Marine Renewables Infrastructure Network

Work Package 4: Research to innovate and improve Infrastructures, technologies and techniques

D.4.8 Database for environmental monitoring techniques and equipment

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ABOUT MARINET

MaRINET (Marine Renewables Infrastructure Network for Emerging Energy Technologies) is an EC-funded consortium of 29 partners bringing together a network of 42 specialist marine renewable energy testing facilities. MaRINET offers periods of free access to these facilities at no cost to research groups and companies. The network also conducts coordinated research to improve testing capabilities, implements common testing standards and provides training and networking opportunities in order to enhance expertise in the industry. The aim of the MaRINET initiative is to accelerate the development of marine renewable energy technology.

Companies and research groups who are interested in availing of access to test facilities free of charge can avail of a range of infrastructures to test devices at any scale in areas such as wave energy, tidal energy and offshore-wind energy or to conduct specific tests on cross-cutting areas such as power take-off systems, grid integration, moorings and environmental data. In total, over 700 weeks of access is available to an estimated 300 projects and 800 external users.

MaRINET is consists of five main areas of focus or 'Work Packages': Management & Administration, Standardisation & Best Practice, Transnational Access & Networking, Research and Training & Dissemination. The initiative runs for four years until 2015.

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University College Cork, HMRC (UCC_HMRC)
Coordinator
Sustainable Energy Authority of Ireland (SEAI_OEDU)

Denmark
Aalborg Universitet (AAU)
Danmarks Tekniske Universitet (RISOE)

France
Ecole Centrale de Nantes (ECN)
Institut Français de Recherche Pour l'Exploitation de la Mer (IFREMER)

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Legal Disclaimer

REVISION HISTORY

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EXECUTIVE SUMMARY

This document provides an introduction to the Database for Environmental Monitoring Techniques and Equipment which presents measuring instruments and survey techniques currently used by the MaRINET project partners. This is a common information source for all MaRINET partners to cross reference. This will be of key importance in synchronising the various approaches across Europe and working towards the creation of best practice methodologies for environmental monitoring.

The first part of this report also consists of a brief introduction on the conceptual basis of monitoring activities in the marine and coastal environment. It then links to a comparative table in which available monitoring techniques are matched with the various environmental compartments that characterize the marine environment.

In the final part of the report, existing gaps in the catalogue of instrumentation are discussed and some considerations about the actual thematic coverage of the techniques and instrumentation available are highlighted.

The DEMTE can be accessed here – D4.8 Instrumentation Database.

The additional databases can be accessed here – D4.8 Physical Measurement and D4.8 Biological Measurement.

CONTENTS

1 INTRODUCTION

This document provides an introduction to the Database for Environmental Monitoring Techniques and Equipment (DEMTE) which are available at D4.8 Instrumentation Database.

The Database for Environmental Monitoring Techniques and Equipment (DEMTE) presents a list of instrumentation and measurement methods for performing monitoring activities in the marine environment related to the installation and operation of Marine Energy Conversion Systems (MECS).

The DEMTE is a common information source which the various MaRINET facilities can refer to when selecting new equipment or techniques, or upgrading or replacing existing equipment or methodologies. It will help the various facilities to standardise instrumentation and allow transferability of results between tests.

This deliverable is part of the Task 4.5 "Environmental monitoring related research" of the Work Package 4 "Research to innovate and improve infrastructures, technologies and techniques" and it is directly related to D.4.7 "Best practice report on environmental monitoring and new study techniques" in which approaches to monitoring and methods and innovations in monitoring are discussed.

2 MONITORING OF THE MARINE ENVIRONMENT

Monitoring in the marine environment is a complex topic. Monitoring is often based on a multidisciplinary approach which includes both abiotic and biotic environmental compartments. This variety of subject involves several research areas which are interconnected via a large set of interdependent processes.

In this context the main challenge in environmental monitoring is to select a robust approach, which:

- complies with environmental regulations and accepted practices
- avoids any potential negative effects on the receiving study environment
- can provide environmental information appropriate for the research needs.

High variability is inherent in the marine environment; therefore monitoring activity has to be based on high resolution and synoptic observations. The following elements must be considered in monitoring design:

- the spatial and temporal scales of marine processes
- interactions between the different environmental compartments
- dynamics.

2.1 Spatial and temporal scales, interactions and dynamics

The spatial and temporal scales of marine phenomena and processes are characterized by specific ranges of time and space [1]. Figure 1 shows a scheme which summarizes the main processes from micro- to macroscale.

The microscale has a spatial limit of 1m and temporal domain of 1-2 days. Microscale processes are dominated by turbulence, including biological and mixed layer as well as vertical structure of coastal water and tidal mixing.

The mesoscale has a spatial range of between 1km and 1000km with a corresponding temporal range from 1 day to 1 year. Processes which belong to this scale include coastal upwelling, mesoscale eddies and circulation.

The macroscale encompasses everything above 1000km and has a temporal scale of over 1 year. The basin scale circulation, gyres and vortex all belong to the macroscale.

