Joint European Research Infrastructure network for Coastal Observatory – Novel European eXpertise for coastal observaTories - **JERICO-NEXT**

Deliverable title	Approaches to monitor European coastal seas
Work Package Title	WP 4
Deliverable number	D4.1
Description	
Lead beneficiary	Covartec
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Submitted by	
Revision number	V3.1
Revision Date	31/05/16
Security	Public

The JERICO-NEXT project is funded by the European Commission's
H2020 Framework Programme under grant agreement No. 654410
Project coordinator: Ifremer, France.

History			
Revision	**Date**	**Modification**	**Author**
V1	February 15	Initial version	WP4 partners
V2	May 15	More information on the sampling strategy is given + answer to comments made by the WP1 &4 leaders and coleader	WP4 partners
V3	May 30	List of parameters to be measured added + answer to specific comments	Durand
V3.1	May31	Addition of information on JRAP1 for each investigation site.	Puillat

Approvals				
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1 Executive Summary

The objectives of JERICO-NEXT are to address the challenge of observing the complexity and high variability of coastal areas at Pan-European level, in the framework established by European Directives (WFD, MSFD) and the operational marine services. The JERICO-NEXT project aims at extending the EU network of coastal observations developed in JERICO (FP7) by adding new innovative infrastructures while integrating biogeochemical and biological observations. The main target of JERICO-NEXT is to provide the researchers with continuous and more valuable coastal data coupling physical and biological information. The JERICO research infrastructure (JERICO-RI) is valorised through six Joint Research Activity Projects (JRAP) that address key environment challenges and scientific questions; the ultimate objectives being to maximise the value and impact of the RI while providing key recommendations for the further development of the infrastructure, in terms of sampling capabilities, representativeness of coastal processes, support to services, among others. Each JRAP gathers a critical mass of expertise from the consortium, allowing tackling the challenges of multi-disciplinarity and the variability of European coastal environments.

The present report (D4.1) summarises the approaches proposed for assessing the value and the present and future relevance of the JERICO-RI, to provide high-value datasets for addressing these key challenges at European level.

Dedicated sampling strategies have been elaborated and formulated to answer key scientific questions, related to these challenges and will be tested during the next two years of the project, with the aim to provide sounded inputs to the JERICO-RI science strategy (WP1.2) for the short term, and concrete recommendations to the roadmap for the future.

Focus is set on (1) integrating physical, chemical and biological observations for improved understanding of complex coastal key-processes; (2) testing/integrating new technologies and methodologies of high added-value for the observation of the coastal processes.

JRAP-1 - Pelagic biodiversity

Biodiversity of plankton, harmful algal blooms and eutrophication

Most phytoplankton species are beneficial to the marine ecosystems, since they form the base of the food-web, but some may be harmful. The EU Marine Strategy Framework descriptors on biodiversity, food webs, invasive/non indigenous species and eutrophication (Harmful Algal Blooms = HAB) are being addressed in JRAP-1. HAB are also relevant e.g. to human health, fisheries, aquaculture and tourism. Traditional phytoplankton monitoring is often made at low sampling frequencies due to high cost. In JRAP-1 automated systems for investigating phytoplankton diversity and abundance with a focus on harmful algae are used on research vessels, ferries and at fixed ocean observatories in the Baltic Sea, the Kattegat-Skagerrak, the North Sea-eastern English Channel area and in the Western Mediterranean Sea. One aim is to combine different methods to make cost efficient observations. Another aim is to measure at a frequency high enough to approach resolving the natural variability. Field work is underway; flow cytometry and bio-optical measurements are some of the methods used. Two workshops on methodology, data handling, planning of common work and early results will be arranged in 2016. An instrumented buoy has been deployed in the Northern Baltic proper. Ferrybox systems on three ships in the Baltic Sea are in operation. Bio-optical data are being collected continuously and automated water sampling is also carried out. Water samples are analysed in the laboratory, e.g. for phytoplankton composition. The Utö observatory in the Archipelago Sea is being set up. The focussed studies in the Baltic Sea will be carried out in 2017. In the Kattegat-Skagerrak a study of plankton dynamics near a mussel farm at the Swedish Skagerrak coast will be made in August-October 2016. Also instrumented oceanographic buoys and a Ferrybox system are in operation. One objective of the study is to investigate the coupling between physical processes and harmful algal blooms. The focus organisms are phytoplankton that produces biotoxins that may accumulate in shellfish. In the eastern English Channel – North Sea area the phytoplankton are being studied using automated systems on several research vessels, ferries, instrumented buoys and also using fixed ocean observatories. Flow cytometers are operated on the research vessels. By combining the different data set the development of algal blooms can be followed. Phytoplankton functional diversity and spatio-temporal distribution at the meso-scale are studied also in the western Mediterranean thanks to the installation of a new Ferrybox system with a flow cytometer and additional instruments on the ferry “Le Carthage”. In 2017 and partly also in 2018, additional field work implying at least two partners and several methods will be carried out in JRAP-1 and the data collected will be combined with results from other

JERICO-NEXT activities. The combination of results from JRAP-1, data on the carbonate system related to primary production, data from HF radar, results from physical models etc. will lead to an improved understanding of the dynamics of algal blooms and to cost efficient observation systems.

JRAP-2

One approach in view of monitoring the ecological quality status of benthic habitats is to: (1) assess the relationship linking disturbance intensity, benthic diversity and ecosystem function, (2) monitor disturbance intensity, and (3) use it as a proxy. In coastal Seas, this approach is clearly complicated by the spatial heterogeneity and the strong temporal dynamics of both disturbances and benthic communities. It is therefore essential to develop approaches allowing for a sound assessment of spatio-temporal changes in disturbance intensity and its effects on benthic habitats. This can be achieved through comparative studies provided that: (1) spatio-temporal changes in disturbance intensity are properly assessed (e.g. through modelling), (2) temporal and spatial integration scales of biological/biogeochemical compartments processes are determined, and (3) appropriate data analysis procedures are used. The overall aim of JRAP-2 is therefore: (1) to carry out several actions (new sequences of observations) in view of practically assessing the interaction between disturbance(s), benthic diversity and functions, and (2) by doing so to contribute to define an optimal strategy to assess the interactions between these three parameters/ processes. More specifically, considering the remineralization of Particulate Organic Matter (POM) settling at the sea-floor as an indicator of the functioning of the sediment-water interface, JRAP-2 will deploy a series of measurements of (1) benthic (both micro and macro-) diversity, and (2) the functioning of the water-sediment interface in different study areas facing different sources of disturbance.

This includes: (1) the West-Gironde Mud Patch, a major pro-delta exhibiting strong spatio-temporal gradient in sediment stability and organic enrichment; (2) the Bay of Brest, an area which is suffering from dredging and is also currently experimenting a colonization by the invasive American slipper limpet *Crepidula fornicata*; and (3) the Cretan Sea, a largely oligotrophic area locally and temporarily affected by the sewage outfall of the city of Heraklion.

JRAP-3

Marine coastal waters are receptors of thousands of chemical pollutants emitted through waste water, deposited from the atmosphere or released directly to the sea from vessels or other coastal infrastructures during both professional and recreational activities. Priority lists for regulations are generally limited to a few dozens of chemicals with well-studied toxic properties. There is a paucity of information on marine water contamination and fate and distribution of contaminants in the marine ecosystem. Gathering fundamental information on the nature of the contaminants present in coastal water, their distribution and possible biological responses is necessary to implement regulation and marine protection (as requested by chapter 8 of the EU-MSFD). These activities are currently out of reach of national and international routine monitoring programmes in Europe and beyond, due to elevated costs and delay in developing adequate regulation.

The overall goal of JRAP-3 is to exploit the coastal infrastructure network and the set of parameters to deliver a “transversal” study where contamination data, biological data and water quality data will be fully integrated. Specifically, the addressed objectives are: i) to identify new contaminants in European coastal waters that are not yet addressed by regulation but which can pose a pressure to the coastal marine ecosystem; ii) to describe spatial distribution of chemical contaminants in European coastal waters exploiting integrated fixed and mobile monitoring infrastructures; iii) to investigate the patterns of the spatial distribution exploiting information from physical and chemical sensors available on the infrastructures; iv) to analyse co-linearity between contaminant signals and biological signals (specifically tracking the presence of pollution feeding microorganisms in areas with high exposure to chemical contaminants. Through these activities, JRAP-3 will contribute in valorising the JERICO-RI in the context of the descriptor 8 of the MSFD.

The work is articulated in 3 tasks in the following areas: Portuguese coasts, Bay of Biscay, North Sea, Kattegat, Skagerrak and Norwegian coasts. Task 1 includes the first pan-European monitoring of chemical pollutants using passive samplers deployed on moorings. Task 2 foresees monitoring campaigns using a set of Ferrybox platforms (mobile) in the outflow of the Baltic (Oslo and Kiel transect), the North Sea, and the Norwegian Sea. Task 3 focuses on a high spatio/temporal resolution campaign based on Ferrybox platform along the Oslo-Kiel transect focusing on the analysis of coupled chemical signals (several pharmaceuticals, personal care products, pesticides and polycyclic aromatic hydrocarbons) and biological responses (DNA-based biomarkers of bacteria adapted in feeding

on chemical pollutants. In all cases, physical/optical parameters from sensors present on the selected infrastructures will be used along with chemical and biological parameters, to identified collinearities between the signals.
Complementary objectives of JRAP-3 are: i) To deliver technical protocols and best practices for the monitoring of chemical pollutants using existing coastal infrastructures. ii) To optimize existing chemical sensor technology for use on fixed coastal monitoring infrastructures. iii) To provide guidelines for the implementation of contaminant monitoring using JERICO infrastructures.
We expect to provide a substantial contribution to expand the list of emerging contaminants discovered in European coastal waters and demonstrate the feasibility of an integrated large scale (pan-European) observation of marine chemical pollution. We will also focus on delivering the first large scale correlative analysis integrating contaminant data and microbial data to tackle biological responses in relation to exposure to pollution.

JRAP-4
Surface transport in coastal areas is driven by a large variety of processes (tides, current instabilities, coastal jets, eddies, fronts, etc.) acting simultaneously, in response to different forcing, and over a broad spectrum of time-space scales. These processes play a key role in the dispersal/retention of pollutants, planktonic species, and more generally in cross-shelf exchanges. The characterisation and better predictability of these structures are critical to understand the physical and biological interactions in the coastal zone and to accurately monitor the resulting complex surface circulation. In this context, the JRAP4 aims to demonstrate the potential of coastal observatories and the JERICO Research Infrastructure for the understanding and monitoring of the 4D shelf/slope circulation. Additional effort is devoted to quantify the potential impact of ocean transport on the distribution of floating and dissolved matter in line with the 2, 7 and 10 Marine Strategy Framework Directive descriptors.
Through JRAP4, several new deployments, in addition to historical observations, will be used to make a step forward on the characterisation of the main coastal ocean processes and resulting 4D transports at different temporal and spatial scales. The work will concentrate in three pilot areas (SE Bay of Biscay, NW Mediterranean and German Bight) and rely on the use of information from Observing Systems (OS) based on HF radar for surface currents, moored high-frequency thermistor chains, drifting buoys and high-resolution numerical model experiments (OSSES). Three main work lines common to all the study areas are defined as follows: (i) retrieval of 4D transports in each study area through an optimal observational strategy and applying eulerian and lagrangian analyses, (ii) use different methods to obtain transport short time prediction using data or combination of data and models and (iii) apply 4D transports to address issues in relation with different MSFD drivers. Specific actions within the different study areas will be devoted on producing information and maps on integrated transport that can be used as a basis for several applications, including those of interest of other JRAPs.

JRAP-5 "Coastal carbon fluxes and biogeochemical cycling"
Marine carbon cycle has a key role on global climate change. In open oceans, carbon uptake is dominated by physical dynamics and chemical processes (solubility pump), while in productive coastal areas with high spatial and temporal variability biological processes may dominate (biology pump). While solubility pump aims in balancing atmospheric and marine pCO_2, the biological pump depends on the rates of primary production and respiration. In both cases the physical state of the sea (mixing, temperature etc.) and carbonate system components need to be evaluated to get comprehensive description of air-sea carbon fluxes
This JRAP will guide development of optimal observation network for C-flux studies, provide concepts and methods towards harmonized measurements and will ultimately give recommendations of setting up a combined physical, chemical and biological measurement network for carbon cycle studies as needed for understanding the role of coastal systems in global C cycles.
During the spring 2016, we will first investigate and analyse the methodology used for carbon and biological observations within the JRAP participants. Based on outcome, a comparison WS may be organized.
The main research period of this JRAP is from spring 2017 to spring 2018, in which we will collect combined carbon and relevant biological data throughout European Sea and analyse the data especially for spatial and temporal variability, and links between the biology, and physical and chemical state of the sea.

Concluded remarks

If each JRAP is dedicated to one priority, efforts have been made to maximise cross-cutting activities between JRAPs, creating bridges where appropriate. For example, the link between physical (transport) process study (JRAP-4), contaminant distribution (JRAP-3) and forecasting capability (JRAP-6) has been reinforced to maximise the outcomes of these JRAPs. Likewise, the connection between JRAP-1 and JRAP-5 has been emphasised when appropriate.

The ambition of the sampling program for each JRAPs may partly be pending on other projects and funding sources, and might therefore need to be adapted the real context. The progress and a first revision of the sampling programs per JRAPs will be presented in D4.2. Feedback on the strategies after the field deployments and analysis will be communicated to the WP1 in the lasted stage of the project (deliverable D4.5).

2 Introduction

In the last decades marine observing systems have been implemented in **coastal and shelf seas** around Europe. They mostly answer local/regional **monitoring** and **oceanographic research demands but heterogeneity and geographical dispersion** are often a limit. Indeed, often driven through short-term research projects, **sustainability of observing systems is not guaranteed.**

One of the main challenges for the European marine research community is now to **increase the consistency** and **the sustainability** of these dispersed infrastructures by addressing their future within a **shared pan-European framework.**

The aim of JERICO-NEXT, as a network of coastal observatories, is to ensure regular and standardized observations in order to provide long term time-series of high-quality data. This needs to combine operational capabilities, innovation and sustainability for high quality European networking research.

2.1 The JERICO-NEXT vision:

The JERICO-NEXT community emphasizes that one cannot understand the complexity of the coastal ocean if one does not understand the coupling between physics, biogeochemistry and biology. Reaching such an understanding requires new technological developments allowing for the continuous monitoring of a larger set of parameter. It also requires an a priori definition of the optimal deployment strategy in view of coupling diverse data monitored over very different spatial and temporal scales. This is why JERICO-NEXT: (1) will focus its main effort to the assessment of the interactions between physics, biogeochemistry and biology, and (2) will not be restricted to pure technological aspects but will also include fundamental scientific considerations within its NA; the two being tightly tied within the JRA.

2.2 Objectives of JERICO-NEXT

The objectives of JERICO-NEXT are to address the challenge of observing the complexity and high variability of coastal areas at Pan-European level, in the framework established by European Directives (WFD, MSFD) and the operational marine services.

The JERICO-NEXT project aims at extending the EU network of coastal observations developed in JERICO (FP7) by adding new innovative infrastructures while integrating biogeochemical and biological observations. The main target of JERICO-NEXT is to provide the researchers with continuous and more valuable coastal data coupling physical and biological information.

Furthermore the project aims at demonstrating the adequacy of the observing technologies and monitoring strategies to provide the information necessary to address a selected set of major environmental issues, for example, : (1) direct and indirect requirements for assessment of Good Environmental Status required by MSFD, and (2) global environmental change impacts on coastal ecosystems.
The overall project structure is presented in Figure 2.1.

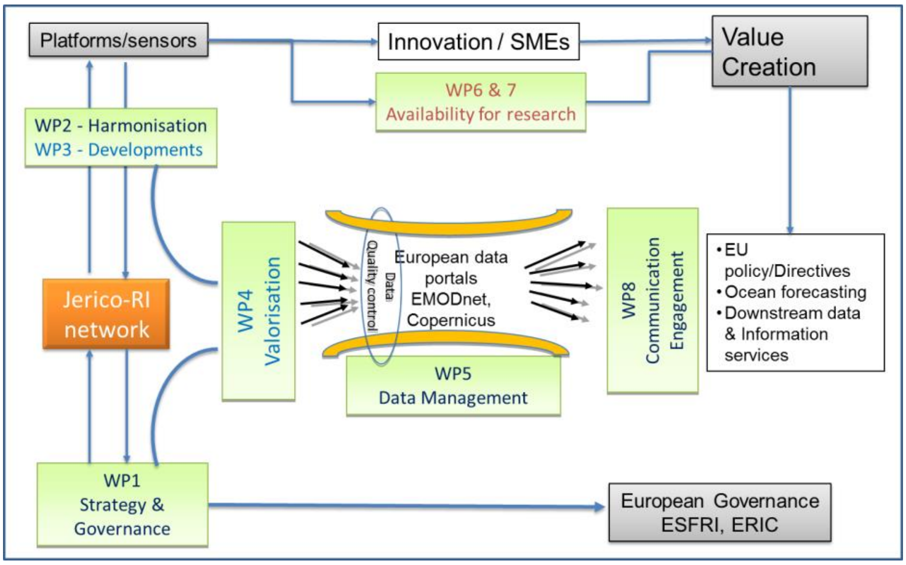

Figure 2.1: Project structure, showing the link between WP4 and WP1, as well as the link to value creation.

In the frame of the JERICO(FP7) project, the consortium clearly identified the need to further specific technology developments and harmonization procedures, insuring the relevance to scientific and societal challenges on an applicative base. Indeed, the success to answer these challenges is based on our ability to cross cut the boundaries between technology harmonization, technology developments and data management, in order to deliver the expected information and data relevant to these challenges on a well-tried concept. JERICO-NEXT is paying particular attention to fill this gap in WP4 by implementing 6 Joint Research Activity Projects (JRAPs) relevant to 6 key environmental questions and/or policy requirements on:

1) pelagic biodiversity with focus on phytoplankton biodiversity, dynamics and algal blooms,
2) benthic biodiversity with focus on the impact of biodiversity on ecosystem functioning and services
3) chemical contaminant occurrence and related biological responses,
4) hydrography and transport, with focus on the use of coastal HF radar and hydrodynamic modelling
5) carbon fluxes and carbonate system in coastal environment
6) operational oceanography with focus on maximising the potential of coastal observation for numerical prediction and forecasting in coastal regions.

Improving the links between physical and biogeochemical data with biological processes is planned to be achieved by developing the methodology and numerical models to define the optimal deployment strategies to efficiently couple the monitoring of physical, biogeochemical and biological compartment and processes. This will first include the definition and the test of optimal deployment strategies for unravelling the interactions between physico-chemical and biological processes.
The JRAPs are targeted projects that address key environment challenges and scientific questions, through the use of the existing JERICO Research Infrastructure (JERICO-RI); the ultimate objectives being to maximise the value and impact of the RI while providing key recommendations for the further development of the infrastructure, in terms of sampling capabilities, representativeness of coastal processes, support to services, among others. Each JRAP gathers a critical mass of expertise from the consortium, allowing to both tackle the challenges of multi-disciplinarity and the variability of European coastal environments.
JRAP-1 will for example make coordinated assessments of both surface currents (e.g. using HF radars) and phytoplankton characteristics (using a multi-disciplinary sampling platform) for studying the dynamics of phytoplankton (including harmful algal blooms) under a large variety of environmental conditions. JRAP-2 will also couple physical, biogeochemical and biological monitoring to assess the environmental factors controlling macrobenthos biodiversity.

2.3 Objectives of this report

The WP4 aims at implementing the JRAPs in close interaction with WP1 (science and governance strategies). The goal is to secure an optimal feedback from the experience and new knowledge arising from the JRAPs for elaborating the JERICO-RI science strategy.
Deliverable D4.1 - *Approaches to monitor European coastal seas* - is the first official deliverable from Jerico-Next and from WP4. The report aims at summarising the initial thinking and strategy plans on how to best collect the data required to answer the key environmental questions that are the focus of the sic JRAPs, using the present JERICO-RI and preparing for the future, enlarged and improved RI.

The JRAPs' plans described in the present report have been elaborated through a comprehensive process, initiated in October 2015 at the occasion of the kick-off meeting. The process encompassed interactions at different levels in the project, combining bottom-up and top-down approaches, as followed:

- Coordination between WP1 and WP4 in terms of sampling strategy, multi-parameter integration, interaction between JRAP and value-addings from linking JRAPs together, mechanisms for optimal feedback and inputs to the science strategy (WP1.2) and more generally to the "roadmap for the future".
- This has been carried out through regular communications and virtual meetings between WP1 and WP4 leadership together with JRAP's leaders in the period October 2015-May 2016.
- Initial inputs from the STAC at the occasion of the KO meeting
- Coordination within each JRAP and between JRAPs

The timeline and milestones towards the submission of D4.1 is presented in Figure 2.2, together with the place of D4.1 in the value chain towards the elaboration of the JERICO-RI science strategy, which version 1 is due in February 2017 (M18).

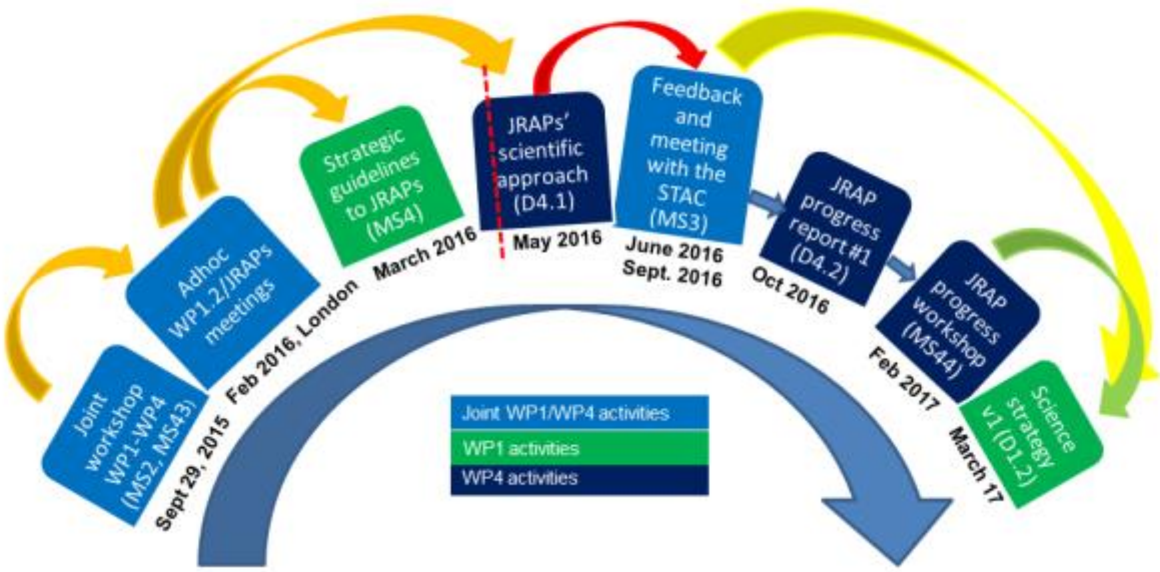

Figure 2.2: Integration WP1/WP4: Timeline, milestones and initial deliverables.

The present document is organised by JRAP. A common structure has been adopted for all the JRAPs in order to ease the readiness of this comprehensive document. JRAPs are presented in form of research project, with focus on:

- the use of the JERICO-RI, the scientific question(s) to be addressed;
- the sampling strategy to be implemented and/or tested;
- how integration between biotic and abiotic factors is addressed;
- the impact of the JRAP for JERICO-NEXT science strategy and roadmap for the future.

3 JRAP-1: Biodiversity of plankton, HAB and eutrophication

3.1 Rationale and expected outcomes

3.1.1 Introduction to phytoplankton and harmful algae

Phytoplankton micro-organisms are the main primary producers in the sea and form the base of the marine food web. Phytoplankton is characterised by a large biodiversity and include organisms from several different taxonomic groups in a size range from ~0.8 µm to ~0.5 mm, which abundance varies from a few hundred per litre for some of the largest organisms to 10^9 cells per litre for the smallest. It is common to find > 50 different species in a few millilitres of sea water. The traits of different species differ substantially; examples: some are good swimmers, some have complex life cycles including small single-cells to big colonies, some are phototrophs while others are mixotrophs carrying out photosynthesis and feeding on other plankton. Cyanobacteria are included in the phytoplankton and can potentially fix atmospheric nitrogen. In general phytoplankton growth is beneficiary to the marine ecosystem and most algal blooms fuel most marine food webs. However, some phytoplankton species or types are harmful, causing Harmful Algal Blooms (HAB). High biomass blooms may cause anoxia when degraded by bacteria, often at or near the sea floor. Blooms of toxin producing species may also be ecosystem disruptive affecting other plankton and benthic organisms in major ways. Aquaculture is susceptible to damage from HAB. Fish farms may be severely affected of fish killing algae. Shellfish feeding on biotoxin producing algae may accumulate toxins. Humans eating the shellfish are at risk since the biotoxins are very potent causing e.g. paralytic shellfish poisoning, diarrhetic shellfish poisoning and amnesic shellfish poisoning. Dinoflagellates and, to a lesser extent, diatoms are the main groups causing problems for mussel farmers.

3.1.2 Main questions - Objectives

The EU Marine Strategy Framework Directive (MSFD) has the goal that the European seas should have reach Good Environmental Status (GES) by the year 2020. The MSFD includes phytoplankton in descriptors related to:

- Biodiversity
- Food webs
- Invasive species
- Eutrophication
- Harmful algal blooms

The focus of the work in JRAP-1 is biodiversity and HAB. A problem for observations of phytoplankton is the large temporal and spatial variability in phytoplankton distribution in the sea. The variability may be related to a combination of biological and physical forcing, e.g. accumulation of phytoplankton near a pycnocline or at the edge of currents, frontal systems and Regions of Freshwater Influence (RoFIs), patchiness induced by both turbulence and biological processes. It can be also due to grazing of zooplankton, parasitism and/or by competition or mutualism amongst different phytoplankton species. Standard monitoring methods, e.g. monthly water sampling or punctual spatial cruises, and subsequent microscope analysis, do not resolve the whole natural variability in the distribution of phytoplankton.

The main objectives of JRAP-1 are:
- to enhance the understanding of the dynamics of algal blooms by combining data on phytoplankton distribution, abundance and diversity with chemical and physical oceanographic data,
- to apply novel *in situ* automated or semi-automated methods to address phytoplankton diversity, abundance , biomass and photosynthesis parameters in marine coastal systems, with a focus on harmful algae and eutrophication,
- to assess their potential for complementing traditional methods, which are based on discrete water sampling and labour intensive laboratory microscope work
- to formulate inputs for science strategy related to the JERICO-RI and recommendation for its further development (roadmap for the future)

This will be carried out in contrasting pelagic habitats during different seasons. The objectives are slightly different in the different geographic areas (see hereafter).

3.1.3 Description of the state of the art related to the science topic

Methods for identifying phytoplankton and estimating their biomass are in general based on one of three basic principles: (1) morphology, (2) content of photosynthetic pigments or (3) genes. Table 3.1 summarizes some advantages and disadvantages of the methods described below.

Table 3.1: Advantages and disadvantages of methods.

Method	Biodiversity	Biomass estimates	Sample throughput	Level of automation	Horizontal coverage
Light microscopy	Good	Good	Low	Low (automated water sampling is available)	Low
Fluorescence microscopy	Medium	Medium	Low	Low	Low
Electron microscopy	Very good	Bad	Very low	Low	Low
Flow cytometry	Bad-Medium	Medium	Hiigh	Semi-automated on research vessels and/or in fixed stations	Medium (Ferrybox)
Imaging flow cytometry	Medium-Good	Medium-Good	Medium	Semi-automated on research vessels and/or in fixed stations	Medium (Ferrybox)
Gene probes	Medium (only a limited number of species)	Bad-Medium	Medium	Semi-automated (ESP)	Low-medium
Barcoding	Good	Bad	Medium	Automated sampling an preservation in development	Low-medium
Chlorophyll a analyses (water sampling)	Bad	Medium	Low	Low (automated water sampling is available)	Low
HPLC-analysis of photosynthetic pigments	Bad-medium	Medium	Low	Low (automated water sampling is available)	Low
In vivo fluorescence methods based on the fluorescence of photosynthetic pigments	Bad-Medium	Medium	High	High	High
Methods based on the absorbance of photosynthetic pigments	Bad-Medium	Medium	High	High	Medium-high
Satellite remote sensing (ocean colour-reflectance of photosynthetic pigments	Bad-medium	Medium	High	Yes	High (during cloud free conditions)

The classic method for estimating phytoplankton biodiversity and abundance is the Utermöhl method (*Utermöhl*, 1931). The method is used in most long-term monitoring programs. Water samples are collected and preserved and later the phytoplankton are concentrated by sedimentation. A phytoplankton identification expert then analyses the samples using an inverted microscope. If the sizes and cell volumes of the organisms are estimated the biomass may be assessed. A disadvantage with the method is that the most abundant phytoplankton, the autotrophic picoplankton (0.2-2 µm), are overlooked. The importance of these was recognized in the late 1970's. Fluorescence microscopy or flow cytometry are needed to count these. Another disadvantage of the Utermöhl method is that organisms <10 µm (small nanoplankton) are difficult to identify. These are of the grouped together as "unidentified flagellates" and "unidentified coccoids".

Fluorescence microscopy is also very useful for identifying and counting the nanoplankton and picoplankton. Fluorescent dyes are used to make the morphology and trophic status (i.e. with or without pigments) of the organisms visible. Auto-fluorescence from chloroplasts is a useful way to discriminate between phototrophic and heterotrophic organisms. Fluorescent molecular probes (FISH) may be used to identify selected species if probes specific for the species of interest exist. Electron microscopy makes it possible to study the finest morphological details of plankton organisms of all sizes. This is often necessary when identifying organisms < 10 µm and when describing new species. Preparation of samples for electron microscopy is unfortunately very time consuming.

A disadvantage with the microscope based methods is the need to collect and preserve water samples that are transported to a laboratory. Also the slow sample throughput is an important problem. Spending 3-4 hours on one sample is common. This restricts the possibility to analyse enough samples to resolve natural variability in plankton communities. There is also a long delay from sampling to results. This makes these methods less useful for producing early-warnings for HAB which may be of interest to aquaculture, fisheries, tourism etc.

Molecular methods have a potential for providing tools for automated or semi-automated analysis of a large number of plankton samples. Most molecular methods rely on that gene sequences, e.g. 18S rDNA, are known for the organisms of interest. Genbank and EMBL/EMBO hold databases of sequenced genes. However, the data for phytoplankton is not well curated. Thus a subset of the data is found in database called PR2 specific for eukaryotic unicellular plankton and curated by phytoplankton specialists. A new initiative known as UniEuk will attempt to produce an even better database with gene sequences and traits of unicellular eukaryotic organisms. Studies of plankton collected on filters and analysed using high throughput sequencing of 18S rDNA (barcoding method) indicate that a large number of the plankton in the sea are not known. They are not in culture and their genes have not been sequenced.

There are a few attempts to build machines for automated analyses of harmful algae based on molecular data. They include the Environmental Sample Processor (ESP) which essentially is an automated mini laboratory for concentrating plankton by filtering and for carrying out FISH (Groben & Medlin 2005) for selected species. Another example is a machine produced by the MIDTAL-project (FP7). This project came up with a device that can handle several (about twenty?) HAB species. A disadvantage with the method is that there are many manual steps in preparing a phytoplankton sample before it can be placed on the machine. There are also other problems using gene based methods. One is that the number of genes copies is often not directly related to cell numbers or to the size of the organisms.

Flow cytometry (FCM) is a type of particle counter in which individual particles, e.g. phytoplankton, are analysed. Organisms are characterized based on the fluorescence of their pigments and on scattering properties after being intercepted by a laser beam. The first instruments used for plankton analyses were quite large, a few meters long. The development of LED-lasers has resulted in small benchtop instruments that can be used in research cruises, some of them being especially built to perform automated analysis of cells/colonies from 1 to 800µm width and to record the complete pulse-shape of particles (CytoSense, Dubelaar & Gerritzen 2000). There are also instruments built for deployment on oceanographic buoys or fixed stations, e.g. the CytoSub (Cytobuoy) that is used in JERICO-NEXT. Imaging flow cytometry is a type of flow cytometry in which the scattering or fluorescence triggers a camera (FlowCAM, Imagining Flowcytobot, Cytobuoy FCMs equipped with image acquisition system). The images are analysed using advanced algorithms and organisms are often identified to the species or genus level. By measuring size of the organisms the cell volumes and biomass may be estimated with both types of flow cytometers.

The concentration of chlorophyll *a* in sea water (in the phytoplankton) is often used as a proxy for phytoplankton biomass. It should be noted that the ratio between chlorophyll and the carbon content of phytoplankton is not constant; it varies between species, due to light history, nutrient conditions etc. Water sampling and subsequent filtering, extraction and analysis of chl. a using a laboratory fluorometer or spectrophotometer are the standard methods for chl. a analysis. High Performance Liquid Chromatography (HPLC) is used to analyse the different types of chlorophyll (a, b, c_1, c_2, c_3, etc.) and carotenoids, e.g. fucoxanthin, 18' hexanoyloxyfucoxanthin and perdinin). Since some algal groups have group-specific pigments the concentrations of these may be used as chemo-taxonomic markers. Unfortunately, the variability in pigments within and in between algal groups is significant. Thus the HPLC-data only gives very rough information on the biodiversity of phytoplankton. Moreover, HPLC-analyses of chlorophyll a are considered the state of the art method for analysis of water samples that should be used as "sea truth data" for satellite remote sensing.

Bio-optical instruments such as *in in-situ* fluorometers and absorption detectors may be used to estimate chlorophyll content of phytoplankton in water. Advanced multispectral versions aim to discriminate major algal groups based on pigment content. An advantage with these instruments is that they may be operated fully automatically and collect data very frequently (several times per second). Disadvantages include problems with biofouling and calibration of instruments. In general instruments should be calibrated with phytoplankton from the area to be investigated.
Air borne and satellite remote sensing may be used to estimate near surface phytoplankton biomass based on the reflectance of photosynthetic pigments in the plankton. Another approach is to use sun induced fluorescence of chlorophyll a as a proxy for chlorophyll a. The concentrations of other constituents of sea water may also be estimated, e.g. the concentration of coloured dissolved organic carbon (CDOM) and of particulate matter. Satellite methods to estimate phytoplankton biomass struggle with problems such as cloud cover and the variable influence of particulate matter and CDOM in coastal waters. Satellites and sensors suitable to ocean colour work currently available include Sentinel 3A with the OLCI sensor (ESA) and Aqua with the MODIS sensor (NASA). These provide daily coverage of European seas during cloud free conditions. When Sentinel 3B is launched overflights twice a day will be a reality. Air borne sensors have the advantage that the sensor platforms may fly under the clouds but cover much smaller areas than the satellites. Platforms include aeroplanes and unmanned flying vehicles such as drones. The quality of remote sensing data relies on the collection of sea truth data both for total chlorophyll as for different phytoplankton functional groups or types which can be detected from space (as the PYSAT method).

