Organisation ETT SpA

Department R&D Unit

D9.5

KPI definition for the NAUTILOS data management and dissemination infrastructure

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

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

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

More information on the project can be found at: https://www.nautilos-h2020.eu/

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Executive Summary

NAUTILOS WP9 is designed to demonstrate and quantify how the new sensors, the new integration in platforms and the new observation approaches can improve the modelling (hydrodynamic, biogeochemical, plastic pollution) and to set up NAUTILOS new data interoperability and legacy towards European Marine data Integrators.

NAUTILOS has designed Task 9.5 - Data Integration in European Platforms, Data Legacy – that moves from the outcome of WP8 and elevate these NAUTILOS tools to the next level within the European Marine data framework.

This activity also includes the development of key performance indicators to measure and assess the system performances, according to demonstration needs and requirements.

These KPIs have to cover information like how long it takes from the NAUTILOS data production to its availability in the European Marine Data Infrastructures (e.g. EMODnet), the amount of data that need further tiers of validation, the amount of data that is included in the SeaDataNet network of National Oceanographic Data Centres and IODE collections, the number of publications etc.

The goal of this report (D9.5) is to discuss and set the KPIs which can be monitored and reported periodically (D9.6 at M36 and D9.7 at M48).

The document also includes external experts' feedback from the interim reviewing meeting and in particular, it covers three main KPIs groups: KPIs on data, KPIs on NAUTILOS Specific Objectives and KPIs on Expected impacts.

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List of Acronyms and Abbreviations

Abbreviation	Definition
CMS	Copernicus Marine Services
DAC	Data Assembly Center
DMP	Data Management Plan
DOI	Digital Object Identifier
DOOS	Deep-Ocean Observing Strategy
DOW	Document of Work
EC	European Commission
EGDI	European Geological Data Infrastructure
EI	Expected Impacts
EMODNET	European Marine Observation and Data Network
EOV	Essential Ocean Variables
ETOOFS	Expert Team on Operational Ocean Forecasting Systems
EurOBIS	European Ocean Biodiversity Information System
FAIR	Findability, Accessibility, Interoperability, and Reusability
IF	Impact Factor
IMP	Impact
IOC	Intergovernmental Oceanographic Commission
IODE	International Organization for Data Exchange
JIF	Journal Impact Factor

KPI	Key Performance Indicator
MEOP	Marine Mammals Exploring the Oceans Pole to Pole
MSFD	Marine Strategy Framework Directive
NOD	National Oceanographic Data Centres
NRT	Near Real Time
OSSE	Observing System Simulation Experiments
PID	Unequivocal dataset identification
RI	Research Infrastructure
SDG	Sustainable Development Goal
SO	Specific Objective
TRL	Technology Readiness Level

1. INTRODUCTION

NAUTILOS has the strategic objective of filling in marine observation and modelling gaps for chemical, biological and deep ocean physics variables through the development of a new generation of cost-effective sensors and samplers, the integration of the aforementioned technologies within observing platforms and their deployment in large-scale demonstrations in European seas. The fundamental aim of the project 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.

The principles underlying NAUTILOS will be those of the development, integration, validation and demonstration of new cutting-edge technologies with regards to sensors, interoperability and embedding skills. The development is guided by the objectives of scalability, modularity, cost-effectiveness and open-source availability of software products produced.

In this framework, the NAUTILOS WP9 is designed to demonstrate and quantify how the new sensors, the new integration in platforms and the new observation approaches can improve the modelling (hydrodynamic, biogeochemical, Plastic pollution) and to set up NAUTILOS new data interoperability and legacy towards European Marine data Integrators.

More specifically NAUTILOS has designed Task 9.5 - Data Integration in European Platforms, Data Legacy – that moves from the outcome of WP8 and elevate these NAUTILOS tools to the next level within the European Marine data framework.

This activity also includes the development of key performance indicators to measure and assess the system performances, according to demonstration needs and requirements.

These KPI have to cover information like how long it takes from the NAUTILOS data production to its availability in the European Marine Data Infrastructures (e.g. EMODnet), the amount of data that need further tiers of validation, the amount of data that is included in the SeaDataNet network of National Oceanographic Data Centres and IODE collections, the number of publications etc.

The goal of this report (D9.5) is to discuss and set the KPIs which can be monitored and reported periodically (D9.6 at M36 and D.97 at M48).

2. SETTING THE KEY PERFORMANCE INDICATORS

The fundamental aim of 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.

NAUTILOS is focusing on 17 instrumentation/tools that can operate from shallow coastal waters to open and deep-sea sites, providing complete datasets for studying the marine ecosystem functions and advanced data products and tools.

NAUTILOS is developing sensors to match and fit needs of operational oceanography platforms and it is covering 14 Biology and Ecosystem and Biogeochemical EOVs (inorganic carbon, stable carbon isotopes, dissolved oxygen, inorganic macronutrients, suspended particulates, ocean colour, ocean sound, phytoplankton biomass and diversity, zooplankton biomass and diversity, marine turtles, birds, mammals, abundance and distribution, live coral, sea grass cover, microbe biomass and diversity (emerging) and invertebrate abundance and distribution (emerging), 2 DOOS specific EOVs (litter including microplastics, seafloor sponge habitat cover) and 9 MSFD Descriptors (D1, D3, D4, D5, D6, D7, D9, D10, D11).

