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# 5 New technologies and approaches to support improved biodiversity monitoring and assessment

## 5.1 Introduction

Despite the various new technologies that can support biodiversity studies, biodiversity monitoring has, through its taxonomic component, a strong conservative aspect that needs to be retained when trying to achieve reliable and comparable results. This comprises not only keeping and retaining trained personnel and expertise, but also to support ongoing training workshops and Quality Assurance routines in all identification programmes.

New technologies, such as high definition television, marine acoustics, marine electronics, new possibilities in SPI technology etc. will clearly augment existing monitoring programmes (Smith & Rumohr, 2012). New technologies in laboratory work, such a genetic bar coding and other genetic tools will facilitate improved taxonomic discrimination. Great potential lies in the use of computer-aided identification of species that is also aided effectively by web-based identification and taxonomic repositories.

The way to a computerized "Coulter Counter" for the identification of benthic invertebrates and fish may nevertheless be still quite long.

However, for long-term biodiversity monitoring, there is a clear and fundamental need that existing long-term monitoring programmes (e.g. the IBTS and CPR surveys) are retained for standardised data collection. Supplementary field methods and special technologies, as and when incorporated into monitoring programmes, should typically be additional studies, and not necessarily result in changes to survey design.

## 5.2 New technologies for the monitoring and assessment of various aspects of biodiversity

### 5.2.1 Acoustic seafloor habitat mapping

According to Smith & Rumohr (2012), acoustic mapping techniques are an essential part of the imaging approach in recording physical attributes, habitat and community patterns of seafloor habitats at different spatial scales. A handbook for seafloor imagery analysis was also produced by Blondel & Murton (1997). Acoustic devices may be ranked according to their resolution and area of coverage. Historically single beam echo-sounders developed for depth measurement have been used to depict bottom structure as well as some sedimentological properties depending on the reflecting properties of the sea-floor. For all acoustic methods the basic principles apply that the lower the frequency the longer the range, but the higher the frequency, the greater the resolution.

Single beam echo-sounders, originally developed for depth measurements, have been used to depict bottom structure as well as some sedimentological properties, depending on the reflecting properties of the sea-floor. Single beam echo-sounders (30 kHz – 3.5 MHz) and acoustic ground discriminating systems (AGDS) allow a variety of information about the reflective characteristics of the seafloor to be collected. Such systems highlight the contours and depths of the seabed, and indicate the thickness and structure of sediment layers. Recent developments apply the analysis of echo-sounder returns to include multibeam systems therefore enabling wider swathes to be analysed.

Side-scan sonar is an acoustic imaging device (100–1000 kHz) used to provide wide-area, high resolution pictures of the seabed. Originally developed for marine geology, it is now used routinely in benthic ecology. This method allows seabed features (e.g. reefs, sand ripples, seagrass beds) to be mapped and can reveal some distinct sediment structures, whether of biogenic (e.g. feeding mounds, feeding depressions) or anthropogenic origin (e.g. wrecks, trawl tracks).

Modern high frequency side-scan sonar devices provide a high resolution image of the seabed, and may detect objects in the order of tens of centimetres at a range of up to some 100 metres on either side of the tow fish. Side-scan sonar can produce, under optimal conditions, an almost photo-realistic picture of the seafloor. Over several geo-referenced swathes, a mosaic image can be built up forming an area map, where geological, sedimentological and some biological features are discernible. Considerable increases in resolving capacity down to centimetres may be available in the future from the full use of synthetic aperture sonar (SAS) in seafloor imaging.

Side-scan sonar may play a larger role in the future in seabed discrimination, and side-scan processing software is becoming available that will automatically classify features on the seabed. As in single beam AGDS, ground-truthing (e.g. sediment grabs, underwater photographs) is still necessary with higher resolution methods.

Swathe bathymetry through hull-mounted multibeam or inferometric methodologies, is a relatively newer seabed mapping technology that produces high density geo-located depth measurements through digital processing techniques, and can be used to create impressive shaded-relief or colour topographic maps. A major advantage of multi-beam systems over side-scan sonar is that they generate quantitative bathymetric data which may be used for habitat classification. They may also utilise backscatter data to form images similar to those of side-scan data, albeit with lower resolution, partly due to the variable height above the seabed of the hull-mounted sensors. The beam width makes them less useful for object detection when the objects are less than 1 m$^2$ and they require accurate information on navigation, roll, pitch and sway and the calibration of sound velocity.

