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**NAUTILOS**

## EthAB Reports

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<b>V0.2</b>	10/06/2025	Gabriele Pieri	Further updates
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<b>V1.0</b>	24/06/2025	Gabriele Pieri	New version with all updates integrated
<b>V2.0</b>	26/06/2025	EthAB	Final version following final EthAB meeting
<b>V2.1</b>	26/06/2025	Michela Martinelli	Revisions
<b>V2.2</b>	26/06/2025	Eva Chatzinikolaou	Revisions
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NAUTILOS - New Approach to Underwater Technologies for Innovative, Low-cost Ocean Observation project fills 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 NAUTILOS project is 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 project is one of the two projects included in the EU's efforts to support the European Strategy for Plastics in a Circular Economy<sup>1</sup> by strengthening the demonstration of new and innovative technologies to measure the Essential Ocean Variables (EOV)<sup>2</sup>.

NAUTILOS project runs from 1 October 2020 to 30 June 2025. NAUTILOS bring together a Consortium of 21 entities from 11 European countries and is coordinated by the National Research Council of Italy (Consiglio Nazionale delle Ricerche, CNR).

More information on the project can be found at: <http://www.nautilus-h2020.eu>

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<sup>1</sup> <https://www.euoparc.org/wp-content/uploads/2018/01/Eu-plastics-strategy-brochure.pdf>

<sup>2</sup> <https://goosocean.org/what-we-do/framework/essential-ocean-variables/>

## EXECUTIVE SUMMARY

The NAUTILOS Project Ethics Advisory Board (EthAB) form an integral part of the External Advisory Board (EAB) Reports, whose Reports have been submitted in M12, M24, M36 and M48. This report is a compilation of all EthAB reports highlighting the main activities and issues encountered, the feedback provided, as well as final decisions taken as regards the ethics policy of the project.

The document provides the final report and evaluation by the EthAB. It provides their overall assessment of NAUTILOS ethics issues and Recommendations concerning the Ethics Protocol in a Multidisciplinary Marine Environment Project. The following deliverable is the outcome of more than four years of EthAB activities.

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## LIST OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Definition
<b>AdriFOOS</b>	Adriatic Fishery & Oceanography Observing Systems (FOOS)
<b>AI</b>	Artificial Intelligence
<b>AUV</b>	Autonomous Underwater Vehicle
<b>CA</b>	Consortium Agreement
<b>CFP</b>	Common Fishery Policy
<b>CS</b>	Citizen Science
<b>DO</b>	Dissolved Oxygen
<b>DOW</b>	Description of Work (Annex of the GA)
<b>EAB</b>	External Advisory Board
<b>EC</b>	European Council
<b>EGE</b>	European Group on Ethics in Science and New Technologies
<b>EIA</b>	Environmental Impact Assessment
<b>EMODnet</b>	European Marine Observation and Data Network
<b>EOV</b>	Essential Ocean Variables
<b>ER</b>	Ethics Requirement
<b>EthAB</b>	Ethics Advisory Board
<b>EU</b>	European Union
<b>FINMARI</b>	Finnish marine research consortium
<b>GA</b>	General Assembly
<b>GDPR</b>	General Data Protection Regulation
<b>GrAgr</b>	Grant Agreement
<b>IT</b>	Information Technology
<b>JERICO</b>	Towards a Joint European Research Infrastructure network for Coastal Observatories
<b>JERICO-NEXT</b>	Joint European Research Infrastructure network for Coastal Observatory – Novel European eXpertise for coastal observaTories
<b>KPI</b>	Key Performance Indicator
<b>MSFD</b>	Marine Strategy Framework Directive
<b>NeXOS</b>	Next generation Low-Cost Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management
<b>NGO</b>	Non-Governmental Organisation
<b>NIR</b>	Near Infra-red

<b>NorSOOP</b>	Norwegian Ships of Opportunity Program
<b>OBPS</b>	Ocean Best-Practices and Standards
<b>QH</b>	Quadruple Helix

## I. INTRODUCTION

This document represents the final report summarising the activities of the NAUTILOS EthAB, besides all the mandatory and foreseen deliverables in the Ethics Work Package (WP13).

The deliverable has four main sections:

- **Section I: Introduction**  
This section briefly reviews the Ethics Board structure in NAUTILOS, with more details about its role in the frame of the project's External Advisory Board and its components' specialisations
- **Section II: Ethics Protocol and the Role of the European Commission** describes the general frame where NAUTILOS ethics check activities are included in terms of EU Research Programmes.
- **Section III:** briefly provides the **Background Information** about the NAUTILOS Project objectives and its multidisciplinary approach and the **rationale behind the proposed "White paper"**. The proposed "White Paper" is based on the NAUTILOS unique and distinctive experience as a Horizon 2020 funded project that successfully adapted its research throughout COVID-19 pandemic, respecting in full the Commission special actions for Horizon 2020 programme, and successfully bridging the innovative and ethical requirements between the Horizon 2020 and Horizon Europe programmes. The proposed "White Paper" builds upon Horizon 2020 programme, incorporating Lessons Learnt and enhancing both cutting-edge innovation and ethical consideration throughout the NAUTILOS project. The White Paper is presented as a discussion document for public consultation before legislation is drafted.
- **Section IV:** discusses the Emerging Ethics Protocol Framework, characterised by key ethics shifts in the **NAUTILOS Project Case Studies and Lessons Learnt**.
- **Section V:** provides an **Analysis and Discussion of the Impact and Benefits on the real activities carried out within the NAUTILOS Project**.
- **Section VI:** reports on the **Conclusion and comparison with initial requirements**, providing a final comparison with the initial Ethics requirements as per the Ethics Summary Report.
- **Section VII:** concludes the document with the **Ethics protocol White Paper Policy Recommendations**.

### 1. ETHICS BOARD STRUCTURE WITHIN NAUTILOS

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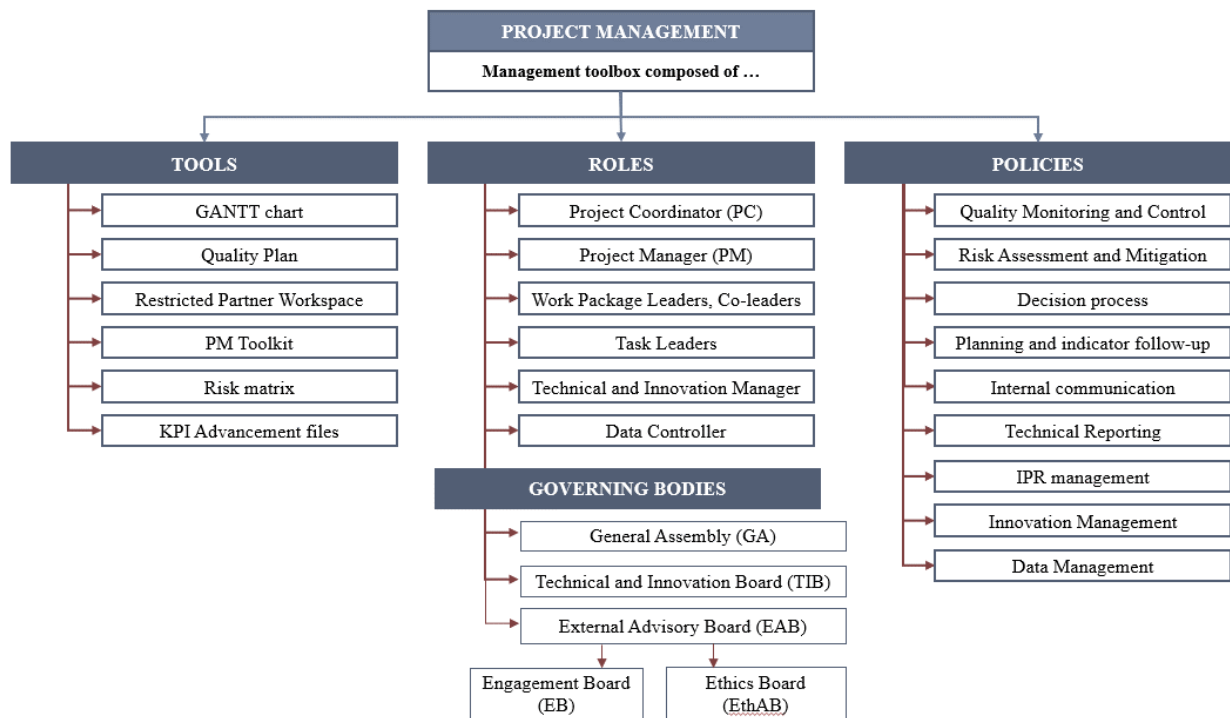
The project management structure of NAUTILOS has been designed as outlined in Figure 1. The management structure and procedures to be applied within NAUTILOS are established in the Grant Agreement (GrAg) and Consortium Agreement (CA).

As reported in the figure, among the **project's governing bodies** (as further detailed in Deliverable D1.1<sup>3</sup>), there is the External Advisory Board (EAB), along with the General Assembly (GA) and the Technical and Innovation Board (TIB).

The *Ethics Advisory Board (EthAB)* is part of the EAB; it supervises and monitors the project's ethical aspects. The EthAB is an independent body advising the GA and all NAUTILOS members on ethical, regulatory and socio-environmental issues raised by the research and development to be undertaken under NAUTILOS. It consists of Dr Nina J. Zugic, an independent ethics research expert.

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<sup>3</sup> <https://nautilus-h2020.eu/wp-content/uploads/2022/10/NAUTILOS-D1.1.-Report-on-Management-Procedures.pdf>



**Figure 1. NAUTILOS Project Management Structure and Governing Bodies**

Due to heterogeneity and cutting-edge research performed throughout the NAUTILOS project, the Consortium and EthAB agreed to extend the composition of EthAB with an Internal Ethics Advisory Board. The NAUTILOS internal components of the EthAB are Michela Martinelli (CNR-IRBIM), Manolis Ntoumas (HCMR), Eva Chatzinikolaou (HCMR), Sandra Sá (EuroOcean), Jorge Fontes (IMAR), Christophe Guinet (CNRS), NAUTILOS Project Manager Lazarina Dimitrova (EuroProject) and NAUTILOS Coordinator Gabriele Pieri (CNR-ISTI).

Each member of the EthAB is specialised in the specific area of the research activities performed within the NAUTILOS multidisciplinary research. In more detail, Michela Martinelli deals with the participation in fisheries activities and related stakeholders; Manolis Ntoumas deals with oceanographic observation platforms and ocean best practices; Eva Chatzinikolaou deals with the participation of citizens, schools and students; Sandra Sá is specialised in information management, knowledge transfer, communication and outreach, Jorge Fontes and Christophe Guinet are experts in the field of Marine Ecology with a particular experience of fish/animal tagging.