In this framework there is not a unique method to monitor the project performance and more indicators have to be designed for better tracking the project impact at different levels. To this end NAUTILOS had already identified a number of measurable objectives, and outcomes.

KPIs have to monitor the number of developed sensors, if they are implementing the planned technology breakthrough (and reaching the planned TRL), if they are covering the targeted EOVs, if they are producing new valuable data, if this data is consumed by policy and directive assessment programs, by marine data infrastructures, by other projects and researchers, etc.

Most of these KPIs are already tracked under D10.1 and periodic reports, while this document focuses on KPI to capture the following categories:

- Data and data product acquisition
- Data product development
- Data and data product delivery through portal and web services
- Data impact

The deliverable introduces the general framework for setting the data management KPI and then describes the indicators.

2.1. DATA FLOW AND DATA MANAGEMENT METRICS

The ocean is vital. About 40% of the world population lives along coasts and the ocean is a source for food, energy, travel, leisure activities, etc. It is estimated that the European blue sector employs almost three and a half million workers. Knowing the ocean and predicting the ocean is of paramount importance. A recent publication from the Expert Team on Operational Ocean Forecasting Systems (ETOOFS), describing the ocean value chain, emphasizes the importance of open, free and easy data provisioning to Marine Core Service and open data access to complementary down-streaming services (Figure 1).

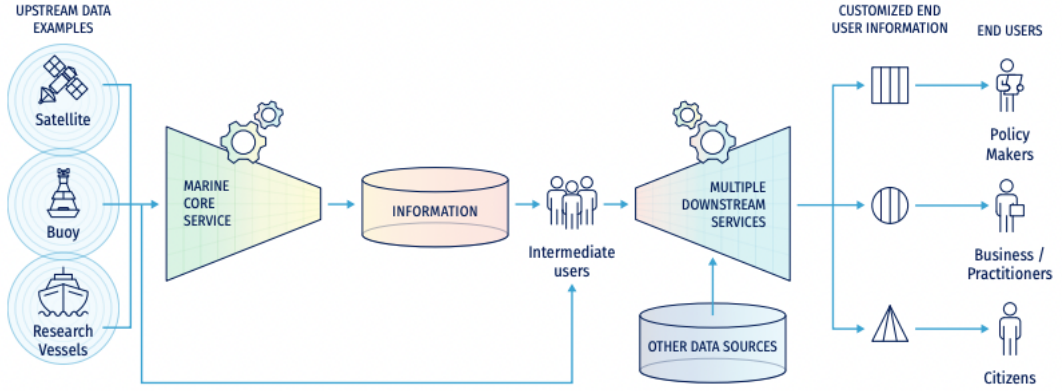

Figure 1. the ocean value chain. Adapted from Alvarez Fanjul et al ETOOFS-2022

Free and open sharing of data, exchange of knowledge, interdisciplinary cooperation are fundamentals to generate at every moment the best possible information to improve knowledge on the ocean and contribute to a sustainable development.

NAUTILOS has developed a set of software and hardware tools (see D8.3) to ease the use of its oceanographic observations, providing consistent and harmonised products ready to be consumed by internal and external stakeholders (e.g. to be for data assimilation and validation) as well as to provide knowledge of the processes that have been undertaken to produce a given observation.

To this end, it is important to ensure that metadata associated with each of the retrieved dataset contain the appropriate information (e.g. instrument/platform characteristics, tests performed and failed, origins of the data stream, data processing history, and information about the datasets) and that those metadata have to be compliant to international conventions.

NAUTILOS is developing a Data Management policy and infrastructure (see NAUTILOS DMP-D1.3, NAUTILOS DMP v2.0 - D1.10 and D8.2) to be compliant with the latest European and international recommendations (e.g. FAIR – Findable, Accessible, Interoperable and Reusable), standards (e.g. ISO, OGC - see D8.3 and D8.4) and enable new knowledge.

In general, to produce ocean knowledge we need to:

1. know what the ocean is doing now (initial condition);
2. calculate how the ocean will change in future (forecast);
3. use oceanographic expertise to validate and refine the output (products).

Hence (new) in situ data is crucial for 1 and 3, whereas 3 major considerations need to be highlighted in the scope of D.9.5:

- **The amount of new produced data is a very basic and crucial indicator.**

Automatic acquisition of the (near real time) data is mandatory for an operational system, while research data (or delayed mode data) usually need retrieval of the instrument and some data cleaning procedure. It could be quite demanding depending on the dataset, the centers (or data providers) involved in data production and treatment, and the available network to connect the centers. This procedure may add delays between the data acquisition and data availability. For the best possible exploitation of this data, an easy-to-access and robust service to visualize and access present and past available observations and associated metadata must be deployed. Metadata include latency information on data availability as a key parameter in the data flow. It is important that new observations are made accessible to the marine integrators' systems with the shortest possible delay.