Acoustic mapping techniques are an essential part of the imaging approach in recording physical attributes, community patterns of seafloor habitats at different spatial scales. In terms of biodiversity monitoring, such techniques and advances in data analysis will aid with studies of benthic habitats and some associated species (where characteristic features are visible), and facilitate more detailed mapping, as described below.

**Mapping**

The use of acoustic information has facilitated broadscale mapping. There is an implicit requirement for continuous mapping that can be applied across regions due to the Marine Strategy Framework Directive (MSFD). One of the initiatives that respond to this requirement is the EU SeaMap project. It is a "Preparatory Action" for development and assessment of a European broad-scale seabed habitat map (EC contract no. MARE/2008/07, funded by the EU Commission, DG MARE). The main goal of the project is to compile broad-scale habitat maps for a large part of Europe's seas (Figure 5.1).

The project has harmonised and improved methods used to produce the MESH EUNIS seabed habitat maps for the North Sea and Celtic Seas, merging these with the seabed maps of the Baltic Sea from the BALANCE project, and extending the methodology to the western basin of the Mediterranean Sea. Through expert application of the EUNIS classification and improved input data layers and seabed habitat modelling techniques, existing maps were refined, and their coverage extended to the specified Marine Regions, and the seabed habitat maps cover nearly 2 million km$^2$. The EU SeaMap has also created confidence maps associated with the seabed habitat maps in order to visualize the variation in quality and resolution of the input data layers (Cameron and Askew, 2011).
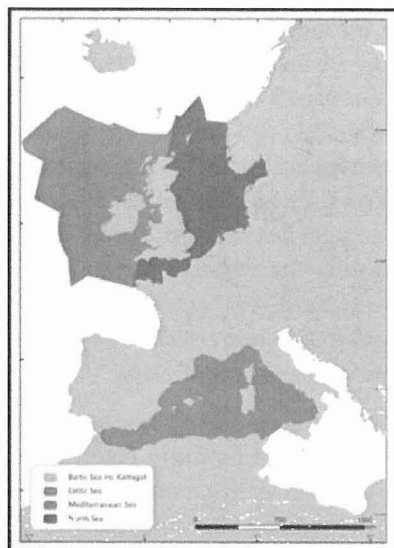
Figure 5.1. The geographic extent of the EU SeaMap project. Map from the EU SeaMap final report (Source: Cameron and Askew, 2011).

The EU SeaMap has compared maps of the marine seabed habitats of Europe at an international level and overcome the difficulties in comparing across regions; from the differences in methods/classifications used; variations in scale etc. (Figure 5.2). This modelled seabed habitat map is freely available and an interactive web mapping portal (a web-GIS) allows users to view and query the data. Another route through which the data are made available is Web Mapping Services, which provides a 'live link' to the data, either directly to a desktop GIS, or to another internet server that hosts a different web-GIS, such as the European Atlas of the Seas or the other EMODnet portals. The EUSeaMap web-GIS uses the open source software MapServer and the OpenLayers API.

Although the EU SeaMap can provide data that can be used to inform on the MSFD and for Marine Spatial Planning, it is important to acknowledge that further studies (e.g. ground-truthing the habitat classes) may still be required for more detailed, applied analyses.
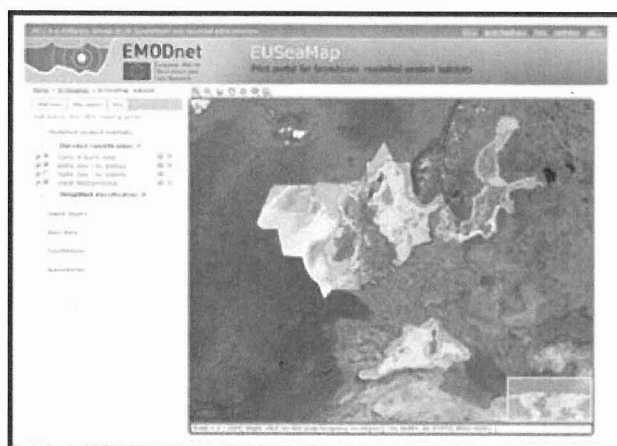


Figure 5.2. EUSeaMap project, highlighting the distribution of modelled seabed habitat maps in European waters. Source: http://ec.europa.eu/maritimeaffairs/emodnet/ preparatory/home.html

### 5.2.2 Sediment profile imagery (SPI)

Sediment profile imagery (SPI) or REMOTS (Remote Ecological Monitoring Of The Seafloor) utilises an imaging device in an inverted periscope (optical prism) that penetrates the sediment and facilitates the imaging of the sediment water interface and upper sedimentary layers (approximately 15 x 20 cm in area), allowing fine scale analysis of physical, chemical and biological features (Rhoads & Germano, 1982). Direct measurements can be made from the images and Rhoads & Germano (1982) developed a computer-aided system for analysis of such parameters as grain size, surface boundary roughness, mean (apparent) redox depth, methane gas pockets, thickness of over-lying (dredged/disposed) material, visible epifauna, tube density and type, faecal pellet layer, microbial aggregations, feeding voids, and dominant fauna. This development has made the collection of a variety of abiotic and biotic measures easier and quicker than with earlier methods (i.e. core sampling).

