

GEOHAB

Marine Geological and Biological Habitat Mapping



Florida Keys, United States - 2025



Proceedings



The GeoHab 2025 Conference

12-16 May, 2025

Edited by Vincent Lecours

GeoHab (Marine Geological and Biological Habitat Mapping) was established in 2001. This annual international forum brings together scientists from around the world who are developing new methods and procedures to link remotely-sensed data (acoustic and optical data, collected from satellites, drones, boats, autonomous underwater vehicles, remotely-operated vehicles, etc.) with seafloor geology and marine biology within a geospatial environment. This approach underpins sustainable management of the ocean and seafloor resources. All information concerning GeoHab is available on www.geohab.org.

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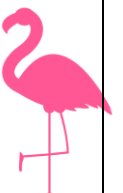
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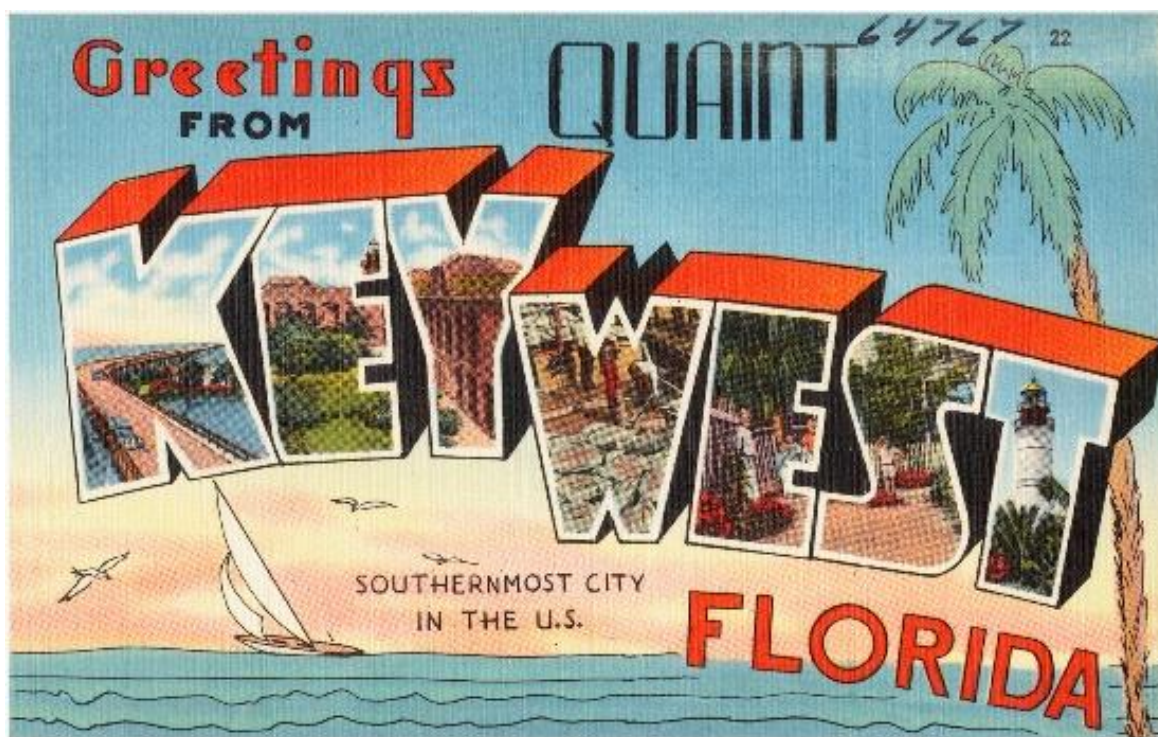


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Introductory Remarks

Welcome to GeoHab 2025!



This year is GeoHab's 25th anniversary! 2025 marks a quarter-century of scientific advances, technological developments, collegial collaborations, and, for many, professional friendships. As a volunteer-run non-profit organization, we have come a long way to make GeoHab a welcoming organization and center of collaboration. The first book of abstracts in our archives (Moss Landing, California, 2002) includes 23 oral and 22 poster presentations divided into five thematic sessions, representing eight different countries from North America and Europe. Since then, the conference series has grown in attendance, quality, and reach, and I am confident that this year's conference will represent a fruitful continuation of this trend. In fact, we received over 175 abstracts this year, divided into 16 thematic sessions, with first authors from 25 countries and all continents – well, technically, there is no author from Antarctica, but there are a couple of abstracts about it!

From GeoHab's inception, delegates spanned industry, academia, and governmental agencies, and this intersectoral melting pot has continued throughout the years. Sponsors from all sectors make our annual meetings possible, affordable, and enjoyable so that participants can build relationships and collective intelligence to better our world through sustainable ocean management. This year is no exception, and it is important to highlight the contributions of our generous sponsors who showed commitment to our organization and supported this year's meeting in a time of economic uncertainty. Their support and financial contributions have been critical to making this event possible. Without them, we would have had to give up on the beautiful venues, nice food, the social program, or worse, on coffee and tea. More importantly, without the continued



support of our sponsors year after year, GeoHab would not be able to encourage and fund student participation through the Ron McDowell Student Awards. This year, 12 students from around the world received it, meaning that all their conference-related expenses are fully covered so they can focus on presenting their research and learning from other delegates. GeoHab is a truly interdisciplinary and exciting forum to exchange knowledge and ideas, and I hope this introduction will make them want to be an active part of our community and return year after year, as I and other past Ron McDowell award recipients have done. The success of past recipients and their continued contributions to our scientific community are significant parts of GeoHab's great legacy.

From the abstracts that you will find in these proceedings, you will see that GeoHab continues to provide a global state-of-the-art perspective on marine habitat mapping. We have an exciting program that showcases the spirit of GeoHab through a single-stream event with ample time for discussion and socializing without compromising the quality of the science. Beyond the science, our yearly meeting is also a collective moment to celebrate our passion and dedication to our discipline. The synergy arising from scientific communication during the GeoHab conferences leads to broader international ties, new joint international research projects, and enhanced scientific cooperation between countries, demonstrating that research transcends political differences for the benefit of all.

This is particularly important in today's world. In the current geopolitical context, the kind of collaboration enabled by GeoHab has never been more critical as the world faces many global challenges that require working together to find solutions. You will undoubtedly notice that many of our colleagues are not with us this year. Organizational and funding upheavals have resulted in an uncertain time for some research programs. Fortunately, as an apolitical international organization, GeoHab remains a bastion of scientific integrity, academic freedom, and international cooperation and stands as a testament to the resilience of science and scientists, demonstrating that research and collaboration can endure despite political challenges. It is the intention of the scientific committee that this GeoHab conference contributes to the tradition of high-quality science, and this is why we have offered accommodations for those in our community who were prevented from participating this year: some presentations this year will be pre-recorded, and some posters will be unattended. I encourage you to give them the attention they deserve and reach out to the authors of these valued contributions to show them support and chat science with them.

The local organizing committee worked hard to show you all a good time and help you discover the cultural and natural richness of the Florida Keys. Key West in particular is a vibrant place and we hope you will keep good memories of our meeting! The choice of location for this year is quite timely. As you know, the main theme of GeoHab 2025 is "Habitat mapping in a time of climate change". The selection of this theme was motivated by the high vulnerability of the Florida Keys and their rich ecosystems to climate change; they are one of the most visibly at-risk regions in the United States regarding the consequences of climate change. Most of the Florida Keys sit less than one meter above sea level, making them at risk of flooding and inundation associated with sea-level rise. Hurricanes are increasing in frequency and intensity, causing



ecosystem damage and socio-economic issues. The Florida Keys are home to the world's third-largest coral barrier reef system, which has experienced bleaching events caused by rising sea temperatures and ocean acidification. As scientists, we want our research to matter; our collective work could contribute to restoring and increasing resilience in places like the Florida Keys.

Organizing an event like GeoHab is a cooperative venture. I want to thank the executive committees of GeoHab and the Circum-Pacific Council for their valuable input and support over the last couple of years, all the past hosts who provided advice and lessons learned, members of the local organizing committee, international scientific committee, and student support award committee, whom I could trust with the critical tasks that were imparted to them, and session chairpersons for ensuring a smooth conference. Many thanks are due to our sponsors, partners, and supporters who provided funds, discounts, or gifts to ensure we have a fantastic event aligned with our objectives and values. A special shoutout to Lauren Keiser, who came to the rescue at a critical time, to Katie Risher, Andy Campbell, and Elaine Brevoort for helping Lauren run a super smooth conference, and to Sarah Paradis for her fantastic logo design.

Finally, thank YOU all for being here in Key West. Your participation strengthens our global scientific community and reinforces the importance of continued research and collaboration. The rich and diverse abstracts you submitted make GeoHab persist and thrive. I hope you will find this meeting informative and constructive, and hats off to you for participating year after year (but especially this year!) to make GeoHab successful. I hope you enjoy your stay in Key West and that the climate and culture of the Florida Keys will leave a lasting and positive impression with you.

A very warm welcome to the Florida Keys!



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Host of the GeoHab 2025 Conference

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First GeoHab conference: 2013 (Rome, Italy)

Ron McDowell Awardee, GeoHab 2016 (Winchester, United Kingdom)



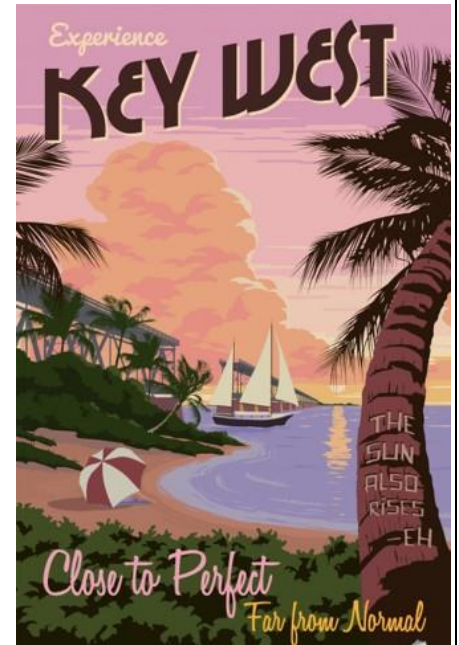
General Information

Conference Objectives

The primary objective of GeoHab 2025 is to bring together scientists and stakeholders from all over the world to share their experiences and expertise about topics related to marine habitat mapping, in line with GeoHab's stated goals to:

- 1) support government spatial marine planning, sustainable ocean management, and decision-making;
- 2) support and underpin the design of marine protected areas;
- 3) conduct scientific research programs aimed at generating knowledge of benthic ecosystems and seafloor geology;
- 4) conduct living and non-living seabed resource assessments for economic and management purposes.

We aim to encourage networking and collaboration by providing formal (and less formal) opportunities for exchange in locations that will showcase our host city. As such, our unofficial motto for this year's conference is *Experience Key West*, which we highlight through the different venues where the conference will be held. We also aim to encourage student participation and supported the Ron McDowell Student Awards again this year.



Conference Values

The organizing committee of GeoHab 2025 is committed to providing a safe, open, respectful, and inclusive environment, and we encourage all attendees to contribute to creating such an environment. We abide by GeoHab's Diversity, Equity, and Inclusion Statement, which reads:

As an organization that serves a global community, GeoHab is committed to supporting the emergence of a diverse, inclusive, and transparent community. We recognize the issues that exist in science and society in general as it pertains to gender parity and identity, geographic representation, and resource availability, among others, and we acknowledge that our organization is not foreign to them. We strongly believe that our activities and community benefit from bringing together a wide range of people, skills, experiences, and ideas/perspectives, and as such, we strive to build a welcoming community where mentorship, support, tolerance, and mutual respect prevail. The Ron McDowell Award, which each year enables student participation from around the world, is part of our ongoing efforts to be an inclusive organization.

Participants in GeoHab must commit to (1) establishing and sustaining a zero-tolerance culture towards discrimination, (2) actively seeking representation in the programs and activities associated with GeoHab, (3) disrupting unspoken rules that promote discrimination and racism,



and (4) acknowledging and valuing diverse experiences of our community and the people targeted by our activities. Also, in support of Indigenous peoples' right to self-determination around the world, we acknowledge the right of Indigenous peoples to access, conduct, and interpret science. We encourage all scientists to engage with Indigenous peoples as partners throughout the scientific process.

The GeoHab community recognizes the value of diversity and inclusion and will implement actions to promote the emergence of a more diverse community. The GeoHab Executive Committee will constantly review our organization's practices to ensure that we withhold our commitments and will identify actions to be taken to maximize diversity in our activities and ensure that we remain inclusive, fair, and supportive.

Many of the organizing committee's decisions regarding the organization of GeoHab 2025 were guided by this statement, including the establishment of a multi-tiered pricing structure that recognizes that opportunities to access conferences such as GeoHab vary with career stage and geographic and organizational contexts, among other factors. In line with this, GeoHab welcomes undergraduate and graduate students to participate actively in the conference and encourages them through the Ron McDowell Student Support Award, which allows them to receive a stipend to cover travel costs and conference registration fees. A total of 12 awards were distributed ahead of GeoHab 2025. Participants are encouraged to contact GeoHab's Executive Committee to express any concerns they may have about diversity, equity, and inclusion.

We are also committed to reducing the environmental impact of GeoHab 2025. Efforts were made throughout the conference's planning to reduce our collective environmental impact. Plastic use was minimized during the conference, and the swag was carefully selected to favor natural materials and local businesses. The conference t-shirt, for example, is made in the United States from 100% ring-spun organic cotton and screen printed using eco-friendly water-based inks; the product is certified Global Organic Textile Standard, a standard that ensures that the cotton is pure, ethically sourced, made without chemical pesticides, forced labor, child labor, or unfair wages. Waterlust, the Florida-based company behind the product, includes educational resources about marine species and ecosystems with each purchase and gives 5% of sales to support marine research and education.

A program to offset our collective carbon footprint for the conference was implemented in collaboration with The Ocean Foundation and their SeaGrass Grow initiative. SeaGrass Grow is the first and only blue carbon offset calculator – planting and protecting coastal wetlands to fight climate change. Since 2008, The Ocean Foundation has been involved in many coastal restoration projects and has widely promoted the concept of Blue Carbon — the capacity of natural coastal ecosystems, including seagrasses, mangroves, and salt marshes, to take up and sequester large quantities of carbon in both the plants themselves and the sediment below. Recognizing that this concept could help address and mitigate climate change



while promoting ocean health, The Ocean Foundation has made an effort to protect and restore these coastal systems while investing in the science and viability of blue carbon projects. Through this innovative program, individuals or businesses can calculate the carbon footprint of their home, workplace, or travel and offset it to restore and protect coastal wetlands. In recognizing the value of meeting in person every year and that it is a privilege with an environmental cost, the local organizing committee aims to offset its carbon footprint for the 2025 conference, hoping it can become a yearly tradition and part of our collective habits.



Conference Themes

The overall theme for GeoHab 2025 is Habitat Mapping in a Time of Climate Change. The choice of this theme was motivated by the high vulnerability of the Florida Keys and their rich ecosystems to climate change; they are one of the most visibly at-risk regions in the United States when it comes to the consequences of climate change. Most of the Florida Keys sit less than one meter above sea level, making them at risk of flooding and inundation associated with sea-level rise. Hurricanes increase in frequency and intensity, causing ecosystem damage and socio-economic issues. The Florida Keys are home to the world's third-largest coral barrier reef system, which has experienced bleaching events caused by rising sea temperatures and ocean acidification.

Beyond this primary theme, contributions related to the mapping of marine and coastal habitats, from tropical to polar environments and from the beach to the abyss, using acoustic or optical remote sensing methods or any other approaches, were welcomed. The abstracts presented in these proceedings are divided into the following themes:

- Climate change effects on marine habitats: This theme includes studies related to habitat mapping focusing on the impacts of climate change on benthic habitats. Topics could include species migration or adaptation, technologies for mapping and measuring environmental changes, and government actions to address climate change impacts.
- Coastal and shallow-water habitats: This theme includes all studies related to habitat mapping in coastal and shallow water without a specific focus on any of the other themes. Besides studies on coastal and shallow-water habitat mapping that span many themes, this theme could focus on linking methodologies from terrestrial remote sensing (including satellite remote sensing, unoccupied aerial vehicles (drones), lidar, and others) to shallow-water environments.



- Continental shelf and slope habitats: This theme includes all studies related to habitat mapping on the shelf and slope without a specific focus on any of the other themes. Presentations could cover various topics, including discussions of specific shelf and slope habitats and how their distribution and specific characteristics may play an important role at broader scales.
- Deep-sea habitats: This theme includes all studies related to habitat mapping in the deep sea without a specific focus on any one of the other themes. Presentations could cover a range of topics, including deep-water methods and technological advances, a discussion of specific deep-sea habitats, and how their distribution and specific characteristics may play an important role at broader scales.
- Habitat mapping for marine restoration: This theme focuses on the use of habitat mapping to support marine ecosystem restoration efforts. Studies could explore methodologies for mapping degraded habitats, identifying restoration targets, and monitoring recovery processes. Contributions were encouraged from studies employing remote sensing techniques to aid restoration projects in diverse environments, and could include case studies of successful restoration, innovative mapping technologies, and interdisciplinary approaches integrating ecological and geospatial data. This theme aims to highlight the critical role of habitat mapping in reversing marine ecosystem degradation.
- Management and communication: This theme includes studies on the use of habitat maps and science communication for marine spatial planning and management. Presentations could cover aspects of the ecosystem-based approach applied to marine spatial planning aimed at maintaining benthic ecosystem integrity and ensuring the sustainable use of its goods and services, which has been adopted in many countries. Topics could include the shift to green energy, and spatial planning related to various industries, among others. Due to the many abstracts submitted under this theme, a sub-theme on Mapping programs, datasets, efforts, and partnerships was established.
- New approaches and technologies: This theme focuses on methodological studies highlighting new technologies and improved approaches across the entire habitat mapping workflow, from data acquisition to map production and dissemination. Topics could include but are not limited to innovations in field survey methods, machine learning and/or artificial intelligence, or other methods advancing data processing and analysis and the production and dissemination of seabed habitat maps or key contributing datasets. This theme provides a forum for updates from methods-related working groups and related initiatives of particular importance to the GeoHab community (*e.g.*, acoustic backscatter, machine learning, geomorphometry, photogrammetry). Due to the many abstracts submitted under this theme, sub-themes were created: 1) Analytical tools and workflows, 2) Backscatter data, 3) Multi-source Data Integration, 4) Modeling and AI, 5) New technologies for new applications.
- Other human impacts on marine habitats: This theme includes studies related to habitat mapping focusing on human effects not directly related to climate change, which are treated in a different theme. Presentations could cover any other aspect of human impacts but with a



focus on benthic habitats. Topics may include technologies for mapping and measuring environmental changes and government actions to address human impacts. They could focus on one or more human impacts, including but not limited to fishing, shipping, seabed mining, and dredging.

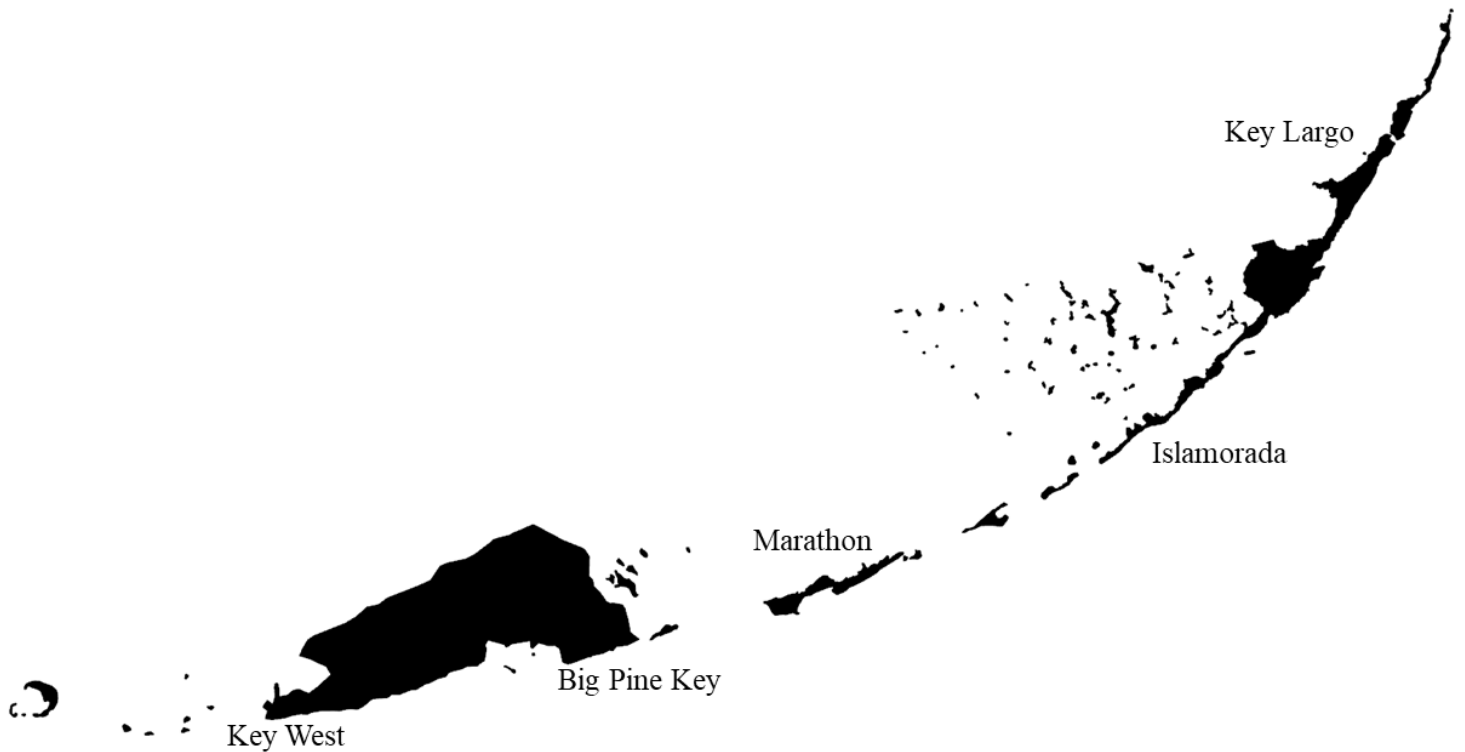
- Participatory mapping, citizen science, and outreach: This theme includes all studies related to the involvement of non-traditional scientists in the scientific process of mapping marine habitats. Presentations could cover aspects of partnerships supporting discovery, learning, and action, data collection protocols for citizen scientists, or the contribution of traditional ecological knowledge, indigenous knowledge, or local ecological knowledge to habitat mapping projects.
- Polar and sub-polar environments: This theme includes all studies related to habitat mapping in polar and sub-polar environments without a specific focus on any of the other themes. Presentations could cover such topics as challenges and adaptation of technologies for habitat mapping in polar settings, glacial-marine environments, polar-specific benthos, and mapping polar benthic habitats for conservation and management purposes.
- Urban seas systems: This theme focuses on using habitat maps to address the issues facing coastal waterways impacted by human activities in heavily developed areas. In such “urban seas”, cumulative human impacts have caused significant changes to benthic ecosystems, which places them in a particular context because these ecosystems are used by large human populations living in close proximity. Studies could include changes in benthic habitats, protection measures adopted, different human uses of the environment, anthropogenic disturbances including shipping, and the future of benthic ecosystems in urban seas.

Conference Location

GeoHab 2025 is set in the Florida Keys, a coral cay archipelago of about 1,700 islands off the southern coast of Florida, only about 80 kilometers from the Bahamas and about 145 kilometers from Cuba. The Florida Keys are a chain of tropical islands stretching about 325 kilometers off the southern tip of Florida. Each island has its own unique charm, but they are known collectively for their breathtaking landscapes, crystal-clear waters, and vibrant marine life. The entire region of the Florida Keys is characterized by a laid-back atmosphere, where outdoor activities like snorkeling, kayaking, and boating are prevalent. The Keys also host diverse ecosystems, including mangroves and coral reefs, making them a paradise for nature lovers and GeoHabbers! The Florida Reef Tract is the only coral reef system off the North American continent and the third largest barrier reef in the world behind Australia and Belize.

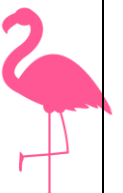


With their stunning sunsets, unique architecture, and rich history, the Florida Keys are a beloved destination for travelers seeking both relaxation and adventure. Key Largo, the largest of the keys, is famous for its coral reefs and excellent diving spots, including the John Pennekamp Coral Reef State Park. Islamorada, known as the “Sport Fishing Capital of the World,” offers great fishing and dining. Marathon is a family-friendly destination with beautiful beaches, while Big Pine Key is home to the endangered Key deer and the National Key Deer Refuge, and offers a more tranquil experience.



The conference venues are located in Key West, the westernmost and southernmost of the inhabited islands of the Keys. It is renowned for its lively nightlife, historical sites, and artistic culture. Key West is a vibrant island with a rich history and boasts a colorful style of architecture that originated in Key West; the conch-style architecture, developed in the 19th century and used into the early 20th century, can be found throughout the Florida Keys and even in Miami. Key West is also known for its beautiful beaches and Duval Street, where the plenary sessions of GeoHab 2025 will be held. Duval Street is the main thoroughfare in Key West and is lined with bars, restaurants, and shops, offering everything from fresh seafood to unique local art.

Key West has a deep literary history, famously home to writers like Ernest Hemingway and Tennessee Williams. Outdoor enthusiasts can enjoy activities like snorkeling, diving, and fishing around the surrounding coral reefs, or exploring the lush nature of the nearby Dry Tortugas National Park. The tropical climate, friendly vibe, and blend of cultural influences make Key West a unique and enchanting destination for GeoHab 2025!



Conference Venues

GeoHab 2025 will be held at the theater of the San Carlos Institute, which can accommodate up to 360 persons. The building is an example of 19th-century architecture that features beautiful neoclassical design elements. The San Carlos Institute is a historic cultural center dedicated to preserving and promoting Cuban heritage and culture in the United States. Founded in 1871, it initially served as an educational and social institution for Cuban immigrants, and it is now home to the Cuban Museum of Arts and Culture, which showcases the rich contributions of Cuban artists.



San Carlos Institute

We will welcome delegates at the Audubon House & Tropical Gardens for the conference icebreaker on Monday evening. The house is a beautifully restored 19th-century home in a mix of Caribbean and Colonial styles that offers a glimpse into the natural and cultural heritage of Key West. Built in 1840, the house is named after the famous naturalist John James Audubon, born in Haiti and raised in France, who visited the island while working on his renowned *Birds of America* work. The book, which features detailed illustrations of 435 species of birds in their natural settings, is considered one of the finest ornithological works ever completed. The choice of this location for GeoHab's icebreaker is not random: Audubon is regarded as a pioneer in ornithology because of his documentation of birds in their natural habitats, enabling him to make detailed notes about their behavior and how they use the environment. Inside the house are exhibits highlighting Audubon's work and historical artifacts from Key West. Outside, where the icebreaker will be held, are lush tropical gardens filled with native plants and vibrant flowers, various paths to stroll on with fellow GeoHabbers, and water features.



Audubon House & Tropical Gardens

The poster session will be held outdoors, in the backyard of the Hemingway Home & Museum. Residence of the renowned American author from 1931 to 1939, it was constructed in 1851 in the Spanish Colonial style by a marine architect, Asa Tift, using local limestone. A unique feature of the property is its population of polydactyl cats (*i.e.*, cats with extra toes). Many of the cats on the grounds are descendants of Snow White, a white six-toed cat given to the house owner by a ship's captain. The lush gardens of the house will be perfect for enjoying a beverage with fellow GeoHabbers while discussing the posters that will be presented!



Hemingway Home & Museum

Finally, the conference dinner will be held at the Truman Little White House, the winter residence of United States President Harry S. Truman from 1946 to 1952. Located on Key West's



waterfront, the house is an example of Mediterranean Revival architecture, featuring a bright white facade, a distinctive red-tiled roof, and lush gardens in which the conference dinner will be held. The Little White House was where President Truman conducted presidential business, hosted dignitaries, and enjoyed relaxation away from the pressures of Washington, D.C. During these stays, he made important decisions regarding post-war America and international relations. This historic residence highlights Truman's personal story through guided tours and serves as a reminder of Key West's role in American political history.



Truman Little White House

The conference picture will be taken by one of the better-known and most photographed landmarks of Key West. The Southernmost Point Buoy indicates the southernmost point in the continental United States (at 24.5465° N), highlights Key West's proximity to and historical relationship with Cuba, and nods at The Conch Republic, a micronation declared as a sarcastic



Southernmost Point Buoy

secession of Key West from the United States in 1982. That said, as scientists, we like to be accurate, so it is important to note that the beach at Fort Zachary Taylor Historic Park in Key West is actually 150 m farther south than the buoy, and that Cuba is actually 94 miles away from Key West, and not 90 miles away as stated on the buoy. The buoy was showcased on a secondary logo of our conference (below) that was used on our website.



GEOHAB

Marine Geological and Biological Habitat Mapping

General Agenda

	Monday May 12, 2025	Tuesday May 13, 2025	Wednesday May 14, 2025	Thursday May 15, 2025	Friday May 16, 2025
AM	Workshop <i>San Carlos Institute</i>	Plenary Sessions <i>San Carlos Institute</i>	Plenary Sessions <i>San Carlos Institute</i>	Plenary Sessions <i>San Carlos Institute</i>	Field Trip - Mel Fisher Maritime Museum and sail on a catamaran in the Keys
PM	Workshop & Plenary Sessions <i>San Carlos Institute</i>	Plenary Sessions <i>San Carlos Institute</i>	Plenary Sessions <i>San Carlos Institute</i>	Plenary Sessions & Business Meeting <i>San Carlos Institute</i>	
Evening	Icebreaker <i>Audubon House & Tropical Gardens</i>	Poster Session <i>The Hemingway Home & Museum</i>	Conference Dinner <i>Truman Little White House</i>		



Conference Workshop

Titled “Big Hydrographic Datasets: Their Successes, Usefulness and Applications”, the traditional pre-conference workshop for 2025 is jointly organized by the Circum-Pacific Council and the Florida Geographic Information Office. An industry-government-academia exercise, it will showcase the Florida Seafloor Mapping Initiative, a \$100 million effort to map Florida waters to 200 meters depth. The workshop will include an introduction of the initiative, presentations by the contractors mandated to collect and process the data, panel discussions of the contractors and the state and federal agencies that will use the data, and a cookbook for other entities that would like to start such project in the future.

For context, in an era of large data collection, accelerated technological advancements, and an AI hunger for all data, new insights and supervised interpretations are now required to handle these datasets. One such data set is being collected today under the Florida Seafloor Mapping Initiative for the entire State of Florida, United States, overseen by the Florida Geographic Information Office (FGIO). Comparisons of similar United States State’s big data collection efforts (*e.g.*, California, Alaska, Washington) will be briefly presented to stimulate discussions on the usefulness of such large data sets. Future plans and applications of this data set will be discussed as well as ideas for other States and Countries.

In 2022, \$100 million in general revenue funds were provided to the FGIO to capture statewide bathymetric data. Two types of data have been collected to date: topo-bathymetric lidar for the seafloor to ~20 meters water depth and multibeam echosounder data for the seafloor from 20-200 meters water depth. The Florida Department of Environmental Protection Office of Resilience and Coastal Protection coordinated with federal partners to maximize funds and guide data acquisition. Multiple contractors were selected to coordinate, collect, and complete the fieldwork, which is still ongoing. Review and present status of these data will be presented along with input from the contractors who participated in the exercise. In addition, presentations and open discussions are planned for insights into the next steps and directions that can provide significant follow-on benefits. This will include direct relevance to GeoHab themes and challenges, including identifying the next layer of data required to maximize the value of the program (*e.g.*, habitat assessments, value added by direct environmental measurements such as chemical, geological, and photo sampling).

The goals of the workshop are to 1) provide large dataset case studies (evolution and progression), 2) address multi-purpose uses (problem-solving), 3) define next steps (usefulness of data to specific concerns), 4) develop a constructive interactive dialog (new insights), and 5) segway into partner collaboration (partnering and funding). A challenge will also be presented to stimulate thinking outside the box (new methods and applications), non-orthodox data presentation (*e.g.*, StoryMaps or others), social applications (for the betterment of society), and educational applications (for public outreach and interest). A reward for the most unique and potentially applicable uses will be awarded.



GeoHab's Machine Learning Working Group Competition

The GeoHab Machine Learning Working Group (MLWG) held the GeoHab 2025 MLWG Competition in the months leading up to the conference! For the competition, participants were invited to build a model to complete a benthic habitat mapping task using a dataset provided. The accuracy of the participants' model predictions were evaluated using withheld test data, and the top scores will be awarded prizes at the 2025 GeoHab conference!

This competition was a regression task. Participants had to predict the mean grain size of seafloor sediment samples given environmental data. The environmental data were provided in both tabular and image (*i.e.*, raster) format, enabling both traditional machine learning and computer vision approaches.

The competition was being hosted on Kaggle, which is the world's largest data science community and competition platform. In the spirit of collaboration, the public competition page was a one-stop shop for everything related to the competition, including complete rules, additional information, a temporary leaderboard, and a discussion space to ask questions or exchange ideas with other participants.



Committee Composition

Convener

Vincent Lecours (Université du Québec à Chicoutimi, Canada)

Local Organizing Committee

Vincent Lecours (University of Florida, United States)

Lauren Keiser (University of Florida, United States)

Liz Love (We've Got The Keys, United States)

Kevin Jackson (University of Florida, United States)

International Scientific Committee

Riccardo Arosio (University College Cork, Ireland)

Alex Bastos (Universidade Federal do Espirito Santo, Brazil)

Hayley Cawthra (Council for Geoscience & Nelson Mandela University, South Africa)

Rozaimi Che Hasan (Universiti Teknologi Malaysia, Malaysia)

Rodolphe Devillers (Institut de recherche pour le développement, La Réunion, France)

Federica Foglini (CNR ISMAR, Italy)

H. Gary Greene (San Jose State University, United States)

Khaira Ismail (Universiti Malaysia Terengganu, Malaysia)

Milad Niroumand Jadidi (University of Florida, United States)

Vincent Lecours (Université du Québec à Chicoutimi, Canada)

Aaron Micallef (Monterey Bay Aquarium Research Institute, United States)

Benjamin Misiuk (Memorial University of Newfoundland, Canada)

Kara Radabaugh (Florida Fish & Wildlife Conservation Commission, United States)

Nicole Raineault (Florida Institute of Oceanography, United States)

Marc Roche (Continental Shelf Service, FPS Économie, Belgium)



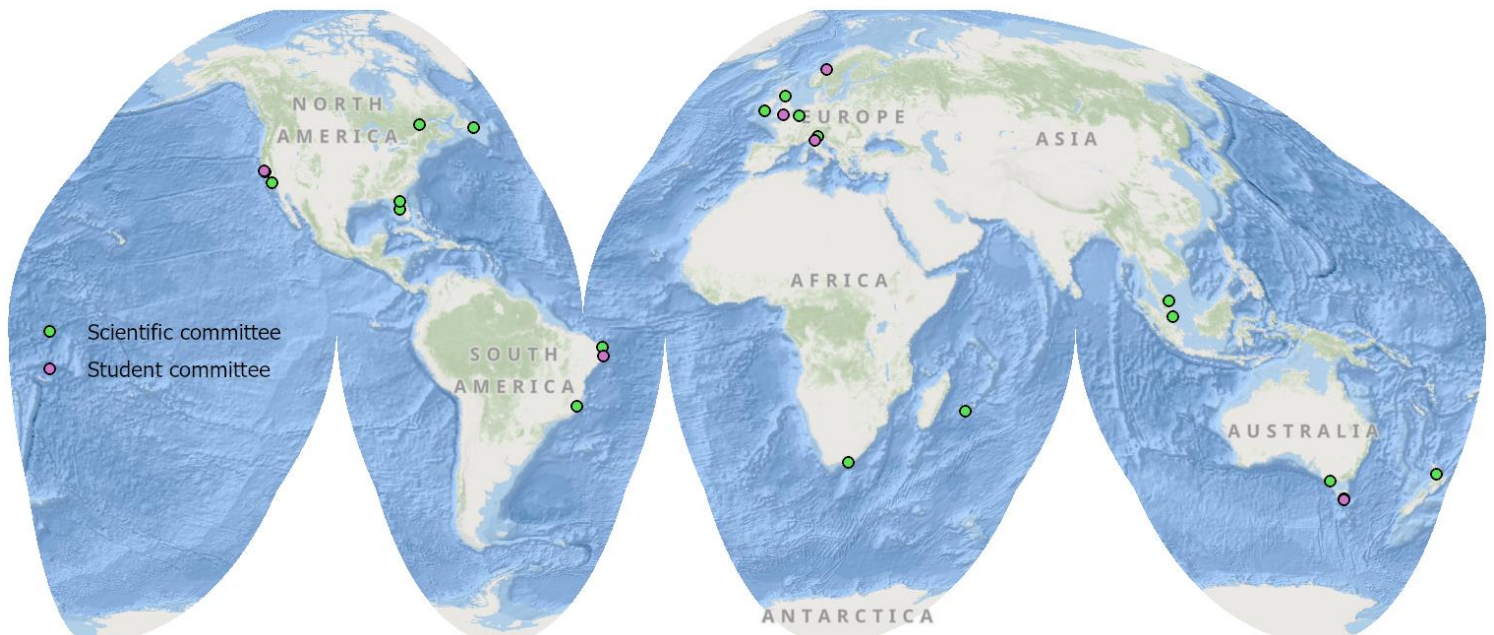
Donna Schroeder (U.S. Bureau of Ocean Energy Management, United States)

Heather Stewart (Kelpie Geoscience, United Kingdom)

Helenice Vital (Federal University of Rio Grande do Norte, Brazil)

Sally Watson (NIWA & University of Auckland, New Zealand)

Mary Young (Deakin University, Australia)



Ron McDowell Student Support Award Committee

Tereza Araújo (Universidade Federal de Pernambuco, Brazil)

Guy Cochrane (United States Geological Survey, United States)

Margaret Dolan (Geological Survey of Norway, Norway)

Peter Harris (University of Tasmania, Australia)

Tim Le Bas (National Oceanography Centre, United Kingdom)

Vanessa Lucieer (University of Tasmania, Australia)

Fantina Madricardo (CNR ISMAR, Italy)

Terje Thorsnes (Geological Survey of Norway, Norway)



Session Chairs

Session 1:

Sally Watson (NIWA & University of Auckland, New Zealand) & Ceridwyn Hunter (Arizona State University, United States of America)

Session 2:

Aaron Micallef (Monterey Bay Aquarium Research Institute, United States of America) & Daniel Ng (Dalhousie University, Canada)

Sessions 3 and 4:

Joana Gafeira (Kelpie Geoscience, United Kingdom) & Audrey-Anne Amyot (Université Laval, Canada)

Sessions 5 and 6.1:

Benjamin Misiuk (Memorial University of Newfoundland, Canada) & Hanna Modin (The Arctic University of Norway, Norway)

Session 6.2:

Margaret Dolan (Geological Survey of Norway, Norway) & Antonia Kotliarov (Memorial University of Newfoundland, Canada)

Sessions 7 and 8:

Lilja Bjarnadóttir (Geological Survey of Norway, Norway) & Alexander Ilich (University of South Florida, United States of America)

Sessions 9 and 10:

Craig Brown (Dalhousie University, Canada) & Ava Besecker (California State University Monterey Bay, United States of America)

Sessions 11 and 12:

Mary Young (Deakin University, Australia) & Cara Brennan (University College Cork, Ireland)

Session 13:

Matthew Hommeyer (University of South Florida, United States of America) & Giorgio Simone (University of Bologna, Italy)

Session 14:

Pedro Menandro (Dalhousie University, Canada) & Caroline Gini (Memorial University of Newfoundland, Canada)



Sessions 15 and 16.1:


Federica Foglini (CNR ISMAR, Italy) & Emmeline Broad (Memorial University of
Newfoundland, Canada)

Session 16.2:

Gary Greene (San Jose State University, United States) & Vasileios Giannakopoulos (University
of Patras, Greece)



Detailed Program

Note: This symbol  denotes the 2025 recipients of the Ron McDowell Awards

Monday, May 12th, 2025

- 7:00-8:00 Registration and check-in
- 8:00-8:05 University of South Florida College of Marine Science and Center for Ocean Mapping and Innovative Technologies (COMIT) sponsor presentation

Pre-conference workshop on big hydrographic datasets

- 8:05-8:20 Greetings and introduction from the Circum-Pacific Council
- 8:20-8:50 Presentation of the Florida Seafloor Mapping Initiative (FSMI) by the Florida Geographic Information Office
- 8:50-10:00 Presentation of the mapping work accomplished by the various contractors of the FSMI (CMOR Mapping, Dewberry, Fugro, Saildrone, Woolpert)
- 10:00-10:30 Break*
- 10:30-11:30 Examples of benefits from previous statewide seafloor mapping initiatives
- 11:30-12:00 Panel discussion with contractors and the Florida Department of Environmental Protection
- 12:00-13:30 Lunch*
- 13:30-14:15 Presentations from instrument manufacturers and software providers
- 14:15-15:00 Review and wrap-up by the Circum-Pacific Council
- 15:00-15:30 Break*



GeoHab 2025 Conference Opening

- 15:30-15:40 Opening remarks – Vincent Lecours, GeoHab 2025 chair
- 15:40-15:50 Welcome remarks – Robert Gilbert, Dean for Research, University of Florida Institute of Food and Agricultural Sciences

Session 1: Habitat mapping for marine restoration

Moderators: Sally Watson (NIWA & University of Auckland, New Zealand) & Ceridwyn Hunter (Arizona State University, United States of America)



- 15:50-15:55 **Mary Young:** Using predictive models to identify kelp refuges in marine protected areas for management prioritisation
- 15:55-16:10 **Giorgio Simone:** Marine litter in two Mediterranean submarine canyons: mapping distribution and impacts to support restoration efforts
- 16:10-16:15 **Arthur Trembanis:** Community-driven habitat restoration: Using consumer side-scan sonar to remove derelict crab pots
- 16:15-16:20 **Glenna Dyson:** Optimal terrain attribute sampling methods for habitat suitability modeling in the fine-scale: Multibeam and structure-from-motion photogrammetry comparison
- 16:20-16:35 **Ava Besecker:** Measuring the impact of substrate on outplanted coral growth in the Galápagos Islands using close-range underwater photogrammetry
- 16:35-16:40 **Julia Greco:** Habitat mapping and sediment transport dynamics of Northern Assateague Island
- 16:40-16:45 **Giorgio Castellan:** Finding a new place to call home: mapping deep-sea habitats to support cold-water coral restoration in two Mediterranean canyons
- 16:45-16:50 **Jennifer Dijkstra:** Applications of diverse mapping technologies for repeat mapping of coral reefs
- 16:50-16:55 Norbit Silver sponsor presentation
- 16:55-17:00 Announcements
- 18:00 Conference icebreaker at the Audubon House & Tropical Gardens



Tuesday, May 13th, 2025

Keynote

8:45-9:30 **Derek Sowers & Daniel Wagner**, Ocean Exploration Trust: Catalyzing deep-sea discoveries and exploration through innovation, collaboration and inspiration

Session 2: Climate change effects on marine habitats

Moderators: Aaron Micallef (Monterey Bay Aquarium Research Institute, United States of America) & Daniel Ng (Dalhousie University, Canada)

9:30-9:35 **Eve Bohnett**: Identifying coastal habitat migration corridors for strategic conservation planning

9:35-9:40 **Ophelia Christoph**: Assessing seabed alterations and ecological impacts of offshore wind turbine installation in the Mid-Atlantic Bight continental shelf

9:40-9:55 **Greg Murphy** (for Sante Francesco Rende): High-resolution multi-scale mapping of seagrasses along the Italian coasts: The Marine Ecosystem Restoration (MER-PNRR) Project

9:55-10:00 **Olivia Bible**: Using autonomous drones as a tool to study the impact of sea level rise on rocky intertidal communities

10:00-10:30 *Break*

Session 3: New approaches & technologies – New technologies for new applications

Moderators: Joana Gafeira (Kelpie Geoscience, United Kingdom) & Audrey-Anne Amyot (Université Laval, Canada)

10:30-10:35 **Robert Moorhead**: Exploiting USVs for water quality analysis.

