Joint European Research Infrastructure network for Coastal Observatories

SEVENTH FRAMEWORK PROGRAMME

Definition strategy and interfaces with the monitoring of marine biodiversity

JERICO deliverable D1.9

Task 1.4 Proposed strategy for biodiversity (part of WP1)

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Definition strategy and interfaces with the monitoring of marine biodiversity

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2. Executive summary

Here the potentials for JERICO to become a network for biodiversity observation are identified. It appears to be not that straightforward to select a limited number of parameters or proxies to describe biodiversity, as biodiversity can be estimated at various levels (e.g. organism -, population -, community -, ecosystem level), for a variety of species groups in need of different methodologies to sense diversity (e.g. phytoplankton, zooplankton, macroinvertebrates, macrophytes and –algae, fish, birds, mammals), in different environments with their own specifics (e.g. pelagic -, benthic -, above water environment). Several aspects that might be of importance towards biodiversity and give potentials for observation as an indicator are amongst others: functional diversity, genetic diversity, habitat diversity, taxonomic diversity, foodweb structure, environmental connectivity, size distribution, biomass, primary production, behaviour and habitat use. Taking this into account, three types of potential strategies for JERICO are identified, of which a combination of the three might be the most promising way to go. 1) JERICO could potentially implement one or a few specific biodiversity related sensing techniques in its existing and foreseen infrastructure of platforms. 2) JERICO could link to existing or developing pan-European initiatives of biodiversity observation and tune mutual activities or finalize cooperation. 3) JERICO could optimize it's for biodiversity relevant or even essential biochemical sensors already present within the network to deliver explaining - or model parameters. Potential (groups of) methodologies considered for implementation to sense aspects of biodiversity are acoustic telemetry, carbon dioxide measurements, camera autodetection, chromatography, in situ collection, direct observation, echosounding, flow cytometry, fragment length polymorphism detection, fluorometry, use of genetic markers, hydrophones, multibeam and sonar applications, oxygen measurements, photo or video analyses, remote sensing techniques, sequencing, spectrophotometry, spectroradiometry and the use of stable isotopes. Making use of literature and expert information (e.g. input from a workshop) methodologies are estimated on usefulness as a potential indicator (i.e. the biodiversity aspects as mentioned before), the multilevel applicability in terms of biodiversity levels, species groups and environment as indicated before, but also on multiplatform applicability, the continuousness of data deliverance, the spatial scale that can be covered, the potentials for integration in current observatories, the current operation status and the operational and installation costs. On basis of estimated scores a ranking of potential methodologies of relevance towards biodiversity observation within the JERICO network was obtained from which it was concluded that particularly semi-automated imaging techniques and passive acoustics might be promising, whereas genetic markers might have potentials in the future. The value towards biodiversity of the already implemented largely biochemical focal parameters is largely that they define boundaries for biodiversity, i.e, habitat diversity and the mosaic of ecotopes, defining the potential biodiversity, however not the actual biodiversity. This is especially the case for temperature, salinity, carbon dioxide and dissolved oxygen, but also for chlorophyll-a, turbidity and nutrient concentrations and ratios that add to the estimation of the quality state of the habitats. Considering the current strengths of the JERICO network, and the JERICO criteria defined for their observation platforms; i.e. observations should potentially be automatic, continuous and (quasi) real-time, the niche that JERICO perfectly could fill in is that of the observation network sensing biodiversity potentials, biodiversity boundaries and explaining variables for observed biodiversity changes. Therewith the network can potentially play an important role towards the upscaling, i.e. in inter- and extrapolation of more local and detailed in situ biodiversity observations to the pan-European scale. An intermediate role between in situ realized biodiversity observations (detailed and local of nature and often with delayed deliverance) and earth observation initiatives is foreseen, where the three levels need each other to cover the pan European scale and achieve sufficient indicator value. Within this light it is of importance to tune mutual characteristics, temporal and spatial resolutions and timing and positioning of observations between the three levels of observations. Promising would be close cooperation with biodiversity observation initiatives like EMBOS and ICES, and probably both as they each have their strengths. To achieve pan-European ecotope identification by the JERICO network (i.e. three-dimensional potential biodiversity mapping), implementation of active acoustic techniques and imaging techniques (for seafloor mapping) and eventually measurements of currents might be promising as well. It is also of importance to be and remain involved in the European and global networks of networks to exchange expertise on biodiversity related sensing between networks covering different realms and geographic regions and ensure smooth transitions in observations. Also connecting to and discussing with initiatives identifying indicators for biodiversity observation and evaluating management tools is of importance, to stay informed and put forward the practical perspective from the observatories point of view.

3. Introduction

JERICO, the Joint European Research Infrastructure network for Coastal Observatories, aims to increase the coherence and sustainability of European coastal observatories within a pan-European network. To achieve this amongst others best practices for design, implementation, maintenance, data distribution and quality standards are designed within the current FP7 Infrastructures project that runs from May 2011 till May 2015. One of the JERICO strategies is to focus on a limited number of parameters, i.e. Temperature, Salinity, Chlorophyll-a, Turbidity, Dissolved Oxygen and Carbon dioxide. Therewith JERICO particularly contributes to the streamlining of observations on the biochemical compartment of especially the European coastal seas. Whereas coastal observatories are largely established driven by domestic interests or resulting from short-term research projects, nowadays there is more demand for the detection, understanding and forecasting of crucial coastal processes over extensive areas. This not only for fundamental research objectives but with increasing importance also for coastal seas management purposes. Within this scope, nowadays particularly the monitoring of marine biodiversity is of increasing importance. This because marine ecosystems, and biodiversity in particular, are heavily under pressure of global change, anthropogenic activities, exploitation, pollution and globalisation. However, also restoration measures are being taken and sustainable coastal management has been implemented on large scale, which asks for evaluation. Additionally, data are needed for assessments regarding the national and European policies and regulations; e.g. the Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD), Common Fisheries Policy (CFP) and Bird and Habitat Directives within the frame of Natura2000. This makes it as well of interest as of importance to investigate the potentials of the JERICO observatories network to develop into an important network to sense and assess the biodiversity state and developments of the European coastal zones. The current report describes the process and findings of an investigation of the potentials of the JERICO network to develop into a network of observatories for biodiversity as well.

4. Methodology

JERICO proposes a pan-European approach for a European coastal marine observatory network. The focus of the network is on physical and biochemical coastal parameters to be measured with automated platforms and sensor systems. To make the network highly valuable or even essential towards the detection, assessment and forecast of the state and development of marine biodiversity in European coastal waters, three strategies can be distinguished. 1) Biodiversity sensors or sensors directly indicative for the biodiversity state or the health of (parts of) the ecosystem, can be implemented in the existing or foreseen JERICO observatory network. 2) The JERICO network can directly link to existing or developing initiatives of biodiversity networks or Pan European biodiversity measurement programs by tuning of the mutual activities or even finalization of cooperation agreements. 3) Optimization of for biodiversity relevant or even essential physical and biochemical sensors delivering explaining - or model parameters, already present or foreseen in the JERICO network. A combination of the three strategies (which do already overlap to some extent) seems to have the highest potential of successfully making the JERICO network an important network to sense and assess the biodiversity state and developments of the European coastal zones.

To come to an implementation strategy existing of a set most promising focal points, in terms of operability, implementability, cost effectiveness and potential importance towards the monitoring, assessment and forecast of biodiversity and biodiversity developments, the following methodology is used:

To start with, a gross list of potential biodiversity sensing methodologies on basis of literature and by consultation of some marine ecology experts is composed. Besides the observatory -, sensor - and data type, the indicator characteristics, the biodiversity level and target group for which it is indicative, the type of environment in which it is used and the scale on which it operates, are described, the estimated implementability in the JERICO observatories network, the estimated indicator value, the estimated timeframe in which it can be made operable and the estimated costs are scored. A first overview was presented and discussed with experts from inside and outside JERICO during a workshop on October 17th in Villefranche-sur-Mer (France), added to the program of the JERICO WP10 workshop. Herewith the number of ideas was extended, the first gross list (which was a mixture of proxies for biodiversity and methodologies to measure proxies for biodiversity) could be adjusted and homogenized, and the estimated scores could be fine-tuned. Amongst others the developments and new tools as identified within WP10 in relation to the monitoring of key biological compartments and processes gave new insights. Herewith a ranking on basis of the implementability could be made. Simultaneously the pan-European biodiversity networks and monitoring initiatives are identified and characteristics described to determine the potentials of fine-tuning monitoring and observing systems between JERICO and the biodiversity related initiatives. Additionally the value of currently identified sensors and physical and biochemical parameters within JERICO towards biodiversity monitoring is described and specific necessities to increase the exchangeability and optimize the data characteristics and quality for biodiversity monitoring purposes are identified.

The current study will end with a proposal for a roadmap to implement, adapt and cooperate to become an observatories network for biodiversity, optimally positioned among ongoing initiatives in this field.

5. Potential methodologies to measure (proxies of) the biodiversity state

5.1. Potential proxies for biodiversity

‘Biodiversity’ or ‘Biological Diversity’ is a concept which refers to the range of variation or differences among living organisms, where global biodiversity refers to the entire living world. Although the concept is simple and one can talk about a biodiversity range from low to high; measuring or evaluating it is more complicated as it is rather difficult, time consuming and/or expensive to measure total diversity. Therefore biodiversity is generally estimated for a restricted group of organisms, spatially and/or temporally defined, evaluated on a certain level, potentially representative for the total biodiversity. However, to minimize the efforts and optimize the representativeness, proxies and/or indicators can be used to evaluate biodiversity. To compare or evaluate biodiversity, it is essential that methodologies (of measurement and evaluation) are well described and standardized.

Here a short (and far from complete) overview of potential methodologies to measure the biodiversity state and/or developments is given:

5.1.1. *Community composition*

Monitoring the species compositions is a way of directly measuring the biodiversity. Species compositions can be analysed for a variety of taxonomic groups, with however differences in indicator value for entire systems and the biodiversity beyond the evaluated taxonomic groups. Each group has its own most effective sampling methodology, representative for different scales. The species composition of various taxonomic groups can be indicative for the biodiversity as a whole. Whereas traditionally for the invertebrate, plant and microorganism groups (e.g. phytoplankton, zooplankton, macrobenthos, hyperbenthos, etc), monitoring is based on sampling programs which ask for specialist knowledge and often rather time consuming species identification in the laboratory afterwards. Taxonomic groups belonging to the invertebrates, plants and microorganisms often give detailed information about the sample sites, with communities directly responding to (local) changes. Often a trade-off is made between costs/time, number of samples and sample frequency and information detail, for instance by reducing the taxonomic level of identification from species to genus, family or higher taxonomic levels or working with functional groups. Vertebrate groups (e.g. mammals, birds, fish, etc.) might be easier to identify to species level and are often indicative for larger areas. However, for those groups it might be more difficult to obtain large datasets (therefore invertebrate community data might be more useful to work with diversity indicators), communities do often not directly respond to changes, and changes might be due to changing conditions in other regions. There are however more species indicated with a special status (protected species, species with conservation objectives) for the vertebrates.

The ratio of functional groups, taxonomic groups and species with special traits and spatial patterns or developments in time can be analysed and be indicative for biodiversity at different levels. Also species numbers and specific biodiversity indices based on numbers, sizes, biomasses or sensitivity scores and patterns and developments there in are common practice to evaluate biodiversity, as there are taxonomic distinctness, phylogenetic structure, fish indices either based on traits or key species, log-normal distributions, Shannon, Margalef, Pielou and Hill indices of diversity, richness and eveness and derives of those and combinations or composed indicators (Clarke & Warwick, 2001; Féral et al., 2003; Borja et al., 2011).

5.1.2. Habitat composition and diversity

Abiotic parameters describe the environment and therewith the potentials for biota (e.g. Ysebaert et al., 2003; McArthur et al., 2010). Singular parameters can give insight is potentials for species, species compositions and eventually in biodiversity. But combinations of abiotic parameters resulting in ecotopes or environmental maps with which also the mosaic of habitats including shapes, areas and connectivity can be described will give more detailed information about the potential biodiversity. Even more accuracy can be achieved by taking habitat quality (e.g. potential pressures) into account as well. Besides visual senses methodologies and direct measurements in the field, a range of methodologies is available to facilitate more efficient, faster, or on a larger scale, habitat mapping, as there are acoustic and imaging techniques from small scale point measurements to satellite borne remote sensing.

5.1.3. Size distribution

Analysing the size distribution within or among taxonomical classes as an indicator of the completeness of the foodweb and therewith the biodiversity is something that can be applied on active or continuous sampling data. It can even been done from species sighting recordings taking average size or weight of species. Size distribution analyses are however also potentially suitable to be done from photo or video recordings and can even be automated in flow through systems or continuous periodical samples, for instance for plankton and hyperbenthos.

5.1.4. Biomass

Biomass on itself is generally not a good indicator for biodiversity, although biomass is often a valuable additional parameter to for instance community compositions or the primary production. Biomass per species or taxonomic or functional group is most valuable although direct collection and species identification after sampling is generally necessary. Total biomass is however for smaller sized specimens often easier to measure and can potentially be automated as well, in the form of a weighing robot possibly combined with an oven (i.e. to measure dry weight or ash free dry weight). A weighing robot is however rather large and needs a stable ground which makes it difficult to implement it e.g. on boats; and is thus mainly suitable for land-based laboratories. Biomass can be estimated from sizes and average weights of species and can therefore potentially be calculated from photo or video recordings as well.

Phytoplankton biomass can also be estimated, when frequently calibrated with cell counts, by measurement of the chlorophyll-a concentration. This can be done by using fluorometry or spectrophotometry (Meire & Maris, 2008; Proctor & Roesler, 2010).