One of its primary uses is in large area surveys where local hotspots need to be identified and sampled in more detail. Systems are frame-mounted and wire-deployed for remote use or can be diver-operated for directed sampling in shallow waters and under fish-farms where boats cannot operate. Germano et al. (2011) comprehensively reviewed the various aspects of SPI technology, which has been increasingly used in the ICES area, particularly to better investigate bioturbation, the vertical distribution of benthic fauna within surface sediments and in helping relate infaunal communities with redox state (e.g. Birchenough et al., 2012).

Such technologies can help interpret the structure and function of benthic diversity, in relation to MSFD Descriptors 1, as well as sea-floor integrity.

### 5.2.3 Digital imagery and underwater photography

Increasingly, knowledge of broad-scale distribution patterns of populations, communities, and habitats of the seafloor is needed for impact assessment, conservation, and studies of ecological patterns and processes (Hewitt et al., 2004). In the last two decades the use of underwater imagery (video and still camera) techniques has become increasingly common in marine ecological research (Coggan et al., 2008). The image quality of cameras suitable for underwater use have improved greatly, now providing high resolution colour images at an affordable cost. These cameras can be used from a wide variety of stationary or mobile platforms such as:

- Divers (hand-held cameras);
- Stationary underwater support (tripods or other stationary platforms, e.g. for bait studies);
- Drop-video/still cameras;
- Remotely operated vehicles (ROVs);
- Autonomous underwater vehicles (AOVs), i.e. submersibles operating without an attached tethering cable for supplying power (Desa et al., 2006).

The more advanced platforms (ROVs or AOVs) may come with other sensors (e.g. acoustic devices or CTD sensors) attached.

Underwater imagery devices all share the ability to collect information (observe) faster and longer than what a diver would be able to, or collect information from depths or hostile environments where no diver would go to (Carbines & Cole, 2009). Underwater imagery is also used to ground-truth remote sensing data from acoustic devices or aerial photography (Hewitt et al., 2004, Lefebvre et al., 2009). Underwater imagery techniques are most successful in capturing macroscopic sessile species but, com-

bined with other sensors or when using bait, images of more mobile species may also be sampled. By using 3D camera techniques (using two cameras) length measurements can be made of mobile species; alternatively lasers or autofocus camera systems can be used for the same purpose (Rochet *et al.*, 2006).

Baited Remote Underwater Video Systems (BRUVS) have been widely used in some tropical areas to inform on the presence of some conspicuous piscivorous/scavenging species, and other forms of baited camera system have also been used in various parts of the ICES area, e.g. for deep-water fish species (Bailey *et al.*, 2007). As with other visual studies, baited camera systems have limitations, in terms of the species sampled, accuracy of identification for smaller or more cryptic species, and that the data may not allow for rigorous statistical analyses of abundance. Nevertheless, they may have a role for informing on the functional role of some scavengers (e.g. fish, crustaceans, cirolanid isopods), and may allow for non-destructive sampling of some species where destructive sampling is not deemed appropriate (e.g. for fish of high conservation interest; for better understanding the fauna associated with biogenic habitats).

Limits to the applicability of these techniques for collecting information on the marine biodiversity must be highlighted. Potential sources of error must be known in order to make it possible to decide which conclusions can be drawn based on the collected data and when to be cautious. Examples of errors that may occur when applying underwater imagery techniques include:

- The temporal resolution is insufficient to capture all relevant events;
- Fast moving species may not be recorded (False absence);
- Failing to cover the entire annual succession of sessile species (False absence);
- Small/cryptic species are not recorded or are overlooked (False absence);
- The image quality is too poor to detect some macroscopic species (False absence);
- Mobile species are affected by photographic equipment (attracted or avoiding) and thus not recorded (False absence or false presence), e.g. in Colton & Swearer (2010);
- Objects obscured by other objects are not identified from the images, e.g. species growing under, or behind, other species (False absence);
- Species identification confuses one species with another (False presence);
- Differences between interpreters may occur;
- Methodological changes make it difficult to compare data between years.

