	*Hippocampus*	*Epinephelus*
Species	***Hippocampus ramulosus ramulosus***	***Epinephelus marginatus***
State of validation	To be tested	Validated
Photo legend / credit	Top: Photo: D. Luquet Bottom:: *Imag*DOP. Photo: P Wirtz	Top: Station Marine d'Endoume. Photo : T. Perez Bottom: *Imag*DOP. Photo: P Wirtz
Feature 1	Charismatic	Charismatic
Feature 2	Rare	Range changing
Stressor 1	Littoral management	Exploitation, fishing
Stressor 2	Temperature change	
Habitat	Hard substrate-subtidal	Hard substrate littoral & subtidal
Geographic distribution	Mediterranean & Atlantic	Mediterranean
Shallowest depth	0	0
Deepest depth	-20	-50
Institute using this species	DOP/Univ.	COM
Identification	Morphological (easily recognizable)	Morphological (easily recognizable)
Changes observed	Decrease of the number	Decrease of the number & Changes in the geographic distribution
Literature	VINCENT, A.C.J. 1996. The International Trade in Seahorses. TRAFFIC International, Cambridge, UK. vii + 163 pp. LOURIE, S.A., A.C.J. VINCENT AND H.J. HALL. (1999) Seahorses: an identification guide to the world's species and their conservation. Project Seahorse, Montreal, Canada and London, UK. 224 pp. Seahorse numbers appear to be declining rapidly as a result of habitat loss, incidental capture in other fisheries, and direct overexploitation for traditional medicines, tonic foods, aquarium fishes and curios. IUCN Red List (http://www.redlist.org/) http://www.seahorse.org/	J.-G. HARMELIN, F. BACHET & F. GARCIA, 1995. Mediterranean Marine Reserves: Fish Indices as Tests of Protection Efficiency. Marine Ecology. 16 (3):233-250. J-G HARMELIN, 1999 Visual assessment of indicator fish species in Mediterranean marine protected areas.Naturalista sicil., Vol XXIII, pp.83-104. FRANCOUR, P.; GANTEAUME, A. (1999). L'arrivée progressive de jeunes mérous (*Epinephelus marginatus*) en Méditerranée nord-occidentale. *Mar. Life* 9(1): 37-45. HARMELIN, J.-G.; HARMELIN-VIVIEN, M. (1999). A review on habitat, diet and growth of the dusky grouper *Epinephelus marginatus* (Lowe, 1834). *Mar. Life* 9(2): 11-20. REÑONES, O.; GOÑI, R.; POZO, M.; DEUDERO, S.; MORANTA, J. (1999). Effects of protection on the demographic structure and abundance of *Epinephelus marginatus* (Lowe 1834): evidence from Cabrera Archipelago National Park (west-central Mediterranean). *Mar. Life* 9(2): 45-53. VACCHI, M.; LA MESA, G.; FINOIA, M.G.; GUIDETTI, P.; BUSSOTTI, S. (1999). Protection measures and juveniles of dusky grouper, *Epinephelus marginatus* (Lowe 1834) (Pisces, Serranidae), in the Marine Reserve of Ustica Island (Italy, Mediterranean Sea). Mar. Life 9(2): 63-70. http://www.fishbase.org/Summary/SpeciesSummary.cfm?genusname=Epinephelus&speciesname=marginatus http://perso.wanadoo.fr/gjl/crc/merous.htm

Phylum/Class	Chordata / Osteichtyes
Genus	*Pagellus*
Species	***Pagellus bogaraveo***
State of validation	Being validated
Photo legend / credit	Top: *Pagellus bogaraveo*. *Imag*DOP. Photo: P Wirtz Bottom: *Trachurus picturatus. Imag*Dop. Photo: P Wirtz
Feature 1	Commercial
Feature 2	Keystone: Trophic role
Stressor 1	Exploitation, fishing
Habitat	Pelagic & Hard substrate-subtidal & Sandy sediment-subtidal
Geographic distribution	Mid Atlantic
Shallowest depth	0
Deepest depth	-500
Institute using this species	DOP/Univ.
Life span	20 years
Identification	Morphological (easily recognizable)
Changes observed	Decrease of the number
Alternative species	*Helicolenus dactylopterus*, *Beryx sp.*, *Trachurus picturatus*, *Sardina pilchardus*, *Scomber japonicus*
Literature	SILVA, H.M., H.M. KRUG E G.M. MENEZES (1994). Bases para a regulamentação da pesca de demersais nos Açores. Arquivos do DOP, Série Estudos, 4(1994): 41p. MENEZES, G (1996). Interacções tecnológicas na pesca demersal dos Açores. Tese realizada para acesso à categoria de Assistente de Investigação da Universidade dos Açores. 186p.
Remarks	Effort developed within a type of fishery along with target-species CPUEs may constitute a proxy for the damage to other species caught by the fisheries and of health of habitats impacted by the fishery. Probably species can be found for every region after comprehensive selection process. Prey-species that compose the basis of pelagic carnivore food web. Evident inter-annual fluctuations in abundance, probably due to environmental factors