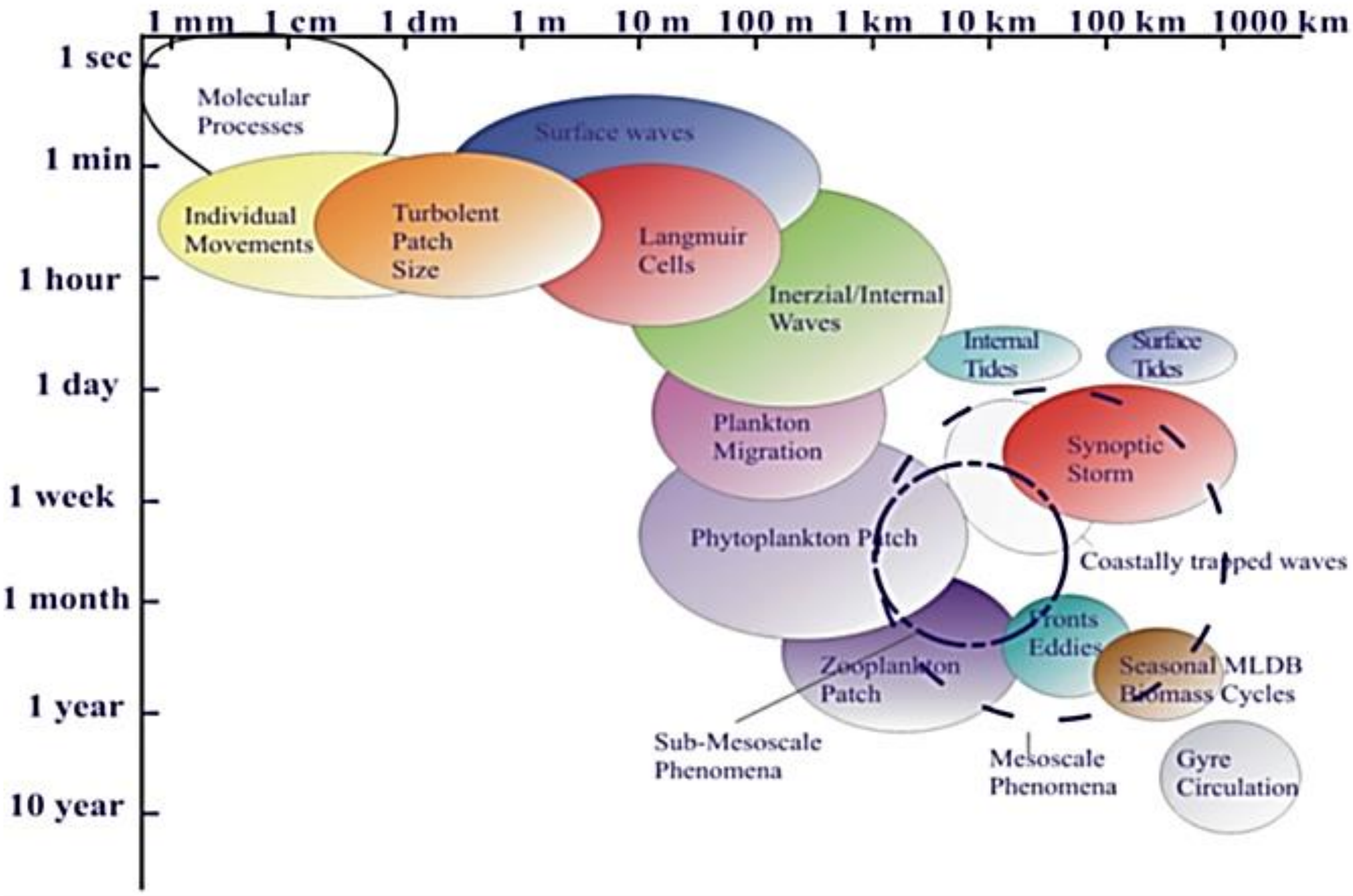

Figure 1: Environmental processes: from micro to macro scale

2.2 INTERACTIONS

All relevant marine environmental compartments should be considered when designing monitoring activities. Some compartments may be deemed of negligible relevance. Other compartments may be relevant but not of a practical scale to monitor. In this situation, existing literature may be consulted to provide the necessary knowledge. Figure 2 shows some of the main coastal benthic processes [2], while Figure 3 illustrates biological, physical and chemical compartments in the marine environment.