10:35-10:50 **Scott Loranger**: Scientific multibeam echosounders for 3-D habitat mapping

10:50-10:55 **Catalina Rubiano**: Autonomous survey of the Gulf of Maine: Identifying potential deep-sea coral habitats using Saildrone technology

10:55-11:10 **Peter Holt**: High-resolution habitat mapping using multi-aperture sonar (MAS) in support of seagrass restoration in the Plymouth MPA

11:10-11:15 **Christopher Taylor**: Underwater robots and AI: Habitat mapping for the next generation ocean planning, ecosystem management and restoration



Session 4: Urban seas systems

Moderators: Joana Gafeira (Kelpie Geoscience, United Kingdom) & Audrey-Anne Amyot (Université Laval, Canada)

- 11:15-11:30 **Gary Greene:** Application of a marine habitat map based digital twin simulation to tidal energy harvesting siting and monitoring
- 11:30-11:45 **Terje Thorsnes:** Habitat mapping for offshore wind farms in Norway
- 11:45-11:55 R2Sonic Gold sponsor presentation
- 11:55-12:00 Announcements
- 12:00-13:30 *Lunch*

Session 5: New approaches and technologies – Backscatter data

Moderators: Benjamin Misiuk (Memorial University of Newfoundland, Canada) & Hanna Modin (The Arctic University of Norway, Norway)



- 13:30-13:45 **Peter Urban:** Field calibration of multibeam water column imagery in turbid waters
- 13:45-14:00 **Cara Brennan:** An Enhanced Angular Range Analysis (eARA) workflow in support of large scale national mapping programmes: a case study on INFOMAR multibeam data, Ireland
- 14:00-14:05 **Asaf Giladi:** High-resolution seafloor grain size classification and mapping using multibeam backscatter data and geostatistical interpolation methods
- 14:05-14:20 **Marc Roche:** Natural reference area for bathymetry and backscatter quality control and calibration: Establishment protocol, benefit and feasibility

Session 6.1: Mapping programs, datasets, efforts & partnerships

Moderators: Benjamin Misiuk (Memorial University of Newfoundland, Canada) & Hanna Modin (The Arctic University of Norway, Norway)

- 14:20-14:35 **Syed Khalil:** Coastal Sediment Distribution Map – an abiotic habitat map for ecosystem restoration of coastal Louisiana
- 14:35-14:50 **Valentina Bracchi:** The submarine *beehives*: Insights from the CORSUB Project



14:50-14:55 **Jennifer Le:** One cruise is better than two: Highly leveraged United States research partnerships simultaneously address geological and biological needs

14:55-15:00 Announcement from GeoHab President Mary Young

15:00-15:30 *Break*

Session 6.2: Mapping programs, datasets, efforts & partnerships

Moderators: Margaret Dolan (Geological Survey of Norway, Norway) & Antonia Kotliarov (Memorial University of Newfoundland, Canada)

15:30-15:45 **Philippe Vandenbossche:** 10 years & 112 research voyages - RV Investigator's contribution to Australian & global seafloor mapping

15:45-16:00 **Lilja Bjarnadóttir:** The MAREANO programme celebrating 20 years of seabed mapping in Norway – selected results and future plans

16:00-16:05 **Aarno Kotilainen:** Wake up your marine data – EMODnet ingestion

16:05-16:20 **Garrett Mitchell:** Developing a comprehensive open-source database of active chemosynthetic seep communities in the Northern Gulf of Mexico

16:20-16:35 **Anthony Knapp:** Broad scale habitat mapping data collected in support of reef fish surveys: Exploring challenges of time and technology

16:35-16:50 **Vincent Lecours:** What, why, and how: Analyzing 25 years of GeoHab conferences

16:50-16:55 SBG Systems Silver sponsor presentation

16:55-17:00 Announcements

18:00 Poster Session at the Hemingway Home & Museum



Wednesday, May 14th, 2025

Keynote

8:45-9:25 **Ved Chirayath**, Aircraft Center for Earth Sciences, Rosenstiel School of Marine, Atmospheric, and Earth Science, University of Miami: Inventing NASA space exploration technologies for our Blue Planet and beyond

Session 7: New approaches & technologies – Data integration

Moderators: Lilja Bjarnadóttir (Geological Survey of Norway, Norway) & Alexander Ilich (University of South Florida, United States of America)

9:25-9:30 **Jennifer Brizzolara** (for Heath Harwood): Advanced lidar and hyperspectral data fusion technique using spectral optimization

9:30-9:35 **Pedro dos Santos**: Improving the mapping of kelp beds in the Southern Gulf of Maine using sonar and bathymetry-mode backscatter (BMB)

9:35-9:40 **Edward Albada** (for Knut Hartmann): Synergetic survey and mapping of the very shallow benthic habitats in the German Baltic

Session 8: Continental shelf & slope habitats

Moderators: Lilja Bjarnadóttir (Geological Survey of Norway, Norway) & Alexander Ilich (University of South Florida, United States of America)

9:40-9:45 **Alex Bastos** (for Fernanda Vedoato Vieira): Geomorphology in a submerged reef seascape environment within the largest reef complex of the South Atlantic

9:45-9:50 **Mor Kanari**: Extravagance versus ordinariness on the shelf edge: a match of geology and biology in the comet structures of the Eastern Mediterranean

9:50-9:55 **Helenice Vital**: SEABEDMAP Project – Slope geomorphic features on the easternmost Brazilian Equatorial Margin

9:55-10:00 **Aaron Micallef**: Integrated multibeam mapping to quantify seafloor changes in Monterey Canyon

10:00-10:30 *Break*



Session 9: Human impacts on marine habitats

Moderators: Craig Brown (Dalhousie University, Canada) & Ava Besecker (California State University Monterey Bay, United States of America)

- 10:30-10:45 **Katrien Van Landeghem:** ECOWind-ACCELERATE: seabed modifications from a changing climate and from windfarms, with consequences for the wider ecosystem
- 10:45-10:50 **Emily Roland:** White zone habitat mapping in the central Salish Sea – Assessing recreational boating impacts, distribution of derelict fishing gear, and eelgrass decline
- 10:50-11:05 **Rachel Mugge:** Temporal succession of biofilm microbiomes on steel near a deepwater historic shipwreck
- 11:05-11:10 **Kelly Kingon:** Seagrass recovery following coastal development, documented using a low-cost sidescan sonar system

Session 10: Participatory mapping, citizen science & outreach

Moderators: Craig Brown (Dalhousie University, Canada) & Ava Besecker (California State University Monterey Bay, United States of America)





- 11:10-11:25 **Yakufu Niyazi:** Where are the gaps? An analysis of global seafloor mapping effort
- 11:25-11:30 **Kyah Chewing:** Braiding indigenous oral histories and habitat mapping to understand urchin barrens in Southern New South Wales, Australia
- 11:30-11:40 HYPACK, A Xylem Brand Gold sponsor presentation
- 11:40-11:45 Announcements
- 11:45-12:00 Group picture at Southernmost Point Buoy
- 12:00-13:30 *Lunch*




Session 11: New approaches & technologies – Modeling & AI

Moderators: Mary Young (Deakin University, Australia) & Cara Brennan (University College Cork, Ireland)

- 13:30-13:45 **Benjamin Misiuk:** GeoHab Machine Learning Working Group: 2025 competition and results
- 13:45-13:50 Machine Learning Working Group 2025 competition winner announcement
-  13:50-13:55 **Hassan Elkholy:** Bridging the gap: Toward a streamlined pipeline for studying benthic habitats using benthic imagery and practical AI models
- 13:55-14:00 **Catherine Hughes:** Streamlining substrate mapping: Comparing automated techniques for habitat detection in a modified river system
-  14:00-14:15 **Emmeline Broad:** Using a newly discovered biodiversity hotspot to validate regional model projections of soft coral taxa
- 14:15-14:20 **Saheed Babatunde Al-Amin:** High-resolution 3D bathymetric mapping and ecological zone classification of Finima Beach, Bonny Island, Rivers State, Nigeria using hydrographic surveying and machine learning

Session 12: New approaches & technologies – Analytical tools & workflows

Moderators: Mary Young (Deakin University, Australia) & Cara Brennan (University College Cork, Ireland)

-  14:20-14:35 **Vasileios Giannakopoulos:** Semi-automated delineation of pockmarks and mound-like seafloor features in Flensburg Bay (Germany-Denmark)
- 14:35-14:40 **Tim Le Bas:** MarineTools – GIS tools for data manipulation and interpretation for ESRI's ArcGIS Pro and ArcMap and QGIS
- 14:40-14:55 **Joana Gafeira:** Geomorphologic diversity of Pacific Ocean's volcanic edifices
- 14:55-15:00 **Genoveva Gonzalez Mirelis** (for Massimo Di Stefano): Groundtruth: A QGIS plug-in for seafloor characterization
- 15:00-15:30 *Break*



Session 13: Management & Communication

Moderators: Matthew Hommeyer (University of South Florida, United States of America) & Giorgio Simone (University of Bologna, Italy)

- 15:30-15:45 **Angela Martinez Quintana:** AI-driven efficiency in benthic and essential fish habitat mapping for offshore wind development
- 15:45-16:00 **Dawn Wright & Kevin Butler** (for Peter Harris): Creating Ecological Benthic Units (EBUs), a new tool for ocean spatial planning and management
- 16:00-16:05 **Fergal McGrath:** EMODnet Seabed Habitats: EUSeaMap in the Caribbean Sea – Approaches to increasing resolution and relevance
- 16:05-16:10 **Lisa Skein:** Predicted effects of offshore windfarms and climate change on the distribution of benthic communities in the Eastern Irish Sea
- 16:10-16:25 **David Fox:** Modelling habitat suitability of American Lobster (*Homarus americanus*) in and around fishing exclusion zones in the Southern Gulf of St. Lawrence
- 16:25-16:40 **Genoveva Gonzalez Mirelis:** Application of the “Nature in Norway” classification system to marine ecosystems for risk assessment of habitat types using MAREANO data
- 16:40-16:45 Integral Consulting Silver sponsor presentation
- 16:45-16:50 Star-Oddi Silver sponsor presentation
- 16:50-16:55 Announcements
- 18:00 Conference Dinner at the Truman Little White House



Thursday, May 15th, 2025

Keynote

8:45-9:25 **David Butterfield**, Cooperative Institute for Climate and Ocean Ecosystem Studies, University of Washington: Searching for hydrothermal vent habitats on the Mid-Atlantic Ridge during the first scientific expedition of the Schmidt Ocean Institute vessel *Falkor (too)*

Session 14: Polar & sub-polar environments

Moderators: Pedro Menandro (Dalhousie University, Canada) & Caroline Gini (Memorial University of Newfoundland, Canada)



9:25-9:40 **Hanna Modin**: Preliminary results from an updated pan-Arctic zoobenthic biodiversity inventory and the way forward to identifying hotspots of blue carbon

9:40-9:45 **Margaret Hanley**: Hidden landscape: Unveiling seafloor habitats and morphology of East Antarctica's Sabrina Coast

9:45-10:00 **Margaret Dolan**: Mapping Norway's seamounts: top down and bottom up through MAREANO

10:00-10:30 *Break*

Session 15: Deep-sea habitats

Moderators: Federica Foglini (CNR ISMAR, Italy) & Emmeline Broad (Memorial University of Newfoundland, Canada)



10:30-10:45 **Daniel Ng**: High-resolution mapping of Pacific white skate (*Bathyraja spinosissima*) nursery habitats at an active Galápagos hydrothermal vent field

10:45-11:00 **Denise Swanborn**: Drivers of abyssal and hadal biodiversity and habitat heterogeneity in Northwest Pacific subduction trenches

11:00-11:15 **Kevin Mackay**: Post-eruption seafloor mapping around Hunga Tonga-Hunga Ha'apai



Session 16.1: Coastal and shallow-water habitats

Moderators: Federica Foglini (CNR ISMAR, Italy) & Emmeline Broad (Memorial University of Newfoundland, Canada)



- 11:15-11:20 **Pavína Podholová:** Discovery of novel mussel reef communities in the Belgian part of the North Sea: Implications for habitat conservation and monitoring
- 11:20-11:25 **Eric Hochberg:** Remote sensing of coral reef benthic community structure
- 11:25-11:40 **Ceridwyn Hunter:** Ecological evaluation of the fraction of absorbed photosynthetically active radiation for coral reef communities
- 11:40-11:45 **Edward Albada:** Analysis of 17+ years of historical physics-based benthic mapping and SDB of a complex reef ecosystem in SW Tobago to determine its contribution to coastal erosion
- 11:45-11:50 **Muhammad Munir Mohd Nor:** Visual analysis of vertical water column features from multibeam echosounder on coral reef identification
- 11:50-12:00 Kongsberg Gold sponsor presentation
- 12:00-13:30 *Lunch*

Session 16.2: Coastal and shallow-water habitats

Moderators: Gary Greene (San Jose State University, United States) & Vasileios Giannakopoulos (University of Patras, Greece)

- 13:30-13:45 **Sally Watson:** Daily reshaping of gravel bedforms by tidal currents in Cook Strait/Te Moana o Raukawakawa
- 13:45-13:50 **Mark Borrelli:** Augmenting seafloor habitat characterization via grain size analysis with low-cost imagery
- 13:50-13:55 **Taha Lahami:** A multi-sensor approach to monitor very shallow tidal environments: a case study from the Venice Lagoon, Italy
- 13:55-14:00 **Rhys Cooper:** Bathymetry and seafloor habitats within Ascension Island's Marine Protected Area
- 14:00-14:05 **William Bigelow:** Assessing the decline of solution holes in the Florida Keys: Integrating remote sensing technologies for habitat monitoring and conservation





14:05-14:20 **Antonia Kotliarov:** Coastal benthic communities of Prince Edward Island, Canada: A 3D approach to seafloor habitat mapping

14:20-14:25 **Marianna Coppola:** Multiscale effects of water quality on seagrass habitat structure: a Biscayne Bay case of study



14:25-14:40 **Audrey-Anne Amyot:** Exploring the submerged vertical walls of the Saguenay Fjord, Québec, Canada: Biodiversity and distribution of epifauna and benthic habitats

14:40-14:45 **Priscilla Dupont:** Very-high resolution coral reef habitat mapping using Pleiades satellite imagery in Mayotte, Indian Ocean

14:45-15:00 **Jeffrey Danielson:** The USGS Coastal National Elevation Database (CoNED): Integrated topobathymetric models – Florida case-study

15:00-15:05 **Bea Combs-Hintze:** Community-scale seagrass habitat mapping using multibeam sonar water column data in Tampa Bay

15:05-15:30 *Break*

15:30-15:50 Closing remarks and presentation of GeoHab 2026 – Malta

15:50-16:30 GeoHab business meeting

16:30-17:00 GeoHab Backscatter Working Group (BSWG) meeting



Friday, May 16th, 2025

Field trip

- | | |
|-------------|---|
| 9:30-12:15 | Behind-the-scenes guided tour of the science labs and museum, Mel Fisher Maritime Museum |
| 12:15-13:00 | Lunch |
| 13:00-16:00 | Explore the local marine ecosystems on a catamaran with a local reef expert. Includes a swimming and snorkeling stop. Open bar on the boat. |



Keynote Speakers

David Butterfield

Principal Research Scientist
University of Washington, Cooperative Institute for
Climate and Ocean Ecosystem Studies

Biography: David Butterfield is a geochemist, Principal Research Scientist and Affiliate Professor in Oceanography at the University of Washington. He holds a PhD in Chemical Oceanography from the University of Washington. Butterfield's research studying submarine volcanoes and hydrothermal systems began with his first deep submersible dive at Axial Seamount in the NE Pacific in 1986. He has participated in 70 oceanographic expeditions to discover and survey active volcanic and hydrothermal sites in the deep ocean, working in large interdisciplinary teams and using chemistry to advance understanding of how the oceans interact with volcanic and magmatic systems at and below the seafloor. Working with engineers at the National Oceanic and Atmospheric Administration (NOAA) Pacific Marine Environmental Laboratory in Seattle, Butterfield developed instruments for remotely operated vehicles to integrate water sampling, in-situ sensor data, microbial incubation and DNA preservation. He has used these instruments to study water-rock reactions, microbial ecology and mineral formation processes in high-temperature vents, microbe-rich diffuse vents, and directly over erupting lava.



David Butterfield in the ROV control room of Falkor (too) exploring the mid-Atlantic Ridge in 2023. Photo courtesy of the Schmidt Ocean Institute.

About the Cooperative Institute for Climate and Ocean Ecosystem Studies: The Cooperative Institute for Climate, Ocean and Ecosystem Studies (CICOES), established in 1977, exists for the purpose of fostering research collaboration between NOAA and the University of Washington, the University of Alaska Fairbanks and Oregon State University. The scientific mission of CICOES is to conduct multidisciplinary research, prepare the next generation of scientists, and engage and educate the public.

Keynote summary: The seafloor is extremely underexplored and poorly mapped. Hot springs on the deep-ocean floor exist along volcanically active mid-ocean ridges, on submarine volcanic arcs, and in other environments where magmatic heat finds a way to escape. Hot, metal-rich fluids produce sulfide mineral chimneys that are covered and surrounded by unique vent-endemic animals in symbiosis with chemosynthetic microbes. With growing pressure to exploit deep-ocean critical mineral resources, what measures are required to protect the unique biological communities living on hydrothermal mineral deposits? Scientific exploration can provide data to help answer that question. Using the first scientific mission on the new Schmidt Ocean Institute research vessel Falkor (too) as an example, this talk will describe how a combination of mapping with ship and AUV, water column sensing, and ROV seafloor survey/sampling methods were used to accelerate discovery and characterization of elusive hydrothermal features.



Ved Chirayath

Professor

Aircraft Center for Earth Sciences, Rosenstiel School of Marine, Atmospheric, and Earth Science, University of Miami

Biography: Ved Chirayath is the Vetlesen Chair of Earth Sciences, a National Geographic Explorer, and the inaugural director of the Aircraft Center for Earth Studies (ACES) at the University of Miami's Rosenstiel School of Marine, Atmospheric, and Earth Science. Chirayath's research focuses on inventing, developing, and testing next-generation sensing technologies for studying the natural world. Ultimately, his aim is to extend our capabilities for studying and protecting life on Earth and to aid in the search for life elsewhere in the universe.



Chirayath grew up in California with a passion for NASA's mission and space exploration. In 2003, a sophomore in high school, he modified a consumer digital camera and telescope to successfully detect an extra-solar planet, 150 light years away, 1.5x the size of Jupiter. Since then, his research interests have relied on the intersection of multiple disciplines including aeronautics, astrophysics, earth sciences, engineering, and optics. Formerly, Chirayath directed the NASA Laboratory for Advanced Sensing in Silicon Valley, California, for ten years. Chirayath received his BSc, MSc, and PhD in Physics, Astrophysics, and Aeronautics & Astronautics from Stanford University after five years studying theoretical physics in Russia. Recently, Chirayath was one of 30 finalists of 12,000 applicants for the NASA Astronaut Candidate Class of 2021 and received several NASA honor awards, including the NASA Equal Employment Opportunity Medal and a NASA Early Career Award. The American Geophysical Union awarded Chirayath the Falkenberg Award for "contributions to the quality of life, economic opportunities, and stewardship of the planet through the use of Earth science information."

About the Aircraft Center for Earth Sciences: The Aircraft Center for Earth Sciences, led by Chirayath, focuses on science-driven sensing and technology development for next-generation instruments that help us better understand our world and benefit humanity. ACES operates in the University of Miami's Department of Ocean Sciences. They welcome collaborations and are a growing team actively hiring faculty, post-doctoral, and doctoral candidates.

Keynote summary: We have mapped more of the surface of Mars, the Sun, and the Moon than our own ocean floor. Chirayath will talk to GeoHabbers about new technologies he is developing for NASA to see beneath the waves and explore oceans across the solar system. We'll dive into coral reefs and meet charismatic sea creatures, learn about the origin of life on our planet and the search for extra-oceanic life across the universe, and learn how to help map our oceans through the NASA NeMO-Net video game (<http://nemonet.info>).



Rachel Medley

Chief, Expedition and Exploration Division
National Oceanic and Atmospheric Administration's
(NOAA) Office of Ocean Exploration and Research



Photo provided by Rachel Medley.

Biography: Rachel Medley is the Chief of the Expedition and Exploration Division within NOAA's Office of Ocean Exploration. She also serves as the NOAA co-chair of the Interagency Working Group on Ocean Exploration and Characterization (IWG-OEC), which falls under the National Ocean Mapping Exploration and Characterization (NOMECE) council. Before joining NOAA Ocean Exploration, Medley worked for NOAA's Office of Coast Survey for 12 years, including 6 years as the Chief of the Customer Affairs Branch. Most recently, Medley completed a Presidential Management Fellowship Interagency Rotation Program (PMF-IRP) working within the Office of Management and Budget (OMB) with a portfolio focused on Environmental Justice and Equity as part of the Justice40 Initiative. A graduate of Mount Holyoke College in South Hadley, MA, she also holds an M.S. from the University of Massachusetts, Amherst in Geosciences. In 2009 she also received her M.S. in Ocean Mapping and IHO-Category A certification from the University of New Hampshire, CCOM/Joint Hydrographic Center. Medley serves as an Executive Board Member and Treasurer of the Women's Aquatic Network (WAN), a non-profit organization that brings together professionals interested in marine, coastal, and aquatic affairs and promotes women's roles and all who seek equity in these fields. In her spare time, she adventures around the world and at home with her husband and three children.

About NOAA's Office of Ocean Exploration and Research: NOAA Ocean Exploration is the only federal program dedicated to exploring our deep ocean, closing the prominent gap in our basic understanding of U.S. deep waters and seafloor and delivering the ocean information needed to strengthen the economy, health, and security of the United States. Using the latest tools and technology, NOAA Ocean Exploration explores unknown or poorly known areas of our deep ocean, making discoveries of scientific, economic, and cultural value. Through live video and data streams, online coverage, training opportunities, and events, we allow scientists, resource managers, students, members of the general public, and others to actively experience ocean exploration, allowing broader scientific participation, and cultivating the next generation of ocean explorers, and engaging the public in exploration activities. To better understand our ocean, our office makes exploration data available to the public. This allows us, collectively, to more effectively maintain ocean health, sustainably manage our marine resources, accelerate our national economy, and build a better appreciation of the value and importance of the ocean in our everyday lives.



Derek Sowers & Daniel Wagner

Mapping Operations Manager & Chief Scientist
Ocean Exploration Trust

Biography: Derek Sowers serves as the Mapping Operations Manager for the Ocean Exploration Trust, and is based at the University of New Hampshire's Center for Coastal and Ocean Mapping. Sowers previously served as an Expedition Coordinator for NOAA Ocean Exploration for nine years leading ocean exploration mapping and remotely-operated vehicle (ROV) missions on NOAA Ship Okeanos Explorer. He holds a B.S. in Environmental Science from the University of New Hampshire, an M.S. in Marine Resource Management from Oregon State University, and a Ph.D. in Oceanography from the University of New Hampshire. Sowers enjoys utilizing ocean mapping data to better characterize marine habitats, and developed standardized geomorphology maps for the entire U.S. Atlantic Margin deeper than 200 m for his doctoral research. Prior to focusing on deep sea mapping and exploration, he conducted coastal research and restoration work for NOAA's National Estuarine Research Reserve network and EPA's National Estuary Program in Oregon and New Hampshire. Sowers has participated in numerous oceanographic expeditions spanning remote areas of the Arctic, Pacific, and Atlantic oceans.

Daniel Wagner serves as the Chief Scientist for the Ocean Exploration Trust. He has conducted fieldwork on deep-sea ecosystems since 2006, and has since participated in 27 multi-disciplinary research expeditions that explored deep-sea habitats throughout the Indo-Pacific, Atlantic, and Southern Oceans. Wagner grew up in Ecuador, where at a young age he interned at the Galapagos National Park, an experience during which he developed a deep fascination for nature and the ocean. He then moved to Hawaii, where he earned a Bachelor of Science in Biology from Hawai'i Pacific University, as well as Master of Science and Ph.D. degrees in Oceanography from the University of Hawai'i at Mānoa. Prior to joining the Ocean Exploration Trust, Wagner worked for the NOAA's Papahānaumokuākea Marine National Monument in 2011-2016, where he coordinated scientific studies in support of resource management for the Monument. These included participation in over a dozen research expeditions to the Papahānaumokuākea Marine National Monument, information from which was used to underpin the expansion of the Monument and make it the largest marine protected area on Earth in 2016. Wagner served as the scientific advisor to the U.S. White House Council of Environmental Quality on the Monument expansion. In 2016, he moved to the U.S. East Coast to coordinate NOAA-led efforts aimed at collecting scientific information to support the management of deep-sea ecosystems in the U.S. Atlantic, which included work for the NOAA Office Of Ocean Exploration and Research, and the NOAA National Centers for Coastal Ocean Science. In 2019-2022, Wagner served as the Ocean Science Advisor for Conservation International, where he led multi-partner research initiatives



The Ocean Exploration Trust at work, recovering the Hercules ROV from the Nautilus. Photo provided by the speakers.



aimed at advancing large-scale marine conservation with a focus on areas beyond national jurisdiction.

About the Ocean Exploration Trust: The Ocean Exploration Trust (OET; <https://nautiluslive.org/about>) aims to explore the ocean, seeking out new discoveries while pushing the boundaries of technological innovation, education, and outreach. Expeditions are launched aboard E/V Nautilus, a 224-foot exploration vessel equipped with telepresence technology, remotely operated vehicles, acoustic mapping systems, and various other state-of-the-art exploration technologies. Scientists and the public from around the world can participate on expeditions remotely via live feeds, as well as via ship-to-shore interactions connecting the ship with science centers and classrooms. In addition to technical experts, educators and students sail on E/V Nautilus expeditions, gaining hands-on experience, serving as role models for the next generation, and disseminating expedition findings to the public around the world.

Keynote summary: This talk will provide an overview of E/V Nautilus' capabilities and planned expeditions in 2025, which include dedicated surveys on the deep seafloor around the Mariana Trench and Mariana Back-arc, Solomon Islands, Marshall Islands, Wake Island, and the Philippines. In addition to E/V Nautilus' seafloor mapping and ROV capabilities, this talk will also highlight OET's work as part of NOAA's Ocean Exploration Cooperative Institute to integrate emerging exploration technologies into ocean exploration missions – including autonomous surface vehicles, autonomous underwater vehicles (AUVs), water column profiling landers, and various sensors.



The Exploration Vessel (E/V) Nautilus – a 68-meter research vessel equipped with remotely-operated vehicles (ROVs), owned by the nonprofit Ocean Exploration Trust. Photo provided by the speakers.



2025 Ron McDowell Awardees

Audrey-Anne Amyot (Université Laval, Canada)

Exploring the submerged vertical walls of the Saguenay Fjord, Québec, Canada: Biodiversity and distribution of epifauna and benthic habitats

Ava Besecker (California State University Monterey Bay, United States)

Measuring the impact of substrate on outplanted coral growth in the Galápagos Islands using close-range underwater photogrammetry

Cara Brennan (University College Cork, Ireland)

An Enhanced Angular Range Analysis (eARA) workflow in support of large scale national mapping programmes: a case study on INFOMAR multibeam data, Ireland

Emmeline Broad (Memorial University of Newfoundland, Canada)

Using a newly discovered biodiversity hotspot to validate regional model projections of soft coral taxa

Kyah Chewying (University of Wollongong, Australia)

Braiding indigenous oral histories and habitat mapping to understand urchin barrens in southern New South Wales, Australia

Hassan Elkholy (Norwegian University of Science and Technology, Norway)

Bridging the gap : toward a streamlined pipeline for studying benthic habitats using benthic imagery and practical AI models

Vasileios Giannakopoulos (University of Patras, Greece)

Semi-automated delineation of pockmarks and mound-like seafloor features in Flensburg Bay (Germany-Denmark)



Ceridwyn Hunter (Arizona State University, United States)

Ecological evaluation of the fraction of absorbed photosynthetically active radiation for coral reef communities

Antonia Kotliarov (Memorial University of Newfoundland, Canada)

Coastal benthic communities of Prince Edward Island, Canada: A 3D approach to seafloor habitat mapping

Hanna Modin (The Arctic University of Norway, Norway)

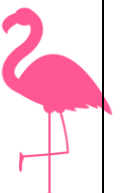
Preliminary results from an updated pan-Arctic zoobenthic biodiversity inventory and the way forward to identifying hotspots of blue carbon

Daniel Ng (Dalhousie University, Canada)

High-resolution mapping of Pacific white skate (*Bathyraja spinosissima*) nursery habitats at an active Galápagos hydrothermal vent field

Giorgio Simone (University of Bologna, Italy)

Marine litter in two Mediterranean submarine canyons: mapping distribution and impacts to support restoration efforts





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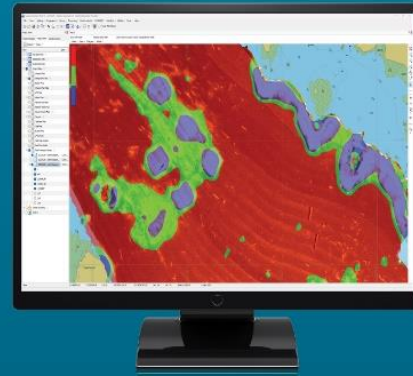
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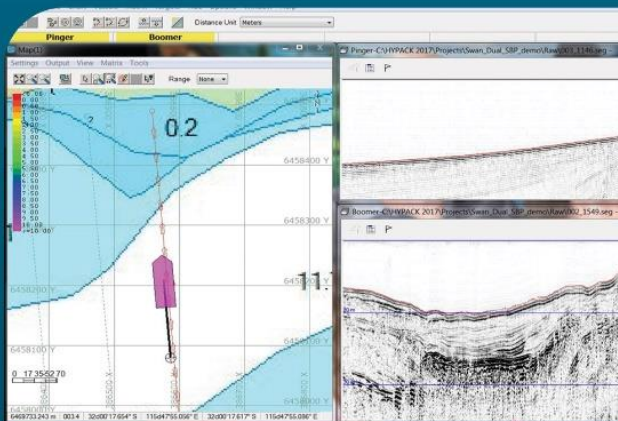
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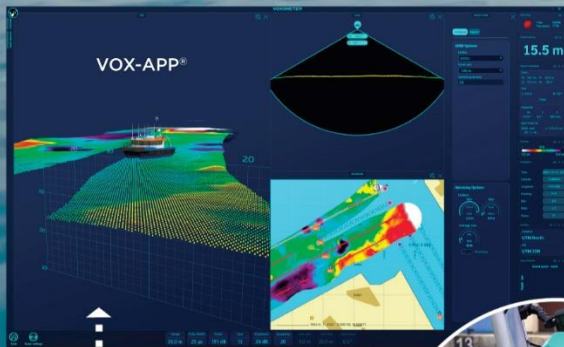
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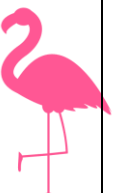


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ABSTRACTS

Complete abstracts listed by conference themes, in alphabetical order by first author



Climate Change Effects on Marine Habitats



Using Autonomous Drones as a Tool to Study the Impact of Sea Level Rise on Rocky Intertidal Communities

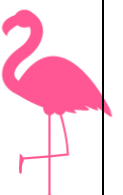
Olivia Bible^{1*}, Corey Garza¹ & Michael Espriella²

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Sea level rise is an increasing threat to many coastal ecosystems. Among those communities, the rocky intertidal zone is particularly susceptible to the impacts of sea level rise. The rocky intertidal is a critical habitat that has been the focus of environmental monitoring for decades. However, current survey methods may not be able to capture data across the spatial and temporal scales needed to detect the impact of sea level rise on intertidal communities. Uncrewed aerial vehicle (UAV) surveying is a tool employed to detect these impacts. UAVs rapidly capture large areas of spatial data at high resolution with minimal ecosystem disruption compared to traditional surveying methods. I aim to understand if UAV surveying is a valuable supplement to point-contact surveying when quantifying the effects of sea level rise on California intertidal ecology for the mussel *Mytilus californianus* and the seastar *Pisaster ochraceus*. In this study, I compared UAV-collected imagery with existing Multi-Agency Rocky Intertidal Network (MARINe) point-contact survey data for *M. californianus* by using object-based classification to calculate the percent cover of photomosaics and estimating mussel extent from tidal heights in ArcGIS Pro. Preliminary results show no significant difference in percent cover for *M. californianus* at Garrapata State Park for both MARINe and my UAV data, and an average kappa coefficient of 0.71 across sites, indicating a substantial agreement between both data sources. The results of this study suggest that UAVs, in conjunction with machine learning-based classification methods, are a valuable tool for rapidly collecting and estimating the impact of sea level rise on intertidal communities.



Identifying Coastal Habitat Migration Corridors for Strategic Conservation Planning

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Florida's 42 aquatic preserves, managed by the Department of Environmental Protection, protect critical marine and coastal habitats supporting a diversity of wildlife, including many endangered and threatened species. The aquatic preserves and other coastal natural areas are projected to experience significant transformations in natural community composition in the coming decades due to sea level rise. The persistence of coastal wetland ecosystems depends on their ability to migrate landward at a pace that exceeds the rate of sea level rise. The potential for habitat migration depends on the hydrological characteristics of adjacent watersheds and geological features of surrounding lands. Human-made infrastructure and development can limit migration potential, exacerbating wetland loss. It is essential to plan climate-resilient conservation strategies that include migration corridors that can support habitat transformations and enable coastal ecosystems in aquatic preserves to adapt to sea level rise.

In this study, we present two approaches for identifying habitat migration corridors that can serve as decision support tools for data-driven conservation planning. Our first approach uses land cover data to identify the most suitable areas within coastal watersheds to support coastal ecosystem migration, using the Cost Distance tool from Esri ArcGIS Pro. Our second approach incorporates additional geospatial data, flood risk models, and infrastructure data, employing the Omniscape model to determine the habitat connectivity and suitability for wetland migration. This analysis integrates projections of wetland responses to sea level rise using the Sea-Level Affecting Marshes Model and Marsh Migration Model from NOAA.

The progression of sea level rise is predicted to decrease connectivity between natural habitats, particularly in Florida's Gulf coast region, where large areas of coastal wetlands and forests are projected to become submerged. Florida's aquatic preserves are predicted to experience substantial shifts in habitat types, with saline habitats expanding and freshwater habitats contracting across most preserves. For example, in the Apalachicola Bay Aquatic Preserve, estuarine open water is predicted to increase dramatically, while tidal freshwater marsh is projected to disappear entirely under a two-meter sea level rise scenario. Both of the approaches presented were able to effectively prioritize critical areas upstream of aquatic preserves that, if protected, can improve ecosystem resilience to sea level rise by allowing for landward migration of coastal wetlands. These models were able to identify inland wetlands that could serve as refuges for wildlife species that occupy Florida's aquatic preserves.



Defoliation Responses of *A. Germinans* and *R. mangle* Mangrove Species to a Freeze Event at Their Northern Range Limit Using Drones

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Climate change is increasing winter temperatures, resulting in shifts in species distributions. Mangroves, which are typically found in subtropical and tropical regions, are expanding poleward. In the Apalachicola Bay region of Florida, this mangrove expansion has increased dramatically over the last decade. However, rare freeze events have occurred, which can slow down expansion for one species of mangrove and possibly favor the expansion of another, highlighting the need to understand the difference in freeze responses of mangrove species at their latitudinal range limit. Therefore, this study assessed the responses of two mangrove species, *Rhizophora mangle* (red) and *Avicennia germinans* (black), to freeze events at the northern edge of their range in Apalachicola Bay, Florida, USA.

We utilized unoccupied aerial systems (UAS) to collect imagery before and after a significant freeze event that occurred in 2022 at two sites in Apalachicola Bay, where both black and red mangrove species are present. We generated orthomosaics to identify both species of mangrove and assess their foliation status after the freeze event. We then classified the imagery and conducted a geospatial analysis to calculate the distance of the species to water and the density of vegetation (mangrove stands, monospecific salt marsh groups, and upland vegetation groups). We also extracted the elevation of the species using elevation data from the publicly available data resources. We developed logistic regression models for each species to evaluate the relationship between these ecological variables and the response of the tree (defoliated or foliated) after the freeze event. Preliminary results for one site show that for the black mangrove, the likelihood of defoliation increased with greater distance to open water, and higher percent coverage of mangrove stands, *Juncus* (a salt marsh species), and upland vegetation, while the likelihood of defoliation decreased with higher elevation values. In contrast, for red mangroves, distance to open water was the only significant predictor of defoliation, with greater distances to water correlating with a higher likelihood of defoliation.

Our study introduces a novel approach to assessing the impact of freeze events on two species at their northern range limit. As climate change continues, this method could serve as a rapid and valuable tool for monitoring mangrove expansion and contraction and may help to predict how these species will respond to future environmental changes.



Assessing Seabed Alterations and Ecological Impacts of Offshore Wind Turbine Installation in the Mid-Atlantic Bight Continental Shelf

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Offshore wind energy development is rapidly growing as a promising solution to mitigate climate change by providing sustainable, low-carbon energy. However, the installation of fixed-bottom turbine foundations—including gravity base, suction bucket (caisson), monopile, and jacket foundations—can significantly alter seabed conditions, impacting sediment dynamics and marine habitats. This study focuses on the Mid-Atlantic Bight, a key wind energy area along the East Coast of the United States between New Jersey and North Carolina, to examine potential seabed changes before and after installation and to understand how different foundation types affect marine flora and fauna, particularly benthic life.

Using a combination of geotechnical and geophysical data, sediment cores, and geomorphological analysis, we assess seabed alterations associated with each foundation type. High-resolution mapping techniques, such as seismic reflection profiling and sediment classification, are employed to evaluate sediment distribution, stability, and ecological impacts. Specific attention is given to how installation processes—such as pile driving for monopiles—affect sound-sensitive marine species like dolphins, as well as how sediment changes from gravity base installations influence benthic communities. Furthermore, prior studies on offshore wind meteorological buoy installations and removals have demonstrated significant seabed impacts, underscoring the importance of continued monitoring.

Aligned with GeoHab's 2025 theme, "Habitat Mapping in a Time of Climate Change," this research emphasizes the essential role of habitat mapping in renewable energy development. By examining the impacts of various foundation types on sediment and marine ecosystems, this study highlights the necessity of comprehensive pre- and post-installation mapping to support sustainable offshore wind practices. The findings contribute to global seabed mapping initiatives like Seabed 2030 and offer actionable insights for minimizing environmental impacts while advancing renewable energy projects.

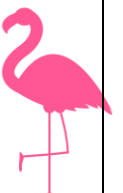


Climate Change and Marine Heatwave Impacts on Coastal Deep-Sea Corals and Sponges in the California Current

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Deep-sea corals and sponges (DSCS) create complex biological habitats that provide structure and support elevated abundance and diversity of invertebrates and commercially important groundfish, and play a pivotal role in benthic-pelagic ecosystem functioning. Due to their slow growth and long-lived nature, DSCS are threatened by oceanographic changes associated with warming, deoxygenation, ocean acidification, and alterations in food supply via changes in currents and source waters. In the California Current Large Marine Ecosystem along the U.S. West Coast, hotspots of DSCS biodiversity are present on the continental shelf and slope, where seamounts, canyons, and rocky outcrops support dense aggregations. The California Current is a global hotspot for decadal trends of ocean acidification and deoxygenation, and contains a vast offshore oxygen-minimum zone. The boundaries of this zone are expanding, compressing habitats and reorganizing faunal communities. The majority of climate-change related work on DSCS has occurred in the North Atlantic, but climate impacts and resiliency are top research priorities for DSCS on the U.S. West Coast that remain largely unaddressed. In addition to long-term change, the region has experienced multiple marine heatwaves reaching depths where most DSCS aggregations occur. Heatwaves have induced mass mortality in shallow-water corals, and laboratory studies indicate that acute thermal stress severely affects DSCS. Despite this, little is known about the extent to which heatwaves have interacted with DSCS in the past, or where these interactions are likely to intensify in frequency and/or magnitude. Here, we present data synthesis, analysis and modeling efforts to assess the effects of climate change and marine heatwaves on DSCS along the U.S. West Coast extending from the continental shelf areas to the upper slope. We create predictive models of climate change impacts on DSCS assemblage distribution on the continental shelf/slope of the U.S. West Coast, and conduct the first assessment of historical and potential future interactions of DSCS with heatwaves. These outputs can be utilized to adaptively manage existing conservation boundaries (*e.g.* bottom-contact fishery closures) or to prioritize areas for additional protections that support the resiliency of essential DSCS habitats and associated fisheries that connect the coastal zone to the wider ocean.



High-Resolution Multi-Scale Mapping of Seagrasses along the Italian Coasts: The Marine Ecosystem Restoration (MER-PNRR) Project

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As part of the Marine Ecosystem Restoration (MER) project, ISPRA is embarking on an innovative initiative to map coastal habitats along the Italian coast under the National Recovery and Resilience Plan (PNRR). It represents the largest projects of high-resolution mapping of submarine and subaerial coasts in Europe. ISPRA has selected the Fugro led consortium (Fugro – CGR), a leading supplier of cutting-edge technologies aiming to revolutionize marine ecosystem conservation and restoration. The mapping programme covers all the Italian coasts, focusing on morphological mapping of *Posidonia oceanica*, *Cymodocea nodosa*, and other key Mediterranean marine phanerogams. This effort integrates multi-scale technologies, including aerial sensors (topo-bathymetric LiDAR, RGB and hyperspectral cameras and gravimeters), multispectral satellite sensors, acoustic multibeam sensors, and autonomous underwater vehicles (AUVs) for high-resolution coastal ecosystem observation. Hydrospatial and geospatial data will be integrated, and advanced machine learning solutions will be used to perform classification at scale.

Especially the mediterranean *Posidonia oceanica* seagrass meadows have a significant contribution to carbon fixation and sequestration and their health is of crucial role in combating climate change and contribute to the biodiversity of the seabed. With the unprecedented survey concept, very high-resolution data and derived information will enhance local administrations' decision-making processes for protecting and restoring marine habitats and seagrass meadows in special. The amount and level of details on the seabed which have been acquired and will be surveyed brings new insights into other aspects which have not been addressed by the original scope, such as the impact of leisure boats and their seagrass scars and anchoring to the ecosystem.

The project is part of the MER project's (Marine Ecosystem Restoration) mapping program, unique in Europe, supplies Italian institutions, including the Ministry of the Environment and regional administrations, with invaluable data on marine habitats. It aligns with the European Biodiversity Strategy for 2030, aiming to create protected areas covering 30% of the EU's terrestrial and marine surfaces, with a special focus on Marine Protected Areas and Natura 2000 Sites.



Monitoring of Macroalgae Distribution around Dokdo in the East Sea (2022-2024) by Underwater Photogrammetric Method

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The waters surrounding Ulleungdo and Dokdo, located in the southwestern part of the East Sea, are characterized by the confluence of cold and warm currents, making them one of the regions with the highest sea surface temperature increase rates around the Korean Peninsula. Geographically, Dokdo, situated 216.8km from the mainland, is the outermost island of the peninsula. Along with Ulleungdo, it is an ideal location for monitoring the impacts of transparency among Korean coastal areas, providing an excellent environment for underwater imaging studies.

From 2022 to 2024, 13 surveys were conducted in the southern ‘Hokdomgul’ underwater cave of Dokdo to facilitate long-term monitoring of macroalgae habitats. Using underwater image-based seafloor mapping techniques, the surveys assessed water temperature, macroalgae coverage, distribution patterns, and dominant species across an average of 151.62m² per survey. Dominant species observed included *Ecklonia cava*, *Eisenia bicyclis*, *Sargassum spp.*, *Padina arborescens*, *Codium fragile*, and *Cladophoraceae sp.*. The macroalgae coverage rates relative to the surveyed area were 18.1% in 2022, 18.4% in 2023, and significantly increased to 53.7% in 2024.

The annual coverage for *Ecklonia cava* and *Eisenia bicyclis* showed consistency across the entire survey area, varying with seasonal and water temperature changes. In the case of *Padina arborescens*, it flourished from May to August before disappearing. *Sargassum spp.* was observed starting in August in 2022 and 2023. However, in 2024, it exhibited a relatively high coverage rate from May to November, significantly contributing to the increased distribution rate of macroalgae in the surveyed area that year. The underwater image-based seafloor mapping technique effectively captured these trends, underscoring its utility as a valuable tool for monitoring short- and long-term changes in marine ecosystems.



Estimating the Current and Future Geographic Distribution of the Queen Conch, *Aliger gigas*, under Different Scenarios of Climate Change

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The queen conch is one of the largest mollusks native to the Caribbean Sea and tropical northwestern Atlantic. This species has been the primary source of income for thousands of fishers in the Caribbean and has represented an important fraction of the production of the fishing sector in different countries such as the Bahamas, Turks and Caicos, Honduras, and Nicaragua. The great economic value and high demand for this mollusk has led to overfishing in different regions of the Caribbean Sea. This, combined with factors such as lack of population connectivity, limited larval dispersal, and low recruitment rates, have resulted in severe decline of population sizes, leading to the overall classification of the queen conch as a threatened species. Additionally, there is a lack of knowledge on the potential impacts of changing climate conditions on populations of this species, making the implementation of effective conservation measures a challenge. Given the current conservation status of the queen conch, it is crucial to investigate and predict, to the greatest extent possible, the potential effects that expected climate change could have on the future distribution of this species. Here, we performed ecological niche models to estimate the potential areas of distribution of the queen conch, and how they are expected to change in the future considering different climate change scenarios. Models were performed based on occurrence data and relevant environmental variables to develop predictions of the distributional range of *Aliger gigas* in current and future scenarios. These models were used to predict suitable areas for the queen conch for each decade from 2000 to 2100. The predicted areas were then overlapped with the current marine protected areas in the region to assess the proportion of the queen conch's potential distribution that falls within these conservation areas. Preliminary results show a consistent loss of most suitable areas for *Aliger gigas* along the north Atlantic coast of South America by 2080, under all the considered climate change scenarios. Interestingly, future predictions under two extreme scenarios of climate change, SSP 126 and SSP 585, agreed on the potential opening of new suitable areas for the species northward along the east coast of the United States. Furthermore, our results show only ~30% potentially suitable areas of the queen conch for the period 2000-2020 are included in the current coverage of the marine protected areas of the Caribbean, and this percentage is predicted to decrease for the future decades explored in our models.



Coastal and Shallow-Water Habitats



Analysis of 17+ Years of Historical Physics-Based Benthic Mapping and Satellite-Derived Bathymetry of a Complex Reef Ecosystem in SW Tobago to Determine its Contribution to Coastal Erosion

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Pigeon Point in SW Tobago within the Ramsar-designated Buccoo Reef Marine Park has been subject to increasing shoreline erosion and vulnerability of critical tourism infrastructure. Suspected drivers of this erosion include degradation of the reef crest, a deficit in sand sourcing from natural processes, seasonal and multidecadal changes to coastal forcing, sea level rise, and updrift anthropogenic shoreline interventions.

With no historical measurements available, satellite data was applied to better understand the complex coastal dynamics. Through a unique physics-based procedure that allows for processing in the absence of in-situ data, shallow water bathymetry, seafloor characteristics, and shoreline mapping were extracted in dense spatial (2m) grids between 2004 to 2021.

The combined SDB and benthic mapping, combined with numerical modelling, demonstrates the evolution of the shoreline against the changes in the nearshore and outer reef system. Spatial and temporal changes to sand pockets, hardbottom, coral reef and seagrass areas were appreciated to better understand the nearshore dynamics. Seagrass meadows migrated and expanded. Man-made structures caused a redirection of the littoral transport from the upper beach to the nearshore zone, interacting with (and smothering) seagrass meadows. Although coral health deteriorated over time, the reef crest elevation remained stable, which indicates the importance of the reef health to the shoreline (and nearshore) erosion.

The satellite derived products accessed from historical imagery presents a new and innovative method to map and understand coastal change on the shoreline and nearshore environment, through quantification of seabed movement and a better understanding of nearshore dynamics.



Exploring the Submerged Vertical Walls of the Saguenay Fjord, Québec, Canada: Biodiversity and Distribution of Epifauna and Benthic Habitats

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The Saguenay Fjord is at the heart of the Saguenay-St. Lawrence Marine Park, in Québec, Canada. While it is protected, pressure from climate change and the anthropic activities that are allowed within its boundaries still exists. Despite its accessible location, economic importance, and particular ecosystems, little is known about its benthic biodiversity, which includes both freshwater and saltwater species. The latest studies come from Dranville (1978) and Bossé (1996); each of them sampled only a few stations on the seafloor, yet they identified several species. The walls of the Fjord, which in this context also provide benthic habitats, have never been studied.

Our objectives were (1) to characterize the epibenthic communities of the vertical walls, (2) to identify the oceanographic drivers of these biological characteristics, and (3) to test whether there exist spatial distribution patterns following an upstream-downstream gradient and a depth gradient.

We sampled the walls using a remotely operated underwater vehicle (ROV) that allowed us to conduct video transects down to 100 m deep at 34 stations. At each station, we deployed a CTD multiprobe to measure the environmental parameters (*e.g.*, conductivity, turbidity, depth, temperature, salinity, dissolved oxygen, fluorescence, pH) in the water column. Video data were then analyzed to identify the species observed and quantify their abundance, richness, and percent coverage at the stations and as a function of depth.

The most abundant species were *Tentorium semisuberites*, *Didemnum albidum*, and organisms from the *Ophiuroidae* family. Results show a bay effect, *i.e.*, abundance and biodiversity are greater at the mouth of the Fjord, potentially due to the saline water supply from the St. Lawrence Estuary. As for the depth gradient, contrary to our hypotheses, species abundance and biodiversity were greater below the observed thermohalocline at 20 meters deep.

In conclusion, when looking at the distribution and biodiversity of benthic organisms in a fjord environment, it is important to adopt a three-dimensional approach that includes not only the bottom of the fjord but also its walls and the different factors influencing the distribution of the different organisms. The next step in this project will be to create 3D models of the walls using multibeam echosounders and structure-from-motion photogrammetry from video data, to link geomorphometric variables to species distribution.



Shifts in Geophysical Drivers of Pismo Clam (*Tivela stultorum*) Population Distributions Across Monterey Bay

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The Pismo clam (*Tivela stultorum*) was once a significant commercial asset to the fishing industry along the California coast, but its populations declined due to overexploitation in the 1990s. Although relatively less abundant in their northernmost ranges compared to their southern counterparts, Monterey Bay supports several populations along its local beaches. However, no long-term monitoring efforts currently exist in this area. Populations have shown signs of recovery, as evidenced by the presence of juveniles, yet no legal-sized adults have been observed. This project investigated how the distributions, abundances, and ages of Pismo clam populations are influenced by sedimentary and hydrodynamic conditions within Monterey Bay. Perpendicular transects were conducted across the bay, spanning from Davenport, CA, to Carmel, CA, over a nine-month period to assess clam densities and size-age relationships. These data were compared with sediment grain size, beach slope, and sediment sorting from each site. The morphodynamic beach state of each site was characterized using Dean's parameter. Average wave height and peak wave period were calculated for the years preceding the field sampling using data from the Coastal Data Information Program (CDIP) Monitoring and Prediction (MOP).

