Introduction
to
Scientific Diving

Student's manual

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2022

Project Id: 863674
EMFF Blue Economy 2018

Science Diver

Cross-sectoral skills
for the blue economy market

With the contribution of the European Maritime and Fisheries Fund of the European Union

Acknowledgement

This edition is delivered with the contribution of the European Maritime and Fisheries Fund of the European Union.

"I just wish the world was twice as big
and half of it was still unexplored."

David Attenborough

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table of contents


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A. Introduction


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About this manual

Conducting scientific work underwater is a challenging endeavor. From collecting samples to protecting underwater cultural heritage sites scientific divers need to address issues concerning scientific methodology, diving safety, professional acknowledgement, training, legal implications etc. Training to become a member of the scientific diving community is an essential step in the development of a successful and productive career in many scientific disciplines.

This manual has been produced as a deliverable in the framework of ScienceDIVER project. ScienceDIVER: Cross-sectoral skills for the blue economy market (Project id: 863674 – EMFF Blue Economy 2018 – Blue Careers) started in November of 2019 and comprises the joint effort of three Universities (Aristotle University of Thessaloniki, Greece - University of Calabria, Italy - University of Stuttgart, Germany), a research Institution (DAN Europe) and three companies representing the advisory maritime industry (Atlantis Consulting, Greece – envirocom, Germany – Marine Cluster Bulgaria). It is funded by the European Maritime and Fisheries Fund and its main objective is to support the development of blue and smart cross-sectoral skills, in order to meet the evolving needs in the labor market of Blue Economy. By building solid -long lasting- collaborations and structures between academia and industry it aims to offer standardized training and clear career pathways to diving scientists within the European Union. Particularly, this project, facing the challenges of UN's "Decade of Ocean Science for Sustainable Development", builds solid -long lasting- collaborations and structures between academia and industry in order to offer standardized training and clear career pathways to the diving scientists. Concerning training the ScienceDIVER project's main objective is to study and analyze the current landscape, in order to provide insight and suggestions towards a commonly accepted framework that will promote scientific diving as a means of forwarding knowledge both within the scientific community and its interaction with the public. Part of this procedure is this manual that was produced as a deliverable in WP3 . This deliverable serves the following goals:

- To provide a reference for the discussion with SD training stakeholders
- To provide training material for the pilot training courses that will be held by the project
- To receive feedback both form trainers and trainees, in order to develop effective training strategies.

The scope of this manual is to provide an overview of the concept of Scientific Diving to people that are starting their involvement in underwater scientific projects. The main goal is to set a threshold of basic knowledge that will help them to have a clear understanding of the scientific framework in which diving is being conducted and to find their role in it. Each feature presented in this manual is a complete chapter on its own and can be further explored in the future.

An important note is the fact that the legal framework of Scientific Diving on a global level is seriously fragmented. The variety of approaches does not allow for a detailed approach here. The general rule provided in this manual is to follow the regional laws on Diving Safety. Another thing to consider is that Scientific Diving refers to a number of scientific disciplines. This manual presents some of the most common scientific procedures in these disciplines offering an overview. SD procedures covering the particular needs of distinct disciplines are part of specialized training. Lastly, one should understand that the training scope of this manual is not to provide basic diving training (e.g. open water diver, enriched air diver etc.). It requires such training, in order to be comprehensible and effective.

The manual is structured in 3 major chapters. The first one entails introductory features such as the current text, a brief history of SD, a presentation of the various disciplines engaged in SD and a short presentation of the ethical aspects. The second and third chapters approach SD through the basic duality of SD, scientific procedures and diving safety. Thus, the second chapter presents the scientific aspect of SD comprising features concerning both the core and the supporting tasks performed in an SD project. The last chapter focuses on the diving and safety parameters that a SD should keep in mind during planning and implementing a scientific dive. At the end of the manual there is an appendix holding support material, such as forms and panels, that can prove useful to a scientific diver.

This manual can be used in SD training courses in any way the training provider seems fit. It does not dictate a certain teaching sequence-procedure. It provides a structure to the knowledge involved without setting a rigid framework of delivery.

History of scientific diving

The Blue Planet is defined by over 3/4 of its surface by water, the oceans. But the land masses are also interspersed with streams, rivers, and lakes. Water therefore plays an extremely important role for our planet, but also for us humans. But the underwater world has long been considered scary, terrible, and inaccessible. Many people are afraid of the deep, dark water, the unknown. For a long time, people only used fishing hooks and nets to get fish and other food animals out of the water, until they finally began to look under the surface. So, they managed to dive for oysters, pearls and sponges and to catch and sell them. The first divers simply held their breath - they have dived in apnea. Especially in the Mediterranean, sponge diving and diving for red coral has a long tradition in free diving and lasted for millennia and remarkable depths and air holding times were achieved under water. It is reported that in 1913, Stathis Hatzis, a sponge fisherman, recovered the Italian battleship Regina Margherita anchor, lost at a depth of over 70 m in the waters of Pigadia Bay of Karpathos, an island of the Aegean Sea, in breath-hold and aided only by a flat stone of about 15 kg!

The equipment of today's divers was developed in the 1930s and 40s. This included a mask, snorkel, and fins. The pioneers of diving were the Frenchmen Emile Gagnan (1910-1979) and Jacques Cousteau (1910-1997), who combined a pressure tank with a two-stage regulator that only supplied air when inhaled. The first automatic regulator was introduced in the USA in 1948 and by the early 1950s these devices were available all over the world. This new revolutionary underwater open-circuit air breathing device, the Aqua-Lung, as an on-demand valve regulator became very popular and allowed to dive safely at least down to a depth of 50-60m, breathing compressed air. What is even more, this self-contained underwater breathing apparatus (scuba) opened new perspectives to the marine sciences generally, and to marine geology, biology, and archaeology, in particular. The first diving waistcoat with which the buoyancy could be changed, was patented by the Frenchman Maurice Fenzy in 1961. Further development led to Scubapro's "stabilising jacket" in 1971 and then to today's modern diving jacket. This buoyancy compensator is designed to be unconscious proof for divers drifting on the surface, replaced the Fenzy waistcoat.

All these revolutionary technical developments made diving accessible to the public for the first time and thus to researchers interested in the underwater world. However, two other equipment developments were also important for scientific diving: the development of the dive computer and the underwater camera. In 1982, the first diving computer, the Decobrain I computer, was marketed. This was the first real dive computer available for the large recreational diver stalls as a decompression device based on five sets of tables with eight compartments, developed by Professor Albert A. Bühlmann (1923-1994) of Zurich university. With this invention the road for the future development of dive computers up to our current powerful devices was opened. Underwater photography is a fundamental means of documentation research and its results. The first, most famous underwater photographs were obtained by the French marine biologist Louis Marie-Auguste Boutan (1859-1934) at Banyuls-sur-Mer (France). Boutan is considered the founder of underwater photography also because he is the author of the first manual, La photographie sous-marine, published in 1900.

Scientific diving has also been widely disseminated through the Marine Biological Stations, such as the stations in Banyuls-sur-Mer (France), Rovigno (Croatia), of the University of the Aegean (Greece), the Centres d'Estudis Avancats de Blanes and the University of Barcelona (Spain), the Laboratory of Benthic Ecology of the Zoological Station on the Island of Ischia (Italy), the Scottish Millport Marine Station (Scotland), the Zoological Station of Naples (Italy).

The first scientific work to be done by a diver with the aid of a diving apparatus is the doctoral thesis of Hans Hass (1919-2013). As an Austrian student from the Faculty of Biology of the University of Berlin, he spent several months at the Zoological Station of Naples (Italy) also at the Marine Biological Institute of Rovigno (Croatia) to study bryozoans for his doctoral thesis in zoology.

Since the 1970s, diving sciences have spread widely, and today, there is no significant scientific institution in the world that does not have at least one diving laboratory or does not use divers to carry out research. And just as diving technology changes and improves, investigations into new habitats and ecosystems become possible and bring new insights, e. g. mixed-gas diving and closed-circuit rebreather systems have enabled scientists to study the deep mesophotic habitats, reaching 100-120 m depth. But it is not only the greater diving depth and diving time that make this new technology so promising for scientific diving. The fact that the exhaled gas is not discharged, this device is very silent and allows to approach many organisms without frightening them with the emission of air bubbles or diving for a long time in shallow waters.

Nowadays, last but not least, citizen science projects are opening up new possibilities for the exploration of aquatic habitats. Citizen science has become a possibility of participation in scientific projects of people who are not tied to institutions in that field of science. Science is more and more recognizing the potential and the manifold possibilities offered by Citizen Science for example surveys where extensive data has to be collected. This also applies to marine and freshwater research and to the exploration of our native waters.

