Environmental monitoring techniques and equipment related to the installation and operation of Marine Energy Conversion Systems

Results of activities under project Marine Renewables Infrastructure Network for Emerging Energy Technologies (MaRINET) are reported, which led to DEMTE, a database, created on the basis of standardized monitoring of the marine environment during installation, operation and decommissioning of Marine Energy Conversion Systems. Obtained with the consortium partners' available techniques and equipment, the database shows that such instruments cover all identified marine environmental compartments, despite the lack of underwater vehicles and the reduced skills in using satellite technologies. These weaknesses could be overcome by an accurate planning of equipment, techniques and knowledge sharing. The approach here presented also leads to an effective analysis even in non-marine contexts.

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Introduction

MaRINET (Marine Renewables Infrastructure Network for Emerging Energy Technologies) is an EC-funded (FP7) consortium of 29 partners bringing together a network of 42 specialist marine renewable energy testing facilities. The network conducts coordinated research to improve testing capabilities, implements common testing standards and provides training and networking opportunities in order to enhance expertise in the industrial sector. The aim of the MaRINET initiative is to accelerate the development of marine renewable energy technology.

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MaRINET 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.

This paper is based on the results of the Database for Environmental Monitoring Techniques and Equipment (DEMTE), which is part of the Task 4.5 "Environmental monitoring related research" of Work Package 4, "Research to innovate and improve infrastructures, technologies and techniques" of the project. The 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). It provides 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. The logical approach used to build the DEMTE could be a useful tool to assess marine environmental issues in a broader context, for it could be used as a standard methodology to evaluate the effectiveness of monitoring activities coverage.

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 subjects 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:

- is compliant 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 the monitoring activity has to be based on high resolution and synoptic observations. The following elements must be considered in monitoring design:

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

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 macro-scale.

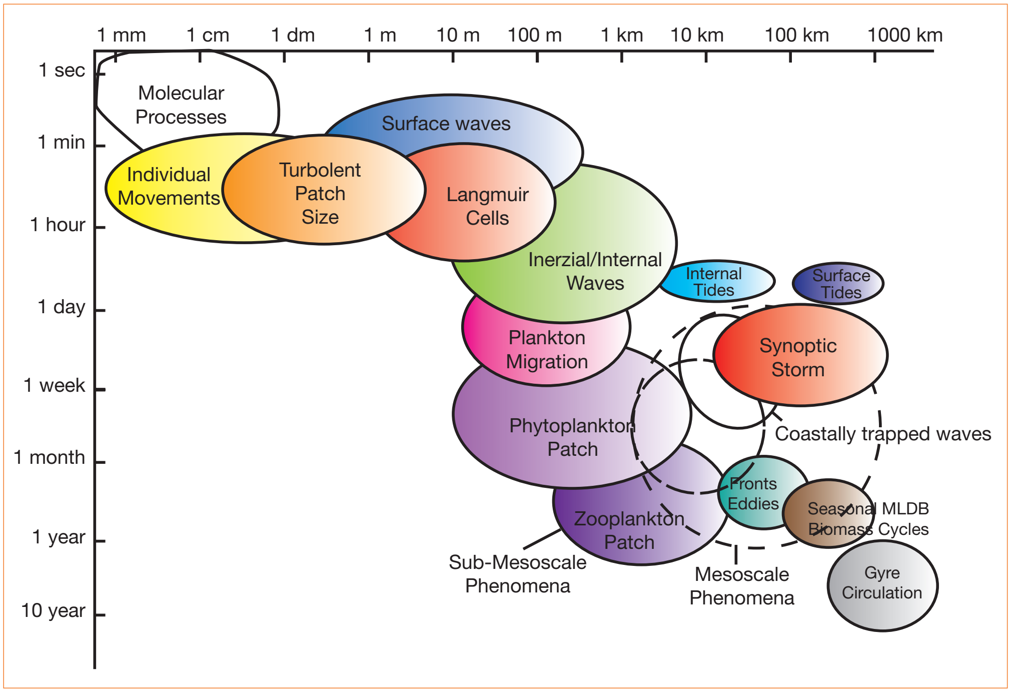

FIGURE 1 Environmental processes: from macro- to micro-scale
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The micro-scale has a spatial limit of 1 m and temporal domain of 1-2 days. Micro-scale processes are dominated by turbulence, including biological and mixed layer as well as vertical structure of coastal water and tidal mixing. The mesoscale has a spatial range between 1 km and 1000 km, with a corresponding temporal range from 1 day to 1 year. Processes belonging to this scale include coastal upwelling, mesoscale eddies and circulation. The macro-scale encompasses everything above 1000 km and has a temporal scale of over 1 year. The basin scale circulation, gyres and vortex all belong to the macro-scale.
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.

