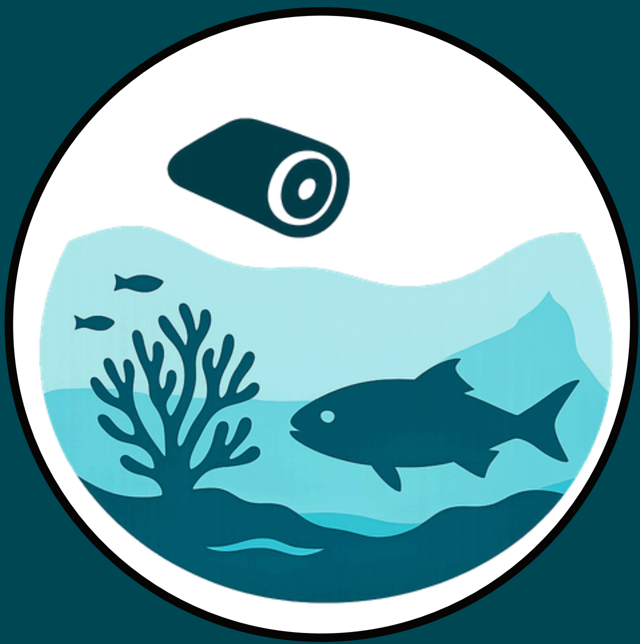
Marine Imaging Workshop 2026



Advancing Global Ocean Observation

May 19–21, 2026
Gibraltar

SubC Imaging | University of Gibraltar | Union Biometrica | Schmidt Ocean Institute

Programme Contents

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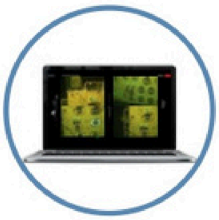
SubC Imaging is renowned for pioneering advanced underwater optical imaging systems. With a commitment to modular, scalable, and adaptable technology, we integrate state-of-the-art solutions for precise and efficient inspections and surveys in challenging environments.

Key Technologies

Cameras:
High-resolution imaging for detailed underwater inspection and surveys.

DVR Software:
Advanced recording, logging, and playback capabilities for comprehensive data management.

Lights & Lasers:
Precision light and laser devices to give image scale and measurements.



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Integrated systems for efficient remote inspections.

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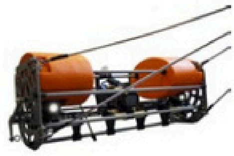

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OCEAN OBSERVATORIES INITIATIVE

Timelapse Systems for Seafloor Surveillance

The NSF-funded Ocean Observatories Initiative uses SubC's Rayfin cameras for Autonomous Timelapse to study methane seeps in deep-sea environments. This advanced system enables long-term monitoring with high-resolution imaging and a full API for customization.

UNIVERSITY OF BERGEN

Advanced DVR Workflows for Deep-Sea ROV Operations

The University of Bergen uses SubC Imaging's DVR+ on the Ægir 6000 ROV to support deep-sea research missions. With high-resolution recording, automated still capture, and multi-camera viewing, the system helps improve onboard workflows and deliver detailed visual data for analysis.

wood.

High-Resolution Subsea Asset Inspection

Wood adopted SubC Imaging's Rayfin camera with Rapid Digital Imaging (RDI) to overcome the time-consuming and costly nature of conventional ROV visual inspections. This new system allows for faster inspections by capturing thousands of high-resolution still images, providing higher-quality data and improving overall operational efficiency.

THE UNIVERSITY OF WESTERN AUSTRALIA

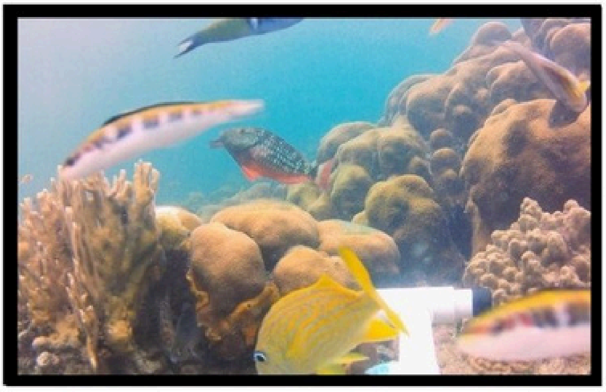
Autonomous Imaging Platforms for Persistent Observation

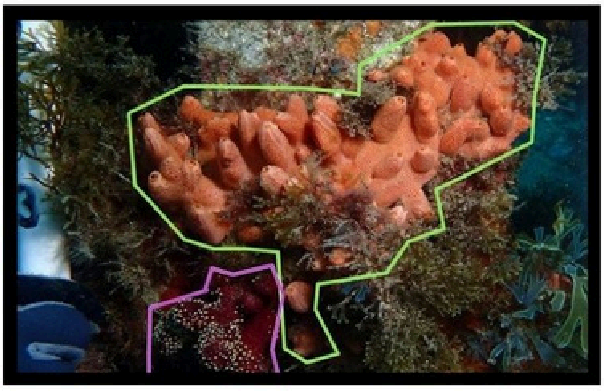
The University of Western Australia deployed two custom-built, long-term observatories equipped with SubC Imaging's Autonomous Timelapse System to explore and monitor Australia's deepest Marine Parks. This 18-month project enables continuous, autonomous data collection, enhancing the scientific understanding of deep-sea biodiversity and ecosystem connectivity.

Scientia est Clavis ad Successum

UNIVERSITY OF
GIBRALTAR

School of Marine and Environmental Sciences
Proud sponsors of the Marine Imaging Workshop 2026





The School of Marine and Environmental Sciences is proud to partner with the Marine Imaging Workshop 2026. For more information about our courses, please see https://www.unigib.edu.gi/school-of-marine-sciences/

Welcome

Welcome to the 6th Marine Imaging Workshop (MIW) 2026!

We are delighted to welcome you to Gibraltar for the Marine Imaging Workshop! Situated at the meeting point of the Atlantic Ocean and the Mediterranean Sea, Gibraltar provides a truly unique setting for an international conference dedicated to marine science, imaging, and technological innovation.

MIW 2026 brings together scientists, engineers, industry professionals, and students from across the globe to share knowledge, present cutting-edge research, and foster collaboration in the rapidly evolving field of marine imaging.

MIW continues to thrive thanks to the support of its sponsors, partners, organisers, and volunteers. We extend our sincere thanks to all those who have contributed their time, expertise, and resources to make this workshop possible. We are also grateful to the scientific committee and organising teams whose dedication has shaped an engaging and high-quality programme.

As international conferences carry both financial and environmental responsibilities, we have sought to make mindful choices in the planning of this event, including encouraging walkable venues, reducing unnecessary waste, and providing digital materials wherever possible. We thank you for supporting these efforts and welcome feedback on how future workshops can continue to improve.

Beyond the conference programme, we hope you will enjoy everything Gibraltar has to offer — from its rich maritime heritage and unique biodiversity to its culture, hospitality, and spectacular scenery.

We wish you a productive, inspiring, and enjoyable Marine Imaging Workshop 2026.

Your MIW 2026 Local Organising Committee

Jaime Davies, Awantha Dissanayake, Kerry Howell, Henry Attard, Elaine Benzecry

Venue

The Marine Imaging Workshop (MIW) 2026 will take place at the Sunborn Gibraltar, located in Ocean Village Marina close to Gibraltar's city centre. The venue provides a convenient and self-contained setting for the conference, with meeting rooms and event spaces suited to talks, posters, and workshops.

Its waterfront location offers views across the marina and towards the Rock of Gibraltar, creating a relaxed environment for both formal sessions and informal discussions. With accommodation, conference facilities, and social spaces all in one place, the venue supports an accessible and focused programme for delegates.

For the duration of the conference (19–21 May), the Sunborn is also offering delegates an additional 15% discount on food and drink when presenting their conference ID badge at the Barbary Restaurant, Gastro Bar, Sapphire Bar, and Aqua Bar. Breakfast and breaks will take place in the Borealis Room with lunches in the Barbary Restaurant on the 7th floor.

Part of the conference programme will also take place at the University of Gibraltar, located at Europa Point on the southern tip of the peninsula. This modern academic setting will host selected sessions and activities, offering delegates the opportunity to engage with the local research community in a dedicated university environment.

Useful Information

Emergency Services

- Emergency number (police, fire, ambulance): 999
- Police (non-emergency): +350 200 72500
- Ambulance (non-emergency): +350 200 72266

Healthcare

- St Bernard's Hospital – Gibraltar's main hospital with Accident & Emergency services
- Primary Care Centre (PCC) – Located near Casemates Square, suitable for minor injuries and general medical care

Pharmacies

Pharmacies are widely available in the town centre. Crown Pharmacy is open until 9pm - telephone +350 200 78598

Taxis

- Gibraltar taxis are reliable and use meters
- Taxi bookings: +350 200 70001 / +350 200 70002
- Taxi ranks can be found at:
    - Gibraltar Airport
    - Casemates Square
    - Main Street
    - Ocean Village Marina

Taxis from Malaga Airport

If needed, there are Gibraltar taxi's that can collect from Malaga airport and drop off at locations within Gibraltar. The cost is £120 (one way) for up to 4 people. Contact Solomon Edery (Gib Tansport) +350 54 002 886



Useful Information

Travel by Bus: Málaga Airport to La Línea (for Gibraltar)

Regular long-distance bus services operate between Málaga Airport and La Línea de la Concepción, the Spanish town directly bordering Gibraltar.

Bus Operator & Booking
The main operator on this route is Avanza Bus, which runs direct services from the airport.

You can view timetables and book tickets online here:

https://www.omio.com/buses/la-linea-de-la-concepcion/malaga-airport-ysazq

Journey Details

- Departure point: Málaga Airport (Terminal 3, just outside Arrivals)
- Arrival point: La Línea Bus Station
- Journey time: approx. 2 hours
- Frequency: Typically 2–5 services daily depending on season
- Indicative fare: approx. €14–€20

Most services run direct, with stops along the Costa del Sol (e.g. Marbella, Estepona).
Arrival & Onward Travel to Gibraltar

Buses arrive at La Línea Bus Station, located just a short distance from the Gibraltar border.The bus station is approximately 5 minutes’ walk from the border crossing. From here, passengers must cross the border on foot into Gibraltar. The walk is straightforward and signposted; you will pass through passport control before entering Gibraltar.

Useful Information

Travel Requirements: Visas, Transit & Entry Permissions

Attendees travelling to Gibraltar may enter via Spain or via the United Kingdom, and requirements differ depending on your route and nationality.

1. Entry via Spain (Schengen Area)

Spain is part of the Schengen Area.

- Visa-required nationals must obtain a Schengen visa before travel
- Visa-exempt nationals may enter for up to 90 days in any 180-day period

After arriving in Spain (e.g. Málaga Airport), you will travel to La Línea de la Concepción and:

- Cross the border on foot into Gibraltar
- Pass through passport control at the frontier

Important: Some nationalities may also require a separate visa for Gibraltar/UK entry

2. Entry via the United Kingdom (Including Transit)

If your journey involves flying via the UK (e.g. London) before continuing to Gibraltar, you must check UK immigration or transit requirements.

a) Transiting Through the UK

Depending on your nationality, you may need:

- A UK Transit Visa, or
- Permission under the UK Electronic Travel Authorisation (ETA)

This applies even if you:

- Do not leave the airport, or
- Are only in the UK for a short connection

Useful Information

2. Entry via the United Kingdom (Including Transit) continued.
If your journey involves flying via the UK (e.g. London) before continuing to Gibraltar, you must check UK immigration or transit requirements.

b) Entering the UK (Short Stay)

If you pass through UK border control (e.g. changing airports or staying overnight):

- **You may need a UK Visitor Visa, or**
- **An approved ETA (for eligible visa-exempt nationalities)**

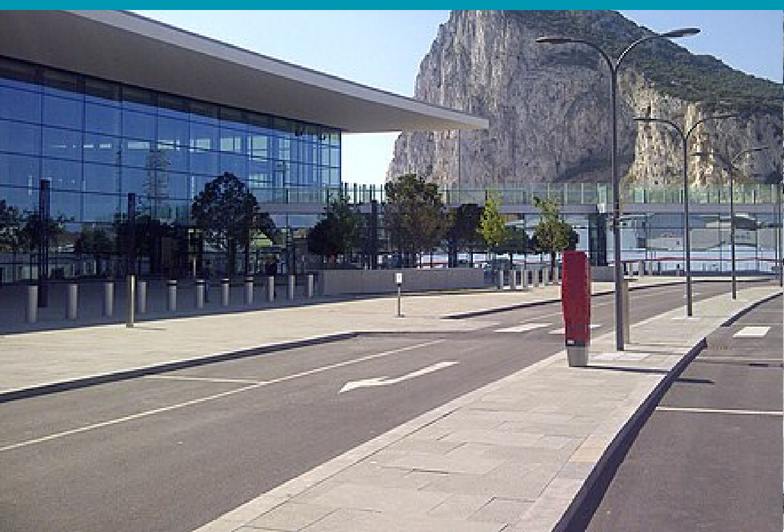
You can c**heck requirements at https://www.gov.uk/check-uk-visa**

3. Entry to Gibraltar

Gibraltar is a British Overseas Territory with its own immigration rules, aligned in many cases with UK policy.

- **Travellers must meet Gibraltar entry requirements**
- **Entry is either:**
  - **Via the land border from Spain, or**
  - **Via direct flights from the UK**

Official information is available at https://www.gibraltar.gov.gi



Useful Information

Border Crossing (to Spain)

The land border with La Línea de la Concepción is within walking distance of Gibraltar airport. Crossing on foot is often quickest. Please carry your passport, and allow extra time during busy periods.

Currency & Payments

- **Gibraltar uses the Gibraltar Pound (£), which is on par with UK Sterling**
- **UK pounds are widely accepted; Gibraltar notes are generally not accepted in the UK**
- **Credit/debit cards are accepted in most places**

Electricity

- **240V supply with UK-style Type G plugs**

Language

- **English is the official language; Spanish is also widely spoken**

Getting Around

- **Gibraltar is compact and easily explored on foot**
- **Local buses connect key areas, including the frontier, town centre, and marinas**

Buses

Bus route 2 runs every 15 minutes from Market Place directly to the University of Gibraltar. See https://www.gibraltarbuscompany.gi/ for routes and timings. You will be given free access to all Gibraltar Bus Comapny buses by showing your lanyard to the driver.

Useful Information

Gibraltar offers a good range of dining options close to the conference venue, particularly around the marina and along Main Street. Visitors will find a mix of casual cafés, international restaurants, and local spots, with seafood featuring prominently. These areas are well suited for both quick meals and relaxed evenings with colleagues.

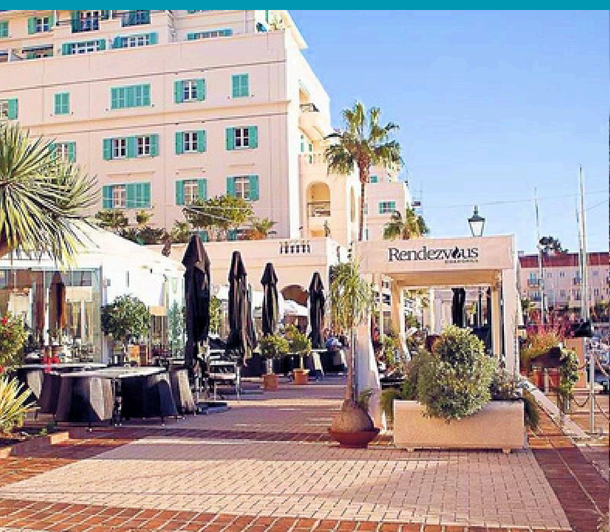
We recommend:

Aquaterra based in Casemates
https://aquaterragourmet.com

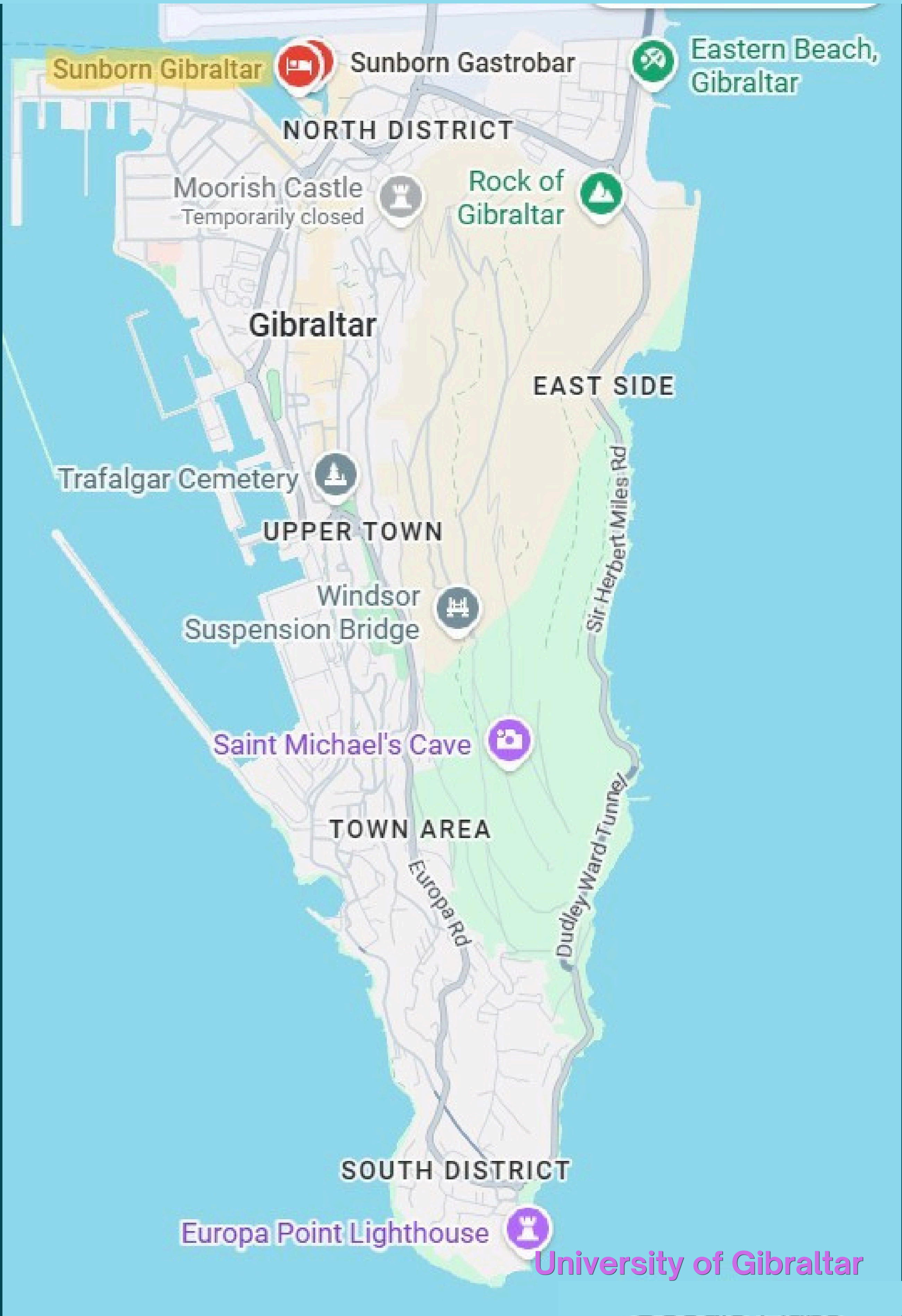
Little Bay Bar and Indian Restaurant in Ocean Village
https://littlebay.gi/

Rendezvous Chargrill in Queensway Quay
https://rendezvousgib.com/

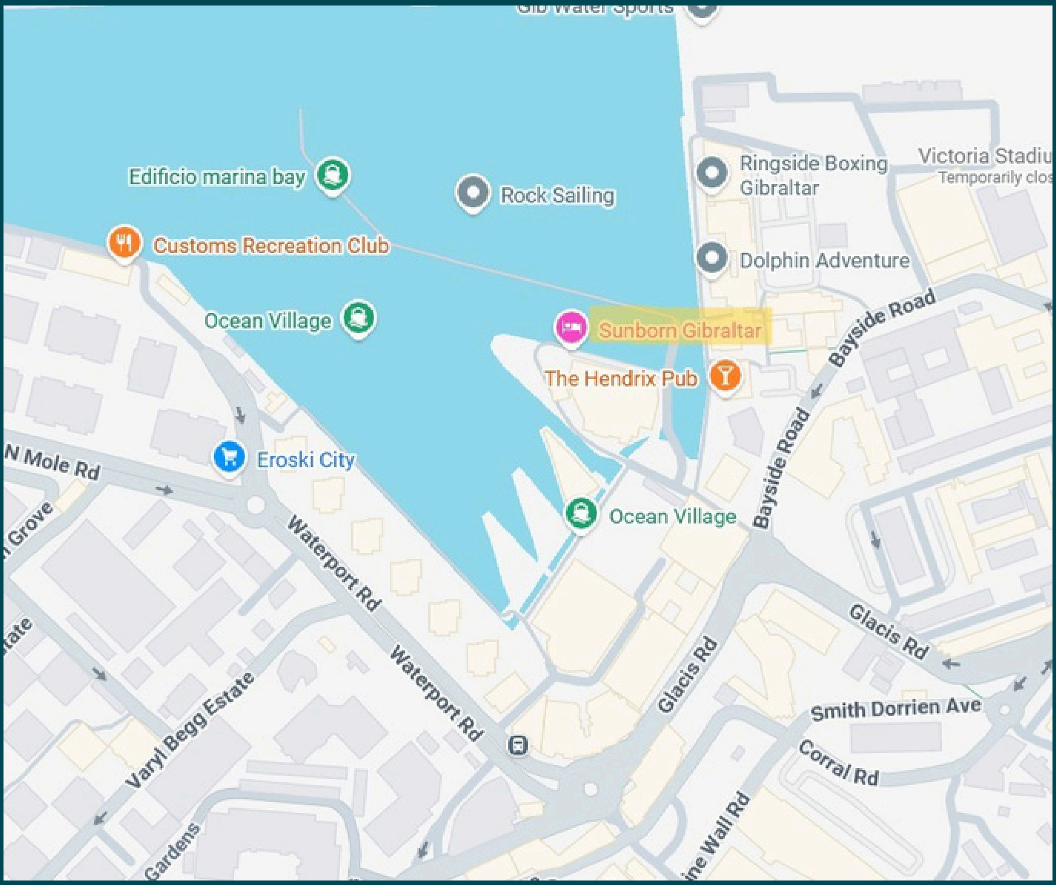
Jury’s Cafe and Wine Bar on Main Street
https://www.jurysgibraltar.com/

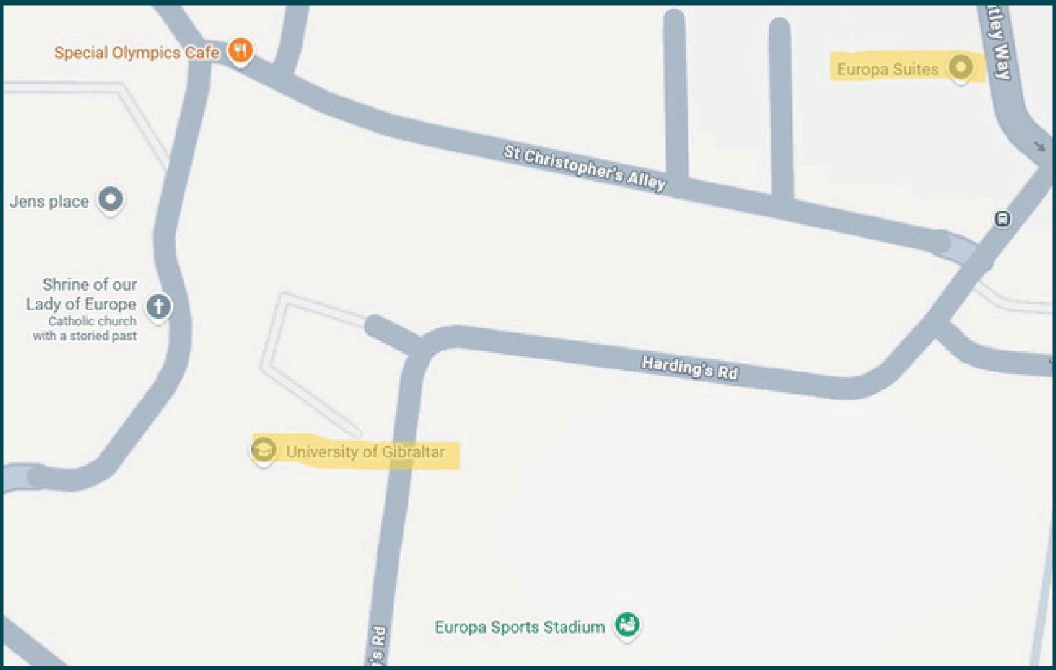


Conference Site Maps



Conference Site Maps





Conference Outline - Monday

Marine Imaging Workshop 2026

Start time	Finish time	Details
1630		Pickup from Sunborn
1700	1900	Icebreaker: University of Gibraltar
1915		Transport leaves Europa Point