Recommended further reading:

Cattaneo-Vietti, Riccardo. 2021. „The essential role of diving in marine biology“. Bulletin of Environmental and Life Sciences 3N1 doi: 10.15167/2612-2960/BELS2021.3.1.1279.

Cerrano, Carlo, Martina Milanese, Massimo Ponti. 2017. „Diving for Science - Science for Diving: Volunteer Scuba Divers Support Science and Conservation in the Mediterranean Sea: Citizen Science for Mediterranean MPAs“. Aquatic Conservation: Marine and Freshwater Ecosystems 27(2):303–23. doi: 10.1002/aqc.2663.

Heine, John N. 1999. Scientific diving techniques: a practical guide for the research diver. Flagstaff, Ariz: Best Pub. Co. ISBN 978-0-941332-69-9.

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Multidisciplinarity

Since the 1960s, scientific diving has been recognised by UNESCO and many scientific institutions worldwide as an important tool, especially in the field of underwater archaeology. Coastal countries have been particularly active in this area, using the "self-contained underwater breathing apparatus" (SCUBA) for their research. While only a few pioneers worked in this field back then, today, thousands of professional research scientists, graduate students, technicians, and undergraduates around the world, carry out scientific diving using scuba and related mixed gas, surface demand, habitat, and lock-out submersible systems.

The fact that scientific diving first developed out of the field of underwater archaeology can be explained by the fact that an archaeological finds must always be evaluated in the context of the respective site. Therefore, archaeologists were the first scientists who, as scientific divers, studied artefacts in their natural environment, whether clay shards, amphorae, or shipwrecks.

In the life sciences, too, observations were no longer recorded as individual observations, but discussed as embedded in an ecosystem. This was especially true in the fields of ecology and behavioral biology. While ecological experiments and investigations in the marine

An underwater archaeologist at work (© V.Tsiairis / MeSEP-EUA)

area, freshwater ecosystems like rivers and lakes, were initially carried out from the shore or boat, scientific diving in particular developed for behavioral research as an indispensable method for studying natural behavior under water. In the field of biodiversity research, scientific diving is also very important to detect and identify diversity, to understand how organismal diversity has evolved and changed and how specific biocenosis work, and what impact biodiversity has on our environment. Diving biologists conduct experimental research in situ with manipulations for testing ecological hypotheses. And, they have to evaluate the increasing frequency of mass mortalities in benthic communities and the arrival and impact of alien species.

Geologists and geographers have also followed this path, developing water- and pressure-tight underwater measuring instruments that enable them to use their chemical and physical measuring techniques underwater. Scientific Divers, for example, are irreplaceable in many areas of speleology for surveying and mapping partially or completely submerged cave sections. The same applies to many underwater volcanoes and their gas emission points.

In addition to scientific diving in basic research, some areas in applied research have developed rapidly. This is especially true in the fields of historical, natural and geosciences where, for example, water, gas and rock samples have to be taken for measurements and investigations at specific locations and where a scientist is important for taking the samples on site (under water) and also for the later discussion of the results.

With the increasing specialisation of the scientific fields, the application options for scientific divers under water have also grown. These include, for example, underwater forensics, as a collective term for scientific and technical fields of work in which criminal acts are systematically investigated underwater. In the field of hyperbaric research, there are also various medical questions that are not dealt with in the laboratory or a pressure chamber, but where scientific divers are active under water.

Ethics

When researching aquatic communities e. g. by performing field collections or exploring underwater heritage sites, we are obliged to follow ethical guidelines. And we must ensure that any potential negative impacts of our research are minimized. Although these national or even regional guidelines are often unknown or even inaccessible, there is an obligation for sustainable management of the underwater world.

Within the scope of this manual, three essential guidelines can be briefly presented: The Convention on Biological Diversity, the Nagoya Protocol and the UNESCO Manual for Activities directed at Underwater Cultural Heritage.

The Convention on Biological Diversity (CBD) is an historic commitment by the world's nations to conserve biological diversity, to use biological resources sustainably and to share equitably the benefits arising from the use of genetic resources. It is the first global legal instrument to comprehensively address all aspects of biological diversity and it was negotiated in response to the global concerns on biodiversity loss and entered into force in December 1993. At present, there are more than 190 Parties to the Convention, which have committed to undertake different measures, both at national and international level, to achieve its objectives. Being a framework and legally binding instrument, the CBD provides general provisions which require efforts at national level to make them operational. One important requirement is the development of National Biodiversity Strategies and Action Plans.

The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity, also known as the Nagoya Protocol on Access and Benefit Sharing (ABS) is a 2010 supplementary agreement to the 1992 CBD. Its aim is the implementation of one of the three objectives of the CBD: the fair and equitable sharing of benefits arising out of the utilization of genetic resources, thereby contributing to the conservation and sustainable use of biodiversity. It sets out obligations for its contracting parties to take measures in relation to access to genetic resources, benefit-sharing and compliance. The protocol was adopted on 29 October 2010 in Nagoya, Japan and entered into force on 12 October 2014. As of April 2022 it has been ratified by 137 parties, which includes 136 UN member states and the European Union.

Following with our underwater research the ethics implemented by e. g. CBD and Nagoya Protocol, we will also contribute to the program of the "2030 United Nations Agenda for Sustainable Development and the Related 17 Sustainable Development Goals (SDGs).

Lastly, The 14 chapters of the UNESCO's Manual for Activities directed at Underwater Cultural Heritage explain the Annex of the UNESCO Convention on the Protection of the Underwater Cultural Heritage (2001) and illustrate the 36 Rules concerning Activities directed at Underwater Cultural Heritage. It provides guidance for the application of the state-of-the-art regarding activities directed at submerged archaeological sites as well as site management and site protection. Equally it serves as a reference tool for site managers, stakeholders and partners in the protection of underwater cultural heritage and for training courses in underwater archaeology.

Detailed information can be found here:

https://www.cbd.int/convention/

https://www.cbd.int/abs/

https://sdgs.un.org/

https://unesdoc.unesco.org/


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B. Scientific procedures

Task organization - Scientific roles

The organization of a scientific dive is a multi-role procedure. The team of scientists involved has to decide the goals, the means and the methodology that will be followed depending on various factors. The plan is then formed comprising a series of tasks, either aimed directly to the pure scientific purpose of the project or to support it by providing auxiliary means. Based on the team's structure it is decided how to appoint roles and tasks to the several individuals involved in order to execute the team's plan efficiently and safely.

Team building and assigning task prior todiving is essential for succesful scientific diving (© E. Karadimou / AUTH)

Theoretical knowledge

Site awareness

Selection

As obvious as it may seem to an outsider, the selection of a site for scientific research is a complex multifactorial procedure that goes beyond the scientific goal. Of course, it all starts with the scientific question at hand. The first question to be posed is how effective can the site deliver data to help the research itself. However, the selection of a diving site has its own rules, mostly concerning safety features, but also practical ones. How accessible is the site, what kind of diving equipment will be required, how will the emergency plan develop etc. In many cases advantages concerning the scientific information entropy of the site are contradicted by disadvantages in its diving characteristics - and vice versa. The scientific diving team should pick a site where both of the above goals (scientific - diving safety) are met.

Marking (surface / underwater positioning)

Before a scientist begins working on the site, it is extremely important to establish a referencing system. Spatial attributes are essential to almost all scientific methodologies whether they are interested in the natural or cultural environment. This can be achieved through the use of a reference system. In the past most of these systems were created locally and were later georeferenced to larger ones. Nowadays, the use of GPS technology has made it easy to establish georeferenced points almost everywhere in the world. However, GPS does not work underwater, thus scientific diving teams are obliged to figure out ways to connect the underwater environment with the GPS grid. These ways vary from single practical solutions, e.g. the deployment of a DSMB to mark the point on the surface, to more elaborate technological solutions such as various underwater positioning systems.

Assessment

The selection of the site requires a first assessment on various key factors. As described above the site needs to be scientifically valid and to fulfill basic diving safety parameters. Beyond this general assessment that validates a scientific diving site, however, the team needs to continuously monitor the elements of the environment that affect its operations. Being environmentally aware means that one can predict and avoid interactions with the environment that can increase the level of risk to cause damage either to the scientist-diver or the environment (natural or cultural). Keeping in mind weather conditions, the level of visibility, currents, the presence of wildlife, potential features of cultural interest, fishing activity etc. is extremely helpful in the organization of each dive, the use of scientific equipment and the surface support needed.

