



Educational material for the Capacity Building Learning Labs

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DEC	Websites, patents, filing, etc.	
DEM	Demonstrator	
O	Other	
ORDP	Open Research Data Pilot	

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PU	Public	✓
CO	Confidential, only for members of the consortium (including the Commission Services)	

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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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I. INTRODUCTION

The open ocean and deep-sea environments hold massive potential for advancing knowledge on unexplored scientific phenomena, natural hazards, and energy opportunities. However, the lack of long-term observation and advanced technological systems has left these areas underexplored and their exploitation in an early stage of development.

To address this gap, the NAUTILOS project (New Approach to Underwater Technologies for Innovative, Low-Cost Ocean Observation), funded under the H2020 Future of Seas and Oceans Flagship Initiative and coordinated by CNR (National Research Council of Italy), developed cutting-edge sensors and samplers to enhance marine observation capabilities. Among its many initiatives, Task 12.3 emphasised capacity building, with a focus on summer schools tailored to train early career scientists and marine technicians.

The summer schools were organised by EurOcean and hosted by NIVA in Oslo (Year 3), and by HCMR in Crete (Year 4). These events provided participants with hands-on training in deploying sensors and samplers developed in WP3 and WP4, along with an introduction to the European Strategy for Plastics in a Circular Economy (ESPCE). Discussions also addressed the role of NAUTILOS technologies in implementing ESPCE objectives and promoting synergies across regional, national, and international initiatives.

Key components of the summer schools included:

- **Learning Labs:** Practical sessions focusing on sensors and samplers, with applications in sampling microplastics, nutrients, and other essential ocean variables.
- **Roundtable Discussions:** Exploring ESPCE-related strategies, policies, and collaborations.
- **Teaching Materials:** Developed by WP3 and WP4 partners, these resources were tailored to ensure effective skill-building for participants.

To expand the impact beyond the in-person events, **e-learning modules** have been designed and made freely available on the project website¹. This ensured open access to the training materials for a broader audience, supporting professional development in the blue economy and fostering a culture of data sharing and marine stewardship.

By combining NAUTILOS technologies with comprehensive training and capacity-building efforts, the NAUTILOS summer schools contributed significantly to improving skills, knowledge, and engagement in monitoring and protecting our marine environment.

1.1. Purpose of this Deliverable

The purpose of this deliverable is to provide a comprehensive overview of the training developed within the project, intended audience, and the most suitable education and

¹ <https://nautilus-h2020.eu/resources/e-learning/>

training formats. This includes a focus on the capacity-building initiatives delivered through two summer schools, organised to address the skills and knowledge gaps in marine observation and monitoring.

Specifically, the deliverable aims to:

- Document the topics of training in the use of advanced sensors and samplers developed in WP3 and WP4.
- Highlight the target audiences, with a particular focus on early career scientists and marine technicians working in the blue economy sector.
- Describe the delivery of the training during summer schools hosted by NIVA in Oslo, (Year 3) and by HCMR in Crete, (Year 4).
- Outline how these trainings were adapted into e-learning modules to ensure broader accessibility and long-term use beyond the project's duration.

This deliverable not only showcases the project's contribution to capacity building in marine science and technology but also demonstrates how the training supports sustainable development in the marine environment and promotes open data sharing.

1.2. Overview of Contributions from WP3 and WP4

During the course, a range of innovative technologies developed under WP3 and WP4 were showcased by the experts directly involved in their design, testing, and optimisation. These technologies represent significant advancements in marine science, focusing on cost-effective, modular, and accessible solutions for environmental monitoring. By integrating these tools with citizen science and professional research initiatives, they aim to enhance data collection, analysis, and sharing for key Essential Ocean Variables (EOVs). The sessions combined theoretical insights with practical demonstrations, allowing participants to gain hands-on experience and a deeper understanding of the technologies' applications and potential impact.

- **Active Acoustic Profiling Sensor:** Aquatec presented an advanced acoustic sediment profiler for zooplankton biomass, sediment dynamics, and oil droplet measurements, using real-world data for demonstration.
- **Fluorometric Oxygen Sensor:** HES-SO introduced a compact and cost-effective oxygen sensor using fluorescence lifetime, designed for precision.
- **Underwater Broadband Sound Recorder:** Aquatec introduced a newly developed Passive Broadband Sound and Click Recorder for the NAUTILOS project. This innovative technology observes echo-locating marine mammals, capturing full waveforms of frequency-modulated whale clicks, broadband dolphin clicks, and narrow-band high-frequency porpoise-like clicks, as well as dolphin communication whistling sounds.