- **The delay between the data acquisition and data availability (timeliness) on data infrastructures is a second important indicator.**

It is important that new observations are made accessible to the marine integrators' systems with the shortest possible delay. As referred above the two types of data differ in many aspects, one of them the easy-to-use of data. Also, due to their different uses, quality control procedures for the two types of data are applied in different ways and with different methodologies. NRT input data, delivered within a few hours to maximum one week from acquisition, are usually automatically quality controlled using a priori agreed upon procedures. For in-situ observations, quality control tests aim mainly at detecting outliers; these procedures check for inconsistencies in the measurements often using local statistics built from a long time series of similar data. As a result, quality flags are positioned to inform the users about the level of confidence and, where possible, the level of accuracy attached to the observations.

- **The amount of operational data**
- **The amount of delayed mode data**
- **The amount of qualified data**

A European initiative that already provides metrics for the amount of data (and qualified data) that are made available to marine integrators is the EMODnet Data Ingestion platform. It encourages and facilitates data providers to share marine data, for which it provides a number of services as well as guidance information for marine data management. A core service is the Data Submission service which facilitates data providers to submit their data

sets. A low threshold is offered by splitting the completion of the submission form in 2 parts, whereby a data submitter only completes a part of the metadata together with the uploading of a data package. Each data submission is then assigned to a competent data centre for completing the metadata of the submission. Thereafter, those completed submissions are published with their data packages 'as is' at the portal in the View Submissions service, where users can search, browse and download the data packages.

As a next step, assigned data centres further elaborate selected submissions to make (subsets of) the data fit for population into national, regional, European and EMODnet thematic portals. This depends on data centres assessing the added-value of the submitted data and the efforts needed for elaborating the data to common formats, if anyhow possible. Elaboration includes activities like review, validation, conversions to standard formats, and further population to the relevant European infrastructures such as SeaDataNet, EurOBIS, EGDI, CMEMS, and others, depending of the theme, which then feed into EMODnet data portals.

As already introduced one main goal of the project is to develop new knowledge and track its impact. WP10 is already monitoring the number of scientific publications, the participation to conferences and workshops, the organized citizen science campaigns, etc. WP10 is then already assessing the "productivity" of the project and one goal of task 9.5 is to complement these indicators with an indicator on the scientific impact. This methodology has to consider both the digital data production and the scientific outcome. Evaluating scientific quality and impact is a difficult topic without standard and easy solutions, and several citation-based metrics are available.

Although citation counts (Citation Impact) are interpreted as a measure of the impact or influence of academic works (papers, books, etc), citation impact is primarily a measure of scientific utility rather than of scientific quality, and authors' selection of references is subject to strong biases unrelated to quality (Seglen, 1997)[1]

During years, several metrics have been developed for assessing the bibliometric impact of individual researchers, the most common are h-index, ResearchScore, i-10-index[2]. The same applies to articles and journal and the most common are the Impact Factor (IF), which is a measure of the frequency with which the article in a journal has been cited in a given year, and the simplest journal-level metric is the Journal Impact Factor (JIF), which reflects the yearly mean number of citations of articles published in the last two years in a given journal.

NAUTILOS is a project and is based on a collective effort, and fall aside from these metrics, therefore, it is important to set up a methodology to track the overall project activity.

Another important tool for managing identification of content over digital networks is the DOI. DOI is an acronym for "digital object identifier", meaning a "digital identifier of an

[1] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2126010/pdf/9056804.pdf
[2] https://en.wikipedia.org/wiki/Author-level_metrics.

object". A DOI name is an identifier (not a location) of an entity on digital networks. It provides a system for persistent and actionable identification and interoperable exchange of managed information on digital networks. It applies to documents and data.

2.2. IMPORTANCE OF DATA DISSEMINATION

The OECD Principles establish that publicly funded research data should be regarded as a public asset and aim to maximise their benefit to society. Open and shared scientific data to promotes scientific cooperation and scientific advancement, improves the efficiency and quality of science, enhances the scientific productivity of data, foster new tools and services, etc. Moreover, open and concurrent access to all data supporting scientific claims is required for transparency and reproducibility in science. Several research communities have demonstrated substantial benefits of immediate data release: published datasets constitute valuable scientific products in their own right (Cousijn et al.2018) and increases citation rates (Piwowar et al. 2013). Having open and free published data let the project to:

- Demonstrate qualification to undertake research project
- Justification for grant renewal
- Performance and impact for the project
- Benchmarking
- Reporting for a grant project
- Institutional reporting

Moreover, it helps telling and tracking the following indicators:

- Publication activity demonstrates willingness to share research findings
- Authorship/collaboration patterns show evidence of working with other authors, with various areas of research and institutional affiliations
- Citations to publications demonstrates knowledge transfer of research findings and can lead to evidence of synthesis into clinical applications
- Citation patterns help shed light on how original research is being used, by whom, in what areas of research, and where
- Grant acknowledgement networks show how original research is being used by other research groups and who is funding those projects
- Cross-disciplinary research efforts demonstrates sharing of expertise and efficient use of resources
- Research foci trends represented by journals and articles illustrate changes in publication activity and possible evidence of cross-disciplinary efforts
- Evidence of public engagement or activity noted for the work

These indicators are well tracked in NAUTILOS Specific Objectives and Expected Impact KPIs and the following paragraphs give more insight about the metrics and tools NAUTILOS is going to use. NAUTILOS agreed to be an Open Research Data Pilot (ORDP) project and these indicators help assessing the impact NAUTILOS data towards the ORDP policy and goals.