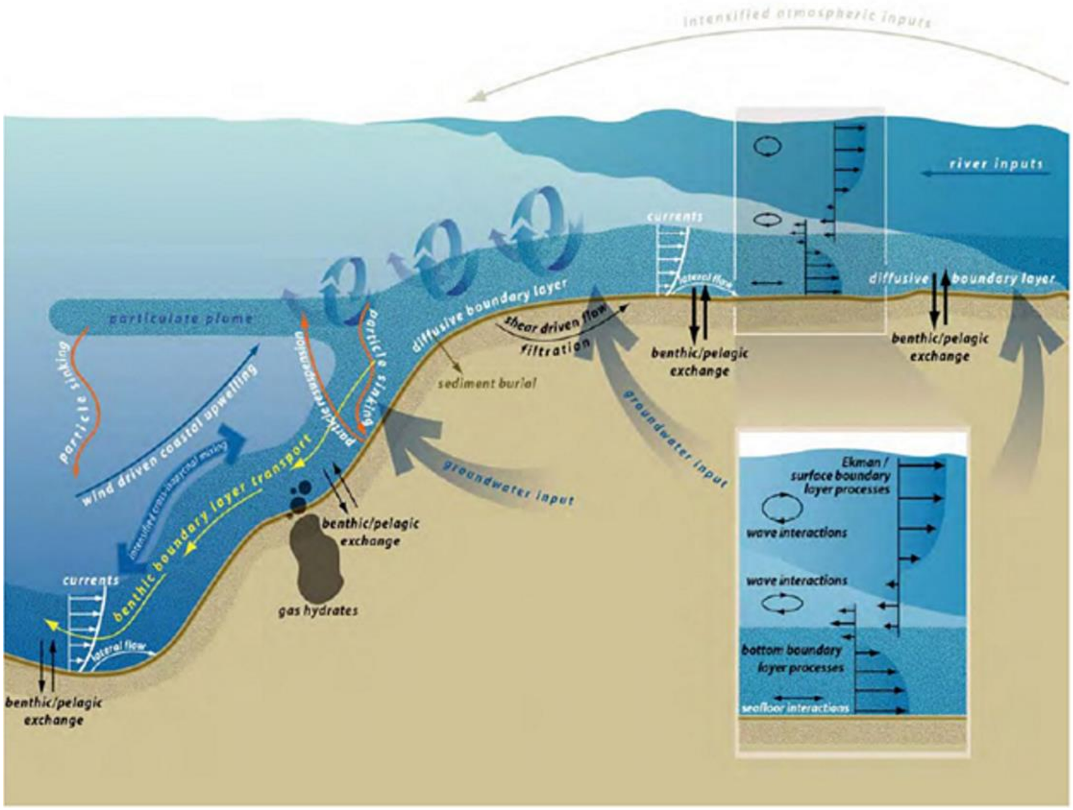

Figure 2: Coastal Benthic Exchange Dynamics (CBED); image from A. Boyette, Skidaway Institute of Oceanography

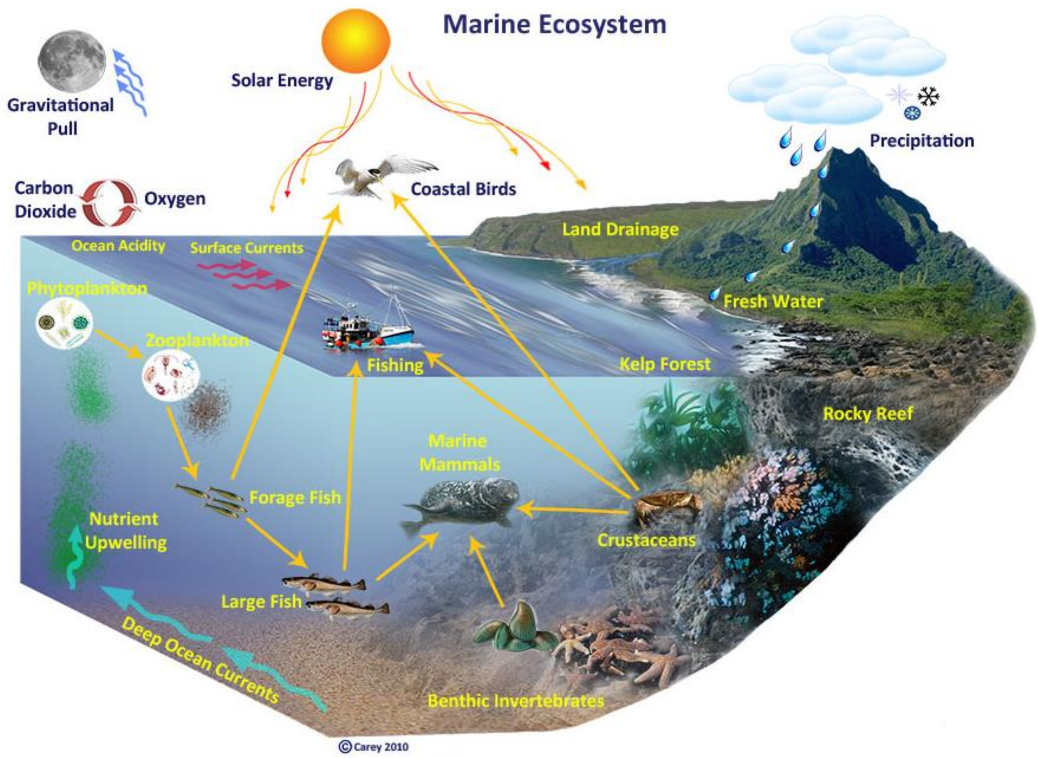

Figure 3: Marine compartments and basic processes. Image from the website of Berwickshire and North Northumberland Coast European Marine Site

3 PRINCIPAL ENVIRONMENTAL PARAMETERS

The collection of information about the measurement tools and methods used by partners in the MaRINET consortium was preceded by the identification of the main environmental areas of interest. A process was developed to assess the suitability of the measurement instruments used by the project partners of MaRINET to the environmental receptor groups. The findings are presented in the table of monitoring equipment and techniques, which is divided into two main groups:

- Measurements of physical parameters

- Measurements of biological parameters

Each group consists of environmental compartments related to climatic forcing (wind, waves and tidal current) and geomorphological parameters (bathymetry, sediment, mixing) as well as the physico-chemical parameters of the water column, and biological parameters which comprise all ecological and biological structures (plankton, macroalgae, benthic communities, fishes, marine mammals and birds).

