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NAUTILOS - New Approach to Underwater Technologies for Innovative, Low-cost Ocean observation is an H2020 project funded under the Future of Seas and Oceans Flagship Initiative, coordinated by the National Research Council of Italy (CNR, Consiglio Nazionale delle Ricerche). It brings together a group of 21 entities from 11 European countries with multidisciplinary expertise ranging from ocean instrumentation development and integration, ocean sensing and sampling instrumentation, data processing, modelling and control, operational oceanography and biology and ecosystems and biogeochemistry such, water and climate change science, technological marine applications and research infrastructures.

NAUTILOS will fill-in marine observation and modelling gaps for chemical, biological and deep ocean physics variables through the development of a new generation of cost-effective sensors and samplers, the integration of the aforementioned technologies within observing platforms and their deployment in large-scale demonstrations in European seas. The fundamental aim of the project will be to complement and expand current European observation tools and services, to obtain a collection of data at a much higher spatial resolution, temporal regularity and length than currently available at the European scale, and to further enable and democratise the monitoring of the marine environment to both traditional and non-traditional data users.

NAUTILOS is one of two projects included in the EU´s efforts to support of the European Strategy for Plastics in a Circular Economy by supporting the demonstration of new and innovative technologies to measure the Essential Ocean Variables (EOV).

More information on the project can be found at: http://www.nautilos-project.eu.

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EXECUTIVE SUMMARY

The purpose of an Environmental Impact Assessment (EIA) is to examine in advance the consequences of the development of an activity on the natural environment. The main objective is to prevent possible significant impacts by assessing the activities predicted in a systematically, holistic and multidisciplinary way, and providing alternatives to reduce or eliminate the undesired effects. The developer of a project must provide to the authority responsible for approving it a report that must include at least a minimum level of information prescribed by the Directive 2011/92/EU, which consists of a description of the project such as location, design and size, as well as features of the project and measures to avoid, prevent, reduce or offset significant adverse effects. It is also seen as a good practice in scientific projects to conduct an EIA to reduce the impact to the minimum levels possible.

The first stage of an EIA is the Screening, where an initial identification of the adverse environmental impacts is performed by screening all the possible impacts, including those that are not fully known. In the NAUTILOS project, the Screening phase was carried out by the means of a questionnaire sent to the partners responsible for the development of each sensor. The responses to this survey provided information about the characteristics of the sensors, location, possible emissions, deployment and recovery procedures. This information was essential to identify the most significant impacts, which special attention should be given.

This is the basis for the Scoping phase, where the impacts that have greater concern are investigated in detail and mitigation measures are provided. Briefly, the main impacts identified from the development of the NAUTILOS activities are toxic materials used in the manufacturing of the sensors, the end of life of these devices, possibly loss in the sea, issues associated with the batteries, antifouling strategies, eventual noise pollution, and potential disturbing of wild animals during the animal-borne tag attachment. These impacts are not expected in all the sensors, also when present they may be expected to different levels in each sensor and sampler.

The respective mitigation measures recommended are the use of biodegradable materials, adoption of circular economy principles, having a backup strategy to recover the sensors from the marine environment, collecting and recycling the used batteries, choosing more sustainable alternatives of antifouling, reducing noise pollution close to sensitive areas, and evaluate empirically the effects of this new animal-borne devices on the tagged animals.

In conclusion, the impacts expected from the development and demonstration phases of the NAUTILOS project are of small magnitude. When compared to the benefits that the improved acquaintance of data and integration to large-scale observatory systems will bring to ocean conservation, and the effectiveness of the mitigation measures, the normal continuation of the project without major restrictions is recommended. Nevertheless, recommendations on how to in improve products from and environmental impact reducing point of view were shared with all WP3 and WP4.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATION	DEFINITION
ARGOS	Advanced Research and Global Observation Satellite
e.g.	For example
EIA	Environmental Impact Assessment
EOVs	Essential ocean variables
EU	European Union
H2020	Horizon 2020 EU Research and Innovation Framework Programme
ISOM	International Ship Operators Meeting
NAUTILOS	New Approach to Underwater Technologies for Innovative, Low-cost Ocean Observation
PNECs	Predicted No Effect Concentrations
UNCLOS	United Nations Convention on the Law of the Sea
VHF	Very High Frequency
WOA II	Second World Ocean Assessment

INTRODUCTION

1.1. DESCRIPTION OF THE PROJECT

This document consists of the screening phase of Environmental Impact Assessment (EIA) regarding the development of different marine sensors within the framework of the project "New Approach to Underwater Technologies for Innovative, Low-cost Ocean Observation", hereafter referred to as NAUTILOS. This is an H2020 project funded by the Future of Seas and Oceans Flagship Initiative coordinated by the National Research Council of Italy (*Consiglio Nazionale delle Ricerche*), and brings together a group of 21 institutes from 11 European countries with the aim to develop a new generation of cost-effective sensors and samplers to monitor essential ocean variables (EOVs).

Moreover, these sensors will be integrated into observation platforms and deployed in large-scale demonstrations off the coastline of Europe, both in shallow and deep waters. It is expected that the expansion of existing tools and services, as well as the facilitated access to data generated by these sensors, will allow researchers to monitor the marine environment at a much higher spatial resolution and temporal regularity than is currently available at the European level. This is essential to acquire reliable information to assess biological, chemical, and physical processes that are very dynamic in nature, and to accurately quantify variables such as temperature, momentum, biological and biogeochemical fluxes, how they are changing, and what processes are forcing these changes. As a result, the high-quality data that will be obtained can be very useful to manage and mitigate events that might have adverse climatic, environmental, social and economic outcomes.

1.2. Legislation

In this document, information about the objectives, justification, description of the project, impacts and mitigation measures are presented based on the Directive 2011/92/EU of The European Parliament modified by the Directive 2014/52/UE, legislation regarding the assessment of the effects of certain public and private projects on the environment. Although the development of new technology of marine sensors does not fall within the categories of projects listed either in Annex I or II of the Directive, which are respectively the projects obliged and subjected to an evaluation through an EIA, this document aims to provide information following the guidelines of the European Union for an eventual environmental license required at a certain stage of the project. Therefore, this document can also be used as a model to produce a more robust environmental impact assessment for a specific sensor under a particular regulation.

The NAUTILOS Consortium consists of the proponent of an environmental license required in a specific country or site to carry out the activities predicted within the scope of the project. The licensing entity is not clearly defined at this stage, since each sensor might be subjected to a different assessment depending on the country and location they will be used; for instance, sensors deployed in marine protected areas.

In addition, this EIA is following the good technological practices recommended by the Code of Conduct for Marine Scientific Research Vessels (ISOM, 2007) by addressing the issues associated with the negative impact on the environment from the activities foreseen within the framework of the project. The emphasis is given on the physical, chemical, acoustic impacts and risk of an accident. Also, to comply with the recommendations from the United Nations Convention on the Law of the Sea (UNCLOS, 2010), this document provides information regarding the main impacts expected during the project and solutions to minimize these negative effects on the natural environment, in particular in environmentally sensitive areas.

2. Methodology

2.1. Objectives

Seeing that the European observation services and tools have the potential to develop novelty technologies to acquire a large amount of data at a higher resolution, temporal regularity and duration, the NAUTILOS project has the objective to develop and integrate a new generation of marine sensors for biological, chemical, and physical EOVs, and also microplastics. This project will raise knowledge on marine and coastal environments, as well as anthropogenic impacts related to marine litter, aquaculture, and fisheries.

By integrating recently developed technologies into a wide range of observing platforms, and deploying these instruments using innovative and cost-effective methods, the project aims to complement and expand existing European observation instruments and services and further enable and democratise the monitoring of the marine environment for both traditional and non-traditional data users. In other words, the project has the objective to improve the current state of marine monitoring systems to enhance the widespread adoption of autonomous *in situ* sensing.

2.2. JUSTIFICATION

There is a consensus in the scientific community regarding the necessity for long-term monitoring and conservation of marine natural resources. In order to maintain ecosystem services and the marine areas within a good environmental status (Directive 2008/56/EC), there is a need to understand and monitor the chemical, physical and biological processes. This fine scale monitoring can be achieved assisted by the means of the EOVs covered by this project. Thus, there is a need worldwide to increase scientific-based management of natural resources and the widespread of standardized monitoring devices. The project NAUTILOS aims to fill the *in situ* observation gaps of ocean monitoring systems, which is essential to achieving the sustainable use of marine natural resources.

According to the Second World Ocean Assessment of the United Nations (UN, 2021), one of the main activities predicted to enhance the health status of the ocean is the improvement of global scientific understanding of the marine environment. This can be achieved also by increasing the scientific knowledge about the physical and biochemical systems in the ocean, and its response to climate change and anthropogenic activities. The ocean observations can be expanded through the development of "cost-effective and user-friendly sensors, along with mobile applications, the enhanced participation of citizens and the deployment of sensors on non-scientific ships… ,as well as enhanced ocean modelling capabilities on the global and regional scales" (UN, 2021). These aims overlap with the activities developed in the NAUTILOS project, evidencing its relevance to the science-based management of the ocean.

The current remote sensing observation systems in Europe have some gaps in modelling and empirical data for some variables, especially in the deep ocean environment. The satellite data is obtained at a large scale, while *in situ* observation needed to validate the satellite data remains lacking in many places. Thus, a significant improvement in forecasting and monitoring systems is expected by comparing the ground truth of this remote sensing data for calibration and continuous monitoring provided by the sensors being developed. Therefore, the development of new technologies and the widespread use of cost-effective marine sensors would represent a massive increase in the acquaintance of data at a local level and in a shorter time span, even though they should be done under the lowest environment impact possible. As a result, these advances aimed by the project NAUTILOS would greatly increase the reliability and volume of data generated from these natural processes, allowing researchers to produce more robust modelling and significant advances in the field of marine sciences.

2.3. Location of the Project

During the development phase, the NAUTILOS activities will be carried out by the 21 partners belonging to the NAUTILOS Consortium (Table 1). The NAUTILOS partners are all over Europe and they are involved in all stages of the project, from development till demonstration.

In addition, the demonstration phase of the NAUTILOS Project will be carried out in different locations within European Maritime Zone, such as the Mediterranean Sea, Atlantic Ocean, North Sea and Oceanic Islands, including environmentally sensitive areas and international waters. The list of places where the demonstration phase will take place is provided in Table 2. Most of these places are known for their environmental relevance, either for their high biodiversity and endemism or to represent an important habitat for endangered species.