Conference Outline - Tuesday

0830	0930	*Registration & coffee (light breakfast)*	
0930	0945	*MW2026 - Opening*	
Session 1: Image capture & processing for marine research (Chair: Katharine Bigham)			
0945	1000	Mojtaba Masoudi	Best practices for image processing in marine biodiversity workflows
1000	1015	Fanny Girard	Hidden in Plain Sight: Unlocking the potential of publicly available video data to increase our knowledge of biodiversity in the deep sea
1015	1030	Daphne Cuvelier	Detect the undetected: First observations of fluorescence in the hydrothermal vent organisms of the Mid-Atlantic Ridge and its potential for automated image analysis
1030	1045	Emma Poliakova	Automated pre-processing of large underwater ROV datasets for 3D photogrammetry
1045	1100	Joost Daniels	Adaptive sampling of midwater animals using long range autonomous underwater vehicles with a multi-camera imaging payload
1100	1130	*Coffee break*	
Session 1: Image capture & processing for marine research (Chair: Katharine Bigham)			
1130	1145	*Michele Grimaldi*	From Surface to Depth: A Benchmark and Cross-Domain Approach to Recover 3D Reconstructions
1145	1200	*Tobias Ferreira*	Paidiverpy: A Python framework for reproducible image processing pipelines, aimed at generating analysis-ready image datasets
1200	1215	*Dhugal Lindsay*	Imaging approaches for construction of digital holotypes: matching tools to taxon
Session 2: Data-driven ocean science: artificial intelligence in marine science (Chair: Chloe Game and Tim Nattkemper)			
1215	1230	*Laura Weihl*	Uncovering Anomalous Events for Marine Environmental Monitoring via Visual Anomaly Detection
1230	1245	Davide Brembilla	Unlocking Legacy Marine Image Annotations to improve AI Models for Benthic Fauna Classification
1245	1300	Rylan Command	Optimizing an image annotation workflow using AI: practical guidance for applying pre-trained object detection models to seafloor imagery data

1300	1400	Lunch	
1400	1415	Ada Carter	Long-Term Ecological Patterns from Automated Species Detection at the Mothra Hydrothermal Field, NE Pacific
1415	1430	David Price	Assessing exploited intertidal fishery resources across complex coastal terrain using 3D photogrammetry
1430	1445	Joseph Marlow	3D photogrammetry and deep-learning deliver accurate estimates of epibenthic biomass
1445	1500	Enrique Montes	Assessing seasonal variability in the biogeography of planktonic communities in south Florida, USA, by merging in vivo plankton imaging observations with dynamic satellite seascapes
1500	1530	*Coffee break*	
1530	1545	Alejandra Mejía-Saenz	From GoPro videos to automated seafloor megafauna identification: An end-to-end pipeline and lessons learned
1545	1600	Meike Nienaber	Increasing Robustness for Underwater Image Matching via Rotation Invariance
1600	1615	Kevin Barnard	Scaling Marine Image Annotations with AI-enabled, Human-In-the-Loop Pipelines
1615	17:30	Lightning talks: posters	

Conference Outline - Wednesday

0830	0930	*Registration & coffee/light breakfast)*	
Session 2: Data-driven ocean science: artificial intelligence in marine science (Chair: Chloe Game and Tim Nattkemper)			
0930	0945	Gaby Kourie	Human-and-AI-in-the-Loop Marine Image Annotation in in the BIIGLE online tool
0945	1000	*David Moffat*	Transferring a YOLOv8 Benthic Species Detection Model to New Sites
1000	1015	*Antonio Al Makdissi*	State of the art of Vision-Language Models and Multimodal Integration for Advanced Semantic Interpretation in Marine Imaging
1015	1030	*Patricia Schöntag*	A Constellation Matching Approach to Increase Robustness of Underwater Image Matching
1030	1045	*Chloe Game*	Enhancing automated image analysis of vulnerable seabed communities with environmental context conditioning
1045	1100	*Lightning talks: workshops*	
1100	1130	*Coffee break*	
1130	1300	*Workshop session 1*	- Ariell Friedman: Hands-on with Squidle+ - Evangelos Alevizos: De-noising shallow-water drone imagery - Kerry Howell: Revisiting the SMarTaR-ID initiative
1300	1400	Lunch	
1400	1530	*Workshop session 2*	- Kevin Barnard: Interactive visual search and segmentation with FathomNet - Megan Cromwell: Feedback Forum: Oceanographic Imagery and AI Application Recommendations - Katharine Bigham: Two years on educational design
1530	1600	*Coffee break*	
1600	1700	*Lightening talks: posters*	
1715	1915	Poster session	

Conference Outline - Thursday

0830	0915	*Registration & coffee/light breakfast)*	
Session 3: Ocean data management (Chair: Awantha Dissanayake)			
0915	0930	Corinne Bassin	From Seafloor to Science: An End-to-End Imaging and Annotation Pipeline for ROV SuBastian
0930	0945	Munsif Ali	AI4DeepSea: Development of Artificial Intelligence for the study of communities in deep marine environments
0945	1000	Ariell Friedman	Squidle+ updates: New and Improved Workflows, Real-Time Field Analysis, Multi-Media Annotation and AI Collaboration
1000	1015	Carolina Ventura-Costa	FAIR & Open Marine imaging data workflow: from deep-sea exploration planning to data reuse
1015	1030	Jonny Savage	A Federated Image Brokerage Service for Scalable Biodiversity Analysis from Marine Imagery
1030	1100	*Coffee break*	
Session 4: Advancing biology through imaging: marine applications (Chair: Kerry Howell and Ana Hilário)			
1100	1115	Christine Morrow	An introduction to the Marine Biodiversity Data Portal – NI
1115	1130	Alexa Parimbelli	Multi-locus species delimitation as a tool to inform image-based identification of deep-sea Antipatharia
1130	1145	Knut Mehler	Integrating Optical and Acoustic Imaging to Improve Benthic Habitat Mapping in the Wadden Sea
1145	1200	Awantha Dissanayake	Observation Per Unit Effort (OPUE): Standardising MaxN-Based Relative Abundance in Remote Underwater Video Surveys
1200	1215	Rob Harbour	Integrating eDNA Metaprobes with Camera Sled Seafloor Imagery in U.K. Offshore MPA Monitoring: A Pilot Study
1215	1230	Melanie Stott	Integrating video analysis and eDNA data to improve taxonomic identification and biodiversity assessments
1230	1245	Catherine Borremans	Making visible the invisible: using quantitative imaging and semi-automatic annotation for the identification of microscopic infauna
1245	1345	Lunch	

Conference Outline - Thursday

Session 4: Advancing biology through imaging: marine applications (Chair: Kerry Howell and Ana Hilário)			
1345	1400	Jaime Davies	Assessing the impacts of litter on deep-sea ecosystem for conservation
1400	1415	Charlene Erasito	Exploring Hidden Worlds: Multiscale Characterisation of Benthic Biodiversity and Mesopelagic Community Abundance on Stylaster Seamount in the Natural Park of the Coral Sea, New Caledonia
1415	1430	Tom Morgan	Beyond Accuracy: Enhancing Seafloor Mapping through Multimodal Fusion and uncertainty aware machine learning
1430	1445	Marc Allentoft-Larsen	ML-Assisted Analysis of Extended-Duration Imaging Using Long-Range AUV: Application to Siphonophore Diel Vertical Migration
1445	1500	Whitney Goodell	Illuminating Deep-Sea Biodiversity: Multi-Tool Deep Sea Imaging and a Pacific-Wide Synthesis of Nautilus Observations
1500	1515	Filippo Varini	Towards Trustworthy AI for Deep-Sea Video Analysis: A Human-in-the-Loop, Foundation-Model–Based Pipeline and Its Ecological Evaluation
1515	1530	Kakani Katija	FathomVerse: Gaming for Ocean Exploration
1530	1600	*Coffee break*	
1600	1700	Discussion session	
1700	1730	Close of conference	
2000	2200	Conference Dinner - Auora Ballroom (Sunborn)	

WORKSHOPS

An Interactive Workshop Feedback Forum: Recommended Standards for National Oceanic and Atmospheric Administration (NOAA)’s Oceanographic Imagery and AI Applications

Cromwell, Megan[1,2]; Eakins, Barry[1,2]; Kegley, Tobey[1,2]

National Oceanic and Atmospheric Administration (NOAA)[1], Colorado University Boulder - Cooperative Institute for Research in Environmental Sciences (CIRES)[2]

Oceanographic imagery (stills, videos, mosaics) is a vital strategic asset for NOAA, supporting science, policy, and resource management. However, managing, analyzing, and sharing this growing volume of data presents significant challenges, particularly concerning consistent stewardship and the labor-intensive generation of standardized metadata.

To tackle these problems, NOAA established the Oceanographic Imagery Stewardship and AI Applications Task Team. This team is working to create a unified, "one-NOAA" approach to collect, manage, and use Artificial Intelligence (AI) and Machine Learning (ML) on ocean video. The Task Team is collaborating across NOAA, aiming to steward video collections using established standards, cut down on duplicated effort across NOAA, and update and enhance video processing with AI/ML tools.

The Task Team's main goals include making a list (inventory) of NOAA's ocean imagery datasets and the AI/ML applications that go with them, and setting clear, consistent, agency-wide standards for how NOAA manages these data, how NOAA makes them "AI-ready," and how they are annotated. All this work will lead to a NOAA Ocean Imagery and AI Application Technical Memorandum on the "one-NOAA" approach to ocean imagery data.

As a final step before officially publishing the NOAA Technical Memorandum, we plan to share the Task Team’s draft recommendations with the Marine Imaging Workshop audience. This session will be your chance to hear what we've recommended, and provide important feedback from the broader ocean imagery community. This proactive move will make sure our guidance is strong, useful for everyone, and includes the expert opinions of people in the field. The Task Team is set to wrap up its work around September 2026.

Removal of specular noise and caustics from shallow-water drone imagery with temporal stacking

Alevizos, Evangelos[1]

Hellenic Centre for Marine Research, P.O. Box 2214, Gournes 715 00, Heraklio, Crete, Greece[1]

Mapping shallow seafloor with drones relies on input image quality that determines the accuracy and validity of quantitative products. The most common source that degrades the quality of shallow-water drone imagery is specular noise from the sea-surface and seafloor caustics. A common characteristic of these two types of noise is their short-living duration (seconds) that depends on sea-surface roughness. By exploiting this behavior, it is possible to remove image noise reliably, by applying a multi-image stacking approach. Thus, the presented method relies on a specific drone image acquisition pattern, according to which each scene is shot with approximately ten images for capturing the full interval of noise at any pixel.

An open-source image stacking tool is introduced for removing specular noise and caustics. The tool initially groups images into chunks captured at different scenes. Then it applies a content-aware image alignment for each chunk using one image as reference. This is done for compensating minor motion effects between consecutive images. Following, images are stacked per chunk and the minimum or median is calculated across pixels of the same bands (Red, Green, Blue). Then, the resulting band products are merged into a final de-noised image that is suitable for quantitative analyses. The final image contains the same metadata as the reference image of each chuck. This approach provides an efficient approach for drone image de-noising with low computational requirements.

Learning objectives:

a)to understand and identify the nature of noise on shallow-water drone imagery.
b)to understand the image acquisition protocol necessary for image stacking.
c)to familiarize with flight planning and image acquisition best practices for reducing image noise.

Software/hardware required: laptop, python interface, google drive optionally
Outline of the demonstration and interactive activities: the workshop will focus on presenting the concept and steps of the image-stacking technique, there will be a test dataset for demonstration, though participants are encouraged to bring their own data as long as they conform to the acquisition protocol (multiple images of the same scene with 70% image overlap between scenes).

Revisiting the proposed framework for the development of a global standardised marine taxon reference image database (SMarTaR-ID) to support image-based analyses.

Howell, Kerry[1,2]; Davies, Jaime[3]

Plymouth Marine Laboratory, Plymouth. UK[1], University of Plymouth, UK[2], University of Gibraltar, Gibraltar[3]

Almost 10 years ago a group of deep-sea biologists came together to discuss challenges of image analysis and to develop a plan for a global standardised marine taxon reference image database (SMarTaR-ID) to support image-based analyses. That plan, published as Howell et al. (2019), proposed a database structure to facilitate standardisation of morphospecies image catalogues between research groups and support future use in multiple front-end applications.

The group proposed a framework for coordination of international efforts to develop reference guides for the identification of marine species from images. They also suggested a management framework where high-level taxonomic groups were curated by a regional team, consisting of both end users and taxonomic experts. They identified a mechanism by which overall quality of data within a common reference guide could be raised over the next decade; and discussed the role of a common reference standard in advancing marine ecology and supporting sustainable use of this ecosystem.

The project attracted limited funding, but sufficient to develop an initial web portal smarter-id.app, with some of the desired functionality. Without further funding the web portal quickly fell into disrepair. A small injection of funding allowed for complete redevelopment of site but no resource to implement further work. New funding is now available for a comprehensive revitalisation of the initiative, but the field of image analysis has moved on dramatically in 10 years.

This workshop will revisit this bold initiative to ask the community whether the goals set out in the original plan are still useful, whether the end uses are still valid; and discuss how to move forward in providing the tools and training needed to raise quality and standards in image analysis.

Hands-on with Squidle+ Real-Time Tools, Multi-modal Workflows and AI Integration

Friedman, Ariell[1]; Monk, Jacquomo[2]; Lindsay, Dhugal[3]; Naresh Sangekar, Mehul[3]

Greybits Engineering[1], University of Tasmania[2], The Japan Agency for Marine-Earth Science and Technology[3]

Overview:
This interactive workshop showcases the advanced ecosystem of Squidle+, focusing on new workflows that bridge real-time data capture, multi-modal media integration and AI-assisted analysis. Participants will gain practical experience with the platform's latest features, moving beyond basic image annotation to explore video, orthomosaics, and automated processing pipelines.

Learning Objectives:
By the end of this session, participants will be able to:
1. Navigate the new media-agnostic interface to annotate streaming video and orthomosaics.
2. Interact with Machine Learning (ML) "bots" to validate automated "magical suggestions" and understand the workflow for deploying custom models via SQBot.
3. Utilise the QA/QC tools for verifying annotation suggestions from algorithms.
4. Understand the "field-to-cloud" pipeline using SQCapture and GreybitsBOX for efficient field data ingestion and real-time annotation.

Workshop Outline: The session will begin with a live demonstration of the GreybitsBOX and SQCapture software, showcasing how to record, visualise, and annotate live video streams and navigation data in a field setting. Following this, participants will transition to a hands-on session using the Squidle+ web portal. They will explore annotating different media types (video and mosaics) and participate in a collaborative annotation task alongside deployed ML algorithms, using the QA/QC tools to cross-validate human and AI outputs.

Prerequisites:
- No programming experience is required.
- Basic familiarity with marine imagery annotation is beneficial but not essential.

Software/Hardware Needs:
- Participants: A laptop with a modern web browser (Chrome or Firefox recommended) and Wi-Fi access.
- Organisers: Projector for demonstrations; reliable internet connection.
- Datasets: Demo datasets (video, orthomosaics, and pre-computed ML suggestions) will be provided within the Squidle+ platform.

Interactive visual search and segmentation with FathomNet

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Recent foundation models trained on visual data from the FathomNet Database, including BioCLIP 2 and Segment Anything Model 3 (SAM 3), enable new workflows for interacting with large marine imagery archives. This interactive workshop presents a set of practical, end-to-end approaches that leverage these models to support discovery, exploration, and annotation of marine imagery without requiring model retraining.

The workshop focuses on five workflows:

(1) similarity-based retrieval of organisms from a single image or region of interest,
(2) zero-shot semantic image search using natural-language queries,
(3) promptable segmentation to accelerate region-of-interest generation and annotation,
(4) structure-aware similarity search using segmented organism regions, and
(5) anomaly and novelty detection across large image collections.

Together, these examples demonstrate how pretrained visual representations can be combined to enable exploratory analysis and annotation at scale. Participants will be guided through demonstrations using curated subsets of FathomNet imagery. Interactive components will allow attendees to experiment with similarity search, text-based queries, segmentation prompts, and embedding-based exploration of image collections. Discussion will focus on where these approaches are effective, where they break down, and how they can be integrated into existing scientific and annotation workflows, using the FathomNet Program as an example.

Learning objectives include understanding how pretrained image embeddings and promptable segmentation can be applied to marine imagery, how similarity-based retrieval differs from class-based detection, and how these techniques can reduce annotation effort while enabling new modes of discovery.

Prerequisites: familiarity with marine imagery and annotation workflows is sufficient. No machine learning expertise is required. A personal laptop or tablet with a web browser is required to participate in interactive portions.

Two Years on: Lessons From Developing Educational Materials for AI in Marine Imaging

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As careers and internships in marine imaging continue to grow, there is a notable lack of customized educational resources for onboarding and skill-building in this specialized field. To address this gap, we have developed a course titled "Computer Vision across the Marine Sciences" which has been taught as a special topics course over the past two years and its materials are available online indefinitely for free.

This course aims to equip students with the best practices and current research in marine imaging techniques, alongside intermediate Python programming skills. Our instructional approach is grounded in constructivist learning theory, emphasizing active, self-guided exploration. Key components of the course include the use of Google CoLabs to facilitate interactive, cloud-based learning environments where students can engage with Python syntax and functions relevant to marine imaging. Through a combination of flipped classroom structures, synchronous activities infused with active learning, and individualized final projects, students are encouraged to apply their learning in practical, research-driven contexts.

The course design prioritizes accessibility, ensuring that learners with varying levels of prior experience can achieve similar success through higher engagement with course resources. During course teaching and development large volumes of data from surveys, student work, and assessments have generated a wide view of the communities current opportunities and challenges. We aim to continuously refine the course to better support self-guided scientific inquiry and skill acquisition.

We believe that this approach to teaching computer vision and Python within the context of marine imaging will be broadly applicable and beneficial across the earth sciences and other scientific domains.

Session 1: Image Capture & Processing for Marine Research

Best practices for image processing[JD1] in marine biodiversity workflows [JD1] It's usually called "processing" in this community. Why the "pre"?

Masoudi, Mojtaba[1]; Van Audenhaege, Loïc[1]; Orenstein, Eric[1]; Ferreira, Tobias[1]; Sauze, Colin[1]; Durden, Jennifer M.[1]

National Oceanography Centre, Southampton, UK[1]

Image processing is a critical step for turning marine imagery into reliable, comparable ecological measurements. Choices around image processing strategy (i.e., how, what, when) have a profound impact on the success of detecting and identifying fauna, and in biodiversity quantification, including critical derived metrics like seafloor area used for analysis and community composition estimates. But these decisions are often made piecemeal, driven by convenience or aesthetics, with limited documentation for reproducibility. Such ad hoc workflows result in poorly reported bias (e.g., unequal observation opportunity, pseudo-replication), limited data comparability, and unreliable biodiversity estimates.

We developed a best-practice guide to inform decision making to optimise image processing, with an eye toward transparency, reproducibility and application. The guide does not prescribe a single pipeline, but offers a purpose-driven framework that starts from the intended outputs, defines what "success" looks like, and then selects only those steps that improve the ability to extract those outputs without compromising reproducibility. This approach helps teams document decisions, minimise unintended bias, and improve comparability and reproducibility across projects.

Here we will introduce the motivation behind the guide and summarise its core principles for designing preprocessing workflows in a purpose-driven fashion. We will emphasise how to connect processing decisions to the intended scientific outputs, avoid bias introduced by inconsistent processing, and support transparent, reproducible workflows tailored to specific monitoring objectives.

Hidden in Plain Sight: Unlocking the potential of publicly available video data to increase our knowledge of biodiversity in the deep sea

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As the pace of ocean exploration increases, massive amounts of data are being collected, producing troves of invaluable ecological information. Specifically, visual observations of the seafloor collected by remotely operated vehicles (ROV) hold the potential to answer critical ecological questions about the deep sea, the largest but least studied living habitat on our planet. Programs, such as NOAA's Ocean Exploration, are increasing accessibility to the deep ocean, allowing the public to watch ROV dives live and explore the deep ocean at the same time as scientists onboard.

Although these videos are publicly available, their potential remains under-exploited as their analysis requires significant resources and expertise. Moreover, as these videos are not collected for the purpose of answering specific scientific questions, extracting quantitative information to test hypotheses remains challenging. Here, we propose a framework to turn exploratory dives into semi-quantitative surveys that can be used to answer questions surrounding biodiversity patterns in the deep sea. Focusing on the Musicians Seamounts Chain and Papahānaumokuākea National Marine Sanctuary (Hawaiʻi, Central Pacific), we applied this framework to characterize the distribution deep-sea coral and sponge assemblages on seamounts.

A total of ~100 fully annotated ROV dives conducted between 2015 and 2025, were included to determine drivers of species distributions, coral size distributions and identify areas suitable for recruitment. We show that, as long as standardized protocols are implemented for video annotation and data analysis, publicly available ROV video can be used many times over to answer a broad range of scientific questions, unlocking their potential to accelerate deep ocean discoveries.

Detect the undetected: First observations of fluorescence in the hydrothermal vent organisms of the Mid-Atlantic Ridge and its potential for automated image analysis.

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Institute of Marine Sciences-OKEANOS, University of the Azores, Horta, Portugal[1], Univ Brest, Ifremer, BEEP, Plouzané, France[2], GENAVIR. La Seyne sur Mer, France[3]

More and more organisms are shown to fluoresce in the deep sea. Contrary to bioluminescence, fluorescence is not an endogenous reaction but a light emission after being illuminated. Why organisms fluoresce in a dark environment characterised by the absence of a light source remains a mystery. However, fluorescence is a useful tool to make features of interest visible and as such detect the undetected. Here we present the first results from our observations of fluorescence in the hydrothermal vent organisms from the Lucky Strike vent field (1700m depth) on the Mid-Atlantic Ridge.

To this purpose, a camera module featuring blue excitation lights (LSL-2000) and a yellow barrier filter (SOLA NIGHTSEA) positioned in front of a IP Multi SeaCam Camera were interfaced with the human-occupied vehicle (HOV) Nautile during the 2025 MoMARSAT cruise. Beside surprising observations, the analysis of the collected imagery highlights the significant potential of fluorescence for quantifying fauna and substratum coverage.

By applying intensity and wavelength-based thresholds, we demonstrate how fluorescence can aid in the assessment of both fauna and substrate coverage and detection. We will discuss the implications of these findings for automated mapping and detection, as well as the perspectives for improvement.

Automated pre-processing of large underwater ROV datasets for 3D photogrammetry

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Tritonia Scientific[1], University of Essex[2]

Handling large datasets has become commonplace for many ecological surveys, often leading to a processing bottleneck. In our case, thousands of images collected by a remotely operated vehicle (ROV) need to be colour corrected and georeferenced to create high-quality 3D photogrammetry models. We present a new software to automate these pre-processing tasks, with a particular focus on underwater colour correction. The software, which requires minimal specialist skills and human input, cuts the time needed to colour correct underwater images by more than 50% compared to the original manual procedure and improves its repeatability by streamlining the workflow.

Traditional image editing applications have many parameters that need to be adjusted manually and supervision is needed to repeat this process for batches of images. Our software focuses on producing the same or better quality results, while being capable of processing the entire multi-day survey in a single pass. It is built to require human input once at the start, with no further attention needed while running and is user friendly, as the colour correction method works with just three parameters - saturation, gamma and clip limit. Using the new software, 188000 images were processed in 84 hours from just minutes of human input, compared to the 180 hours needed with the old method, which includes a minimum of 5 hours of tedious manual work. We are currently updating the software to include data cleaning by organising images into groups per dive and matching them to GPS locations. This removes the requirement to purchase or maintain multiple separate applications to achieve the same result.

The software is a part of a larger end-to-end photogrammetry pipeline at Tritonia Scientific. The pipeline features advanced data collection, 3D photogrammetry and machine learning aided area analysis. The final georeferenced 3D models are displayed on the Hydrophis platform. This platform makes it possible for the models to be viewed by anyone, anywhere, through a browser, without requiring expensive photogrammetry software or large GPUs.

Adaptive sampling of midwater animals using long range autonomous underwater vehicles with a multi-camera imaging payload

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Monterey Bay Aquarium Research Institute, Moss Landing, CA, USA[1], Institut de Ciències del Mar, Barcelona, Spain[2]

While traditional trawl-based sampling of midwater species works well for many crustacean and vertebrate organisms, it is less effective for gelatinous species. While these animals represent a large part of the midwater biomass, they are often damaged to an extent that challenges accurate identification and counting. For those species, ROV-based operations and transects have become the status quo.

To an extent, those expensive operations are being replaced by time-series transects performed by autonomous underwater vehicles (AUVs), such as MBARI's I2MAP AUV. However, reliable distribution metrics of animals with sparse or patchy distribution ranges cannot usually be obtained in this way. Therefore, we developed new algorithms for targeted sampling of specific organisms, driving adaptive behavior of AUVs using realtime observations and classifications of organisms. To enable this in-situ, we developed Triton, a new, three-camera imaging payload with onboard compute for deployment on long-range AUVs (LRAUVs). The multi-camera array enables animal sizing estimates, and the compute unit allows for realtime inferencing using object detection models trained on similar imagery.

We demonstrate successes in targeting both sparsely distributed and patchwise densely distributed animals, specifically, siphonophores and krill. This paves the way for more accurate organism distribution mapping, as well as targeted observations of specific taxa, making the most of our limited assets that can observe the ocean's midwaters.

From Surface to Depth: A Benchmark and Cross Domain Approach to Recover 3D Reconstructions Degraded by Scattering Media and Lighting

Grimaldi, Michele; Nakath, David; Pizarro, Oscar; Scharff Willners, Jonatan; Carlucho, Ignacio; Petillot, Yvan R.

