# Steed METHODOLOGY

## DEPLOYMENT & DATA ANALYSIS

**Seastems**
Siret : 834 481 889 000 22
Thomas Pavy
thom.pavy@gmail.com
+33(0)7 72 07 38 07

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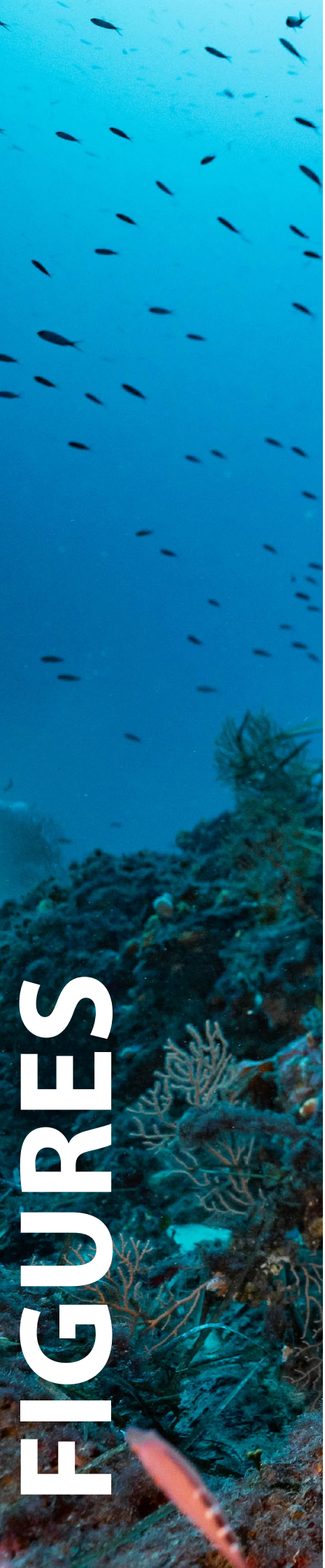

# FIGURES

# 1. CONTEXT

Because of their difficulty of access, mesophotic ecosystems (ME) benefit from a limited knowledge and understanding of their biodiversity, ecological dynamics, and connectivity. The method known as banded transects has been used for several decades to describe and study the biological communities of ecosystems. However, depending on the level of precision of the data and the level of experience of the divers, data collections can appear time consuming. Furthermore, due to environmental and physiological constraints, the available time is extremely limited at great depths (60-150m), making data collection from several biological communities unfeasible.

To address this constraint and contribute to the improvement of knowledge on mesophotic ecosystems, Thomas Pavy designed and developed the STEED methodology. The first prototype was built in June 2022. The device has been subject to a patent publication in the official journal on December 29, 2023, under the reference FR3137059. Initial deployment and data collection took place during the year 2023.

This document defines at first the innovation framework and the tool's technical features. In the second part, it presents the methodological principles for implementation and different analysis strategies.

This study was funded by the Rhône-Méditerranée Corse Water Agency, the Unviersitat de Barcelona (UB), l'Institu de ciències del Mar du Consejo Superior de Investigaciones Científicas (ICM-CSIC) and Seastems.

In continuation of the period of innovation and tool conception, **this study will :**

**- define data collection and treatment methodologies.**

**- Compare the results obtained with the STEED method to those obtained with the currently used methods.**

**- Details data analysis strategies based on the needs and resources available.**

Acknowledgement : Data collection on the Macinaggio and Punta Palazzu sites were accomplished using Andromède Océanology technical means.

Data collection in Medes Islands have been conducted by Yanis Zenter, Martí Vilanova et Cristina Linares andJoaquim Garrabou.

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Photo credit: Thomas Pavy if not mentioned

Diver : Nicolas Molon if not mentioned.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

# 2. RATIONALISATION

## 2.1. MESOPHOTIC ECOSYSTEMS

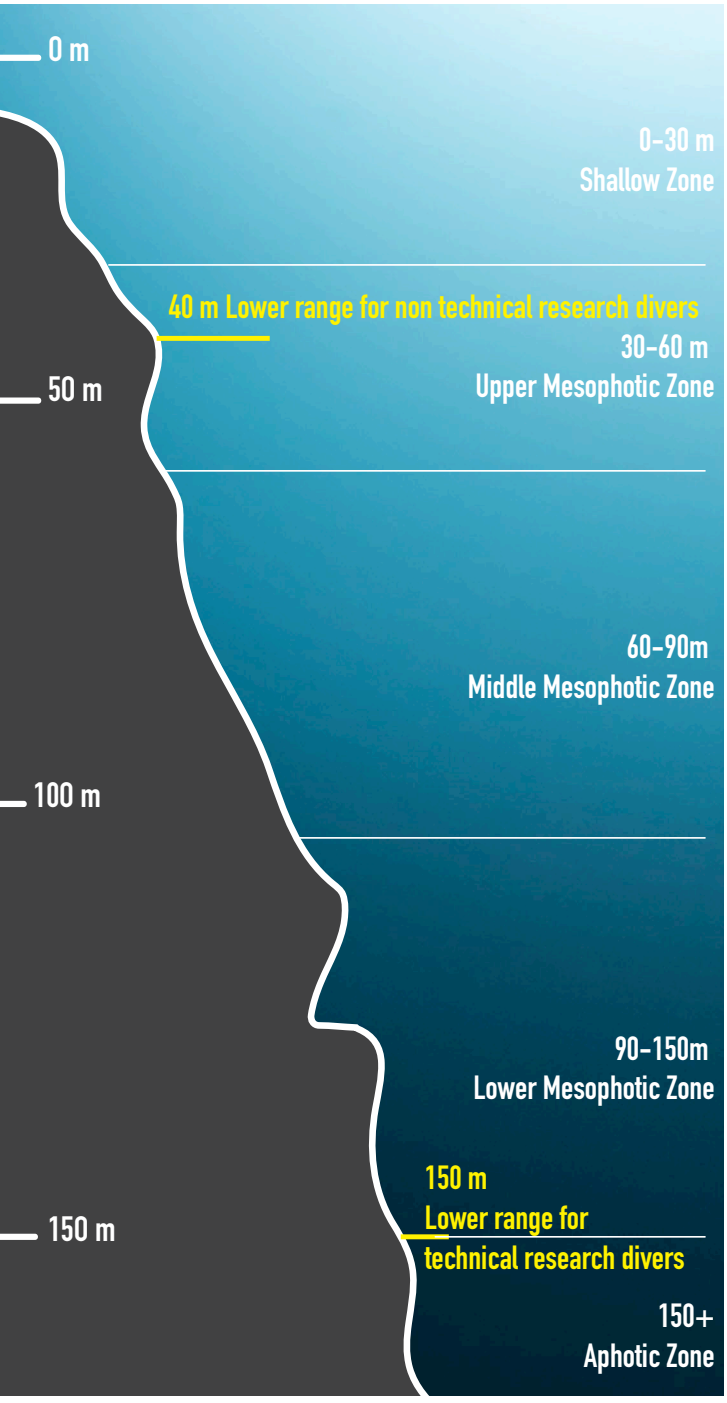


Figure 1 : Depths gradient of MCE

Mesophotic ecosystems (ME) can be defined as ecosystems that receive 1% of surface irradiation on their upper limit[1] (30 to 60 m depending on environmental conditions) and constraints at their lower limit with primary producer disappearance, usually around 150m (see figure 1). The zone of extension of mesophobic ecosystems is commonly referred to as the twillight zone.

They could account for 60 to 80% of all reef ecosystems[2] and have been divided into two main categories: mesophotic coral ecosystems (MCE) and temperate mesophotic ecosystems (TME)[3].

Despite the start of ME research in the early 1960s by submariners and pioneers of technical diving[4], they received little interest and have mostly gone unreported until recently. It was necessary to wait until 2010 for the emergence of new ecological theories.

The recent interest in ME may be related to three main schools of thought:

-The hypothesis that, in the context of climate change, ME could provide a refuge for shallower ecosystmes[5].

- The lack of knowledge regarding how ecological processes alter throughout the course of depth gradients and their potential impact on resource management policies[6].

- The identification and description of new communities as well as a high level of biodiversity.

Today, ME continue to face a lack of knowledge and understanding regarding their biodiversity, ecological dynamics, and connectivity with limitrophes due to their difficult access.

1 Cerrano, C., Bastari, A., Calcinai, B., Di Camillo, C. G., Pica, D., Puce, S., & Torsani, F. (2019). Temperate mesophotic ecosystems: Gaps and perspectives of an emerging conservation challenge for the Mediterranean Sea. The European Zoological Journal, 86(1), 370–388.

2 Gal Eyal. and Hudson T. Pinheiro. Mesophotic Ecosystems: The Link between Shallow and Deep-Sea Habitats. Diversity. 2020, 12, 411

3 Bongaerts,P., Perez-Rosales,G., Radice,V. Z.. et al. Mesophotic.org: a repository for scientific information on mesophotic ecosystems. Database (2019) Vol. 2019

4 Strasburg,D.W., Jones,E.C. and Iversen,R.T. (1968) Use of a small submarine for biological and oceanographic research. ICES J. Mar. Sci., 31, 410–426.

5 Bongaerts,P., Ridgway,T., Sampayo,E.M. and Hoegh- Guldberg,O. (2010) Assessing the 'deep reef refugia' hypothesis: focus on Caribbean reefs. Coral reefs, 29, 309–327.

6 Bridge, T. C. L., Hughes, T. P., Guinotte, J. M., and Bongaerts, P. 2013. Call to protect all coral reefs. Nature Climate Change, 3: 528–530.