Among all the geological characteristics analyzed, beach slope emerged as the strongest predictor of clam presence. Additionally, smaller sediment grain size and higher degrees of sediment sorting were associated with greater clam densities. Clams are most abundant in the northern sites of Monterey Bay and are more likely to be associated with smaller Dean's numbers, suggesting a preference for more reflective beaches. By continuing to identify the physical factors that exert the most significant impact on Pismo clam population dynamics, this study elevates our understanding of the habitat conditions necessary for the rehabilitation of Pismo clam populations in Monterey Bay.



Assessing the Decline of Solution Holes in the Florida Keys: Integrating Remote Sensing Technologies for Habitat Monitoring and Conservation

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The nearshore hardbottom habitats of the Florida Keys are essential for maintaining marine biodiversity but face increasing pressures from both natural and human-induced disturbances. Among these habitats, solution holes—karst-limestone miniature cave systems—serve as critical biodiversity hotspots, providing shelter and protection for species such as spiny lobsters, groupers, and juvenile reef fish. These habitats are crucial for various life stages of marine species before they migrate to oceanside reefs for reproduction or growth. However, Florida Bay has experienced significant environmental stressors, including hurricanes, algal blooms, and rising water temperatures, contributing to the loss of these complex habitats.

Surveys of nearshore hardbottom habitats in the Gulfside of the Florida Keys over the past two decades have shown a troubling decline in solution hole abundance. From an initial 22 solution holes in 2010, only 11 remained in 2023, marking a 50% reduction. Additionally, only 20 of the original 39 sites retained identifiable structures, signalling a 171.43% increase in habitat filled by sedimentation or succession into seagrass. While traditional in-water diver surveys have provided a good baseline assessment, they are limited by range and frequency, are insufficient to capture the full scale of these changes over the wider region.

Given these findings, there is a pressing need for advanced monitoring techniques to assess the degradation of solution hole habitats and inform conservation strategies. Remote sensing technologies, including drone photogrammetry, remote camera deployments, and bathymetric LiDAR surveys, offer more efficient and expansive monitoring tools. These technologies can overcome the limitations of traditional surveys by providing broader-scale coverage and more frequent assessments. By integrating these methods, we can enhance our understanding of how solution holes support marine species at various life stages and track habitat changes over time. Further development of this multi-method approach is necessary to ultimately inform targeted conservation efforts aimed at protecting these critical habitats in the Florida Keys.



Augmenting Seafloor Habitat Characterization via Grain Size Analysis with Low-Cost Imagery

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Bottom grab samplers have long been the standard to describe nearshore marine habitats both qualitatively and quantitatively. However, all small, sediment samplers are designed to collect specific grain sizes and therefore have biases towards those sediments. Here we discuss seafloor characterizations based on grain size analysis alone vs grain size analysis augmented with quantitative benthic imagery. We also use both datasets to inform a prevalent benthic habitat classification system. The Coastal and Marine Ecological Classification Standard (CMECS) was used to test this hypothesis. CMECS was adopted by the federal government to standardize habitat classification in coastal U.S. waters. CMECS provides a hierarchical framework to define and interpret benthic habitats but does not prescribe specific sampling methods. Photography has been utilized for many decades in benthic ecology but have rarely been employed in habitat classification using CMECS. No study to date has quantitatively examined the benefit of incorporating benthic imagery into the classification of biotopes using CMECS. The objective of this study is to classify a roughly 1 km² subtidal area within Herring Cove in Provincetown, MA with CMECS, and to quantify the benefit of augmenting classification with low-cost imagery.

A benthic habitat survey of the study area included grab sampling for grain-size analysis and invertebrate taxonomy, benthic imagery, water quality sampling at 24 sampling stations, as well as acoustic mapping of the study area. Multivariate statistical analyses were employed to classify biotic communities and link environmental and biological data to classify biotopes. Results showed that benthic imagery improved classification and mapping of CMECS components. Furthermore, the classification of habitats and biotopes were improved using benthic imagery data. These findings imply that the incorporation of low-cost benthic imagery is warranted in coastal benthic biotope classification and mapping studies and should be regularly adopted.



Community-Scale Seagrass Habitat Mapping using Multibeam Sonar Water Column Data in Tampa Bay

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Seagrass meadows are vital coastal ecosystems, providing critical services such as marine habitat support, sediment stabilization, and carbon sequestration. Despite their importance, these habitats are increasingly threatened by anthropogenic activities and environmental stressors, necessitating the development of advanced monitoring techniques, including mapping and monitoring that can be conducted during the growing season that is typically too turbid for traditional landscape scale seagrass mapping. In addition, the restoration community has highlighted a need for rapid, detailed restored seagrass site monitoring at centemeter scales, to monitor new growth that cannot be detected by satellite and aerial surveys. This research investigates the application of multibeam sonar (MBS) with a focus on water column analysis to achieve fine-scale resolution of seagrass habitat structures in Tampa Bay.

The study combines controlled tank experiments, Autonomous Surface Vehicle (ASV) field trials, and shipboard multibeam surveys of two seagrass sites in Tampa Bay that demonstrate a variety of seagrass habitat, including seagrass species transition, loss, and regrowth. Controlled tank experiments which highlighted useful frequencies for these scales and structures, were conducted using a Kongsberg 2040P multispectral capable MBS to explore the useful frequencies and acoustic backscatter properties of seagrass, focusing on the detection of height, density, and other structural attributes. Field trials during the growing season aligned with satellite surveys to validate MBS-derived water column data for assessing seagrass structure in dynamic coastal environments. By integrating acoustic backscatter and water column data, this research provides new insights into the spatial variability, species composition, and ecological function of seagrass habitats.

Preliminary findings demonstrate that single-frequency MBES technology can capture detailed structural and water column characteristics of seagrass meadows, offering a robust method for habitat monitoring in turbid and shallow waters. This data is being incorporated into a predictive seagrass community model, leveraging Generalized Additive Models (GAMs) to link sonar observations to biomass and ecosystem dynamics.



Bathymetry and Seafloor Habitats Within Ascension Island's Marine Protected Area

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The Ascension Island Marine Protected Area (MPA) is one of the largest areas of protected ocean in the world and safeguards a unique ecosystem in the South Atlantic Ocean. The British Geological Survey (BGS) recently undertook a programme of high-resolution bathymetry surveys and drop-camera sampling within the nearshore areas of the MPA to better understand the character, distribution, and extent of nearshore habitats.

Collecting data in such a remote and exposed location was a challenge. BGS had to adapt existing technology to work with the available survey platform and staff within the limits of Ascension's wonderfully varied and unpredictable operating environment. Here we present the data acquisition and processing methods for collection of multibeam bathymetry, backscatter intensity and ground truth datasets, and discuss how we integrated new and existing datasets and the use of semi-automated mapping techniques. In addition, we present the first complete geomorphology and substrate map of the Ascension Island MPA, depicted at 1:10,000 scale, to depth of 1000m and 300m respectively. The geomorphological map revealed a collection of features including seamounts, ridges, submarine landslides and channels, whilst the substrate map was limited to a depth of 300m to focus on the nearshore areas composed of sandy sediments and rocky outcrops which are fundamental habitats for the marine communities. Both maps enhanced our understanding of the seabed processes and geological features of Ascension Island and enabled us to create habitat maps. These will be used by the Department of Conservation on Ascension Island to inform better management and monitoring of the marine environment.



Multiscale Effects of Water Quality on Seagrass Habitat Structure: a Biscayne Bay Case of Study

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Seagrasses form highly productive coastal habitats that provide crucial ecosystem services worldwide. In Biscayne Bay, an estuarine lagoon along Miami's coastline (USA), extensive seagrass beds support rich biodiversity and ecosystem functions. However, declining water quality, primarily driven by freshwater discharges from coastal canals, has triggered concerning seagrass losses throughout the bay. These declines represent a critical challenge for environmental managers and highlight the urgent need to understand how water quality shapes seagrass habitat structure and stability. This study employs remote sensing techniques to examine the relationship between eutrophication levels and seagrass habitat structural characteristics in Biscayne Bay. While seagrass landscapes are influenced by numerous biotic and environmental factors interacting across multiple spatial scales, traditional ecological studies often focus on single-scale analyses. This limited approach constrains our understanding of the dynamic processes governing seagrass habitat patterns and their responses to environmental stressors. To address this knowledge gap, we conducted a comprehensive multi-scale analysis investigating how seagrass habitat distribution patterns respond to varying water quality. Benthic habitat maps of Biscayne Bay underpin this project as they provide quantitative information on seagrass spatial structure. In this study, we integrated *in situ* data with satellite imagery to build a Random Forest classification model. Our model was then applied to a time series of satellite image data to create the habitat maps, from which spatial pattern metrics were extracted at multiple scales under variable water quality conditions. The relationships between spatial pattern metrics (response variables) and water quality parameters (predictor variables) were finally addressed using generalized linear models. Our research specifically aims to quantify the spatial scales at which seagrass seascape structure responds to eutrophication conditions. By identifying these characteristic response scales, this study provides environmental managers with crucial information for developing targeted conservation strategies.



Integrating the Seascape into the Process of Offshore Wind Planning in Brazil

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The intensification of global climate change has led to a growing incentive for the energy transition, stimulating the expansion of renewable energy. Brazil has one of the greatest potential to explore offshore wind due to significant capacity factors along more than 8.000 km of coastline. However, all this renewable energy potential overlaps with one of the largest carbonate dominated continental shelves in the world, where important marine ecosystems made up of limestone algae banks, sandstone reefs, coral reefs and seagrass meadows comprises a great habitat heterogeneity.

With the aim of making the implementation of offshore wind farms (OWF) compatible with the conservation of marine ecosystems, PETROBRAS is carrying out research studies to develop innovations in the process of characterization of marine environments able to foster the spatial planning of OWF from an integrated seascape perspective. Three R&D projects are being developed with the general scope of discriminating marine geohabitats using appropriate methodologies for the distinctive characteristics of the Brazilian coast.

In the Southeastern region, the *SeascapeWind* project will apply techniques for scanning the seafloor with multispectral sonar (170, 240, 400 kHz) and develop an Angular Range Analysis modeling to increase the spatial resolution of the backscatter response. In the Northeastern region, the lower water turbidity allows the use of Satellite Derived Bathymetry (SDB) for discrimination of the seafloor, including canyons and paleochannels. Other complementary techniques will be used to increase spatial resolution, such as overflights with UAVs (Unmanned Aerial Vehicles) and USVs (Unmanned Surface Vessels) to acquire more detailed aerial images and subsequent hydrographic survey of selected areas. Complementary surveys and data acquisition using research vessels will provide the “groundtruthing” where the previously described methodologies are not applicable. In the Southern region, the survey of geohabitats will have a greater emphasis on paleostratigraphic reconstruction of the Quaternary, aiming to identify regions with a greater probability of occurrence of ancient shorelines whose marine cementation gave rise to large lineaments of sandstone reefs (parcels), an important structuring element of local biodiversity. The Local Ecological Knowledge (CEL) of artisanal fishermen and recreational diving operators will also be used within geohabitat mapping methodologies, associated with fishing acoustic techniques to evaluate the ecosystem services provided by the parcels.



The seascape perspective of geohabitats will be given by geological and shallow geophysical surveys, evaluation of benthic biota as well as genomic and geochemical analysis to determine the environmental quality of the region, from past to present.



Morphological Characterization of Bedforms in the Forgotten Reefs Region, Southern Abrolhos Shelf

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Bedforms are the results of the interaction between waves, currents and surface sediments. Depending on sediment type and near-bed shear stress, bedforms can be erosional or depositional structures with varying scales, classified as Longitudinal, Transversal, or Transitional. Considering that the study of bedforms and their classification contributes to understanding the seabed mobility, which could be used as an indication of bed disturbance, this study aims to identify and describe the bedforms present in an inter-reef area (Forgotten Reefs), located in the southern shelf of Abrolhos. This study also tries to relate bedforms with seabed types. The study uses bathymetrical data obtained using R2Sonic 2024 multibeam echosounder, sediment sampling, and seabed images obtained from a drop camera, which contains a considerable extent of submerged reefs and rhodolith banks.

Dimensional analysis was conducted from bathymetric profiles, considering length, height, spacing, and asymmetry parameters. Additionally, complementary statistical analyses were performed to understand the distribution pattern of the features, aiming to identify size differences and the predominant features in each region. Based on the analyses, it was observed that the distribution of seafloor features in the area varies between sand waves (or dunes/ripples), furrows, sand ribbons, and potentially comet scours. In the shallower region, the predominance of furrow-type features around reef structures was observed, while in the deeper areas, transversal features ranging from 0.15 to 0.5 meters in height were found. Comet scours were associated with reefs bordering an unfilled paleo-valley at depths greater than 30m, being the only location where they were identified. Based on the dimensional characteristics of the bedforms, a simple potential classification model was proposed, grouping the features according to their proportions and categorizing them into three main classes defined as "narrow", "intermediate", and "wide", with widths ranging from approximately 13 to 78 meters.

In terms of habitats, the study area is characterized by submerged reefs and extensive rhodolith beds. The presence of bedforms (longitudinal or transversal) defines a different type of physical habitat marked by carbonate sands with living maerl/calcareous algae. Rhodolith habitats do not show bedforms, and reef morphology can induce the formation of erosive bedforms, such as furrows. Therefore, these studies highlight the importance of bedforms in understanding local hydrodynamics and their application in issues such as planning potential conservation units, due to their role as hydrodynamic indicators and specific benthic habitats.



Very-High Resolution Coral Reef Habitat Mapping using Pleiades Satellite Imagery in Mayotte, Indian Ocean

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Tropical coral reefs are the most biodiverse ecosystems on the planet. Unfortunately, increasing direct (*e.g.*, overfishing, change in land use) and indirect (*e.g.*, ocean acidification, sea-level rise, global warming, storms) human pressures are causing rapid declines in marine biodiversity globally, calling for more careful monitoring of sensitive ecosystems. If environmental baseline data like marine habitat maps are increasingly required to manage coastal environments, they are often lacking or are only available at a resolution that do not meet the needs of management. Such deficiencies hamper the implementation of effective management strategies and monitoring efforts.

Here, we developed a method for conducting very high-resolution (sub-meter) mapping of benthic habitats semi-automatically across the 195km of Mayotte's reef flat, a French island of the southwestern Indian Ocean. The mapping was performed using 50-cm resolution Pleiades satellite imagery from 2021-2023 and LiDAR-derived bathymetry. Satellite images were supplemented by underwater images acquired along 185 transects using a GoPro camera fixed to a diver propulsion vehicle. To achieve a very high spatial accuracy, underwater images were positioned with a few centimeters accuracy using a Global Navigation Satellite System (GNSS) system and post-processed kinematic (PPK) corrections. Geo-referenced image frames were extracted from the videos and integrated for annotations into CoralNet, a free online benthic image analysis software using semi-automatic deep learning analysis. About 10% of the video frames (3045 images) were annotated, allowing the analysis of over 27,000 image and calculate habitats' covers on the reef. Satellite images were segmented using an Object-Based Image Analysis (OBIA) approach (*i.e.*, the "Large-Scale Mean-Shift" (LSMS) segmentation method) and segments properties were used with other variables in a Random Forest pixel-based classification. To ensure replicability, data processing and analyses were conducted using free and open source software Orfeo ToolBox, QGIS, and R Stats.

Thirteen benthic habitats, extending from coastal mangroves to the outer reef slope, were mapped at the pixel level. The LSMS segmentation method applied to Pléiades images created 54,706 segments. CoralNet classifiers achieved 65% accuracy, while the Random Forest models



reached an accuracy of 76%. The composition of benthic assemblages varied significantly around the island, with changes in live corals accompanied by a rise in muddy habitats, turf, and dead corals as anthropogenic pressures intensify.

The detailed habitat maps produced through this project will serve as an essential management tool to inform the management of Mayotte's coastal waters. In December 2024, Mayotte experienced the very destructive Chido cyclone that strongly impacted the island, its population, and its terrestrial and marine ecosystems. By using satellite images acquired just before the cyclonic event, maps can serve as reference data, and help assess the cyclone's impact on the island's marine ecosystems.



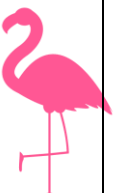
Leveraging Low-Cost, Commercial-Off-The-Shelf Technologies for Rapid Assessment of Submerged Aquatic Vegetation Habitat

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Detailed and accurate mapping of very shallow, coastal and estuarine habitats is challenging. Very shallow waters (< 2 m) limit the size and capabilities of traditional survey platforms (*e.g.* crewed surface vessels) and reduce sonar swath coverage. Turbid or choppy waters often present in shallow environments can impact sonar quality as well as inhibit other surface or aerial-based survey technologies, such as optical or LiDAR-based systems. The challenges are amplified in sensitive habitats, where the objective is to limit disturbance activities, yet the habitat may present entanglement hazards to platforms (*e.g.* Submerged Aquatic Vegetation [SAV] to survey vessels) or prevent use altogether (*e.g.* shorebird nesting to unscrewed aerial systems). We present our efforts to leverage low-cost, commercial-off-the-shelf (COTS) technologies to survey and assess the health of SAV habitat around the very shallow waters of Tyndall Air Force Base, Panama City, FL. We utilized a BlueRobotics BlueBoat Uncrewed Surface Vehicle equipped with Cerulean Dual-Omniscan 450kHz Side-Scan and Surveyor 240-16 240 kHz multibeam sonars and GoPro Hero10 camera to survey SAV in waters between 1 – 2 m deep. The entire package costs less than \$20,000. As a comparison, we surveyed the same SAV habitat with a Teledyne Z-Boat 1800RP equipped with Norbit iWBMSH-STX 400kHz multibeam sonar and GoPro Hero10, a package that costs over 10 times more than the BlueBoat. We found that the BlueBoat delivered high-quality sidescan sonar imagery and contextual bathymetry in a smaller, less intrusive, and logistically simpler platform. Although positioning was less accurate (~1 - 2 m accuracy) on the BlueBoat, the Cerulean Omniscan imagery was ideal for quantifying spatial extent of SAV and identifying areas of SAV loss in repeat surveys. Further, the BlueBoat was not susceptible to entanglement in SAV that presented a problem with the larger Z-Boat. We suggest that the positional and attitude accuracy of the BlueBoat and data quality of the Cerulean sonars could be improved through the use of fiducials and careful survey design, or through simple and low-cost integration of other COTS coupled Real-Time Kinematic GNSS and Inertial Motion Units if required. Overall, the reasonable cost and ease of use of the BlueBoat and Cerulean sonar systems could facilitate wider adoption by federal, state, academic, and non-profit group for habitat mapping and monitoring of shallow water habitats.



Establishing a CMECS Baseline Dataset for Sleeping Bear Dunes National Lakeshore

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Sleeping Bear Dunes National Lakeshore (SLBE) is a National Park Service (NPS) unit located on the eastern shore of Lake Michigan in northwestern Michigan. Encompassing a diverse range of habitats, SLBE's coastal and aquatic geography support important native fisheries and migratory birds that are the subject of intensive management and research efforts by NPS and partner agencies. Of particular concern are impacts due to the expanding range of invasive species and loss of native habitat. This project aims to establish a comprehensive understanding of lakebed structure and composition to monitor future changes in coastal processes, characterize essential fishery habitats, and map the distribution of invasive species along with their suitable habitats.

The Coastal and Marine Ecological Classification Standard (CMECS) provides a framework for classifying and describing ecological data, including for lacustrine environments. The CMECS Geoform component classes provide richer insights into the area's geological past while also providing a better understanding of current ecological conditions. This project used high resolution bathymetry as input into the Bathymetric and Reflectivity-based Estimator of Seafloor Segments (BRESS) technique, a semi-automated method for benthic geomorphon identification, to develop initial CMECS Geoform classes. These classes were ground-truthed and refined using underwater video data.

This poster will describe the methodology for creating the CMECS Geoform component for SLBE and the resulting map output. The poster will also highlight the management applications of the the output, including guiding multi-agency reef restoration efforts in Great Lakes habitats affected by invasive dreissenid mussels. Furthermore, this project has broader implications, including documenting methods for benthic mapping in Great Lake national parks and aiding in the adaptation of CMECS for freshwater systems.



Synergetic Survey and Mapping of the Very Shallow Benthic Habitats in the German Baltic

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The very shallow coastal waters of the German Baltic coasts include ecologically valuable habitats such as reefs, boulder fields, and seagrass meadows. The State Agency for Environment (LfU) is responsible for managing and monitoring benthic and coastal habitats and reports, among other things, to the European directives which aim for ecosystem improvement. The (in)accessibility of the shallow waters and the total area of the coast necessitate new ways of mapping and monitoring benthic habitats. In two projects in 2023 and 2024 for the Kieler Förde and Eckernförder Bucht, both inlets of the southern Baltic Sea, covering about 250 sq km in total, we designed a cost-effective survey solution that combined different survey and mapping methods. It included sidescan sonar, drop-down videos, and grab samples. Recent satellite imagery was analyzed and combined with the on-site information and compared with additional on-site data from previous years.

Different analytical methods were applied, from AI-trained models for boulder detection on sidescan backscatter to ML-based density and extent mapping of seagrass beds and the (bio)physical inversion of the multispectral satellite data for bathymetry, reflectivity analysis, and classification. The methods identified dense boulder fields (reefs according to the national definition) with 200,000 single boulders, and seagrass meadows and their densities in the shallow water zone from 0 to 10m depth.

The information is of high importance for reporting, coastal planning, and nature conservation of these habitats and serves as a baseline for future management. In addition, the benefits and challenges of this combined survey and mapping approach greatly contribute to future planning, as well as survey and monitoring strategies.



Remote Sensing of Coral Reef Benthic Community Structure

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It is incontrovertible that many coral reefs are in various stages of decline and may be unable to withstand the effects of global climate change, jeopardizing vital ecosystem goods and services to hundreds of millions of people around the world. To assess reefs, local and regional surveys have disparate objectives and often utilize different methods, but they invariably share a common metric for reef status: benthic cover, or the relative abundances of corals, various algae, and sediment, which are fundamental reef benthic types. Coral cover, in particular, occupies the most focus among those assessing and predicting reef trends. The typical assessment approach is to make small-scale observations (10s of m) of benthic cover at multiple, well-separated (100s of m to km) sites using in-water methods, such as quadrats, transects, orthomosaics, and manta-tows. However, these surveys are sparse and non-uniform, with little methodological consistency between programs, and logistics place a strong limit on total global surveyed reef area. Ultimately, this impedes modeling and predicting the impact of a changing environment at the ecosystem scale.

Remote sensing offers the only viable approach to collect uniform, high-density data at the ecosystem scale across reef regions, much less globally. Numerous case studies have demonstrated the ability for multispectral sensors with moderate or high spatial resolution to produce reasonably accurate maps of reef “habitats.” These efforts have generated good depictions of reef location and ecological zonation within reefs, but thus far they have failed to achieve one of the most fundamentally important objectives in reef assessment: discriminate between live coral and algae. Though fewer, hyperspectral studies have demonstrated a stronger capacity to accomplish that objective. In virtually all cases, both multi- and hyperspectral, the greatest obstacle has been development of an algorithm that provides accurate retrievals and is generalizable across scenes and, ideally, sensors.

NASA’s CORal Reef Airborne Laboratory (CORAL) mission leveraged the most recent (at the time) algorithmic approach and a state-of-the-art hyperspectral imager, and generated reasonable initial results. Refinements to the algorithm have increased accuracy to about $\pm 15\%$ benthic cover, which is comparable to spot in-water observations, but also provides detailed spatial context that is absent in diver-based surveys. Algorithm advances have also improved retrievals from multispectral imagery, such as from the WorldView satellites. While less accurate than their hyperspectral counterparts, these data still provide very useful spatial context. Early work with deep learning points to good potential for synthesizing multi- and hyperspectral data into a robust reef benthic cover product. This presentation first provides a brief review of the field, then highlights developments in recent and ongoing airborne and satellite efforts to map reef benthic cover, focusing on retrieval successes and limitations. The presentation ends with discussion of unmet challenges in both remote sensing science and the soon-to-be-enabled coral reef science.



Ecological Evaluation of the Fraction of Absorbed Photosynthetically Active Radiation for Coral Reef Communities

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The fraction of absorbed photosynthetically active radiation (fAPAR) quantifies the capacity of an organism or community to capture light for photosynthesis, and thus sets a limit on primary production. In terrestrial systems, fAPAR has been designated as an essential climate variable, used to evaluate global productivity. fAPAR may be applied similarly to analogous marine ecosystems, such as coral reefs, which are driven primarily by photosynthesis. A novel approach has been recently developed to estimate coral reef fAPAR from underwater orthomosaics at the community scale ($\sim 10 \text{ m} \times 10 \text{ m}$). In this study, we apply the new method to 282 sites visited during the validation campaigns for the NASA Coral Reef Airborne Laboratory (CORAL) mission, including locales in the Great Barrier Reef, Palau, Guam, and Hawai'i. Sites span virtually all reef geomorphological zones, and benthic community structure varies widely between algae-, coral-, and sand-dominated. Broadly, fAPAR is near $0.702 (\pm 0.050)$ for sandy areas and $0.914 (\pm 0.026)$ for coral/algae dominated areas. Community fAPAR values are highly negatively correlated with the amount of sand present in the community. Disregarding sand-dominated sites, robust regression indicates that community fAPAR increases slightly with increasing depth. Furthermore, robust regression indicates that fAPAR increases slightly with increasing coral cover and the inverse is true for algae. There are no apparent differences in community fAPAR trends between regions. Taken together, these statistically significant trends help explain why coral-rich areas generally exhibit higher primary productivity, as well as why production rates are generally consistent across and between reef biogeographic regions.



Geodiversity of the Archipelago Sea, Finland, Baltic Sea

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Geodiversity describes the diversity of abiotic nature and highlights that nature contains not just biotic components but also abiotic ones. To expand our understanding of marine geodiversity, we have studied the geodiversity of the Archipelago Sea in the northern Baltic Sea, focusing on geological features and their spatial distribution. We adapted methods used in previous Baltic Sea studies, and conducted spatial analyses of geological datasets, including bedrock type, seabed substrates, and seabed structures. We quantified geodiversity using a geodiversity index, which considers the variety of physical elements, roughness, and area of the unit.

Our results show a diverse seabed environment in the Archipelago Sea of Finland with varying geodiversity throughout the study area. Bedrock fracture and fault zones along with large end-moraine formations seem to contribute to geodiversity patterns of the area. Similar patterns have been observed in terrestrial areas of Finland. Areas of open sea were generally more homogeneous than the middle and inner archipelago, implying that there are also relationships between archipelago zonation and geodiversity.

Our study formally recognizes the complexity of the seabed in the Archipelago Sea and highlights the importance of understanding the geological processes shaping the region. These results can inform maritime spatial planning and sustainable resource management.

The study utilized research infrastructure facilities provided by FINMARI (Finnish Marine Research Infrastructure network).



SeaMoreEco – Filling the Gap of Marine Data in the Land-Sea Interface

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Shallow coastal waters are biologically important marine areas, but heavily impacted by human activities like dredging and various constructions such as harbors and offshore wind farms. A current challenge in sustainable marine management remains the lack of marine data *e.g.*, the knowledge of occurring species and habitats. In the SeaMoreEco project, we have studied shallow water areas of the Gulf of Bothnia, northern Baltic Sea. The Baltic Sea is a European inland sea, a heavily impacted, shallow brackish water basin with ~90 million people in its catchment area.

To fill the gap in knowledge of shallow water bathymetry, vegetation and seabed substrates we have used various methods like satellite data analysis, airborne drone imaging, scuba/surface divers and shipborne acoustic-seismic methods. Here we focus on bathymetry and vegetation information gathered from the shallow water areas in Finland and Sweden.

Satellite derived data was studied in the Gulf of Bothnia in Finland and Sweden. Sentinel-2 optical satellite images were used for satellite derived bathymetry estimations. Models based on machine learning have been used for creating maps of the seabed with a focus on SAV (submerged aquatic vegetation). In-situ ground truth data were collected by divers, drop video and with hydroacoustic methods mounted on the research vessels and boats.

The preliminary results suggest that the area possible to analyze is greater than 1200 km². The analysis will cover approximately 60 % of the depth interval between 0 and 3 meters, and 11 % for the interval 3 to 6 m water depth. SAV is covering around 30 % of the analyzed shallow water areas. The accuracy analyzed using separate data from the ground truth and drone images is around 70% in the area.

The results of this analysis will serve as a crucial first step toward large-scale monitoring of our sea areas, enabling us to meet and track national and European requirements for habitat and environmental status classification. Furthermore, cross-national data provide an opportunity to develop harmonized methods that transcend country borders.

This study is part of the SeaMoreEco project funded by the Interreg Aurora.



Coastal Benthic Communities of Prince Edward Island, Canada: A 3D Approach to Seafloor Habitat Mapping

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Seafloor habitat mapping approaches often combine multibeam echosounder (MBES) data with seafloor video or photographic ground validation data. This methodology relies on seafloor surficial information when other factors such as water column parameters and subsurface geology may also play a role in determining benthic habitat patterns. Integrating sub-surface geology and water column information with surficial data can provide a more comprehensive approach to habitat mapping.

In 2021, MBES and sub-bottom data were collected off the northern coast of Prince Edward Island (PEI), Canada, as part of an Ocean Frontier Institute (OFI) project investigating the presence of offshore freshwater reserves. The presence of freshwater was confirmed using pore water samples extracted from sediment gravity cores during this expedition, and the area was mapped using a Kongsberg EM710 MBES. This area was revisited in 2024 to pinpoint zones of potential groundwater discharge and to identify any effects of freshwater on benthic communities. The 2024 survey included 24 stations within which water column and biological data were collected using a CTD, ADCP, and video footage from a drop camera, along with some additional bathymetric and backscatter data collected with a Kongsberg EM 2040P MBES. Video data was annotated using BIIGLE 2.0 (Browsing and Annotating Large Marine Image Collections) to identify benthic fauna and surficial substrates. Sub-bottom and MBES data from the 2021 survey were integrated to map benthic assemblage patterns, integrating both subsurface geology and water column data sets.

Four substrate classes were identified and 8 taxonomic groups were observed. Overall, diversity of the study area was low. Sub-bottom data showed that a Holocene sediment layer was the dominant substrate which corresponded with surficial sand, which in turn was associated with the presence of the dominant sand dollar taxa. Additionally, faunal diversity and richness within the area was associated with bathymetric depressions at the site. Deformation features within the sub-bottom were interpreted as a result of freshwater advection. However, there appeared to be no effect of these features on faunal diversity at the seabed, and the ADCP and CTD measurements revealed no evidence of freshening within the water column.

All data sets were integrated to generate a benthic habitat map of the study area, linking biological diversity patterns with surficial sediment patterns, seafloor morphology and subsurface geology. The resulting project map will help with future resource planning around PEI as well as act as a baseline characterization for future monitoring activities at the site.



A Multi-Sensor Approach to Monitor Very Shallow Tidal Environments: A Case Study from the Venice Lagoon, Italy

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Understanding complexities and dynamics of tidal habitats is crucial for their conservation and management. Tidal environments such as deltas, estuaries, and lagoons are often located in highly urbanized areas, and threatened by mean sea level rise, pollution and climate change. However benthic habitat mapping and monitoring are generally difficult in such environments, owing to a combination of extremely shallow waters, strong tidal currents and high turbidity. In this study, we present a multidisciplinary approach that integrates different cutting-edge technologies and data to map, monitor, and ecologically characterize tidal environments.

The study focuses on a natural tidal channel in the northern Venice Lagoon, wherein high-resolution bathymetric data were collected using a multibeam echo sounder. Moreover, sub-bottom profiler data, in-situ grab samples and underwater imagery were acquired, enabling a detailed mapping of the underwater topography, sedimentary features and benthic habitats. Complementing the underwater investigations, a UAV DJI Matrice 350 equipped with LiDAR technology was used to map the topography of the surrounding salt marshes. This data was integrated with bathymetric measurements, creating a comprehensive dataset that bridges terrestrial and aquatic domains revealing the inextricable links between above and below-water environments.

The study highlighted the presence of large demosponge formations covering the shallowest areas of the tidal channel. Through underwater 3D reconstruction techniques we examine the demosponge structural complexity, highlighting their ecological role and spatial distribution. Refining the ecological characterization of such formations, a fixed autonomous underwater camera system, paired with an underwater sound monitoring system, has been deployed for capturing visual and auditory data. These data can be used to identify and analyse the dynamics of the fauna surrounding the demosponge dynamics, included the sound-emitting organisms inhabiting the channel.

The findings of this multi-sensor approach highlight the intricate interplay between hydrodynamics, sediment dynamics, and ecological diversity within the tidal channel. The study emphasizes the value of a multidisciplinary approach that is transferrable to similar environments



and usable to gain a thorough understanding of tidal environments by providing critical insights needed to support their conservation and sustainable management.

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The Use of High Resolution Drone Imagery to Detect Green Sea Turtles Around Guam using Machine Learning

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Marine megafauna such as sea turtles, sharks, and whales are impacted by anthropogenic stressors such as overfishing, bycatch, and climate change. Due to these factors, many species have been placed onto the International Union for Conservation of Nature (IUCN) Red list. In recent years, quantifying and detecting marine megafauna populations such as green sea turtles (*Chelonia mydas*) are difficult to assess due to their large migratory patterns which leads to limited conservation management strategies targeting different life stages. Despite these challenges, the use of remote sensing techniques on satellite imagery are able to cover large spatial and temporal scales, however, resolution and image clarity may decrease the accuracy of species identification. To further research and monitoring efforts, implementing new survey techniques such as using uncrewed aerial vehicles (UAVs) may provide opportunities to study megafauna populations and behaviors in remote areas like Guam while reducing the impact to the species behavior. In this study, we aim to measure the efficacy of UAV use in scientific data collection using green sea turtles for our model species.

To determine the efficacy, we will analyze high resolution drone imagery to detect and count the number of green sea turtles. Using a pre-programmed keyhole markup language (kml) file, a Zenmuse P1 payload, a red-green-blue (RGB) sensor, attached to a DJI Matrice 300 will fly perpendicular from shore taking individual pictures every 0.7 seconds at nadir. Collected UAV images will be post-processed using the Python package Patchify to split images with overlap into smaller chunks of 512 x 512 pixels. Each split image will be reviewed and annotated prior to training a supervised classification machine learning (ML) model. Model performance will be evaluated by comparing results from the training datasets and manual counts. During peak sea turtle nesting season on Guam, the pre-trained model will be used to count sea turtles which will be helpful for natural resource managers for future conservation efforts.



Utilizing Photogrammetry to Quantify 3-D Structural Metrics Across Stony Coral Species in the Dry Tortugas National Park, Florida, USA

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Structural analyses for Scleractinian corals have been conducted at fine scales (<1 meter); however, few of these studies have taken place along the Florida Reef Tract, a region that has recently experienced profound losses in coral cover and reef-flattening due to a variety of stressors including temperature stress, coral disease, and nutrient enrichment. Studies have shown that the loss of structural complexity on reefs reduces biological diversity, habitat availability, and overall ecosystem resiliency.

The Florida Fish and Wildlife Conservation Commission's Coral Reef Evaluation and Monitoring Project (CREMP) began annual monitoring of coral reefs in Dry Tortugas National Park (DRTO) in 1999, and in 2019 and 2020, orthomosaic imagery was collected in the same region. Through the combined use of CREMP survey data, orthomosaic imagery, and digital surface models (DSMs) generated from Structure-from-Motion photogrammetry at five DRTO monitoring sites, the specific objectives of this study were to: 1) derive several fine-scale terrain attributes from these DSMs previously shown to be ecologically meaningful, and 2) determine if each coral genera have significantly distinct topographic structure.

This study found that when divided into functional groups (*i.e.*, massive reef-builders vs. weedy opportunistic species), stony corals were topographically distinct with varying levels of contribution to the reefs' overall structural complexity. Massive corals such as *Orbicella*, *Colpophyllia*, *Montastraea*, and *Pseudodiploria* were the dominant coral genera on the reef. These genera had the highest relative abundance, and they were also shown to provide the highest structural complexity of all studied corals; specifically, they had the highest topographic position index, slope, and profile curvature, all of which are indicative of largely steep and convex forms. We also found that within the massive reef-builders, there was a clear topographic distinction between star corals (*Orbicella*, *Montastraea*) and brain corals (*Colpophyllia*, *Pseudodiploria*) based on their differing growth morphologies.

The techniques outlined in this study demonstrate that it is possible to catalogue significantly distinct fine-scale topography between coral genera in this region. Using this information, we can begin to create topographic signatures for coral genera and other organisms present on the benthos; these 'topographic signatures' could be utilized in large-scale mapping efforts within this region to create accurate distribution models or characterize the structure of benthic communities across large areas in a time efficient manner using remote sensing methods that result in DSMs. With the emergence of stony coral tissue loss disease in this region in 2021 and a mass bleaching event in



2023, it is also critical to determine how a potential loss of coral coverage will impact reef functionality and ecosystem services in DRTO moving forward.



Visual Analysis of Vertical Water Column Features from Multibeam Echosounder on Coral Reef Identification

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Multibeam echosounder (MBES) water column data offered transformative possibilities for underwater surveys and marine ecosystem studies. The ability to obtain information along the water column data will enhance the knowledge and understanding for the underwater environment itself. In this paper, a new approach to improve coral reef habitat mapping is introduced using the visualization technique of vertical data on the water column feature. This paper aims to extract feature information from water column data using a visualization method of the vertical data to improve coral reef mapping.

The data was collected using a Kongsberg EM2040 MBES for high-resolution data around the Redang Islands in the state of Terengganu, Malaysia. By utilizing GLOBE software, the vertical data of the water column feature will be extracted using the longitudinal slicer tools and the parameters setting (*i.e.*, beam, specular, value range, depth range, etc.) will be setup to find the best method in processing the feature extraction while reducing the processing time. A total of 482 points of features extracted from the coastal area of Ling Island and Penang Island. The extracted features are integrated within a generated raster suitability coral map of Redang Island to conduct a visual and spatial analysis. The visual analysis will interpret the accuracy and the strength of the relationship between the feature extracted and the coral reef area, while the spatial analysis is done by setting up buffer analysis to 3m, 5m and 10m before conducting the zonal statistic to calculate the summary statistics (mean, max, sum, etc.) for the raster values within the buffer of the extracted feature. The correlation between the three zones will then be calculated to identify the best zone for spatial analysis of water column features.

Overall, this research will present a new approach to improve habitat mapping using the feature extraction of water column data. The finding will provide a proper method in extraction of water column features using the vertical data approaches and its accuracy towards the identification of coral reef. Moreover, this study will also opens up the possibility of further exploring on the other approaches to utilize water column data for more accurate and detailed habitat mapping.



Adding Temporal Scale to Multispatial Scale Habitat Mapping: Mapping of Shallow Maërl Bed and Seagrass Habitats and Occurrence of Invasive *Sargassum muticum* in Norway

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Maërl (red coralline algae) beds and eelgrass meadows are diverse and ecologically valuable benthic habitats that play crucial roles in coastal ecosystems. However, these habitats are increasingly threatened by invasive species such as the brown wreck *Sargassum muticum* (Japanese wireweed), which can disrupt native ecological balances. Recognized as a high-risk species by Artsdatabanken, Norway for its invasion potential and ecological impacts, *S. muticum* presents a pressing challenge for habitat management and conservation.

Hyperspectral imaging (HI) is an emerging tool for benthic habitat mapping, offering high spatial resolution for classifying benthic macrofauna and detecting ecosystem gradients. In this study, HI was deployed on both a surface vehicle and an aerial drone to map maërl beds in Sletvik, Trøndelag, with a focus on evaluating habitat dynamics and the spread of *Sargassum muticum*. Complementary data from eelgrass meadows (*Zostera spp.*) are also presented to demonstrate the applicability of multispatial scale mapping methods.

Surface vehicle-based imaging, with its high spatial resolution (0.5 cm per image pixel)), allows for precise classification of small-scale features but is limited in spatial extent. Aerial drone based imaging, offering a broader spatial overview at 10 cm resolution, complements surface imaging by identifying large-scale patterns, albeit with less spectral detail. Adding temporal scale further provides insights into seasonal variations, including peak *S. muticum* growth periods when dense algal canopies obscure the seafloor, complicating habitat classification. These findings underscore the importance of timing in mapping efforts to account for seasonal dynamics.

This study underscores the value of integrating high-resolution imaging platforms with temporal monitoring to improve multispatial scale habitat mapping. The findings aim to support informed management strategies for maërl and eelgrass habitats, building knowledge by monitoring the impacts of invasive species in coastal ecosystems.



Discovery of Novel Mussel Reef Communities in the Belgian Part of the North Sea: Implications for Habitat Conservation and Monitoring

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The Belgian part of the North Sea (BPNS) is a highly dynamic area subject to natural sediment mobility and a variety of human activities, including shipping, fishing, dredging, and the development of offshore wind energy. These activities exert significant anthropogenic pressures on benthic habitats, leading to substantial alterations in their integrity and function over time. In particular, the geogenic and biogenic subtidal natural hard substrates (SNHS) in the BPNS play a pivotal ecological role as biodiversity hotspots, providing essential ecosystem functions such as habitat complexity, nursery grounds, and foraging areas for various marine species.

Despite their ecological importance, these substrates have been overlooked in the past and only relatively recently have become the focus of conservation efforts and scientific research. Extensive monitoring efforts such as acoustic seabed mapping, biological sampling and ground-truth validation have increased our knowledge of their biodiversity and ecology, and have led to the development of high resolution models of SNHS potential occurrence. In 2023, while deploying a towed high-resolution underwater camera system, our team discovered novel mussel reef communities growing on these hard substrates in two distinct locations. The communities consisted of *Mytilus edulis* mussels attached to *Sabellaria spinulosa* clusters (reef-building polychaetes) and/or geogenic substrate. Furthermore, the sand mason worm *Lanice conchilega*, was growing abundantly on/and around the mussel clusters while a high number of the common spider crab *Maja brachydactyla* was observed moving between the clusters.

The reasons and conditions behind the sudden appearance of this mussel reef community are currently a matter of investigation as there are no past records of extensive mussels patches growing in these particular areas. At the same time, it raises further questions regarding their resilience and thus long-term survival. Fisheries management measures aiming to restrict all bottom-disturbing activities are presently underway, covering in extent the areas where the mussel-reefs were discovered. However, the process is slow and may take years before effective protection takes place.

Continuous and systematic application of broad-scale non-invasive methodologies is essential for spatially explicit investigations of these fragile biotopes, while further long-term studies are needed to explore community dynamics and connectivity under varying environmental and anthropogenic pressures. Gathered data will not only provide insights into the mechanisms supporting their existence but also inform future restoration initiatives. This discovery highlights the urgency of implementing the proposed fisheries management measures to safeguard such sensitive habitats, aligning with the conservation goals outlined in European marine directives and the Belgian Marine Spatial Plan.



Multibeam Echosounder Data Reveals Dynamic Seabed Environments in Estuaries in the Gulf of Bothnia, the Baltic Sea

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The shallow coastal waters of the northern Gulf of Bothnia in the Baltic Sea, distinguished by meadows of underwater vegetation, influence the entire surrounding aquatic environment. However, these shallow areas face threats from climate change and human activities, putting their species and habitats at risk. Features of the Baltic Sea, including the low salinity, young geological age, and ongoing isostatic rebound with significant land uplift, create unique estuarine environments. Their distinct hydrodynamic and sedimentary processes make them scientifically valuable for understanding brackish water ecosystems and the impacts of geological and climatic changes. The challenge is still the lack of geological information and knowledge of the estuary habitats. Understanding the seafloor's geological features and environmental conditions is vital for gaining deeper insights into the species that inhabit these unique ecosystems. High-resolution bathymetric and backscatter data can provide detailed information of the seafloor's characteristics, geological formations, and dynamics.

During 2024 three different estuaries were studied on the Finnish coast, conducting surveys across the estuaries, also extending into the rivers. A research boat equipped with a multibeam echosounder, sediment echosounders, reflection seismic sounding, and a side-scan sonar was used for the study, including sediment sampling. Water depths in the surveyed area ranged from 20 meters to as shallow as 1 meter.

Preliminary results indicate that the seafloor in different estuaries varies depending on the openness of the estuary, the characteristics of the river, and the material transported to the area. It was also evident whether the area was more influenced by the river or the open sea. The Lapuanjoki river in the southernmost study area, has the calmest flow, and the vicinity of the river is clearly a sediment accumulation zone. Here the seabed substrate mainly consists of loose, organic-rich mud. A bit further from the Lapuanjoki river, where the seabed is more influenced by the wave action, resulting in a highly dynamic depositional environment, “mud waves” were observed, with heights ranging from 0.1 to 0.6 meters and an average width of around 10 meters. These features are formed from mixed mud or gyttja clay layers. In the northernmost study areas, particularly in the Iijoki river, the river discharge is higher, and the seabed sediments were significantly coarser, consisting mostly of sand. At the confluence of the river and the sea, underwater sandy dune fields were identified, with dune heights ranging from 0.2 to 1 meter and widths between 10 and 20 meters. Created seabed substrate and bathymetry maps and descriptions of the seabed dynamics support the planning of conservation and restoration efforts in these areas. The study is a part of the SeaMoreEco project funded by the Interreg Aurora. The study utilized research infrastructure facilities provided by FINMARI (Finnish Marine Research Infrastructure network).



Mapping Underwater Habitats of the Vertical Walls of the Saguenay Fjord, Québec, Canada, using a Multifrequency Multibeam Echosounder

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The Saguenay Fjord is among the longest in the world, the southernmost one in North America, and one of the rare intracontinental fjords. Its submarine environment is particular because of the presence of a thermohalocline caused by the separation of saltwater from the St. Lawrence Estuary and freshwater from the Saguenay River. These heterogeneous conditions are responsible for the biological richness of the Fjord; it hosts unique and neighbouring freshwater and saltwater ecosystems, including habitats for marine mammals such as the resident population of beluga whales. However, little is known about its benthic habitats, which are vulnerable to the anthropic activities occurring in the Fjord.

This project focuses on benthic habitats provided by the vertical submarine walls, which were shown to sustain important habitats for biodiversity. Recently, 34 stations were sampled in the Fjord: video data were collected using a remotely operated vehicle (ROV), and CTD measurements were taken. The epibenthic communities and spatial distribution patterns were characterized (see Amyot *et al.*, this conference). In the summer of 2025, an R2Sonic 2020 multifrequency multibeam echosounder will be deployed at an angle at the 34 stations sampled to map and image the submerged section of the walls at multiple acoustic frequencies.

The 3D model resulting from the data processing will be used to extract geomorphometric variables to characterize the structure, roughness, and complexity of the vertical walls in different sections of the Fjord. These will be coupled with backscatter, CTD, and video data to map distinct biological and physical habitats. The transferability of species distribution models from one area of the Fjord to another will also be tested.

In conclusion, this project will allow the acquisition of new knowledge about the ecology, biology, and geology of the Saguenay Fjord and improve its biodiversity and habitat assessments. In addition, in the context where the Fjord is a marine park, the findings could inform decision-making for the conservation and management of natural resources and help establish new targets for assessing and monitoring climate change and anthropogenic effects on the Fjord's ecosystems.



Insight to the Seabed Characteristics Within and Around the uThukela Banks Marine Protected Area, South Africa

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We present an approach integrating multibeam bathymetry, backscatter and angle vs range analysis (ARA), using ~200 km² of multibeam echosounder data acquired from the Natal-Bight, South Africa, to acoustically classify the seabed. This contribution discusses: 1) the value of multibeam echosounder's data and ground-truth data towards generating benthic habitat maps, 2) the reef complexes in relation to the different restrictive-use and management zones within and around uThukela Banks Marine Protected Area (MPA), specifically.