Heriot-Watt University, Christian-Albrecht University Kiel, NTNU and Frontiers

Robust 3D reconstruction across varying environmental conditions remains a critical challenge for robotic perception, particularly when transitioning between distinct physical domains such as air and water. In this work, we leverage a controlled benchmark, to systematically study modern 3D reconstruction techniques under variations in medium and illumination.

Our setup features a custom water tank with a monocular camera and an HTC Vive motion tracker, providing accurate ground-truth poses. We collected 13 datasets spanning two media (air and water) and three lighting conditions (homogeneous, artificial, and mixed), along with variations in motion type, scanning pattern, and the presence or absence of an initialization trajectory. We also investigated cross-domain reconstruction by augmenting Page 2 of 3 underwater images with a minimal set of in-air images captured under similar lighting. We evaluated Structure-from-Motion reconstruction using COLMAP, analyzing its ability to recover accurate camera trajectories and scene geometry.

These reconstructions serve as inputs to state-of the-art Neural Radiance Fields and 3D Gaussian Splatting methods, evaluated both with and without an initialization trajectory. Reconstruction accuracy is assessed by comparing the estimated camera trajectories with ground-truth poses. To evaluate scene geometry, dense reconstructions across all datasets are benchmarked against the in-air reference obtained under directional lighting.

Finally, rendered outputs from Gaussian Splatting and NeRF are compared using perceptual and photometric metrics. Our results suggest that basic Gaussian Splatting with simple preprocessing (e.g., white balance) already outperforms specialized underwater methods, and question whether improved preprocessing may be more effective than developing new underwater-specific algorithms.

Paidiverpy: A Python framework for reproducible image processing pipelines, aimed at generating analysis-ready image datasets

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The scientific value of image collections depends on consistent and well-documented provenance, including processing workflows. Processing remains a fragmented step that limits reproducibility and scalability and is difficult to tailor to specific project needs.

Here we present Paidiverpy, an open-source Python package designed to support the construction and execution of reproducible image processing pipelines for marine imaging workflows. Paidiverpy provides a structured framework to combine established operations— including image loading, format conversion, color correction, resampling, spatial alignment, and orientation handling—into documented, reproducible pipelines. Processing steps are implemented as modular layers that can be combined, inspected, and validated through a central pipeline abstraction.

Paidiverpy integrates image data and metadata to facilitate both image-level and image set-level processing. Images are stored as "xarray datasets" thatpreserves spatial, temporal, and contextual metadata alongside pixel values. This representation enables metadata-aware operations such as grouping, filtering, and batch processing based on camera configuration, or deployment context, and supports consistent spatial resampling and alignment across image collections. Padding and validation strategies enforce consistent image dimensions required by downstream analysis tools, such as machine-learning training, computer-vision pipelines, and quantitative image analysis that require fixed-size inputs.

The framework is designed to scale to large image archives. Optional parallel execution supports multi-core and distributed processing. Benchmark experiments using multi-gigabyte image collections (including RGB and grayscale images) show order-of-magnitude reductions in processing time compared to sequential execution.

Paidiverpy supports common marine imaging metadata formats, including iFDO-compliant records. Explicit workflow definitions, specified through human and machine-readable configuration files, allow processing steps to be reapplied consistently across different datasets and projects. Paidiverpy can be accessed via Python scripts, a command-line interface, containerised deployments, or a web-based graphical interface, lowering barriers for users with different technical backgrounds.

By promoting transparent, repeatable, and metadata-aware processing, Paidiverpy contributes a reusable software component for generating analysis-ready marine image datasets and supporting reproducible imaging science.

Imaging approaches for construction of digital holotypes: matching tools to taxon

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In March 2017, the International Committee for Zoological Nomenclature (ICZN) published a Declaration that “establishing new species-group taxa without preserved name-bearing type material is permissible under the Code”, dependent on several caveats. Since then, we have tested various imaging technologies for their suitability for recording different gelatinous midwater taxa to the level we consider necessary for these images to be able to replace a preserved, physical holotype specimen. Here we introduce our results for multi-angle reflected light videography, plenoptic (light field) imaging, multi-camera optical slicing with a laser sheet, polarized light imaging, and multi-axis shadowgraphy. Successful recording of key morphological features was highly dependent on the taxa being imaged.

Session 2: Data-Driven Ocean Science: Artificial Intelligence in Marine Science

Session 2: Data-Driven Ocean Science: Artificial Intelligence in Marine Science

Uncovering Anomalous Events for Marine Environmental Monitoring via Visual Anomaly Detection

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Underwater video monitoring is a promising strategy for assessing marine biodiversity, but the vast volume of uneventful footage makes manual inspection highly impractical. In this work, we explore the use of visual anomaly detection (VAD) based on deep neural networks to automatically identify interesting or anomalous events. We introduce AURA, the first multi-annotator benchmark dataset for underwater VAD, and evaluate four VAD models across two marine scenes.

We demonstrate the importance of robust frame selection strategies to extract meaningful video segments. Our comparison against multiple annotators reveals that VAD performance of current models varies dramatically and is highly sensitive to both the amount of training data and the variability in visual content that defines "normal" scenes. Our results highlight the value of soft and consensus labels and offer a practical approach for supporting scientific exploration and scalable biodiversity monitoring.

Unlocking Legacy Marine Image Annotations to improve AI Models for Benthic Fauna Classification

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Over the years, marine science has collected large amounts of visual data using ROVs, AUVs and other platforms. Unfortunately, only a subset of these data has been annotated, and most of these annotations are point annotations, i.e. a point associated with a taxonomic category. Although point annotations are preferred as they are the quickest and most convenient way of annotating, the door to their use for AI training is locked. This is because AI training requires boxes or polygons, not simple point annotations. To overcome this limitation, they must first be transformed to object outlines or masks.

Here, we present a technique that enhances existing point annotations, to “unlock the door” to state-of-the-art computer vision tasks. This is achieved using the Segment Anything Model (SAM), which is improved via a collection of techniques. We demonstrate the effectiveness of our approach by applying it to a deep-sea benthos dataset consisting of 523 point annotations.

Our method generates effective mask annotations for 98.2% of the point annotations, achieving a median Intersection over Union (IoU) of almost 65%. By comparison, the Segment Anything Model (SAM) converted only 18.2% of the annotations, with a median IoU below 50%. This creates significant opportunities for the reuse of older marine datasets and makes the annotators' job easier.

Optimizing an image annotation workflow using AI: practical guidance for applying pre-trained object detection models to seafloor imagery data

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Image annotation often involves hours of manual image review and is the main bottleneck between at-sea data collection and final analysis results. Rapid advances in computer vision for marine fauna annotation offer impressive efficiency improvements over manual annotation; ecologists with little to no experience in computer vision can leverage existing models, such as those found in FathomNet's Model Zoo, to speed up their imagery analysis. However, various factors can influence whether a model will perform well on an unseen dataset. "Out-of-distribution" (OOD) data – which differ from the training data in terms of taxonomic groups, marine regions, habitat types, or sampling platforms represented – provide an opportunity to evaluate how well pre-trained models generalize outside their training context. Evaluating OOD performance can highlight the situations in which the model does well and can be easily applied, and identify gaps where the model needs improvement. Here, we evaluate the OOD performance of FathomNet's Megalodon detector and the zero-shot object detector GroundingDINO using various seafloor image datasets collected on the Newfoundland and Labrador shelf and the Eastern Canadian Arctic. We included data from different types of equipment such as drop cameras, tow cameras, and remotely operated vehicles, collected from depths ranging between 160-1500 m. Using labelled data previously unseen by these models, we assessed how model performance varies across different sampling gears and habitat types. We used Precision-Recall curves to determine the best combination of confidence and intersect-over-union (IOU) thresholds during prediction to maximize the number of correct detections. Overall, the models performed well with low confidence thresholds (<0.05), although both models had higher recall (fewer false negatives) in homogeneous soft-sediment habitats compared to heterogeneous habitats with complex species assemblages. We present recommended model parameters that depend on the habitat being studied and the image acquisition gear type to enable efficient integration of these models into existing imagery analysis pipelines. Finally, we describe an example pipeline which maintains the human-in-the-loop using the open source software BIIGLE, and provide a set of Python functions to facilitate applying these models in a simple and efficient way.

Long-Term Ecological Patterns from Automated Species Detection at the Mothra Hydrothermal Field, NE Pacific

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Long-term cabled observatories have made it possible to collect large-scale, high-frequency time series of oceanographic data from previously understudied hydrothermal vent ecosystems. Despite the availability of this data, the time consuming nature of manually annotating imagery has left the behavior of transient and persistent megafauna at these sites understudied. To leverage previously collected imagery to investigate these communities we used automated image-based species detection on still frames extracted from four-minute video sequences, recorded every four hours by Ocean Networks Canada at a vent in the Mothra hydrothermal field on the Endeavour Segment (47.923905°,-129.108519°).

The time series began in September 2020 and was analyzed through July 2025. A YOLO object detection model, trained on 10 distinct morphotaxa, was applied to the sharpest frame from each video to identify species presence and count. Using this information, we examined emerging patterns in species composition over time; correlations between changes in biological communities with co-located environmental parameters; and evidence for seasonal cycles in community structure. Multiple time series analysis techniques were used to quantify trends, detect periodicities, and explore relationships with environmental data. Results show distinct morphotaxa temporal regimes, and correlations between environmental fluctuations (e.g. temperature, and salinity) as well as changes in community composition.

These findings show the potential of integrating preexisting cabled observatory data with computer vision tools to detect long-term ecological trends. This approach offers an indefinitely scalable workflow for understanding how any megafaunal marine community may respond to environmental variability and long-term ocean change.

Assessing exploited intertidal fishery resources across complex coastal terrain using 3D photogrammetry

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Limpets (Patella aspera and P. candei) are keystone grazers in intertidal and shallow subtidal ecosystems, shaping algal cover and benthic community structure in the Azores. They are also culturally and economically significant to the region, yet decades of overharvesting led to stock collapse in the1980s and limited recovery despite management measures. Effective conservation is hindered by the lack of recent, robust population assessments, partly due to the logistical and methodological challenges of surveying wave-exposed intertidal habitats.

Traditional monitoring approaches are invasive, labour-intensive, and spatially constrained. Structure from Motion (SfM) photogrammetry, combined with Uncrewed Aerial Vehicles (UAVs), offers a non-invasive alternative capable of capturing high-resolution spatial and biological data across complex coastal terrain. By generating detailed 3D reconstructions, SfM enables individual-level detection, size estimation, and spatial analysis of benthic organisms within their habitat context. However, large wave amplitudes, steep cliffs, species discrimination, integration of subtidal with intertidal environments, under-developed 3D analytical frameworks, and the need for sub-millimetre geometric accuracy all present methodological challenges in the context of shallow and intertidal benthic species in the Azores.

Here, we present the 3D LAPAS project. We overcome these challenges through manual UAV manoeuvring, close-range imagery, Real-Time Kinematic positioning and development of 3D analysis frameworks. We integrate UAV-based aerial surveys with shallow underwater imaging to produce continuous 3D models spanning intertidal to shallow subtidal zones. We test the feasibility of accurately measuring individual limpet size without ground control points and validate 3D model accuracy (average error of 0.5 mm), enabling quantification of population size structure. We explore how terrain complexity and environmental gradients influence limpet distribution in 3D using Ecological Niche Factor Analysis and Point Pattern Analysis, furthering our understanding of their ecological niche. Preliminary results show they favour a narrow depth range, and terrain orientation and slope angle influence their distribution.

This work demonstrates the potential of drone-enabled 3D photogrammetry as a scalable, cost-effective tool for monitoring threatened intertidal species in difficult-to-access environments. The approach provides a foundation for automated (flight paths and AI image analysis), repeatable population assessments, and offers broader applicability to coastal systems where traditional ecological surveys remain constrained.

3D photogrammetry and deep-learning deliver accurate estimates of epibenthic biomass

Marlow, Joseph[1]; Halpin, John E.[1]; Wilding, Thomas A.[1]

Scottish Association for Marine Science, Oban, UK[1]

The capacity to accurately measure biomass is essential for our understanding of ecosystem functioning, energy flow, and biodiversity patterns. However, in epibenthic ecology, traditional biomass estimation approaches have relied heavily on either destructive sampling or simple geometric conversions of two-dimensional imagery. These are constrained by substrate type (soft vs hard), accessibility (e.g. depth or surface orientation), morphological complexity and limited scalability.

To overcome these limitations, we present an integrated methodology that combines 3D photogrammetry with deep-learning-based taxonomic semantic segmentation, and taxon-specific density coefficients to produce high-accuracy, non-destructive estimates of epibenthic biomass across morphologically diverse taxa. We present a case study of our approach using surveys of three epibenthic species of varying morphologically complexity on a North Atlantic rocky reef. Our results show that photogrammetric biovolume measurements closely matched human observer estimates, and biomass estimates exhibited mean similarities to ‘true’ biomass values ranging approximately from 88% to 133% depending on species and underlying substrate characteristics. These results indicate that our integrated pipeline reliably captures biomass variation without the need for organism extraction or simplification of morphology.

We will present how the methodology is broadly applicable to a variety of environments (e.g. fjord walls and offshore structures) and imaging platforms (e.g. SCUBA, ROVs & AUVs), making it suitable for large-scale ecological surveys where manual annotation is prohibitive and extractive sampling impracticable. By increasing efficiency, repeatability and spatial coverage, this technique offers a powerful tool for advancing quantitative assessments of benthic community structure and function, with implications for monitoring, conservation, and management of marine ecosystems.

Assessing seasonal variability in the biogeography of planktonic communities in south Florida, USA, by merging in vivo plankton imaging observations with dynamic satellite seascapes.

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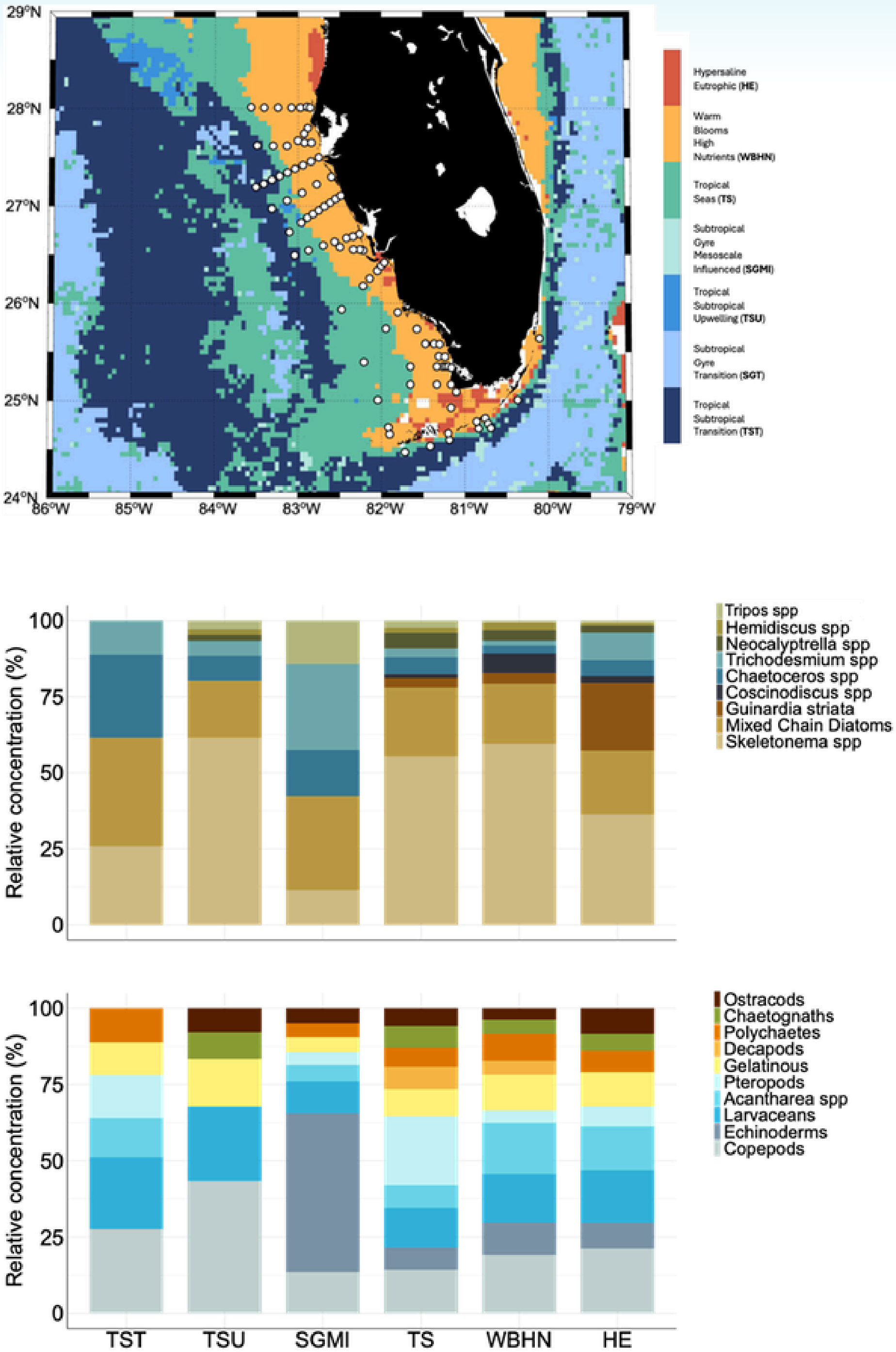
Cooperative Institute for Marine & Atmospheric Studies, Rosenstiel School of Marine[1], Ocean Chemistry & Ecosystems Division, Atlantic Oceanographic and Meteorological Laboratory, National Oceanic and Atmospheric Administration[2], University of South Florida, College of Marine Science, St. Petersburg, Florida[3], College of Earth, Ocean, and Atmospheric Sciences, Oregon State University[4], Virginia Institute of Marine Science[5], Northern Gulf Institute, Mississippi State University[6], Office of Science and Technology, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Maryland[7]

Repeated, frequent (at least seasonal) and long-term measurements of plankton abundance and composition, and of environmental drivers, are critical for understanding and predicting changes in abundance and biodiversity across benthic and water column habitats. These observations help understand trophic interactions, fisheries productivity, water quality, and overall ecosystem health. We examined marine plankton using in situ imaging techniques in field surveys in south Florida (USA) shelf and nearshore waters every two months over a period of three years as part of the Southeast U.S. Marine Biodiversity Observation Network. The primary goal was to characterize the biogeography and phenology of observed micro-phytoplankton and meso-zooplankton. Plankton data were collected with a Continuous Particle Imaging and Classification System (CPICS) mounted on a CTD rosette. A total of 24,483 regions of interest (ROIs) were classified using a Residual Network (ResNet) deep convolutional neural network model. This allowed us to quantify diatoms, Trichodesmium spp., Tripos spp. dinoflagellates, copepods, larvaceans, gelatinous, Rhizaria spp., pteropods, and larvae of echinoderms, polychaetes, and other rare taxa. To evaluate the affinity of plankton groups to specific water types, imaging data were matched to a machine-learning seascape classification based on multiple satellite and modeled data sources. Plankton abundance and community composition showed seasonal variability linked to seascape occupancy. For example, abundances of chain diatoms, copepods, larvaceans, and gelatinous zooplankton were generally higher during summer and fall versus winter and spring. Seascape class "Warm-Blooms-High-Nutrients" (WBHN) occupied up to ~ 80% of the surveyed area during fall months, coinciding with peak freshwater discharge. During cool, dry periods, the Tropical Seas (TS) seascape class dominated. Phytoplankton abundance in WBHN was, on average, ~ 4-fold higher than in TS, likely due higher land-based nutrient supply fuelling blooms of Skeletonema spp., Chaetoceros spp., Pseudosolenia spp., and other diatoms. Farther offshore, mean relative abundances of Trichodesmium spp. (29%), Tripos spp. (14%), echinoderm larva (53%) and pteropods (23%) were higher than in shelf and nearshore WBHN and TS seascapes. Embedding plankton observations in a seascape framework helped to disentangle effects of seawater temperature, land-based nutrient supply, water quality, and food web structure on multi-trophic level diversity in regional ecosystems.



Caption: Map shows location of stations where plankton imaging observations were collected during CTD casts (white dots) overlaid on mean monthly satellite seascapes for September of 2024 as an example of seascape conditions in the area. The color bar indicates seascape categories. Stack plots show mean relative concentration of phytoplankton (upper plot) and zooplankton (lower plot) groups derived from imaging observations per seascape class.

From GoPro videos to automated seafloor megafauna identification: An end-to-end pipeline and lessons learned

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Benthic megafauna, such as corals and sponges, are key components of seafloor ecosystems and are widely used as indicators of vulnerable marine ecosystems. Camera-based surveys offer valuable information on their distribution and biology, yet large volumes of imagery remain underused due to the time required for manual annotation. While deep-learning methods are promising tools for automating species identification, their performance depends strongly on upstream decisions in video pre-processing, such as frame selection and annotation strategy, which remain largely unstandardised.

Here, we present an end-to-end pipeline developed to assess benthic megafauna diversity from a challenging imagery dataset. The data consist of GoPro videos from >600 stations around Greenland, collected over the last decade. The primary sampling gear was a benthic sledge, with depths ranging from 30 to 1600 m. Across the dataset, we encountered variable camera angles, inconsistent survey speed, frequent sediment clouds generated by the sledge, and intermittent laser scaling. Rather than discarding large portions of the data, we designed methods to work within these constraints while minimising manual effort.

The main steps in the pipeline are: 1) a classification model to separate water-column, sediment-cloud, and seafloor video segments; 2) a Laplacian variance-based frame extraction method to reduce motion blur; 3) target-taxa selection based on representation across a spatially and bathymetrically balanced subset of stations; 4) pragmatic image annotation; and 5) training and validation of a YOLO object-detection model.

This contribution highlights practical trade-offs, limitations, and lessons learned when developing deep-learning workflows from imagery collected using varied techniques and over heterogeneous environments. The aim is to share transferable insights for researchers working with legacy or low-cost imaging systems, and to demonstrate how automated tools can be developed without relying on idealised survey conditions.

Increasing Robustness for Underwater Image Matching via Rotation Invariance

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Many marine imaging applications, such as mapping, 3D-reconstruction or visual navigation require finding correspondences between images as a preliminary step. However, image matching is particularly challenging in underwater environments due to a variety of visual effects and the lack of rotation invariance. We therefore investigate the use of transformer-based neural network architectures for rotation-invariant feature matching and analyse how their advantages in terrestrial applications can be transferred to marine imaging.

Marine imaging is characterized by a complex interaction of different optical effects such as artificial lighting, discolouration and blurring. These effects depend on changes in perspective, making feature matching underwater a non trivial task. Moreover, the increased number of degrees of freedom of underwater imaging platforms as well as the limited ability to accurately track camera poses increase the demand for algorithms that are robust to strong rotations and perspective changes.

This limits the performance of feature matching algorithms in underwater applications, as most conventional convolutional neural networks are not rotation invariant. Recent advances in the terrestrial domain utilize transformer-based architectures that describe the feature points in the spatial image context and thereby improve the matching quality for complex and repetitive structures. However, existing models remain insufficiently adapted to the specific challenges of the underwater domain.

To address these challenges, we present a comprehensive analysis of transformer based architectures. Thereby providing valuable insights to enable the development of a feature matching model that is robust against rotations and adapted to underwater imaging conditions. The improvements directly benefit downstream tasks, enabling more reliable mapping, navigation, and 3D reconstruction under challenging visual conditions.

Scaling Marine Image Annotations with AI-enabled, Human-In-the-Loop Pipelines

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Monterey Bay Aquarium Research Institute[1]

Large and rapidly growing collections of marine imagery support quantitative, data-driven marine science, but manual annotation and expert review remain major bottlenecks. The FathomNet Database – an open-source, expertly curated repository – contains high-quality marine imagery, localizations, and classifications, but its geographic and taxonomic coverage remain limited. While large aggregators of biodiversity datasets exist for both institutional and citizen science contributors such as iNaturalist, GBIF, and InvertEBase, they often lack instance-level localizations necessary for training object detection models and exhibit variable taxonomic specificity. Expanding coverage and maintaining annotation quality at scale requires AI-enabled pipelines that unify machine learning and review from human experts.

We present a pipeline for ingesting large biodiversity datasets into FathomNet Database and automatically enriching them with localizations and classifications generated by state-of-the-art foundation models. Candidate images are filtered using visual quality metrics to prioritize high-value content for expert validation. Newly developed review tools in the FathomNet Database enable human reviewers and taxonomic specialists, including collaborators from the World Register of Marine Species (WoRMS), to rapidly verify model outputs and correct errors. These tools also allow experts to flag exemplar images they find valuable for integration into the WoRMS taxonomic reference. We also outline methods to evaluate the quality of the resulting annotations.

This expert-in-the-loop approach demonstrates how AI can accelerate the scale and rate at which we can generate localizations for high-quality taxonomic annotations from large-scale image datasets. By combining automated enrichment with targeted human review, we establish a repeatable framework that accelerates dataset growth, strengthens interoperability between biodiversity databases, and supports large-scale, collaborative analysis of marine ecosystems.