4 DATABASE FOR ENVIRONMENTAL MONITORING TECHNIQUES AND EQUIPMENT

The Database for Environmental Monitoring Techniques and Equipment available within the MaRINET consortium can be accessed at D4.8 Instrumentation Database.

This database has been constructed using information from the tables of monitoring equipment and techniques (Section 3). Methodological approaches have been outlined as a function of both the characteristics of the parameters of interest, both spatial and temporal, and from consideration of the measurement technology available.

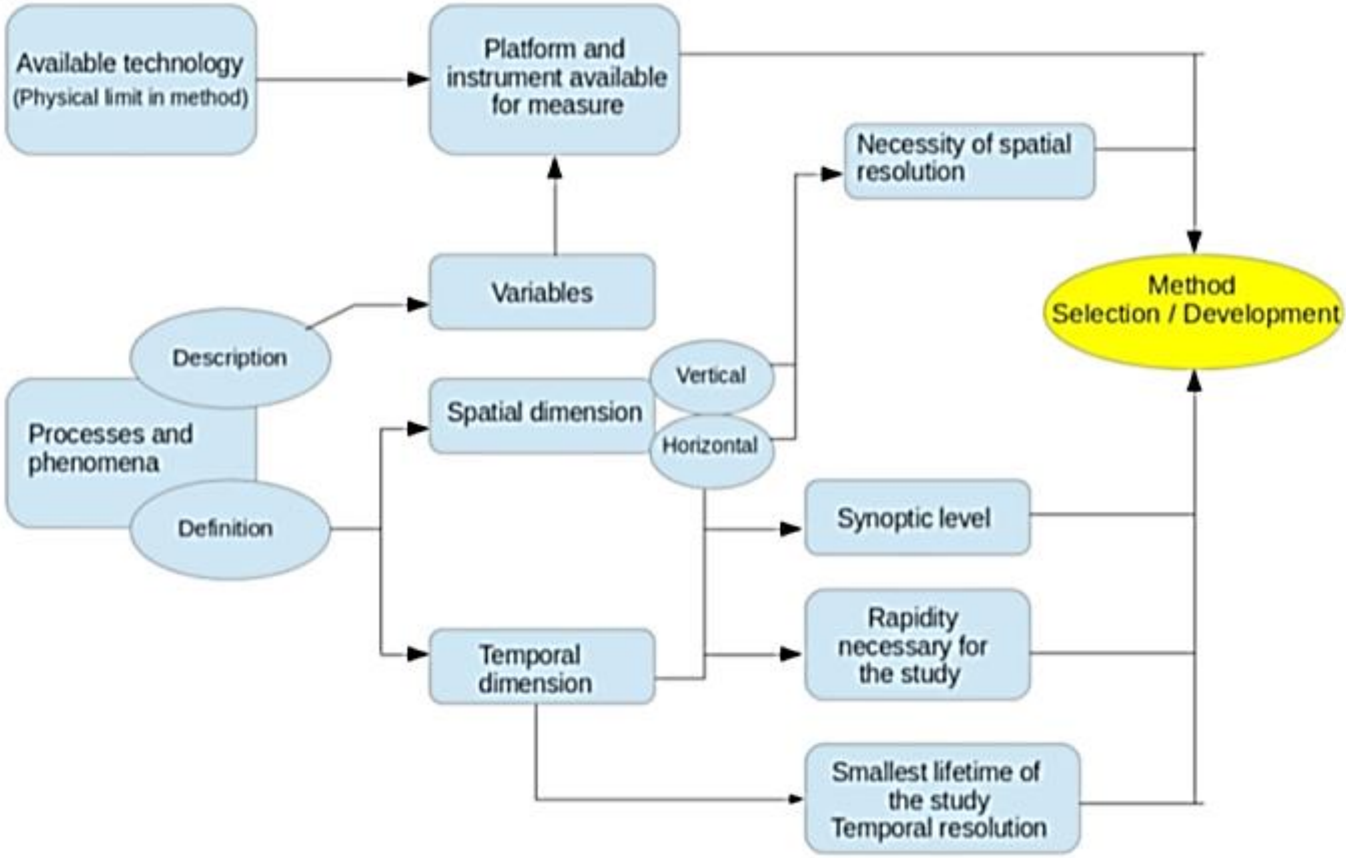

Figure 4: Conceptual framework for the implementation of monitoring in the marine and coastal environment

Processes which characterize the receiving environment of the marine monitoring activities have been divided into two groups: processes related to the physical parameters and processes related to biological parameters.

4.1 PHYSICAL PARAMETERS

4.1.1 Hydrodynamics

Physical parameters, generally included in the group of so-called climatic forcings, are of fundamental importance to the planning of monitoring activities to assess the impacts induced by the installation and operation of marine energy power plants. Almost all climatic forcings are a form of solar energy, for example wind, waves and marine currents, with the exception of tides which arise due to gravitational forces.