Seeing that the magnitude of the impacts identified so far is not expected to transcend local boundaries and these sensors are designed to increase monitoring of these environmentally significant areas, it is concluded that the location of the demonstration phase should not be an obstacle to the normal development of the activities. On the other hand, the fact that some activities will be carried out in marine protected areas (such as Portofino cetacean's sanctuary, Azores and Península de Valdez), raises concern about the reduction of the impact caused by the demonstration phase, in particular if these areas are the habitat of threatened populations. Therefore, special attention must be given when carrying out activities close to areas with outstanding ecological importance or environments already subject to anthropogenic pressure, following the measures and required permissions discussed in the Deliverables 13.5 and 13.3.

Table 1: List of the partners engaged in the NAUTILOS Consortium.

Participant organisation name	Acronym	Country
Consiglio Nazionale delle Ricerche (coordinator)	**CNR**	**Italy**
Hellenic Centre for Marine Research	HCMR	Greece
Norsk institutt for vannforskning	NIVA	Norway
Suomen ympäristökeskus	SYKE	Finland
Institut Francais de Recherche pour L'exploitation de la Mer	IFREMER	France
Centre National de la Recherche Scientifique	CNRS	France
ETT Spa	ETT	Italy
EdgeLab s.r.l.	EL	Italy
Universidade do Algarve	UALG	Portugal
NKE Instrumentation	NKE	France
Aquatec Group Ltd	AQUATEC	UK
SubCtech - Subsea technology for the Marine Environment	SCT	Germany
Centro de Engenharia e Desenvolvimento (Associação)	CEiiA	Portugal
CoLab +Atlantic (Third Party)	COLAB	Portugal
Haute Ecole Spécialisée de Suisse Occidentale	HESSO	Switzerland
Centre Suisse d'Electronique et de Microtechnique SA	CSEM	Switzerland
University of Ljubljana, Faculty of Electrical Engineering, Laboratory of microsensor structures and electronics	UL-FE	Slovenia
Fundação EurOcean	EUROCEAN	Portugal
Deutsches Forschungszentrum für Künstliche Intelligenz	DFKI	Germany
Universita Della Calabria, Department of Environmental Engineering	DIAM	Italy
Instituto do Mar	IMAR	Portugal
Europroject	EP	Bulgaria

Table 2: Locations of the demonstration phase.

Demonstration	Location
Fisheries Observing Systems	Adriatic Sea; French waters
Aquaculture Observing Systems	Coastal Norway and Greece
Marine Mammals Monitoring Systems	Swedish Sound/Kullaberg/Lysekil waters; Italy: Portofino MPA cetaceans' sanctuary
Platforms of Opportunity	Coastal Norway: Trollfjord; Gulf of Finland; Cretan Sea
Argo Platform	Mediterranean Sea, up to 2000 m
Animal-borne Instruments	Portugal: Azores islands; Argentina: Valdes Peninsula

2.4. Environmental Impact Assessment Process

In essence, EIA is a systematic process that aims to examine in advance the consequences on the natural environment from the development of an activity. The objective is to prevent possible significant impacts by assessing the activities predicted in a systematically, holistic and multidisciplinary way (Glasson & Therivel, 2013). This assessment is carried out following consecutive steps as outlined in

Figure 1, which can slightly vary depending on the current legislation.

Regardless of the country, the fundamental steps in EIA can be summarized as the project screening, the scoping stage, presentation of the partial results, collecting feedback from the stakeholders, and re-evaluating the impacts and mitigation measures. Hence, guaranteeing that the environmental considerations are properly taken into account during the decision-making process, contributing to a more sustainable development (EU, 2021).

In fact, the developer of a project has to provide to the authority responsible for approving it a report that must include the essential information necessary for the assessment (EU, 2021). Morgan (1999) claims that very often the aim of an EIA is contained in some form of environmental policy stated, either as part of the current legislation or as guidelines in non-legal systems. In this EIA, the current legislation will be taken as a basis, and guidelines will be provided for the development of the activities within the project NAUTILOS.

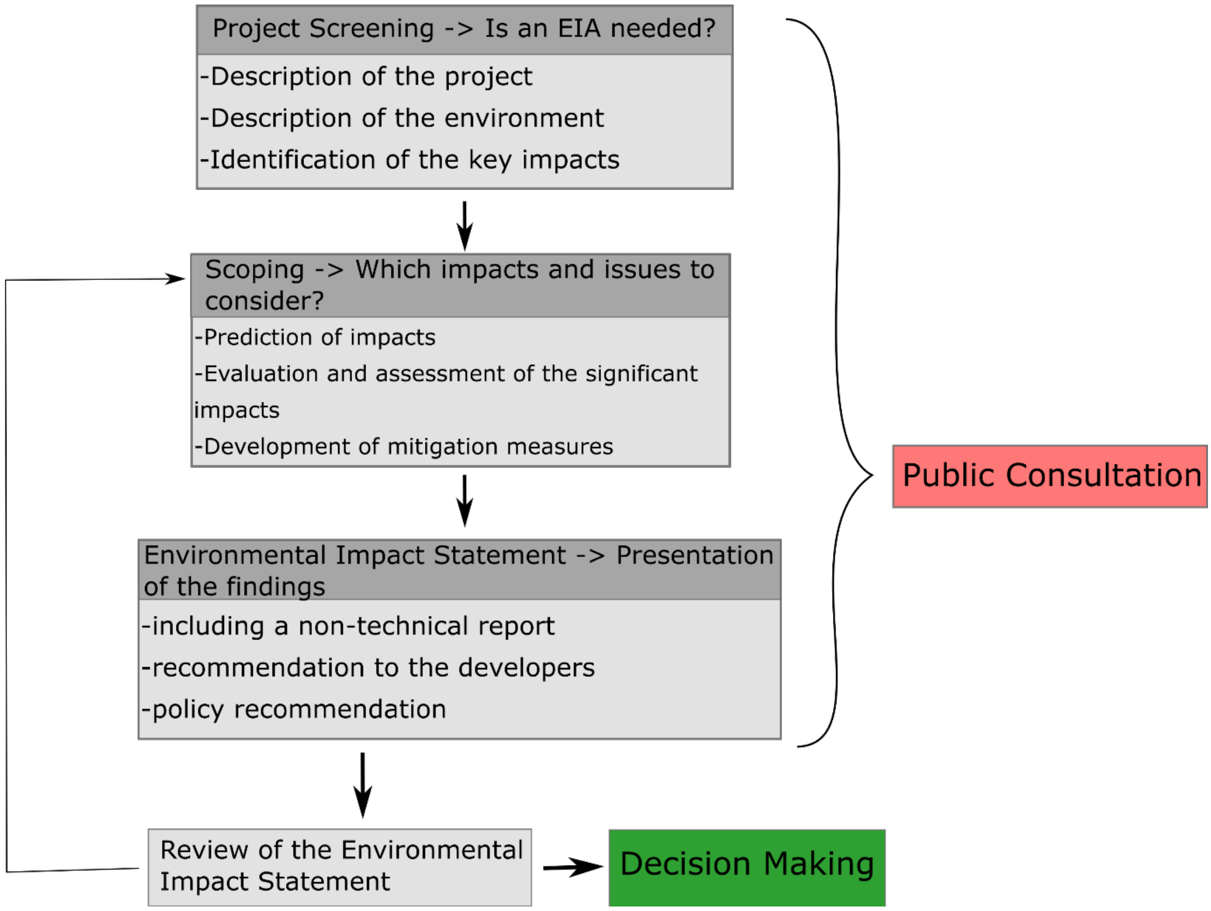

Figure 1: Scheme of the stages of the process to produce an Environmental Impact Assessment.

2.5. Screening

A standard practice in EIA and recommended by many authors (Morgan, 1999) is the screening phase which consists of the first stage of the assessment. A screening mechanism is required to initially identify adverse environmental impacts and effects that are not fully known (Glasson & Therivel, 2013). Followed by a detailed evaluation, the projects with few significant impacts screened out are allowed to proceed without further investigation, while those above the threshold established by the current legislation or carried out in sensitive areas are required to produce a more robust environmental impact assessment.

Therefore, the screening process was conducted to identify the possible impacts originated from the activities in the NAUTILOS project. Usually, there are two main approaches to screening, either the use of a threshold or a case-by-case approach. The orientations to this screening were given in the Annex III mentioned in the paragraph 3 from the article 4 of the Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 on the assessment of the effects of certain public and private projects on the environment which states that:

"*Where a case-by-case examination is carried out or thresholds or criteria are set for the purpose of paragraph 2, the relevant selection criteria set out in Annex III shall be taken into account.*"

Therefore, in order to evaluate if the sensors should be subjected to a robust environmental impact assessment, a spreadsheet was prepared based on the selection criteria presented in the Annex III collecting information regarding:

1. the characteristics of project;
2. the location of project;
3. type and characteristics of the potential impacts.

This information included materials used in the manufacturing, location where the equipment will be deployed, information about the equipment and technology, emission of residues and life cycle of the devices. A copy of the spreadsheet with the respective answers can be found in the Appendix 2 of this document. The spreadsheet was sent to the partners developing each sensor to provide information during the development and demonstration phases, as well as at the end of life of the devices. Information about the materials used in the construction of the prototypes and possible pollution impacts reaching the natural environment was provided through a spreadsheet. After examining the information provided, additional information was required for some equipment on a more detailed explanation about the nature of the impacts described in the spreadsheet, so the people in charge of these sensors were contacted for clarification.

Table 3: Example of the spreadsheet questionnaire sent to the developer of each equipment to collect information about the screening process.

Screening Questionnaire
Location
Location where the equipment will be deployed
Size and design of the equipment
Cumulation with other known existing and/or approved projects
Presence of nature reserves or very sensitive environmental areas nearby
Information about the equipment
Description of the composition and quantity (approximated) of materials
Use of biodegradable materials?
Explanation of the sensor technology used / sampling technique
Type of battery used
Anti-fouling strategy
Photo or schema of the design of the sensor
Emission of residues, pollution, nuisances (if possible include intensity and probability of these impacts).
Heat
Noise pollution
Radiation
Electricity
Light
Release chemicals substances
Any other significant negative impact?
Possible alternative to these impacts?
Life cycle of the equipment
Deployment
Operation / Demonstration
Recovery-at-sea strategies
Disposal and recycling alternatives
Risk of accidents / failing to recover the equipment
Measures to mitigate in case of loss
Legislation
Do you have to follow a national/international legislation to develop the sensor? Which one?