Phylum/Class	Mammalia
Genus	*Tursiops*
Species	***Tursiops truncatus***
State of validation	To be tested
Photo legend / credit	*Imag*DOP. Photo: R Gaspar
Feature 1	Charismatic
Stressor 1	Exploitation, fishing
Stressor 2	Contaminants
Habitat	Pelagic
Geographic distribution	Europe
Shallowest depth	0
Deepest depth	-500
Institute using this species	DOP/Univ.
Life span	50 years
Identification	Morphological (easily recognizable)
Changes observed	Decrease of the number
Alternative species	Any mysticete, delphiniid or phocoeniid
Literature	Marine Monitoring Handbook, section 4-5 p129-132. 1. BARLOW, JAY AND BOVENG, PETER. . MYRBERG JR., ARTHUR A. (1990). The effects of man-made noise on the behaviour of marine animals. Environment International; 16:575-586. (1991). Modelling age-specific mortality for marine mammal populations. Marine Mammal Science; 7(1):50-65. ISSN: 0824-0469. CALZADA, NURIA; LOCKYER, CHRISTINA H., and AGUILAR, ALEX. (1994). Age and sex composition of the striped dolphin die-off in the western Mediterranean. Marine Mammal Science. 10(3):299-310. ISSN: 0824-0469. GLEMOT, JEAN-MARC. Le mercure chez les cetaces: intoxication, et detoxication par le selenium. Poitiers: Universite de Poitiers - U.E.R. de Medicine et Pharmacie; 1986-97. ICES. (1998). Report of the working group on marine mammal habitats. Copenhagen (Denmark): ICES; (1998); CM 1998/E:6 Ref. ACME+G. KETTEN, DARLENE R. (1998) Marine mammal auditory systems: a summary of audiometric and anatomical data and its implications for underwater acoustic impacts. La Jolla, CA: National Oceanic and Atmospheric Administration - U.S. Department of Commerce; NOAA-TM-NMFS-SWFSC-256. 65 pp. . O'SHEA, THOMAS; REEVES, RANDALL R., and LONG, ALISON KIRK, (1998). Editors. Marine mammals and persistent oceans contaminants;. Keystone (USA). Maryland: Marine Mammal Commission; 1999. FRISK, GEORGE V.; JACKSON, DARRELL; DEFERRARI, HARRY; SIMMEN, JEFF; SPINDEL, ROBERT C.; BUCK, JOHN R.; D'SPAIN, GERALD; HILDEBRAND, JOHN A., and GREENE, CHARLES R. (1999):Ocean AcousticsGisiner, Rober C., Editor. Proceedings of the Workshop on the Effects of Anthropogenic Noise in the Marine Environment; 1998 Feb 10-1998 Feb 12: Office of Naval Research; 10-18. 141. ALLEN, MARK C. AND READ, ANDREW J. (2000). Habitat selection of foraging bottlenose dolphins in relation to boat density near Clearwater, Florida. Marine Mammal Science. 16(4):815-824. ISSN: 0824-0469. PATRICIA A. AND BECKER, PAUL R. (2000) Review of stress in marine mammals. Journal of Aquatic Ecosystem Stress and Recovery; 7:335-354. GOVAN, L. J. (2000) Navy guidelines for cetaceans. Marine Pollution Bulletin. 40(9):726. 36. MANN, JANET; CONNOR, RICHARD C.; BARRE, LYNNE M., and HEITHAUS, MICHAEL R. (2000). Female reproductive success in bottlenose dolphins (Tursiops sp.): life history, habitat, provisioning, and group-size effects. Behavioral Ecology. 11(2):210-219. PARSONS, E. C. M.; SHRIMPTON, J., and EVANS, P. G. H. (2000). Cetacean conservation in Northwest Scotland: perceived threats to cetaceans. European Research on Cetaceans. 13:128-133. SHERMAN, BENJAMIN H. Marine Ecosystem Health as an Expression of Morbidity, Mortality and Disease Events. Marine Pollution Bulletin. 2000; 41(1-6):232-254.
Remarks	There are some monitoring requirements and suggested techniques for this species in the Marine Monitoring Handbook of the UK Marine SAC's project. Top predator which abundance should represent good health status in the pelagic environment. IUCN Red List (http://www.redlist.org/)