Results of morphology showed that the relationship between submerged palaeoshorelines (observed at water depths of -45, -50, -60, -70, -80, -90, -100, -110, -125 m below mean sea level) linked to glacio-eustatic sea-level oscillations. The multibeam bathymetry data and its derivatives (slope and rugosity) reveal a highly variable relief and rugosity seabed geomorphology. There exists varying restrictive-use and management zones within the uThukela Banks MPA. However, these zones were delineated without consideration of the contribution geomorphological factor's within localized spatial scale. For example, in the northern Natal-Bight, the shelf is characterized by narrow, distinct, highest in relief and rugosity reef complexes (*i.e.*, greater accommodation space for inhabitants). However, these reef complexes fall within the controlled zone which has with lesser restrictions imposed than those reef complexes of the central Natal-Bight which have the restricted ("no take) zone status imposed on them. The central Natal Bight is characterized patchy/mottled reef complexes that at times is indistinct. These findings will help understand why these areas support high biodiversity and how best to manage and impose levels of restrictive-use upon them within the current marine spatial planning framework in general.

In addition, the raw backscatter were produced from the reflected acoustic signal response, reliant on the physical seabed properties (*e.g.*, grain size, surface hardness). Using the ARA classification method this study was able to delineate meaningful geological sediment properties of the seabed from the insonified area. Significantly accurate substrata classes were resolved from the automated classification, although at times this had to be corroborated with ground-truth data from the stereo-BRUVs imagery. This showed the rocky reef complexes to be classified as gravel (*i.e.*, hardest substrate) with the adjacent areas comprising of various grain sizes of unconsolidated sediment occurring within the study area. Such data can improve the shelf's sediment distribution map and monitoring migration along and across the shelf. In the context of uThukela Banks MPA, these data are critical to optimizing protection of marine habitat and biodiversity.



Daily Reshaping of Gravel Bedforms by Tidal Currents in Cook Strait/Te Moana o Raukawakawa

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Cook Strait/Te Moana o Raukawakawa is known globally for its vigorous tidal flows, ocean waves and winds, and dynamic seabed environment. This narrow passage of water is also the primary connection between Aotearoa New Zealand's main islands, hosting a busy shipping passage and subsea cables (*i.e.*, HVDC Inter-Island link). During a multibeam hydrographic survey in 2017, a unique helical network of gravel bedforms on the continental shelf (~50-100 m water depth) was revealed for the first time. These bedforms were subsequently resurveyed using the same multibeam system in 2020 and 2021, documenting morphological changes to plan-view dune geometry and bifurcation of crestlines over annual timescales. Modelling suggests that average hydrodynamic conditions in Cook Strait are capable of mobilising coarse-grained seabed substrate (*i.e.*, sand to gravel), indicating that the observed morphological changes could be a snapshot of continuous incremental modification, rather than only during infrequent, high-magnitude events.

In 2023, a rare data co-collection opportunity arose to resurvey this set of extraordinary bedforms seven times over at near-daily intervals to assess high-frequency morphological changes. These novel remapping campaigns spanned a range of tidal conditions (*e.g.*, flood, ebb and slack) and included coincident water-column measurements, including multibeam backscatter, ADCP velocity, direction and turbulence. Initial results indicate that the gravel waves are highly dynamic over the week-long survey, with vertical changes of up to 1.5 m and horizontal shifts up to 15 m. The maximum observed change between 3–5 August coincided with the 2nd largest spring tide of the year. This study provides the first high-frequency multibeam dataset documenting daily seabed change in Aotearoa New Zealand. Unravelling the frequency, variability, magnitude and mechanisms driving bedform change has implications for ocean dynamics and marine habitats. In addition, this location is of high importance for present and future seafloor and near-bed infrastructure.



Using Sidescan Sonar and Bathymetry to Map Hardbottom Reef Characteristics in Southeast North Carolina, USA

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This study investigates an outcropping submarine reef, known as John Creek Hardbottom, located on the shoreface off Masonboro Island, North Carolina. The exposure is likely associated with the high-relief Pleistocene coquina calcarenite hardbottom reefs, which are prevalent off southeastern North Carolina. The reefs provide essential ecosystem services, which include habitat for a wide range of biological communities, in addition to acting as an important sand source for local beaches and providing substantial recreational fishing and diving opportunities. Due to their local importance, the National Oceanic and Atmospheric Administration (NOAA) has classified the reefs as Essential Fish Habitat (EFH) under the *Magnuson-Stevens Fisheries Conservation and Management Act 1976* and the *MSA Reauthorization Act 2007*. In this study, a range of different hydrographic survey techniques, including sidescan sonar and single-beam echosounding, were collected to produce a geo-referenced mosaic and bathymetric grid of the reef. The reef's various morphological features ('high-relief scarp,' 'rubble mound,' 'rubble ramp,' 'rubble field,' and 'pavement') are classified based on terminology from previous studies, and upon further examination, a new term for local hardbottom reef morphology, known as 'boulder fields' is presented. John Creek's unique morphology differs from other nearby hardbottoms, allowing this study to provide a wider understanding of local hardbottom characteristics. Underwater photos of biota and sediment samples were also provided and analyzed for this study. Due to their protected status, in addition to natural and anthropogenic threats they face, mapping and monitoring southeastern North Carolina's reefs provides critical information for all stakeholders involved in sustainable coastal management decision-making.



Continental Shelf & Slope Habitats



MWP-1C and Reef Drowning: Morphological Evidence along the Eastern Brazilian Margin

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This study investigates the influence of known eustatic events triggered in the Northern Hemisphere during the last deglaciation on the occurrence of drowned reefs along the eastern Brazilian margin.

The analysis was based on the comparison of RSL curves with high-resolution depth signatures of different geomorphometric classes from a sector of the outer reef arc of the Abrolhos National Marine Park, known as California Reef.

The frequency of the bottom class identifying low-relief reef banks with tops around ~30 m deep does not show a genetic relationship to some post-LGM eustatic events already described in the literature. These structures are probably inherited from the MIS5a or MIS7c stillstands. The main concentration of the class related to reef pinnacles between 18-25 m (median of 21 m) and the decrease around ~10 m depth indicates a drowning trend of these features. This drowning process would correlate with the MWP-1C, which was triggered shortly after the ~8200 years B.P. cooling event. Extrapolation of the MWP-1C depth range on the regional morphological dataset reveals a potential simultaneous influence in the drowning of other coastal and reef areas along the western South Atlantic margin.

Despite the consistent morphological evidence presented, it is important to note that the hypothesized impact of the eustatic phenomena discussed here on the establishment and drowning of reef features in the region would still need to be confirmed by sampling and geochronological methods.



Extravagance versus Ordinarily on the Shelf Edge: A Match of Geology and Biology in the Comet Structures of the Eastern Mediterranean

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Multibeam and backscatter bathymetry from several sites covering ~135 km along the Eastern Mediterranean continental shelf at water depths 90-120m reveal hundreds of comet structures: exposed sandstone rocky knolls surrounded by unstable soft-sediment scouring at their base, forming comet-like 'head and tail' structures, providing conditions for hard bottom insular habitats, proven to host diverse ecological niches and unique faunal communities. A geomorphological comparison between the 90 comets of the central-northern part (~110 km long) versus the southern shelf of Israel (~15 km long) reveals significant differences. The central-northern comet structures are large, and range in diameter between 15-140m, with relative elevations from their surroundings varying up to 36m. The continental shelf here is ~12-15 km wide. While in the south, the hundreds of comet structures are smaller, up to ~70 m in diameter, but the significant difference is their elevation: they are 1-8 m above their surrounding scouring mores (vs up to 36 m above), and their elevation above the general neighbourhood is almost zero (vs tens of meters in the north). The continental shelf here is up to 25 km wide, and the comets appear in a wide belt up to 5 km. Clearly, their geomorphology between these two provinces is different.

The highlight of this study is the match between geology and biology. Our observations from ROV video surveys show a significant difference between the faunal societies. In the center-north, the large comet structures towering over their immediate surrounding inhabit an extravagance of creatures and variance of species, as the rocky knolls teem with unique life forms. In contrast, the relatively minute comet structures of the south reveal a poorer selection of species and less abundance of various species. This match of geology and biology, which is still under study, offers a glimpse of the potential correlation between the role of the geomorphological forming forces and their impact on the faunal communities of the eastern Mediterranean.



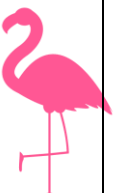
Deriving Substrate and Biotope Maps from Multibeam and Grab Sample Data in the Gulf of Maine

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Large areas of the Gulf of Maine have not been mapped in over a century, so existing habitat maps for the region are often of poor resolution and based on a paucity of ecological data. Between 2014 and 2024, the Maine Coastal Mapping Initiative (MCMCI) collected 3,375 km² of high resolution multibeam bathymetry and backscatter data along with benthic grab samples, video, and water column data throughout the mapped area. We used sediment grabs and seafloor video to parameterize a substrate classification model based on multibeam data. The model effectively delineated seven substrate types at broad scales, though its fine-scale accuracy was affected by backscatter artifacts and uncertainty in the precise location of sediment grabs. To investigate the identity and distribution of biological communities, we conducted distance-based redundancy analysis to model the influence of substrate, depth, and bathymetric derivatives (e.g., slope, rugosity, BPI) on infaunal and epifaunal composition. Depth and substrate emerged as primary drivers of community structure. We then performed clustering on community variation constrained by depth and substrate to empirically define and map eight biotopes across the region. This bottom-up approach allowed us to test which environmental variables and thresholds most strongly influence benthic community structure, avoiding assumptions inherent in surrogate-based mapping. We present a continuous habitat map with distinct layers for bathymetry, substrate, and biotopes across the MCMCI study area. While the resulting habitat map offers valuable coarse-scale guidance for management and research, we found that clustering schemas and resulting biotope maps were sensitive to minor changes in data and statistical methods. This highlights the need for increased biological sampling density to produce more robust and spatially consistent biotope classifications.



Integrated Multibeam Mapping to Quantify Seafloor Changes in Monterey Canyon

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Submarine canyons are critical geomorphic features that act as conduits for sediment transport from continental margins to the deep sea. Steep gradients, diverse substrates, and episodic sedimentary processes create a mosaic of habitats ranging from soft sediment plains to rocky outcrops, which support a variety of benthic organisms. Sedimentary flows within these canyons are powerful agents of change, capable of transporting vast sediment volumes over long distances and significantly altering the seafloor. These processes impact habitat availability, substrate composition, and benthic species distribution, underscoring the need for high-resolution studies to better understand their effects and interactions.

Between November 2024 and March 2025, we conducted a multidisciplinary experiment in Monterey Canyon offshore California to monitor sedimentary flows and their interactions with canyon habitats. This effort included monthly multibeam echosounder mapping of the canyon head and axis using multibeam echosounders deployed from an Autonomous Underwater Vehicle (AUV) and a small vessel. The AUV surveys captured seafloor changes at depths of >100 m, whereas the small vessel surveys mapped changes in the shallowest 100 m of the canyon head.

These surveys provided valuable insights into the interactions between sedimentary flows and submarine canyon morphology and substrate at monthly timescales. Erosional signatures associated with individual flows were quantified, revealing new scarps and bedform migration within the channel axis. Terrace regression of more than 100 m laterally was observed, along with localized deposition. On the canyon flanks, instability features and localized aggradation were detected. These findings highlight the spatial and temporal scales of sediment flows, habitat shifts, and substrate alterations, emphasizing the dynamic nature of canyon environments.



Submerged Paleoshorelines in the Eastern Gulf of Mexico: Investigating Sea Level History and the Potential Extent of Mesophotic Coral Ecosystems

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An inventory of multibeam bathymetry containing relict drowned and lithified paleoshorelines has been compiled and analyzed in the first ever shelf-wide investigation of paleo sea level indicators on the west Florida shelf (WFS). In addition, new evidence pointing to the significance of these features as important fish and coral habitats suggests more focus should be put on this region to identify areas that currently do not fall under federal protection.

On the largest scale, the WFS is a wide and gently sloping terrain that is characterized by a carbonate-rich sediment regime. This framework coupled with the region's tectonic stability provided a setting in which sea level changes since ~ 20 ka have been recorded to a remarkable degree of resolution in the form of paleoshorelines which formed at sea level and were subsequently drowned and preserved in place. Previously described geophysical datasets along with new unpublished datasets were compiled and analyzed in a suite of geoinformatic softwares (ArcGIS, Fledermaus, Qimera) to obtain information about the depth, geomorphology, and dispersal of paleoshoreline features. In total, 27 paleoshorelines were identified and classified based on geomorphic identifiers, and a hypothetical scenario for sea level history between 14.3 ka – 11.0 ka is put forth.

Within the inventory of bathymetric data, grouper holes were identified within the boundaries of protected marine areas (*e.g.* Pulley Ridge), as well as scattered across expanses of unprotected paleoshorelines suggesting the potential for essential fish habitats that would benefit from further study and protection.

As a result of these findings, recommendations and basemaps have been laid forth regarding deep light-dependent mesophotic coral ecosystems which have been documented on the lithified ridges formed by paleoshorelines and drowned reefs across the Gulf of Mexico, particularly on the WFS between -45 to -90 m. The overarching conclusion of this work is the need for continued high-resolution mapping on the WFS in the interest of paleoclimatological, geological, hydrographical, and ecological research.



Geomorphological Interpretation of the Newfoundland and Labrador Shelves Bioregion

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Understanding the nature of seafloor geology has long been recognized as crucial for effective management of marine biological resources. The continental shelves and slopes off Newfoundland and Labrador have been a focus of investigations by the Geological Survey of Canada (GSC) over many decades, resulting in a wealth of published information. Leveraging this wealth of information, we developed a geomorphic classification of the Newfoundland and Labrador Shelves Bioregion while incorporating sediment transport modeling to characterize tide- and current-driven seafloor disturbances.

The Newfoundland and Labrador Shelves Bioregion, located on a glaciated continental shelf and adjacent continental slope, is classified into thirteen geomorphic classes that reflect its great physiographic diversity. The ten shelf units comprise a bedrock dominant zone, fjord systems, a large inland sea, shelf-crossing troughs, four types of offshore banks, a basin, and glaciotectonic terrain (found nowhere else on Canadian shelves). The three continental slope units are channelized areas, trough-mouth areas, and large sedimentary drifts. A series of vignettes based on interpretation of single beam and multibeam sonar data illustrates both the distinguishing characteristics of the principal geomorphic units as well as the morphologic diversity within them.

A sediment mobility analysis reveals the character of seafloor processes in the various geomorphic units. Wave and current-generated disturbance is dominant and largely depth-controlled on the shelf, while the south-flowing Labrador Current impacts sediment transport on the uppermost continental slope. More prominent habitat structuring disturbance is imposed by icebergs, coastal and pack ice, and mass wasting of sediment.

In addition to long-term processes (*e.g.*, Cenozoic shelf progradation, variable crustal subsidence) the geomorphology strongly reflects Quaternary glaciations, in particular the dissection of the shelf by glacially-overdeepened troughs and the resultant sedimentation on the continental slope. The presence of large areas of glacially-tectonized terrain is unique in the context of Canadian continental shelves.



Geomorphology in a Submerged Reef Seascape Environment within the Largest Reef Complex of the South Atlantic

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Interest in studying reef structures began with Charles Darwin. Since then, scientists have focused on understanding and explaining reef formation, morphology, geomorphology, ecological relationships, and how they respond to sea-level changes. Unlike other carbonate platforms globally, the Abrolhos Shelf is a shallow and open carbonate shelf, comprising two reef arcs formed by emergent and submerged reefs. The South Atlantic is home to one of the smallest and least diverse coral provinces in terms of reef coverage and species richness compared to the Indo-Pacific and Caribbean regions; however, it exhibits a high level of endemism. This study presents, for the first time, the morphological complexity of a submerged reef system located in the northern Abrolhos Shelf.

The objective of this study is to provide a detailed description of the geomorphology of the submerged reef seascape environment. The research primarily relies on geomorphological and backscatter analyses, utilizing high-resolution multibeam and multispectral acoustic surveys. The four mapped areas are characterized by highly diverse morphologies associated with both reef and inter-reef substrates. Across these four areas, more than 34,000 reef structures were mapped, which range from pinnacles to reef banks. Notably, Area 2 exhibited the highest concentration of reef structures compared to the other areas. Reefs can reach up to 21m in height in southern part of the Abrolhos Channel.

A gradual shift in reef type was also observed, transitioning from pinnacles to reef banks, along with an increase in the width of these structures in the southern direction. This study presents and describes a highly heterogeneous reef seascape forming a complex mosaic of distinct reef and inter-reef habitats, characterized by reef banks, pinnacles, reef halos, channels, and flat areas, results from a combination of distinct oceanographic processes acting on different time scales.



SEABEDMAP Project – Slope Geomorphic Features on the Easternmost Brazilian Equatorial Margin

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More than 22.000 km² have been surveyed on the continental slope, of the easternmost point of the Brazilian Equatorial Margin, as part of the SeabedMap Project. The main aims were mapping the seabed and training human resources, with an emphasis on sustainable development objectives 4 - Quality Education, 5 – Gender Equality, 13 – Climate Action and 14 – Life below Water. This contribution represents the first multibeam mapping for the corner of Brazil, between 80 and 3,000 m depth.

The data were acquired aboard the Brazilian Navy Hydrographic and Oceanographic Research Ships (NpqHOc) Vital de Oliveira and Cruzeiro do Sul. Multibeam bathymetry, sub-bottom profiles, and sound speed measurements along the water column were obtained. Bathymetric data were processed using Caris HIPS & SIPS software, and the geohabitats map was generated in ArcGIS. using the Benthic Terrain Model (BTM). This area is important for the scope of SeabedMap Project in relation to the study of submarine canyons as a potential for lifting and transporting masses of cold water over the shelf and edge of the continental shelf.

Geomorphic features such as submarine canyons and submarine plateaus were observed; further erosive features such as landslides and gullies also were present. The morphology was also influenced by tectonics. Twelve BTM classes were identified. These results obtained add to recent studies that have shown how submarine canyons generate the ideal flow-topography environment, inducing the process of seasonal uplift of colder and saline water masses from the deepest to the shallowest areas, resulting in the formation of vortices, ecological differentiations, as well as the seasonal fertilization of the waters of the Northeast coast of Brazil, breaking the paradigm of an exclusively oligotrophic zone. Additionally, the SeabedMap project has contributed to the training of Human Resources, with priority given to those from the Brazilian Equatorial Margin, with attention to SDG nº 5 of the United Nations; as well as adopting and strengthening sound policies and applicable legislation to promote gender equality and the empowerment of all women and girls at all levels. 42 women and 23 men participated in the cruises.



Reviewing the Distribution of Rocky Reefs off the U.S. West Coast

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The U.S. National Marine Fisheries Service is mandated to identify “essential fish habitat” in coordination with regional fishery management councils, consider adverse effects on those habitats, and provide information to further its conservation and enhancement. In 2006 the Pacific Fishery Management Council designated Rocky Reef Habitat Areas of Particular Concern (HAPC) off the U.S. West Coast (*i.e.*, the states of Washington, Oregon, and California) as particularly important for healthy demersal fish (“groundfish”) stocks. The geographic extent of Rocky Reefs HAPC in this area has not been updated until now. Rocky reefs are submerged outcroppings of rock with varying relief that occur along continental margins, island shelves, inland seas, and on seamounts and knolls. They are highly productive benthic habitats that provide important ecosystem services associated with their physical structure. The complex substrate of rocky reefs provides surface area for the attachment of sessile invertebrates (*e.g.*, deep-sea corals, sponges) and submerged aquatic vegetation (*e.g.*, kelp). Groundfish species (including rockfish, flatfish, roundfish, and elasmobranchs) rely on rocky reefs as refugia and to forage for prey, and several species exhibit high site fidelity to rocky reefs.

For this study we identified classified seafloor substrate coverages not included in the 2006 HAPC map, aligned those datasets to the Coastal and Marine Ecological Classification System (CMECS), and identified substrate component units that met the regulatory definition of Rocky Reefs HAPC. The updated inventory incorporates 71 new datasets, includes a total of >3500 individual substrate polygons, and represents the best available information on the distribution of rocky reefs for the U.S. West Coast continental margin (*i.e.*, shoreline to 2500 m water depth). This updated dataset will help resource managers assess impacts to essential fish habitat from projects in the coastal and marine space, and identify measures to avoid, minimize, mitigate, or otherwise offset those impacts.



Deep-Sea Habitats



Benthic Habitat Characterization on Three Features of Hawaiian-Emperor Seamount Chain

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There are large knowledge gaps of habitat composition and spatial distribution on the North Pacific Hawaiian-Emperor Seamount Chain (HESC) seamounts, which leaves diverse seafloor communities at risk from both contemporary and future anthropogenic impacts. Research has predominantly focused on bottom-contact fishing disturbance on coral and sponge communities shallower than 1000m. However, climate change and future resource extraction such as seafloor crust mining will extend far beyond 1000 m. As well, the focus on bottom-contact fishing disturbance has led to piecemeal visual and multibeam surveys on these features, leaving most of the seafloor habitats uncharacterized. Therefore this study aims to characterize seafloor habitats and investigate spatial patterns of habitat heterogeneity on three seamounts of the HESC. Daikakuji, Kammu, and Yuryaku seamounts are features within the Emperor Seamount Chain, exposed to historical bottom-contact fishing effort and also coated in cobalt rich ferromanganese crusts of potential economic interest for future mining. Geomorphological and oceanographic water mass variables derived from publicly available resources were clustered using a non-hierarchical approach. The seascape characterization defined 16 habitat classes across all three seamounts from summit to 3,500 m where the three features become distinct. Preliminary results find a greater diversity of habitat classes on Kammu than either Yuryaku or Daikakuji. Kammu also has the greatest number of patches and patch density. While Yuryaku contains the greatest average percent of like adjacencies and contiguity and the same habitat class richness as Kammu. Daikakuji contains only 10 of the 16 habitat classes and is the smallest feature, with the greatest standardized average patch area by total area and greatest contagion. When the positions of known cold-water coral reef presence is overlaid on the habitat characterization, cold-water coral reef presence on Kammu and Yuryaku is found within a single habitat class. While this habitat class is found on all three features, Kammu contains the greatest number of patches and Daikakuji contains only one patch of the habitat class. Further research will highlight the feature and class specific patterns, however these initial analyses suggest seafloor habitats composition and spatial patterns on these features are heterogeneous. This has implications for contemporary and future management of these features within the Emperor Seamount Chain.



Habitat and Benthic Fauna of the Wallaby Cuvier Escarpment and Wallaby Zenith Fracture Zone, Eastern Indian Ocean

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Structurally complex deep-sea geomorphological features can serve as ecological hotspots, shaping the diversity and distribution of benthic faunal assemblages through substrate complexity and habitat heterogeneity. This study integrates data from two rarely explored regions of the eastern Indian Ocean—the Wallaby-Cuvier Escarpment (WCE) and the Wallaby-Zenith Fracture Zone (WZFFZ)—to characterize benthic habitats and their associated fauna.

The WCE and WZFFZ were surveyed using a multibeam echosounder, free-fall baited landers, and a crewed, full-ocean depth rated submersible, *Limiting Factor*. A total of eight submersible dives were conducted between 4650 and 6590 m, and 18 lander deployments between 2930 and 6590 m. Habitat classification integrated bathymetric derivatives with direct observations of seafloor substrate from the submersible which identified distinct habitat classes, including a polymetallic nodule field. These data were paired with the abundance of morphotaxa identified from video footage collected using the submersible to understand how community composition is linked with habitat classes.

More than 150 different morphotaxa were identified from more than 10 hours of video footage collected during submersible dives. Deposit feeders dominated the community assemblage in soft sediment habitats and suspension feeders dominated the community composition in habitats covered with pebble and cobble debris. However, hard substrates in surrounded by soft sediment such as outcropping bedrock and polymetallic nodules were key in shaping the spatial distribution and diversity of morphotaxa and functional groups. Despite recording a high number of morphotaxa, the total abundance of organisms is considered low which we attribute to oligotrophic surface waters. However, the distribution of organisms and their feeding strategies were well-aligned with habitat type.

Other notable discoveries include piles of “mud balls”, most likely xenophyophore tests, a large, a dense polymetallic nodule field at the WZFFZ, and high diversity of anemones at both locations. These data represent the most detailed description of habitat and benthic fauna for these features and the first description of fauna for Wallaby-Cuvier Escarpment.



Exploring and Monitoring the Deepest Parts of Australia's Marine Parks

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Australia has the third largest exclusive economic zone in the world, of which 70% is deeper than 1000 m and 48% is deeper than 3000 m. Much of this deep sea falls within the extensive network of Australian Marine Parks, including some of the country's deepest locations offshore Christmas Island, Macquarie Island and the eastern portion of the Diamantina Fracture Zone. This research has adopted three survey methods to explore the deepest locations offshore Australia in the eastern Indian Ocean, including: long-term (18+ months) surveys using deep-sea observatories, short-term (7 hours) surveys using baited landers, and multibeam echo sounding.

A total of 96 baited lander deployments were completed across four Australian Marine Parks spanning 27 degrees of latitude and 1000 m to 6177 m water depth. Baited landers recorded the seafloor substrates and continuous footage of the fauna attracted to the bait, in addition to conductivity, temperature, pressure, current speed and direction. An autonomous, long-term deep-sea observatory was deployed simultaneously in both the Perth Canyon Marine Park (PCMP; 4600 m water depth) and the Gascoyne Marine Park (GMP; 5100 m). Observatories were soaked for three, 9-month periods, totalling 18 months of near-continuous recording. Each observatory collected falling marine snow in a sediment trap and still images of the seafloor at 12-hour intervals, as well as conductivity, temperature, pressure, current speed and direction. These data were accompanied by newly acquired, high resolution bathymetric data.

Seabed morphologies were classified from the bathymetric derivatives and integrated with the video footage to use as a proxy to the seafloor habitats. Baited landers revealed distinct faunal assemblages linked to depth and these habitats. Latitudinal differences in the assemblage composition were more pronounced at shelf and shelf break depths compared to those deeper than 3000 m.

Seasonal differences in the amount of marine snow reaching the seafloor at PCMP and GMP was significantly different, however the abundance of organisms recorded from images of the seafloor show no change in season or correlation to the volumes of marine snow. This is likely due to the oligotrophic nature of this region and the relatively low abundance of benthic organisms and their life history strategies. Other notable discoveries include the re-discovery of the Leeuwin nodule field, extensive submarine landslides off Christmas Island with avalanche blocks up to 1.8 km across and 400 m high, the deepest locations ever filmed off mainland and territorial Australia, the deepest fish ever caught in Australia, and a large range extension for the Southern Sleep Shark *Somniosus antarcticus*.



Preserve Deep-Sea Habitats by Strengthening the Natura 2000 Network in Deep Marine Environments

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Natura 2000 is the largest international network of protected areas in the world, and its marine component is still under development. The LIFE DREAM Project aims to support the restoration of deep reefs through both active and passive measures, promote prevention from human threats and strengthen Natura 2000 network in deep marine environments.

In this context, LIFE DREAM has submitted four new proposed Sites of Community Interest (pSCIs) with the following codes:

1. IT9120013: Deep oyster reef offshore Monopoli
2. IT6040044: Deep reefs of the Canyon Dohrn
3. IT6040045: Black coral forests of the Gulf of Naples
4. IT0000003: Cold-water corals of the Bari Canyon

The targeted habitats are deep reefs located within the Italian waters except for site IT0000003 that is situated more than 12 nautical miles from the coast. These habitats fall under category 1170 of Annex I of the Habitats Directive (92/43/EEC), specifically including deep oyster reefs, cold-water coral reefs, and black coral forests. The designation of these new Natura 2000 sites is intended to ensure and increase long-term protection for habitats and species of conservation importance at European scale.

The process of defining the boundaries for the four pSIC involved reviewing existing data, collecting new information, and creating high-resolution distribution maps of both biodiversity and human uses. A multi-criteria analysis was conducted to account the main human activities within the target areas. Here we report the new pSCI extents and summarize the process that led to their proposal.



Post-Eruption Seafloor Mapping around Hunga Tonga-Hunga Ha'apai

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Hunga Tonga - Hunga Ha'apai (HTHH), one of 22 volcanoes in the waters around the Kingdom of Tonga, erupted violently on 15th January 2022. This eruption triggered shock waves through the atmosphere and generated a tsunami across the Pacific Ocean. No part of the caldera of the volcano remains above water following the eruption, and the islands of Hunga Tonga and Hunga Ha'apai were vastly reduced in size. During an oceanographic survey 3-months after the eruption, we assessed the impacts of this eruption on the surrounding ocean environment, from underwater topography to ecosystem structure and function. While the HTHH edifice was largely intact, erosional channels were identified radiating out from the summit caldera indicating turbulent volcanoclastic density flows which are supported with our modelling. At least 6 km³ of material was deposited on the seafloor in areas downstream of these pyroclastic flows, and >50cm of fine ash deposition was observed on the seafloor in some areas. Mid-water volcanic ash layers north of the HTHH caldera were identified which indicate on-going venting from the volcano. Significant seafloor ecosystem impacts were found throughout much of the region, with little signs of life remaining on the flank of the volcano and along the deeper slope. However, diverse and abundant invertebrate and fish communities were seen on the summits of several of the adjacent seamounts. This study is a rare account of the initial impact of a large-scale eruption which can be used to better understand volcanic risks to the ocean environment in the future.



High-Resolution Mapping of Pacific White Skate (*Bathyraja spinosissima*) Nursery Habitats at an Active Galápagos Hydrothermal Vent Field

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Pacific white skate (*Bathyraja spinosissima*) nurseries were discovered in 2015 at the active Galápagos hydrothermal vent field Iguanas-Pinguinos. At these nurseries, skate eggs of various forms (e.g. brown, yellow-green, white) appeared to be clustered together in proximity to active hydrothermal vents. It was hypothesized from Remotely Operated Vehicle (ROV) observations that the skates were utilizing the slightly elevated water temperatures caused by the vent fluids to accelerate egg development (the eggs have a 4-year incubation period). However, the specific environmental drivers that influence these skate egg distributions remain unquantified and unconfirmed. Our study aimed to determine environmental predictors of *B. spinosissima* nurseries at a Galápagos hydrothermal vent field by exploring the relationship between skate egg presence with seafloor morphology, geology, and distance and direction from active vents.

We utilized 17.8 km² of high-resolution multibeam sonar (MBES) data collected at Iguanas-Pinguinos (depth: -1576 to -1762 m) and collected in 2010 by the *Sentry* Autonomous Underwater Vehicle. Bathymetry and backscatter data were processed using QIMERA and FMGT to generate bathymetry and backscatter raster at 1 m resolution, and additional morphology derivatives were generated from the bathymetry data (e.g. slope, benthic positioning index, curvature). Three ROV dives were conducted at the site in 2023 during a research expedition aboard the Schmidt Ocean Institute vessel, the *RV Falkor Too*. The georeferenced high-resolution video footage collected by the ROV, was analysed and annotated using the software BIIGLE 2.0 (Browsing and Annotating Large Marine Image Collections). Georeferenced skate egg locations from the video footage were imported into ArcGIS Pro and overlaid on the seafloor environmental data layers. A random forest habitat suitability model was also run to spatially predict skate nursery habitat based on the observed presence and absence of eggs.

Our results confirmed significantly higher concentrations of skate eggs of all colour forms within close proximity (91% of all eggs observed were within 50 m from active vents) to active vents, were more commonly found southeast from active vents. Eggs were also found more frequently on narrow-flat ridges and were associated with scarps and pillow lava. The Random Forest SDM revealed that the main environmental predictors for skate egg presence were distance from active vents, bathymetry, and broad-scale benthic positioning index. The model had an accuracy of 94% and a kappa value 0.94. Our findings provide the first quantitative evidence of *B. spinosissima* laying their eggs near active vents and targeting specific seafloor geomorphologies



on which to lay their eggs at a Galápagos hydrothermal vent field. These results further contribute our ecological understanding of *B. spinosissima*.



Quantitative Characterization of Deep-Sea Benthic Habitats of a Newly Identified Isolated Seamount in the Southeastern Pacific

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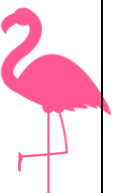
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Seamounts are one of the most prominent and abundant features on the seafloor and play a critical role in shaping deep-sea ecosystems, serving as biodiversity hotspots, and influencing regional oceanographic processes. Despite their ecological importance, many seamounts remain unexplored, particularly in remote regions of the global ocean. This study presents an unsupervised broad-scale characterization of areas with similar geomorphological conditions, a proxy for benthic habitats, on a newly identified isolated seamount in the Southeastern Pacific. The first high-resolution multi-beam echosounder bathymetry of the seamount was collected by the *R/V Falkor (too)* (FKt240108). The seamount is cone-shaped and has a diameter of 37 km, with a summit of 500 m below sea level rising 3500 m from the adjacent seafloor. To quantitatively characterize the benthic geomorphological habitat of this isolated seamount, we have used multi-beam echosounder bathymetry, backscatter, and remotely operated vehicle (ROV) imagery. The analysis consisted of three steps: 1) scale selection and terrain attribute extraction; 2) PCA on terrain attributes and 3) K-means clustering of the seascape in broad-scale geomorphological clusters.

Using the rate of change of local variance (ROC-LV), 18 terrain attributes were derived from bathymetry at resolutions of 100 m and 250 m. A principal component analysis (PCA) was conducted to reduce data dimensionality and compute a set of new and linearly independent abiotic variables. Seven principal components (PCs), which explained 95% of the total variance in the data, were retained for subsequent analysis. A K-means clustering algorithm was applied to the retained PCs to generate clusters of similar abiotic conditions. The optimum number of clusters was decided using a combination of elbow plots and the Calinski–Harabasz index. The environmental conditions represented by each cluster were visualised using boxplots. ROV imagery of substrate composition and associated benthic communities was used to provide further validation of cluster character, but was not available for all broad-scale geomorphological habitats identified. The spatial distribution of geomorphological habitats was visualised using a map highlighting spatial patterns and heterogeneity across the seamount seascape. The results highlight the seamount's role as a habitat for diverse benthic communities, including deep-sea corals, sponges, and fish species. Quantitative metrics of habitat diversity and species distribution



underscore the ecological significance of this seamount within the regional deep-sea ecosystem and provides a baseline for future ecological and conservation assessments in the Southeastern Pacific.



Seafloor Mapping and Characterization of Deep-Sea Coral Habitats in the Gulf of Maine to Inform Habitat Protection and Fisheries Management

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The Gulf of Maine is a diverse and ecologically important marine region because of its complex benthic features and ocean circulation patterns. Its sensitive habitats, including deep-sea coral and sponge gardens, and significant fishery resources are vulnerable to permanent impacts from expanding infrastructure to support offshore wind energy, aquaculture, and other emerging industries. However, the vast majority of the seafloor in the Gulf of Maine has yet to be mapped in high resolution or characterized with visual surveys, thus severely limiting informed and effective resource planning and management.

As part of the NOAA Deep Sea Coral Research and Technology Program's regional initiative in the Northeast United States (2023–2026), NOAA scientists and resource managers are coordinating with partners in other federal and state agencies to expand the spatial coverage of seafloor mapping data and to conduct visual surveys in the Gulf of Maine. High-resolution seafloor mapping data are necessary to delineate hard bottom features likely to support deep-sea corals. This information is critical for planning systematic visual surveys to locate, explore, and improve characterization of these habitats. Seafloor mapping data and observations from visual surveys are also fundamental inputs into species distribution models that are used to predict the occurrence and/or abundance of deep-sea corals in areas where surveys have not been conducted.

In 2023 and 2024, ships and uncrewed surface vehicles collected seafloor mapping data using multibeam sonar. Preliminary data from these mapping efforts were used to guide visual surveys conducted in 2024 using a remotely operated vehicle. Additional mapping and visual surveys are planned for 2025. Data from these field efforts and the species distribution models fitted using these and existing data will be crucial to aid resource managers in making informed decisions to avoid detrimental impacts to deep-sea coral habitats in the Gulf of Maine.



Unravelling the Geological and Geomorphic Evolution of the Nova Canton Trough (Central Pacific Ocean) and Links to Habitat Distribution

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First described in the 1960s, the Nova Canton Trough was first thought to be an abandoned spreading centre. Subsequently, the Nova Canton Trough has been shown to be a major fracture zone, key to unravelling the evolution of the Miocene Central Pacific Ocean due to its proximity to three major Large Igneous Provinces and the Farallon-Phoenix-Pacific triple junction. The Nova Canton Trough Expedition, part of the Inkfish Open Ocean Program, acquired 194,761 km² of multibeam echosounder data, 119 scientific lander deployments and 17 submersible dives. These combined data allow us to explore how the variability in environmental conditions such as terrain structure, hydrography, oceanography and substrate composition influences the occurrence and distribution of biodiversity and habitats across a 1000–8000 m depth range. Due to its highly complex geological evolution, the Nova Canton Trough is a heterogenous environment hosting a range of seafloor habitats.

The data acquired during this expedition reveals much of the tectonic history preserved on the seafloor, with multiple ridges and fracture zones indicative of a scissor-like opening of the feature. Additionally, primary spreading / abyssal hill fabric, numerous volcanic knolls (<1000 m high), seamounts (>1000 m high) and submarine landslides were also imaged.

Fine-grained calcareous sediments were prevalent at stations shallower than 4000 m depth with fine-grained clay sediments observed at the deeper stations located on the abyssal plains north and south of the Nova Canton Trough and at hadal depths (>6000 m) along the trough axis. Soft-sediment associated benthic communities were characterised by echinoderms including asteroids (sea stars), ophiuroids (brittle stars), holothurians (sea cucumbers) and echinoids (sea urchins) as well as ceriantharians (tube-dwelling anemones) and xenophyophores. The complex shapes of xenophyophores can provide habitat to a range of organisms and as such are thought to increase biological diversity.

Polymetallic nodules and crust were observed predominantly on the abyssal plains north of the fracture zone. Bedrock was visible cropping out at a small number of lander stations located on the outcropping seafloor fabric and on submersible dives that explored the median ridge and fault escarpments. Pillow basalts, stacked sheet flows, debris from rock falls, and more massive volcanic terrain were documented. These areas of complex topography and steeper slope angles result in an increased availability of hard substratum that creates more attachment opportunities for sessile benthic organisms. The associated epibenthic community therefore showed a larger



abundance of glass sponges, antipatharians (black corals), octocorals including primnoids (sea pens) and bamboo corals, crinoids (sea lilies) and actinarians.



Drivers of Abyssal and Hadal Biodiversity and Habitat Heterogeneity in Northwest Pacific Subduction Trenches

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The complex interplay between spatial and temporal variability in environmental conditions and resulting habitat structure is key for understanding the organisation of biological assemblages. Here, we present findings from two complementary studies that investigate the composition and environmental drivers of faunal assemblages and habitats across abyssal (3000 m – 6000 m) and hadal (> 6000 m) depth gradients in subduction trenches in the Northwest Pacific.

Data was collected during multiple expeditions between 2019-2022 aboard DSSV *Pressure Drop* using free-fall baited landers, submersible video transects (DSV *Limiting Factor*) and multibeam bathymetric surveys. 96 abyssal and hadal baited lander deployments across five subduction trenches were used to assess the community structure, vertical zonation and environmental drivers of mobile bait-attending and incidental fauna. Additionally, six hadal submersible dives in the Japan, Ryukyu, and Izu-Ogasawara trenches - characterised by varying seismic regimes and productivity- permitted fine-scale observations of benthic habitats and associated biota to understand the impact of location, depth and habitat type on benthic community composition.

Analysis of lander data revealed three depth-driven faunal zones: an abyssal-hadal transition community (~5500–6500 m), an upper hadal community (~7000–7500 m) and a lower hadal community (> 8500 m). Assemblage characteristics and depth boundaries also exhibited geographical variation, linked to broad-scale oceanographic patterns but limited effect of habitat characteristics was observed. Submersible video transect data revealed that megafaunal benthic community composition, abundance, and morphotaxa richness varied across trenches, reflecting variations in productivity regime and depth. Within individual trenches, differences in community structure, morphotaxa abundance and richness were explained by variations in seismic disturbance and resulting habitat heterogeneity.

Together, these studies permitted unique observations of the habitats and biodiversity in the Northwest Pacific subduction trenches. Depth, productivity and seismic disturbance emerged as critical factors influencing habitat structure and biodiversity. We highlight the need for continued visual surveys and high-resolution mapping studies to refine our understanding of hadal habitat heterogeneity and associated biodiversity patterns.



Habitat Mapping for Marine Restoration



Measuring the Impact of Substrate on Outplanted Coral Growth in the Galápagos Islands using Close-Range Underwater Photogrammetry

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Close-range underwater photogrammetry is an emerging method used to measure coral growth and identify coral bleaching across entire reefs, but few studies have used it to evaluate growth at restoration sites. Coral reefs, vital for biodiversity and human economies, are under threat due to climate change-induced bleaching. Restoration efforts, such as outplanting corals from nurseries, are gaining traction, but success depends on factors like substrate type. The Galápagos Reef Revival nursery on Isabela Island is the first coral nursery of its size and kind in the Galápagos. It contains 36 individual colonies of different genotypes encompassing three genera (*Pocillopora*, *Pavona*, and *Porites*). Our objective was to use photogrammetry to track survival and growth over a six-month period at the nursery while evaluating the impact of substrate on growth. Using a GoPro, photos were captured and inputted into Pix4Dmapper software to generate dense point cloud 3D reconstructions of the coral colonies at two outplanting sites with varying environmental conditions in January 2024 and July 2024. Point clouds were compared in CloudCompare to quantify linear growth. Coral branch extension rates were measured between point clouds to estimate mean growth. Survival was assessed by presence/absence in photos over time. Statistical analysis was performed using repeated-measures ANOVA to compare mean growth rates between the sites. Results illustrate that most coral colonies increased in size over time with minimal bleaching. There was approximately a 92% survival rate across all colonies, with *Pavona* and *Porites* corals having a significantly lower survival rate than *Pocillopora*. Substrate slope and perturbation also had an effect on coral growth, while depth and substrate composition did not. Future goals of this project include resampling six months from the last time points to establish a one-year time series dataset. This project fulfills an urgent conservation need to maximize the chance of survival of the limited number of corals in the Galápagos and will inform ongoing global coral restoration efforts.



Finding a New Place to Call Home: Mapping Deep-Sea Habitats to Support Cold-Water Coral Restoration in Two Mediterranean Canyons

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Cold Water Coral (CWC) habitats are threatened by climate change and human activities that could severely affect their survival in the future with a concomitant loss of associated ecological functions. While management and conservation actions continue to play a pivotal role in mitigating pressures, the importance of active ecological restoration interventions to support the recovery of degraded, damaged, or destroyed habitats — and to preserve the essential ecological services they provide — has grown significantly in recent years.

In 2024, a collaborative effort between the LIFE DREAM project, the Horizon Europe REDRESS initiative, and the Italian National Recovery and Resilience Plan (NRRP) resulted in the establishment of a deep-sea monitoring system (300–1000 m depth) within two Mediterranean canyons: the Dohrn Canyon (Tyrrhenian Sea) and the Bari Canyon (Adriatic Sea). This network comprises 22 artificial structures designed to provide hard substrates for CWC colonization while enabling long-term monitoring of CWC habitats and recruitment using cameras and various oceanographic sensors.

The deployment of these structures was guided by a detailed mapping of the seafloor and benthic habitats to pinpoint sites most suitable for coral settlement and growth but also ensure accurate positioning and long-term stability of the structures.

In this contribution, we outline the decision-making framework and technical workflow involved in the creation of this deep-sea monitoring system, offering insights to inform and guide future restoration initiatives.



Applications of Diverse Mapping Technologies for Repeat Mapping of Coral Reefs

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Coral reefs are of economic and ecological importance, with multiple agencies around the globe focused on restoring these vital ecosystems using various mechanisms, including coral outplanting. Monitoring the long-term success of coral outplants is highly time-consuming, as it requires divers to measure each coral individually. Additionally, this approach makes it challenging to assess the overall health of a reef at spatial and temporal scales that are meaningful for effective management. Since 2021, we have acquired annual datasets of nine coral reefs in the Florida Keys, USA using uncrewed aircraft systems (UAS), multibeam echosounders (MBES), and diver collected underwater imagery processed in Structure-from-Motion (SfM) photogrammetry software. The datasets collected from the different platforms are enabling multiple comparisons between both different years and different combinations of data sets. We examine the spatial accuracy of photogrammetry and explore how MBES and SfM can be utilized to detect changes in reef systems. SfM had higher rugosity and curvature values than MBES and captured sediments, and a wider range of coral types than MBES. These differences underscore the relative contributions of reef-building corals, calcifying weedy corals, and octocorals within the Florida Keys reefscape.



Optimal Terrain Attribute Sampling Methods for Habitat Suitability Modeling in the Fine-Scale: Multibeam and Structure-from-Motion Photogrammetry Comparison

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Habitat suitability modeling (HSM) has been gaining widespread usage within the field of restoration ecology, due to the potential to identify and build favorable habitats for endangered species, as well as better understand species' environmental needs. A primary example is within coral restoration, where HSMs have helped to explore the future of coral survival as ocean temperatures rise. The majority of HSMs developed for shallow marine restoration utilize multibeam echosounder (MBES) derived digital elevation models (DEMs), which range in resolution from 1m to 50m and capture bare-earth geomorphology. However, coral outplantation has resulted in mixed and unexplained success, at the scale of meters, within the reefscape. This has necessitated the development of site-specific HSMs using finer-resolution data (centimeters to meters) and to include surface features. Structure-from-Motion (SfM) photogrammetry constructed Digital Terrain Models (DTMs) capture surface features and fine-scale data, but data acquisition quality is subject to water conditions, camera specifications, and image overlap. Additionally, traditional data sampling methods utilized at such fine-scale resolutions are vulnerable to artifacts and amplifying noise. Previous explorations of fine-scale terrain attribute sampling methods and computational approaches are continued through comparing MBES DEMs to SfM DTMs ability to account for the variability in healthy outplanted staghorn coral coverage within the lower Florida Keys. Bathymetry data was resampled to seven different resolutions, ranging from 1cm to 1m. The resampled bathymetry data was then used to construct 18 terrain attribute rasters, using 4 different computation windows. Five different aggregate functions were used to calculate terrain attributes for each coral outplant. Partial Least Square Regression results find MBES DEMs are more consistently able to explain variation in percent healthy cover of outplanted staghorn coral than SfM DTMs, across sampling methods. Further exploration of model results and predictions of site suitability are compared. Climate change driven coral reef deterioration requires comprehensive and fine-scale modeling within the reefscape to delineate variance in coral health. While photogrammetry SfM capabilities can bridge the gap towards such models, data acquisition and sampling procedures require further research before reaching MBES robustness.



Habitat Mapping and Sediment Transport Dynamics of Northern Assateague Island

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This study seeks to understand sediment transport dynamics utilizing advanced mapping technologies on the Assateague Island National Seashore (ASIS)—a sandy barrier island located south of the Ocean City, Maryland. For the past century, the shoreline of the northern portion of ASIS has undergone significant erosion. Climate change and sea level rise are significant threats that will likely increase the severity of erosion of the ASIS shoreline. To protect the island's habitat, the National Parks Service (NPS) in collaboration with the United States Army Corps of Engineers (USACE) manage an ongoing shoreline restoration project. The restoration effort involves annual inlet bypass dredging operations which borrow sediment from the Ocean City Inlet and place the material within a ~620 acre consolidated placement area on the island's northern shore. This research focuses on expanding our understanding of the consolidated placement area morphology and sediment transport processes to evaluate the effectiveness of the current restoration project. Aerial photogrammetric surveys were conducted of the consolidated placement area before and after the dredging operations in September 2024 using an autonomous Wingtra drone. The software Pix4Dmapper was used to produce topographical 3D models with a resolution of 1.6 cm/pixel. Additionally, the Norbit multibeam sonar was used to map the nearshore consolidated placement area. A depth model integrating subaqueous and aerial post-dredge survey data is under development, demonstrating the potential for seamless mapping of barrier islands by combining bathymetric and topographic models.