2.6. Evaluation Methods

With the purpose to identify the nature of the impacts at all the stages of the development, the method adopted was based on the approach proposed by Bonvoisin *et al.* (2012) which consisted of scanning the possible impacts since the extraction and manufacturing, passing through the proper use, until the end of life. This task-oriented methodology takes to account the possible impacts from the deployment, the operation and maintenance, and long-term dismantling of the devices.

Therefore, the environmental impacts from the sensors were assessed following the consecutive steps: identification, evaluation and magnitude comparison, prevalence, duration, risk, importance, and possible mitigation (Mongkol, 1982). Then, general recommendations are given in this EIA which can be applied to all the sensors, since some impacts are expected in most sensors, although to a different extent. Finally, policy recommendations will be given with the objective to reduce the negative impacts caused by the sensors on the marine environment.

In the end, a comparison between the positive and negative impacts will be presented, considering both the benefits and the drawbacks expected from the development and demonstration of these marine sensors.

Table 4: List of the 14 sensors being developed in the NAUTILOS project. The variables measured are described and the main development compared to the current state-of-art of these technologies.

Marine Technologies Demonstrated in NAUTILOS	Variables covered	Main Innovation Potential	Reference
Sensing and Sampling Technologies			
Fluorometric Sensors/dissolved oxygen	Dissolved Oxigen	Measurements can be expanded to additional variables (e.g. mercury). Fluorescent O2 sensors may be reduced both in terms of sizes and costs while preserving high precision measurements resulting in a very promising approach for plenty of oceanic applications.	ST3.1.1
Dissolved Oxygen and Fluorescence Ser	Dissolved Oxigen, Chlorophyll	The development of EAF sensors for chl-a and DO will contribute to several GES descriptor, will allow a better environmental characterization of the fishing area, and will increase knowledge on the spatial distribution of fishery resources.	ST3.1.2
Downward-looking multi/hyperspectral and laser induced fluorescence sensors and cameras	Sea surface temperature, laser induced chlorophyll-a fluorescence, ocean colour	The deployment of downward looking sensors on UAVs and ships will greatly increase the spatial scale of observations of important ocean variables that will help to improve the large satellite remote sensing dataset.	T3.2
Passive broadband acoustic recording sensor for noise monitoring	Marine environmental sound recording of natural and anthropogenic origin	The addition of edge computing to optimise and update sampling will allow instruments to be deployed by relatively unskilled users in a wide variety of settings without advanced knowledge of the sounds to be monitored. Source localisation will provide the capability to track mobile sound sources.	ST3.3.1
Passive acoustic event recorder (porpoise & dolphin clicks for abundance estimation)	marine mammal sound detection	The improved instrument will allow widespread use on vessels of opportunity by fishermen, scientists, extending the range of passive cetacean monitoring, and improving observation statistics in regions with sparsely marine mammal populations.	ST3.3.2
Active Acoustic Profiling Sensor	Suspended particle concentration / distribution	The improved instrument will be able to operate in a much wider range of suspensions, with increased tolerance of bubbles. It will extend its coverage range from just the sand fraction to fine sediment particles, as well as adding the capability to measure settling velocity and assess particle density.	T3.4

Marine Technologies Demonstrated in NAUTILOS Sensing and Sampling Technologies	Variables covered	Main Innovation Potential	Reference
Carbonate system/ocean acidification sensors	pH, pCO2, Total Alkalinity, CO3	Development of lab-on-chip spectrophotometric sensors for pH and total alkalinity alongside conventional pH and pCO2 sensors accepted by the carbonate chemistry oceanographic community on ships of opportunity and other autonomous platforms to demonstrate the potential for these sensors to be used on a widespread basis on various ocean observing platforms at various ocean depths.	T4.1
Silicate Electrochemical Sensor	Silicate concentration	Modification to the mechanical design will improve monitoring frequency of the sensor and enhance temporal and spatial coverage of Si concentration allowing to observe the high variability and a better understanding of its cycle and connection with Carbon cycle.	T4.2
Submersible Nano- and Microplastics Sampler	Concentrated suspended matter samples	The autonomous instrument which can be easily deployed in the water column allows the sampling at a predetermined depth. Beside its rough design and cost-effective deployment, the system also allows immediate size fractioning of the sample. Hence, significant more oceanic plastic pollution data can be collected in a more cost-effective and reliable way.	T4.3
Low-cost Microplastic sensors based on selective Nile Red staining and fluorescence detection	Concentration and characterisation of Microplastics	Newly developed sensor will allow a faster and accurate on-site quantification of micro-plastics in the µm and sub-µm range, providing valuable data on the presence of nano-plastics in water, currently underestimated. The sensor will increase the capacity of observing platforms to measure micro-plastics in real-time.	T4.4
Deep Ocean CTD	Conductivity, temperature, pressure (salinity and density der.)	Development of a cost-efficient, lightweight CTD system design, including the latest solid-state sensors, electronics and data processing. Pursued open source policy will allow CTD systems to be used widespread within the Citizen Science Community	T4.5
Deep ocean low-level radioactivity senso	Marine radioactivity	The upgraded in-situ low level radioactivity sensor of NAUTILOS will be easy integrated into existing ocean observation systems (as plug and play detection system) providing long term operation (low consumption and operation) measuring from the very low concentration of isotopes (such radioactive gases). smart	T4.6
Animal-borne Instruments	perature, salinity, fluorescense, ox	Capitalize on the MEOP initiative and Argo floats initiative via ERC REFINE. Deployments, e.g. in the Azores islands, to serve as a precursor to collaboration expansion to many regions worldwide and create a worldwide network of supplemental in-situ marine data obtained from animals for the wider community. Support policy for the protection of species, habitats, oceans.	T5.5

2.7. Scoping

After receiving the information from each partner, the most significant impacts were identified for each sensor and will be addressed in the following sections as priority issues related to the impacts from the sensors. A complete description and mitigation measures will be provided for the significant impacts, in addition to the measures to mitigate the environmental risks proposed in the Deliverable 13.5, throughout this document and during the next steps of the T11.3. It is understood that all projects can improve their strategies to reduce their impacts, by refining the methods and techniques to reach a level where minimal negative impacts are expected from the development of scientific research (UNCLOS, 2010).

Briefly, the significant impacts identified consist of some toxic compounds used during construction, the end of life of batteries and possible leaking issues, the composition of antifouling paints, the disturbance of marine animals during the attachment of animal-borne sensors, loss of devices in the water, waste created by the use of the sensors, an eventual lead-based solder used during the manufacturing, and possible noise pollution during the demonstration phase close to sensitive areas. Although the magnitude of these impacts is presumed to be low when compared to the impacts produced by the projects listed in the Annex I and II in the Directive 2011/92/EU, a more detailed description will be provided, and mitigation measures proposed to reduce the impacts to the minimal levels possible.

3. Specific recommendations

As some sensors present some features of their own, some impacts that are expected in specific sensors will be described in this section, followed by the respective mitigation measures.

3.1. Animal-borne sensor

The remote monitoring of animal behaviour using satellite tracking systems is an important tool for conservation, by providing information about how animals use dynamic seascapes (Godley et al., 2008). This geo-referenced data allow researchers to understand more about behaviour, physiology of animals, and the environments they use (McIntyre, 2014); hence, more effective management decisions can be taken to mitigate threats to these species. However, the use of animal-borne tagging systems can cause some negative effects on the tagged individuals, which must be addressed. McMahon *et al.* (2011) divide the potential impacts caused by animal-borne devices into four categories:

1. Capturing the animal.
2. The type of the device (shape, size and coloration).
3. The attachment method chosen.
4. The timing and duration of the device attachment.

The animal-borne instruments developed and integrated within the framework of the NAUTILOS project are expected to collect several geo-referenced variables, with emphasis on the innovative oxygen sensor. These two main types of tags developed are expected to be attached to elasmobranchs and marine mammals, in the Azores islands (Portugal) and the Valdes Peninsula (Argentina), respectively. These two areas have remarkable environmental relevance, being considered marine hotspots and critical habitats for many species. Therefore, the procedure to attach these devices to wild animals in these sensitive areas should be done aiming at the smallest level of disturbance possible. A preliminary evaluation of these technologies has been performed and some mitigation measures already adopted by the experienced professionals carrying out this task in the field (Deliverable 13.3).

Regarding the tags designed for sharks and manta rays, this novel tag relies on a non-invasive method to attach the tag to the animals, and it has been already identified measures adopted to minimize the impact caused on these organisms. Firstly, the animals are attracted with food. Then, the attachment of these devices is done by placing a line between the head and the pectoral fins of the animals (Figure 2) which can be done from a boat (A) or by a diver (B). In the case of the six-gill sharks, the animals are fished, tagged and immediately released to reduce retention time to the minimum necessary. These animals can drag the devices for a maximum of 72 hours (typically 24 hours). Finally, the metal connector in the line oxidizes releasing the tag from the animal and allowing the device to float to the surface. The ARGOS satellite in combination with the VHF transmitter communicates the position to the boat to recover the device. It has been reported a recovery success rate around 99% using this method.

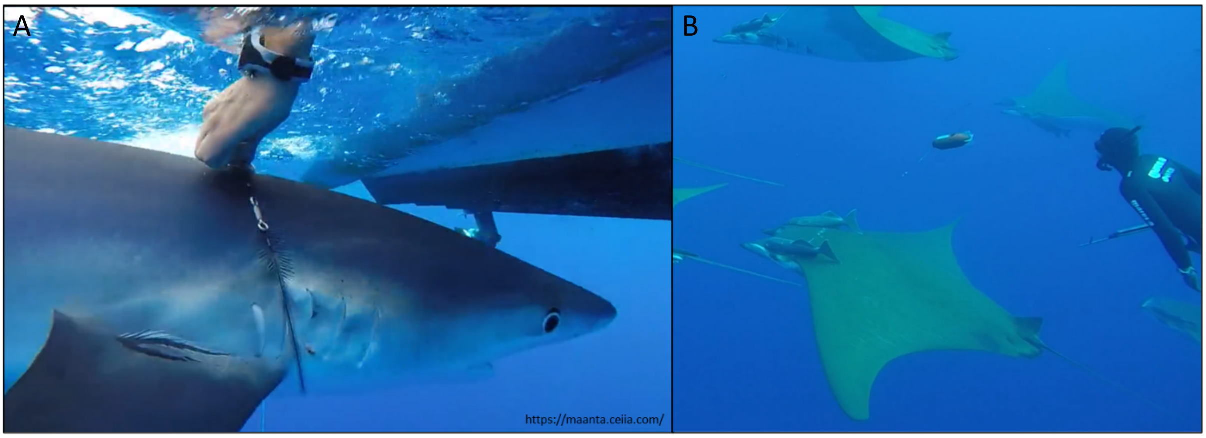

Figure 2: Deployment method of the animal-borne tag for elasmobranchs. A: tag deployed from a boat. B: tag deployed by a diver. Pictures were extracted from videos on the website https://maanta.ceiia.com/ accessed on 06/07/2022.