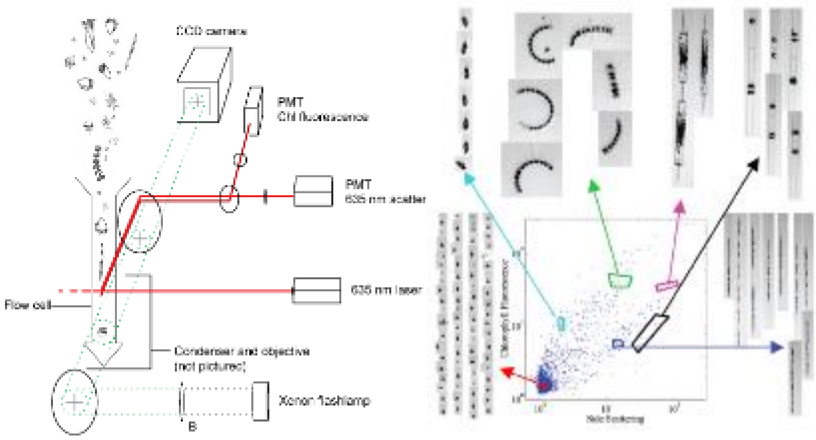

Figure 3.1: The principle of imaging flow cytometry (Sosik and Olson, 2007).

3.1.4 The role of the JERICO research infrastructure

Ferrybox systems, research vessels and instrumented oceanographic buoys are used as sampling platforms in JRAP-1. Ferrybox systems, in particular, provide cost effective sampling of near surface waters. In a few localities several types of sampling platforms are combined into ocean observing systems. Some sampling platforms will be used for automated water sampling and subsequent analysis of samples in the laboratory. Automated measurements will be carried out using bio-optical sensors and flow cytometers. The results of analyses of water samples will facilitate quality controlled reference data.
Satellites and air borne sensors are outside the scope of JERICO. However, in some instances satellite data will benefit from and complement the *in situ* data. Thus, comparisons between remote sensing data and *in situ* data will be made.

3.1.5 Expected progress beyond the state of the art

The use of high frequency sampling and continuous measurements will make it possible to study the biodiversity and distribution of phytoplankton in ways previously not possible. The focus on harmful algae is likely to result in an improved understanding in harmful algal bloom development and relation with other species/groups and in particular those which are responsible for phytoplankton outbursts. It is expected that the use of multi spectral bio optical sensors will give new insights into the distribution of phytoplankton at the group level. For cyanobacteria and other groups that have particular pigments, it is likely that the bio-optical sensors will give new insights into bloom development. Flow cytometers are deployed on research vessels, in ferrybox-systems and as part of ocean observatories in JRAP-1. This is at the cutting edge of using these advanced instruments in the field to give detailed high temporal and spatial data on phytoplankton biodiversity and biomass. Sampling approximately every 1 to 60 minutes will be made revealing variability at a scale not possible using traditional sampling which is often carried out monthly or bi-weekly. Flow cytometers have previously been used mainly in laboratories and from docks or jetties. Also the use of automated sampling for later gene sequencing in the laboratory is new.

The approach, to combine the novel automated methods with reference sampling and analyses in existing monitoring programs, is expected to result in input to improved operational guidelines in monitoring programs.

It is also expected that the novel methods will be more cost effective than the classic methods when analysing large number of samples.

3.2 Research Methodology and approach

3.2.1 Main tasks and work plan

JRAP-1 covers five European regions. An overview technologies/methodologies and working team by region is given in Table 3.2. A summary of the planned activities and the data sampling is given in section 3.2.1.7 Table 3.3.

3.2.1.1 Study areas

Table 3.2: Study areas and partner involved.

Area name	Main sampling platforms - JERICO infrastructures	Main methodologies	Partners
Western Mediterranean	Ferrybox system, oceanographic buoy	Flow cytometry, bio-optical sensors, water sampling, microscopy	CNRS (Marseille and Villefranche)
The eastern Channel and the Southern/Western North Sea	Research vessels and Ferrybox systems and oceanographic buoys	Flow cytometry, bio-optical sensors, water sampling, image in flow, microscopy	Ifremer, CNRS (Caen and Wimereux) VLIZ, RWS, Cefas, Deltares
The Skagerrak-Kattegat	Ferrybox systems and oceanographic buoys	Flow cytometry, image in flow, bio-optical sensors, water sampling, microscopy,	SMHI, NIVA (+ subcontractors WHOI and Scanfjord AB)
The Baltic Sea	Ferrybox systems and oceanographic buoys	Flow cytometry, bio-optical sensors, water sampling, microscopy	SYKE, SMHI, CNRS
The Benguela current	Oceanographic buoys	Bio-optical sensors, water sampling, microscopy	DAFF, (South Africa)

3.2.1.2 Proposed approaches for the Western Mediterranean

In the northern western Mediterranean Sea, the occurring of intermittent events and patchy distribution due to terrestrial inputs and flooding, fast changes in stratification due to wind bursts, etc. can lead to important modifications on the communities' structuring and its associated net production. More in details, previous work pointed out the importance of pico- and nanophytoplankton in addition to seasonal diatom and dinofleagellate bloom. The former one, nearly detected by microscopy, shows a complex dynamics liked to the seasonality as well as to sporadic events. The succession of these events conditions the status of the communities and their integration in time over the season and in space over the basin. (Dugenne et al. 2014, Thyssen et al. (2008), Thyssen et al. (2015). To understand the relationships between the environmental conditions on short time and locally and the communities structuration and its production, two main strategies will be considered in the Western Mediterranean – Ligurian Sea:

- the implementation of a FerryBox into the Marseille-Tunis and Tunis-Genova line coupled to an automated pulse-shape-recording and an imaging flow cytometer. It will inform on the community structuration and on the surface hydrography. In addition satellite images will help describing the mesoscale structures: size, shape, type etc. Numerical simulation, like with ECO3M model would give information on the vertical stratification, nutrient distribution, as well as pico and nano-plankton composition. River discharges and wind conditions are available in an operational way.

- the high frequency analysis in a fixed station in Endoume (Marseille) testing different sensors and, if possible, an implementation of automated flow cytometry and other techniques in the EoL buoy (bay of Villefranche sur Mer, having been implemented in the past, Thyssen et al., 2014)

A work on how to put these data into a database is carried out as well.

JERICO-NEXT infrastructure:

The EoL buoy (Villefranche) and the Endoume (Marseille) Fixed Station for testing automated sensors.
Ferrybox system on route Marseille-Tunis-Genova.

Figure 3.2: The CytoBuoy cytometer used in the Ferrybox system and the ferry boat line in the western Mediterranean.

3.2.1.3 Proposed approaches for the Channel – Western North Sea

The occurring of HAB bloom in this area is strongly related to frontal conditions linked to estuarine input and tidal conditions and, in addition, intermittent events such as storms which can alter the seasonal cycle (in less than 24h).Moreover there is a need of better understanding the succession of the different communities at different spacio-temporal scale which can lead to sporadic or massive bloom events. (Hernandez et al. 2014; Bonato et al. 2015 & 2016, Lefèvre et al. 2011), The strategy in the Eastern English Channel and Southern/Western North Sea will consist in tracking the starting, extension and end (spatial and temporal) of the spring bloom and more specifically of the *Phaeocystis globosa* bloom (main HAB in the area) as well as *Pseudonitzchia spp*. blooms, from the Bay of Seine towards the North Sea. Sporadic blooms of dinoflagellates would also be detected in summer and autumn.

For achieving this, we propose to implement different automated and semi-automated sensors coupled to biogeochemical and hydrological sensors, within three different approaches:

- fixed stations (SMILE and MAREL Carnot buoys, already measuring basic hydrological and biogeochemical parameters) in the Channel, both operational but not yet having added biological optical sensors yet, SMILE will do it in 2016 at least for one sensor and MAREL-Carnot in 2017-2018 for two of them at least),

- implementation in ferry lines, like the Calais-Dover ferryline to be implemented current 2017 and fully operational in 2018. Proposition to also implement biological sensors in the Ouistreham-Portsmouth ferry line (already implemented in the past) and the Zeebrugge-Hull line (by association to JRAP#5),
- dedicated scientific cruises in which at least two or three participants will be involved since 2016 from the Channel to the North Sea (CNRS, IFREMER, Cefas, VLIZ and RWS monitoring cruises).

In 2017, we have planned to coordinate temporarily a series of cruises following the development of the spring bloom from South to North (corresponding to the residual coastal flow from Bay of Seine towards the North Sea), from April to May-June, cruises coordinated by CNRS (Channel), VLIZ and Cefas (Southern North Sea) and by RWS (North Sea). Extra cruises would be performed in 2018, whereas we will seek the possibility of joining fisheries cruises (IFREMER, Cefas) in the Channel and North Sea by implementing continuous measuring with at least multi-spectral fluorescence, automated flow cytometry (pulse-shape recording, including image acquisition) image analysis and/or and photosynthetic parameters from variable induced fluorometry (PAM, FRRF).

JERICO-NEXT infrastructure

- MAREL Carnot Buoy
- SMILE Buoy
- Research vessels
    - R/V Endeavour (Cefas)
    - R/V Simon Stevin (VLIZ)
    - R/V Zyrphaea (RWS)
    - R/V Côtes de la Manche (CNRS-INSU)
    - R/V Thalassa (IFREMER)
- Calais-Dover Ferrybox (and, if possible, Ouistreham-Portsmouth and/or Zeebrugge-Hull lines as well)



3.2.1.4 *Proposed approaches for the Skagerrak-Kattegat*

The general strategy is to carry out an intense study covering a few months in a restricted area near a mussel farm. The focus of the study will be dinoflagellates belonging to the genus *Dinophysis*. These produce diarrhetic shellfish toxins that may accumulate in mussels causing problems for the mussel industry. Harvesting is stopped when toxin levels reach the regulatory level. The Kattegat Skagerrak area is characterized by strong stratification due to outflow from the Baltic Sea. The water in the Baltic Current (salinity ~20-25 psu) flows north along the Swedish coast on top on more saline water (~30-33psu) originating from the North Sea. *Dinophysis* are sometimes found in high abundances in the pycnocline at ~15 m depth. Farmed mussels are suspended at approximately 0-10 m depth. Two hypotheses will be tested:

1. *Dinophysis* are transported from the open sea to the coast during downwelling caused by certain wind conditions.
2. *Dinophysis* occur near the pycnocline. When the pycnocline are lifted due to physical forcing the dinoflagellates meet the mussels that become toxic.

To investigate these both the physical oceanographic situation and the phytoplankton will be studied. In addition to testing the two hypotheses the short term variability in phytoplankton composition will be investigated using novel methods (see hereafter) that will be compared to classic methods. There is a risk that *Dinophysis* are not abundant during the study. In that case other harmful species will be in focus.

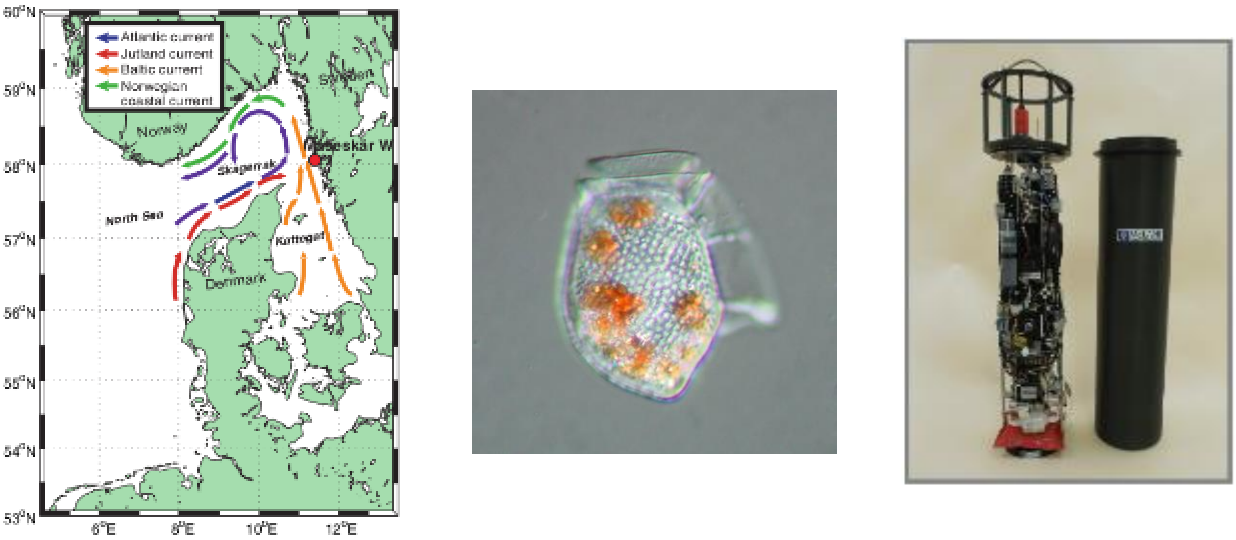

Figure 3.3: Left: Map depicting the major currents in the Kattegat Skagerrak area. The red dot is close to the Tångesund observatory. Middle: The target organisms Dinophysis sp. Right: The Imaging Flow Cytobot.

Study period: August-October 2016
Study site: Tångesund, Sweden

JERICO-NEXT infrastructure:

The Tångesund observatory:

- SMHI oceanographic buoy (salinity, temperature, oxygen at several depths, chlorophyll fluorescence a 1 m, ADCP for current measurements.
- Imaging Flow Cytometer deployed in situ
- Facilities for water sampling and handling of samples
- Weekly collection of reference samples for phytoplankton (Utermöhl), chlorophyll a etc.

The Ferrybox system on MS *Color Fantasy* operating the route Oslo-Kiel

- Automated sensors including bio-optical sensors
- Water sampling device for collecting e.g phytoplankton samples.

Non-JERICO-NEXT activities in connection with the study

- Scientist from the University of Gothenburg (UGOT) plan to deploy additional fixed platforms for physical oceanographic parameters and carry out research cruises during the study.
- Master students (joint UGOT and SMHI) will be involved in the work.
- Scientists from the Alfred Wegener Institute (AWI) plan to measure toxin concentrations in the plankton.
- Scientists from the EU-project AFIS from the Science for Life laboratory (Stockholm) and Institut für Ostseeforschung Warnemünde (IOW, Germany) plan to test automated sampling device suitable for sampling molecular samples (gene sequencing etc.).
- Scientist from the Swedish National Food Administration plan to analyse biotoxins in mussels (*Mytilus edulis*)

An additional short term study in the Kattegat-Skagerrak may be carried out in 2017. The decision about this will depend on the outcome of the Tångesund study. A focus of the possible 2017 study may be the spring bloom which is sometimes directly followed by a bloom of the fish killing flagellate *Pseudochattonella* spp. Another possibility is a follow up study on *Dinophysis*.

3.2.1.5 Proposed approaches for the Baltic Sea

In the Baltic Sea spring blooms consist of diatoms and dinoflagellates. Their relative abundance is related to the physical and chemical forcing factors which vary from year to year: the factors include e:g: ice conditions during winter; mixing conditions and fresh water flow and associated organic matter input: The fate of diatom and dinoflagellate blooms are different in most cases; as the diatoms tend to sink to the sediment layer while dinoflagellate blooms more often disintegrate in the surface layer: these have different consequences for carbon and nutrient fluxes.
In summer, a minimum biomass is observed with a very efficient microbial loop activity, followed in most summers by blooms of filamentous cyanobacteria: these blooms are influenced by chemical (P concentration) and physical (temperature and mixing depth) forcing: often the picocyanobacteria, which are not forming blooms but are important for biogeochemical cycles; co-occur with filamentous ones: occasionally also blooms of flagellates can be found, sometimes dominated by toxic species.

In the Baltic Sea two studies are planned: (1) The spring bloom and (2) the summer cyanobacteria bloom. The focus area will be the northern Baltic Proper where the Utö observatory is located (Figure 3.4). In addition, Ferrybox systems will be used for automated measurements and for automated collection of water samples. The UVP5 underwater video vertical profiling system will be used to study vertical distribution of cyanobacteria colonies.
Study period: April and July 2017
Study site: Baltic Sea, focus area the northern Baltic proper

JERICO-NEXT infrastructure:

The Utö observatory, with water pumped near 5m from the surface to measure temperature, salinity, turbidity, and chlorophyll content. Next to the sampling location and ADCP will inform on the current profiles.
The Ferrybox system on MS/Finnmaid operating the route Helsinki-Lübeck-(Gdynia)-Helsinki

- Automated sensors including bio-optical sensors
- Water sampling device for collecting e.g. phytoplankton samples.

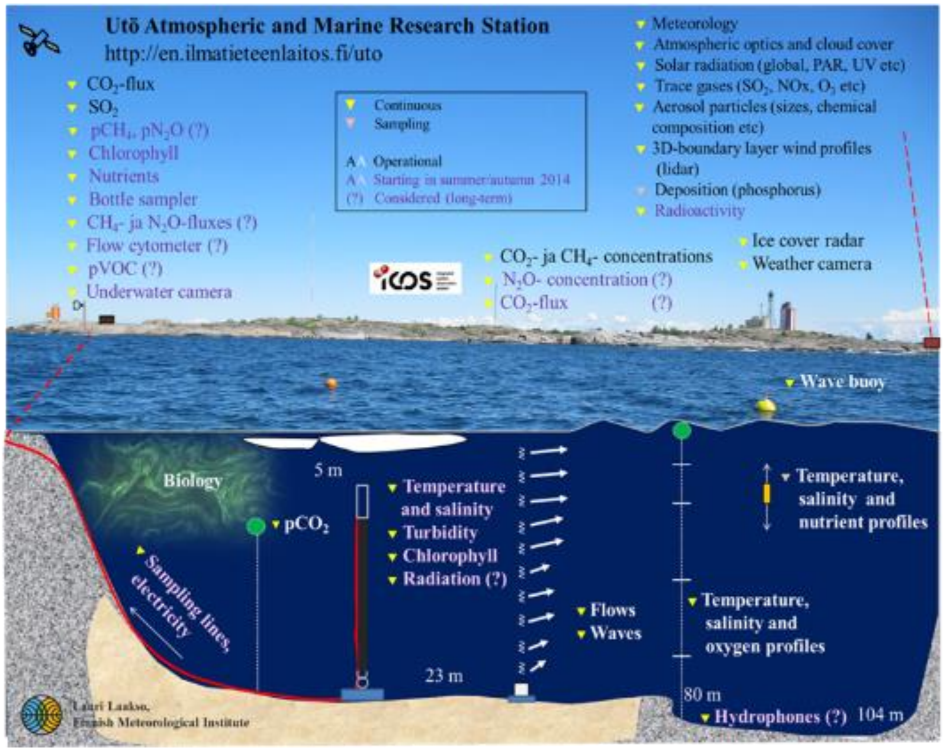

Figure 3.4: Illustration of the Utö observatory.

The Ferryox system on TransPaper operating the route Lübeck-Kemi-Olulu-Lübeckl

- Automated sensors including bio-optical sensors
- Water sampling device for collecting e.g. phytoplankton samples.

The instrumented oceanographic buoy Huvudskär E.
- Automated sensors including bio-optical sensors

The UVP5 underwater video profiler
- In situ imaging of cyanobacteria colonies, zooplankton etc.

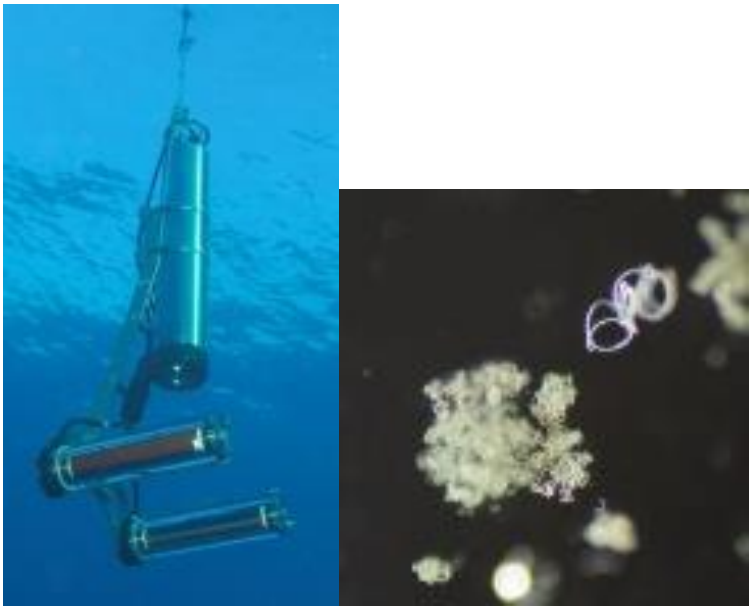

Figure 3.5: Left: The UVP5. Right: Examples of cyanobacteria colonies.

3.2.1.6 Proposed approaches for the Benguela current

Activities are to be decided. JERICO-NEXT only have funds for covering travel and subsistence cost for relevant meetings/workshops for the South African partner DAFF.

3.2.1.7 Data sampling and Integration

In the Kattegat-Skagerrak study the data on phytoplankton biodiversity, abundance and biomass will be used together with bio-optical data, data on stratification (salinity and temperature) and currents (ADCP). In addition, an automated phosphate analyser will be evaluated during the Tångesund study. Reference nutrient samples will be collected and analysed in the laboratory. The 3D physical oceanographic model NEMO-Nordic will support the study. NEMO-Nordic results have been compared with HF-radar data in 2015.
In the eastern Channel-North Sea area, the bio-optical results data will be analysed in the frame of dedicated biogeochemical and hydrological measurements that will be performed during the targeted high spatial and temporal resolution studies as well as referring to current hydrological, biogeochemical and phytoplankton data gathered by the different monitoring and observation networks that are permanently implemented by Cefas (cruises and smart-buoys), RWS (cruises), VLIZ (cruises), CNRS (cruises, fixed stations) and IFREMER (cruises and fixed stations, at low frequency (one or twice a month). The results will also be analysed referring to previous results gathered in the area by both reference classical and innovative bio-optical techniques.
In the Mediterranean studies, high frequency measurements carried out at fixed stations will be analysed in the frame of current CNRS low frequency hydrological, biogeochemical and phytoplankton regular monitoring, whereas Ferrybox measurements data including basic environmental measurements as well will be analysed by referring to Western Mediterranean Oceanographic integrated Observing System (MOOSE).

Table 3.3: Sites for JRAP-1, the timing of studies, contact institutes and persons, the platforms used and parameters measured

Site	Timing of data collection	Data reference contact	Platform - Instrument used	Parameters collected
Baltic Sea	Spring and summer 2017.	SYKE - Jukka Seppälä (jukka.seppala@ymparisto.fi)	Utö Atmospheric and Marine Research Station (SYKE and FMI) Several different instruments including flow cytometer and fluorometers	Water samples for analysis of phytoplankton using flow cytometry and/or microscopy, pCO_2, pH, Temperature, salinity, O_2, Chlorophyll, phycocyanin & CDOM fluorescence from a flow-through system (sampling depth -5 m). Meteorological parameters (T, WS, WD, solar radiation etc.). Surface waves.
Baltic Sea	Spring and summer 2017	SYKE - Jukka Seppälä (jukka.seppala@ymparisto.fi)	Ferrybox Helsinki-Lübeck e.g. fluorometers and automated water samplers	Water sampling for phytoplankton analysis using microscopy, Temperature, salinity, Chlorophyll, phycocyanin and CDOM fluorescence from a flow-through system (sampling depth -5 m)
Baltic Sea	Spring and summer 2017.	SMHI – Johanna Linders (johanna.linders@smhi.se) and Anna Willstrand-Wranne (anna.wranne@smhi.se)	Ferrybox Kemi-Lübeck e.g. fluorometers and automated water samplers	Water sampling for phytoplankton analysis using microscopy, pCO_2, Temperature, salinity, O_2, Chlorophyll fluorescence, phycocyanin fluorescence, CDOM fluorescence, turbidity (sampling depth 3 m). Meteorological parameters (air temperature, air pressure, solar radiation-PAR). In addition water samples are collected for analysis of several parameters.
Baltic Sea	Summer 2017	SMHI – Johanna Linders (johanna.linders@smhi.se) and CNRS Lars Stemmann (stemmann@obs-vlfr.fr)	R/V Aranda UVP5for in situ imaging of plankton	Distribution of cyanobacteria colonies in the water column, composition of phytoplankton community, salinity, temperature, nutrients, chlorophyll a, oxygen, etc.

Baltic Sea	Spring and summer 2017	SMHI – Johanna Linders (johanna.linders@smhi.se) and Lars Stemmann (stemmann@obs-vlfr.fr)	Huvudskär E instrumented buoy, Fluorometers for chlorophyll a and phycocyanin	Chlorophyll fluorescence, phycocyanin fluorescence, salinity, temperature
Eastern English Channel	2016-2017	CNRS BOREA-Caen Pascal Claquin (pascal.claquin@unicaen.fr)	SMILE buoy Fast Repetition Rate Fluorometer – ACT2	Temperature conductivity oxygen turbidity chla (fluorescence) PAR, temperature conductivity oxygen turbidity Bio-optical parameters (photosynthetic parameters)
Eastern English Channel	Parts of 2016-2017	CEFAS (Veronique.creach@cefas.uk)	Smart buoys	Phytoplankton abundance and biodiversity, bio-optical parameters, physical oceanographic parameters
Eastern English Channel	2017-2018	Ifremer Alain Lefebvre (Alain.Lefebvre@ifremer.fr)	MAREL Carnot instrumented station The Pocket Ferry Box (PFB) , Algae Online Analyser (AOA), CytoSub	Temperature, salinity, Oxygen, Turbidity, pH, Fluorescence, PAR, Relative Humidity, Wind, Water level, Nitrate, Phosphate, Silicate, Phytoplankton spectral groups, abundance,
Around the British Isles	2016-2017, short term cruises	CEFAS Veronique Creach (veronique.creach@cefas.co.uk) RWS Machteld Rijkeboer	R/V Endeavour Ferrybox - Flow Cytometer - CytoSense	Phytoplankton abundance and biodiversity, bio-optical parameters, pCO_2, physical oceanographic parameters
Eastern English Channel	Spring 2017-2018, short term cruises	CNRS LOG-Wimereux Felipe Artigas (Felipe.Artigas@cnrs.fr) IFREMER Alain Lefebvre Cefas Véronique Créach RWS Machteld Rijkeboer VLIZ Lennert Tybeghien	R/V Cotes de la Manche The Pocket Ferry Box (PFB) , Algae Online Analyser (AOA), Fluorroprobe, PhytoPAM, FRRF, FlowCAM, Automated Flow Cytometer (CytoSense)	Bio-optical parameters, physico-chemical oceanographic parameters, pigments, phytoplankton spectral groups, cell counts and imagery, photosynthetic parameters

Eastern English Channel	2016-2017-2018, short term cruises	Ifremer Alain Lefebvre (Alain.Lefebvre@ifremer.fr) CNRS LOG/Univ Littoral Felipe Artigas	R/V/ Thalassa The Pocket Ferry Box (PFB) and the Algae Online Analyser (AOA), FlowCAM, Automated Flow Cytometer (CytoSense)	Bio-optical parameters, physico-chemical oceanographic parameters, pigments, phytoplankton spectral groups, cell counts and imagery, zooplankton
Eastern English Channel	End 2017-2018, short term cruises	Ifremer Alain Lefebvre (Alain.Lefebvre@ifremer.fr) CNRS LOG/Univ Littoral Felipe Artigas	FB Calais -Douvre and the Algae Online Analyser (AOA), FlowCAM, Automated Flow Cytometer (CytoSense)	Bio-optical parameters, physico-chemical oceanographic parameters, pigments, phytoplankton spectral groups, cell counts and imagery, zooplankton
Eastern English Channel	2016-2017, short term cruises	VLIZ Klaas Deneudt (klaas.deneudt@vliz.be) U. Gent Reinhoud de Blok RWS Machteld Rijkeboer CNRS LOG/Univ. Littoral Felipe Artigas	R/V Simon Stevin Automated Flow Cytometer and Fast Repetition Rate Fluorometer (FRRF), Fluoroprobe	Phytoplankton abundance and biodiversity, biooptical parameters, physical oceanographic parameters
Eastern English Channel – Western North Sea	2016-2017, short term cruises	RWS Machteld Rijkeboer (machteld.rijkeboer@rws.nl) CNRS LOG-Wimereux Felipe Artigas	R/V Zirfaea Flow Cytometer CytoSense Fast Repetition Rate Fluorometer (FRRF), Fluoroprobe	Phytoplankton abundance and biodiversity, biooptical parameters, physical oceanographic parameters
Eastern Mediterranean Sea	Parts of 2016-2017	CNRS MIO Melilotus Thyssen (melilotus.thyssen@mio.osupytheas.fr)	Ferry Le Carthage Flow Cytometer CytoBuoy	Phytoplankton functional diversity, oxygen, partial pressure of carbon dioxide, pH, temperature, salinity, fluorescence of chlorophyll-a
North Sea-Skagerrak-Kattegat	August-October 2016	SMHI – Johanna Linders (johanna.linders@smhi.se) IRIS Catherine Boccadoro Catherine.Boccadoro@iris.no, NIVA wenche.eikrem@niva.no	Tångesund ocean observatory Imaging Flow Cytobot Water sampling and laboratory analyses	Distribution of *Dinophysis* spp., phytoplankton abundance and biodiversity, chlorophyll, chlorophyll fluorescence, oxygen, nutrients, salinity, temperature, current speed and direction.
North Sea-Skagerrak-Kattegat	August-October 2016 (three short cruises)	SMHI – Johanna Linders (johanna.linders@smhi.se)	R/V Skagerak Water sampling and laboratory analyses	Distribution of *Dinophysis* spp., chlorophyll, chlorophyll fluorescence, oxygen, salinity, temperature

North Sea-Skagerrak-Kattegat	2016-2017	NIVA (wenche.eikrem@niva.no, kai.sorensen@niva.no & andrew.king@niva.no) SMHI (phytoplankton) – Johanna Linders (johanna.linders@smhi.se)	Ferrybox Oslo - Kiel	Water samples for analysis using microscopy (SMHI), pCO_2, pH, temperature, salinity, O_2, Chlorophyll fluorescence, turbidity from a flow-through system (sampling depth about 3 m). Meteorological and light parameters (Solar radiation etc.).

3.2.1.8 *JRAP team: Role and undertakings*

See Table 3.2 for information on what sea areas the different partners are working.

- SMHI: Bengt Karlson and Malin Mohlin. Subcontractors Woods Hole Oceanographic Institute (Michael Brosnahan and Don Anderson) and Scanfjord AB.
- NIVA: Wenche Eikrem and Kai Sørensen
- SYKE: Jukka Seppälä
- RWS: Machteld Rijkeboer. Subcontractors Thomas Rutten b.v. and CytoBuoy b.v.
- Deltares - Anouk Blauw
- VLIZ: Klaas Deneudt, Sub-contractor Univ. of Gent - Wim Vyverman
- CEFAS: Veronique Creach
- Ifremer: Alain Lefebvre
- CNRS: CNRS LOG Wimereux Felipe Artigas (Univ Littoral) & Fabrice Lizon (Univ Lille) – CNRS BOREA Caen Pascal Claquin (Univ Caen) CNRS OSU Villefranche sur Mer Lars Stemman (Univ Paris VI) –, CNRS M.I.O. Marseille Melilotus Thyssen and Gérald Grégori
- Collaborator in Republic of South Africa: DAFF – Grant Pitcher.

3.2.2 *Specific cross-cuttings with other JRAPs and WPs*

WP2

The work in JRAP-1 depends on activities in WP2, i.e. the operation of major research infrastructures such as Ferrybox systems and buoys and more specifically the synthesis of existing approaches and methodologies related to biological optical sensors for studying phytoplankton (WP 2.4.2).

WP3

Overview of cross cutting activities with WP3:
Task 3.1: The work in JRAP-1 is closely connected to the activities in WP3.1 where flow cytometers and bio-optical instruments are evaluated and further developed or improved on both technical, operational and analytical features.

- Development of imaging in flow methods
- Development of single-cell optical characterization methods
- Development of other bio-optical methods (multi-spectral in-vivo fluorometry and spectrophotometry, variable induced fluorometry

Task 3.2 HF radar (e.g. advection of algal blooms)
Task 3.3 Profiling coastal waters
Task 3.4 Microbial and molecular sensors (joint activities at the Tångesund observatory)
Task 3.5 Carbonate system (connection between variable induced fluorometry and pCO_2 measurements)
Task 3.6 Benthic compartments and processes (benthic microalgae)

Task 3.7 OSE/OSSE (e.g. advection of blooms)

.

WP4

JRAP-2

- Task 4.2 Benthic biodiversity – benthic microalgae (exploration of pelagos-benthos interactions regarding general marine biology and food-webs).

JRAP-3

- Task 4.3 Chemical contaminants (some common platforms for sampling and relation with phytoplankton dynamics).

JRAP-4

- Task 4.4 Hydrography and transport (e.g. advection of blooms, coupling with current measurements analysed by hydrological experts).

JRAP-5

- Task 4.5 Coastal carbon fluxes (e.g. primary production addressed within JRAP#1 and effects of blooms on pH and *vice-versa* in common platforms that could be implemented with both bio-optical and Carbon and pH sensors).

JRAP-6

- Task 4.6 Operational oceanography and forecasting (e.g. advection of blooms, establishing early warning procedures).

WP 5

- A connection will be necessary between WP3.1 – JRAP #1 and WP5 WP5: Task 5.2: Integration of biological data, in order to define which level of complexity in raw data and already analysed data can be defined for each bio-optical sensor in the different study sites and how to be better integrated into databases.