NAUTILOS Internal EthAB closely observes all research activities throughout the NAUTILOS project and conducts all ethics assessments. All the EthAB members collaborate closely with Dr Nina J Zugic, the Chair of NAUTILOS EthAB. More details about the EthAB are given in the respective deliverables submitted in WP13.

## 2. ETHICS PROTOCOL AND THE ROLE OF THE EUROPEAN COMMISSION

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The European Commission, as the EU's executive body, plays a crucial role in shaping and implementing EU policies, including those related to ethics and good administration, and has established an interinstitutional Ethics Body to ensure common ethical standards across EU institutions.

Data protection is both a central issue for research ethics in Europe and a fundamental human right. In research settings, data protection imposes obligations on researchers to provide research subjects with detailed information about what will happen to the personal data that they collect. It also requires the organisations processing the data to ensure the data are properly protected, minimised and destroyed when no longer needed.

While individual EU-funded research projects processing personal data must comply with EU and national data protection laws, the objective of this White Paper is to ensure that, in addition to respecting legal obligations, all projects are guided by ethical considerations and the values and principles on which the EU is founded.

Hence, this White Paper addresses the scale and complexity of data processing and the Ethics Protocol in a Multi-disciplinary Marine Environment Project and New approach to Research and Innovation Excellence.

## II. BACKGROUND INFORMATION

### 1. NAUTILOS PROJECT OBJECTIVES

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The NAUTILOS project's overall objective was to fill in the marine observation and modelling gaps for biogeochemical, biological and deep ocean physics essential ocean variables and micro-nano-plastics. Throughout the HORIZON 2020 57-month funding lifetime, the NAUTILOS project developed a new generation of cost-effective sensors and samplers, which will be integrated within observing platforms and deployed in large-scale demonstrations in European seas.

The principles underlying the NAUTILOS project are those of the deployment, integration and demonstration of new cutting-edge technologies concerning sensors, interoperability and embedding skills. This new approach to underwater technologies for innovative, low-cost ocean observation was guided by the objectives of scalability, modularity, cost-effectiveness, and open-source availability of software products, all heavily underpinned by EU Research Ethics principles<sup>4</sup> and Ethics Protocols<sup>5</sup>.

Bringing together 21 entities from 11 European countries with multidisciplinary and already recognised excellence in their field of research expertise, the NAUTILOS project had the fundamental objectives to:

1. Complement and expand current European observation tools and services
2. Obtain a collection of data at a much higher spatial resolution, temporal regularity and lengths that are currently available at the European level
3. Enable and further democratise the monitoring of the marine environment data to both researchers and citizens

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<sup>4</sup> [https://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/ethics\\_en.htm](https://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/ethics_en.htm)

<sup>5</sup> [https://www.bbmri-eric.eu/wp-content/uploads/The-Ethics-Appraisal-Scheme- BBMRI-webinar-september-2021\\_version-for-dessimination.pdf](https://www.bbmri-eric.eu/wp-content/uploads/The-Ethics-Appraisal-Scheme- BBMRI-webinar-september-2021_version-for-dessimination.pdf)

## 2. WHITE PAPER RATIONALE

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NAUTILOS Project “New Approach to Underwater Technologies for Innovative, Low-cost Ocean Observation”<sup>6</sup>, is the European Commission HORIZON 2020 Programme (H2020)<sup>7</sup> project funded under the Future of Seas and Oceans Flagship Initiative<sup>8</sup>, coordinated by the National Research Council of Italy (CNR)<sup>9</sup>.

The NAUTILOS Project aims to fill marine observation and modelling gaps for chemical, biological and deep ocean physics variables by developing a new generation of cost-effective sensors and samplers. These technologies are then integrated within observing platforms deployed in large-scale demonstrations in European seas. The fundamental aim of the project was to complement and expand current European observation tools and services and to obtain a collection of data at a much higher spatial resolution, temporal regularity, and length than currently available on the European scale. In addition, in today’s world, the possibility to use consumer and readily available technologies allow for the direct involvement of common citizens in the Big Data acquisition process also in the oceanographic field, thus, NAUTILOS aim was also to raise awareness of related issues, the ethical research and ethics, in particular.

NAUTILOS’ goal was to support and enable informed decisions and actions for the sustainable management of resources. However, ocean observation should not be a task for experts and scientists alone. In this respect, NAUTILOS aimed to further democratise the marine environment monitoring for both traditional and non-traditional data users.

NAUTILOS brought together 21 partners 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 as water and climate change science, technological marine applications and research infrastructures.

NAUTILOS was one of the two projects supporting the European Strategy for Plastics in a Circular Economy<sup>10</sup> by demonstrating new and innovative technologies to measure the Essential Ocean Variables (EOV)<sup>11</sup>.

NAUTILOS Project, a European Union HORIZON 2020 Innovation Action funded project under the Future of Seas and Oceans Flagship initiative, was also recognised by the “Mission Restore our Ocean and Waters” for its significant contributions to protecting and restoring marine and freshwater ecosystems and biodiversity.

Hence, given the NAUTILOS’s unique and distinct encounter, the proposed “White Paper” rationale is based on the evidence of the NAUTILOS as a Horizon 2020 funded project that adapted its research throughout COVID-19 pandemic, respecting in full the Commission special actions for Horizon 2020 programme, and successfully bridging the innovative and ethical requirements between the Horizon 2020 and Horizon Europe programmes.

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<sup>6</sup> <https://nautilus-h2020.eu/>

<sup>7</sup> [https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020\\_en](https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-2020_en)

<sup>8</sup> [https://cordis.europa.eu/programme/id/H2020\\_BG-07-2019-2020](https://cordis.europa.eu/programme/id/H2020_BG-07-2019-2020)

<sup>9</sup> <https://www.cnr.it/en>

<sup>10</sup> <https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy.pdf>

<sup>11</sup> [https://www.goosoocean.org/index.php?option=com\\_content&view=article&id=14&Itemid=114](https://www.goosoocean.org/index.php?option=com_content&view=article&id=14&Itemid=114)

The proposed “White Paper” builds upon Horizon 2020 programme, incorporating Lessons Learnt and enhancing both cutting-edge innovation and ethical consideration throughout the NAUTILOS project. The White Paper is presented as a discussion document that outlines proposals for EU action in the realm of the “*Ethics Protocol in a multi-disciplinary marine environment project: New approach to Research and Innovation Excellence*”. It is proposed for the White Paper to be published by the European Commission for public consultation before legislation is drafted.

Last but not least, this White Paper aims to highlight the importance of the:

1. Ethics Protocol in a multi-disciplinary marine environment project: New approach to Research and Innovation Excellence, the NAUTILOS partners came across with since the start of the project, the 1<sup>st</sup> of October 2021.
2. Encourage ethical research and provide new Ethics Protocol guidelines for a multi-disciplinary marine environment project.
3. Contribute to the EU Mission to Restore our Oceans and Waters by 2030.

### 3. NAUTILOS GENERAL MULTIDISCIPLINARY APPROACH

The NAUTILOS project inherently represents a mix of highly multi-sectoral and multi-disciplinary activities and expertise. Ranging from technologies for detection and observation up to the design of forecasting models, together with the control and integration of observation platforms of various types, including marine animals with multisensor tags contributing as evolutionary informed oceanographers.

The heterogeneity is also perfectly reflected in the composition of the consortium, including private industries, academia, research centres, and foundations, all established on many different types of backgrounds and domains. Concerning heterogeneity, the geographical diversity that makes up the team should also be mentioned, made up of both EU and non-EU members and, therefore, not necessarily subject to the same regulations and laws; moreover, part of the project activities take place in South America, including a further variable to take into account. This interdisciplinary approach and diversity of perspectives allowed for a more comprehensive and robust solution to the challenges addressed by the NAUTILOS project.

In summary, the overarching diversity of the NAUTILOS Consortium (e.g., industries, research institutions, etc., regulations in both EU and non-EU countries, South America, and different scientific backgrounds) that reflects the diverse and interdisciplinary nature of the NAUTILOS project, not only strengthened its potential for success but also fostered innovation and collaboration among experts from different fields and sectors. This multi-dimensional approach was essential for addressing the complex challenges involved in NAUTILOS, which required diverse perspectives, expertise and resources.

By promoting collaboration and innovation across different sectors and domains, NAUTILOS was well-positioned to deliver a comprehensive solution to meet the complex challenges of ocean observation, environmental monitoring, and sustainable management of marine resources.

Furthermore, the NAUTILOS project was committed to maintaining transparency and accountability throughout the project.

As a first practical solution to approach the multi-disciplinary issues, as a Consortium, in agreement with the project External Advisory Board, ethical checks were developed regarding the project

documents and deliverables that went through a robust project quality control, both internally and externally. This rigorous quality control process ensured that the project outputs were of high technical and scientific quality and adhered to ethical standards. This is crucial for ensuring the integrity and trustworthiness of the NAUTILOS project and maintaining ethical standards in all aspects of the project's execution and dissemination. This approach is aligned with the European Commission's guidelines on research integrity and ethics and with best practices in the field.

Before submitting the project deliverables to external bodies, the NAUTILOS Coordinator and the Ethics External Advisory Board ensured that all deliverables were aligned according to the project Grant Agreement. The Consortium agreed to add a common and specific Ethical section to each deliverable of Work Packages 3, 4, 5, 6 and 7.

These have mainly focused on Work Packages 3 and 4, which deal with producing sensors, samplers, or any material that may directly affect the environment or human personnel. Nonetheless, a similar approach was followed by subsequent Work Packages focusing on those dealing with developing and using technologies.

Consequently, starting with M18, all deliverables dealing with technologies and on-field demonstrations contained a section named "Ethical Consideration", organised with the following subsections:

- I. Data Protection, e.g., can the acquired data be seen as personal or requiring special protection?
- II. Environmental Protection, e.g., batteries, loss or disposal
- III. Health and Safety, e.g., battery safety, dangerous goods classification, pressure housings.
- IV. Protection of Marine Life, e.g., marine mammal testing, where relevant
- V. Dual-use potential, e.g. where relevant, details of any potential dual-use issues are highlighted

All deliverables related to demonstrations of the use of the developed sensors and samplers held in Work Package 7 contained the listed sections (see deliverable D7.1<sup>12</sup>). Considering what was declared in deliverables related to development and testing work packages, the content was adapted to the various scenarios by the involved partners and especially the Environmental Protection section was also checked by partners that carried out the Environmental Impact evaluation in Work Package 11 (see deliverable D11.4<sup>13</sup>).