Each scientific diving site is a unique environment with special attributes and needs (photo © A. Ktistis)

Supporting tasks

Navigation

Being able to navigate provides to the scientific diver an essential skill both for scientific and safety reasons. The latter are quite self-evident to the educated diver since being able to find your way underwater can literally save your life in hazardous situations. Scientific-wise, navigational skills are important in the implementation of field activities. Plans on paper that need to be carried out underwater are often compromised by the inability to navigate and locate the points of interest, or require more time and energy than expected. Especially in challenging environments (low visibility, blue water, deep water, distant locations etc.) easy and effective navigation skills can make the difference between success and failure. Moreover, spatial awareness is important for the understanding of the scientific context and the wider environment that surrounds and interacts with the features under investigation.

Establishing datum

The essential feature in spatial reference is a single point. A single point with known coordinates is the baseline for a)simple referencing of items of scientific interest and simple mapping of their interspatial connections, b) the creation of more elaborate systems of reference such as transects and quadrats, that provide multiple referencing abilities. Thus, the insertion of datum points on a working site is one of the first and most important works performed by scientific divers.

Transects – baselines

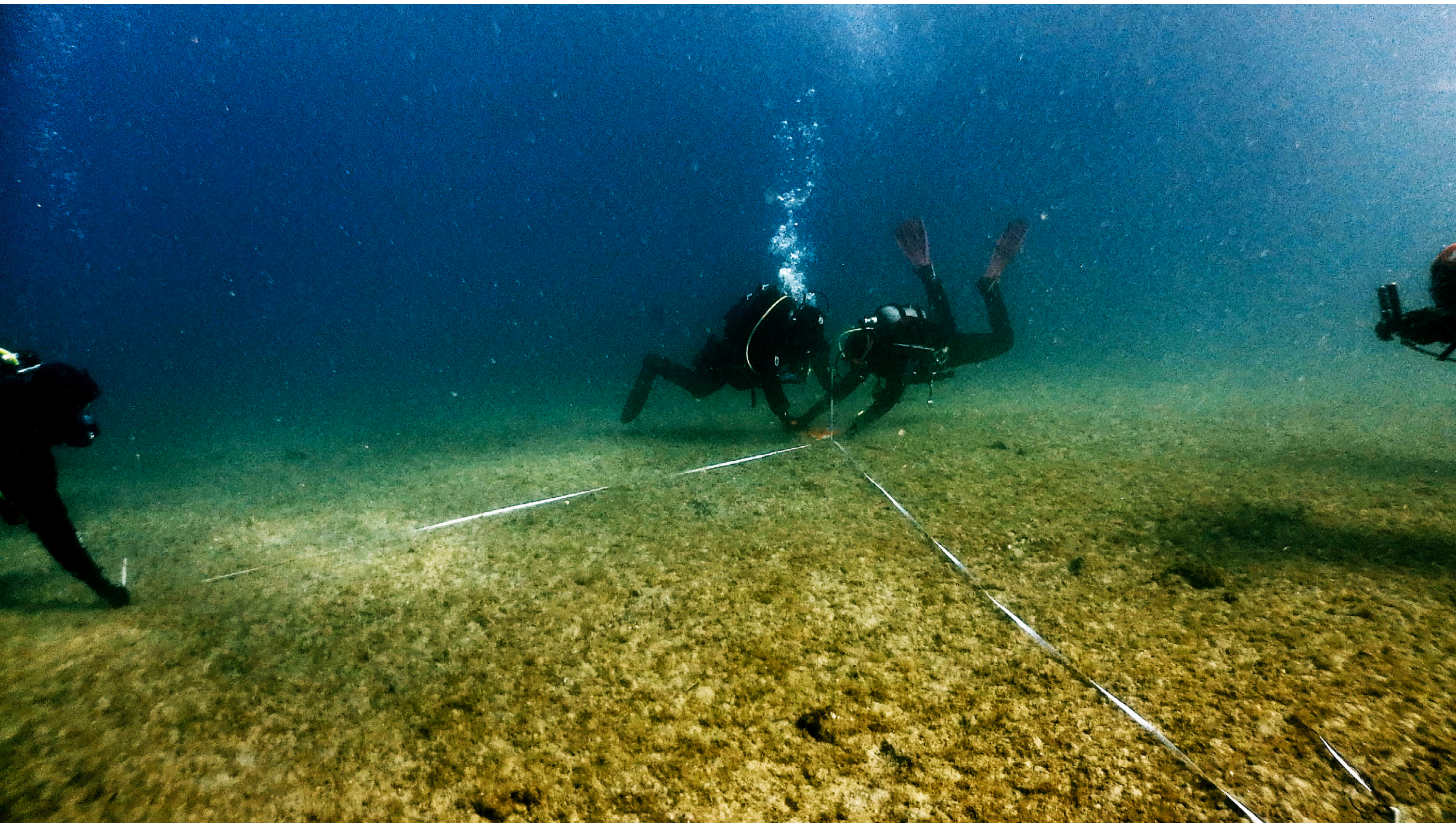
One of the most common spatial referencing techniques is the creation of a transect. The transect is essentially a single straight line with known attributes (location of starting and ending point, dimensions, orientation etc.) that "transects" an underwater research site providing reference points at its complete length. A transect line can serve as a path along which one counts and records occurrences of the objects of study, it can divide the site into two halves, provide a guideline for photogrammetry shots etc.


DATUM
1

Quadrat – Grid

A quadrat is a frame, most often square, used to isolate a standard unit of area for study of the distribution of an item over a large area. Once again, having known attributes (location of corners, dimensions, orientation etc.) the quadrat provides a referencing system to the scientist that contributes to the analysis of the collected data.

When the area under investigation is large, then one has the option of creating multiple adjacent quadrants in the form of a grid. Each quadrant receives its own identification number that usually follows an axial system. Creating grids can prove extremely helpful both in documentation - mapping and organization of research procedures.



Ceating transects and quadrats facilitates the organization of the site (photo © E. Seretakis)

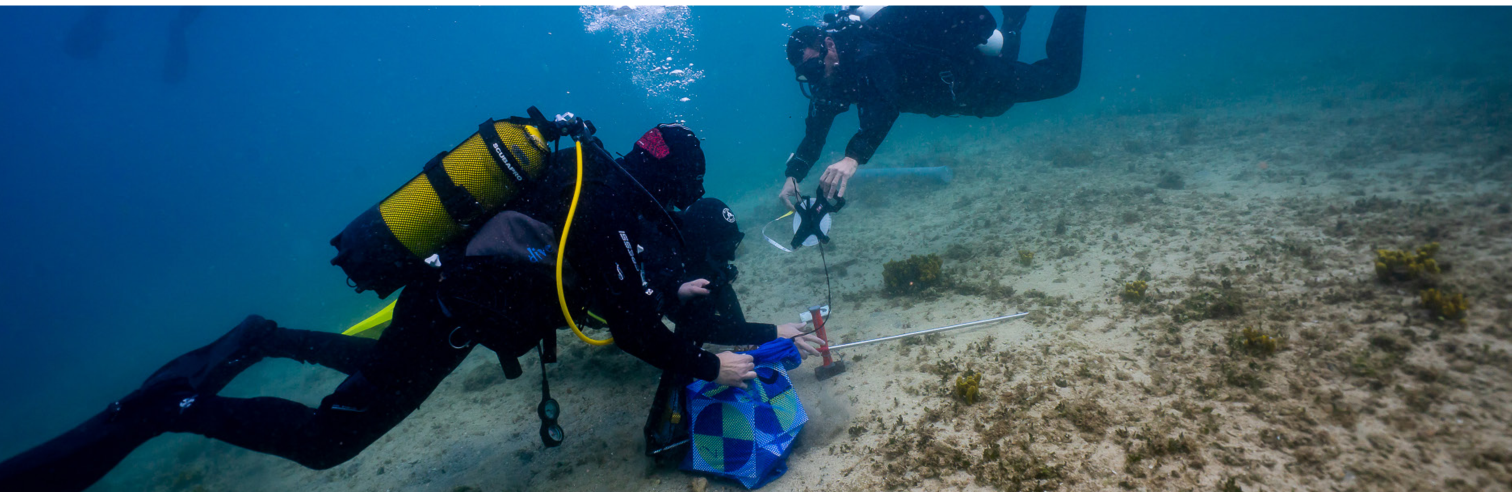
Sketching -drafting

"An image is the equivalent of a thousand words" the Chinese used to say and in most cases is quite true. Words can sometimes be confusing and a single sketch can clarify a lot of things. That's why scientists working on the field need to be able to schematize information into draft sketches. Of course, one does not have to be an artist to be able to do that. Simple lines and helpful annotation can make a sketch quite clear and convey much information about the item of interest and its environment. Whether someone uses pen and paper or a tablet makes no difference to the concept, rather than a mere choice of the right tools. The same goes for underwater scientific work that requires tools that can work in the underwater environment.