Technological advances in underwater camera systems can be useful when developing criteria for the determination of GES. These include structural analyses of seafloor communities or assessing advances in fishing technology towards gears with less physical impact on the seabed and its associated biota (McShane *et al.*, 2007; Carbines & Cole, 2009).

### 5.2.4   Image analysis

A large amount of data can be recovered from an image, ranging from anecdotal (description of a process); semi-quantitative data (e.g. degree of coverage of a fixed organism on a rock: a, none; b, low; c, medium; d, high; e, total); or more quantitative estimates. Quantitative data can be abstracted manually from a calibrated image by

direct measurement and transformation. Computer software programmes are readily available to undertake this automatically. Computer image analysis systems can be extensive, covering the entire operation from image collection to output of analysis. These systems tend to be expensive and it is more common for the scientist involved in image analysis to have his own image input and storage system and to utilise readily available software ranging from professional analysis software to simpler image processing software (e.g. Adobe PhotoShop) and shareware (e.g. NIH Image). Most software allows on-screen measurement or, in more detailed systems, the filtering of images, automatic abstraction of shapes or parts and their automatic measurement.

Consideration should be given to the intended application of the final images, whether they are for internal use, scientific publication or public domain publication. For high quality output, high quality original images are needed as well as access to good printers. A grabbed video image may be acceptable on-screen, but it will not print in sufficient detail for publication. Storage and archiving are also important as different storage formats have different shelf-lives. Thermal print-outs from side scan sonar records will be affected by temperature, digital media by external voltage changes or magnetic fields. CDs quoted as having an indefinite shelf life may have a more limited shelf life. Important images should be kept at least in duplicate in separate locations in fireproof conditions. The quality of the material should be periodically checked and recopied if necessary onto newer standardised archiving formats. A comprehensive review of principles on this subject can be found in Glasbey & Horgan (1995).

Furthermore, recent advances in image processing and pattern recognition of plankton have made it possible to automatically or semi-automatically identify and quantify the composition of plankton assemblages at a relatively coarse taxonomic level (Benfield et al., 2007). The Underwater Vision Profiler (UVP) can record abundances and size distributions of particles >100 μm and mesozooplankton in the water column up to 3000 m depth (Picheral et al., 2010). The images are treated and analyzed in real time, and when the UVP is interfaced with a Conductivity Temperature Depth (CTD) sensor, physico-chemical information will complement the biological data. Considering these logistic advantages, the UVP is an ideal instrument for investigating the 'twilight' and deep-ocean zones, from meso- to global scales.

Image analysis can also be used to analyze zooplankton that has been sampled using traditional methods, e.g. by nets, pumps or water bottles. ZOOSCAN, for example, is an automatic image technique for zooplankton identification and enumeration (Gorsky et al., 2010). However, the speed of analysis is comprised by the accuracy of identification and therefore, human visual recognition will still be needed to identify organisms at the species level. One of the advantages of this type of data analysis, however, is that a homogenous and secure digital zooplankton image data bank can be established and can be used for comparison of images across systems world-wide.

### 5.2.5 DIDSON

The DIDSON (Dual frequency IDentfication SONar) is a portable, high-resolution sonar system that uses acoustics (sound) to generate acoustic images with much more detail than conventional sonars. The images are comparable to those of echograms in hospitals and allow researchers to study fish behaviour, measure fish lengths and even determine species composition in turbid waters and even during the night. Currently, the DIDSON has been used in studies of fish behaviour in offshore wind farms and in studies of fish behaviour around obstacles (including the migratory routes of eel around sluices, Figure 5.3) to determine whether fish make use of escape routes.

The DIDSON has a range of 1–30 m and can function to a depth of 100 m (www.imares.nl). The use of the DIDSON for biodiversity monitoring, other than observing local behaviour, is not obvious at this stage.
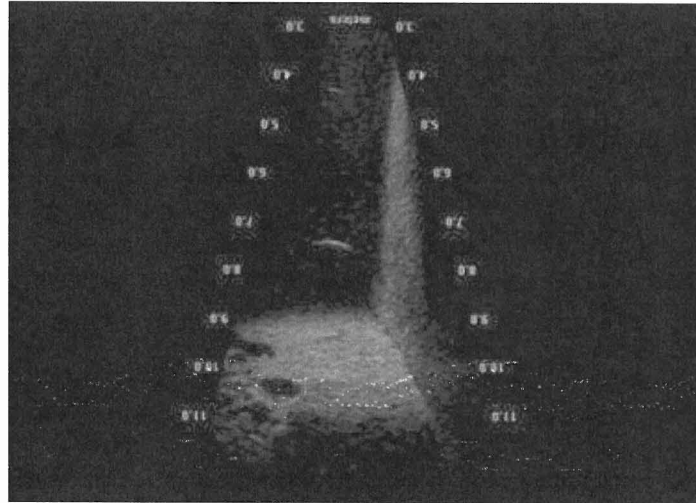


Figure 5.3. Video-still of DIDSON recording of an eel swimming towards a sluice (photo: Olvin van Keeken/ IMARES).