### III. EMERGING ETHICS PROTOCOL FRAMEWORK: KEY ETHICS SHIFTS IN THE NAUTILOS PROJECT CASE STUDIES

#### 1. ETHICS REQUIREMENTS

As per Ethics Requirements identified during the Ethics Screening performed by the Research Executive Agency (REA), the NAUTILOS project was to comply with the Key Aspects of Ethics within the Horizon 2020 framework.

In addition, considering the demand for scrutiny of research and development by society and its alignment with the Responsible Research and Innovation (RRI) principles throughout the NAUTILOS project execution, all relevant national, EU and international legislation were followed, including the Charter of Fundamental Rights of the EU and the 6 sets of the Ethics Summary Report requirements:

<sup>12</sup> [https://nautilus-h2020.eu/wp-content/uploads/2024/12/D7.1\\_NAUTILOS\\_10-04-2024\\_v3.1\\_GP\\_doi.pdf](https://nautilus-h2020.eu/wp-content/uploads/2024/12/D7.1_NAUTILOS_10-04-2024_v3.1_GP_doi.pdf)

<sup>13</sup> [https://nautilus-h2020.eu/wp-content/uploads/2025/05/D11.4\\_NAUTILOS\\_26-07-24\\_v5.0\\_doi.pdf](https://nautilus-h2020.eu/wp-content/uploads/2025/05/D11.4_NAUTILOS_26-07-24_v5.0_doi.pdf)

### **A. Ethics Requirement (ER) 1 on human beings**

Considering the active engagement of cross-sectorial stakeholders through the entire project length, as well as the participation of citizen scientists, the following actions have been implemented with the aim of respecting the involvement of human participants:

- I. Informed consent forms, to be used throughout the project actions involving external people, were first drafted and submitted as **D13.1 H - Requirement No. 1**, and these have been extensively adapted and amended within the deliverable D13.7 and its annexes;
- II. The informed consent forms have been used through the project's case studies and all dissemination actions;
- III. The forms have also been developed to include vulnerable individuals, such as minor-aged students involved in the CS activities;
- IV. The forms have also been used in the demonstration activities involving commercial fishing vessels, ferrybox ships and aquaculture management.

### **B. ER 2 on the protection of personal data and compliance with the GDPR**

Concerning the Protection of Personal (POP) data, a specific deliverable was submitted as **D13.2 POP - Requirement No. 2**. The document provides recommendation on the procedures of the Information Systems and is inspired by the principles of correctness and diligence and in compliance with the provisions contained in the Privacy code and in the European regulation GDPR.

The dissemination and use of information technology expose the project to risks in terms of:

- Processing of personal data (GDPR 679/2016 and related)
- Quality of Service
- Confidentiality, integrity and availability of data (ISO 27001 and related);

Given therefore that the use of IT resources and IT systems in the project must always be inspired by the principle of diligence and correctness, behaviours that are normally adopted in the context of an employment relationship, the Consortium has defined internal guidelines to limit situations of risks. These recommendations may possibly be supplemented with further and more specific instructions that may be provided by the respective functional and hierarchical managers, i.e., NAUTILOS Data Controller and the Data Protection Officers identified by the partners.

### **C. ER 3 on animals**, particularly in the research activities performed with animals, in particular animal-borne instruments and the use of non-invasive marine animal tags.

It was clearly stated that the NAUTILOS research activities will rely on **two different approaches to attaching animal born tags**:

- I. **IMAR: Non-invasive towed tags** are typically attached using an adjustable harness that sits around the body, between the head and pectoral fins (sharks) (or wings in manta rays) and is retained on the animal's shoulders (fins) as they constantly move forward in order to breathe, trailing the tag behind and above the animal. The harness and tags are typically deployed by hand by a free diver. In the case of the six-gill sharks, the animals are fished, tagged and immediately released.
- II. **CNRS-CEBC (elephant seals)**: Tags are glued to the head or back fur using a two-component fast setting araldite. 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 ( $338 \pm 65$  kg). We are confident that the instruments did not affect at-sea behaviour. Previous studies have demonstrated that seals carrying twice this load (instruments of up to 0.6% of their mass) were unaffected in either the short-term (mass gain) or the long-term (survival) by carrying these instruments. If we are unable

to catch the seal when back ashore, the tags will be lost on land during the moult (the renewal of the fur)<sup>14</sup>.

In addition, **Animal Welfare Issues involving potential risks were mitigated ethically and responsibly:**

- i) As regards elephant seals handlings and anaesthesia were performed in accordance with relevant guidelines and regulations, after approval by the French (APAFIS N°19-040 #21375 delivered on the 13/07/2019) and Argentinian Ethics Committees and animal handling and experimentation authorisations provided by the French Polar Environment Committee. Elephant seals were found to be unresponsive to micro-sonar emissions (i.e. above their hearing threshold, Goulet et al. 201915).
- ii) The tags are either recovered from the animals when they haul out or they fall off in the subsequent moult, so that a tag can never remain attached on a SES more than 12 months if deployed just after the moult. This program will also contribute to the knowledge provided on elephant seal ecology and to the conservation of the marine environment.

#### **D. ER 4 on Third Countries**

To ensure full compliance with Ethics Requirement 4, the following has been submitted as part of **D13.4 NEC - Requirement No. 4:**

- i) Details on the materials which will be imported to/exported from the EU must be submitted as a deliverable
- ii) Copies of import/export authorisations, as required by national/EU legislations will be kept on file and submitted to the Agency upon request

#### **E. ER 5 on Environment & Health and Safety, especially environmental protection**

Closely related to Ethics Requirement 3 is Ethics Requirement 5 on Environment, Health & Safety. A comprehensive Environmental Impact Assessment (EIA) is an integral part of all NAUTILOS activities and was carried out within NAUTILOS starting in M1. This allowed for environmental issues to be addressed early on within the project planning. Issues were identified, and any possible adverse environmental impacts were predicted, and alternatives and solutions to mitigate negative consequences on the environment and man provided. The EIA also ensured that the project abides by national and EU EIA regulations and supported the exchange of know-how and promotion of good practices as regards healthy, safety and environmental material aspects, e.g. post-use material collection and recycling. The final NAUTILOS Environmental Impact Assessment has been submitted as part of above mentioned deliverable D11.4.

NAUTILOS partners also ensures that both staff and participating marine citizen scientists, especially such as the ones involved in T10.4 - Citizen Science Campaigns and Task 12.2 - Citizen Science Plastics-Related Campaigns, have followed appropriate health and safety procedures and abided by local and national guidance in relation to diving activities.

To ensure full compliance with Ethics Requirement 5 the following has been submitted as part of **D13.5 EPQ – Requirement No. 5:**

- i) Further information about the possible harm to the environment caused by the research and the measures that will be taken to mitigate the risks,
- ii) Details on the endangered species and/or protected areas involved in the research, and the measures to minimise the impact of the activities,

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<sup>14</sup> McMahon C.R. et al. Tracking and data-logging devices attached to elephant seals do not affect individual mass gain or survival. *Journal of Experimental Marine Biology and Ecology* 360(2):71-77. 2008.

iii) Appropriate health and safety procedures conforming to relevant local/national guidelines/legislation were followed for staff involved in this project and for citizens involved in diving activities in the framework of the project.

#### **F. ER 6 on Dual Use**

The compliance of NAUTILOS project with the use of Unmanned Aerial Vehicle and Underwater autonomous vehicles that is used in demonstrations is specified in the deliverable **D13.6 DU - Requirement No. 9**.

Details on the potential dual-use items in the sense of Council Regulation (EC) No 428/2009, where certain items may need an authorisation for export, were included in the Grant Agreement before signature. This was performed as a precautionary measure, as the vehicle and platforms to be used in NAUTILOS activities are intended for civil purposes, and recognition of the regulation and all necessary procedures is due process to ensure compliance, as necessary.

## **2. NAUTILOS ETHICS PROTOCOL**

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As per NAUTILOS Grant Agreement, an Ethics Protocol was created in Month 6 (M6) to ensure compliance with national, EU and international laws and ethical principles in the context of marine observation geoethics. An Ethics Advisory Board (EthAB) was selected in Month 12 (M12) as part of the External Advisory Board (EAB). On the basis of the Ethics Requirements, the Ethics Protocol was completed in M12 and has served as an ethical marine observation framework, which was followed throughout the NAUTILOS project.

## **3. TOWARDS AN ETHICS PROTOCOL IN A MULTIDISCIPLINARY MARINE ENVIRONMENT PROJECT**

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Based on the NAUTILOS increased interest and extended involvement in the external activities, such as the demonstrations and Citizen-Science activities, NAUTILOS EthAB envisaged setting out Ethical Protocols and providing recommendations based on the multidisciplinary work and cutting-edge research activities throughout the NAUTILOS Project.

Thus, this White Paper document has been conceived to be a research-based guidance, offering a focused description of the NAUTILOS cutting-edge and innovative ethical research approach using specific case studies, and in addition, provide recommendations for an Ethics Protocol aligned with the specific objectives of the European Union Mission to Restore our Oceans and Waters by 2030<sup>15</sup>, which will provide possible adjustments to existing EU legislative framework related to Ethics Protocol as well as serve as an Ethics Framework for future Multidisciplinary Environment Projects

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<sup>15</sup> [https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters\\_en](https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters_en)

## IV. NAUTILOS PROJECT CASE STUDIES

Considering the importance and the extent of Demonstration and Citizen Science activities in NAUTILOS, the EthAB raised the importance of discussing and providing a joint document outlining the various risks identified with the foreseen activities. This was done in advance and has been updated during the development of the activities.

This task was fulfilled through consultations among the involved partners. The basis for this consultation was outlined as a sequence of questions:

- “Who is involved?” also including a timeline and other Work Packages interactions
- “What?” detailing what the focus of the activities was, along with indicators and evidence
- “Where?” locating where the demonstration and Citizen Science activities were performed, with the specific distinction between EU, non-EU countries
- “When?” describing when the activities were planned to happen and then took place.

Following the consultations with each Task within Work Package 7, a comprehensive table was drafted representing the “WP7 Ethics Table”, provided in Annexe 1 of deliverable D13.7 – Demonstration Ethics Risks Table. The content of the document was also shared with the EAB. The same type of interviews was also conducted for the Citizen Science activities in Work Packages 10 and 12, and the consequent table was drafted in the same deliverable D13.7 as Annexe 2 – Citizen Science activities Ethics risks table.

The proposed solutions are based on NAUTILOS project case studies arising from both the specific NAUTILOS project activities and the partners' long-term experiences in their respective fields of research. These case studies, mainly connected with the NAUTILOS demonstration and Citizen Science activities, are in the realm of:

- a) Scientific access to private observation platforms for demonstrations;
- b) Citizen Science and students;
- c) Animal tagging welfare;
- d) Usage of possible dual-use platforms.