3.3 Implementation Risks and mitigation measures

Risk	**Mitigation measure**	**Comment**
Ship with Ferrybox system changes route or decides to stop the collaboration with partners	Moving of Ferrybox system and/or specific bio-optical sensors to another ship Changed focus of study	This may be very time consuming and expensive (if possible) The ship TransPaper no longer goes to the harbour in Gothenburg. This has partly moved the focus for SMHI to the study at Tångesund.
Damaged equipment, e.g. leaks in underwater enclosures	Proper routines for working with *in situ* equipment	Some instruments, e.g. flow cytometers, are essential in the planned studies and difficult to replace.
Algal bloom or target organisms do not occur where or when expected	Moving the study in time if possible. Choosing other target organisms.	The development of algal blooms are partly stochastic phenomena. The blooms cannot always be predicted.

3.4 Main references

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4 JRAP-2: Monitoring changes in macrobenthhic biodiversity

1.1. Rationale and expected outcomes

4.1.1 Main questions - Objectives

A major challenges of today's marine science consists in identifying the causes of current diversity loss and the interaction linking biodiversity and ecosystem functioning (Naeem et al. 1994, Naeem & Li 1997, Naeem & Hahn 2000, Naeem 2002, Naeem & Wright 2003). Marine ecosystems are however among the most productive on earth (Poore & Wilson 1993). Their role in controlling major biogeochemical cycles is well acknowledged so as their contribution to human food sources (Costanza et al. 1997). Coastal ecosystems for example contribute for about half of the mineral carbon fixed by the world's ocean and for about 90% of the remineralization achieved in marine sediments (Wollast 1998). Their biodiversity (and possibly their ecological functions) is (are) now clearly at threat due to a large variety of disturbances including: eutrophication (Diaz & Rosenberg 1995), contaminants (Dauvin 1998), overfishing (Pauly et al. 1998, Jackson et al. 2001) and habitat loss (Fortes 1988, Short & Wyllie-Echeverria 1996). Benthic species especially suffer from those disturbances because of their low mobility (Solan et al. 2004), which probably explains that the study of the interaction between diversity and functions in the marine realm have mostly focused on benthic ecosystems (Duffy & Stachowicz 2006).

The species composition of benthic macrofauna is classically used as an indicator of the ecological quality status of benthic habitats due to its response to a large variety of disturbances, which may act at different levels of the biological organization and scales of observation. The monitoring of the biodiversity of this biological compartment has, accordingly, been included in both the WFD and MSFD. Such a monitoring at the scale of the whole EU by using classical approaches would however require a huge effort, which would by far exceed current time and financial capacities. There is therefore a strong need for identifying proxies of benthic macrofauna composition. This is one of the two main questions, which will be tackled in JRAP-2.

The question of the interaction between diversity and ecosystem functioning has now been studied for more than thirty years in terrestrial ecosystems but only much more recently in marine ecosystems (Duarte 2000, Bolam et al. 2002, Waldbusser et al. 2004, Waldbusser & Marinelli 2006, Norling et al. 2007) probably because: (1) a lower awareness of the decline of marine diversity in marine systems, and (2) the difficulty in measuring ecosystem functions in aquatic environments (Raffaelli 2006). Different approaches have been used to do so (Bulling et al. 2006). None of the proved is fully satisfactory. Within JRAP-2JRAP-2, we will tackle this question through a comparative study of several field surveys, which will be associated with an original data analysis procedure.

4.1.2 Description of the state of the art related to the science topic

The assessment of benthic biodiversity classically relies on sampling procedures involving long and tedious steps (i.e., sieving and manual sorting). Moreover, the determination of benthic fauna based on morphological criteria requires a specific know-how (which is now declining) and is also highly time consuming. Overall, this clearly limits the number of samples that can be processed both in terms of time and money. Conversely, there is an increasing need for the assessment of benthic diversity due to the increasing awareness of its decline and the rise of corresponding remediation procedures (which includes both the WFD and MSFD as far as coastal seas are concerned). This paradox has led to several recent methodological developments including the use of imaging and molecular techniques to infer benthic biodiversity. Even though some preliminary studies have been carried out, there is still a clear need for intercalibration surveys comparing the ecological quality assessments obtained using these different approaches.

Another possible approach in view of monitoring the ecological quality status of benthic habitats is to: (1) assess the relationship linking disturbance intensity, benthic diversity and ecosystem function, (2) monitor disturbance intensity, and (3) use it as a proxy. In coastal Seas, this approach is clearly complicated by the spatial heterogeneity and the strong temporal dynamics of both disturbances and benthic communities. It is for example essential to develop approaches allowing for a sound assessment of spatio-temporal changes in disturbance intensity. These may clearly differ depending on the nature (biological, physical, biogeochemical, mixed…) of the disturbance itself. In most cases, however they will require a coupling between physical, biogeochemical and biological processes. This can be achieved through modelling provided that the spatio-temporal integration scales of both biological and biogeochemical parameters are well defined.

The MSFD clearly acknowledge that, together with benthic compartments, benthic processes are key constituents in defining a good ecological status. This clearly raises the question of the relationship between benthic diversity and ecosystem functions. This question can be first tackled through *ex situ* experiments during which the same function is measured within different species assemblages differing in species richness (Mermillod-Blondin & Carcaillet 2005, Norling et al. 2007). Most often, this approach has mostly led to rather erratic results (Emmerson et al. (2001), partly because of: (1) the low number of functions which can be measured, (2) the low number of species that can be considered, and (3) the lack of consideration for benthic microbial diversity although microbes may be the organisms directly involved in the considered function (e.g. in most cases sedimentary organics remineralization). Another weakness of the experimental approach lies in the fact that it does not allow for the proportion of the natural variance of the function that is effectively die to changes in biodiversity. An alternative approach consists in carrying out comparative field measurements of benthic diversity and function and to derive the relationship between these two parameters. A classical potential flaw in this approach is due to the occurrence of confounding factors (i.e., factors other than benthic diversity, varying between compared sites). A possible approach to tackle this approach such as proposed by Zajac & Whitlatch (1985) is to infer the determinism of soft bottom secondary succession.

Overall, and due to both the spatial scales associated to the different European directives (eg the MSFD) and the specific characteristics (strong spatial heterogeneity and temporal dynamics) of coastal seas, there is a clear need to infer the relationships between disturbance (nature and intensity), benthic diversity (macro- using both classical and imaging approaches and micro-fauna using metabarcoding) and functions to derive sound proxies. This can be achieved through comparative studies provided that: (1) spatio-temporal changes in disturbance intensity are properly assessed (e.g. through modelling), (2) temporal and spatial integration scales of biological/biogeochemical compartments processes are determined, and (3) appropriate data analysis procedures are used.

4.1.3 The role of the JERICO research infrastructure

By the start of JERICO-Next, the JERICO-RI does not encompass a benthic component. This is indeed one of the main objectives of this 2nd consolidation phase, together with developing ways of observing the physical, chemical and biological compartments that can support a better understanding of the complex couplings between coastal processes.
JRAP-2 aims at providing fundamental recommendations and sound scientific evidence for the future implementation of a Pan-European benthic observing system component in the JERICO-RI.

4.1.4 Expected progress beyond the state of the art

The main expected outputs of JRAP-2 are as follows:

(1) JRAP-2 will first contribute to test some of the technological developments achieved within JERICO (Sediment Profile Imager, SPIArcBase software, AviExplore software) and JERICO-NEXT (Pagure towed video acquisition system, sediment O_2 microprofiler, eddy-covariance system). It will thereby contribute to validate the use of new methodologies to assess biological compartments and biogeochemical processes over larger spatial scales and/or at a higher sampling frequency

(2) JRAP-2 will test the adequacy of: (1) the "almost real-time- use of AIS data to infer spatial data regarding dredging pressure, and (2) hydrosedimentary modelling to infer spatio-temporal changes in the intensity of disturbances caused by natural and anthropogenic inputs of the sea-floor. It will thereby contribute to the *a priori* and *a posteriori* coupling of physical, biological and biogeochemical observations.

(3) JRAP-2 will associate new observations derived from other projects. Together with the experience gained from its different actions, it will thereby contribute to the definition of the observation strategy at the European scale that will be later developed in WP 1.

(4) JRAP-2 will provide recommendation for the development and integration of a benthic observing component within the present JERICO-RI, which is foreseen to be a major contribution to the roadmap for the future (WP1.6).

(5) Moreover, JRAP-2 will allow assessing the relationship between the intensity of various sources of disturbances and benthic biodiversity. It will thereby contribute to establish the validity of proxies of benthic biodiversity.

(6) At last, JRAP-2 will allow for the assessment of the relationship linking benthic diversity and sedimentary organics in a large variety of ecological situation, which will allow to further tackle the question of the "diversity-function relationship".

4.2 Research Methodology and approach

4.2.1 Main tasks and work plan

The aim of JRAP2 is to assess the impact of different sources of disturbances on: (1) benthic diversity, and (2) the functioning of the water-sediment interface. The assessment of benthic diversity will include both macro- and micro-fauna. The remineralization of sedimented Particulate Organic Matter (POM) will be considered as an indicator of the functioning of the sediment-water interface. The objectives of JRAP-2 will be achieved through the deployment of a series of measurements gathering some of the know-hows of the different partners in different study areas facing different sources of disturbance.

This includes: (1) the West-Gironde Mud Patch, a major pro-delta exhibiting strong spatio-temporal gradient in sediment stability and organic enrichment; (2) the Bay of Brest, an area which is suffering from dredging and is also currently experimenting a colonization by the invasive American slipper limpet *Crepidula fornicata*; and (3) the Cretan Sea, a largely oligotrophic area locally and temporarily affected by the sewage outfall of the city of Heraklion. The interaction between study areas and tackled questions results in the definition of 4 actions, corresponding to the study of the impacts of:

(1) Discharge of the Gironde River in the West-Gironde Mud Patch,
(2) Benthic dredging in the Bay of Brest,
(3) Proliferation of an invasive species: *Crepidula fornicata* in the Bay of Brest,
(4) Sewage outfall in the Cretan Sea.

The completion of all of these actions will basically include the 4 same following steps:

(1) Assessment of spatio-temporal changes in disturbance intensity,
(2) Assessment of the impacts on benthic diversity based on new field observations,
(3) Assessment of the impacts on the remineralization of sedimented POM based on new field observations,
(4) Data analysis procedure to infer the quantitative relationships between: (i) disturbance intensity and benthic diversity, (ii) disturbance intensity and sedimented POM remineralization, and (iii) benthic diversity and sedimented POM remineralization.

Conversely to the assessment of temporal changes in disturbance intensity and the sampling strategy for the acquisition of new observations, the list of parameters to be acquired during new observations is largely action-independent. The so-defined common action will include the measurement of:

(1) Main physico-chemical parameters (T, S, O_2, turbidity…),

(2) Main sedimentary parameters (granulometry, permeability, porosity, OC, TN, THAA, EHAA, chl *a*, phaeo *a*…),
(3) Benthic diversity including macrobenthos through both classical sampling/sorting Procedures and video imagery, and microbenthos through metabarcoding,
(4) Bioturbation and Benthic Habitat Ecological Quality through sediment profile imagery,
(5) Structuration of the trophic network through stable isotopes,
Sedimented POM Remineralization through O_2 and nutrient fluxes at the Sediment-Water Interface (computation of diffusive O_2 fluxes will be achieved through sediment microprofiling, whereas total fluxes will be assessed both *ex situ* through classical core incubations and *in situ* through eddy covariance measurements).

4.2.1.1 Assessment of spatio-temporal changes in disturbance intensity during each action

➢ West-Gironde Mud Patch

The assessment of temporal changes in the quantitative and qualitative outputs of particles from the Gironde River will first benefit from the high frequency data (T, S, O_2, turbidity) obtained by the MAGEST network (http://www.magest.u-bordeaux1.fr/). This network is composed of 4 MAREL stations. A fifth one will be installed close to Le Verdon at the immediate vicinity of the mouth of the Gironde River during 2016. The characterization of these particles will involve the use of data collected by the SOMLIT network (http://somlit.epoc.u-bordeaux1.fr/fr/). This network is achieving monthly measurements (Seston, POC, PON, Chl a, $\delta^{13}C$, $\delta^{15}N$) at three stations located along the Gironde River Estuary.

The dispersion, sedimentation and resuspension of the particles originating from the Gironde River will be modelled during a PhD thesis (starting in October 2016) carried out within the AMORAD ANR project. This thesis will be supervised by P. Le Hir and F. Grasso (IFREMER Brest) and A. Sottolichio (EPOC). The developed hydro-sedimentary model will be based on the coupling between the hydrodynamical model MARS-3D (Lazure and Dumas, 2008) and the sedimentary module SEDIMARS (Le Hir et al., 2011). It will simultaneously consider the Gironde Estuary (from its upstream limit of tide propagation) and the continental shelf (including the West-Gironde Mud Patch). One of its specific objectives consists in assessing the dispersion and the deposition of the particles originating from the Gironde River towards and in the West-Gironde Mud Patch. This model should be available by the beginning of 2018, which will allow for the modelling of particles inputs over different time periods preceding each sampling cruise within the framework of JERICO-NEXT.

➢ Bay of Brest-dredging

Spatial maps of dredging intensity in the Bay of Brest will be derived from Marine Traffic data during the fishing season provided by the Comité Départmental des Pêches Maritimes et des Elévages Marins de Finistère. The exact modalities of the conversion of these data into tow estimates have been defined based on data collected between October 2012 and January 2015 (J. Grall, personal communication).

Briefly put, the scatter plot of ship speed versus time of day shows bands of points at medium speed during the 09:00 to 11:30 fishing window. These are assumed to be points transmitted during fishing. This allows for a documentation of an estimated fishing speed range (Figure 4.1), which will later be used to infer the fishing status of each individual vessel.

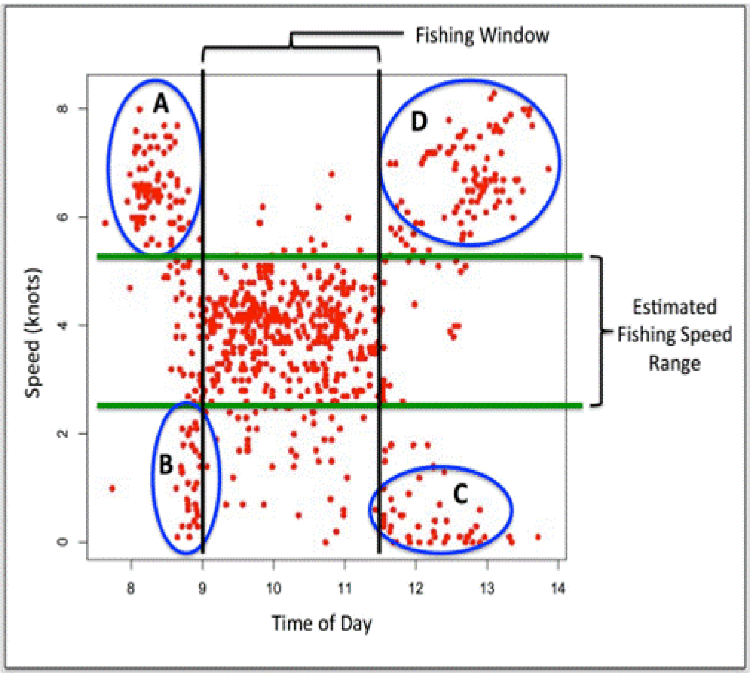

Figure 4.1: Bay of Brest-benthic dredging. Relationships between time of the day and ship speed. The crossing between these two parameters allow for an estimation of dredging fishing speed range.

Data (position, speed, day time and course) recorded during each and day for each vessel are analysed separately. The fishing status of each vessel is derived from its speed and time of the day. The modalities of each tow is derived from the analysis of the consecutive status of each point within a search radius (i.e., at time t+1) defined by the speed of the considered fishing vessel (i.e., at time t). Basically, points corresponding to fishing vessels at times t and t+1 within this radius can only be attributed to the same tow (i.e., the same fishing vessel) only if they: (1) fall within the fishing speed range, (2) share the same course.

The trajectories of each tow can then be reconstructed and broken down into approximately 10 m long segments (Pantalos 2014). All the trajectories recorded for each vessel and during the whole fishing season are then pooled, which allows for the assessment of spatial changes in dredging intensity. This is achieved through the creation of a grid of (50 m x 50 m) squares covering the entire fishing area. For each square, cumulative trawl surfaces care assessed by multiplying the sum of all tow distances by the dredge width (1.8 m). This value can then be divided by the surface of each square to derive a dredging index (Figure 4.2).

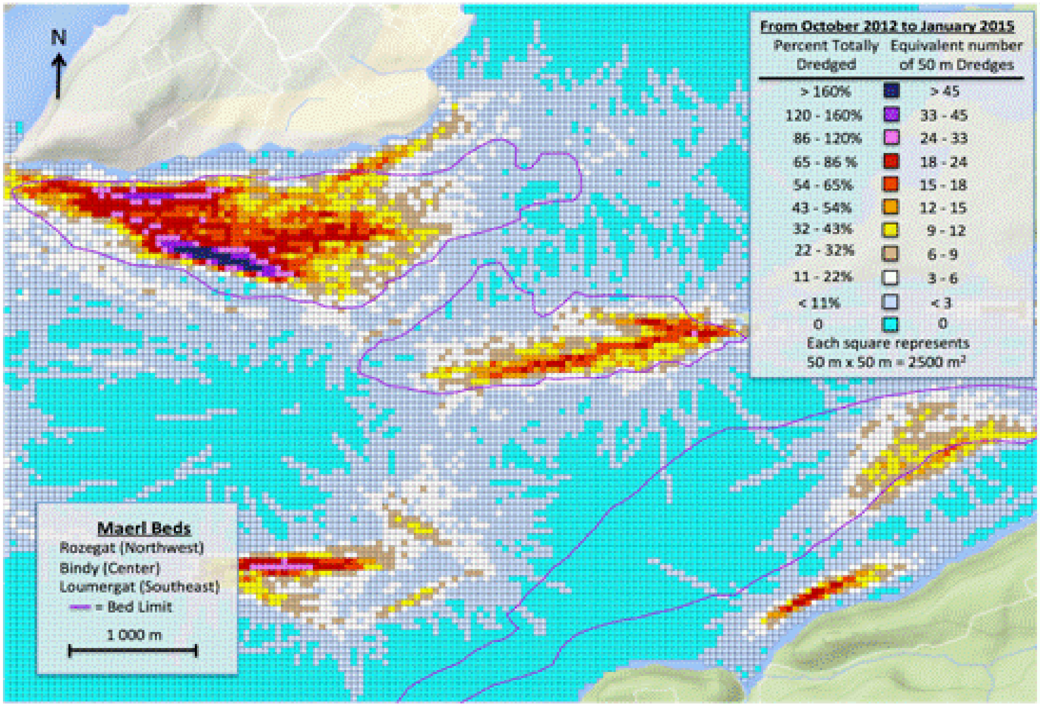

Figure 4.2: Distribution of dredging pressure from clam dredges in the south basin of the Bay of Brest as an example from October 2012 to January 2015. Each square of the grid is 50 m x 50 m. Pressure is given both in terms of the percent of a square's area covered by dredges and the number of 50 m dredges crossing the square.

- <u>Bay of Brest-invasive species</u>

For this particular action, the intensity of the disturbance is directly linked with the abundance and status (i.e., dead or alive) of the American slipper limpet *Crepidula fornicata*. These two parameters will be spatially assessed before the acquisition of new observations and the corresponding results will be used to define the exact modalities of the sampling strategy deployed during this action. More specifically, spatial changes in benthic diversity will be investigated within 3 colonized areas at different invasive stages (due to recent changes in colonization dynamics): (1) a high biomass area (3-5 kg m^{-2}), (2) a low biomass area (0.5 -1 kg m^{-2}), and (3) a dead bed (only composed of accumulated empty shells). A control area (without any, living or dead slipper limpets) characterized will be also investigated and considered as a reference (Figure 4.3).

- <u>Cretan Sea</u>

As for the *West-Gironde Mud Patch* action, the quantification of disturbance during the Cretan sea-sewage outfall action is depending on (1) temporal (i.e., mostly seasonal) outflow from the sewage; and (2) modelling of the dispersal and deposition of the particles originating from this outflow, which will be conducted by HCMR. The operation of the sewage outfall is the responsibility of the Municipal Water Supply and Sewerage Company of Heraklion (http://www.deyah.gr/).

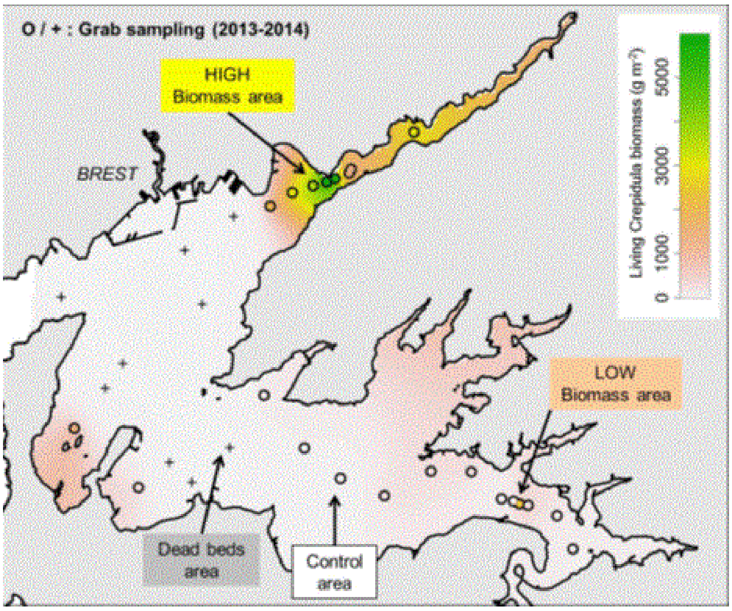

Figure 4.3: Bay of Brest-invasive species action. Map showing the possible (i.e., based on a 2013/2014 survey) locations of the 4 sampling areas differing by the nature and the intensity of the considered disturbance (invasion by the American slipper limpet).

Quantitative data on the outfall discharges will be accessed through the Monitoring Database of Sewage Treatment Plants Operations
(http://astikalimata.ypeka.gr/Services/Pages/View.aspx?xuwcode=GR431001017).

4.2.1.2 Strategy for the acquisition of new observations during each action

➢ West-Gironde Mud Patch

The sampling during the *West-Gironde Mud Patch* action will consist in four spatial surveys set to account for average seasonal changes in the water discharge of the Gironde Estuary (Figure 4.4). This will allow for a comparison with a survey carried out in the same area but on a much more restricted number of stations during July 2010 (Massé et al. 2016). All of the 4 new observation surveys will include the assessment of both biodiversity and functions. The first cruise will take place in October 2016 on board of the RV Côte de la Manche. The other ones are planned in December 2017, February 2018 and June 2018, respectively.

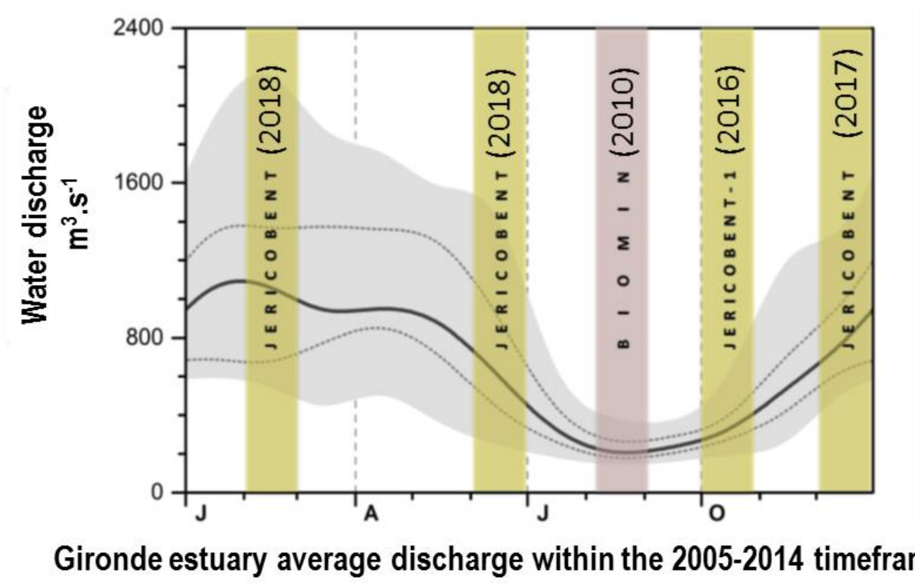

Figure 4.4: West Gironde Mud Patch action. Average seasonal changes in the water discharge through the Gironde River between 2005 and 2014. Vertical bars represent planned new surveys with JRAP2 (yellow) and already carried out surveys within the West-Gironde Mud Patch (pink).

Ten stations will be sampled during each survey. Six will be sampled for diversity and function and four for diversity and sedimentary POM characteristics alone. These stations will be located along two inshore-offshore transects located in the two main lobes of the mud patch (Figure 4.5).

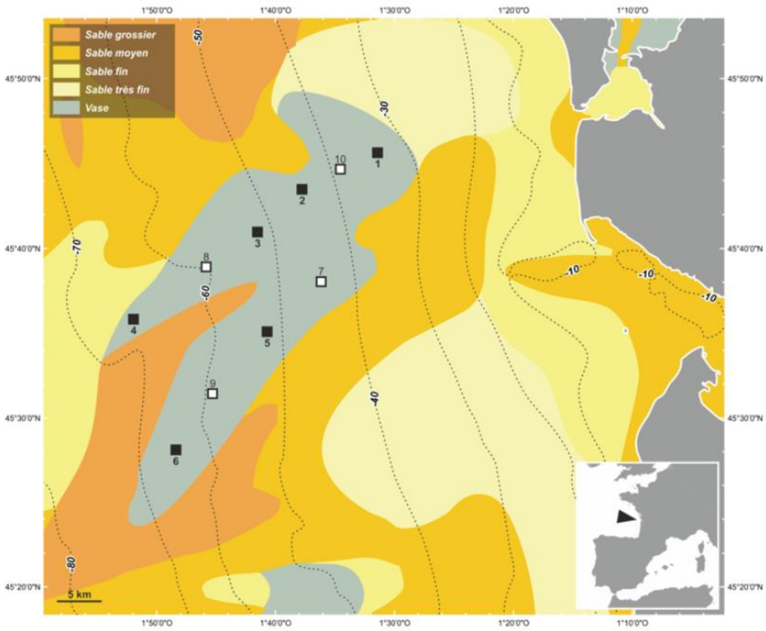

Figure 4.5: West-Gironde Mud Patch action. Locations of the sampled stations along the two inshore/offshore gradients. Open symbols refer to the sampling of biodiversity alone, whereas black ones refer to the sampling of both diversity and functions.

➢ Bay of Brest-dredging

The sampling during the *Bay of Brest-dredging* action will consist in several spatial surveys (carried pout in relation with the IMPECAPE national project) during the 2015-2017 time period. Most of these surveys will be restricted to the sampling of biodiversity. They will be carried out: (1) before the fishing season (September), (2) during the middle of the fishing season (late December), (3) at the end of the fishing season (late March), and (4) during summer time (July). The March 1997 survey will include the assessment of both biodiversity and functions. Two surveys have already been achieved in September 2015 and January 2016. Two other ones are already planned for April and July 2016. Five other surveys (i.e., during September and December 2016 and during March, July and possibly September 2017) should take place before the end of the project.

Ten stations will be sampled during each survey. Their exact locations will be set based on the procedure described above regarding the assessment of dredging intensity. Briefly put, we will draw a frequency histogram of dredging pressure within each individual square (Figure 4.6).

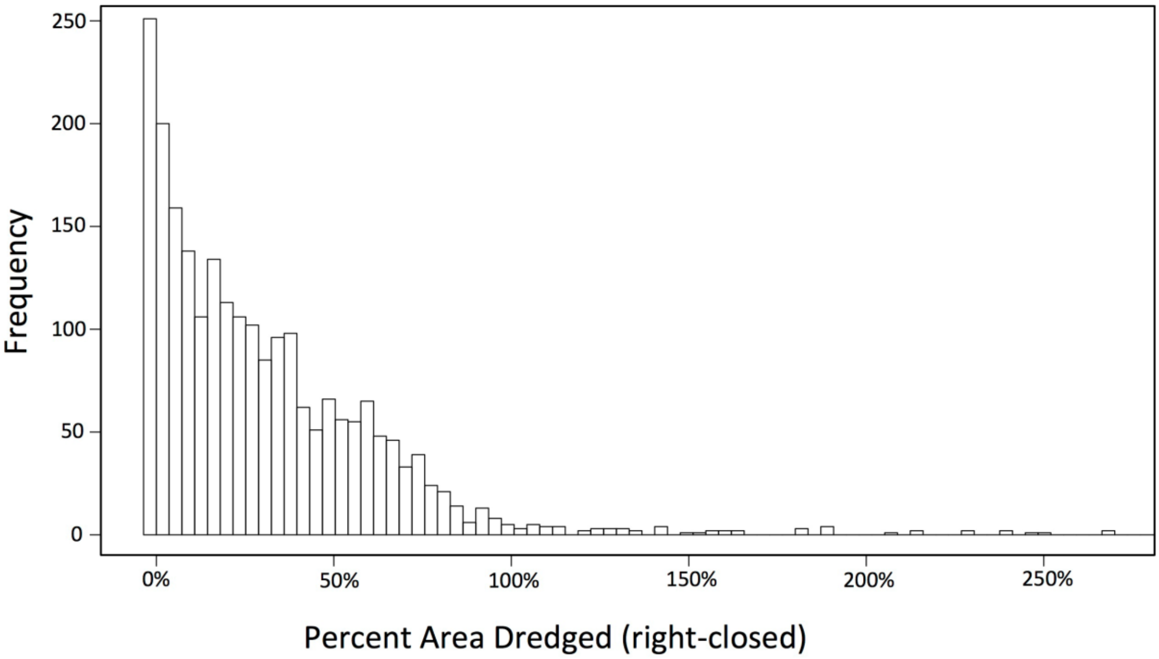

Figure 4.6: Bay of Brest – dredging action. Histogram of fishing pressure (example from October 2012 to January 2015) in squares from the south basin grid. The fishing pressure is expressed as percent of the square's area which has been dredged.

Three stations will be selected in not trawled areas, whereas the other seven will be located so as to account for the whole range of dredging intensity. Care will be taken to limit potential border effects at the edge of the beds and to account for the existence of three geographical zones. (see Figure 4.7 for an example based on the retrospective data first presented in Figure 4.2).

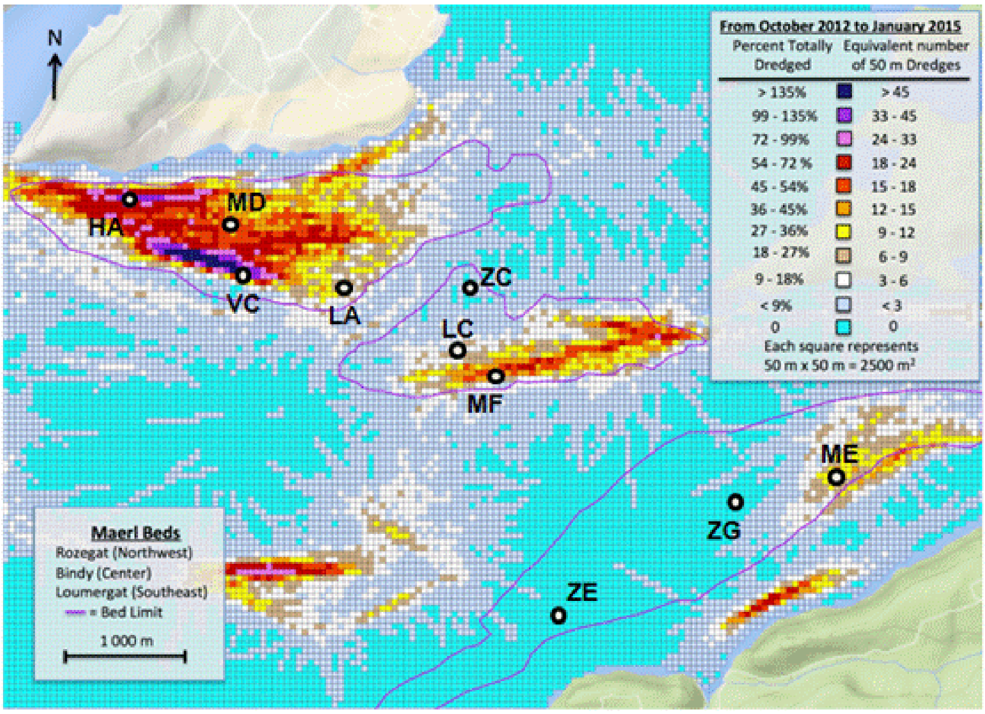

Figure 4.7: Bay of Brest-dredging action. Example of the possible locations of sampling stations based on fishing data collected between October 2012 and January 2015.

- <u>Bay of Brest-invasive species</u>

The sampling during the *Bay of Brest-invasive species* action will consist in a single spatial survey carried out during late spring 2017, during a season corresponding to intense pelagic-benthic coupling mediated by dense living *Crepidula fornicata* beds. The towed video system (Pagure-2) will be deployed over the four hereafter-described areas, and 3 different horizontal tracks (100 – 200 m length) will be achieved within each of these areas (see Figure 4.8 for an example in the high biomass area). Each video profile will include a station previously sampled (with quantitative 0.1 m^2 in-faunal grab) in 2013 and 2014 (French National EC2CO "EVOCREP" project). This sampling strategy will allow determining the degree of complementarity between the video and the classical grab sampling approach. Each video profile will be replicated twice in order to compare data obtained using two modes of video recording ("sledge" mode with skates vs. "flying" mode without skates).

Depending on accessory funding and time limitation, this biodiversity sampling survey might be coupled with the sampling of functions since the EPOC team will take part during March 2017 to the Bay of Brest-dredging action. This would allow to couple vertical profile imagery (SPI system) with the horizontal approach described above, in order to access a bi-dimensional view of the potential impact of living *Crepidula fornicata* on benthic (in-faunal and epifaunal) diversity and sediment characteristics (oxygenation and reworking).