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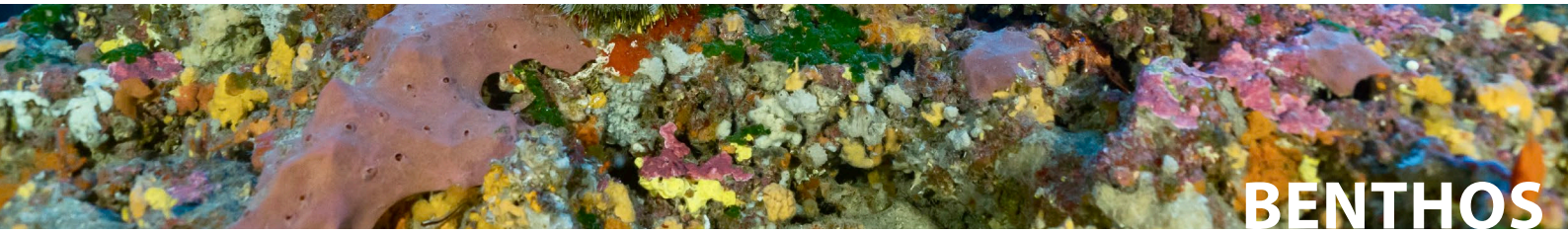
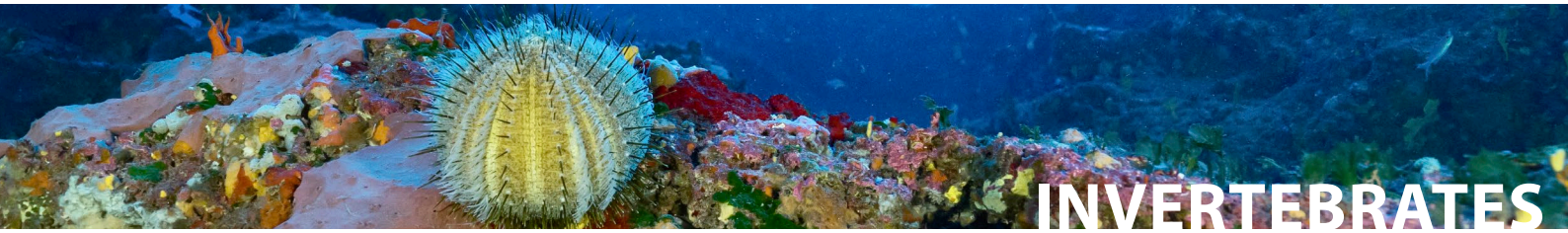
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022









## 2.2. MESOPHOTIC ECOSYSTEMS SURVEY

### 2.2.1. BIOTIC COMMUNITIES

Marine ecosystems communities can be divided into four sections:

- **Benthos:** made up of all living things that are attached to a substrate (sessile). They make up the habitat and are especially vulnerable to changes of environmental conditions.
- **Suspension feeders:** Within the benthos, we may identify the sub-community sometimes known as "animal forests". It is dominated by fixed erected suspensivores (such as gorgonians, sponges, and corals). They can build extremely intricate three-dimensional structures.
- **Invertebrates:** consists of all mobile (vagile) invertebrate organisms, such as crustaceans, echinodermes, and céphalopodes. This category is mostly composed of herbivorous grazers and detritivores organisms.
- **Ichtyofauna:** made up of all individual fish, whether they are pelagic, semi-demersal, or demersal.

### 2.2.2. BELT TRANSECTS

The band transect method has been used for several decades to study biotic communities because it allows data collection from several targeted communities on a common area. Data are typically directly obtained by underwater visual census (UVC). The transects are suitable for medium-scale surveys. Based on the desired level of precision and the divers' training level, the data collection process may appear time consuming. We estimate that each biotic community requires 20 to 30 minutes to collect visual data for a 25 m transect.

However, data can also be gathered through the use of photographs and videos; in this case, the level of precision can be adjusted during the processing of these materials based on the requirements and available resources.





SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

## 2.3. DEPTH AND TIME

Working at great depths requires a high level of expertise and experience. In fact, using Trimix gas (oxygen, azote, and helium) is mendatory deeper than 40 metres.

Decompression stops are necessary when ascending to the surface after spending time at great depths. On average, 20 minutes spent at 120 metres will produce 240 minutes of decompression time.

A lot of equipment, such as extra tanks or specific tools, must be carried by divers in order to perform deep dives and collect scientific data. These items have a tendency to make every movement more difficult and to increase water resistancy.

Due to environmental and physiological limitations, there is very little time available during deep diving, so every movement needs to be optimised.


Figure 3 : Thibault Rauby during a dive in 2019. Credit : Laurent Ballesta / Andromède Océanologie

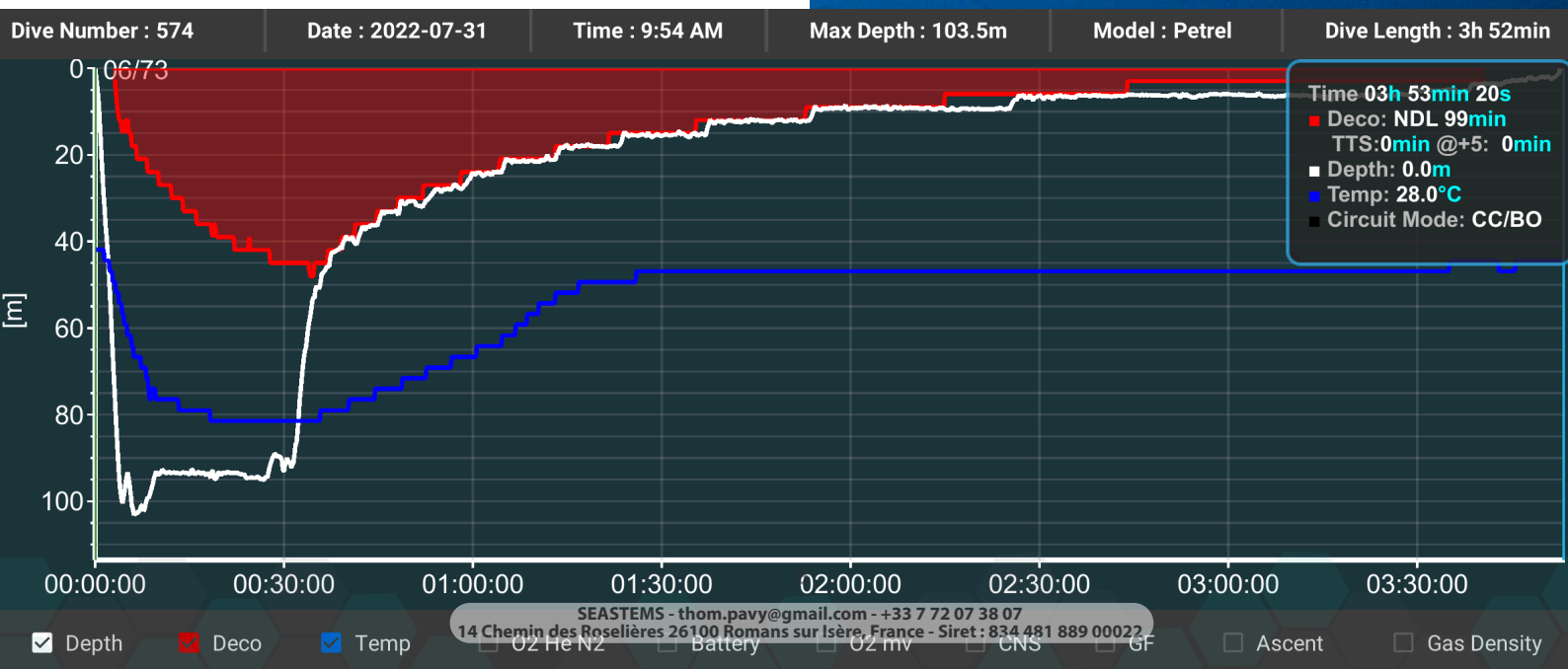



Figure 2 : Dive profil using Trimix gases during an ecosytem survey. It ended up with a decompression stop of 235 min for 26 min of bottom time at 100m.

## 2.4. SPECIFICATIONS

**Contribute to MEs's ecological knowledge and understanding**

Need to

- Valorise every opportunity at great depths to obtain a general ecosystem description

- Systemise data format and indicators to allow comparison and correlation

- Sample all MEs encountered during explorations

- Maintain diver safety at depth

By

- Accelerating data collection of all ecosystem communities at great depths (60-150m)