Methodology

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 tables 2 and 3 in which monitoring equipment and techniques are 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).

Physical parameters

Physical parameters, generally included in the group of the 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.

Hydrodynamics

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 [2]:

- 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 for measuring 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 Acoustic Doppler Profiler (ADP) on the seabed. The difference between the two systems is that in the first case it is possible to have a near-real-time communication and access to data easily, in the second case they are often used for long-term auto-acquisition deployment.
- Wind: the main instrument is the anemometer. Measurements are also possible through satellite observations and radar.

Morphology and sedimentology

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 sonar, which measures depth in a single point, Side scan sonar

[3], which is an extension to a sonogram that is function of seabed morphology, and Multi-beam sonar, which allows total, high-resolution coverage of the area.

Sedimentology is closely related to morphology and geology. Climatic forcing, energy extraction and human activities such as dredging can all 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 [4, 5]. 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 advantages of speed of execution and minimal disturbance of the sample.

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 water, including depth, conductivity, temperature and the derived variable salinity and density, can be measured by multiparametric probes [4]. 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 (Fig. 1).

Biological parameters

The techniques and tools for measuring 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 assessing the anthropogenic effects, both direct and indirect, on the entire biotics. In the following paragraphs three groups are summarized: plankton and macroalgae, benthos, fish and marine mammals.

Plankton, Macroalgae and Seagrasses

Phytoplankton, the photosynthetic fraction of plankton, usually smaller in dimension than animal one, is studied through the use of samplers and probes. Phytoplankton is sampled with towed nets for the microscopic assessment of species and relative abundance [6, 7]. Bottles are used in the evaluation of pigment concentration, typically chlorophyll a, by sampling of microalgal cells in the water column at selected depths. 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 [8]. 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, the 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 [8, 9]. 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 a statistical basis.

Macroalgae and Seagrasses are sampled using different equipment and techniques involving scientific diving, remote imaging, sonar and laboratory operations [10, 11, 12]. 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. 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 laboratory.

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 result 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 [4, 13]. 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 the 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.

Fish, birds and mammals

Monitoring methodologies and strategies designed to understand the potential impact of offshore renewable energy development on marine fishes are varied and differ according to the aim of the survey and the site characteristics [14, 15]. 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

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 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.

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.

Database for environmental monitoring techniques and equipment

The Database for Environmental Monitoring Techniques and Equipment has been constructed using information from the tables of monitoring equipment and techniques (Tab. 2 and Tab. 3), in which each technique is ordered in function of the related environmental compound. Methodological approaches have been outlined as a function of both the characteristics of the parameters of interest, both spatial and temporal, and considering the measurement technology available (Fig. 2). The DEMTE (Tab. 3) covers the availability of the instrumentation and of the monitoring techniques present within the consortium, and represents the result of a logical approach that can be used as a standard in different contexts. Considering the high number of partners in the consortium MaRINET, the gaps highlighted in the construction phase of the database can be a framework not really characteristic of the actual difficulty in setting up an effective monitoring plan for the impacts in the marine environment applied to the use of energy from renewable sources. However, the logical approach used can be an effective tool for the rapid assessment of any gaps as it can represent a standard methodology in the planning of this type of monitoring activities. The identification of the gaps also allows a quick estimate of the costs involved since the extension and multidisciplinarity of monitoring activities in the marine environment can result in a significant financial commitment.

Technique	Wind	Tides & Currents	Waves	Geomorphology	Sediments	Mixing	Water Column
Acoustic Backscatter Systems					Primary		Primary
Underwater Sonar		Secondary		Primary			
Acoustic Velocimeter		Primary	Primary		Secondary		
Passive Acoustic							
Optical Backscatter Systems				Secondary	Secondary		Primary
Lagrangian Drifter		Primary					
Sediment Particle Tracking					Primary		
Satellite Obs. and Tracking	Primary	Primary	Primary				Primary
Video		Secondary	Secondary	Secondary	Primary		
Wave Buoys		Secondary	Primary				
Conductivity meter						Primary	Primary
Fluorimeter							Primary
Tagging							Primary
Visual Surveys							Primary
Anemometer	Primary			Primary	Primary		
Non-Acoustic Current Meters		Primary	Secondary			Secondary	
Thermometer						Secondary	Primary
Sampler: Grabs					Primary		
Sampler: Nets					Primary		
Sampler: Vehicles					Primary		Secondary
Sampler: Corers					Primary	Primary	
Radar	Secondary	Primary	Primary	Primary			
Eh Meter					Primary		
Oxygen							Primary
Transmissometer						Secondary	
Water Column Profiler						Secondary	Primary
CTD						Secondary	Primary