5.1.5. Primary Production

The primary production forms the basis of the foodweb and determines the potential energy available for higher trophic levels. In coastal seas especially phytoplankton determines the primary production where macrophytes and macroalgae are generally only of importance in nearshore habitats. However, in intertidal and shallow zones also microphytobenthos can be of importance and therefore account for almost 50% of the primary production in certain estuaries (Underwood & Kromkamp, 1999). The primary production is dependent of the algal biomass, light radiation and penetration, water temperature and nutrient concentrations and can change with the planktonic composition or impacts of pollutants (Meire & Maris, 2008). Algal biomass, often estimated by measurement of the chlorophyll-a concentration does not reflect the available energy for higher trophic levels as the biomass present, depends on the plankton turn-over and grazing. Therefore primary production is often evaluated relative to the phytoplankton biomass. In general, at a high primary production – phytoplankton biomass ratio (P:B ratio) the system is in a good environmental state where biodiversity can be high. At a low P:B ratio the system might suffer from eutrophication when phytoplankton biomass is high or from other deteriorating aspects (e.g. pollutants, high turbidity) when also the biomass is low which can be considered a poor ecological state with resulting low biodiversity (Underwood & Kromkamp, 1999). Primary production therefore does not only reflect the diversity among phytoplankton populations but as the basis of the foodweb, also at higher trophic levels.

Primary production is often measured using the ^{14}C methodology where radioactively labelled CO_2 is added to water samples after which the biomass production is measured at different light intensities. This method is time consuming and can only be measured with regular intervals which ask for temporal and spatial interpolation. Although still in development, there are several promising techniques that facilitate continuous primary production measurements. Such techniques are Fast Repetition Rate Fluorometry (FRRF), Pulse Amplitude Modulated Fluorometry (PAM) and potentially the calculation of primary production from continuous oxygen or CO_2 concentration measurements (Meire & Maris, 2008; Houliez et al., 2013; Lawrenz et al., 2013). There are several initiatives to develop devices for continuous primary production measurements suitable for application in ferryboxes, ships of opportunity* and moorings. E.g. within a 7th framework project 'PROTOOL' an instrument combining a fluorometer, an absorption meter and a reflectance module was developed (based on the FRRF approach) and tested (Kromkamp, 2012).

Depending on the methodology used, the assessment scale goes from very local and for specific time points (^{14}C method), to larger scale prediction when the temporal and spatial measurement density is increased. As indicated, better predictions can be obtained when using techniques that can be applied continuously, preferably in combination with physical and biochemical parameters as nutrient concentrations (P, N, Si), light extinction, oxygen concentration, temperature and chlorophyll-a concentration or phytoplankton biomass. Continuous measurement of the primary production of the benthic communities might be more problematic as the pigments are not in suspension. There a combination of point measurements (with either one of the above-mentioned techniques) and spectroradiometry or remote sensing colour mappings might be the best solution at present.

*Ships of opportunity = Ships with non-science objectives on which equipment is installed that collects scientific data during the daily voyages without hampering the daily activities (e.g. ferryboxes, cameras or detectors on fishing vessels, etc)

5.1.6. Pigment analysis

Pigments act as tracers to elucidate the fate of phytoplankton. They can both be used in in situ and remote-sensing applications, detecting algal biomass and major taxa or functional groups through changes in water colour. Pigment analyses can be done for the phytoplankton as well as the microphytobenthos. It is for instance valuable to monitor the share of diatoms in the total phytoplankton biomass, but also other developments indicating (potentially toxic) algal blooms or the presence or expansion of pest – or exotic algae can be of importance. It is however essential to combine pigment analyses with frequent sampling of algal communities and species identifications for calibration using microscopy, or to use pigment standards for calibration (Thyssen et al., 2011). It is particularly valuable to monitor the composition of the phytoplankton in combination with the monitoring of the primary production and the phytoplankton biomass (which can directly be calculated from achieved data). Pigment analyses can be done using High-Performance Liquid Chromatography (HPLC). HPLC measurements can be automated in case of phytoplankton analyses using an auto-sampler (Van Leeuwe et al., 2006; Meire & Maris, 2008). However, as the equipment needs quite some space and chemicals must be added, measurements using HPLC can be installed on fixed coastal platforms, in ferryboxes or on ships of opportunity (needs control on a daily basis) or samples should be collected using other devices with analyses afterwards.

Another way to determine phytoplankton composition is to analyse the absorption spectrum with an absorption meter. Such measurements must be validated with absorption spectra of monocultures and taking background absorption of detritus into account, after which mathematical correlation result in the composition and biomass of phytoplankton species. A technique that can result in real time data, for instance in flow-through systems running from ferryboxes or fixed stations. Pigments and therewith fytoplankton or microfytobenthos composition can also be measured using a spectrophotometer. As indicated this can either be done directly in the field or by scanning from above; e.g. from a plane or using satellite observation. Another possibility is to measure fluorescence with a fluorometer, at which typically pigment concentrations are indirectly measured at pigment specific wavelengths (Proctor & Roesler, 2010). Although often used to quantify for instance chlorophyll-a biomass, it can be used to measure proportional pigment distributions as well. Absorption meters, spectrophotometers and fluorescence meters can all be applied underwater, e.g. on fixed platforms, buoys and gliders or can be used on water samples when implemented in ferryboxes. For instance sea surface or location specific measurements can be very useful for ground truthing of satellite images (Lawrenz et al., 2013).

For scanning purposes of intertidal zones at low water or water surfaces also devices using other wavelengths can be used. It can be stated that principally all types of wavelengths from ultra-violet to infrared as measured with spectroradiometers can be indicative for plankton or fytobenthos developments, at which they have in common that for calculations abiotic parameters have to be taken into account.

5.1.7. *Biotic activity*

All kinds of biotic activity measurements might be indicative for biodiversity as well; particularly when different types of species (e.g. functional groups, taxonomic groups, size classes) can be distinguished. Types of biotic activity that can be monitored are oxygen and CO_2 production and consumption, visual biotic activity on and in sediments (e.g. burrowing activities, oxygenation, sediment compaction; Burrows et al., 2003; Todd & Kostylev, 2011; Romero-Ramirez et al., 2013) and decomposition rate. Ways to monitor these are sequentially optodes or electrodes, photo- or video-analyses and sediment profile analyses, and artificial provision of organic material. Also the detection of specific biota related molecules by tracing odours, excretes like urine or signalling chemicals (Atema, 1995) can be a way of measuring biotic activity. This is however a field of science, poorly developed so far.

5.2. Potential methods to measure biodiversity

5.2.1. *Direct observation*

Measuring biodiversity by direct observation consists of all mapping, scoring, counting and identification work done directly on side without the use of equipment to record data or the use of parameters or proxies that are measured and should be converted into biodiversity data. Generally these biodiversity recordings are indicated with a term like ‘visual senses’ as the methodology, although also inventories on basis of sounds and probably more theoretically also on basis of odours, tastes and touch sense are optional. Direct observations can either be done from land or from boats or planes in standardized areas, for standardized periods or by doing transects (to monitor mammals and birds) or while diving/snorkelling (to monitor fish, macrofauna, macroalgae and macrophytes). The difference between direct observation or visual senses and the collecting of biota is actually that species, populations or communities remain rather undisturbed, although the presence of observers can influence behaviour, and that specimens are not taken out of their habitat. The advantage of such method is that observations can be repeated without having to take earlier extraction of specimens or physical disturbance of the habitats into account. Disadvantages are however that there will be differences in the visibility of specimens, e.g. smaller specimens, camouflaged or more mobile species are more likely to be missed, specimens in and under obstacles and sediment will be missed, and methodology should be standardized taking possible variation in the field of view due to differences in the matrix into account. Additionally it is uncertain whether there are opportunities for having a closer or a second look, making identifications more uncertain and reducing the recording of additional parameters, like size, shape and weight, to estimates. The likelihood of observer related effects on differences in recordings is generally also larger than with other methods. The use of binoculars, telescopes or amplifiers (devices that close the gap between direct observation and the recording or conversion of signals as described below) can enlarge the detection range.

5.2.2. *Collecting*

The difference between direct observation and collecting is actually that specimens, species or entire population or communities are physically taken out of their environment which enables to have a better, closer or more frequent look and gives opportunities for measurements. Therewith standardization is often easier and the reliability can improve.

5.2.2.1. Active sampling

There are several ways to sample communities depending on the environment and the taxonomic group. For several groups, all kind of nets (different sizes, meshes and operating devices) can be used sampling the water column. Examples are plankton nets and fishing nets, either operated horizontally or vertically, and standing nets and fykes (optionally baited) which all can be to some extent selective for specific organisms. Trawls optionally equipped with chains or working with electric pulses particularly sample the seafloor fauna (epibenthos and/or benthic fish). Macrobenthos and mesofauna can be sampled with dredges, corers and grabs either exploited from boats or in the intertidal zones by hand. Another way to sample pelagic or shallow subtidal benthic communities is the use of flushing samplers, hydraulic dredges and pumps where water (optionally after being blown on sediment to be sampled) is filtered over a certain mesh. A special case of active sampling is collecting species at higher trophic levels (e.g. predators) and analyse species diversity on stomach and/or gut contents (Féral et al., 2003). Other methods consist of collecting standardized areas or during standardized periods either on foot in the intertidal zone or shallow water or by snorkelling or diving. The methodologies differ in a way that they either sample specific locations (point measurements: e.g. corers, grabs and flushing samplers) or specific transects (e.g. nets, trawls and dredges) or sample potentially during a longer time (e.g. standing nets, fykes and pumps) or sample larger areas (depending on species mobility and behaviour: e.g. standing nets and fykes).

Active sampling can optionally be combined with other methodologies like pigment analyses, spectrometry, size distribution estimations, the measurement of biomass and genetic analyses.

Active sampling is potentially very informative but difficult to perform in an automated way. However, the sampling of smaller specimens (e.g. phytoplankton, zooplankton or microorganisms) could potentially be automated and integrated in platforms like ferryboxes, ships of opportunity, gliders, landers, moorings and land based stations. In the smaller sized platforms particularly the number of samples that can be stored before it is manually emptied will be limiting. Automated measurements or analyses are therefore preferred as samples are only temporary stored during measurements, after which the device can be emptied and a new sample can be taken. However, all biodiversity indicators resulting from active sampling ask for physical and biochemical parameter data potentially explaining the observed patterns. It is therefore highly recommended to adjust active sampling for biodiversity campaigns and physical and biochemical measurements. For instance, follow ferrybox or glider transects for sampling, or connect biodiversity sampling sites to existing platforms of physical and biochemical measurements. Potentials for such collaborations are dealt with in chapter 6.

5.2.2.2. Artificial substrates

The methodology of artificial substrates is actually a way to collect or study species settling on the substrate during certain periods at which the substrate can be a surface to which species attach or bags or nets with material in which species settle or cores with sediment in which species settle. It is therefore very useful to study temporal and spatial patterns in species presence or community developments and succession (Pacheco et al., 2010; Pardo et al., 2010). The methodology is particularly useful to study algae and invertebrates. Besides the use for active sampling, which can potentially be used on ships of opportunity, fixed platforms and buoys, it is also possible to combine artificial substrates with camera observation (e.g. photo quadrats) giving opportunities to automate monitoring or the deliverance of real-time data over distance. A related methodology with similar application opportunities is to attract species by providing shelter (e.g. floating objects, artificial reefs or artificial vegetation) or food or attracting species with light, applicable for groups as invertebrates and fishes (Girard et al., 2004).

5.2.2.3. Continuous sampling

As indicated, automated sampling creates potentials for integration of sampling devices in JERICO platforms. Examples are continuous plankton recorders (CPR) where plankton is filtered on a slow moving band, covered by a second band and preserved before being collected. The band can be split up in parts before community analyses. The oldest CPR survey is already running since the 1920's, which is the one that has given a name to several devices that have been used afterwards using a similar procedure (Reid et al., 2003). Continuous plankton recorders can be running from ferryboxes or ships of opportunity. CPR's also give opportunities for direct continuous measurements with for instance fluorometers and spectrometers. If samples are not directly analysed, some kind of preservaytion of the specimens or the entire sample might be essential. Also automated repeated sampling, i.e. sampling with intervals, is generally considered a continuous sampling methodology which can be used to collect a variety of biota. When samples are not directly analysed or the intention is to store the samples as well, the storing capacity on/in the observation platform might be limited.

5.2.3. Hydrophones

Passive acoustic detectors record sounds made by marine animals and can be applied from fixed platforms or towed by ships. Their application is well known for the monitoring of whales, but the methodology can actually be used for all marine mammals including dolphins and seals and is also applicable to detect certain fish species. Although the advantage of the technique is that continuous recordings can be made, monitoring continues during the night and poor weather conditions (difficult with visual senses) and real-time data can be achieved, it is always necessary to take behavioural aspects of the animals into account as vocal behaviour will show seasonal variability. The detection range is highly dependent of the species going from huge areas for large whales to a few hundred metres for certain fish species (Van Parijs et al., 2009). The hydrophones can also be used to detect species with acoustic tags (i.e. in combination with a tagging campaign or coincidently) also applicable on marine mammals and fish (Hayes et al., 2013).

5.2.4. Echosounders

Other acoustic methodologies are based on the production of sound and the recording of back-scatter. A widely used technique to locate particularly fish schools is the echosounder which is a downward observing device that can be installed on ships of opportunity, buoys or fixed platforms. However echosounders can also be used to detect zooplankton or even individual fish or mammal species at which differences can be detected between types of organisms by using different frequencies and analyses of the backscatter patterns (Hawkins et al., 2012). A challenge is however to distinguish different species or species groups from observed patterns which asks for validation with other methodologies and training in case of automated detection.