In the following, specific details for each case study are presented along with a comparison of the proposed ethics protocol with respect to existing literature and other case studies.

### 1. CASE STUDY 1: SCIENTIFIC ACCESS TO PRIVATE PLATFORMS

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NAUTILOS intends to provide the technological innovations needed to support the growing demand for wider, cost-effective global ocean and coastal observing systems to establish environmental baseline conditions, detect and monitor environmental changes, and underpin the provision of primary environmental services. Platforms of Opportunity (e.g. commercial or private vessels and facilities) are among the most powerful tools suitable to host these technological improvements to expand the capacity of already mature monitoring systems and provide data products at local, regional or global scale; these products can be used both by the scientific (e.g. model validation, processes investigation etc.) and private sectors for example the fishing and aquaculture community (e.g. to prevent interactions with harmful algal blooms or discharges of noxious compounds, to provide information on maritime conditions, allowing the establishment of safer routes for maritime activities etc.) as well as stakeholders (e.g. to allow resources conservation and management etc.<sup>16</sup>).

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<sup>16</sup> <https://doi.org/10.3390/jmse9040366>

NAUTILOS indeed aimed to expand the capacity of observational systems based on Ships of Opportunity (SOOPs; e.g. ferries, fishing vessels), adding new sensors and parameters observed and using novel approaches (e.g. Ferries operating in coastal regions with mariculture and fish farms) to provide data products useful for both scientists (e.g. marine resources research, oceanography, etc.) and stakeholders (e.g. stock managers, farm owners, consumers and regulatory authorities).

One of the most common applications of the SOOP concept in operational oceanography consists in taking advantage of already existing commercial routes, equipping vessels with scientific payload, known as FerryBox systems, to collect data in areas that could not reasonably be covered with traditional research vessel efforts without access to significant, sustained funding<sup>17</sup>. Compared to other existing marine observatories and infrastructures, FerryBox systems require, in fact, low maintenance and operation costs, although they provide high-resolution sea surface observations.

A more recent though already well-established development uses specifically designed sensors deployed from commercial fishing vessels; indeed, the deployment of sensors together with fishing gears allows for filling spatial and temporal gaps in the collection of subsurface oceanographic data, especially in coastal areas<sup>18</sup>. Furthermore, it is well known that fish distributions and stock sizes are linked to environmental variables (e.g. temperature, salinity, oxygen and chlorophyll) and their changes in time and space, with subsequent influence on fishery sustainability and economy; therefore, an “Ecosystem-based Fisheries Management” strategy, requires a comprehensive knowledge of both georeferenced catch data and as much simultaneous environmental data as possible<sup>19,20,21</sup>. Similarly, multi-parameter environmental data could be of high value concerning commercial aquaculture systems, providing key data for operators, product quality and welfare information to consumers, and environmental status data to regulatory authorities. These data generated in commercial fishing and aquaculture applications have considerable additional value in both oceanographic and ecological models<sup>23,22</sup>. This integrated approach has a significant potential to support various European environmental management priorities, including the Common Fisheries Policy (CFP) and the Marine Strategy Framework Directive (MSFD).

Sensor demonstrations on ships of opportunities (e.g. fishing vessels and ferries) held in the NAUTILOS framework<sup>23</sup> took advantage of the support offered by some regional programmes and infrastructures already in place in the areas selected for demonstration. In particular, AdriFOOS<sup>24,25</sup> and RECOPECA<sup>26</sup> programs provided support for demonstrations to be carried out by using fishing vessels in the Adriatic Sea and the Bay of Biscay, respectively, while the Norwegian NorSOOP<sup>27</sup>, the Greek POSEIDON<sup>28</sup>, and the Finnish FINMARI<sup>29</sup> research infrastructures provided their support for the use of ferryboxes as well as other applications, such as the use of scientific and private aquaculture plants.

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<sup>17</sup> <https://doi.org/10.1016/j.jmarsys.2014.07.003>

<sup>18</sup> <https://doi.org/10.3389/fmars.2020.485512>

<sup>19</sup> <https://doi.org/10.1111/fog.12126>

<sup>20</sup> <https://doi.org/10.1371/journal.pone.0270703>

<sup>21</sup> <https://doi.org/10.3389/fmars.2022.969071>

<sup>22</sup> <https://doi.org/10.1016/j.jmarsys.2016.03.002>

<sup>23</sup> See NAUTILOS deliverables D7.1, D7.2 and D7.3

<sup>24</sup> <https://doi.org/10.1080/1755876X.2015.1120961>

<sup>25</sup> <https://doi.org/10.5194/essd-15-3513-2023>

<sup>26</sup> <https://archimer.ifremer.fr/doc/00858/97035/>

<sup>27</sup> <https://doi.org/10.5194/egusphere-egu23-16706>

<sup>28</sup> <https://doi.org/10.3390/jmse10121932>

<sup>29</sup> <https://meetingorganizer.copernicus.org/EGU2018/EGU2018-7650.pdf?pdf>

Pearlman et al. 2019<sup>30</sup> stated that Ocean Best Practices and Standards (OBPS) should include societal and ethical factors impacting ocean observations, for example including in best practices information on how to do cost/benefit analyses, on advice and methodologies for obtaining research authorizations, navigation rights, legal status of seabed resources or ship passage, conservation and management of marine living resources, etc. While for providing ethical recommendations for ocean observation, Barbier et al 2018<sup>31</sup> recommended that when third parties (such as private industry) are involved in a project, it is imperative to communicate clearly to the participants of their role in the proposed research and to inform them promptly about any changes; furthermore they suggest that traceability and transparency of data and processes can help defuse potential unwanted conflicts.

Thanks to the knowledge acquired by the partners while building the above-mentioned infrastructures and platforms and to their participation in previous EU projects (e.g. EU FP7 JERICO “Towards a Joint European Research Infrastructure network for Coastal Observatories”, EU FP7 NeXOS “Next generation Low-Cost Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management” and H2020 JERICO – NEXT “Joint European Research Infrastructure network for Coastal Observatory – Novel European eXpertise for coastal observatories”), during the preparation of demonstrations involving commercial and private ships or facilities, some “lessons learnt” from the ethical point of view were applied.

Therefore, before starting any collaboration with commercial fishing vessels to be included in a Fisheries Observing Systems Demonstration (or in general in an observational infrastructure, e.g. AdriFOOS<sup>28</sup>), it was important to take into consideration, define and inform any third party on aspects on:

- Contact point (e.g. research institute, information on the project and demonstration responsibilities)
- Purpose of the study (e.g. scientific data collection, no data transfer to control authority)
- Modality of collaboration (e.g. voluntary or paid participation)
- Collaboration duration
- Involvement (e.g. instruments installed on board, technical requirements, degree of interaction with usual activities, effort required to the fishermen as instruments deployment/maintenance or data input)
- Benefits (e.g. data access)
- Possible risks (e.g. power supply details, interactions with onboard instruments, etc.)
- Privacy and confidentiality (e.g. anonymised data, respect of national and EU regulations)

Most of the above-listed considerations could also be applied to FerryBox applications and aquaculture plants.

In the latter application, it is also required to take into account the risks and thus give information about possible interactions between deployed instruments and farmed fish.

To help with the planning of the demonstrations and to guide the interaction with the private participants, a special NAUTILOS Project Informed Consent Document for participation in demonstrations was prepared in different languages (see Annexe 3-12 in deliverable D13.7). The forms should be adapted to each type of demonstration and third-party user. It is important to underline that the interaction with private and commercial activities could be influenced not only by national regulations but also by local habits that should be taken into account while planning the activities and adapting the documents. As an example, while dealing with fishing fleets, there are different challenges depending on local and cultural differences, fishing gear used, and the area

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<sup>30</sup> <https://doi.org/10.3389/fmars.2019.00277>

<sup>31</sup> <https://doi.org/10.5194/adgeo-45-343-2018>

fished<sup>32</sup>. Before starting the real NAUTILOS demonstration period, the document was already supplied to 2 of the vessels belonging to the AdriFOOS fleet to check for fishermen's reactions and willingness to sign it; positive feedback was received, and copies of the documents were stored in the archive of the leading institution. The same forms translated into various languages were then used for demonstrations involving fishermen and adapted for aquaculture purposes.

## 2. CASE STUDY 2: CITIZEN SCIENCE AND STUDENTS

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Citizen science and crowdsourcing can be used to introduce the concept of opening up and democratising marine observation science<sup>33</sup> and this is one of the aims of the NAUTILOS project. Citizen science campaigns, synergies, events and online tools have been developed and strongly support NAUTILOS social interface.

More specifically, NAUTILOS aims to enable the widespread adoption of the simple instrumentation and cost-effective *in situ* observation technologies developed within the project by a wide range of typical and non-typical data users, thus achieving sustainable and scalable results and the system's long-term sustainability. Samplers, sensors and a smartphone micro-plastic NIR scanner device have been developed and applied as citizen science tools for imaging, collecting, identifying, and characterising plastic contaminants in the marine environment.

A series of citizen science campaigns, engaging school students and other local teams (e.g. leisure divers, NGOs, citizen associations), have been organised within the course of the project, aiming to create awareness and, at the same time, to encourage the participation of citizens in the collection of data regarding marine plastic pollution. The first batch of these plastic litter data collected by citizens and students during 12 campaigns that were organised in Crete (Greece) during the period May 2022 – May 2023 has already been published in the European Marine Observation and Data Network (EMODnet) database<sup>34</sup>. A second dataset with data from 8 more campaigns in Crete during the period May 2023 – May 2024 has also been published in the EMODnet repository<sup>35</sup>, while the more recent data batch (May 2024 – May 2025) is now pending publication. The dissemination and open sharing of CS plastic litter data through a popular data ingestion platform, such as EMODnet, has increased the visibility of the project and, at the same time, has offered to the scientific community and to the public sector openly and freely available marine pollution data for an understudied region<sup>36</sup>.

The beginning of the NAUTILOS project coincided with the COVID-19 pandemic, and this has affected, at least during the project's first year, the potential opportunities for physical events and field activities reaching out to the wider public. Only online awareness events could be organised during this period since on-site data collection was impossible. However, NAUTILOS partners managed to use alternative virtual means that were deployed to facilitate CS activities. School students in Italy were given the opportunity to perform real surveys using orthophotos collected by aerial drones, which were analysed using the open-source program QGIS for the identification and virtual cataloguing of marine plastic litter<sup>37</sup>. Finally, in 2022, the CS activities of NAUTILOS resumed to normal and reached a wide and diverse audience, mainly in three countries (Greece, Italy and Norway).