## 5.2.6  Electronic tagging

There have been several studies using electronic tags to better understand the behaviour, movements and migrations, and stock structure or a variety of marine taxa, including shellfish, elasmobranchs, teleosts and other marine vertebrates (Figure 5.4). The various technologies can include data storage tags (which may pop off), satellite tags and pinger tags (recorded by listening stations). A comprehensive review of these technologies and techniques is beyond the scope of the present report, and the reader is referred to, for example, Arnold & Dewar (2001).

In terms of biodiversity monitoring, such techniques can help better understand the behaviours and home range of individuals/stocks, including species of conservation and management interest (e.g. Hunter *et al.*, 2005; Stokesbury *et al.*, 2005; Metcalfe, 2006; Righton *et al.*, 2007; Wearmouth & Sims, 2009), and so then inform on potential merits of spatial management. It might also inform on the connectivity between different regions or sub-regions which are being monitored separately.
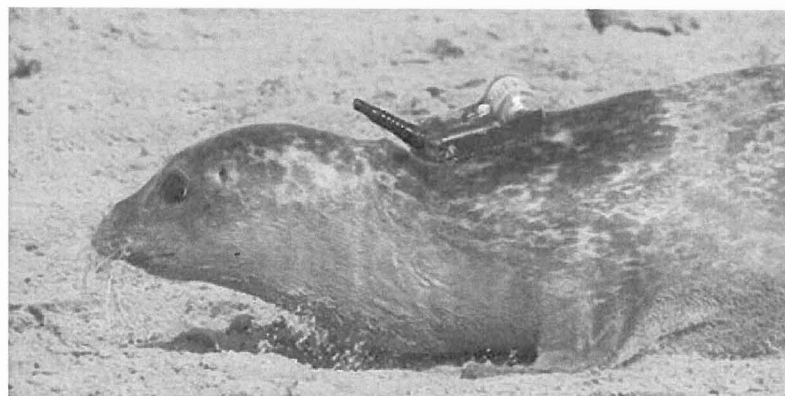


Figure 5.4. Harbour seal equipped with electronic tag (photo: Oscar Bos/IMARES).

### 5.2.7 Remote sensing

Remote sensing of the marine environment can provide high frequency and large-scale information on physical and biological processes such as oceanic fronts, eddies, primary production and toxic algal blooms. Eddies and fronts play an important role in supplying nutrients to the euphotic zone and, therefore, are often associated with enhanced biological production (Oschlies & Garçon, 1998). However, due to the high spatial and temporal dynamics of oceanic fronts, locating these features is not always straightforward. Novel analytical methods show improved precision in the visibility of these frontal features by combining frontal information from a sequence of satellite data (Miller, 2009). In addition to Advanced Very High Resolution Radiometer (AVHRR) SST fronts, the method has been validated on SeaWiFS chlorophyll fronts and is equally applicable to other ocean colour products for visualizing biological processes, such as algal blooms. As for all automated detection methods, the accuracy of detection must be validated by comparison with the true locations of fronts through the analysis of *in situ* transect sampling (Miller, 2009).

Remote sensing data can also be used for monitoring the spatial and temporal variations of the distribution of dominant phytoplankton groups. Recently, an algorithm has been developed to detect the major dominant phytoplankton groups from anomalies of the marine signal measured by ocean color satellites. This method, called PHYSAT, allows identifying nanoeucaryotes, *Prochlorococcus*, *Synechococcus* and diatoms (Alvain *et al.*, 2008). A synoptic approach combining the remote sensing data with novel *in situ* analysis methods (as carried out within the Interreg IVA DYMAPHY EU project) will allow functional groups of phytoplankton in the upper water column to be followed at a high spatial and/or temporal resolution. Phytoplankton functional groups can also be identified *in situ* by employing HPLC (Claustre *et al.*, 2004), or in some cases multispectral fluorometry in case of monospecific blooms by means of specific signatures (Beutler *et al.*, 2002) or flowcytometric identification (Dubelaar & Geerders, 2004; Thyssen *et al.*, 2008).