Scientific equipment (deployment-recovery)

The use of equipment underwater is a challenging feature of scientific diving. First of all, the diver has to follow the right deployment and recovery protocols, in order to avoid hazardous situations. In many cases, scientific equipment can be difficult to handle due to its size, weight or delicate nature. Moreover, the use of special equipment, such as dredges (airlift-hydrolift), lift bags, core samplers etc. can become extremely dangerous, if not handled properly. Scientific-wise, the right use of scientific equipment is crucial in the right implementation of methodology and process. Thus, it requires specific training that is based on the nature of the scientific discipline of the diver and the relevant safe use practices.

A variety of tools is being used while performing underwater SD tasks (photo © Atlantis)




Kg 100
photo © A.Ktistis

Core tasks (Collecting data)

Measuring

Measuring is one of the most common tasks involved in scientific research.

Measuring time is essential both for keeping ourselves safe underwater, since our safety protocols are time related, and for certain scientific tasks. For example, many sampling techniques have specified time intervals.

LIkewise, measuring three dimensional space is necessary in the majority of scientific tasks underwater. Besides establishing a referencing system and placing the items of scientific interest within the studied environment (see above in supporting tasks) a scientific diver may also need to measure the features themselves or their spatial relationship. It is true that since digital mapping became available some decades ago and is developing rapidly into a sine-qua-non in modern day research that a lot of measuring tasks can be performed on the digital model. However, measuring distances or areas on the site is necessary for the creation of the model and should be performed in order to check its accuracy.

Although one tends to relate intuitively measurements to time and space, keeping account can take various forms in scientific diving beyond the two admittedly more common aforementioned implementations of the task (e.g. measuring environmental attributes, such as temperature and salinity, making biodiversity observations, estimating coverage).

Tagging

A wider definition of tagging would be placing attribute features on items of interest. These "annotations" can take the form of codes, descriptions, measurements and other characteristics that accompany the scientific item. This is easily achieved in the digital environment. In the physical world tagging is usually a small card with indications that is attached to the item, in order for someone to identify it and get some basic information about it that can help its study, handling or storing.

Depending on the nature of scientific research performed underwater tags can be placed on top of artifacts, sample bags and boxes, features of the natural environment etc. Obviously, the tagging cards should be suitable for the underwater environment and the same goes for the materials used to write on them.

Media recording (Photo-Video-Sound-other)

Collecting data in various forms is of course a vital process in scientific methodology. Although this task can occasionally be the main objective of a scientific project in the vast majority of cases recording media is a procedure that contextualizes the scientific investigation.

The basic medium that is captured in most scientific projects is image, either still or moving. Taking photos has replaced the vivid literary descriptions and the impressively elaborate drawings of explorers and scientists of the past and the abundance of information that can be captured in video has in a way become the easiest way to actively document an ongoing scientific procedure.

Taking photos or video underwater is sometimes quite challenging. The first one is light related and has to do with diving conditions. Depth performs a filtering process gradually removing certain wavelengths and desaturating the landscape. Low visibility due to floating particles has also major effects on the way images can be captured. Marine life is often either elusive or disturbing, making things even more difficult. In any case, underwater photography and videography have their own rules that combine the basic principles of their

Taking photos has become a sine-qua-non in modern day underwater scientific work
(© E. Karadimou / MeSEP-EUA)

medium with the special characteristics of the underwater environment.

One of the most common alternative documentations of the environment in modern research is the mapping of soundscapes. Oftenly fringed in the past, sound has become more and more used in the documentation of scientific context. Moreover, sound becomes in many cases (e.g. the study of great sea mammals) the major goal of the investigation.

Beyond optics and sonic media, scientific research interests lie also in the capture of haptic and olfactory data. Documenting textures and odors is integral in various investigations of the natural environment (e.g. geological, ecological) and can provide valuable insight if added to the data pool.

Technology is nowadays our most valuable ally, since all the above data become more easily accessible and acquire higher information entropy through innovative technological equipment.

Sampling

For the purposes of this manual the term sampling describes the procedure of retrieving physical data from a scientific site for purposes of further examination, process and archiving. Depending on the nature of the project these samples can vary from water samples and plants to submerged artifacts and geological cores. Each discipline follows their own rules when it comes to sampling methodology, however there are some basic shared features that apply to every sampling dive. Some of the most obvious measures refer to the protection of the diver e.g. number of divers involved, equipment and recovery techniques, as well as for the protection of the sample from contamination, breaking and other potential hazards.

Basic steps in sampling methodology:

1. Choose the sample - type of data retrieved - answer scientific question
2. Document context- environment
3. Document sample
4. Retrieve sample
5. Recover to surface
6. Store
7. Surface documentation
8. Archiving
9. Storage
10. Data management

Mapping

Producing visual representation of the area under investigation, annotated with features of methodology and results is essential for either the development of research procedures or the publication of results. Mapping methodologies can vary in form, size, appearance and creation techniques. Depending on the purpose of the mapping task, the site preferences and the available tools, a scientific team can choose different ways of capturing, editing and publication.

Some of the most common mapping techniques require measuring, sketching, photo or video capture, underwater and land positioning, estimating coverage, orientation and other tasks of referencing and data capturing. The results can be simple or elaborate topographical and architectural drawings and maps, interpretative illustrations, Geographical Information Systems etc.

Underwater positioning

Underwater positioning systems are commonly used in a wide variety of underwater work, including ocean sciences, salvage operations, maritime archaeology and other activities. The location of features underwater is a challenging feat, since one cannot use the nowadays easily available GPS applications that are being used out of the water. The change of medium requires a different set of tools that can be later connected to world reference systems. The majority of underwater positioning systems use sound waves, since sound is extremely effective underwater to pinpoint the geometry of the targeted features. These systems can be either used for mapping and georeferencing or for actively tracking divers, animals and other moving targets underwater.


photo © A.Ktistis


photo © A.Ktistis

Data management

Processing

Most -if not all- of the data collected in a scientific dive need to be properly processed in order to deliver the valuable information they carry. Processing can vary significantly based on the nature of the data (e.g. basic measurements probably need transcribing from our wetnotes to a computer fiole, whereas large scanning data need extensive software handling to produce interpretable images).

Evaluation

The difficulties we encounter working underwater have in many cases unwanted results in our data collection. Evaluating the data is needed both in order to single out the ones that are not valid or helpful in the scientific process and to understand mistakes or incompetencies in our underwater data collection process.