- Using only proven and widely recognized methods for data collection

- Increasing exploration potential

- Not increasing equipment clutter for divers

With

- A belt transect sampling methodology

- A unique standardized and synchronized system for all 4 ecosystem communities

- A propelled system for a safe and fast deployment



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

# 3. STEED

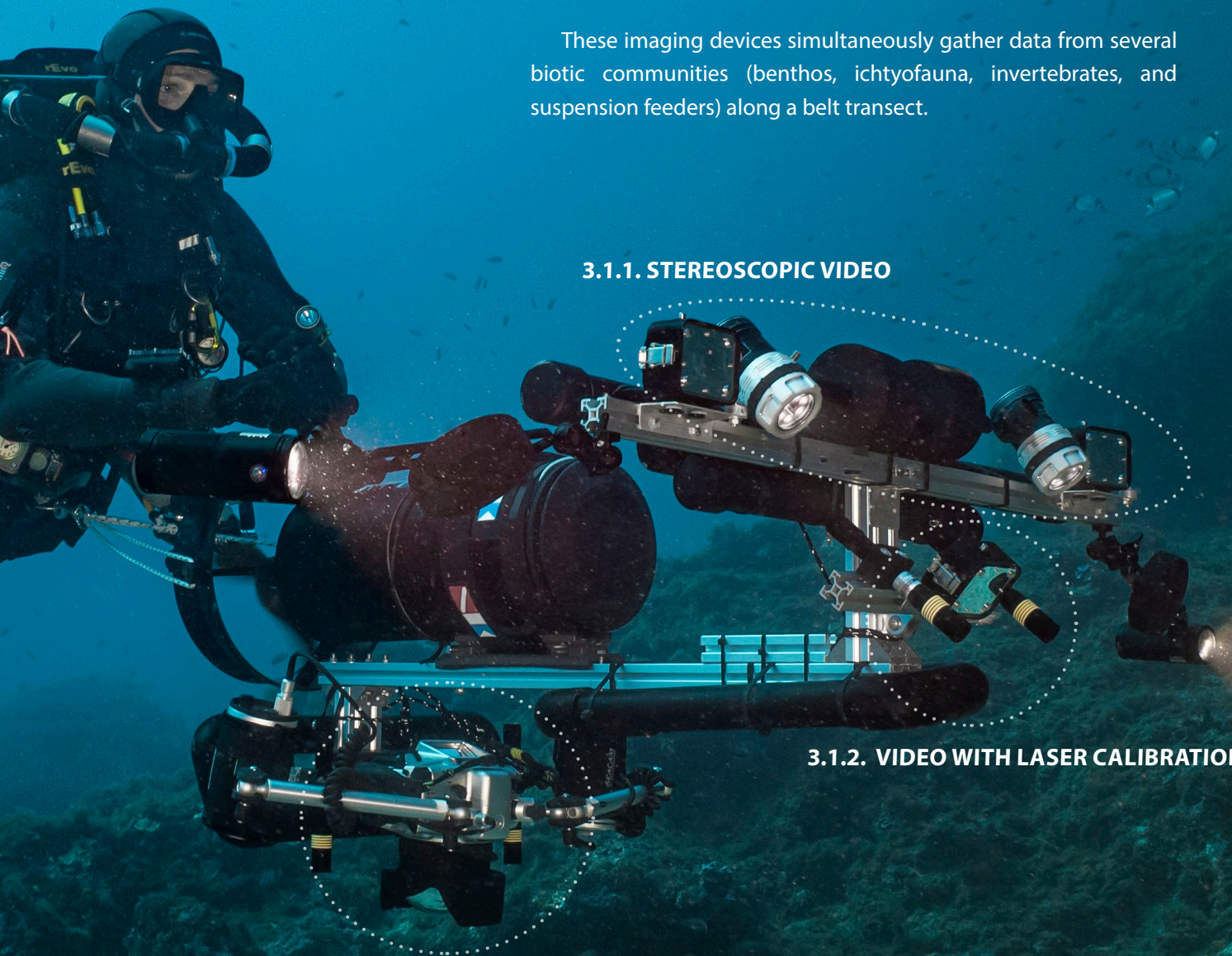
Credit : Marta Sostres

# 3.1. TECHNICAL CHARACTERISTICS

**STEED** means **Synchronized Transect** for **Exploration** and **Ecosystem Description.**

The entire system consists of a submerged propeller coupled to a frame that supports three different imaging devices. In addition to having neutral buoyancy, it is balanced according to its intended use, making manipulation easier and diver security maintained. It can be used down to a maximum depth of 150 metres.

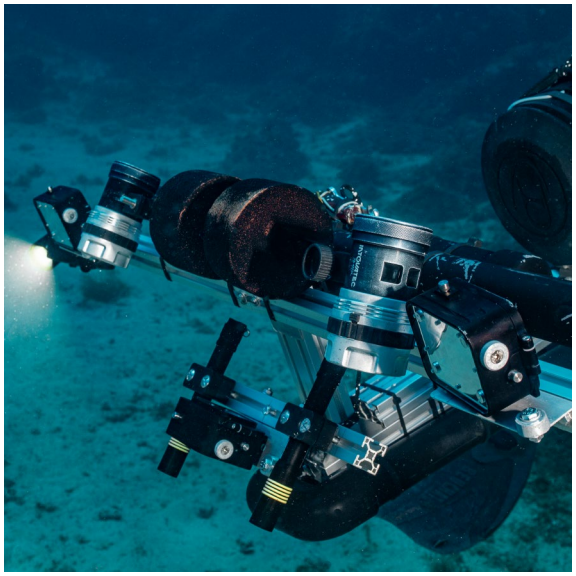
These imaging devices simultaneously gather data from several biotic communities (benthos, ichtyofauna, invertebrates, and suspension feeders) along a belt transect.



### 3.1.1. STEREOSCOPIC VIDEO

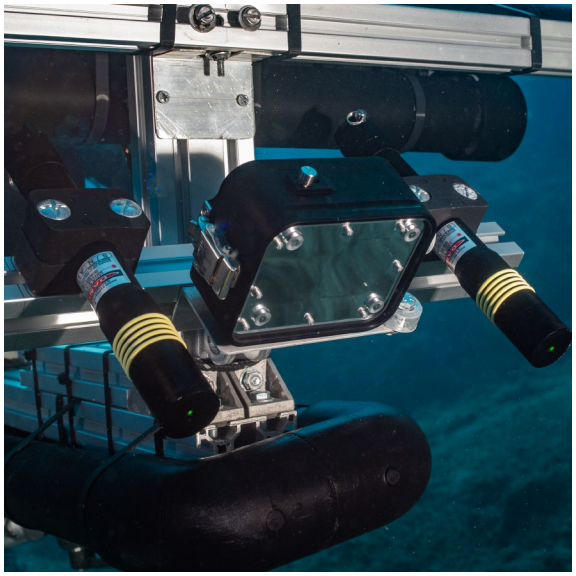
### 3.1.2. VIDEO WITH LASER CALIBRATION

### 3.1.3. PHOTO-QUADRATS



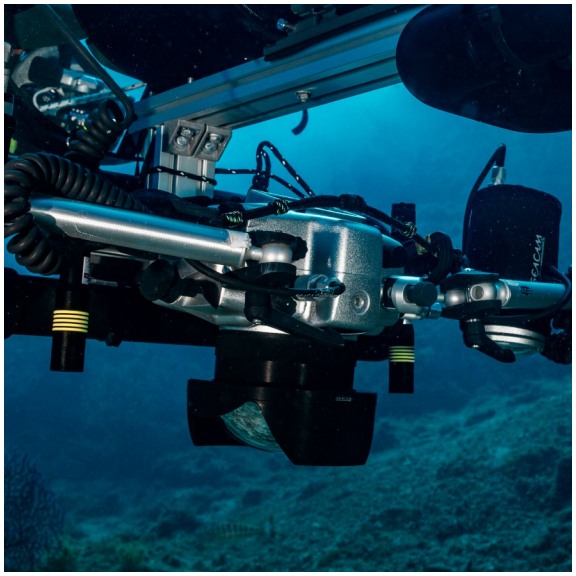
### 3.1.1. STEREOSCOPIC VIDEO

The stereoscopic video system is composed of two GoPro Hero 8 black cameras set to 4k/30fps. The distance between the lenses is 60 cm, and the cameras are positioned with an convergent angle of 8°. Two Bigblue lights of 9000 lumen illuminate the field of vision to improve image quality and species identification.



### 3.1.2. VIDEO WITH LASER CALIBRATION

A GoPro Hero 8 black camera is positioned at a 45° angle and records at 4k/30fps. Two lasers are placed 25 cm apart from each other on both sides of the camera to provide scale and size estimation. Two Bigblue lights of 9000 lumen illuminate the field of vision to improve image quality and species identification.



### 3.1.3. PHOTO-QUADRATS

With a 20mm lens, a Sony A7II camera with a 24 megapixels censor takes a vertical photo of the substrate every two seconds. Two lasers are placed 30cm apart from each other on both sides of the camera to allow cropping of photo-quadrats during data processing. The camera is synchronised with waterproof flashes with a power of 100 watts.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

# 4. DEPLOYMENT

# 4.1. DATA COLLECTION

### 4.1.1. GENERAL PROCEDURE

The procedure for data collection using the STEED methodology consists of the following steps:

- conducting continuous depth transects (we consider three transects per station).
- keep the device horizontal at a distance of around one metre from the substrate.
- make long-distance travels without abrupt changes in direction.

The operator will carefully record the following information for each station and each transect: depth, visibility, current, water temperature, time, date, and site name.

**The STEED tool is designed to be operated by a single diver; however, for safety reasons, this operator must be accompanied by another diver who is also equipped with a submerged propeller.**

In this document, cameras used will be referred to as follows:

- GP1: Stereoscopic left camera
- GP2: Stereoscopic right camera
- GP3: 45° vision camera
- A7II: Photo camera with intervalometer

### 4.1.2. SYNCHRONISATION OF IMAGES

The system's cameras are all synchronised using a chronometer on a dive computer. The chronometer will be placed in front of each device for at least three seconds in order to use the change of second as a synchronisation element. This also allows us to associate the depth and temperature of the water at the start of each transect.

After being imported into the VidSync[1] software, the videos are synchronised. With this technic, GP1 and GP2 videos can be synchronised with a presicion of 30ips (images per seconde) to allow for stereoscopic measurements. The GP3 and A7II cameras require second-by-second synchronisation in order to correlate data from several biotic communities.

The figure below shows the time displayed on the chronometer by the four imaging devices at the start of a belt transect.

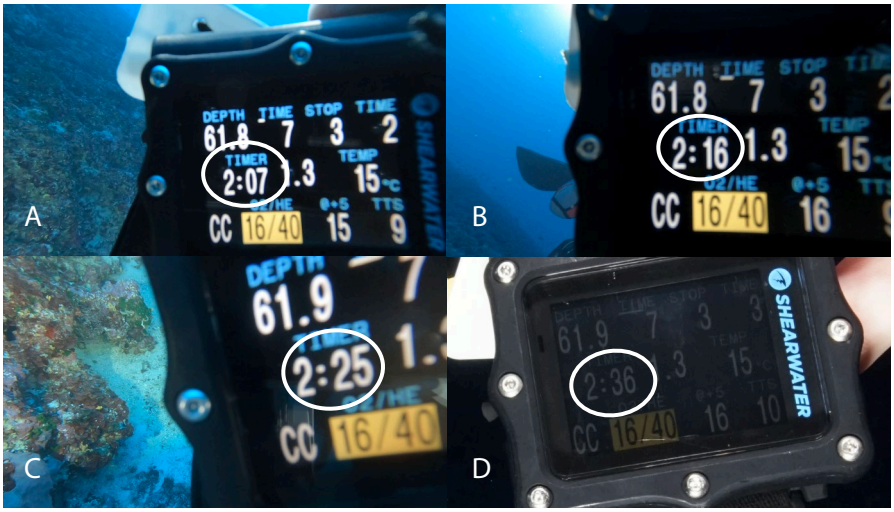



Figure 4 : Screen shot of the dive computer showing the chrnonometer used for synchronisation of images (GP1=A, GP2=B, GP3=C, A7II=D).

1 Neuswanger, Jason R., Wipfli, Mark S., Rosenberger, Amanda E., and Hughes, Nicholas F. 2016. Measuring fish and their physical habitats: Versatile 2-D and 3-D video techniques with user-friendly software. Canadian Journal of Fisheries and Aquatic Sciences 73(12): 1861-1873.



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14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

### 4.1.3. 2D & 3D CALIBRATION

Calibration on the VidSync1 software is done using footages of a 50cm side aluminium cube (50*50*50) and a plexiglass board covered with a 1cm chessboard patern. The software calculates the optical distorsion of the lenses automatically. The calibration cube contains a total of 32 targets. They are distributed equitably throughout the two depth of field of the cube four targets for each side fo the cube (see illustration below). Each target is defined in the software with its X, Y, and Z coordinates for the two stereo cameras (GP1 and GP2).