### 5.2.8 Fishery acoustics

Fishery acoustics allows not only for the remote detection of schools and layers of (often commercial) pelagic fish such as herring or anchovy, but also provides information on other ecosystem components in the water column, such as zooplankton layers and larger-bodied non-schooling fish species.

The fundamental results of fisheries acoustics are well-constrained solutions to the so-called 'inverse problem' for marine organisms (Holliday, 1977a,b; Simmonds & MacLennan, 2005), where the number, size, and type of acoustic targets (fish and plankton) are estimated from acoustic volume backscatter measurements. The corresponding 'forward' problem involves computing the expected backscatter, given known numbers, sizes, and types of targets. A model that predicts the acoustic target strength is required in either case. Although inverse methods can in principle be used to estimate abundance, size, and composition of fish and zooplankton from backscatter measurements at multiple, appropriately selected frequencies (Holliday, 1977a,b), the problem is generally underdetermined (i.e. the number of unmeasured, or unknown, variables is greater than the number of measured, or known, variables) and complementary data collection is required to establish the size and species composition of dominant acoustic targets as well as to parameterize the scattering models. Complementary biological data are often collected with trawls or underwater cameras. Active underwater acoustic methods provide a means of collecting a wealth of ecosystem information with high space–time resolution (Table 5.1). Worldwide, fish-

eries institutes and agencies carry out regular acoustic surveys covering many marine shelf ecosystems, but these data are often underutilized.

In addition, increasing amounts of acoustic data collected by vessels of opportunity are becoming available. In a recent paper, Trenkel *et al.* (2011) reviewed and proposed indicators for assessing and monitoring zooplankton, population dynamics of fish and other nekton, and changes in diversity and food-web functioning (Table 5.2). The evaluation of new indicators and developing suitable reference points in different ecosystems are the current challenges.

Table 5.1. Overview of types of quantities and processes for which information can be extracted from active acoustic data, and their actual or potential use for ecosystem-based management (EBM) including the MSFD. MY: multi-year monitoring time series; E: experimental process study of limited duration. The space and time scales indicated are those relevant for EBM (Source: Trenkel *et al.* 2011).

| Quantity or process of interest | Spatial scale | Time scale | Ecosystem components | EBM usage |
| --- | --- | --- | --- | --- |
| Stock biomass or abundance index | Stock | MY | Fish, krill | Fish stock assessment; interpretation of single-species results; ecosystem models |
| Abundance index | Ecosystem | MY or E | Zooplankton, jellyfish, fish, species groups | Resource (prey) assessment; ecosystem models |
| Relationship between stock biomass and spatial spread | Stock | MY | Fish | Monitoring catchability |
| Predator-prey spatial relationships | Local or ecosystem | E | Fish-zooplankton interactions, marine mammals-zooplankton interactions | Identifying and monitoring food web structure; ecosystem models |
| Spatial distribution-physical habitat relationship | Ecosystem | E | Fish, zooplankton, hydrography/substrate | Ecosystem models; habitat mapping; climate change scenarios; spatial management |

Table 5.2. Indicators and metrics for assessing environmental status of exploited marine ecosystems, derivable from acoustic data, and expected direction of change due to fishing and environmental changes (Source: Trenkel *et al.* 2011).

| Category | Indicator/ Metric | Description | Theoretical basis | Effect of changes in environment | Effect of changes in fishing | Reference points |
|---|---|---|---|---|---|---|
| Species | $B/N$ | Biomass/ abundance index | Yes | Unknown | Decrease | Biomass or abundance relative to historical situation |
| | $L_{bar}$ | Mean length | Yes | Decrease by favourable recruitment | Decrease | Unknown |
| | SA | Spreading area | Yes | Depends on species | Decrease | Relative to historical situation |
| | $B_{zooplankon}$ | Timing of zooplankton peak biomass | Yes | Spatio-temporal shifts in peak abundance | None | Relative to prey abundance timing |
| Diversity | acoustic diversity | Diversity of acoustic species | Empirical | Depends on definition of acoustic species | Depends on definition of acoustic species | Relative to historical situation |
| | acoustic spectrum | Slope of acoustic energy spectrum | Empirical | Depends on definition of acoustic groups | Depends on definition of acoustic groups | Relative to historical situation |
| | acoustic dominance | Acoustic energy by frequency | Empirical | Unknown | Unknown | Relative to historical situation |
| Food web | $B_k$ | Biomass of key group | Empirical | Depends on trophic position | Depends on trophic position | Relative to historical situation |
| | GIC | Predator-prey global index of co-location | No | Unknown | Decrease | Relative to historical situation |

### 5.2.9 VMS and fisher behaviour

The Vessel Monitoring through Satellite (VMS) system sends information on the position of fishing vessels to authorized data managers. By analysing the data it is possible to reconstruct when and where a ship was fishing, show the importance of specific areas for the fishery, get insight in fishers fishing behaviour and estimate pressures on e.g. the bottom-living animals in that area. One problem in relation to VMS data is the very limited and restricted availability to the research community of aggregated and standardised international effort data by metier.