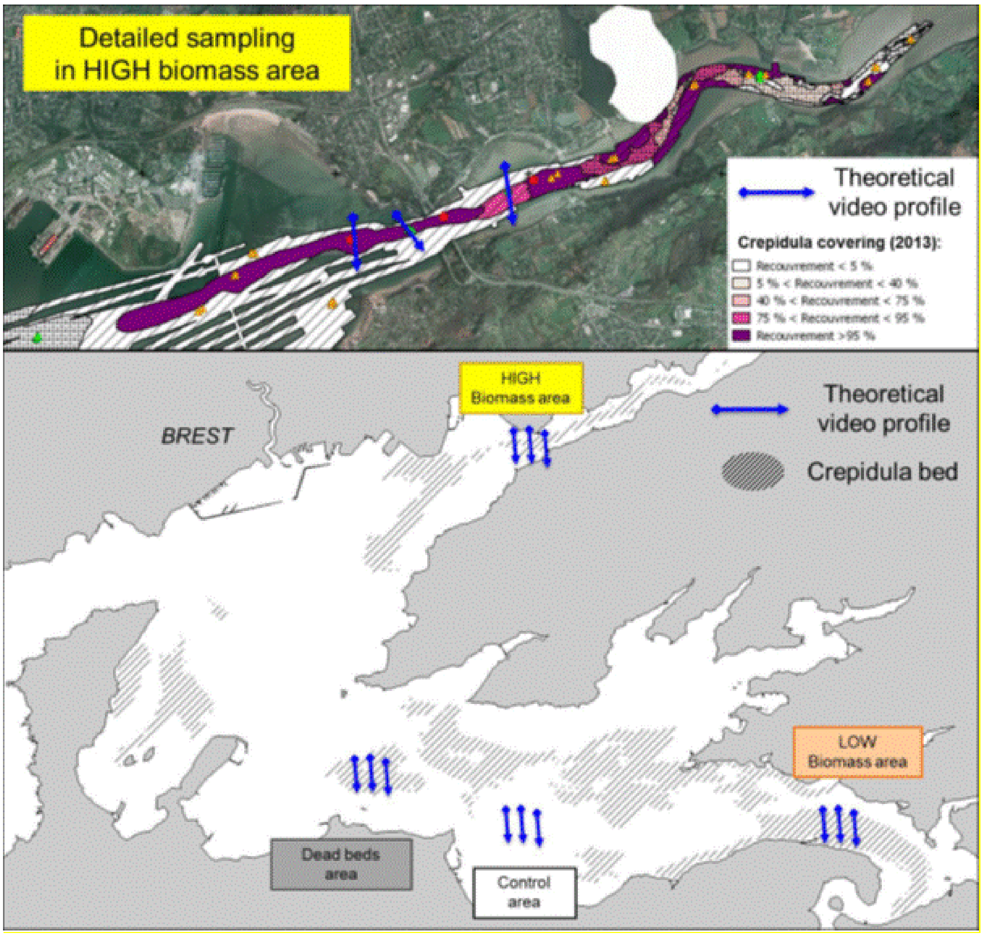

Figure 4.8: Bay of Brest-invasive species action. General sampling strategy showing the detailed locations of the 3 video-profiles within the High Biomass area.

- <u>Cretan Sea</u>

The sampling during the *Cretan Sea – sewage outfall* action will consist in four spatial surveys set to account for seasonal changes in both sewage outputs and natural in the composition of natural undisturbed communities. The first cruise will take place in October 2016. Sampling will be carried out seasonally, based on the expected temporal changes in the output of the sewage, and more specifically in October 2016 (autumn), July 2017 (summer), January 2018 (winter) and April 2018 (spring). The highest sewage output is expected in summer due to the increased number of tourists arriving in Heraklion during that season.

Five stations will be sampled along a predefined gradient, starting from the sewage outfall (close to the shore and at shallow depth) until a control station at 200-meter depth, where no effect of the sewage outfall should be detected (Figure 4.9, Table 4.1). All the stations are located in untrawled seafloor in order to focus only on the effect of the sewage outfall. Stations (stations H2-20, H2-25) belonging to the "ecotone" (i.e., the extended transition zone between high and low energy zones, that is deeper than 20m and shallower than 35m in the Heraklion Gulf, and where high abundance/biomass of macrobenthic organisms is expected as a result of sediment mixture which creates more ecological niches and allows for species from the shallower and deeper waters to settle and thrive) will also be sampled within JRAP-2.

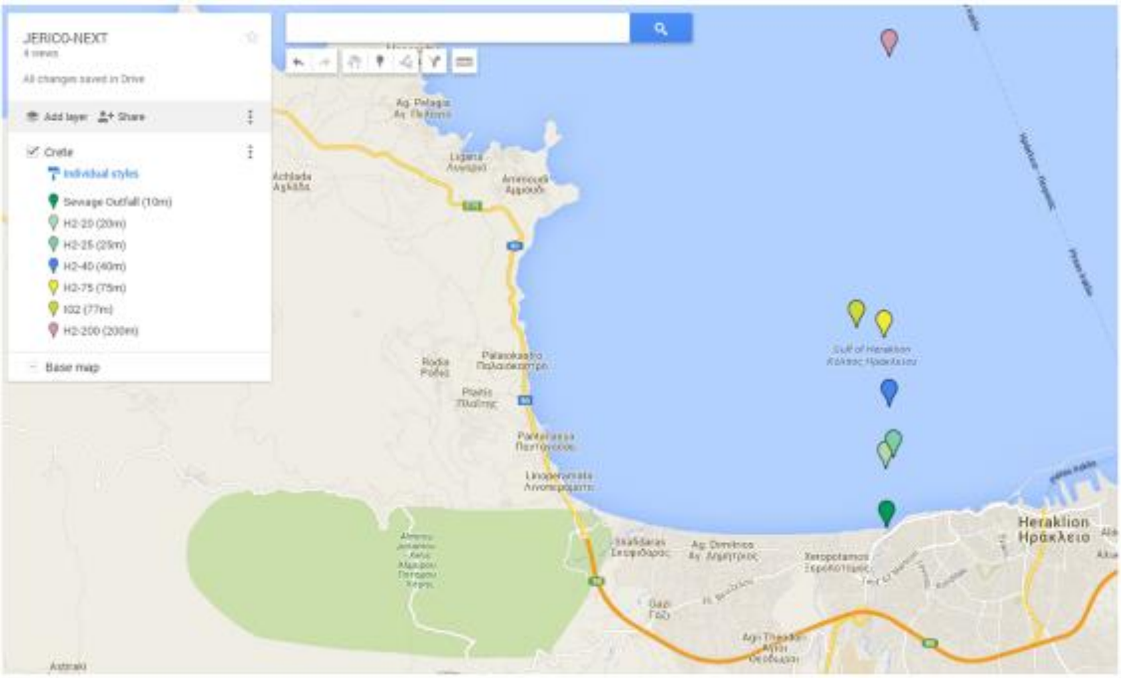

Figure 4.9: Cretan Sea-sewage outfall action. Locations of the stations considered for sampling

Table 4.1: Coordinates and depths of the stations considered for sampling.

Station No.	Station Code	Depth (m)	Latitude	Longitude
1	Sewage outfall	~10	35.33905	25.11076
2	H2-20	20	35.34866	25.11066
	OR			
	H2-25	25	35.35049	25.11216
3	H2-40	40	35.35883	25.11133
4	H2-75	75	35.36999	25.11033
	OR			
	IG2	77	35.37169	25.10479
5	H2-200	200	35.41583	25.11133

Depending on accessory funding, time limitation, and technology transfer from other JRAP2 partners to HCMR, one (all) biodiversity sampling survey(s) might be coupled with the sampling of functions.

- <u>Overall time schedule</u>

The overall time schedule of the surveys carried out in JRAP-2 is provided in Figure 4.10.

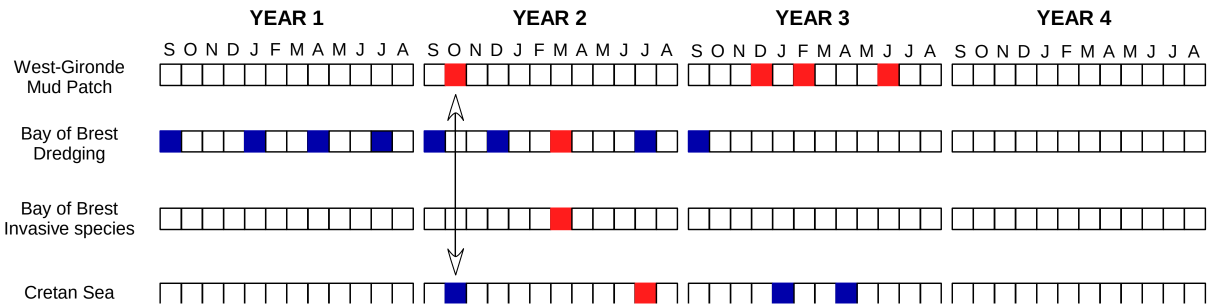

Figure 4.10: JRAP-2. Overall time schedule of the whole JRAP. Blue squares indicate partial (i.e., mostly diversity) survey, whereas red squares also include the assessment of functions. The vertical arrow indicates the inter-calibration workshop, which will take place in Bordeaux prior the West-Gironde Mud Patch action first cruise.

Table 4.2: Sites for JRAP-2, the timing of studies, contact institutes and persons, the platforms used and parameters measured.

Site	Timing of data collection	Data reference contact	Platform - Instrument used	Parameters collected
West-Gironde mud patch	October 2016 December 2017 January 2018 June 2018	CNRS – Antoine Grémare (a.gremare@u-bordeaux.fr)	RV- Côte de la Manche Sediment profile Imaging (SPI) Sediment microprofiler Eddy correlation system	Main physico-chemical parameters (T, S, O2, turbidity…), main sedimentary parameters (granulometry, permeability, porosity, OC, TN, THAA, EHAA, chl a, phaeo a…), Macrobenthic diversity, Microbenthos (metabarcoding), Bioturbation and Benthic Habitat Ecological Quality, Sediment-Water oxygen and nutrient fluxes and depth profiles. Modelled Gironde estuary discharge
Bay of Brest (dredging)	September 2015-July 2017 9 campaign, 1 common (all parameters) in March 2017	CNRS- Jacques Grall Jacques.Grall@univ-brest.fr	Sediment profile Imaging (SPI) Sediment microprofiler Eddy correlation system	Main physico-chemical parameters (T, S, O2, turbidity…), main sedimentary parameters (granulometry, permeability, porosity, OC, TN, THAA, EHAA, chl a,

				phaeo a…), Macrobenthic diversity, Microbenthos (metabarcoding), Bioturbation and Benthic Habitat Ecological Quality, Sediment-Water oxygen and nutrient fluxes and depth profiles, dredging intensity
Bay of Brest (invasive species)	March 2017	IFREMER- Antoine Carlier Antoine.Carlier@ifremer.fr	Integrated multi-sensors video array towed fish Sediment profile Imaging (SPI) Sediment microprofiler Eddy correlation system	Main physico-chemical parameters (T, S, O2, turbidity…), main sedimentary parameters (granulometry, permeability, porosity, OC, TN, THAA, EHAA, chl a, phaeo a…), Macrobenthic diversity, Microbenthos (metabarcoding), Bioturbation and Benthic Habitat Ecological Quality, Sediment-Water oxygen and nutrient fluxes and depth profiles, Crepidula density
Cretan Sea	October 2016, July 2017 (all parameters), January 2018, April 2018	HCMR- Christos Arvanitidis arvanitidis@hcmr.gr	Sediment profile Imaging (SPI) Sediment microprofiler Eddy correlation system	Main physico-chemical parameters (T, S, O2, turbidity…), main sedimentary parameters (granulometry, permeability, porosity, OC, TN, THAA, EHAA, chl a, phaeo a…), Macrobenthic diversity, Microbenthos (metabarcoding), Bioturbation and Benthic Habitat

				Ecological Quality, Sediment-Water oxygen and nutrient fluxes and depth profiles, Sewage outfall discharge

4.2.1.3 Data Processing and Integration (Physical, chemical and biological data)

Data processing

As stated above, the aim of JRAP2 is to assess the impact of different sources of disturbances on benthic diversity and on the functioning of the water-sediment interface. These two questions will be tackled by comparing/correlating the between stations (as defined in space and time) correlation matrices based on (1) disturbance intensity and (2) either benthic fauna diversity or the function intensity.

The collected data set will however also allow to explore the link between benthic diversity and the intensity of the remineralization of sedimented POM based on a field comparison approach. This is far from casual because of the occurrence of many possible confounding factors. In order to unravel this relationship, we will use a hierarchical approach, which consist in considering that the effects of diversity are superimposed on those of quantitative changes in benthic fauna, which are themselves superimposed to those of quantitative changes in sedimented POM characteristics, which are themselves superimposed to qualitative changes in sedimented POM characteristics, which are themselves superimposed to those of changes in abiotic parameters (Figure 4.11). This approach has already been used within the BIOMIN French national project and has suggested the lack of influence of benthic macrofaunal species richness on sedimented POM remineralization within the Rhône River prodelta (Grémare et al. unpublished).

- Integration between physical, chemical and biological data

The integration between physical, biological and biogeochemical data mostly refers to the assessment of spatio-temporal changes in disturbance intensity with three different situations:

(1) Disturbance intensity is biological such as in the *Bay of Brest-invasive species* action and there is therefore no need for and explicit coupling,
(2) Disturbance is physical but directly derived from other data such as AIS data in the *Bay of Brest – benthic dredging* action and there is no need for an explicit coupling as well.

Disturbance mainly consists in organic matter enrichment originating from a point source and is therefore highly dependent on dispersion/destabilisation processes cued by local hydrodynamics and there is a clear need for a tight coupling. This is clearly the case for the *West Gironde Mud Patch* and the *Cretan Sea* actions. In both cases, this coupling will be achieved through hydro-sedimentary modelling, which will first allow for the computation of disturbance intensity for all combinations of sampling locations and dates and more largely for the assessment of spatio-temporal changes in the intensity of disturbances within the studied area. This will allow determining the integration periods relevant to describe temporal changes in benthic macrofauna diversity and benthic remineralization, which could then be used to predict such changes based on physical modelling alone.

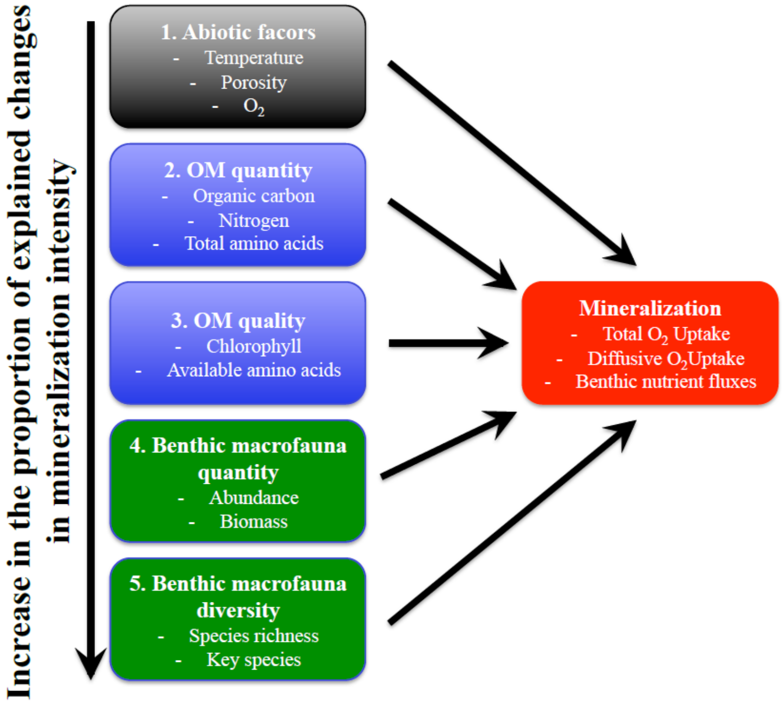

Figure 4.11: Schematic representation of the proposed hierarchical approach, which consists in taking successively into account the effect of: (1) abiotic parameters (black), (2) quantitative and qualitative characteristics of sedimented POM (blue), and (3) the diversity of benthic fauna (green).

4.2.1.4 JRAP team: Role and undertakings

The JRAP-2 team includes 4 partners: (1) the EPOC laboratory from Bordeaux (person in charge: A. Grémare), (2) the LEMAR laboratory from Brest (person in charge: J. Grall), (3) the IFREMER laboratory from Brest (person in charge: A. Carlier), and (4) the HCMR laboratory from Crete (person in charge: C. Arvanitidis). These 4 partners will tightly interact within the project, which will generate significant added values:

(1) Each partner will be responsible for coordinating/carrying out an individual action, which will allow for assessing the impact of different sources of disturbance. This will insure the efficient realization of each action and will thus help in deriving more general conclusions/recommendations from JRAP-2 as expected by WP1 (Task 1.2).
(2) The specific know-hows of each partner (e.g. Sediment profiling for EPOC, Molecular tools for assessing biodiversity for HCMR, Assessment of dredging effort based on AIS data for LEMAR, Stable isotope analysis for IFREMER) will be combined within different actions to optimize observations. This may induce sample exchanges and/or participations to common cruises depending on the success of future applications. In any case, the first *West Gironde mud patch* action cruise which will take place in October 2016 will allow for a common field workshop, which will insure the homogeneity of sampling and analytical procedures used within the different actions of JRAP-2.
(3) and analytical procedures used within the different actions of JRAP-2.

4.2.2 Specific cross-cuttings with other JRAPs and WPs

The main steps and general strategy JRAP-2 together with its interactions with other JRAPs and WPs and other projects are shown in figure 4.12. The interactions with other WPs of JERICO-NEXT are first technological. The new towed video system (Pagure-2) that will be used in the Bay of Brest–invasive species action is being developed in Task 3.6 of WP3. This is also the case of the eddy co-variance and sediment micro-profiling system that will be used to assess the remineralization of sedimentary POM. Moreover, JRAP-2 will also make use of some of the software developments achieved within the former project JERICO to process: (1) sediment profile images (SPIArcBase) and (2) video sequences acquired with a mobile carrier (AVIExplore). In this sense, there will be clear interactions with WP6 (virtual access) and possibly WP7 (transnational access for the Sediment Profile Imager). The Cretan Sea action will make use of the Heraklion Coastal Buoy and the Poseidon ferry box data. In addition, the Cretan Sea will interact with JRAP 6 ("Operational oceanography and coastal forecasting"), for the modelling of the dispersal and deposition of the particles originating from the sewage outflow, and with WP3 ("Innovations in Technology and Methodology"), and more specifically with Task 3.4 ("Microbial and Molecular Sensors"). At last JRAP-2 will contribute to WP5 (Data management) activities and more specifically its task 5.2 (Integration of biological data).

From a more conceptual standpoint, the experience gained from JRAP-2 will contribute to feed the optimization of observations in space and time to soundly tackle key scientific questions or specific social needs related to coastal processes and environmental status. This will be achieved through a tight interaction with the task 1.2 (Science strategy) of WP1 (integrated Science Strategy and Governance from local to European Scales).

In addition, it should be stressed that the work that will be achieved in JRAP-2 will not only rely on interactions with other components of JERICO-NEXT or even JERICO, but also on the collaborations with other projects. This is the case of: (1) the IMPECAPE AMP project for the Bay of Brest – dredging action, (2) the AMORAD ANR project for the *West-Gironde Mud Patch* action, and (3) the KRIPIS GSRT project and small scale monitoring studies on the effect of the wastewater treatment plant in the Gulf of Heraklion. Regarding this last action, it should be pointed out that station IG2 is the reference station that is being sampled on a regular basis for the implementation of the MSFD in Greek territorial waters. Moreover, the project falls within the content of the core-project of HCMR on marine biodiversity (LifeWatchGreece), which provides the electronic infrastructure for both the appropriate storage of data in the data bases (e.g. MedOBIS) and the statistical environment for the analysis of data (the R virtual laboratory). Some components of the optimal sampling plan described above will also clearly rely on the success of future applications. Here again, we believe that such interactions between projects will have to be part of a future observing strategy at a European scale. In this sense, the experience gained for JRAP-2 will clearly contribute to fill WP1.

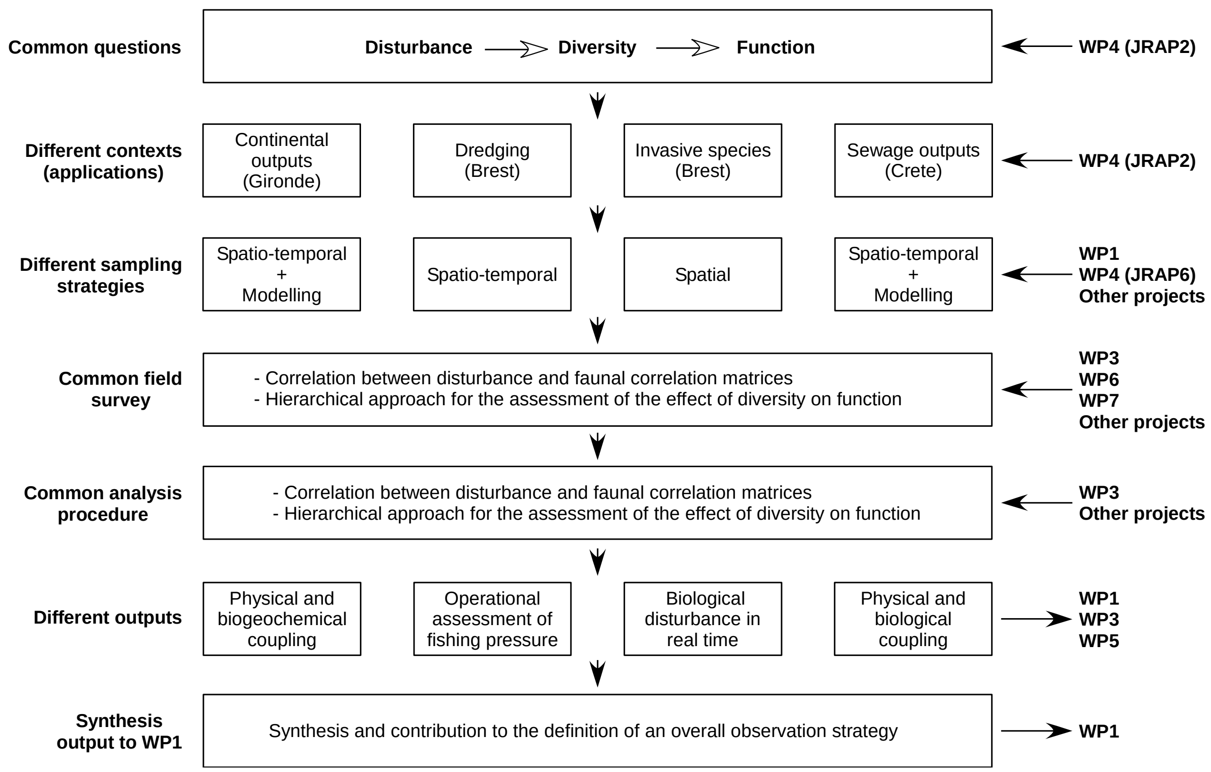

Figure 4.12: Flow chart showing the main steps and general strategy of JRAP-2JRAP-2 together with its interactions between the other components of JERICO-NEXT and other projects.

4.3 Implementation Risks and mitigation measures

Operational risks are common to all operation at sea. Some cruises may be rescheduled in case of bad weather conditions. However, there are some risks of not completing the integrity of the optimal sampling plan.

The willingness to draw widely applicable conclusions from JRAP-2 requires to adopt an ambitious approach both in terms of questions tackled and number of systems studied. The completion of the above-described optimal sampling plan will therefore also function of the success of complementary project applications. We will optimize the chance of success of these applications through: (1) appropriate selection of the programs to apply for, and (2) careful writing of the proposals. Finally, it should be underlined that a general time schedule for all field operations might prove difficult to establish in case of full success in all these associated applications.

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5 JRAP-3: Occurrence of chemical contaminants in coastal waters and biological responses

5.1 Rationale and expected outcomes

Synthetic chemicals have become central to food production, water disinfection, energy, medicine, personal and house care and virtually any type of industrial process. Up to date over ninety million chemical substances have been described and listed in the Chemical Abstracts Service Registry (CAS, 2015a). Several millions of them have been traded, used and potentially emitted to the environment while 350 000 are somehow regulated in the international markets (CAS, 2015b). More than 140 000 chemicals are currently traded globally at environmentally relevant volumes (ECHA, 2015) and about 5000 are listed as high production volume chemicals by OECD (OECD, 2009). In contrast with the number of traded chemicals, available data on their safety and occurrence in the environment are very limited. As a result, most of chemicals on the market do not have sufficient data to accurately assess human and ecological risks.
Marine coastal waters are receptors of thousands of chemical pollutants (Dachs and Méjanelle, 2010) emitted through waste water, deposited from the atmosphere or released directly to the sea from vessels or other costal infrastructures during both professional and recreational activities. Priority lists for regulations are generally limited to a few dozens of chemicals with well-studied toxic properties. Only 45 priority substances or group of substances are currently listed under the Water Framework Directive and 42 substances or groups of substances are included in the priority list under the OSPAR Convention (OSPAR Commission, 2015). Unregulated chemicals, referred to as Contaminants of Emerging Concern (CECs) by EPA (EPA, 2015) or Emerging substances by NORMAN network (NORMAN, 2015) are defined as those substances frequently detected in environmental samples. These include several classes of chemicals encompassing both high- and low- production volume substances (Loos et al., 2013; Munschy et al., 2013; Picot Groz et al., 2014; Weigel et al., 2002).
There is a paucity of information on marine water contamination and fate and distribution of contaminants in the marine ecosystem, especially concerning the universe of Emerging substances. Gathering essential information for the regulation has been hindered by the impossibility for environmental chemists, to access and use integrated monitoring infrastructures, and to perform “transversal” studies combining in-field observation of chemical occurrence and biological responses. **The aim of this JRAP-3 is to exploit the coastal infrastructure network and the set of parameters to deliver a “transversal” study where contamination data, biological data and water quality data will be fully integrated.**

5.1.1 Main questions - Objectives

Descriptor 8 of the MSFD enforces member countries to conduct an assessment of the ecological status of their coastal ecosystems and transitional marine water with regards to chemical pollution. This task includes the implementation of monitoring programs and definition of Environmental Quality Standards (EQSs) for priority substances (European Commission, 2010, 2008). The overall aim of descriptor 8 is “to ensure that the levels of contaminants in the marine environment do not to give rise to pollution effects”. JRAP objectives focus around this descriptor. Specifically, the addressed objectives are:

1) To identify new contaminants in European coastal waters that are not yet addressed by regulation but which can pose a pressure to the coastal marine ecosystem.
2) To describe spatial distribution of chemical contaminants in European coastal waters exploiting integrated fixed and mobile monitoring infrastructures.
3) To investigate the patterns of the spatial distribution exploiting information from physical and chemical sensors available on the infrastructures.
4) To analyse co-linearity between contaminant signals and biological signals (specifically tracking the presence of pollution feeding microorganisms in areas with high contamination exposure.

Specific objectives of the JRAP-3 are:

- To deliver technical protocols and best practices for the monitoring of chemical pollutants using existing coastal infrastructures
- To optimize existing chemical sensor technology for use on fixed coastal monitoring infrastructures
- To provide guidelines for the implementation of contaminant monitoring using JERICO infrastructures

(e.g. information on outcomes from adopting different spatial resolutions.

5.1.2 Description of the state of the art related to the science topic

European coastal waters are among the most monitored for chemical pollution. Despite this, available information is still very fragmentary both in terms of the spatial coverage of the monitoring, spatial resolution and types of monitored contaminants. **A European integrated monitoring programme for marine contaminants is not in place**. Currently available data derive from a relatively small number of case studies that focused in particular on regulated substances. There is no standardization of sampling and analytical methods, not cross validation and cross comparability of data from different laboratories. Finally, a common platform where these data can be accessed is currently not available. Only few study tackled in recent years the challenge of discovery new unregulated contaminants in marine waters. Loos et al. reported the results of a seminar screening of emerging contaminants in European marine waters (Loos et al., 2013). Analysed substances included antifouling pesticides, industrial additives (e.g. plasticizers, anticorrosive agents, surfactants and flame retardants), several pharmaceuticals and personal care products, herbicides and a food additive (namely: sucralose). During a large scale screening performed in different coastal systems, Nödler et al. also reported the detection of 37 substances including pharmaceuticals, pesticides and corrosion inhibitors (Nödler et al., 2014). Zhong et al. (Zhong et al., 2012) reported occurrence of 6 currently used pesticides (CUPs) in open ocean waters at pg/L levels. Discovering new contaminants in coastal waters is a simple matter of pointing the mass spectra detectors towards undisclosed "signals". Nevertheless, the real challenge is to perform this operation systematically, under rigid protocols and covering spatial scales and spatial resolutions to provide useful data for source apportioning, impact assessment and ultimately problem management.

Source apportioning is an important step to lead to sound management. Analysing origin of contaminations in marine waters require an integrated use of information from different types of sensor and cross-discipline competences. Rarely, environmental chemists had the opportunity to access to data from integrated monitoring. The challenge to resolve source apportionment instead is that of opening to the possibility of designing ad-hoc large-scale integrated contaminant/biophysical monitoring programmes.

It is clear that mining for evidences of chemical pollution impacts at regional level is very difficult, standing current paucity of data with a non-integrated/non-homogeneous structure. To this regard recent developments in the field of microbiology and molecular biology are now opening the possibility to investigate chemical pollution through its influence on microbial community composition. Pollutant exposures in the marine environment have been shown to trigger specific changes within the microbial communities, resulting in some species and genes becoming much more prominent following contaminant exposure or environmental changes (Krolicka et al., 2015). Subtle microbial population shifts can be very informative about acute spills as well as chronic low levels of exposure which can be extremely challenging to detect and quantify using more traditional chemical analysis.

Only through the use of integrated monitoring infrastructures delivering harmonized multi-parametric data, goal such the analyses of contaminant distribution, their source apportionment and the coupling with biological responses signals, can be successfully achieved. JRAP-3 will provide a solid proof of concept of the viability of JERICO infrastructures for these scopes.

5.1.3 The role of the JERICO research infrastructure

Within JRAP 3, European costal fixed and mobile infrastructures will be used to carry out integrated monitoring of chemical pollution, water physical chemical parameters and biological signals through the quantification of key marker bacterial organisms. The ambitions is to full exploit extension and spatial resolution multi-sensorial observation offered by the infrastructure to tackle contaminant discovery at continental scale, analysis of contaminant spatial distribution and analysis of contaminant co-linearity with chemical-physical and biological data. **To our knowledge this is the first time such an analysis is possible at such a broader scale using harmonized sensor technology**. So far such an analysis was hindered by the lack of accessible infrastructure. We will exploit a large set of platform including: three Ferrybox routes in the Baltic, North Sea, and Norwegian Sea) and 15 mooring stations deployed all along the Atlantic and North-sea coasts.

5.1.4 Expected progress beyond the state of the art

We expect to provide:

- A substantial contribution to the expansion the list of emerging contaminants discovered in European coastal waters.
- The first large scale (Pan European) integrated analysis of contaminant occurrence and distribution in European coastal waters
- The first large scale analysis of covariance between contaminant distribution and water biological, physical and chemical parameter of water, useful for source apportioning.
- The first large scale correlative analysis between contaminant data and microbial community data to tackle biological responses in relation to exposure to pollution.
- We will deliver a set of best practices and new tools for the technical implementation and interfacing of contaminant monitoring on oceanographic infrastructures.
- Results on optimal strategies for monitoring resolution which will be essential to plan future routine monitoring in the most cost-effective way.

On the medium term we believe the data we will generate will be useful for the development of European marine protection, chemical risk management and in general the development and implementation of MSFD.

5.2 Research Methodology and approach

5.2.1 Study areas

The work will be articulated in 3 different tasks in the following areas: Portuguese coasts, Bay of Biscay, North Sea, Kattegat, Skagerrak and Norwegian coasts.

Figure 5.1: fixed platform based deployments (stars) and Ferrybox based monitoring (lines)

5.2.2 Main tasks and work plan

The three monitoring tasks are as follows:

Task 1: A pan European monitoring campaign using passive samplers deployed on moorings in the Portuguese coasts, Bay of Biscay, several locations of the North Sea, Kattegat, Skagerrak and Norwegian coasts
Task 2: One monitoring campaign using a set of Ferrybox platforms (mobile) in the outflow of the Baltic (Oslo and Kiel transect), the North Sea, and the Norwegian Sea.
Task 3: A high spatio/temporal resolution campaign based on Ferrybox along the Oslo Kiel transect focusing on the analysis of coupled chemical signals and biological responses.

5.2.2.1 Sampling strategy

Task 1: The monitoring from fixed platform will be conducted using silicon based passive sampling technology. Passive samplers allow the determination of time-integrated average concentrations of hydrophobic and moderately polar contaminants dissolved in water. Contaminant accumulation into passive samplers is driven by diffusion resulting from the difference in chemical activity of the contaminant dissolved in water and that in the sampler. Silicon passive samplers are simple sheet of pure silicon with standardize dimensions and properties. In this case 10 sheets of 90x60x2mm will be used for each sampling event. The sheets are pre-cleaned in laboratory before deployment in the field through a thorough solvent extraction that remove chemical contaminants pre-adsorbed to the silicon during production, transport and generally, exposure to air in laboratory. The cleaned passive samplers are then spiked through diffusive equilibration with a set of labelled substances that mimic the dynamic of accumulation in the samplers of the contaminants to be sampled in the environment. The sheets are deployed in the field inside a protective cage.

Figure 5.2: Left: Image of silicon passive samplers deployed in one of the new cages designed for Jerico infrastructures. Right; the cage ready for deployment.

Accumulation of contaminants in water depends on the characteristics of the substance such as the size of the molecule, its affinity for the receiving phase material, and transport across phases, (namely the diffusive boundary layer and any biofilm layer developing at the surface of the sampler during extended exposures). Sampling performance is pre-calibrated based on the results of laboratory or previous field exposure samplers carried out under constant conditions of contaminant concentration, water temperature and turbulences. Since the application of laboratory-determined uptake rates to field situations is unreliable, the dissipation of performance reference compounds (non-naturally occurring chemicals spiked into the sampler prior to deployment), allows to in situ calibration at each individual deployment (Allan, Booij et al. 2009). In JRAP a brand new protective cage to facilitate installation on different type of mooring is under development. This design allows the samplers to be easily handled by non-qualified operator reducing the risk of involuntary sample damage and contamination.