Primary Technique
Secondary Technique

TABLE 1 Primary and secondary techniques for physical parameters measurements

Technique	Plankton	Macro-algae	Benthic Communities	Fish	Mammals	Birds	Inter-tidal communities
Acoustic Backscatter Systems		Secondary Technique					
Underwater Sonar	Secondary Technique	Secondary Technique		Primary Technique	Secondary Technique	Secondary Technique	
Acoustic Velocimeter							
Passive Acoustic				Secondary Technique	Primary Technique	Secondary Technique	
Optical Backscatter Systems	Secondary Technique	Secondary Technique		Secondary Technique			
Lagrangian Drifter							
Sediment Particle Tracking							
Satellite Obs. and Tracking	Primary Technique	Primary Technique			Secondary Technique	Secondary Technique	
Video		Primary Technique	Primary Technique	Primary Technique	Secondary Technique	Secondary Technique	Primary Technique
Wave Buoys							
Conductivity meter	Secondary Technique						
Fluorimeter	Primary Technique						
Tagging				Primary Technique	Primary Technique	Primary Technique	
Visual Surveys		Primary Technique	Primary Technique	Primary Technique	Primary Technique	Primary Technique	Primary Technique
Anemometer							
Non-Acoustic Current Meters							
Thermometer							
Sampler: Grabs			Primary Technique				Secondary Technique
Sampler: Nets	Primary Technique			Primary Technique			
Sampler: Vehicles	Primary Technique	Primary Technique					
Sampler: Corers							
Radar		Secondary Technique			Primary Technique	Primary Technique	
Eh Meter							
Oxygen							
Transmissometer							
Water Column Profiler	Primary Technique						
CTD	Primary Technique						

Primary Technique
Secondary Technique

TABLE 2 Primary and secondary techniques for biological parameters measurements

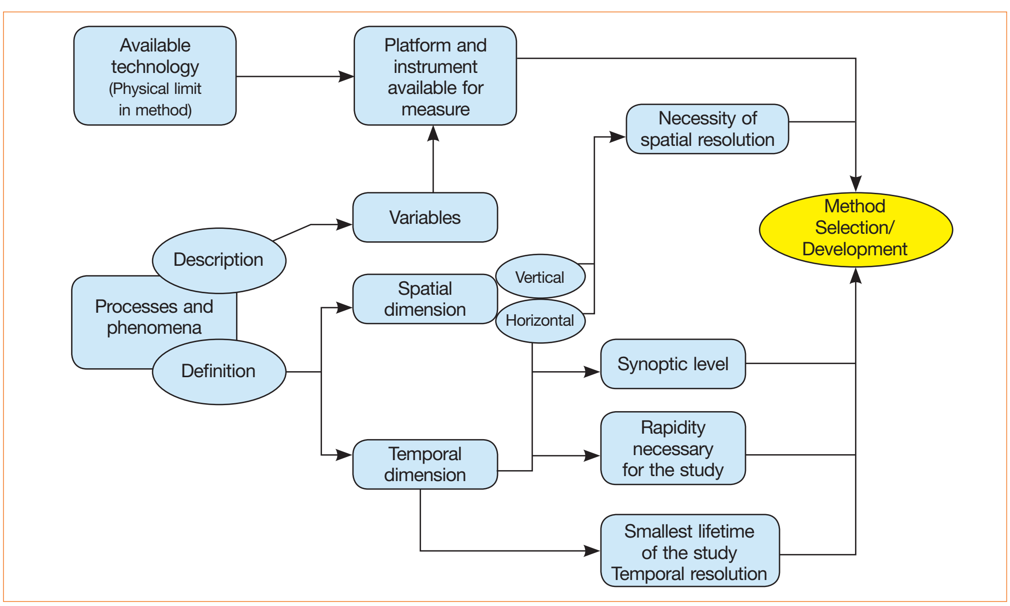

FIGURE 2
Conceptual framework for the implementation of monitoring in the marine and coastal environment