Human-and-AI-in-the-Loop Marine Image Annotation in in the BIIGLE online tool

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In marine science and engineering, imaging data are used in exploration and monitoring. Due to the rapid advances in digital imaging and mobile marine observation platforms (AUV, ROV etc.) large volumes of visual data are collected. The process of manual visual data annotation (i.e. marking and describing objects of interest with labels), to extract quantitative data or to collect many examples for AI applications, is a very time-consuming task and requires a high level of user/expert experience to achieve annotations of sufficient quality and consistency.

To address the challenge of making this process more efficient, we introduce the BIIGLE-LabelBOT, a human-in-the-loop image classification assistant that supports and accelerates the annotation process by providing relevant, real-time label suggestions. Rather than replacing human annotators, LabelBOT works as a collaborative tool to reduce repetitive work and decision fatigue, benefiting both experts and non-experts. LabelBOT operates on 384-dimensional feature vectors extracted using the DINOv2 self-supervised model and performs classification through similarity–based Approximate-Nearest Neighbors (ANN) using the Hierarchical Navigable Small World (HNSW) index for fast vector search reducing it from seconds to milliseconds.

The system has been evaluated on the marine fish imagery dataset OBSEA, and achieved a 94% Top-3 and 68% Top-1 accuracy. LabelBOT is fully integrated into the BIIGLE image annotation platform utilizing ONNX-runtime, for fast and efficient browser–based feature vector generation. Its responsive user interface offers immediate classification suggestions accelerating the workflow without disrupting the user’s control.

Transferring a YOLOv8 Benthic Species Detection Model to New Sites.

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Artificial intelligence (AI) applications for identifying key marine benthic species and taxa from imagery are expanding rapidly. However, progress faces two primary constraints: the labour-intensive nature of image annotation and difficulties achieving standardised annotation protocols with reliable inter-annotator agreement. We address these challenges by demonstrating how AI-generated annotations can serve as an initial framework to enhance both efficiency and consistency in the annotation process.

We developed an object detection model based on YOLOv8 architecture, trained on 2,905 images containing 29,387 species annotations across 39 taxonomic classes. Training data originated from the NERC-funded DeepLinks project (JC136 research cruise), which surveyed banks and seamounts within the UK's Exclusive Economic Zone [Howell et al., 2016]. The trained model was then deployed to generate preliminary annotations in two unannotated study areas. First, we applied it to the remaining JC136 cruise imagery, which are 21775 images after removal of duplicates, yielding 172,735 automatically generated annotations. Expert marine annotators reviewed and validated AI-generated annotations, identifying a further 96101 annotations which were missed by the AI generation system.

We demonstrate that employing AI models for initial annotation passes on extensive datasets yields promising results. Annotators reported multiple instances where the AI identified organisms they would likely have overlooked during manual annotation. However, model performance varied by location and taxa, with reduced accuracy when applied to sites beyond the original training area. Quantitative assessment revealed 34% mean Average Precision at 0.5 confidence threshold (mAP_50) and mean average recall of around 38%, but this varied highly with species, and we will compare the species prediction distributions with original training data distributions to better understand the impact of training data distributions.

This workflow establishes a practical foundation for integrating AI assistance into marine benthic image annotation, improving both annotation speed and detection consistency whilst highlighting the importance of site-specific model training for optimal performance.

State of the art of Vision-Language Models and Multimodal Integration for Advanced Semantic Interpretation in Marine Imaging

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Marine imaging plays a vital role in advancing ocean science by enabling non-destructive exploration, long-term monitoring, and data-driven decision-making for marine conservation. However, underwater imagery presents persistent challenges for automated analysis due to adverse visual conditions, turbidity, limited visibility, colour distortion, and environmental variability. In recent years, multimodal learning and Vision-Language Models (VLMs) have emerged as a promising paradigm to address these limitations in arial and urban domains; while multimodal fusion integrates complementary physical sensors or environmental data, VLMs leverage natural language to provide context-aware interpretation, enhancing the robustness of semantic understanding beyond RGB imagery.

This work presents a comprehensive state-of-the-art review of multimodal machine learning methods with a particular focus on semantic segmentation and scene understanding in underwater environments, along with some first experimental results. We synthesize advances in multimodal fusion strategies, condition aware perception, and vision–language models, drawing from general multimodal learning literature and domain-specific marine imaging applications. Crucially, we explore the integration of textual modalities through VLMs, examining how large-scale pre-training can enhance the robustness of underwater image understanding. The review covers classical multimodal integration approaches, contemporary transformer-based fusion architectures, and emerging vision–language frameworks, highlighting how acoustic, optical, polarization, material, and textual modalities can be combined to improve robustness under adverse conditions. It also discusses the growing role of foundation models in bridging the gap between raw visual data and high-level semantic interpretation.

Special attention is given to recent benchmark datasets, fusion taxonomies, and condition-aware segmentation methods adapted to underwater scenes (as well as the growing role of large-scale vision–language models in this field). We aim to combine scalar environmental information with RGB images to improve underwater segmentation for exploration.

By consolidating insights across disciplines, this work identifies current limitations, open challenges, and promising research directions for multimodal perception in marine imaging.

Overall, this review aims to provide a structured reference for researchers and practitioners, facilitating the adoption of multimodal approaches to enhance semantic interpretation, scalability, and reliability of marine image analysis workflows.

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A Constellation Matching Approach to Increase Robustness of Underwater Image Matching

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Image matching is a computer vision task that is very sensitive to the optical conditions of the underwater domain and at the same time crucial for a multitude of underwater vision use cases, including detailed mapping of the sea floor, localization of underwater vehicles, or the 3D reconstruction of objects and terrain.

We propose a novel approach that addresses a major challenge in underwater image matching:

Underwater scenes tend to have significantly reduced semantic detail relative to terrestrial imagery. The color spectrum or brightness range of image regions relevant to matching algorithms, typically the seafloor and rigid objects on it, is in many settings much lower than that of confounding effects such as floating particles, artificial lighting patterns, or backscattered light.

The applicability of existing algorithms is therefore limited to water and illumination conditions with sufficiently mild confounding effects or particularly detailed image content. Deep neural network approaches that aim to train more robust image matchers from underwater image datasets still lack sufficiently diverse training data.

Our novel approach aims to extend the applicability of underwater image matching to more complex conditions through a new method that combines a robust constellation matching algorithm with trained instance segmentation models. The instance segmentation performs a binary classiffication of image pixels into objects relevant to the image matching and others such as noise or background. The constellation matching is applied to its output and identifies corresponding constellations between the segmented relevant objects.

We evaluated our approach on two different seafloor surveys, one in turbid coastal waters and a second in the deep sea. Ground-truth correspondences were established manually. Our results showed that two algorithms, SIFT as a representative of engineered image matchers and DISK as a deep learning image matcher, were outperformed by our method on both test sets.

- The extension of the applicability of underwater image matching to more turbid, featureless or noisy imagery promises to increase the availability of visual underwater maps and 3D models and to facilitate visual navigation of autonomous vehicles.

Enhancing automated image analysis of vulnerable seabed communities with environmental context conditioning

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Effective protection of vulnerable seabed communities requires monitoring systems capable of delivering data at scales far beyond what manual annotation can provide. Automated image analysis using deep learning offers a path forward, yet performance is often limited for example by the complexity of benthic ecosystems and difficulties relating to data quality.

To address these challenges, we investigate multimodal learning approaches that integrate environmental context into computer-vision pipelines, merging predictive habitat mapping with image classification. Our goal is to develop generalizable approaches that improve classification robustness across surveys, communities and imaging conditions.

We evaluate these methods on a large benthic image dataset (~138k ROV images) in the Norwegian Sea between 2007 and 2021. The dataset includes key indicator taxa of Vulnerable Marine Ecosystems (VMEs), such as Cauliflower Coral Fields, Sea Pen Gardens, Soft and Hard-bottom Sponge Aggregations, Coral Reefs and Gorgonian Assemblages.

5-fold cross-validation experiments on a 6k image subset, show that popular image-only classifiers such as YOLO V.8 can be improved by conditioning image predictions on environmental variables derived from bathymetry, geomorphology, and oceanography. This is achieved with an intermediate-fusion architecture, in which a simple Multilayer Perceptron (MLP) is trained on YOLO V.8 image features combined with tabular environmental predictors, resulting in improvements to class-performance metrics by 6-7% on average.

These results highlight the value of multimodal learning to improve seabed monitoring. We discuss considerations for multimodal learning strategies, emphasizing the importance of underlying data quality and outline steps to improve this work further.

Session 3: Ocean Data Management

From Seafloor to Science: An End-to-End Imaging and Annotation Pipeline for ROV SuBastian

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Schmidt Ocean Institute[1]

Schmidt Ocean Institute operates a comprehensive, end-to-end pipeline for collecting, managing, and disseminating deep-sea video, imagery, sensor data, and scientific events acquired by the remotely operated vehicle (ROV) SuBastian. This presentation describes how these data are captured at sea, made rapidly available to scientists during and after expeditions, and ultimately contribute to community platforms such as FathomNet to support research, collaboration, and machine learning development.

During ROV dives, high-definition video and still imagery are recorded alongside synchronized navigation, environmental sensor streams, and structured scientific event annotations generated by onboard experts. These events are logged in real time using Sealog and can be reviewed while on the ship. In addition, we have created a semi-automated system to produce highlights from tagged imagery for media.

Following expeditions, scientists have access to a cloud-based version of SeaLog, SeaCloud, to review and reference their event logs. In parallel, events, sensor data, and video are ingested into the Schmidt Ocean Institute's Scientific Annotation Platform, which is built on Tator. SeaCloud is directly linked to the Scientific Annotation Platform, enabling tight integration between event records and annotated media. This platform brings together video, imagery, event logs, and sensor context, allowing scientists to seamlessly move between media, annotations, and dive information while conducting detailed post-cruise analysis. We describe how this system supports structured annotation workflows and prepares labeled datasets for downstream reuse.

To broaden accessibility and interoperability, we are developing mechanisms to distribute static imagery and metadata to external annotation platforms such as BIIGLE, allowing researchers to work within familiar tools while maintaining data provenance and consistency.

In parallel, unannotated or lightly annotated video is contributed to FathomVerse, a citizen-science game that engages the public in labeling marine imagery. These community-generated annotations are used to train new machine-learning models for underwater object classification, with resulting labeled imagery curated and deposited into the FathomNet database.

Together, this pipeline demonstrates a scalable approach to transforming deep-sea imaging data into reusable scientific and machine-learning assets, spanning shipboard operations, expert analysis, citizen science, and open data dissemination.

AI4DeepSea: Development of Artificial Intelligence for the study of communities in deep marine environments

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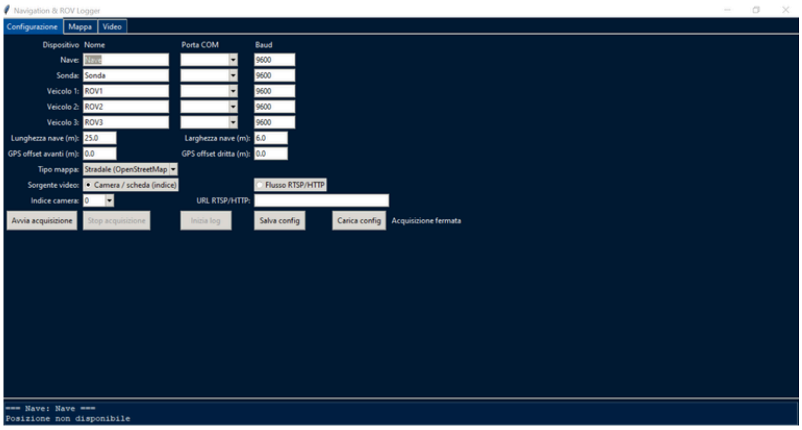
The increasing use of marine imaging for ecological monitoring and deep-sea exploration generates large volumes of video and telemetry data, posing challenges for timely analysis and real-time decision-making. To address these challenges, we present AI4DeepSea, an integrated platform for onboard real-time monitoring, image analysis, and telemetry visualization onboard vessels.

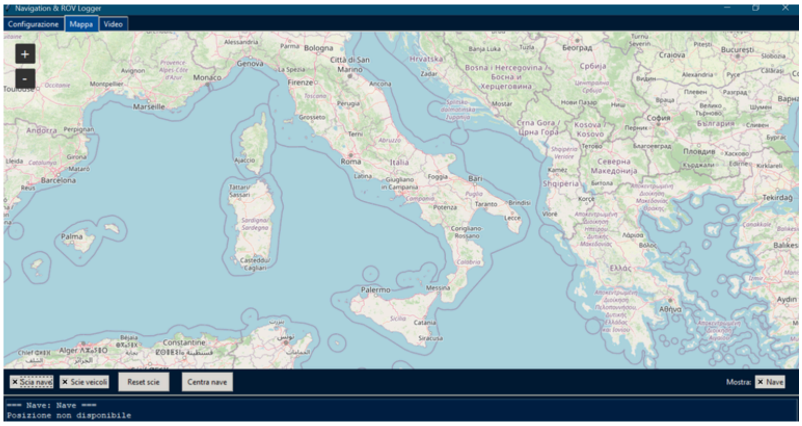
The proposed system integrates ship, vehicle, and probe tracking with high-resolution video streams from ROVs in an interactive interface that visualizes positions, movements, and associated telemetry data in real time. GPS and other information from multiple sources are continuously parsed, mapped, and logged, enabling diagnostics, replay, and longitudinal analyses. A multi-threaded architecture ensures responsive handling of data streams from video, navigation, and onboard sensors.

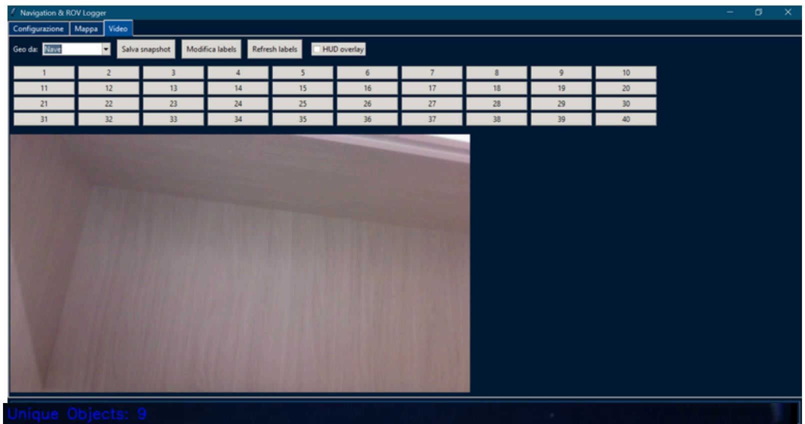
AI-based species detection is embedded within the platform to automatically identify deep-sea organisms in live video feeds. Detected organisms are stored as annotated images together with corresponding telemetry and navigation data, which reduces manual annotation effort, supporting data management, and supports ecological analyses and monitoring. High-quality video data collected in the Mediterranean Sea off the coast of Italy at multiple locations are used to train deep learning YOLO model, with frames extracted and annotated by biological experts to enable robust species recognition.

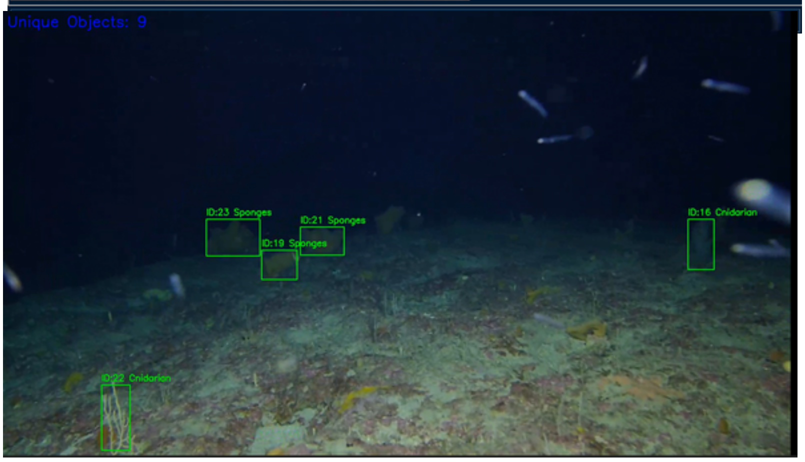
The platform is implemented as a desktop application, enabling real-time onboard analysis, visualization, and data storage during expeditions. By integrating these capabilities within a unified system, AI4DeepSea supports practical, end-to-end workflows for data collection, annotation, and management during field operations.

This approach accelerates ecological research through automated species image extraction, which align with the objectives of the Marine Imaging Workshop.









Squidle+ updates: New and Improved Workflows, Real-Time Field Analysis, Multi-Media Annotation and AI Collaboration

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Greybits Engineering[1], University of Tasmania[2], The Japan Agency for Marine-Earth Science and Technology[3], Norwegian University of Science and Technology[4], The University of Sydney[5]

As the collection of marine imagery continues to outpace analysis, the need for scalable, end-to-end data management solutions has never been more critical. Squidle+ has evolved into the largest known repository of openly accessible, georeferenced marine images, now hosting over 10 million images from global contributors. This presentation will showcase the platform's latest major capability expansions designed to unify workflows from the field capture to the cloud.

We will showcase the media-agnostic annotation interface, which standardises the user experience across diverse data types. Whether working with still images, streaming video, or large-scale orthomosaics, users can now utilise a consistent set of tools within a single centralised portal. We will overview the QA/QC features and also the label vocabulary translation capabilities.

A key focus will be the integration of Machine Learning (ML) through the SQBot framework, which treats algorithms as "users" within the system. We will demonstrate how these "bots" collaborate with human annotators by providing "magical suggestions" and facilitating active learning workflows, allowing independent researchers to operationalise custom models without complex backend integration.

Finally, we will highlight developments in real-time field analysis using SQCapture and the GreybitsBOX. This ruggedised hardware-software solution enables live video streaming, real-time navigation plotting, and on-site annotation, streamlining the ingestion of survey data directly from the field to the Squidle+ cloud. These advancements collectively enhance the Findability, Accessibility, Interoperability, and Reusability (FAIR) of marine data, empowering the community to turn vast archives of imagery into actionable scientific insights.

FAIR & Open Marine imaging data workflow: from deep-sea exploration planning to data reuse

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The deep ocean is the largest biome on our planet, hosting remarkable diversity, providing climate regulation, food resources and biomaterials, yet less than 0.001% of the seafloor has been visually observed. Different observation technologies (e.g. ROVs, AUVs) are used to collect video and still imagery in expeditions. These data have become crucial for characterising and monitoring benthic marine communities across a wide range of seabed habitats and depths. However, marine imaging equipment frequently generates multi-terabyte datasets that require a robust server infrastructure to support data storage and processing.

Here, we present the development of a marine imaging data workflow developed within TwinDEEPS, an EU project which aims to advance exploration and observation capacity and increase “big data” management capabilities at CIIMAR (Portugal). Using an oceanographic expedition to the Gorringe Bank as a case study, the workflow addresses key stages of the data lifecycle, including data management planning, collection, image pre-processing quality control, storage and (meta)data preservation compliant with the FAIR data (Findable, Accessible, Interoperable, Reusable) principles. Here, we illustrate how data stewardship and international collaboration promote robust workflows and support institutional capacity building, ensuring marine imaging data remains usable and accessible beyond the lifespan of the projects. We discuss current gaps and practical challenges associated with image collection, pre-processing and long-term storageand reusability when dealing with large datasets.

Endorsed by the Ocean Decade, TwinDEEPS is actively contributing to Ocean Decade Challenge 8, supporting interoperability of the data collected, capacity-building development, and free access to ocean data, improving our knowledge of the deep ocean.

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A Federated Image Brokerage Service for Scalable Biodiversity Analysis from Marine Imagery

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Joint Nature Conservation Committee[1], National Oceanography Centre[2], Marine Biological Association[3]

The rapid growth of image-based marine monitoring has created major opportunities for biodiversity assessment, but also exposed a persistent bottleneck: access to diverse, well-described imagery across institutional boundaries. Although large volumes of marine imagery exist, they are dispersed across independent repositories, described using heterogeneous conventions and local access policies. This fragmentation limits reuse for machine learning, ecological analysis, and large-scale synthesis.

Several solutions have created centralised platforms to aggregate data. While valuable, these approaches rely on data duplication and central governance, which can limit participation by institutions with established archives, security requirements, or stewardship responsibilities. This work explores an alternative federated approach and articulates design criteria for an image brokerage service that enables cross-repository discovery and access without centralisation.

Rather than centralising image data, the proposed brokerage model is designed to provide a single access point that mediates discovery and retrieval across multiple repositories, allowing data holders to retain control over their assets while exposing them for analysis under agreed terms. The service is designed to operate by brokering user queries, such as spatial, temporal, and biological, across compliant repositories using shared metadata standards and interoperable APIs.

To evaluate the feasibility of this approach, a demonstrator implementation has been explored within two UK institutions: the National Oceanography Centre and the Joint Nature Conservation Committee. These pilot deployments serve as case studies for assessing how heterogeneous back-end infrastructures can be exposed through a common brokerage interface. The experience highlights the importance of accommodating institutional diversity while minimising local constraints.

An openly published API specification underpins the federated design, providing a foundation for interoperability and network integration. This is complemented by a web-native access layer aligned with existing practices, supporting discovery and retrieval of imagery without prescribing storage or database technologies. Together, these elements guide design criteria aimed at reducing onboarding effort for data providers.

Overall, this work outlines a practical design space for federated marine image access, illustrating how standards-based brokerage can balance openness with institutional autonomy. The findings contribute design guidance for developing interoperable image infrastructures that support efficient, transparent, and reproducible biodiversity analysis from marine visual data.

Session 4: Advancing Biology through Imaging: Marine Applications

Session 4: Advancing Biology through Imaging: Marine Applications

An Introduction to the Marine Biodiversity Data Portal – NI

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The Marine Biodiversity Data Portal (MBDP–NI), is a five-year DAERA Environment Fund project based at Queen's University Marine Laboratory. The aim of the project is to build an innovative web-based portal for exploring Northern Ireland's marine biodiversity. The interactive website incorporates recent as well as archive imagery and data from legacy surveys from around Northern Ireland as well as images and video from private collections. The survey sites are displayed as GIS layers on an EMODnet Bathymetry layer. The sites link through to site descriptions, photographs/video, biotopes and species lists. The species lists are linked to detailed species pages with descriptions, photographs, distribution maps on NBN Atlas and links to maps on GBIF and iNaturalist.

Photographs are edited, georeferenced and species names added in Adobe Lightroom. Videos from legacy surveys as well as recently obtained 4K videos are edited and annotated using Adobe Premiere Pro. The videos are hosted on YouTube and play in a customised viewer within the portal. Each video is scored for species present, SACFOR abundances and EUNIS biotopes. The video highlights tab allows the user to skip to species within the video.

Multi-locus species delimitation as a tool to inform image-based identification of deep-sea Antipatharia

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Black corals (Anthozoa: Hexacorallia: Antipatharia) are ecosystem engineers that are found at all latitudes and depths. Antipatharians are characterised by a distinct phenotypical plasticity, and traditional taxonomical characters are not visible from in-situ pictures, making image-based identification challenging. Ecological studies conducted through image-based surveys may thus be unreliable, particularly when standardised reference catalogues are not available, as distinct species may be treated as a single group, masking differences in habitat preferences and environmental niches.

The aim of this study is to explore the phenotypical plasticity of molecularly delimited black coral species, in order to establish whether certain gross morphological features could be species-specific and could aid image-based identification for ecological studies.

Three mitochondrial intergenic regions (IgrN, IgrW, IgrS) and a section of the nuclear ribosomal cluster (ITS1–5.8S–ITS2) were amplified from black corals collected across multiple locations of the Northeast Atlantic margin. The colonies were classified as morphospecies based on gross morphological characters visible in in-situ images. Haplotype networks were constructed for the mitochondrial, nuclear, and concatenated mito-nuclear markers, and several species-delimitation methods (ASAP, ABGD, s/m/bPTP, s/mGMYC and bGMYC) were applied to compare molecularly-delimited species and image-defined morphospecies.

Only six morphospecies consistently corresponded to delimited species. The gross pinnulation pattern seems to be a reliable character to distinguish between Cladopathidae (true bottlebrush colonies) and Schizopathidae (feather-like colonies) in the Northeast Atlantic. However, fine variations in pinnulation patterns are not always reliable for identification at the genus or species level. The colouration of the tissue does not seem to be a taxonomically diagnostic character and should not be used in defining morphospecies for image-based studies.

Overall, our results suggest that image-based classification should carefully be used to identify Antipatharia colonies at species level. Linking gross morphological characters that are observable in situ with molecularly delimited species may than be beneficial for future image-based ecological studies, and could be used as a tool improve the standardisation and reliability of species identification catalogues.

Integrating Optical and Acoustic Imaging to Improve Benthic Habitat Mapping in the Wadden Sea

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Benthic habitats of the Wadden Sea are shaped by strong tidal dynamics and complex sedimentary processes, resulting in a highly heterogeneous seabed that plays a central role in ecosystem functioning. Habitat characteristics such as sediment composition, seabed morphology, and hydrodynamic exposure strongly influence benthic biodiversity. However, capturing the spatial variability of benthic habitats and associated communities across ecologically relevant scales remains challenging using conventional sampling methods alone, particularly given the patchy distribution and partly infaunal lifestyle of many benthic species.