2.3. DATA MANAGEMENT KPIs

A primary set of KPI on data flow:

- number of NAUTILOS datasets submitted to EMODnet Ingestion
- number of NAUTILOS datasets published as EMODnet Ingestion phase 1
- number of NAUTILOS datasets published as EMODnet Ingestion phase 2
- number of registered datasets DOI in NAUTILOS
- number of NAUTILOS DOI citations

3. SPECIFIC OBJECTIVES (SO) KPIS

Starting from the already defined clear and measurable specific objectives and targets (NAUTILOS document of work – DOW), this paragraph recalls the NAUTILOS specific objectives (SO) and complement the already set KPIs with KPIs on data management and dissemination. The specific scope of this deliverable is to set up the metrics, while deliverable D9.6 and D9.7 will report on the status.

SO1: Develop and demonstrate improved observing systems in coastal and shelf-sea environments

- NAUTILOS sensors are going to improve our understanding of environmental change and anthropogenic impacts related to aquaculture, fisheries, and plastic litter in coastal and shelf-sea environments
- Demonstration will be performed in Adriatic Sea, Aegean Sea, Baltic Sea, Coast of Norway and Archipelago of the Azores islands
- Integration platforms ships of opportunity, fixed platforms, unmanned vehicles, and animals

The SO1 KPI is:

	Description	Target	Status
DOW SO1.1	Number of sensors and samplers developed for coastal and shelf sea environments	13	
DOW SO1.2	Number of field demonstrations at coastal and shelf-sea sites carried out	4	

SO1 KPI for data management and dissemination

Demo Site	Number of generated datasets for field of demonstration			Integration platform
	aquaculture	fisheries	plastic litter	
Adriatic Sea				ships of opportunity
				fixed platforms

				unmanned vehicles
				animals
Aegean Sea				ships of opportunity
				fixed platforms
				unmanned vehicles
				animals
Baltic Sea				ships of opportunity
				fixed platforms
				unmanned vehicles
				animals
Coast of Norway				ships of opportunity
				fixed platforms
				unmanned vehicles
				animals
Archipelago of the Azores islands				ships of opportunity
				fixed platforms
				unmanned vehicles
				animals

SO2: Develop and demonstrate improved observing systems in the open ocean and deep-sea environments

- Long-term observation in open-ocean and deep-sea environments (below 2000m)
- sampler for phytoplankton and other suspended matter, silicate electrochemical sensor, deep ocean CTD, deep ocean low-level radioactivity sensor and finally demonstrated in deep sea deployments using lander and Argo floats platforms supported by R/Vs missions.

The SO2 KPI is:

	Description	Target	Status
DOW SO2.1	Number of deep-sea capable (>2000 m water depth rated) sensors developed and demonstrated	4	
DOW SO2.2	Number of field demonstrations at deep-water sites (>200 m water depth) carried out	3	

Advanced KPI specifies the details of the SO2:

Sampler/Sensor	**Reached depth (during NAUTILOS field demonstrations)**	**Cost of technology**
Phytoplankton and other suspended matter		
Silicate electrochemical sensor		
Deep ocean CTD		
Deep ocean low-level radioactivity sensor and		

SO3: Develop and demonstrate improved observing systems for anthropogenic debris (i.e. macro-, micro-, nano-plastics)

- microplastic sensor
- micro- and nano-plastic sampler technologies
- NIR scanner device for citizen science

Sensor and samplers will be respectively demonstrated in the coastal areas of Norway, Gulf of Finland and Aegean Sea, as well as through citizen science efforts on an explorer cruise ship that transects Northern European Seas. The SO3 KPI is:

	Description	Target	Status
DOW SO3.1	Number of cost-effective, portable micro and nanoplastics sensing and sampling technologies developed and demonstrated	3	
DOW SO3.2	Number of field demonstrations carried out for micro- and nano-plastics detection	3	

Advanced KPI specifies the details of the SO3:

Demo Site	Number of datasets for Sampler		
	Microplastic sensor	micro- and nano-plastic sampler technologies	NIR scanner device for citizen science
Norway			
Gulf of Finland			
Aegean Sea			
Transects Northern European Seas			

SO4: Develop and demonstrate improved observing systems in commercial operations, i.e. fishing vessels, aquaculture facilities, ships of opportunity

- New generation dissolved oxygen and chlorophyll a fluorescence sensor
- sampler for phytoplankton and other suspended matter
- hyperspectral and laser induced fluorescence sensors
- ocean acidification sensors
- microplastic sensors
- marine mammal passive click recorder

The SO4 KPI is:

	Description	Target	Status
DOW SO4.1	Number of sensors and samplers developed and demonstrated on vessels of opportunity and commercial facilities	5	
DOW SO4.2	Number of field demonstrations carried out with vessels of opportunity and commercial facilities	3	

The advanced SO4 KPI is

# of datasets	Demo Site				
	Italian waters	French waters	Greek waters	Norwegian waters	Baltic waters
dissolved oxygen					
chlorophyll a fluorescence					
phytoplankton					
hyperspectral and laser induced fluorescence sensors					

ocean acidification sensors					
microplastic sensors					
passive click recorder					

SO5: Develop and demonstrate improved observing systems that utilise animal-borne instruments

- Oxygen sensors on animal tags deployed in the archipelago of the Azores islands as well as in the Valdes Peninsula in Argentina. SO5 KPI is already exhaustive.