Instrument options	Operating principle	Methodology	Primary parameters	Secondary parameters	Operating range	Sampling frequency	Estimated cost (Euro)
			Acoustic Backscatter Systems				
Aquascat 1000	Record travel time and amplitude of backscattered acoustic signal	Frame mounted, downward facing	Sediment concentration		1 m	128 Hz	>10k
			Underwater Sonar				
Lowrance Structure Scan	Sonar	Fixed to boat	Geomorphology	Mixing benthic communities	Depth dependent	455 kHz and 800 kHz	1-10k
Nortek AWAC wave/current profilers	Doppler effect	Fixed to seabed	Current speed/ direction, wave height	Mixing benthic communities, fish, mammals, birds	Depth dependent	Depth dependent (1 MHz, 600 kHz, 400 kHz)	>10k
Teledyne RDI Sentinel Current Profiler	Doppler effect	Fixed to seabed or boat	Current speed/ direction, wave height	Mixing benthic communities, fish, mammals, birds	Depth dependent	0.05-1 Hz depth dependent, surface trace >1 sec period	>10k
M3i Satellite GPS buoy with echo sounder - Marine Instruments	Satellite GPS buoy with echo sounder	Moored to seabed	Fish	Sea water temperature	From 6-50 m with a 3 m resolution	500W and 50 kHz	1-10k
RESON Sea Bat 7125	High resolution multibeam echosounder	From boat	Sea floor characterization		0.5-500 m	1-50 Hz	>10k
			Acoustic Velocimeter				
Active sonar	Doppler effect	Fixed to seabed or boat	Currents, waves		Depth dependent	4-200 Hz	>10k
			Passive Acoustic				
Drifting Acoustic Recorder and Tracker (DART)	Acoustic recorder	Drifting hydrophone	Underwater noise, marine mammals	GPS location, temperature	5 m depth	4-96 kHz	1-10k
W.A. Inc. SM2M	Autonomous acoustic recorder	Fixed to seabed	Underwater noise, marine mammals	Temperature	150 m max depth	4-96 kHz	1-10k
Cetacean Research C55	Hydrophone	Fixed to seabed or boat	Underwater noise, marine mammals		Depth variable, dependent on attachment options	0.2-44 kHz	<1k
Neptune Sonar d/70	Spherical Hydrophone	Fixed to seabed or boat	Underwater noise, marine mammals		Depth variable, dependent on attachment options	10 Hz-100 kHz	1-10k
Bruel and Kjaer 8104	Hydrophone	Fixed to seabed or boat	Underwater noise, marine mammals		Depth variable, dependent on attachment options	0 Hz-180 kHz	1-10k
High Tech Inc. 99 UHF Broadband Hydrophone	Hydrophone	Fixed to seabed or boat	Underwater noise, marine mammals		Depth variable, dependent on attachment options	Designed for ultrahigh frequency response - Hz to 250 kHz	1-10k
DigitalHyd SR-1	Autonomous acoustic recorder	Fixed to seabed	Underwater noise	Temperature, pressure	35 m max depth	1 Hz - 25 kHz	1-10k
RTSYS EA-SDA14	Autonomous or cabled acoustic recorder	Fixed to seabed or deployed from boat	Underwater noise, marine mammals	Pressure, temperature, attitude	150 m max depth	Variable 39 kHz to 2.5 MHz	>10k
Jasco AMAR G2	Autonomous acoustic recorder	Fixed to seabed	Underwater noise	Temperature		64 kHz - 96 kHz	1-10k
Chelonia Ltd. CPOD	Autonomous acoustic recorder	Fixed to seabed	Cetaceans (whales, dolphin, porpoise), sonar	Temperature	100 mm max depth	20-160 kHz	1-10k
D11 Sonstec sonobuoy	Autonomous acoustic recorder	Fixed to seabed	Underwater noise, marine mammals		300 m max depth	1 Hz - 80 kHz	1-10k
Bruel and Kjaer Hydrophone - type 8105	Autonomous acoustic recorder	Towed	Underwater noise, marine mammals		100 m max depth	0.1 Hz - 160 kHz	1-10k

(continue)

(continue Tab. 3)