The initial calibration was performed on May 17, 2023 at a depth of 11,5m. The precision of measurement was verified and calculated using 50 random measurements on various layouts and orientations of the calibration cube. The results show a mean measurement error of 1.48% across all measurements.

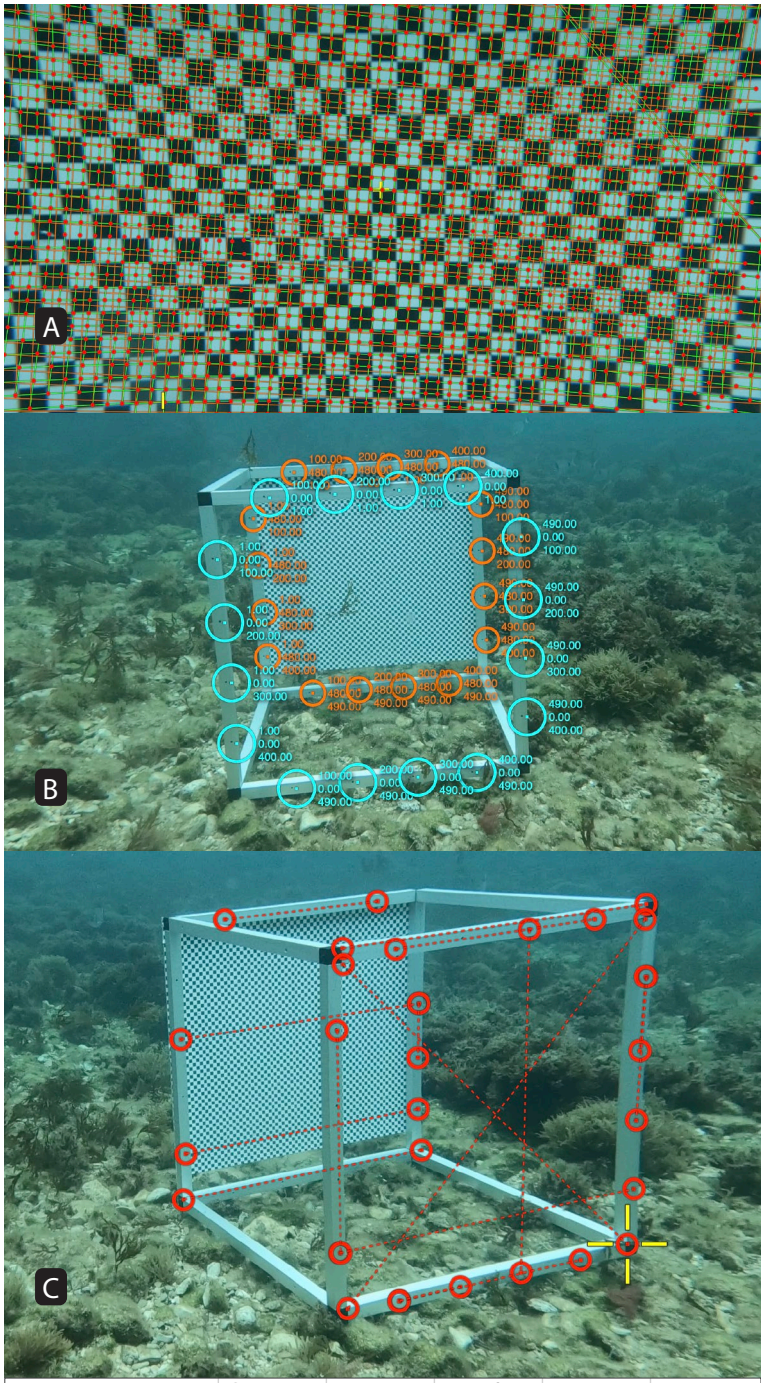
In the course of this study, we recorded the calibration cube at each data collection in order to validate the calibration systematically. Those verifications are conform to the previously observed average error rate.

### 4.1.4. TRANSECT LENGTH CALCULATION

It is critical to be able to standardise the length of transects in order to standardise data collection and allow for correlation between transects, sites, and depths. However, in order to speed up data collection along many transects, the STEED methodology does not include the deployment of a decameter.

But we can calculate our speed by calculating distance to an object at different time intervals. Indeed, using stereoscopy, the distance to an object may be measured via the VidSync software.

During the initial deployments, the average speed of data acquisition was calculated to be 0.3m/s. In this case, a 50m transect corresponds to 2min46s of video. The speeds can be calculated throughout each analysis to adjust the length of video to be selected.




D

| Session | Id | Dimension | Mesurée | % erreur |
|---|---|---|---|---|
| 18_05 | 1805_1 | 50 | 49,85 | 0,30 |
| 18_05 | 1805_2 | 50 | 48,76 | 2,48 |
| 18_05 | 1805_3 | 50 | 48,37 | 3,26 |
| 18_05 | 1805_4 | 46 | 45,93 | 0,15 |
| 18_05 | 1805_5 | 46 | 45,68 | 0,70 |
| 18_05 | 1805_6 | 46 | 44,2 | 3,91 |
| 18_05 | 1805_7 | 48 | 47,98 | 0,04 |
| 18_05 | 1805_8 | 48 | 46,96 | 2,17 |
| 18_05 | 1805_9 | 46 | 45,87 | 0,28 |
| 18_05 | 1805_10 | 50 | 49,41 | 1,18 |
| 18_05 | 1805_11 | 46 | 44,64 | 2,96 |
| 18_05 | 1805_12 | 50 | 48,3 | 3,40 |
| 18_05 | 1805_13 | 50 | 47,69 | 4,62 |

Figure 5 : Screenshots from the VidSync software of a 2D calibration image of camera lentils (A) and a 3D calibration image of camera position relative to the reference targets (B). Figure C depicts calibration verification measurements. The table D is an excerpt from calibration verification measurements.

1 Neuswanger, Jason R., Wipfli, Mark S., Rosenberger, Amanda E., and Hughes, Nicholas F. 2016. Measuring fish and their physical habitats: Versatile 2-D and 3-D video techniques with user-friendly software. Canadian Journal of Fisheries and Aquatic Sciences 73(12): 1861-1873.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

### 4.1.5. TRANSECT WIDTH MEASUREMENT

The size of the field of view, and thus the width of transects to be used for data analysis, might vary depending on visibility. In order to standardise data collection and allow for correlation amongst transects, sites, and depths, the software VidSync can be used to measure the width of the field of view. It is therefore possible to obtain this measurement for each transect, thereby defining the transect's surface and calculating densities per $m^2$.

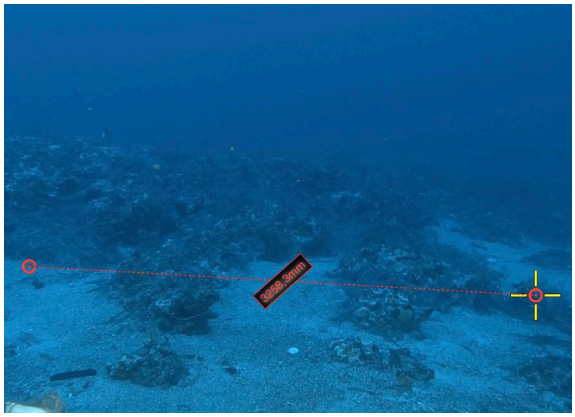


Figure 6 : Screen capture in VidSync of a field of vision measurement at the start of a transect.

## 4.2. DATA TREATMENT

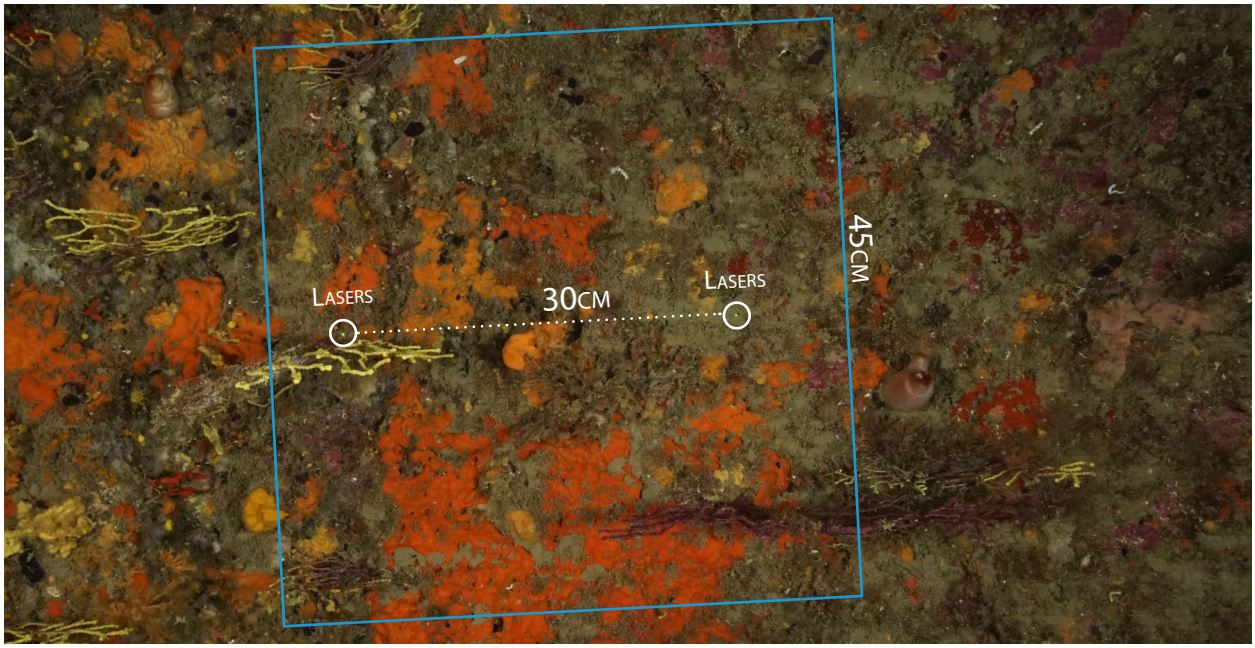



Figure 9 : Example of the extraction of a 45cm * 45cm photo-quadrat from 30cm laser points.