5.2.5. Multibeam and sonar systems

It is however also possible to use horizontally oriented acoustic techniques where not only back-scatter but also forward-scatter can be recorded (Reeder, 2011). Such a technique is Ocean Acoustics Waveguide Remote Sensing. Herewith huge continental shelf areas (thousands of square kilometres) can be scanned for large fish schools or nekton concentrations; however such biota aggregations should be really large. A vertical source array sends out a short broadband transmission of sound that is omnidirectional in the horizontal. Obstacles, which can be large schools, produce scattered returns which are continuously recorded by a horizontally towed line array of receivers (Makris et al., 2010). One could image a transmitter on a buoy and a receiver line towed by ships of opportunity.

Acoustic technologies are widely used for habitat mapping (e.g. to estimate habitat heterogeinity and diversity). Techniques that can be used or combined are Single-beam, Acoustic Ground Discrimination Systems (SB-AGDS), Sidescan sonar systems (SSS) and Multi-beam echosounders (MBES). With these techniques in principle seafloor bathymetry and acoustic backscatter strength are recorded from which amongst others the slope, positioning, terrain variability, hardness, roughness and the acoustic class, can be calculated. The single beam echosounder in fact enables classification of the seafloor and its vegetation, a Multi-beam sonar generates a map of the micro-relief, and a side scan sonar, images the seafloor reflectivity and thus enables the spatial classification of seafloor types and vegetation and is particularly useful to detect eco-elements like bivalve beds or reefs. The resolution depending on equipment and water depth differs from tens of centimetres to tens of metres (Brown et al., 2011). Ground-truthing with benthic community data or visual observations is however essential to increase the accuracy or to improve the applicability from a biodiversity point of view. Ideal, measurements are combined with chlorophyll-a, temperature, salinity, oxygen measurements and/or determination of the sediment characteristics and hydrodynamics at the seafloor, to come to floral and faunal community representative habitat maps (i.e. ecotope maps).

5.2.6. Acoustic telemetry

Acoustic telemetry is the methodology where specimens are tagged and their position detected by one or more receivers. The specimens must generally be caught first to implant or attach the transmitters (for some species there might be options to attach a tag from a short distance, e.g. using a gun or stick). The methodology (i.e. detectors) can be implemented on and near fixed stations, landers and buoys. It is very useful to monitor seasonality and behaviour of resident species or the returning of migrating species (Giacalone et al., 2006; Reubens et al., 2013). Acoustic telemetry can be used with fish, mammals, reptiles or larger invertebrates where the detection range and the lifetime depends on the frequency of emitting signals, the size of the battery and therefore the size of the tag and therewith the size of the animal. The detection range is typically a hundred metre to one or two kilometre. To retrieve exact positions, more than 2 receivers are needed covering the study area. To study less resident offshore species, particularly the use of ships of opportunity equipped with receivers is promising (Hayes et al., 2013), particularly when relative large numbers of specimens or species have been tagged in certain regional seas. I.e. monitoring can actively focus on specific specimens, species or populations where receivers should be placed as such that the positioning of those biota in the area of investigation can be determined, whereas there is also a more passive way of monitoring where receivers are placed as such that they record tagged specimens passing by. For frequently surfacing species and particularly birds, satellite (e.g. GPS) tags might be more efficient.

5.2.7. Photo/video analyses

Camera observation is a methodology that makes it possible to observe parts of the ecosystem, where difficult to monitor with an observer, without disturbing it, and for extended periods or even continuously. The taxonomic groups or species to be observed determine the distance at which species can be observed, the area that can be scanned and the clarity and magnification. Camera observation can be used in the field or in flow through systems and although often image analyses, e.g. counts, measurements, species identifications, are necessary afterwards, some of these aspects can potentially be automated. Although the species identification might sometimes be more difficult from images or film than when specimens have been collected, continuous observations in time and space can be made of which the resulting images can easily be stored. In that way one can easily go back to analysed material or analyse additional material (not analysed yet) for certain regions or periods of interest. Additionally for several groups camera observation makes it possible to study behaviour.

Camera observation can be very useful to study birds or mammals in the intertidal zone at low water or at the sea surface from fixed platforms or from land based observatories. To scan larger areas, cameras can be run from boats, planes, kites, radiographic controlled aircraft vehicles or drones. In that way also landscapes/seascapes or specific eco-elements can be studied. Examples are ecotope mapping (habitat diversity) from aerial photographs or monitoring of intertidal bivalve reefs. To give better contrast, besides the visible wavelengths also near-infrared pictures can be made. For these purposes also satellite images can be used.

Submerged; turbidity and light (colour and intensity) is playing a role although cameras can be combined with light sources. But in several environments fixed observation settings are possible, e.g. in benthic environments or on reefs to monitor benthic organisms or fish. Cameras can also be integrated in Remotely Operated underwater Vehicles (ROV's), landers and gliders. With ROV's underwater landscapes difficult to sample actively (e.g. hard substrates or boulder rich environments) can be monitored at which particularly epi- and hyperbenthic communities, benthic fish communities or burrowing activities of specific endobenthic species can be inventoried. To do this periodically or continuously at fixed locations with fixed cameras or returning to identified spots (e.g. photo quadrats) developments like growth, recruitment, fouling or succession can be monitored. Cameras attached to sampling gear like trawls, dredges or nets can be useful to evaluate the efficiency of the sampling gear or to characterise the underwater environment. Camera observation results can be used for the habitat mapping of the underwater landscape (Waddington et al., 2010).

It is also possible to combine artificial substrates with camera observation (e.g. photo quadrats) giving opportunities to automate monitoring or the deliverance of real-time data over distance.

5.2.8. Camera autodetection

Pelagic sampling with flow-through systems as part of ferryboxes or fixed platforms have the highest potential for automated species recognition and counting in the form of plankton imaging, like there are FlowCam and Zooscan respectively focussing on microorganisms/phytoplankton and zooplankton. Although plankton imaging systems are at present largely used on conserved samples, they have the potential to be used fully automatic on future platforms. Besides species recognition they are particularly useful for size distribution measurements and biomass estimates (Sieracki et al., 1998; Gorsky et al., 2010; Jakobsen & Carstensen, 2011). Besides plankton recognition there are also initiatives to automate benthic species recognition, which appears already applicable for some benthic species (Schoening et al., 2012). Developments in these cutting edge technologies are worked out in WP10 'Improved existing and emerging technologies'.

A special case of automated camera observation in development is the use of thermal images to detect and identify birds and bats for instance near offshore wind farms particularly during dawn and dusk and the night (Duberstein et al., 2012).

5.2.9. *Spectrophotometers*

Spectrophotometers are actually devices to detect the reflectance of pigments at one to several channels determining the wavelengths that can be detected. Spectrophotometers can be used during daytime, preferably during good weather conditions as they detect the reflectance of sunlight (field-spectrophotometers for in situ measurements), or the meters contain a light source for in vitro measurements. Absorption meters are actually also a type of spectrophotometers, however measuring the light attenuation. The measurement of attenuation and reflectance can also be combined in one device. For both principles, the specific wavelengths absorbed or reflected can be linked to pigment types or combinations indicative for phytoplankton species (Mercado et al., 1996; Simeon et al., 2003). From differences in irradiance and detection also pigment concentrations, transferable into biomass, can be calculated. Spectrophotometers can potentially be deployed from underwater fixed platforms, buoys or ROVs or as part of ferryboxes.

New developments are in the direction of combining techniques like camera autodetection making use of illumination of light from a light source or combined with a fluorometer, to detect and record size, shape, nature and distribution of living and non-living particles in the water column. By combining techniques a large size range can be covered from a few micrometers anorganic substances to centimeters large zooplankton (Picheral et al., 2010). Not only the constitution of aggregations of biotic entities on its own (e.g. phytoplankton and zooplankton) is a measurement of biodiversity, but also particle size distributions can be indicative for biological processes and the pelagic ecosystem trophic state and functioning (Stemmann & Boss, 2012).

5.2.10. *Spectroradiometers*

Spectroradiometers are in principle similar devices as Spectrophotometers, however working beyond visible wavelengths. Submersible sensors are available for planar and scalar irradiance measurements, using flat and spherical diffusers, and working with a single detector or as multi-waveband sensors. High resolution (hyperspectral) sensors can have spectral resolutions of the order of a few nanometers. The sensitivity of a radiometric sensor is largely determined by size of the detecting element, typically square millimetres for a multi-waveband sensor and square microns for a high resolution sensor. High resolution sensors generally have limited sensitivity, which can limit their use as profiling instruments in coastal conditions. Traditionally spectroradiometry is used to identify vegetation characteristics and condition. Other applications are species diversity recordings and species recognition applications for underwater flora and fauna (Cheney et al., 2009) like identification of areas covered by habitat-forming plants and macroinvertebrates and identification of higher taxa diversity of particularly shallow water benthic communities and coastal vegetation.

5.2.11. *Remote sensing*

Remote sensing principally includes the entire range of broad-scale observations from devices/platforms that are not directly or in close contact with the area or objects to be scanned or monitored temporally or spatially. Generally information can be collected for large areas or for a long temporal scale, however where detail is lacking. Therefore remote sensing is generally used for up-scaling or to collect general information and often in combination with more local and/or detailed measurements, i.e. in combination with ground-truthing. Such platforms can be for instance satellites, planes or boats, also determining whether remote sensing can directly be part of a JERICO biodiversity observation network or if collaboration with a specialized network is more obvious. Also remote sensing can involve a range of spectra including the visible range, radio waves and infrared in line with the spectrometry techniques and can also be distinguished in the active and passive sensors depending on whether devices only receive or first transmit and detect returned energy (e.g. Turner et al., 2003). Common applications and new developments are the detection of surface roughness en relief (water and seafloor), sediment concentrations, currents, fytoplankton/fytobenthos concentrations and primary production, temperature, micro-plastics and pollutants like oil-derives, etc, that potentially connect to or affect biodiversity patterns (e.g. Valavanis et al., 2008; Herkül et al., 2013). Remote sensing can be a very useful technique to identify habitats and/or ecotopes both benthic and pelagic, but is also applicable for the identification of organism aggregations (e.g. zooplankton aggregations, fish schools, large mammals, plankton aggregations, eco-elements, etc.) depending of the type of sensing.

5.2.12. *Fluorometers*

Fluorometers are devices to detect specific wavelength reflectance of pigments after the flashing of a light source. Herewith pigment ‘species’ and concentrations but, by the repetitive excitation of light pulses, also primary production or dissolved oxygen concentrations can be measured. Nowadays fluorometry is not restricted to singular wavelengths and excitation and emission is not restricted to the visible light. Promising techniques are Fast Repetition Rate Fluorometry (FRRF) and Pulse Amplitude Modulated Fluorometry (PAM) (Lawrenz et al., 2013) also submerged applicable. This makes fluorometry a promising technique to monitor the phytoplankton diversity and functional diversity in particular, but also to monitor developments in phytoplankton biomass or to evaluate the primary production. It is recommendable to combine fluorometric measurements with light irradiance and temperature measurements (Houliez et al., 2013), but also the chemical constitution of the seawater (e.g. background emission) shoud be taken into account. Fluorometers can be integrated in ferryboxes, buoys, or on fixed platforms, but with submersible equipment available it can potentially be applied from a range of platforms like landers and gliders as well.

5.2.13. *Flow cytometry*

Flow cytometry combines the determination of the size and shape of particles by measuring the scatter of a laser beam and the detection of the fluorescence making a classification of the cells into clusters, whereas also the numbers of cells are counted. Although conventional cytometers are in need of discrete water samples taken in the laboratory or on board a ship, nowadays submersible flow cytometers are available making automated (sampling with intervals for processing) analyses of water samples of cells into clusters possible (Olson et al., 2003; Thyssen et al., 2011). This allows application from landers, buoys, ships or fixed platforms. Cytometry is therefore very useful for microbial and phytoplankton diversity analyses even in water (samples) with detritus abundantly present.

5.2.14. *Chromatography*

Chromatography like High Performance Liquid Chromatography (HPLC) is a very useful methodology to scan phytoplankton community, functional group or size-class compositions and developments. A real benefit is the wide application and large data availability from data libraries. On the other side, methodology asks for ground-truthing with cell counts and identifications, and it has to be taken into account that algorithms depend on temporal and spatial scale and the matrix (Peloquin et al., 2013). Chromatography is therefore a useful technique for the identification of phytoplankton and/or micro-organism diversity and primary production estimations. It can be applied as part of a ferrybox or integrated in fixed platforms, buoys or landers. HPLC can function semi-automatically and is promising in combination with satellite imaging and in situ sampling.

5.2.15. *Oxygen meter*

Oxygen is of relevance towards biodiversity in two ways. On the one hand many species are dependent of oxygen which implicates that certain (temporal) oxygen levels and particularly the lack of oxygen has huge consequences for the biodiversity and the groups or species that can be expected in particular. Oxygen in this case however is not directly a proxy for biodiversity but a habitat descriptor with implications taking the tolerance of species into account. On the other hand oxygen concentrations and the daily fluctuations in particular can be a good indicator for primary production and/or dissimilation. Oxygen levels should be measured in combination with at least temperature and salinity levels should be considered. There are two types of meters: the electrochemical sensors and the optical sensors. Oxygen meters can be implemented in a range of platforms like buoys, gliders, moorings, applied from ships or fixed platforms, integrated in ferry boxes, etc., and dissolved oxygen is one of the focal parameters in the JERICO network of observatories (Coppola et al., 2013).

5.2.16. *Carbon dioxide meter*

In principle also carbon dioxide concentrations and fluctuations in particularly can be measured as a proxy for primary production. Additionally, carbon dioxide partial pressure (pCO_2) is an important parameter concerning ocean acidification. Although ocean acidification might be more a large scale problem (as it is related to atmospheric conditions more than local changes) affecting species over entire regions, it might have implications for certain groups of species more than for others setting boundaries for the most sensitive species. Compared to oxygen, the measurement of CO_2 in seawater might be slightly more complicated (to implement in a variety of platforms) as it generally goes with the infrared detection of CO_2 in a carrier gas with seawater. pCO2 is however one of the focal parameters of the JERICO network, so broad-scale implementation is expected.