- **NIR-Based Plastic Identification:** NIVA presented portable near-infrared tools, including a smartphone scanner and USB spectrometer, to identify marine litter polymers, enhancing citizen science initiatives.
- **Carbonate System Sensors:** NIVA showcased modular sensors for measuring seawater pH and pCO₂, focusing on their role in studying ocean acidification and carbonate systems, while adhering to EMODnet data-sharing guidelines.
- **Above Water Radiometry:** NIVA demonstrated radiometric techniques to measure oceanic parameters like phytoplankton and suspended matter concentrations, with sessions on ocean colour, instrument calibration, drone piloting, and data processing.
- **Phytoplankton and Suspended Matter Sampling:** NIVA presented an automatic filter sampling system adapted for use on ships of opportunity and unmanned vehicles. The session included hands-on demonstrations of its operation, integration with vessel systems, and applications for collecting EOY data such as chlorophyll a, particulate organic carbon and nitrogen, phytoplankton DNA, and total suspended matter.
- **Citizen Science App:** CNR-ISTI introduced a multifunctional app supporting plastic data collection campaigns, integrated with the NAUTILOS data portal.
- **Deep-Ocean Radioactivity Sensor:** HCMR presented a sensor capable of detecting low-level radioactivity in extreme environments, equipped with advanced autonomy and communication capabilities.
- **Micro-Plastic Sampling:** Within the NAUTILOS project, SubCtech developed an autonomous deep-sea microplastics sampler. This device can collect multiple samples over long deployments, triggered by time or sample volume. Water is pumped through a cascade filter to pre-sort particles by size.
- **Microplastic sensor:** developed by NIVA and CSEM it is a low-cost system for semi-autonomous sampling and analysis of microplastics ranging from 1 to 300 µm. The sensor filters microplastic particles from seawater, removes organic material through oxidation, and stains the particles with a fluorescent dye. Each particle is then measured individually by recording fluorescence signals in multiple colour channels.

The course featured both theoretical lectures and practical demonstrations, emphasising the real-world application of these technologies. Course materials were further adapted into e-learning modules to ensure broad accessibility and continued knowledge transfer. These contributions highlight WP3 and WP4's commitment to advancing marine monitoring tools and fostering the next generation of ocean scientists.

1.3. Target Audiences for the NAUTILOS Summer School and E-Learning Modules

The NAUTILOS Summer School and e-learning modules together provide a comprehensive approach to knowledge sharing and capacity building. Early career scientists and marine technicians gain direct exposure to innovative tools and methodologies, ensuring they are well-equipped to address the challenges of marine litter and broader ocean monitoring. Meanwhile, e-learning modules expand the reach of NAUTILOS technologies, enabling diverse audiences, from citizen scientists to educators, to contribute to global efforts in ocean sustainability.

Through these initiatives, the NAUTILOS project advances both the technical and societal dimensions of marine science, fostering a collaborative and inclusive framework for environmental stewardship.

Below is an expanded overview of the key target groups and their benefits from making use of these educational offerings.

1. Early Career Scientists

This group includes graduate students, postdoctoral researchers, and professionals in the early stages of careers in marine science, oceanography, environmental studies, and related disciplines. The summer school offered to this audience:

- **Foundational Knowledge in Marine Litter Science:** Participants were introduced to the latest research and developments in marine litter, including an overview of international treaties such as the UN Global Treaty on Plastic Pollution. This foundational understanding positions them to engage critically with global environmental challenges.
- **Practical Training with Advanced Technologies:** Through hands-on sessions, participants learnt to use cutting-edge sensors and measuring systems developed within the NAUTILOS project, including microplastic and macro litter samplers, acoustic sensors, and other environmental monitoring devices.
- **Exposure to Interdisciplinary Approaches:** Lectures and fieldwork encouraged participants to consider cross-disciplinary solutions, blending biology, chemistry, physics, and policy.
- **Networking and Collaboration Opportunities:** Interaction with peers, experts, and professionals fosters collaborative relationships that can continue beyond the program.

2. Marine Technicians and Specialists

This audience includes environmental engineers, marine biologists, and technical staff working in marine monitoring, research, and technology development. For these participants, the summer school provided:

- **Skill Development in Advanced Sampling and Analysis:** Marine technicians gained firsthand experience with state-of-the-art sampling devices, such as sensors for

microplastic detection, macro litter identification, and other instruments essential for environmental monitoring.

- **Real-World Applications of Technology:** The program emphasised the practical deployment of tools in various settings, including coastal environments and at-sea operations. Participants were exposed to field challenges and solutions, enhancing their operational knowledge.
- **Integration of New Technologies:** Insights into modular and scalable technologies, such as autonomous sensors and real-time data integration, are particularly beneficial for professionals looking to optimise marine monitoring systems.
- **Cross-Sector Relevance:** Marine technicians engaged in industries like fisheries, shipping, or offshore energy can also adapt these tools and methodologies for applications beyond the specifications of NAUTILOS project, including biodiversity studies or climate impact assessments.

3. Beneficiaries of the E-Learning Modules

To ensure inclusivity and broader impact, the NAUTILOS project offers e-learning modules for remote training, designed to complement the summer school curriculum. These modules provide scalable and flexible learning opportunities, targeting audiences unable to attend in person. In addition to the aforementioned target groups, the modules offer key benefits to:

- **Citizen Scientists:** Volunteers and community members involved in local or regional marine monitoring initiatives can learn about sampling techniques, sensor applications, and data interpretation. This enhances their ability to contribute effectively to scientific efforts and strengthens the role of citizen science in marine conservation.
- **Educators and Trainers:** Teachers, trainers, and facilitators can incorporate the modules into their curricula or outreach programs, equipping them with up-to-date knowledge and tools. This ensures broader dissemination of marine science concepts, reaching youth and underrepresented groups.
- **Remote Monitoring Teams and Data Managers:** Professionals working in marine observation networks or environmental data management can benefit from training in sensor integration and data analysis. The modules provide methodologies for effectively utilizing NAUTILOS technologies for data collection, storage, and interpretation.

Additionally, the modules introduce novel technologies and tools, supporting the improvement and extension of activities for both citizen scientists and other professionals. By offering an accessible format, they address barriers related to geography, finances, or logistics, expanding the reach and impact of NAUTILOS training initiatives.