List of cited species and photo credit

Cited Species	Common Name	Geographic distribution	Photo Credits	Notes	page
		PORIFERA			
Cliona celata	Boring sponge	Europe	J. Vacelet/COM	Riou Archipelago, 15m	89
Cliona deletrix		Europe			89
Cliona inconstans		Europe			89
Cliona viridis		Europe	J. Vacelet/COM	Maire Island, 12m	89
		CNIDARIA			
Antipathes wollastoni	Antipatherian	Mediterranean & Atlantic	F. Cardigos/ImagDOP	www.horta.uac.pt/ImagDOP/	90
Cladocora caespitosa	Coral	Mediterranean	D. Luquet/OOV	www.davidluquet.com	89
Corallium rubrum	Red coral	Mediterranean			90
Eunicella cavolinii					90
Eunicella verrucosa	Sea fan (white)	Europe	J.-P. Féral/OOB	Bay of Banyuls, Close-up	90
Lophogorgia ceratophyta					90
Paramuricea clavata		Mediterranean	J.-G. Harmelin/COM	Coralligenous habitat	90
		CTENOPHORA			
Mnemiopsis leydyi	Leydycomb	Black Sea	T. Shiganova		101
		MOLLUSCA			
Brachidontes pharaonis		Mediterranean	B. Galil/IOLR		101
Cerastoderma edule	Common cockle	Europe	NIOO-CEME		92
Cerastoderma glaucum	Lagoon cockle	Europe	R. Hamblett	lancingvillage.co.uk/nature/ Widewater/gallery/shell/index.htm	92
Cerithium scabridum		Mediterranean			101
Chama pacifica					101
Crepidula fornicata	Slipper limpet	Atlantic & Mediterranean	D. Thieltges/AWI		102
			IFREMER	Saint Brieuc Bay, Brittany	102
Dendropoma petraeum		Mediterranean	J. Templado & B. Galil		91
Dreissena polymorpha		Baltic, Black Sea			102
Hydrobia ulvae	Mud snail	Europe	J.-P. Ducrotoy/GEMEL		91
Macoma balthica	Baltic tellin	Atlantic & Arctic & Baltic	H. Hummel/NIOO-CEME		92, 109
Mya arenaria	Sand gaper	Atlantic & Mediterranean & Black Sea	H. Zybrowius/COM	Berre Lagoon	101, 102
Mytilus edulis	Common mussel	Europe	K. Hiscock		92, 109
Mytilus galloprovincialis		Europe			92, 109
Mytilus trossulus		Europe	N. Nappu	www.mv.helsinki.fi/home/nappu	92, 109
Patella aspersa		Atlantic	R.S. Santos/ImagDOP	www.horta.uac.pt/ImagDOP/	115
Patella vulgata	Common limpet	Europe	J.-P. Ducrotoy/GEMEL	Yorkshire coast	109
Pinna nobilis	Pen shell	Mediterranean	D. Luquet/OOV	www.davidluquet.com	115
Pintacta radiata				Fouling species	101
		ANNELIDA			
Capitella capitata		Europe	S. Degraer/RUG-SMB		110
Chaetozona setosa					110
Lanice conchilega	Sand mason	Atlantic & Mediterranean	S. Scott		93
Marenzelleria					93
Sabellaria alveolata			K. Hiscock		93
		CRUSTACEA			
Balanus perforatus		Atlantic & Mediterranean	J.-P. Féral	Brittany coast	94
Calanus finmarchicus		Europe	J.M. Weslawski/IOPAS		110
Calanus glacialis		Europe	J.M. Weslawski/IOPAS		110
Calanus helgolandicus		Europe			110
Calanus hyperboreus		Europe			110
Crangon crangon	Brown shrimp	Atlantic & Mediterranean & Baltic	J. Lecomte/OOB	Sigean lagoon	95
Gammarus oceanicus		Atlantic & Baltic & Arctic			94
Gammarus setosus		Atlantic & Baltic & Arctic	J.M. Weslawski/IOPAS		94
Homarus gammarus	European lobster	Europe	D. Luquet/OOV	www.davidluquet.com	116
Idotea baltica		Europe	J.-P. Ducrotoy/GEMEL		93
Idotea emarginata		Europe	L. Gutow/AWI		93
Marsupenaeus japonicus		Europe	B. Galil/IOLR		103
Megabalanus azoricus		Mid Atlantic	R.S. Santos/ImagDOP	www.horta.uac.pt/ImagDOP/	94
Metapenaeus monoceros		Mediterranean	B. Galil/IOLR		103
Oithona nana		Europe	C. Razouls/OOB		95
Pontella sp		Europe	J. Lecomte/OOB		95