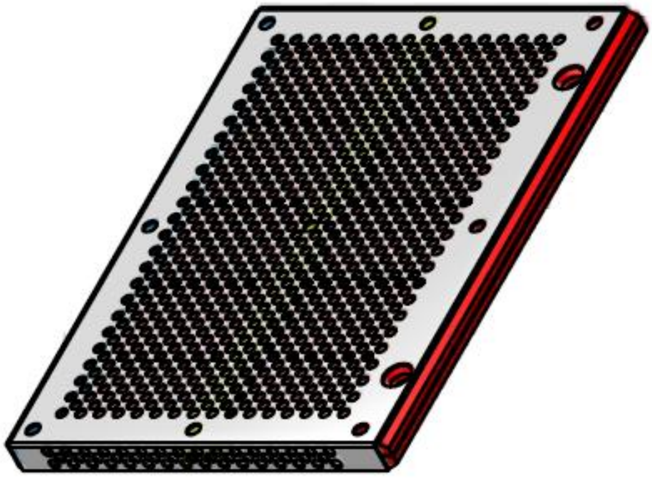

Figure 5.3: A rendering of the passive sampler cage developed during JRAP-3.

The samplers will be installed in provisionally 11 moorings as described in Figure 5.1 between March and September 2016. The deployment of the cages will not be synchronized across the different infrastructures and regions. Deployments will occur during scheduled visit to the infrastructures. This is obviously to contain costs and guarantee the feasibility of a long term strategy in contaminant monitoring from fixed platform. Lack of synchronization in deployment periods and different deployment times do not constitutes in se problems for the interpretation of results given the very long integration time of the observations and the use of performance reference compounds (described above) that will allow standardizing data based on performance of individual sampling events. The sampling will target non polar and moderately polar substances, including persistent organic pollutants listed under the Stockholm Convention (e.g. DDT, PCBs, HCB, PBDEs) as well as polycyclic aromatic hydrocarbons (PAHs) deriving from oil spills and combustion sources. In order to fulfil quality assurance and control criteria a set of field blanks and laboratory blanks will complement the monitoring activities.
This Task will contribute to the Jerico-Next overall strategy by establishing and demonstrating the effective use of passive samplers and coastal infrastructure to monitor contaminants in coastal water. This brings a significant added value in the overall capacity of coastal infrastructure. Continental scale contaminant monitoring in marine water is, in fact, not included in any other observation system. Task 1 will expand capacity of monitoring infrastructure to deliver data in an area (environmental protection from chemical pollution) that is prioritize by all official document at national, European and international level. The task includes the development of tools, practices and protocols that optimize the use of Jerico infrastructures for this scope, while guaranteeing quality-proofed data. This information will be fed back to WP1.

Part of the monitoring conceived in this Task will be used to integrate JRAP-3 to JRAP4.

Task 2: The monitoring from the Ferrybox platforms will be conducted exploiting automatic water sampler installed on the selected ferries as part of the standard equipment of Ferrybox units. This sampling will focus on the detection of emerging polar contaminants. In particular, we will focus on the discovery of new pharmaceuticals, antibiotics, personal care products, current used pesticides and food additives never measured before in marine waters.
Samples will be collected into one-litre high density polyethylene bottles inside the refrigerated cabinet of the automatic sampler. After the collection of the water samples the bottles will be stored on board (contained in the closed cabinet) during the full duration of the cruise. Samples will be retrieved from the ferries at their next visit to harbours and sent to laboratory for analysis.
No pre-filtration of the samples will be performed during collection. Gathered data will represent contamination of the bulk water (in agreement with European directives guidelines).
Automatic sampling on board allows collection and storage of up to 24 samples per cruise leg. Collection points will be selected based on the analysis of major gradients of water physical properties or proximity to expected sources (river estuaries, harbours). Although the focus will be to gather information on possible sources, also "open

water" samples will be analysed in order gather information on diffuse and background pollution levels. In order to fulfil quality assurance and control criteria a set of field blanks and laboratory blanks will complement the monitoring activities.
Task 2 will be conducted during spring/summer 2016.

NOTE: Task 1 and Task 2 are designed to target chemical contaminants with very different properties. Task1 will target hydrophobic substances present in water in ultra-trace levels (typically sub-ng/L). Passive samplers are effective means capable of pre-concentrating directly in the field the signal from these substances which otherwise will require the collection and extraction of several hundred litre of water to achieve detectability. The technology currently deployed on Ferrybox systems does not allow this operation. Materials used in automatic samplers on Ferrybox will also interfere with the measurement of these substances.

In task 2 the focus is to measure signal of hydrophilic substances present in water at ng/L to hundreds of ng/L levels with not strong interaction with plastic materials used in Ferrybox auto-samplers. The two different approaches obviously result in very different temporal and spatial resolutions that are of difficult integration. The rationale of having the two methodologies included in Jerico observation systems is to guarantee a broad spectrum of the substances that can be monitored and fully demonstrating/exploiting the infrastructural network capability.

Task 3: Is based on same sampling infrastructure and analytical technology as adopted in Task 2 (Ferrybox), but will focus only on the Oslo Kiel transect. A sampling campaign will be conducted during May 2016. Samples for molecular biology analysis will be collected consistently with the sample for chemical pollution, filtered through a 0.2 µm filter and frozen at -80oC for further analysis. In WP3 Activity 3.4 on Microbial molecular sensors, specific markers of hydrocarbon pollution suitable for coastal marine areas will be identified and current sampling methods will be adapted to perform the necessary qPCR assays for the quantification on microbial communities and specific organisms. Markers and methods developed in WP3 will be used to monitor organisms in this JRAP.

The biological monitoring is designed to quantitatively track the presence of specific strains of bacteria, rather than addressing the description of microbial community structure.

This study is aimed at analysing the transect with the highest possible spatio/temporal resolution. Sampling frequency along the route will be modulated to increase resolution along transient areas where water properties (or perceived anthropic impact) present maximum variability. The challenge is that of identifying geographical clusters where pollution may have selected for the presence of pollution adapted bacteria strains. Provisionally these areas are expected to be harbour areas, estuarine areas, areas with intense marine traffic, presence of industry along the coast, etc.
The high resolution strategy adopted here will be also essential to inform future optimization of monitoring design. Data on contaminant concentrations generated from Task 3 will be used to complement the dataset from task 2. Results obtained using low and high sampling resolution approaches will be compared to gain insights on the added information extracted from the high resolution data. This will allow an assessment of best monitoring practices. Such information will be fed back to WP1.

Table 5.1: Sites for JRAP-3, the timing of studies, contact institutes and persons, the platforms used and parameters measured.

Site	Timing of data collection	Data reference contact	Platform - Instrument used	Parameters collected

North Sea	Spring 2016 - Autumn 2016. Timing of deployment and duration will vary depending on the timing of routine visits to used fixed platforms and morings.	NIVA – Luca Nizzetto, luca.nizzetto@niva.no	Buoy-Skagerrak (Norway) (IMR) Thornton Bank buoy Bligh Bank buoy (Belgium) (VLIZ) Warp buoy, West Gabbard buoy Dowsing buoy (UK) CEFAS Cosyna Buoy (Germany) HZG	Time integrated concentrations of several chemical contaminants in surface water (provisionally: 15 polycyclic aromatic hydrocarbons, 12 Polychlorinated byphenils, DDT, Hexachlorobenzene)
Kattegat	Spring 2016 - Spring 2016. Timing of deployment and duration will vary depending on the timing of scheduled visit to the mooring.	NIVA – Luca Nizzetto, luca.nizzetto@niva.no	Tångesund_SMHI_MOS buoy (Sweden SMHI)	Time integrated concentrations of several chemical contaminants in surface water (provisionally: 15 polycyclic aromatic hydrocarbons, 12 Polychlorinated byphenils, DDT, Hexachlorobenzene)
Portugal coasts	Spring 2016 - Autumn 2016. Timing of deployment and duration will vary depending on the timing of routine visits to used fixed platforms and morings.	NIVA – Luca Nizzetto, luca.nizzetto@niva.no	Monican1 (offshore mooring Monican2 (coastal mooring RAIA (Leixoes) mooring Faro mooring	Time integrated concentrations of several chemical contaminants in surface water (provisionally: 15 polycyclic aromatic hydrocarbons, 12 Polychlorinated byphenils, DDT, Hexachlorobenzene)
Norwegian Sea	Spring 2016 - Spring 2016. Timing of deployment and duration will vary depending on the timing of scheduled visit to the mooring.	NIVA – Luca Nizzetto, luca.nizzetto@niva.no	Tromsø mooring (Norway) (NIVA)	Time integrated concentrations of several chemical contaminants in surface water (provisionally: 15 polycyclic aromatic hydrocarbons, 12 Polychlorinated byphenils, DDT, Hexachlorobenzene)

North Sea	Summer 2016. Measurements every approx. 3-8 hours	NIVA – Luca Nizzetto, luca.nizzetto@niva.no	Lysbris FerryBox – Moss (Norway)-Ghent (Belgium)-Immingham (UK) – Moss (Norway) (HZG)	snapshot concentrations of several emerging contaminants (Provisionally: 44 currently used pesticides, 22 Pharmaceutical and personal care products, 3 artificial food additives). Salinity, temperature, optical properties.
Kattegat-Skagerrak-Baltic	Summer 2016. Measurements every approx. 3-8 hours	NIVA – Luca Nizzetto, luca.nizzetto@niva.no	Color Fantasy FerryBox – Oslo (Norway)-Kiel (Germany)	snapshot concentrations of several emerging contaminants (Provisionally: 44 currently used pesticides, 22 Pharmaceutical and personal care products, 3 artificial food additives). Salinity, temperature, optical properties.
Norwegian Sea	Summer 2016. Measurements every approx. 3-8 hours	NIVA – Luca Nizzetto, luca.nizzetto@niva.no	Troll Fjord FerryBox – Bergen (Norway)-Kierkenes (Norway)	snapshot concentrations of several emerging contaminants (Provisionally: 44 currently used pesticides, 22 Pharmaceutical and personal care products, 3 artificial food additives). Salinity, temperature, optical properties.
Kattegat-Skagerrak-Baltic	Summer 2016. Measurements every 1 hour	NIVA – Luca Nizzetto, luca.nizzetto@niva.no IRIS - Catherine Boccadoro cbo@iris.no	Color Fantasy FerryBox – Oslo (Norway)-Kiel (Germany)	snapshot concentrations of several emerging contaminants at high spatio/temporal resolution (Provisionally: 44 currently used pesticides, 22 Pharmaceutical and personal care products, 3 artificial food additives). Salinity, temperature, optical properties. Polycyclic aromatic Hydrocarbons. DNA biomarkers

5.2.2.2 *Data Integration (Physical, chemical and biological data)*

The chemical and physical data collected from the Ferrybox platforms (Oslo-Kiel transect) will be integrated with biological data on total microbial community biomass and abundance of organisms specific to hydrocarbon pollution.

The data will be quality checked and the variability of parameters assessed. Different techniques of multiparametric statistical analysis will be applied to the combined dataset to verify the parameters correlations, collinearity and the regression power. The most appropriated technique will be used to establish a statistical tool to suggest the best sampling frequency for this parameter combination as well as predicting the contaminant distribution with the

minimum number of parameters. Spatial interpolation techniques will be used to map the contaminant distribution along the selected transect. Correlations between physical, chemical and biological data will be investigated using multivariate statistics. This is helpful for exploring how the combination of these parameters provides further information on the environmental status. Multi-variated statistics, in contrast to analysis of individual parameters will provide hopefully provide a more holistic assessment of ecological status in relation to chemical pollution.
In addition to the principal tasks elucidated above, we will support the work conducted within JRAP-4. This JRAP focuses on the calibration of high resolution models for the transport of materials by streams. More specifically we will contribute by delivering information on chemical tracers during the case study in the Bay of Biscay. We will deploy passive samplers in the mooring in Biscay Bay at two depths (7m and 50 m). Observed concentrations gradients of chemical contaminants will be useful to calibrate the description of diffusivity in the water column.

5.2.2.3 JRAP team: Role and undertakings

NIVA (Luca Nizzetto) will coordinate the JRAP. Main operative tasks include: Preparation of materials for monitoring (including the development of the new tools for integrating passive sampling to JERICO fixed monitoring infrastructures); organizing logistics (including arranging transfer of passive sampler sensor across JERICO partners); planning and executing water sampling on board of Ferrybox units; Running part of the chemical analysis; sharing ferrybox sensor data; coordinating share of information with other with other JERICO-NEXT WPs and JRAPs, reporting and dissemination.
IRIS (Catherine Boccadoro, Elisa Ravagnan) coordinating data analysis in task 3. Tasks include: Planning of task 3 activities, biological analysis, statistical analysis, reporting and dissemination.
CEFAS (Kate Collingridge). Providing access to four Oceanographic moorings in the North Sea. Tasks include coordinating in situ, logistics for deployment and collection of sensors; and sharing data from fixed platform sensors.
IMR (Henning Wehde). Providing access to 1 oceanographic mooring in the North Sea. Tasks include: Coordinating in situ, logistics for deployment and collection of sensors. Sharing data from fixed platform sensors.
HZG (Wilhelm Petersen). Providing access to 2 fixed platforms in the North Sea. Tasks include: Coordinating in situ, logistics for deployment and collection of sensors. Sharing data from fixed platform sensors. Remotely executing sampling campaign from the LysBris ferrybox unit.
Access to other fixed platforms in Portugal, Spain, France, Sweden and Norway will be provided by other JERICO-NEXT partners on a voluntary basis.

5.2.3 Specific cross-cuttings with other JRAPs and WPs

The main cross-cutting with other JRAPs includes the delivery of chemical contamination data from ferrybox unit to the coordinator of JRAP 1. Data will be used to analyse possible drivers controlling phytoplankton assemblages.
Main cross cuttings with other JERICO-NEXT WP include:
WP1. Delivery of best practice documents on the use of Jerico infrastructure for the implementation of chemical contaminant monitoring.
WP2 Task 2.4: Delivery a new harmonized tool and standard procedures for the routine inclusion of chemical contaminant sensing on JERICO fixed platforms through the use of passive samplers.
WP2 Task 2.6: Providing inputs for the inclusion of passive sampling based measurements of chemical pollutants into the context of JERICO quality label.
WP 3 Task 3.4 Field testing of microbial molecular methodology for pollution detection. Delivery integrated chemical and biochemical data for in field demonstration activities.
WP3 Task 3.2 Providing chemical contaminant data (including specific tracers for wastewater-related pollution in surface data.

5.3 Implementation Risks and mitigation measures

Pilot studies related to Task 1 and 2 of this JRAP have been recently conducted proving high feasibility of the experimental activity. Task 3 is explorative and this is the first time such an integrated chemical biochemical monitoring will be conducted. There is no guarantee of individuating co-linearity between chemical and biochemical signals, nevertheless the sampling campaign will be designed to tackle strong environmental gradients across contrasting background and impacted areas. This will largely increase the possibilities of identifying common trends in chemical exposure and biological responses.

Task 3 will be conducted by maximizing spatio/temporal resolution of monitoring from the Ferrybox. This may generate a certain level of redundancy in the information contained in the dataset, due to spatio/temporal autocorrelation. Currently there is no available information to guide optimization of sampling design. A high resolution monitoring campaign will however be essential to gather data on optimal design for chemical and biochemical monitoring in future.

If time/budget constraints will allow, we will plan a more resolved spatial monitoring from fixed platform in the area of Biscay Bay, in coordination with JRAP 4.

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6 JRAP-4: 4-D characterisation of trans-boundary hydrography and transport

6.1 Rationale and expected outcomes

6.1.1 Main questions - Objectives

Surface transport at coastal areas is driven by a large variety of processes (tides, current instabilities, coastal jets, eddies, fronts…) acting simultaneously, in response to different forcing and over a broad spectrum of time-space scales. These processes play a key role in the dispersal/retention of pollutants, planktonic species (potentially toxic), and more generally in cross-shelf exchanges. The characterisation and better predictability of these structures is critical to understand the physical/biological coupling in the coastal zone. More generally, the accurate monitoring of the resulting complex surface circulation is key for the effective integrated management of coastal areas (where the use of the marine space is concentrated); this is why coastal observatories are developing along the global ocean coasts (Weisberg et al.,2015)
In this context the three main objectives of JRAP-4 are:

- To use of JERICO infrastructures to study the 4D shelf/slope circulation and transports and their time variability year-round in three trans-boundary areas; through the joint analysis of multiplatform data of surface currents and hydrography (High Frequency Radars (HFR), drifters, satellite imagery …) and information from the water column (drifters, moorings, gliders, satellite data, coastal profilers…).
- To quantify the potential impact of the ocean transport on the distribution of floating and dissolved matter (plankton or other pelagic organisms, marine litter and contaminants, etc.) in line with MFSD main descriptors (2, 7 and 10).
- To provide recommendations on methodologies and approaches for maximising the impact of the JERICO-RI for assessment of coastal transport.

JRAP-4 will focus on three study areas, which involve different ocean dynamics (see Figure 1), these are the German Bight (GB), the SE Bay of Biscay (SE BOB) and the NW Mediterranean (NW MED).

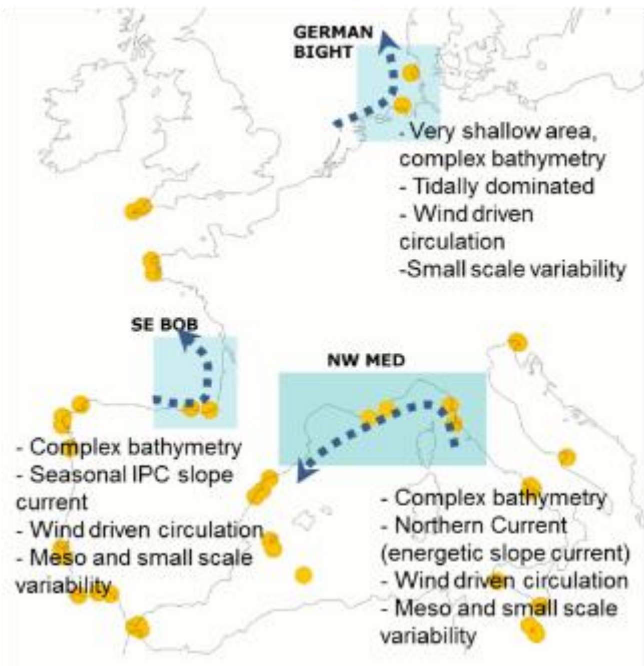

Figure 6.1: JRAP-4 study areas

The study areas are, in addition, submitted to different human pressures/activities which will, in turn, drive specific applied research activities. To work in a coordinated way through this heterogeneity is a challenge but also is also a very interesting aspect of the JRAP-4.

The research work in JRAP-4 will be based on: (i) Historical data available at each of the study areas; (ii) New observations using JERICO_NEXT infrastructure, which will allow to improve the existing observatories to solve smaller scales and to make a step forward in the understanding of coastal ocean processes; (iii) Observing System Simulation Experiments (OSSES, link with Task 3.7 and JRAP#6) which will be used, depending also on technical and economic criteria, to objectively propose optimization in existing observing network (new HFR antennas, different fixed stations position).

The JRAP-4 aims to contribute in assessing the following MFSD descriptors:

- D2 (Non-indigenous species introduced by human activities): Ocean changes (e.g. ocean warming) induced by the climate change (partly induced by human activities) could be the reason of the arrival of non-indigenous species (including gelatinous organisms such as the Portuguese man-of-war *Physalia physalis*), with low swimming abilities and whose spatial distribution is highly depending on hydrodynamics
- D7 (Permanent alteration of hydrographical conditions). JRAP-4 will allow for the continuous monitoring of hydrographic conditions.
- D10 (Properties and quantities of marine litter): Marine litter is advected or drifted by marine currents. JRAP-4 will provide information about hydrodynamics and derived transport to infer the spatial distribution (e.g. convergence areas and coastal arrivals) of this not-desirable material.

JRAP-4 will also provide inputs for other multidisciplinary approaches in connection with other WPs and JRAPS (mainly #3 and #6) in JERICO_NEXT.

6.1.2 Description of the state of the art related to the science topic

The main goal of JRAP-4 is to provide estimates of 4D transport (3D in space and time) in three pilot areas (SE BOB, NW Med and GB) using information from Observing Systems (OS) based on HFR for surface currents, hydrographic instrumentations (thermistors, CTD and gliders) for the water column, as well as the outputs of OSSES. A correct knowledge of Lagrangian transport by ocean currents is at the core of many crucial applications such as mitigation of pollutant or marine litter spreading and ecological management of fisheries and Marine Protected Areas.

Estimating transport is very challenging because it is inherently chaotic and therefore depends on the details of the velocity field at various scales. This is especially true for the surface ocean, where a host of competing processes at various scales and dynamics influence transport of advected quantities. HFRs play a very important role in monitoring the surface ocean and in estimating transport, thanks to their coverage (range of 30-200 km) and high resolution in time (order of 1 hour) and space (order of 1-3 km). HFR information though is confined to the first upper meter, while ecological quantities such as larvae, planktonic organisms as well as pollutants and microplastic move also in the water column. The next crucial challenge that motivates JRAP-4 is, therefore, how to expand the very surface information from HFR s to the interior ocean. The integration of HFR data with other traditional sensors like, e.g., tide gauges, surface Lagrangian drifters or moored instruments and the combination of the observations with numerical models, which can also be used to provide forecast, are new interesting work lines for the estimation and forecast of 4D ocean transports at the core of JRAP-4.

In addition to assimilating HFR data in numerical models, other approaches like empirical models can be used to forecast future currents based on a short time history of past observations. Some recent works have applied empirical models to HFR data to obtain Short Term Forecasts (STP) using several approaches. Barrick, et al. (2012) used OMA decomposition (Lekien et al., 2004) and then a set of temporal modes was fitted to the time series of OMA coefficients over a short training period. Frolov et al. 2012 used EOF decomposition and applied a vector autoregressive model on the leading EOFs time series for prediction, incorporating wind stress forecast from a regional atmospheric model. In Orfila et al. 2014, the spatial and temporal decomposition of current variability is also performed using EOFs, then the forecast approach relies on a Genetic Algorithm (GA) (using only past observations) to identify mathematical expressions that best forecast the evolution of the amplitudes associated with statistically significant EOF modes. Recently Solabarrieta et al. (in revision) applied the linear autoregressive models described in Frolov et al., 2012 (using only HFR data) to perform an analysis of the model spatio-temporal performances in a multiyear experiment in the SE BoB. Because of the combination of the EOF pre-processing and the time-embedding in the autoregressive model with extended training periods, these forecast models are in principle able to simultaneously learn both the high-frequency signal (tidal and inertial) and the basin-wide modes of the circulation; however, these studies show that the skills of the model are limited and suggest that they can be improved by using multivariable approaches and by improving the learning strategy of the models.

In any case, the choice of the different approaches to 4D transports estimations and forecast has to be done very carefully taking into account the different processes driving the ocean circulation in each of the JRAP-4 study areas. A short review of previous work and the main characteristics of the circulation are provided here:

NW Mediterranean

The NW Med area is characterized by the presence of the Liguro-Provenco-Catalan Current also called Northern Current (NC) that originates in the Ligurian Sea due to the convergence of two currents flowing along each side of the Corsica Island. The NC flows westward along the coasts of Italy and France and it is characterized by a complex time variability covering a large spectrum of scales. At the seasonal scale, the current is especially energetic in winter and weaker in summer. Mesoscale motions (Alberola et al., 1995; Millot and Taupier-Letage, 1995) are characterized by meanders with wavelength of 30-40 km and two main frequency bands, with periods of 10-20 days and 3-6 days respectively. The frontal structure of the current also responds to direct wind forcing (Piterbarg et al., 2014), even though the role of local wind is not completely understood. Submesoscale instabilities characterized by strong vertical velocities have also been suggested to occur in response to different wind regimes (Schaeffer et al., 2011).

SE BoB

The primary surface circulation pattern in the shelf/slope SE BOB presents a marked seasonal variability (Charria et al., 2013). A key component of this variability is associated with the surface signature of the slope current (Iberian Poleward Current, hereafter IPC). In winter, the IPC flows eastward along the Spanish coast and northward along the French coast, affecting the upper water column from the surface to 300 m (Le Cann and Serpette 2009, Solabarrieta et al., 2014) and it is associated with warm surface waters along the northern Spanish slope (Pingree and Le Cann 1990). In summer, the circulation over the slope is reversed, i.e., presents a westward (southward) flow over the Spanish (French) slope, with intensities three times weaker than those observed in winter (up to 70 cms-1) and a stronger vertical shear (Solabarrieta et al., 2014, Rubio et al., 2013a). In addition to the marked seasonality of the shelf/slope current regime, several authors have described the presence of mesoscale eddies in the area, generated most frequently during winter by the interaction of the IPC with the abrupt bathymetry (Pingree and Le Cann 1990, Le Cann and Serpette, 2009; Caballero et al., 2014). Recently, Rubio et al. (2013b) provided evidence for the presence of coherent mesoscale structures within the HFR footprint area and on their potential effect on local transport paths.

Overlaid to the density-driven slope circulation, wind-induced currents are the main drivers of the surface ocean circulation in the HFR foot print area and are observed in a wide range of time scales, from seasonal to high-frequency (Fontán et al., 2015, Solabarrieta et al., 2015, Kersalé et al., 2016). During autumn and winter, SW winds dominate and generate northward and eastward drift over the shelf. The wind regime changes to the NW during spring, when it causes sea currents toward the W-SW along the Spanish coast. The summer situation is similar to that of spring, but the weakness of the winds and the greater variability of the direction of the general drift make currents more uncertain (González et al., 2004; Lazure, 1997; Solabarrieta et al., 2015). At shorter time-scales, the variability is dominated by inertial oscillations and tides (mainly semidiurnal), although energy contents around the main tidal peaks are lower than in other areas of the Bay (Le Cann, 1990). From HFR data, inertial oscillations have been observed to be seasonally modulated and intensified in summer in the central part of the study area (Rubio et al., 2011; Solabarrieta et al., 2014). Recent current measurements during the ASPEX experiment have revealed the intriguing nature of the tidal currents over the Aquitanian shelf. Near the bottom, by depth of 60 m, the tidal currents decrease from about 20 cm/s during the stratified period (June-October) to less than 5 cm/s from fall to spring. The root cause of this seasonal variability turns out to be the summer stratification that allows internal waves to propagate onshore close to the coast (Lazure et al., 2014). An EOF analysis of the vertical mode of these currents shows that 63% of the variance is due to the first mode of internal tide, whereas the barotropic mode accounts from only 21% of the variance. Meanwhile, SAR images show complex wave fronts propagating on shore with multiple interactions and probably many generation sites over the shelf breaks. Moreover, the propagation of internal waves is affected by all modifications of the 3D temperature field, which evolve at several frequencies from few days for wind variability to several weeks for the mesoscale circulation.

The SE BoB is an area characterized by complex circulation patterns and where relevant human activities linked to marine resources is concentrated (sport, artisanal and commercial fishing, tourism, industry, increasing offshore aquaculture and marine renewables, etc.) and thus, represents a particular challenge for the accurate monitoring and forecast of 4D transport patterns.

German Bight

The German Bight is a shallow area with maximum water depth of about 50 m. The circulation is dominated by the semi-diurnal tidal signal with water elevation amplitudes of the order of 1.5 m and tidal currents of the order of 1 m/s. The nonlinear component of the tides together with the wind forcing lead to a residual circulation, which is typically from the west and then up to the north. The order of magnitude of this residual circulation is of the order of 3 cm/s (Maier-Reimer, 1977). The dynamics is further influenced by the fresh water input from the Elbe, Weser and Ems rivers, which can lead to significant stratification in some areas. This not only plays a role for current velocity profiles but also for the vertical distribution of water constituents (Pein et al., 2016). Another characteristic feature of the German Bight is the barrier islands and the Wadden Sea area. The exchange between the open water and the Wadden Sea is strongly influenced by the shape and location of tidal inlets (Staneva et al., 2009). These bathymetry features change over time due to morphodynamic processes.

The major challenges in the modelling of 4D transports in the German Bight is the uncertainty concerning bathymetry and the turbulence parameterisation, which is key for simulating stratification and mixing processes. For the latter also ocean surfaces have to be taken into account (Staneva et al., 2015).

A big progress for the estimation of currents in the German Bight was the availability of continuous HFR measurements in the framework of the COSYNA system (Stanev et al., 2011). These measurements are assimilated into numerical models on a routinely bases and have shown to improve surface current forecasts (Stanev et al., 2015).

Still some work is required however to estimate vertical mean transports from observations. Ideally this requires some additional profile observations, which are not available very frequently. Another approach followed by HZG is to combine HFR data with traditional tide gauge measurements.

6.1.3 The role of the JERICO research infrastructure

The progress needed for more accurate estimation and monitoring of coastal transport will benefit from the JERICO research infrastructure in many ways. The coordinated inclusion of new measuring systems or data into existing Coastal Observatories, the availability of quality-controlled multiplatform and data, and the progress in DA methodologies, are some of them. Also, the networking with research groups with wide spread expertise and experience concerning the use of HFR and the coastal ocean processes is of great value. More specifically, the role of the research infrastructure around HFR and MASTODON moorings technology is provided here.

HFR

To get a comprehensive view of the ocean circulation data are needed throughout the coastal oceans from the shoreline to the outer continental shelf. Due to the highly non-linear and complex circulation in coastal waters, the data sampling must be dense and frequent enough to capture such variability. The key point about HFR measurements, and why they are crucial for JRAP-4, is that they provide both a spatial and temporal picture of ocean surface currents.

HFR systems are already present in the three study areas. The added-value in JRAP-4 concerning this technology is related to different tasks:

- Installation of a new antenna in SE BOB (task 3.2.2) will allow to overcome one of the clearest limitations of the present configuration which is the lack of HFR coverage along the Basque Coast, due to the small angle amongst existing radials (which prevents from recovering accurate total vectors). The installation of the third antenna will enable the inter comparisons between a Phased Array (PA) and a Broad-Beam (BB) system in the area, make further analysis on observational errors (in the area covered by the three antennas where there will be redundant data) and on wave data retrieval.

- Harmonization of operations, data formats and QA/QC protocols (tasks 2.3.1, 3.2.1). This will enhance data quality and enable the creation of a database of HFR data harmonized formats and QA/QC flags will simplify the data exchange among the researcher in the collaboration on the joint analysis of data, data assimilation tasks and retrieval of 4D transports and forecasts.
- New developments for 4D characterization of shelf/slope hydrodynamics and short term prediction tools (task 3.2.3) based on HFR and other observations/models will be capital to develop the applications of JRAP-4 in all the study areas.

Coastal profilers with MASTODON moorings (thermistors)

To better describe the true nature of internal waves over the continental shelf, in situ measurements of the high frequency temperature variability is needed and still lack to our understanding. So far, classical mooring with temperature probes deployed from surface to bottom or thermistor chains are the unique mean to assess the vertical movements of isotherms under the action of internal waves. However, such deployment requires many moorings due to the small horizontal scale of the internal wave (few km) and could become quickly a costly and risky experiment. The Mastondon-2d development aims at increasing the number of fixed moorings by reducing dramatically their cost and allowing us to demonstrate trough a high spatial resolution monitoring array that coastal internal waves can be accurately observed in both cross and alongshore directions.

Within the JERICO_NEXT project, we propose to develop to whole water column, a new version of the MASTODON mooring, originally designed to measure at very low cost the bottom temperature (Lazure et al., 2015). The modification of the original concept consists on locating the buoy originally fixed to the bottom frame, to subsurface with low cost temperature sensors along the line. The main bottom frame will only contain enough rope (typically 50 m) for the buoy to surface at the time of recovery.

6.1.4 Expected progress beyond the state of the art

Ocean dynamics of the coastal and shelf-break zones are characterized by a large variety of processes acting simultaneously over a broad spectrum of scales. JRAP-4 will offer the opportunity to identify, isolate and characterize some of these processes as well as the interactions between them. These processes play a key role in the dispersal/retention of pollutants, marine biology, and more generally in cross shelf exchanges and transport. Thus, these are crucial issues for the integrated management of coastal areas. Finally, the study of ocean processes at small scales is a cutting-edge topic. Thus, several scientific contributions are expected.

More specifically JRAP-4 will contribute to the progress on several research lines and methodological developments like:

- A better understanding of ocean processes and their effects on the surface transports. Identification of the key processes for accurate transport estimates.
- A better characterization of the observability of these key processes by the existing systems and suggest new approaches and elements to improve coastal observatories.
- Better understanding of the observability of the different processes in the HFR and the other observing systems and of the observational errors as a first step towards their assimilation in coastal circulation numerical models.
- A process oriented validation of numerical simulations, which will lead to future improved model configurations
- Development of new methodological tools necessary for improve applications of operational oceanography to relevant societal needs.

6.2 Research Methodology and approach

JRAP-4 proposes the 3D characterization of shelf/slope circulation and its time variability year-round in three trans-boundary areas, through the joint analysis of multiplatform data of surface currents and hydrology (HFRs, drifters, satellite imagery) and information from the water column (drifters, moorings, gliders, satellite altimetry). Besides characterizing the main physical processes in relation with the shelf/slope circulation (Fig. 1) and their response to the main forcings (wind, buoyancy) effort will be put in quantifying transport by ocean currents and its potential impact on the distribution of floating matter (plankton - jellyfish or other pelagic organisms, marine litter, pollutants, etc.).

In this context the three main work lines common to all the study areas are defined as follows:

1. Retrieve 4D transports in each study areas through an optimal observational strategy, and characterize them and using common eulerian and lagrangian analyses. The first step in the JRAP-4 strategy consists in using historical and JERICO_NEXT data and numerical circulation models to identify the main dynamical processes and scales that characterize the surface velocity field in the three pilot areas. They are expected to include: mesoscale processes characterized by geostrophic dynamics with vertical scales of the order of the main thermocline, horizontal scales of the order of the Rossby radius and time scales longer than a few days; ageostrophic sub-mesoscale processes such as MLI (mixed layer instabilities) with vertical scales of the order of the mixed layer, horizontal scales of few km and time scales of the order of 1 to few days; ageostrophic Ekman processes with vertical scales of the order of the Ekman layer, synoptic time scales of a few days and horizontal scales that depends on the coastal responses in terms of upwelling and downwelling. For shallow flows also the interaction with bottom friction is expected to play a role, and, at higher frequencies, nonlinear tidal and inertial residual currents have an impact on transport. Also smaller scale motions with high divergence such as Langmuir cells and surface waves influence transport, and even though they might not be resolved by the OS they could be included through parameterizations. All these processes and scales often act at the same time and are present in the HFR velocity fields. Unravel this complexity and identify the main processes and scales is a complex but necessary task in order to choose the most appropriate methodology to project the surface signature in the water column.