Further survey operations are planned for early spring 2025, in which aerial drone surveys and multibeam sonar nearshore surveys before and after a storm event will be completed to visualize storm-driven morphological changes. Moreover, RBR and Aqua TROLL wave sensors will be deployed across a transect of the consolidated placement area from the landward shore to the seaward shore. The sensor data will be used to perform a spectral analysis of the storm wave conditions and monitor overwash on the island for the duration of the storm. The comprehensive models of the consolidated placement area produced from the spring 2025 surveys will be compared to the fall 2024 models to evaluate the volume of sediment displacement and transport patterns during the energetic winter season. The sediment transport patterns indicated by the combined models will provide essential knowledge to determine the functionality of the USACE dredging operations in restoring the northern shoreline and how to proceed in future restoration efforts.



Long-Term Mapping of Seagrass Provides Insight into the Persistence and Potential for Recovery in the Indian River Lagoon, Florida

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Mapping seagrass is widely recognized by state and federal programs as a critical tool for establishing restoration goals, assessing restoration outcomes, and guiding adaptive management. Historical seagrass mapping in the Indian River Lagoon (IRL) was completed using aerial photographs from 1943, with updates completed approximately every 2-3 years since 1986. Between 2011 and 2021, lagoon-wide losses of seagrass exceeded 24,000 hectares driven by widespread, prolonged phytoplankton blooms. Analysis of water quality, mapping data, and in-water transect data determined that reduced light availability during these intense blooms was the primary factor impacting seagrass cover and extent. However, effects varied spatially and were likely influenced by the persistence of seagrass cover as identified in mapping, particularly in the 0.5 to 1.0m depth range. In the less developed northern IRL and Mosquito Lagoon, many seagrass beds remained stable for over 20 years prior to the first unusual bloom in 2011. Conversely, the highly urbanized central IRL and Banana River Lagoon had fewer persistent beds during this same period. The 2023 maps revealed signs of seagrass recovery, with the greatest increases in extent and cover occurring in areas where persistent seagrass beds had been identified, bringing to light the importance of long-term mapping and monitoring projects. Restoration through planting has focused heavily on where seagrass beds previously occurred, but managers also should consider the persistence of those beds as an indicator of where natural recovery is likely. Monitoring through a multi-tier program that includes mapping allows for adaptive management in restoring macrophyte-based systems.



Seagrass Recovery Following Coastal Development, Documented using a Low-Cost Sidescan Sonar System

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Globally seagrasses are threatened and disappearing due to a variety of human activities. One of the most productive seagrass beds in Trinidad and Tobago disappeared from Williams Bay in 2014 with the construction of a boardwalk and other infrastructure along its shore. After construction concluded, the seagrasses started to slowly recover naturally. We documented this regrowth using a Lowrance HDS mapping system mounted to a kayak that towed a kickboard with a downward-facing action camera underneath. The camera provided groundtruthing imagery for the acoustic mosaics for verification and accuracy assessments. The Lowrance HDS collected sidescan sonar imagery, single beam sonar data converted into depths, hardness and roughness, as well as GPS coordinates. Using this system, we mapped the shallow areas of Williams Bay in 2017, 2018 and 2023. Parallel tracks 10 m apart were run using a 50 m swath width and at a frequency of 455 kHz. The data were processed using ReefMaster software, which is another low-cost tool. The resulting map products were sidescan mosaics, bathymetry, hardness and roughness maps. Manual interpretations of these map layers were then performed to delineate the boundaries between seagrass and bare sand or rocks. A subset of the groundtruth data was used to enhance the interpretations, and the rest of the data were used later to perform an accuracy assessment. Across the years, the extent, density, height and composition of the seagrasses changed, especially between 2018 and 2023 when shoal grass expanded, grew taller and more dense and turtle grass patches increased in area and height. Extracting these patterns using the sidescan mosaics and other map layers was difficult and requires further efforts to better model the seagrass distribution and extract the relevant variables of interest, such as species, height and density. Artificial Intelligence may be a suitable means for improving the interpretation of the acoustic data and decreasing the time required to perform delineations. If the processing can be streamlined and standardized, these inexpensive tools can be more effectively used to monitor seagrass beds across the globe and help us document impacts to them and develop more effective monitoring and restoration.



Restoration of *Posidonia oceanica* Meadow Using Cuttings from an Area Impacted by Harbor Extension Project

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In the Mediterranean Sea, restoration of marine habitats has mostly focused on the endemic seagrass *Posidonia oceanica*. Despite several transplanting experiments, large-scale projects are rare, and their success is poorly known. The present work describes a restoration project of a large, degraded area in northern Sardinia (Italy) using cuttings harvested from a donor meadow that was destined for destruction due to harbor expansion. The receiving site was selected through a multidisciplinary study including acoustic mapping, ROV surveys, sediment assessment, and analyses of satellite images across ten years to evaluate the site suitability. Plants were manually uprooted from the donor meadow and cuttings were selected and transplanted within 24 h by environmental engineering techniques. The cuttings were transplanted onto degradable mats of natural coconut nets coupled with a double-twist steel mesh and anchored to the bottom. Overall, 7000 patches, each containing 20 cuttings, were transplanted in three periods: June–July 2022, October–November 2022, and February–March 2023. One year after the restoration, all the patches were in situ, with an overall cutting survival of 59%. The results are comparable to those of previous small-scale projects using the same technique and also endorse its suitability for the restoration of large, degraded areas.



Marine Litter in Two Mediterranean Submarine Canyons: Mapping Distribution and Impacts to Support Restoration Efforts

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Marine litter (ML), defined by UNEP as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment", poses a global threat to ocean ecosystems. Submarine canyons, recognized as biodiversity hotspots and key conduits for nutrient transport to the deep sea, are particularly vulnerable to ML accumulation. Among the most affected communities, cold-water corals (CWCs) suffer physical damage, entanglement and habitat degradation, compromising benthic biodiversity and ecosystem functioning.

To investigate the impacts of ML on deep-sea ecosystems, two research cruises - ECOREST and ECOREST II - were conducted between April and July 2024 aboard the R/V *Gaia Blu* of the Italian National Research Council (CNR). The surveys focused on two Mediterranean submarine canyons, namely the Bari Canyon (South Adriatic Sea) and the Dohrn Canyon (South Tyrrhenian Sea). During these expeditions, ~ 100 hours of high-resolution video footage were acquired using a Remotely Operated Vehicle (ROV) at depths between ~ 200 and 1000 m. Real-time observations of ML occurrences were logged during each dive, followed by post-cruise video analysis to identify, count, georeference, and categorize benthic ML items. Particular attention was given to mapping the spatial distribution of ML in relation to CWC habitats, with detailed observations of ML directly affecting these ecosystems. By overlaying ML occurrences with multibeam bathymetric data, the relationship between ML presence and geomorphological features was also investigated. Furthermore, data collected *in situ* within the Bari Canyon were compared with predictions from a three-dimensional model designed to forecast the spatial distribution of the ML based on the hydrodynamics of the Adriatic Sea, with the aim of validating the model.

The findings of the ROV surveys in the Bari and Dohrn canyons offer an assessment of the spatial distribution of macro-litter and its effects on biodiversity, and aid in developing specific conservation and restoration strategies, enhancing efforts to reduce anthropogenic pressures on fragile deep-sea ecosystems.

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Benthoscape Maps as Monitoring Tools for Sponge Marine Protected Areas in the Gulf of St. Lawrence, Canada

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The government of Canada has a stated goal of conserving 30 % of their territorial ocean by 2030. As part of this goal, Other Effective Area-Based Conservation Measures (OECMs) for sponges and sea pens were established in the Gulf of St. Lawrence in 2017 by Fisheries and Oceans Canada (DFO). In these OECMs, the use of all bottom-contact fishing gear is prohibited. Effective monitoring is an integral component of conservation management for these areas, as it enables stakeholders to track changes over time, assess effectiveness, and ensure that restrictions are being followed.

Benthoscape maps, which delineate the seafloor based on broad biophysical characteristics, can act as a baseline for monitoring changes in the benthos over time. Here we generate benthoscape maps for three sponge refuges surrounding Anticosti Island in the Gulf of St. Lawrence, covering 1574 km², with depths ranging from 57 m to 424 m. We conducted multibeam echosounder (MBES) surveys to collect bathymetry and backscatter data. In 2023, 99 transects were surveyed with a 4K drop camera as ground validation and to quantify benthic ecosystem characteristics.

Video data were processed using BIIGLE 2.0 (Browsing and Annotating Large Marine Image Collections) to quantify the substrate type and count and identify benthic fauna at the lowest taxonomic level possible. Benthic community composition was evaluated using multivariate statistical methods, revealing patterns in community composition across the sites which broadly reflected changes in sediment composition. These data sets were used to define benthoscape classes at each site which were spatially mapped using a categorical supervised classification approach (Random Forest) with the MBES bathymetry and backscatter data sets used as environmental covariates. The three OECMs were dominated by glaciomarine sediments with drapes of postglacial sediments of varying thickness depending on local seafloor morphology and hydrodynamics. Sponge habitat was associated with areas of coarser sediments and on large boulders within soft sediment regions. These mapping products can be integrated into OECM management and serve as monitoring tools to track any changes in these environments.



The Zip Project: An Oyster Restoration Project

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The Zip Project is an organic approach to oyster reef restoration by utilizing biodegradable and plastic-free materials to ensure a safe and natural way for oysters to grow. The benefits of this project include, but are not limited to, improved water quality and clarity, protection from predators and storms, and creating habitats for various marine species. The Zip Project currently has two projects in the works, one in Panacea, Florida and one in Calloway Bay, Florida, with many projects in the works in various locations, including New Smyrna Beach, Florida, Jacksonville, Florida, and Fort Myers, Florida. The first project, the Panacea location, launched in July of 2023 and has since survived three hurricanes (with no damages or loose shells), flourished into its own self-sufficient ecosystem, and improved the clarity in the surrounding water in the area. The second project, the Calloway Bay location, launched in August of 2024 and has since survived a hurricane, has seen more animals in the area, and improved the clarity in the surrounding water in the area. Our hope and goal is to expand our project design to various ecosystems and regions in Florida (and later along the Atlantic and Gulf Coast), to help improve the overall ecosystem and water quality in areas that are in desperate need for filter feeders.

A single adult oyster is able to filter up to 50 gallons of water A DAY! Oysters are able to filter out nutrients, such as nitrogen and phosphorus, that would otherwise harm and pollute marine ecosystems. The ability to filter out harmful nutrients and chemicals from the water also reduces harmful algae blooms from spreading, as species of algae feed on nitrogen and phosphorus, causing them to bloom rapidly. Oyster reefs also have the capability to act as wave barriers and can reduce wave energy, preventing erosion along shorelines and coastlines. Oysters reefs are able to buffer wave energy, which helps promote sediment deposits, thus allowing seagrass areas and marshes to form and flourish. Oyster reefs also create habitat for various marine species, including multiple invertebrate species, crustaceans, small fish, and other animals that bigger species consume. Oyster reefs can be found in various different ecosystems, such as estuaries, bays, and lagoons. Oysters have the ability to withstand drastic environmental changes, like changes in water temperature, salinity, and pH, allowing oysters to live in various different ecosystems and regions.



Community-Driven Habitat Restoration: Using Consumer Side-Scan Sonar to Remove Derelict Crab Pots

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Derelict crab pots pose a significant threat to benthic habitats, marine species, and the sustainability of recreational fisheries. This project, “Fish-finders for Stewardship”, demonstrates the efficacy of community-led efforts to locate and remove derelict crab pots using consumer-grade side-scan sonar technology. By recruiting and training volunteers to operate Mobile Mapping Units (MMUs), a total of 164 derelict crab pots were removed from Delaware’s Inland Bays during targeted clean-up events in 2023 and 2024. These efforts not only restored approximately 1,350 pounds of benthic debris but also engaged local communities in marine stewardship.

The project incorporated hands-on workshops and web-based training modules to educate participants in sonar operation, data interpretation, and debris removal techniques. Four MMUs, equipped with side-scan sonar devices, were deployed to enable volunteers to map and identify derelict pots efficiently. Utilizing the open-source processing software PingMapper and Deep Learning AI for object detection allowed us to rapidly process the data in the field to generate both target reports for recovery efforts and benthic habitat substrate maps quickly for operational usage.

This initiative also included educational workshops targeting recreational crabbers, reaching over 100 participants and retrofitting 150 crab pots with sustainable gear to prevent future dereliction.

Our results highlight the potential of combining accessible technology with grassroots participation to address marine debris issues. The removal of derelict crab pots not only reduces habitat degradation but also mitigates the loss of marine life and promotes sustainable fisheries. This approach provides a scalable model for habitat restoration in other coastal and estuarine environments.

This study aligns with GeoHab 2025’s theme of “Habitat Mapping in a Time of Climate Change” by showcasing innovative methods for habitat restoration and community engagement. It emphasizes the critical role of habitat mapping and citizen science in mitigating anthropogenic impacts on benthic ecosystems.



Using Predictive Models to Identify Kelp Refuges in Marine Protected Areas for Management Prioritisation

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Kelp forests serve as the foundation for shallow marine ecosystems in many temperate areas of the world but are under threat from various stressors, including climate change. To better manage these ecosystems now and into the future, understanding the impacts of climate change and identifying potential refuges will help to prioritise management actions. In this study, we use a long-term dataset of observations of kelp percentage cover for two dominant canopy-forming species off the coast of Victoria, Australia: *Ecklonia radiata* and *Phyllospora comosa*. These observations were collected across three scuba sampling programs that extend from 1998 to 2019. We then associated those observations with habitat and environmental variables including depth, seafloor structure, wave climate, currents, temperature, and population connectivity in generalised additive mixed effects models and used these models to develop predictive maps of kelp cover across the Victorian marine protected areas (MPAs). These models were also used to project kelp coverage into the future by replacing wave climate and temperature with future projections (2090, RCP4.5 and RCP8.5). Once the spatial predictions were compiled, we calculated percent cover change from 1998-2019, stability over the same period, and future predicted change in percent cover (2019-2090) to understand the dynamics for each species across the MPAs. We also used the current percentage cover, stability, and future percentage cover to develop a ranking system for classifying the maps into very unlikely refugia, unlikely refugia, neutral, potential refugia, and likely refugia. A management framework was then developed to use those refugia ranking values to inform management actions and we applied this framework across three case studies: one at the scale of the MPA network and two at the scale of individual MPAs, one where management decisions were the same for both species and one where the actions were species-specific. This study shows how species distribution models, both contemporary and with future projections, can help to identify potential refugia areas that can be used to prioritise management decisions and future-proof restoration actions.



Human Impacts on Marine Habitats



Aquaculture Influences Patterns on Turbidity and Algal Dynamics in a Chinese Coastal Bay

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The rapid growth of China's coastal cities, including Xiamen Bay (XB), has intensified pressures on marine environments, particularly from aquaculture activities. As a critical site for both aquaculture and the endangered Chinese white dolphin (*Sousa chinensis*), XB plays a vital role in the region's ecological and economic landscape. However, the bay faces growing concerns over water quality, turbidity, and harmful algal blooms (HABs), which pose significant risks to aquaculture sustainability, public health, and local biodiversity.

This study investigates the spatiotemporal dynamics of water quality, turbidity, and algal communities in XB, utilizing data from field observations and Sentinel-2 satellite imagery. Advanced processing techniques, including customized YOLOv8m deep learning for aquaculture activity identification and self-organizing map (SOM) analysis for water quality clustering, were employed to evaluate the data. Results show that, in general, there is no significant overall decline in water quality. However, areas near coastal parks and river estuaries consistently exhibited lower water quality. Aquaculture activities appeared to have a limited effect on dinoflagellate densities, with only the areas adjacent to pond outlets showing increased fluctuations in dinoflagellate abundance over the past four years. Turbidity levels were found to be lower in raft aquaculture systems compared to pond and cage systems, though some notable fluctuations in turbidity were observed in recent years. Algal biomass concentrations remained low to moderate, with SOM clustering identifying eight distinct water quality patterns across the bay.

The findings of this study underscore the importance of integrated monitoring and management strategies for both aquaculture and environmental systems in XB. Effective management is crucial to sustaining the region's ecological integrity, preserving biodiversity, and ensuring the long-term viability of aquaculture as a major economic activity in the area.



Comparing the Impacts of Ship Anchoring on Sediment Structure and Composition in Wellington Harbour/Te Whanganui ā Tara

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Ship anchoring impacts the seabed with direct and indirect implications to the health of the shallow marine environment. Previous research has demonstrated that anchoring can gouge into soft sediment habitats by up to 80 cm, with an average excavation depth of ~30 cm. This study aims to assess the impact of ship anchoring on sediment structure and composition in the Wellington Harbour anchorage, Aotearoa New Zealand. In April 2024, we obtained sediment cores from three sites within Wellington Harbour: a highly disturbed site, a recently disturbed site and an undisturbed site. The highly disturbed site is characterised by substantial morphological roughness in bathymetry data attributed to ship anchoring. The recently disturbed site was the location of a known ship anchoring event that occurred ~1 month prior to sediment core collection. Finally, the undisturbed site was a location of similar depth and oceanographic regime to the other two sites, but with no morphological evidence for anchoring, and outside the primary designated anchorage zone. A suite of analyses will be conducted to determine any changes and effects disturbance via anchoring on sediment composition and structure. Sediment structure and relative density will be determined via Computed Tomography (CT) scans. Grainsize, total organic matter (TOM), inorganic carbon (carbonates), and porosity down core will be determined and compared across recently disturbed, highly disturbed, and undisturbed sites. Cores will also be scanned using portable X-Ray Fluorescence (pXRF) to identify any potential heavy metal pollutants such as copper, zinc, nickel, and chromium. The undisturbed core will be used as a background to observe how heavy metal pollutant contents may be affected by anchor disturbance. This study provides new insights into the role of regular physical disturbance by anchoring gear on soft sediment habitats in the context of an urban harbour anchorage. The results of this study will contribute to a wider understanding of ship anchoring impacts and assist in our understanding of the complete environmental signature of anchoring on the marine and coastal zone.



Seafloor Mapping 80 years after World War II at War in the Pacific National Historic Park, Guam

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War in the Pacific National Historical Park (WAPA), located in the U.S. Territory of Guam in the Western Pacific Ocean, was established to interpret the events of World War II (WWII) in the Pacific to the public. The Park encompasses significant historic battle grounds, including the Asan and Agat beach units which were the scenes of the initial attack during the battle for Guam sustaining multiple days of heavy aircraft and artillery bombardments, covert demolitions, and amphibious assaults deploying troops to the shores over fringing reef habitat. Now, almost 80 years later, the park is aware of unmapped WWII resources and recognized the need for comprehensively locating and identifying unmapped cultural resources remaining on the seafloor while simultaneously identifying a need for better understanding the long term impacts WWII to the marine system and recovery of the natural environment. To address this need, the National Park Service (NPS), funded by NOAA Ocean Exploration, develop a unique integrated natural and cultural resource exploratory project designed to use modern benthic mapping techniques to search for, map, and identify cultural resources in a context of natural resource modification and recovery. To accomplish this, an autonomous surface vessel (ASV) equipped with a multibeam sonar was used to map varied terrain (less than 1 m to over 100 m water depth), including areas inshore of the barrier reef not accessible to larger vessels. Multibeam data was collected in conjunction with magnetometer, sidescan sonar, and photogrammetry data of sunken vessels, craters, and unexploded ordnance (UXO). High resolution (sub-meter) bathymetry mosaics were created for these study areas and resulted in the documentation of sunken artifacts and blast craters that remain visible after 80 years of coral regrowth and storms restructuring the nearshore and coastline. We supplemented bathymetry coverage with NOAA published LiDAR data (DEM at 1 m resolution).

This project is a significant step forward in improving stewardship and management of park resources while also fulfilling a priority goal of the NPS national Ocean and Coastal Resources Program (OCRCP) - benthic habitat mapping. The OCRCP has a priority goal of focused benthic mapping within NPS units to address targeted management needs across our 88 ocean and Great Lakes parks. This presentation highlights the efforts of the WAPA mapping project and demonstrates the broader benthic mapping goals for NPS.



Monitoring the Distribution of Submerged Marine Debris in the Jeju Jaguri Subtidal Zone by Underwater Photographic Survey

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In order to determine the distribution characteristics of plastic debris deposited on the coastal seabed, an underwater video survey was conducted in the southern Jaguri coastal area of Seogwipo, Jeju Island, over three periods: summer 2021, spring 2022, and summer 2022. The survey was carried out using high-resolution underwater DSLR cameras, with divers directly capturing 2D vertical images of the seabed within a range of 95–150 m in length and 2–3 m in width. The survey was conducted at a depth of 12–15 m along the sandy-rocky boundary near Seogwipo Port breakwater, moving from the deeper offshore areas towards the inner waters. The captured footage was color-corrected and then stitched into a single image using video mapping software (Fix4D). The total area was calculated, and the debris was counted by type. The debris density was then calculated per unit area. Plastic debris was distinguished from non-plastic debris, including metal, paper, glass, rubber, and wood. The results showed that in the summer of 2021, 232 items of debris were identified in a surveyed area of 285 m², with an average density of 8.14 items per 10 m². In the spring of 2022, 224 pieces of debris were found in an area of 380 m², with an average density of 5.89 items per 10 m². In the summer of 2022, 65 items of debris were found in a surveyed area of 348 m², showing a reduced density of 1.87 items per 10 m². Among the identified debris, the occurrence of plastic debris was significantly higher compared to non-plastic items. Within the plastic debris, beverage bottles, plastic bags used for packaging, and damaged plastic items were found to have the highest densities. A comparison of the survey results with debris findings from the Heonpo Port area in Ulleung-gun showed that in regions with high-density debris, analyzing distribution characteristics through area-based surveys, rather than line-based surveys, would be more effective in estimating debris distribution. For general areas, random line-based surveys would be more effective in estimating debris distribution.



Temporal Succession of Biofilm Microbiomes on Steel near a Deepwater Historic Shipwreck

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The seabed in the northern Gulf of Mexico hosts thousands of built structures, including oil and gas infrastructure, shipwrecks, and artificial reefs. Microbial biofilms colonize the surfaces of these structures, slowly transforming them into biodiverse habitats capable of supporting higher trophic levels on the seabed. A recent study of sediment microbiomes near the historic shipwreck *Anona*, a steam yacht sunk in 1944 and resting at 1250 m, posits that shipwrecks act as island-like habitats for microbiomes, and additional work demonstrates higher biofilm diversity near structures on the seafloor. There is a paucity of long-term (>1 year) biofilm exposure studies, especially in the deep ocean, as the majority of marine biofilm studies have focused on short-term colonization and development. Accordingly, the objective of this study was to characterize and compare steel biofilm microbiomes recovered near *Anona* across time, to address long-term biofilm succession and stability near a structure in the deep ocean. Seafloor biofilm experiments were constructed by installing replicate carbon steel surfaces for biofilm settlement into PVC towers. Using a remotely operated vehicle, towers were deployed at 2-25 m from *Anona* and recovered at 3 months, 4 months, 4.5 months, and 5 years. Genomic DNA was extracted and quantitated, and 16S rRNA and metagenome sequencing were performed to assess differences in community structure, diversity, and functional potential over time. Preliminary analysis of 16S data shows significant shifts in community composition, dominant taxa, and alpha diversity from short-term to long-term biofilms. Results from this study will inform how long-term stability of marine biofilms is influenced by proximity to a biodiverse structure on the seabed.



From Commissioning to Post-Decommissioning: Unravelling the Life Cycle of North West Hutton, a representative North Sea Oil and Gas Platform

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Despite the growing presence of offshore structures, a comprehensive study on their whole life cycle and understanding of their ecological impact is still lacking. This gap in knowledge leaves critical questions unanswered about the roles these platforms play in marine ecosystems. As decommissioning increases and new offshore energy infrastructure emerges, understanding these ecological effects becomes more urgent. Without sufficient research, policymakers and environmental managers lack the data needed to make informed decisions, potentially overlooking both benefits and risks.

Decommissioning, mandated by the United Kingdom's Petroleum Act in 1998, involves dismantling facilities, clearing wells, and restoring the area to its natural state. Some infrastructure may remain to form artificial reefs, offering ecological benefits, while most are removed or recycled to minimize environmental impact. In the North Sea, over 170 platforms will eventually require decommissioning, raising concerns about biodiversity disturbance, waste disposal, and pollution. Studies show "leave-in-situ" decommissioning, chosen for the North West Hutton platform is the least disruptive, as they can foster diverse marine communities and act as breeding grounds and habitats for fish, enhancing species diversity and productivity

This talk aims to describe the physical changes on the seabed related to activities throughout the entire life cycle of North West Hutton, analysing the chemical alterations in sediments, and biological adaptations of the surrounding benthic communities. Understanding how these variables interact provides insight on the broader topic of decommissioning, how to balance the legacy impacts, and the potential benefits of structures as artificial reefs in the North Sea.



White Zone Habitat Mapping in the central Salish Sea – Assessing Recreational Boating Impacts, Distribution of Derelict Fishing Gear, and Eelgrass Decline

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Recreational boating is a popular activity within the Salish Sea of the Pacific Northwest U.S and B.C., Canada. It increased in activity during the Covid shut down (2021), and recently has become concentrated within the San Juan Islands' (central Salish) bays and sounds. In 2022 the County of San Juan's Marine Resources Committee (MRC) became aware of the potential adverse impacts that recreational boat anchoring could do to marine benthic habitats and recommended funding shallow water habitat mapping for those enclosed areas where small boats often concentrate. Funds were partially acquired from the US EPA under Agreement CE-0IJ65401 to the Puget Sound Partners to address the health of local marine and near shore ecosystems in San Juan County. With assistance from the MRC, we undertook a multibeam echosounder (MBES) bathymetric survey of Lopez Sound, Lopez Island, an area not surveyed in the past.

We used a pole mounted R2Sonic™ 2020v MBES system and acquired nearly 200% seafloor coverage to obtain both bathymetric and backscatter data. This provides us with a high-resolution map of 20-25 cm, which allows us to distinguish and map small features such as derelict crab pots, anchor scours, and isolated eelgrass plants. Through this mapping effort (a work in progress) we will be able to illustrate those areas most adversely impacted by recreational boat anchoring, concentrations of ghost trapping derelict fishing gear, and disturbances to eelgrass meadows. From this assessment, recommendations will be made to the county government on how to zone areas for no anchoring and fishing, extending into shallow-water marine protected areas (MPAs). MBES acquisition was done with QPS Qinsy™ and post-survey processing was done with QPS Qimera software and FMGT, navigation was processed using SBG Qinertia™

In addition, while the mapping of the shallow water white zones takes considerable time, we have been able to expedite such surveys by using an 8 m (~27 ft.) twin engine, dual hull Munson PakCat™ (landing craft) drawing less than 0.6 m (~2 ft.), capable of slow survey speeds (~5 kts), and fast transit speeds (~24 kts). Mobilization and demobilization of equipment was reduced to less than 2 hours once the pole base and GPS mounts were permanently installed, patch tests undertaken, and calibrations accomplished allowing for versatility and flexibility in equipment usage. This also allowed for a two-person data acquisition team resulting in a considerable data collection cost savings.



ECOWind-ACCELERATE: Seabed Modifications from a Changing Climate and from Windfarms, with Consequences for the Wider Ecosystem

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Large marine infrastructure on the seabed is part of an accelerated schedule to switch away from fossil fuels and to protect coastlines. When natural currents in the sea deviate around such infrastructure, it can change the shape and composition of the seabed. In the near-field, forces on the seabed will be dominated by the local flow amplification. In the far-field of the infrastructure, the cumulative effect of flow amplification and climate-driven changes can still influence seabed mobility and sediment composition significantly enough to modulate habitat suitability. Some animals might be affected negatively from such changes, and some positively.

In our ECOWind-ACCELERATE project (2022-'26), we are assessing the combined impacts of climate change and large offshore windfarms on the rate and nature of seabed (ecosystem) changes over various spatial and temporal scales. We use a multi-proxy approach with concurrent information on physical and biological processes in the marine environment, large flume laboratory experiments and strengthened model capability (*e.g.* UKCP18-ORCA1/4 and TELEMAC-TOMAWAC-SISYPHE) under different climate predictions.

We quantified and mapped changes to bed stresses by 2050 and by 2100 for the NW European Continental Shelf. We quantified how and where (1) waves dominate change to bed stresses, (2) sea level rise lowers energy transfer to the bed, (3) seabed warms in mixed areas and (4) stratification increases in strength and length in stratified areas. Our maps of predicted sediment transport capacity show that in certain hotspots, sand and gravel will be mobilised more by mid and end century in places where sand and gravel does not move today.

To best assess impact from diverted flows in the wake of monopiles, we show how mean flow velocities will underpredict bed stresses, and Turbulent Kinetic Energy needs to be measured. Accelerated seabed mobility can create new fields of bedforms or strip top sediments from the bed, and can cause creation/removal/alteration of benthic habitats >40 monopile diameters away, 3-4 monopile diameters wide. At a regional to local scale, we are investigating benthic habitats inside and outside OWFs. From a unique, concurrent local dataset of environment, fish and seabirds, we assess consequences of benthic habitat changes to diving seabirds via their movement decisions, energy budget and foraging success.

In summary, we show (1) what aspects of future climate will impact seabed stresses and sediment mobility (thus habitat suitability) over which time scales, (2) the extent and magnitude of impact on the water column and seabed mobility in the wake of a monopile and (3) what observations serve best to assess impact from infrastructure on seabed, benthic habitats and diving seabirds. This will help inform the design and evaluation of approaches to effective environmental monitoring, compensation measures and decommissioning. We want to provide the context within



which nature recovery can be promoted at the same time as future climate change-adaptive and resilient offshore structures are designed.



Management and Communication



A Classification Methodology for the Management of Biogenic Reef in the UK Aggregates Industry

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Biogenic reef, in particular those formed by *Sabellaria spinulosa*, have been identified as being of nature conservation importance and are protected within the UK's network of Marine Protected Areas as the structures qualify as Annex I habitat, according to the European Commission (European Commission, 2007). The reef structures preferentially occur in shallow water (generally <20 m) and coarse sediments, as identified by the OSPAR (2013) definition of 'S. spinulosa reefs in mixed substrata' as "[seabed] comprised variously of sand, gravel, pebble and cobble". Due to this preference an overlap with sites used by the UK aggregates extraction industry often occurs. As part of the aggregates licensing process, reef structures are required to be protected from impact particularly via direct removal through designated exclusion zones. A secondary impact may be suspended sediment (particulate matter) and plumes from the dredging activity. While *S. spinulosa* can be vulnerable to smothering, research suggests that some individuals, and therefore reefs, can benefit from an increase in suspended particulate matter, such as that caused by aggregate dredging (Last *et al.* (2011)). The positive association between *S. spinulosa* and suspended particulate matter further increases the likelihood of co-location of *S. spinulosa* reefs and aggregates extraction activity. For marine aggregates, biogenic reef are primarily identified through assessment of the geophysical survey data. Improvements in survey technology mean that greater expanses of reef structures can now be mapped and excluded. Therefore, a pragmatic approach to the placement of exclusion zones is required. Current classifications of reef measure "reefiness" via characteristics identified within video and still imagery of the seabed (Hendrick & Foster-Smith, 2006; Gubbay, 2007). While this provides a useful frame of reference, the values are not directly applicable to geophysical data. Methods proposed for geophysical datasets in the current literature tend towards automation of mapping and the use of secondary derivatives such as roughness, ruggedness and slope. To glean successful results these methods require high quality data sets, beyond a practicable level many operators usually receive.

The authors used the datasets routinely collected during regional geophysical monitoring surveys (multibeam echosounder, backscatter and sidescan sonar) to map the presence, extent and quality of the reef structures. A rating system was developed, building on current methodologies from imagery analysis, but designed for use with geophysical datasets. The ratings are primarily based on reef structure height and patchiness, with consideration for data quality, interpretation confidence and longevity of the structure. The application of this methodology in the monitoring of licence areas enables the continued use for aggregates extraction while protecting high quality reef structures, using the datasets that are already available without the additional need for seabed imagery.



Using Water Quality to Infer Seagrass Recovery in the Indian River Lagoon

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Over the past decade, the Indian River Lagoon (IRL) has experienced a significant loss of seagrass extent due to prolonged algal blooms, threatening the stability of the ecosystem. While some recovery of seagrass has been observed recently in the Mosquito Lagoon (ML), heavily urbanized southern areas have not seen similar improvement. We analyzed 27 years of ambient water quality (WQ) monitoring data to compare trends in nutrient concentrations across the IRL with differing levels of urbanization. Despite more than a decade of interventions aimed at reducing runoff, trends across these areas have shown no net improvement. Restoration strategies often underestimate the lag time between interventions and measurable outcomes, relying heavily on modeling. However, the timing of intervention implementation and landscape-scale changes are critical to understanding the varied responses in WQ and seagrass recovery across the IRL. Understanding the temporal mismatch between intervention and ecosystem recovery can guide successful restoration strategies.



Modelling Habitat Suitability of American Lobster (*Homarus americanus*) in and around Fishing Exclusion Zones in the Southern Gulf of St. Lawrence

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In the Southern Gulf of St. Lawrence, fishing exclusion zones were implemented to mitigate habitat degradation caused by scallop bottom-dredging and to protect nursery grounds for American Lobster (*Homarus americanus*; lobster, hereafter), a species of both ecological and economic importance to Atlantic Canada. However, the effectiveness of these zones in protecting suitable habitat and supporting multiple life history stages of lobster remains poorly understood. Our study focuses on broadscale mapping of lobster habitat suitability in the Northumberland Strait, aiming to inform conservation strategies and evaluate the effectiveness of these fishing exclusion zones.

We integrated multiple datasets to model adult habitat suitability. Bathymetric data were acquired from the Canadian Hydrographic Service NON-NAvigational (CHS NONNA) Data Portal and interpolated at 100m resolution across the Strait via inverse distance weighting (IDW). Subsequently, the bathymetric derivatives bathymetric mean and standard deviation, standardised broad and finescale BPI, slope, rugosity (VRM), eastness, and northness were generated and exported at the same resolution for inclusion in the model. Benthic video surveys were conducted at 133 stations across the study area by teams at DFO (2023) and Dalhousie University (2023-2024) over a two-year period using 4K drop camera systems. The video was annotated in the web-service interface BIIGLE 2.0 to identify and classify seafloor substrata into distinct seafloor habitats based on visible seafloor attributes (*e.g.*, surficial sediment types) using a modified Folk 5 classification scheme, and to record the presence of lobster before export to ArcGIS Pro. These geological and lobster records were used in tandem with the geospatial data layers to model 1) seafloor substrate based on the classified video transects, and 2) lobster habitat suitability based on the georeferenced video locations, across the study area.

To assess the effectiveness of the exclusion zones, we analyzed differences in both the distribution of suitable habitat and the importance of geospatial predictors in and around the zones. Our results show that the spatial distribution of lobster in the Strait is impacted by substrate type. Further, we found high habitat suitability to be generally associated with areas of multiple substrate types, suggesting lobster prefer habitat on the edge of both hard and soft substrates. Our substrate maps show edge habitat nearshore, aligning with the established fishing exclusion zones; however, many patches of suitable adult habitat farther offshore remain unprotected. This research contributes to the broader understanding of benthic habitat use in the Southern Gulf of St. Lawrence, offering insight into lobster spatial distribution and habitat preference. These findings will expand our knowledge of the effectiveness of marine refuges and support the development



and evaluation of future marine conservation areas to ensure the long-term sustainability of commercial fisheries and targeted populations.



Multiple Uses in Southeast Atlantic: Prospects and Challenges of Introducing Offshore Wind Farms

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There is growing pressure and demand for multiple uses on the marine realm, which could lead to more spatial conflicts pertaining to sea resources. Marine spatial planning (MSP) could contribute to managing the sea in areas where there is an overlapping of uses, with local-scale planning. Looking at the compatibility of different uses may help identify critical areas that need more detailed management and a fine-scale MSP. Seeking to contribute to the MSP's stages, our proposal is to compile available data for the Espírito Santo continental shelf (ESCS), in the Brazilian Southeastern coast, looking at how the introduction of offshore wind energy farms could affect the use and conservation scenario as a future-oriented use.

The software ArcGIS Pro (3.2.2) was used to convert all the available information into polygon shapefiles; then, the analysis of uses overlapping the following methodological steps: i) creation of 10 km² transverse hexagons grid using the Tessellation tool; ii) performing a Spatial Join between the tessellation grid and the merged polygons file; and iii) classification of the joined grid according to the number of overlapping uses. The list of activities and uses was analyzed applying a compatibility matrix according to scientific literature. This matrix classifies each intersection among the different activities/uses, identifying which uses can occupy the same space (compatible uses) and which uses need appropriate spatial measures (compatible under certain conditions) or even cannot be used together (conflicting uses). The results of the compatibility matrix were then analyzed in terms of space to identify areas of particular concern where different incompatible uses overlap.

The results show that there are between 2 and 11 overlapping uses throughout the ESCS. When we look at how these uses overlap using a GIS, and how compatible they are, we can spot potential areas of conflict, including the Southern region, where the introduction of offshore wind energy is planned. The main human activities considered incompatible with the wind production in the area are fishing and marine transportation. The primary factor that renders offshore wind energy utilization incompatible is the prohibition of navigability within the designated area of the wind farms.

The GIS-based methodology has shown that it can be used again and changed to suit different situations. It has been found to be useful for mapping and identifying areas of particular interest of different scales. Given the high level of pressure on the area, the introduction of offshore wind energy projects must involve negotiation between stakeholders and allow for flexibility in marine use. While geomorphological and geomorphometric analysis can be carried out on a regional scale, future research should include high-resolution habitat mapping in areas where there is a lot of conflicting use, to inform potential suitability models and guide management efforts.



Application of the “Nature in Norway” Classification System to Marine Ecosystems for Risk Assessment of Habitat Types using MAREANO Data

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EcoSyst is a theoretical framework for the classification of eco-diversity, and in Norway it has resulted in the “Nature in Norway” (NiN) system, a system to describe natural variation developed and maintained by the Norwegian Biodiversity Information Center (NBIC). This year, the Norwegian Red List for Ecosystems and Habitat Types, which assesses the risks that ecosystems and habitat types may disappear from Norway, is due for a revision. As a novelty, the NBIC has mandated to extend the use of NiN to marine ecosystems, which had been exempt from the use of this classification system in previous editions of the Red List. This presentation is a summary of the workflow developed for the deep-sea habitats, where we have relied heavily on MAREANO data to answer the fundamental question of what is the total area covered by each NiN mapping unit in offshore Norway?

The NiN system is built around a series of environmental gradient variables that are binned into classes according to the turnover in species composition that they generate. Within the marine, aphotic units, a first split is made according to dependence on habitat-forming organisms giving rise to the deep sea coral reef unit. At this same level, called the process level, types are also split according to the degree of stability of the substrate, and thus, another split occurs between “fixed” substrate and sediment. Subsequent splits are made according to exposure, content of fine-grained material, substrate type, and water mass attributes. At the most detailed level, the classification splits according to the dominant taxa of the benthic community, with options for soft coral, sponge, or sea-pen dominance. Video data, and data products collected by the MAREANO marine data collection program have proven critical for the implementation of this system.

We created polygon layers that represented a proxy for each needed environmental variable, categorized into the bins dictated by the NiN rules. Substrate stability was derived from a regional grain size map and translations to NiN variables (fine material content and dominant grain size) developed by the Geological Survey of Norway. Water masses were classified according to temperature and salinity simulations derived from the NorKyst oceanographic models. Benthic fauna composition was derived from MAREANO video data. We built a classification tree that followed the NiN system rules and predicted biological composition of polygons. We have thus made the broadest NiN map so far for Norwegian offshore habitats. This assessment of conservation status of habitats based on distribution area is transparent and reproducible.



Biological Associations with Classified Shoal Features on the Northwest Atlantic Shallow Marine Shelf

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Sand is a finite resource facing growing demand around the world. Sand shoals may be targeted for dredging to support beach nourishment projects, and simultaneously support diverse biological communities. While the relationship between geomorphology and the associated ecosystems has been investigated on a site-by-site basis, a more systematic and regional approach has lagged. Recent research has improved the understanding of shoal habitat associations along the shallow shelf in a more consistent and quantifiable way.

A common definition of shoals was needed to better characterize factors that influence the distribution of marine organisms. Using publicly available bathymetry data for the northwest Atlantic, shoals were modelled based on depth, standard deviation of depth, slope, bathymetric position index, and distance to shoreline. Following unsupervised classification, modelled shoals were validated with 65-93% agreement. Shoal descriptions were subsequently adopted by a U.S. federal classification system, enabling a common standard among resource managers. With a reliable map of modelled shoals on the Atlantic and Gulf of Mexico shallow shelf, the significance of relationships between these features and benthic infauna and fishes were investigated in multiple regions. Predictor variables representing a variety of ecosystem scales, including bottom type, oceanographic conditions, and wetland/estuary proximity, were tested for influence on marine animal distribution at different trophic levels. Oceanographic variables tended to have the greatest influence on fish distribution, though shoal presence occasionally emerged as a small but significant variable. Quantifying the influence of physical, chemical, and biological features on marine animal presence allows resource managers to better characterize important habitats and therefore make more informed decisions.



Creating Ecological Benthic Units (EBUs), A New Tool for Ocean Spatial Planning and Management

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Society's interest in exploiting deep sea resources is growing rapidly the same cannot be said for our ability to effectively conserve and manage the high seas. The recent adoption by the United Nations of a new Ocean Treaty indicates that there is a growing need to plan conservation strategies for the oceans' resources and the biodiversity that it contains. We propose to create a map of Ecological Benthic Units (EBUs) that would provide a new marine spatial planning tool relevant to, for example: a) exploitation of living marine resources; b) deep sea mining; c) impacts of pollution; d) establishing high seas marine protected areas; and e) understanding climate change impacts. EBUs will be based on the sub-classification of an existing global map of seabed geomorphic features using existing spatial data (eg. water depth, seabed slope, sediment thickness, primary production, dissolved oxygen, temperature, etc.). In this presentation we provide a progress report on our work in building a global map of EBUs. Using model output of ocean bottom currents we present the results of an analysis of geomorphic feature aspect orientation towards bottom flow, an important consideration for niche modelling of sessile, filter-feeding benthos.



Identifying Essential Fish Habitat and Providing Sampling Design Guidance to Inform Offshore Energy Development

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Offshore wind is a key step in the transition to renewable energy. The Wilmington-East Call Area (WECA), which begins about 29 km offshore of Bald Head Island, North Carolina, has been opened for offshore wind farm leasing by the Bureau of Ocean and Energy Management (BOEM). It is critical however to ensure development does not harm Essential Fish Habitat (EFH). High relief rocky reefs are well-known EFH, but the importance of low relief hardbottom habitats has been recently recognized. These are more difficult to identify as they are not easily delineated from the bathymetry or simple derivatives such as slope and topographic position index. This work aims to map hardbottom habitats that may serve as EFH and provide sampling design guidance for future surveyors and developers.

Between summer 2013 and spring 2014, the NOAA Ship *Nancy Foster* surveyed the WECA using a variety of technologies including multibeam sonar and underwater cameras for ground-truthing. We focus on a portion that has full coverage multibeam data as well as ground-truth samples. Terrain attributes and backscatter texture measures were calculated at several spatial scales of analysis, and hardbottom habitats were predicted via a random forest model using a hybrid pixel and object based framework. Model performance was assessed using leave-one-out cross validation. An overall accuracy of 83.33% and a Kappa score of 0.56 was achieved indicating moderate performance. This map was created and assessed based on a relatively small dataset (36 ground-truth points), that was not collected using any sort of statistical design. Future surveys should use a rigorous statistical design for ground-truthing.

To assess different potential designs, we ran a simulation where we treated our predicted hardbottom map as truth and then virtually sampled from it using simple random sampling (SRS), systematic sampling (SYS), balanced acceptance sampling (BAS), balanced acceptance sampling with stratification (SBAS), and conditioned Latin hypercube sampling (cLHS) at 14 different sample sizes (15-210 samples in increments of 15). Using the same modelling procedure, we then assessed how well each approach could reproduce the original map at a given sample size. The results of this simulation were inconclusive with no clear design showing the best performance; however, from a theoretical and logistical point of view, we suggest SBAS. This method allows for targeting of classes of interest, has desirable statistical properties, ensures that geographic space is well sampled, is flexible, can incorporate legacy sites, and can easily be split into two design



independent datasets for rigorous model fitting and accuracy assessment. This SBAS procedure was then used to create a ground-truthing sampling design for a newly mapped portion of the WECA.



AI-Driven Efficiency in Benthic and Essential Fish Habitat Mapping for Offshore Wind Development

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Site characterization for offshore wind development is a data-intensive and time-consuming process. A key aspect of this process is identifying benthic communities and essential fish habitats (EFH) to assess potential impacts on marine ecosystems and to plan avoidance, minimization, and mitigation measures. This presentation features a case study of an offshore wind project in the Mid Atlantic U.S., demonstrating how artificial intelligence (AI) has made benthic and EFH mapping more efficient without sacrificing quality of results.

The mapping of EFH began by delineating benthic substrates and features using high-resolution acoustic data from a multi-beam echosounder (MBES) and side-scan sonar (SSS). The MBES backscatter and SSS data were processed following the latest National Marine Fisheries Services (NMFS) recommendations to map the distribution of sediments and benthic features. These interpretations were validated with targeted sampling, including surface profile and plan view images (SPI-PV) as well as sediment grabs for grain size and taxonomy data. Convolutional Neural Networks (CNNs, *i.e.*, iSPI and SPY-View) were employed to annotate sedimentological and biotic features in the images, reducing the time to generate results by 50% compared to manual procedures. Optical grain size analysis from the SPI imagery has achieved 90% accuracy levels and efficiently produces Coastal and Marine Ecological Classification Standard (CMECS) data sets for incorporation into EFH projection models. These AI-assisted analyses trained, and validated a CNNs that efficiently identified, and catalogued habitat types in the project area in a fraction of the typical time. By analyzing geophysical reflective intensities of both soft and complex habitats, the model efficiently interpreted EFH distributions and regional substrate trends, achieving a performance range of 75-85% utilizing mean accuracy metrics, depending on location.

The application of machine learning algorithms at multiple stages of EFH and benthic mapping—ranging from SPI-PV image analysis to large-scale projection models—allowed users to map habitats and features up to three times faster on average. Offshore wind farm development in the U.S. Mid-Atlantic is increasingly challenged by a complex regulatory environment and rising costs. AI-generated maps offer exceptional efficiency and flexibility, enabling the integration of diverse data variables to enhance marine site characterization and benthic monitoring. Additionally, incorporating new data types, such as eDNA, could further refine habitat and species distribution maps across spatial and temporal scales.



EMODnet Seabed Habitats: EUSeaMap in the Caribbean Sea - Approaches to Increasing Resolution and Relevance

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The European Marine Observation and Data Network (EMODnet) is a network of organisations supported by the EU's integrated maritime policy. These organisations work together to observe the sea, process the data according to international standards and make that information freely available as interoperable data layers and data products with the overarching aim of facilitating blue growth.