The identified SO5 KPI are exhaustive, therefore no other KPI for data management and dissemination are proposed. SO5 KPI are:

	Description	Target	Status
DOW SO5.1	Number of sensing devices (oxygen sensors) demonstrated as part of animal-borne instrument campaigns	1	
DOW SO5.2	Number of deployments in the oceans at regions of interest on a variety of animals for a richer dataset than currently available	60	
DOW SO5.3	Amount of data retrieved from the animals and to feed into NAUTILOS data and modelling activities, inserted into the MEOP initiative and sharing with the wider community	1TB	

SO6: Quantitatively assess the potential improvements on ocean simulation, ocean forecasting and remote sensing derived from NAUTILOS developments

- Observing System Simulation Experiments (OSSE) to statistically assess the impact of of data quality (accuracy, precision, completeness, relevance, and fit to use) in different scenarios and analysed from a cost-benefit perspective. SO6 KPI is already exhaustive:

The identified SO6 KPI are exhaustive, therefore no other KPI for data management and dissemination are proposed. SO6 KPI are:

	Description	Target	Status
DOW SO6.1	Number of physical and biogeochemical model implementations benefiting from new sensors and observing strategies emerging from NAUTILOS	5	
DOW SO6.2	Number of marine plastic pollution model implementations benefiting from new sensors and observing strategies emerging from NAUTILOS	2	

SO7: Appropriately collate, process, and archive all primary environmental data generated during NAUTILOS to ensure that it is maximally Findable, Accessible, Interoperable, and Reusable.

- Amount of data made available and consumed by National Oceanographic Data Centres, EMODnet, SeaDataNet, Copernicus Marine Services, etc.
- Number and type of interoperability interfaces

SO7 KPI are:

	Description	Target	Status
DOW SO7.1	Amount of data transferred to external repositories (i.e. data integrators)	80%	
DOW SO7.2	Qualified data vs uncontrolled data (note: some data may be confidential and unreleasable)	50%	

DOW SO7.3	Publicly accessible data vs total produced data (note: some data might be avalilable after an embargo period to allow scientific production)	80%	

SO7 is very pertinent with the specific goal of task 9.6, the advanced KPI for SO7 are indeed the once identified in DOW.

SO8: Promote and enable the widespread adoption of the NAUTILOS developments to the widest possible range of users and stakeholders (UN legislators to citizen scientists)

- Low-cost *in situ* observation technologies for citizens science
- online tools for data and opinion collection
- Policy round table and presentations,
- project-specific capacity building initiatives for young researchers,
- 5 citizen science initiatives

SO8 KPI are:

	Description	Target	Status
DOW SO8.1	Number of citizen science campaigns carried out	5	
DOW SO8.2	Number of capacity building activities carried out	2	
DOW SO8.3	Policy-related initiatives carried out	4	

Complementary KPI is the number of low-cost[3] in situ observation technologies for citizen science.

[3] Low-cost technology to enable citizen science is a technology with an affordable cost, i.e. tens of Euros.

SO9: Promote and develop a broad range of collaborations and contributions to international, regional, and national fora concerned with the sustainable management of marine resources and the protection of marine biodiversity with a specific focus on the European Strategy for Plastics in a Circular Economy

- monitoring and mapping of marine plastics, harmonised protocols and validated methods to implement measures under the MSFD.
- Engagement with working ESPACE working groups

The identified SO9 KPI are exhaustive, therefore no other KPI for data management and dissemination are proposed.

SO9 KPI are:

	Description	Target	Status
DOW SO9.1	Number of collaborations targeted within the timeframe of the project	>30	
DOW SO9.2	Number of collaborations in relation to ESPCE targeted within the timeframe of the project	>20	

4. EXPECTED IMPACTS (EI) KPIS

The Impact is like a preliminary, but substantial, business plan of the project.

NAUTILOS is an ambitious project with expected impacts on technology, society and knowledge. This paragraph recalls the NAUTILOS expected impacts (EI) and extend the proposed approach to measure them.

- **IMP1: Support the implementation of the G7 Future of the Seas and Oceans initiative, the Paris Climate Agreement, the UN Decade of Ocean Science for Sustainable Development, and the needs of the Marine Strategy Framework Directive**

IMP1 deals with the political and societal requirement and legislation and targets outcomes for supporting Common Fisheries Policy (EU REGULATION 1380/2013), Marine Strategy Framework Directive (Directive 2008/56/EC), and Intergovernmental Oceanographic Commission (IOC) of UNESCO UN's Decade of Ocean Science for Sustainable Development.