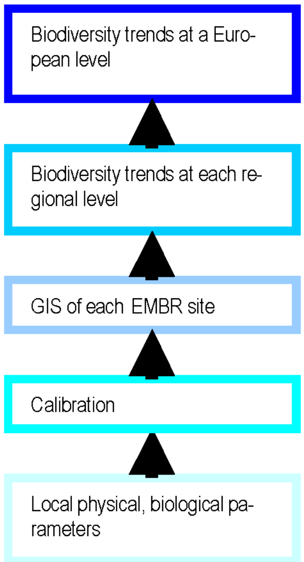
		ECHINODERMATA			
Amphiura filiformis		Atlantic & Baltic	B.E. Picton	©BioMar project, TCD	96
Synaptula reciprocans		Mediterranean	B. Cihangir	Turkish coast	103
			J.-P. Féral/OOB	Aqaba, Red Sea	103
		CHORDATA – CHONDRICHTYES			
Cetorhinus maximus	Basking shark	Europe	L. Lipej	Gulf of Trieste	116
		CHORDATA – OSTEICHTYES			
Balistes carolinensis		Atlantic & Mediterranean	D. Luquet/OOV	www.davidluquet.com	111
Beryx sp		Mid Atlantic			118
Canthigaster rostrata		Atlantic & Mediterranean	J. Fontes/ImagDOP	www.horta.uac.pt/ImagDOP/	111
Epinephelus marginatus	Dusky Grouper	Mediterranean	T. Perez/COM	Port-Cros Island	117
			P. Wirtz/ImagDOP	www.horta.uac.pt/ImagDOP/	117
Helicolenus dactylopterus		Mid Atlantic			118
Hippocampus ramulosus	Sea horse	Atlantic & Mediterranean	D. Luquet/OOV	www.davidluquet.com	117
			P. Wirtz/ImagDOP	www.horta.uac.pt/ImagDOP/	117
Halobatrachus didactylus		Atlantic & Mediterranean			111
Pagellus bagaraveo		Mid Atlantic	P. Wirtz/ImagDOP	www.horta.uac.pt/ImagDOP/	118
Sardina pilchardus		Atlantic & Mediterranean			118
Saurida undosquamis		Mediterranean	J.-G. Harmelin/COM	Lebanon coast, Saïda	104
Scomber japonicus		Atlantic & Mediterranean			118
Siganus luridus		Mediterranean	J.-G. Harmelin/COM	Lebanon coast, off Tripoli	104
Siganus rivulatus		Mediterranean	B. Galil/IOLR		104
Sphoeroides marmoratus		Atlantic & Mediterranean	F. Cardigo/ImagDOP	www.horta.uac.pt/ImagDOP/	111
Stephanolepsis diaspros		Mediterranean	J.-G. Harmelin/COM	Lebanon coast, off Tripoli	104
Trachurus picturatus		Atlantic	P. Wirtz/ImagDOP	www.horta.uac.pt/ImagDOP/	118
Zoarces viviparus		Atlantic & Baltic	F. Wieland	www.unterwasserfoto-und-story.de	96
		CHORDATA – MAMMALIA			
Tursiops truncatus	Bottlenose dolphin	Europe	P. Gaspar/ImagDOP		119
		CHLOROPHYCEAE			
Caulerpa prolifera		Atlantic & Mediterranean	A. Meinesz/LEML	www.unice.fr/LEML/	97
Caulerpa racemosa		Mediterranean	S. Ruitton/GIS Posidonie		105
Caulerpa taxifolia		Mediterranean	D. Luquet/OOV	www.davidluquet.com	105
Enteromorpha sp	Gut weed	Europe	M. Verlaque/COM		97
		FUCOPHYCEAE			
Cystoseira amentacea					81
Cystoseira mediterranea			J. Templado		81
Cystoseira spp			P. Francour/LEML	www.unice.fr/LEML/	81
Cystoseira tamariscifolia					81
Fucus vesiculosus	Bladder wrack	Europe	N. Nappu	www.mv.helsinki.fi/home/nappu	81
Fucus serratus		Atlantic	C. Emblow/EcoServe		81
Laminaria digitata	Oar weed	Atlantic & Baltic	J.-P. Ducrotoy/GEMEL		82
Laminaria saccharina		Atlantic & Baltic	J.-P. Ducrotoy/GEMEL		82
		RHODOPHYCEAE			
Acrothamnion preissii					106
Asparagopsis armata	Harpoon weed	Atlantic & Mediterranean	A. Meinesz/LEML	A female gametophyte	106
			P. Wirtz/ImagDOP		106
Mesophyllum alternans	Coralligen	Mediterranean			82
Lithophyllum cabiochae	Coralligen	Atlantic & Mediterranean	A. Meinesz/LEML	coralligen	82
Lithophyllum byssoides	Trottoir, coralligen	Mediterranean	A. Meinesz/LEML	trottoir	82
Lithothamnion corallioides	Maerl	Atlantic & Mediterranean	M. Verlaque/COM		83
Phymatolithon calcareum	Maerl	Atlantic & Mediterranean	M. Verlaque/COM		83
Womersleyella setacea		Mediterranean	M. Verlaque/COM	Corsica, herbarium	106
		MAGNOLIOPHYCEAE			
Cymodocea nodosa		Atlantic & Mediterranean			83
Posidonia oceanica		Mediterranean	T. Perez/COM		83
Ruppia maritima	Beaked seaweed		T. Malkovec	Gulf of Trieste	84
Spartina	Cord grass		J.-P. Ducrotoy/GEMEL		84
Zostera marina	Common eel grass		B.E. Picton	©BioMar project, TCD	85
			J.-P. Féral/OOB	Galway Bay, close-up	85