The use of non-invasive methods to attach tags in marine animals is preferred, in contrast to other methods that rely on affixing the tag in the musculature or cartilaginous tissue using a tagging lance (Hammerschlag et al., 2011). The approach that allows free-swimming animals to be equipped without any form of restraining is indicated in this EIA as the most appropriate practice. Moreover, it is discouraged methods that involve temporarily removing the sharks from the water or using bolt systems to mount the tag on the animal. The adoption of these more invasive methods has some negative impacts on the animals. For instance, edemas and injuries where the tag penetrates the tissue, making the attachment location subjected to bacterial infections and other parasites (Hueter et al., 2007). This reaction to a foreign body or the damage caused by the attachment process can lead to tissue degradation or more serious physiological effects which ultimately can affect the ecological fitness of tagged animals.

Furthermore, another main impact caused by the attachment of tags in marine animals is the change in the hydrodynamic drag of the individual, resulting in decreased swimming efficiency and consequently a higher energetic demand by these animals while carrying the device (Hammerschlag et al., 2011). It has been recorded abnormal swimming patterns in different species after the deployment of other animal-borne tags which can be caused either by the stress from the attachment or until the animal gets used to the drag of the device (Gleiss et al., 2009). In the case of this new technology, the stress response observed from the tagging procedure was minimal (Fontes et al., 2018), since this method does not require restraining or manipulation of the animals. Regardless, the drag and lift forces continue to act until the device is released (Grusha & Patterson, 2005). Although this alteration in the buoyancy and dragging through the water column may not influence the displacement of large organisms (Gleiss et al., 2009; Clive R McMahon et al., 2008), it might not be suitable for some species and age groups (Grusha & Patterson, 2005).

It is clear that animals carrying a device spend more energy, but an acceptable threshold has to be established based on empirical data to orient ethical decisions (Wilson & McMahon, 2006). Since Grusha & Patterson (2005) advocates that the swimming power of a species of ray allows it to carry (without being energetically significant) an animal-borne satellite tag that increases its normal drag up to 5%, we assume that the potential energetic costs associated with carrying a device until this threshold should be understood as acceptable in this project.

For that reason, to guarantee that undersized individuals are not instrumented in the field, a "tag to animal drag ratios" has been estimated by using computational fluid dynamic (CFD) models to simulate fluid flow over tagged animals and towed tags. The water flow was simulated for velocities between 0.5 and 4 meters per second for 2.5 and 3.0 meters disc width devil ray and for 2.5, 3.0 and 3.5 meters blue sharks. Then, it was calculated the tag associated drag increase as the percentage of drag added by the tag in respect to body drag for each combination of water velocity and body size (Fontes et al., 2022). As a result, the minimum size acceptable for each species to be tagged is established.

Due to the fact that the tag for sharks and rays has been already subjected to several measures to evaluate and reduce the impact of the device, the negative impact of carrying this equipment in larger species of sharks and rays is seen as not significant, also considering the remarkable benefits it brings to the conservation of these populations. In case the target individuals for tagging lie under the threshold indicated, the miniaturization of the tag and streamlining of the fairing should be done in order to reduce the impact on the animal's behavior and well-being (Braun et al., 2022).

Moreover, another factor that must be considered is the color of the device. Some authors report that the color of the device can affect the survivorship of the tagged individuals by excessively exposing them, resulting in either reduced success in acquiring food or making them more susceptible to predation (Wilson & McMahon, 2006). Therefore, they recommend that the devices should follow the color and shape of the tagged species. On the other hand, a more visible device is easier to be located floating on the sea, reducing the chances of the equipment being lost.

Seeing the duration that this equipment stays attached to the animals, we assume that the coloration should not significantly compromise the survivorship of the animals. However, bright colored tags should be avoided in order to not influence the relationship between predator and prey, in particular red colored tags (Hawkins, 2004). To sum up, we recommend more cryptic coloration for the devices in a way that does not reduce their capacity to be visible when floating on the surface. For example, a light that turns on when out of the water. For longer deployments, special attention should be given to this issue, by assessing if the animals are able to find food normally after being tagged (which usually can be done with the data acquired by the tag itself).

The devices developed to track southern elephant seals (*Mirounga leonina*) also have some concerns regarding the well-being of the animals while they carry the device. Aspects of the design such as mass and shape, as well as the part of the body of the animal for deployment, should be analyzed carefully (Hawkins, 2004). Nevertheless, it has been observed that the usually attached data-logger devices to elephant seals have a low impact on mass gain and survivorship of these animals on both short and long-term scales (Clive R McMahon et al., 2008). Although the drag caused by the device is not of great concern in this species since it is a large marine animal, the procedures to attach the tags may cause significant distress in the tagged individuals as tags will be glued externally using fast setting araldite on elephant seal fur (Figure 3).

Figure 3: Example of the device to track southern elephant seals. Picture courtesy from Christophe Guinet.

However, if not recovered the tags will fall out during the moult (the renewal of the fur) preventing any long-term impediment of the animal. This way, a tag can never remain attached on a southern elephant seal more than 12 months if deployed just after they moult. The combined weight of the devices and glue is approximately 0.9 kg, i.e., 0.26% of the mean departure weight of adult female elephant seal (338 ± 65 kg).

While there is a large number of ecological studies using animal-borne tags to track the movements of wild animals, there is a relatively low number of studies addressing the impact of the deployment of these devices (McIntyre, 2014). Many authors discuss the need for more studies quantifying the effects of animal-borne tags on the energetic cost, fitness and survival of free-ranging animals carrying these devices (Gleiss et al., 2009; Hawkins, 2004; C. R.

McMahon et al., 2011; Wilson & McMahon, 2006). Note that the aim of these studies is not to criticize the research performed, but to suggest better practices to improve the methods in order to reduce the negative impact of animal tagging.

In many cases, the data to evaluate the effects of handling and attaching these devices to wild animals already exists; however, it seems that it has not yet been analyzed in terms of assessing the impacts of the tagging process and presented in a quantifiable way for ethical considerations (C. R. McMahon et al., 2011). Therefore, it is recommended that researchers evaluate empirically the effects of these devices on the tagged organisms; hence, providing information that can be useful for other researchers to reduce their impact while conducting surveys tracking animals in their natural environment. For instance, using variables collected by the tags (such as frequency of deep dives, directional persistence, speed, drag and others) to compare how long the tagged animals take to return to normal swimming patterns and diving modes. The comparison of different tagging methods to the one developed within the scope of NAUTILOS project, would provide directions to future remote sensing studies about the less invasive tagging methods in these free-swimming animals.

4. Main impacts, mitigation, prevention and management of potential adverse effects

4.1. Materials

Through the course of the screening phase, the developers' groups were inquired about the materials used in the manufacturing of the new sensors and samplers. Although many sensors were not completed yet, the main materials expected to be used were listed. Seeing that these devices will be deployed in the ocean or remain on board, it is essential that these technologies have a degree of protection against oxidation from the marine environment. Most of the devices are going to be made of titanium, aluminum, stainless steel, resins and polymers. So far, no biodegradable materials were reported in the construction of these devices. We recommend that materials with a higher potential to have a negative impact on the marine environment be replaced by biodegradable similar materials, when it does not compromise the performance of the device. This negative potential impact is understood either when the material releases harmful substances into the seawater or when it relies on high impact activities to obtain these elements.

Since no device is expected to be left permanently in the marine environment under normal circumstances, the use of trace metals and very contaminating materials raise the concern in case of accidental loss of these devices or due to contact with the seawater releasing harmful substances into the marine environment. In this case, it is strongly recommended that substitutions in the design of the sensors are made aiming either to minimize the risk of loss in extreme events or improve housing technology by preventing the contact of these toxic substances with the environment.

Following the guidelines from the Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, the development of marine monitoring sensors and samplers falls under the category "*monitoring and control instruments*" listed in the Annex I. Thus, the use of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs), polybrominated diphenyl ethers (PBDEs) are highly controlled and the use is strongly discouraged in this project. When the adoption of these restricted materials is essential to the development of the new sensors, the levels permitted by law are listed in the Annex II with the maximum concentration values tolerated by weight in homogeneous materials listed in the Table 5 (these maximum concentration values include, *inter alia*, surface coatings).

Table 5: Maximum concentration values tolerated are given in percentage of weight in homogeneous materials of these hazardous substances used in electrical and electronic equipment (Directive 2011/65/EU)

Restricted substance	**Maximum concentration tolerated (% of weight in homogeneous materials)**
Lead	0.1%
Mercury	0.1%
Cadmium	0.01%
Hexavalent chromium	0.1%
Polybrominated biphenyls (PBB)	0.1%
Polybrominated biphenyls ethers (PBDE)	0.01%

Moreover, the use of lead in solder in electrical and electronic equipment is also restricted (Directive 2011/65/EU). There are other alternatives to this practice that are far less toxic, although might contain lead to some extent. Thus, the adoption of lead-free solder is recommended in this project, since the harmful effects of lead is a well-known and the hazardous waste generated by this practice requires special discard.

4.2. ADOPTION OF BIODEGRADABLE MATERIALS

Seeing the issues associated with material selection, there is a balance between efficiency, costs, and ecological footprint. The materials chosen to compose the devices must guarantee the proper functioning of these sensors and samplers to provide a long-term and precise monitoring of the EOVs to reach the goals of this project. However, it is strongly discouraged the use of materials that cause substantial pollution or other significant impacts on the marine environment.

When the use of materials that constitute a major threat to the marine environment is inevitable, the recommendation is to isolate these parts from the marine environment preventing their release into the seawater. The decision regarding the materials should be done prioritizing those which are not harmful to the environment, bearing in mind that in case of loss due to extreme events, these devices will be subject to long-term degradation in the marine environment.

In Table 6 a list of harmful substances it is provided which the adoption is strongly discouraged in the manufacturing of the sensors and samplers of this project. In case the use of some of these materials cannot be replaced, it should be guaranteed that the concentration of these substances in the seawater around the sensors remains below the levels of Predicted No Effect Concentrations (PNECs) for naturally occurring substances. The PNECs values of the controlled substances can be found in the background documents "*Establishment of a list of Predicted No Effect Concentrations (PNECs) for naturally occurring substances in produced water*" (OSPAR Agreement 2014-05) (Appendix 1 – item 6).

Table 6: Substances potentially harmful when found in the seawater above certain concentrations.