Phase 5 of the EMODnet Seabed Habitats project commenced in September 2023, and will run for two years through to September 2025. The project aims to build on the existing data products hosted on the EMODnet Seabed Habitats Map Viewer and improve EUSeaMap (broad-scale habitat map for all European sea basins, and for the Caribbean) with new and revised input data. New partners in this phase include National Museum of Natural History (France) and Flanders Marine Institute (VLIZ, Belgium) and contractors: Mid-Atlantic Environment Research Institute (MAERI) and the South Atlantic Environmental Research Institute (SAERI).

In 2023, an updated version of EUSeaMap (2023) was published, and for the first time extended to the Caribbean and Caspian Seas. EUSeaMap provides full coverage of benthic habitat types in the Caribbean Region where habitats are classified according to an EUSeaMap classification and translated into MSFD BBHT and EUNIS 2022 Level 2.

Delivery of EUSeaMap in the Caribbean required collation and aggregation of existing environmental layers, and development of new ones where necessary. Benthic data were identified, collated and used to establish threshold values for classifying the environmental layers into ecologically relevant classes for the determination of habitat types. One biogenic substrate is included: 'tropical coral reefs'. The main data source used was the UNEP Global Distribution of Coral Reefs. Other fine-scale coral reef polygons from French maps from survey in the Guadeloupe and Martinique islands were included. To construct the Biological Zone habitat descriptor dataset, the amount of light available at the seabed is used. For the Caribbean, the number of available MERIS Full Resolution images was insufficient. As a result, KdPAR was estimated using SENTINEL-3 OLCI A and B images (300m).

These data, combined with the DTM 2022 produced as part of EMODnet Bathymetry (100m resolution) and other environmental layers, informed the broad-scale seabed habitat map in this



region. In the Caribbean, the classification used for EUSeaMap 2023 is largely based on that published in June 2022 by the MNHN (French Museum of Natural History) for the island of Martinique (Andres *et al.*, 2022).

The data sharing environment outside the EU can be challenging due to different policy controls, lack of FAIR data, and the limited opportunities for engagement with regional data holders and users. Using the lessons learned from the efforts in the Caspian region, an enhanced model for engagement in the Caribbean is proposed, to include training courses and workshops in co-operation with relevant organisations/agencies. A workshop is planned in Q2/Q3 2025 for the Caribbean, to present the current status of EUSeaMap and EMODnet Seabed Habitats composite products relevant for the region. It is hoped that this approach will facilitate identification and ingestion of data, which in turn will lead to increased resolution of EUSeaMap. This will facilitate policy makers and researchers, and can be used to inform effect monitoring of climate change on the ecosystem and biodiversity of the Caribbean Region and associated SIDS.

All deliverables are freely available via the EMODnet Central Portal which provides a standardised, centralised and free access point for all spatial information on seabed habitats in Europe: <https://emodnet.ec.europa.eu/en>.



Enhancing Marine Spatial Planning through Integrated Seabed Mapping and Science Communication

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Australia's vast ocean estate offers significant potential for the emerging ocean energy industry, critical to achieving the nation's net zero targets. However, only 35.2% of the continental shelf has been mapped in sufficient detail to inform government and industry decisions. Pre-competitive geoscience information, including seabed mapping data such as bathymetry compilations and seabed geomorphology maps, is essential for supporting the ocean energy sector. These integrated, multidisciplinary datasets enhance our understanding of Australia's seabed at regional and national scales, with wide-ranging applications across multiple ocean sectors. They inform targeted surveying, identify areas suitable for offshore infrastructure, and provide important regional context for environmental impact assessments, thereby reducing investment risk and supporting evidence-based decisions consistent with government policies and regulations.

To sustain our ocean economy and ensure our ocean remains healthy and productive, managers require a deep understanding of its complexity. Australia's marine estate features diverse seabed landforms shaped by a range of processes across multiple spatial and temporal scales. Mapping and interpreting seabed features require the integration of bathymetry, seabed composition (*e.g.*, sediment samples, imagery), and sub-surface datasets, along with streamlined methodologies. This integration provides valuable insights into the distribution and evolution of seabed features and their associated habitats and communities, translating data into information and knowledge for decision-makers.

Geomorphology maps provide baseline data to effectively evaluate, monitor, and manage environmental impacts from ocean energy developments. This robust scientific information enables government and industry to sustainably manage Australia's oceans, drive growth of the ocean economy, and protect the marine environment.



The Marine Geodiversity as a Tool for Identifying Possible Biodiversity Hotspot and for Managing Marine Resources

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Geodiversity is one of the abiotic counterparts to habitats. It encompasses the variety of rocks, sediments, landforms, and physical processes that shape our environment—or more simply, the diversity of geological and geomorphological features within a specific area. While geodiversity has been studied extensively on land over the past 30 years, its significance in the marine environment received limited attention in scientific research.

Abiotic environmental components are widely acknowledged and demonstrated to strongly influence the presence and spatial distribution of benthic habitats and species, and ultimately, biodiversity. However, geodiversity is far less recognized or celebrated than its biotic equivalent, biodiversity, which has garnered greater political and public interest, particularly in marine contexts.

This study focuses on evaluating marine geodiversity at a regional scale in the southern Adriatic Sea and the Gulf of Naples (Italy). By calculating a geodiversity index that incorporates bedrock geology, seabed substrate, and geomorphology, the research aims to investigate the relationship between geodiversity and biodiversity in these regions, where benthic habitat distribution studies have been conducted in recent years.

This work establishes a crucial stepping stone for future studies on marine geodiversity and its applications in various fields, including marine geohazards, spatial planning, resource conservation and management, and geoheritage preservation.

Additionally, this research is part of ongoing pilot studies on biodiversity monitoring and restoration in Italian marine ecosystems, conducted under the National Biodiversity Future Center (NBFC). The NBFC is a project within Italy's National Recovery and Resilience Plan (NRRP), supported by the NextGenerationEU (NGEU) initiative. The findings will be made available through the NBFC Geoportal (<http://seamap-explorer.data.ismar.cnr.it:8080/mokaApp/applicazioni/pnrrb>) and the Biodiversity Science Gateway.



Predicted Effects of Offshore Windfarms and Climate Change on the Distribution of Benthic Communities in the Eastern Irish Sea

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The UK is among the leading countries in the shift toward offshore renewable energy, with 13 GW currently produced through offshore windfarms (OWFs). The government has made further commitments to ramp this up to 50 GW by 2030, and currently around 77 GW is planned for installation.

Among the main knowledge gaps regarding the environmental impacts of this rapidly expanding sector are questions about its influence on the spatial distribution of benthic communities at a regional scale and in the long-term, whilst accounting for interactive climate change effects. This is being examined in the ECOWind-ACCELERATE project that focuses on the Eastern Irish Sea, where several monopile foundation OWFs are currently in operation, with more planned in the coming years.

The present-day distribution of benthic biotopes and characteristic taxa across this area was described through an extensive dataset comprising both new seafloor images and existing biotope information. In addition to collated bathymetry, state-of-the-art hydrodynamic and oceanographic models were used to produce a set of high-resolution predictor variables that describe the environmental conditions of relevance to the benthic communities in the area. Using machine-learning Random Forest models, the distributions of particular benthic biotopes across the study area were investigated, for different OWF lay-outs under both present and future climate scenarios. Here we share preliminary model outputs and predictive maps that provide insights into the impacts of climate change and OWFs on benthic biotopes and characteristic taxa, including implications for their future distribution across the Eastern Irish Sea.



Benefits of Collaborating with Private Industry - Building Towards Marine and Coastal Environmental Solutions along the U.S. West Coast

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In the ocean observing and mapping community, there are a variety of organizations and companies with common goals of protecting, conserving, and researching the ocean. Despite these shared interests, there has been a lack of communication or knowledge among public-private partnerships about how to connect with one another to achieve similar goals. Fugro has joined forces with multiple partners through stakeholder engagement to answer questions about the ocean in support of the goals of the United Nations Decade of Ocean Science for Sustainable Development. This engagement includes the Ocean Decade Corporate Data Group which is co-chaired by Fugro and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organisation (IOC/UNESCO). The Ocean Decade Corporate Data Group focuses on creating frameworks and mechanisms to enable privately-owned ocean science data to become publicly available. Also, through in-kind support of the Nippon Foundation-GEBCO Seabed 2030 mapping project, Fugro has collected over 3,000,000 square kilometers of in-transit bathymetry, contributing to over 25% of high-resolution data collected towards the program goal of a completely-mapped ocean by 2030. In addition, in 2007, Fugro collaborated with multiple partners as part of the California Seafloor Mapping Program, collecting ocean mapping data from the shoreline to the three-nautical mile limit for the entire state of California. This multi-million-dollar project funded the collection and analysis of multibeam bathymetry, backscatter, lidar, coring and sampling, seismic reflection profile, and groundtruthing data, including photography and video, which aided in the creation of a comprehensive digital map set available online. These data sets contribute towards defining habitats for ecosystem-based management, modeling of coastal flooding, identifying geohazards, and improving maritime safety, for example.

Fugro and Central and Northern California Ocean Observing System (CeNCOOS) partnered together in 2023 to build a U.S. West Coast Habitat Classification model. This project involved using bathymetric data from publicly available sources combined with other benthic environmental model layers to generate habitat classifications using reproducible geoprocessing workflows. This type of work will aid in UN Ocean Decade goals and provide links between habitat and ecological quantities as well as aid in areas of offshore wind development and create applications towards place-based management, marine sanctuary monitoring, resource management, and marine carbon dioxide removal. Unlike other habitat maps, these include water mass structure (temperature, salinity) and particulate organic carbon flux (food supply). In October 2023, Fugro participated in a Deep Ocean Observing Strategy (DOOS) meeting, entitled the “Deep Ocean Collective Solution



Accelerator,” which encouraged organizations from around the globe to learn these methodologies and apply them based on their areas of interest.

Fugro continues to expand its relationships with research/academic institutions, federal, state, non-profit and other private sectors working towards a “safe and livable world.” When organizations work together with the private sector, the power of collaboration strengthens as they share their data and work towards common goals.



Mapping Programs, Datasets, Efforts & Partnerships



The EMODnet Seabed Habitats' Coastal Wetlands in European Waters dataset – Harmonized Data for Conservation and Sustainable Use

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Coastal wetlands are important habitats that provide essential ecosystem services, including protection against coastal erosion, regulation of water quality, and provision of spawning and nursery areas for fish and other marine species. Wetlands are also critical for mitigating climate change, serving as significant reservoirs of blue carbon. Despite their ecological and economic importance, coastal wetlands face increasing pressures from human activities and climate change, making their conservation and sustainable management a global priority.

The European Marine Observation and Data Network (EMODnet) is a marine data service providing free access to harmonized and FAIR data. Access to all seven disciplinary themes – bathymetry, geology, physics, chemistry, biology, seabed habitats and human activities – is provided through a single access point at the EMODnet Portal, spanning the entire marine environment from coast to open ocean, and from surface to deep seafloor whilst also offering data and information on the Blue Economy operations, from vessel density and offshore platform locations, to hosting EU Member State Maritime Spatial Plans.

EMODnet Seabed Habitats' marine and coastal habitats data products include *the Coastal Wetlands in European waters*, showing the current known extent and distribution of coastal wetland types in European waters and jurisdictional waters of EU Member States and the UK in the Caribbean. The dataset was produced by combining coastal wetland datasets from EMODnet Seabed Habitats with Copernicus Corine Land Cover 2018 data. The first version was created in May 2023 and will be updated with upcoming additional data.

Harmonized data products on habitat distribution across European Seas are essential for assessing ecosystem services and enhancing their conservation by supporting evidence-based policies in restoration, management, and sustainable use of marine and coastal areas.



The MAREANO Programme Celebrating 20 years of Seabed Mapping in Norway – Selected Results and Future Plans

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The Norwegian national offshore seabed mapping programme MAREANO celebrates 20 years of successful operation in 2025. MAREANO is a multi-disciplinary ecosystem-based mapping programme focusing on mapping different aspects of seabed habitats, including bathymetry, geology, biology and chemistry, along with anthropogenic influences such as trawling, littering and pollution. The programme is well anchored in national and international policy, and delivers knowledge on seabed habitats for use in ecosystem-based ocean management plans, and for marine industries such as fisheries, offshore wind, fish farming, oil and gas and seabed minerals. The results from MAREANO form part of Norway's contribution to national and international initiatives such as UN-SDG14, which have influenced the development and focus of the programme over the last 20 years.

Since the programme started in 2005, about 306 000 km² of Norway's marine areas have been surveyed with multibeam echosounders and sub-bottom profilers, and about 287 000 km² of the seabed have been sampled according to MAREANO standards for geology, biology and chemistry (pollution). Following data analyses, a suite of maps spanning these themes have been published, so far covering about 255 000 km². We show some examples of recent results, with a focus on geological and habitat maps. Additionally, we demonstrate how MAREANO mapping has gradually improved the overall knowledge of the Norwegian seabed, by sampling across both geographic and environmental space. In 2025, the main focus areas are the North Sea and deep parts of the Norwegian Sea.

In 2019, MAREANO acquired multibeam echosounder bathymetry from 64 000 km² in the deeper parts of the Norwegian Sea (mean depth 3000 m, max depth 5569 m). In October 2025 follow-up *in situ* surveys will begin, initially focussing on three areas on Mohns Ridge, which is part of the Arctic Mid-Ocean Ridge system. Survey plans build on a dedicated MAREANO deep sea methods strategy and will complement pre-existing data from other sources to make fieldwork as effective and efficient as possible. Also, in 2025, MAREANO will continue mapping in the North Sea, both in areas planned for offshore wind, and areas considered to be particularly valuable and vulnerable. Here too MAREANO will build on previous experience and apply new methods to make surveys, map and information delivery as efficient as possible while maintaining standards. We show some examples of *e.g.* how machine learning and new survey technologies are contributing to MAREANO's ongoing evolution.



The Submarine *Beehives*: Insights from the CORSUB Project

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Submerged terraces off the Punta Licosa Promontory (Tyrrhenian Sea, Campania, Italy), located at depths of 75 to 100 meters, feature previously unidentified morphological structures. These formations, initially observed during a 2024 survey, display a beehive-like arrangement. A biogenic origin was proposed, but no further investigation was conducted until now. The CORSUB project employs an interdisciplinary and integrated approach, combining geophysical, stratigraphical, sedimentological and palaeontological to explore the formation, evolution, and ecological significance of these submerged morphologies.

In December 2024, during the “TREMOR” oceanographic cruise aboard the CNR Italy research vessel Gaia Blu, the CORSUB team collected high-resolution data, including multibeam bathymetry, sub-bottom profiles, and box-corer sediment samples from the study area.

Our results restrict our targets at depths between 75 and 85 meters, consisting of clusters of subcircular features with diameters of less than one meter, sunken edges, and gently elevated central portions. Chirp profiles reveal a thin sedimentary layer overlying these structures, underlain by a rocky substrate, likely part of the Cilento Flysch Unit. Box-corer samples show a stratified subseafloor, with coarse detrital sand and gravel at the surface (mostly biogenic in origin) transitioning to muddy-sandy sediment below. Notably, all samples contain dead, centimeter-sized boxwork rhodoliths, at depth of 8 to 20 cm below the seafloor preserved at the top of the box-corer. Only one sample contains live rhodoliths showing clear evidence of ongoing mudding.

These preliminary results suggest multiple interpretations. The structures may have a biogenic origin, possibly linked to past rhodolith bed development. Alternatively, they could be related to glacial and post-glacial sea-level changes, potentially forming as erosional features during the Last Glacial Maximum when sea levels were up to 120 meters lower than today. These features may have then provided a substrate for biological colonization as sea levels rose during the deglaciation and into the Holocene. Ongoing geophysical and sedimentological analyses, including absolute dating, will further clarify the nature and evolution of these intriguing submarine features.

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Global-Scale Mapping of Seafloor Material Properties using Information-Processing Methods

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Global mappings of the materials and mesoscale features of the seabed are described and mapped in great detail in the dbSEABED system. All ocean zones, coastline to deep-ocean, are covered. Over 6 million observed sites contribute to the mappings, resulting in coverage of over 29% of the ocean's area at 0.1° cellwidth. Many areas are exceptionally well-covered and data ingestion continues at pace. dbSEABED complements the acoustic, bathymetric and swath mapping which is generally associated with GeoHab.

A feature of the system is the use of word-based descriptive data on a large scale, without which adequate spatial/temporal coverage of the globe is not possible. Use of this data type is also critical for reducing the biases which often attend seabed studies, particularly between lithogenic and biogenic terrains, and over scales from micro- to boulder-sizes. Collection/reporting biases are also managed by drawing on diverse sources of data and data collection techniques – sampling, probing, observing, from the geo- and bio-sciences, survey and engineering fields, professional- and crowd-sourced.

Outputs from the system have supported a multitude of projects over time: fisheries management, marine protected areas, ocean acidification, EEZ compilations, extreme events, species adaptations and trophics, fate of human objects, blue carbon, data visualization, bottom roughness, and geoacoustics. The purpose of this presentation is to make the GeoHab audience more aware of the facility and applications.

The use of site-observational data in producing a global coverage involves many challenges to do with data-management, quality assurance, choice of math and stats tools, and data presentation. For example, compositional data analysis, spherical geometry, fast marching, and fuzzy set theory have been employed to good effect. This is combined with with an understanding of parameters such as sediment grainsizes, carbonate and carbon contents, rock exposure and sediment cover, material colors, porosities, bottom roughness, and age datums. Harmonization between multiple variants of input parameters (such as mean grainsize statistics) is a key concept. Outputs are mostly in numerical engineering units – accompanied with uncertainties. This facilitates their use in numerical models and AI / ML.

For this event we will present statistics on correlation distances for various parameters by geomorphic- and ecologic- regions.



Harmonizing Marine Geological Data: Insights from EMODnet Geology with focus on Seabed Substrate

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The European Marine Observation and Data Network (EMODnet), funded by the European Commission since 2009, provides high-quality marine data from across Europe to support research, policy-making, and sustainable resource management. Accessible through its Central Portal (<https://emodnet.ec.europa.eu/en>), EMODnet covers themes like bathymetry, biology, chemistry, geology, human activities, physics, and seabed habitats.

EMODnet Geology brings together marine geological data providing full coverage of European seas and has expanded to new areas including currently the Caspian Sea and the Caribbean Sea. It is offering information on seabed substrate, sedimentation rates and seabed erosion index database, sea floor geology, Quaternary geology and geomorphology, coastal behaviour, geological events, marine mineral resources, as well as submerged landscapes. The project is currently coordinated by the Geological Survey of Finland (GTK) and executed by a consortium of 40 organizations. The core of the partnership is formed by members of the EuroGeoSurveys network, supported by other organizations with valuable expertise and data.

One part of the project is focusing on seabed substrates and substrate characteristics, such as sedimentation rates, seabed erosion and other complementary information. Multiscale Seabed substrate using a modified Folk classification system, harmonized from the national data by the sediment grain size, is one of the key data products of EMODnet Geology. In addition, the seabed substrate database includes information on the seabed surface characteristics that have significance to the marine environment but cannot be solely defined by grain size (*e.g.*, seagrass meadows, moving sediments, ferromanganese concretion bottoms and bioclastic features). These data sets are crucial for various applications, including habitat mapping, resource management, and environmental monitoring.

During the fifteen years of its existence, the EMODnet Geology has become one of the main producers of publicly available, marine geological datasets covering broad European areas (and beyond) with a widely recognized methodology. Also, third-party data submission is supported through EMODnet Data Ingestion (www.emodnet-ingestion.eu). The continuous development of the data products ensures the relevancy of the EMODnet data in the future as well.

The EMODnet Geology project is funded by The European Climate, Environment and Infrastructure Executive Agency (CINEA) through contract EASME/EMFF/2020/3.1.11 - Lot 2/SI2.853812 EMODnet – Geology.



Coastal Sediment Distribution Map – An Abiotic Habitat Map for Ecosystem Restoration of Coastal Louisiana

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Land loss, particularly the loss of coastal wetlands, threatens the sustainability of Louisiana's coastal ecosystem. Sediment is critical to the sustainability of coastal Louisiana, and, proper management of limited sediment resources is vital. The Louisiana Sediment Management Plan (LASMP) is being implemented to meet these sediment needs. To implement LASMP, various sediment management tools have been developed to mitigate the ongoing severe landloss. The Coastal Sediment Distribution (CSD) map {previously known as the Surficial Sediment Distribution (SSD)} map is one of these tools. The CSD map is a product of the analysis and synthesis of existing geoscientific data (mainly sedimentological and seismic data) residing in the Louisiana Sand Resources Database (LASARD). This first-of-its-kind map shows the surficial distribution of sand, fine-grained sediment (fines - silt and clay), and mixed sediment along coastal Louisiana and the Lower Mississippi River. The data density to compile these sediment distribution maps is sufficient enough to qualify these as first-order maps. These maps were initially compiled as a sediment management tool for sediment resource evaluation for coastal restoration program being undertaken in coastal Louisiana. However these are valuable for several applications including 1) volume estimate of existing sediment resources; 2) assisting in the development of the 2029 Coastal Master Plan (CMP) and its coastal restoration projects; 3) planning and implementation of the 77 projects proposed in the 2023 CMP; 4) analyses of data gaps to determine and prioritize future data collection; 5) helping state and federal regulatory agencies identify and prioritize the removal of decommissioned oil and gas infrastructure that is limiting access to useable sediment resources; 6) helping industry and government incorporate the need for and protection of sediment resources into their plans for locating new oil and gas infrastructure, wind energy areas /transmission cables; 7) helping state and federal regulatory agencies identify significant sediment resources in need of protection and 8) finally these abiotic habitat maps serves as a base for habitat map development for various geomorphic features (*i.e.* barrier islands, sandy shoals).

Similar sediment distribution maps could be generated for the entire U.S. Gulf Coast if the hydrographic, geophysical, geotechnical, and sedimentological data available from federal and state agencies, academic institutions, and private industry were integrated. Such maps could help maintain and update the management of sediment resources across the U.S. Gulf Coast by allowing each state to participate in a regional approach to sediment management. Such maps could serve as templates for adaptively managing any such future restoration efforts by individual states and/or regional collaborative efforts across the entire U.S. Gulf Coast.



Addressing U.S. Federal Needs in Ocean Exploration and Characterization

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The U.S. National Ocean Mapping, Exploration, and Characterization (NOMECE) Council and its Interagency Working Groups on Ocean and Coastal Mapping (IWG-OCM) and Ocean Exploration and Characterization (IWG-OEC) coordinate federal agency implementation of the NOMECE Strategy, a framework with goals, objectives and milestones to better map, explore, and characterize the nation's waters. Results to be presented include updates to the 2024 Implementation Plan, which further refine this framework by prioritizing collaboration, data integration, and actionable outcomes across federal agencies and non-federal partners.

Central to these efforts is the IWG-OEC's role in accelerating ocean exploration and characterization, with an emphasis on addressing critical data gaps that limit important uses such as geologic and biologic habitat mapping and classification. IWG-OEC deliverables such as the 2025 Pacific Strategic Priorities Report and the national 2022 Strategic Priorities Report detail interagency thematic and regional priorities by synthesizing expertise from subject matter experts in benthic ecology, cultural heritage, non-living marine resources, water column, and seafloor hazards. The new Pacific Strategic Priorities Report's preliminary findings emphasize the critical need for baseline datasets—including high-resolution bathymetry, sediment characteristics, and biological samples—across priority areas, including the Hawaiian Islands, Guam, the Commonwealth of the Northern Mariana Islands, and American Samoa.

To further improve data usability, the IWG-OEC is developing a dynamic online repository of good practices for acquiring, processing, and storing ocean exploration and characterization data, beginning with a pilot study on video data collected below 40 meters. Interviews with federal users of ocean exploration and characterization video data have highlighted key challenges with data interoperability, such as file size, diverse file formats, storage costs, and the need for publicly available standard operating procedures to improve accessibility. Identifying and addressing these barriers ensures that ocean exploration and characterization datasets can be integrated effectively into habitat mapping and other workflows.

By linking high-quality mapping to targeted exploration and characterization efforts, the IWG-OEC fosters interdisciplinary collaboration and encourages the collection of environmental data necessary to refine seafloor classification maps and models, enhance our understanding of marine ecosystems, and support science-informed management.



Broad Scale Habitat Mapping Data Collected in Support of Reef Fish Surveys: Exploring Challenges of Time and Technology

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Following Deepwater Horizon, billions of dollars have been spent on restoration efforts to recover affected populations, restore habitats and improve resilience of Gulf of Mexico (Gulf) ecosystems. For reef fishes, funding has been used to develop the Gulf Fishery Independent Survey of Habitat and Ecosystem Resources (G-FISHER) program. G-FISHER is a comprehensive monitoring program that provides broad-scale data on reef fish populations while also generating complementary data on the distribution and composition of associated hard bottom habitats. From these efforts, baseline data on benthic habitats were generated from over 4,200 randomly selected surveys using side scan and multibeam sonar. Following standardized protocols to delineate and classify individual reef features, 40 unique habitat classes have been identified, representing a diversity of natural and anthropogenic hard bottom habitats. Robust habitat mapping data have been essential to guiding reef fish survey efforts under a habitat-stratified design; however, critical challenges remain, both in terms of the temporal stability of identified habitats as well as the comparability in habitat classification among multiple mapping technologies (*i.e.*, side scan and multibeam sonar).

We assessed the temporal stability of hard bottom habitats by conducting re-mapping efforts at a randomly-selected subset of previously mapped sites beginning in 2018. Habitat persistence was evaluated for each microgrid (0.1nm x 0.1nm) surveyed, with each survey containing 63 microgrids. We examined 16,280 microgrids across the six spatial strata of the reef fish survey within the eastern Gulf. The greatest amount of change was identified within nearshore (10 – 25m depth) strata; there was a net habitat gain within areas of south Florida and Big Bend, whereas the Florida Panhandle exhibited habitat loss. Habitat change was also detected in deeper areas, although to a much lesser degree. Observed temporal changes in hard bottom habitats are likely attributable to the impacts of multiple strong hurricanes over the past five years.

Moving forward, multiple habitat mapping technologies will be utilized to collect valuable habitat mapping data, including both side scan and multibeam sonar. We are in the early stages of developing alternate analytical approaches to more quantitatively assess temporal habitat changes as well as evaluate consistency in habitat classification between different mapping technologies. Preliminary results will be presented on the percent coverage and habitat classification differences between manual digitization of side scan sonar data and semi-automated habitat classification of multibeam sonar within overlapping survey areas. Our aim is to generate discussions on the utility of these and other approaches for addressing the ongoing challenges.



Wake Up Your Marine Data - EMODnet Ingestion

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Intensifying human activities are placing growing pressure on marine and coastal areas worldwide. Ensuring the sustainable use of marine resources and preserving the integrity of the marine environment depend on effective management. Such management requires comprehensive and accurate spatial datasets across vast areas. However, limited access to marine environmental data hampers governmental decision-making, constrains scientific research, and hinders economic development.

The European Commission adopted the European Marine Observation and Data Network (EMODnet) in 2009 to combine dispersed marine data into publicly available datasets covering broad areas and themes. Today EMODnet involves more than 160 organisations that work together on assembling and harmonising marine data, products and metadata, making them more available to public and private users. EMODnet Ingestion and safe-keeping of marine data 3 (EMODnet Ingestion 3) is one of the EMODnet projects together with EMODnet Bathymetry, Biology, Chemistry, Geology, Human Activities, Physics and Seabed Habitats projects. The EMODnet Ingestion project aims to develop and operate an EMODnet portal with services that will facilitate data holders from public and private sectors to submit new marine data sets for further processing and safe-keeping data repositories and subsequent distribution through Central Portal (<https://emodnet.ec.europa.eu/en>). The data repositories involved in EMODnet Central Portal are existing data managing organisations such as National Oceanographic Data Centers (NODCs), Hydrographic Offices, Geological Surveys, Biological institutes, and others. The project's primary focus is on data providers and their data sets that are not yet handled and are part of the mainstream processes of these data repositories.

The EMODnet Ingestion portal (www.emodnet-ingestion.eu) activities are undertaken by a European network of 46 organisations from 29 coastal countries, including one international organisation. Geographically the network has nodes in the countries around all European marine basins and it covers all EMODnet data themes. Most partners are data centres qualified as National Oceanographic Data Centres (NODC), National Geological Surveys, Biology Institutes, or National Hydrographic Agencies. Moreover, the consortium includes the coordinators of the EMODnet thematics (*e.g.*, EMODnet Geology) through which also those networks are involved.

MARIS from Netherlands is a coordinator of the project, and The Hellenic Centre for Marine Research (HCMR) from Greece is a scientific coordinator of the project. The EMODnet Ingestion 3 project is funded by the European Commission, European Climate, Infrastructure and Environment Executive Agency (CINEA) through contract “CINEA/EMFAF/2021/3.4.10/02/SI2.868290”.



What, Why, and How: Analyzing 25 Years of GeoHab Conferences

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In 2025, GeoHab is celebrating its 25th year of existence. Between the 2002 and 2025 conferences, more than 2,200 abstracts with primary affiliations originating from 47 countries were published in the various books of abstracts. As the organization grows and continues to evolve, it is important to objectively situate the new knowledge created by the GeoHab community each year within the broader scientific body of literature. This paper aimed to better understand how the scientific corpus produced by the GeoHab community through its annual conference evolved over time. Through text mining and textual analysis performed in the software IRaMuTeQ and TXM, we quantified word frequencies, semantic patterns, and co-occurrences to describe the GeoHab corpus as a whole and by year to describe the evolution and trends of our discipline.

When considering the entire corpus, the analysis revealed three core themes, each subdivided into two sub-themes. The most important theme addresses “what” our community maps, and is subdivided into geomorphology (*e.g.*, shelf, slope, canyon, bank, ridge) and sediment and substrate (*e.g.*, sand, gravel, mud, grain size). This second sub-theme also includes some biological concepts (*e.g.*, biomass, organisms, macroalgae, species). The second most important theme includes the “why” our community maps habitats: its first sub-theme contains terms such as conservation, management, protection, and assessment, and verbs such as understand, inform, plan, and improve. Its second sub-theme represents the “who” and lists national and international projects or programs (*e.g.*, MAREANO, EMODnet) and terms such as agency, partner, and institute. The final theme represents the “how” and is subdivided into technologies and data (*e.g.*, multibeam, sidescan, video, grab, bathymetry, backscatter), and methods (*e.g.*, classification, algorithm, software, segmentation, automation). The year-by-year analysis revealed three eras, all with the same core themes (see above) but each with their own characteristics. The decade 2002-2012 represents GeoHab establishing itself as an organization and is different from the other years by a stronger focus on fishes, more general and broad-scale habitat characterization, and the use of geophysical surveys and sidescan sonars. Sidescan was particularly important from 2002 to 2006 compared to other technologies. GeoHab 2013 marks the beginning of a transition towards the second era, 2014-2018, characterized by a greater focus on quantitative methodological developments (*e.g.*, object-based image analysis) and the rise of backscatter as an important component of habitat mapping. Finally, 2021 to 2024 marks an increase in coastal habitat mapping studies, both in terms of the topics of study (*e.g.*, oysters, seagrass, marsh, mesophotic) and the techniques used (*e.g.*, drones, photogrammetry, satellites). Other themes, such as microplastics and restoration, also arose in these years. In short, this analysis highlights what technologies, methodologies, and foci of studies were and remain at the core of the GeoHab corpus and how new ones have been integrated as our community has evolved.



Updates to Florida's Unified Reef Map, a Seamless Representation of Florida's Coral Reef Tract

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The Florida Unified Reef Map (URM) is a geospatial data product supported by the Florida Fish and Wildlife Conservation Commission (FWC) that provides a seamless view of the benthic habitats across Florida's Coral Reef. The URM supports conservation, monitoring and research efforts throughout the FCR. The latest update to the URM represents the first major revision since 2017 and was accomplished through collaborative, multi-agency project. Key project tasks included the integration of newly mapped habitats in the Tortugas Bank and Riley's Hump regions, refinement of patch reef classifications in the Lower Keys, and the collection of ground truth data in the Marquesas to support future habitat mapping.

To expand the URM's spatial coverage, staff incorporated over 50,000 hectares of newly mapped seafloor adjacent to the Dry Tortugas, including 5,891 hectares of coral reef and 5,005 hectares of hardbottom. This expansion enables monitoring programs such as NOAA's National Coral Reef Monitoring Program (NCRMP), the Florida Fish and Wildlife Conservation Commission's Disturbance Response Monitoring (DRM), and the multi-agency Reef Visual Census (RVC) to extend their survey efforts into previously unmapped areas of ecological significance. In the Lower Keys, high-resolution LiDAR data and new benthic imagery were used to manually delineate patch reefs in areas of low mapping confidence, particularly in Hawk's Channel. Ground truth surveys revealed a strong agreement between the existing URM classifications and field observations, with only 4 of 38 surveyed sites requiring changes.

In the Marquesas, staff conducted research cruises and compiled 38 field-verified sites to create a comprehensive geodatabase of benthic habitat photos and survey data. This ground truth dataset was combined with partner data from DRM surveys and shared with NOAA's National Centers for Coastal Ocean Science (NCCOS) to support ongoing habitat classification in these remote regions. The URM v2.2 update reflects the integration of improved spatial data, refined habitat classifications, and field validation, making it a more accurate and valuable tool for reef conservation and management in Florida.



Developing a Comprehensive Open-Source Database of Active Chemosynthetic Seep Communities in the Northern Gulf of Mexico

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Effective monitoring and the adaptive management techniques of mesophotic and deep benthic communities (MDBC) in the Gulf of Mexico (GOM) requires a fundamental understanding of the spatial distribution of discrete, isolated, and remote habitats on a regional scale. Despite a concerted focus by federal agencies to develop a comprehensive inventory of MDBC habitats following the 2010 Deepwater Horizon oil spill, the extent of chemosynthetic communities in the GOM are not well constrained, impeding essential decision-making for benthic habitat restoration, spatial management, and ecosystem protection.

To refine the spatial distribution of chemosynthetic habitats with active gas emission sites in the GOM, a multibeam derivative data product generated using only raw water column backscatter data acquired from an industry-acquired multibeam echosounder (MBES) dataset is used to identify novel clusters of acoustic anomalies from vertically integrated midwater backscatter mosaics. Interpretation of high-amplitude acoustic anomalies indicative of active seeps in the 2D mosaics is used as a first-order geophysical proxy for locating seep-related seafloor habitats underlying the observed ascending midwater plumes of oil droplets and gas bubbles. Using the BOEM Northern GOM Deepwater Bathymetry Grid as a base reference layer for 3D seafloor terrain and the BOEM Seafloor Seismic Amplitude Anomalies GIS layer derived from industry-donated seismic datasets, the vertically integrated 2D midwater backscatter surface is draped over the BOEM bathymetry grid for an interactive seafloor visualization that can potentially serve as a future multi-scale 4D digital twin of GOM biodiversity for future spatial planning and monitoring.

These acoustic anomalies interpreted as oil and gas plumes add to an increasing public inventory of new cold seep locations and provide a valuable, contemporary baseline of chemosynthetic community distribution. Updated seep habitat maps can improve predictive modeling and simulation, reducing uncertainty of seafloor methane flux may be a significant and unaccounted for source of atmospheric methane, and provide fundamental information to prioritize and support MDBC protection and management activities. This effort is aimed at augmenting current efforts by NOAA, BOEM, and other stakeholders in the ecosystem-based management of ecologically and economically valuable benthic habitats that are potentially vulnerable to anthropogenic disturbances while simultaneously safeguarding proprietary geochemical datasets. This “Map Once Use Many Times” approach underscores the importance of cross-sector collaboration needed to accelerate the American Blue Economy.



One Cruise is Better than Two: Highly Leveraged United States Research Partnerships Simultaneously Address Geological and Biological Needs

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The United States Bureau of Ocean Energy Management (BOEM) mission is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way for programs managing offshore seabed minerals, oil and gas, renewable energy, and sub-seabed carbon sequestration. BOEM develops and funds scientific research by multidisciplinary scientists that is needed to accomplish its mission and legal obligations by informing required resource and environmental assessments and consultations. Especially relevant for GeoHab attendees is BOEM's focus on seafloor mapping and characterization data (particularly seafloor backscatter) needed to develop management-useful geological and biological classification products. Seafloor critical minerals are of increasing U.S. and global interest, yet there are significant information gaps requiring improved scientific understanding of both the resources and the associated ecosystems that could potentially be impacted by future extractive activities. To make the most of limited resources needed for expensive and logistically complicated at-sea data collection efforts, BOEM encourages innovation, forms partnerships, and leverages shared funding across the Bureau, with academia and industry, with other individual government agencies (especially USGS and NOAA), and with U.S. interagency bodies such as the National Ocean Mapping, Exploration and Characterization Council and its Interagency Working Groups. This presentation will provide an overview of BOEM's holistic approach to environmental and resource stewardship and detail several recent examples of completed or ongoing interagency research cruises in federal waters (offshore Hawai'i, the Aleutian Arc, American Samoa, and the Blake Plateau) designed to collect data useful for both geological/economic resource evaluation and for environmental information needs such as species presence and habitat classification.



10 Years & 112 Research Voyages - RV *Investigator*'s Contribution to Australian & Global Seafloor Mapping

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On the 12th of December 2024, Australia's dedicated ocean research vessel (RV) *Investigator* celebrated 10 years of service to Australian marine science. Owned by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and managed by the Marine National Facility (MNF), RV *Investigator*'s mission is to support atmospheric, oceanographic, biological and geoscience research between the tropics and Antarctic ice-edge. Seafloor mapping has remained the constant activity across all voyages, thereby contributing a wealth of valuable habitat data across the Australian region and neighbouring territories.

RV *Investigator* has had a significant impact on seafloor mapping and marine science during its 10 years of operation. Having completed 112 voyages and engaged 1,427 participants (from 215 institutions and 23 countries), the vessel has transited over half a million kilometres, acquired more than 3.2 million km² of multibeam bathymetry data, contributed to 153 newly described marine species, and resulted in 1,844 scientific publications.

As of December 2024, 35.2% of the Australian EEZ has been mapped according to AusSeabed. The efforts of CSIRO and RV *Investigator* have contributed a remarkable 13.3% of that total and encompasses mainland & external territories as well as the Australian Antarctic Territory. These contributions underline CSIRO's and the vessel's crucial role in advancing marine research and enhancing both Australian and global seafloor mapping efforts.

We showcase RV *Investigator*'s remarkable research journey over the past decade, including its recent mid-life technological upgrades. We highlight some of its notable explorations and discoveries that have significantly progressed our understanding of shelf and deep-sea habitats across the Australasian region.



New Approaches & Technologies – Analytical Tools & Workflows



A Remotely Sensed Semi-Automated Workflow for Mapping Mid-Shelf and Offshore Reef Extent Outlines in the Great Barrier Reef of Australia

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The Great Barrier Reef (GBR) of Australia is the world's largest coral reef system, spanning 345,000 km² and comprising approximately 3,000 shallow reefs (0–20 m deep). Many offshore reefs of the GBR are located more than 200 km from the mainland, posing significant challenges for accurately mapping their extents. Enhancing the accuracy of spatial information of the GBR benefits decision-making by resource managers who aim to preserve this unique ecosystem and the vital ecosystem services it provides. Efforts to map the reef extent outlines in the GBR date back to 1924, with several iterations over the years using data from in situ field surveys, aerial photography, echo-sounding, airborne LiDAR (Light Detection and Ranging), and satellite imagery. Mapping accuracy has greatly improved due to recent advancements in remote sensing data and data processing technologies. Our workflow integrates multi-date satellite imagery, derived spectral indices, satellite-derived bathymetry, object-based image segmentation routines, and field data to train a machine learning model for predicting the extent outlines of mid- and offshore reefs in the GBR. The mapping approach we will present is designed to be flexible, consistent, replicable and allows for the creation, modification, and inclusion of multi-source training data to achieve higher levels of map accuracies. Additionally, it supports refinement using ancillary information such as habitat maps, depth layers, and previous reef extent maps. Preliminary results show significantly higher qualitative accuracy in consistently detecting reef extent outlines compared to previous mapping efforts, particularly in capturing complex reef structures. Reef extent outlines derived from this research may contribute to spatially explicit authoritative datasets for the GBR, facilitating more informed decision-making and supporting effective conservation strategies.



Groundtruther: A QGIS Plug-In for Seafloor Characterization

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This work focuses on developing a software system for concurrently analyzing co-located multi-beam echo sounder (MBES) datasets and sea-floor imagery, fulfilling the need for a unified seafloor data exploration and analysis platform. The system comprises a graphical user interface where image browsing and geospatial data are linked, and several toolboxes for extracting backscatter distribution, its angular response, and bathymetric derivatives to ultimately build detailed quantitative reports.

The main processing core in GroundTruther, is based on the development of a GRASS Representational State Transfer (REST) API service, which allows multi-user and remote access to a number of geospatial processing routines. Specifically, it exposed the basic tools to extract bathymetric derivatives (including slope, aspect, and various types of terrain curvature) and geomorphological features, and various descriptors of the form such as intensity, exposition, range, variance, elongation, azimuth, extent, and width.

The overall objective is to provide an efficient means of understanding the relationships between morphology, backscatter, and the observed biota and, thus, understanding the relationship between the physical and ecological elements of the seafloor. In addition, Groundtruther provides new ways to interpret remotely sensed information derived from MBES and aid the development of spatial distribution models. Furthermore, it could lead to the enrichment of ground-truth databases used to develop formal geophysical models that link acoustic backscatter observations to intrinsic properties of the seafloor.

Groundtruther is made available as a Plug-In for the QGIS software, it is multi-platform, entirely written in Python, and is licensed as open-source software under the GPLv3 license.



Geomorphologic Diversity of Pacific Ocean's Volcanic Edifices

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Large areas of the Pacific Ocean remain unmapped, presenting a significant gap in our understanding of the oceans' seafloor. The Trans-Pacific Transit Expedition (TPT), part of the INKFISH Open Ocean Program, aimed to reduce this gap through an extensive seafloor mapping effort. The expedition consisted of six legs, travelling between Ensenada, Mexico; Hawaii, USA; and Tahiti, French Polynesia, and collected approximately 374,000 km² of multibeam echosounder (MBES) data.

The MBES data provides detailed information on various morphological features, including seafloor ridges, fracture zones, seamounts, and adjacent abyssal plains. Many of the volcanic structures surveyed during the TPT expedition were either poorly resolved in existing low-resolution datasets or were previously unknown, making them significant discoveries. A total of 1,346 volcanic edifices were identified, rising from depths between 3.2 and 6.5 km below sea level. These features have circular to elongated bases and often present either a conic or flat-topped shape, with heights from 200 m to nearly 3,400 m (comprising 902 mounds, 310 hills and 134 seamounts).

To consistently delineate these seabed features and extract various morphometric attributes, a novel ArcGIS Pro toolbox was created specifically for semi-automated seabed geomorphological mapping, called CoMMa Toolbox. The extensive range of morphological attributes extracted includes morphometrics such as average slope, max. vertical relief, circularity and aspect variability index. The seamounts completely imaged in the data were also characterised using the MorVolc, which is a set of Matlab scripts developed to analyse the morphology of volcanic edifices. Plus, the presence of craters and landslides was also manually detected.

The extensive morphometric characterisation of these features allows us to categorize them into different morphological types, using cluster analyses. This categorization provides valuable insights into the formation and development of these volcanic features. Plus, the different morphotypes are likely to exhibit distinct biodiversity characteristics.



Semi-Automated Delineation of Pockmarks and Mound-like Seafloor Features in Flensburg Bay (Germany-Denmark)

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Fluid flow is a dynamic and natural process that can create distinct imprints on the seabed, including negative and positive geomorphological features (*e.g.*, pockmarks, seabed domes, carbonate reefs). Studying these features offers valuable insights into fluid migration and related marine geological processes. However, manual mapping is time- and labor-consuming and impractical when working with high-resolution bathymetric data and for monitoring purposes. In this study, a semi-automated workflow is developed that aids in efficient delineation and better quantitative analysis of such geomorphological features. This study focuses on Flensburg Bay in the western Baltic Sea, located between Germany and Denmark, a notable case study area that hosts abundant geomorphologic features.

Here, we follow a geomorphological delineation approach centered on the Bathymetric Position Index (BPI). Unlike previous studies relying on standard bathymetric surfaces, the BPI highlights topographic highs and lows relative to the surrounding seabed, making it especially useful for detecting these morphologies. We used BPI-derived surfaces to identify positive and negative morphologic features by a systematic approach that included mathematical filtering, vertical cutoffs, and morphometric parameter analysis. The CoMMA toolbox in ArcGIS Pro supported this process as it simplifies the integration of important geomorphometric parameters through automated scripts, making feature extraction more precise and allowing for detailed spatial analysis. After the delineation procedure was complete, threshold-based selection and exclusion of polygons, outside the defined criteria, were taken to refine the results. Statistical analysis was conducted to identify the most suitable thresholds of key geomorphometric parameters, mainly slope, relief, and circularity, significantly reducing false positives. The percentage of false positives dropped from 61.18% in the baseline dataset to just 18.6%, whereas the interaction percentages between semi-automated and manually mapped features were greater than 80%. Metrics like area and aspect ratio similarity closely matched manual delineations, ensuring high accuracy. The Random Forest (RF) method was also applied to this area's pockmarks using the calculated morphometric descriptors to train a model. This model was then tested in a neighboring validation area, yielding promising results in refining feature detection and reducing noise. The outcomes support the workflow for mapping pockmarks and mound-like features and can demonstrate its transferability to adjacent regions with similar geomorphological characteristics. The area's diverse geomorphology, particularly the positive anomalies, suggests future studies into their genesis.



MarineTools – GIS Tools for Data Manipulation and Interpretation for ESRI's ArcPro and ArcMap and QGIS

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GIS provide tools for manipulating, transforming and interpreting data so that the user can understand what the data is telling us. They can provide objective and numerical insight on datasets that might otherwise rely on expert (but subjective) interpretation. Most GIS tools were designed for terrestrial data and so new toolbars have been created specifically for marine data. The new toolbar is called “MarineTools” and is available, free of charge, for ESRI's ArcPro and ArcMap, as well as QGIS. The tools are open-source and so can be edited or added to by users if so desired.

The tools are a collection of operations and calculations designed for marine datasets and surveys such as multibeam bathymetry and backscatter, navigation data and samples (cores, photos and grabs). This collation is designed to accelerate the production of results in the first instance allowing users to evaluate the results more quickly and try different methodologies or parameters to test the robustness of their data and validation of the results.

MarineTools for ArcPro and ArcMap is downloadable as installable executables from <https://projects.noc.ac.uk/atlantis/impact/resources>. The ArcPro installation is a replacement for ArcMap's previous RSOBIA toolbar. Some of the tools included have been written by other researchers but are included for ease of use.

Highlights for these toolbars include: Object Based Image Analysis, Benthic Terrain Model, Bathymetry derivatives (such as slope, roughness, and Geomorphometry), Feature delineation (from the CoMMA toolboxes), Imagery manipulation (such as GLCMs and pixel editing), and Marine Survey utilities (such as survey lines, coverage estimates and sampling campaign design).

MarineTools for QGIS is downloadable via the plugin menu. It is compatible with version 3.34 and above. It has similar highlights as the above. It is classed as experimental as new techniques are regularly being added to it.

Always looking for new models, techniques and manipulations which can be added and then made available to the whole community. Do you have a fancy new method that you feel others would like to use?