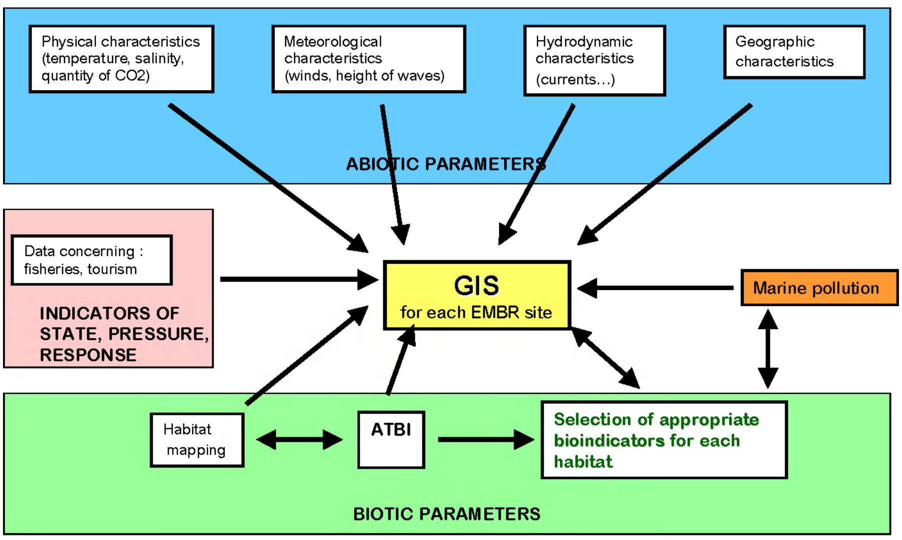
How to manage biodiversity data?