Substance group	**Substances**
Metals	arsenic, cadmium, chromium, copper, mercury, lead, nickel and zinc, iron and barium
The monoaromatic hydrocarbons (BTEX)	benzene, toluene, ethylbenzene and xylene
Dispersed oil:	C7-C40 aliphatic hydrocarbons
16 US-EPA Polycyclic Aromatic Hydrocarbons (PAHs)	naphthalene, acenaphtene, acenaphtylene fluorene, anthracene, phenanthrene, fluoranthene, pyrene, benz(a)anthracene, chrysene dibenzo(a)anthracene, benzo (g,h,i)perylene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3,-cd)pyrene
Other PAHs	C1-naphthalenes, C2-naphthalenes, C3-naphthalenes, C1-phenanthrenes, C2-phenanthrenes, C3-phenanthrenes, dibenzothiophene, C1-dibenzothiophenes, C2-dibenzothiophenes, C3-dibenzothiophenes
Phenol/alkylphenols	phenol, C1-alkylphenols, C2-alkylphenols, C3-alkylphenols, C4-alkylphenols, C5-alkylphenols, C6-alkylphenols, C7-alkylphenols, C8-alkylphenols and C9-alkylphenols
Organic acids	formic acid, acetic acid, propionic acid, butyric acid, valeric acid, isobutyric acid and isovaleric acid and naphthenic acids.

The adoption of biodegradable materials during the development and demonstration phases is encouraged, also in the view of the decomposing process after the end of life of the devices. For instance, the use of eco-friendly buoys for mooring the sensors, that are not easily broken, are easy to recycle, and can secure their own buoyancy with increased durability. This is preferred in contrast to the conventional buoys made of foams and polystyrene which can be broken and pollute the marine environment.

4.3. DISPOSAL ALTERNATIVES

At the end of the life of these devices, the parts must be separated into types of materials and each substance need to have a proper destination, preferably recycling and reuse with the aim to close the industrial loop. The concept of "closing the loop" is when you turn goods that are at the end of the service life into resources for other products, reducing discard and the need for raw materials. The chemical separation of the materials, such as extracting different metals from electronic equipment, is a good example of how to reuse these obsolete devices and pieces in the industry.

Realistically, sometimes it is necessary to use some metals and resins in these devices that are not biodegradable substances. In these cases, the possibility to repair used devices must be guaranteed by the manufacturer. Thus, aiming for waste prevention created by the end of life of these sensors, the group working on the environmental impact assessment recommends the adoption of principles from Circular Economy, where the company in charge of the manufacturing of these products, also provides ways to reutilize parts, repair them and properly discard of used devices.

Usually, conventional waste management is driven by reducing the costs associated with collecting and disposal (Stahel, 2016). However, by boosting the remanufacturing and reuse of these devices, the negative environmental impact is significantly reduced, and the creation of waste is minimized. To reach this goal, the design of the sensors must be done in such a way that facilitates the repair and change of parts. This is the responsibility of the manufacturer to offer this type of service, which is the reuse, repair, remanufacture and properly discard of the devices produced by the company.

4.4. Lost at the sea

Although all devices are supposed to be recovered from the marine environment, in certain situations, such as extreme weather events and malfunction of the recovery system, some devices will probably fail to be recovered, thus remaining in the ocean to disintegrate. It is important to have these possible accidents in mind when building these devices and adopt mitigation strategies to minimize the impact caused by the loss of these devices at sea.

As mentioned before, it is imperative the adoption of biodegradable materials, when possible, to reduce the impact created in the marine environment by the decomposition of harmful materials, such as trace metals, persistent organic compounds and plastic, in case of loss. This measure would also reduce the overall impact created by the sensors by reducing the need for materials that can be toxic to the environment. In case the use of very toxic materials is essential in the design of a sensor, it is required that the responsible institution develop an environmental management plan, including a contingency plan for responding to incidents that can have a significant impact on the marine environment.

Moreover, it is required that the recovery systems have a backup to retrieve the devices from the water in case the normal recovery system fails. Therefore, it is recommended that all the sensors provide at least two strategies to recover the device from the marine environment. Note that, the development and adoption of this backup recovery system should not represent a higher impact than if lost at sea. This recommendation applies only to those sensors that are unmanned in the water column.

4.5. Batteries

One of the main impacts expected from the development of the sensors is regarding the batteries needed for energy supply. Although battery energy storage technologies are considered more sustainable alternatives to provide energy supply, there is a significant impact associated with this type of technology that needs to be addressed. The main impacts associated with this technology within the scope of the NAUTILOS project are hazardous substances possibly reaching the marine environment and the end of life of the batteries.

Currently, batteries are a promising alternative to provide power, they have a lower carbon footprint and can store significant amounts of chemical energy. Nevertheless, some drawbacks must be addressed in this technology. Some of the main environmental issues associated with the extensive use of batteries worldwide are metal pollution and the consumption of resources. The manufacturing and inappropriate disposal of batteries have the potential to pollute the air, soil and water bodies through the leaching of toxic metal nano-oxides, toxic gas release (e.g. hydrogen fluoride and cyanide) and the formation of dangerous degradation products from the electrolyte (Mrozik et al., 2021).

In fact, batteries rely on several materials inside their cells to charge and provide energy supply. For example, in the manufacturing of lithium-ion batteries, different elements are used such as lithium, nickel, copper, gold, silver, cobalt, tin, palladium, tantalum, neodymium, and carbon (CNBC, 2021). Special attention is given to cadmium compounds, lead and mercury inside batteries whose use is highly restricted. In fact, all these substances are mainly extracted through mining and can be very toxic (to a different extent) if released into the marine environment or not discarded properly. The electronic waste created from used batteries is flammable and toxic, thus cannot be dumped in landfills neither burned. However, the metals and critical materials inside the batteries are highly recyclable, they can be extracted from used batteries straight to reuse nearly infinity.

Some recycling companies recover more than 95% of nickel, cobalt, aluminum and graphite and around 80% of the lithium from used batteries, bringing these materials back to the supply chain. Thus, this recycling process helps to address the need for raw materials and society's reliance on newly mined elements to produce new batteries. Seeing that the demand for these raw materials is expected to peak in the next decades, the recycling process also contributes to significantly reducing the CO_2 emissions associated with the impact of obtaining raw materials, mainly due to mining activity itself and long transport (i.e. shipping to different continents for refinement and manufacturing).

Therefore, to minimize the impact of the use of batteries in the recently developed sensors and samplers the following recommendations are given. Firstly, these batteries must not release any chemical compound into the seawater, which can be guaranteed by a proper case to isolate the battery from the marine environment. Although this measure would not avoid contamination in case of an accident and/or loss of the device in the water, it would, however, avoid possible leaking from normal use of the devices.

In the light of the current crisis of the availability of metals to produce electronic devices, recycling battery technology is a promising and feasible solution to reduce the demand for mined materials. Therefore, it is required in this EIA that all the sensors and samplers that rely on batteries develop a strategy to recycle the used batteries, guaranteeing that the latter are collected, and have all fluids and acids removed from inside the cells, refined, and re-used in the industry. The recycling and storage procedures must follow the requirements described in the Annex III of the Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators. Even though the use of recycled substances from batteries can address the issues related to the end of life of batteries, it is still predicted that recycling alone cannot supply the demand for newly mined materials for batteries in the next decades.

In addition, it is recommended that the batteries used in the sensors are the types which contain fewer polluting substances, in particular mercury, cadmium and lead. The adoption of lithium-ion batteries or nickel–metal hydride is preferred in comparison to nickel-cadmium batteries due to the higher environmental impact from the latter (Rydh & Svard, 2003). As an alternative to battery energy supply, some marine sensors use the power of the boat or platform of opportunity to provide energy, for example adopting solar panels. These other alternatives have a lower impact when compared to fossil fuels technologies, and are recommended to reduce the impact associated with energy supply.

4.6. ANTIFOULING

In oceanographic autonomous sampling, one of the main issues that compromise the measurement accuracy and deployment longevity of marine sensors is biofouling (Manov et al., 2004). Biofouling is the settlement of macro and micro-organisms on submerged surfaces, and it has several problems associated with its prevention and the development of marine economic activities. Commonly, the antifouling strategies involve coating surfaces using toxic substances making them unsuitable for settlers (A. Terlizzi et al., 2001). However, these toxic compounds eventually reach the seawater, creating serious environmental problems, accumulating in the sediment and organisms, including economically important species (Tian et al., 2021). According to Terlizzi *et al.* (2001), there are three categories of antifouling paintings depending on the chemical properties of the paint matrix and the mechanisms involved in releasing toxic compounds. These coatings have different duration of paint life, but eventually all of them release toxic compounds into the marine environment.

The most widely used biocide to prevent biofouling accumulation is copper (Bloecher et al., 2021), which can be used in different forms, such as plates, tapes, external coats, and so on. Since most of the traditional methods require to maintain the concentration of the biocides above a threshold level (A. Terlizzi et al., 2001), it led to copper emissions to different extents, which can be a threat to non-target species due to accumulation. Therefore, there is a need for the adoption of less toxic and more cost-effective antifouling systems in marine monitoring.

Therefore, when the sensor requires an antifouling strategy, we do not recommend the adoption of technologies that release significant amounts of toxic substances in the ocean, such as oxides of lead, arsenic, mercury, copper or the globally banned tributyltin. On the other hand, we recommend technologies more environmentally safe based on the low toxicity or non-toxicity antifouling agents and materials. For instance, ultrasonic, electrical and radiochemical technologies (Matsunaga et al., 1998), low frequency sound waves (Branscomb & Rittschof, 1984), and proteolytic enzymes inhibiting larval adhesion. Silicon technology is also a feasible alternative which could be easily removed by periodic cleaning operations (Antonio Terlizzi et al., 2000).

The eco-friendly alternative for antifouling strategies can be divided into bionic and non-bionic. Where the bionic antifouling technologies mainly include simulated shark skin, whale skin, dolphin skin, coral tentacles, lotus leaves and other biological structures. In comparison, non-bionic antifouling technologies mainly include protein resistant polymers, antifoulant releasing coatings, foul release coatings, conductive antifouling coatings and photodynamic antifouling technology (Tian et al., 2021).

4.7. Noise pollution

Although no sensor has reported an expected release of acoustic energy with significant amplitude to impact the local fauna, it is understood as a possible impact from the activities predicted within the scope of the project during the demonstration phase. Thus, this possible impact will be described in this section and recommendations will be given, especially for sensitive areas with presence of species sensible to noise, such as cetaceans.