5.2.17. *Sequencing*

Genetic detection and the measurement of diversity using molecular techniques is a proliferating field of science. In principle all kind of methodologies including DNA/RNA sequencing, gene microarrays detection, the use of genetic markers, techniques using restriction enzymes or DNA barcoding can be used in the marine realm to indicate diversity as well. Techniques differ in a way that they either focus on specific species for which genetic analyses have diversity-related indicator value (genetic markers), focus on genetic diversity among populations (sequencing, restriction enzymes), measure diversity of traits (microarrays) or measure total community diversity (sequencing, restriction enzymes, DNA barcoding). Often specific species must be sampled, or techniques are species specific for which an environment sample (total community sample; e.g. water sample, sediment sample) is needed or such an environmental sample is homogenised and total DNA is analysed (Féral, 2002; Wu et al., 2008; Stern et al., 2010; Köchling et al., 2011; Collins et al., 2013). Genetic samples ask therefore for the collection of species according to traditional techniques (e.g. trapping, netting, coring, flushing, etc) and genetic analyses afterwards or environmental DNA analyses for a selected number of target species. Several of those sampling techniques can be run from various platforms and potentially be automated on landers, gliders, moorings, ferryboxes or fixed platforms. A challenge is to also automate the analyses making delivery of real-time data possible. First steps in the direction of autonomous environmental sampling and molecular analyses have been taken (Ussler et al., 2013) for which particularly analyses of the diversity of microbial communities or plankton communities are promising.

Sequencing is the technique of clarifying the nucleic - or amino acid or protein sequence of certain organisms to identify the diversity or diversification among populations, communities or ecosystems, or to identify the presence and number of species. In principle very little genetic material is necessary which makes that environmental sampling (i.e. detecting the presence of species in certain water bodies without sampling the organisms themselves) becomes optional. A disadvantage is that it is not certain whether detected species are really present there alive and how abundant. Sequencing is often used in combination with restriction enzymes or specific primers that result in the selection of certain regions of the genome to be sequenced or the selection of specimens, species or organism groups. As indicated, the sampling for genetic analyses using sequencing techniques can potentially be automated (depending on the type of organisms) and also sequencing itself up to the presentation of results can potentially largely be automated, but combining the two in a semi-autonomous platform might be problematic which makes that sequencing in generally restricted to land-based fixed platforms. The use of sequencing techniques however allows diversity estimations on all levels from organismal to ecosystem or regional level.

5.2.18. Fragment length polymorphism

The methodology of Fragment Length Polymorphism (FLP) combines a technique of selecting parts (fragments) of DNA or RNA and the physical and/or chemical characteristic of different sized and/or structured fragments. In practice this means the selection of specific regions using Amplifiers (AFLP) or cutting into fragments using Restriction enzymes (RFLP). Different fragments are separated on a column/gel after amplification to analyse fragment patterns. The technique potentially allows sequencing afterwards. FLP is generally used to identify differences between populations or relatedness among closely-related species (e.g. Rajagopal et al., 2009; Palesse et al., 2011). As for sequencing, genetic sampling can potentially be automated, but subsequent laboratory analyses are needed.

5.2.19. Genetic markers

With techniques using genetic markers we here mean the detection of specific regions in the genome present in specimens, species or populations that can be related to specific traits (e.g. allozymes) or that are known to show a certain (natural) variability top analyse lineage (Féral, 2002). Again these techniques are in need of laboratory analyses after sampling. Potentially there is the possibility to detect species presence from environmental DNA although there are some accuracy issues and challenges how to cope with for instance species remnants or 'contaminations' (Kelly et al., 2014). A derivative of this methodology is the use of DNA microarrays. Basically the methodology uses species specific probes on solid surfaces that are developed for in situ application. Probes hybridize with DNA samples present in the environment for which sample-probe complexes fluoresce in UV light or potentially can be used with other kinds of stains. One might also detect species or group specific enzymes that can be detected with enzyme-linked immune-sorbent assays (ELISA), for instance to detect algal toxins in the environment (Bourlat et al., 2013). The present status of these techniques is that the detection of singular or a few species is already very well possible, but the implementation of such a technique as a substitute for community sampling to sense diversity is a development not there yet, and a vision that has already been forwarded several decades ago but not very likely to occur on the short term. The potential implementability of such techniques on a variety of platforms is however high.

5.2.20. Stable isotopes

The background occurrence of stable isotopes in the environment (that can be traced back to major natural and anthropogenic events) and the quality of stable isotopes to be either preserved in tissues or accumulated from one to the other level in the food chain, can act as tracers for the region of origin of migrating species, the connectivity of regions for certain species, the food sources of certain species and life stages, the tropic positioning of species and interactions between species in food webs. Commonly used tracers are Carbon (^{14}C) and Nitrogen (^{15}N) concentrations, but also Sulphur and Oxygen isotopes are frequently used, and Hydrogen, Iron, Silicium and Strontium isotopes have potentials be used (Michener & Lajtha, 2007). Carbon and Sulphur isotopes particularly allow tracing back to sources whereas Nitrogen isotopes record trophic information. In this way stable isotopes can give insight in food webs; e.g. number of levels in food chains, food sources and/or dietary shifts related to life stages or events, and in the connectivity of environments; e.g. land-ocean interactions, origin of introduced species. These aspects are related to biodiversity but are not directly a proxy for biodiversity; although certain (combinations of) isotopes might indicate the completeness of foodwebs when the range of species and life stages is analysed. Although the sampling for stable isotope analyses can rather easy (i.e. collecting the species and organic sources of interest), it is a methodology that is in need of subsequently laboratory analyses as a mass spectrometer like an IRMS (Isotope Ratio Mass Spectrometry) is needed. Therefore the sampling can potentially be implemented in a variety of platforms, with potentials to automate this for certain components of the foodweb, with laboratory analyses of the samples of interest afterwards.

Another way of using stable isotopes is the in situ provision of radioactive labelled potential food sources to identity food uptake routes and/or production under natural conditions. A widely applied method is the provision of ^{14}C to measure primary production (Arnold & Littler, 1985). Particularly for phytoplankton and phytobenthos this is common practice; it is however a method difficult to automate and rather time and labour consuming when a certain spatial and temporal resolution is pursued as measurements need to be applied on location. The method is still frequently used for the validation of other more automated methods to measure primary production, like fluorometric methodologies. In situ radioactive labelling however, is certainly also of use for more local studies on nutrient uptake, for example for studies on macrophytes, sponges, or the benthic foodchain (Van Oevelen et al., 2006).

6. Biodiversity networks and measurement programs

6.1. EEA

The European Environment Agency (EEA) is an agency of the European Union with 33 member countries with the main task to provide sound, independent information on the environment. The EEA aims to help the community and member countries making informed decisions about improving the environment, integrating environmental considerations into economic policies and moving towards sustainability, and coordinates amongst others the European environment information and observation network (Eionet). One of the main activities of the EEA is to improve the coordination and dissemination of environmental data and knowledge across Europe, amongst others in the fields of 'Biodiversity' and 'Marine' data. The coming years it is foreseen to deliver information, data and analyses of biological diversity amongst others in water, via an integrated analytical framework that will support each priority area and considerations across them, including tracking progress towards, and providing outlooks for, the achievement of targets *inter alia* as defined in relevant EU and international legislation and evaluating the effectiveness of European policies and measures (EEA, 2009). Specific for the marine realm it is foreseen to support European and international marine‐related policies and implementation by providing integrated EEA marine assessments, covering *inter alia* linkages between marine ecosystem health and human well-being, supported by up-to-date data, indicators, models and analyses (EEA, 2013).

The EEA makes available free data with amongst others biodiversity related data; although these are merely physical-chemical or include policy related data (e.g. species red lists, Natura 2000 areas, etc). They provide an extensive overview of biodiversity related indicators implemented in each of the European countries, and link to variety of biodiversity related sites of European networks and initiatives.

It might be particularly valuable for JERICO to link biodiversity measurement initiatives to indicators (and data needs of those indicators) in use in several European countries, although the final goal of JERICO should be to assess trans boundary biodiversity developments and select those indicators, sensors and parameters that can potentially fulfill that role.

6.2. LTER-Europe

Long Term Ecological Research (LTER) Network programs concentrates on studies of ecological processes that play out at time scales spanning decades to centuries. To support fundamental research on ecosystem processes, sites are selected where, as core topics, primary production, population ecology, biogeochemical cycles, organic matter dynamics, disturbances and biodiversity are studied. At present there is more attention for management incorporation in the network where traditional LTER sites (local level) are extended with LTSER platforms (sub-regional and landscape level). LTSER platforms are intended to serve as hot spot regions for socio-ecological research, to inter alia improve the knowledge base for efficient nature conservation and management (LTER-Europe, 2013).

The network consists of a large amount of research sites all over Europe where generally several biodiversity parameters and for biodiversity relevant parameters are monitored. However, as the network initially started as a terrestrial and freshwater network, at present only 8 marine sites are included. It might, however, be very valuable towards JERICO to learn from the integrative way of investigating biodiversity within the LTER-Europe network, and there might be opportunities for JERICO to fill in the marine gap within LTER-Europe with developing several JERICO observatories into biodiversity research sites.

6.3. GEO BON

The Group on Earth Observations Biodiversity Observation Network (GEO BON) coordinates activities relating to the societal benefit area on Biodiversity of the Global Earth Observation System of Systems (GEOSS). Some 100 governmental, inter-governmental and non-governmental organizations are collaborating through GEO BON to organize and improve terrestrial, freshwater and marine biodiversity observations globally and make their biodiversity data, information and forecasts more readily accessible to policymakers, managers, experts and other users. The Biodiversity Observation Network is a voluntary partnership that is guided by a steering committee comprising the key stakeholders, including DIVERSITAS, GBIF, IUCN, NASA, UNEP-WCMC and others and draws on GEO's data-sharing principles to promote full and open exchange of data, and on the GEOSS common infrastructure to enable interoperability through adoption of consistent standards.

GEO BON works through 9 topical working groups (including marine biodiversity, biodiversity indicators, genetics, etc) with their own practical activities and biodiversity products, although they mostly seem to discuss and initiate new proposals and participate in other initiatives and meetings. GEO BON is however trying to formulate a set of Essential Biodiversity Variables (EBVs) to achieve in the end harmonization and standardization in the study and monitoring of biodiversity (Pereira et al., 2013) and has a current candidate list on its site (GEO BON, 2013). Additionally, GEO BON links (or gathers) to several large providers of biodiversity data like the Global Biodiversity Information Facility (GBIF) and the Continuous Plankton Recorder Survey.

It would be advisable for JERICO to keep track on the developments within the GEO BON network concerning EBVs. On the longer term JERICO biodiversity observatories might link to GEO BON.

6.4. ICES

The International Council for the Exploration of the Sea (ICES) is a global organization for enhanced ocean sustainability existing of a large network of scientists and science institutes. ICES is an intergovernmental organization whose main objective is to increase the scientific knowledge of the marine environment and its living resources and to use this knowledge to provide advice to competent authorities. Therefore ICES prioritizes, organizes, delivers and disseminates research needed to fill gaps in marine knowledge related to issues of ecological, political, societal, and economic importance at the pan-Atlantic and global levels. The main ICES deliverables are scientific publications, and scientific information and management advice requested by member countries and international organizations and commissions such as OSPAR, HELCOM, NEAFC, NASCO, and the European Commission (EC). ICES works with a Science Committee and an Advisory Committee. The first exists amongst others of 5 steering groups covering 'ecosystem functions', 'human interactions on ecosystems', 'sustainable use of ecosystems', 'regional sea programmes' and 'ecosystem surveys science and technology', which all relate in some way to marine biodiversity observation and monitoring. Science Committees jointly operate with the Advisory Board in the fields of strategic initiatives on 'stock assessment methods', 'biodiversity science and advice' and 'climate change effects on marine ecosystems' (ICES, 2013).

In its strategic plan it is stated that ICES will work the coming years on a strategy how to manage its data, and whether it should become a regional data center and how it will be resourced, as marine policy is looking increasingly to performance measures and indicators for marine management for which data are an essential element (ICES, 2008). Although ICES does not have a standardized biodiversity monitoring program with measurements at regular intervals in place, the organization gathers and makes available a lot of biodiversity data with traditionally but not solely particularly fisheries and trawling data. Further ICES has developed a series of data collecting protocols and maintains long-term data series via their participants. It would be wise for JERICO to take those actions into account, to not duplicate ICES activities but particularly see where JERICO observatories and potential additional measurements can bring added value. Potentially JERICO might deliver biodiversity (related) data to ICES.

6.5. LifeWatch

LifeWatch the E-Science European Infrastructure for Biodiversity and Ecosystem Research is a European research infrastructure in development, for which the first services to users are planned for 2013. The idea is that users will benefit from integrated access to a variety of data, analytical and modeling tools as served by a variety of collaborating initiatives. Also data and tools will be offered in selected workflows for specific scientific communities. In addition, LifeWatch will provide opportunities to construct personalized ‘virtual labs', also allowing to enter new data and analytical tools (LifeWatch, 2013). Herewith LifeWatch aims to accelerate frontier science on a variety of topics. This might include the development of biodiversity indicators and developmental analyses of the biodiversity related to environmental aspects and pressures. LifeWatch plans to make use of a variety of data sources like GBIF and BioVel. LifeWatch might potentially develop a set of leading biodiversity indicators or essential tools, although this is not a clearly defined objective. For JERICO it might be recommendable to keep notice of the LifeWatch progress, possibly to join virtual laboratories or discussion sites to be in the front of research on biodiversity observation potentials and evaluation tools. JERICO might develop into an important data provider to LifeWatch, therefore take necessary data quality characteristics and formats into account. JERICO can however potentially set the standard for continuous large-scale biodiversity observation in combination with physical chemical monitoring of the European coastal zones and therewith be of importance or essential for LifeWatch.