Various methodologies to compute subsurface velocity and transport will be considered and their choice will depend on the nature of the flow in the three areas. Broadly speaking, there are two main classes of methods that can be used. The first one is given by Data Assimilation (DA) methods, where data information is combined with numerical models and the information are dynamically propagated by the model to correct the interior velocities (links with WP3, Task 3.7 and JRAP#6) . The other class that we will refer loosely to as “fusion” combines information from HFR data with other types of data using statistics and/or dynamics, in order to project the velocity in the interior (link with Task 3.2.3).

DA of surface velocity from HFR is still relatively new because of the complexity of the velocity field, even though HFR observations have a tremendous potential for estimating coastal circulation and transport. Several methods have been investigated, such as Optimal Interpolation (OI), variational methods and ensemble based error covariance methods. The work concerning DA approaches is to be developed within JRAP#6 and Task WP3.7. The cross-cuttings with these tasks and JRAP-4 involve mainly the use of OSSEs outputs to define the best sampling strategies but can also be of use in the estimation of 4D transports.

Fusion methods also encompass several methodologies, and there is no clear answer on how to optimally use them to estimate subsurface transport. Because of the complexity of the velocity field, some type of horizontal mode decomposition is usually performed, such as EOFs (empirical orthogonal functions) or NMA (normal mode analysis) or OMA. The OMA method is especially interesting because it accommodates for open boundaries, and it separates the field in divergent free and irrotational modes. In order to project the velocity in the water column, also vertical mode decomposition is necessary and some type of dynamical analysis is likely to be necessary to treat the various processes. Mesoscale divergent free processes can be assumed to be geostrophic, while for Ekman flows several models have been suggested, even though they are mostly valid in the open ocean. Projecting sub-mesoscale processes is challenging, and methods based on Surface Quasi Geostrophy (SQG) can be investigated (LaCasce and Mahadevan, 2006). An alternative method to retrieve information on 4D velocity is based on neural networks, as SOM (Self Organizing Maps), that allow to identify spatial structures at different time scales extracted from a joint analysis of HFR and data sets in the water column (Liu et al., 2006). The choice of the scales to be targeted and of the optimal method to use will depend on the initial analysis of the three areas. It is likely that only dominant scales and dynamics will be chosen to estimate 4D transport, especially if fusion methods are used.

2. Apply 4D transports to address issues (at least one) in relation with MSFD (issues that can be different for each study area). Once the methods will be investigated and tested, specific applications will be performed in the three areas using data from the JERICO_NEXT OS. Potential impact on the distribution of floating matters (larvae, plankton or other pelagic organisms, marine litter…) will be considered, if synergies with other projects will allow it providing additional data on these quantities (that are not included in the present approved version of the DoA). An effort will be made to make these actions possible, but it is important to keep in mind that they provide an interesting (but not mandatory) addition to the funded actions in the DOW, that are mostly concerned with providing estimates of 4D transport.

Estimates of 4D transports from the JERICO_NEXT OS and data will be provided. Potential impact on issues related to MSFD D2 and D10 will be addressed if synergies with other projects will allow it. In particular, for the NW Mediterranean, ISMAR-CNR and French universities (partners of the CNRS - MIO) recently submitted a proposal (IMPACT) to INTERREG Italy-France Maritime Cooperation. If funded, IMPACT will provide data on contaminants and ecological quantities in the NW Med area that can be used also in JERICO_NEXT. In the case of the SE BOB, the application of the JERICO_NEXT OS to study the impacts of transport on marine litter (ML) will be addressed using open sea distribution and arrival historical data. This action is subjected to the approval of the LEMA proposal on ML submitted to 2016 LIFE call. The idea is to infer the influence on ocean transport on the coastal arrivals of marine litter and convergence areas of marine litter in the open sea. Besides, a crosscutting with JRAP-4, the effects of hydrodynamics on open sea pollutants distribution will be studied using in-situ data of currents and passive tracer samplers for several periods (depending on external funding).
Finally, in the GB area, the impact of ocean currents on the distribution of marine litter and other pollutants will be investigated. For material with buoyancy close it is expected water stratification become important.

3. Test STP methods / assimilation using HFR and available data to forecast 4D estimates with applications to 2. Given the background on STP methods applied to HFR data given in 8.1.2 the aim here is to improve and to expand the existing capabilities for STP trough four different approaches:

- Parametric statistical models: Regression and Autoregressive models. Statistical or stochastic models have the advantage of requiring relatively short data to be implemented and they have been used in oceanographic context for predicting usually weekly or monthly estimates of several parameters (SST, SSH, etc.). We propose the use of statistical approaches to link independent variables (such as the wind speed at the ocean surface) in order to predict the radial velocities. Such a model can have a simple structure such as,

$$V_r\,(t) = a_0 + a_1\ W(t) + \varepsilon(t)$$

  where Vr(t) are the radial velocities at time t,, W(t) the wind velocities at time t , a0 and a1 simple regression coefficients and ε(t) the error. Besides, Auto-regressive models take into account the autocorrelation of the velocities and can also account for the correlation with other external variables to build the predictor at various periods. Variability in the time series can be modelled using Fourier series.
- Empirical models based on the CCA of HFR and wind fields. We propose to expand the use of EOF and CEOF to explore the possibility of deriving a 2-d predictor of (u,v) velocities using past measurements of HFR velocities and 2-d fields of surface winds provided by high resolution numerical models.
- Lagrangian models from FSLE. In the last years, lagrangian tools have been used to characterize the dynamics of coastal flows under a Lagrangian point of view and mainly through the study of the so-called Lyapunov exponents of finite size (FSLE). Lagrangian diagnostics exploit the spatio-temporal variability of the velocity field by following fluid particle trajectories, in contrast with Eulerian diagnostics, which analyse only frozen snapshots of data. FSLEs are very well suited to study the Lagrangian Coherent Structures organizing the fluid motion being also able to reveal oceanic structures below the nominal resolution of the velocity field. Despite the growing number of applications of FSLEs, to our knowledge

they have not been used for forecasting purposes. Here, we propose to use the total HFR velocity fields to compute de FSLE to provide a STP of certain surface patterns.

- Models on analogous. Neural network methods have several advantages in clustering and feature extraction compared to EOFs (e.g., Liu et al. 2006). These non-linear methods have been widely applied in meteorology and oceanography (Liu et al. 2006; Camus et al. 2011; Espejo et al. 2014, Solabarrieta et al. 2015). They offer a valuable opportunity to improve the characterization of surface ocean dynamics and can provide a basis for STP.

Synergies between work lines 1 and 3 in terms of the basic methods identified for these approaches have been identified and will be explored further in order to converge to integrated methodologies for 4D transports forecasts.

6.2.1 Study areas

NW Mediterranean

CNR-ISMAR HFR infrastructure consists of four remote stations (Model Codar SeaSonde @25MHz). Each radar station (see figure 2) produces hourly current radial velocity map with a typical range of 35 km, with a spatial resolution equal to 1 km and an angular resolution equal to 5°. Data are combined in near real time in 2-dimensional velocity maps at the central data processing server in La Spezia and exported in NetCDF format. The typical spatial resolution is 1,5km. The NetCDF data structure is compliant with Climate and Forecast (CF) Metadata Conventions 1.6, Attribute Convention for Data Discovery (ACDD), INSPIRE convention, Unidata Dataset Discovery Convention, and U.S. HFR Network recommendations. Data are presently used in a number of applications regarding coastal management like larvae transport, connectivity between MPA, transport of sediments. As secondary product, each radar station can provide local estimates of the directional wave spectrum, giving information on significant wave height, wave period, peak wave direction and wind direction for onshore area. An oceanographic campaign is expected (NON Jerico-Next funded), providing CTD measurements in the East Ligurian sea. Confirmation of the grant is pending.

CNRS (MIO) operates two HFR systems (see figure 2), one off the coast of Toulon, and the second off the coast of Nice. The first target area off the coast of Toulon is a key zone conditioning the behaviour of the North Current just upstream of the Gulf of Lions. It displays significant cross-shelf exchanges correlated to the strong northwesterlies present in the region (Mistral, Tramontane). This fully operational site is composed of two Wellen Radar systems (WERA (Gurgel et al., 1998)) manufactured by Helzel Messtechnik GmbH and providing real-time data. The first HFR system has been installed at the Cap Sicié in 2010 and works in quasi-monostatic configuration with a non-linear, W-shaped, 8-antenna receiving array and a single emitting antenna. Such irregular configuration of the array was the only solution to cope with the insufficient space available. This site has been complemented in May 2012 with a fully bistatic second system, a pioneering configuration for WERA, at the time of the setup. The receiver, a regular linear 8-antenna array, is located at Cap Bénat while the transmitter, GPS-synchronized, is installed in the Porquerolles Island, 17 km away from the receiver, in order to circumvent the presence of several large islands. The bistatic configuration has required some dedicated and original hardware and software processing. It also allowed us to experimentally study the effects of bistatism on the HF Doppler spectra, namely evidencing good potential for the purpose of wave spectrum inversion (Grosdidier et al., 2013).

CNRS (MIO) systems are continuously working in the frequency band of 16.1 to 16.2 MHz allocated by the ITU (International Telecommunication Union) to the oceanographic HFR operators. They sweep over a 50 kHz bandwidth, i.e. half of the allocated bandwidth, resulting in a 3 km range resolution over 80 kilometres of distance from the coast. A 2 azimuthal resolution is achieved through a Direction Finding method based on Music (Lipa et al., 2006; Molcard et al., 2009). The integration time can vary from 20 minutes to one hour. The radial velocities maps are transmitted every 20 minutes. Cartesian velocities are then reconstructed on a regular grid of 3x3km2 and displayed in near real-time on a dedicated website: http://hfradar.univ tln.fr. These data would be re-formatted in NetCDF as recommended by the WP5.The installation of the second HFSWR site off the coast of Nice in the Ligurian Sea area extended the observation zone to the full coastal area, from Italian coast to the gulf of Lion, allowing a much larger coverage of the Northern Current. The selected equipment is a pair of more compact HFR system, namely 2 SeaSondes from CODAR Ocean Sensors (Barrick, 1979). The two locations are the lighthouse of Cap Ferrat in Saint-Jean Cap Ferrat and the semaphore of Cap Dramont in Saint-Raphaël, resulting in a 50 km baseline. CNRS (MIO) SeaSondes works in the 13.5 MHz frequency band allocated by the ITU. The parameters are similar to those of the WERA systems, except for the azimuthal resolution set at 5 deg.

For the deployment/recovery of MASTODON moorings that will be deployed in late summer-autumn 2017, two short oceanographic campaigns will be conducted in the coastal area off Provence (see Figure 6.2) in September-October. The second campaign is planned to last for a few days in order to be able to perform additional hydrographic observations and to get complementary data in agreement with the applications defined for this study area. This action is depending from external funding (ongoing ANR funding request).

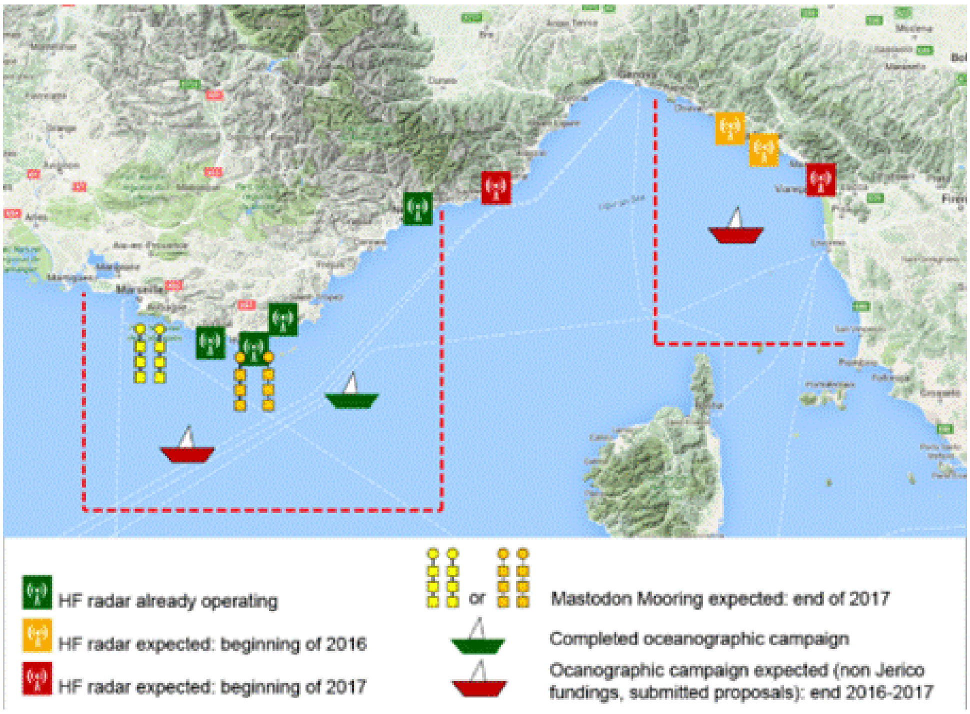

Figure 6.2: Illustrative map of the NW Mediterranean study area and the JERICO_NEXT research infrastructures.

The work plan concerning 4D estimates is organized as follows, in agreement with the main strategy discussed in 8.2:

- The main dynamics and scales of motion will be investigated first analysing historical and JERICO_NEXT data in the area. In particular, we will consider a 4D data set jointly collected by CNRS (MIO) and CNR-ISMAR in the framework of the TOSCA project (Berta et al., 2014) in December 2011 that includes data from: HFR, ship based CTD and ADCP, drifters, gliders.
- Main scales of motion and methods for the estimation of 4D transport will be identified. These will include the EnKF developed by the CMCC and used in OSEE in the NW Med region. Other possible fusion methods will also be considered and if appropriate they will be tested first using data from a numerical model in order to quantify the performance.

SE BOB

At the SE BOB the Directorate of Emergency Attention and Meteorology (Euskalmet) of the Basque Government promoted, since 2001, the progressive installation of different in-situ observing marine platforms in the SE BOB. Starting by a network of coastal stations, the observing system was extended offshore in 2007 through the mooring of two slope buoys equipped with meteorological sensors, a CTs chain and a downward looking ADCP (only that offshore San Sebastian is working nowadays) and, in 2009, through the installation of a HFR (two sites, see Figure

6.3). An additional offshore buoy (equipped with ADCP and meteorological sensors) is currently operating in bimep area (close to Bilbao city, at 80m depth). During the last years, several comparison exercises of HFR data with other Basque COO data available, have proved the performances of the Basque HFR system and have shown its potential for the study of the ocean processes and the complex transport patterns in the area (Ferrer et al. 2009; Rubio et al. 2011; Solabarrieta et al., 2014, 2015).

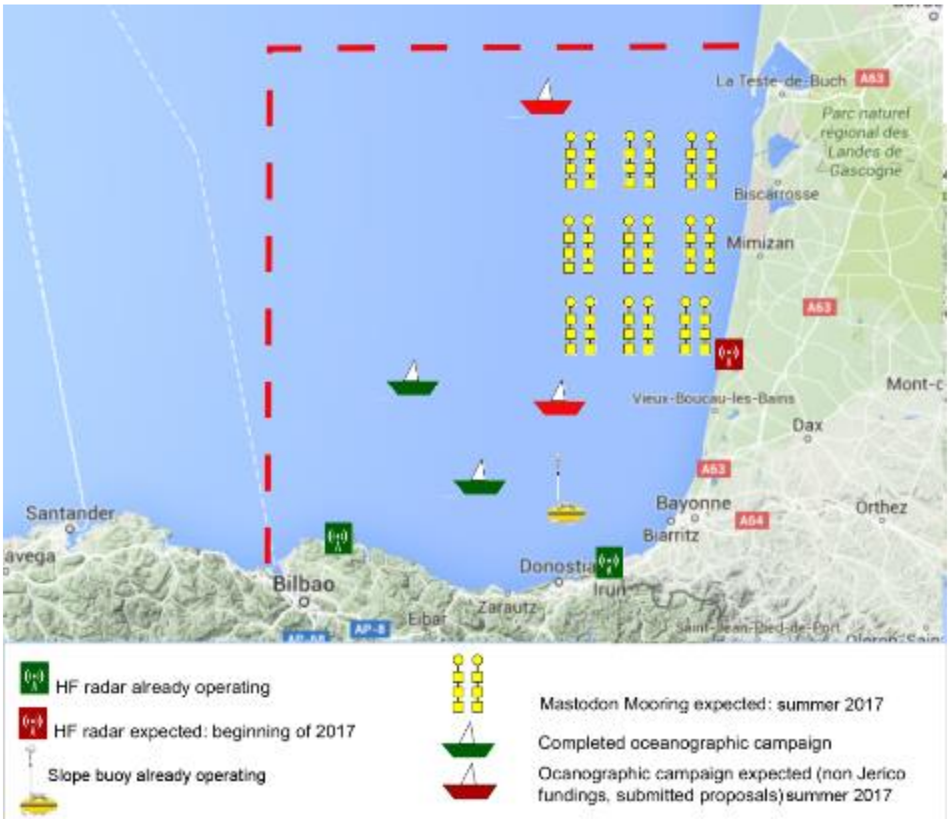

Figure 6.3 -Illustrative map of the SE BOB study area and the JERICO_NEXT research infrastructures.

New deployments in this area, in the framework of JERICO_NEXT, will be started after month 18 (first half of 2017) in order to be able to concentrate the maximum number of observational systems in the same period:

- New HFR antenna – Beginning of 2017 (expected to be running at least for a year)
- MASTODON moorings – summer 2017
- DRIFTERS - summer 2017, most likely during the mastodon campaigns

For the final planning of the deployments and sampling strategy and the deployments of complementary instrumentation (drifters) this will permit to wait for numerical experiments outputs (analysis of ensemble runs) to update and refine location and periods.

The deployment of new HFR antenna along the Landes coast in the SE BOB will be coupled with the improvement of a method to optimize OOS. In the frame of the WP3.7 dedicated to OSE/OSSEs, the ArM (Array Modes) method (Le Hénaff et al., 2009; Lamouroux et al., 2016) is being extended to HFR observations. This method allows estimating the most efficient location of measurements to constrain the ensemble model variance. In the JRAP-4, the method will be used in the deployment of the new system along the French coast taking into account existing HFR system along the Spanish coast.

For the deployment/recovery of MASTODON moorings two short oceanographic campaigns will be conducted in the SE BOB in summer 20017. The second campaign is planned to last for one week in order to be able to perform

additional hydrographic observations and to get complementary data in agreement with the applications defined for this study area. This action is depending from external funding (demand submitted in April 2016).
To analyse 4D transport in the SE BOB, historical data will be considered as a reference material for interpreting recent observations collected in the frame of JERICO-NEXT. These data are available through COriolis ReAnalysis validated products (CORA), in the regional version (CORA-IBI for Iberian-Biscay-Ireland) including a large collection of profiles from cruises and observing systems over the shelf to the deep ocean in the BOB. Based on identified datasets in CORA-IBI, it will be extended with local cruises from partners in JERICO-NEXT project.

Other complementary data will be used in the SE BOB for multidisciplinary approaches in line with MSFD issues:

- ML arrivals to beaches: Local and regional governments register regularly the amount of litter that arrive to the Basque beaches on a daily and weekly basis, during summer and winter respectively. In addition, there are other institutions that register also regularly the marine litter near the coast. The recovery, processing and analysis of these data are foreseen in the framework of the LEMA project (if funded).
- ML monitored by observed on board different research vessels: there are ML data bases obtained by during different yearly campaigns. Biological/acoustical data as e.g. BIOMAN (May) and JUVENA (September) carry on board observers that monitor and classify the ML during the cruises. These records began in 2012. Depending on funding/technological limitations, ML data will be also collected during MASTODON CAMPAINGS in SE BOB (demand submitted in April 2016).
- In order to complement the information of the HFR in the SE BOB, we expect to cover the study area mode densely during 2017 from other campaigns in the SE BOB in summer 2007. The CTD stations of regular biological campaigns within the study area could be adjusted for the JRAP-4 study period, in order to obtain synoptic maps of S/T, dynamic topography and geostrophic currents.

German Bight

The situation in the German Bight is that three HFR stations located at the islands Wangerooge, and Sylt as well as on the mainland in Büsum are already operating on a routinely basis. These systems provide surface current fields every 20 minutes. The first step within JERICO_NEXT will be the application of these data for 4D transport specific issues. In particular, the data will be used to estimate Lagrangian trajectories at the surface. The impact of the tides and the wind will be analysed separately. Of particular interest is the stability of the results. For example, one interesting question is whether drifters, which typically move in north easterly direction pass the island Helgoland, which is located in the centre of the German Bight, on the northern or the southern side. It is well known that in drifter experiments where two drifters are dropped at the same location the respective trajectories often depart after some time. This effect, which is most likely associated with convergence and divergence properties of the current field will be analysed.

The HFR data derived trajectories will also be compared to numerical model results. HZG runs a three-dimensional primitive equation model (GETM) for the German Bight area with 1 km resolution on a routinely basis. In addition, volume transports through different transects derived from the model will be compared to respective HFR estimates, which are based on surface observations alone. Two interesting transects are, for example, between Wangerooge and Helgoland as well as between Büsum and Helgoland. Together with the coastline, these two transects define a closed box, for which different budget calculations will be performed. The limitations of the HFR to provide vertical mean transports will be quantified depending on stratification conditions.
Furthermore, the potential of combining HFR data with tide gauge measurements for the estimation of transports will be assessed. There is a larger number of tide gauges available in the German Bight including one gauge in the central part at the island of Helgoland. The idea is that water level changes as measured by tide gauges are a direct consequence of the divergence or convergence of the vertical mean currents and therefore contain valuable information on the volume transports. In a first step an empirical approach is used to combine HFR data and tide gauge observations using numerical model data for fitting.

Finally, the potential of the combined use of HFR data and tide gauge measurements in an assimilation procedure is analysed. A pre-operational assimilation system for HFR data is already running at HZG in the framework of the COSYNA system. The added value of water level measurements for this system will be assessed with a particular focus on the estimation of 4D transports. This includes the definition of suitable metrics for both Lagrangian trajectories and volume transports through transects.

Figure 6.4: Illustrative map of the GB study area and the JERICO_NEXT research infrastructures.

6.2.2 Main tasks and work plan

The development of the work in JRAP-4 will be done following the tasks and subtasks detailed the following table.

Table 6.1: JRAP-4 Phases and main tasks

PHASES / TASKS	Start/End	Description
P 4.1 PREPARATION T4.1.1 State of the art concerning hydrodynamics and methods T4.1.2 Analysis of nature runs T4.1.3 Discussion of best sampling strategies T4.1.4 Report JRAP-4 Science Strategy to D4.1	Sep 2015/ May 2016	i. Review using literature/past work at each study area to identify the key points to be considered for 4D estimates ii. Review on methodologies for 4D transport estimations and forecasts (link with TASK 3.2.3 led by CNR-ISMAR) iii. Analysis of the capacity of existing infrastructures to resolve the key processes, reference for demonstrating value-added provided by JERICO_NEXT developments iv. Case by case definition on the planned sampling strategy and the strategy for OSSES to future definition /evaluation of the sampling strategy in order to reach accurate 4D estimates (and the ability to validate them) v. Joint identification of metrics/strategy to assess accuracy of 4D estimations and forecasts and of Lagrangian diagnostics (in relation with MSFD)

P 4.2 ON-SITE IMPLEMENTATION T4.2.1 MASTODON T4.2.2 HFR T4.2.3 Analyses of OSSES T4.2.4 Auxiliary instruments T4.2.5 Data processing & analysis	Jun 2016/ Dec 2017	i. JERICO-NEXT infrastructures deployment: MASTODON moorings, HFR ii. Deployment of auxiliary instruments: Drifters (& gliders) iii. Update of JERICO-NEXT infrastructures: HFR / others. iv. Recovery of JERICO-NEXT and other infrastructures v. Collection of (new and historical) data for multidisciplinary approaches vi. Data collection from deployments; Harmonization of all the outputs. Data analysis for each area and multidisciplinary approaches.
P4.3 DATA ANALISYS T4.3.1 Data processing T4.3.2 Data analysis T4.3.3 Synthesis and diffusion	Jan 2018/ Aug 2018	i. Data analysis for each area and multidisciplinary approaches. ii. Share of the results of each subarea. iii. Integrated synthesis of the results: Output for WP1; Publication and/or presentation in scientific forums of the main results of circulation and transport in trans boundary areas and implications (MFSD and other EU marine policies)
JRAPs END		

Table 6.2: Sites for JRAP-4, the timing of studies, contact institutes and persons, the platforms used and parameters measured.

Site	Timing of data collection	Data reference contact	Platform - Instrument used	Parameters collected
German Bight	all the period	HZG johannes.schulz-stellenfleth@hzg.de	3 HF radar stations already operating	Surface ocean currents (frequency > 1 h)
			Tide gauges	Sea height level (frequency > 1 h)
			ADCP	Ocean current in the water column (frequency > 1 h)
NW Med	beginning of 2016	CNR annalisa.griffa@sp.ismar.cnr.it or carlo.mantovani@cnr.it	2 new HF radar stations	Surface ocean currents (frequency ~ 1 h)
	beginning of 2017		1 new HF radar station	Surface ocean currents (frequency ~ 1 h)
	all the period	IFREMER quentin@univ-tln.fr	4 HF radar stations already operating	Surface ocean currents (frequency ~ 1 h)
	beginning of 2017		1 new HF radar station in Nice area	Surface ocean currents (frequency ~ 1 h)
	end of 2017	IFREMER Ivane.Pairaud@ifremer.fr	MASTODON moorings	Temperature in the water column (frequency > 1 h)
SE BoB	all the period	AZTI arubio@azti.es	2 HF radar stations already operating	Surface ocean currents (frequency ~ 1 h)
	beginning of 2017	IFREMER: guillaume.charria@ifremer.fr	1 New HF radar station	Surface ocean currents (frequency ~ 1 h)

		AZTI: jmader@azti.es		
	all the period	AZTI jmader@azti.es	1 slope buoy already operating	Surface -200 m ocean currents, temperature and salinity (frequency ~ 1 h)
	summer 2017	IFREMER pascal.lazure@ifremer.fr	MASTODON moorings	Temperature in the water column (frequency ~ 1 h)
	summer 2017	AZTI jmader@azti.es	Drifters	Surface ocean drift (hourly positions)

6.2.3 *Specific cross-cuttings with other JRAPs and WPs*

JRAP-4 main efforts will be put in quantifying transport by ocean currents and its potential impact on the distribution of floating matter (plankton - jellyfish or other pelagic organisms, marine litter, pollutants, etc.). In addition to the transport estimations, specific actions within the different study areas will be devoted on producing information and maps on integrated transport that can be used as a basis for several applications, including those of interest of other JRAPs. Only the most specific cross-cuttings that have been identified after several discussions with JERICO_NEXT colleagues with other JRAPs and WPs are detailed here:

NW MED

JRAP-6 and WP3.7: Involvement in assimilation of HFRs (CMCC, SOCIB)- In the Mediterranean Sea, a 4-dimensional variational data assimilation system has been recently applied to HFR data in the Gulf of Naples (Iermano et al., 2015). In the framework of WP3.7, an ensemble Kalman Filtering method (EnKF) will be tested and applied by CMCC, and a strict synergy with the JRAP-4 activities is planned. So far, the EnKF DA has capability to assimilate in situ salinity and temperature observations, while assimilation of HFR radial velocity observations is currently under development. The EnKF DA is performed sequentially by cycling over even time intervals (i.e., the analysis time windows). Within each window an ensemble of model forecasts (simulations) is generated starting from the ensemble analysis of the previous analysis cycle. This ensemble is then used for the background error mean and covariance statistics together with all of the observations that fall within the same time window to generate the new ensemble analysis. The EnKF with a regional application of NEMO at high resolution will be used to perform OSSEs in the NW Med area.

SE BOB

JRAP-3: A join study on the impacts of coastal ocean physical processes on the offshore occurrence of different chemical contaminants in coastal waters is planned as a main crosscutting between JRAP#3 and #4. The controlled pollutant will be: PAHs (polycyclic aromatic Hydrocarbons, several compounds); Organochlorine pesticides (DDT, HCB, HCHs), PCBs, PBDEs (polybrominated difenil ethers) and novel brominated flame retardants (several compounds). The work will be structured following 2 approaches: (i) Experimental approach in collaboration with JRAP#3 team: In-situ measurements of chemical contaminants will be conducted during different stratification periods using passive samplers installed on existing permanent or new moorings. Two existing points along the Basque coast are identified as potential locations for the deployment of passive samplers. The mussel longline cultures system of Menxdexa (located near Bilbao, over 50m grounds) and the Donostia oceanic mooring (located off Donostia city, over 450 m grounds). During 2016 two passive samplers will be installed at these points at of 5 m and for a deployment time of six months. These will be used to characterize the concentration of the chemical compounds in the area independently of the ocean dynamical conditions. Then, other strategies to make a multidisciplinary approach to study the effect of the coastal transport (and eventual coastal sources) on the spatial distribution of the pollutants will be evaluated. Among the possibilities, one is the installations of two passive tracers in an offshore location at two depths over and under the mean seasonal thermocline depth (see Rubio et al. 2013a) in order to measure concentration though the water column in two periods of one month, under different vertical mixing conditions (e.g. summer 2017 and winter 2017). The data will be used to study the effects of vertical diffusion on the distribution of the dissolved contaminants in the water column. The vertical diffusion is depending on high frequency ocean processes that can be measured by the HFR and on the stratification conditions that will be continuously monitored by the CTs chain installed at Donostia mooring. Seasonal differences are expected in the distribution of contaminants in this area where a marked seasonal variability is observed concerning the main shelf/lope current regime and the intensity and spatial distribution of high frequency processes (i.e. inertial variability, see for instance Solabarrieta et al 2014). The feasibility of this approach is under evaluation since it implies significant extra coast and technical efforts. Another possibility is to the mastodon mooring network in summer 2017 to deploy different passive tracers in the Landes shelf area during one month and explore the spatial distribution of the pollutants and the potential links with the ocean surface circulation observed in the integration period. (ii) Numerical approach in collaboration with JRAP#6 team: HFR currents and vertical information from the buoy and moorings will be used to characterize the different hydrodynamic scenarios and their effect on potential offshore concentrations. A Lagrangian tool will be used to study the horizontal dispersion or transports measured by the HFR in the sampling period. The numerical simulations performed in the area in the framework of JRAP#6 will be also used as input of the Lagrangian model. The inter-comparison of the results obtained using numerical simulations and HFR data will be an interesting exercise for model assessment in this framework of chemical pollutants monitoring (see more details on this in the next point) but can also provide further information on the 4D dynamics of the study area, key to understand the occurrence/distribution of the monitored pollutants.

JRAP#6 and task WP3.7: Two crosscutting activities with JRAP-4 are foreseen. On the one hand, in the frame of the WP3.7 dedicated to OSE/OSSEs, the ArM (Array Modes) method (Le Hénaff et al., 2009; Lamouroux et al., 2016) is being extended to HFR observations in the SE BoB. This method will allow to estimate the most efficient location of measurements to constrain the ensemble model variance and will be will be used in the deployment of the new system along the French coast taking into account existing HFR system along the Spanish coast. On the other hand, AZTI (L. Ferrer) will be working in the JRPA#6 in the development of high resolution (670 m) Operational Simulations for the SE BOB using ROMS and realistic forcing without DA. The specific cross-cuttings with JRAP-4 will involve joint analysis of data and simulations for model assessment, model outputs to complete data description of currents and transport. SE Bob study is strongly influenced by wind-induced circulation, river inflows, a seasonal slope circulation and mesoscale variability. These processes will be the main focus for the inter-comparison between model outputs, HFR data, surface drifters and other data form new deployments in JRAP-4. High frequency processes (inertial oscillations and tidal variability) will be explored as well.

German Bight

JRAP-3: The drift of contaminants (e.g., oil) potentially released from ships in the German Bight will be investigated based on numerical models and HFR data. Because of the well-defined ship routes the most likely release locations are known. The potential of measurements from fixed platforms (e.g., at FINO-1 or FINO-3) and moving systems (e.g., Ferrybox) to identify this kind of pollution will be assessed. For this purpose, simulated observations from hypothetical pollution events will be investigated. Different scenarios regarding wind conditions and tidal phase at the time of the release will be considered. Pollutant dispersion (e.g., depending on wave conditions) will be considered in addition.

6.3 Implementation Risks and mitigation measures

Risks:

- Delay in OSSES since several new deployments will depend on them
- Delay in the deployment of instruments and availability of new data (mostly at the SE BOB where they are starting later)
- Lack of data from new or existing systems
- Needed close cooperation with other WPs. Inputs of WP3 (3.2 –HFR, 3.3 MASTODON, 3.7 OSSES) are key for scientific and technical advances in JRAP-4
- Diversity of processes in study areas
- Delay in the deployment of HFRs in the NW MED. Installation sites have been identified in summer 2015 and permits have been requested, but they are still under process by the Navy and by the Public Authorities of 5 Terre.

- For the NW MED applications to MSFD issues require data on contaminants and ecological quantities that will be acquired in other projects, presently pending. Further hydrographic data in the area depend on another project presently pending
- Difficulty to maintain all the equipment of HFRs for 2017-2018. high stress of having to move the instruments in the coming months because of work planned on sites
- In NW Med, although our radars follow the ITU's recommendations and operate over the frequency bands specified for oceanographic purposes, strong Radio Frequency Interference (RFI) is often present, due to official and non-official radio services. The result is a radical reduction in coverage and the presence of outliers in the velocity maps.
- Intensive CTD stations during biological campaigns will be subjected to the time limitations of these campaigns.
- ML databases recovery and processing will depend on the final approval of LEMA LIFE proposal.
- Possible cross-cuttings in the SE BOB reported between JRAP-4 and JRAP#1 will depend on external funding, first, for performing the monitoring of plankton and harmful algae, secondly, for analysing jointly the information, and finally for reporting the results.

Mitigation measures

- Close monitoring of the progress of the JRAP will be done with respect to the specified plan of deployments dates, deadlines and milestones in order to detect quickly any delay; Analysis of the origin of the delay will be done and specific mitigation measures will be proposed
- In the case of lack of data from a specific HFR system methodological developments will be done when possible using other existing data, i.e. historical data or data from other HFR system. For the most theoretical approaches the use of model data can be also foreseen.

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7 JRAP-5: Coastal carbon fluxes and biogeochemical cycling

7.1 Rationale and expected outcomes

7.1.1 Main questions - Objectives

Marine carbon cycle has a key role on global climate change. In open oceans, carbon uptake is dominated by physical dynamics and chemical processes (solubility pump), while in productive coastal areas with high spatial and temporal variability biological processes may dominate (biology pump). While solubility pump aims in balancing atmospheric and marine pCO_2, the biological pump depends on the rates of primary production and respiration. In both cases the physical state of the sea (mixing, temperature etc.) and carbonate system components need to be evaluated to get comprehensive description of air-sea carbon fluxes (e.g. Millero 2007, Bakker et al 2014).