1.4. Endorsement by the Ocean Decade

NAUTILOS Summer Schools have received endorsement^{2,3} from the United Nations Decade of Ocean Science for Sustainable Development (Ocean Decade), further supporting the significance of these educational programs in the global effort to protect and sustainably manage the ocean. The Ocean Decade, which runs from 2021 to 2030, is a global initiative designed to promote scientific research, innovation, and collaboration to address the most pressing challenges facing our oceans. The endorsement highlights the alignment of the NAUTILOS Summer Schools with the broader goals of the Ocean Decade, which include advancing ocean science, fostering sustainable development, and empowering the next generation of marine scientists and practitioners.

The NAUTILOS Summer Schools have been recognised for their contribution to the Ocean Decade's objectives, specifically in fostering capacity building, advancing ocean literacy, and enhancing the participation of early career scientists in ocean-related research. The training provided during these programs equips participants with the knowledge, skills, and tools needed to address marine environmental challenges, particularly marine litter pollution and its impact on biodiversity. By combining innovative technologies, marine pollution monitoring, and citizen science, the NAUTILOS Summer Schools contribute to the Ocean Decade's vision of using science to enable effective ocean governance, conservation, and restoration.

II. THE SUMMER SCHOOLS

2.1. NAUTILOS Summer School – Oslo, Norway

Held from September 4–7, 2023, the NAUTILOS Summer School in Oslo focused on Marine Litter Management, bringing together 17 early career scientists and marine technicians from around the world. The program combined academic instruction with practical fieldwork to equip participants with essential skills and knowledge for addressing marine litter challenges. Activities took place at two renowned locations:

- The Norwegian Institute for Water Research (NIVA), where foundational lectures and discussions were held.
- The OceanLab facilities at OsloMet University, located along the scenic Oslo fjord, providing an ideal setting for hands-on training.

² <https://oceandecade.org/events/nautilus-summer-school-on-marine-litter/>

³ <https://oceandecade.org/events/nautilus-summer-school-2024/>



Figure 1 - Group Picture First Summer school

Program Highlights

Key components of the four-day program included:

- Foundational Knowledge: Lectures on the impacts of marine litter, mitigation strategies, and global frameworks like the UN Global Treaty on Plastic Pollution.
- Field-Based Applications: Practical sessions in the Oslo fjord, showcasing innovative sampling and measurement techniques for marine litter.
- Data Analysis: Training on interpreting marine litter data to derive actionable insights for management and policy-making.

2.2. NAUTILOS Summer School – Crete, Greece

From April 17–19, 2024, the NAUTILOS Summer School convened at the Hellenic Centre for Marine Research (HCMR) facilities in Crete, Greece. This transformative three-day program attracted 10 early career scientists and marine technicians from diverse backgrounds, offering an intensive learning experience in marine science and technology.

The course was designed to provide participants with a comprehensive understanding of marine litter science and cutting-edge technologies while highlighting practical applications in ocean observation.



Figure 2- Group Picture Second Summer school

Program Highlights

The agenda for the Crete summer school included:

- **Marine Litter Legislation and Global Frameworks:** Insightful discussions on international treaties like the UN Global Treaty on Plastic Pollution, the MARPOL International Shipping Treaty, the Basel Convention, the GPML partnership led by UNEP, the UNEP Honolulu Strategy, the G7 Action Plan, as well as the relevant EU Directives (MSFD, Plastic Bags, SUP, Circular Economy Action Plan, WFD) and many others. Their role on monitoring activities in mitigating marine litter was discussed.
- **Advanced Sensor Technologies:** Practical demonstrations of sensors developed within the NAUTILOS project, showcasing their integration into various ocean monitoring systems.
- **Ocean Observation Techniques:** Exploration of emerging technologies promoting sustainable practices and open data sharing for marine management, including Citizen Science approaches (CS App, CS initiatives).
- **Synergies** where the CLAIM⁴ and TechOceans⁵ projects have been presented.

The curriculum was structured over three days:

1. An in-depth introduction to marine litter science and its regulatory context.
2. Fieldwork sessions at sea to practice microplastic sampling techniques and sensor applications.

⁴ <https://www.claim-h2020project.eu/>

⁵ <https://techoceans.eu/>

3. Insights into macro litter management, citizen science opportunities, and advanced monitoring tools, some of these activities took place on board of RV Philia.

The success of the NAUTILOS Summer Schools in Crete and Oslo underscores the importance of interdisciplinary education and hands-on training in fostering expertise in marine science and technology.

By combining theoretical knowledge with practical application, these programs have empowered early career scientists and marine technicians to address critical marine environmental challenges. The NAUTILOS Project extends its gratitude to all partners, speakers, and participants for their invaluable contributions to these impactful educational initiatives.

III. TRAINING MATERIALS FOR SUMMER SCHOOLS

3.1. Content Program

A core element of the NAUTILOS Summer Schools was the carefully crafted course content, designed to maximise both impact and uptake among a diverse range of participants. The program provided a combination of foundational knowledge and practical experience with cutting-edge technologies used in real-world marine science contexts. Participants were introduced to a variety of advanced marine monitoring tools, including sensors and samplers for detecting microplastics, macro litter, ocean acidification, as well as other physico-chemical and biological data. These technologies represent the forefront of marine observation, pushing the boundaries of what is possible in the field. Additionally, they promoted the democratisation of science by incorporating citizen science initiatives and using low-cost sensors developed through the NAUTILOS project, ensuring broader accessibility and engagement. The NAUTILOS Citizen Science App was also highlighted as an essential tool for involving local communities in data collection, allowing citizen scientists to actively participate in marine litter monitoring and contribute to a global effort.