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<sup>32</sup> <https://doi.org/10.3389/fmars.2023.1176814>

<sup>33</sup> <https://doi.org/10.1145/3677525.3678642>

<sup>34</sup> <https://emodnet.ec.europa.eu/geonetwork/srv/ita/catalog.search#/metadata/61ab1504-dc02-4685-b3e9-1748cf439358>

<sup>35</sup> <https://emodnet.ec.europa.eu/geonetwork/srv/ita/catalog.search#/metadata/dd7f5d48-7eca-45cb-9980-5240b3c72399>

<sup>36</sup> <https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2019.00313/full>

<sup>37</sup> <https://www.mdpi.com/2071-1050/17/11/5048>

One of the underlying foundations of NAUTILOS is the idea of mass expansion of marine observations conducted by citizens, as well as the promotion of awareness raising and widespread outreach. Such activities are in line with the Belém statement, noting that citizen scientists can increase the temporal and spatial frequency as well as the sampling duration, contribute to the cost-effectiveness (labour cost and time savings) for monitoring programmes of differing scales, increase awareness of marine-related issues, building rudimentary STEM skills and also bridge the science to society gap<sup>38</sup>. Citizen scientists participating in the NAUTILOS activities can upload their data to a dedicated online Data Portal<sup>39</sup>. This portal hosts all the operational data acquired by the various technologies developed in the project, including the CS data. It has a simple interface with an explorable map where retrieved data can be visualised, filtered and displayed in graphical reports. More details about the Data Portal and how it is used are available in Deliverable D8.7, “Fully developed Graphic User Interface”<sup>40</sup>.

A dedicated CS App<sup>41</sup> has been created as a tool to facilitate the involvement of local communities in data collection through data uploading and integration into the portal. The application is designed to provide two main usages, storing and visualisation, for the five different CS scenarios that have been included in the App: 1) plastic litter beach campaigns, 2) image annotation for the classification of plastic litter, 3) image annotation of marine organisms using underwater photography, 4) monitoring of algal blooms and phytoplankton, and 5) recording of physical parameters (temperature, salinity, chlorophyll) by divers using the project’s sensors. The application is also devoted to the promotion of data sharing, since it follows the EMODnet guidelines in order to produce data integrable into the respective aggregator. These guidelines specify which fields are mandatory and, if applicable, the list of accepted values. This feature is available only for Plastic Campaigns regularly submitted to EMODnet.

The participation of citizens is required in all the above-mentioned activities, thus enforcing the use of ethics and consent forms. During the very early stages of the project, informed consent forms were compiled for both adults and under-aged citizens. These forms include information and seek permission to store and publish photos and video recordings of the participants, which may be made during the Citizen Science campaigns, for scientific, cultural, educational and dissemination purposes without any aim for profit.

It is indicated that data protection, as well as the protection of privacy and individuals’ rights, will be based on the principles of fairness, lawfulness and transparency, based on the EU Regulation 2016/679 - General Data Protection Regulation<sup>42</sup> and DL.g.s 101/2018. The participants have the right to access the data being processed, including the right to receive a copy. The participants are voluntarily participating in the citizen science campaigns, and they are reassured that no personal data is requested and that the faces of participants will be blurred and non-recognisable in any photos derived.

The NAUTILOS scientists commit to clearly explain the nature and purpose of the citizen science activity, the procedures to be undertaken and any risks that may be involved. A similar form has been prepared for under-aged participants (under eighteen years old), which has to be signed by their parent or guardian. The Ethics Consent Forms of the NAUTILOS project have been produced in English and translated into three more languages (Greek, Italian and Portuguese)<sup>43</sup>.

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<sup>38</sup> [https://www.aircentre.org/wp-content/uploads/2019/12/belem\\_statement\\_2017\\_en.pdf](https://www.aircentre.org/wp-content/uploads/2019/12/belem_statement_2017_en.pdf)

<sup>39</sup> <https://nautilus-h2020.eu/data-portal/>

<sup>40</sup> <https://nautilus-h2020.eu/wp-content/uploads/2022/10/NAUTILOS-D8.7-Fully-developed-Graphic-User-Interface.pdf>

<sup>41</sup> <https://nautilus-h2020.eu/nautilus-cs-app/>

<sup>42</sup> <https://eur-lex.europa.eu/eli/reg/2016/679/oj/eng>

<sup>43</sup> <https://nautilus-h2020.eu/nautilus-consent-forms-for-citizen-science-engagement/>

Considerable effort has been taken to simplify the language used in the NAUTILOS consent forms and to signify that their main purpose was to protect the participants and their personal data. However, there have been some cases where parents hesitated to allow the participation of their children in citizen science activities after having been requested to sign the consent forms. The formal type of language that had to be used in the forms and the strong legal identity of the documents stimulated increasingly cautious and reserved reactions, especially in the case of parents or guardians.

Hesitations were efficiently resolved in most cases after personal contact with the responsible scientists; however, it is obvious that the general public is not yet familiar with the Data Protection laws and the formal documents that need to be signed to protect their own or their children's rights.

A significant number of CS campaigns related to plastic pollution have been implemented during the NAUTILOS project and the respective data are now hosted in the NAUTILOS data portal: a) 24 datasets of plastic litter from Cretan beaches in which 923 participants collected 20,405 items of plastic litter; b) 4 datasets (hauls) of plastic litter collected from commercial fishing vessels in the Adriatic Sea; c) tracking lines of 9 experiments with 46 Marine Litter Trackers in Italy; d) plastic litter identified on drone photos using a GIS platform by 122 students during 3 seasonal periods in San Rossore Park (Italy); e) 10 activities demonstrating the NIR scanner for macro- and micro- plastics in Norway and 1 similar activity in India. These activities are described in detail within deliverables D12.2 and D12.3, as well as for the KPIs of the SO8 as indicated in D9.7 (see Table 16). Non-plastic related data have also been collected using sensors developed within the NAUTILOS project during the activities described in deliverable D10.9<sup>44</sup>: a) monitoring of algal blooms using the AlgaWarning kit in 15 demo sites in Greece, 6 in Norway and 17 in Italy; b) one campaign in Italy for the collection of dissolved oxygen (DO) and chlorophyll (Chl-a) data by recreational divers; c) three campaigns in Crete for the collection of acoustic data by recreational divers. According to the DOW SO8.1, a total number of 5 citizen science campaigns had to be carried out, while following the completion of the project, an impressive number of 93 citizen science campaigns was performed in 4 countries (42 in Greece, 16 in Norway, 31 in Italy and 1 in India).

### 3. CASE STUDY 3: ANIMALS TAGGING/WELFARE

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Animal-borne instruments have been used in the project as described within the Work Plan, as detailed in the Annexes of the Grant Agreement of the NAUTILOS Project.

The involved species included: Mobula rays (*Mobula tarapacana*), broad-nose six-gill sharks (*Hexanchus griseus*), blue shark (*Prionace glauca*), shortfin mako shark (*Isurus oxyrinchus*), whale shark (*Rhincodon typus*) and southern elephant seal (*Mirounga leonina*). The animals were equipped with multisensor biologging systems, including environmental, behavioural, geolocation sensors and, in some cases, integrated miniaturised cameras or microsonars (acoustic sensors).

Consortium members have extensive experience working with animals and animal-borne instruments<sup>45,46,47</sup>. With increased human activity on marine habitats and the potential of climate-driven changes on the rise, there is a need to deepen the knowledge of ocean dynamics and quantify the impacts of the anthropogenic threats to these habitats and key species. Animal-borne multisensor tracking devices allow in-situ monitoring of remote open-ocean and deep-sea habitats and provide

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<sup>44</sup> <https://zenodo.org/records/14856149>

<sup>45</sup> New non-invasive methods for short-term electronic tagging of pelagic sharks and rays. J. Fontes et al. Marine Biology 2018 Vol. 165 Issue 2 Pages 34

<sup>46</sup> The advantages and challenges of non-invasive towed PILOT tags for free-ranging deep-diving megafauna. J. Fontes et al. Animal Biotelemetry 2022 Vol. 10 Issue 1 Pages 1-13

<sup>47</sup> The Multi-Annual Residency of Juvenile Smooth Hammerhead Shark in an Oceanic Island Nursery. P. Afonso et al. Frontiers in Marine Science 2022 Pages 957

valuable insights into the behaviour and habitat use of wide-ranging and vulnerable marine species, such as sharks and manta rays. These technologies not only enhance scientific understanding of species' ecological patterns and the impacts of human activities, but also play a crucial role in informing evidence-based conservation and management strategies. By integrating these data into policy frameworks, decision-makers can develop more adaptive and effective measures to mitigate the combined pressures of ocean resource exploitation and climate change.

All procedures proposed in NAUTILOS adhere to established animal welfare standards under European, national, and regional regulations. For example, the non-invasive towed tag attachment system developed by IMAR has been successfully tested on various shark and mobula ray species and validated by the Ethics and Animal Welfare Committee of the University of the Azores (ORBEA). Its approval by the scientific community is further demonstrated through peer-reviewed publications (Fontes et al., 2018, 2022). Similarly, research conducted by CNRS-CEBC has received ethical approval under the French regulatory framework, specifically through the "Autorisation de Projet utilisant des Animaux à des Fins Scientifiques (APAFIS) 14."

NAUTILOS relied on two different approaches for attaching animal-borne tags:

- I. IMAR: Non-invasive towed tags are typically attached using an adjustable harness that sits around the body, between the head and pectoral fins (sharks) (or wings in mobula rays), which is retained on the animal's shoulders (fins) as they continuously move forward in order to breath (forcing water through the gills), trailing the tag behind and above the animal. The harness and tags are deployed by hand by a trained and experienced free diver, except for the six-gill sharks that are captured at night, when they migrate to shallow nocturnal habitats (approximately 200m), to reduce the risk of barotrauma and prevent exposure to direct intense sunlight and radiation while being handled at the surface. Individuals are caught using hook-and-line, then slowly reeled to the surface, tagged, and released immediately to minimise handling time and stress. Tagging is conducted only on sharks that meet the 5% maximum drag increase threshold (Casper, 2009), ensuring minimal disruption to their natural swimming performance. The tags are attached using a self-releasing harness, which is detached after 24 to 48 hours, according to the galvanic time release used.
- II. CNRS-CEBC (elephant seals): Tags are glued to the head or back fur using a two-component fast-setting araldite. The combined weight of the devices and glue is approximately 0.9 kg, i.e., 0.26% of the mean departure weight of an adult female elephant seal ( $338 \pm 65$  kg). We are confident that the instruments do not affect at-sea behaviour since previous studies have demonstrated that seals carrying twice this load (instruments of up to 0.6% of their mass) were unaffected regarding either short-term (mass gain) or long-term (survival) aspects. When we could not catch the seal when back ashore, the tags were lost on land during the moult (the fur renewal). Tracking and data-logging devices attached to elephant seals do not affect individual mass gain or survival (McMahon et al. 2008).