### 5.2.10 Deck cameras /CCTV

Technology-based fishery monitoring, or electronic monitoring (EM), has emerged as an alternative to human observers on board fishing vessels and is being applied in a variety of fisheries. Deck cameras and CCTV systems are a central part of this approach. They have recently been used for implementing management measures such as reporting of total catches in Danish fisheries (Kindt-Larsen *et al.*, 2011) or verifying fishers self-reporting of catches in a hook-and-line fishery in British Columbia (Stanley *et al.*, 2011). Comparison between CCTV-based catch numbers by species and those recorded by onboard observers generally shows good agreement, but also some differences (Ames *et al.*, 2007).

Although the current motivation behind the development of CCTV systems is primarily enforcement and collection of catch data for quota management, information on conspicuous species, including unmanaged, protected species, or species of conservation interest (e.g. marine mammals, elasmobranchs), could be collected which could be useful for biodiversity monitoring and management. Using these data would require development of appropriate data treatment methods given the strong behavioural component (where fishing takes place, what gear is used etc.) and absence of any statistical sampling design in this "data collection" procedure.

### 5.2.11 Genetic tools and barcoding

Genetic techniques to identify specimens to the species level are developing rapidly and are very promising, but are not used yet for regular biodiversity monitoring purposes.

DNA barcoding is a taxonomical method that uses a short unique sequence (genetic marker) in an organisms DNA to identify species. DNA barcoding cannot be used to determine variation within species. Databases such as the Marine Barcode of Life already contain over 6100 barcoded marine species worldwide, including 50% of known elasmobranch species and 35% of known fish species. In contrast, less than 1% of benthic invertebrates have been identified. The rapid development of these techniques allows researchers to analyze as many as 15 000 different sequences in a few hours' time.

DNA barcoding can be used for the analysis of the species composition of zooplankton, benthic meiofauna samples, young stages of benthos on settlement plates, samples of fish eggs and larvae, and stomach contents, although the quality of such analyses can be dependent on preservation techniques etc. The technique can also be used to check for non-indigenous species in ballast water or growing on ship hulls, provided that the barcodes are known (www.marinebarcoding.org; Van Pelt, IMARES, Pers. Com.).

### 5.2.12 Internet-based identification and biodiversity data portals

Internet based data portals providing information on species identification, taxonomy, abundance and distribution have become increasingly important for large-scale biogeography and biodiversity studies.

An important example of an open access data portal providing identification keys includes the **Marine Species** Identification Portal (www.species-identification.org). To date, this portal compiled information on 9900 marine species and 5553 higher taxa, most of which with a description and one or more illustrations and total of 7941 taxa are keyed out in 52 identification keys. The information was assembled over a period of 10 years by a global network of collaborating taxonomists that was started with UNESCO support.

Another example of a comprehensive database, in this case on species taxonomy, is the World Register of Marine Species (WoRMS; www.marinespecies.org). In contrast to most data portals, the content of WoRMS is controlled by taxonomic experts, not by database managers; however, quality control is still carried out by the editorial management system (Appeltans *et al.*, 2012).

Large-scale biogeographic studies often require assembling extensive biological datasets from disparate sources. An increasing number of institutes are now sharing their data through user-friendly and open access data portals where information on marine species can be freely downloaded. Some of these online data portals also provide

interactive tools to visualize species occurrences for a chosen spatial extent and even predict species distributions using ecological niche based models.

The Ocean Biogeographic Information System (OBIS; www.iobis.org), with EurOBIS as the European node (www.marbef.org/data/eurobis.php) for example, is a web-based provider of global geo-referenced information on marine species, with online tools for visualizing relationships among species and their environment. This database was created by the Census of Marine Life and is now part of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, under its International Oceanographic Data and Information Exchange (IODE; www.iode.org) programme. A more comprehensive open access data portal is the Global Biodiversity Information Facility (GBIF; www.gbif.org) including information on marine and terrestrial biodiversity. Through a global network of countries and organizations, GBIF promotes and facilitates the mobilization, access, discovery and use of information about the occurrence of organisms over time and across the planet. More specialist data portals focus on single groups, such as fish (Fishbase; www.fishbase.org), but can provide extensive information and data on taxonomy, geographical distribution, biometrics and morphology, behaviour and habitats, ecology and population dynamics as well as reproductive, metabolic and genetic data on a large spatial scale. Moreover, interactive tools can used for calculating trophic pyramids, fishery statistics and perform biogeographical modelling.