NAUTILOS is developing, integrating and testing 11 sensors and 2 samplers to capture 14 EOVs, 4 deep ocean EOVs and 8 MSFD descriptors. The primary expected impact is to enhance the observational capacity of already existing observing systems, which is well measured by the Specific Objectives KPI. KPIs for IMP1 are:

	Description	Tracked by
DOW EI.1.1	Enhance the observational capacity of already existing observing systems	SO1 SO3 SO4 SO5
DOW EI.1.2	Enhance the observational capacity of already existing fisheries observing systems (with more accurate sensors, more parameters observed and new technological application) and develop new approaches (e.g. for aquaculture) /data produced during the demonstrations	SO4 SO6

- **IMP2: Achieve at least TRL 6 for ocean observation systems and tools**

NAUTILOS is working on emerging marine operational monitoring technologies, with high potential for future applications. Some are low to mid-TRL levels (starting from TRL 3 – experimental proof of concept) and the NAUTILOS goal is to develop them further to reach at least prototype stage (TRL 7) by the end of the project. The IMP2 indicators are:

	Description	Target
DOW EI.2.1	Number of types of sensors increased to TRL 6 or above	≥ 11
DOW EI.2.2	Number of types of samplers increased to TRL 6 or above	≥ 2
DOW EI.2.3	TRL achieved by the interface for data management and sharing	≥ 7

Advanced KPI for IMP2 are well captured by tracking the TRL progress in sensor and marine technologies development (Table 1). This new proposed Advanced KPI will be reported periodically (D9.6 at M36 and D9.7 at M48) by requesting data about "Current TRL" to partners.:

Table 1. Sensors and TRL

Marine Technologies Demonstrated in NAUTILOS	Starting TRL	Maximum Operating Depth (m)	(Aimed) Ending TRL	Current TRL	IMP
Sensing and Sampling Technologies					
1. Fluorometric Sensors/dissolved oxygen (ref. ST3.1.1)	3	250 m	7		2.1
2. Dissolved Oxygen and Fluorescence Sensors (ref. ST3.1.2)	5	600 m	8		2.1
3. Downward-looking multi/hyperspectral and laser induced fluorescence sensors and cameras (ref. T3.2)	4	subaerial	7		2.1
4. Passive broadband acoustic recording sensor for noise monitoring (ref. ST3.3.1)	4	1000 m	7		2.1

5. Passive acoustic event recorder (porpoise & dolphin clicks for abundance estimation) (ref. ST3.3.2)	5	300 m	7		2.1
6. Active Acoustic Profiling Sensor (ref. T3.4)	5	1000 m 4	7		2.1
7. Sampler for phytoplankton and other suspended matter (ref. T3.6)	3	5500 m	8		2.2
8. Carbonate system/ocean acidification sensors (ref. T4.1)	5	<100 m	9		2.1
9. Silicate Electrochemical Sensor (ref. T4.2)	5	2000 m	8		2.1
10. Sampler for Nanoplastics and Microplastics (ref. T4.3)	7	600 m	9		2.2
11. Low-cost Microplastic Sensor (ref. T4.4)	3	0	6		2.1
12. Deep Ocean CTD (ref. T4.5)	4	2000 m	7		2.1
13. Deep Ocean low-level radioactivity sensor (ref. T4.6)	4	5000	7		2.1
data management and sharing					
- *Data Products: Services and tools for data transfer towards external DACs*	4	N/A	8		2.3
- *Modelling Products*	7	N/A	9		2.3

- **IMP3: Contribute to regularly measure 50% of biological and biogeochemical EOVs, including in the sea below 2000 m, and predict negative impacts of ocean acidification and other selected stressors to take timely preventive measures, notably to protect aquaculture resources**

IMP3 is tracking the NAUTILOS improvement on capacity to observe biological and biogeochemical EOVs, in a range of environmental conditions. The IMP3 indicators are:

	Description	Advanced KPI
DOW EI.3.1	14 EOVs measured in the timeframe of the project	
DOW EI.3.2	2 DOOS specific EOVs measured in the timeframe of the project	SO2
DOW EI.3.3	8 MSFD Descriptors measured in the timeframe of the project	
DOW EI.3.4	6 Models developed in 3 different geographic regions in the timeframe of the project	SO6

While EI3.2 and EI3.4 are well tracked by SO2 and SO6 respectively, the advanced KPI for EI3.1 and EI3.3 need to be proposed (Table 2). This new proposed Advanced KPIs will be reported periodically (D9.6 at M36 and D9.7 at M48).

Table 2. Sensors and legislations

	NAUTILOS Marine Technologies	Task	Variables targeted	Target disciplinary groups	MSFD Descriptor	Delivered/adopted	Proof (e.g. link to document, etc)
1	Dissolved Oxygen Sensors	(ref. Sub-Task 3.1.1 & Sub-Task 3.1.2)	Dissolved oxygen	Marine biogeochemistry	D3 - Population of commercial fish/shell	Chemistry	
				Regulatory environmental monitoring	D4 - Elements of Marine food webs	Physics	
					D5 - Eutrophication		
2	Fluorescence Sensor	(ref. Sub-Task 3.1.2)	Chlorophyll-a fluorescence	Marine biology/ecology	D5 - Eutrophication	Chemistry	
				Regulatory environmental monitoring		Physics	

3	Ocean surface multi/hyperspectral and laser induced chlorophyll-a fluorescence sensors and cameras	(ref. Task 3.2)	Sea surface temperature, Laser induced chlorophyll-a fluorescence, Ocean color	Marine biology/ecology	D4 - Elements of Marine food webs	Physics	
				Regulatory environmental monitoring Ocean colour community	D5 - Eutrophication	Chemistry	
4	Passive broadband acoustic recording sensor	(ref. Sub-Task 3.3.1)	Marine noise (anthropogenic and natural sources, including marine mammals, sea ice cracking, seismic activity, meteorological sources)	Marine biology/ecology	D11 - Energy and Water noise	Physics	
				Regulatory environmental monitoring	D1 - Biological diversity	Biology	
5	Passive acoustic event recorder	(ref. Sub-Task 3.3.2)	Marine mammal sound detection (porpoise & dolphin clicks for abundance estimation)	Marine biology/ecology	D1 - Biological diversity	Biology	
				Regulatory environmental monitoring			
6	Active Acoustic Profiling Sensor	(ref. Task 3.4)	Suspended particle concentration / distribution (zooplankton, microplastics, organic and inorganic sediment)	Marine biology/ecology Marine pollution	D10 - Marine litter	Chemistry	
					D1 - Biological diversity	Physics	
						Biology	