### 3.1. Animal Welfare Ethics Issues and Ethics Protocols

The non-invasive deployment of multi-sensor towed tags on pelagic sharks and mobula rays utilises an adjustable, self-releasing harness technique, as developed and validated by Fontes et al. (2018, 2022). No animals are sacrificed, permanently incapacitated, or subjected to significant pain beyond what would be experienced during a standard veterinary needle procedure. Previous studies have demonstrated that this attachment technique does not induce significant behavioural changes in sharks and manta rays (Fontes et al., 2018). To avoid potential long-term impacts on fitness and survival, deployment durations are strictly limited to a maximum of 48 hours. The six-gill sharks are

fished at depth (200 m) using circle hooks, which prevent deep hooking and minimise injury to the throat or digestive system. Sharks are slowly brought to the surface (approximately 4m/min), immobilised by turning the animals into a ventral side-up position, inducing tonic immobility, a reflex that causes a temporary state of “trance”. This allows for safe and quick deployment of the harness and hook removal. The harness is fitted with 150 g of LED spheres to compensate for the positive buoyancy of the tag. Six-gill sharks are thought to use their marginally positive buoyancy to glide up and potentially ambush their prey (Coffey et al. 2020). No intramuscular anchors are used, ensuring a fully external tagging procedure. Tagging is performed swiftly, typically within two minutes after the animal is immobilised. Individuals are released after ventilating the animals the tonic immobility state is reversed. Observations indicate minimal behavioural alterations within the first 12–24 hours post-release, and no mortality has been recorded. Only wild individuals are used in this research, with animals handled briefly and never held in captivity or scientific facilities prior to tagging.

As regards elephant seals, handlings and anaesthesia have been performed in accordance with relevant guidelines and regulations after approval by the French (cf. APAFIS N°19-040 #21375 delivered on 13/07/2019) and Argentinian Ethics Committees and animal handling and experimentation authorisations provided by the French Polar Environment Committee. Elephant seals were found to be unresponsive to micro-sonar emissions (i.e. above their hearing threshold (Goulet et al. 2019)). The tags are either recovered from the animals when they haul out, or they fall off in the subsequent moult. This way, a tag can never remain attached to a southern elephant seal for more than 12 months if deployed just after they moult. This program also contributed to the knowledge provided by elephant seal ecology to the conservation of the marine environment. In addition, previous work conducted on southern elephant seals has shown that long-term deployments of tracking and data-logging devices attached to elephant seals do not affect individual mass gain or survival (McMahon et al. 2008). Addressing and quantifying research effects<sup>48</sup> showed that the handling intensity had no effects on the short- and long-term survival of elephant seals.

The non-invasive tagging and deployment of animal-borne tags by IMAR are conducted in full compliance with the Azorean legal framework governing access to and use of natural resources for scientific purposes. This includes obtaining the Internationally Recognized Compliance Certificate (CCIR) and the License for the Study and Handling of Wild Marine Animals and Access to Marine Protected Areas (LMAS). Furthermore, the research protocols have received positive evaluation from the Animal Welfare Committee (ORBEA) of the University of the Azores, ensuring that all procedures align with international animal welfare standards.

Partners involved in the animal experiments declared that copies of relevant authorisations for animal experiments will be kept on file and submitted to the Agency upon request (see NAUTILOS D13.3). Moreover, eventual training certificates or personal licenses of the animal experiment staff exist and will be forwarded to the Agency upon request.

All ethical issues raised by animal experimentation in the wider context of the other uses of animals in society have been fully taken into account in NAUTILOS:

- the impact on the lives and welfare of animals that different uses might have;
- the broader consequences if there was a ban on using animals under specific circumstances;
- a comparison of the benefits arising from the different uses of animals; and

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<sup>48</sup> McMahon et al. Climate change and seal survival: evidence for environmentally mediated changes in elephant seal, *Mirounga leonina*, pup survival. *Proceedings of the Royal Society B: Biological Sciences*, 2005, 272.1566: 923-928.

- the number of animals involved. The involvement of animals in research cannot be justified simply by the fact that animals are used or abused in other ways. Each use requires special consideration.

Partners are fully compliant with EU Directive 2010/63/EU “on the protection of animals used for scientific purposes”, which has one of the most stringent ethical and welfare standards worldwide. The Directive repealed EU Directive 86/609/EEC and became formally applied across the EU on 1 January 2013. The new Directive aims to strengthen legislation and improve the welfare of those animals still needed to be used, as well as to firmly anchor the principle of the Three Rs: Replace, Reduce, and Refine the use of animals, in EU legislation. Directive 2010/63/EU took full effect on 1st January 2013.

Despite the NAUTILOS project's commitment to implementing the most ethical and minimally invasive tagging methods currently available — such as the harness technique<sup>49</sup> — it is vital to put the potential impacts of non-lethal animal-borne tags in perspective relative to current threats faced by marine ecosystems. These impacts are negligible when compared to the far more severe and widespread consequences of anthropogenic pressures such as industrial fishing, pollution, habitat degradation, climate change, and marine traffic<sup>50</sup>. For example, one-third of all elasmobranchs are at risk of extinction<sup>51</sup>.

The ecological data obtained through animal-borne sensors are essential to informing science-based conservation and management strategies. Such knowledge, which would otherwise remain inaccessible, significantly outweighs the limited and typically short-term impacts on a small number of individuals.

#### 4. CASE STUDY 4: USAGE OF DUAL-USE PLATFORMS AND ROBOTICS

Given the nature of the planned demonstration activities in the NAUTILOS project to field test the developed sensors and samplers, several different marine and aeronautical vehicles and platforms are used and may fall within certain dual-use restrictions despite their purely civilian conception and intended use for scientific and non-military use.

Details on the potential dual-use items in the sense of Council Regulation (EC) No 428/2009<sup>52</sup>, where certain items may need an export authorisation, needed to be explicit at the time of the Grant Agreement signature. This was performed as a precautionary measure, as the vehicles and platforms used in NAUTILOS activities are intended for civil purposes, and recognition of the regulation and all necessary procedures is due process to ensure compliance, as necessary.

Currently, the recognised platforms possibly impacted by the list in Annexe I of the Regulation are part of two specific categories: Category 8 - Marine and Category 9 - Aerospace and Propulsion. Among these two categories, several components, pieces of equipment or tools have been included for use within NAUTILOS activities.

All efforts have been made to ensure the correct export licenses and authorisations were obtained from the authorities for the platforms identified as being covered in the regulation for the activities of the NAUTILOS project, as necessary.

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<sup>49</sup> Fontes et al. 2018; Fontes et al. 2022

<sup>50</sup> Queiroz et al. 2019, Sequeira et al. 2025

<sup>51</sup> Dulvy et al. 2014

<sup>52</sup> <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R0428&from=EN>

The NAUTILOS ethics protocol, created to ensure compliance with national, EU and international laws and ethical principles in the context of marine observation geoethics<sup>53</sup>, has been completed and served as an ethical marine observation framework followed throughout the project.

For each identified asset among the two categories mentioned above, explicit explanations and justifications have been provided; two case study examples are given below for this explanation.

As a first example of this case study, the use of **autonomous or unmanned underwater vehicles** (AUV or UUV) produced and operated by one of the NAUTILOS beneficiaries. Currently, a number of sensors and samplers developed in NAUTILOS were integrated into the UUV and tested and demonstrated in Italy and Portugal, which are all countries within the European Union; therefore, no export outside the EU is expected. Any requirements for export licenses between countries of the EU via the national authorities were to be sought if necessary. The NAUTILOS-developed sensors and samplers described in the NAUTILOS project to be integrated into the UUV, are destined for marine scientific purposes as described in the Grant Agreement and are currently not identified on the regulation list.

Another example of this case study is represented by the **unmanned aerial vehicle** (UAV or drone). The identified platform is a mature and proven product, existing since 2014, with several prototypes built and improved upon. This platform was designed to be assembled with commercial off-the-shelf materials and equipment for purely civil applications. The development phase followed ISO9001, ISO9100 and STANAG guidelines to guarantee that the UAV development was performed according to typical aeronautical safety requirements, even though there is currently no legislation that imposes this approach for UAVs of this class. Regarding flights abroad, the local authorities have been contacted with the assistance of experienced local partners in NAUTILOS to guarantee full compliance with the country's regulations regarding drone operations.

Furthermore, concerning the use of camera sensors on these UAVs, it is explicitly mentioned that the cameras used for environmental and scientific purposes in NAUTILOS are multispectral and hyperspectral cameras, which have the potential to capture a wide range of information, including imagery beyond what the human eye can perceive. In this respect, the operation of the NAUTILOS drones has always been performed in open and public areas and following all established laws and regulations governing the operation of drones. Compliance with these regulations is a legal requirement and an ethical obligation to protect privacy. Considering the data collection objectives, in terms of hyperspectral information, and the regulation followed, no risk was foreseen for what concerns privacy issues.

In conclusion, all operations followed applicable rules and guidelines and the necessary planning for safe and collaborative operations with all stakeholders involved. All necessary formal authorisations from the authorities have been sought where applicable, and records kept.

All the demonstrations and tests for the NAUTILOS Project have been planned for a safe and controlled environment.

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<sup>53</sup> "Geoethics consists of research and reflection on the values which underpin appropriate behaviours and practices, wherever human activities interact with the Earth system. Geoethics deals with the ethical, social and cultural implications of geoscience education, research and practice, and with the social role and responsibility

## V. LESSONS LEARNT FROM NAUTILOS PROJECT CASE STUDIES

In this section, building on the NAUTILOS project Case Studies, we examine in detail the ethical challenges and ethical impacts on the real activities carried out within the NAUTILOS project, highlighting both the problems encountered and the benefits achieved. Through this discussion, we aim to provide a comprehensive understanding of how the project's methodologies and approaches translate into tangible outcomes. Furthermore, the discussion of these results serves as a valuable lesson learned, particularly for future demonstration activities conducted in a multi-disciplinary marine environment project. By reflecting on successes, areas for improvement, and key takeaways, we contribute to the broader knowledge base that can guide similar initiatives in achieving more effective and sustainable results.

The discussion will focus on 6 specific areas that have also been reported in the project website: Citizen Science and its tools, NAUTILOS data and data portal, use of Sensors and Samplers, Policy engagement, Demonstrations involving animals, and data collection and processing as a whole (including data innovation).