Long term, large scale monitoring will induce the production of a tremendous quantity of data. These data must be organized and made accessible by means of databases, which must be regularly updated and which must be upgradeable (to follow the progresses of hardware and software). With these data it will be possible to make distribution maps of biodiversity and/or habitats. However, maps are static and likely to become outdated real soon. A solution would be the use of Geographic Information Systems (GIS). This approach was beyond the scope of BIOMARE but has been identified as a major objective for future research on biodiversity.

Large-scale biogeographic distributions and biodiversity gradients should be GIS-mapped spatially and temporally in association with oceanographic, meteorological and other parameters. The EEA has identified the use of GIS in the marine and coastal environment as a mean of achieving increased efficiency for assessment of impacts. GIS makes possible to map the changes in an area, to anticipate future conditions or needs, to decide on a course of action, or to evaluate the results of an action or policy.

The availability of relevant data sets is a major catalyst for encouraging people to use GIS. It is therefore important that environmental character and species location data sets are made easily accessible and usable by the end users. This is currently not the case. With the appropriate databases made accessible at a European level and with the functionality of GIS analysis, the development of useful biodiversity and species habitat distribution models are possible. Such initiatives will also need independent validation. Data will have to be shared and results and findings to be made known. GIS also requires coordination and calibration at a strategic management level.





Using a GIS with standardized management process allows biodiversity trends to be comparable at a European level

Socio-economic relevance and policy implication

The sea includes both non-living resources (e.g. minerals, energy sources as hydrocarbon, wind and waves) and living resources (e.g. fisheries, genetic richness, natural substances of biotechnological interest) and ecosystems. It is also the source of recreation and a very important transport arena. The sea plays also crucial roles in the assimilation of waste and the regulation of the world's climate. All these items are potential threats for biodiversity, which is in itself the main constituent of some of the resources. Sustainable exploitation of marine resources and protection of the marine environment have been identified as key drivers for marine research. The intensity of exploitation of marine resources is accelerating to unprecedented and often unsustainable levels. Therefore, there is a need of specific indicators to monitor marine biodiversity. BIOMARE has made a state of the art of the questions and has proposed a set of indicators and indices, which, if not all totally validated, represent at least different fields of research necessary to sustainable management and decision-making.

From a practical point of view, the indicators of biodiversity must enter within the more general framework of the tools for monitoring of the impact of human activities on the one hand and the impact of natural disturbances like climatic changes, on a very large scale, or storms or floods, for example, on a more local scale. For that only one indicator cannot be enough. In each study, it is then necessary to define a system of indicators, not just a basket. In order to differentiate between natural and human causes, these indicators must be evaluated in sites as much as possible subjected only to the natural disturbances in order to calibrate them for monitoring in zones impacted by mankind.

However such biodiversity indicators are not sufficient by themselves. They must be used together with other indicators allowing a more total evaluation of the ecological risk and especially able to give an early warning of a negative change for the environment. Biodiversity by itself indeed needs its proper indicators, but it also needs, for its protection, indicators which react very fast, at a cellular or sub-cellular or biochemical level, even of low ecological relevance, but given a as short as possible response, such as biomarkers. Policy decisions must take this point into account.

To date, it is clear that the marine realm is considered separately from terrestrial and other aquatic environments. Almost nothing concerns marine biodiversity. The BIOMARE recommendation meets that of EEA. Given the need for further scientific research and testing, a two-way approach is recommended: select some indicators that can be used in the short term (even when imperfect) and meanwhile continue developing or fine-tuning other indicators for long-term use.

Due to the economic value of marine biodiversity, in the framework of sustainable development, biodiversity indicators should be included together with indicators of marine science and technology, socio-economic indicators and environmental indicators – indicators of the status of marine resources – that will contribute to the implementation of effective resource management and protection protocols. Such indicators would provide input to the reports on the marine environment produced by European organisations such as ICES, EEA, OSPAR, etc.

Following the classification adopted by the "Millenium Assessment" initiative, the goods and services provided by marine biodiversity are grouped as: provision, regulatory, and enriching. Examples of those are presented in the table below (proposed by J.M. Weslawski). BIOMARE WP2 also provided preliminary sets of indicators that can be used in assessing the values of marine biodiversity. Other examples are extensive studies on the relation between tourism and marine biota (SCUBA diving and underwater marine reserves, eco-tourists in marine wildlife refugees, mass tourism and sandy shores).