### 4.2.1. BENTHOS

The two laser points on each photo-quadrat are used as a scale to crop each image to the desired surface. The two lasers are 30cm apart, however by keeping the proportions, the images can be resized to 45cm*45cm. This corresponds to a 0.2025m2 surface. Some photos are ineligible for treatment due to low resolution or field of vision issues. The images are then treated with the CPCE photo-quadrat processing software, which randomly project 64 points per photo-quadrats[1]. Necrosis, diseases, and stages of life can all be recorded as observations.

1 Deter J., Boissery P., Descamp P., Ballesta L., Holon F., 2012. A rapid photographic method detects depth gradient in coralligenous assemblages. Journal of Experimental Marine Biology and Ecology 418–419 (2012) 75–82



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

### 4.2.2. ICHTYOFAUNA

Videos from GP1 and GP2 are viewed twice after they have been calibrated and transect lengths calculated. The first reading allows us to identify, and measure individuals alone or in small schools. The second reading allows us to identify species, and measure the individuals in the schools. VidSync measures sizes in millimetres. Only a few individuals of representative size will be measured for schooling species to facilitate treatment.

Figure 7 : Measurement of a *Sparus aurata* individual during a transect in the Medes Islands (Spain).

### 4.2.3. INVERTEBRATES

In this case we use the video of GP3. This camera's field of view is approximately 1m width on the substrate. Viewing can identify species, and estimate individual size by using laser scales (25 cm).

In the presence of extremely dense populations of some species, such as sea urchins, photo-quadrats may be used to count individuals per quadrat and thus obtain a density per $m^2$.

Figure 8 : Example of numbering 17 oursins Stylocidaris affinis on a photo-quadrta of 45*45cm. d=83,3/$m^2$.

### 4.2.4. SUSPENSION FEEDERS

Suspension feeders community requires several data processing procedures in order to study population demography. Photo-quadrats are used to calculate individuals densities/$m^2$ and species. GP1 and GP2 videos are used to estimate the necrosis cover and measure sizes (height and width) of at least 30 colonies identified by species.

Another, faster and simpler method will use GP1 videos to determine the presence or absence of necrosis (presence = necrose >10%) on 100 colonies[1] and their typology (colonised, non-colonized, or both).

Figure10 : Measurement (Hight and width) of a *Paramuricea clavata* colony in the Medes Islands (Spain).

1 Garrabou J., Bensoussan N., Di Franco A., Boada J., Cebrian E.,Santamaria J., Guala I., Grech D., Cerrano C., Pulido T., Jou M., Marambio M. & Azzurro E., 2022. Monitoring Climate-related responses in Mediterranean Marine Protected Areas and beyond: ELEVEN STANDARD PROTOCOLS.74 pp. Edited by: Institute of Marine Sciences, Spanish Research Council ICM-CSIC, Passeig Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

## 4.3. DATA COMPARISON

### 4.3.1. COMPARATIVE STUDY

The objective of this section is to assess the relevance of data collected using the STEED method in comparison to results obtained using a commonly used method that demonstrates scientific consensus: the UVC (Underwater Visual Census).

The results obtained for the benthic community will not be compared because the method used by the STEED is identical to the commonly used method of photo-quadrats. However, we will examine the portion of photo-quadrat that can be used out of the total amount of photo-quadrat taken along a transect.

Data collection sites for this study locations are :
- Callelongue : 43°12.599 - 05°21.104, (Marseille)
- Punta Palazzu : 42°23.040 - 08°32.652, (Corsica)
- Macinaggio : 42°56.870 - 09°31.268, (Corsica)
- Medes Islands : Tasco Gros = 42°02.520 - 03°13.611, 0607 et Pota del Llop = 42°02.883 - 03°13.561, (Spain)

The following map shows the data from biotic communities used in the comparative study:
- Ichtyofauna : Callelongue and Tasco Gros
- Invertebrates : Callelongue and Punta Palazzu
- Animal Forests : Tasco Gros, Pota del Llop(18 et 30m) and Macinaggio

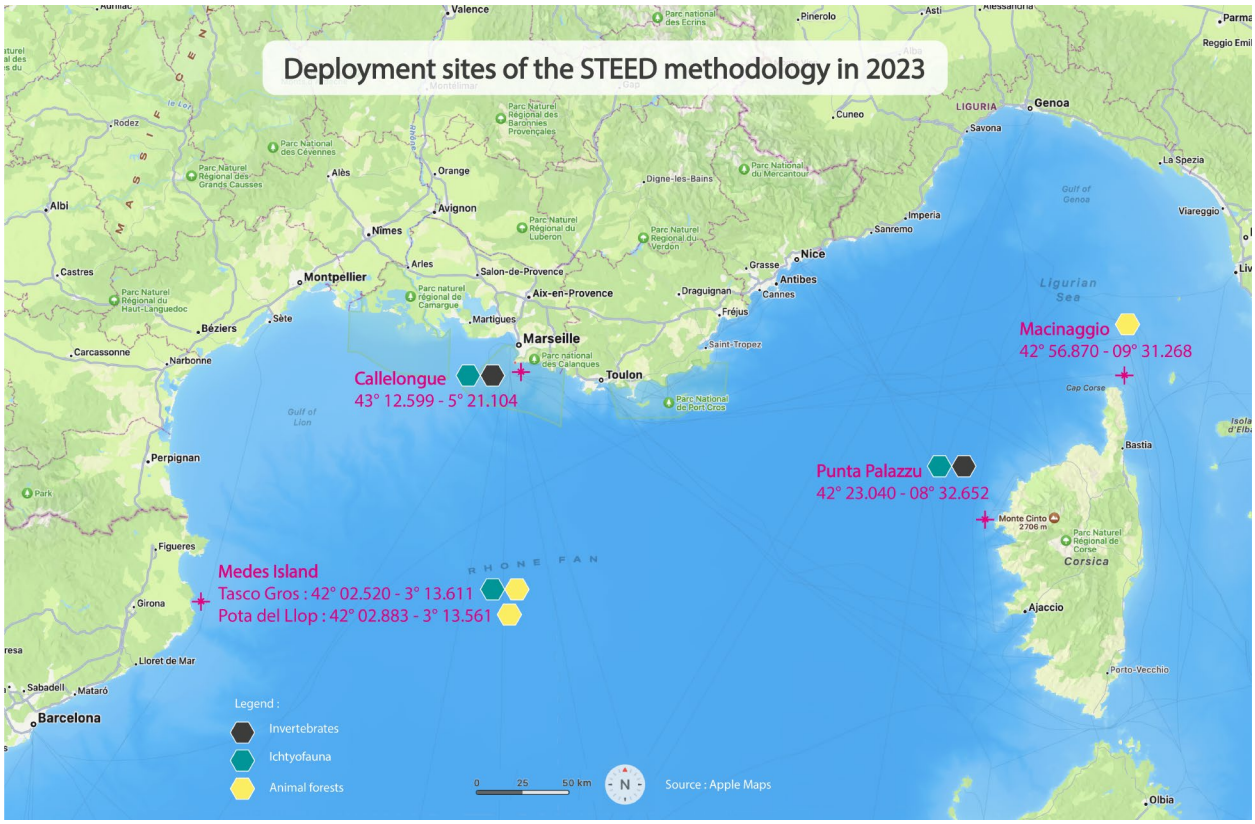



Figure11 : Map of data collection sites in 2023 using the STEED methodology. The community data used for the comparative study are detailed by site.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

### 4.3.2. UVC METHODOLOGY

**Ichtyofauna :** Each individual is named and identified by the diver. Individual sizes are not taken into account. The transects are 50 metres long, 5 metres wide, and 5 metres high. The transects are established at a constant depth, and three transects are collected for each location. The transect is traversed by a single passage. The size measurements are not included in this comparative study because the calibration has already been verified[1]. The species *Anthias anthias* and *Chromis chromis* are excluded from the study.

**Invertebrates :** For this study, we consider the echinoderms (holothuria, sea stars, sea urchins) and the decapods (lobster, slipper lobster, etc.). These groups are indentified by species along a 50m long and 1m wide transect[2]. The transects are established at a constant depth, and three transects are installed for each location. Data collection is done on a single passage.

**Suspension feeders :** In this case, we focus on gorgonians populations. We use two methods.

A method for population demography monitoring that consists of 30 quadrats (50*50cm) in which gorgonians are identified by species, percentage of necrosis, and necrosis type based on their distribution (localised or spreaded) and stage (new or old). And a $2m^2$ square in which gorgonians are identified by species and sizes (Hight and width)[3].

A method for mass mortality monitoring that involves determining the presence or absence of necrosis[4] (presencen = >10%) in 100 colonies as well as their typology (colonised, non-colonized, or both).

The data collected using the STEED methodology were collected on the same transects as the data collected with UVC.

In Callelongue (43°12.599 - 05°21.104), data have been acquire along transects in the following order :

- 1st pass-> UVC for Ichtyofauna
- 2nd pass -> UVC for Invertebrates + UVC for Animal forests (2nd diver)
- A minimum of 15 minutes without the presence of a diver in transect zones has been respected
- 3rd pass -> STEED data collection

In Punta Palazzu (42°23.040 - 08°32.652), Macinaggio (42°56.870 - 09°31.268) and Medes islands (Tasco Gros = 42°02.520 - 03°13.611, 0607 and Pota del Llop = 42°02.883 - 03°13.561) data have been acquire along transects in the following order :

- 1st pass -> UVC for Ichtyofauna + STEED data collection (same diver)
- 2nd pass -> UVC for Invertebrates + UVC for Animal forests (2nd diver)

The UVC data from the Macinaggio location were obtained by the Andromède Océanologie team during the RECOR networks survey. The data for Tasco Gros and Pota del Llop were collected by the Unisersitat de Barcelona and the Institute of Marine Sciences, Spanish Research Council ICM-CSIC, as part of the Monitoring Climate-related Responses in Mediterranean Marine Protected Areas and Beyond[5] project.

1 Tessier A., Pastor J., Francour P., Saragoni G., Crec'hriou R., Lenfant P., 2013. Video transects as a complement to underwater visual census to study reserve effect on fish assemblages. AQUATIC BIOLOGY. Vol. 18: 229–24. doi: 10.3354/ab00506.

2 Charles, K.E., Packham, J. Bureau, D., Lessard, J. 2022. A comparison of underwater photo, video and visual survey methods to assess nearshore algae and invertebrate communities. Can. Tech. Rep. Fish. Aquat. Sci. 3446: vii + 37 p.