### 1. CITIZEN SCIENCE DATA COLLECTION AND CS-APP TOOLS<sup>54</sup>

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Citizen Science data on plastic litter collected during the beach cleaning campaigns are anonymised regarding names and other personal details of the participants. The name of the school is mentioned in the "contributors" field only as an ethical reward to the students. In addition, for the submission of these data in the EMODnet platform it was required to exclude any photos of people/students, even if no faces were shown.

Concerning the CS-App tool, the download and subscription operations are available only on request, and the use of the App is always linked with a person in charge of a specific "campaign" whose objectives are to collect and share data. No personal data are stored by NAUTILOS partners; the user ID needed to access the App is not linked with the email address, which is only used to send the user ID and password and is never stored.

### 2. NAUTILOS DATA AND NAUTILOS DATA PORTAL<sup>55</sup>

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NAUTILOS data are generally not personal or sensitive data. In some cases (e.g. metadata of a vessel name connected with a sensor/sampler mounted and demonstrated onto that vessel) the data are anonymised.

Within the data portal, for instance in connection with Citizen Science data, the uploaded photos are all without faces of people. In rare cases in which people are shown on the photos, combination of factors related to camera settings guaranteed that heavily blurred images are not recognisable.

### 3. SENSORS AND SAMPLERS<sup>56</sup>

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During the NAUTILOS project a range of tests and demonstrations activities<sup>57</sup> were performed across EU and global sites, integrating new sensors into existing research infrastructures and vessels. These deployments were carefully designed to align with environmental regulations and best practices, with special attention to minimise additional impacts on already sensitive ecosystems. Most activities occurred in areas with ongoing scientific monitoring, allowing for efficient implementation and a reduced environmental footprint.

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<sup>54</sup> <https://nautilus-h2020.eu/citizen-science/>

<sup>55</sup> <https://nautilus-h2020.eu/data-portal/>

<sup>56</sup> <https://nautilus-h2020.eu/sensors-samplers/>

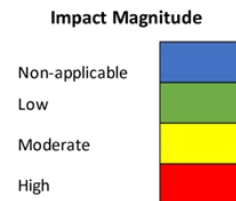
<sup>57</sup> <https://nautilus-h2020.eu/demonstrations/>

In the context of WP11 (Task 11.3 “Environmental Impact Assessment”), an assessment of the environmental impact (EIA) of each of the sensors and samplers was performed.

The environmental impact matrix (Table 1) presents a structured overview of the expected environmental impacts associated with sensors developed within the scope of NAUTILOS. The matrix organises impacts across three key phases of each sensor’s life cycle: manufacturing, use, and end-of-life. Each impact is further categorised into environmental themes. Magnitude is visually represented using a colour-code system, and sensors are listed along the lines for clarity.

**Table 1. Matrix of impacts. The list of sensors, the identified impacts and respective magnitude, divided by phases (manufacturing, use and end of life).**

	Manufacturing				Emissions	Use recovery rates	End of Life	
	Pollutive materials	Source of Power	Antifouling	Sensitive areas			Facility of Repair	Recycling alternatives
Fluorometric DO Sensor	Green	Blue	Green	Green	Blue	Green	Green	Green
DO and Fluorescence Sensors	Green	Green	Green	Green	Blue	Green	Green	Green
IR sensor, LIDAR, Cameras (UAVs)	Green	Green	Blue	Blue	Blue	Green	Green	Green
Passive Acoustic sensor	Green	Green	Green	Yellow	Blue	Green	Green	Green
Active Acoustic Profiling Sensor	Green	Green	Blue	Green	Blue	Green	Green	Green
Sampler for phytoplankton and other suspended matter	Green	Blue	Blue	Green	Blue	Green	Green	Green
Carbonate system/ocean acidification sensors	Green	Green	Green	Green	Green	Green	Green	Green
Silicate sensor	Green	Yellow	Green	Yellow	Red	Yellow	Green	Green
Submersible Nano- and Microplastics Sampler	Green	Green	Green	Green	Green	Green	Green	Green
Low-cost Microplastic sensors based on selective Nile Red staining	Green	Blue	Blue	Green	Green	Green	Green	Green
Deep-ocean CTD	Green	Green	Green	Green	Yellow	Green	Green	Green
Deep ocean low-level radioactivity sensor	Green	Green	Green	Green	Green	Green	Green	Green
Animal-borne tag (elasmobranchs)	Green	Green	Blue	Red	Green	Green	Green	Green
Animal-borne Instruments (elephant seals)	Green	Green	Blue	Red	Yellow	Green	Yellow	Green



Across all demonstrations, mitigation measures were integral to planning and execution. These included using existing platforms, limiting duration, ensuring recovery of equipment, and avoiding sensitive habitats. Where risks existed—such as deep-sea deployments or work with marine fauna—experienced teams followed strict protocols. As a result, the overall impact of NAUTILOS demonstrations was low, showcasing a responsible model for integrating new technologies into marine observing systems<sup>58</sup>.

<sup>58</sup> Authors thanks Prof. Maria Joao Bebianno and Andrè Costa from University of Algarve for the work on EIA and NAUTILOS deliverable D11.4

#### 4. DEMONSTRATIONS – ANIMAL TAGGING<sup>59</sup>

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In the context of NAUTILOS, demonstrations were performed on marine species ranging from large fish and southern elephant seals, raising concerns about animal welfare. The protection and welfare of animals is a priority for the EU.

As such, it is of uppermost importance, that research projects requiring, the capture, handling and equipment with biologgers of marine vertebrates, such as fish, reptiles, seabirds and marine mammal, to be assessed by an independent ethical committee to ensure animal welfare by implementing the best practices and insure that the effects on animals are minimal and that the sample size is adequate, thanks to sensitivity analyses.

Effects of the deployed bilogger on the energetic/ foraging performances of the equipped species is critical, as such studies should not be performed at the cost of the animal welfare and survival. In addition, the data collected should benefit both a better observation and understanding of the marine environment and also benefit the conservation of the studied species, by better characterising their marine habitat and their at-sea ecology. Such data are critical in defining Marine Protected Areas according to the ecological needs of species.

The use of consent forms was crucial for the involvement of fishermen and private sector partners in order to be able to share data and other material related to project outreach (e.g. photos and videos), but also to allow them to understand the project aims and ensure a proficuous collaboration. The assessment of the potential sensors' impact on the environment and human health was also important in view of the future commercialisation of the products.

#### 5. DATA PROCESSING AND DATA PROTECTION AND DATA INNOVATION

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Within T7.1, raw and processed data are exchanged among partners to carry out joint evaluation on the behaviour of the prototypes encountered during the demonstration phases. All the information publicly shared outside the project for the purposes of project dissemination, follow the procedures already established in D13.2 and all relationships with people or private companies external to the project followed and will follow in further developments what was recommended in D13.7.

In particular, the consent forms developed in WP13 and described in D13.7 were made available and signed by the involved commercial fishermen before installing the sensors on board and are stored in the archives of the partners who lead each demonstration. Activities that will be carried out in the future will also utilise consent forms with participants.

Stored acoustic data fall outside the purview of data protection regulations. Nevertheless, users of the instrument possess the capability to annotate data with unstructured text during the configuration of a data logging session. This unstructured text may encompass personal or commercial information, such as names and geo-tagging details.

As a further notice concerning lessons learnt, it is worth to mention that the use of Artificial Intelligence (AI) in the NAUTILOS proposal was only mentioned in the Annexe 1 - Description Of Action (part B, pg. 47 of 168) as a generic “Use of artificial intelligence algorithms”. Although these topics were written in 2019, it is worth mentioning that the use of these AI tools in the NAUTILOS project has been rather limited, with such tools always applied to images related to environmental observation and never including humans. Nevertheless, the NAUTILOS Consortium is well aware and

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<sup>59</sup> <https://nautilus-h2020.eu/demonstrations/>

acknowledges the adoption of the “EU AI Act: first regulation on Artificial Intelligence”<sup>60</sup> entered into force on 1<sup>st</sup> August 2024 and recommends its integration for future activities and projects that include an ethical protocol.

## 6. POLICY ENGAGEMENT<sup>61</sup>

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In the context of policy engagement, extensive work has been performed since the early stage of the project, involving various communities external to the NAUTILOS project. Coping with such a multidisciplinary work, the involved communities are heterogeneous and sometimes distant from each other, even if the safeguard of the Ocean and environment is a major point of contact. Under this topic, the work of WP10 (Task 10.3 “Policy Stakeholder Engagement”) was instrumental in representing NAUTILOS’ interests to decision makers and the National and International communities.

One of the main activities under this task was the development and publication of three different Policy Briefs covering different aspects to represent NAUTILOS’ interests, resulting from the common agreement of all the beneficiaries in the project.

The three policy briefs cover a range of issues that are of importance to NAUTILOS, drafted by collecting insights, expertise and feedback from all valued project partners to help improve the quality and ensure that NAUTILOS policy recommendations are well-informed and effective.

The three policy briefs are titled:

1. Empowering Citizens through Ocean Knowledge Co-Production
2. Supporting Ocean observations to address Climate Change
3. Beyond Climate Change, sustained observation in support of the Blue Economy.

Each of the policy briefs was structured with a specific focus, which was also aligned with the main activities of the project at the time of the publication, followed by a series of recommendations.

Among the Task activities, the main focus was on the organisation of a policy round table, which was held in Genoa (Italy) in the context of the Ocean Race Grand Finale on June 27<sup>th</sup>, 2023. A dynamic table was centred around the topic of the NAUTILOS project’s second policy brief, titled “Supporting Ocean Observations to Address Climate Change”. The event underscored the critical importance of cooperation, citizen engagement and ongoing commitment to ocean observation in the context of a changing climate. More than 60 experts, policymakers and stakeholders came together (face-to-face and online) to explore the pivotal role of informed decision-making, knowledge sharing and innovative technologies in achieving collective success.

In addition, as a further event organised by NAUTILOS, a workshop took place as a side event, hosted during the UN Ocean Decade Conference, which took place on April 10-12, 2024, in Barcelona, Spain. The workshop went beyond one-off efforts to explore the critical role of continuous ocean observation and was centred on the third policy brief. Experts and attendants were able to openly discuss and share ideas as an opportunity to advance the cause of making continuous observations a cornerstone for a prosperous and sustainable Blue Economy.

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<sup>60</sup> [https://www.europarl.europa.eu/thinktank/en/document/EPRS\\_BRI\(2021\)698792](https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2021)698792)

<sup>61</sup> <https://nautilus-h2020.eu/policy-engagement/>

## VI. CONCLUSION WITH POLICY RECOMMENDATIONS

The NAUTILOS Project's novel approach to Research and Innovation Excellence, as demonstrated in the four Case Studies, goes beyond introducing a new Ethics Protocol. It offers tangible benefits and practical solutions for citizens, environmental protection and preservation of marine life, all while embedding an ethical and responsible approach in the use of cutting-edge and low-cost technologies in innovation and research.