The sound has a higher propagation velocity in the water than in the air; hence, the marine environment is highly susceptible to noise pollution. Many species rely on sound for different aspects of their biology, for example communication, orientation, prey capture, predator avoidance, and reproduction. Numerous fishes (more than 800 species) are known to depend on sounds for vital activities, as well as some invertebrates. Marine mammals are the species with more information about the dependency on sound for different aspects of their biology, with emphasis on the family Cetacea. Some adverse effects expected in these animals are behavioral changes, hearing loss, physiological stress, masking natural sounds, and even death (Au and Hastings, 2008).

Some activities predicted within the NAUTILOS project have the potential to disturb the acoustic environment temporarily, for example the engine of boats and unmanned vehicles, as well as the functioning of some sensors. If the amplitude of the sound produced by these equipment is significantly high and close to sensitive areas, we suggest that measures are taken to reduce the noise from the source. Moreover, the range of frequencies used by cetacean species is listed below. Thus, when demonstrations are carried out in the habitat of threatened populations, it is essential that the noise produced does not lie in the frequency range used by these animals as the ones listed in Table 7.

Table 7: Range of frequencies used by cetacean species.

Functional Group	Estimated auditory bandwidth	Species	Species Common Name
Low-frequency cetaceans	7 Hz to 22 kHz	Balaenoptera acutorostrata Balaenoptera borealis Balaenoptera physalus Balaenoptera musculus Eubalaena glacialis Megaptera novaegliana	Minke whale Sei whale Fin whale Blue whale North Atlantic Right whale Humpback whale
Mid-frequency cetaceans	150 Hz to 160 kHz	Delphinapterus leucas Delphinus delphis Globiocephala melas Grampus griseus Hyperoodon ampullatus Lagenorhynchus acutus Lagenorhynchus albirostris Mesoplodon bidens Mesoplodon europeus Mesoplodon mirus Orcinus orca Pseudorca crassidens Physeter macrocephalus Stenella coeruleoalba Tursiops truncatus Ziphius cavirostris	Beluga Short-beaked common dolphin Long-finned pilot whale Rissos dolphin Northern bottlenose whale Atlantic white-sided dolphin White-beaked dolphin Sowerby's beaked whale Gervais beaked whale True's beaked whale Killer whale False killer whale Sperm whale Striped dolphin Bottlenose dolphin Cuvier's beaked whale
High-frequency cetaceans	200 Hz to 180 kHz	Phocoena phocoena Kogia breviceps	Harbour porpoise Pygmy sperm whale

The cumulative effect of noise is also a concern for the sensors that will be deployed in places where there is already significant noise pollution. Regarding the chronic exposition to sensitive populations of marine mammals, the effects of noise vary depending on the intensity and duration, ranging from habitat reduction and communication breakdown to physical damage (Slabbekoorn, 2019). Since no sensor is supposed to cause such an impact on the acoustic environment, these remarks are more in the ambit of vessels and persistent noise sources that eventually are used during the demonstration phases. The precautionary principle is recommended when carrying out activities in sensitive areas, such as the temporary cessation of the activities and turning off the engine of the boat when a group of cetaceans is observed close to the area.

5. Final considerations

Considering the justification of the project, the benefits it will bring by filling the observational gaps and the data acquaintance to better management of the marine and coastal environment, it is concluded that the negative impacts caused by the project NAUTILOS are small when compared to the positive impacts. Thus, this document recommends the continuation of the project without major restrictions.

Moreover, when compared to other projects that are compulsorily subjected to a robust environmental assessment by the Directive 2011/92/EU, such as crude-oil refineries, thermal power stations, construction of express roads, waste disposal installation and others, the impact predicted from the development and deployment of 14 marine sensors is insignificant.

Nevertheless, it is still imperative that the mitigation measures proposed for impact reduction are adopted, bringing the levels of the impacts identified to the lowest possible. Further investigation is recommended in order to collect feedback from the stakeholders, and more detailed information to regard the significant impacts and the feasibility of the mitigation measures.

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7. Appendix 1 – References And Related Documents

ID	Reference or Related Document	Source or Link/Location
1	Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment Text with EEA relevance	*https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011L0092*
2	Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment Text with EEA relevance	*https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014L0052*
3	Code of Conduct for Marine Scientific Research Vessels International Ship Operators Meeting	*https://www.irso.info/wp-content/uploads/International_RV_Code_final.pdf*
4	Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment Text with EEA relevance	*https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32011L0065*
5	Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) Text with EEA relevance	*https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0019*
6	Background Document Establishment of a list of Predicted No Effect Concentrations (PNECs) for naturally occurring substances in produced water (OSPAR Agreement 2014-05)	*List of substances*

8. Appendix 2 - Screening Table Filled

Sensor	**Fluorometric Sensors/dissolved oxygen**
Reference	**ST3.1.1**
Location	
Location where the equipment will be deployed	Mediterranean Sea, Atlantic Ocean
Size and design of the equipment	Demonstration on fishing vessels / 20mm Ø x 90mm
Cumulation with other known existing and/or approved projects	No
Presence of nature reserves or very sensitive environmental areas nearby	No
Information about the equipment	
Description of the composition and quantity (approximated) of materials	PMMA, Titanium, Cupronickel, Pd-TFPP
Use of biodegradable materials?	No
Explanation of the sensor technology used / sampling technique	Fluorescence measurement and Quenching of IR luminescence
Type of battery used	none
Anti-fouling strategy	Passive protection
Photo or schema of the design of the sensor	3D diagram
Emission of residues, pollution, nuisances	
Heat	No
Noise pollution	No
Radiation	No
Electricity	No
Light	LED (blue) and fluorescence (orange-red)
Release chemicals substances	No
Any other significant negative impact?	No
Possible alternative to these impacts?	No
Life cycle of the equipment	
Deployment	Mediterranean Sea, Atlantic Ocean up to 600 m depth
Operation / Demonstration	DO and Fluorescence Sensors integrated on fishing vessels
Recovery-at-sea strategies	IFREMER and CNR teams
Disposal and recycling alternatives	3 sets will be manufactured in NAUTILOS project
Risk of accidents / failing to recover the equipment	Sensor damage (broken) during deployment
Measures to mitigate in case of loss	Provide robust sensor protection
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	No

Sensor	Dissolved Oxygen and Fluorescence Sensors
Reference	**ST3.1.2**
Location	
Location where the equipment will be deployed	Mediterranean Sea, Atlantic Ocean
Size and design of the equipment	Demonstration on fishing vessels
Cumulation with other known existing and/or approved projects	No
Presence of nature reserves or very sensitive environmental areas nearby	No
Information about the equipment	
Description of the composition and quantity (approximated) of materials	PMMA, Titanium, Cupronickel
Use of biodegradable materials?	No
Explanation of the sensor technology used / sampling technique	Fluorescence measurement and Quenching of IR luminescence
Type of battery used	Lithium Battery
Anti-fouling strategy	Passive protection
Photo or schema of the design of the sensor	3D diagram
Emission of residues, pollution, nuisances	
Heat	No
Noise pollution	No
Radiation	No
Electricity	No
Light	Fluorescence and IR light
Release chemicals substances	No
Any other significant negative impact?	No
Possible alternative to these impacts?	No
Life cycle of the equipment	
Deployment	Mediterranean Sea, Atlantic Ocean up to 600 m depth / platforms of opportunity (fishing vessels)
Operation / Demonstration	DO and Fluorescence Sensors integrated on fishing vessels / These sensors will be used on commercial fishing gears and a WiFi link will allow automatic data recovery to a 'Hub System', placed on-board the vessel
Recovery-at-sea strategies	IFREMER and CNR teams
Disposal and recycling alternatives	3 sets will be manufactured in NAUTILOS project. Plan to borrow sensors from one of the other 2 oceanographic campaigns in case of lost
Risk of accidents / failing to recover the equipment	Sensor damage (broken) during deployment
Measures to mitigate in case of loss	Provide robust sensor protection
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	No

Sensor	Downward-looking multi/hyperspectral and laser induced fluorescence sensors and cameras
Reference	**T3.2**
Location	
Location where the equipment will be deployed	UAVs, ferrybox ships of oportunity
Size and design of the equipment	lidar: 1/2m3, radiometer: cylinder 30x7cm, camera 30x20x20cm
Cumulation with other known existing and/or approved projects	Will be in connection to a national infrastructure project
Presence of nature reserves or very sensitive environmental areas nearby	not decided yet, but very likely yes
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Aluminum, Steel, plastic, composits, titanium
Use of biodegradable materials?	No
Explanation of the sensor technology used / sampling technique	the radiometers and camera are measuring the signal from the sun light backscattered by the ocean, the lidar is measuring at the signal backscattered by the ocean of the light it has emited itself.
Type of battery used	lithium or none
Anti-fouling strategy	none
Photo or schema of the design of the sensor	 
Emission of residues, pollution, nuisances	
Heat	lidar: high, camera and radiometers: none
Noise pollution	none
Radiation	none
Electricity	lidar: 220VAC, camera and radiometers: 12VDC
Light	lidar:high power laser, camera and radiometers: none
Release chemicals substances	none
Any other significant negative impact?	no
Possible alternative to these impacts?	water sampling
Life cycle of the equipment	
Deployment	lidar:several weeks/months, camera: several days, radiometers: several months
Operation / Demonstration	on ferrybox and UAV flights
Recovery-at-sea strategies	recovery from land or ship
Disposal and recycling alternatives	not known
Risk of accidents / failing to recover the equipment	damage from crash of UAV, weather hazard
Measures to mitigate in case of loss	commercial sensors are insured and can be exchanged.
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	no