The programs also integrated emerging trends in marine science, including data processing and citizen involvement, equipping participants with knowledge of the latest environmental monitoring techniques. This approach was strategically aligned with international treaties, partnerships, and EU directives addressing marine litter, emphasising the role of monitoring activities in mitigation efforts, and reinforcing the importance of collaboration in addressing plastic pollution and promoting sustainable, circular solutions for the marine environment monitoring. Through hands-on training, participants learned how to generate high-quality, standardised data that supports ESPCE's objectives, helping to inform policy decisions and environmental strategies.

The interdisciplinary nature of the NAUTILOS Summer Schools was another key aspect of the program's success. By bringing together experts from various fields—including marine

biology, environmental engineering, and data science—participants were exposed to a wide range of perspectives and techniques for tackling ocean monitoring. This collaborative approach mirrored the interdisciplinary solutions needed to address the complex challenges outlined by ESPCE, empowering attendees to approach marine litter monitoring from multiple angles. The diverse curriculum not only covered technical aspects of ocean monitoring but also stressed the broader environmental, social, and policy contexts in which these technologies are deployed.

In addition to technical talent, the summer schools provided participants with the necessary tools to ensure their data collection methods aligned with global standards. The training highlighted the integration of data into global data frameworks, such as EMODnet, highlighting the importance of data sharing and international collaboration. This integration is essential for producing reliable, comparable data that can guide effective policy decisions. Participants were trained to operate sophisticated monitoring tools and apply them in real-world contexts, ensuring that they could implement these practices in their own research or professional work.

Finally, the NAUTILOS Summer Schools played a key role in supporting Ocean Monitoring goals by equipping the next generation of marine scientists and technicians with the skills, knowledge, and collaborative mindset necessary to confront the growing challenge of protecting our Oceans. The program's focus on data sharing, interdisciplinary collaboration, and innovative technologies ensured that participants were prepared to contribute meaningfully to sustainable ocean stewardship and circular resource management.

The Content Programs are publicly available on the NAUTILOS website:

1st NAUTILOS Summer Course: <https://shorturl.at/PGwsW>

2nd NAUTILOS Summer Course: <https://shorturl.at/GelKc>

3.2. Course Modules

The NAUTILOS Summer School modules followed a well-structured and diverse format, combining theoretical sessions, practical demonstrations, and hands-on experiences to provide participants with both the conceptual understanding and practical skills required for effective marine litter management and monitoring. Each module was designed to align with marine technologies, offering participants a balanced approach to learning.

Both Summer Schools exploited a modular design for their courses, with each day dedicated to specific themes, such as marine litter, citizen science, and new technologies for marine monitoring. This structure allowed for a progressive learning experience, building from foundational knowledge to advanced field applications. Practical modules such as high-volume pump sampling and marine litter tracking provided direct exposure to the technologies being used to combat marine pollution, while also offering the opportunity to interact with experts and learn through peer discussions.

In terms of format, interactive, hands-on training was a central feature across all sessions. For example, the *Data Crackathon* in Crete provided a platform for participants to develop their data management skills in oceanographic applications, using tools like ERDDAP and GeoServer. Similarly, in Oslo, participants engaged with drones and remote sensing technologies like Above Water Radiometry and Waterdrones, which were demonstrated and tested in field-based settings.

Theoretical Sessions of the NAUTILOS Summer Schools

The theoretical sessions of the NAUTILOS Summer Schools played an important role in shaping participants' understanding of marine litter science, environmental monitoring, and sustainable ocean stewardship. These sessions provided foundational knowledge, covering a broad range of topics from international marine policies to advanced monitoring technologies, ensuring that participants were equipped with both the theoretical background and the practical skills required to tackle marine pollution and observation of essential ocean variables. Delivered by project partners and synergetic collaborators in the field, the theoretical lectures were designed to adopt an interdisciplinary approach, combining scientific theory with real-world applications.

1. Global Marine Litter Legislation and Policy Frameworks

One of the core themes of the theoretical sessions was marine litter legislation and the global efforts to combat plastic pollution. Participants were introduced to the UN Global Treaty on Plastic Pollution, the MARPOL International Shipping Treaty, the Basel Convention, the GPML partnership led by UNEP, the UNEP Honolulu Strategy, the G7 Action Plan, as well as the relevant EU Directives (MSFD, Plastic Bags, SUP, Circular Economy Action Plan, WFD), exploring their framework, goals, and the importance of binding international agreements in driving policy changes. The lectures emphasised the need for standardised data collection to assess pollution levels effectively, with a particular focus on the role of policy makers, NGOs, and international organisations in shaping regulations. Additionally, participants were introduced to regional and national policies, including the European Strategy for Plastics in a Circular Economy (ESPCE), highlighting their alignment with sustainable development goals and the ongoing challenges of implementing effective waste management and plastic reduction strategies.

2. Advanced Marine Litter Monitoring and Sampling Techniques

The theoretical sessions also covered marine litter and essential ocean variables monitoring technologies and the scientific principles behind the tools and methods used to measure and analyse marine pollution. Lectures focused on the application of sensors and samplers for detecting microplastics, macro litter, and other pollutants in the marine environment. Experts provided in-depth explanations of how acoustic sensors, fluorometric sensors, and near-infrared scanners work to detect and analyse particles at various depths and sizes.

Participants learned about the principles of each technique, the types of data generated, and their applications in real-world scenarios. These theoretical sessions also discussed the challenges of ensuring data accuracy and comparability, particularly in remote or underrepresented regions.