In JRAP-5, we aim at understanding and quantifying the influence of biological activity on carbon release or uptake, relative to physical and chemical processes affecting sea-air carbon fluxes.

JRAP-5 will cover both temporal and spatial variability, for time ranges of few minutes up to one year and spatial resolution, from few hundred meters up to more than a thousand kilometre. Geographically the conditions vary from Arctic Ocean conditions on Svalbard to warm and saline waters of Aegean Sea in Greece.

In particular, the scientific focus is in the variability of carbon cycle relevant biological processes in different environments. We will couple physical (temperature, salinity, mixing etc.), chemical (carbonate system) and biological (biomass, production) measurements to get better description which are the major driving forces of air-sea carbon fluxes in different European coastal sea areas. At all study sites we use both fixed and moving observatories, and high-frequency measurements to get information on the relevant scales such observations need to be carried out. Our measurements cover one annual cycle at each location to retrieve also the seasonality of processes. As our study covers wide range of locations, we are also able to observe how some specific conditions (like salinity and temperature gradients, ice covers, specific phytoplankton blooms) affect fluxes.

This JRAP will guide development of optimal observation network for C-flux studies, provide concepts and methods towards harmonized measurements and will ultimately give recommendations of setting up a combined physical, chemical and biological measurement network for carbon cycle studies as needed for understanding the role of coastal systems in global C cycles. The interaction between the partners is increased by partners sharing and creating networked observatories with comparable methodology. The aim is also to help partners to develop mature sensor and observing technologies sustainable in long-term use. These observations include pCO_2, alkalinity and pH, but also support development of relevant biological methods.

Our work has direct links to work done within ICOS Ocean Thematic Centre (ICOS-OTC). In general, the main focus of ICOS-OTC is on open ocean areas and physical and chemical processes. While the importance of marine biology is shortly discussed and some of the Jerico-next VOS/fixed platforms are part of ICOS-OTC, the biological carbon cycle not a major research topic in ICOS-OTC. Thus, our work in Jerico-next will largely contribute to this understudied topic and provides a preliminary harmonization of this component especially important on coastal and marginal seas. **Based on our harmonization work within this JRAP we are able to create a solid observation component which is easier to integrate in ICOS at some later stage. As biological carbon cycle is a key process in productive seas, results of our JRAP may support activities towards marine ESFRI with strong biological component and potentially closely linking with ICOS-OTC**.

7.1.2 Description of the state of the art related to the science topic

Oceans are able to absorb large parts of anthropogenic releases of CO2. The accurate estimates of the increase of CO_2 in the oceans, rates and trends thereof, as well as regional distributions of those are however under debate. The effect of CO_2 increase in marine waters on pH is well described, and the effects of this ocean acidification on marine biota and biological processes is currently largely studied.

In general, carbon observations on open oceans are well coordinated and also partially harmonized. In EU some of the ecosystem, atmospheric and marine measurements are integrated in ICOS-ESFRI (Integrated Carbon Observing System). However, coastal carbon observations and especially the biological carbon system is not yet clearly integrated or harmonized and knowledge on different feedback processes remain only partially understood (Hjalmarsson et al, 2008, 2010; Schneider et al., 2006; Cantoni et al., 2012). **Equally, the methodology for coastal and marginal seas with high variability in biology and carbonate chemistry is still not mature enough for harmonization. One of the remaining main challenges is the limited knowledge of effects of biologic material (phytoplankton and DOM) and high temperature and salinity variability on accuracy of observations.** This is connected to limited knowledge of scales of variability related to biological activity and required procedures to meet such environmental conditions (e.g. Laruelle et al., 2010).

While the laboratory-based measurements of ocean carbonate system (pCO_2, alkalinity, pH, DIC) and phytoplankton biomass, taxonomy and productivity are matured, the online automated instruments are still at the stage of development (Gonzalez-Davila et al. 2016, Reggiani et al. 2016). Many online instruments have become recently commercially available but a lot of development is still required. For example, reliable pH sensors for low saline waters are still somewhat lacking. Consistent and reliable methods for calibration and maintenance for online instruments measuring different components of carbonate system are still largely under development. Instrument and method comparison, along with defining calibration methods, are key items for future developments.

Measuring biological activity, primary production or respiration rates, may be approached using pCO_2 and O_2 measurements, but such gas balance calculations do not entirely solve the magnitude of biological C fluxes. There have been attempts to measure phytoplankton primary productivity using active fluorometric methods. So far the global solution has not been found to convert fluorometrically derived photosynthetic electron transport rates into carbon fixation rates and more studies are required which phenomena controls the conversion factors (Lawrenz et al. 2013.).

7.1.3 The role of the JERICO research infrastructure

As the online methods for carbonate system and biological productivity mature, there is need to design future measuring campaigns and platforms where these are combined, and merged with available networks of physical oceanographic measurements and atmospheric measurements. JRAP-5 takes first steps in this direction, exemplifying that reliable estimate of C fluxes, and understanding the phenomena behind the fluxes, requires large integration of different techniques.

JRAP-5 use Jerico infrastructure of ferryboxes and fixed platforms. The infrastructures have been selected to cover the high variability of carbon cycle through the European seas from Arctic Ocean to Mediterranean Sea and from low salinities of the Baltic Sea to saline conditions of Aegean Sea. In each area we have selected infrastructures that can provide complementary information, either in spatial scales or combining spatial scale observations (e.g. ferryboxes) with seasonal scale observations (e.g. fixed platforms). Through the partners JRAP is also able to address the diversity of methods and platforms used for observations of pCO_2, alkalinity and pH.

The experiment helps in harmonizing the methodology and integration of coastal observations in ICOS-ESFRI, when the methodology is mature enough to comply with observations carried out in less challenging conditions.

7.1.4 Expected progress beyond the state of the art

Often, in the coastal seas the physical, chemical and biological observations have been done in slightly isolated manner, without joint objectives. When studying carbon air-sea fluxes, such coordination is elemental. JRAP-5 will perform a full set of coordinated measurements aiming to provide sound description of major driving forces of air-sea carbon fluxes in different European coastal seas. Such novel information not only give an idea of the magnitude and rates of C-fluxes but also provides background information for future build-up of coastal C-flux observation network. Such a network is needed to understand the role of coastal areas in climate change, and on the other hand, to record how climate change affect coastal ecosystems.

Currently, most of the partners participating in JRAP-5 have built their observations systems individually without much coordination. Within this activity, the different approaches are tested and best practices created. After the 12-months intensive period, scales of variability known lead to improved planning of observations and observing networks. From purely scientific perspective, biological carbon cycle and environmental variables influencing it will be relatively well characterized and differences between the different marine ecosystems better understood.

In JRAP-5 we also take the advantages offered by development work done in WP3 and integrate well adapted sensors, observing systems, control and processing procedures to have validated *in-situ* data and information and develop coherent spatial and temporal sampling strategies of core variables in marine carbon cycle.

7.2 Research Methodology and approach

7.2.1 Main tasks and work plan

The main tasks of the JRAP are intensive measuring campaign (project months 18-30) and subsequent joint data analyses and creating recommendations for future C-flux studies.

Task 1 Inventory of methodologies and instrumentation (M6-M9)
To start, within JRAP-5, we will collect detailed information of existing instruments and methodology during the first 12 months (Table 7.1). First, we will collect information for each main type of instrument (pCO_2, pH, alkalinity, chlorophyll, O2), their status and maintenance and the typical ranges of analysts. This information provides first-hand information on the diversity of sites and methodologies involved. After this primary information has been pooled (spring 2016) we still have ample time to react if immediate issues in comparability of methodologies arise (Tamburri et al., 2011). This data in investigated in the context of ICOS-OTC measurement protocols, which are currently (March 2016) under development.

Table 7.1: Detailed information collected for study sites and instruments (below some examples of questions to describe the instrumentation and methodology). The questionnaire was sent to all JRAP-5 partners March 2016.

General	Typical temperature range at the site (Celsius)
	Typical salinity range at the site (psu)
	Algae blooms frequently present
	Ice cover
pCO_2/alkalinity/pH/Chlorophyll/O_2-instrument	Instrument producer and name
	Instrument status
	Instrument methodology
	Typical variability of pCO_2 at the site (ppm)
	Calibration procedures applied
	Maintenance frequency and methodology
	Problems & challenges encountered
Other analysis during campaigns	

Task 2 Inter-comparison of methodologies (M14 -M17)
In the Jerico-next community, partners have a wide range of instruments measuring pCO_2, alkalinity and pH. The methods and responses, as well as operating ranges of different instruments are significantly different. Within Jerico-next e.g. pCO2 is measured with at least 6 different methods and instruments, the same diversity of instruments applies also to alkalinity and pH measurements. This diversity may lead to observation results which are not comparable between the sites (Atamanchuk et al., 2015).

Based on the collected knowledge (Task 1), we have elaborated a preliminary plan for a scientific inter-comparisons exercise in Oslo in late 2016 or early 2017 where instruments by partners will go through a well-planned set of experiments covering main environmental conditions throughout European seas. The extent and practical realization of the inter-comparison depends if partners can receive funding to perform scientific work e.g. using JERICO-NEXT TNA funding. The actual content of the inter-comparison also depends on the participants, e.g. there might be some companies willing to participate and thereby including the well needed industry-academia exchange of knowledge. This will be coordinated with WP8.

This planned activity is also scientifically interesting as presently most of instruments are tested and calibrated in controlled laboratory conditions, but not necessarily tested so far for example in different conditions with DOM and phytoplankton, as typical for field observations and especially for coastal areas that are the focus of Jerico-next.

Due to new installations and variable instrument setups within JERICO-NEXT, an earlier comparison of new instrumentation has not yet been possible. Additionally, because some instruments require a relatively high flow of water (L/min) to operate, the typical inter-comparison study in which preserved seawater samples with assigned values (e.g., 500 mL bottles) are sent to different labs for analysis is not possible.

Depending on the extent of the inter-comparison, it will result in a scientific publication or a report.

Task 3 Measurement campaigns (M18-30) and data analysis (M18-36)
The intensive period of observations will take place from M18 to M30, especially in co-operation with JRAP-1. Intensive measurements are done from spring 2017 to spring 2018 at all sites (**Erreur ! Référence non valide pour un signet.**). At each marginal sea several platforms are used. In following, each study area is described with area specific objectives and specific links to JRAP-1 are presented.

Baltic Sea
Baltic Sea is characterized by low salinity (0-10), highly variable temperature of the surface water (0-20°C), and high load of nutrients and dissolved organic matter. Phytoplankton abundance has a large seasonality from very low concentrations in winter to high seasonal spring and summer blooms (up to 20µg Chla L^{-1}). The magnitude and spatial structure of the blooms vary from year to year due to physical and chemical forcing factors. Occasionally there are periods or areas which are net-heterotrophic due to high load of organic matter or due to decomposition of algal blooms. Due to such biological activity gradients, Baltic Sea shows very large fluctuations in pCO_2 (100-1100 ppm) and pH,(6.4-9.4). To track variability in C-fluxes, we provide high resolution measurements using fixed platform (Utö) and ferryboxes (Helsinki-Stockholm, Kemi/Oulu-Lübeck). One of the ferrybox lines (Helsinki-Stockholm) crosses daily the water masses recorded in fixed station (Utö), and the two ferries have at least weekly crossing of their routes. The ship routes cover the major Baltic Sea salinity, temperature, productivity and dissolved organic matter gradients. Besides continuous measurements of carbonate system, physical state of the sea and abundance of phytoplankton (Chlorophyll a), cyanobacteria (phycocyanin) and dissolved organic matter, we also perform dedicated measuring campaigns, lasting 1-3 weeks each, to measure phytoplankton primary production parameters (FRRF fluorometry, O_2,, and ^{14}C) and taxonomy (optical groups, microscopy) during different phytoplankton successional stages. This information allow us to get better description on the interplay of biology, carbonate chemistry and physics in determining C fluxes in the Baltic Sea. These intensive measuring campaigns are conducted at the same time as the JRAP-1 studies in Utö.

Mediterranean Sea, Adriatic Sea
The Northern Adriatic Sea is a continental shelf region (depth <100 m) located in the northernmost part of the Mediterranean basin and is characterized by high river loads along the western coast and a pronounced seasonal cycle with strong variations in seawater temperature (8-27°C), salinity (25-38) and water column stratification. The Gulf of Trieste is a shallow bay (<25 m) lying in the northernmost part of the Adriatic Sea and presents, on a smaller scale, oceanographic properties that are similar to those of the whole continental shelf of the Northern Adriatic.
The year is characterized by several phytoplankton blooms, which are variable in magnitude and length, triggered by the combination of meteorological conditions and river loads. During winter, under the combined effect of favourable meteorological conditions and strong cold North-Eastern winds, dense water formation can occur. In this highly variable coastal region, surface pCO_2 values show fluctuations typically between 250 and 450 µatm,

but most of the data have been acquired as discrete samples under favourable weather conditions, when air-sea CO_2 fluxes were lower.
The PALOMA fixed station is located in the central area of the Gulf of Trieste and well represents the conditions of the off-shore Northern Adriatic Sea. The automatic measurement at this station of sub-surface pCO_2 values, dissolved oxygen concentration and the main physical properties, will be integrated by monthly measuring campaigns where other biogeochemical data will be acquired. This information will allow us to better understand the interplay of physical and biological forcing in determining the variability of air-sea CO_2 fluxes in the area even under strong wind conditions, when higher fluxes are expected.

Mediterranean Sea, Aegean Sea. The Cretan Sea is the largest and deepest basin (2500 m) in the south Aegean Sea (Temperature: 15.8 - 27.7 C, Salinity: 38.85 to 39.45, Alkalinity (AT) : 2267 to 2299 μmol kg-1 ,Total dissolved inorganic carbon (CT) : 2624 to 2663 μmol kg-1,Dissolved Oxygen : 4.8 to 5.5 ml/l, Chl a : <0.01 to 0.55 mg m-3) . It is linked with the Levantine basin and the Ionian Sea through the eastern and western straits of the Cretan Arc respectively; via sills that are no deeper than 700 m. The hydrological structure is dominated by multiple scale circulation patterns and is an area of deep-water formation. It acts as a reservoir for heat and salt for the Eastern Mediterranean, and is characterised by intense mesoscale activity which is not necessarily seasonally driven. The circulation is dictated by the combined effect of two gyre features, an anticyclonic eddy in the west and a cyclonic eddy in the east. The surface waters are dominated by Modified Atlantic Waters (MAW). During spring, summer and autumn the Cretan Sea is stratified and exhibits an oligotrophic ecosystem characterized by a food chain composed of very small phytoplankton cells and a microbial loop, both of which have a negative effect on energy transfer to the deeper water layers and the benthos. The area is characterized as one of the most oligotrophic areas in European waters and one of the key places to study climate and biodiversity changes, while the open area characteristics of the coastal zone create an integral system, which cannot be studied separately. It thus requires the combined effort in three major dimensions coupled in a coherent way:

- automated high frequency measurements both offshore and coastal (POSEIDON E1-M3A Buoy, POSEIDON Heraklion Coastal Buoy, POSEIDON Ferrybox)
- in situ samplings on appropriate time scales (Monthly in situ samplings at the POSEIDON – E1-M3A and at the POSEIDON – HCB, Two NaGISA sites (Heraklion bay and Elouda) with samplings on soft-bottom seagrass beds, EMBOS site with samplings on the benthic communities)
- simulations models.

It is important to note that all those parameters identified, as being important for the analysis, study and prediction of any particular ecosystem, must be included in the research effort.

Norwegian Shelf has a broad latitudinal range, extending from the North Sea along the Norwegian coastal line, north to the Barents Sea. It exhibits great heterogeneity in its physical, biogeochemical and biological characteristics. The region is interconnected through the Norwegian Coastal Current of which, the underlying influence to the carbon biogeochemistry is from Norwegian Atlantic Current. However, significant traits can be traced to the Baltic in the South, land-source contributions through the fjords and from the Kara Sea to the northwest. pCO_2 varies greatly both seasonally and spatially with maximums seen in the winter (>400 ppm), especially near the fjord outlets, and minima (down to under 150 ppm) on the Barents Shelf and near Svalbard during the spring bloom. To determine air-sea fluxes of CO_2 along the Norwegian Shelf, we measure directly underway pCO_2 and also characterize the underlying driving mechanisms on carbonate chemistry through contemporaneous spectrophotometric measurements of pH_T (~7.8-8.3), chlorophyll *a* fluorescence (up to ~10 μg chl a L^{-1}), temperature (~2-15 °C), salinity (~12-35), and oxygen. We also take discrete samples for the analysis of chlorophyll *a*, nutrients, phytoplankton pigments, CDOM, dissolved inorganic carbon, and total alkalinity NIVA monitors continuously from MS Color Fantasy, (Daily) – Kiel – Oslo; MS Trollfjord, (Biweekly) – Bergen-Kirkenes, and MS Norbjørn, (Biweekly) – Tromsø – Longyearbyen

North Sea
The North Sea is a shelf sea on the margin of the North Atlantic, covering the area between the English Channel in the southwest, the Skagerrak in the east and the Shetland Islands in the Northwest. Its average depth is about

90 m, with the deepest area being the Norwegian Trench (approx. 700 m). The North Sea includes furthermore the Wadden Sea, an intertidal mudflat area which is located between the Frisian Islands and the Dutch, German, and Danish coast (reaching from Den Helder to Skallingen). Due to its geographical position, the North Sea exhibits a variety of environmental conditions, which result from the interaction of oceanic and coastal influences. Especially in the southern and eastern parts, the coasts are influenced by riverine input and outflow from the Wadden Sea, leading to large variations in salinity (10-35), and also turbidity. Also temperature shows large seasonal and annual variations (0-22 °C), as well as pH (8-8.5) and pCO_2 (50-400 µatm). Phytoplankton blooms dominated by diatoms occurring regularly in spring, while the summer biomass is frequently dominated by (dino)flagellates, especially in the more stratified offshore regions.
Continuous observations of carbonate-related as well as other environmental parameters (temperature, salinity, pH, chlorophyll-fluorescence, turbidity, dissolved oxygen, pCO_2, and CDOM) are performed using a stationary FerryBox installed in a container near the mouth of the Elbe River (Station Cuxhaven), two Ferryboxes running on cargo ships (Cuxhaven-Immingham, Immingham-Halden/Moss-Zeebrugge), and one running on a ferry (winter time: Cuxhaven-Helgoland, summer time: Büsum-Helgoland). Transects were monitored in a frequency of one week or less. On both cargo vessels as well as on the station, automated sampling units provide the opportunity to take discrete water samples for laboratory analyses (e.g. microscopy, phytoplankton pigments, total alkalinity). However, as the Ferryboxes are part of the observation network COSYNA which has been set up in the North Sea area, also data from other platforms (e.g. buoys, poles, satellite imagery) are available in addition. Thus, the obtained high resolution data covers a large area and enable an analysis of carbon flux with respect to heterogeneous environmental conditions, contributing to a better understanding of the governing processes.

Bay of Biscay, Western Channel

The Western English Channel (WEC) is part of one of the world's most expanded margin, the North-West European continental shelf. This area is characterized by relatively shallow depth and by intense tidal streams with maximum speeds ranging from 0.5 to 2.0 m.s-1 (maxima for the entire English Channel - EC). The WEC hosts three different hydrographical provinces: all year well-mixed, seasonally stratified and thermal fronts structures, which can all exert different control on the pCO2 dynamics.
Along the French coasts (southern WEC), where the tidal currents are the strongest, the water column remains vertically mixed whereas near the English coasts (northern WEC), where tidal streams are less intense, seasonal stratification occurs. Between these two distinct provinces, a frontal zone oscillates around 49.5°N, separating well-mixed and stratified waters. Such water column characteristics are also observed in adjacent seas of the North-West European continental shelf, i.e. in the Irish/Celtic Seas and Bay of Biscay. We will rely on 2 Ferrybox crossing the EC and the aforementioned shelf seas to assess the variability of air-sea CO2 fluxes and of the carbonate systems in these areas. We will combine those Ferrybox measurements with high-frequency data at the ASTAN Buoy located 5 miles of Roscoff to quantify the short-term variability of the carbonate system in this well mixed area of the WEC.

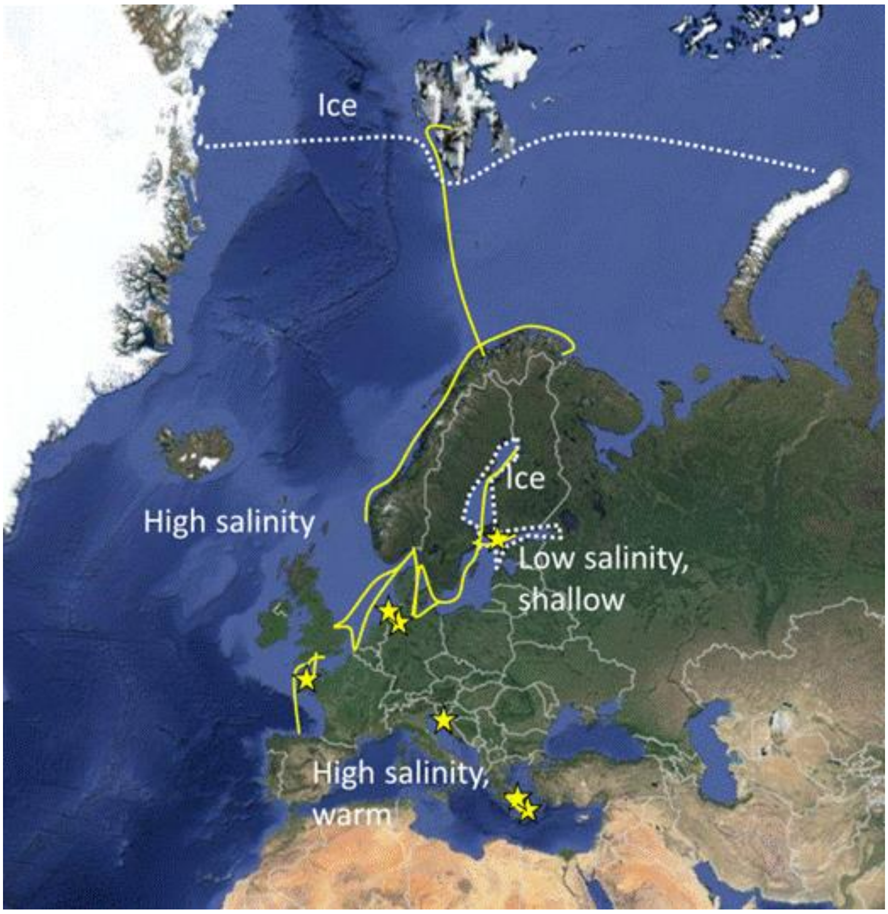

Figure 7.1: JRAP-5 measurement sites. Also some important aspects of variability are shown on the map.

Table 7.2: Sites for JRAP-5, the timing of studies, contact institutes and persons, the platforms used and parameters measured.

Site	Timing of data collection	Data reference contact	Platform - Instrument used	Parameters collected
Baltic Sea	Spring 2017 - spring 2018. Different instruments with varying time intervals (from 1/2 hour to 10 days)	FMI - Lauri Laakso (lauri.laakso@fmi.fi) / SYKE - Jukka Seppälä (jukka.seppala@ympar isto.fi)	Utö Atmospheric and Marine Research Station	pCO_2, pH, Temperature, salinity, O_2, Chlorophyll, phycocyanin & CDOM fluorescence from a flow-through system (sampling depth -5 m). Meteorological parameters (T, WS, WD, solar radiation etc.). Surface waves.
Baltic Sea	spring 2017 - spring 2018. Different instruments with varying time intervals (from 1/2 hour to 10 days)	SYKE - Jukka Seppälä (jukka.seppala@ympar isto.fi)	Ferrybox Helsinki-Mariehamn-Stockholm	pCO_2, Temperature, salinity, Chlorophyll, phycocyanin and CDOM fluorescence from a flow-through system (sampling depth -5 m)
Baltic Sea	Spring 2017 - Spring 2018. Approximately every 10 minutes.	SMHI - Anna Willstrand-Wranne (anna.wranne@smhi.s e)	Ferrybox Kemi-Lübeck	pCO_2, Temperature, salinity, O_2, Chlorophyll fluorescence, phycocyanin fluorescence, CDOM fluorescence, turbidity (sampling depth 3 m). Meteorological parameters (air temperature, air pressure, solar radiation-PAR). In addition water samples are collected for analysis of several parameters.

Mediterranean Sea	Spring 2017 - Spring 2018. Different instruments with varying time intervals (from 15 min hour to 6 hours)	CNR - ISMAR - Carolina Cantoni - carolina.cantoni@ts.ismar.cnr.it	PALOMA - Advanced Oceanographic Laboratory PlatforM for the Adriatic sea (Elastic Beacon)	pCO_2, Temperature, Salinity, O_2 (avg. sampling depth -3 m); Temperature (-15 m, -25m). Athmospheric XCO_2, temperature; (wind speed and other meteorological parameters avialable trought OSMER.FVG)
Mediterranean Sea	Spring 2017 - Spring 2018. Measurements every 3 hours	HCMR - A. Kalampokis - alkiviadis.kalampokis@hcmr.gr	POSEIDON HCB (Buoy)	Temperature, Salinity, Air Pressure, Temperature, Wind speed, wind direction, surface currents, wave height
Mediterranean Sea	Spring 2017 - Spring2018. Measurements every 3 hours	HCMR - A. Kalampokis - alkiviadis.kalampokis@hcmr.gr	POSEIDON E1-M3A (Buoy)	pH, Temperature, Salinity, O_2, Chlorophyll (Fluorescence), Air pressure+temperature, Wind speed+direction, surface currents, wave height, turbidity
Mediterranean Sea	Spring 2017 - Spring 2018. Every 1 min (during 6 hours every day)	HCMR - A. Kalampokis - alkiviadis.kalampokis@hcmr.gr	Ferrybox PFB Heraklion-Athens	pH or pCO_2, Temperature, Salinity, Chlorophyll (Fluorescence), O_2
Norwegian Shelf, Barents Sea	Spring 2017-Spring 2018 (12 days of data collection Bergen-Kirkenes-Bergen, continuous, data sent daily)	NIVA (kai.sorensen@niva.no & andrew.king@niva.no)	Ferrybox Bergen-Kirkenes	pCO_2, pH, temperature, salinity, O_2, Chlorophyll fluorescence, turbidity from a flow-through system (sampling depth about 3 m). Meteorological parameters (WS, WD, solar radiation etc.).

Norwegian Shelf, Barents Sea	Spring 2017-Spring 2018 (~5 days of data collection Tromsø-Svalbard-Tromsø followed by 5-7 days at port in Tromsø, data sent every second day)	NIVA (kai.sorensen@niva.no & andrew.king@niva.no)	Tromsø-Svalbard	pCO_2, pH, temperature, salinity, O_2, Chlorophyll fluorescence, turbidity from a flow-through system (sampling depth about 3 m). Meteorological and light parameters (WS, WD, solar radiation etc.).
North Sea	Spring 2017-Spring 2018 (2 days of data collection Oslo-Kiel-Oslo, continuous, data sent daily)	NIVA (kai.sorensen@niva.no & andrew.king@niva.no)	Ferrybox Oslo - Kiel	pCO_2, pH, temperature, salinity, O_2, Chlorophyll fluorescence, turbidity from a flow-through system (sampling depth about 3 m). Meteorological and light parameters (Solar radiation etc.).
North Sea	Year around 2017-2018	HZG - Wilhelm Petersen (wilhelm.petersen@hzg.de)	Stationary FB Cuxhaven	Temperature, Salinity, Chlorophyll-a_Fluorescence, O_2, pH, CDOM (Fluorescence), turbidity
North Sea	Year around 2017-2018	AWI/HZG (philipp.fischer@awi.de)	Underwater node Helgoland	Temperature, Salinity, Chlorophyll-a_Fluorescence, O_2, turbidity
North Sea	Year around 2017-2018	HZG - Wilhelm Petersen (wilhelm.petersen@hzg.de)	Ferrybox Moss/Halden-Zeebruegge-Immingham-Moss (Lysbris)	Temperature, Salinity, Chlorophyll-a_Fluorescence, O_2, pCO_2, pH, total alkalinity, CDOM (Fluorescence), turbidity
North Sea	Year around 2017-2018	HZG - Wilhelm Petersen (wilhelm.petersen@hzg.de)	Ferrybox Cuxhaven-Immingham (Hafnia Seaways)	Temperature, Salinity, Chlorophyll-a fluorescence, O_2, pCO_2, pH, CDOM-fluorescence, turbidity, (total alkalinity)

Bay of Biscay, Western Channel	Spring 2016 - Spring 2017. Measurements every 30 minutes	CNRS - Yann Bozec (bozec@sb-roscoff.fr) or Thierry Cariou (cariou@sb-roscoff.fr).	Western Channel Astan	Temperature, Salinity, Chlorophyll (Fluorescence), O_2, pCO_2. Air Pressure and Temperature, Wind speed and direction.
Bay of Biscay, Western Channel	Spring 2016 - Spring 2017. Measurements every 1 min. 6 hours per day from Spring to Fall, 12 hours per week during winter.	CNRS - Yann Bozec (bozec@sb-roscoff.fr) or Eric Macé (mace@sb-roscoff.fr).	Ferrybox Plymouth-Roscoff	Temperature, Salinity, Chlorophyll (Fluorescence), O_2, pCO_2.
Bay of Biscay, Western Channel	Spring 2017 - Spring 2018. Measurements every 1 min. 20 hours per week.	CNRS - Yann Bozec (bozec@sb-roscoff.fr) or Eric Macé (mace@sb-roscoff.fr).	Ferrrybox Cork-Roscoff	Temperature, Salinity, Chlorophyll (Fluorescence), O_2, pCO_2.

After the exercise is completed, and data quality assured, data is analyzed to derive how different factors affect the C fluxes in different marginal seas. Based on these analyses, a joint publication focusing on biological carbon cycle and its scales of variability will be published. Data collected is also submitted to relevant databases like SOCAT and from those observing locations part of ICOS, to ICOS carbon portal currently under development. In addition, we expect that the results from each region would provide new scientific evidence of the C-fluxes, and

7.2.1.1 *Sampling strategy*

The sampling is based on existing instrumentation and varies between the sites as explained in JRAP-5 Task 3 description above. However, in general the minimum list of observations at each measurement location includes pCO_2, Chlorophyll, SST and salinity. Additional, preferable observations are basic meteorology, O_2, primary production, phytoplankton community structure, alkalinity, pH, DIC and mixing depth. Details of measurement are collected during M6-M9 (Task 1).
In the most sites of JRAP-5, sampling is conducted using moving platforms (ferrybox) and fixed platforms in order to obtain spatio-temporal data to analyse C-fluxes. Data is collected at high frequency (depending on the instrument and platform at s-h scale and m-km scale). Sampling will be carried out from spring 207 until spring 2018, aiming to cover 1 year of continuous measurements at each study site.

7.2.1.2 *Data Integration (Physical, chemical and biological data)*

As one of the key aims of the JRAP-5 is to understand biological carbon cycle, we measure simultaneously physical, biological and chemical variable as described above. As the calculations of biological carbon cycle require observations of all three, the data is automatically integrated.
Dynamics of the carbonate system will be analysed against variability of biological components (mainly distribution of chlorophyll a, phytoplankton taxonomic components and productivity in some cases) and physical state of the sea. We aim collecting more detailed data on biological variables during phytoplankton bloom and post-bloom conditions, to be able to provide accurate short term (daily-weekly) dynamics in C-fluxes, driven by biological processes.

7.2.1.3 *JRAP team: Role and undertakings*

The JRAP is coordinated by Lauri Laakso from Finnish Meteorological Institute, with Jukka Seppälä from Finnish Environment Institute providing in-depth understanding on photosynthesis and biological carbon cycle.
The planned intercomparisons exercise in Oslo is organized by Lauri Laakso (FMI) and Jukka Seppälä (SYKE) with support from Kai Sørensen and Andrew King from NIVA. Preparations started in February 2016 with a joint meeting at Oslo calibration facility, where technical details and approach of workshop was planned.
Behind this coordination work, all partners are responsible for their own observations. In Baltic Sea SYKE and SMHI will interact, in order to collect coherent dataset for Baltic Sea.

7.2.2 *Specific cross-cuttings with other JRAPs and WPs*

At the distinct JRAP 5 sites, the effects of biological and physical processes on biogeochemical cycling and C-fluxes will be estimated by integrating physical, chemical and biological techniques especially focusing on those developed in WP3 (phytoplankton biomass, community structure, productivity and traits, pH, pCO_2, CO_3, CT, alkalinity). At each site, the added value of using multiple platforms will be demonstrated through analyzing the spatiotemporal variability in the high-resolution data. As a link to WP1, task 1.6, results from JRAP#5 will guide development of optimal observation network for C-flux studies throughout European sea areas.

The planned cross-cutting activities between the JRAP and WPs are the following:
WP1: Communication of the feedback after JRAP-5 experiment task 1.2. Science strategy
WP2: Communication and feedback (especially with Subtask 2.4.3: Sensors for parameters of the marine carbonate system)
WP3: Applying instrument developments from WP3 (especially with subtask 3.1.3: Optical Instrumentation combination and task 3.5: Combined sensors for carbonate systems)
WP4: Joint Research Activities (JRAP #1: Biodiversity of plankton, harmful algal blooms and eutrophication)
WP5: Quality control steps of marine biological data (D5.4: Data flow from measurements to data centers)
WP6: Operational data flows from measurement sites
WP7: TNA projects on appropriate topics (especially planned JRAP-5/Task2)
WP8: Feedback for instrument developers

7.3 Implementation Risks and mitigation measures

The main potential risks and challenges are listed below:
Some of the instruments are operational at fixed routes (VOS) and do not have spare instruments. Thus it is not possible to bring them to the calibration workshop. This is a challenge we cannot completely solve within this project.

Instrument losses on field. Many of the institutes have difficult economic situation due to European depression having led to reduced funding. As in some cases there are no spare instruments, the service breaks can limit the continuous data collection. This challenge is tackled with the large number of observing sites: inevitable problems at few individual sites are not critical for JRAP-5 in general.