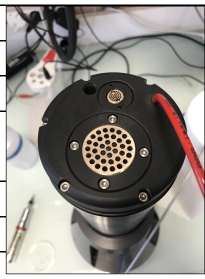
Sensor	Passive broadband acoustic recording sensor for noise monitoring
Reference	**ST3.3.1**
Location	
Location where the equipment will be deployed	Coastal and offshore seas up to 600m water depth. Locations not yet fixed.
Size and design of the equipment	ad hoc deployments on gliders, moorings, and subsea frames
Cumulation with other known existing and/or approved projects	Not known
Presence of nature reserves or very sensitive environmental areas nearby	Deployment in marine reserves is possible. Locations not yet fixed.
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Main body acetal, fixings stainless steel, connectors and sensor brass/rubber/polyurethane
Use of biodegradable materials?	No
Explanation of the sensor technology used / sampling technique	Acoustic hydrophone comprising encapsulated piezo-electric ceramic element
Type of battery used	Typically Nickel Metal Hydride rechargeable
Anti-fouling strategy	None
Photo or schema of the design of the sensor	Can be provided later
Emission of residues, pollution, nuisances	
Heat	None
Noise pollution	None
Radiation	None
Electricity	None
Light	None
Release chemicals substances	None
Any other significant negative impact?	None
Possible alternative to these impacts?	None
Life cycle of the equipment	
Deployment	From hours to months. Reusable multiple times.
Operation / Demonstration	From hours to months. Reusable multiple times.
Recovery-at-sea strategies	Retrieved on supporting platform e.g. buoy, frame, vehicle, fishing gear
Disposal and recycling alternatives	Covered by WEEE regs and carries logo
Risk of accidents / failing to recover the equipment	Risk of pressure build-up within pressure housing due to leakage or battery fault. Specific post-deployment procedures must be followed. If not recovered, will gradually degrade and disintegrate in sea water
Measures to mitigate in case of loss	Supporting platform should have means of tracking/location and recovery
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	2011/65/EU ROHS, WEEE, 2014/30/EU EMC, SI 2016/1091 EMC

Sensor	Passive acoustic event recorder
Reference	ST3.3.2
Location	
Location where the equipment will be deployed	Coastal and offshore seas up to 600m water depth. Locations not yet fixed.
Size and design of the equipment	ad hoc deployments on gliders, moorings, subsea frames, and fishing vessels
Cumulation with other known existing and/or approved projects	Not known
Presence of nature reserves or very sensitive environmental areas nearby	Probable, since monitoring marine mammals e.g. Portofino Marine Protected Area. Other locations not yet fixed.
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Main body acetal, fixings stainless steel, connectors and sensor brass/rubber/polyurethane
Use of biodegradable materials?	No
Explanation of the sensor technology used / sampling technique	Acoustic hydrophone comprising encapsulated piezo-electric ceramic element
Type of battery used	Typically Nickel Metal Hydride rechargeable
Anti-fouling strategy	None
Photo or schema of the design of the sensor	Can be provided later
Emission of residues, pollution, nuisances	
Heat	None
Noise pollution	None
Radiation	None
Electricity	None
Light	None
Release chemicals substances	None
Any other significant negative impact?	None
Possible alternative to these impacts?	None
Life cycle of the equipment	
Deployment	From hours to months. Reusable multiple times.
Operation / Demonstration	From hours to months. Reusable multiple times.
Recovery-at-sea strategies	Retrieved on supporting platform e.g. buoy, frame, vehicle, fishing gear
Disposal and recycling alternatives	Covered by WEEE regs and carries logo
Risk of accidents / failing to recover the equipment	Risk of pressure build-up within pressure housing due to leakage or battery fault. Specific post-deployment procedures must be followed. If not recovered, will gradually degrade and disintegrate in sea water
Measures to mitigate in case of loss	Supporting platform should have means of tracking/location and recovery
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	2011/65/EU ROHS, WEEE, 2014/30/EU EMC, SI 2016/1091 EMC

Sensor	Active Acoustic Profiling Sensor
Reference	T3.4
Location	
Location where the equipment will be deployed	Coastal and offshore seas up to 1000m water depth. Locations not yet fixed.
Size and design of the equipment	ad hoc deployments on gliders, moorings, and subsea frames
Cumulation with other known existing and/or approved projects	Not known
Presence of nature reserves or very sensitive environmental areas nearby	Deployment in marine reserves is possible. Locations not yet fixed.
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Main body anodised aluminium, fixings nylon or aluminium, sensors stainless steel, connectors aluminium/rubber/polyurethane
Use of biodegradable materials?	No
Explanation of the sensor technology used / sampling technique	Acoustic hydrophones comprising encapsulated piezo-electric ceramic elements. Temperature sensor is thermistor with stainless steel protective body. Pressure sensor is stainless steel.
Type of battery used	Typically Alkaline.
Anti-fouling strategy	None
Photo or schema of the design of the sensor	Can be provided later
Emission of residues, pollution, nuisances	
Heat	None
Noise pollution	Pulsed acoustic emissions typically from 300 kHz to 5 MHz at approximately 1 Watt
Radiation	None
Electricity	None
Light	None
Release chemicals substances	None
Any other significant negative impact?	None
Possible alternative to these impacts?	None
Life cycle of the equipment	
Deployment	From hours to months. Reusable multiple times.
Operation / Demonstration	From hours to months. Reusable multiple times.
Recovery-at-sea strategies	Retrieved on supporting platform e.g. buoy, frame, vehicle
Disposal and recycling alternatives	Covered by WEEE regs and carries logo
Risk of accidents / failing to recover the equipment	Risk of pressure build-up within pressure housing due to leakage or battery fault. Specific post-deployment procedures must be followed. If not recovered, will gradually degrade and disintegrate in sea water
Measures to mitigate in case of loss	Supporting platform should have means of tracking/location and recovery
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	2011/65/EU ROHS, WEEE, 2014/30/EU EMC, SI 2016/1091 EMC

Sensor	Sampler for phytoplankton and other suspended matter
Reference	**T3.6**
Location	
Location where the equipment will be deployed	FerryBox ships of opportunity, possibly buoy/fixed platform
Size and design of the equipment	< 1 m3, pump connected to filter holders, also a CPU
Cumulation with other known existing and/or approved projects	Will be in connection to a national infrastructure project
Presence of nature reserves or very sensitive environmental areas nearby	Not planned, but WP7 needs to provide updates regarding deployment regions
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Aluminum, Steel, plastic
Use of biodegradable materials?	No
Explanation of the sensor technology used / sampling technique	A pump will pump water to filter onto GF/F or membrane filters (47 mm diameter, pore size ranging from 0.2-2 um)
Type of battery used	Ideally using platform-provided power, but also can use D cell alkaline
Anti-fouling strategy	None
Photo or schema of the design of the sensor	https://mclanelabs.com/phytoplankton-sampler/
Emission of residues, pollution, nuisances	
Heat	None
Noise pollution	Pump noise?
Radiation	None
Electricity	36 VDC
Light	None
Release chemicals substances	None
Any other significant negative impact?	Not that we are aware of
Possible alternative to these impacts?	n/a
Life cycle of the equipment	
Deployment	not known, but ideally up to several weeks
Operation / Demonstration	yes, on FerryBox ships of opportunity, possibly buoy/fixed platform
Recovery-at-sea strategies	follow typical deployment/recovery protocols
Disposal and recycling alternatives	not known
Risk of accidents / failing to recover the equipment	this is possible on buoys/fixed platforms if cables/attachements break
Measures to mitigate in case of loss	use secondary connections in case primary connections fail
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	No

Sensor	Carbonate system/ocean acidification sensors
Reference	**T4.1**
Location	
Location where the equipment will be deployed	FerryBox ships of opportunity, possibly buoy/fixed platform
Size and design of the equipment	<30 cm3, stand alone sensor, possibly with battery and logger if required by demonstrations
Cumulation with other known existing and/or approved projects	No
Presence of nature reserves or very sensitive environmental areas nearby	Not planned, but WP7 needs to provide updates regarding deployment regions
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Aluminum, plastic/polymers
Use of biodegradable materials?	No
Explanation of the sensor technology used / sampling technique	solid state sensors and membrane-based equilibrator
Type of battery used	Ideally using platform-provided power, but possibly external battery to be determined
Anti-fouling strategy	None, but possibly copper plating if needed
Photo or schema of the design of the sensor	None available at this stage
Emission of residues, pollution, nuisances	
Heat	None
Noise pollution	None
Radiation	None
Electricity	Not yet know, probably 12 VDC
Light	None
Release chemicals substances	None
Any other significant negative impact?	Not that we are aware of
Possible alternative to these impacts?	n/a
Life cycle of the equipment	
Deployment	no known, but ideally up to several week/months
Operation / Demonstration	yes, on FerryBox ships of opportunity, possibly buoy/fixed platform
Recovery-at-sea strategies	follow typical deployment/recovery protocols
Disposal and recycling alternatives	not known
Risk of accidents / failing to recover the equipment	this is possible on buoys/fixed platforms if cables/attachements break
Measures to mitigate in case of loss	use secondary connections in case primary connections fail
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	No

Sensor	Silicate Electrochemical Sensor
Reference	**T4.2**
Location	
Location where the equipment will be deployed	Mediterranean Sea
Size and design of the equipment	Intercomparison with colorimetry from a pontoon of the Marine Station of Sète (France)
Cumulation with other known existing and/or approved projects	OceanSensor project
Presence of nature reserves or very sensitive environmental areas nearby	No
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Anodized aluminium cylinder
Use of biodegradable materials?	No
Explanation of the sensor technology used / sampling technique	Electrochemical technology
Type of battery used	No
Anti-fouling strategy	No
Photo or schema of the design of the sensor	To be included 
Emission of residues, pollution, nuisances	
Heat	No
Noise pollution	No
Radiation	No
Electricity	No
Light	No
Release chemicals substances	Silicomolybdic complex
Any other significant negative impact?	No
Possible alternative to these impacts?	No
Life cycle of the equipment	
Deployment	<1 month
Operation / Demonstration	
Recovery-at-sea strategies	Use Oceanographic field (HCMR team)
Disposal and recycling alternatives	
Risk of accidents / failing to recover the equipment	Float collision and loss
Measures to mitigate in case of loss	Know the currents in the deployment zone Estimate the drift according to the seawater currents Plan the number of deployment days
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	No