Archiving

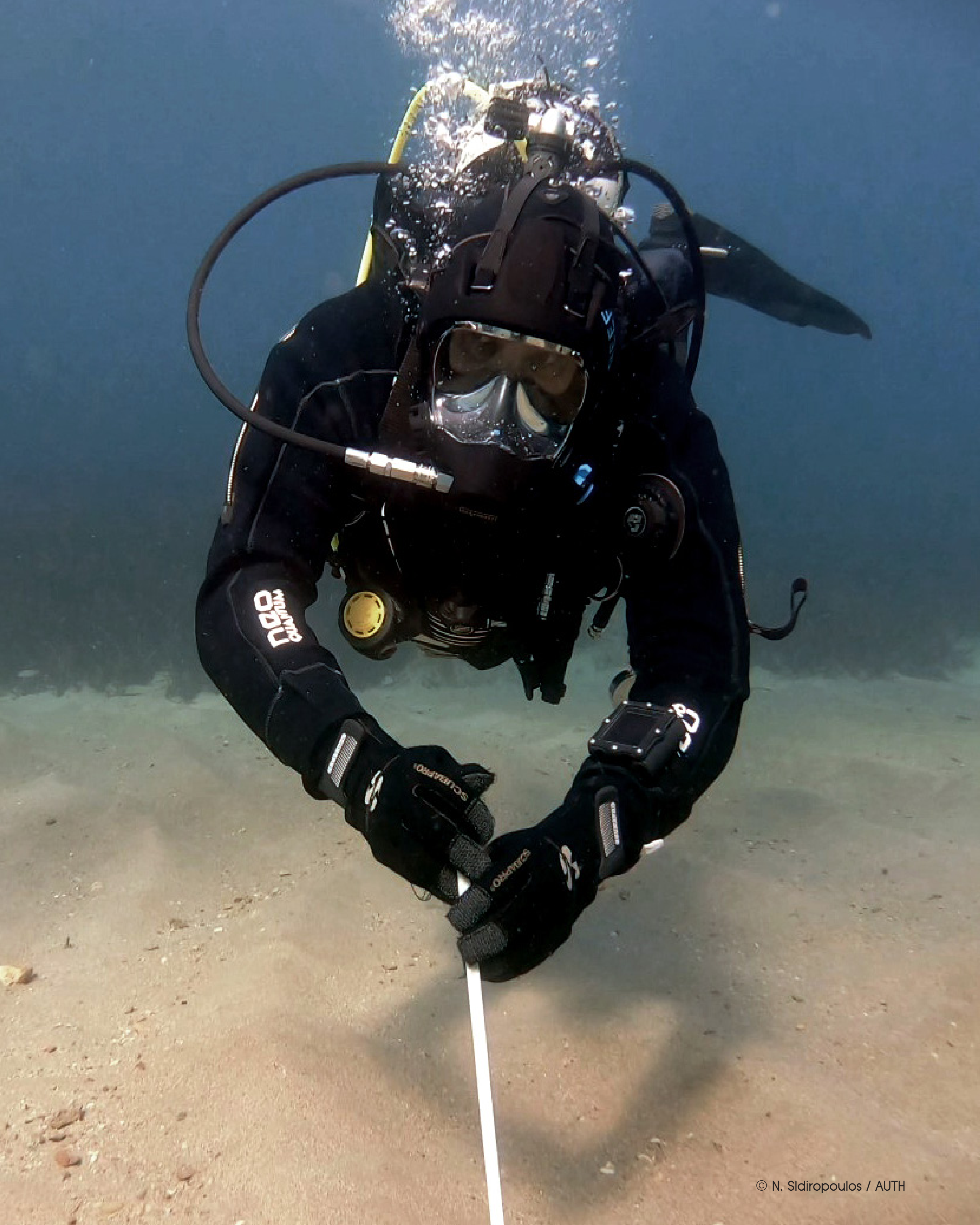
The fact that collection of underwater data is often a challenging and costly procedure dictates an effective archiving system that keeps data safe. A proper archiving method means that all the collected data can be easily retrieved and used in all stages of the scientific process by researchers and that they are systematically categorized based on distinctive attributes that the scientific methodology followed in the project demands.

Reporting

Finally, publishing our results is in many ways the quintessential part of a scientific procedure. Nowadays, there are many ways to share project results whether physically or digitally. A scientific report can take many forms and sizes. Depending on the audience/s one aims to engage, a report can be short or long, general or focused on certain aspects of the scientific procedure, written in compressed scientific language or using a more accessible vocabulary for the general public etc. In any case, a report needs to follow a basic structure that includes:

1. An introduction setting the framework within which the scientific project was formed
2. The methodology followed
3. The results
4. A discussion based on the results and the hitherto bibliography
5. A Conclusion that summarizes the outcome of the scientific project.

Most project managers require reports in order to follow the financial and administrative reasons. The scientific community anticipates the project's report in order to evaluate the results and the public gets to know the scientific content and becomes engaged in the scientific procedure.



Skill development

General considerations

In order to better understand the basic features of Scientific Diving described in this manual, one has to perform set of kill development dives . Some general considerations while exercising these skills underwater are the following:

- always put safety first, even before the scientific objectives (visual contact, communication) of your dive
- maintain good buoyancy control
- follow the buddy system
- regulary monitor depth, time and gas supplies

All skills should be performed with neutral buoyancy, without touching the bottom or breaking the surface. When using or transferring negatively buoyant equipment of up to 4kgs, buoyancy control should be achieved with minor use of BCD or dry suit. In case of use or transfer of excessively negatively buoyant equipment (more than 4 kgs) an independent buoyancy control system should be used (e.g. lift bag)

After the decent and before the approach to the position for the performance of each skill, allow some time (1min while swimming or 30sec static), to become neutrally buoyant, check starting depth, run time and gas supplies, group together in buddy/teams and establish communication.

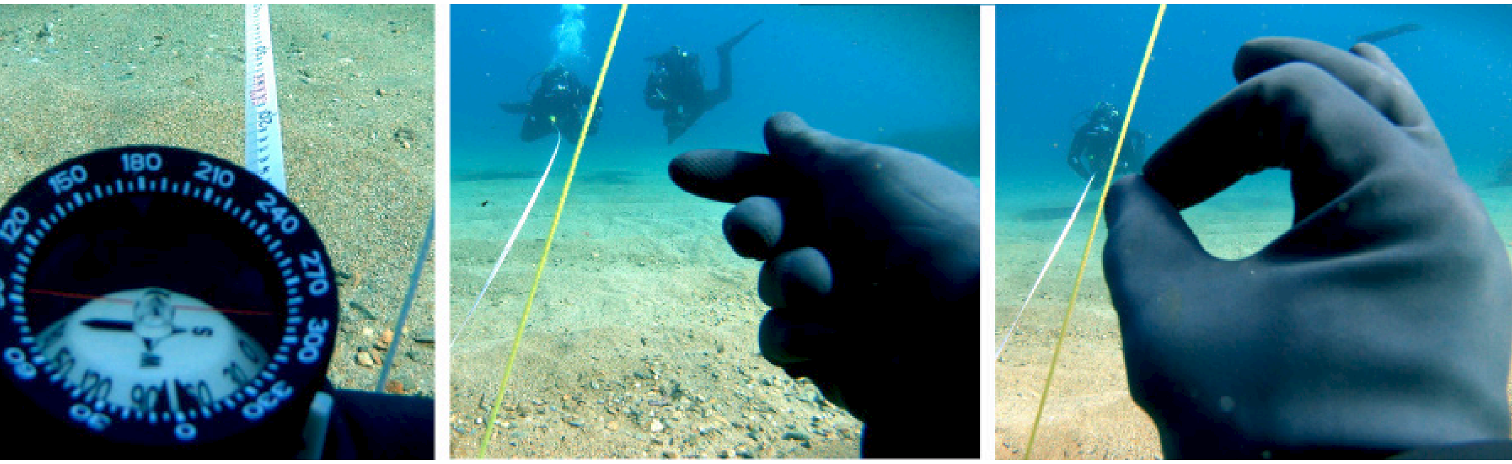
Datum

Steps:

- Descent
- Approach
- Establish a Datum point
    - Measure Depth at Datum point
    - Record Depth at Datum point
- Marking and labeling Datum point
- Ascent

Skill features: static, reference point, depth measurement, measuring period, mean value calculation, measurement recording

Training material (indicative): poles (metallic, plastic), hammer, writing surface (slate, wetnotes), writing tool (pencil), carrying bag/net, labels (metallic, plastic), marker (permanent or UW pen), SMB, reel



Skill variation: aligning the transect line to a specific azimuth (© N. Sidiropoulos / AUTH)

Transects

Steps:

- Descent
- Approach
- Establish first Transect point
    - Measure Depth at first Transect point
    - Record Depth at first Transect point
- Establish second transect point
    - Measure Depth at second Transect point
    - Record Depth at second Transect point
- Sketch the Transect
- Marking and labeling
- Check Transect and do any fixings
- Ascent

Skill features: linear, orientation, reference line, bearing measurement, distance measurement, mean value calculation, depth measurement, measurement recording