In this study, we apply an integrated optical–acoustic imaging approach to improve the spatial characterization of benthic habitats and associated benthic communities in the Wadden Sea. Underwater optical imagery provides detailed visual information on seabed features and enables the identification of key benthic taxa, while acoustic seabed mapping captures sediment structure and seabed morphology over larger spatial extents. The combination of these complementary datasets allows for a comprehensive assessment of habitat heterogeneity shaped by tidal processes, including sediment ripples, channel margins, and gradients in sediment type.

Our results reveal strong relationships between benthic habitat characteristics and the occurrence of habitat-associated fauna, particularly in areas exposed to high hydrodynamic energy. Distinct seabed structures and sedimentary features were consistently linked to specific habitat types and benthic assemblages. Species such as razor clams, crabs, and starfish exhibited clear spatial patterns corresponding to variations in sediment composition and seabed morphology, highlighting the importance of fine-scale habitat variability for structuring benthic communities.

By integrating optical and acoustic imaging, this habitat-oriented approach enhances the understanding of benthic ecosystem structure across broader spatial scales. These insights contribute to improved benthic habitat mapping, more robust assessments of ecosystem functioning, and informed, sustainable management of the Wadden Sea, including evaluations of habitat quality, nutrient cycling, and food-web dynamics.

Observation Per Unit Effort (OPUE): Standardising MaxN-Based Relative Abundance in Remote Underwater Video Surveys

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Remote underwater video techniques, including Baited Remote Underwater Video (BRUV) and unbaited Remote Underwater Video (RUV), are widely used to assess fish assemblages, functional trophic structure and the occurrence of rare or mobile species across marine ecosystems. Central to these approaches is the use of MaxN, defined as the maximum number of individuals of a species observed simultaneously within a single video frame, which provides a conservative and repeatable index of relative abundance while minimising double counting. Despite its widespread adoption, MaxN is typically interpreted without explicit reference to deployment duration, limiting comparability among surveys that differ in soak time or sampling effort.

Here, we propose the formal adoption of Observation Per Unit Effort (OPUE) as a standardised metric for digital underwater imagery, calculated as MaxN divided by deployment time. Conceptually analogous to Catch Per Unit Effort (CPUE) in fisheries science and Sightings Per Unit Effort (SPUE) in wildlife and marine mammal surveys, OPUE explicitly links observed relative abundance to sampling effort, thereby strengthening inference and comparability across studies. CPUE and SPUE theory demonstrates that effort-standardised indices can provide robust proxies for relative abundance when assumptions and biases are clearly articulated and, where necessary, statistically standardised.

BRUVs are particularly effective at detecting mobile predators and mesopredators attracted by bait plumes, often capturing higher functional richness than diver-based methods, while RUVs and complementary surveys tend to better represent herbivores and cryptic taxa. Detection probability for both common and rare species is strongly influenced by soak time, with studies indicating that deployments of approx. 60 minutes capture the majority of observation events, particularly for elasmobranchs and other wide-ranging taxa. Expressing MaxN relative to time explicitly incorporates these dynamics into abundance indices.

As detection improves (esp. with AI approaches) the adoption of OPUE offers several advantages: (i) improved comparability among studies with differing deployment durations; (ii) clearer alignment with established effort-based ecological metrics; and (iii) enhanced interpretability of functional and trophic patterns derived from video surveys. Adoption of OPUE, alongside transparent reporting of soak time, habitat context and survey design, would represent a practical step towards greater standardisation and analytical robustness in remote underwater video research.

Integrating eDNA Metaprobes with Camera Sled Seafloor Imagery in U.K. Offshore MPA Monitoring: A Pilot Study

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Joint Nature Conservation Committee (JNCC)[1]

The Joint Nature Conservation Committee (JNCC) uses seafloor imagery extensively in the monitoring of offshore MPAs in the U.K. Still imagery and video provide detailed information on epifauna communities and the mapping of habitats and features, respectively. Recently, JNCC conducted a pilot study to investigate environmental DNA (eDNA) sampling as a complementary approach to image-based surveys. eDNA techniques can provide high-resolution data on biodiversity from micro to macro scales and inform on assemblage composition and biological processes, potentially reducing costs and time in comparison to other sampling methods. 3D-printed “metaprobes” containing sampling gauze were mounted on a towed camera sled to collect near-seabed eDNA alongside imagery transects at the North West of Jones Bank Marine Conservation Zone, 165 km offshore from south-west England. These novel eDNA samplers are compact enough to be integrated directly into imagery platforms such as sleds and drop frames.

In this study, metaprobes filtered water and suspended particles continuously during 30-minute camera sled tows, enabling comparisons between imagery-captured taxa and eDNA detections. Additionally, eDNA from conventional sediment grab and Niskin bottle water-sampling methods were compared. Metaprobe sampling generated consistently strong marker amplification and broad taxonomic coverage across microbial, invertebrate and vertebrate groups. The metaprobes detected high species richness, reflecting the wider sampling footprint, relative to grab or Niskin bottle methods. The metaprobe approach detected a range of ecologically and conservation-relevant taxa, including mobile vertebrates that rarely appear in imagery, highlighting the value of eDNA for expanding the range of detectable taxa.

These preliminary results demonstrate that co-located eDNA metaprobes and seafloor imagery could provide more detailed data for monitoring the health of offshore MPAs. Imagery enables morphological identification of the taxa it captures, while eDNA could increase taxonomic breadth, improving detection of cryptic and mobile species.

Integrating video analysis and eDNA data to improve taxonomic identification and biodiversity assessments

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Video imagery is currently an integral part of deep-sea exploration, enabling non-destructive approaches essential for sustainable ecosystem management. However, the shift away from traditional sampling methods such as trawling and dredging has made species-level identification from in situ imagery increasingly challenging in the absence of physical specimens. While deep-sea species guides have improved imagery-based identification, identifiable in situ imagery remains limited, particularly from lower abyssal and hadal depths. Environmental DNA (eDNA) metabarcoding has emerged as a powerful tool for assessing deep-sea biodiversity, enabling species-level identification across a wide range of taxa. When integrated with video imagery, eDNA can improve taxonomic confidence in visual datasets, while imagery-based observations can in turn support eDNA interpretation by helping resolve primer and reference database limitations, together strengthening biodiversity assessment and biodiscovery.

Here, we present examples from two expeditions aboard RV Dagon to abyssal and hadal depths in the Pacific Ocean, demonstrating how eDNA and video imagery can be used synergistically to improve taxonomic resolution. Video data were collected using free-fall baited landers that recorded the seafloor for 6-8 hours, with all observed mobile fauna annotated to the lowest possible taxonomic level. Active and passive eDNA sampling was conducted concurrently using Niskin bottles, filter papers, and polyurethane foam (PUF) collectors attached to the landers. Video and eDNA datasets were analysed independently to generate species lists, which were then compared. Preliminary results indicate that small invertebrates, such as annelids that are difficult to identify from imagery alone due to size and morphological ambiguity, were consistently resolved to species level using eDNA. Conversely, video observations provided ecological and morphological context that aided interpretation of eDNA detections, particularly in cases affected by primer or reference database limitations. While conservative interpretation remains necessary, continued expansion of deep-sea barcode reference databases will further enhance the value of integrated eDNA-imagery approaches for taxonomic identification, biodiversity assessment, and biodiscovery.

Making visible the invisible: using quantitative imaging and semi-automatic annotation for the identification of microscopic infauna

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To fill the marine biodiversity knowledge gap in the benthic domain, we first require methods to reliably measure biodiversity across biological complexity and taxonomy. When we consider how long it takes the process from the collection of a specimen of a new species to its formal description, a decades-long shelf life is essentially considered, contributing significantly to the taxonomic impediment.

The MEIODYSSEA project aspires to overcome the meiofauna1 taxonomic bottleneck by leveraging cutting-edge technology and innovative tools based on imagery. The project has developed a pipeline that combines flow cytometry, high-resolution imaging and machine learning to isolate, count and identify organisms of meiofauna in a high-throughput, high-resolution, non destructive, and reproducible manner. Sediment-extracted fauna is automatically separated in microplates and imaged at low resolution by COPAS cytometer after general staining. Artificial intelligence (AI) automatically classifies the individuals, providing an initial overview of the sample biodiversity. All or specific individuals can then be selected for 2D focus stacking high resolution or 3D imaging.

Both cytometer and 2D high-resolution images can be uploaded and predicted on the EcoTaxa platform thanks to newly developed tools (COPAPP, E.Y.E.S) adapted to the meiofauna imaging pipeline. These efforts have led to the generation of reference training datasets based on automatically processed images combined with visual and manual image analysis, in order to improve classifier and develop deep-learning algorithms. The resulting nematode-specific deep feature extractor has been integrated into the EcoTaxa platform.

In parallel, MEIODYSSEA scientists aim at enlisting citizens in the process of supervised machine learning prediction provided in EcoTaxa. To this end, a new interface has been developed in Ocean Spy enabling users to contribute to the validation of AI generated annotations. In return, participants can discover microscopic benthic life and get involved in ocean exploration. This collaborative loop accelerates the review of annotations for AI models improvement and accurate image labelling. MEIODYSSEA works will ultimately result in the release of massive open-access image datasets of meiofauna contributing to marine biodiversity discovery.

1Meiofauna is a term used to describe the animals living in the sediment and ranging in size from 42 µm to 1 mm.

Assessing the impacts of litter on deep-sea ecosystem goods and services

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Deep-sea ecosystems provide essential ecosystem goods and services (such as climate regulation, refuge), but are vulnerable to anthropogenic pressures such as fisheries, litter etc. Assessing these impacts is vital for appropriate management but requires a connection between the ecology and policy. Vulnerability and sensitivity assessments (MarESA) can be used to bridge this gap, by assessing the likely sensitivity of habitats to a given pressure (sensitivity) and using ground-truthing data to assess the exposure of habitats/species to pressures (vulnerability); habitats can be assessed to investigate potential harm from anthropogenic pressures, such as litter.

Marine litter is a persistent problem and is well documented to cause harm to organisms (e.g. entanglement, smothering, ingestion). Imagery is a useful tool to quantify litter in the marine environment. Using a standardised Litter-Fauna (L-F) framework, it is possible to link these observations to biological impacts, which can then be related to potential impacts on ecosystem goods and services.

Using the SW Approaches (UK) as a case study, litter type and L-F interaction were annotated using the open-source software BIIGLE to allow quantification across different habitat types. A sensitivity and vulnerability assessment were undertaken for coral VME types. This work investigates the use of litter as a proxy to determine affects anthropogenic pressures have on the functionality of vulnerable deep-sea habitats, allowing links to be made with impacts on ecosystems goods and services.

Exploring Hidden Worlds: Multiscale Characterisation of Benthic Biodiversity and Mesopelagic Community Abundance on Stylaster Seamount in the Natural Park of the Coral Sea, New Caledonia

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Stylaster Seamount, located in the Norfolk Natural Reserve (IUCN Classif : Ib : Wilderness Area since 2023) within the Natural Park of the Coral Sea in New Caledonia, represents a compelling case study for understanding seamount biodiversity across benthic and mesopelagic realms. This study applies a multiscale approach integrating high-resolution ROV and active acoustic imagery to visually examine spatial patterns in benthic and mesopelagic community structures. ROV transects were conducted along the seamount's slopes and summit during the KANADEEP 2 expedition, yielding over 35,000 images. These were annotated using an adapted version of the Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) classification scheme via the web-based BioImage Indexing Graphical Labelling and Exploration (BIIGLE) platform, resulting in ~122,000 annotations. Benthic communities were analysed across the summit, upper slope, and lower slopes in different regions. Complementary acoustic data from the Simrad EK80 echosounder during the KASEAOPE expeditions were processed in MATECHO, an open-source tool for processing fisheries acoustic data. Preliminary results from ROV transects showed differences in both abundance and composition of benthic megafauna with cnidarians and sponges showing alternating densities in the upper slopes and summit, particularly in the northern and eastern regions, while lower slopes showed reduced densities of benthic megafauna across all regions. Acoustic profiles revealed elevated mesopelagic densities above the summit and slope regions during the day and at night, supporting potential bentho-pelagic coupling and possible 'resident' seamount mesopelagic community hypotheses. Ongoing analyses examining spatial relationships between benthic and mesopelagic communities and the importance of an adapted classification scheme will be presented. This integrated approach offers a unique overview into the ecological functioning of Stylaster Seamount's benthic and mesopelagic communities. The study provides critical baseline data for continued conservation of seamount ecosystems as a whole, within one of the world's largest marine protected areas, using a combination of imaging techniques.

Beyond Accuracy: Enhancing Seafloor Mapping through Multimodal Fusion and uncertainty aware machine learning

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Autonomous Underwater Vehicles (AUVs) are transforming seafloor mapping by enabling high-resolution surveys in remote and challenging environments. However, the volume of data generated often exceeds what could be annotated manually. We developed a tool for automated benthic habitat mapping that classifies habitats from AUV-collected images, bathymetric sonar, and side-scan sonar simultaneously, while also providing calibrated Bayesian model certainty estimates. These uncertainty estimates allow experts to identify uncertain predictions requiring review and can be used to guide future sampling efficiently.

We trained the model on annotated AUV datasets and compared its performance to models using each data source individually. Fusing multiple data types improved overall classification accuracy to 85.1%, outperforming single-source models by approximately 5%. Further, uncertainty analysis highlights remaining challenges: rare classes, such as horse mussel beds, exhibit high predictive uncertainty from limited training data, while visually confused habitats, like kelp and rock, remain uncertain due to inherent data ambiguity.

By combining scalable classification with principled Bayesian uncertainty estimates, our approach supports monitoring strategies and helps prioritise expert review through identifying areas of high uncertainty. We release our full pipeline as an open-source Python library, multimodal-auv, including all model weights and code.

ML-Assisted Analysis of Extended-Duration Imaging Using Long-Range AUV: Application to Siphonophore Diel Vertical Migration

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Diel vertical migration (DVM) of fragile gelatinous zooplankton such as siphonophores is difficult to quantify due to limited observational capability in the deep ocean and daylight-biased ROV sampling. To address these limitations, we developed a long-duration imaging payload for MBARI's long-range autonomous underwater vehicles (LRAUVs) designed for continuous, low-disturbance, high-resolution video acquisition during multi-day mesopelagic deployments. The payload integrates autonomous operation, power-efficient illumination, and high-capacity onboard data storage to enable continuous video collection for more than 72 h. The LRAUV is designed to support extended fixed-depth or depth-stratified sampling while minimising behavioural disturbance and operational intervention. To evaluate platform capability and data-processing scalability, the imaging system was deployed in Monterey Bay, producing five near-continuous 24-h video time series at 250 m depth between April and June 2025. The deployments generated over 120 h of high-resolution video requiring automated processing to enable quantitative biological analysis. Video data were analysed using a machine-learning object detection pipeline based on YOLO11 that was trained to identify siphonophore taxa. Detection outputs were integrated with multi-object tracking (ByteTrack) to generate taxon-specific encounter time series and reduce manual annotation requirements. This workflow enabled automated extraction of organism presence and behavioural observations from large-volume video datasets, demonstrating a scalable framework for processing long-duration midwater imaging surveys. The siphonophore Nanomia dominated observations and exhibited clear diel vertical migration, with nocturnal ascent beyond the sampled layer. Larger siphonophores such as Apolemia and Praya dubia were rare and largely depth-stable, while calycophorans showed modest crepuscular and midday abundance peaks. Encounter rates displayed consistent diel patterns alongside day-to-day variability, illustrating the importance of sustained observational coverage. These results demonstrate that long-range autonomous imaging combined with computer vision analysis enables scalable, minimally invasive observation of fragile pelagic organisms, and supports extraction of taxon-specific behavioral time series. Future integration of depth-stratified sampling, acoustic sensing, and environmental measurements will further enhance the capability of autonomous imaging platforms for quantitative midwater ecosystem studies.

Illuminating Deep-Sea Biodiversity: Multi-Tool Deep Sea Imaging and a Pacific-Wide Synthesis of Nautilus Observations

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The National Geographic Pristine Seas program is driven by a mission to support the establishment of national-scale marine protection globally. To provide comprehensive biodiversity data that are foundational for informed conservation decisions, the program has developed a robust deep-sea research initiative focused on exploring the world's remote underwater environments. Using a multi-method technological toolkit, including baited deep-sea dropcams, a remotely operated vehicle (ROV), a submersible, and deep sea environmental DNA (eDNA) methods, the program gathers critical data to illuminate the habitats, biodiversity, and ecology of a world where existing information is sparse. As the deep sea remains one of the least understood components of marine ecosystems, our work aims to fill critical knowledge gaps in this realm where information is lacking, for application towards national marine conservation decision-making.

We highlight the program's capabilities through a synthesis of the chambered nautilus (Nautilus spp.), a character of the deep sea that is as emblematic as it is enigmatic. We present a comprehensive exploration of over 30 in situ observations encompassing at least four nautiloid species across the Pacific, including sites in Palau, Papua New Guinea, the Solomon Islands, Vanuatu, Rotuma, and Fiji. By integrating datasets from multiple imaging and observation tools, we provide updated insights into the vertical and geographic distribution of these "living fossil" organisms. The synthesis examines patterns of associated water characteristics measured by on-board sensors, shares novel imagery of behavior driven by physiological limitations, and documents habitat associations of an early-life stage individual via non-attractive (i.e. unbaited) observation methods. These findings demonstrate how an integrated, multi-tool approach to deep-sea research can translate novel imagery into ecological insights that provide a scientific foundation to inform and inspire the conservation of fragile deep-sea ecosystems while bringing to life a world long hidden from sight and mind.

Towards Trustworthy AI for Deep-Sea Video Analysis: A Human-in-the-Loop, Foundation-Model–Based Pipeline and Its Ecological Evaluation

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OceanX[1]

Deep-sea biodiversity assessments rely heavily on manual analysis of remotely operated vehicle (ROV) and submersible video imagery. While these expert-led methods are scientifically robust, they remain time-consuming and thus difficult to scale to the growing volume of high-resolution deep-sea imaging data. Artificial Intelligence (AI) could streamline video analysis, but its application in the deep sea has been limited because (1) traditional AI approaches require large volumes of training data, often unavailable in poorly explored deep-sea areas, and (2) their predictions can contain bias and errors, raising concerns about the validity of downstream ecological insights.

To address these challenges, we present an AI pipeline under active development that is specialized for video analysis of deep-sea environments. The pipeline combines recent advances in foundation models, with human-in-the-loop workflows to enable accurate video analysis under limited supervision. Unlike traditional deep learning approaches, foundation models can better generalize to previously unseen environments and taxa, reducing the amount of domain-specific training data required. Expert supervision is integrated through a dedicated mobile application that enables rapid validation, correction, and improvement of the model, in real time while at sea. This design aims to minimize expert annotation time while preserving AI accuracy and generalizability.

In parallel, we are conducting a rigorous evaluation of whether this AI pipeline can be trusted for ecological and conservation-relevant products, focusing on species distribution models (SDMs). Using video data collected during OceanX's Digital Deep Expedition at the Nola Seamount (Cabo Verde), we compare SDMs derived from expert-only video annotations with SDMs derived from AI-assisted annotations. Rather than evaluating AI performance solely at the level of image detections, this approach enables an end-to-end assessment of the pipeline, from video analysis to spatial ecological modelling. This allows us to assess whether AI-assisted workflows, increasingly advocated in the marine imaging and ecological literature, can in practice be trusted to support ecological interpretation and conservation decision-making.

Together, this work aims to advance marine imaging workflows through a new AI-based video analysis pipeline while exploring whether emerging AI methodologies preserve conservation-relevant ecological insights.

FathomVerse: Gaming for Ocean Exploration

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In order to fully explore our ocean and effectively steward the life that lives there, we need to increase our capacity for biological observations. FathomVerse, a mobile game designed to inspire a new wave of ocean explorers, teaches casual gamers about ocean life while improving machine learning models and expanding annotated datasets to accelerate processing of imagery for biological understanding. FathomVerse taps into the gaming community – where 70% of the 3 billion gamers say they care about the environment – with innovative gameplay and rich graphics that draw players into the captivating world of underwater life and cutting-edge ocean science.

In the two years since launching on May 1, 2024, 50k players from 199 different countries have generated >29M annotations that are used to generate consensus labels and retrain machine learning models, resulting in >100k newly annotated images published to the open-access FathomNet Database. While data contributions to FathomVerse have mostly come from large research institutions (e.g., MBARI, SOI, NOAA, and others), successful community science platforms like iNaturalist and eBird have demonstrated the power of aggregating data from a variety of enthusiast sources.

We have developed FathomVerse ID, a mobile app that lets users identify ocean animals in their own images and contribute those photos to science. Users can run FathomNet models on their underwater images, and contribute collections to FathomVerse and FathomNet Database for annotation and model retraining, forming a feedback loop in which shared data strengthens the very models used to create identification proposals. Here we share our process of designing FathomVerse ID, discuss early lessons in conducting a global-scale community science effort, and touch on ways for researchers to expand their reach with FathomVerse and FathomVerse ID. Through these FathomVerse apps, we can engage global audiences, increase public awareness, and inspire empathy for ocean life.

POSTER ABSTRACTS

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Real-time machine learning visualization and data logging during deep-sea ROV dives

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We describe the development and shipboard deployment of a real-time machine learning (ML) detection workflow that enables live visualization and logging of object detections during MBARI's deep-sea ROV operations. The system is based on a modified Ultralytics real-time inference pipeline, adapted to output bounding boxes rendered on a transparent background, allowing seamless overlay onto live video displays within the ship's control room. This approach enables detections to be viewed simultaneously across multiple monitors without interfering with existing video workflows. In parallel, detection outputs can be logged on a separate computer running the same model, decoupling visualization from data capture and minimizing performance impacts on shipboard systems.

We outline the system architecture, model format, hardware configuration, and software modifications required to support real-time inference at sea and discuss practical considerations and lessons learned from operational testing using the ROV Doc Ricketts aboard the R/V David Packard. This work demonstrates a scalable, low-overhead approach for integrating ML-assisted video analysis into active research cruises, enabling human-in-the-loop decision-making during deep-sea exploration and data collection.

Adding images to underwater laser scans of cold-water coral reefs for high resolution coloured 3D reconstructions.

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Cold-water corals are important habitat-forming species which create complex frameworks inhabited by a diversity of associated species.To understand the functional role that this fine-scale habitat complexity plays in driving biodiversity, and how this may vary over time and space, we need to map these habitats in ultra-high resolution. Structure-from-motion (SFM) allows three-dimensional reconstructions from overlapping images or video frames, creating coloured point clouds which can be used for automated segmentation of cold-water coral and sponges. Previous work showed that the RGB color channels were useful features to inform classification, but were strongly influenced by the distance between the camera and the target.

In 2023, as part of the Schmidth Ocean Institute expedition FKt20230918, we employed a Voyis Imaging MicroInsight laser scanner mounted on a remotely-operated vehicle (ROV) to scan cold-water corals (300m in depth) at 50Hz with concurrent 2Hz still imagery collection. Over 79,000 images were collected across three ROV dives. Every third image was used to build SfM reconstruction in the software 3DF Zephyr following colour-correction in Voyis' ViewLS software, and registered to the ultra-high resolution laser point cloud.The combined use of the laser and imagery enabled retention of color in reconstructions. The laser was particularly well suited to capturing negative space such as between coral polyps and branches or unconsolidated material such as aggregations of organic matter. The reconstructions will be used to extract measures of fine-scale habitat complexity to assess its influence on benthic biodiversity.

Laser-independent morphometrics in Cold-Water Corals

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Morphometric analyses of deep-sea habitat-forming species are often limited by the lack of consistent metric references in underwater imagery, which strongly reduces data availability and hinders robust ecological assessments.

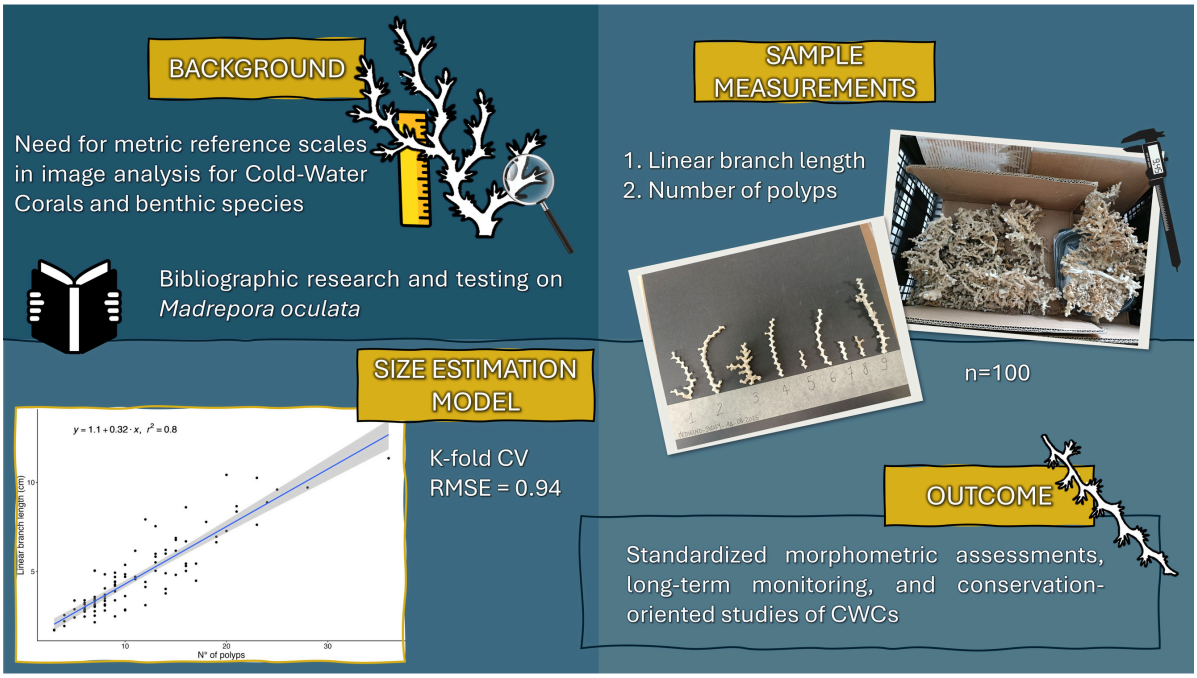
Cold-Water Corals (CWCs) are slow-growing, longevous habitat-forming species that support high biodiversity and contribute to global biogeochemical cycles. Given their ecological importance and vulnerability to anthropogenic impacts, CWCs are indirectly protected through Sites of Community Importance designated for Annex I habitat 1170 (Reefs; sensu 92/43/EEC) and addressed within national monitoring programmes (MSFD, 2008/56/EC). In this context, morphometric characterization of CWC populations and their spatial distribution is essential to support effective monitoring and conservation strategies.