6.6. EMBOS

As a COST action the pan-European Marine Biodiversity Observatory System (EMBOS) is in development. EMBOS will install a permanent international pan-European network of observation stations with an optimized and standardized methodology to monitor biodiversity, biodiversity changes and their causes over large scales of time and space taking natural and anthropogenic gradients into account. The aim of the cooperation is to achieve a focused and cost effective long term research agenda for EU marine observatories, contributing to ERA, LIFEWATCH and GEOSS/GEOBON actions, and supporting legal obligations of the EU regarding the CBD, OSPAR and Barcelona conventions as well as EU directives (Bird and Habitat Directive, WFD, MSFD, ICZM). This will be done by optimization of novel interdisciplinary approaches for research, and facilitation of knowledge-based environmental management (Pavlova & Masset, 2012; EMBOS, 2013). At present a list of candidate sites including Reference Sites for certain geographical regions with low human impact that can serve as a reference (baseline) for natural evolvement of marine biodiversity, and a number of related Satellite Sites with a gradient in direct human impacts but that are within the recognized geographic regions related to the reference station(s), has been composed covering the entire European coast. On the short term a set of indicators and standardized methodology will be selected in workshops to be implemented at the observatory sites.

For JERICO there might be an opportunity to connect to EMBOS by tuning of the positioning of each other’s observatories and each other’s parameters to be measured. EMBOS observatories will be in need of physical-chemical monitoring data as explanatory parameters for biodiversity developments, whereas EMBOS observatories can provide the (delayed) local data to ground truth, calibrate or convert the continuous and/or large scale JERICO measurements. JERICO gliders, ships of opportunities and ferry-boxes might be very useful to extent (inter- and extrapolate) EMBOS fixed platform observations.

6.7. Other initiatives with links

Then there is a range of initiatives, projects and networks that do not directly cover biodiversity observations but that definitely have links, or that do focus on biodiversity observation however in other realms:

The European Seafloor Observatory NETwork (ESONET) will in the form of ESONET - Vi (ESONET the Vision) amongst others organize specialized workshops on data management, data dissemination, new sensors, new technologies and inter-comparison of results (ESONET-Vi, 2013). Although the focus of ESONET is on deep sea observatories, it might be a good platform to discuss experiences of biodiversity observations also for JERICO.

The European Multidisciplinary Seafloor & water column Observatory (EMSO) is a European network of fixed point, deep sea observatories with the basic scientific objective of real-time, long-term monitoring of environmental processes related to the interaction between the geosphere, biosphere, and hydrosphere composed of several deep-seafloor and water-column observatories, which will be deployed at key sites in European waters, spanning from the Arctic, through the Atlantic and Mediterranean, to the Black Sea (EMSO, 2013). Although certain parameters will be measured continuously to achieve long-term data series, several more are offered, including biodiversity related parameters and techniques. Although these are not standardized or measuring according to a fixed scheme, JERICO might exchange coastal experiences with deep sea and water column experiences on different techniques with the EMSO network or specific stations.

FixO^3, the Fixed Point Open Ocean Observatory Network, aims to bring together all of the sustained open ocean multidisciplinary observatories which are operated by EU institutions as one coordinated network, to extend the geographical coverage substantially stretching from the Arctic to the Antarctic and throughout the Mediterranean covering a wide range of disciplines (biology, biogeochemistry, chemistry, physics and geology) and environments from the surface to the seafloor (FixO3, 2013). A specific biodiversity measurement program with standardization and extension to all the stations is not yet foreseen, although the network might develop in that direction. As for EMSO (that has some similarities with FixO^3 but covers another geographical region although with overlap) it is advisable for JERICO to keep in touch with the FixO^3 network as experiences can be exchanged. However, at the moment JERICO is already one step ahead in the project development as FixO^3 is just starting.

The Argo network is a global array of autonomous instruments, deployed over the world ocean, reporting subsurface ocean properties to a wide range of users via satellite transmission links to data centers. The Euro-Argo Research Infrastructure will allow active coordination and strengthening of the European contribution to the international Argo program with the aims to provide, deploy and operate an array of around 800 floats contributing to the global array, to provide enhanced coverage in the European regional seas and to provide quality controlled data and access to the data sets and data products to the research and operational oceanography communities. Euro-Argo links to biodiversity observation in the same way as JERICO so far, i.e. focusing amongst others on Chlorophyll-a concentrations and Dissolved oxygen concentrations as the parameters with the strongest link to biodiversity.

EMODnet, the European Marine Observation and Data Network, is a consortium of organisations within Europe that assembles marine data, data products and metadata from diverse sources in a uniform way. JERICO does already have the aim to link to EMODnet via SeaDataNet. The portal could be a good starting point for the identification of relevant sites and the identification of biodiversity knowledge gaps taking for instance the Seabed Habitat and Biology sub-portals into account. It is however more likely that JERICO could become an important data provider and set a standard for biodiversity observation data as well as EMODnet in this stage solely provides (modeled) habitat maps and species distribution maps. The strength of EMODnet however that it combines the data of several important sources.

DEVOTES (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status aims to improve the understanding of human activities impacts (cumulative, synergistic, antagonistic) and variations due to climate change on marine biodiversity, using long-term series (pelagic and benthic). Their strongholds are to develop, test and validate indicators and innovative integrative modelling tools for the assessment of biodiversity developments. In this way it would be wise to discuss mutual findings, interests and developments between JERICO and DEVOTES, and it could be valuable to link foreseen biodiversity observations to proposed indicator and modelling needs. The role of JERICO could particularly be that of the network that is really going to measure and provide pan-European data in a standardized way.

Other initiatives that could be mentioned but without a specific focus on biodiversity observation are EuroSITES, CARBOOCEAN and Eurofleets.

7. Relevance of JERICO sensors for biodiversity

7.1. Temperature

In this era of climate change, temperature and the change of spatial and temporal temperature patterns and fluctuations in particular are very important environmental parameters that affect biodiversity at various levels. Temperature can determine the tolerance of species, might influence whether, where and when reproduction takes place and how successful it can be and can affect growth. Temperature will also influence oxygen levels, assimilation and dissimilation processes and food availability, besides a whole range of biochemical processes that can directly affect species. Then there are of course the oceanographic aspects with potentially changing currents and streams and mixing of water layers potentially affecting the connectivity of regions. Direct effects of changing temperature conditions are for example changing biogeographic distribution ranges of species, influence on success rate of exotic species introductions, changing productivity and shifts in foodweb structures. Although temperature and biodiversity are definitely related, there is not a clear relationship between temperature and biodiversity, as it depends on the level of biodiversity, the groups under investigation, the region, the connectivity and available species pools, and it depends not only on the temperature levels, but also on the fluctuations, differences, timing and spatial patterns. There are evolutionary based global temperature related biodiversity patterns (Tittensor et al., 2010), but this does not implicate that temperature can be a good proxy for biodiversity in heavily anthropogenic impacted regions, under changing conditions or on smaller than the global scale. In that case temperature functions as an environmental descriptor that can determine ecological boundaries for species. Together with other parameters temperature determines the mosaic of habitats, and the potential species presence and abundance; i.e. the potential biodiversity. *Vice versa*, temperature can however be a reason (explaining parameter) for observed changes in biodiversity.

Although average temperature might be the most recorded parameter, minimum and maximum temperature might be more important, as are annual fluctuations. Particularly the temperature at or just in the bottom will be of importance for a lot of (benthic species), whereas a profile over the water column can be valuable. Temperature differences might often, but not necessarily, be largest between the bottom and the surface water. From a biodiversity observation point of view ideally temperature profiles are taken with a temporal and spatial resolution that allows to identify seasonal fluctuations and interpolation to a pan-European scale. Emerging technologies to create temperature maps from earth observation data, i.e. satellites like Sentinel-1 and 3 and MODIS Aqua, are very useful to be combined with in situ measurements from profiles and bottom temperatures as satellite data only measure the surface layer (Science Communication Unit, 2012; NASA Earth Observations, 2013).

7.2. Salinity

Another parameter determining habitats, the potential species composition and potential biodiversity is salinity. Biodiversity patterns related to salinity as indicated for the first time by Remane (1934) are well known. Brackish waters potentially are of lower diversity than fresh or marine waters. However, it is also well known that it are the salinity fluctuations potentially problematic for a range of species resulting in lower biodiversity at large salinity fluctuations (Attrill, 2002). But also in this case it is largely species and/or group dependent whether and to what extent salinity determines the diversity. Benthic and less mobile pelagic organisms are potentially most vulnerable to salinity changes and unnatural fluctuations. Salinity is particularly playing a role in coastal zones and estuaries in particular as open sea and oceanic environments generally have a sufficient stable environment concerning salinity fluctuations that these are of importance in determining diversity changes (McArthur et al., 2010). However, also here it is a matter of scale; where patterns for biodiversity with salinity can be observed at a global scale, but where it is the variability determining local diversity. Although salinity fluctuations might be problematic for certain species, several species are particularly attracted by or adapted to 'natural' salinity fluctuations or estuarine conditions as estuaries and coastal zones are generally also the most productive regions due to high natural nutrient inputs and there are several species that need both fresh- and saltwater conditions during different stages of their live, for which the transitional zones are very important.

As for temperature, the most frequent recorded value is average salinity whereas for several species it is particularly the tolerance to minimum or maximum values that is playing a role. Additionally natural daily and annual fluctuations and salinity differences are of importance. For a biodiversity point of view the salinity at or in the bottom and in the water column is of importance dependent of the type of organisms. Again it would be most valuable to have the availability over salinity profiles at a spatial and temporal resolution to allow interpolation to a pan-European scale and to identify daily and annual fluctuations. Besides implications for osmoregulatory issues, salinity has an impact on element availability, both for organisms essential and potential toxic elements. Due to differences in density of water with differing salinity, salinity differences can result in water masses flowing on top of each other creating haloclines and/or stratification which can result in thermoclines or sharp transitions in oxygen concentrations. Additionally water masses with differences in salinity can create streams and currents with associated communities that under changing salinity conditions can also completely change. Also with respect to salinity there can be a link with climate change, taking effect of changes in ice melt and/or precipitation into account.

7.3. Chlorophyll-a

The Chlorophyll-a concentration or the derived phytoplankton or phytobentos (especially when talking about intertidal zones) biomass is a widely used ecological indicator with indicator value in particularly for environmental (water) quality and/or productivity. A relation with biodiversity is however less obvious. Depending on the group under investigation, species diversity often benefits from reduced chlorophyll-a concentrations, although a certain production should be present as it is an important food source. It is therefore often not the chlorophyll-a concentration that is of importance, but more the primary production and the amount and way of circulation in the foodweb. High productivity is often essential to maintain a high biomass and potential high diversity concerning higher trophic levels like fish and birds but also bivalves. At high productivity the chlorophyll-a concentration is not necessarily high, when productivity is in balance with grazing. There is also a large difference in the way chlorophyll is present in the system, whether it is mainly planktonic, benthic or particularly in macroalgae or macrophytes, as that determines the potential and way of uptake in the foodweb (Barber & Hiscock, 2006). This largely depends on nutrient and element levels and ratios like Nitrogen, Phosphor, Silicium and Iron, and in what chemical constitution they are present. Phytoplankton itself will have an impact on the light penetration, whereas high turbidity will lead to reduced chlorophyll-a concentration (which in that case is often not a good indication) (Butrón et al., 2009). Primary production will also have an impact on oxygen levels, and can lead to hypoxic conditions. Therefore it is recommended to measure chlorophyll-a concentrations in combination with turbidity, oxygen concentrations, nutrient levels and hydrodynamics.

Talking about chlorophyll-a and nutrient availability for higher trophic levels or potential negative impacts of blooms, temporal trends in concentrations are of importance, and particularly the timing and amounts of peak concentrations. Therefore it is of importance to implement a grid with a spatial resolution that allows up-scaling to the pan-European level, potential in combination with satellite data, and a temperal resolution dense enough to identify annual developments and to not miss peak concentrations. In shallow and intertidal areas the benthic chlorophyll-a concentrations (phytobenthos, macroalgae and macrophytes) can be of importance. For the pelagic realm the concentrations in the surface water will be most important; it is however of interest to identify the way of mixing, circulation and potential transport to deeper layers and or other regions (Moreno et al., 2012).

As chlorophyll can potentially be measured with a variety of sensors (e.g. fluorometers, absorption meters, chromatographs, spectrophotometers), it can be implemented on a variety of platforms often in combinations with other techniques and observations. From a biodiversity point of view (not only at the algae level but also for higher trophic levels) it is of interest to know what species are responsible for the observed chlorophyll-a concentrations in what ratios, which asks for combinations with analyses of other pigments and their concentrations or cell counts and identifications.

7.4. Turbidity

Turbidity is an important parameter as it determines light penetration and therewith affects primary production and the depth zonation of communities. Turbidity might be related to the presence of algae but also of organic matter and sediment in the water column. The presence of abiotic particles in the water column, in turn, affects the food quality for amongst others filter feeding organisms. Therefore turbidity should be analyzed in combination with aspects like hydrodynamics, the sediment composition in shallow waters and the phytoplankton composition. In general biodiversity is expected to be lower in high turbidity zones, but a direct relation between turbidity and biodiversity is not straightforward and depends on the groups of organisms to be studied. However, (long-term) changes in turbidity are a clear indication for changes in the system that might have serious implications towards biodiversity (Chou et al., 2012).

As for chlorophyll-a there are several ways to measure turbidity for which the combination of continuous field measurements with sample analyses for ground-truthing and satellite observation for up-scaling and interpolation might be most promising. However as a proxy for biodiversity it is probably not specific and not distinctive enough. As a warning signal it is definitely of use. Also for this parameter it would be of use to have a view of the temporal developments and annual fluctuations and it would be of use that a spatial grid is considered that allows up-scaling to a pan-European scale.