Fine-Scale Semi-Automated Mapping of Xenophyophores in the Nova Canton Trough, Central Pacific Ocean

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Xenophyophores, enigmatic multinucleate single-celled organisms, are key contributors to biogenic habitat heterogeneity in sedimentary environments. Their agglutinated tests add three-dimensional complexity to predominantly homogeneous seafloor habitats, at scales relevant to benthic macro- and megafaunal organisms. By providing shelter, attachment surfaces, and seabed stabilisation, xenophyophores may enhance benthic biodiversity. Despite their likely ecological importance, their identity, morphological diversity and spatial distribution remain enigmatic, particularly at hadal depths (>6000 m). While topographic features extending to hadal depths, such as subduction trenches and fracture zones, are predicted to provide high habitat suitability for xenophyophores, quantitative data on their occurrence and ecological roles remain limited.

In this study, we aim to advance quantitative semi-automated mapping approaches for xenophyophores from video data. We focus on observations made during an 8000 m dive of the DSV *Bakunawa* in the deepest section of the Nova Canton Trough (Central Pacific, -2.26°, -172.48°). Using a novel combination of fine-scale bathymetry derived from Structure-from-Motion (SfM) photogrammetry and morphometric characterisation tools (Confined Morphologies Mapping (CoMMA) Delineation Toolbox v1.2), we 1) semi-automatically delineate individual xenophyophores; 2) classify them into broad morphological categories; 3) quantify the morphological characteristics of identified xenophyophores (*e.g.* geometry, size) and 4) describe their spatial distribution using landscape metrics. Delineation performance optimization was achieved by testing multiple derivatives and scales of analysis, enhancing the accuracy of mapping outputs.

The results provide insights into xenophyophore occurrence, morphology, spatial distribution, and their contribution to fine-scale seascape structure. By quantifying variability in morphological traits and spatial patterning, this study underscores the ecological significance of xenophyophores in shaping deep-sea habitats. Methodologically, it supports advancements in morphometric techniques and demonstrates the potential of semi-automated tools to enhance our ability to analyse biological structures in the deep sea.



New Approaches & Technologies – Backscatter Data



An Enhanced Angular Range Analysis (eARA) Workflow in Support of Large Scale National Mapping Programmes: A Case Study on INFOMAR Multibeam Data, Ireland

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Multibeam backscatter has proven to be a useful tool in deciphering seabed sediments. While traditional image-based backscatter processing methods are commonly used, signal-based approaches such as Angular Range Analysis offer a robust sediment characterisation, albeit with a relatively low spatial resolution which hinders its widespread use. Thus, this research aims to improve the spatial accuracy of ARA; and investigate influences (geophysical, sediment geotechnical, and sediment sampling parameters) on sediment prediction accuracy. This research utilises the MBES database of the Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (INFOMAR) programme, which spans >20 years. Our framework applies object-based image analysis (OBIA) to backscatter data and incorporates ARA characterisation to create a more spatially robust sediment classification workflow without the need for reprocessing large volumes of MBES data. Here, the developed workflow is applied to four sites offshore Ireland, with ranging water depths (59-2000 m), operating frequencies (12-300 kHz), and MBES sonars. Statistical analyses focus on: 1) correlation between observed and estimated grain size; 2) thematic accuracy; 3) spatial accuracy; 4) relationship between residuals (Φ) (observed - predicted mean grain size) with sediment geotechnical properties and; 5) sediment sampling parameters. Accuracy assessment yielded a Spearman's rank correlation of up to 0.75 ($p < 0.01$) with overall accuracies of up to 96.15% ($k = 0.84$) and improved spatial accuracies across almost all standard metrics compared to traditional ARA. Overall, these results showcase the predictive capacity of the workflow as a robust sediment predictor, while improving spatial accuracy. Therefore, we provide a scalable approach for seafloor characterisation applicable to large governmental programmes such as INFOMAR, MAREANO, and Seabed2030. Thus, this research can be utilised to support sustainable marine spatial planning and management, in-turn improving decision making.



High-Resolution Seafloor Grain Size Classification and Mapping Using Multibeam Backscatter Data and Geostatistical Interpolation Methods

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Grain size distribution along continental shelves is essential for understanding benthic habitats, supporting environmental management, and guiding coastal infrastructure planning. This study presents the results from the first phase of a project analyzing grain size distribution on a continental shelf using integrated acoustic and geostatistical methods. Backscatter data were collected during annual monitoring programs (2017–2023) using multibeam sonar aboard the R/V Bat-Galim. The data underwent angular response corrections (ARA) and were validated against field-collected sediment samples to ensure accuracy. Normalization and validation processing focused on flat, homogeneous seafloors. Optimal correction values, achieved with muddy sand (Phi 3.3), produced highly accurate classifications for grain sizes ranging from medium silt (Phi 5.5) to medium sand (Phi 1.5), with an error margin of less than 1 Phi value across water depths from 10 m to 100 m. Seafloor classification revealed clear transitions in grain size, including shifts from fine to very fine sand and from coarse to medium silt at specific depth ranges. Hard substrates, such as platforms and ridges, were identified using both bathymetry and backscatter data, with strong acoustic returns offering distinct signatures. Areas with hard substrates surrounded by softer sediments were excluded from interpolation due to their artifact effect on surrounding values. In regions where hard substrates were widely distributed, their values were included in the interpolation process. The resolution and accuracy of the interpolated maps were closely linked to data density and spatial distribution. Kriging, leveraging spatial autocorrelation, produced the most reliable results, balancing data density and resolution at a 250 m grid scale maps. The results highlight the value of combining normalized backscatter with geostatistical tools for cost-effective, precise seabed classification, offering valuable insights into sediment dynamics and supporting broader applications in marine spatial planning and environmental monitoring.



Developing Sites in West Florida Nearshore Region to Calibrate Multibeam Seafloor Backscatter

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Calibrating multibeam backscatter acquired during independent surveys and with different sensors is presently a difficult, but important task. Backscatter values should be comparable for a multibeam system operated at the same frequency in different geographic locations, or independent multibeam systems with the same make and model acquiring backscatter data in different regions of a much larger survey area. Repeatability and consistency of backscatter data can be accomplished by completing an absolute backscatter calibration of the multibeam system. In this study three sites meeting the criteria for backscatter calibration stations were selected based on multibeam bathymetry and backscatter data acquisition in summer 2023. Absolute calibration of a Kongsberg EK80 split beam echosounder was completed using 38.1 and 22 mm diameter tungsten carbide spheres with 6% cobalt binder with known target strength and isotropic properties. The spheres were used to calibrate 200 and 300 kHz transducers. Spheres were placed at the approximate depth of the centered transducer and moved systematically to various depths in the far-field, obtaining intensity values at each depth. The EM2040P and calibrated EK80 were installed on an unmanned surface vehicle and simultaneously acquired backscatter data along the calibration sites at frequencies of 200 and 300 kHz, with the EK80 tilted at 45°. The difference in angular response curves between the EM2040P and calibrated EK80 were computed to generate an EM2040P compensation curve. The angular response compensation curve was used to correct the EM2040P angular response curve and output calibrated multibeam backscatter values. The calibrated EM2040P angular response curve can be used by federal, industry and academic partners to calibrate an EM2040P at one of the backscatter calibration sites located in west Florida nearshore region.



Combining Multifrequency Seafloor Backscatter Response with Roughness Measurements from Seafloor Photogrammetry

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Linking acoustic backscatter measurements from multispectral systems to seafloor characteristics is challenging but offers great opportunities for enhanced benthic habitat mapping. While traditional ground truthing techniques are often not enough to fully explore the acoustic response of the seabed, photogrammetry appears to have potential as a tool to explore influences of bottom roughness on backscatter measurements. Detailed investigations of acoustic/seafloor relationships through field tests are scarce, and typically the relationship between acoustic measurements and seabed properties are based on results from theoretical acoustic modelling. Here, we present the results from an empirical field trial exploring the relationships between multifrequency backscatter and measured seafloor properties. Acoustic data were collected from Head Harbour, Nova Scotia, Canada, using an R2Sonic 2026 MBES operating at 9 frequencies (ranging from 90 to 450 kHz) over a soft sediment study site with tightly spaced survey lines. Processing was carried out using the QPS FMGT software to obtain backscatter mosaics and angular response information. Patches within the study area were delineated where there were records of corrected BS values for all frequencies across all angular sectors (0-20°, 20-40°, 40-60°). Ground truthing was provided by video transects from a 4k drop camera system, which were converted into high-resolution point clouds of the seafloor using the photogrammetry software, Pix4D.

Underwater video and backscatter mosaics suggested most of the area was characterized by homogeneous soft sediments. However, the roughness calculated based on video point clouds captured fine-scale seafloor features (*e.g.* bioturbation). In general, the backscatter values were similar in the near-nadir region (0-20°) across frequencies, with comparatively higher values observed for lower frequencies. The trend of decreasing backscatter as the angle of incidence increased was observed for most of the data, with the exception of the highest frequencies (360 and 450 kHz) where the decrease in backscatter between intermediate and outer angular sectors was minimal. The 450 kHz data exhibited the highest backscatter at the outer beams (40–60°), indicating that surface rather than volume scattering is likely dominant at the site for this frequency. These results will be combined with the bathymetric roughness calculated for each frequency, contributing to the generation of a surface and subsurface multi-frequency generic seafloor acoustic response model. The current lack of knowledge regarding potential variations in bathymetry across different frequencies offers an opportunity to assess for next steps of this project the impact on terrain attributes derived from geomorphometry analysis.



Natural Reference Area for Bathymetry and Backscatter Quality Control and Calibration: Establishment Protocol, Benefits and Feasibility

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Multibeam echosounders (MBES) are extensively utilized in marine habitat mapping due to their capacity to concurrently obtain high-resolution bathymetry and backscatter (BS) data with remarkable operational efficiency. However, BS often remains poorly calibrated and quality-controlled, which limits the reliability and the cross-comparability of the acquired data. To address these challenges in shallow waters, natural reference areas have emerged as a pragmatic solution. Natural reference areas are deliberately selected locations characterized by flat bathymetry, homogeneous sediment coverage and a low variability with time, hence offering stable and consistent seafloor properties that are essential for BS quality control and calibration.

The primary question guiding the utilization of a natural reference area pertains to its stability, the confirmation of which requires considering several criteria. The absence of a trend towards sediment accretion or erosion must be demonstrated by a series of bathymetric measurements of certified hydrographic quality. The stability assessment must also consider the consistency of seabed morphology over time to ensure consistent BS responses. Short bathymetric and BS time series survey, substantiated by ground truthing as video transects or sediment sampling, can ascertain the stability prerequisites for transitioning a candidate area to a reliable reference area.

The efficacy of employing natural reference areas to attain BS consistency in long-term environmental monitoring and scientific research is exemplified by numerous practical case studies. This approach offers a straightforward alternative to costly in-tank calibration methods. Nevertheless, the feasibility and cost-benefit ratio of this approach are questionable for large-scale mapping projects involving multiple research vessels and numerous multibeam systems that are frequently replaced or upgraded.

The creation of a worldwide network of reference areas, and the promotion of their utilization among geoscientists and hydrographers, are expected to further advance MBES BS calibration protocols, improve data standardization, and support more robust geophysical analyses. This strategy addresses the inherent limitations of MBES technologies while paving the way for accurate, integrated, repeatable and intercomparable marine habitat mapping.



A Standardized Protocol for Establishing Backscatter Reference Areas

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Multibeam echosounder (MBES) backscatter data provides critical insights into seafloor composition and habitat mapping, but its quality depends on reliable system calibration. To address the lack of standardized practices, the Backscatter Working Group has developed a comprehensive protocol for establishing natural reference areas specifically designed for MBES backscatter calibration. This protocol leverages expert consensus and real-world application to ensure robustness and replicability.

The proposed protocol consists of five sequential stages: Potential Reference Area, Candidate Reference Area, Pre-Reference Area, Reference Area, and Calibration Area. Each stage applies specific criteria, such as flat bathymetry, seabed homogeneity, and minimal anthropogenic impact, with progressively stringent evaluations, including video surveys and repeat MBES data acquisition. A final calibration step integrates MBES data with scientific echosounder (*e.g.*, EK80) measurements to ensure traceability to acoustic standards.

By following this protocol, researchers and hydrographers can establish one or several MBES backscatter reference areas that meet rigorous scientific and operational requirements. Initial implementations of the protocol in candidate sites have demonstrated its feasibility, with newly established reference areas gaining in popularity for backscatter calibration.

This protocol represents a significant advancement in MBES backscatter calibration methodology, offering a standardized approach to defining areas that allow improving the reliability and comparability of backscatter data. The Backscatter Working Group invites the GeoHab community to adopt and refine the protocol through collaborative efforts.



Accessing Intensity Products: The Canadian Hydrographic Service Intensity Inventory

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The Canadian Hydrographic Service (CHS) has completed a one-year pilot project (May 2024/25) to disseminate backscatter intensity products to the general public. The pilot project's initiation was declared at the 2024 GeoHAB conference, and the purpose of this abstract is to communicate that preliminary results are now available.

The Canadian Hydrographic Service established the Hydrographic Data Access Centre of Expertise (HDACoE) in 2016. Our initial goal of releasing gridded bathymetric datasets for non-navigational use was achieved with the launch of the CHS-NONNA Data Portal in 2020. Since then, over ten million bathymetric datasets have been downloaded at no cost.

The success of the CHS NONNA Data Portal led the HDACoE to further identify, recover and facilitate access to other forms CHS data of use to our clients. The CHS has been collecting multibeam echo sounder (MBES) and Light Detection and Ranging (LiDAR) data for bathymetric purposes for decades. The concurrent collection of backscatter information from hydrographic surveys has been identified as a valuable product for publication as an additional layer through the CHS NONNA Data Portal.

In 2024, CHS initiated a pilot project to make intensity data accessible, with four main objectives: an immediate release of existing intensity products, the development of a Client Feedback Loop, the collection of user metrics to gain insights, and the development of intensity product metadata standardization.

Over twelve thousand intensity datasets have been distributed, with numbers expected to rise as awareness of availability and our inventory expands. These products will remain freely accessible from the Intensity Layer of the CHS-NONNA Data Portal in GeoTiff and/or ASCII format with associated metadata.

These products are extremely valuable for environmental/habitat mapping, and the management of the Blue Economy. The HDACoE has faced challenges in making the intensity inventory free and publicly available, but continues to strive for wider accessibility, inventory growth and continued responsiveness to clients needs.



Field Calibration of Multibeam Water Column Imagery in Turbid Waters

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Multibeam water column data offers valuable insights for marine studies, enabling investigations of *e.g.* underwater gas seepage, fish, kelp, seaweed, shipwrecks, and suspended particulate matter (SPM). However, these measurements require careful calibration to account for the system's varying sensitivity to targets at different positions within the water column image. Uncalibrated data is often distorted, complicating interpretation and hindering quantitative analyses. This is especially true within the transducer's near-field, where many simplifying assumptions for backscatter processing become less reliable. Compared to the significant efforts towards calibrated sea-floor backscatter, water column calibration has received relatively little attention in the existing literature.

Within the TURBEAMS project, valuable insights on multibeam water column calibration were gained through a cross-calibration experiment conducted in the Belgian part of the North Sea. We compared simultaneous SPM volume backscattering measurements from a singlebeam (Simrad EK80, 333 kHz) and a dual-head multibeam echosounder system (Kongsberg EM2040, 300 kHz) at various water depths and beam angles. The experiment enabled the derivation of a calibration pattern to correct the multibeam measurements across different beam angles and ranges.

The derived multibeam calibration pattern varied with both range and beam angle for targets within ~15 m from the transducer. Beyond this range, the pattern transitioned to a far-field regime, depending solely on the beam angle. Applying the calibration pattern greatly improved the consistency of backscatter measurements at different locations within the water column images. Corrected multibeam measurements correlated well with those from the scientific singlebeam. The calibration pattern was transferable across different parts of the multi-day survey, but not between campaigns, likely due to significant differences in seawater temperature.

Our research highlights the need and the challenges for water column specific calibration methods. Natural SPM in near-shore environments proved to be an effective target for cross-calibrating high-frequency echosounder data even within the nearfield and at high beam angles.



New Approaches & Technologies – Data Integration



The USGS Coastal National Elevation Database (CoNED): Integrated Topobathymetric Models – Florida Case-Study

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The USGS Coastal National Elevation Database (CoNED) Applications Project develops enhanced topographic (land elevation) and bathymetric (water depth) datasets that serve as valuable resources for coastal hazards research. These datasets are used widely for mapping inundation zones from riverine flood events, hurricanes, and sea-level rise and for other Earth science applications, such as sediment transport, erosion, and storm impact models. As part of the vision for a 3D Nation, the CoNED Project is working collaboratively with the USGS National Geospatial Program, the National Oceanic and Atmospheric Administration, and the U.S. Army Corps of Engineers through the Interagency Working Group on Ocean and Coastal Mapping (IWG-OCM) to build integrated elevation models in the coastal zone by assimilating the land surface topography with littoral zone and continental shelf bathymetry. CoNED topobathy development is focused on select regions around the U.S. coast, such as the Northern Gulf of Mexico, the eastern seaboard, California, the Pacific Northwest, North Slope of Alaska, and select central Pacific islands and atolls. This presentation will highlight the development of an integrated 1-meter topobathymetric model for statewide Florida from multiple sources using the best available data from federal repositories and the Florida Department of Environmental Protection seafloor mapping initiative. Finally, a new innovative integration method will be demonstrated that uses enhanced binary stacking and spatial blending to improve seamless transition between disparate data sources. The relative accuracies of the blending improvements were quantified with the micro blend ranging from 0.203-m to 0.147-m RMSE while the macro blend ranged from 0.241-m to 0.126-m RMSE compared to bathymetry control sources.



Improving the Mapping of Kelp Beds in the Southern Gulf of Maine Using Sidescan Sonar and Bathymetry-Mode Backscatter (BMB)

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Mapping kelp beds in shallow water environments without ground-truthing through time-intensive diving surveys remains challenging due to limited reference datasets for sonar signatures. The complexity of submerged aquatic vegetation (SAV), combined with varying seafloor bottom types, water column stratification and other environmental factors make it difficult to distinguish kelp from other SAV using standard acoustic methods alone. Phase-measuring sidescan sonars (PMSS) provide a valuable tool for improving seafloor habitat mapping by simultaneously collecting high-resolution sidescan imagery and co-located swath bathymetry data. These integrated datasets enhance habitat characterization by capturing both seafloor reflectivity and structural complexity.

The PMSS employed in this study further improves habitat identification by collecting bathymetry-mode backscatter (BMB) data, a derived acoustic return that reflects both substrate properties and biological features. By combining BMB intensity values with the three-dimensional bathymetric dataset, the presence of kelp can be more effectively identified. This study was conducted in the Southern Gulf of Maine, USA, where kelp beds were surveyed using the Edgetech 6205 for simultaneous acquisition of sidescan imagery, bathymetry, and BMB data.

The results demonstrated that integrating BMB data with bathymetric elevation values successfully highlighted kelp features based on variations in backscatter intensity and structural patterns. This combined approach improved the accuracy of kelp bed delineation compared to sidescan imagery or other single-dataset methods. The study emphasizes the potential for using PMSS data fusion to enhance the detail and coverage of shallow water habitat mapping. The findings support ongoing efforts in coastal habitat monitoring and conservation, with future work focusing on refining these techniques for broader applications in high-resolution habitat assessments and ecosystem management.



Enhanced Mapping of Coral Reefs and Seagrass Meadows through Fusion of Hyperspectral and High-Resolution Panchromatic Imagery

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Coral reefs and seagrass are vital marine ecosystems facing numerous threats, making accurate and frequent monitoring crucial for effective conservation and management. Recent advancements in satellite remote sensing, particularly the launch of new space-based hyperspectral sensors, offer exciting new opportunities for mapping these coastal ecosystems with higher spectral resolution than has been previously possible. However, limitations in the spatial resolution of these hyperspectral sensors can hinder accurate classification of small and sparse benthic habitats. Conversely, high resolution satellite sensors lack the spectral resolution to differentiate between coral and seagrass habitats with subtle spectral differences—particularly when algae or other aquatic vegetation is present. This study investigates a novel approach to improve the accuracy of benthic habitat mapping by fusing data from two complementary satellite sources: coincidentally captured hyperspectral imagery from the Wyvern Dragonette-001 cubesat and high-resolution panchromatic imagery captured by the Maxar WorldView-3 satellite over Hanak, Saudi Arabia. Equivalent average background reflectance corrected 30cm Worldview-3 imagery was used to pansharpen atmospherically corrected 5m hyperspectral Wyvern data using a modified Brovey approach, resulting in a high-resolution image that preserves the original hyperspectral information. This fused dataset was subsequently classified using a support vector machine algorithm informed by in situ habitat data and analyst-derived training classes to assess the suitability of this approach for benthic habitat mapping.

Results indicate that this data fusion approach improves the classification accuracy of coral and seagrass habitats by up to 5% compared to using either the hyperspectral or pansharpened multispectral imagery alone. This study shows how the increased spatial resolution provided by pansharpening can significantly improve classification results in complex benthic habitats and highlights the significant potential of integrating high-resolution panchromatic data with hyperspectral imagery for marine habitat mapping and monitoring.



Encouraging the Use of a Common Generic Sensor Format for Bathymetry; a GEBCO Technical Strategic Priority

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As the archives of raw swath sonar data continue to grow, the ocean mapping community can further leverage their value and reduce the time for inclusion in regional and global bathymetry models by also archiving the processed swath data in a generic, open source, and accessible file format. Combined with additional tools, it will ensure interoperability and the longevity of archived data, and the quality of public compilations, such as the global GEBCO grid. It also avoids redundant bathymetric processing, and improves the quality of backscatter processing and analysis for seabed characterization. Such a format will also facilitate broader access and further analysis with general geospatial software.

Currently, the Generic Sensor Format (GSF) is the only available option widely adopted for the archive and use of processed swath data, and supported in the majority of bathymetric processing software. However, there are a number of challenges and issues that hinder use of the format. GEBCO's Technical Sub-Committee on Ocean Mapping has a strategic priority and project to encourage the use of a common generic sensor format for preserving and sharing processed swath data in public archives. TSCOM plans to facilitate a technical stakeholder meeting in 2025 to address issues with the existing GSF meeting current and future requirements. The project will also support the development of tools to enable the validation and consistency of generic sensor format output data, and translators to facilitate the conversion of valid data from different formats.



Advanced Lidar and Hyperspectral Data Fusion Technique using Spectral Optimization

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The Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX), in partnership with Teledyne Geospatial, leads coastal mapping innovation through advanced sensor-fusion technology. As a Technical Center of Expertise within the United States Army Corps of Engineers (USACE), JALBTCX employs the cutting-edge Coastal Zone Mapping and Imaging Lidar (CZMIL) system. This integrated platform combines three powerful sensors: a CZMIL bathymetric lidar, an Itres CASI 1500 hyperspectral imager, and a high-resolution Phase One 150MP digital camera. By fusing data from these advanced sensors, JALBTCX enables more precise coastal engineering and enhanced environmental monitoring of shallow water ecosystems within USACE project areas, ultimately supporting better coastal management decisions.

In October of 2019, JALBTCX collected 3 flights over shallow and deep waters perpendicular to the shoreline at 400m (~1250ft) bidirectionally with 48-band CASI imagery at JALBTCX's calibration site in Fort Lauderdale, Florida between Golden Beach and Sunny Isle Beach. During this collection, the CZMIL lidar sensor consistently achieved max depth measurements of 65 meters (~213 feet). Thus, the goal of this study was to examine the ability of the passive CASI sensor to reliably extract bottom classifications and depth in these clearer waters using a sensor-fusion technique called Spectral Optimization (SO). SO is a spectral fitting approach which inverts the hyperspectral image using radiative transfer theory for atmospheric correction and directional effects of sea surface reflectance. This can be employed using only the CASI data or constrained with the simultaneously collected lidar depth and active lidar reflectance data. During SO, the Levenberg-Marquardt non-linear optimization algorithm is used to extract the inherent optical properties (IOP), while ground truth spectra and bounding limits help fine tune the fitting process. At the completion, a series of images are produced consisting of remote sensing water-leaving reflectance, remote sensing reflectance (non-water leaving), water column attenuation, bottom classification, bottom depth, and a spectral seafloor reflectance image (water column removed).

Preliminary results from flight lines oriented away from sun glint suggest that bottom classifications were consistent across all three flights, with bottom depths observable up to 21m (~69ft) using CASI-only processing. To improve classification accuracy and data quality, future assessments will focus on four key areas by analyzing annual/bi-annual calibration data collects, incorporation of lidar depth and reflectance data, validating SO's classification results against documented bottom types in a variety of environmental water column conditions, and using enhanced algorithms to minimize cloud shadow and sun glint effects.



Improving Vertical Accuracy of Optical Satellite Derived Bathymetry: Fusion with Lidar Data

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A critical challenge in creating regional topographic-bathymetric (TBDEM) models is locating bathymetry data to fill gaps that occur along the land/water interface. The USGS Coastal National Elevation Database (CoNED) Applications Project is investigating satellite-derived bathymetry (SDB) methods to fill these gaps in support of coastal inundation modeling, sediment transport studies and adaptive planning.

With an emphasis on methods that do not require external in-situ bathymetric data for underwater elevation calibration, USGS developed the photogrammetric module for the open-source NASA Ames Stereo Pipeline (ASP) using stereo imagery, and the physics-based methodology for Landsat data, while NOAA developed a band-ratio methodology based on Sentinel-2 data and a novel technique that minimizes the need for external in-situ bathymetry measurements. All methods achieve sub-meter vertical root mean square error (RMSE) for depths less than 10 m, increasing to approximately 2.5 m RMSE at depths up to 30 m.

The SDB vertical accuracy can be improved by up to 40% when the topographic part of a photogrammetric seamless TBDEM is aligned to external high-accuracy topographic data (such as airborne lidar, spaceborne ICESat-2 and GEDI data), since the TBDEM is a rigid single surface. The physics-based and band-ratio derived bathymetry can be similarly aligned to ICESat-2 derived bathymetry. In this case the bathymetry accuracy improves up to 20 – 30%. All methods can offer a pure spaceborne solution to generate near shore shallow bathymetry. Results are discussed for Cabo Rojo, Puerto Rico, Key West, Florida, and Cocos Lagoon barrier reef and Achang Reef Flat Marine Preserve, Guam.



Habitat Mapping and Mesophotic Community Characterization on the Magoodhoo Reef, Maldives (Maldivian Archipelago)

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Combining optical imagery and acoustic seafloor mapping data has greatly enhanced habitat mapping techniques in tropical coral reef environments. Our study utilized multisource elevation data (*i.e.*: satellite-derived bathymetry, 3D optical models generated via photogrammetric techniques applied to UAV imagery, and multibeam bathymetry) covering the entire Magoodhoo Reef, located on the discontinuous south-western marginal rim of Faafu Atoll in the Maldivian archipelago. Remote data collection was complemented by ground-truthing using an observational ROV on the forereef and lagoon areas, as well as photo-transects conducted on the reef flat.

We developed a comprehensive, multiscale habitat map of the Magoodhoo Reef, encompassing the island, reef flat, backreef zone, and submerged sections of the reef, extending to depths of 120 m along the oceanic edge and 60 m along the lagoon edge. The oceanward margin features steep terraced slopes indicative of a dynamic geological history shaped by late Pleistocene and Holocene sea-level fluctuations. These terraced slopes host distinct habitat zones that vary with depth, exhibiting a unique spatial patterns in their distribution and supporting a wide range of marine life. The lagoon hosts instead various reef-associated sedimentary landforms and patch reefs, that contribute to habitat heterogeneity and provide critical insights into sediment transport and island evolution.

Our findings underscore the ecological significance of mesophotic habitats and highlight the potential for detailed habitat mapping in the deeper region of coral reef environments to better understand their ecological functioning and contribution to reef resilience.



New Approaches & Technologies – Modeling & AI



High-Resolution 3D Bathymetric Mapping and Ecological Zone Classification of Finima Beach, Bonny Island, Rivers State, Nigeria Using Hydrographic Surveying and Machine Learning

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This project aimed to i) ensure that all data collection methods adhered to the International Hydrographic Organisation standards for the conduct of hydrographic surveying, ii) produce high-resolution 3D bathymetric and topographic charts of the terrain iii) apply Machine Learning (ML) models to predict depth variations, habitat stability and sediment transport patterns of the study area. Both primary and secondary sources of data were acquired. Over the course of 4 days, primary data were gathered utilising a Multibeam Echo Sounder (MBES) on board the EPENAL Survey Boat that operated at 200 kHz to obtain bathymetric soundings. Additionally, 20 sediment samples were acquired using the van Veen grab at 100-meter intervals. The sea conditions were moderate during the survey, with wind speeds ranging from 7 to 12 kt. Tidal data were also collected to determine the dynamic effects of tides on the beach. Secondary data included ERA5, which supplied oceanic parameters such as temperature and wind speed as well as Sentinel-2 imageries spanning 2004 to 2024. The Digital C-Max Side Scan Sonar, deployed for sub-bottom imaging of the seafloor, was unable to capture any imagery due to being partially obscured by sand. However, the MBES and sediment samplings provided critical insights into its bathymetry and sediment composition. Subsequently, high-resolution 3D bathymetric and topographic charts were produced using CARIS HIPS/SIPS, HYPACK and ArcGIS to provide precise spatial representations of the Finima Beach seafloor. Depths varied from 0 m near the beach to about 30 m offshore. The major sediment type was found to be compact sharp sand. Gradient analysis of the terrain revealed 4 distinct zones (G1 - G4) with varying slopes ranging from 1:21 to 1:25. The Extreme Gradient Boost (XGBoost) ML model was selected because of its high predicted accuracy and ability to handle complex datasets. It was used in this project to assess 10 key conditioning factors, such as bathymetric sounding, tide, temperature, slope and others; to forecast depth changes, habitat stability and sediment transport. To avoid overfitting, the dataset was partitioned into a 70:20:10 ratio for training, testing and validation, respectively. XGBoost achieved remarkable prediction accuracy of 99.81% and an Area Under the Receiver Operating Characteristics (ROC) Curve (AUC) score of 0.95, demonstrating the model's robustness and reliability. Three different ecological zones were identified by the model: a shallow coastal zone (0 - 9 m) that is home to seagrass and juvenile fish nurseries; a moderate depth zone (9 - 18 m) that is home to coral communities and benthic species; and a deep offshore zone (18 - 30 m) that is home to larger predatory fish, such as croaker fish. The croaker fish is a popular species in the Niger Delta region and is historically and culturally significant, frequently appearing in local markets and festivals. Movement of sediments from the higher beach towards deeper water was analysed by XGBoost, mainly influenced by tidal currents, wave action and local fishing practices



such as dredging and trawling. This contributes to mild coastal erosion, which could disrupt local habitats and affect the park's biodiversity.



Using a Newly Discovered Biodiversity Hotspot to Validate Regional Model Projections of Soft Coral Taxa

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Machine learning models are widely utilized in the field of marine habitat mapping to understand species-environment relationships in geographic space and visualize the extent of their distributions. Knowledge generated through model projections can inform marine spatial management measures, estimate biodiversity hotspots and predict how habitat could fragment, expand and contract under future ocean climates.

Biogeographic data hosted in open-access databases can provide regional to global scale training data for spatial models, however, sampling bias within this data can influence model projections as data may only reflect a subset of an organism's environmental niche. In Atlantic Canada, spatial surveys of benthic taxa are undertaken by Fisheries and Oceans Canada, by multispecies trawl surveys that assess the state of marine resources across major shelf areas. Trawl surveys are often not conducted over areas designated ‘untrawlable bottom’ including areas of high relief, which may bias data used to model the distribution of benthic taxa that occupy these complex habitats. Projections of habitat suitability can be evaluated via cross-validation, but are rarely calibrated through independent fieldwork, meaning such data limitations are often not considered and are further inhibited by financial, operational or technical demands associated with sampling complex benthic habitats.

Here we present a Hierarchical Habitat Suitability Model (H-HSM) that estimates present-day habitat suitability across the Canadian Atlantic for soft coral taxa. The H-HSM is a set of nested Random Forest classification models which integrate ocean climate and seabed terrain covariates in ecologically informed spatial scales (11 km and 200 m respectively). Drop camera imagery was used to evaluate the H-HSM projection of habitat suitability within the marine refuge “Funk Island Deep” offshore Newfoundland, Canada, which encompasses a densely populated soft coral garden discovered in June 2024. The fidelity of the H-HSM projection across Funk Island Deep was assessed using a binary projection (presence-absence) which was compared to field sampling observations using indicators of model performance (sensitivity, specificity and accuracy) and the agreement between the predicted habitat suitability and observed occurrence through a binomial Generalized Linear Model.

We show how soft coral presence scales positively with the H-HSM projected habitat suitability, and sub-optimal habitats that support lower-density occurrences of soft coral are projected highly suitable. As such, the H-HSM promotes habitat occupied by populations



persisting in moderate substrate complexity, reflecting the spatial bias in trawl surveys. We discuss how calibration of model projections is vital to understanding data limitations and can help inform habitat suitability threshold selection used to estimate the extent of habitat loss and gain under future climates.



Bridging the Gap: Toward A Streamlined Pipeline for Studying Benthic Habitats using Benthic Imagery and Practical AI models

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While benthic imagery provides valuable insights and ground truthing of seafloor environments for habitat mapping, the large volume of data collected during campaigns often requires significant time and human effort for analysis. This work introduces a streamlined workflow for analysing benthic imagery using practical AI models and the Squidle+ platform, an annotation platform and centralized data management for marine imagery. It also offers SQBOT, a suite of machine learning models designed to suggest annotations and identify objects of interest, thereby reducing the effort required for manual annotation. Users can upload datasets, leverage SQBOT's annotation suggestions, and perform minimal human supervision to finalize the annotations. Current SQBOT models are limited in handling diverse datasets, requiring new models to address different species and variations in environments and imaging systems. This study outlines a workflow pipeline to efficiently integrate datasets and new trained models with Squidle+. The first step in the proposed pipeline includes processing the collected imagery and the navigation logs and link them with Squidle+. Then, new machine learning models for habitat classifications will be obtained through fine-tuning of pre-trained models and seamlessly integrating updated models with SQBOT for future community use.

The pipeline was tested during the fieldwork week of one of the academic courses at NTNU where a group of seven students managed to collect georeferenced benthic imagery from Hopavågen Bay using a BlueyeX3 mini-ROV with USBL acoustic positioning during the morning and the afternoon and by the evening, the collected imagery was successfully integrated with Squidle and ready for annotating. This streamlined part of the pipeline enabled the students to do thousands of annotations during the fieldwork week leading to quick analysis of the new datasets. Moreover, the pipeline was tested on another dataset collected from Adventfjorden, Svalbard where the BlueyeX3 setup was used to collect georeferenced benthic imagery from different locations in the fjord to study the impact of untreated sewage as part of the EU-funded CLIMAREST project. After processing the manual annotations made on Squidle+, a fine-tuned ResNet50 model, pre-trained on BenthicNet, a large open-access benthic imagery dataset, achieved high accuracy in identifying images with anthropogenic debris. The integration of this model into Squidle+ significantly reduces human effort for similar future studies. To sum, the proposed workflow pipeline aims to accelerate and normalize the process of integrating datasets and new machine learning models with a centralized platform for analysing marine imagery (Squidle+), making it a step closer towards the ideal scenario of relying on machine learning models for efficient data analysis with minimal human supervision.



Input Sensitivity in Machine Learning-Based Benthic Habitat Mapping: A Case Study in Hanak, Saudi Arabia

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Accurate benthic habitat mapping is essential for marine management and conservation. Satellite remote sensing offers a powerful, non-invasive approach to mapping seafloor habitats across extensive, difficult to access areas. Supervised classification machine learning algorithms are one of the most commonly used tools for benthic habitat mapping using satellite imagery. These algorithms use labeled training data to learn and predict the relationship between input features and their corresponding classes. This work assesses benthic habitat classification sensitivity to machine learning input layer combinations by comparing the accuracies of habitat maps derived from a histogram gradient boosting classifier when given a wide range of input combinations. All inputs were generated using WorldView-3 eight band multispectral imagery for a test site in Hanak, Saudi Arabia. Classification accuracy was assessed using a combination of in-situ points and analyst-generated validation data. Assessed inputs include top-of-atmosphere reflectance, remote sensing reflectance derived from several atmospheric corrections including ACOLITE, MAIN, and IDA, principal components and colorspace (HSV, XYZ) transformations, and seafloor shape including satellite derived bathymetry, slope, and rugosity.

The highest classification accuracies, 94%, were achieved when the classifier was given either remote sensing reflectance or top of atmosphere reflectance in combination with colorspace conversions, slope, and rugosity. Interestingly, the inclusion of principle components did not improve classification accuracies. When used alone, ACOLITE, and MAIN derived remote sensing reflectances, 89%, performed better than IDA remote sensing reflectances, 86%, and top of atmosphere reflectances, 86%. These results show that atmospheric correction does not universally improve multispectral classification accuracy and suggest that it may not always be required for benthic habitat mapping. Additionally, they highlight the usefulness of colorspace conversions when used in combination with eight band imagery.



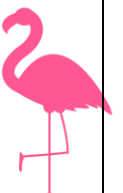
Streamlining Substrate Mapping: Comparing Automated Techniques for Habitat Detection in a Modified River System

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Substrate and bedform identification can help regional managers make informed decisions on conservation strategies. However, the process of delineating these substrates and bedforms is a time-intensive process that requires prior knowledge of interpreting these features in side-scan sonar or bathymetric data sets. This research aims to make habitat classification and detection simpler by evaluating current and accessible modelling techniques, with the end goal to provide an open source tool to identify habitats in aquatic ecosystems. More specifically, three existing modelling techniques (Roboflow, Doodler, and ArcGIS Pro) will be evaluated on their efficiency and accuracy to train and automate substrate and bedform identification in a dynamic and urbanized river system. The models are trained using research-grade side-scan sonar surveys completed along a segment of the Delaware River from the Tinicum Range, Pennsylvania/New Jersey (RKM 163) downriver to the Bellevue Range, Delaware/New Jersey (RKM 139). This area has been intensively altered starting in the late 1800s to support commercial shipping and has historically provided important spawning habitat for the critically endangered Atlantic Sturgeon. Atlantic Sturgeon prefer areas of bedrock and coarse substrate for spawning habitat, so the preliminary focus for habitat detection is identifying exposed bedrock and gravels in side-scan sonar imagery. This research aims to create a more inclusive and efficient tool for resource managers to use for quick analysis of a region prior to activities that may disturb benthic habitats. Developing a long-term, detailed database of sea and river bed environments builds a comprehensive understanding of the consequences of ongoing and future anthropogenic activities.



Bridging the Gap Between Legacy Data and Modern AI in Marine Science

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Analyzing underwater images is crucial for understanding marine ecosystems and geological features. Modern computer vision and machine learning offer powerful tools for automating the analysis of these images, enabling efficient segmentation, detection, and classification of objects. However, unlike images from everyday sources, marine images pose unique challenges for AI algorithms. Accurate analysis often requires specialized taxonomic or geological knowledge, making the creation of training data (images with labeled content) a complex and time-consuming task. While software tools like BIIGLE, VIAME, and SQUIDLE have streamlined the annotation process, the limited availability of domain experts and the sheer volume of data create a significant bottleneck.

Consequently, much of the existing annotated marine image data, particularly older datasets ("legacy data"), relies on point annotations. Researchers marked objects of interest with simple points and associated labels, which, while valuable, are incompatible with modern AI algorithms. These advanced algorithms, such as Segformer, Yolo, or Mask R-CNN, require more detailed "areal" annotations like bounding boxes or polygons to accurately segment and detect objects.

This work presents a novel method for mobilizing legacy data of point annotations and making it usable for cutting-edge computer vision tasks. By leveraging the Segment Anything Model (SAM) and a set of heuristics, we have developed an approach that automatically converts point annotations into machine-predicted polygons. We demonstrate the effectiveness of our method on a diverse collection of 18 deep-sea benthic datasets from the HAUSGARTEN observatory, encompassing over 56,901 point annotations. Our method achieves a median success rate of 91.5% in converting these points to polygons. This approach unlocks the potential of valuable legacy data for training state-of-the-art AI models, accelerating research and conservation efforts in marine science.



New AI-Assisted Three-Step Workflows in BIIGLE Image Annotation

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Analysis of large marine image and video data sets is still predominantly conducted manually to date. Although new breakthroughs in computer vision and machine learning (a subfield of Artificial Intelligence (AI)) continuously show remarkable advancements in performance, the detection and classification in marine image and video is performed manually with tools like BIIGLE, SQUIDLE or VIAME. BIIGLE is a free open source software that can be installed on individual servers or used for free online at biigle.de (with more than 4,100 registered users) for all kinds of image and video annotation tasks. In this contribution we want to introduce how BIIGLE workflows have been changed recently, due to the implementation of new AI functionality and citizen science.

We present a three step workflow for species detection and classification that takes into account the hierarchical decision task in taxonomic classification and the cognitive mechanism of (feature) crispening. The latter describes the effect that the human visual sensitivity for object feature details (morphology, color, texture etc) can be increased when the object is inspected in direct neighborhood with similar objects. So a higher level taxonomic classification (like order, family or genus) of a sea star is easier when it is inspected in a grid with many other similar sea stars from the same order or family. To address both the hierarchical nature of taxonomic classification and the influence of crispening, we present a new BIIGLE workflow that makes use of a deep learning – based similarity sorting of image patches showing biota.

In the first step (detection) and before the taxonomic classification starts, the species of interest, or even generic objects that are different from the seafloor are detected and marked by a simple quick manual process, citizen scientists using the recently introduced BIIGLE.party tool, or a computational object detection. This is efficient and effective, because detecting without classification is a lot easier. In the second step (semi-automatic coarse classification), the similarity sorting is applied to quickly select groups of image patches showing objects with similar morphology, which are pre-classified on a coarse taxonomic level like phylum or class or based on morphological features. In the third step (fine-grained classification), BIIGLE's LARGO tool is used for each coarse group to display a grid of image patches of one group and to select and assign higher level taxonomy to selected subgroups. By incorporating the cognitive mechanism of contrast crispening and the hierarchical nature of taxonomic annotation, this workflow allows for more efficient and reproducible taxonomic classification, while also saving expert annotators time. To assist the second and third step, we will also present first results of the new BIIGLE AI label bot, that can assist in forming subgroups more easily.



Geospatial Machine Learning to Regionally Predict Benthic Habitats Presence/Absence

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Benthic habitats are foundations necessary for many marine ecosystems to thrive. Quantifying the spatial distribution of benthic habitats (*e.g.* hardgrounds, deep sea corals) is important for efforts centered around the blue economy initiative, particularly mitigating anthropogenic influence (*e.g.* pipeline construction, oil spills, dredging) on marine ecosystems. However, identifying locations of these benthic habitats is resource-intensive, as generally these habitats are identified either visually (*e.g.* ROV video) or through tedious manual interpretation of geophysical data (*e.g.* acoustic backscatter). One means to expedite this process is to utilize machine learning to delineate habitats utilizing large curated datasets already available to the scientific community. This would provide an *a priori* estimate and uncertainty on the presence and/or absence of a habitat. Further, this would provide the framework for future predictions to incorporate more quantitative variables such as type of habitat and/or metrics of biodiversity.

Here, we establish a proof of concept using a geospatial machine learning (GML) classifier to predict presence/absence of benthic habitats along the western continental shelf of Florida. We utilize and hyperparameterize several algorithms including Random Forest, k-Nearest Neighbor and Gradient Boosting. In this effort, collocated delineated observed benthic habitat data and multibeam data was used for validation of our predictive capabilities. We expand on previous efforts by investing new geospatial machine learning classifiers, inclusion of new regions of observed data, uncertainty analyses, a “where to sample next metric” and the addition of high-resolution environmental predictors. Our future focus includes the incorporation of new predictor datasets and the development of software that allows near-real-time habitat assessment as multibeam is acquired.



GeoHab Machine Learning Working Group: 2025 Competition and Results

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Over the past six months, the GeoHab Machine Learning Working Group (MLWG) organized and hosted its first ever data science competition. Participants were provided with a seafloor mapping dataset and were required to submit predictions from statistical models that describe the properties of the seafloor. The purpose of the competition is i) to promote machine learning education within the GeoHab community by sharing methods and expertise; ii) to work towards consensus on optimal modelling approaches for different benthic habitat mapping applications; and iii) to establish datasets that are useful for benchmarking statistical modelling methods within the field.

The competition format was designed to promote good modelling practices. It was hosted on Kaggle – the world's largest data science competition platform. We selected a partially blind competition design, whereby participants receive training data where response observations are known, and test data where they are hidden. Test data predictions are submitted to Kaggle, where the participant receives a “public” accuracy score on a random subset of the test data, which populates a public leaderboard. The final “private” score is not shown. This means the participant is responsible for training and validating their models without knowing the correct answers or the true accuracy of their predictions – mimicking what researchers must do in practice when making map predictions.

The 2025 competition was a regression task. Participants were required to predict the mean grain size of seafloor sediment samples off the coast of Nova Scotia, Canada. Predictor variables included the water depth, minimum, maximum, and mean annual bottom current velocity, latitude and longitude coordinates, and an additional GIS raster for a coastal polygon layer. Participants submitted mean grain size predictions using a range of modelling approaches. The winner of the competition with the highest private score will be announced at the 2025 conference in Key West, Florida.



Enhancing Reef Mapping in the Baltic Sea Using AI-Based Boulder Detection to Define New Classification Strategies

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The advancements in AI-based boulder detection have created new possibilities for mapping geogenic reefs in the Baltic Sea. This is particularly significant, as sublittoral hard substrate habitats are included in all relevant European environmental directives and conventions. As AI-based detection approaches the accuracy of human interpretation in small-scale test areas, it opens up the opportunity to efficiently analyze larger regions. Only through AI can single boulder detection be effectively applied on a large scale.

For the German Baltic Exclusive Economic Zone, boulders were previously manually identified by experts within 50x50 m grid cells and, due to time constraints, categorized into three groups: none, 1–5 boulders, and more than 5 boulders per grid cell. These counts per raster were then used in a standardized procedure to delineate the reef outline. In contrast, AI-based methods identify individual boulders independently of grid cells. Preliminary findings have shown that with up to 200 AI-detected boulders per grid cell the largest category of 5 boulders is exceeded by far. Furthermore, 95% of boulders were classified in the 'more than 5 boulders' category.

This highlights the need for new classification categories based on the spatial distribution of boulders. The approach aims to identify natural boundaries for reef classification by integrating statistical analysis of boulder distribution with geological data. The study aims to refine classification frameworks to better reflect natural variations observed in the field, enhancing our understanding of both inter-reef variability and within-reef heterogeneity. These new classifications, based on individual boulder detection, should facilitate more efficient monitoring, which is essential for identifying measures necessary to maintain or restore good environmental status.



Integrating AI and Physics-Based Models for Enhanced Retrieval of Total Suspended Matter in Coastal Waters Using Landsat-9 Imagery

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Remotely mapping total suspended matter (TSM) is vital for characterizing coastal habitats, influencing water quality, light penetration, and marine life distribution. Remote sensing offers detailed spatial and temporal TSM information, facilitating ecosystem health analysis and informed conservation and management decisions. There are various methods for retrieving TSM from optical imagery based on either physics-based (radiative transfer) or machine learning approaches. This study bridges the gap between these two modelling approaches by utilizing a novel approach that synergistically integrates AI and physics to retrieve TSM concentration in coastal waters. The integrated approach first employs radiative transfer models to retrieve the TSM concentration for a subset of image pixels (a few hundred pixels selected at random). The inverted samples are then divided into training and validation sets. The training samples are used to train the AI component which is based on the neural network (NN). The trained NN is then employed to predict the TSM concentration for the entire water pixels including the validation set. The agreement between the integrated and physical model retrievals is then quantified in terms of the coefficient of determination (R^2) and root mean square difference (RMSD). This agreement analysis provides a feedback to the physical modelling as a strong agreement indicates appropriate physical model parameterization, while weak agreement highlights spectral ambiguity in radiative transfer inverse modeling, suggesting the need for parameter tuning. The new model retains the advantages of physical modelling such as adaptation of the model to site-specific bio-optical conditions and being applicable to any multi- and hyper-spectral data. On the other hand, the AI integration provides feedback to resolve ambiguity issues and significantly accelerates the inversion process.