In this section methods and tools for measuring currents, tides, wind and waves are presented [3]:

- Currents and tides: the main techniques for measuring currents and tides involve the use of acoustic velocimeters, Lagrangian drifters and satellite observations. Secondary measurement techniques include wave buoys and underwater sonar.
- Waves: the main techniques of measurement of the wave climate are wave buoys, acoustic velocimeters, radar and satellite observations. In particular the most popular method is based on measurements carried out by surface buoys which are often coupled with the currents via installation of an ADP on the seabed. The difference between the two systems is that in the first case it is possible to have easily a near-real time communication and the access to data, in the second case often they are used for long term auto-acquisition deployment.
- Wind: the main instrument is the anemometer. Measurements are also possible through satellite observations and radar.

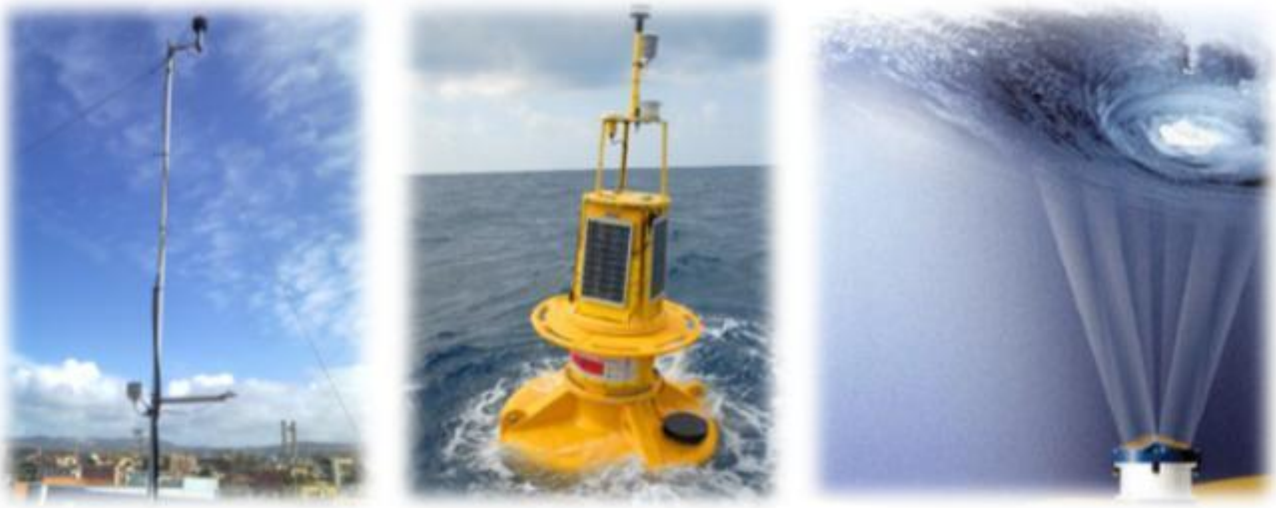

Figure 5: Anemometric station (left), wave buoy (centre) and Acoustic Doppler Profiler fixed on the seabed (right)

4.1.2 Morphology and sedimentology

Morphology

Morphology and sedimentology of the marine environment exist in a feedback relationship with both geology and climatic forcing parameters; wind, currents, waves and tides all shape coastal morphology.

The technique of choice for morphological measurements is active acoustics. Techniques such as Single beam which measures depth in a single point, Side Scan [4] sonar which is an extension to a sonogram which is function of seabed morphology, and Multibeam sonar which allows high-resolution total coverage of the area.

Figure 6: Single beam (left), Side Scan sonar (centre) and Multibeam techniques (right)

Sedimentology

Sedimentology is closely related to morphology and geology. Both climatic forcing, energy extraction and human activities such as dredging can affect sediment transport.

Sediment investigation often requires direct sampling of the seabed. The most used sampling techniques involve grabs, for example Van Veen and Eckman grabs, gravity corers, piston corers and box corers [5-6]. The choice of equipment to be used depends on both the sampling depth and the degree of disturbance of the substrate. The best sampling techniques often involve divers giving the advantage of speed of execution and minimal disturbance of the sample.

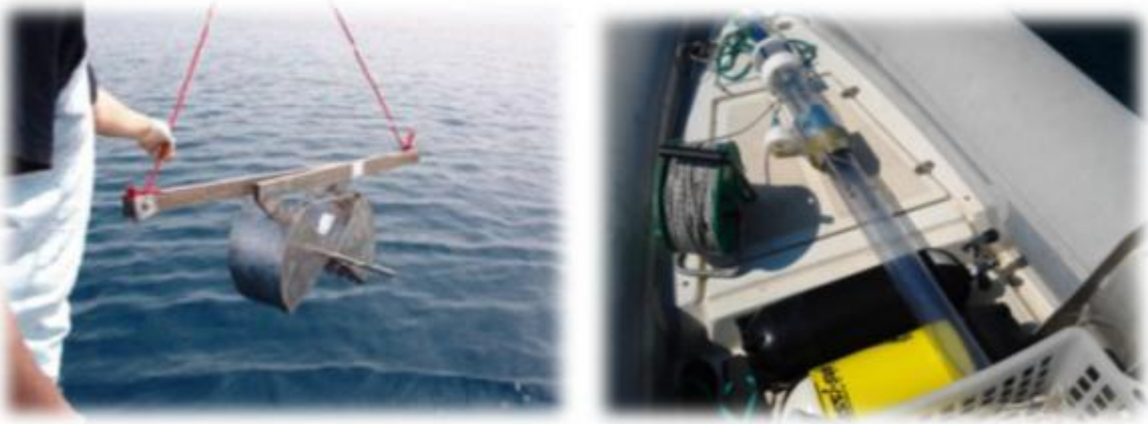

Figure 7: Van Veen grab (left) and gravity corer (right)

4.1.3 Water column

Water column analysis plays a central role in the knowledge of the dynamics and dispersion of chemical, physical and biological parameters and their vertical and horizontal distribution in marine waters.