7	Sampler for phytoplankton and other suspended matter	(ref. Task 3.5)	Concentrated suspended matter samplers for analyses of phyto-pigments, particulate organic matter, microbe biomass and diversity	Marine biology	D1 - Biological diversity	Biology	
				Marine ecological monitoring Climate research	D5 - Eutrophication	Chemistry	
				Marine pollution		Physics	
8	Carbonate system/ocean acidification sensors	(ref. Task 4.1)	pH, pCO2,Total Alkalinity	Marine biogeochemistry Climate research	D1 - Biological diversity	Chemistry	
9	Silicate Electrochemical Sensor	(ref. Task 4.2)	Silicate concentration (Si)	Marine biogeochemistry	D5 - Eutrophication	Chemistry	
10	Submersible Nano- and Microplastics Sampler	(ref. Task 4.3)	Concentrated suspended matter samples	Marine ecology Marine pollution	D10 - Marine litter	Physics	
11	Low-cost Microplastic sensors	(ref. Task 4.4)	Concentration and characterisation of microplastics	Marine ecology Marine pollution	D10 - Marine litter	Chemistry	
12	Deep Ocean CTD	(ref. Task 4.5)	Conductivity, Temperature, Pressure (Salinity and Density derived)	Physical oceanography	D7 - Alteration of hydrographical	Physics	

13	Deep ocean low-level radioactivity sensor	(ref. Task 4.6)	Radon gas, potassium 40K, radium 226Ra and 228Ra, and other natural isotopes	Environmental monitoring	D9 - Contaminants in fish and seafood	-	
14	Integration of existing technologies in animal tagging systems	(ref. Task 5.5)	Temperature, Salinity, Chlorophyll-a fluorescence, Dissolved oxygen	Physical oceanography Marine biology/ecology	D7 - Alteration of hydrographical	Physics	
15	Demonstration of novel equipment for key seabed habitat mapping	(ref. Task 6.2)	Live corals, hard corals, seafloor sponges	Marine biology	D6 - Seafloor integrity	Seabed habitats	
16	Smartphone NIR Scanner	(citizen science application, ref. Task 8.4)	Plastics	Marine pollution	D10 - Marine litter	Chemistry	
17	Visual marine image annotation	(citizen science application, ref. Task 10.4)	Macroplastics, Sponge and cold-water coral cover, major seafloor organism types.	Marine pollution Marine biology/ecology	D10 - Marine litter	Chemistry	

- **IMP4: Lay the foundations for and contribute to the sustainable management and protection of marine and coastal ecosystems to avoid significant adverse impacts (UN SDG 14).**

SDG14 puts a focus on ocean acidification, marine pollution, sustainable management of marine resources and the need for increasing scientific knowledge, etc. The project addresses multiple targets under SDG14: 14.1 which aims to "prevent and significantly reduce marine pollution of all kinds …including marine debris and nutrient pollution" is integral to the project (as covered under IMP11), 14.2 on ecosystem-based approaches (see IMP1), 14.3 on ocean acidification (see IMP3), 14.A on research capacity and TMT (see IMP 5), 14.C on policy for the conservation and sustainable use of the oceans and their resources (see IMP9). Access to relevant and high-quality data is critical to informing sustainable management and use of the ocean (see IMP10).

- **IMP5: Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, to improve ocean health (UN SDG 14).**

NAUTILOS is developing direct links between technology providers and technology users, ranging from reaching out target communities and projects to involving citizens in science, and to capacity building actions. IMP5 KPIs are:

	Description	Target	Advanced KPIs
DOW EI.5.1	Number of young researchers reached via the capacity building initiatives	> 80	SO8
DOW EI.5.2	Number of stablished contacts with projects outside the scope of NAUTILOS	> 30	SO9

- **IMP6: Improve forecasting of climate changes, weather and ocean conditions to protect human activities, in support of UN SDG 14 and other relevant goals, and of the objectives of related conventions (for example on biodiversity).**

One specific focus of NAUTILOS is the improvement of forecasting tools towards SDG14, and this impact is well tracked under IMP3.