3. Citizen Science and Public Participation

A central theme in the NAUTILOS Summer Schools was the integration of citizen science in marine research. Theoretical sessions explored into how public participation can enhance marine monitoring and contribute to data collection in areas where traditional methods may not be feasible. The lectures explored the role of citizen science platforms like the NAUTILOS Citizen Science App, which allows volunteers to collect data on marine litter and other variables, and contribute to broader research efforts. Experts discussed the benefits of involving local communities such as increasing public awareness of marine pollution and building capacity for sustainable conservation efforts, by presenting on going projects such as the *Adopt a Dune*⁶, *SeaCleaner*⁷, *INSPIRE*⁸ and *The Power of Collective Intelligence* initiatives.

4. Data Management and Global Integration

Theoretical sessions also accentuated the importance of data management and the integration of marine litter data into global frameworks like EMODnet. Experts explained the technical aspects of data collection, storage, and analysis, focusing on best practices for managing large datasets generated by marine monitoring systems. Participants were introduced to the concept of open-data sharing, with discussions on how data is integrated into international repositories to enable global collaboration. The sessions highlighted the role of standardised protocols and quality control measures in ensuring that marine data is comparable and usable for informing policy decisions and scientific research. This integration into global frameworks supports effective marine conservation efforts and helps policymakers make data-driven decisions.

5. Emerging Technologies in Marine Observation

A key focus of the theoretical sessions was on the latest innovations in marine observation technologies. Lectures introduced participants to the most recent advancements in remote sensing, drones, water drones, and above-water radiometry, as well as their applications in marine monitoring. Experts provided insights into how these emerging technologies can improve data accuracy, spatial coverage, and real-time monitoring capabilities. Participants learned about the potential of autonomous systems and real-time data analytics to enhance large-scale environmental assessments and contribute to a better understanding of marine ecosystems. These technologies are crucial in addressing challenges such as climate change,

⁶ <https://adoptadune.com/>

⁷ <https://sites.google.com/view/seacleaner/home-page>

⁸ <https://inspire-europe.org/>

marine biodiversity loss, and plastic pollution, as they enable more effective and efficient monitoring on a global scale.

The presentations delivered are available on NAUTILOS shared folder to the participants:

1st NAUTILOS Summer Course: <https://shorturl.at/MZWVG>

2nd NAUTILOS Summer Course: <https://shorturl.at/dSet0>

Practical Demonstrations of the NAUTILOS Summer Schools

The practical demonstrations were a keystone of the NAUTILOS Summer Schools, providing participants with the opportunity to apply their theoretical knowledge and gain hands-on experience with the latest marine monitoring technologies. These demonstrations offered valuable insights into the real-world applications of advanced sensors, samplers, and data analysis techniques, equipping participants with the skills necessary to tackle marine litter and oceanographic challenges. The practical components were designed to complement the theoretical sessions, reinforcing the importance of field-based learning in marine science and enabling participants to engage directly with cutting-edge tools and methodologies.

1. Sensor and Sampler Demonstrations

A major focus of the practical demonstrations was the use of innovative sensors and samplers developed through the NAUTILOS project.

- **Microplastic Samplers:** Participants were shown how to deploy high-volume samplers that collect microplastics from seawater. These samplers use specialised filters to capture particles in a range of sizes, and participants were taught how to set them up, calibrate them, and retrieve samples for further analysis.
- **Acoustic Profiling Sensors:** Demonstrations also focused on deploying and operating active acoustic profiling sensors designed to measure zooplankton biomass, sediment dynamics, and even oil droplets. Participants learned how to set up and operate the sensors both in shallow waters and during deep-water moorings.
- **Fluorometric Sensors:** A practical demonstration of fluorometric sensors allowed participants to see how fluorescence is used to measure dissolved oxygen levels and other key oceanographic parameters. They were introduced to the operation of the sensors and how they are applied to marine research.

These demonstrations familiarised participants with the practical aspects of sensor deployment, including calibration, data logging, and sample collection, reinforcing the importance of accurate data for successful marine litter monitoring.

2. Data Collection and Analysis Exercises

After the sensor demonstrations, participants engaged in real-time data collection exercises that allowed them to observe how sensors are used to gather environmental data. These exercises were designed to show the entire process of marine data collection, from deploying the sensors to analysing the data.

- **Field-based Data Collection:** In both Crete and Oslo, participants gained hands-on experience deploying various sensors in the field, practicing water sampling, and using real-time data collection tools to monitor microplastic pollution, ocean temperature, and pH levels. They also learned to manage the logistics of field-based sampling, maintain equipment, and ensure data accuracy in dynamic marine environments. In Crete, participants had the added opportunity to work aboard a real research vessel, where they gained unique experience in deploying advanced technological and sampling marine equipment.
- **Data Processing and Interpretation:** Once the data was collected, participants worked with instructors to process the data, identify trends, and analyse the results. They were introduced to data visualisation techniques, including the use of data management platforms like EMODnet, to see how the collected data can be integrated into larger monitoring efforts and shared with global databases thus enhancing FAIR data principles.

Through these exercises, participants gained a comprehensive understanding of how data is collected, processed, and interpreted, helping them to make informed decisions based on marine monitoring results.

3. Citizen Science Applications

Participants were trained to use the NAUTILOS Citizen Science App (CS-App), which allows community members and volunteers to collect data on marine litter.