This study presents an integrated methodological framework applied to the CWC Madrepora oculata to extract accurate morphometric information from image datasets when colonies fall outside the laser-calibrated focal plane. This framework uses an indirect method to infer colony size from polyp counts, allowing each colony within an image to be “self-scaled”.

The approach is grounded in the hypothesis that the number of visible polyps along a branch represents a proxy for branch linear length and, by extension, colony size. We measured both linear branch length and polyp count by using M. oculata samples (n = 100) collected via different Mediterranean scientific surveys. We then fitted a simple linear regression, using polyp count as the predictor and linear branch length as the response.

Our model showed a statistically significant relationship between polyp count and branch length (p-value << 0.05) and a high goodness-of-fit ($R^2 = 0.79$). The model was validated by k-fold cross-validation (RMSE = 0.94). We then tested the overall robustness of the approach under real field conditions by using high-resolution 6K ROV images in which laser beams were at a known distance and pointed at the colony. Independent estimates derived from polyp counts closely matched laser-calibrated measurements, confirming the approach's reliability.

Although tested on M. oculata, decoupling morphometric analyses from the strict requirement for laser-scaled imagery unlocks large volumes of previously unusable ROV data and may offer a basis for future extension to other CWCs, enabling standardized morphometric assessments, long-term monitoring, and conservation-oriented studies.



Autonomous Reef Survey and Species Classification using RGB and Multispectral Underwater Imaging with Deep Learning

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University of Limerick[1], MERC Consultants Ltd[2], CRIS[3]

Reef habitats play a crucial role in marine biodiversity but are traditionally monitored using diver based visual surveys or manually operated equipment, which are time-consuming, costly, operationally challenging, and subject to observer bias. This work presents an autonomous marine imaging workflow for reef surveying and classification in close offshore coastal environments, with a focus on automating data acquisition and analysis to support marine conservation efforts off the coast of Ireland.

Image data were collected using a BlueROV equipped with a high-resolution camera system and artificial lighting, operating at depths of approximately 10–20 m along shallow reef areas off the coast of Ireland. Survey missions were executed as repeatable autonomous transects with fixed image capture intervals and a controlled vehicle altitude, allowing consistent image overlap across the survey area. The acquired imagery was processed into georeferenced photomosaics using dead-reckoning-based navigation.

Figure 1: BlueROV system modified with the custom camera and lighting configuration used for autonomous reef data acquisition.

Both RGB and multispectral imagery are acquired to investigate the strengths and limitations of each method. While RGB imagery is expected to perform well for visual discrimination, multispectral data are explored for their potential to reveal classification for spectral differences not apparent in the visible range. Collected imagery is processed into georeferenced photomosaics using dead reckoning.

The resulting mosaics are used as inputs for a supervised learning pipeline trained on previously labelled reef imagery. A Convolutional Neural Network (CNN) is employed to automatically classify specified species, enabling scalable, repeatable, and high-resolution spatial mapping of reef environments while reducing reliance on manual interpretation.

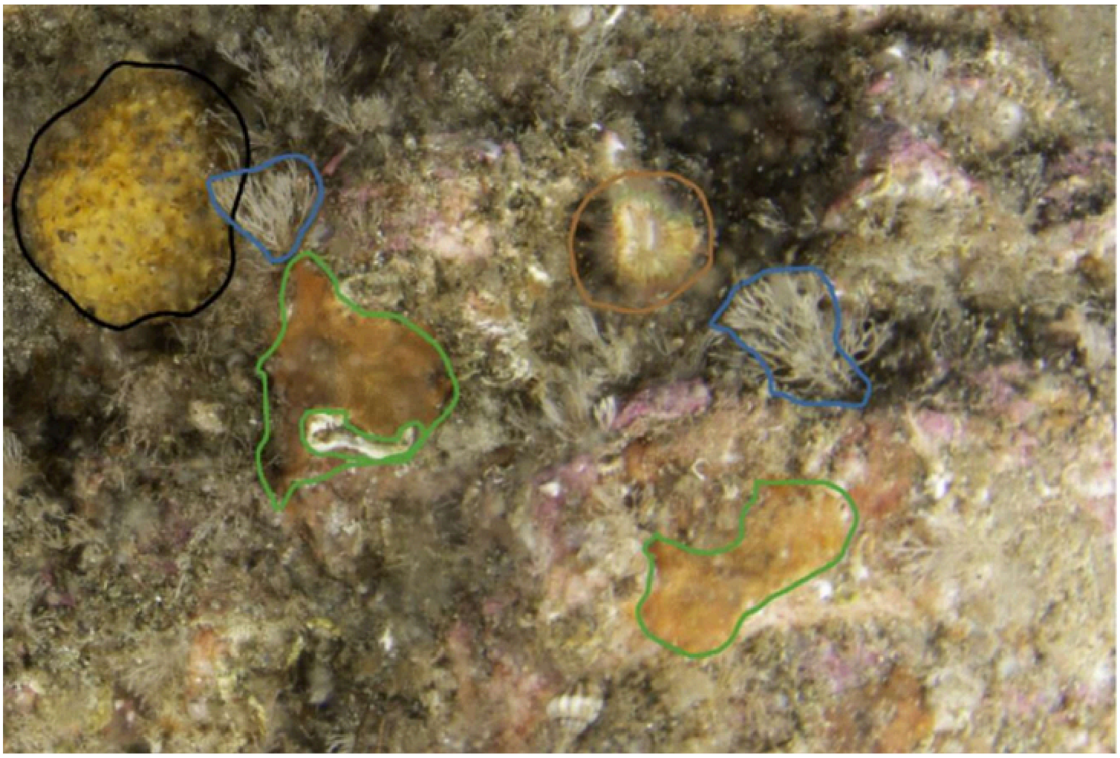


Figure 2: Segmentation mask illustrating specific species used to train the Convolutional Neural Network.

Inter- and intraobserver biases in biodiversity monitoring from seabed photographs, and their reduction with independent classification review

Durden, Jennifer M.[1]; Curtis, Emma J.[2]; Slavík, Petr[1]; Putts, Meagan[3]; Bingo, Sarah R.D.[3]; Moriwake, Virginia[3]; Bett, Brian J.[1]

National Oceanography Centre, UK[1], University of Southampton, UK[2], University of Hawai'i at Manoa, USA[3]

Biodiversity is increasingly monitored using photography, and consistency in making observations in photographs is important to generating reliable biodiversity metrics. Bias has been shown to be ecologically significant between observers, but there are few studies that compare inter- and intraobserver biases.

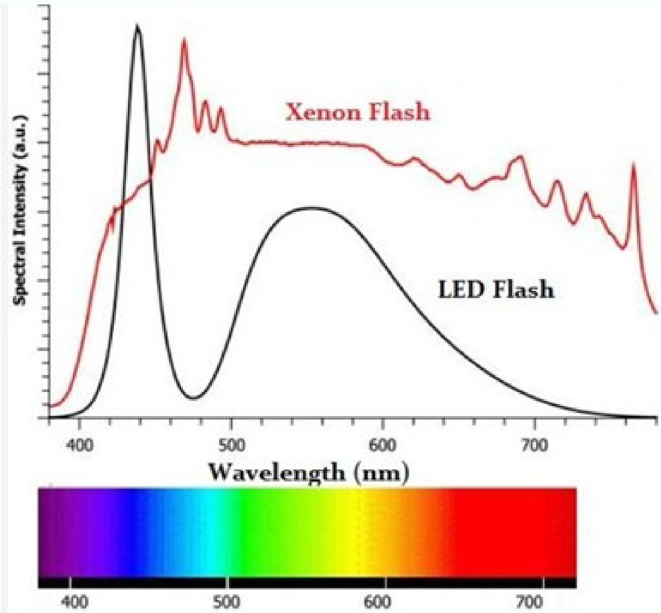
We evaluated the intra- and interobserver variation in detecting and classifying megafaunal specimens in seafloor photographs by direct comparison in repeated subsets of images. We found that interobserver consistency was lower than intraobserver consistency, but both types of variance were substantial: observer consistency in the interobserver comparison was 36% and 47-64% in the intraobserver comparisons. Consistency was worse in the detection of specimens than in their identification (classification), with observers each missing 32-51% of specimens in one pass of an image and repeatably finding only about two-thirds of specimens, whereas only 4-37% of detected metazoans were initially classified incorrectly on the first pass. These inconsistencies in detection and classification resulted in diverging estimates of density and morphotype richness between observers.

We also assessed the impact of the re-evaluation of identifications by an independent expert, a common quality control step. This revision changed the identifications of large proportions (~40%) of specimens and resulted in substantial improvements in classification consistency (16 – 20 percentage points).

Finally, we make recommendations for reducing observer bias in detection and classification, and for recording quality control actions and their results.

Broad-Spectrum Xenon Strobe Lighting for Improved Benthic Still-Image Colour Fidelity

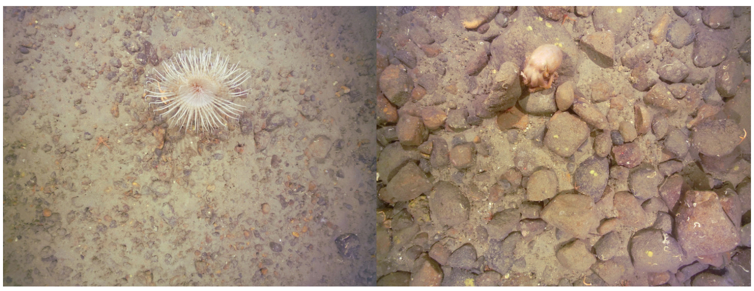
Donohue, Gavin; Donohue, Keiron



High-quality benthic still imagery is central to global ocean observation, yet underwater lighting options remain biased toward continuous illumination and asset-inspection use cases. Most commercially available “strobes” for subsea work are high-power RGB LED systems whose spectral power distribution is dominated by a pronounced blue peak. Increasing output typically amplifies the blue channel disproportionately, which can reduce colour fidelity and compress diagnostically important hues (cyan–yellow–orange–red) needed for reliable species identification.

We propose the development of a camera-synchronised xenon strobe optimised for benthic ecology. Xenon flash emission provides a broader and more even spectrum compared with RGB LED strobes, supporting more natural colour rendering in still images. In addition, xenon’s ultra-short flash duration enables exceptionally high instantaneous peak output (high effective luminous flux per unit stored energy), improving motion freezing and sharpness while allowing operation at lower ISO and smaller apertures.

This work will outline the rationale and practical design considerations for a xenon system (energy storage, recharge management, thermal control, and integration with DSLR/mirrorless triggers).



AUV-Based Visual Habitat Mapping for Standardized Marine Imaging

Barnhill, Kelsey Archer[1]; Galtung, Kristin[1]; Navjord, Caroline[1]; Christiansen, Kristoffee[1]; Nordøy, Fredrik[1]; Fossum, Trygve Olav[2]

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Visual habitat surveys are essential for documenting vulnerable marine ecosystems and species for environmental impact assessments, monitoring programs, and regulatory decision-making. Traditionally, remotely operated vehicles (ROVs) have been the primary platform for such work, however, autonomous underwater vehicles (AUVs) provide methodological advantages for standardized, and repeatable high-quality visual data acquisition.

Aspecto AS applies autonomous survey platforms and established data processing workflows to acquire high-resolution seabed imagery and habitat information that is processed to attain large-scale georeferenced image mosaic maps. For visual habitat mapping, we deploy the Coastal ROV AUV Explorer (CORAX) developed by Skarv Technologies AS, designed for close-range optical and acoustic surveys with precise navigation, terrain-following, and autonomous operation.

AUVs such as CORAX operate at a stable altitude and speed relative to the seafloor and use downward-facing optical high-resolution cameras, resulting in consistent image angle and quality, accurate size measurements, and predictable overlap between frames. This, combined with state-of-the-art inertial navigation, allows us to attain georeferenced high-quality photomosaics suitable for quantitative habitat analyses. The consistency of AUV-derived datasets also enhances comparability across surveys and time, strengthening their application in long-term monitoring and change detection.

Beyond 2D photomosaics, ongoing work includes the development of turbidity-resilient 3D photogrammetric workflows that use overlapping imagery and precise positioning to reconstruct habitat structure in three dimensions. These products provide additional metrics that support ecological interpretation of 3D habitat complexity and assessment of seabed condition.

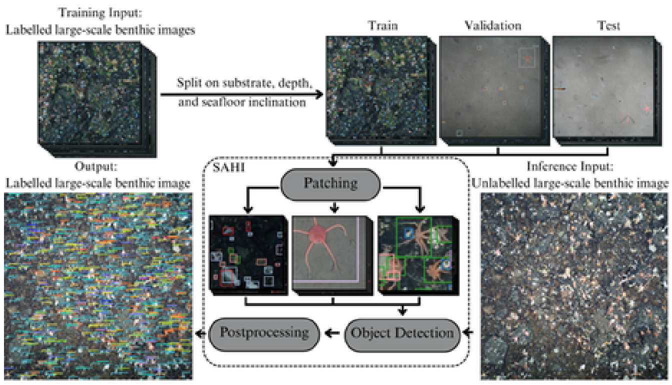
Overall, our experience shows that AUV-based visual habitat surveys, in demanding and steep underwater coastal terrain, provide repeatable, well-anchored spatial data that complement existing ROV approaches and offer a reliable alternative for many survey objectives.

Automated Detection of Benthic Organisms in High-Resolution In-Situ Imagery

Trotter, Cameron[1]; Griffiths, Huw[1]; Ming Khan, Tasnuva[1]; Whittle, Rowan[1,2]

British Antarctic Survey[1] and University of Cambridge[2]

Monitoring Antarctic benthic biodiversity is essential for assessing ecological change under climate-driven pressures. Such monitoring is commonly conducted using high-resolution in-situ imagery; however, manual annotation of these data is time-consuming and requires specialised expertise, thereby constraining large-scale ecological analyses. We present a tailored object detection framework (Fig. 1) for the detection and classification of Antarctic benthic organisms in high-resolution towed camera imagery.



The proposed framework is designed to address key challenges inherent to marine ecological imagery, including limited annotated data availability, substantial variation in organism size, and complex, heterogeneous seafloor environments. It integrates resolution-preserving image patching, spatial data augmentation, model fine-tuning, and post-processing using Slicing Aided Hyper Inference to improve detection performance in large, high-resolution scenes.

We evaluate and benchmark multiple state-of-the-art object detection architectures and demonstrate strong performance in the detection of medium- and large-sized organisms across 25 fine-grained benthic morphotypes, exceeding the taxonomic resolution reported in comparable studies. While the framework shows robust results for common and visually distinct taxa, the detection of small and rare organisms remains challenging, reflecting persistent limitations in current object detection architectures and the scarcity of representative training data.

We further explore the use of the framework as part of a human-in-the-loop review process, whereby backlogged images are first processed by our framework, with resulting organism identifications reviewed by a human taxonomic expert. Any edits are returned to the model, facilitating updates to its worldview. This approach helps mitigate performance degradation arising from changes in environmental conditions, imaging platforms, or organism assemblages, a problem known as concept drift.

Our work provides a scalable and extensible foundation for machine-assisted, in-situ monitoring of benthic biodiversity in Antarctica and beyond. By reducing reliance on manual annotation and enabling analysis at greater spatial and taxonomic resolution, the proposed framework supports future research aimed at understanding benthic ecosystem structure and change.

To aid the community, we release our framework's code fully open-source, alongside the first publicly available computer vision-ready dataset for benthic biodiversity monitoring in the Weddell Sea.

The Community Fish Detector: A Collaborative Approach to Building a Generalizable Fish Detection Model for Marine Imaging

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OceanX[1]

Marine imaging technologies generate rapidly growing volumes of visual data. Artificial intelligence (AI) has the potential to streamline the analysis of these datasets, reducing manual annotation effort. However, despite significant progress in computer vision, the marine domain still lacks a broadly applicable fish detection model that performs reliably across different environments and taxa. As a result, research groups often develop dataset-specific and task-specific AI models, leading to fragmented solutions that are costly to build, difficult to maintain, and poorly transferable across projects.

To address this gap, we present the Community Fish Detector (CFD), an open-source object detection model trained to detect a single, universal class, “fish”, across highly diverse visual domains. CFD was developed through a community-led effort, in which contributors worldwide collaborated to compile, standardize, and process fragmented marine datasets. This collective effort resulted in the Community Fish Detection Dataset, a large-scale image dataset comprising over 1.9 million images and 935,000 annotated fish instances, aggregated from more than 30 open datasets. The dataset adheres to established metadata and annotation standards, promoting interoperability, reuse, and future expansion.

We open-sourced both the dataset and the trained model, providing researchers, conservation practitioners, and policymakers with tools to scale AI-enhanced image analysis and integrate automated fish detection into existing marine imaging workflows. Beyond the model itself, this work demonstrates how community-led collaboration can effectively overcome data fragmentation and lower the barrier to building broadly applicable AI tools. We share insights from this project to inform similar collaborative efforts, promoting collaboration and the development of scalable, standardized tools for marine imaging.

iSEA: Intelligent Seafloor & Animal Image Annotator

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Oceanographic Institute of the University of São Paulo[1]

Artificial intelligence (AI), particularly computer vision algorithms like YOLO (You Only Look Once) and SAM (Segment Anything Model), has become standard for automated organism detection and segmentation. However, the complexity of AI implementation remains a barrier to accessibility for non-specialist researchers, limiting its widespread adoption in marine biodiversity studies. This project presents iSEA (Intelligent Seafloor & Animal Image Annotator), an interactive graphical user interface integrated with AI for automated detection and classification of seafloor and marine fauna in underwater videos.

Developed in Python, iSEA combines the YOLO and SAM algorithm with an intuitive interface that allows researchers to train their own custom models. This tool reduces analysis time while improving dataset quality through human-in-the-loop refinement. The system also includes real-time processing for its use aboard research vessels, intending to be an active decision-support tool during expeditions. A seafloor classification module will be developed in collaboration with GEOMAR's Data Science Unit, significantly expanding the tool's analytical capacity beyond fauna detection.

This module will enable dual-mode operation, allowing researchers to analyze organisms (fauna detection) and characterize the physical habitat (seafloor classification) within the same video transect. The platform will be tested using ROV footage from two contrasting ecosystems: deep-sea coral banks in Brazil's Campos Basin and shallow benthic habitats in Antarctica's Martel Inlet. Comparative statistical analyses (nMDS, ANOSIM) will assess differences in community composition between AI-assisted and traditional manual annotations across taxonomic groups. The classifier's performance will be evaluated by the F1-score Page 2 of 3 and the confusion matrix. Completing the evaluation, the distribution of confidence scores by class will be inspected graphically to identify patterns of uncertainty and robustness of the model.

Designed to be user friendly, this tool bridges the gap between technical AI knowledge and practical marine science applications, enabling researchers without programming expertise to leverage AI. The outcome is a functional system that significantly accelerates image analysis, ultimately enhancing conservation strategies for vulnerable ecosystems.

Underwater Organism Tracking in Video Footage through use of Computer Vision and Deep learning

Cross, Eleanor[1]; Bazazian, Dena[1,2]; Howell, Kerry; Shanks Katie[3]

University of Plymouth[1], Plymouth Marine Labs[2], University of Exeter[3]

Marine ecosystems across the globe are under threat due to anthropogenic impacts like overfishing, deep sea mining, ocean acidification and more. Surveying these habitats gives researchers a better understanding of the organisms living there and this information is crucial to creating effective legislation for the protection of these areas. In recent years, use of underwater video cameras has become an increasingly common research method for marine biodiversity surveys due to their cheap, safe and non-invasive nature. However, organisms in this footage must be counted and identified before the data can be used for research, requiring expert taxonomists to engage in time-consuming manual annotation. The use of computer vision and deep learning models to automate annotation of video footage is a possible solution to this problem.

Some video tracking models have been used in marine research, but these are mostly outdated by computer science standards and have persisted due to the fact they are more easily accessible to those unfamiliar with advanced coding. In this project, three video tracking models are compared, highlighting the pros and cons of each. The target organisms selected for this study were black and octocorals, due to their status as and indicator species for overall health of deep-sea environments.

The first model selected, YOLO, is highly accessible but uses an outdated video tracking method. The second and third models are based on Siamese networks and transformer-based methods, which have shown promise in other areas of video tracking but are more complex to implement. The results of this comparison will ultimately be used to inform the creation of a model tailor-made for underwater video tracking which will also be accessible to ecologists with limited coding knowledge. This will contribute to the advancement of the field of underwater video tracking and a possible solution to the bottleneck that manual annotation creates in research.

BenthicAI: Seeing What Burrows — Image-Based Detection of Elusive Benthic Fauna

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GEOMAR Helmholtz Centre for Ocean Research[1], Alfred Wegener Institute (AWI)[2]

Surveying benthic organisms that retreat into the sediment remains a major technical challenge for optical seafloor observations. The razor clam Ensis exemplifies this problem: individuals burrow deeply when disturbed, rendering conventional sampling and contact-based survey methods ineffective and biasing observations toward juvenile specimens.

Conventional benthic surveys typically rely on grab sampling, coring, and hydroacoustic mapping, which disturb the seafloor, provide limited spatial coverage, or lack the resolution to resolve small-scale biological features. Although underwater imaging has increasingly been used to complement these approaches, reliably detecting partially buried and behaviorally evasive organisms under highly dynamic environmental conditions remains challenging. This work presents an imaging- and AI driven survey approach designed to detect such evasive benthic organisms without physical interaction.

Optical imagery acquired using remotely operated vehicles (ROVs) is used to develop and validate an AI-based detection pipeline, with the workflow designed for future deployment on autonomous underwater vehicles. A YOLO-based object detection pipeline was developed to identify Ensis presence based on distinctive visual features at the sediment surface, such as paired siphon openings. These features enable detection without triggering a behavioral response and form a robust visual target for automated analysis.

Beyond detection, we investigate integrating image-based observations into spatially consistent products. Image sequences are processed using photogrammetric methods to generate georeferenced orthomosaics and local 3D seabed reconstructions. This enables detections to be referenced within a common geometric framework and allows relative size measurements that can serve as inputs for biological analyses.

Particular emphasis is placed on the challenges of imaging in the North Sea, where strong currents, high suspended particle loads, and variable illumination significantly affect image quality.

The presented workflow explores how AUV-based imaging combined with deep learning and 3D reconstruction can generate reproducible, non-invasive survey data under highly dynamic environmental conditions. By focusing on the technical foundations required for reliable image-based detection and spatial referencing, this contribution provides a methodological basis for complementary ecological and habitat-mapping studies.

Building a machine learning-aided video annotation workflow in concert with MBARI's Video Annotation and Reference System (VARS)

Jacobsen Stout, Nancy[1]; Lundsten, Lonny[1]; Walz, Kristine[1]; Barnard, Kevin[1]; Sainz, Giovanna[1]; Schlining, Kyra[1]; Lemon, Larissa[1]; Bassett, Megan[1]; Schlining, Brian[1]

Monterey Bay Aquarium Research Institute (MBARI)[1]

The Video Annotation and Reference System (VARS) is a cornerstone of MBARI's strategic roadmap—delivering tools, techniques, data, and visual products to support researchers and developers at MBARI and beyond. Since the late 1980s, all deep-sea videos from our ROVs have been archived and expertly annotated to capture the biological, geological, and environmental elements as well as experimental work recorded during these surveys.

More recently, our team has focused on three major challenges:
(1) curating an exponentially increasing amount of imagery data,
(2) integrating automated technologies to assist our expert human annotators with processing those data, and
(3) enabling more effective and broad dissemination of both the technology and the observational data.

Digitization of our entire 29,000-hour video archive in combination with rapid advancements in machine learning (ML) technologies within the last several years has propelled these efforts forward. Building on four decades of experience in deep-sea animal expertise, video annotation, data management, and software development—and a requirement to maintain human-quality annotations—we have established a framework that accommodates the entire video annotation workflow, from video file creation to machine-assisted annotation to broad dissemination of these one-of-a-kind assets. Here we present an overview of our journey including how we manage our video library, leverage existing VARS data to create ML training data (1.5 million localizations to date), train and evaluate ML models, and develop custom ML tools that seamlessly integrate into the VARS annotation workflow. Originally developed for core ROV videos, we show how this workflow has been successfully utilized for visual data from other collection platforms (e.g., AUVs, towed cameras, still image platforms, stationary observatories).