Type of service	*Example*	*Proposed indicator*	*Biodiversity importance for the service*	*Socio-economic importance*
Provisioning	Sea food	Number of marine species offered on the market	High	High
	Non-living products of marine organisms (e.g. maerl, sponges, coral)	Number of species providing products	Medium	Medium
Regulatory	Natural biocatalytical filters (permeable sediments)	Percent reduction of pollutants	High	High
	Atmospheric trace gases	Number of marine plant species – local active emitters	Low	Medium
Enriching	Tourism & recreation	Number of charismatic species, recognized by broad public in given area	Medium	High
	Education	Number of biodiversity-related media products offered on the market (books, movies, journals)	High	Medium
	Scientific	Number of papers in peer reviewed journals on marine biodiversity	High	High
	Spiritual	Percent of people declaring spiritual - emotional link to local marine biota	Medium	Medium

Table of abbreviations

AAU	Abo Akademi University, FI
AFEN	Atlantic Frontier Environmental Network
AN/UNIS	Akvaplan-Niva AS and University Studies on Svalbard, NO
ATBI	All Taxa Biodiversity Inventory
AWI	Alfred-Wegener Institute for Polar and Marine research, DE
BEEP	Biological Effects of Environmental Pollution in marine ecosystems
BEQUALM	Biological Effects Quality Assurance in Monitoring programmes
COM	Centre d'Océanologie de Marseille, FR
CORPI	Klaipeda University, Coastal Research and Planning Institute, LT
CPUEs	Catch per unit efforts
CIESM	International Commission for the Scientific Study of the Mediterranean Sea
DIVERSITAS	An international programme of biodiversity science
DOP	University of the Azores, Department of Oceanography and Fisheries, PT
EEA	European Environmental Agency
EIA	Environmental Investigation Agency
EMBRS	Europen Marine Biodiversity Research Sites
EPBRS	European Platform for Biodiversity Research Strategy
EU	European Union
EUROSTAT	The Statistical Office of the European Commission
FAO	Food and Agriculture organization of the United Nation
GEBIF	Global Biodiversity Information Facility
GEMEL	Institute of Estuarine Studies, The University of Hull, UK
GIS	Geographic Information System
GIS Posidonie	Groupement d'Intérêt Scientifique sur les posidonies, FR
IBOY	International Biodiversity Observation Year 2001-2002
ICES/CIEM	International Council for the Exploration of the Sea
IFREMER	Institut Français de Recherche pour l 'Exploitation de la Mer
IMBC	Institute of Marine Biology of Crete, GR
IMEDEA	Instituto Mediterraneo de Estudios Avanzados, ES
IMS	Institute of Marine Sciences, Middle East Technical University, TR
IO-BAS	Institute of Oceanology, Bulgarian Academy of Sciences, BU
IOC	Intergovernemental Oceanographic Commission, UNESCO
IOLR	Israel Oceanographic and Limnological Research, IL
IOPAS	Institute of Oceanology PAS, PO
JNCC	Joint Nature Conservation Committee, UK
LEML	Laboratoire Environnement Marin Littoral, FR
LTBR	Long Term Biodiversity Research
MAP	Mediterranean Action Plan
MARS	The European Marine Research Station Network
MEI	Estonian Marine Institute, Estonia
MPA	Marine protected area
NIOO-CEME	Netherlands Institute of Ecology, Centre for Estuarine & Coastal Ecology, NL
OBIS	Ocean Biogeographic Information System
OOB	Observatoire Océanologique de Banyuls sur Mer, FR
OOV	Observatoire Océanologique de Villefranche sur Mer, FR
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic (Oslo-Paris)
ROV	Remotely Operated Vehicle
RUG-SMB	University Gent, Marine Biology Section, Zoology Institute, BE
SAC	Special Areas of Conservation, UK (cf ZNIEFF)
TEPI	Towards Environmental Pressure Indicators
UNEP	United Nations Environment Programme
ZNIEFF	Zone Naturelle d'Intérêt Ecologique, Faunistique et Floristique, FR (cf SAC)

A searchable list of acronyms is avaioable at < http://ioc.unesco.org/iocweb/default.htm>

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