Suspended solids and turbidity can be measured with transmissometers and irradiance techniques, and phytoplankton presence can be measured by fluorimetric sensors.

The main physical properties of the water, including depth, conductivity, temperature and the derived variable salinity and density, can be measured by multiparametric probes [5], shown in Figure 8 below.

Figure 8: Multiparametric water column profilers.

Water column parameter measurements can be performed using three main platforms: ships, towed vehicles and buoys. The measurement platform should be chosen according to the spatial and temporal scales of the phenomena to be investigated (Figure 9 and Figure 10).

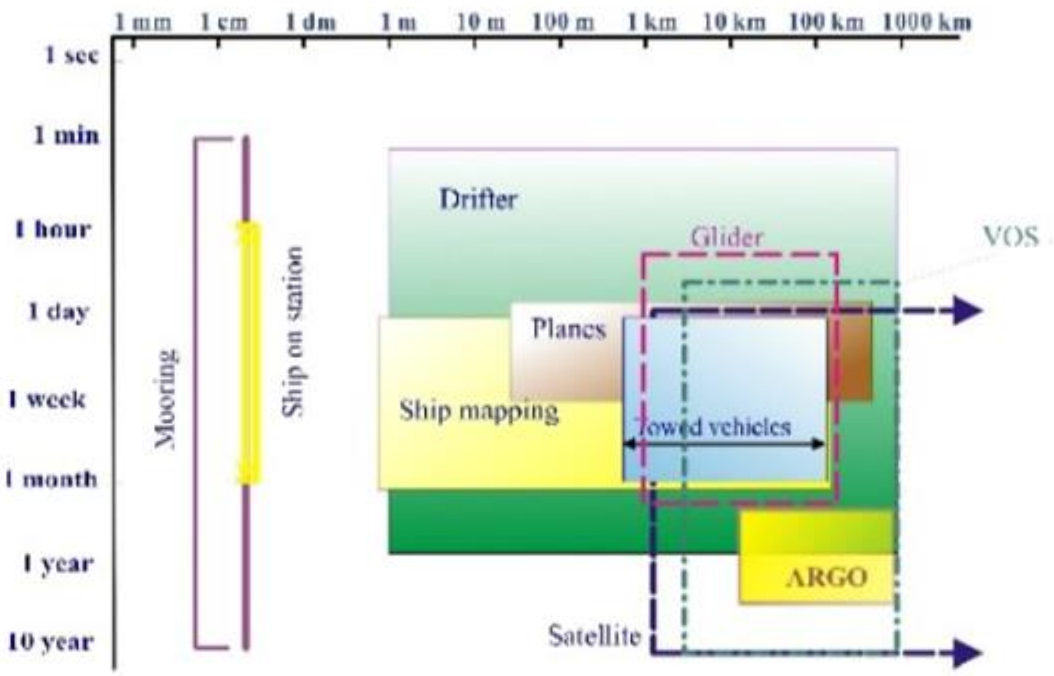

Figure 9: Horizontal, spatial and temporal coverage of different measurement platforms (Bidigare et al., 1992 modified)

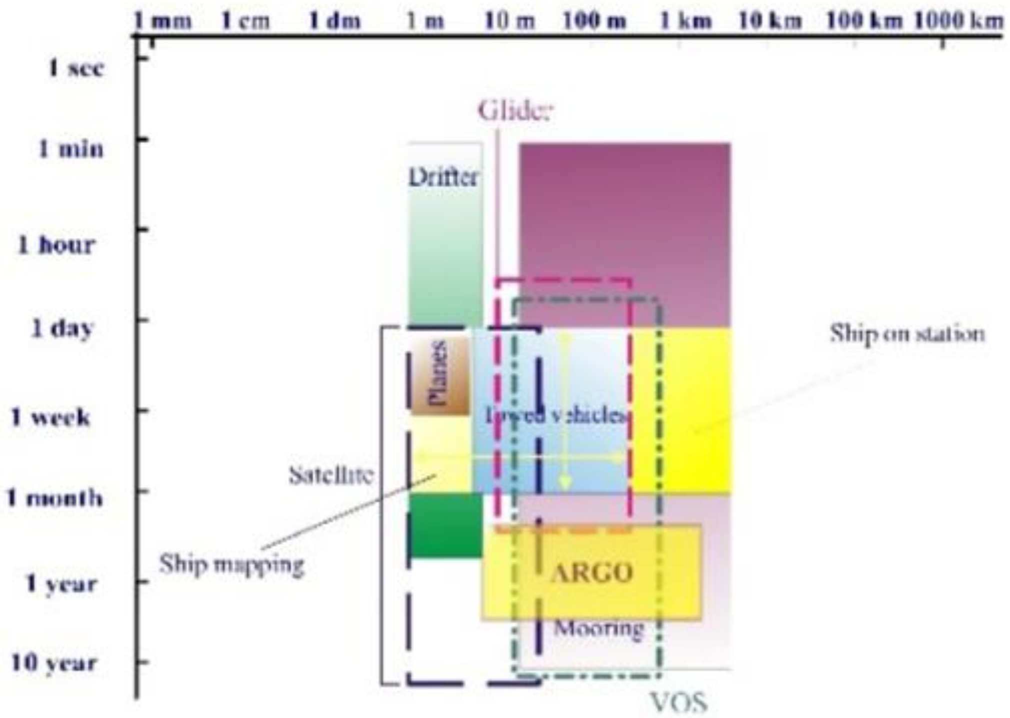

Figure 10: Vertical, spatial and temporal coverage of different measurement platforms (Bidigare et al., 1992 modified)