With these components in place, we now embark on our final challenge of revitalizing our data dissemination tools, including forthcoming updates to our external VARS Query and Deep-Sea Guide (DSG) applications. Looking ahead, prototype development of several complementary ML tools, including tools for real-time ML visualization and novel visual similarity searches, has also begun. This work provides the foundation for further iterative improvements in automated video annotation workflows necessary to sustain and expand robust observational datasets critical for monitoring and understanding ocean health.

Training a marine organism detector with point annotation survey data

Doig, Heather[1]; Pizarro, Oscar[1]; Williams, Stefan[1]

University of Sydney, NTNU[1]

Object detectors are useful in identifying the presence and abundance of marine organisms with distinct boundaries in benthic imaging surveys. Fully supervised object detector training requires images with every instance of a visible object annotated with a labelled bounding box. The time required to annotate all object instances with a bounding box is much higher than for weaker annotations, such as a point or scribble on the object, or for annotating only a subset of instances.

Labelling point annotations, placed randomly or in a grid arrangement, has been popular for statistical measurement of benthic coverage and biodiversity indicators. We present a new training method for a marine organism detector that uses labelled points from previous point annotation surveys. The sparse point annotations are converted into bounding boxes using the CLIP language-vision model as a zero-shot classifier, followed by box refinement using SAM. The generated sparse bounding box annotations are then used to train an object detector.

The pipeline is demonstrated using three marine species: long-spined urchins, red cup sponges and true anemones. The process offers a novel approach to using available legacy point annotations to detect specific marine species, thereby reducing human annotation effort.

Megalodon object detection model applied with BIIGLE annotation software for biodiversity assessment of CWC reefs

Marcayata-Vaca, Esther[1,3]; Command, Rylan[2]; Banks, Stuart[3]; Robert, Katleen[1]

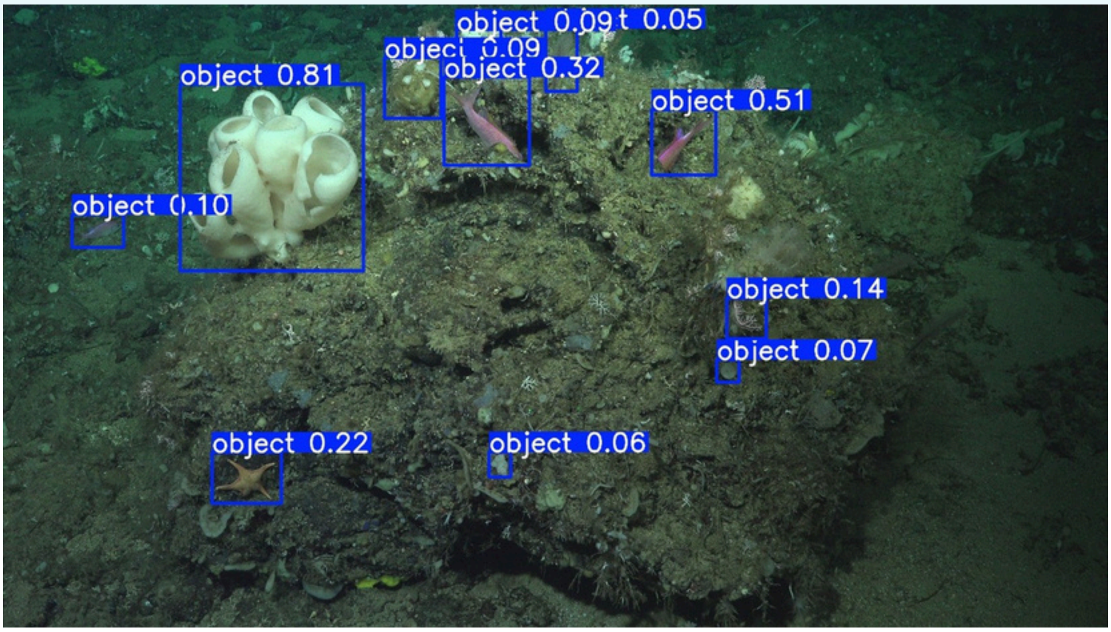
Memorial University of Newfoundland, Marine Institute of Memorial University of Newfoundland[1], Fisheries and Oceans Canada, 80 East White Hills Road, St. John's, Canada[2], Charles Darwin Research Station, Charles Darwin Foundation, Santa Cruz, Galapagos, Ecuador[3]

Extensive video and image datasets from scientific expeditions present significant challenges during data analysis and are a recognized bottleneck between data acquisition, scientific output, and conservation applications, as one hour of video may require several hours to analyze. Imagery analysis is usually performed through annotation software that allows species identification and labelling. Recently, the use of bounding boxes as a tool for identification has become common, given the potential to use the data to train new deep-learning object detection models.

In deep-sea ecosystems, where harsh conditions limit available methodologies, underwater imagery is an essential data collection tool. These challenges are amplified in poorly studied regions, with limited baseline information, highlighting the need to assess machine learning performance under limited training data conditions. To tackle this problem, we developed and tested a linking code between the object detection model Megalodon and the BIIGLE annotation software.

Megalodon, developed by MBARI and trained with FathomNet information, marks a new era of data analysis in the marine field. The use of the model linked directly to the image and video annotation software BIIGLE (BioImage Indexing, Graphical Labeling and Exploration) reduced the time required to draw bounding boxes in images during the annotation task.

This approach was applied to a subset of benthic imagery from the "Cacho de Coral" seamount in the Galápagos Islands, Ecuador. The use of the model drastically reduced annotation time, as manually drawing 18,228 bounding boxes took 3 months to complete. With the use of the Megalodon model, 14,679 bounding boxes have been drawn in ~35 minutes, giving a time frame of ~1.7 seconds per image to be analysed. Despite the strong performance of the Megalodon model across rocky, soft, and mixed substrate habitats around the seamount, object detection of certain taxa, such as sponges, bryozoans, and hydroids, remains challenging. As a result, manual review and annotation are still required.This tool is recommended as a good initial step in the analysis stage. Although the FanthomNet database has limited representation from the Tropical Eastern Pacific, the Megalodon model still shows much potential to facilitate benthic image analysis for underexplored regions.


object 0.09
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object 0.10
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object 0.07
object 0.22
object 0.06

NorthSea3D – A tool for biovolume/biomass measurements on offshore structures.

Halpin, John E.[1]; Marlow, Joseph[1]; Wilding, Thomas A.[1]

Scottish Association for Marine Science, Oban, UK[1]

Man-made structures (MMS) are common in the marine environment and with the introduction of renewables, such as offshore wind power, are becoming more so. The siting of hard and often morphologically complex substrates in what are typically soft-sediment environments, and their subsequent epibenthic colonisation with epibenthic species, results in the formation of what are essentially de-facto artificial reefs. Understanding the ecosystem effects of these MMS is a research priority.

A knowledge gap exists around the productivity of these marine growth communities, with limited scope for biomass measurement at appropriate ecological scales. Operators of offshore structures maintain libraries of General Visual Inspection (GVI) footage of their structures – if biomass can be extracted from this footage, it is a potential solution to this knowledge gap.

Here we present a computer vision tool for accurate measurements of epibenthic biomass biovolume/biomass on offshore structures from GVI footage, using a combination of Structure from Motion (SfM), deep learning based semantic segmentation and 3D modelling. The use of GVI footage in a computer vision pipeline presents a number of unique challenges. There is commonly no inherent scaling in the footage, and it is not acquired in a methodology suited for SFM. Biovolume extraction requires a closed mesh (volume), which is not provided by SFM. We will describe how our tool negates these challenges. The process of the biomass extraction involves generating closed meshes for each species, which have the potential to be used for per species morphometric analysis.

We present a test case of the tool being used at depth intervals on a North Sea oil and gas structure, providing per species measurements of biovolume/biomass, and the area of their supporting substrate. This capacity to quantify the benthic community on MMS offers a step change in how the ecosystem function of MMS can be assessed.

A Hierarchical Detection Model and Applications to Fisheries Science.

Brown, C Scott[1]

U.S. National Oceanographic and Atmospheric Administration (NOAA)[1]

We present a Loss function for training existing classifier and detection computer vision models to predict hierarchical categories. An application of this method to detection models trained on imagery in a Marine Fisheries context is demonstrated. We provide an implementation of the loss function and associated detection models in pytorch.

Deploying Benthic Detection Models on Live Video Feeds using Standard Production Hardware

Räis, Kaarel Kaspar[1]; Bassin, Corinne[1]

Schmidt Ocean Institute[1]

Background

Large-scale annotated underwater datasets, such as the FathomNet Database, have enabled effective deep learning models, such as the MBARI Benthic Object Detector, for post-dive analysis. However, there is often a disconnect between these archival tools and live operations. When rare or unfamiliar specimens appear on camera, the opportunity to sample or observe them depends entirely on the immediate recognition of the watch team. If a specimen is missed in the moment, we're likely to never know.

Approach

We demonstrate a straightforward method to bridge this gap by running existing pre-trained models on live video during ROV dives. The setup utilizes standard production equipment (e.g., Blackmagic Design capture cards) and a consumer laptop, avoiding the need for specialized embedded hardware or complex software stacks.

The implementation consists of a simple Python script using off-the-shelf libraries. By utilizing a threaded architecture, the system separates video display from the inference process. This allows the object detection model to run asynchronously in the background, processing frames as fast as the hardware allows, without introducing lag or stutter to the live video feed. Any high-confidence targets matching the user-specified configuration triggers Slack alerts to a common channel.

Observation

This proof-of-concept serves as a second pair of eyes in the control room. By overlaying bounding boxes on a secondary display, the system can flag potential targets that might otherwise be overlooked due to fatigue or lack of specific taxonomic expertise among the current personnel. The project demonstrates that integrating real-time computer vision into a live workflow is technically trivial and can be accomplished with minimal code and existing hardware.

Integrating machine learning (ML) tools into MBARI's existing VARS video analysis workflow

Sainz, Giovanna[1]; Lundsten, Lonny[1]; Walz, Kristine[1]; Jacobsen Stout, Nancy[1]; Schlining, Kyra[1]; Lemon, Larissa[1]; Bassett, Megan[1]; Schlining, Brian[1]; Barnard, Kevin[1]; Roberts, Paul[1]

Monterey Bay Aquarium Research Institute (MBARI)[1]

For nearly 40 years, the Monterey Bay Aquarium Research Institute (MBARI) has maintained an extensive archive of deep-sea footage. Recent advances in imaging systems have dramatically increased both the volume and resolution of incoming video data, creating a significant analysis bottleneck. Traditional manual annotation is no longer sufficient to keep pace with this growth.

To address this challenge, we have integrated machine learning (ML) throughout our annotation workflow, with a focus on developing novel deep-sea models, enabling human-in-the-loop validation, maintaining data quality, and improving model performance. This effort is supported by the Video Annotation and Reference System (VARS), a software system developed at MBARI that supports video data management, annotation, and provides searchable access to both the observation database and archived video. Here, we highlight two customized tools, VARS-localize and VARS-gridview, that are tightly integrated with the VARS database.

These programs have accelerated our machine-assisted annotation workflow by facilitating efficient creation and rapid review of ML training data. VARS-localize enables the creation of localizations, or regions of interest (ROIs), within image data by querying for specific concepts across the video archive. With VARS-gridview, users can rapidly review, correct, and verify localizations generated by either human annotators or ML models, helping to ensure consistency and data quality. Together, they streamline localization, review, and validation, while improving accuracy across our workflow. Using this integrated system, we have generated over 1.5 million localizations of diverse taxa. The volume of localizations created has strengthened model training and performance while creating an efficient path from data collection to analysis.

This work demonstrates how thoughtfully integrated ML tools can transform analysis workflows for large, long-term video archives, offering lessons applicable to others facing similar data growth challenges.

Standardising Megafauna Observations in the Abyssal and Hadal Zones: Integrating Submersible Video Data with the BIIGLE Annotation Framework

La Bianca, Giulia[1]; Stott, Melanie[1]; Jamieson, Alan[1]; Swanborn, Denise[1]

University of Western Australia[1]

The abyssal and hadal zones (depths exceeding ~ 3,000 m) have notoriously limited biological observations given the extreme technical challenges of deep-sea imaging. As acquisition of high-definition videos from these depths increase, there is an urgent need for standardised, scalable workflows to transform raw video footage into datasets for imagery-based biodiversity inventories and ecological assessments. This poster outlines an ongoing project aimed at developing and evaluating abyssal and hadal megafauna annotation approaches from submersible-acquired video data, using the open-source annotation tool BIIGLE (www.biigle.de).

The Tonga-Kermadec subduction zone, located in the western Pacific Ocean, extends for over 2000 km from New Zealand to Samoa, where the Pacific Plate subducts westward beneath the Australian Plate (Jamieson et al., 2024). During the Inkfish Tonga Trench Expedition, fourteen submersible scientific deployments using the submersible Bakunawa were completed between ~2,000 m and 10,805 m depth at an average depth interval of ~600 m, resulting in more than 56 hours of high-definition video data of the seafloor (Jamieson et al., 2024). This dataset provides a rare opportunity to evaluate megafauna annotation approaches across a broad depth gradient.

By leveraging BIIGLE's web-based interface, we are implementing an annotation process that utilises standardised taxonomic vocabularies to ensure data interoperability, applies quality assurance protocols to ensure consistency in intra and inter-observers' annotations, and accounts for future deep learning applications. This methodology facilitates the transition from qualitative visual observations to a quantitative biotic inventory. While formal results are pending, our preliminary work demonstrates how structured annotation frameworks can overcome the logistical hurdles of deep-sea data management. While BIIGLE has been widely applied to still imagery from deep-sea environments, this project also evaluates how BIIGLE performs in the annotation of larger quantities of continuous video data, including workflow modifications required. We aim to share our practical experiences in workflow design—from video pre-processing to expert validation—and discuss how these state-of-the-art tools can bridge the gap between remote deep-sea exploration and standardised biodiversity monitoring. This work ultimately seeks to provide a baseline for the community to better understand the distribution and diversity of life in the world's deepest marine environments.

Jamieson, A.J., Stewart, H.A., Kolbusz, J., Swanborn, D., Nester, G. (2024) Tonga Trench Expedition. Report. Inkfish Open Ocean Program. 73pp.

From Pixel to Knowledge

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Marine imaging has evolved from a complementary observation technique into a core methodology for addressing complex scientific and societal questions in ocean research. Autonomous platforms, high-resolution optical sensors, and advances in artificial intelligence now enable large-scale, non-invasive observation of the seafloor and its inhabitants. However, fully exploiting this potential requires coordinated expertise across imaging, data processing, machine learning, and research infrastructure. We present a strategic perspective on marine imaging as a unifying framework that connects data acquisition, automated analysis, and knowledge integration. Our group combines expertise in underwater image acquisition (e.g. AUV-based and towed camera systems), image correction and normalization, object detection and segmentation, 3D reconstruction, and scalable computing environments. This integrated approach allows imaging data to be used not only for visualization but as a quantitative data source that complements hydroacoustics, sampling, and environmental observations.

A central challenge in marine imaging is the high variability of underwater data caused by illumination conditions, suspended particles, platform motion, and differing acquisition geometries. We address these challenges through robust preprocessing pipelines and machine-learning-based analysis methods that reduce dependence on exhaustive manual annotation while remaining transparent and reproducible. Use cases such as benthic monitoring in dynamic environments demonstrate how imaging can overcome limitations of traditional survey techniques and enable repeated, disturbance-free observations. Beyond algorithms, we focus on lowering barriers to the adoption of imaging-based methods.

By developing shared, accessible platforms for running analysis workflows and AI models, we aim to make advanced image analysis usable by non-experts and transferable across projects. Standardized metadata, FAIR data principles, and interoperability with environmental and spatial datasets are treated as integral components rather than afterthoughts. By consolidating imaging expertise within a single group, we contribute a scalable and method-driven approach to marine imaging that supports collaboration, reproducibility, and long term data value. This poster highlights how coordinated imaging strategies can accelerate insight from pixels to knowledge and strengthen the role of imaging within interdisciplinary ocean science.

Accelerating Deep-Sea Image Analysis Through Regional Collaboration in the Eastern Tropical Pacific

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Recent deep-sea expeditions across the Eastern Tropical Pacific have generated an unprecedented volume of underwater imagery, creating new opportunities to integrate visual data while strengthening regional knowledge and local research capacity. Ecuador, Colombia, Panama, and Costa Rica have independently, through academic, governmental, and private-sector partnerships, collected extensive imagery using diverse platforms, vehicles, and acquisition strategies that reflect distinct scientific questions and national priorities. Aligning these heterogeneous datasets remains both a challenge and an opportunity for regional collaboration, accelerated through the Deep Ocean Alliance in the Eastern Tropical Pacific, a regional initiative promoting coordinated understanding and stewardship of deep-sea ecosystems across national boundaries.

We present a region-wide collaborative effort to improve taxonomic identification and strengthen baseline biodiversity knowledge derived from deep-sea imagery. The initiative addresses key components of the imagery workflow, including data processing, image annotation, and data management, while fostering shared learning that informs future data acquisition strategies. The effort emphasizes coordination, knowledge exchange, and capacity enhancement across institutions and countries.

A key outcome of this collaboration is the consolidation of a regional working group and progress toward a shared deep-sea imagery catalogue that supports cross-country comparison and future alignment of approaches. Image annotation workflows are supported through platforms such as BIIGLE and Tator, alongside regional training activities and ongoing exchange between experienced and early-career researchers.

To date, the initiative focuses on the analysis of megafauna from 14 expeditions, representing approximately 2280 hours of video and close to 9000 images, collected to depths of up to 4111 m. Data were collected using a range of platforms, including ROV SuBastian, DSV Alvin, additional underwater vehicles, deep-sea baited camera systems, and drift cameras. Participating countries contribute complementary local objectives that support the project's overall goal of developing a regional scientific baseline for deep-ocean ecosystems, enabling comparable multi-country monitoring through interoperable data, and contributing to global knowledge and collaborative frameworks.

This ongoing effort highlights shared challenges and lessons learned, underscoring the need to accelerate coordinated image-based analyses, optimize analytical and interpretative pipelines, and strengthen collaboration to shorten the time from data acquisition to results and dissemination.

A standard format for biological annotations in marine images to make them FAIR

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Biological information extracted from photos is important data for the assessment, monitoring and research on the marine environment. These annotations contain the taxonomic identification of an organism, along with its location and other attributes, such as measurements or behavioural observations. They are largely made by humans, and increasingly also by artificial intelligence, often using one of several commonly-available software tools. While the biological information is common to surveys or monitoring, its provenance from imagery presents a unique challenge in data management. A lack of taxonomic precision, the common use of bespoke label hierarchies without controlled vocabularies, and the need to connect annotations to both imaging repositories and international biological data repositories (e.g., Ocean Biodiversity Information System) present further challenges. We present a standard format for biological annotations, which establishes annotation data as a data product by standardising the list of fields required and associated data formats, and providing a template for communication and transmission of annotation data, while linking the annotations to the associated imagery set(s).

This standard format consists of three parts:
(i) annotation set metadata,
(ii) annotations, and
(iii) label hierarchy.

The standard format for the annotation set metadata is based on the image FAIR Digital Object standard. The standard format for the annotations unifies the formats used by common annotation platforms, the outputs of which are mapped to this standard. The standard for the label hierarchy is designed to define the taxa of interest for the study (including any not found in the image set), facilitate the use of both bespoke hierarchies and the taxonomic hierarchy defined by the World Register of Marine Species, provide sufficient consistency for searching across annotation datasets, and connect to DarwinCore fields. As designed, this annotation data standard defines the biological aspects of the work and facilitates databasing, with a user-friendly template designed to make data preparation efficient.

SeaRover Synthesis – Website Prototype Development For ROV Imagery and Biodiversity Data

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The SeaRover Synthesis Website Prototype was developed as part of EMFF SeaRover Synthesis Project in co-operation with contractors MERC Consultants Limited. This was done using Open-Source software wherever possible to minimise cost and avoid licensing issues.

The SeaRover Synthesis Website prototype was the developmental step in allowing for interactive access to seabed imagery (including ROV video), species and habitats information collected during offshore geogenic and biogenic reef surveys carried out by the Marine Institute (MI) during the SeaRover project. This paper details the steps taken in building this prototype and the solutions developed for presenting large amounts of biodiversity and seabed imagery data in an accessible and interactive way.

Elements of this prototype been integrated into Irelands Marine Institute Data Centre as an Interactive mapping service; SeaRover.

EMFF Sensitive Ecosystem Assessment and ROV Exploration of Reef (SeaRover) survey took place between 2017 to 2019. It was co-ordinated and delivered by the Advanced Mapping Servies team based at the MI (Ireland). The primary aim of the survey was to map the distribution and abundance of biogenic and geogenic reef habitat along Ireland's continental margin with a view to protecting them from deterioration due to fishing pressures. The MI ROV Holland I was used, equipped with a high-definition (HD) camera, various composite video feeds, and a robotic arm for sample collection. 310 hours of seabed video were gathered which was analysed by a team at Plymouth University. First pass analysis was for habitats, matched to the MNCR biotope classification. Dive video summaries were compiled detailing times for habitat transitions, appearance of notable species, and seabed pressures. Species lists were compiled on a second pass.

Putting this video and habitats data into the public domain with accompanying analysis and metadata has proven a valuable resource for deep-sea biologists and will hopefully provide an inspiration to the next generation of marine biology students.

Enabling visual similarity search in VARS

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The Monterey Bay Aquarium Research Institute (MBARI) maintains decades of annotated marine imagery within the Video Annotation and Reference System (VARS), supporting a wide range of biological and ecological research workflows. While VARS excels at structured annotation and retrieval, emerging foundation vision models create new opportunities for semantic, similarity-based, and multimodal interaction with this archive at scale. We present an extension to the VARS ecosystem that introduces dedicated vector embedding infrastructure for similarity-based retrieval of marine imagery. The system integrates state-of-the-art image embedding models (e.g. CLIP, DINO) via a purpose-built vector database that operates alongside existing VARS relational data stores. By decoupling embedding storage and similarity search from the core SQL schema, the system enables fast, flexible, and scalable retrieval while preserving VARS' authoritative annotation and metadata model. As an initial application, we demonstrate similarity search within the VARS GridView tool, allowing users to retrieve visually or semantically related observations directly from annotated regions of interest. Beyond this first use case, the embedding infrastructure unlocks a range of future capabilities, including natural-language image search, anomaly detection, zero-shot classification, and interactive annotation using precomputed embeddings. By integrating modern visual representation learning directly into the VARS ecosystem, this work lays the foundation for more intuitive, scalable, and discovery-oriented interaction with MBARI's marine imagery, while remaining compatible with established annotation practices and scientific data stewardship.

Benthic Clicker: A versatile manual annotation tool for cost-effective deep-sea imaging workflows

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Deep-sea exploration is becoming increasingly accessible through affordable underwater imaging technologies, which generate large volumes of video. In the Azores, for example, the widespread use of the locally developed Azor drift-cam has produced >1,100 hours of footage in recent years. This wider accessibility and growth exposed a key bottleneck in our pipeline for a cost-effective deep-sea exploration, which lacked on a simple, broadly accessible and versatile manual annotation tool. Existing options are often restrictive or poorly aligned with the day-to-day annotation needs and constraints faced by our research team. Here we present Benthic Clicker, a lightweight desktop platform developed within the Azores Deep-Sea Research (ADSR) group and built iteratively with the aid of widely available AI-assisted development tools. Benthic Clicker is designed for simple and intuitive manual marine fauna annotation. It is not intended to replace existing annotation platforms, but rather to fill a specific gap in an end-to-end pipeline that supports the democratization of deep-sea exploration. With keyboard-driven logging, minimal clicks, and immediate visual feedback, its key capabilities include:

1) Offline operability: runs locally, no server needed;
2) Database resilience: SQLite storage with session recovery and traceability;
3) Quick to adapt: project vocabularies and modules defined in simple text configs;
4) Dual-camera workflow: secondary video window with time offset controls;
5) Standardised outputs: analysis-ready exports with consistent identifiers, supporting integrated databases;
6) Video and image clip export: one-click clip creation with optional auto-clipping for different use cases;
7) Integrated measurements: laser calibration and size measurements linked to annotations.

Future developments of the Benthic Clicker suite will allow for human assisted bounding box creation to support AI driven annotation workflows. These outputs will provide traceable ground truth for validating emerging automated approaches as well as enable the creation of training datasets for computer-vision models (e.g., object detection). Beyond its immediate application, the development of Benthic clicker demonstrates how research teams without strong computing backgrounds can leverage AI tools to build and maintain practical software solutions.