- **IMP7: Shorten the time span between research and innovation and foster economic value in the blue economy**

NAUTILOS is addressing cost-effective technologies and capacity building for enabling new opportunities in the European blue economy. IMP7 KPIs are:

	Description	Target	Advanced KPIs
DOW EI.7.1	Reduction in the development and maintenance cost of NR sensors, Target: Reduction of more than one order of magnitude in development costs	> 5	SO2
DOW EI.7.2	Multi-stakeholder collaboration schemes set up as a result of the project	> 10	SO9
DOW EI.7.3	Increase in the TRL of marine technologies	> 12	IMP3 advanced KPI

- **IMP8: Improve the professional skills and competences of those working and being trained to work within the blue economy and in the context of open data sharing**

Capacity building and training initiatives will be organised, adopting all RRI principles, including in the organisation and selection process, specifically targeting the ESPCE (T12.3), thus contributing to the implementation of the G7 Action Plan on Marine Litter. The courses will also generate open access online teaching material to be available on the project's website and widely disseminated through the project social media to a great number of students, scientists and the general public. IMP8 KPIs are:

	Description	Target	Advanced KPIs
DOW EI.8.1	Number of attendees to the European Strategy for Plastics capacity building Initiatives	>40	SO8 SO9
DOW EI.8.2	Unique downloads/views of the e-learning capacity building modules	>500	SO8

- **IMP9: Contribute to policy making in research, innovation and technology**

NAUTILOS is designing three policy briefs to be carried out for European institutions and 1 roundtable to be organized in Brussels to contribute to this impact

The identified IMP9 KPI are already tracking the impact (the table adds detail on tracking tool)

	Description	Target	Tracked by
DOW EI.9.1	Reach of the 3 policy briefs	>1000 people	distribution list/number of readers …
DOW EI.9.2	Attendance of policy bodies during NAUTILOS event	>10 people	List of attenders
DOW EI.9.3	NAUTILOS presentations and in NAUTILOS multi-stakeholder events	3 conferences and 1 event	Program and list of attenders

- **IMP10: Increase data sharing and increase integration of data**

NAUTILOS is developing a data infrastructure enabling the integration of the different types of data, models and citizen science tools for data sharing and dissemination. IMP10 KPI are well tracked and quantified in SO7.

- **IMP11: Contribute to determining the distribution and fate of marine litter and micro-plastics**

NAUTILOS adopts a multi-side, multi-disciplinary and multi-user approach in relation to litter and micro- and nano-plastics observation. Besides designing and developing new tools to capture and track the fate of marine litter, NAUTILOS is organizing citizen science initiatives and interaction with major marine initiative on **marine litter and micro-plastics.** IMP11 KPIs are:

	Description	target	Tracked by
DOW EI.11.1	Deployment of micro and nano-plastics instrumentation	>5	SO3

DOW EI.11.2	Improvement in modelling for nano and micro-plastics	>25%	SO6
DOW EI.11.3	Reach of the plastics-related citizen science campaigns	>1000 people	SO8

NAUTILOS has also Impacts outside the work program, namely they are:

- **IMP12: Enabling the democratization of the marine environmental monitoring system**
- **IMP13: Dissemination**

Both IMP12 and IMP13are are both well tracked under the WP10 and WP12 periodic reporting indicators.

5. STRATEGIES AND TOOLS TO TRACK ACTIVITIES

Counting the number of downloads is an easy, traditional but crude measure, anyhow, with data citations becoming common practice in scholarly publishing, datasets citations are gradually becoming a more common factor for productivity or impact assessment. To use dataset citation impact assessment, persistent and unique identifiers are key to linking research data with scientific results and tracking data reuse.

Unequivocal dataset identification (PID) is key to long-term data preservation, identification, attribution, data citation, provenance tracking, linking research data with scientific results, and tracking of the distribution and impact of data collections. For data and research products this includes the use of Digital Object Identifiers (DOIs) and other persistent identifiers that can be applied to both datasets and observations. Another PIDs that is helpful in managing the data is ORCIDs. With these in mind, the proposed strategies to track NAUTILOS activities are:

- Create an ORCID[4] - Open Researcher and Contributor ID – and embed ORCID iDs in funding workflows
- Create author citation alerts in databases to be notified when your work is cited by another work.
- Establish an author profile in **Google Scholar**[5] and create an alert to be notified when your work is cited by another work
- Establish a **Google Alert**[6] based on your name or research study for email notification of the latest relevant Google results on the alert
- Apply a DOI to each official NAUTILOS document
- Apply a DOI to each NAUTILOS dataset
- Submit NAUTILOS data to EMODnet Ingestion/Physics

[4] Create an ORCID - Open Researcher and Contributor ID,
[5] Google Scholar
[6] Google Alert

6. Appendix 1: References and Related Documents

ID	Reference or Related Document	Source or Link/Location
1	NAUTILOS DOW	
2	NAUTILOS DMP – D1.3	10.5281/zenodo.716362
3	Common Fisheries Policy (EU REGULATION 1380/2013)	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R1380
4	Marine Strategy Framework Directive (Directive 2008/56/EC)	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0056
5	Decade of Ocean Science for Sustainable Development	Intergovernmental Oceanographic Commission (IOC) of UNESCO UN's Decade of Ocean Science for Sustainable Development
6	ETOOFS	*https://www.mercator-ocean.eu/wp-content/uploads/2022/07/ETOOFS-Guide.pdf*
7	Cousijn et al., 2018	Cousijn, H., Kenall, A., Ganley, E. *et al.* A data citation roadmap for scientific publishers. *Sci Data* **5**, 180259 (2018). https://doi.org/10.1038/sdata.2018.259
8	Piwowar et al., 2013	Piwowar HA, Vision TJ. 2013. Data reuse and the open data citation advantage. *Peer J. https://doi.org/10.7717/peerj.175*