4.2 BIOLOGICAL PARAMETERS

The techniques and tools for the measurement of biological parameters in the marine environment are the basis of study for the processes that generate and regulate the life of marine organisms. Biological parameters are therefore the key elements for assessment of the anthropogenic effects, both direct and indirect, on the entire biotic. In the following paragraphs three groups are summarized: plankton and macroalgae, benthos, fish and marine mammals.

4.2.1 Plankton, Macroalgae and Seagrasses

Phytoplankton, the photosynthetic fraction of plankton, usually smaller in dimension than the animal one, is studied through the use of samplers and probes. Phytoplankton is sampled with towed nets, shown in Figure 12, for the microscopic assessment of species and relative abundance [7-8]. Bottles are used in the evaluation of pigment concentration, typically chlorophyll a, by sampling of microalgal cells in the water column at selected depths, see Figure 11. The collected water, filled with phytoplankton, is filtered, then the filter is analysed through spectrophotometer or liquid chromatography (HPLC).

Additionally, probes can be used for the *in-situ* assessment of phytoplankton populations [9]. The probes must be equipped with fluorometer sensors to exploit the principle of the fluorescence of chlorophyll in photosynthetic cells under a known light impulse. During the immersion of the probe, the absorption-emission behaviour of phytoplankton cells gives information on the abundance and distribution of the populations in the water column, for example the Deep Chlorophyll Maximum (DCM). When water layers with high population are detected, sampling procedure will allow a better assessment of the abundance.

Zooplankton, the animal microorganisms in plankton population, are mainly studied through the use of towed nets that collect animals on a vertical profile or along a fixed bathymetry [9-10], as shown on the left side of Figure 12. Collected water samples are then evaluated at the microscope, allowing the identification of phyla, families and even species of living animals. Information on the abundance of the species is assessed on statistical basis.

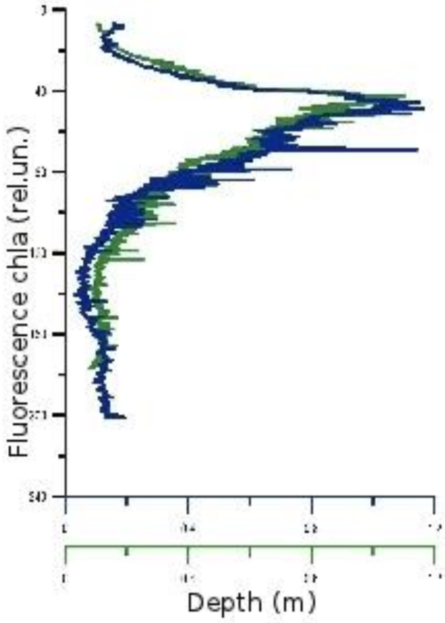

Figure 11: On the left a Niskin sampler. On the right a Chlorophyll a profile with DCM

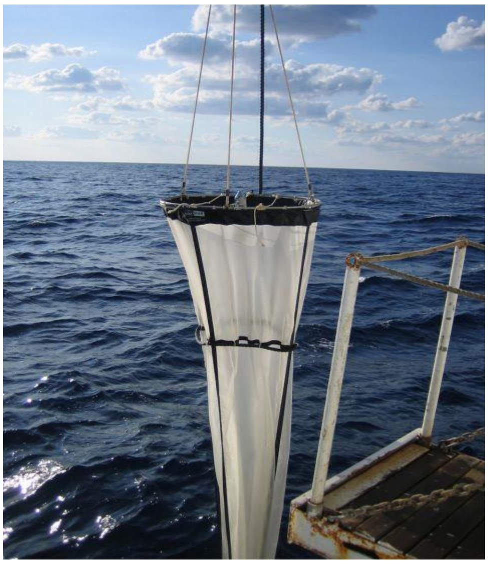

Figure 12: A zooplankton net ready to be towed

Macroalgae and Seagrasses are sampled using different equipment and techniques involving scientific diving, remote imaging, sonar and laboratory operations [11-12-13]. Tools like Remotely Operated Vehicles (ROV) and Side Scan Sonar (SSS) are used not only to assess the presence of species and their distribution, but also to collect information on the density over the sea bottom substrate. Scientific divers can assess the status and the density by measuring the number of organisms or shoots in a spatial unit as reported in Figure 13. Divers can also collect information on the status and the trend of a typical meadow by observing particular features that characterize a certain species, for example the lower meadow limit in *Posidonia oceanica* or the presence of other target types of algae. If needed, divers can withdraw living samples for further phaenological and genetic analysis at the lab.