From Pixels to Products: Standardized Workflows for Deep-Sea Benthic Imagery Annotation by the Deep-Sea Animal Research Center

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Despite the rapid expansion of deep-sea imagery collection, manual extraction of animal data from such benthic surveys remains a bottleneck for large-scale ecological synthesis and model development. These datasets include video, environmental, and spatial metadata that require coordinated processing to ensure consistency and long-term usability. To address this need, the University of Hawai'i Deep-Sea Animal Research Center (DARC) employs a structured, end-to-end annotation workflow designed to create FAIR (Findable, Accessible, Interoperable, and Reusable) biological data products from a variety of imaging programs. Deep-sea still and video imagery collected from the Pacific basin by a range of deep-sea platforms, including human occupied vehicles (HOVs), remotely operated vehicles (ROVs) and baited stationary cameras are annotated. ROV footage is annotated using the Video Annotation and Reference System (VARS) developed by MBARI and baited stationary camera footage is annotated in Tator developed by CVision. Annotations capture animal occurrences and numbers with georeferenced species level identifications, habitat context, and behavioral interactions.

Following annotation, quality control procedures include internal image review, validation against established knowledge bases, external consultation with taxonomic experts, and metadata validation to comply with archival requirements. Datasets are formatted to align with Darwin Core controlled vocabularies, standardized national database schemas, and cross-referenced with the World Register of Marine Species (WoRMS). Final products are archived and submitted to partner programs and repositories, which include NOAA's Deep Sea Coral Research and Technology Program, National Geographic Society's Pristine Seas program, Fathomnet, SeaTube, and the NOAA Ocean Exploration Benthic Animal Guide. In the last four years, DARC has annotated 165 dives from NOAA OE and OET ROVs that represent 1438 hours of bottom time and over 375,000 individual annotations. Over the last three years for the Pristine Seas program, we have annotated 223 baited camera deployments.

By presenting this workflow, we aim to share practical methods for generating high-quality, integrated deep-sea imagery data products. These practices support biodiversity research, ecosystem assessments, and emerging machine-learning applications, which aligns with the Marine Imaging Workshop's goal of advancing community standards for marine imaging and data integration.

Optical Survey Design for VME Mapping

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IPMA has recently acquired complementary video survey platforms, a SeaSpyder towed camera system (Sidus Technology & Research) and ROV Defender (VideoRay), establishing new operational capacity for systematic benthic habitat assessment in Portuguese waters. These systems will support Portugal's first comprehensive survey of Vulnerable Marine Ecosystems (VMEs) on the continental margin, planned for Summer 2026.

Survey approach integrates broad spatial coverage using towed camera transects with targeted ROV investigation of Points of Interest, enabling efficient detection of patchily distributed VME aggregations across depth gradients. Initial deployment will focus on poorly surveyed sections of the Portuguese continental margin where VME presence remains undocumented despite habitat suitability.

Methodology development is currently underway, including annotation workflows in BIIGLE, application of ICES VME classification frameworks, and integration with EMODnet environmental data layers. The project aims to establish reproducible protocols for Portuguese waters while contributing georeferenced VME occurrence data to regional databases.

Collaboration opportunities exist for taxonomic validation (video-based identification challenges), cross border biogeographic comparison, and methodological exchange. We welcome input from the marine imaging community on annotation best practices, quality control procedures, and regional VME expertise.

This initiative represents a significant expansion of Portugal's deep-sea monitoring infrastructure, transitioning from opportunistic VME records to systematic spatial assessment. We seek to engage with the marine imaging research community to strengthen methodological rigor and foster international collaboration in Northeast Atlantic VME research.

Marine imaging for non-destructive monitoring of corals of opportunity in temperate coral restoration: Astroides calycularis as a model species

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Temperate coral restoration requires accurate, non-destructive monitoring methods, particularly for threatened endemics like Astroides calycularis (orange cup coral), which has experienced population declines due to climate stressors, invasive species, and habitat loss. Project CORA demonstrates marine imaging as a rapid, scalable, non-destructive approach to track "Corals of Opportunity" (CoPs) from reef collection through nursery propagation to transplantation on artificial reefs in Gibraltar.

Naturally detached coral colonies (CoPs), vulnerable to sand-smothering mortality, were collected and stabilised as "Coral Cupcakes" using underwater cement adhesive and small concrete blocks, then cared for in an in-situ PVC nursery tree or in ex-situ laboratory systems. Monthly standardised videography (GoPro 13, dual Suptig LED lighting, L-shaped scale reference) was analysed using PhotoQuad's image segmentation, working on differences in contrast and pixel intensity. Coral surface area (cm^2) was quantified to track growth, while partial mortality (%) was assessed by distinguishing live from necrotic or dead tissue as a proxy for colony health.

The project optimised CoP-stabilisation (as “Coral Cupcakes”) with a high attachment success (80 %), markedly reducing natural sand-smothering mortality, and explored coral performance (survival and health) across contrasting in-situ and ex-situ conditions, such as light and temperature gradients, giving insights into A. calycularis resilience to environmental variability and ocean warming. Successfully-reared “Coral Cupcakes” were out-planted onto shipwreck artificial reefs with natural A. calycularis presence, enhancing population connectivity and preserving genetic diversity within its western Mediterranean range.

Marine imaging combined with PhotoQuad segmentation provides a robust and scalable monitoring solution for (temperate) coral restoration, particularly for brightly pigmented species such as A. calycularis. The cupcake-stabilisation proves effective for rescuing dislodged CoPs, while standardised imaging protocols ensure data comparability across Mediterranean restoration initiatives. Project CORA establishes A. calycularis as a model species for non-destructive, imaging-based conservation of habitat-forming temperate corals, contributing to genetic preservation and reef resilience under global change.

Ecology and structural complexity analysis of Isidella elongata using ROV imagery

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Isidella elongata (Esper, 1788) is a key habitat-forming species of the Mediterranean bathyal muds. Its peculiar candelabrum-like morphology increases complexity of muddy seabed and contributes to the establishment of ecological facilitation processes. Capable of forming facies that host several commercial species, it is severely impacted by deep-sea trawling. I. elongata is now classified as “critically endangered” by the International Union for the Conservation of Nature (IUCN), protected by the Barcelona convention and identified as Vulnerable Marine Ecosystem according to the International Guidelines for the Management of Deep-Sea Fisheries in the High Sea. However, due to the rarity of dense aggregations, distributional and ecological data of this species are still limited.

This study aims to identify the environmental and geomorphological data that majorly affect the distribution of I. elongata and influence its colonial morphology structure. Video ROV (Remotely Operated Vehicle) transects, from both 6K and HD camera, were analysed to collect biological data (abundance, size, tissue damage, epibiosis and associated fauna). Environmental and geomorphological data were extracted from ROV-mounted sensors, acoustic surveys and free-access online databases.

A novel approach was used for modelling and analysing the colony structure, based on the formulation of a “colonial-complexity” index. Video frames extracted from the 6K camera were used to perform digital skeletonization and automated identification of branching and polyps insertion points. The sum of extracted points constituted the “colonial-complexity” index of the specimens. A Python script was used to automatically process 6K frames to extract a user-defined region of interest, segment the target structure and generate a skeletonized representation. Endpoints and branching nodes were then identified and the results were exported for quantitative analysis.

Zero-inflated models will be used for identifying fine-scale variables capable of influencing both the distribution and the “colonial-complexity” index of I. elongata. These results will contribute to define I. elongata ecological requirements, essential for designing more powerful predictive models and efficient conservation plans.

The EMFAF Irish Shelf & Upper Slope Habitat Assessment (SeaShelf) –-Mapping and Tools To Inform Policy

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The EMFAF Irish Shelf & Upper Slope Habitat Assessment (SeaShelf) project aims to collect the scientific evidence base needed to reconcile sustainable fisheries objectives with nature conservation objectives.

To achieve this, there is a requirement to extend our benthic habitat mapping knowledge across the shelf and upper slope, taking a systematic and scientific approach to survey design and data gathering. It is essential that we evolve our understanding and approach to time series habitat mapping assessments, leveraging existing data, and deploying modern technology.

The SeaShelf project will extend benthic habitat mapping knowledge beyond Irish coastal waters and offshore reef habitat, identify VME habitats (Vulnerable Marine Ecosystem), improve MSFD assessments on seabed integrity (GES D6), support Marine Spatial Planning, underpin future MPA designations and nature restoration efforts, enable Offshore Renewable Energy development, and underpin Strategic Environmental Assessments. The project commenced in 2024 and will run until 2027. It is the current iteration of mapping work to inform policy carried out by the INFOMAR programme and builds upon the previous projects such as SeaRover.

Its outputs include acquisition of imagery (ROV, stills), sediment and biological sampling, and geophysical survey. Assessments carried out to date include; 'Best Available Habitat Mapping Data and Habitat Suitability Models', 'Development of Mapping and Monitoring Methodologies', and 'Prioritisation Approach for Regional Habitat Mapping'.

These will augment the products developed as part of The EMFF funded SeaRover Synthesis programme. This work developed a visualisation tool that informed policy and facilitated an EEZ scale offshore reef habitat mapping assessment.

Developing a strategic and scientific approach to benthic habitat assessment, while considering current and future pressures including bottom fishing and offshore renewable energy, will increase our understanding of sectoral impact. Moreover, it will improve our site monitoring capacity and knowledge, and will improve our ability to assess change, and manage our resources accordingly.

Deriving Essential Ocean Variables and Essential Biodiversity Variables from benthic marine imagery: application to fish abundance and biodiversity distributions in New Caledonia

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In marine ecosystems, both fish and habitats are subject to multiple anthropogenic pressures and to global change. Effective management decisions need to be underpinned by data-driven assessments. Essential Biodiversity Variables (EBVs) were defined by the Group on Earth Observations Biodiversity Observation Network (GEO BON) to describe the complexity of ecosystems. In complement, Essential Ocean Variables (EOVs) were defined by the Global Ocean Observing System as a common framework for describing ecosystem functions and components that are critical for monitoring ocean health and broadly applicable to international management. The EOVs and EBVs have not yet been well described in terms of their application to benthic imagery.

This study aims to evaluate how EOVs and EBVs derived from benthic imagery reflect spatial and temporal changes in fish communities. Data were collected using the STAVIRO rotating underwater lander throughout New Caledonia from 2007-2017. Data are spatially-replicated and encompass a variety of habitats and anthropogenic pressures. This study utilized spatial analysis of fish community composition and temporal change through joint species distribution modelling. EOV and EBV metrics related to fish community and diversity were modelled in relationship to geomorphology, habitat, marine protection status, fishing pressure, and anthropogenic impact to assess strength of effect size from EOV and EBV-related metrics for imagery data.

Future change in fish abundance and distribution is forecasted through predictive modelling based on associations with environmental covariates and anthropogenic stressors. The outcomes include assessment of spatial and temporal MPA effects on fish biodiversity and habitat distribution in New Caledonia, as well as sensitivity of EOVs and EBVs to detecting change.

Use of Benthic Imagery to Validate Regional Model Projections of Temperate Mesophotic Ecosystems in Atlantic Canada

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Distribution models are widely used in marine habitat mapping to predict and map ecological patterns. Knowledge generated from these approaches can inform marine spatial management measures. Species occurrence data compiled in open-access databases often provide training data for models; however, sampling bias can strongly influence predictions. In Atlantic Canada, for example, occurrence data for benthic species relies heavily on bottom trawl surveys conducted across the continental shelf, yet trawls cannot be deployed across steep or complex seabed terrains. Therefore, benthic species associated with complex, high-relief habitats that support Temperate Mesophotic Ecosystems (TMEs) are systematically undersampled, and their contribution to regional seabed biodiversity estimates remains unknown.

TMEs characterized by rugged seabed geomorphology and dense aggregations of soft corals were discovered for the first time in 2024 in the Funk Island Deep (FID) marine refuge off the coast of Newfoundland, Eastern Canada. This area was explored further in 2024 - 2025 during three dedicated expeditions using both a low-cost drop camera system and a small ROV integrated with a compact stereo camera. Benthic imagery surveys provided an opportunity to assess whether broad-scale model projections of TME habitat estimated using a Hierarchical Habitat Suitability Model (H-HSM) framework align with observed conditions inside a complex, data-poor environment.

The H-HSM comprises soft coral occurrence data obtained from bottom trawl surveys and nested Random Forest classifiers integrating broad-scale ocean-climate (11 km) and fine-scale seabed-terrain predictors (0.2 km). We ground-truthed H-HSM model predictions using benthic imagery collected inside FID and across the Newfoundland shelf, and used a binomial GLM to define an appropriate suitability threshold. Results show that most areas containing low-density soft coral assemblages were projected as highly suitable, while the spatial extent of high-densities, such as that observed in FID, was underestimated. This is likely influenced by the sampling biases inherent in trawl-derived occurrence data and the analysis scale of some environmental predictors. We demonstrate how incorporating benthic imagery from complex seabed habitats can highlight bias in regional model predictions, enhance interpretation of habitat suitability projections, and support a scalable approach for targeting and exploring unmapped potential marine biodiversity hotspots.

Mapping Deep-Sea Habitat Complexity at the Centimetre Scale: A Large-Area Photogrammetric Study from the Southeast Indian Ridge

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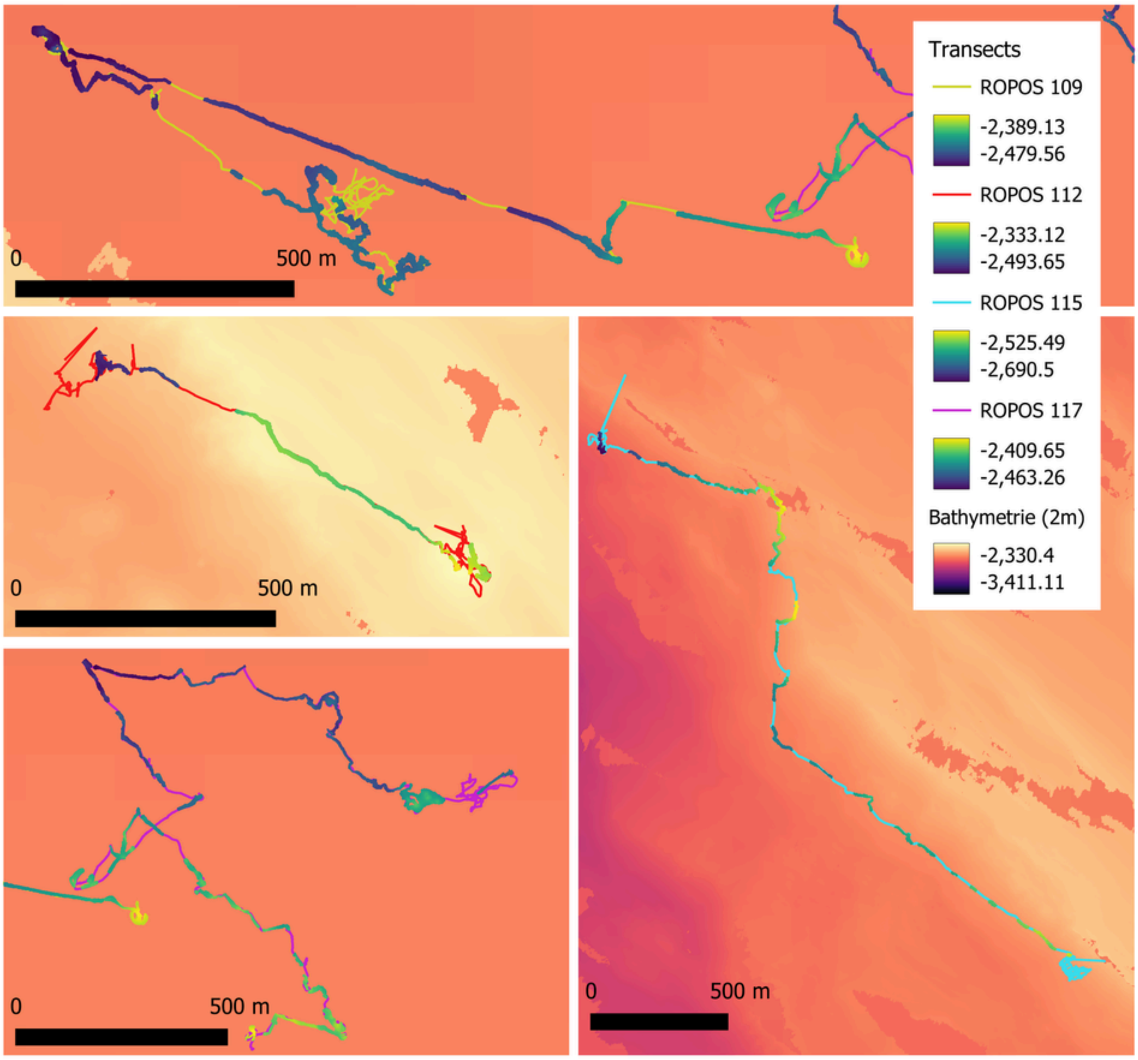
Seafloor structure and complexity are widely recognized as key drivers of deep-sea megafauna distribution and community composition. However, the lack of high-resolution data has limited our ability to quantify how fine-scale habitat heterogeneity shapes these communities.

Most studies investigating habitat–fauna relationships rely on acoustic surveys with resolutions ranging from several meters to tens of meters. At these scales, fine-scale habitat features are smoothed out, despite their potential influence on megafauna spatial distribution. Consequently, ecologically relevant habitat variability remains unresolved, with significant implications for biodiversity assessments and environmental management.

This ongoing photogrammetric study focuses on the Southeast Indian Ridge (SEIR), a topographically complex system that hosts active and inactive hydrothermal vent fields and regions of interest for polymetallic sulphide extraction. Using nine opportunistic ROV transects from the 2023 INDEX expedition (conducted by the Federal Institute for Geosciences and Natural Resources, BGR), we generated high-resolution (2 cm x 2 cm), three-dimensional (3D) seafloor reconstructions using Agisoft Metashape.

The resulting digital elevation models and orthomosaics cover a seafloor area of 100,000 m^2 and capture a diverse range of habitat types, providing a spatially explicit framework for integrating micro-topographic seafloor structure with image-based biological annotations.

This study represents one of the first large-area applications of photogrammetric habitat mapping in deep-sea ridge environments. By integrating high-resolution reconstructions with biological observations, our approach will provide new quantitative insights into habitat–fauna relationships. Ultimately, this work supports the identification of ecologically relevant habitats for conservation and environmental impact assessments in areas potentially affected by deep-sea mining.



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ROPOS 109
-2,389.13
-2,479.56
ROPOS 112
-2,333.12
-2,493.65
ROPOS 115
-2,525.49
-2,690.5
ROPOS 117
-2,409.65
-2,463.26
Bathymetrie (2m)
-2,330.4
-3,411.11
0
500 m
0
500 m
0
500 m
0
500 m

Artificial Intelligence Annotations Capture Ecological Patterns in Sponge-Dominated Temperate Mesophotic Ecosystems

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Manual image annotation is a major bottleneck for widespread and long-term benthic community monitoring, particularly as recent advances in marine imaging have generated volumes of data that far exceed our capacity for manual processing. Sponge-dominated temperate mesophotic ecosystems (TMEs) are ecologically important but remain poorly understood, and their complex visual characteristics pose challenges for automated image annotation. Here, we evaluated the performance of an existing AI-based annotation framework (CoralNet) for annotating sponge-dominated TMEs using a long-term photoquadrat dataset from Lough Hyne, Ireland (2018–2024). A classifier was trained on 300 manually annotated images and validated against an independent test set of 265 images. Classifier outputs were compared to expert annotations using species-level classification accuracy, taxonomic confusion patterns, percent-cover estimates, temporal community trends, and multivariate community structure. The trained classifier achieved an overall accuracy of ~75%, with higher performance for visually distinct and common taxa and lower accuracy for rare or morphologically complex forms. Despite species-level misclassifications, AI-derived annotations closely matched expert-derived ecological patterns, preserving site-level structure and temporal community trajectories across the time series. Together, these results demonstrate that AI-assisted annotation can provide a reliable and scalable alternative to manual image annotation for monitoring benthic community dynamics in sponge-dominated temperate mesophotic ecosystems.

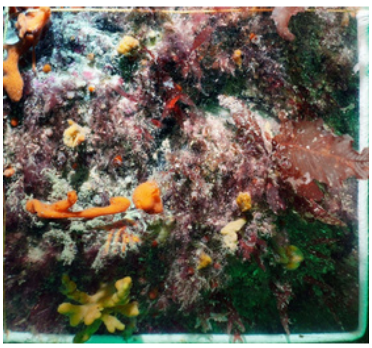

Figure 1: Example photoquadrat from Whirlpool Cliff, Lough Hyne, Ireland (June 2023), showing a sponge-dominated temperate mesophotic community. High taxonomic diversity, morphological complexity, and fine-scale heterogeneity exemplify the visual challenges faced by automated image annotation frameworks.

Assessing the spatial ecology of sea pens, Veretillum cynomorium in British Gibraltar Territorial Waters (BGTW)

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Corals are known to increase habitat heterogeneity, leading to greater biodiversity; however, the majority of scientific research places focusses on hermatypic corals. An equally important but less well-studied group are sea pens (Order Pennatuloidea), colonial octocorals that can form dense aggregations known as sea pen fields in soft sediment environments. Sea pens increase the structural complexity of benthic environments, creating habitats for associated fauna, and are highly threatened by fishing activities; and considered indicators of (relatively) undisturbed habitats, particularly from bottom trawling.

The finger-shaped sea pen, Veretillum cynomorium (Pallas, 1766), has been reported in shallow waters around Gibraltar but has never been assessed in terms of extent and distribution, or the faunal diversity these fields support. The present study aimed to define the spatial ecology (extent and distribution) of V. cynomorium fields, while also assessing associated fish biodiversity between fields within and outside of an MCZ (known as Rosia Bay).

Comparative analysis of video imagery attained from both DropFrame and dive surveys (SCUBA) was used to assess sea pen spatial ecology (abundance and Nearest Neighbour Distance - NND). Sea pen abundance and nearest neighbour distance measurements yielded higher sea pen counts (ind/image frame) and closer mean neighbouring distances (17 cm) within Rosia Bay (adjacent to MCZ), specifically in areas of mixed sediment or sandy substrate. However, higher levels of fish diversity (n = 22) were observed in areas of coarse sediment, particularly within the boundaries of the MCZ, compared to the adjacent denser Rosia sea pen field (n = 8). Comparing the density of sea pens in Rosia Bay found both with Dropframe footage and SCUBA video footage revealed the use of a Dropframe provides an accurate representation of sea pen abundance and thus provides a safer, cheaper and replicable non-invasive method to be employed compared to dive surveys.

The use of marine imagery in monitoring the health of UK MPAs

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Marine imagery surveys offer a valuable means of gathering high-quality information about benthic communities. At JNCC the imagery collected in the process of monitoring the health of the U.K.'s offshore MPA network has grown almost exponentially as the usefulness of this technology has increased. We now routinely capture thousands of still images for the enumeration of epifauna communities and video footage to map broadscale habitat features. Often imagery is used in tandem with more traditional extractive methods such as benthic grab sampling, but in some cases, surveys are exclusively imagery-based – particularly in locations where grabbing and coring is impractical, or impossible (e.g., rocky reefs). Compared to physical sampling, imagery can be deployed more effectively across larger and more physically variable study areas, it is non-destructive, and often more cost-effective.

Analysis of benthic community data from imagery is not without significant challenges with respect to data resolution and quality. In this poster we will explore these challenges, provide recommendations, and invite collaboration, showcasing JNCC's work towards producing more useful, accessible, and accurate imagery data. We will detail our recent work with academics from the University of Plymouth in contributing to, and implementing, the SMarTaR-ID platform, which offers a standardised approach to the identification of taxa from imagery, to enable a more accurate and complete capture of epibiotic diversity in U.K. In addition, we will show work that JNCC has lead on the UK Morophotaxa System (based on the popular CATAMI classification scheme) and the Epibiota Identification Protocol with NMBAQC, a guide for the standardisation of taxon identification linked to image quality. Looking to the future, we will present ideas on the implementation and the production of training datasets to be used with machine learning algorithms.

CV for mapping the deep-sea in MAREANO: the challenges of gathering a large and high-quality dataset

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MAREANO is a national mapping program that aims to combine the expertise of several institutes (geology, hydrography, chemistry and biology) to deliver a holistic description of seabed habitats, extent, distribution and biophysical characteristics. It has, so far, collected many samples and provides scientific products that inform scientists and environmental managers nationally and internationally with data and habitat maps. Meanwhile, Norway is actively exploring the mid-Atlantic ridge in the Norwegian Sea to map its biodiversity and estimate potential effects of deep-sea mining on the local ecosystem. Thus, the demand for a fast turnaround from data collection to product delivery is higher than ever.

A consistent and cost-effective imagery analysis workflow is needed in order to ingest and combine the growing amount of data obtained by camera platforms and other sensors by a widening community extending beyond academic research. MAREANO is seeking solutions to loosen this bottleneck while maintaining data quality, continuity with its prior 20 years of data delivery and leverage its existing expertise in benthic taxonomy.

Although improvements have been made with new analysis software and refined protocols, efficiency gains in the order of tens or hundreds of times in analysis speed are required. True standardisation allowing two institutions to seamlessly pool their data together is just as important but also remains distant. The use of computer vision (CV) to automatically detect and identify objects while also relying on the input of multiple taxonomic experts is currently being investigated in the project.

CV models require large amounts of data of consistent quality and high taxonomic resolution adequate to the model's capabilities which, in turn, requires standardising and careful annotator coordination. The challenges are many and come from the data and staff management at every stage as well as the models training and deployment itself.

This poster presents the working prototype of the workflow MAREANO intends to adopt to extract biodiversity data from images and videos from the Norwegian Sea. We hope to engage with the MIW community to discuss existing solutions to the challenges we encounter and help us push for standardisation.