- **Engagement in Data Collection:** Participants took part in beach clean-up activities, where they used the app to record and categorise marine litter. These clean-up efforts, combined with the use of the app, provided participants with a hands-on understanding of how data collection and standardisation can be incorporated into citizen science efforts.
- **Monitoring and Reporting:** The CS-App enabled participants to report their findings directly to databases, contributing to large-scale and long-term citizen science campaigns. This demonstrated how technology can bridge the gap between the public and scientific research, allowing for greater community involvement in environmental monitoring.

4. Drone and Remote Sensing Demonstrations

To further enhance the practical learning experience, the summer schools also included drone and remote sensing demonstrations, which showcased the potential of these technologies for marine monitoring.

- **Above Water Radiometry:** In the Oslo Summer School, participants observed the use of drone-based radiometers for measuring ocean colour and identifying the concentrations of phytoplankton, dissolved organic matter, and other marine components. They were introduced to the technology behind above-water radiometry and participated in drone flight and data collection exercises.

- **Remote Sensing Tools:** Drones were used to monitor marine pollution, enabling participants to see how remote sensing can be applied to large-scale environmental assessments. This also provided valuable experience in flight planning, data collection, and data interpretation related to marine monitoring.

These demonstrations showed how unmanned aerial vehicles (UAVs) and remote sensing technologies are transforming the landscape of marine observation, offering new opportunities for researchers to monitor vast marine areas quickly and efficiently.

5. Real-World Application and Collaboration

The practical demonstrations also fostered a collaborative environment where participants could learn from each other and from the experts. In both the Crete and Oslo summer schools, group work and peer learning were essential aspects of the demonstrations, with participants working together to deploy sensors, collect data, and analyse results. This hands-on collaboration not only helped participants refine their technical skills but also highlighted the importance of interdisciplinary cooperation in solving complex environmental problems.

Hands-On Experiences of the NAUTILOS Summer Schools

The hands-on experiences provided during the NAUTILOS Summer Schools were a crucial component of the program, ensuring that participants gained not only theoretical knowledge but also practical skills that they could apply in real-world marine science settings. These immersive activities allowed participants to engage directly with the technologies, methodologies, and processes used in ocean monitoring, data collection, and environmental management. The hands-on experiences spanned a variety of tasks, from sensor deployment to data analysis, and were designed to foster collaboration, critical thinking, and technical proficiency.

1. Sensor Deployment and Calibration

A significant portion of the hands-on experience involved the deployment and calibration of innovative monitoring tools. In both the Crete and Oslo Summer Schools, participants had the opportunity to practice using marine sensors developed under the NAUTILOS project and other provided by Synergetic partners. These included microplastic samplers, acoustic sensors, fluorometric oxygen sensors, low level radiation sensor, temperature (CTD, IR) and carbonate system instruments.

- **Field Deployment:** Participants engaged in real-time sensor deployment at sea and along coastlines. In Crete, for example, they deployed several available sensors from RV PHILIA, learning how to ensure proper installation in challenging marine environments. In Oslo, sensors like acoustic profiling devices were set up to monitor marine mammal populations, sediment dynamics, and water quality parameters.
- **Calibration and Maintenance:** Participants also learned the importance of sensor calibration to ensure accurate data collection. They worked directly with experts to calibrate the sensors in the field, a crucial step in ensuring that the data collected

could be used effectively. This experience reinforced the idea that accurate data is critical to understanding and mitigating marine pollution.

2. Sampling Techniques and Data Collection

Additionally, summer course participants had the opportunity to practice marine sampling techniques. These activities provided participants with real-world exposure to the challenges of sampling in dynamic environments, including field-based water sampling and beach litter collection.

- **Water Sampling:** Participants took part in water sampling exercises, where they used high-volume sampling systems to collect microplastics from the water column. They learned how to manage different sampling depths, ensuring that their samples were representative of the marine environment they were studying.
- **Biological devices:** collection of plankton samples and demonstration of the operation and deployment of fisheries nets were also among the techniques explored for analysing biodiversity onboard the PHILIA R/V.
- **Litter Monitoring:** Participants also took part in beach clean-ups, where they collected macro litter and classified the items by type according to the official EMODnet J-Code list. They also had the opportunity to classify the polymer type of plastic litter found on the beach using the NIR scanner and camera. In addition, monitoring of floating macro-litter through visual transects took place while navigating onboard the PHILIA R/V JRC monitoring App⁹. This practical experience highlighted the significance of both land-based and marine-based litter collection and allowed participants to understand the relationship between shoreline pollution and oceanic waste.

3. Data Analysis and Interpretation

The hands-on experiences also included opportunities for participants to gain skills in data analysis and interpretation. After the data was collected in the field, participants worked with real-world datasets during dedicated data processing sessions.

- **Data Processing:** Using the data collected from the field, participants learned how to process and analyse the data to identify pollution trends, source points, and distribution patterns. In particular, they used software tools to process sensor data and visualise results, ensuring that the collected data could be effectively interpreted and used to inform marine conservation efforts.
- **Interpreting Results:** In these sessions, participants were tasked with interpreting their findings in the context of marine litter management. They evaluated the significance of the data they had collected, discussing how their results could be applied to real-world problems like plastic pollution, climate change and ocean acidification. This experience taught participants not only how to collect data but also how to translate it into actionable insights.

⁹ <https://inspire-europe.org/solutions/jrc-floating-litter-monitoring-app>

4. Integration of Citizen Science

Another key aspect of the hands-on experiences was the integration of citizen science initiatives, demonstrating how the public can be involved in marine conservation efforts. In both Crete and Oslo, participants used the NAUTILOS Citizen Science App to collect and report data on marine litter.