### 1. ETHICS PROTOCOL WHITE PAPER POLICY RECOMMENDATIONS

In conclusion, the NAUTILOS Ethics Protocol, White Paper and Policy Recommendations provide a strong foundation for the responsible implementation of the project's Specific Objectives (SO1–SO8, from the NAUTILOS GA and DoW). By integrating ethical guidance across all phases of technological development, data collection, and stakeholder engagement, these instruments ensure that innovation aligns with principles of transparency, inclusiveness, and societal relevance. They directly support the deployment of new sensor systems and platforms (SO1–SO4), promote participatory approaches through citizen science (SO5), and uphold FAIR data practices to improve data accessibility and interoperability (SO7).

As a result of the work presented in this document, we are able to provide 10 targeted policy recommendations that reflect the project's scientific outcomes and ethical commitments. These recommendations are designed to guide policymakers, researchers, and technology developers in advancing marine observation systems that contribute to environmental sustainability, informed decision-making, and long-term societal benefit. They also reinforce NAUTILOS' contribution to broader ocean governance frameworks and EU policy goals related to climate, biodiversity, and innovation (SO6, SO8). The Consortium, and in particular the Ethical Advisory Board (EthAB), is continuing to build on this foundation, working towards a White Paper that will serve as a stepping stone for future initiatives and projects.

#### 1.1. Recommendation 1: Case study 1

The integration of commercial and private vessels as Platforms of Opportunity (PoO) in NAUTILOS required a delicate balance between technological innovation and ethical engagement. Collaborations with fishers, ferry operators, and aquaculture practitioners offered a valuable pathway to expand ocean observations cost-effectively and across under-monitored regions. However, this approach also introduced potential tensions around consent, data ownership, and operational disruption. To ensure responsible research conduct, NAUTILOS partners co-developed tailored Informed Consent Documents in multiple languages, addressing the purpose, risks, and benefits of participation. These documents were adapted to cultural and operational contexts, reflecting a commitment to mutual respect and transparent dialogue.

This experience highlights the need for marine research projects to embed ethical foresight in the planning of collaborative observation strategies. Inspired by the European Group on Ethics in Science and New Technologies (EGE) call for transparency and inclusion in research practices, future projects should treat local knowledge holders and private actors not merely as data sources but as active contributors to marine monitoring. This requires a shift from transactional agreements to long-term relationships grounded in trust, co-benefits, and ethical accountability.

#### 1.2. Recommendation 2: Case Study 1

Despite the technical feasibility of deploying sensors on Ships of Opportunity, the success of these operations in NAUTILOS often depended on navigating local norms, economic pressures, and logistical constraints. Differences in fishing gears, routes, and cultural practices shaped the willingness of participants to engage, as well as the design of the demonstrations themselves.

This underscores the importance of social context in operational oceanography. Ethical reflexivity—understood as the capacity to adapt actions to the lived realities of participants—should be integrated into project planning from the outset. Rather than assuming a one-size-fits-all approach, future initiatives should foster local co-design processes that recognize stakeholder expertise and adapt tools and protocols accordingly. Such relational approaches are crucial not only for scientific success but also for building inclusive, sustainable marine observation networks.

#### 1.3. Recommendation 3: Case Study 2

The NAUTILOS project encountered ethical tension between the legal obligation to uphold GDPR (e.g. via formal consent forms) and the practical inclusion of minors in citizen science. While well-intentioned, the legalistic format of consent forms—despite translation and simplification—created hesitation among guardians, leading to reduced or delayed participation.

This highlights a structural ethical issue: the procedural demands of data protection can unintentionally exclude or deter vulnerable populations, particularly minors. In future projects, ethical frameworks should allow flexibility in consent processes by co-developing them with target groups (e.g. teachers, parents, minors), making legal safeguards meaningful without being alienating. Participatory ethics tools—such as visual assent forms or staged consent—can be adopted to make consent a truly informed and inclusive process, especially for under-aged participants.

#### 1.4. Recommendation 4: Case Study 2

The extensive data collected through NAUTILOS (e.g. 20,000+ plastic litter items by 923 participants) was integrated into centralised platforms like EMODnet. While this contributes to open science, it raises an ethical concern around data justice: citizens contributed labour and time, yet it is unclear whether they retain any agency over how their data is used, interpreted, or credited.

This asymmetry reflects a deeper ethical issue: citizens often provide data without reciprocal benefits or long-term involvement in decision-making. Future projects should move beyond extractive data collection models and embed mechanisms for shared governance over data—e.g. data stewardship committees involving citizen participants, or feedback loops where data leads to local policy change. Ethical citizen science requires more than openness; it requires power-sharing in how knowledge is produced, used, and owned.

#### 1.5. Recommendation 5: Case Study 3

NAUTILOS used animal-borne sensors to gather crucial ocean data, raising ethical concerns around animal welfare, particularly for vulnerable and understudied marine species. While ethical approvals were secured and tagging protocols minimised harm (e.g. drag <5%, limited tagging duration), public and stakeholder concerns about animal well-being persist—especially in projects using invasive methods or charismatic megafauna.

Future projects should adopt species-specific welfare protocols that are co-designed with veterinarians, marine biologists, and ethicists. These protocols should be transparently documented and made publicly available, including justification for species selection, risk mitigation strategies, and post-deployment welfare monitoring. Open communication about these safeguards can enhance public trust, particularly in citizen-facing or policy-relevant initiatives.

#### 1.6. Recommendation 6: Case Study 3

While NAUTILOS adhered to Directive 2010/63/EU and national regulations, the implementation of the 3Rs (Replace, Reduce, Refine) can often become procedural rather than reflexive. For example, tagging elephant seals has become routine in long-term monitoring, but less effort may be directed at refining alternatives to tagging.

Projects should treat the 3Rs as ongoing ethical commitments rather than static checkboxes. This includes investing in non-invasive sensor technology, developing in situ behavioural assessments to detect distress, and integrating local ecological knowledge to inform animal interaction strategies. Ethical review boards should require iterative welfare reflection throughout the project lifecycle, not just during initial approvals.

#### 1.7. Recommendation 7: Case Study 3

The use of large marine animals as data carriers raises broader questions about the instrumentalisation of non-human lives for scientific gain. While human ethical oversight exists, animals cannot consent or dissent, creating an inherent power asymmetry that warrants more than technical mitigation.

Future projects should engage in ethical storytelling, acknowledging this asymmetry rather than concealing it behind regulatory compliance. This could include open-access impact logs describing not only scientific outputs but also animal interactions, stress events, or recovery outcomes. Reflexive narratives can prompt more responsible research cultures and stimulate public dialogue on the ethical limits of wildlife-based sensing.

#### 1.8. Recommendation 8: Case Study 4

NAUTILOS employed marine and aerial robotic platforms—such as AUVs and UAVs—for scientific sensing and sampling. Although designed for civilian research, some platforms and components potentially fell under EU dual-use export control regulations. NAUTILOS took precautionary steps, including regulatory assessments, obtaining export authorisations, and adhering to national and EU laws. However, the complexity of dual-use classification and the evolving regulatory landscape can raise concerns about transparency, ethics, and potential misuse.

Future projects using robotic or dual-use platforms should integrate export control compliance into early planning stages and maintain open documentation on platform use, classification decisions, and licensing status. Collaboration with legal experts, ethics advisors, and national authorities should be formalised in the ethics protocol. Publicly communicating the civilian intent, legal safeguards, and operational transparency of such platforms can reduce reputational risk and build stakeholder trust, particularly in projects operating at the intersection of technology, policy, and sensitive ecosystems.

#### 1.9. Recommendation 9: General

The early stages of the NAUTILOS project were deeply affected by the COVID-19 pandemic, limiting the ability of partners to organise physical outreach events and conduct in situ data collection. In response, the consortium pivoted to online formats to ensure continuity in public awareness and engagement activities. While this digital shift allowed the project to maintain visibility and stakeholder interaction, it also raised ethical considerations regarding inclusivity, accessibility, and the quality of public engagement. In line with the ALLEA Code of Conduct's emphasis on "reliability, respect, and responsibility," NAUTILOS partners took care to adapt their communication tools to diverse audiences, ensuring that virtual formats did not exclude participants lacking digital literacy or access<sup>62</sup>.

This experience underscores the importance of embedding ethical reflexivity in communication strategies. Informed by the EGE's principles of solidarity, inclusion, and responsiveness, future marine research projects should proactively design flexible communication approaches that uphold the right to participate, particularly during times of crisis. Ethical communication must go beyond dissemination to create spaces for dialogue, co-responsibility, and mutual learning. By documenting these ethical

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<sup>62</sup> <https://allea.org/code-of-conduct/>

adaptations and making them transparent, projects contribute to collective learning and reinforce public trust.

#### 1.10. Recommendation 10: General

Develop a structured framework to create a core set of principles **to guide the adoption of a Responsible and Ethical Approach to Research and Innovation (REaRI)**, fostering collaboration among four key stakeholders: industry, government, academia, and civil society – The Quadruple Helix (QH) model. Within the European Union, the QH model is recognised as a vital element of innovation policy, particularly in advancing sustainable and inclusive regional growth.

Hence, the **Ethics Protocol outlined in the *White Paper on Multi-disciplinary Marine Environment Projects* serves as a stepping-stone to establishing a Responsible and Ethical Approach to Research and Innovation (REaRI) in future initiatives.**

## APPENDIX 1: REFERENCES AND RELATED DOCUMENTS

Deliverable 1.5 has been developed under the provisions outlined within the following related documents:

ID	Reference or Related Document	Source or Link/Location
1	NAUTILOS Grant Agreement	NAUTILOS Team GDrive, SyGMA platform
2	NAUTILOS Deliverable D1.2.	NAUTILOS Team GDrive, Zenodo NAUTILOS community, SyGMA platform
3	NAUTILOS Deliverable D1.6.	NAUTILOS Team GDrive, Zenodo NAUTILOS community, SyGMA platform
4	NAUTILOS Deliverable D1.7.	NAUTILOS Team GDrive, Zenodo NAUTILOS community, SyGMA platform
5	NAUTILOS Deliverable D13.7.	NAUTILOS Team GDrive, SyGMA platform
6	NAUTILOS Deliverable D11.4	NAUTILOS Team GDrive, SyGMA platform
7	Ethics Summary Report from the EU Commission	NAUTILOS Team GDrive
8	D13.8 GEN - Requirement No. 11	NAUTILOS Team GDrive, SyGMA platform
9	D13.9 GEN - Requirement No. 12	Submitted contextually at M57