3 ANDROMEDE OCEANOLOGIE, 2019. Evaluation de l'état écologique du coralligène et pose de thermomètres (Lot2) – Est de la région Provence-Alpes- Côte d'Azur, Analyse des données 2019. Contrat Andromède Océanologie / Agence de l'eau. 386p.

4 Garrabou J., Bensoussan N., Di Franco A., Boada J., Cebrian E.,Santamaria J., Guala I., Grech D., Cerrano C., Pulido T., Jou M., Marambio M. & Azzurro E., 2022. Monitoring Climate-related responses in Mediterranean Marine Protected Areas and beyond: ELEVEN STANDARD PROTOCOLS.74 pp. Edited by: Institute of Marine Sciences, Spanish Research Council ICM-CSIC, Passeig Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain.

5 Garrabou J., Bensoussan N., Di Franco A., Boada J., Cebrian E.,Santamaria J., Guala I., Grech D., Cerrano C., Pulido T., Jou M., Marambio M. & Azzurro E., 2022. Monitoring Climate-related responses in Mediterranean Marine Protected Areas and beyond: ELEVEN STANDARD PROTOCOLS.74 pp. Edited by: Institute of Marine Sciences, Spanish Research Council ICM-CSIC, Passeig Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

# 4.4. RESULTS

## 4.4.1. BENTHOS

The cropping and exportation of photo-quadrats yields favourable results. 76% of photo-quadrats are usable.

On average, 70 photos are acquired for a 50m long transect, yielding around 50 quadrats measuring 45cm*45cm.

## 4.4.2. ICHTYOFAUNA

### 4.4.2.1. Callelongue Site

The number of species observed is slightly higher in UVC (15 versus 12) on Callelongue's transects.

The abondances are higher with the STEED method (notice the high abondance of *Coris Julis*).

The species *Spicara smaris* is also well represented.

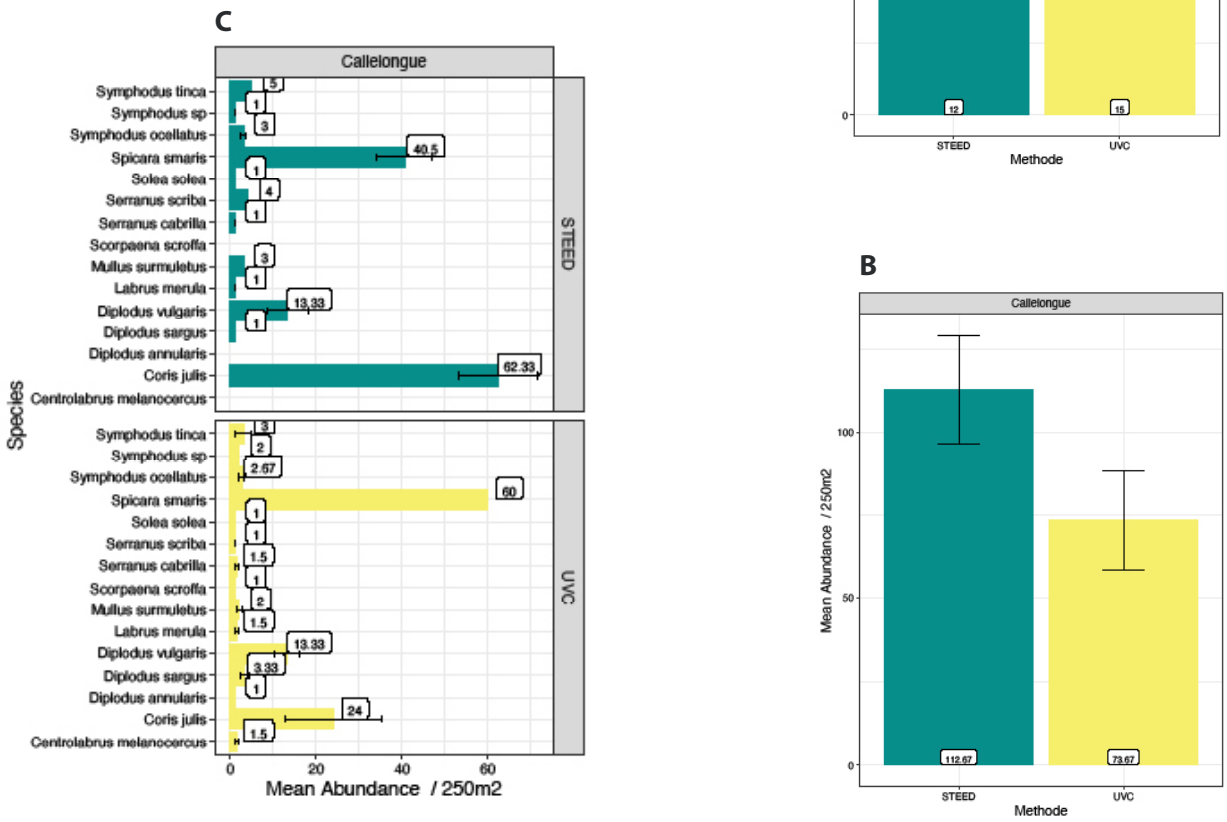



Figure12 : A : Specific ichtyofauna richness by site and method, B: Average ichtyofauna abundance per site and method, C: Average ichtyofauna abundance per species per site and method.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

#### 4.4.2.2. Punta Palazzu and Tasco Gros Sites

The number of species observed on the Punta Palazzu site is the same for both methods (4). On the Tasco Gros location, 11 species are observed using the STEED method, compared to 9 using the UVC method.

Mean abundances are comparable between the two methods on both sites.

The abundances of *Coris Julis* are greater when using the STEED method.

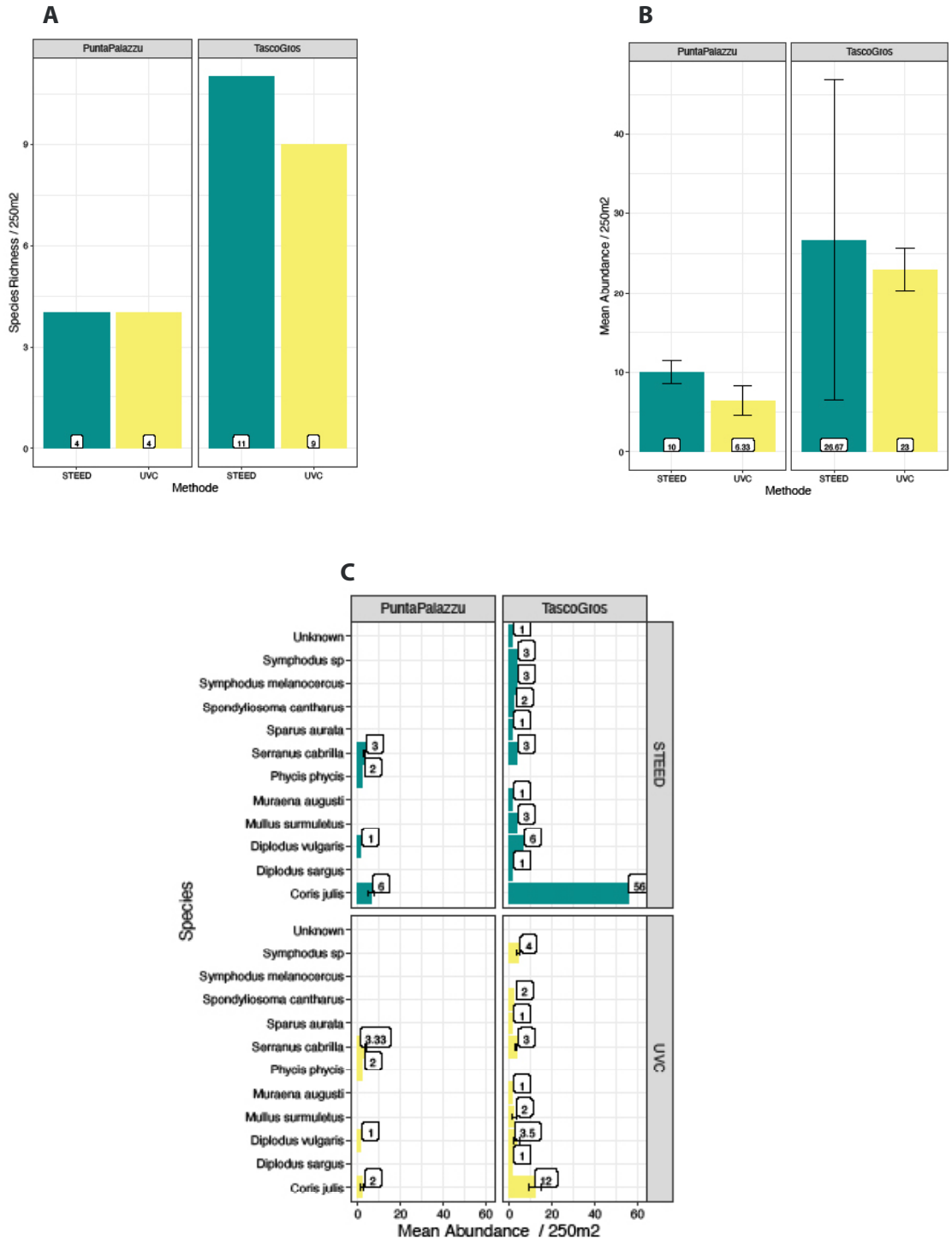



Figure13 : A : Specific ichtyofauna richness by site and method, B: Average ichtyofauna abundance per site and method, C: Average ichtyofauna abundance per species per site and method.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

### 4.4.3. INVERTEBRATES

Scores are similar for the two places visited (Callelongue and Punta Palazzu). Overall, the same number of species are observed for each method (3).

The abundances are dominated by holothurias on both sites. However, in the Callelongue site, the average abondances are higher with the STEED method (6) than with the UVC method (3,67).