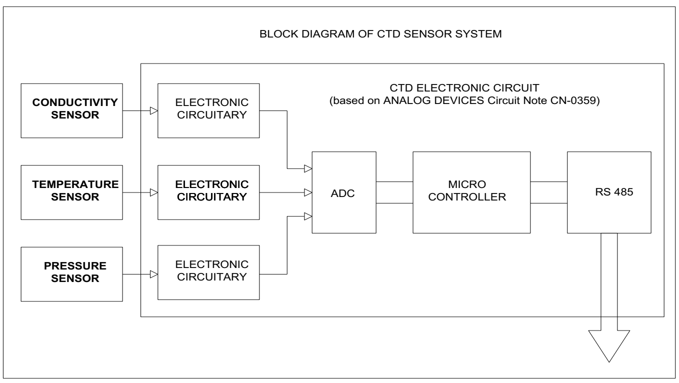
Sensor	Submersible Nano- and Microplastics Sampler
Reference	T4.3
Location	
Location where the equipment will be deployed	underwater deployment up to 600 meters depth on moorings, buoys or from ships
Size and design of the equipment	development still in progress; approximately 500 mm diameter, 600 mm length, cylindrical shape
Cumulation with other known existing and/or approved projects	unknown
Presence of nature reserves or very sensitive environmental areas nearby	unknown
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Main components will be made of titanium and PFA/PVDF/PTFE, also used: POM, stainless steel, copper
Use of biodegradable materials?	unknown
Explanation of the sensor technology used / sampling technique	samples taking by pumping water through filter mesh, no chemicals used
Type of battery used	Li-Ion / Pressure housing for batteries and data logger
Anti-fouling strategy	not decided yet, first prototype will be for short deployments
Photo or schema of the design of the sensor	still working on several individual parts, scheme of whole system still in progress
Emission of residues, pollution, nuisances	
Heat	very little, due to pump movement and electronics / Reaction Temperature 40-70 °C
Noise pollution	very little, very quiet pump
Radiation	-
Electricity	-
Light	status LED (green/red)
Release chemicals substances	No / waste (reagent and liquids [staining substance]) and backflush
Any other significant negative impact?	unknown
Possible alternative to these impacts?	
Life cycle of the equipment	
Deployment	Buoy deployment for several days, profiling from ships
Operation / Demonstration	
Recovery-at-sea strategies	
Disposal and recycling alternatives	System can be send back to manufacturer for recycling
Risk of accidents / failing to recover the equipment	
Measures to mitigate in case of loss	
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	

Sensor	Low-cost Microplastic sensors based on selective Nile Red staining and fluorescence detection
Reference	T4.4
Location	
Location where the equipment will be deployed	**The instrument is not deployed at sea**. The instrument is mounted onboard a ship, in the FerryBox. The ships are ferries in Skandinavia.
Size and design of the equipment	Continuous deployment onboard ships of opportunity
Cumulation with other known existing and/or approved projects	Monitoring projects for Norwegian and Danish environmental agencies
Presence of nature reserves or very sensitive environmental areas nearby	Depending in ship route we might pass by sensitive environmental areas
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Stainless steel filters and piping, glass, PTFE tubing, oxidized aluminium; consumables see below
Use of biodegradable materials?	not relevant
Explanation of the sensor technology used / sampling technique	Microplastic sampling by filtration, fluorescent staining of microplastic particles and detection by laser fluorescence
Type of battery used	Powered from ship
Anti-fouling strategy	KOH oxidation
Photo or schema of the design of the sensor	can be provided at a later stage
Emission of residues, pollution, nuisances	
Heat	None
Noise pollution	None
Radiation	None
Electricity	None
Light	None
Release chemicals substances	Consumables going back into sea: Potassium hydroxide (oxidizing agent, see note (1) below) / H2O2, NaOH, Nile Red (5- 10 ml)
Any other significant negative impact?	None
Possible alternative to these impacts?	None
Life cycle of the equipment	
Deployment	equipment stays on ship, not single-use
Operation / Demonstration	only on ferries and cruise ships
Recovery-at-sea strategies	not deploxed at sea
Disposal and recycling alternatives	Nile Red (fluorescent staining agent) will be collected as waste water and disposed of professionally.
Risk of accidents / failing to recover the equipment	not applicable
Measures to mitigate in case of loss	not applicable
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	None during the development phase. Permits might be needed for measurements in sensitive areas.

(1) Potassium hydroxide (KOH) is used to oxidize the organics matter ins the raw sample of microplastic. It is discarded back into sea in small amounts that should have no impact in sea water pH value.
extract from : OECD UNEP report: SIDS Initial Assessment Report on KOH (p.26)
The risk that KOH poses for the environment is essentially restricted to a pH increase of the aquatic compartment, which is dependent on the hardness of the waters. This effect is well known, as are the ways to control it. Therefore, no further testing is required.
link for OECD report

Sensor	Deep Ocean CTD
Reference	**T4.5**
Location	
Location where the equipment will be deployed	Mediterranean Sea
Size and design of the equipment	16 P/M; 1-24M
Cumulation with other known existing and/or approved projects	NO
Presence of nature reserves or very sensitive environmental areas nearby	NO
Information about the equipment	
Description of the composition and quantity (approximated) of materials	CTD components with electronics build in standard housing (1 to 3 pcs)
Use of biodegradable materials?	NO
Explanation of the sensor technology used / sampling technique	Temperature and conductivity sensors (CT) are integrated on glass substrate as RTD and TFE devices, respectively, while depth sensor (D) is an OEM silicon pressure sensor. Sensor electronics is built on a two-layered PCB.
Type of battery used	
Anti-fouling strategy	NO (Cu net arround CT sensor chip optionally)
Photo or schema of the design of the sensor	see attached block diagramin this sheet (1)
Emission of residues, pollution, nuisances	
Heat	NO
Noise pollution	NO
Radiation	NO
Electricity	NO
Light	NO
Release chemicals substances	NO
Any other significant negative impact?	NO
Possible alternative to these impacts?	NO
Life cycle of the equipment	
Deployment	less than 1 month
Operation / Demonstration	
Recovery-at-sea strategies	
Disposal and recycling alternatives	NO
Risk of accidents / failing to recover the equipment	float collision and loss
Measures to mitigate in case of loss	knowing seawater currents and weather conditions
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	NO

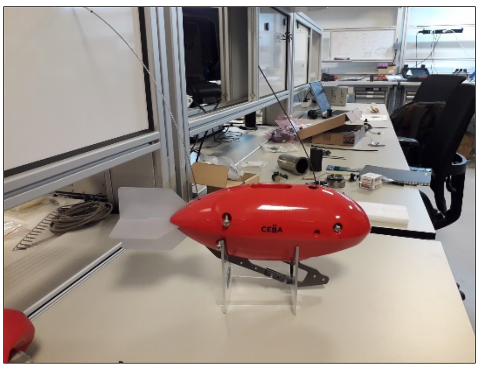
(1)



Sensor	Deep ocean low-level radioactivity sensor
Reference	T4.6
Location	
Location where the equipment will be deployed	Greece (deep basins, Pylos well)
Size and design of the equipment	
Cumulation with other known existing and/or approved projects	
Presence of nature reserves or very sensitive environmental areas nearby	
Information about the equipment	
Description of the composition and quantity (approximated) of materials	low resolution crystal, multichannel analyser, voltage diveders, logger, communication module
Use of biodegradable materials?	no
Explanation of the sensor technology used / sampling technique	passive scitillator crystal and detection of gamma radiation
Type of battery used	external rechargable battery (deep discharge)
Anti-fouling strategy	typical painting
Photo or schema of the design of the sensor	cylinder of 40cm length and 10cm diameter
Emission of residues, pollution, nuisances	
Heat	No
Noise pollution	No
Radiation	it is passive detection.
Electricity	No
Light	No
Release chemicals substances	No
Any other significant negative impact?	Recycle the low resolution crystal after 5 years of life
Possible alternative to these impacts?	
Life cycle of the equipment	
Deployment	continuous monitoring using stand alone and/or real time operation
Operation / Demonstration	total life time of 5 years
Recovery-at-sea strategies	Recovery is reccommended every 6 months
Disposal and recycling alternatives	The recyclying of the crystal via typical procedure.
Risk of accidents / failing to recover the equipment	Acoustic releaser problem, inappropriate mounting to the morring line
Measures to mitigate in case of loss	To integrate the sensor in existing platform/lander
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	no

Sensor	Animal-borne Instrument (elasmobranchs)
Reference	**T5.5**
Location	
Location where the equipment will be deployed	Azores
Size and design of the equipment	check the photo with scale
Cumulation with other known existing and/or approved projects	?
Presence of nature reserves or very sensitive environmental areas nearby	yes, very sensitive area
Information about the equipment	
Description of the composition and quantity (approximated) of materials	Titanium, lead, epoxy, poliuretano (?), ARGOS satallite transmiter, VHF trasmissor)
Use of biodegradable materials?	no
Explanation of the sensor technology used / sampling technique	a line is placed around the pectoral fins of the animal and it drags the sensor behind it
Type of battery used	lithium
Anti-fouling strategy	No. Only a black ink (epoxi base) used as a coat
Photo or schema of the design of the sensor	(1)
Emission of residues, pollution, nuisances	
Heat	no
Noise pollution	no (?)
Radiation	no
Electricity	no
Light	yes
Release chemicals substances	lead oxidizing
Any other significant negative impact?	disturbing the animal
Possible alternative to these impacts?	reduce the size of the tag and streamline
Life cycle of the equipment	
Deployment	attract the animals with food, dive with them and place the line between the fins
Operation / Demonstration	tests carried out in Azores
Recovery-at-sea strategies	deattache from the animals, floats, ARGOS satellite indicates the approximate location and the VHF assists to find the device on the surface of the water
Disposal and recycling alternatives	
Risk of accidents / failing to recover the equipment	recovery rate is >99% (seeing that this device costs around 35K euros)
Measures to mitigate in case of loss	
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?	

(1)



Sensor	Animal-borne Instruments (southern elephant seal)
Reference	T5.5
Location	
Location where the sensors will be deployed	Valdez Peninsula, Argentina
Size and design of the project	5 elephant seal females/yr
Cumulation with other known existing and/or approved projects	Yes,
Presence of nature reserves or very sensitive environmental areas nearby	Valdez Peninsula National Park, Unesco Mondial Reserve
Information about the equipment	
Description of the composition and quantity (approximated) of materials	
Use of biodegradable materials?	No, but all sensor are moulded into epoxy,
Explanation of the sensor technology used / sampling technique.	Integration of a Pyro Oxygen sensor into the SMRU SRDL oceanographic tag measuring already pressure, temperature and Salinity.
Type of battery used	Lithium D-cells to allow a long autonomy
Anti-fouling strategy	No need for that as elephant seals are very deep divers within the twilight zone where there is not enough light to allow algal development.
Photo or schema of the design of the sensor	Yes, see joined picture below.
Emission of residues, pollution, nuisances	
Heat	No
Noise pollution	No
Radiation	No
Electricity	No
Light	No
Release chemicals substances	No
Any other significant negative impact?	No
Possible alternative to these impacts?	No
Life cycle of the equipment	
Deployment	Tags are deployed on female southern elephant seal by the end of the breeding season and recover on the seals when they come back on land to moult. If we don't recover the seal, in case the tag has stopped transmitted its Argos location, the tag will fall on land during the moult. Tag may be lost at sea, if the seal dye at sea. The tag will sink to the ocean floor.
Operation / Demonstration	
Recovery-at-sea strategies	
Disposal and recycling alternatives	
Risk of accidents / failing to recover the equipment	
Measures to mitigate in case of loss	
Legislation	
Do you have to follow a national/international legislation to develop the sensor? Which one?