AquaMaps (www.aquampas.org) is a species distribution model available as an online web service that generates standardized range maps and the relative probability of occurrence within that range for currently more than 9000 marine species from available point occurrences and other types of habitat usage information (Kaschner *et al.*, 2008). By overlaying AquaMaps predictions for a subset of individual species (namely 115 marine mammals), a global map of biodiversity patterns was produced that shows the co-occurrence of predicted hotspots of marine mammal species richness and off-shore seamounts.

Although internet-based sources can provide easily accessed and comprehensive data, it must be remembered that not all internet-based information and data sources are thoroughly peer-reviewed, and so outputs may need to be critically evaluated.

## 5.3 Improved opportunities of data collection

### 5.3.1 Better use of existing scientific surveys

More work of relevance to biodiversity monitoring could be undertaken on existing surveys, including those internationally-coordinated by ICES (e.g. through IBTSWG and WGBEAM). Such work could include collecting tissue samples for genetic studies, data on other ecosystem components (sea birds, marine mammals, benthos), and other aspects of ecosystem structure and function (acoustics, oceanography, feeding habits). Such issues have been discussed in several other ICES reports (e.g. the Working Group on Integrating Surveys for the Ecosystem Approach) and are not detailed here.

### 5.3.2 Improved use of platforms of opportunity

Platforms of opportunity (e.g. ferries and merchant ships) can provide a cost-effective means to collect large spatial oceanographic data by on-board observers or by carrying scientific instruments (Evans & Hammond, 2004; Kiszka *et al.*, 2007). To date, the biological data collected in Europe using platforms of opportunity include phytoplankton, zooplankton, seabirds and marine mammals. For example, the European

FerryBox Network incorporates 11 research institutes from eight countries and deploys automated sensors for measuring biological, chemical, and physical variables, which are attached to commercial ferries. Other projects include the Continuous Plankton Recorder (CPR) survey, the largest plankton monitoring programme in the world. The plankton sampling instrument (Figure 5.5) is towed from merchant ships on their normal sailings and has monitored the presence or abundance of more than 400 plankton species on a monthly basis over the North Atlantic since 1946. After a CPR has been towed, it is returned to the laboratory at SAHFOS, UK, for analysis to obtain estimates of chlorophyll *a* concentration using a "greenness index" known as the Phytoplankton Colour Index (PCI) and zooplankton abundance and species composition. The CPR's long time-series and extensive spatial coverage and unchanged methodology has enabled the development of statistically significant complex multivariate indicators encompassing many levels of ecosystem state, structure, and functioning (McQuattors-Gollop *et al.*, 2010).
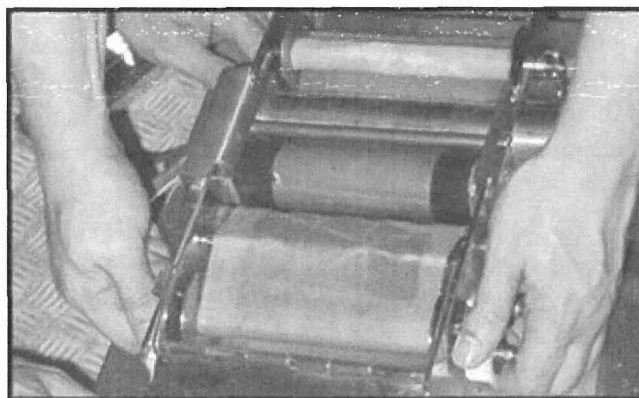


Figure 5.5. Continuous Plankton Recorder on a Dutch ferry (photo Robbert Jak/ IMARES).

### 5.3.3 Better use of fishery-dependent data sources

The EU-funded onboard observation schemes, whose primary purpose is to collect information on discards, might provide a valuable data source for biodiversity monitoring. For example, spatial indices from the French onboard observation program in the Bay of Biscay were compared to those derived from survey data (see Section 2). The two sources showed a good overall agreement. Further studies are needed to evaluate the potential and limits of onboard observations and other fishery-dependent data for biodiversity monitoring.

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