Additionally it is not only turbidity that is an important aspect of the constitution and density of aggregations of living and non-living particles, but these aggregations are also indicative for biodiversity of particularly lower level organisms like bacteria and zooplankton and potentially for higher tropic levels like fish, as organic rich flocculation and ‘marine snow’ can be important food sources. Correlations of particle size distributions and a certain biodiversity have been shown (Stemmann & Boss, 2012).

7.5. Dissolved oxygen (DO)

Dissolved oxygen is a strong determining factor for a range of species once concentrations are getting lower to hypoxic or anoxic levels. Several species are in need of a minimum concentration in their environment that can be absolute, or low levels that they can stand for often a limited time period. Most vulnerable are benthic and low-mobility species. Once benthic environments have been in an anoxic state for a while it can take extended periods of time before they are recolonized again and become biotic active on the various species levels. As for pelagic environments this has to do with connectivity and available species pools but besides recolonization processes take much longer as the physical and chemical substrate constitution has also changed which asks for a gradual succession of communities (Van Colen et al., 2008). This makes that when oxygen conditions are taken into account, also the oxygen history has to be considered as the lowest levels and duration of low levels largely determine the biodiversity state. Particularly in coastal zones oxygen levels can be impacted by organic inputs and/or algal production. In low dynamic environments or environments with stratification (salinity or temperature), oxygen levels can be particularly low in the deeper parts (Clark et al., 2013).

Taking oxygen levels into account in relation to biodiversity it is of importance to consider the entire depth profile and the values on or in the seafloor in particularly. Additionally oxygen should be considered in combination with temperature and salinity, and also hydrodynamics and algae concentrations (chlorophyll-a) will be of importance as those can explain observed patterns. Oxygen profiles should be taken with spatial resolution that allow interpolation to the pan-European scale. The temporal scale should be sufficient to observe the occurrence and duration of low oxygen levels, which means that monitoring might focus on specific periods with known potential oxygen problems and a lower measuring frequency during the remainder of the year. It also has to be taken into account that when primary producers play a role in the oxygen production and consumption there will be a daily pattern in the oxygen levels with lowest levels during the night.

Oxygen measuring sensors can be implemented in a range of platforms allowing broadscale application.

7.6. pCO_2 (Carbon dioxide partial pressure)

Carbon dioxide partial pressure in relation to biodiversity is an emerging field of science related to global change effects and prospects. It is expected that ocean acidification due to increased carbon dioxide partial pressure will result in the loss of particularly shell-forming and calcifying organisms (e.g. Gazeau et al., 2013). Although there are several experiments showing potential effects of ocean acidification on a variety of species, Hendriks et al. (2010) shows in an overview that most species might be more resistant than expected. At least this shows that the relation between pCO_2 and biodiversity is not that clear that pCO_2 could easily be used as a proxy for biodiversity. Again pH might be an environmental parameter determining whether certain species can be present or fulfill their lifecycle, but it will largely depend on the groups of species and the pH differences to be expected, to what extend and in which direction biodiversity will develop.

Analyzing developments in pCO2, it will be of importance to take into account oxygen levels, primary production and temperature as well. It is however expected that sensors can be implemented in a range of platforms allowing broad scale application.

7.7. Nutrients (Nitrates, Silicates, Phosphates, Ammonium)

Within JERICO, besides the above mentioned primary parameters to be part of the network foreseen to be implemented at the various platforms, the nutrients are identified as optional parameters. From a biodiversity point of view, they are relevant as they determine the potential primary but also secondary production, as nutrient ratios determine to a large extent the route that nutrients will take through the food web. Herewith the nutrient availability to species pools and the efficiency of uptake in the foodweb is determined (Barber & Hiscock, 2006). So there are definitely links between nutrient concentrations and ratios and biodiversity at various levels. Generally it can be stated that some nutrient inputs are necessary to support a certain level of biodiversity particularly at higher trophic levels. However, in the nowadays highly anthropogenic impacted seas and the coastal zones in particularly, several nutrients are generally available in high concentrations and not limiting at all. From a biodiversity point of view this would not necessarily be a problem as long as the (dissolved) nutrient ratios would be in balance. In practice, it are generally the high dissolved Nitrogen and Phosphorus levels causing the problems, although particularly phosphorus concentrations have decreased significantly in several regions the last decennia due to active legislation. Dissolved Silicium concentrations to a large extent determine whether nutrients come to benefit of diatom communities or whether non-diatom species (e.g. green and blue-green algae) can flourish, with large consequences to nutrient cycling in foodwebs (Billen & Garnier, 2007). In case of low dissolved Silicium availability, typical eutrophication patterns can be observed with potentially problematic algal blooms and the likelihood of reduced biodiversity at various levels. Co-occurring impacts of differences in nutrient inputs are effects on turbidity (light attenuation) and oxygen levels.

Nutrient levels are important conditions defining which type of species can be expected and determining the potential biodiversity. From a biodiversity point of view particularly the dissolved fraction or the chemical form in which the elements are present, is of importance, more than the total amount. Depending on whether chemical or optical techniques are used and/or available for nutrient concentration analyses, sensors can be implemented on a variety of platforms. Nutrient concentrations are particularly useful to explain observed biodiversity patterns. Therefore measurements in the water column and at the sea floor or just in the sediment layer can be of use.

8. Towards an implementation strategy for biodiversity

To accelerate the evolution of the JERICO network to become an important network towards biodiversity observation of the European coastal waters, it is important to focus on the strengths of the current network. This means that at present there is a solid network focusing on a limited number of physical-chemical parameters, applied from a variety of platforms with a reasonable spatial resolution, focusing on automatic and continuous measurements on annual or seasonal basis of real-time or quasi real-time in situ measurements. It is recommendable to consolidate or strengthen this approach, by focusing on the parameters (with their respective sensors and techniques) already within the network, that all have specific importance towards interpreting potential changes in biodiversity, setting the environmental boundaries for a variety of species and allowing inter- and/or extrapolation of local biodiversity observations, eventually making use of overarching technologies, to a large and ultimately the pan-European scale, by taking essential spatial and temporal resolutions and data formats into account. Additionally a limited number of promising parameters and/or sensing technologies with direct relevance towards biodiversity observation could be considered, however these should meet the same abovementioned requirements as the current parameters and associated sensors. However as measurements of actual biodiversity will be largely missing, it would be wise to come to close cooperation with one or more pan-European in situ sensing biodiversity initiatives for adjustment of mutual activities. Similarly close cooperation with one or more networks of Earth Observation would be achieved as JERICO could exactly be the link between field observations focusing on species compositions and satellite images covering large parts of or the total European coastal seas.

8.1. Sensors for biodiversity observation

The first results of an inventory and estimation of biodiversity sensing methodologies and their potentials for application and implementation in the JERICO network taking the current framework into account are shown here. Listings and scorings are the result of a literature inventory and the input from colleagues and feedback during the workshop held in October 2013 in Villefranche-sur-Mer. A potential way to calculate scorings and a rank on basis of qualifications if presented.

The current rating is based on a scoring for 7 aspects identified to be of importance (Tabel 1).

The first aspect is the potential indicator value (*Val*). This aspect is composed from a scoring of whether the methodology can be used to measure 11 biodiversity related aspects which are each identified as being of a certain importance to biodiversity in general (Appendix 1). The potential measurement of Taxonomic diversity is for instance rated as important whereas the potential detection of Behaviour is of interest but not rated as very important towards Biodiversity observation in general. To our opinion this is a very important aspect; as biodiversity observation is the aim, it is also essential that the methodology will yield biodiversity relevant information.

The second aspect is potential multi-platform use (*Plat*), where it is identified whether methodologies can potentially be applied from a variety of platforms (Appendix 2). If a methodology is very specific for a certain platform, this leads to a low score as the strength of the JERICO network is that several platforms are combined. Ideal the methodology can be applied from all identified platforms. For completeness also the potential application by a researcher (active sampling) is shown here, but no score is given for this as JERICO opts to come to a network of semi-automated observation (Active sampling might be more the strength of other networks).

Tabel 1. Scoring of potential biodiversity sensing methodologies on a variety of aspects that might be of importance to come to a ranking of most promising techniques to be implemented in the JERICO network in the near future. Aspects that are scored are the potential indicator value towards biodiversity (Appendix 1), potentials for integration in a variety of platforms (Appendix 2), type of data in relation to the delivered temporal data density (Appendix 3), the spatial scale that can be covered (Appendix 3), the current status towards integratebility and operability in nowadays platforms (Appendix 3), the estimated costs (Appendix 4), and the applicability and usefulness to detect biodiversity and various levels (Appendix 5) for several biota groups (Appendix 6) in various habitat types (Appendix 7). The indicator value indicates the maximum score that can be achieved for each category with a diversification of the scores in the above mentioned appendices. The total score is calculated according to Equation 1, which allows to make a ranking.

Methodology\To measure	Potential indicator value (*Val*)	Multi-platform use (*Plat*)	Data type (*Dat*)	Spatial scale (*Spat*)	Integratebility in current observatories (*Inte*)	Operability (current status) (*Oper*)	Total costs (*Cost*)	Multilevel biodiversity indication (*Lev*)	Multi-target groups (*Group*)	Multi-environments (*Env*)	Total score (*Total*)
Indicator value	*36*	*7*	*5*	*5*	*5*	*5*	*5*	*4*	*7*	*3*	*5,25*
Acoustic telemetry	2	5	5	4	4	5	1	1	4	3	**2,72**
Carbon dioxide meter	2	6	5	3	5	5	4	1	1	1	**2,89**
Camera autodetection	20	6	5	3	3	3	3	2	5	2	**3,53**
Chromatography	7	5	2	1	3	5	2	2	1	2	**2,11**
Collecting	24	1	2	1	1	5	2	3	7	2	**2,69**
Direct observation	26	0	1	2	1	5	5	3	5	3	**3,03**
Echosounders	4	6	3	3	3	3	5	2	3	1	**2,73**
Flow cytometry	10	5	3	2	3	4	2	2	1	2	**2,42**
Fragment length polymorphism	8	1	1	3	1	4	5	1	7	3	**2,42**
Fluorometers	9	6	5	2	3	4	4	1	1	2	**2,91**
Genetic markers	15	6	2	3	3	2	5	2	5	2	**3,14**
Hydrophones	7	6	5	3	4	5	4	2	2	1	**3,12**
Multibeam and sonar systems	5	3	3	4	3	3	5	2	4	1	**2,71**
Oxygen meter	2	6	5	3	5	5	4	1	1	1	**2,89**
Photo/video analyses	22	7	2	2	4	5	3	3	5	3	**3,47**
Remote sensing	12	1	4	5	1	3	5	1	2	2	**2,88**
Sequencing	18	1	1	2	1	5	5	2	7	3	**2,82**
Spectrophotometers	9	7	5	3	3	4	3	2	2	2	**3,08**
Radiospectrometer	9	7	5	3	3	4	3	2	2	2	**3,08**
Stable isotopes	9	1	1	2	1	4	2	2	7	3	**2,00**

The third aspect is the type of data that will be delivered or the type of measurement (*Dat*); whether measurements concern singular measurements, repeated measurements, high frequency measurements or continuous data deliverance (Appendix 3). The last is rated the highest as the JERICO network is striving for near-real time continuous observation; i.e a high temporal resolution.

The fourth aspect is the area that can be covered with the methodology (*Spat*), indicated by a spatial scale that can be described as local, to small areas, covering certain regions or entire regional seas (Appendix 3). As the scope of JERICO is pan-European, where observations should identify over-arching developments and general trends, a large spatial coverage is rated the highest.

The fifth aspect covers the current status and prospective to what extent the methodology can be integrated in the network of observatories on the already present platforms (*Inte*) and what the operation status is like (*Oper*) (Appendix 3). If the methodology can be implemented relative easy and is fully developed to be applied for biodiversity observation, the methodology gets a high score. The opposite is true for methodologies that are difficult to implement and that are currently highly theoretic and have barely been put in practice.

The sixth aspect estimates the costs of applying a methodology (*Cost*), taking both operational and installation costs into account (Appendix 4). To standardize the way of estimation it is assumed, when appropriate, that an area of 100 km^2 has to be inventoried, for which observations from at least 4 stations are necessary and at least a 100 measurements should be done. Necessary equipment usually lasts for several years, but should however be replaced, revised or upgraded after a while, especially as in innovative science new technologies might arise. We presume an amortize period of 4 years which means that the estimated yearly installation costs equal the total installation costs divided by four.

The last aspect combines whether the methodology is applicable to measure biodiversity at various scales of interest (*Lev*), from the organism to the ecosystem level (Appendix 5), whether the methodology is applicable for various groups of species (*Group*), from phytoplankton to mammals (Appendix 6), and whether the methodology can cover different types of habitats (*Env*), i.e. above the water level, the pelagic -, and the benthic habitats (Appendix 7).

Equation 1. Equation to calculate the total score (*Total*) for each of the methodologies.

$$Total = \frac{\left(\frac{Val}{3}\right) + \left(\frac{5(Plat+1)}{8}\right) + Dat + Spat + \left(\frac{Inte + Oper}{2}\right) + Cost + \left(\frac{5(Lev + Group + Env)}{14}\right)}{8}$$

Total = Total score

Val = Potential indicator value

Plat = Multi-platform use

Dat = Data type

Spat = Spatial scale

Inte = Integratebility in current observatories

Oper = Operability (current status)

Cost = Total costs

Lev = Multilevel biodiversity indication

Group = Multi-target groups

Env = Multi-environments

To calculate the total score of the methodologies; equation 1 is applied. This might look like a rather complicated equation, but it essentially only reduces the score for each of the 7 above mentioned aspects to a score between 1 and 5, except for aspect 1 (*Val*), as this is rated as being the most important aspect. The maximum score for *Val* is potentially 12, but is practice the highest score for this aspect was 8.67, making the aspect about twice as important as the other 6. Therefore the sum of scores for all aspects is divided by 8 bringing the potential maximum score to 5.25, but in practice the highest score will not transgress a value of 5. The total score herewith is reduced to a value between 1 and 5 with the highest scores for the most promising methodologies. As a huge variety of very different aspects subdivided in various facets is considered, all methodologies do score some points whereas also no methodology can cover everything. At least a certain ranking can be made that could give handles for discussion when certain methodologies are considered or implementation of (new) sensors for biodiversity in the JERICO network comes on the agenda.