- **Public Engagement:** During beach clean-ups and monitoring activities, participants engaged with local communities, encouraging citizens to use the app to record marine litter. This allowed participants to experience firsthand the challenges and opportunities of engaging the public in scientific research and data collection.
- **Real-Time Data Collection:** Participants practised real-time data collection through the app, learning how to ensure that data gathered by citizen scientists adhered to the same standards as professional research data. They saw how crowdsourced data could contribute to larger marine litter monitoring initiatives, providing a valuable tool for large-scale environmental assessments.

5. Working in Teams and Interdisciplinary Collaboration

The hands-on activities also fostered a strong sense of collaboration and teamwork, essential skills for addressing complex environmental challenges. Participants were encouraged to work in interdisciplinary teams, with each group tasked with addressing a specific aspect of marine pollution. The diverse backgrounds of the participants, including marine biologists, environmental engineers, and data scientists, provided a unique opportunity for cross-disciplinary learning and collaboration.

- **Collaborative Problem Solving:** In the field, participants worked together to deploy sensors, collect samples, and analyse data. This collaborative environment helped reinforce the idea that solving marine pollution requires interdisciplinary solutions that draw on the expertise of various scientific and technological fields.
- **Networking and Professional Development:** These activities also provided an opportunity for participants to network with experts and peers, fostering connections that could lead to future collaborations in marine conservation. The team-based activities encouraged professional development, with participants gaining confidence in their technical skills while learning how to work effectively in a scientific team.

IV. NAUTILOS E-MODULES – BUILDING A LASTING LEGACY

The NAUTILOS e-modules¹⁰ are an integral part of the NAUTILOS project. To extend the reach and impact of the summer schools, they are accessible on the project website and YouTube¹¹ channel, ensuring their legacy continues beyond the project's conclusion. These modules

¹⁰ <https://nautilus-h2020.eu/resources/e-learning/>

¹¹ <https://www.youtube.com/@NAUTILOSHProject>

serve as enduring resources, allowing learners worldwide to access knowledge on marine science, monitoring technologies, and data management. Each e-module focuses on a key area of expertise, reinforcing the skills and concepts introduced during the summer schools and ensuring their long-term relevance. The NAUTILOS e-modules encompass a diverse range of topics designed to expand and complement the knowledge shared during the NAUTILOS Summer Schools. These digital resources enable global accessibility and provide specialized learning opportunities for tackling marine litter, plastic pollution, and other pressing oceanographic challenges. Each module integrates practical insights, theoretical understanding, and interactive demonstrations to equip learners with essential tools for environmental monitoring and sustainable ocean management.

By targeting a wide audience, the e-modules ensure that the knowledge shared during the NAUTILOS Summer Schools reaches beyond the initial participants. They provide ongoing access to the tools and insights that were the foundation of the summer courses, empowering learners globally to contribute to sustainable marine practices and policy. This digital expansion supports the European Strategy for Plastics in a Circular Economy (ESPEC), the EU Mission: Restore our Ocean and Water and the broader goals of the UN Ocean Decade by promoting capacity building, innovation, and international collaboration.

4.1. Monitoring Methods for Plastic Pollution in the Marine Environment¹²

This module explores methodologies for tracking and analysing plastic and microplastic pollution it delves into the Global Plastics Treaty and stresses the importance of monitoring systems for understanding pollution pathways from sources to the sea.

4.2. Citizen Science in Practice¹³

Highlighting the role of public engagement, this module focuses on how citizen scientists contribute to marine litter monitoring. It showcases tools like the NAUTILOS Citizen Science App, highlighting its impact on data collection and fostering broader involvement in marine research.

4.3. Carbon, Phytoplankton, and Suspended Matter Sensors and Samplers¹⁴

This module introduces technologies for assessing water quality, including biogeochemical sensors and instruments for studying the coastal and open ocean. Participants gain insights into phytoplankton monitoring and its significance in understanding ecosystem health.

¹² <https://www.youtube.com/watch?v=rH0igHL5NHs>

¹³ https://www.youtube.com/watch?v=1uTph_o-TU4&t=1s

¹⁴ <https://www.youtube.com/watch?v=ltKvC0kN1IQ>

4.4. NAUTILOS Active Acoustic Profiler and Sound and Click Recorder Sensor¹⁵

Focusing on cutting-edge underwater technologies, this module covers the use of acoustic profiling and sound recorders to monitor marine mammals, sediment dynamics, and soundscapes, showcasing innovations developed by the Aquatec Group.

4.5. NAUTILOS Microplastic Sensor¹⁶

This module highlights the development and application of a low-cost, semi-autonomous microplastic sensor, capable of analysing particles in the 1–300 µm range. It includes methods for filtering, staining, and fluorescence-based detection, with applications onboard vessels like the FerryBox.

4.6. High-Volume Pump Sampling¹⁷

Participants learn to operate high-volume water pumps equipped with inline filters to sample microplastics across different depths. This module underlines replicable sampling protocols and best practices for obtaining accurate data in variable marine conditions.

4.7. Monitoring Plastic Pollution with the Manta Trawl¹⁸

This module details the use of Manta Trawl systems for sampling floating plastic debris. It stresses the importance of harmonised and reproducible monitoring technologies to address the complexities of plastic pollution and inform mitigation strategies.

4.8. Data Crackathon¹⁹

A hands-on module offering practical insights into data visualization and analysis. Participants explore tools like ERDDAP, ncWMS, and GeoServer, enabling them to effectively manage and map oceanographic data for improved decision-making.