Instrument options	Operating principle	Methodology	Primary parameters	Secondary parameters	Operating range	Sampling frequency	Estimated cost (Euro)
			Video				
Baited Remote Underwater Video system	Video	Multiple 1 hour deployments of underwater video cameras	Biodiversity and abundance of mobile marine species	Sediments	100 m max depth	Seasonal to annual dependent on resource available, always at least annual	1-10k
SEAEYE Falcon DR	ROV with underwater camera	From boat	Biodiversity and abundance of mobile marine species	Sediments	1000 m max depth		>10k
Seabotix LBC300-5	ROV with underwater camera	From boat	Biodiversity and abundance of mobile marine species	Sediments	300 m max depth		>10k
Seabotix LBC 200-4	Small Observation class ROV	Visual inspection	Images, depth, temperature	Collection of small samples, fauna and flora identification, other equipment can be attached	200 m max depth		>10k
			Wave buoys				
Fugro Oceanor Seawatch mini II	Surface following accelerometer	Moored to seabed using a clump weight and bungee	Surface motion, waves (height, period and direction)	GPS location	150 m max depth	2 Hz	>10k
Datawell Directional Waverider mk III	Surface following accelerometer	Moored to seabed using a clump weight and a bungee	Waves (height, period and direction)	GPS location	150 m max depth	3.84 Hz	>10k
Fugro Oceanor Seawatch Wave Scan	Sensor for wave direction	Moored to seabed	Waves (height, period and direction)	Wind speed, air pressure, air temperature, solar radiation, currents, water temperature	Unknown		>10k
			Fluorometer				
Seapoint Chlorophyll Fluorometer	Optical	Water column profiler module	Water column quality (chlorophyll a)	Mixing	6000 m max depth	10 Hz	1-10k
Sea Tech Fluorometer	Optical	Water column profiler module	Water column quality (chlorophyll a)	Mixing	3000 m max depth	0.1 - 10 Hz	1-10k
			Visual Surveys				
Scientific divers	Visual survey	Boat-based point-point sample assessment	Seagrass coverage and density			Monthly	<1k per day
Human observers	Visual survey	Shore based wildlife observations	Marine mammals and seabirds	Vessel traffic and weather	4km max	20 hrs per week in 5x4 hr watches	<1k per day
Human observers	Visual survey	Boat-based point-sample assessment	Bird abundance and species diversity			Monthly	<1k per day
			Tagging				
Baited fishing pots	Baited traps	Twice yearly assessment of crabs and lobsters using potting	Species abundance and diversity		100 m max depth	Twice yearly	<1k

(continue)

(continue Tab. 3)

Instrument options	Operating principle	Methodology	Primary parameters	Secondary parameters	Operating range	Sampling frequency	Estimated cost (Euro)
			Meteorological				
1st class Anemometer from Thies, Vector Instruments, Risoe	Cup Anemometer	Help at a position of between 40-100 m above the ground	Wind speed		0-45 m/s wind speed	20 Hz	<1k
WindMaster Ultrasonic Anemometer, Metek, Thies, Lufft	Ultrasonic	Held at a position above ground	Wind speed and direction	Air temperature, humidity, barometric pressure, dew point	0-45 m/s wind speed	3 sec average wind speed, 10 min averages for all other parameters, up to 50 Hz	1-10k
Wind Vane, Thies	Potentiometer	Held at a position of between 40-100 m above the ground	Wind direction	Air temperature, humidity, barometric pressure, dew point	0-360°	1 Hz	<1k
Thies	PT 100, K-Element	Held at a position of between 40-100 m above the ground	Air density determination and correction, thermal effects, stratification		-30°C - +70°C	1 Hz	
GillMet meteorological station	Wind speed/ direction: ultrasonic probe. Air pressure: standard sensor. Temperature, humidity, dewpoint: standard probe	Ground mounter, continuous operation	Wind speed and direction, air temperature, humidity, barometric pressure, dew point		0-60 m/s wind speed, -35°C - +70°C air temp, 1-100% relative humidity, 600-1100hPa air pressure	Outputs 10 min average results	1-10k
Vaisala		Held at a position of between 40-100 m above the ground	Air density determination and correction		500-1100hPa	1 Hz	<1k
Lidar (Leosphere, Sgurr Energy, Halo Photonics, Zephir Ltd, Pentalum)	Laser doppler anemometry	Installed on ground: up to 220 m. Installed on nacelle of WTG: wind field in front/ in wake of turbine	Wind speed and direction	Air temperature, humidity, barometric pressure, dewpoint	0-60 m/s wind speed	0.5 Hz	>10k
Lidar (Sgurr Energy, Leosphere)	Laser doppler anemometry	Installed on ground: up to 4000 m	Wind speed and direction	Air temperature, humidity, barometric pressure, dew point	0-70 m/s, 80-4000 m		>10k
			Non-acoustic current meters				
Electromagnetic current meters	Strength of induced magnetic field of moving conductor	Frame mounted	2 components of velocity			Variable 1-32 Hz	>10k
			Sampler - Grabs				
Mini Van Veen Grab	Gravity grab	Small vessels operations	Benthic communities	Sediments	Depth dependent	Sampling area: 0.1 m2	<1k
Van Veen Grab	Gravity grab	Small vessels operations	Benthic communities	Sediments	100 m	Sampling area: 0.1 m2	1-10k
Modified Smith-McIntyre grab	Gravity grab	Medium-big vessels operations	Benthic communities	Sediments	300 m	Sampling area: 0.1 m2	1-10k
Shipeck Grab Sampler	Gravity grab	Small vessels operations	Benthic communities	Sediments	100 m	Sampling area: 0.04 m2	1-10k
			Sampler - Corers				
Uwitec Gravity Core	Gravity corer	Small vessels operations	Sediments	Mixing	Depth dependent		1-10k