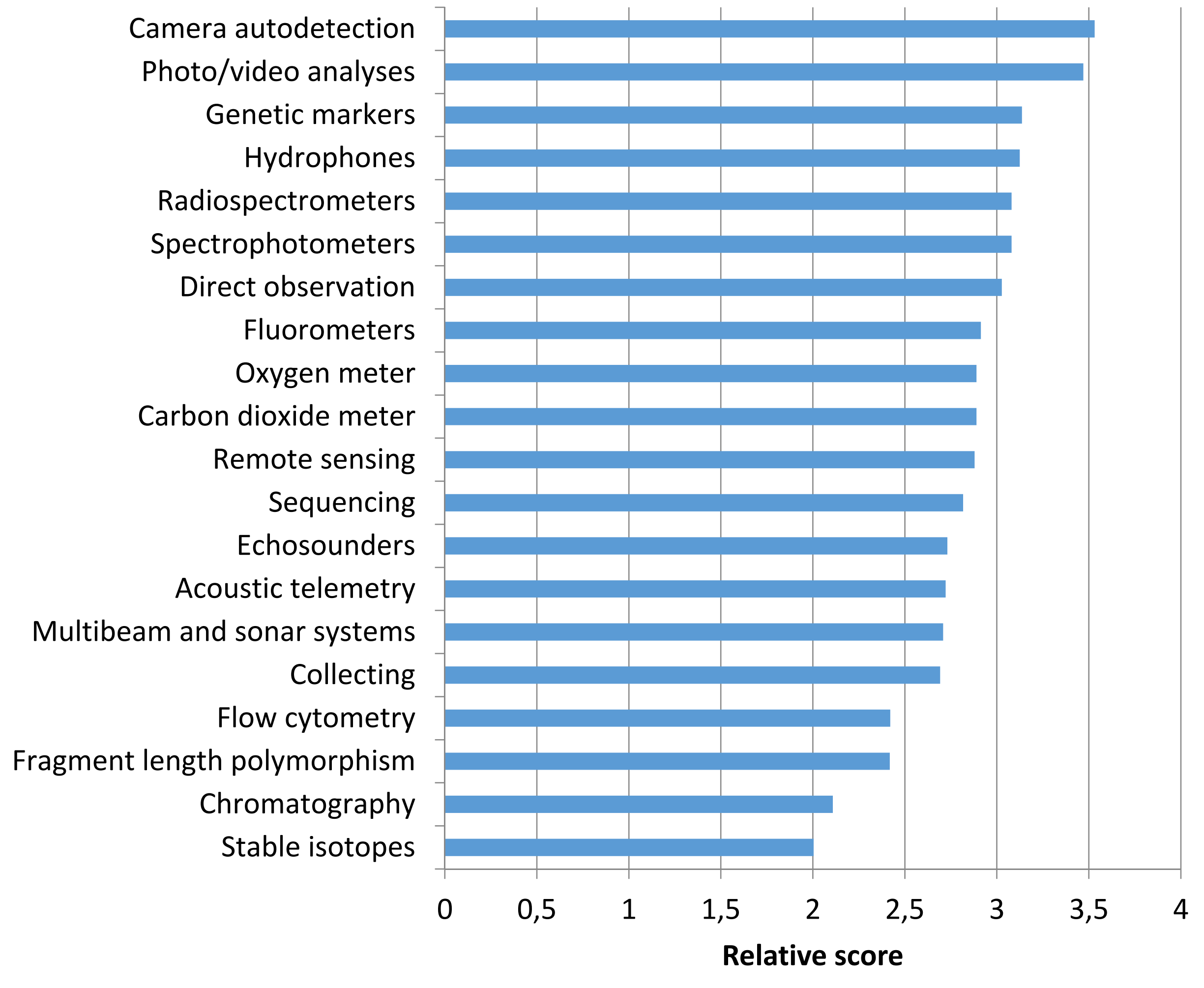

Figure 1. Ranking and relative score of potential methodologies to be integrated in the JERICO network to become an important network for biodiversity observation. Relative scores are calculated according to equation 1 and equal the total score (*Total*), the composition from scorings on several aspects is indicated in Table 1 and further detailed in the Appendices.

Progressive insight can always ask for an adjustment of the scores, or the need for certain characteristics, for instance additional to information already available from other networks or initiatives, can ask for putting of some more weight on certain aspects or facets. The aspects and facets taken in consideration is also not exhaustive and one could consider to take sensor type (e.g. acoustic, genetic, manual, imaging, chemical) or other characteristics also into account.

The results of our calculations and estimations indicate that particularly camera autodetection and photo - or video analyses (i.e. innovative imaging technologies) are promising methodologies for biodiversity observation within a future JERICO framework (Figure 1). Observations resulting from these methodologies are expected to be potentially relevant towards a range of biodiversity related aspects (i.e might have a good indicator value for several aspects). Only direct observation or collecting are expected to score higher on relevance towards the potential indicator value for biodiversity; but these methodologies are for instance scoring particularly low on the aspect of potential applicability from a variety of platforms the integratebility in current observatories and the temporal and spatial scale that they can potentially cover. These active sampling methodologies, difficult to automate, are very valuable or even essential for ground truthing of the more automated methodologies, whereas the (semi-)automated observations can be very valuable for the temporal and spatial upscaling of the local but more detailed active sampling results. It is not evident that active sampling will become a core activity of the JERICO network, as it conflicts with several of the main criteria for JERICO observatories; i.e. that observations should be (semi-)automated or continuous and (quasi) real-time, which makes that it is more obvious to cooperate with other initiatives and tune mutual activities on this point. Camera autodetection and photo - or video analyses are also expected to be applicable from a variety of platforms, to measure biodiversity for a broad range of biota, are not among the most expensive methodologies, and are not scoring below average on other aspects, with a possible exception for the range aspect (temporal and spatial) particularly for photo – and video- analyses. Photo – and video analyses might be restricted to a smaller range whereas camera autodetection has the potential to cover larger ranges, particularly in time. Another high potential methodology might be the use of genetic markers, however here the current operability status might be limiting aspect where definitely further development of the methodology for wide and broadscale application to estimate biodiversity at various levels and a range of biota is necessary. The application of hydrophones scores good on a variety of aspects, but for this methodology the relevance towards the detection and estimation of biodiversity, i.e. the indicator value for biodiversity, is still rather low, as is the applicability for a variety of species groups. One can imagine however, that such a methodology can fill in a gap (if there is) for a specific species group, in this case marine mammals or even fish, as an additional technique to one or a few other methodologies. The same actually accounts for spectrophotometry and radiospectrometry that can be particularly valuable towards the detection and estimation of diversity among phytoplankton or even macrophytes and macroalgae. Similarly there can be very good reasons to select one of the other techniques. Additionally most methodologies and their applications are developing, which can make that weak points at present can be rated otherwise in the future.

8.2. JERICO among (other) biodiversity observation initiatives

Taking the current pan-European biodiversity related networks and initiatives into account, it becomes clear that the majority links to biodiversity but is not particularly focusing on biodiversity, as is the case for JERICO as well. The actual standardized measurement of marine biodiversity at various levels over larger temporal and spatial scales is largely a gap not filled in yet. Largely this has to do with the fact that it is complicated to measure full-scale biodiversity in all its aspects at the various levels covering the range of biota, with just a few parameters, indicators or proxies and a limited number of techniques and methodologies. As it is this complicated, the way of measuring biodiversity differs from country to country and even from research group to research group. Where one focusses on processes or functionalities, the other identifies species distributions and ratios, whereas others seek refuge in proxies and derivatives, yet others identify key species representative for a certain diversity.

Particularly the combination of automated physical-chemical large scale and continuous observation that can serve as proxies, habitat characterizations and/or explaining variables in combination with more detailed local in situ biodiversity observations seems to be promising. Results of the last can herewith potentially be inter- and extrapolated to larger scales. The strength of JERICO lies definitely in the first part. There might be opportunities to incorporate 'real' in situ biodiversity observations to some extent as identified in chapter 8.1 as well, but for most species groups it is essential that ground truthing can take place with local more detailed information for which so far (semi-)automated broad scale observation methodologies are not specific enough. It would be advisable to join efforts and tune observations (e.g. in time and space) with other initiatives that focus on such observations, taking into account efforts that are made to standardize and tune monitoring activities and management objectives over Europe.

With respect to the marine realm and the coastal seas in particular, especially EMBOS is precisely installing a pan-European network of coastal biodiversity observatories focusing on standardized in situ observations to provide management and policy with the essential information and the research community with long term biodiversity baseline information and temporal and spatial patterns and trends. It seems to be obvious that a cooperation between the two; JERICO and EMBOS, will have mutual beneficiaries as both networks have their strengths but can get to a next level (e.g. JERICO could link their valuable observations directly to biodiversity observation, whereas EMBOS could find a way to get from local and/or transect information to pan-European mapping). Also ICES deploys several activities related to standardized long term biodiversity observation, which might focus particularly on other species groups and/or other parts of the European seas. It would therefore be wise to adjust biodiversity observations and the positioning and timing of measurements with them as well, and preventing duplication of activities when it can be foreseen that this does not deliver much added value. Regarding other initiatives it is particularly of importance to stay in contact and discuss each other's progress and opinions. It would for instance be wise for JERICO to consider indicators already in use in the individual European countries in policy and management, and those commonly used in particular, and try to connect with observations to their needs. But also vice versa, promote those indicators for which observations with the essential temporal and spatial resolution is more likely to be realized in the near future with the current network(s). The same accounts for suggested indicators and modelling needs to develop understanding of marine biodiversity and developments therein. The EEA, GEO BON and DEVOTES are operating in these fields. Then there is a series of related networks with similar aims, i.e. ocean observation and the intention to add to biodiversity observation as well, however focusing on other regions and/or environments, like there are ESONET, EMSO, FixO^3 and Argo. These are interesting networks to exchange experience and tune activities in such a way that biodiversity observation and interpretation of observed patterns can smoothly go beyond the European coastal seas, e.g. into the deep sea and the worlds' oceans. The same might account for LTER-Europe to achieve a fluent land-ocean transition in observations. LTER-Europe does already include some marine sites, but JERICO could give marine observation a similar body as terrestrial and aquatic observation amongst others within LTER at present. Then there are also several initiatives that are in need of standardized large scale long term biodiversity observation data, or aim to function as a portal or aim to accelerate biodiversity data use and research based on existing data, like there are LifeWatch and EMODnet. It could be of interest to discuss their needs and suggested data formats as JERICO might set the standard for certain coastal observation data and it is also of JERICO's benefit that data are widely distributed, used and recognized. Besides tuning JERICO activities with in situ biodiversity initiatives, also the link with satellite observation networks and initiatives is of importance so that up- and downscaling of biodiversity information and information on boundary conditions for biodiversity is secured.

8.3. Focusing on own (current) strengths

Although current focal parameters within JERICO are largely not directly related to biodiversity observation, although parameters as chlorophyll-a, oxygen concentrations, particle size distributions and nutrient ratios do have consequences for biodiversity, all parameters, and the combination of parameters in particular, do describe boundary conditions for biodiversity. Herewith particularly the potential biodiversity is identified. Combining the information with recordings on depth, sea floor characteristics (e.g. type of substrate and sorting) and hydrodynamics, which can and is already largely integrated in the current observatories, allows to identify habitat diversity or allows to create ecotope mappings in a three-dimensional way. Ecotopes do per definition reflect the potential biodiversity. The realized biodiversity is than a matter of the quality state. The quality state is amongst others described by parameters as there are temperature, turbidity, oxygen and nutrients, whereas chlorophyll-a might be an indication, but particularly direct anthropogenic impacts like disturbances, sea floor integrity issues, fisheries and harvesting, pollutants including chemicals and noise or just human presence, should also be monitored to estimate realized biodiversity without directly measuring it. The direct large-scale in situ monitoring of biodiversity is however a time-consuming and costly affair. Therefore the combination of a grid or transects of in situ biodiversity observation stations along the European coastal seas for detailed and in depth biodiversity measurement, with a network of more large-scale semi-autonomous biodiversity boundary and boundary development monitoring and the over-arching mapping of European-broad trends using satellite information is the most reliable and cost-effective way of pan-European monitoring of biodiversity and biodiversity changes. Therefore it is essential that the European network of biodiversity boundary measurements (i.e. JERICO) measures the set of parameters in a standardized way maintaining the essential spatial and temporal resolution taking timing and positioning into account over the European coastal seas. This allows, or it can even be beneficial, to implement a variety of platforms including fixed and mobile ones (as long as they cover the essential grid within the foreseen period taking timing and positioning into account). This also allows the implementation of different techniques, sensors or methodologies as long as the data outputs can be standardized and validated. Essential temporal and spatial resolution and timing and positioning is parameter dependent. It might be valuable to combine measurements on platforms but it is probably not necessary to implement the measurement of each of the selected parameters on each platform.

8.4. A roadmap for the future

It has to be realized that this exercise is just a first scanning of the potentials with a limited amount of efforts within limited available time. It is therefore advisable to handle this document as a starting point for a further discussion and to continue with the analyses of the potentials for JERICO to become an important network for biodiversity observation. However, the current report might help in focusing the discussion.