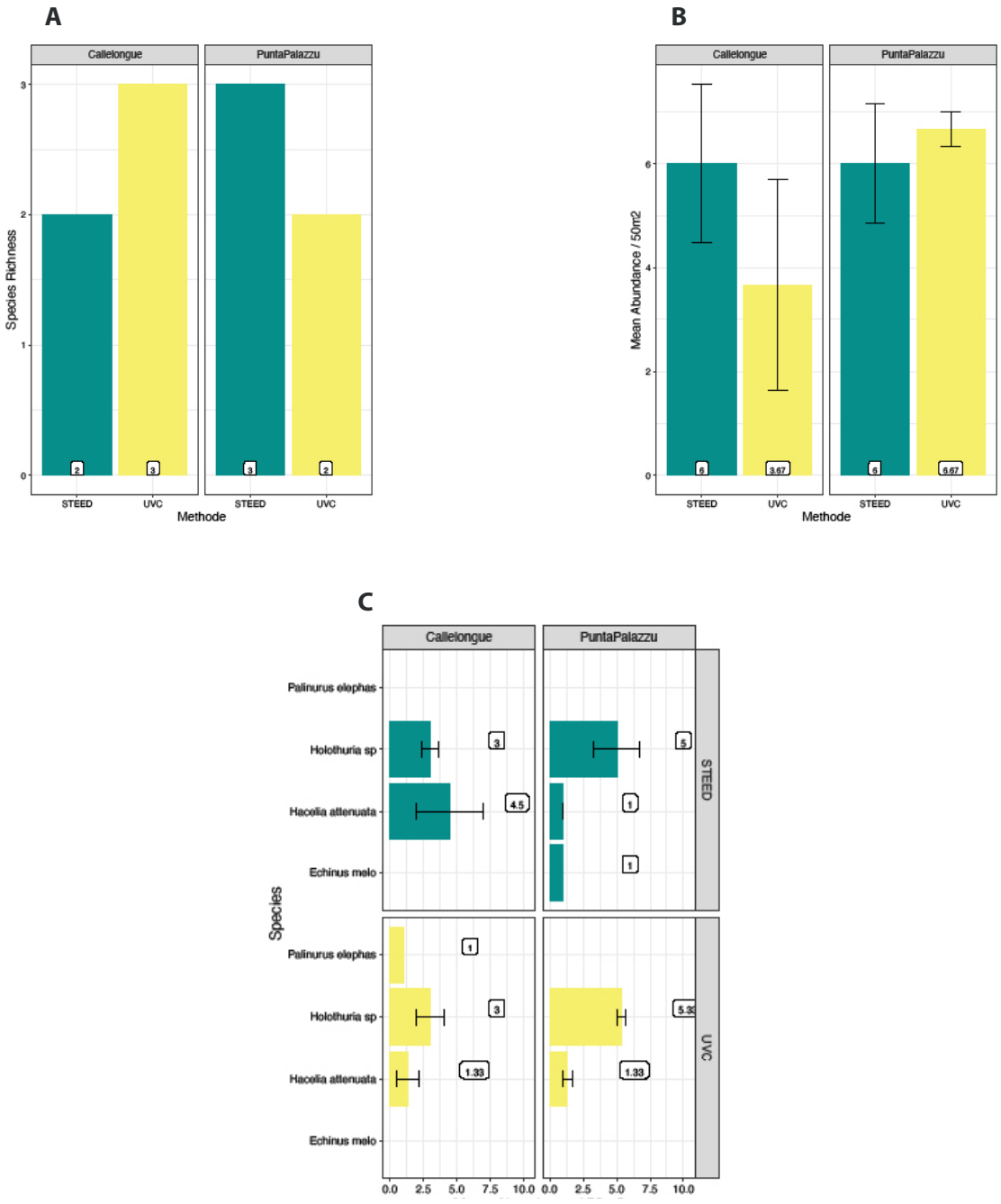



Figure14 : A : Specific ichtyofauna richness by site and method, B: Average ichtyofauna abundance per site and method, C: Average ichtyofauna abundance per species per site and method.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

### 4.4.4. SUSPENSION FEEDERS

The densities of gorgonians are similar with methods at Pota del Llop and Tasco Gros. However, densities on the Macinaggio site differ (1.11 using the STEED method and 7 using the UVC method).

The sizes of gorgonians colonies are comparable between methods across all sites.

The percentages of colonies affected by necrosis are similar between methods for the Macinaggio and Tasco Gros sites. For the Pota del Llop 18m site, the STEED method yielded a score of 46% while the UVC method yielded a score of 65%.

The percentages of necrosis cover per colonie vary between methods at Macinaggio site where the STEED method identifies a higher number of colonies with necrosis cover higher than 75%. The percentages differ on the Pota del Llop 18m site, where UVC methodology identifies a higher number of colonies with necrosis cover higher than 75%.

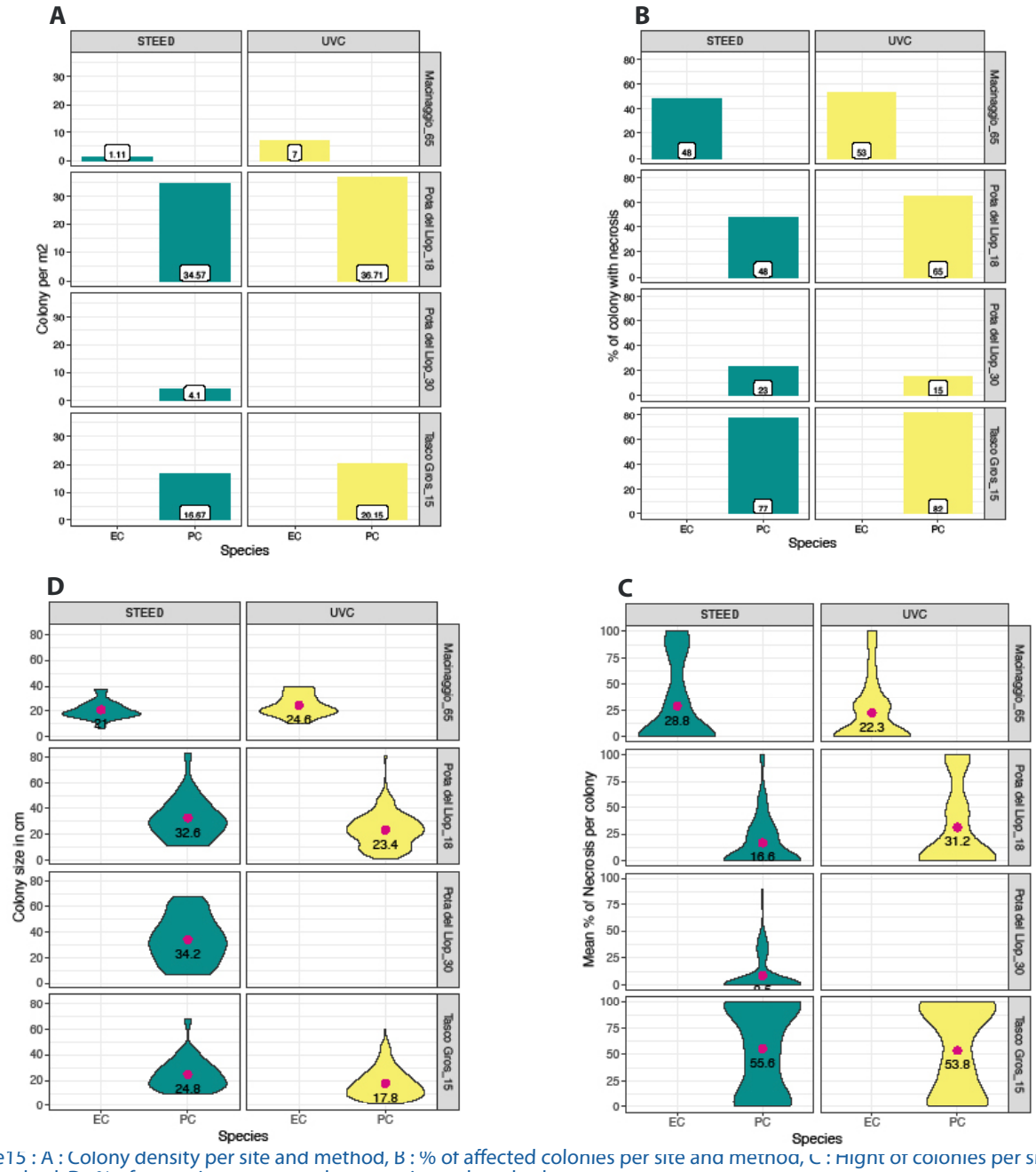



Figure15 : A : Colony density per site and method, B : % of affected colonies per site and method, C : Right of colonies per site and method, D : % of necrosis cover per colony per site and method.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

## 4.5. DISCUSSION AND ANALYSIS

This comparative study of the STEED method and the UVC method was carried out on 5 sites and 4 depth levels. Environmental conditions such as substrate orientation and turbidity varied depending on the location.

**- Benthos :** The percentage of photo quadrats that can be used is satisfactory (76%). There are around 150 photo-quadrats available for each site (3 transects of 50 quadrats). However, we can see that the definition of photographs varies depending on the distance between the lense of the camera and the substrate, influencing the level of identification of individuals and species. The entire set of quadrats allows for group identification, but a selection out of the 150 available quadrats (50 per transect) is required to identify the species.

- **Ichtyofauna :** The Callelongue site allows us to measure the effect of the STEED device (propeller, lights and size) on the ichtyofauna. The results show a greater number of species observed with UVC (15 versus 12), but lower abundances, particularly for the species *Coris julis* and *Spicara smaris*.

The Punta Palazzu and Tasco Gros sites allow for the analysis of the device's field of view because the UVC counts are acquired during the same passage as the STEED device. The number of species observed in this context is equal to or greater using the STEED method. The abundances are greater when using the STEED method.

As a result, we may conclude that the field of view and system settings are good enough for describing and quantifying the ichtyofauna community. However, we observe the STEED device to have a minor effect on the diversity and number of detectable individuals. This corresponds to the findings of other studies that show a better detection of specific diversity by UVC in complex ichtyofauna communities and comparable results when the assemblage is more limited. In other cases, these differences may also be attributed to difficulty identifying objects in videos due to image quality.

**- Invertebrates :** The results are comparable across methods. However, it appears that individuals and/or species of small size located in infractuosities and overhanging are more difficult to spot using the STEED method. In fact, a small langouste (20cm) was seen during UVC on a overhanging rock on Callelongue's transect number 3 but not seen with STEED. This is due to the camera's fixed with a 45° field of view and must be considered throughout analysis.