Limited amount of biological instruments at some sites. This challenge is known, and as the project has been planned already in 2014, partners have been partially able to obtain in-house investment funding from their own institutes. As in case of challenge 2, limited observations at individual sites are not critical for the overall results.
Partly limited instrumentation for studying all processes relevant for ecosystem-carbon interactions. Partners do not have comprehensive instrumentation for biological observations. This challenge is met by doing more in-depth research on sites with wider range of instruments while sites with limited instrumentation can provide more support for e.g. spatiotemporal studies.

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8 JRAP-6: Operational oceanography and coastal forecasting

8.1 Rationale and expected outcomes

8.1.1 Main questions - Objectives

The coastal ocean is a particularly complex system due to the wide range of processes at play driven by multiple forcing factors and characterized by small spatio-temporal scales and non-linear interactions. From a physical point of view, it is a very dynamic area where the wind-driven circulation interacts with buoyancy and tidal currents, where energetic mesoscale and sub-mesoscale processes develop under the influence of both the surrounding open ocean conditions and the details of the coastal topography. This complex hydrodynamics significantly impacts biogeochemical processes, which leads to a highly variable primary production in the coastal and shelf environments.

Numerical models are essential elements of coastal operational oceanography systems as they help 1) understanding the complexity of the observed coastal ocean processes and 2) representing the three-dimensional coastal oceanic conditions and forecast their evolution in time. Operational regional models (hydrodynamic, waves, biogeochemical) have been settled in a number of European coastal observatories in support of local multiplatform observing infrastructures so as to better respond to society needs and help the implementation of the Marine Strategy Framework Directive (MSFD). In particular, realistic models provide a useful support to efficiently protect the European marine environment through the characterization of the alteration of hydrographical conditions, the analysis of the dispersion of contaminants and marine litter, or the prediction of harmful algal blooms (MSFD descriptors 5, 7, 8 and 10).

However, operational ocean modelling is still highly challenging when approaching the coastal zones due to the intrinsic variability of the coastal ocean and the limitations inherent to numerical modelling. While the internal model dynamics needs to properly represent a wide range of processes, air-sea fluxes, freshwater river fluxes, deep ocean interactions, and details of the coastline and bathymetry, which are all specified as external model forcing, are also critical to achieve realistic simulations.
In this context, it is essential to properly evaluate the model performance to first improve as much as possible the simulations before they can be used efficiently to address scientific and societal questions.

There have been significant advances over the last five years in terms of availability of multiplatform observations in coastal observatories (e.g. first JERICO project), allowing a new detailed evaluation of the model results. Today, the JERICO-RI network provides a unique opportunity to evaluate the operational oceanography capabilities in the European coastal ocean, to assess the existing skills, gaps and needs, and to establish a roadmap for improvements both in terms of models and observations.

JRAP-6 will show the importance of JERICO-RI observations for the assessment and improvement of operational regional models implemented in the coastal ocean. This JRAP will focus on the assessment of physical models (hydrodynamics and waves), mainly due to the relative immature development of operational biogeochemical models in European coastal waters. Note that even if focused on physical models, the results of the JRAP are expected to have ecological implications given the very strong influence of hydrodynamics on biogeochemical processes. In particular, the model assessment will be focused on aspects directly related to MSFD implementation, in particular the surface circulation and the physical processes involving vertical velocities or surface mixing with an impact on ecosystems.

8.1.2 Description of the state of the art related to the science topic

The recent advances in numerical ocean modelling together with the increase of available computer resources has allowed the development and implementation of operational coastal ocean forecasting systems with resolutions of the order of 1 km (see for example Kourafalou et al., 2015a for a recent review). This high spatial resolution allows representing most of the coastal physical processes such as upwellings, fronts, river plumes, slope currents, shelf break mesoscale and sub-mesoscale processes and surface waves. Yet, models are intrinsically limited by the

errors in the surface and lateral forcing fields, the use of approximate parameterizations and numerical errors. (Kourafalou et al., 2015b).
These predictive models are generally run on a daily basis, providing short term predictions of the coastal environment. They aim at being useful to both improve our understanding of the complex coastal environment and support the management of the coastal zones in terms of maritime security, search-and-rescue, ecosystems and fishing, or response to oils spills or chemical accidents (e.g. Tintoré et al., 2013; Stanev et al., 2011; Siddorn et al., 2007; Chao et al., 2009; Nittis et al., 2001; Russo et al., 2009, Marta-Almeida et al. 2012).
Today, these models are important elements of Coastal Observatories where they are integrated with Coastal Ocean Observing Systems. A list of worldwide available coastal forecasting systems is maintained and updated within the framework of the GODAE OceanView Coastal Ocean and Shelf Seas Task Team (COSS-TT) and can be consulted on the following web page: https://www.godae-oceanview.org/science/task-teams/coastal-ocean-and-shelf-seas-tt/coss-tt-system-information-table/.
Data assimilation is an additional key element in most of these systems. This procedure allows minimizing model errors by constraining the model solution to be close to observations given particular dynamical constraints. In the coastal ocean, the complexity of the dynamics makes theoretically necessary the use of advanced approaches (e.g. 4D-Var or Ensemble Kalman Filter) representing the full spatio-temporal evolution of the model error covariances (Auclair et al., 2003, Mourre et al., 2006, Barth et al., 2007, Li et al. 2008). However, the most sophisticated methods generally remain unaffordable in an operational context and simplifying assumptions are necessary for operational coastal forecasting systems (e.g. Optimal Interpolation, 3D-Var).

The coastal ocean is generally under-sampled with respect to the short spatio-temporal scales of the processes at play. Satellite observing systems are facing specific limitations when approaching the coast and the resolution of profile observations is insufficient to fully describe the subsurface ocean variability. This generally limits the capacity of a comprehensive evaluation of the model results.
In this context, the evaluation of the model realism using enhanced multi-platform observations is essential to improve the simulations and allow the model-derived products to be successfully used for scientific or societal applications (e.g. Juza et el., 2016; Capo et al. 2016; Chiggiato and Oddo, 2008; Oke et al. 2002; Mourre et al., 2012, Marta-Almeida et al. 2013).
When applying data assimilation, model-data comparisons also allows assessing the impact of particular observations on the model performance. This is achieved through the so-called "Observing System Experiments" approach. In addition, and following this line, a data-assimilative system also enables to assess the impact of virtual observations and then to optimize the sampling by performing "Observing System Simulation Experiments" (see for instance Oke et al. 2015 for a recent review).

8.1.3 The role of the JERICO research infrastructure

The integration of models and observations in European Coastal Observatories presents a unique opportunity to improve the evaluation of the model performance. The continuous monitoring and availability of quality-controlled multi-platform observations is a chance to provide new insights into model skills, identify model limitations and allow to improve numerical simulations.
In particular, autonomous platforms (gliders) provide continuous high resolution profile observations that describe mesoscale and sub-mesoscale processes and fine details of the thermohaline structure. When deployed on repeated transects, they allow to characterize the high-frequency and fine-scale ocean dynamics. HF radars provide unique measurements to characterize the small scale surface transport variability over coastal areas. Time series at fixed stations allow to precisely evaluate the temporal variability of oceanic variables at particular locations. Ferry Boxes provide a very regular monitoring of oceanic variables along surface transects.
The use of these platforms has been very limited until now to better understand model capabilities and limitations in the coastal areas.

8.1.4 Expected progress beyond the state of the art

This JRAP should provide new insights into the following questions:

- How realistic are our coastal ocean models for different variables and processes?
- What do we have to improve in our models?
- What is the impact of coastal observations on the model performance when data are assimilated?
- How should we best sample the coastal ocean in the future?

8.2 Research Methodology and approach

8.2.1 Main tasks and work plan

This JRAP will successively address two main objectives: first the assessment and then the improvement of operational coastal forecasting systems used for harmful algae blooms prediction, oil spill applications, drifting of gelatinous organisms, eggs and larvae dispersion or maritime search-and-rescue operations.

Task 1 - Model assessment

The first objective of the JRAP will be to demonstrate that the existing multiplatform coastal ocean observing infrastructures allow an improved evaluation of the realism of the present European coastal ocean forecasting systems. This model assessment will be performed in different European coastal regions, considering either seasonal or short-term variability linked to mesoscale and episodic processes of particular regional relevance. The first subtask will consider regional models without local data assimilation (although some observations can be assimilated in the larger scale model used for initial and boundary conditions), while the second subtask will focus on operational models including the assimilation of local measurements.

Subtask 1.1 - Models without data assimilation

High-resolution hydrodynamic models will be assessed in six different European areas selected because of the existence of key coastal ocean processes in each of them (water mass adjustment, upwelling, shelf slope exchanges, wind-driven circulation, Fjords and river plumes). These areas include the Bay of Biscay, the Western Iberian Margin, the Norwegian coast, the Balearic Sea, the Adriatic-Ionian basin and the Aegean Sea. JERICO-NEXT multiplatform observations from fixed buoys, Ferryboxes, HF radar, underwater gliders, surface drifters and coastal research vessel CTDs will be used for this evaluation, also including Argo floats. The assessment will be focused on aspects directly related to society needs and MSFD implementation, in particular the surface circulation and the physical processes involving vertical velocities with an impact on ecosystems. In addition, the capacity of a wave model to properly represent the surface vertical mixing and its potential effect on harmful algae blooms will be assessed in the Baltic Sea.

Subtask 1.2 - Models with data assimilation

Data assimilation allows to incorporate measurements into the model solution, with the aim to improve model results and predictions. In the coastal ocean, the complexity of the dynamics makes theoretically necessary the use of advanced approaches. However, the most sophisticated methods generally remain unaffordable in an operational context and simplifying assumptions are necessary for operational coastal forecasting systems. Some of these systems in Europe now include the routine assimilation of remote sensing and in situ data.
In this subtask, the results of operational data assimilative models will be evaluated using JERICO-NEXT multiplatform observations in four different coastal zones, namely the Balearic Sea, Adriatic-Ionian basin, Aegean Sea and Western Iberian margin. Observing Systems Experiments (OSEs) will be conducted to evaluate the contribution of the different existing observing systems in terms of model results improvement. In particular, the impact of HF radar and moorings will be evaluated in the Balearic and Southern Adriatic Seas. The impact of gliders will be assessed in the Southern Aegean Sea, and the impact of moorings will be evaluated on the West coast of Portugal.

Task 2 - Coastal ocean forecasting system improvements

The detailed model evaluation carried out in the framework of the first objective of this JRAP will allow to identify gaps and needs of the present European coastal forecasting systems. This analysis is the necessary step to address the second main objective, which is to bring recommendations for the improvement of operational model simulations in the coastal zones, both in terms of modelling strategy and observing system requirements.

Subtask 2.1 - Modelling improvements

Based on the results of the evaluation carried out in Task 1, this subtask will investigate the way to improve the modelling strategy implemented in the European coastal observatories. The main identified model limitations will be summarized and sensitivity studies will be performed to provide recommendations in terms of model spatio-temporal resolution, bathymetry representation, lateral boundary conditions, atmospheric forcing, need for consideration of current-wave interactions, internal model parameterizations or design of the prediction system.

Subtask 2.2 - Observing System improvements

Using numerical models and data assimilation, Observing System Simulation Experiments (OSSEs) will be performed in three different European coastal regions to evaluate the needs for improved coastal observing systems. OSSEs allow a quantitative estimation of the impact of potential observations on the performance of ocean prediction models. This subtask will specifically investigate the contribution of gliders, fixed stations and HF radar in the coastal ocean, with numerical experiments in the western Iberian margin, Balearic Sea and Adriatic-Ionian basin. It will bring recommendations for the design of future coastal observing systems aiming at improving the model prediction skills.

8.2.1.1 Study areas

Seven European coastal areas have been selected because of key science and societal relevance and availability of integrated observing and forecasting systems. These areas are the Atlantic Iberian margin, South-East Bay of Biscay, Balearic Sea, Adriatic-Ionian basin, Aegean Sea, Baltic Sea and Norwegian coast.

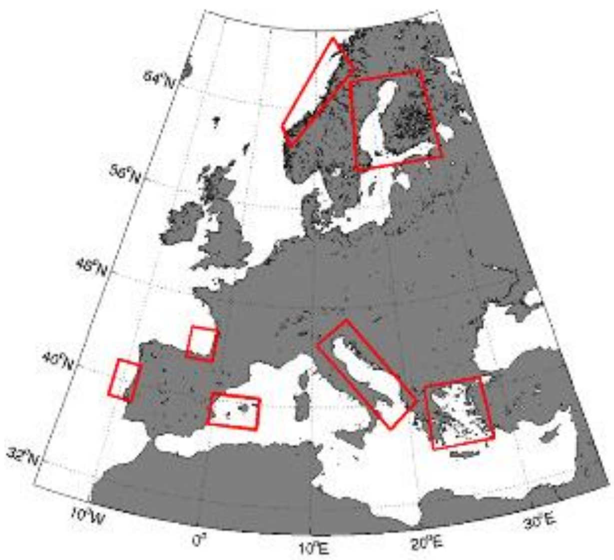


Figure 8.1: Illustration of the seven areas selected for this JRAP.

These areas offer of wide panel of governing dynamical processes:

- Meridional water masses exchanges, slope current and mesoscale processes in the Balearic Sea
- Upwelling, slope current and shelf circulation under the influence of a submarine canyon along the Atlantic Iberian margin
- Wind-driven circulation, slope current and mesoscale variability in the South Bay of Biscay
- Mesoscale to small-scale variability in the Aegean Sea
- Buoyancy-driven circulation associated with the Norwegian Fjords
- Wind-driven circulation, mesoscale and river plumes in the Adriatic Sea
- Wave-induced turbulence in the Baltic Sea

This JRAP will consider both the episodic variability linked to coastal ocean mesoscale processes and short-term atmospheric transients, and the longer term seasonal and inter-annual variability of the coastal ocean. The spatial scales of interest range from a few km to 100 km. Six hydrodynamic models will be used (Atlantic Iberian margin, South-East Bay of Biscay, Balearic Sea, Adriatic-Ionian basin, Aegean Sea and Norwegian coast) as well as one wave model (Baltic Sea).

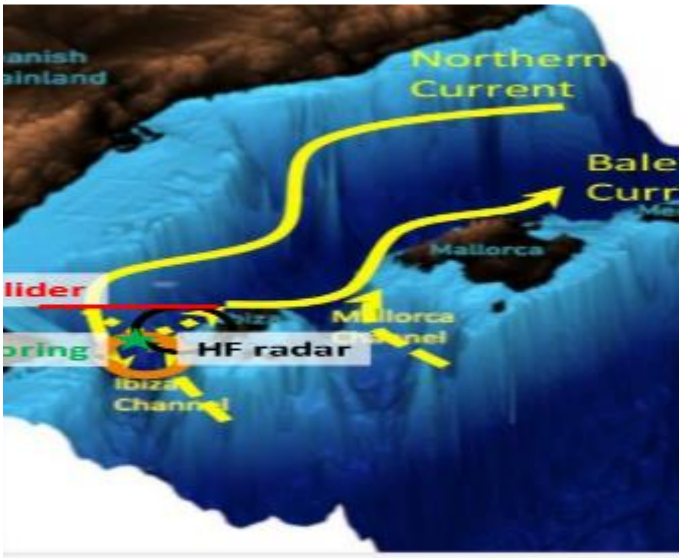
Relation to MSFD descriptors

By analysing the surface circulation and associated dispersion likely to affect contaminants or marine litter, the JRAP will support the implementation of the MSFD in the Balearic Sea, Atlantic Iberian margin, South Bay of Biscay, Aegean Sea, Adriatic Sea and Norway Sea (descriptors 9 and 10).
Moreover, the study of wave-induced turbulence on algae blooms in the Baltic Sea will provide specific information related to the MSFD descriptor 5 concerning eutrophication of the seas.
Finally, the improvement of the representation of the physical ocean conditions achieved during this JRAP in the different study areas is expected to provide an enhanced scientific support to the MSFD descriptor 7 on hydrographical conditions.

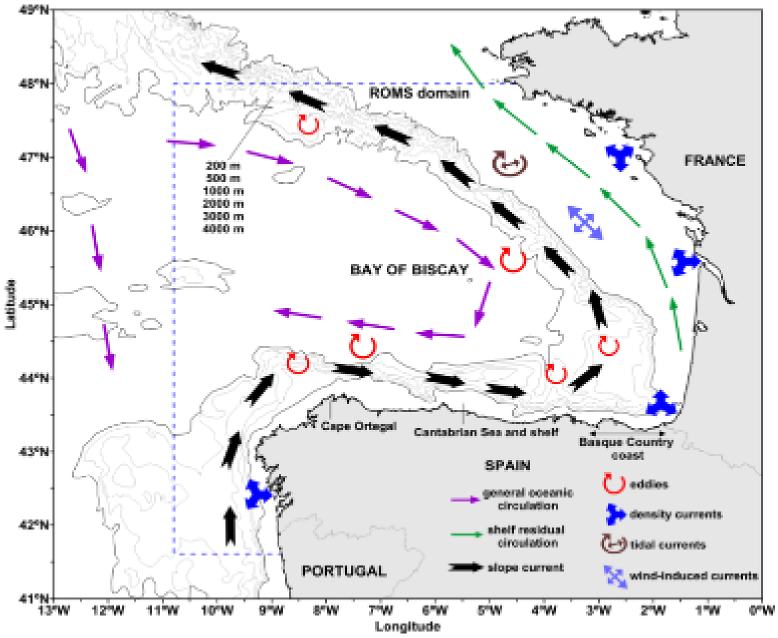
8.2.1.2 Sampling strategy

Observations from HF radar, gliders, Ferry Boxes, fixed moorings, CTDs and ARGO floats will be used in this JRAP. The specific sampling strategy in each area of study will depend on the characteristics of the associated Coastal Observatories:

- **Balearic Sea**
  Platforms: gliders, fixed mooring, HF radar, Argo and ship CTDs, surface drifters
  Parameters: T, S, surface currents
  Sampling period: continuous 2015-2019



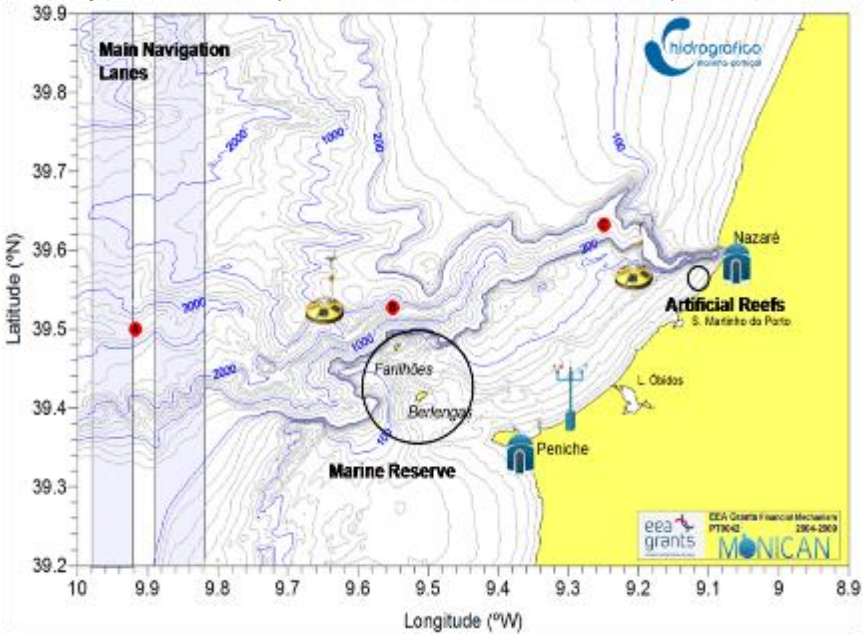
- **South Bay of Biscay**
  Platforms: fixed mooring, HF radar, ship CTDs, surface drifters
  Parameters: T, S, surface currents
  Sampling period: continuous 2009-2017



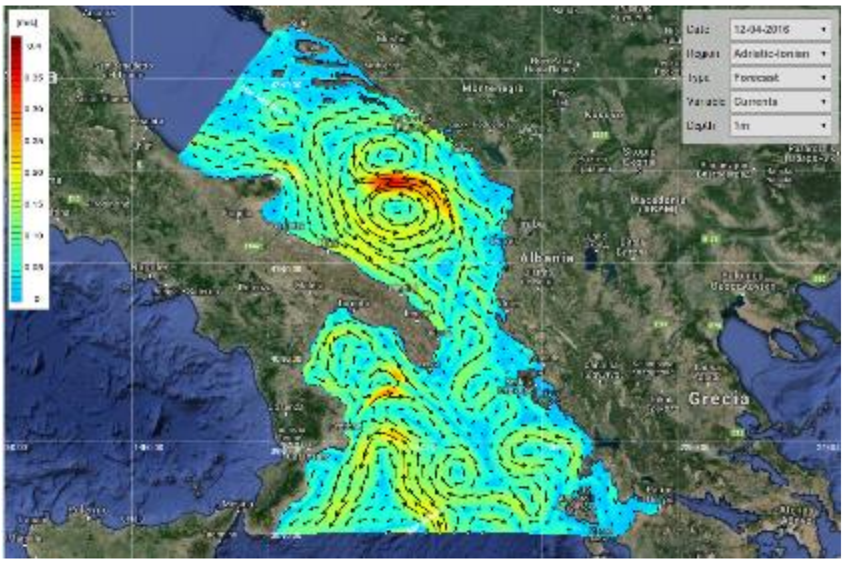
- **Aegean Sea**
  Platforms: gliders, FerryBox, ARGO floats
  Parameters: T, S
  Sampling period: 2015-2019

- **Nazare Canyon area**
  Platforms: fixed mooring, ship CTDs

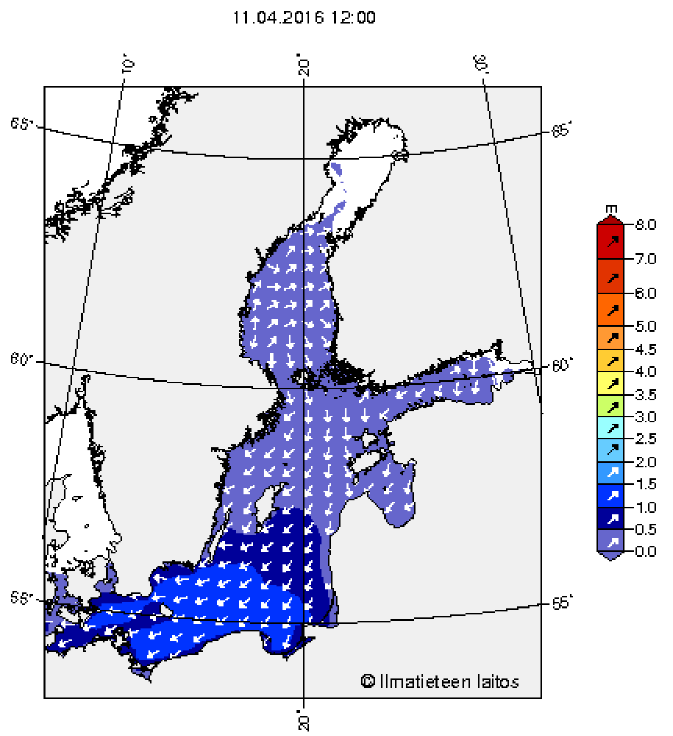
Parameters: T, S, currents + fluorometry, turbidity
Sampling period: June-July 2007, March-April 2011 + potentially some period in 2016-2017



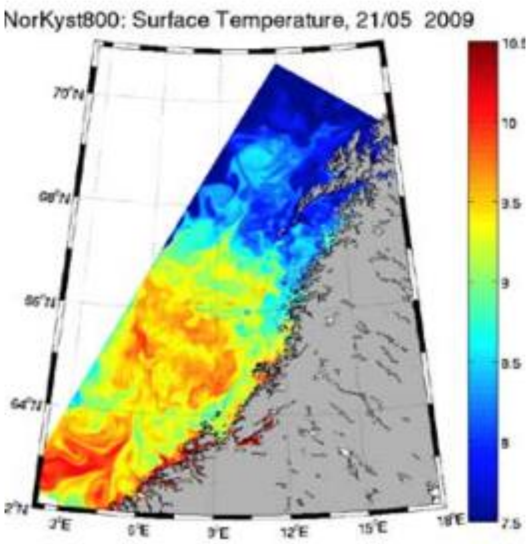
➤ **South-West Adriatic Sea**
Platforms: fixed moorings, HF radar, Argo floats, surface drifters
Parameters: T, S, surface currents
Sampling period: 2014-2015



➤ **Baltic Sea**
Platforms: VOS
Parameters: phytoplankton
Sampling period: April 2017-March 2018



- **Norwegian Coast**
  Platforms: fixed mooring, FerryBox, ship CTDs
  Parameters: T, S
  Sampling period: continuous 2015-2019



Participant	Study area	Observations used for model assessment / data assimilation	Data assimilation approach	Model (resolution)
SOCIB	Balearic Sea - Ibiza Channel	Fixed stations, HF radar, glider	EnOI	ROMS (2km)
IH	Atantic margin (Nazare Canyon)	Fixed stations, glider, CTDs, tide gauges	OI	HOPS (0.3km)
CMCC-CNR	Adriatic Sea	Fixed stations, HF radar	EnKF	NEMO (2km) / SHYFEM (unstructured)
HCMR	Aegean Sea	Fixed stations, glider, FerryBoxes, ARGO	SEEK filter	POM (3km)
IMR	Norway Sea	Fixed stations, FerryBoxes, CTDs	--	ROMS (0.8km)
AZTI	South-East Bay of Biscay	Fixed stations, HF radar, drifters	--	ROMS (0.67km)
FMI	Baltic Sea	Fixed stations, FerryBoxes, CTDs	--	WAM

8.2.1.3 Data Integration (Physical, chemical and biological data)

Note that JRAP6 will consider six hydrodynamic models and one wave model, but no biogeochemical model. The outputs of these models will be mainly compared to physical measurements. In some cases, biogeochemical measurements will also be considered to provide insight into the validation of physical outputs. In particular, phytoplankton observations collected in the Baltic Sea will be used to evaluate the impact of the wave-induced turbulence on algae blooms. Biological data will also be considered as part of the analysis of the ocean circulation in the Nazare Canyon area off Portugal.

8.2.1.4 JRAP team: Role and undertakings

The JRAP team is composed of 8 European partners: SOCIB (Spain), IH (Portugal), AZTI (Spain), CMCC (Italy), CNR (Italy), FMI (Finland), HCMR (Greece) and IMR (Norway).
SOCIB will coordinate the whole JRAP. Subtask leaders have been designed for each of the four subtasks. IH will lead subtask 1.1, HCMR subtask 1.2, AZTI subtask 2.1 and CMCC subtask 2.2.
While all the partners will participate in subtasks 1.1 and 2.1, a reduced number of partners will participate in subtasks 1.2 and 2.2 which address data-assimilative model performance. HCMR, SOCIB, IH and CMCC/CNR will participate in subtask 1.2 and perform Observing System Experiments. CMCC/CNR, SOCIB and IH will participate to subtask 2.2 and perform Observing System Simulation Experiments.

Title	Subtask	Leading institution	Participants	Delivery date
Model assessment using JERICO observations	1.1	IH	SOCIB, IH, AZTI, HCMR, CMCC, CNR, FMI, IMR	March 2017 (M19)
Data-assimilative model assessment and Observing System Experiments (OSEs)	1.2	HCMR	SOCIB, IH, HCMR, CMCC, CNR	November 2018 (M39)
Recommendations for modeling strategy improvements	2.1	AZTI	SOCIB, IH, AZTI, HCMR, CMCC, FMI, IMR	March 2018 (M31)
Observing System Simulation Experiments (OSSEs) and recommendations for coastal observing systems	2.2	CMCC	SOCIB, IH, CMCC, CNR	November 2018 (M39)
JRAP6 synthesis	all	SOCIB	SOCIB, IH, AZTI, HCMR, CMCC, CNR, FMI, IMR	January 2019 (M41)

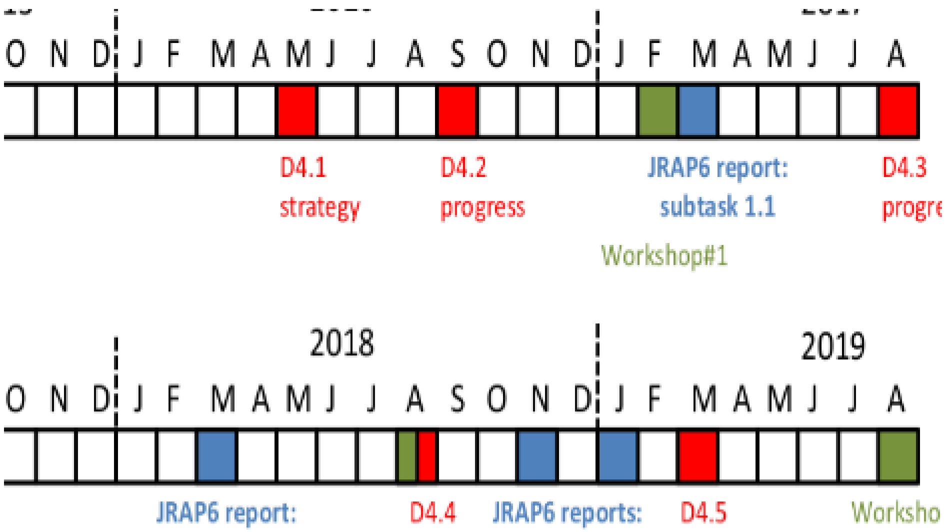


Figure 8.2: JRAP6 timeline

8.2.2 Specific cross-cuttings with other JRAPs and WPs

Through the analysis of the slope current in the Balearic Sea, South Bay of Biscay and Atlantic Iberian margin, JRAP6 will be linked to JRAP4 which addresses the problem of trans-boundary transports. A summary of model assessment outputs in these areas will be integrated in JRAP4 synthesis.

Moreover, two additional crosscutting activities with JRAP4 are planned. On the one hand, the JRAP4 OSSE activity based on the use of the Array Modes method to assess the impact of HFR observations in the South East Bay of Biscay will be integrated in the JRAP6 final synthesis. This method will allow to estimate the most efficient

location of measurements to constrain the ensemble model variance and will be will be used in the deployment of the new system along the French coast taking into account existing HFR system along the Spanish coast.
On the other hand, the numerical model assessment carried out by AZTI in JRAP6 will mostly rely on measurements collected in the Bay of Biscay in the framework of JRAP4. This will allow both a joint analysis of data and simulations for model assessment (JRAP6), and the use of model outputs to complete data description of currents and transport (JRAP4).

Besides, the study of the impact of wave-induced turbulence on harmful algae blooms will link JRAP6 with JRAP-5 since the same team and measurements will be used. In improving the understanding of algae blooms in the Baltic Sea, the results of this particular study might also be integrated in JRAP-1 synthesis.

JRAP6 will be supported by the work carried out in Work Packages 2, 3 and 5. In particular, in WP2 the work on the harmonization of data from the initial network and HF radar is expected to help to improve the quality of fixed stations, gliders, Ferry Boxes and HF radar measurements that will be used for the model evaluation. In WP3, the optimal OSE/OSSE infrastructure as well as the improved HF radar data assimilation technology will support the implementation of JRAP6 data assimilation studies and OSSEs. Finally, the observations used for JRAP6 will follow the procedures for data management defined in WP5, in particular concerning HF radar and glider observing platforms.

8.3 Implementation Risks and mitigation measures

Risks	Mitigation measures
Large panel of areas/models/observations, results might diverge from the common objective	Initial coordination to focus the work along the JRAP line
Delays in data assimilation developments at SOCIB and CMCC	Delay report on data-assimilative model assessment
Delay in glider data availability in the Aegean Sea	Model assessment limited to ARGO, satellite and moorings
Delay in Baltic Sea measurement campaign	Delay report on Baltic Sea case study

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9 Conclusions

JERICO-Next addresses six societal challenges and priorities through six Joint Research Activity Projects (JRAPS):
1) pelagic biodiversity with focus on phytoplankton biodiversity, dynamics and algal blooms,
2) benthic biodiversity with focus on the impact of biodiversity on ecosystem functioning and services
3) chemical contaminant occurrence and related biological responses,
4) hydrography and transport, with focus on the use of coastal HF radar and hydrodynamic modelling
5) carbon fluxes and carbonate system in coastal environment
6) operational oceanography with focus on maximising the potential of coastal observation for numerical prediction and forecasting in coastal regions.

The present report (D4.1) summarises the approaches proposed for assessing the value and the present and future relevance of the JERICO-RI, to provide high-value datasets for addressing these key challenges at European level.
Dedicated sampling strategies have been elaborated and formulated to answer key scientific questions, related to these challenges and will be tested during the next two years of the project, with the aim to provide sounded inputs to the JERICO-RI science strategy (WP1.2) for the short term, and concrete recommendations to the roadmap for the future.

A particular focus is set on integrating physical, chemical and biological observations for improved understanding of complex coastal key-processes.
Another focus is set on testing/integrating new technologies and methodologies of high added-value for the observation of the coastal processes.

If each JRAP is dedicated to one priority, efforts have been made to maximise cross-cutting activities between JRAPs, creating bridges where appropriate. For example, the link between physical (transport) process study (JRAP-4), contaminant distribution (JRAP-3) and forecasting capability (JRAP-6) has been reinforced to maximise the outcomes of these JRAPs. Likewise, the connection between JRAP-1 and JRAP-5 has been emphasised when appropriate.

The ambition of the sampling program for each JRAPs may partly be pending on other projects and funding sources, and might therefore need to be adapted the real context. The progress and a first revision of the sampling programs per JRAPs will be presented in D4.2. Feedback on the strategies after the field deployments and analysis will be communicated to the WP1 in the lasted stage of the project (deliverable D4.5).

10 Glossary

ADCP	Acoustic Doppler Current Profiler
ECOOP	European COastal-shelf sea OPerational observing and forecasting system
EGO	Everyone's Glider Observatories
EMODNET	European Marine Observation and Data Network
FCT	Forum for Coastal Technolgy
GEOSS	Global Earth Observing System of Systems
GMES	Global Monitoring for Environment and Security
GOOS	Global Ocean Observing System
INSPIRE	Infrastructure for Spatial Information in the European Community
JERICO	Joint European Research Infrastructure network for Coastal Observatories
JRA	Joint Research Activities
MSFD	Marine Strategy Framework Directive
OCO	Operational Coastal Oceanography
ROOS	Regional Ocean Observing System
SA	Service Access
TNA	Trans National Access
TOP	Targeted Operations
WFD	Water Framework Directive