The focus of JERICO on a limited number of parameters, that cover most of the most important parameters to describe boundaries for biodiversity (i.e. to monitor habitat diversity and allow three-dimensional ecotope mapping) might be the optimal strategy for JERICO to become an important network towards biodiversity observation, as well. Current gaps in JERICO to cover habitat identification entirely might be sea floor characterization and measurement or estimation of the hydrodynamics. For the first aspect there might be good opportunities to implement active acoustics (e.g. side scan sonar) and/or imaging techniques (e.g. video transects) that can be combined with satellite observations (i.e. tuning of activities with earth observation networks or initiatives). To cover hydrodynamics and/or currents might be a huge challenge for which particularly the modelling on basis of point measurements in combination with salinity, temperature and/or turbidity measurements and bathymetric, substrate and weather information, for which a link with satellite observation might be essential. However, as indicated by the parameters that are of use, JERICO observations can already play an important role, particularly when in situ current measurements and/or substrate observation can also become part of the JERICO standardized observatory network.

The implementation of new sensors for observation of realized biodiversity might be most promising for imaging techniques with auto-detection potentials, the more as it might be combined with habitat detection. Also passive acoustic techniques might be promising as these could cover large areas, have potentials to be implemented in the current platform infrastructure and cover biodiversity not directly monitored in other initiatives at the pan-European scale. In the future there might be high potential for particularly genetic marker methodologies that if further developed might fit well with the JERICO platforms infrastructure.

However in the short term it would be most promising to connect to current pan-European biodiversity observation initiatives and take action to tune activities for mutual interests. Taking the current mutual infrastructures, foreseen activities and developments and interests into account, it is probably most obvious to join forces with EMBOS. A tuning of the temporal and spatial resolutions, timing and positioning of observations, and standardization of a selection of parameters within both networks could be realized on a relative short term (indicative a couple of years), whereas the combination of networks could cover a large part of the essential observations to identify biodiversity and biodiversity changes in all its facets at a pan-European scale. In the meantime also tuning activities with ICES, particularly in relation to their activities focusing on the diversity of higher trophic levels might be promising as it appears to be of mutual interest and can potentially fill in gaps not directly covered by the current activities of JERICO and EMBOS. It is recommendable to establish and/or further develop the link with earth observation initiatives as well. The ideal opportunity might be the initiation of common activities and cooperation between the indicated networks, e.g. in Horizon 2020 proposals and the resulting infrastructures and/or projects. Naturally it is of importance that JERICO remains active in the European and/or even global networks of networks, to discuss mutual interests with other initiatives and stays informed on developments and findings from initiatives like GEO BON, EEA and DEVOTES working on the essential parameters and indicators to sense biodiversity. Also the tuning of activities with networks covering bordering or slightly overlapping geographical regions and/or realms is of importance to ensure smooth transitions in observations and biodiversity related information.

9. Literature

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10. Appendices

Appendix 1. Scoring of potential observation methodologies on the potential indicator value for biodiversity. Methodologies are scored on a range of biodiversity related aspects. The indicator value of the biodiversity aspects shows the maximum score that can be reached with the highest values (5) indicating that the aspect is very relevant towards biodiversity in general, whereas a low score indicates that there is a link with biodiversity but that a relation is less straightforward. The column 'Potential indicator value' shows the total score that is achieved, where the maximum score that can be reached equals 36.

Methodology\To measure	**Behaviour**	**Biomass**	**Environmental connectivity**	**Foodweb structure**	**Functional diversity**	**Genetic diversity**	**Habitat diversity**	**Habitat use**	**Primary production**	**Size distribution**	**Taxonomic diversity**	**Potential indicator value**
Indicator value	*1*	*2*	*3*	*4*	*5*	*5*	*5*	*1*	*2*	*3*	*5*	*36*
Acoustic telemetry	1							1				**2**
Carbon dioxide meter									2			**2**
Camera autodetection	1	2		4	5					3	5	**20**
Chromatography		2			5							**7**
Collecting		2		4	5		5			3	5	**24**
Direct observation	1	2		4	5		5	1		3	5	**26**
Echosounders	1	2						1				**4**
Flow cytometry		2			5					3		**10**
Fragment length polymorphism			3			5						**8**
Fluorometers		2			5				2			**9**
Genetic markers					5	5					5	**15**
Hydrophones	1							1			5	**7**
Multibeam and sonar systems							5					**5**
Oxygen meter									2			**2**
Photo/video analyses	1	2			5		5	1		3	5	**22**
Remote sensing					5		5		2			**12**
Sequencing			3		5	5					5	**18**
Spectrophotometers		2			5				2			**9**
Spectroradiometer		2			5				2			**9**
Stable isotopes			3	4					2			**9**

Appendix 2. Scoring of potential observation methodologies on the potential applicability from several platforms. Semi-autonomous application from a platform is scored with the value 1, for active sampling no point is given. The total score indicates the multi-platform applicability score that at maximum reaches a score of 7.

Methodology	**Research vessel**	**Glider**	**Fixed platform**	**Buoy**	**Lander**	**Satellite (remote sensing)**	**Ship of opportunity**	**Researcher**	**Multi-platform use**
Maximum score	*(semi-) autonomous (1)*							*Active sampling (0)*	*7*
Acoustic telemetry		1	1	1	1		1		**5**
Carbon dioxide meter	1	1	1	1	1		1	0	**6**
Camera autodetection	1	1	1	1	1		1		**6**
Chromatography	1		1	1	1		1		**5**
Collecting	1							0	**1**
Direct observation								0	**0**
Echosounders	1	1	1	1	1		1		**6**
Flow cytometry	1		1	1	1		1		**5**
Fragment length polymorphism			1						**1**
Fluorometers	1	1	1	1	1		1	0	**6**
Genetic markers	1	1	1	1	1		1		**6**
Hydrophones	1	1	1	1	1		1		**6**
Multibeam and sonar systems	1	1					1		**3**
Oxygen meter	1	1	1	1	1		1	0	**6**
Photo/video analyses	1	1	1	1	1	1	1	0	**7**
Remote sensing						1			**1**
Sequencing			1						**1**
Spectrophotometers	1	1	1	1	1	1	1	0	**7**
Radiospectrometer	1	1	1	1	1	1	1	0	**7**
Stable isotopes			1					0	**1**

Appendix 3. Scoring of potential observation methodologies on 1) to what extent continuous data deliverance can be achieved, 2) the scale that can be covered, 3) to what extent methodologies can be integrated in the current JERICO observatories, and 4) the current operability status of the suggested observation techniques to put them into practice.

Methodology	**Data type**	**Spatial scale**	**Integratebility in current observatories**	**Operability (current status)**
Scale	Single – Repeated - High frequency - Continuous	Local - Small areas – Regions - Regional seas	Difficult – Possible - Relative easy	Highly theoretic - Needs investigation - Implementable on short term - Already implementable
Indicator value	*5*	*5*	*5*	*5*
Acoustic telemetry	5	4	4	5
Carbon dioxide meter	5	3	3	5
Camera autodetection	5	3	3	3
Chromatography	2	1	1	5
Collecting	2	1	1	5
Direct observation	1	2	2	5
Echosounders	3	3	3	3
Flow cytometry	3	2	2	4
Fragment length polymorphism	1	3	3	4
Fluorometers	5	2	2	4
Genetic markers	2	3	3	2
Hydrophones	5	3	3	5
Multibeam and sonar systems	3	4	4	3
Oxygen meter	5	3	3	5
Photo/video analyses	2	2	2	5
Remote sensing	4	5	5	3
Sequencing	1	2	2	5
Spectrophotometers	5	3	3	4
Radiospectrometer	5	3	3	4
Stable isotopes	1	2	2	4

Appendix 4. Scoring of potential observation methodologies on costs aspects taking installation and operational costs into account. Costs are estimated in euros per year with the assumption that observations are done for a period of 4 years (equipment amortized in 4 years) and that the methodology should at least give a representative view for a 100 km^2 area for which at least observations from a minimum of 4 different stations in necessary (or a mobile platform) and a total of at least 100 individual measurements (or continuous observations). Aspects taken into account are further specified if essential

Methodology\Costs		**Operational costs (€/Y)**	**Instalation costs (€)**	**Total costs (€/Y) for 4 years of application***	**Total costs score**
(To inventory 100 km^2 with at least 100 measurements/observations from at least 4 stations)	Specification of method taken into account to calculate costs	Maintanance + application + manhours per year			
Acoustic telemetry	100 tags, 4 receivers, boat time catching specimens	100000	150000	137500	**1**
Carbon dioxide meter	4 fixed platforms or 1 mobile platform	35000	20000	40000	**4**
Camera autodetection	4 fixed platforms or 1 mobile platform	30000	100000	55000	**3**
Chromatography	4 fixed platforms or 1 mobile platform	45000	100000	70000	**2**
Collecting	boxcorer	65000	15000	68750	**2**
Direct observation	binoculars / diving gear	30000	5000	31250	**5**
Echosounders	4 fixed platforms or 1 mobile platform	25000	25000	31250	**5**
Flow cytometry	4 fixed platforms or 1 mobile platform	15000	200000	65000	**2**
Fragment length polymorphism		25000	25000	31250	**5**
Fluorometers	4 fixed platforms or 1 mobile platform	15000	120000	45000	**4**
Genetic markers		25000	25000	31250	**5**
Hydrophones	4 fixed platforms or 1 mobile platform	30000	20000	35000	**4**
Multibeam and sonar systems		20000	35000	28750	**5**
Oxygen meter	4 fixed platforms or 1 mobile platform	35000	20000	40000	**4**
Photo/video analyses	4 fixed platforms or 1 mobile platform	45000	30000	52500	**3**
Remote sensing		20000	1000	20250	**5**
Sequencing		25000	25000	31250	**5**
Spectrophotometers	4 fixed platforms or 1 mobile platform	35000	75000	53750	**3**
Radiospectrometer		35000	75000	53750	**3**
Stable isotopes	C14 tracer for PP, MS	15000	300000	90000	**2**

*Five categories of total costs per year are identified; i.e less than 35000 €, between 35000 and 50000 €, between 50000 and 65000 €, between 65000 and 100000 €, and more than 100000 €; which respectively get a score of 5, 4, 3, 2, and 1.

Appendix 5. Scoring of potential observation methodologies on the levels of biodiversity for which they potentially generate information. By counting the distinguished biodiversity levels an indicator of potential multilevel application is obtained with a potential maximum score of 4 and the lowest score of 1.

Methodology\Biodiversity level	**Organism**	**Population**	**Community**	**Ecosystem**	**Multilevel indication**
Acoustic telemetry		1			**1**
Carbon dioxide meter				1	**1**
Camera autodetection		1	1		**2**
Chromatography		1	1		**2**
Collecting		1	1	1	**3**
Direct observation		1	1	1	**3**
Echosounders		1	1		**2**
Flow cytometry		1	1		**2**
Fragment length polymorphism		1			**1**
Flourometers			1		**1**
Genetic markers		1	1		**2**
Hydrophones		1	1		**2**
Multibeam and sonar systems			1	1	**2**
Oxygen meter				1	**1**
Photo/video analyses		1	1	1	**3**
Remote sensing				1	**1**
Sequencing	1	1			**2**
Spectrophotometers			1	1	**2**
Radiospectrometer			1	1	**2**
Stable isotopes			1	1	**2**

Appendix 6. Scoring of potential observation methodologies on the number of biota groups to which it is applicable to measure the diversity. By counting the distinguished biota groups an indicator of potential multilevel application is obtained with a potential maximum score of 7 and the lowest score of 1.

Methodology\Target group	Phytoplankton	Zooplankton	Macroinvertebrates	Macrophytes & Macroalgae	Fish	Birds	Mammals	Multilevel indication
Acoustic telemetry			1		1	1	1	**4**
Carbon dioxide meter	1							**1**
Camera autodetection	1	1	1		1	1		**5**
Chromatography	1							**1**
Collecting	1	1	1	1	1	1	1	**7**
Direct observation			1	1	1	1	1	**5**
Echosounders		1			1		1	**3**
Flow cytometry	1							**1**
Fragment length polymorphism	1	1	1	1	1	1	1	**7**
Fluorometers	1							**1**
Genetic markers	1	1	1	1	1			**5**
Hydrophones					1		1	**2**
Multibeam and sonar systems		1	1	1	1			**4**
Oxygen meter	1							**1**
Photo/video analyses			1	1	1	1	1	**5**
Remote sensing	1			1				**2**
Sequencing	1	1	1	1	1	1	1	**7**
Spectrophotometers	1			1				**2**
Radiospectrometer	1			1				**2**
Stable isotopes	1	1	1	1	1	1	1	**7**

Appendix 7. Scoring of potential observation methodologies on the type of habitats where it can be applied. By counting the distinguished habitat types an indicator of potential multilevel application is obtained with a potential maximum score of 3 and the lowest score of 1.

Methodology\Environment	Pelagic	Benthic	Above water	Multilevel indication
Acoustic telemetry	1	1	1	**3**
Carbon dioxide meter	1			**1**
Camera autodetection	1	1		**2**
Chromatography	1	1		**2**
Collecting	1	1		**2**
Direct observation	1	1	1	**3**
Echosounders	1			**1**
Flow cytometry	1	1		**2**
Fragment length polymorphism	1	1	1	**3**
Fluorometers	1	1		**2**
Genetic markers	1	1		**2**
Hydrophones	1			**1**
Multibeam and sonar systems	1			**1**
Oxygen meter	1			**1**
Photo/video analyses	1	1	1	**3**
Remote sensing	1	1		**2**
Sequencing	1	1	1	**3**
Spectrophotometers	1	1		**2**
Radiospectrometer	1	1		**2**
Stable isotopes	1	1	1	**3**