**- Supension feeders :** The results of population demography using the STEED method are consistent with the data collected in UVC for all indicators. On the Macinaggio site, there is a significant difference in density. This is explained by a methodological difference, as RECOR surveys are focused on a densely populated area of the site, allowing for the survey of a sufficient number of individuals in a restricted area. On the Pota del Llop_18m site, there is also a difference in the percentage of colonies affected by necrosis (48% for STEED and 65% for UVC). This is due to the colonies being 100% affected by necrosis and colonised by épiphytes, which are less detectable by the STEED method on densely populated site. On the other hand, on the Macinaggio site with low density, the colonies with high cover of necrosis are better represented by the STEED method.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

Based on the results, the STEED methodology appears to capture consistent and relevant data on targeted biotic communities. This is the result of a small study that used a limited number of replicas for each of the biotic communities.

The results of the STEED method must be analysed and discussed in light of the preceding elements and characteristics.

We may already draw the conclusion that, this approach saves time and money when it comes to obtaining biological data, with a few identified methodological biases. However, these biases can be reduced using to the large amount of data gathered and the large sampling strategy.

As a result, it is a good initial method to characterize ecosystems and their biological communities.

One advantage of this method is that it can quickly and uniformly gather large amounts of data. This could make it possible to compare the results on a temporal as well as a horizontal and vertical geographic plan. Depending on the needs and goals of the study being conducted, the data may also be the subject of various treatments and analysis once they have been archived.

The method also has the benefit of gathering a large number of pictures and graphics showing the condition of ecosystems at a single moment in time. This image collection may be used as visual memory and communication material.

Researching correlations between the obtained ecological data and external factors such as fishing pressure, coastal distance, nutrient rate, gradient of anthropogenic pressures, and others may also be made possible by the standardised data character.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

# 5. ANALYSIS STRATEGIES

## 5.1. ANALYSIS LEVEL AND OBJECTIVES

One advantage of the STEED method is the collection of data using images, which allows post-processing and analysis. In fact, the data collected is standardised and always contains the same level of information. However, treatment and analysis criteria might be adjusted based on the study's objectives and available human resources.

The indicators and levels of precision will differ depending on whether we want to describe ecosystems or assess their conservation status.

The table below provides indicators and various levels of precision based on the study's approach and methodology. The description of ecosystems approach refers to the characterization and improvement of knowledge of the ecosystems present on the site. The other approach seeks to determine the state of ecosystem protection and the presence of anthropogenic impacts.

Times referenced in the table does not include the time spent for calibrating the stereoscopy (45 minutes per site), cropping of photo-quadrats before processing (120 minutes per site), and analysing in R software (120 minutes per site).

| | | | | Biotic Communities | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Ichtyofauna | Benthos | Invertebrates | Suspension feeders | others | Total time |
| Analysis strategies | Ecosystem Description | Fast | Indicators | Species Abundance | Species Groups Habitat classification | Species Abundance | Species Density Fast Necrose | Abiotic factors (luminosity, temperature, current, etc.) | |
| | | | Labour Time | 60min/Site | 90min/Site | 45min/Site | 60min/Site | 30min/site | 4h45/Site |
| | | Detailed | Indicators | Species Abundance Biomass | Species Habitat classification | Species Abundance Biomass | Species Density Necrose, Canopy height | Abiotic factors (luminosity, temperature, current, etc.) | |
| | | | Labour Time | 120min/Site | 180min/Site | 60min/Site | 120min/Site | 30min/site | 8h30/Site |
| | Ecosystem Conservation Status | Fast | Indicators | Commercial Species Abundance | Necrosis rates Siltation | Grazers abundance Invasive species | Necrosis rate | Abundance of trashs | |
| | | | Labour Time | 60min/Site | 60min/Site | 45min/Site | 45min/Site | 45min/Site | 4h15/Site |
| | | Detailed | Indicators | Species Abundance Biomass Trophic level Invasive species | Rate and type of necrosis Siltation Habitat destruction Engineer species | Grazers abundance Bioturbation Invasive species | Rate and type of necrosis Specimen damage | Abundance and type of trashs | |
| | | | Labour Time | 120min/Site | 180min/Site | 60min/Site | 60min/Site | 75min/Site | 8h15/Site |

Figure16 : Table of proposed indicators and precision levels for data processing and analysis using the STEED method.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

## 5.2. NECESSARY RESOURCES

Considering sites deeper than 60m (maximum 150m) and subject to a single depth of survey (equivalent to 3 transects of 50m), the STEED method is estimated to cost 2400 € TTC against 5700 € TTC for UVC data collection. In terms of data processing, we believe that the STEED method requires three times the amount of human ressources for a cost of 600€ TTC per site, compared to 200€ TTC per site for the UVC.

The total cost (collection + treatment) is divided by two between the two methods (8220€ TTC for UVC vs 3600€ TTC for STEED).

It should be noted that the costs referred to in the table do not include the costs of analysis in the R software or the costs of writing because they are shared by the two methods. The costs of data processing using the STEED method were calculated using the "detailed description of ecosystems" analysis strategy (see Chapter 5.1.). For the calculations, we used a site with a single depth of survey (3 transects).

| **UVC Method** | | | |
|---|---|---|---|
| **Data collection** | **Unit Price HT** | **Unit** | **Total HT** |
| 2 divers ECCR | 1400 | 3 | 4200 |
| Boat + Pilot | 500 | 3 | 1500 |
| | | **Sout Total** | **5700** |
| **Data treatment** | **Unit Price HT** | **Unit** | **Total HT** |
| Labor time | 400 | 0,5 | 200 |
| | | **Sub Total** | **200** |
| | | **TVA** | 2320 |
| | | **Total TTC / Site** | **8220** |

| **STEED Method** | | | |
|---|---|---|---|
| **Data collection** | **Unit Price HT** | **Unit** | **Total HT** |
| 2 divers ECCR | 1400 | 1 | 1400 |
| STEED system rent | 500 | 1 | 500 |
| Boat + Pilot | 500 | 1 | 500 |
| | | **Sout Total** | **2400** |
| **Data treatment** | **Unit Price HT** | **Unit** | **Total HT** |
| Labor time | 400 | 1,5 | 600 |
| | | **Sub Total** | **600** |
| | | **TVA** | 600 |
| | | **Total TTC / Site** | **3600** |

Figure17 : Breakdown of the costs of data collection and processing based on the methods used.



SEASTEMS - thom.pavy@gmail.com - +33 7 72 07 38 07
14 Chemin des Roselières 26100 Romans sur Isère, France - Siret : 834 481 889 00022

agence de l'eau RHÔNE MÉDITERRANÉE CORSE
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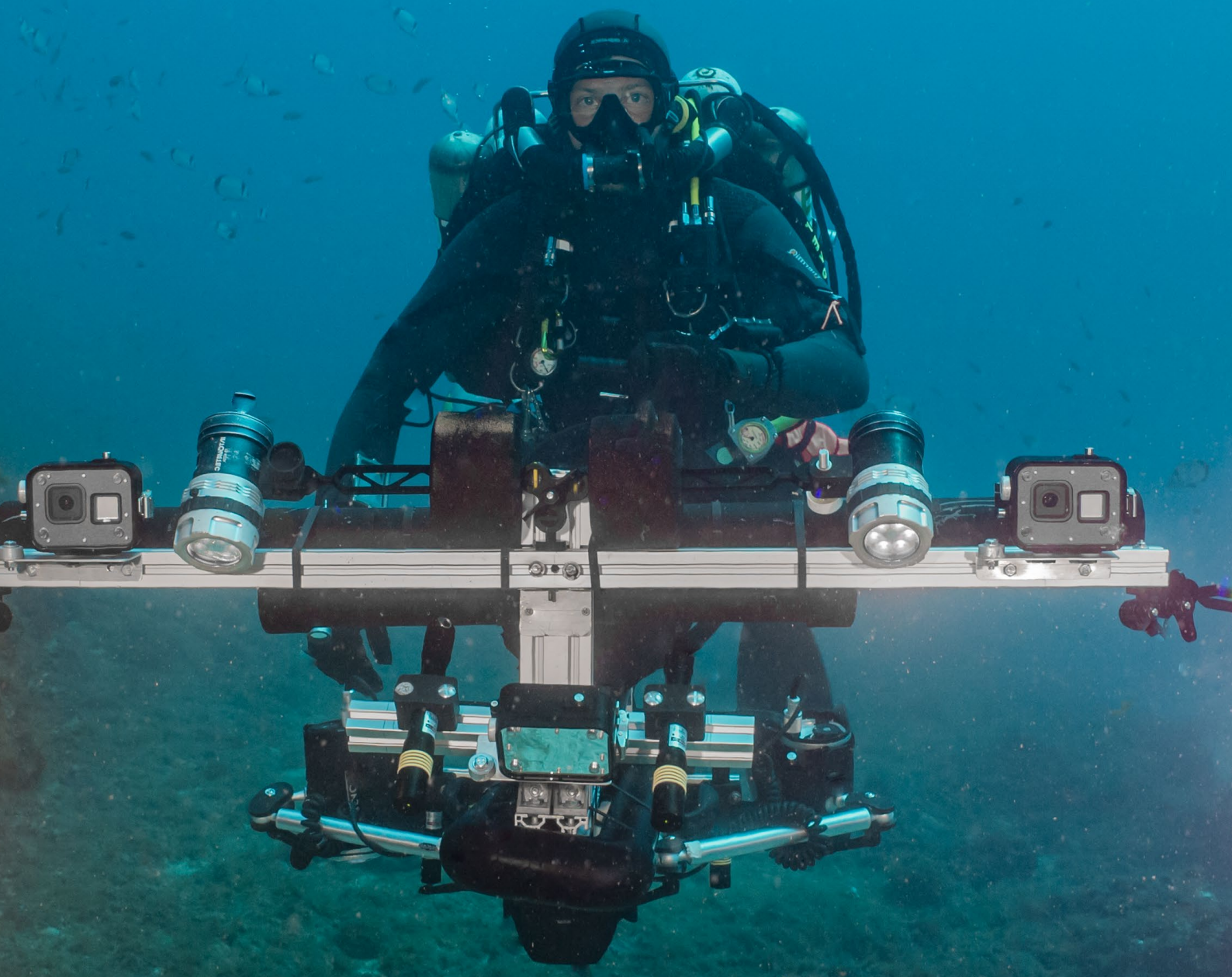
# Steed



**Seastems**
Siret : 834 481 889 000 22
Thomas Pavy
thom.pavy@gmail.com
+33(0)7 72 07 38 07