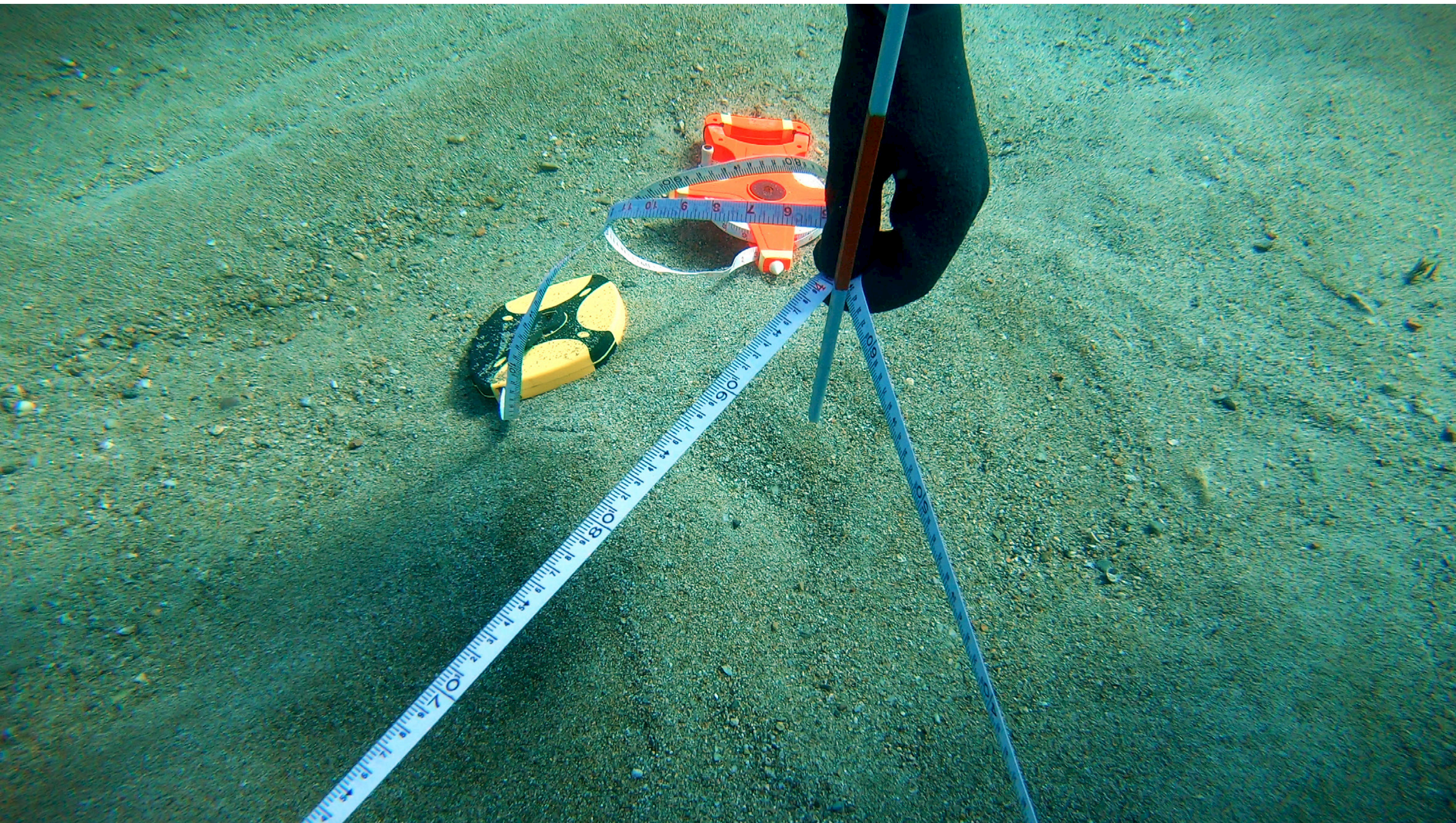
Training materia (indicative):: poles (metallic, plastic), hammer, distance measuring equipment (measuring tapes), writing surface (slate, wetnotes), writing tool (pencil), carrying bag/net, labels (metallic, plastic), marker (permanent or UW pen), SMBs, reels

Quadrats

Steps:

- Descent
- Approach
- Establish first Quadrat point
  - Measure Depth at first Quadrat point
  - Record Depth at first Quadrat point
- Establish second quadrat point
  - Measure Depth at first Quadrat point
  - Record Depth at first Quadrat point
- Establish third quadrat point
  - Measure Depth at third Quadrat point
  - Record Depth at third Quadrat point

Creating the quadrat using polar coordinates (© N. Sidiropoulos / AUTH)



- Establish forth quadrat point
    - Measure Depth at third Quadrat point
    - Record Depth at third Quadrat point
- Sketch the Quadrat
- Marking and labeling
- Check Quadrat and do any fixings
- Ascent

Skill features: boundary, orientation, bearing measurement, distance measurement, intersection, depth measurement, measurement recording, sketching

Training material (indicative): poles (metallic, plastic), hammer, distance measuring equipment (measuring tapes folding rulers), writing surface (slate, wetnotes), writing tool (pencil), carrying bag/net, labels (metallic, plastic), marker (permanent or UW pen), SMBs, reels

Media (image-sound-other) recording

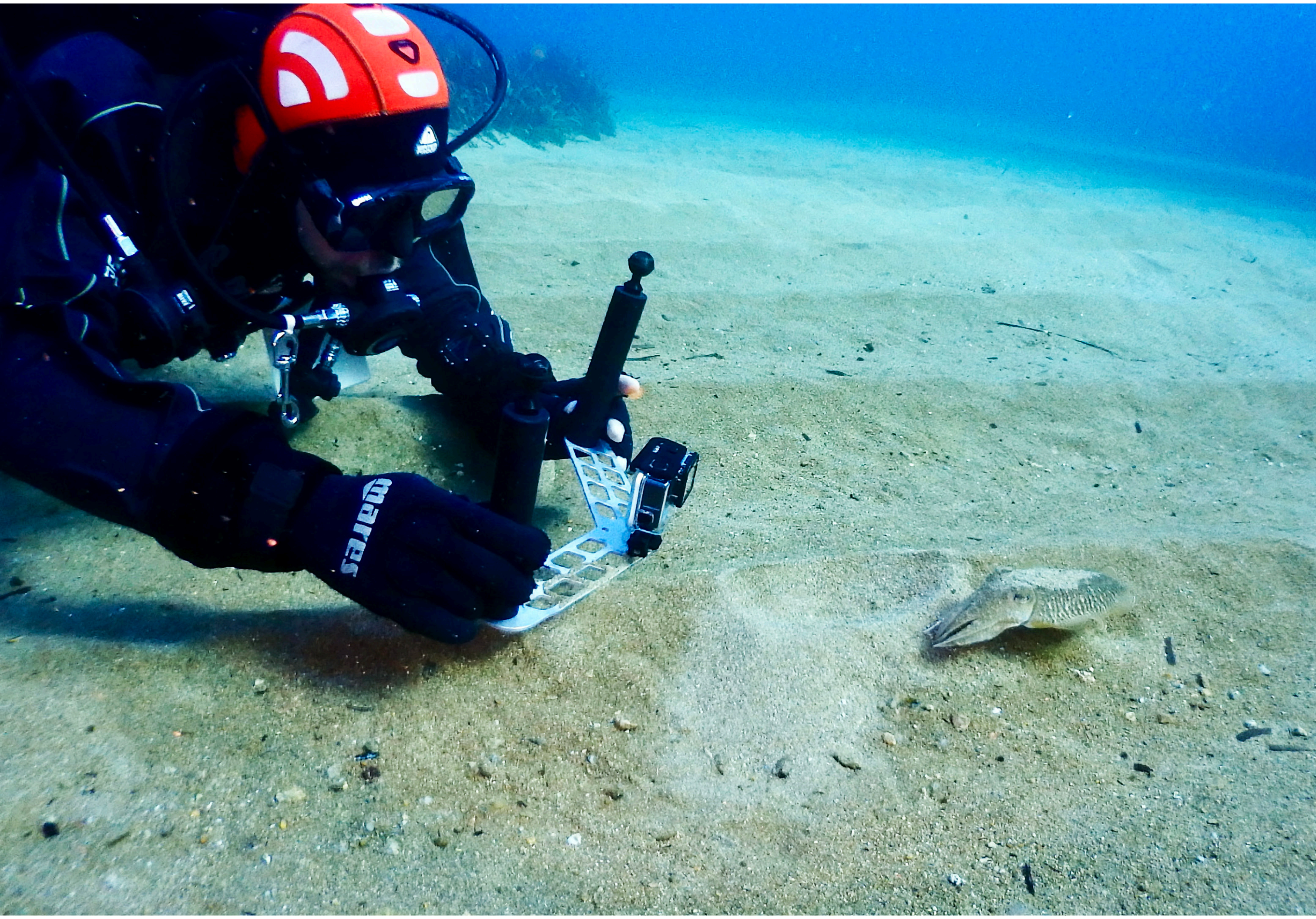
Steps:

- Descent
- Approach
- Place a scale bar
- Take oblique Photo
    - Check Run Time, Measure Depth and Orientation
    - Record Run Time, Depth and Orientation
- Take orhto Photo
    - Check Run Time, Measure Depth and Orientation
    - Record Run Time, Depth and Orientation
- Video
    - Check Run Time, Measure Depth and Orientation
    - Record Run Time, Depth and Orientation
- • Other media
    - Check Run Time, Measure Depth and Orientation
    - Record Run Time, Depth and Orientation
- Ascent

Skill features: static, linear, position, orientation, nadir, photo/video frame, run time, bearing measurement, depth measurement, measurement recording, sketching

Training material (indicative): scale bar (folding rulers), media recording devices (photo camera, action cameras, digital, acoustic or chemical sensors), writing surface (slate, wet-notes), writing tool (pencil), carrying bag/net, labels (metallic, plastic), marker (permanent or UW pen), SMBs, reels