4.9. Above Water Radiometry²⁰

This module focuses on remote sensing technologies for analysing ocean colour, phytoplankton concentration, and water quality. Participants learn to use hyperspectral cameras and drones, highlighting calibration, maintenance, and real-time data processing.

V. SATISFACTION RESULTS AND FEEDBACK FROM THE NAUTILOS SUMMER SCHOOLS

A survey was conducted after the NAUTILOS Summer Schools to gather feedback from participants. Links to the survey are available below:

Summer School 1: <https://forms.gle/PJfsLDurVV7xjd4r8>

¹⁵ <https://www.youtube.com/watch?v=D-5PNiKH1IU>

¹⁶ <https://www.youtube.com/watch?v=U5XC6H1YNQs>

¹⁷ https://www.youtube.com/watch?v=6K-bnzX_rV4

¹⁸ <https://www.youtube.com/watch?v=ivcpGPUyQ7g>

¹⁹ <https://www.youtube.com/watch?v=tp3n-nxIVaA>

²⁰ <https://www.youtube.com/watch?v=WmBkN9txq48>

Summer School2: <https://forms.gle/GAwgPcdS2QVpqMGA8>

A total of 14 provided valuable insights into various aspects of the course, including lectures, practical demonstrations, and networking opportunities. This feedback has been crucial in identifying the strengths of the program, such as the hands-on activities, while also highlighting areas for improvement, such as the need for more fieldwork, extended focus on marine litter policy, and data-driven collaboration. Overall, the NAUTILOS Summer Schools garnered largely positive feedback, with several key strengths and a few areas for improvement identified. The following is an analysis of the results based on satisfaction surveys.

Overall Satisfaction

- **High Satisfaction:** Participants expressed strong approval of the course structure, content delivery, and engagement in hands-on sessions. Overall, the course was seen as highly beneficial for those involved in marine science, especially in terms of practical learning and networking.
- **Participant Rating:** Many respondents rated their overall experience highly, with specific praise directed towards the combination of practical demonstrations, interactive workshops, and the opportunity to learn from experts in various marine science fields.

Highlights

- **Hands-On Experience:** The practical demonstrations were repeatedly mentioned as a highlight, particularly the chance to work with innovative marine sensors, microplastic samplers, and other monitoring technologies. These real-world experiences enabled participants to better understand the complexities of marine pollution monitoring and environmental management.
- **Networking Opportunities:** Attendees valued the opportunity to connect with international peers, fostering professional relationships that will aid future collaborative research efforts. Many participants noted the benefit of interacting with experts across a range of disciplines, contributing to a deeper understanding of interdisciplinary approaches to marine science.

Low Points

- **Desire for More Fieldwork:** Several participants recommended more fieldwork activities or interactive group tasks. There was a consensus that the course could benefit from fewer lecture-based sessions and more practical, real-time involvement in sampling, data collection, and field demonstrations.
- **Data Crackathon Feedback:** The Data Crackathon received mixed reviews. While it was a valuable opportunity to analyse real-world data, some participants felt that the lack of provided sample data made it difficult to fully engage with the task. A suggestion was made to incorporate pre-collected data for a more structured, hands-on learning experience.

Recommendations for Future Courses

- **Incorporate More Field-Based Learning:** Based on the feedback, a stronger emphasis on field-based activities would be beneficial. For example, having more time allocated to practical sampling, where participants can engage directly with the environment, would enrich their learning experience.
- **Enhance the Data Crackathon:** Providing sample data or better-guided steps during the Data Crackathon could help participants better understand the data analysis process and its real-world applications. This could also include more collaborative work during the data analysis phases, encouraging deeper engagement.
- **Extend Focus on Marine Litter Policy:** Participants indicated interest in exploring marine litter legislation in more depth. Dedicating additional time to the Global Plastics Treaty and its practical implications for marine pollution management could make the course even more impactful for future participants.
- **More Networking and Collaboration Time:** Suggestions were made to expand opportunities for open discussions, Q&A sessions, and informal networking. By allocating more time for interactions with experts and peer collaboration, participants would have the chance to exchange ideas and build stronger professional networks.

VI. CONCLUSION

The NAUTILOS Summer Schools in Oslo and Crete have successfully contributed to addressing marine environmental challenges by providing interdisciplinary training tailored to the needs of early career scientists and marine technicians. By blending theoretical sessions, practical demonstrations, and hands-on experiences, participants gained critical skills in utilising innovative technologies for marine monitoring.

The integration of these activities with global initiatives, such as the European Strategy for Plastics in a Circular Economy (ESPCE), the UN Ocean Decade, the MARPOL International Shipping Treaty, the Basel Convention, the GPML partnership led by UNEP, the UNEP Honolulu Strategy, the G7 Action Plan, as well as the relevant EU Directives (MSFD, Plastic Bags, SUP, Circular Economy Action Plan, WFD) and many others, highlights the program's relevance and alignment with international sustainability goals. The development of accessible e-modules, available on the project's YouTube channel and the project's website, ensures the legacy of these courses, offering long-term capacity-building opportunities beyond the project's timeline.

Feedback from participants underscores the program's success in fostering collaboration, enhancing technical competencies, and encouraging data-driven decision-making. Incorporating suggestions, such as expanded fieldwork and enhanced focus on data analysis, will further strengthen future iterations. The NAUTILOS Summer Schools stand as a model for

capacity-building initiatives, bridging knowledge gaps and empowering the next generation to lead sustainable ocean stewardship efforts.