(continue)

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(continue Tab. 3)

Instrument options	Operating principle	Methodology	Primary parameters	Secondary parameters	Operating range	Sampling frequency	Estimated cost (Euro)
			Radar				
WaMoS	X-band radar	Shore based	Waves and currents	Vessel traffic, flying birds	Variable depending on radar setup	Variable depending on radar setup	>10k
WERA	High frequency radar	Shore based	Waves and currents	Wind speed and direction, vessel traffic	300km max range depending on setup	Currents every 5 mins, waves every 17 mins	>10k
			Transmissometer				
Wetlab C-Star	Optical	Water column profiler module	Water column quality	Mixing	2000 m max depth	8 Hz	1-10k
SeaTech	Optical	Water column profiler module	Water column quality	Mixing	2000 m max depth	10 Hz	1-10k
			Water Column Profiler				
Primprod 1.08 and Primprod 1.11	Multiparametric profiler	Water column profiler	Water column quality (temperature, pression, biomass, photosynthetic activity, underwater irradiance)	Mixing	200 m max depth	1-4 Hz	>10k
Idronaut 316 and Idronaut 317	Multiparametric profiler	Water column profiler	Water column quality (pressure, temperature, conductivity, oxygen, pH)	Mixing	1000 m max depth	20, 30, 40 Hz	>10k
T-FLAP	Multiparametric profiler	Water column profiler	Water column quality (pressure, temperature, conductivity, oxygen, pH)	Mixing	1000 m max depth	5.6 Hz	<1k
			CTD				
SBE 19 Seacat	CTD	Profiler and moored mode	Water column quality (CTD)	Mixing	6800 m max depth	4 Hz	1-10k
Seabird 911	CTD	Water column profiler	Water column quality (CTD)	Mixing	6800 m max depth	24 Hz	>10k
RBR XR 420	CTD	Moored to seabed	Conductivity (salinity), depth, temperature	Mixing		0.05 Hz	>10k
Aanderaa 4120 IW	CTD and salinity	Fixed on the facility buoy	Water column quality (CTD)	Mixing	300 m max depth	0.5 Hz	>10k
Valeport miniCTD	CTD	Water column profiler	Salinity, temperature, depth	Mixing	500 m max depth	4 Hz	<1k
Seabird SBE25	CTD	Water column profiler	Water column quality: conductivity, temperature, pressure, oxygen, irradiance, light transmission, fluorescence (chlorophyll a), pH	Mixing	3000 m max depth depending on senser	8 Hz	>10k

Conclusions

This work shows 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 work is to present any gaps in the instrumentation and equipment database, especially in view of a proper coverage of all the activities necessary for the implementation of robust environmental impact monitoring plan.
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; database gaps pertain mainly to the lack of facilities and laboratories endowed with of underwater vehicles as well as to the reduced skills of the consortium partners in the use of satellite technologies. However, the logical approach adopted can be an effective tool for the rapid assessment of any gaps as it can represent a standard methodology in the planning of this type of monitoring activities. The identification of the gaps also allows a quick estimate of the costs involved since the extension and multidisciplinarity of monitoring activities in the marine environment can result in a significant financial commitment.

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