Capturing image underwater poses various challenges (© E. Seretakis / AUTH)



Mapping

Steps:

- Descent
- Approach

A. Photogrammetry

- Place a perpendicular/square frame
- Take an ortho photo shot for Photoquadrat
    - Check Run Time, Measure Depth and Orientation
    - Record Run Time, Depth and Orientation
- Sketch the Photoquadrat
- Place scale bars
- Place ground control points
- Take a sequence of photos for Photomosaicing
    - Check Run Time, Measure Depth and Orientation
    - Record Run Time, Depth and Orientation
- Sketch the sequence of photo shots
- Place scale bars
- Place ground control points
- Take a sequence of photos for 3D recording
    - Check Run Time, Measure Depth and Orientation
    - Record Run Time, Depth and Orientation
- Sketch the sequence of photo shots

B. Distance measurements

- Use the Polar method
    - Measure Distance, Orientation and Depth
    - Record Distance, Orientation and Depth
- Sketch

- Use the Offset method

- Measure offset Distance, reference Distance and Depth
- Record offset Distance, reference Distance and Depth

- Sketch
- Use the Intersection method
  - Measure Distance from first reference point, Distance from second reference point and Depth
  - Record Distance from first reference point, Distance from second reference point and Depth
- Sketch

C. Positioning

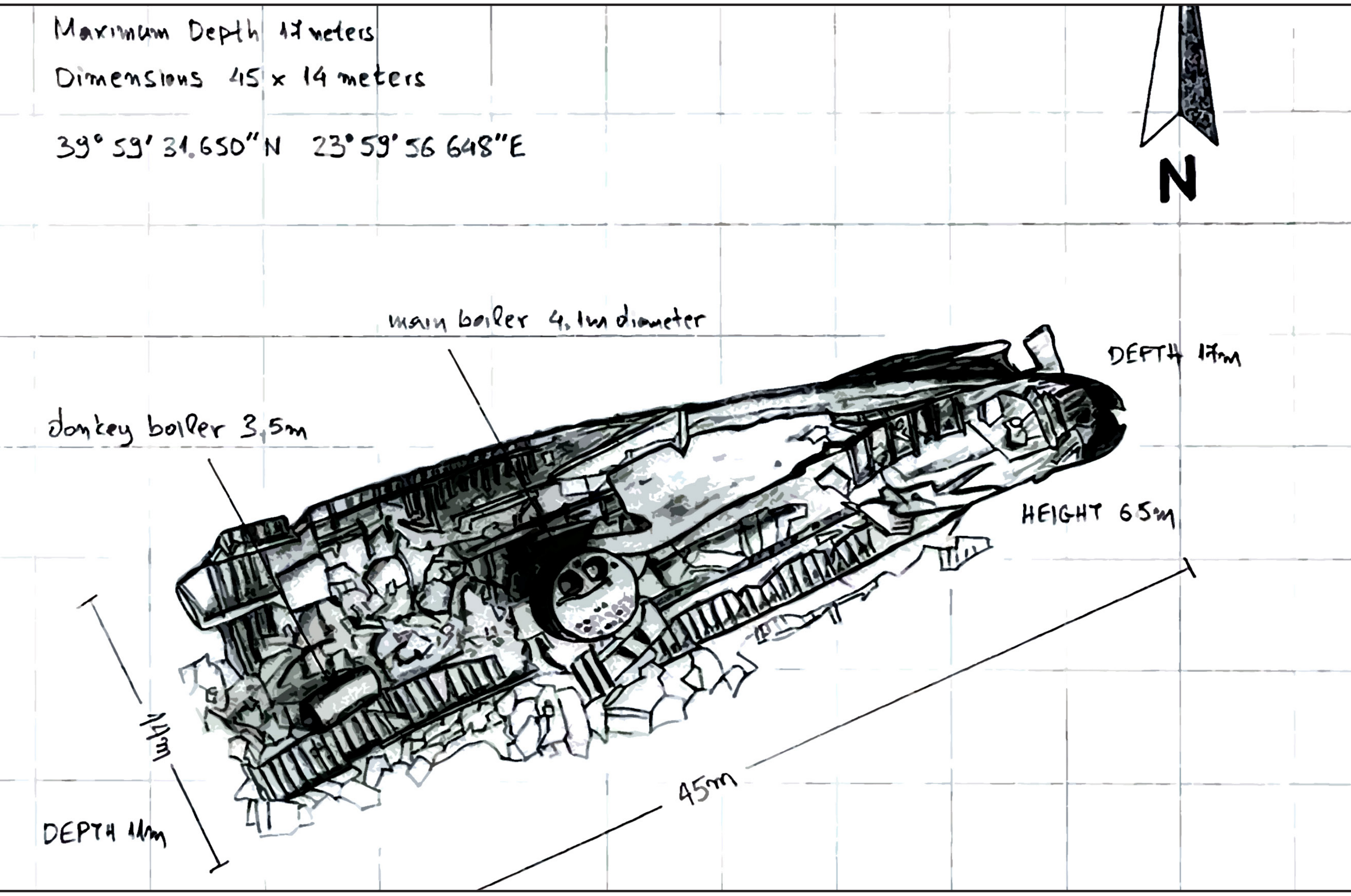
- Use the USBL (or GNSS) system
  - Check Run Time and Measure Depth
  - Record Run Time and Depth
- Sketch

- Ascent

Mapping is a complecated and challenging endauvor (© A. Ktistis / AUTH)

Skill features: static, linear, areal, position, orientation, nadir, photo frame, run time, depth measurement, mean value calculation, distance measurement, intersection, measurement recording, sketching

Training material (indicative): measuring tapes (two for intersections), positioning system devices (USBL, floating GNSS), photogrammetric system (single/dual/multi camera system, action cameras), scale bars (folding rulers), pre-measured frames, targets (metallic, plastic), writing surface (slate, wetnotes), writing tool (pencil), carrying bag/net



Sketching is an essential part of documentation (© AUTH)

Collecting data (coring, artifacts etc.)

Steps:

- Descent
- Approach
- Collect data (take sample)
  - Check Run Time and Measure Depth
  - Record Run Time and Depth
- Sketch
- Ascent

Skill features: static, run time, depth measurement, mean value calculation, depth measurement recording, sketching

Training material (indicative): containers (bags, cups), writing surface (slate, wetnotes), writing tool (pencil), carrying bag/net

Recovering samples requires following the right procedures (© V. Tsiaris/ MESEP/ EUA)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C. Diving – Safety

Organizing the dive

The fact that a scientific dive has a distinct scientific purpose does not of course imply in any way that safety concerns are to be subjugated. As always, safety comes first and it is the scientific aspect of the dive that has to be aligned to the safety protocols. Thus, the dive plan is based on the selection of the optimal dive mode, the necessary equipment, the right gas management, the formation of emergency plans and other safety essentials.

It is really important to perform briefing and debriefing procedures, so as to clarify the dive plan, communication details, assign distinct roles (not only scientific but also concerning safety) either in or out of the water, point out potential hazards and evaluate the plan and its implementation. Moreover, it is always beneficial toy work on team building and perform dives with fellow scientific divers that toy are comfortable working with and have common understanding of both scientific and diving protocols.

Dive modes

The current diving landscape comprises a variety of choices in the way one works underwater. Before hitting the water a scientific diver must decide which is the most effective way and provides the necessary diving safety. Some of the basic factors that dictate this choice are depth, environmental conditions (temperature, waving, currents etc.), diving level, distance from shore, supporting equipment etc. Furthermore, we should point out that the selected dive mode should be eligible for all divers. In the case of mixed diving modes, different safety plans should be prepared for each dive mode.

Ta basic diving modes that are most commonly used in SD are:

1. Snorkeling is the most simple way of working in the water and is very popular in shallow waters and in reconnaissance procedures. During snorkeling the diver may want to reach the bottom with freediving to take a closer look or retrieve a preliminary sample.
2. Basic SCUBA equipment is used in the majority of scientific dives, since it is the most familiar way of working underwater in ordinary conditions.
3. Surface supply diving is the right choice in challenging environments, tasks that require longer stays or advanced safety measures. Surface supply diving may engage simple procedures, when performed in protected waters or advanced "commercial diving" protocols when performed in hazardous conditions.
4. Closed Circuit Rebreathers (CCR) are increasingly being used in scientific diving, since they provide substantial advantages in deep water dives. Of course, CCR is a more elaborate way of diving, requiring more time and funds and thus one must evaluate the cost-effectiveness of a CCR scientific diving program before getting into it.