Figure 13: A scientific diver performing a density measure on the Mediterranean seagrass Posidonia oceanica (Tuscia University 2013)

4.2.2 Benthic communities

Benthic communities are directly dependent on the type of substrate. Physical (particle-size class and depositional gradients) and chemical (total organic matter, total organic carbon and metals) changes of the substrate results in a direct effect on intra-and interspecific distribution of benthic organisms.

Benthos sampling is carried out with Van Veen grabs by capturing sediment samples of comparable volumes [5-14]. After sampling, sieving is performed in order to separate the organisms from the sediment using a mesh size equal to 1 mm. The biological and non-biological material that remains after sieving is transferred into suitable containers and fixed with a solution of formaldehyde and filtered seawater.

Typically a first phase of analysis involves identifying priority taxa - polychaetes, molluscs, crustaceans and echinoderms - into distinct groups. Subsequent analysis can lead to further identification of the lowest possible taxonomic level. The quantification of priority taxa already provides very important information when compared with the data obtained from the analysis of chemical and sedimentological characteristics of the substrate.

4.2.3 Fish, birds and mammals

Monitoring methodologies and strategies designed to understand the potential impact of OREDs on marine fishes are varied and differ according to the aim of the survey and the site characteristics [15-16]. Methodologies which can be applied to fish monitoring include:

- Desk study
- Commercial techniques (pots, trawls, fixed nets and lines)
- Underwater video and stills photography
- Grabs
- Acoustic Ground Definition System
- 'Scientific' echo-sounder

- Side scan sonar
- Landings data
- Effort data
- Fisheries liaison
- Socio-economic evaluations

An overview of fishing monitoring activities in relation to offshore renewable energy developments is presented in the following table.

Method	Metric	Equipment required	Survey design	Suggested monitoring interval	Analysis of change
Passive acoustic tracking	Habitat use Behaviour	Acoustic transmitting tags Underwater acoustic modem aboard a boat	At the site, 2m high seabed landers carry data-logging acoustic receivers. Suitable number (hundreds) of fish tagged with acoustic transmitters	Continuous Data uploaded remotely every few months	Fish behaviour over large spatio-temporal scales (departures, arrivals and occupancy times)
HD wide angle cameras	Presence/ absence Diversity Abundance	HD wide-angle cameras	Cameras deployed upon seabed and mid water column located along the interested zone	Continuous	Census of mobile species diversity and abundance

Table 1: Fish monitoring methodologies

For marine mammals, different monitoring approaches have been developed. Techniques vary from desk studies to visual observation and acoustic surveys. In particular, visual assessment is carried out mainly through boat observation. Ad-hoc campaigns can be scheduled but also ships of opportunity are commonly used in the surveys. In presence of capes and headlands, observation from strategic points on the coast can also be an effective method. In case of large marine areas and of migratory species, aerial surveys can be employed. Adverse marine condition can inhibit the quality of visual observation. Acoustic surveys are mainly deputed to sonar instrumentation, mainly through passive techniques. Outside shipping routes hydrophones surveys are a resource. Active sonar is currently being trialled and developed to detect and image diving marine mammals. In the following table methodologies for cetaceans (✓) and seals (◆) monitoring are listed in Table 2 below.

Monitoring Objective	Monitoring Method							
	Vantage point	Video range	Boat based Line Transectº	Aerial line transect	Autonomous Acoustic Monitoring	Photo ID	Telemetryº	Stranding schemes
Species present	✓◆		✓◆	✓◆	✓	✓	◆	◆
Density/abundance	✓◆		✓◆	✓◆	✓	✓◆	✓	
Productivity	◆			◆				
Distribution	✓◆	✓	✓◆	✓◆	✓		✓◆	
Behaviour	◆	✓	◆				◆	
Injury/mortality		✓					◆	✓◆
Communication/ masking					✓			
Barrier effects	✓							
SAC connectivity						✓◆	✓◆	

Table 2: Different techniques used in marine mammals monitoring

Seabirds are typically surveyed from a land-based visual observations point, or for larger developments further offshore, boat-based surveys may be used. Active sonar is currently being trialled and developed to detect and image diving seabirds. X-band radar techniques are being developed to image birds in flight above the sea surface too.

5 CONCLUSIONS AND RECOMMENDATIONS

This report links to the Database for Environmental Monitoring Techniques and Equipment which details the instrumentation, equipment and techniques presently in use by MaRINET project partners. The DEMTE database lists all the commonly used techniques, tools and equipment necessary for monitoring the marine environment as related to the installation and operation of marine energy devices.

An additional purpose of the report is to present any gaps in instrumentation and equipment database especially in view of a proper coverage of all activities necessary for the implementation of robust environmental impact monitoring plan. The guidelines, research and recommendations are discussed in D4.7 “Best practice report on environmental monitoring and new study techniques”.

From the analysis of the database it is clear that the number and quality of instruments and the equipment of MaRINET consortium can cover all marine environmental compartments shown in D4.8 Physical Measurement and D4.8 Biological Measurement.

Database gaps pertain mainly to the lack of facilities and laboratories in possession of underwater vehicles as well as by the reduced capacity of the consortium partners in the use of satellite technologies. These weaknesses could be easily overcome by ensuring a rational plan of equipment, techniques and knowledge sharing.

The Database for Environmental Monitoring Techniques and Equipment can be accessed at D4.8 Instrumentation Database.

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