5. Additionally, although applicable to the above dive modes,we can make a special reference to mixed gas diving, since it is an essential factor that changes the way they are being performed. Mixed gasses, either EAN (nitrox) or TMX (trimix), can improve efficiency by extending dive time or depth limits and increase safety. Nonetheless, we should stress that in order to achieve the aforementioned improvements without risks they need to be used in the right way and by following the necessary protocols and rules.

Diving environments

One of the most prominent factors concerning the safety planning of a scientific dive is the environment in which the diving will take place. Most of the time, the environment is the one single factor dictating the dive mode, the equipment, the emergency plan and any other part of the dive plan. In order to evaluate environmental conditions for diving one should take into account the following features:

1. Altitude
2. Depth
3. Temperature (in and out of the water)
4. Visibility
5. Pollution
6. Salinity
7. Water movement (waving, tides, currents etc.)
8. Blue water (no reference)
9. Overhead
10. Ice
11. Ports and marinas
12. Remote locations

Each of the above features requires their own safety measures and can be approached in various ways. A combination of the ones applicable form the overall environment that the dive will take place and the final dive plan should meet the safety prerequisites for all of them.

Communication

Communication underwater is essential for all dives. Especially while working underwater, being able to communicate is not just a safety issue, but a matter of efficient labor. Thus, performing scientific tasks underwater requires a good set of communication tools that will allow divers to communicate both with other divers underwater and with the surface team. There are several ways of doing that. Here are some of the most popular:

Being able to communicate and cooperate underwater is essential to a scientific diver (© N. Sidiropoulos / AUTH)

1. Hand signals. The usual diving gestures along with a set of specialized ones defined by the diving team and based on the special framework of the project
2. Ropes. One of the oldest, yet quite efficient ways of sending signals to the surface through a combination of short and long pulls.
3. DSMBs (Diver Surface Marker Buoy) are used in various cases either as signaling devices or as carriers of notes from the diver to the surface. Color coding, size or number of DSMBs can mean different things according to the predefined by the team communication code.
4. Audio. Full face masks, hardhats and other configurations that allow the diver to speak are very often used due to their ability to let the diver communicate clearly with other divers and the surface team.
5. Video. Cameras carried or mounted on the diver, or on underwater vehicles (most often ROVs) can provide live video feed to the surface team. The diver can indicate things regarding himself or the site and make hand signals.
6. Light. Developed mostly for low visibility - low light environments light signals can be used to transmit various messages. Either to replace hand signals for divers, or as yes/no or number indicators in ROV flashes and other submersible devices and other applications they can prove really useful in scientific diving scenarios.

Beyond the above, there are other ways of communicating, either simple or elaborate (e.g. underwater wi-fi devices). The choice of the most efficient way for transmitting information depends on various factors and most of the time is a combination of different mediums and methodologies.

Safety Equipment

As with all the previous features, scientific diving safety equipment depends on the diving environment, the dive mode and the emergency plan designed by the team. However, we can list here some of the sine-qua-non safety equipment that corresponds to the majority of scientific diving plans:

1. Marking buoys that indicate the diving area
2. Oxygen supply, either in the form of a specified kit or other means of emergency oxygen providing that can sustain an injured diver until he/she reaches proper hyperbaric treatment.
3. First aid kit, equipped with all the necessary features that correspond to the hazards of the specific environment and can help the injured team member until he/she receives proper medical treatment.
4. Communication with land. It is essential, especially for onboard operations or remoted locations, to constantly keep an open channel of communication with a medical center and the authorities.
5. Special environments. Besides the all around features that we presented so far, it is very often necessary to acquire specified safety equipment to confront needs that arise from special environments (e.g. polluted waters, wildlife).

Usually, the necessary safety equipment presente above is listed in safety regulations and other legal documents. Beyond that threshold of safety, the choice of additional safety equipment may vary in different diving situations depending on the nature of the scientific tasks, the team and other variables. What is considered to be absolutely essential to one situation may be just extra baggage to another. However, it should be stressed out once more that safety is the first priority and is the guideline on which every other part of the plan is being formed.


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D. Appendix

1 3 5 7 9 11 13

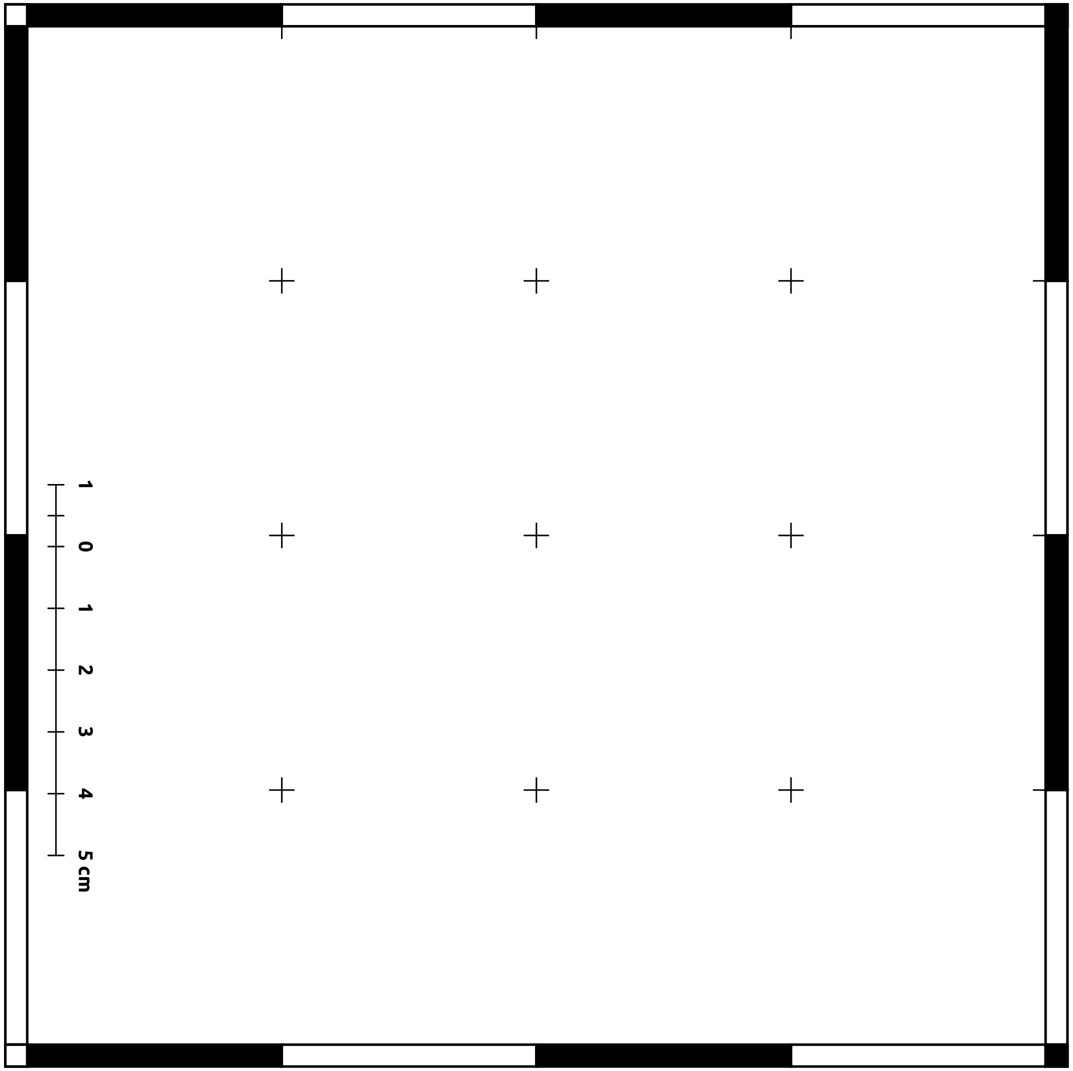
Dive Limits

Max Depth _____ (m/ft)

Max Time _____ (min)

Turn Press. _____ (bar)

Notes



Dive Limits

Max Depth ___________ (m/ft)

Max Time ___________ (min)

Turn Pressure __________ (bar)

Notes

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Science
Diver

Cross-sectoral skills
for the blue economy market

With the contribution of the
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Science Diver

This manual aims at providing an introduction to Scientific Diving. In its pages the reader can find basic information about the history, the theory and the methodology of Scientific Diving and begin the journey of becoming one. The scope of Scientific Diving is of course very wide and multifarious. However, this manual presents the main features comprising a safe and scientifically productive way of working in underwater environments.

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