The new AI-empowered physical inversion model is applied to the optically complex waters of San Francisco Bay to retrieve TSM concentration using Landsat-9 imagery. Validation against in-situ measurements demonstrates the model's effectiveness in capturing a broad range of TSM concentrations, up to 40 g/m^3 , with an R^2 value of 0.82 and an RMSE of 3.4 g/m^3 .



Application of Machine Learning Techniques on Underwater Imagery to Assist in Benthic Habitat Mapping

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The rapid expansion of the offshore wind, renewable energy and subsea cable industries necessitates accurate and efficient baseline characterization of seafloor habitats. Underwater imagery has been supplying seabed ground truth data for several decades, capturing surface substrate distributions and documenting the presence of flora and fauna. Regulators in the United States, such as BOEM and NMFS, have adapted CMECS (the Coastal and Marine Ecological Classification Standard) to promote consistency in defining substrates, biological characteristics, and benthic habitat delineations.

Integral deploys a Sediment Profile and Plan View Imaging system that captures high-resolution images of the seafloor. Thousands of paired sediment profile and plan view images have been collected across broad seafloor areas. To efficiently analyze these images, Integral has developed robust image analysis platforms (iSPI, SPY-View) that allow analysts to annotate features in support of benthic habitat mapping. These annotations are stored in an organized data structure, serving as training sets for supervised learning and the development of Convolutional Neural Networks (CNNs).

Recent advances in image detection and machine learning have significantly enhanced the efficiency and robustness of data extraction from underwater imagery. By leveraging supervised automation and neural networks, iSPI and SPY-View can rapidly annotate features of interest and automate CMECS designations in surveyed areas. Along with supplemental data, such as physical sediment samples, the image-based data can be used to ground truth interpretations from acoustic survey classifications. Supervised automation analysis of underwater imagery ensures consistent measurements and CMECS designations and significantly expedites the processing time spent on each image pair.

These technological advancements not only improve the accuracy and consistency of habitat characterization, but they also open the door to real-time, on the water, adaptive survey planning for offshore infrastructure projects. Furthermore, the applications of these technological advancements extend beyond offshore wind, benefiting marine engineering, archaeological investigations, and other environmental monitoring studies.



High-Resolution Mapping of Benthic Habitats in Apollo Marine Park Using Convolutional Neural Networks

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Marine habitat maps are essential tools for marine spatial planning, providing crucial information for decision-making in conservation and resource management. Accurate classification of benthic habitats, especially in complex marine environments, supports their sustainable use and identifies key areas for protection. While many machine learning tools are already in the marine spatial ecologist's arsenal, few have ventured into the deep learning space. Convolutional neural networks (CNNs), powerful deep-learning algorithms, have shown promise for advancing habitat classification tasks and mapping complex marine environments.

In this study, we explore the use of CNNs to create high-resolution habitat maps for the Apollo Marine Park, Victoria, Australia. Using bathymetric, multibeam backscatter, and environmental datasets, the CNN was trained to classify three distinct habitat types: high-energy circalittoral rock with seabed-covering sponges, low complexity circalittoral rock with non-crowded erect sponges, and infralittoral sand and shell mixes in waters ranging from 50 m-100 m depth.

The CNN achieved an overall classification accuracy of 67.32%, with precision, recall, and F1-scores varying across habitat types (0.54-0.77). The highest performance was observed for the infralittoral sand and shell mixes class (0.79), while the model faced challenges in accurately classifying areas with habitat transitions or overlaps. Uncertainty mapping revealed regions of higher model uncertainty, pointing to areas requiring further refinement or validation. These areas of uncertainty were primarily found in transition zones and over habitat types that share similar acoustic qualities, such as those with overlapping backscatter signatures or subtle textural differences.

When compared to traditional machine learning methods, the CNN demonstrated advantages in automatically extracting hierarchical features from raw spatial data, but their limitations in environments with transitional habitats were evident. To address these challenges, future work will explore marine areas that house habitats with more defined boundaries and incorporate additional environmental variables. Additionally, CNNs hold great promise for classifying optical datasets, such as additional multibeam backscatter derivative layers (*e.g.*, angular response, water column) and imagery captured by drones. This study highlights the potential of CNNs for marine habitat mapping, while also identifying avenues for further refinement to enhance their utility in complex marine spatial planning tasks.



**New Approaches & Technologies – New Technologies for
New Applications**



Am I Where I think I am? Determining Error in Positioning in Uncrewed Imaging Systems for Ground Truthing Seabed Habitat Maps

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Predictive seabed habitat models are being developed at broader extents and finer resolution to support offshore ocean planning, ecosystem management and restoration. Many modalities exist for capturing ground validation images to support habitat mapping and seabed characterization. Uncrewed underwater vehicles (UUVs) are becoming increasingly accessible to habitat mapping practitioners and with these UUVs come increasingly precise inertial navigation systems (INS) and other tools, like doppler velocity loggers (DVL), and acoustic tracking systems for determining vehicle location. Each of these navigation solutions has a theoretical bias and drift associated. Empirical measures of positioning uncertainty would provide guidance on determining the suitable resolution of models and resulting habitat maps.

This work presents two case studies from two different classes of UUVs with imaging payloads. A micro UUV equipped with a doppler velocity log (DVL), and long base line (LBL) repositioning system was evaluated in shallow, structured habitats. During an individual dive the UUV gets an LBL navigation string every 12 seconds and the onboard Kalman filter resets the vehicle's location based on the new information (repositioning). This case study looks at survey points between two identical UUVs. Navigation repositioning indicates bias between 0.5m - 8m. Absolute error in positioning images on the seabed are also compared against features extracted from remotely sensed data from multibeam derived elevation models.

A second case study used a 600m rated Remus UUV aided by DVL-INS. Without the aid of LBL navigation jumps to provide measurable metrics in the navigation, photogrammetric analysis was completed on the imagery from 3 dives. Antiparallel lines of geotagged images were input into photogrammetry software. The resulting photogrammetric alignment was assessed both through intra-line error as well as a comparison to a bathymetry surface. Preliminary results indicate a range of error between 0.5m - 1.5m from antiparallel lines in a photogrammetric model. Comparisons of photogrammetric digital elevation models to bathymetry show between 3m - 6m of geographic offset.

These results will inform predictive seabed model acceptable resolution. Next steps in this process are to develop a toolset to further automate future assessments of positional uncertainty.



The MBARI Low Altitude Survey System for 1 cm Scale Seafloor Surveys in the Deep Ocean

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The Monterey Bay Aquarium Research Institute (MBARI) has developed a Low Altitude Survey System (LASS) to conduct 1 cm scale seafloor surveys of complex terrain in the deep ocean. The LASS is integrated with a Remotely Operated Vehicle (ROV), which is operated at a 3 m standoff to obtain 5 cm lateral resolution bathymetry using a multibeam sonar, 1 cm resolution bathymetry using a wide-swath lidar laser scanner, and 2 mm/pixel resolution color photography using stereo still cameras illuminated by strobes. Surveys are typically conducted with 3 m line spacing and 0.2 m/s speed, and executed autonomously by the ROV. The instrument frame actively rotates to keep the sensors oriented normal to the seafloor. The strobe lights, mounted on swing-arms on either side of the ROV, similarly rotate to face the seafloor. Areas of 120 m x 120 m can be covered in about 8 hours. Example surveys are presented of deep-sea soft coral and sponge communities from Sur Ridge, offshore Central California. An advantage of combining optical and acoustic remote sensing is that the lidar and cameras map soft animals while the multibeam sonar maps the solid seafloor. Initial efforts to automatically annotate benthic animals in these two habitats using semi-supervised machine learning are promising. The long-term goal is to field these sensors from a hover-capable autonomous platform rather than ROVs, enabling efficient 1 cm scale seafloor surveys in the deep ocean.



Estimating Saline Lake Chlorophyll-a, Total Suspended Solids and Colored Dissolved Organic Matter via Electro-optical Remote Sensing

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Aquatic remote sensing data is a vital means to understand and measure water resources, water quality, ecosystem health and productivity, as well as forecast sustainability. The electro-optical properties of saline inland lakes are unique when compared to previously electro-optically characterized freshwater, estuarine and oceanic waters. These unique saline lake hydrologic electro-optical properties require new remote sensing calibration, validation and development activities in order to conduct and test provision of aquatic algorithm updates.

In this presentation, we convey progress and updates on saline lake electro-optical remote sensing algorithm activities. Several Western US saline lake ecosystems are intensively studied via several multiple decades of coincident in situ and remote sensing data in order to test chlorophyll-a, total suspended solids and colored dissolved organic matter aquatic remote sensing estimation and retrieval algorithms.

Due to their daily temporal and multi-decadal Earth observation records, the NASA Moderate Resolution Imaging Spectroradiometer (MODIS) and the NASA/NOAA Visible Infrared Imaging Radiometer Suite (VIIRS) missions were utilized. Aquatic algorithm development is useful to these named Earth observation missions as well as a plethora of other current and forthcoming remote sensing missions. Further, overlapping, highly-calibrated and understood satellite missions provide a useful secondary source of validation.

Overall, we found that the preliminary saline aquatic remote sensing algorithm testing proves extremely promising towards capturing important remotely sensed water quality variable records. One area with very distinct saline and biologic conditions was highlighted and recommended for further in situ data collection and algorithm testing. During project activities, the new saline aquatic algorithm characterizations were found to be important and applicable to a wide variety of high-salinity terrestrial and planetary analog water bodies under investigation. Development of remote sensing monitoring techniques was also identified as being key to understanding lake trophic status and biological productivity, especially as widespread routine in situ data collection remains sparse.



Fine-Scale Mapping of Lava Flows Along the Galapagos Spreading Center using Interferometric Synthetic Aperture Sonar

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The construction of the oceanic crust at mid-ocean ridges is dominantly achieved through the emplacement of lava flows at the seafloor, providing insights into crustal formation processes, mantle dynamics, hydrothermal circulation patterns, biological habitats, and oceanographic processes. Lava flow morphologies are primarily controlled by effusion rate, seafloor rugosity and slope, eruption temperature, and composition, with morphologies ranging from sheet flows (highest effusion rates) to pillows (lowest effusion rates). Tectonic processes, including faulting and fissuring, can modify primary flow morphologies, and, along with volcanic features, may act as barriers to lava propagation. Identification and classification of volcano-tectonic morphologies typically rely on high-resolution, narrow field of-view optical techniques (mm to cm resolution, <50 m swath) from near-bottom platforms (*e.g.*, remotely operated vehicles – ROVs) and/or lower-resolution, wide area acoustic techniques (5-100 m resolution, >100 m swath) from surface vessels, autonomous underwater vehicles, and/or ROVs. The recent development of interferometric synthetic aperture sonar (InSAS), a technology providing high-resolution acoustic imagery and bathymetry (3 and 25 cm/pixel, respectively) over a large swath (~300 m) enables the identification and characterization of lava flows over wide areas of seafloor but at resolutions approaching those from visual or optical techniques.

Here, we present preliminary results from on- and off-axis mapping of volcano-tectonic seafloor morphologies at ~2 km depth along the Galapagos Spreading Center (GSC) using InSAS data validated by video imagery. Data were collected during the FKt231024 expedition aboard Schmidt Ocean Institute's R/V *Falkor (too)* using Kraken Robotics' *MINSAS60* system mounted on the *SuBastian* ROV. We report lava flow orientations, extents, and morphologies. We find that lava flows are predominantly oriented parallel to the axis, indicating a primary tectonic control on lava flow and crustal accretion. These results will contribute to reconstructing the eruptive and tectonic history of this segment of the GSC, provide a basis for future habitat maps, and demonstrate the potential of InSAS for integrated volcanic and tectonic studies at mid-ocean ridges.



High-Resolution Habitat Mapping using Multi-Aperture Sonar (MAS) in Support of Seagrass Restoration in the Plymouth MPA

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This paper describes the use of a novel high-resolution sonar for mapping subtidal seagrass (*Zostera Marina*) in Jennycliff Bay in the Plymouth Sound Marine Protected Area (MPA). This work was done to support seagrass restoration efforts by the non-profit organisation the Ocean Conservation Trust funded by the LIFE Recreation ReMEDIES project. The sonar survey aimed to determine the as-laid location of deployed seagrass mats and seed bags within the restoration area and a secondary aim was to accurately record the seabed types in detail to place the restoration work in context.

The survey was done using a Wavefront Solstice Multi-Aperture Sonar (MAS), which uses sound signals to produce very high-quality images of the seabed. The sonar is lightweight, has a waterproof housing and consumes very little power so can be mounted on a small boat, a towfish or a UUV. The Wavefront Solstice family of sonars are built on unique Multi-Aperture Sonar (MAS) technology and are designed to fill the gap between standard side scan sonars which are simple in design but give low image resolution and Synthetic Aperture Sonar (SAS) which provide detailed images but is expensive, very complex and produces very large amounts of data. Solstice was used for this application because it produces very high-resolution images, recording details on the seabed as small as 1.5cm x 3.75cm (0.6in x 1.5in) in a swath 200m wide using a proprietary technique to focus every pixel in the image. The sonar had several advantages over conventional side scan and single beam sonar methods for mapping seagrass. The sonar was used in water depths as shallow as 4m (13ft) and could image 100m to one side into shallower water and amongst foreshore reefs where the seagrass grows. The sonar provided wide-area images that were repeatable, georeferenced and high resolution at a maximum coverage rate of 1.6km² (160 Ha) per hour. The initial field trials were successful, so the UK government agency Natural England commissioned a sonar survey of the restoration area. The sonar successfully identified the seagrass restoration mats on the seabed and identified the area where seed bags had been deployed. Jennycliff Bay was also mapped providing information about spatial variation of marine habitat types at large and small scales, clearly identifying areas of sediment, reef, kelp and seagrass. The sonar also detected previously unknown seagrass beds within Jennycliff Bay so demonstrated its usefulness for seagrass prospection and recorded the effects of mooring scours and large marine litter on the seagrass. Repeat surveys are planned for 2025 so that any changes in the seagrass can be recorded, and the sonar data has been used to create detailed habitat suitability maps to aid in planning further restoration work.



Cetacean Aerial Survey Project

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Cetacean species are notoriously difficult to study in the wild because of their size, mobility, and lack of continuous visibility (Nowacek *et al.*, 2016). The use of unmanned aerial systems (UAS) has reduced these challenges and provides a stable, relatively quiet, and inexpensive platform that increases the ability of observation and sample collection for prolonged periods of time with minimal disturbance (Torres *et al.*, 2018). The goal of this study was to collect photogrammetry data using a DJI Phantom 3 quadcopter to calculate body condition scores (BCS). The other goal of this study was to collect blow samples using the UAS to analyze various parameters of bottlenose dolphin (*Tursiops truncatus*) populations in the Florida Bay and to establish non-invasive sampling techniques to achieve these results. Photogrammetry data were first taken at various altitudes ranging from 3m to 10m from the resident population of bottlenose dolphins at Dolphin Research Center to standardize the UAS methodologies used and establish baseline BCS for healthy individuals. The BCS were calculated by collecting measurements (*e.g.*, total length, half girth (doubled)) from photos taken with the UAS using the software Morphometrix, and exporting these measurements to excel. Blow samples were collected using a petri dish that was swabbed and placed into a Zymo DNA/RNA shield for storage and processing. The sampling techniques and data collected in this study can be utilized to establish baseline BCS for bottlenose dolphins in the Florida Bay and improve conservation and ecological studies in an effort to minimize disturbance and potential detrimental effects on wild dolphins.



Scientific Multibeam Echo Sounders for 3-D Habitat Mapping

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Multibeam echo sounders (MBES), specifically bathymetric MBES, excel at providing high-resolution bathymetry and backscatter data capable of classifying habitat. MBES provide water column data for qualitative work, but they are primarily designed for and excel at seafloor measurements. Split-beam echo sounders, which can be calibrated due to their ability to measure the position of a target in the beam, have traditionally been used to quantify targets in the water column. Those targets consist of physical targets, such as turbulence, oil droplets, gas bubbles, sediment, and biological targets from plankton to apex predators such as tuna. Traditionally, split-beam echo sounders work as single beams, focusing on a narrow section of the water column and providing a single vector of backscatter values, compared with MBES water column data where each beam is a vector of data. To fully map habitats at large scale requires a scientific MBES – a combination of MBES for coverage and split-beam echo sounder technology for quantitative seafloor and water column backscatter. Scientific MBES are not limited to water column measurements; they combine calibrated seafloor backscatter measurements with bathymetry. The key features of scientific MBES is that they combine flexibility and configurability with quantitative measurements of the seafloor and water column. Calibrated backscatter from scientific MBES provides data that can be more efficiently used for 3-dimensional habitat mapping (*i.e.*, water column plus seafloor). Here, we propose an overview of the uses of such a system that can greatly improve the efficiency of habitat and fisheries surveys by reducing uncertainties and providing other 3-D data including school morphology and angle and frequency scattering dependencies. Knowledge of these dependencies improves acoustic estimates of biomass. The pros and cons of scientific MBES are analyzed, and ideal use cases for scientific MBES vs bathymetric MBES are explored.



Exploiting USVs for Water Quality Analysis

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Ocean and coastal water quality monitoring has become more important in recent decades as onshore anthropogenic activities contribute more pollutants to surface water runoff that flows to offshore systems and disaster prevention activities such extended openings of the Bonne Carre spillway insert nutrient rich freshwater into offshore systems. Many coastal and estuary systems are major sources of income and natural resources for human populations. The Mississippi Sound (MSS) is one such system in the Northern Gulf of Mexico (GOM) that is bound by the mainland coast of Mississippi to the north, Mobile Bay to the east, Lake Borgne (Louisiana) to the west, and a series of barrier islands (Cat, Ship, Horn, Petit Bois, and Dauphin Islands) to the south. The barrier islands present an obstacle to water exchange between the MSS and the GOM suggesting prolonged weather or anthropogenic events (*i.e.*, hurricanes or spillway openings, respectively) can greatly impact the biota and reliant ecological processes of the MSS due to reduced water exchange with the GOM. Water quality of the MSS is dynamic and can change seasonally, thus, a baseline understanding of water quality and algal density across the MSS can aid resource managers by providing a better understanding of freshwater particulate and solute impacts to the MSS over time. Algae is typically measured via pigments like chlorophyll A (universal algal pigment), phycoerythrin (saltwater cyanobacteria), or phycocyanin (freshwater cyanobacteria) which can contribute to water turbidity and therefore affect plant and fish growth. Water quality (DO, CDOM, Temperature, Turbidity, pH, and Salinity) and algal metrics were characterized spatially in the MSS. A generalized linear model was used to detect differences among transects. In general, all metrics were significantly impacted by proximity to the mainland coast and proximity to major freshwater inputs. Algal metrics were correlated more strongly with turbidity, CDOM, pH, and salinity than temperature or dissolved oxygen suggesting that these four metrics may have more influence over algal density than the others.

The purpose of this work was to simultaneously collect water quality (dissolved oxygen, turbidity, salinity, pH, conductivity, partial pressure of CO₂, CDOM, temperature) and algal data (Chlorophyll A, phycoerythrin, and phycocyanin) in real time with a USV for establishing a baseline of each across the MSS. Water quality and algal metrics were characterized spatio-temporally in the MSS via USV and validated with in-situ sampling with a CTD system from a manned vessel. Turbidity and algal concentrations were also correlated to spectral reflectance values in hyperspectral aerial images captured with an uncrewed aerial system (UAS). Sampling occurred along 500 m transects located every 3.2 km on groupings of adjacent north-south navigational paths between the mainland and the barrier islands. The survey team collected USV, manned vessel, and UAS data over a five day period. All three sensor platforms navigated the same GIS transects to ensure data collected overlapped spatially.



Autonomous Survey of the Gulf of Maine: Identifying Potential Deep-Sea Coral Habitats Using Saildrone Technology

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The Gulf of Maine, a biologically rich and ecologically significant region, is home to diverse marine life, including deep-sea corals that play a crucial role in maintaining marine biodiversity. However, the identification and mapping of these habitats have been challenging due to their remote locations and the vastness of the ocean. The recent autonomous survey conducted by Saildrone marks a significant advancement in marine exploration and conservation efforts, utilizing state-of-the-art uncrewed surface vehicle (USV) technology to identify potential deep-sea coral habitats in this critical area.

This project employed a pair of Saildrone Voyager USVs, equipped with NORBIT WINGHEAD i80s long-range multibeam echosounders, to survey an expansive area in the north-central Gulf of Maine. The mission aimed to gather high-resolution bathymetric and backscatter data with the goal of informing new species distribution models and filling important gaps in bathymetric coverage. The Saildrone USV, primarily powered by wind and solar energy, operated remotely covering 1500 nm²—focusing on the Jordan and Georges Basins, at depths up to 300 m—in an area that was previously difficult to access with traditional research vessels. The data has revealed a complex and varied underwater landscape, reflecting its glacial history and dynamic oceanographic processes.

In addition to bathymetric data, backscatter, temperature, salinity, and depth profiles, which are essential for understanding the habitat preferences of these corals, were also collected. This presentation will discuss the methodologies employed in the survey, including the deployment and navigation of the Saildrone USV, data acquisition techniques, and the integration of acoustic and environmental sensors. The use of autonomous technology not only enhanced the efficiency and scope of the survey but also minimized the environmental impact and risk to personnel typically associated with manned missions.

Heather Coleman, a researcher with the NOAA Fisheries Office of Habitat Conservation's Deep Sea Coral Research and Technology Program, whom this mission supported, said of the work: "The Saildrone Voyagers are filling in a substantial gap in seafloor data in the Gulf of Maine. NOAA and partners are very interested in better understanding habitats in the region that may support fish production. These high-resolution seafloor maps will inform future surveying and modeling efforts, as well as aid in the New England Fishery Management Council (NEFMC)'s fishery management decisions."



Underwater Robots and AI: Habitat Mapping for the Next Generation Ocean Planning, Ecosystem Management and Restoration

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Maps of seabed habitats are a fundamental decision support tool for marine spatial planning and ocean ecosystem management. Decision-makers and stakeholders are requiring maps at broader extent, finer resolution, and richer detail. We have reached the capacity to characterize and groundtruth the seabed using point samples such as drop cameras and even remotely operated vehicles (ROVs) and human annotations. This presentation will showcase how NOAA National Centers for Coastal Ocean Science is using autonomous underwater vehicles (AUVs) to rapidly fill gaps in remote sensing and direct observations of the seabed. Sensors recently made available from military and industry are providing unprecedented resolution in imagery and the ability to characterize seabed geoforms and biological communities at broad spatial extents. But these sensors have increased the velocity in data acquisition, creating new bottlenecks. Cloud computing and artificial intelligence are being operationalized and increasing the through-put of data into interpretations of the seabed characteristics. The acceleration of our programmatic approach to habitat mapping and modeling is ensuring timely delivery of decision-ready maps for the next generation ocean planning, ecosystem management and restoration.



Participatory Mapping, Citizen Science & Outreach



Strategies and Activities to Promote Mapping Education and Outreach to Youth Audiences in Florida

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The University of Florida's School of Forest, Fisheries, and Geomatics Sciences has recently developed a Geomatics Extension program designed to reinforce workforce development throughout the state. One of the goals of this program is to provide education and outreach to youth audiences, promoting knowledge of both mapping principles and careers. The placement of the program within the Geomatics program and within the structure of the co-operative extension service provides a unique opportunity to integrate the departmental subject matter expertise with the infrastructure of extension through 4-H, a robust, nationwide youth development program that has a presence in every county of the state run by a 4-H County Extension Agent.

Feedback from stakeholders in the surveying and mapping industry has indicated both the need to reach youth at a younger age to create a pipeline of future employees to the profession and also the need for ready-to-use curriculum and activities to facilitate easy integration into existing youth education channels. By working with 4-H to create ready-to-use materials that align with educational standards, the cost in time and effort of planning lessons can be reduced for the teachers and volunteers. The network of 4-H professionals statewide can be used to promote these activities to agents in every county, effectively multiplying the efforts of the department's subject matter experts. These curriculum and activities can further be distributed through the department and 4-H's digital resource database for use by industry professionals looking for ways to engage youth in their own communities.

Curriculum development is ongoing, with lessons being added at the request of engaged 4-H agents, to build series of sequential lessons from initial lessons, and to include 4-H summer camp activities that may have unique spatial settings and logistical needs. Curriculum is focused on matching educational standards of learning for future parallel use in classrooms, teaching basics of map use, and to integrate hands-on elements to further engage youth. Topics include reading maps, map elements, creating maps, GIS analysis of habitat suitability, and map reading and data collection in an outdoor environment.



Braiding Indigenous Oral Histories and Habitat Mapping to Understand Urchin Barrens in Southern New South Wales, Australia

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The sea urchin *Centrostephanus rodgersii* is a native sea urchin to New South Wales (NSW), Australia. *C. rodgersii* diet mainly consists of macroalgae, forming urchin barrens along the southeastern coast that are characterised by little or no kelp cover. Due to the proliferation of *C. rodgersii* stakeholders have been divided, including Indigenous Traditional Owners and scientists, as to whether their current densities are naturally occurring, the result of mismanagement, or a result of warming waters. Studies have typically neglected Traditional Owners' perspectives on urchin barrens; their knowledge could provide crucial insight to the spatiotemporal dynamics of *C. rodgersii*, extending the current timeline which western science has provided.

This study utilises western science habitat mapping and Traditional Knowledge to improve current understandings of the urchin barren dynamics in NSW. Remote sensing techniques using a remotely piloted aircraft mounted LiDAR sensor (Zenmuse L1) and multispectral sensor with red-edge and near infrared bands (Micasense) were developed and implemented to quantify macroalgae dense areas and urchin barren dynamics. Yarning circles were the approach used to incorporate Traditional Knowledges. Yarning circles have been historically used by Indigenous Traditional Owners to share ideas and stories between a group of people; these yarning circles aim to identify how or if urchin barrens have impacted local Indigenous communities. Yarning circles are held with local Traditional Owners; a space for them to lead discussions and openly share their perspectives on a given topic. Preliminary findings from yarning circles indicate that Traditional Owners perceive urchin barrens as hindering their cultural practices. They have identified several potential factors contributing to the urchin's proliferation, including overfishing and climate change. Marine Protected Areas were also a key topic raised, with some groups identifying them as preventing cultural practices, and others seeing MPAs improving overall biodiversity.

'Braiding' is the final approach used in this study, which brings together western scientific methodologies and yarning circle discussions, identifying where the approaches align and diverge. By synthesising the overall findings, this approach demonstrates a new framework for valuing different knowledges which could be utilised by researchers who want to include Traditional Knowledge within their research. Braiding in this study has shown there are commonalities between western scientific literature and the findings of the yarning circles, particularly relating to the decline of key cultural species. Drop cameras will be used to validate both the accounts from Traditional Owners and habitat mapping. Discrepancies between the LiDAR and Multispectral



imagery will be points of interest in underwater validation, as well as the possible sites mentioned in yarning circles.



Where Are the Gaps? An Analysis of Global Seafloor Mapping Effort

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Oceans' role in the biosphere is fundamental. They have crucial environmental and socio-economic controls on achieving sustainable development of human society. Water depth and seabed morphology influence environmental factors that govern species distribution patterns and productivity in the ocean. They are also critical to regulate underwater resource exploration and extraction, marine spatial planning, and marine ecosystem management. From this perspective, seafloor mapping is vital to understand the geology, biology, oceanography, and the dynamics of marine habitats.

Despite the long history of seafloor mapping and variety of available mapping instruments and technologies, only one quarter of the global seafloor has been comprehensively mapped, leaving vast areas uncharted. In addition, progress in seafloor mapping coverage is uneven across the world's ocean due to regional differences in accessibility, technical challenges, and resource availability. In this study, we used datasets from the General Bathymetric Chart of the Oceans (GEBCO) to quantitatively describe and evaluate the global seafloor mapping effort in the past six years, since 2019, by comparing progress across different ocean basins and seas, Exclusive Economic Zones (EEZs), areas beyond national jurisdiction (ABNJ) at different depth zones.

The North Atlantic (NAO) and North Pacific (NPO) oceans have the highest mapping coverage, with over a third of each ocean mapped by the end of 2024. The Southern Ocean (SO), South China Sea & East Asian Seas (SCS&EAS), South Pacific Ocean (SPO), and Indian Ocean (IO) each approach 30% of coverage. Across different depth zones, approximately one-quarter of shallow areas (0-200 m) and the abyssal zone (3000-6000 m) have been mapped, comprising 7% and 74.5% of global seafloor area, respectively. Nearly 40% of seafloor in the upper (200-1000 m) and lower (1000-3000 m) bathyal zones has been mapped, corresponding to 4.3% and 12.9% of global seafloor area. The hadal zone (>6000 m) has the highest mapping coverage, albeit accounting for only 1.0% of the global seafloor. Mapping progress is also strongly influenced by EEZ size, economic status, and the presence of offshore resources.

This study reveals the uneven mapping efforts worldwide and suggests that more focus should be given to the two polar oceans, IO, and Southern Hemisphere, as well as the EEZs of African and Asian states. Considering the ~3.2% of increase in mapping coverage since 2019, we predict that the global seafloor could be mapped in 20 years. Analysis of the seafloor mapping by depth zones of ocean basins, EEZs, and ABNJ reveals critical gaps in coverage. Identifying these gaps helps prioritize future areas of exploration for the Seabed 2030 initiative, ensuring a more equitable and strategic allocation of mapping resources.



Polar & Sub-Polar Environments



Mapping Norway's Seamounts: Top Down and Bottom Up through MAREANO

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Seamounts are a prime example of an ecologically relevant landform. They are internationally recognized under OSPAR as a threatened and/or declining habitat, yet estimates of their distribution are not yet adequately reported in databases used for ocean management and MPA design. Whilst the benthic communities and substrates associated with seamounts require *in situ* observations their distribution and extent can be determined from bathymetry data. Here we report on work conducted by the Geological Survey of Norway, through the MAREANO seabed mapping programme to map the distribution of seamounts, and related topographic features of comparable size, in Norwegian waters. We employ a combination of semi-automatic methods to both detect and characterize peaks and associated areas of elevated terrain using GEBCO bathymetry, which incorporates MAREANO multibeam data. The resulting broad-scale map includes not only seamounts (over 1000 m high) but also lower knolls and mounds as well as many ridges, some of which are also over 1000 m high. These occur either as isolated features on the abyssal plain or as part of complex terrain, particularly near the Mid-Atlantic Ridge. Evaluation of the bathymetry source data shows that close to half of the detected features are incompletely mapped with direct measurements (multibeam bathymetry etc.). We examine the technical and user implications of this and show how our results may help prioritise areas for future data acquisition that will facilitate better knowledge-based management.

Finally, we look in more detail at the mapped seamounts and other elevated terrain features within areas to be studied by *in situ* video and sampling surveys by MAREANO in 2025. We show how the results will be incorporated into survey planning and how follow up studies will further characterize morphology, geomorphology, seabed sediments and habitats within detailed survey areas as part of MAREANO's ecosystem-based mapping of the deep Norwegian Sea.



Hidden Landscapes: Unveiling Seafloor Habitats and Morphology of East Antarctica's Sabrina Coast

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The Aurora Subglacial Basin, East Antarctica (Sabrina Coast), is a climatically sensitive catchment that has been proposed as a Marine Protected Area. The geomorphology and sedimentary records of ice retreat on the continental shelf have implications for regional benthic marine habitats. This study emphasizes the use of backscatter intensity data to analyze seabed features and their impact on benthic habitats along the Sabrina Coast. Multibeam data collected aboard *RV/IB Nathaniel B. Palmer* in 2014 have revealed detailed geomorphological features, including grounding zone wedges, glacial lineations, and transverse ridges. Backscatter intensity, combined with yoyo camera footage, has been instrumental in determining sediment types, enabling a detailed habitat map of the Sabrina Coast. Images from the survey indicate that benthic fauna are distributed based on substrate and landform characteristics. Linking seafloor morphology, sediment types derived from backscatter, and benthic community composition, this work provides critical insight into the habitat features that support Antarctic shelf communities and their resilience to ongoing warming.



Evidence of Glacial Geomorphological Processes and Landforms in a Deep-Sea Environment, South Shetland Trough, Antarctica

Devin Harrison^{1,2*}, Heather Stewart^{1,2}, Jez Everest³ & Alan Jamieson²

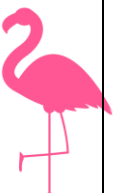
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The landform record produced by glacial processes during retreat from the last glacial maximum (LGM; *approx.* 18 – 22 thousand years ago) can provide an important record of processes and patterns associated to ice retreat. This historic archive can be used to provide constraint and supporting analogous information for present-day change. The extent of the LGM ice sheet in the Antarctic Peninsula around the region of the South Shetland Islands (SSI) is largely unconstrained and valuable glacial geomorphological evidence is likely preserved on the seafloor up to 2000 m water depth. This work presents a compilation of data from the 2015 EUROFLEETS and the 2024/25 INKFISH expeditions to the South Shetland Trough, which we believe is the first trough-wide study of the seafloor glacial geomorphology, and the recent glacial history of the SST. The SST is a subduction trench that is situated ~50 km northwest of the SSI at water depths of 800 – 5200 m, and runs parallel to the island chain.

Data collected during the 2015 EUROFLEETS expedition includes: 3 gravity cores, high-resolution (100 m gridded resolution) MBES data, and ~600 km Topas sub-bottom profiles. The 2024/25 INKFISH expedition collected high-resolution (25 m gridded resolution) MBES data at multiple sites along the SST, a series of baited lander transects, and numerous 1 km long submersible transects.

The collected data reveals a complex network of downslope channels, gullies and canyon systems that are a product of sediment-rich flows emanating from the palaeo-ice-margin. The complexity, directionality and morphology of these systems vary along the trough suggesting varying fluxes of sediment and meltwater along the former ice-margin. Sub-bottom data shows evidence of grounding zone wedges and moraines that provide the first empirical constraints of the former ice-margin. Furthermore, in some locations sub-bottom profiles penetrated up to 150 ms below the seafloor and revealed packages of stacked debris flows that evidence a fluctuating ice-margin that was grounded to, and retreated from, the shelf break on several occasions. Information from the landers and submersible transects combined with core data provide insight into the pervasiveness of ice rafted debris (IRD) and dropstones in the region which signify mass calving events during the break-up of the LGM ice sheet. The data reveals that this is not only a process adjacent to the ice-margin as large amounts of IRD are identified to have been transported to the deepest reaches of the SST. The deposition and presence of IRD (ranging in size from gravel to boulders) is also significant for deep sea ecological communities as it provides habitat for deep sea life due to its blocky and angular morphology and its ability to increase the ruggedness of the seafloor.



Preliminary Results from an Updated Pan-Arctic Zoobenthic Biodiversity Inventory and the Way Forward to Identifying Hotspots of Blue Carbon

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Human-induced pressure and benthic biodiversity sampling effort have increased concurrently in the Arctic over the past decades, in part due to the rapidly retreating ice cover. In light of the increased production of biodiversity data, the high rate of large-scale changes to the environmental conditions and the increasing anthropogenic pressures, there is a need for a pan-Arctic update of currently available biodiversity data. To date, one major inventory of benthic invertebrate biodiversity in pan-Arctic shelf areas, two inventories of benthic biodiversity in the basins and one inventory of Russian Arctic Seas have been compiled. This study represents the first attempt at a pan-Arctic inventory of currently available biodiversity data for both basin and shelf environments and can contribute toward a more cohesive and complete view of the biodiversity in the Arctic Ocean. The inventory is currently being compiled and preliminary results are estimated to be ready at the time of the conference.

High latitude continental shelves have been identified as highly important to global carbon sequestration potential. As the anthropogenic pressure in the Arctic Ocean increases, activities such as bottom trawling and mining can however cause remobilization of the semi-permanent carbon stocks in the sediments and can disturb and damage the benthic communities, thus both immediately releasing carbon from the sediments and altering the conditions for future carbon sequestration. Without protection, carbon-rich marine sediments risk becoming a large source of metabolic carbon dioxide, which can have an impact both on the atmospheric level of carbon dioxide and on calcium carbonate preservation in marine sediments. Knowledge about the distribution of hotspots of carbon storage and sequestration potential is needed to identify areas with particularly high values for protection. Without knowledge about the distribution of carbon storage and sequestration hotspots, protection of marine habitats for their climate mitigation potential is likely to be overlooked in ocean conservation efforts.

In later stages of this study, I aim to identify present and potential future hotspots of zoobenthic carbon storage and sequestration potential on a pan-Arctic scale. The way forward goes via habitat mapping, functional groups, species distribution models, environmental controls and future predictions. In the latter part of my talk or poster, I discuss and problematize the available methodologies related to blue carbon.



Urban Seas Systems



Application of a Marine Habitat Map Based Digital Twin Simulation to Tidal Energy Harvesting Sitting and Monitoring

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Seeking clean, dependable alternative energy sources in the marine environment has increased a global scale demand for accurate bathymetric data, including interpretive substrate and benthic habitat maps. Floating and stanchion wind turbine farms, current turbines, and tidal energy apparatus installations are becoming more common and require maps that can be used to assess seafloor geotechnical conditions and habitats. While maps are desired, the ability to detect change and to monitor these energy sites is now being considered based on maps as historical data.

We report upon a developing methodology for assessing and monitoring marine benthic and pelagic habitats in the central Salish Urban Sea System applicable to detecting environmental and ecological change at tidal energy harvesting sites. With the use of maps, AI, and real-time data we constructed a digital twin simulation, which will be demonstrated to show how tidal turbines and other alternative energy harvesting devices can be monitored and controlled to reduce or eliminate adverse impacts on the environment and ecology. This simulation is an initial step in the design of a complex Salish Urban Sea System digital twin.



Identifying Chronic vs. Episodic Stressors on Managed Coastal Systems

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Managed environmental systems still contain critical habitats and are potentially less resilient to continued or multiple concurrent stressors causing habitat degradation in conditions that fall below traditional risk thresholds. Managed coastal and estuarine systems are common in the present-day USA due to coastal infrastructure development of the land and immediate marine environments. Thereby complicating environmental conservation, restoration, and management, particularly with acute impacts due to regional climate change.

Our objective was to determine the main stressors causing shoreline change and seagrass aerial extent losses within the St. Andrew Sound system surrounding Tyndall Air Force Base (TAFB), Florida. TAFB received Restoration and Environmental Protection Initiative (REPI) funding for the initial feasibility analysis of Nature Based Solutions (NBS) projects around the base for coastal and climate resiliency. The work focused on observed seagrass aerial extent, shoreline, and oyster reef recruitment losses following the direct impacts of Hurricane Michael in 2018. Initially, the losses were thought to be caused by the single storm event (episodic stressor) however, historical satellite imagery analysis determined the losses are primarily due to chronic anthropic stressors within the coastal estuarine system over the past ~50 years. We determined the main stressors by analyzing the St. Andrew Sound estuary system for coastal shoreline, seagrass aerial extent, and land-use change using CoastSat v3.0 (tidal corrections with beach slope estimate), seagrass extent using the vegetation index GreenNDVI (presence vs. absence), and NASA's EarthData datasets, respectively. These analyses were cross-referenced with known beach nourishment events to track the movement of the unconsolidated sediments across the sediment budget of the system compared to shoreline and seagrass extent changes.

The main anthropic stressors included land-use change due to residential development surrounding the estuary and coastline impacting the watershed characteristics combined with shoreline hardening (*e.g.* inlet stabilization, seawalls) and periodic coastal sediment nourishments with unconsolidated quartz sands. Land- and marine-use change, including recreational boating, Naval boating (Panama City Naval Sea Warfare Center), DoD infrastructure development (TAFB), and closure of one coastal inlet contributed to modifications of the watershed and marine sediment transport pathways resulting in reduced water quality of the shallow water benthic ecosystems. These chronic anthropic stressors need to be quantified and incorporated into current and future coastal resiliency projects at the watershed level for NBS success and improved habitat restoration.



Vulnerable Marine Habitats in Oslofjord, Norway

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The area around the Oslofjord, Norway, has the country's highest population density, making the Oslofjord a pressure area with several intersecting interests and activities. Over the recent years, the health of the fjord has been under scrutiny, prompting two projects to shed light on the challenges the fjord ecosystems are facing: "Healthy Oslofjord" (2018-2021) and "Healthy Oslofjord 2.0" (2022-2024).

The underwater topography of Oslofjorden is very varied; stretching from open coast to sheltered bays, the topography includes everything from steep cliffs to sandy and mud beaches, from shallow waters to deep-water plains. This allows for a high diversity of different habitats, including habitats considered vulnerable, such as sponge aggregations, coral reefs and sea pen fields. As part of the "Healthy Oslofjord 2.0" project, two cruises were conducted according to the Environment Agency's instructions, focusing on collecting data to map the presence of these vulnerable habitats.

We conducted 150 ROV surveys at various depths to increase the knowledgebase of the distribution of vulnerable habitats in the fjord. One vulnerable habitat that received particular focus, was the Tisler Reef – a *Desmophyllum pertusum* coral reef situated in the south-east part of the fjord, bordering to Sweden. We mapped the extent of the reef by combining ROV and autonomous underwater vessel (AUVs) surveys. A selection of the maps will be presented, including habitats subject to pressure from different human activities.

The "Healthy Oslofjord" (2018-2021) and "Healthy Oslofjord 2.0" (2022-2024) projects were multi-institutional partnerships with the overall aim to create a lasting environmental awareness and commitment to the Oslofjord, through teaching and communication, based on research, monitoring and environmental mapping.



Habitat Mapping for Offshore Wind Farms in Norway

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Offshore wind farms (OWF) are an important emerging industry in Norway, with an ambitious goal of assigning areas for production of 30 000 MW within 2040. The first contract for commercial offshore wind was won by the Belgian company Ventyr SN II AS, in the southern North Sea. The plan is to have a bottom-fixed wind farm, with a production capacity of 1500 MW. This project area was tendered by the authority based on a strategic impact assessment from 2012. Twenty areas with a total area of c. 54 000 km² were identified as technically suitable and with low conflicts in 2023. This is followed by strategic impact assessments in 2024-2025. The strategic impact assessment is performed in two stages. The first part was published in November 2024 and included assessment of three areas that were assessed with a view to tendering in 2025. The strategic impact assessment of the remaining seventeen areas is expected in June 2025. In 2022-2023 extensive geophysical investigations were done in two of the three areas that are relevant for tender in 2025, to find the best places for bottom-fixed and floating wind turbines. From 2023, the focus has switched from geophysical investigations to environmental investigations in the initial phase of mapping. Identifying areas with potentially vulnerable habitats is one of the goals for this, avoiding spending big money on geophysical surveys later identified as no-go areas because of environmental values.

MAREANO has mapped hydrography, geology, biology and chemistry in the three areas, following a strategic impact assessment. Habitat maps have not been produced yet, but aggregated field observations of vulnerable marine ecosystems are available on www.mareano.no. Two of the areas (Vestavind B and Vestavind F) are in the Norwegian Trench with water depths between 180 to 300 metres. The deepest parts are dominated by muddy sediments, with extensive occurrences of seapen fields, and some occurrences of soft-bottom coral garden, and hard-bottom and soft-bottom sponge gardens. Locally pockmarks and authigenic carbonate crusts were found. Coarser sediments (sand, gravel, cobbles and boulders) and even exposed bedrock are found in the shallower parts. Soft-bottom sponge garden and particularly hard-bottom sponge gardens are common where coarse sediments or exposed bedrock occur. A few occurrences of gorgonian corals were also observed. The third area, Sørvest F, is totally different. Located on the southern North Sea Plateau with water depths between 50 to 70 metres, the sediments are coarser. Around 90% of the area is covered with sand (muddy to gravelly), with ripples. The fauna in this area was generally poor, dominated by the common starfish (*Asterias rubens*), sand sea star (*Astropecten irregularis*) and various flounder. Surrounding sandy areas provide important sand eel habitats. The remaining 10% is dominated by sand, gravel, cobbles and boulders, providing habitat for hard-bottom fauna such as Flustridae bryozoans and the dead man finger (*Alcyonium digitatum*), a common soft coral in shallow waters.



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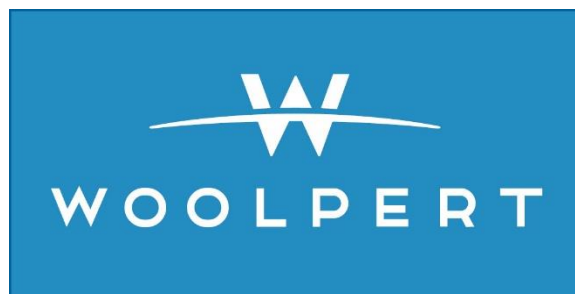
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Appendix A: List of Authors

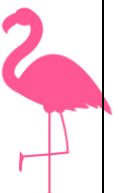
A

Agnesi, Sabrina
Aiello, Gemma
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Almeida Fontenele, Luiz Fernando
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Cetto, Paulo

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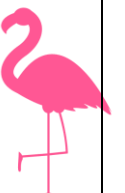
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Trembanis, Arthur



Troni, Giancarlo

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Kerwin, Declan	Seasats	United States
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Klipp, Emily	Dewberry	United States
Knapp, Anthony	Florida Fish and Wildlife Conservation Commission	United States



Knisley, Gerald	Hypack	United States
Koehler, Karl	Maine Department of Marine Resources	United States
Kolonay, Neal	Florida Department of Environmental Protection	United States
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Kotilainen, Aarno	Geological Survey of Finland	Finland
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Kozich, Robert	Woolpert	United States
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Moorhead, Robert	Mississippi State University/Northern Gulf Institute	United States
Mugge, Rachel	Naval Research Laboratory Stennis Space Center	United States
Ng, Daniel	Dalhousie University	Canada
Niyazi, Yakup	University of Western Australia	Australia
Olsen, Lasse	EIVA	Denmark
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Appendix C: GeoHab 2025 in Numbers (Post-Conference Summary)

- 179 submitted abstracts, of which 165 were published in these proceedings
- 85 oral presentations (3 keynote presentations, 38 long presentations, 44 short presentations)
- 177 registered participants, including 161 full registrations, 7 workshop-only registrations, and 9 guest registrations
- 29 students registered (1 undergraduate and 28 graduate students, including 10 Ron McDowell Awardees), representing 18% of delegates
- Machine Learning Working Group (MLWG) GeoHab 2025 challenge winners: Team Rock Bottom (Alexander Ilich & Klaus Huebert)
- 30 supporting partners (3 Gold sponsors, 4 silver sponsors, 16 bronze sponsors, 3 conference partners, 4 conference supporters)
- Over 30 lanyards reused from 2024, and tens from 2025 recycled for reuse in 2026
- More than \$200 was reinvested into marine research and education through the partnership with Waterlust
- \$639 donated to the SeaGrass Grow program of The Ocean Foundation (15% of delegates contributed to offsetting our collective carbon footprint)
- Limited food waste through collaboration with local restaurants and donations to a homeless shelter, limited plastic use through the purchase of a water cooler

Countries	Numbers of Delegates
United States	96 (including 7 workshop-only delegates)
Canada	17
United Kingdom	9
Italy	8
Norway	7
Australia & Finland	5 each
Republic of Korea	4
Belgium	3
Bermuda, Brazil, Ireland, Israel & New Zealand	2 each
Denmark, Greece, Iceland & Malta	1 each
Accompanying guest registrations	9
Total	177 delegates



Appendix D: 2025 Group Pictures

All conference photos are available at <https://www.flickr.com/photos/202888706@N03/albums>.











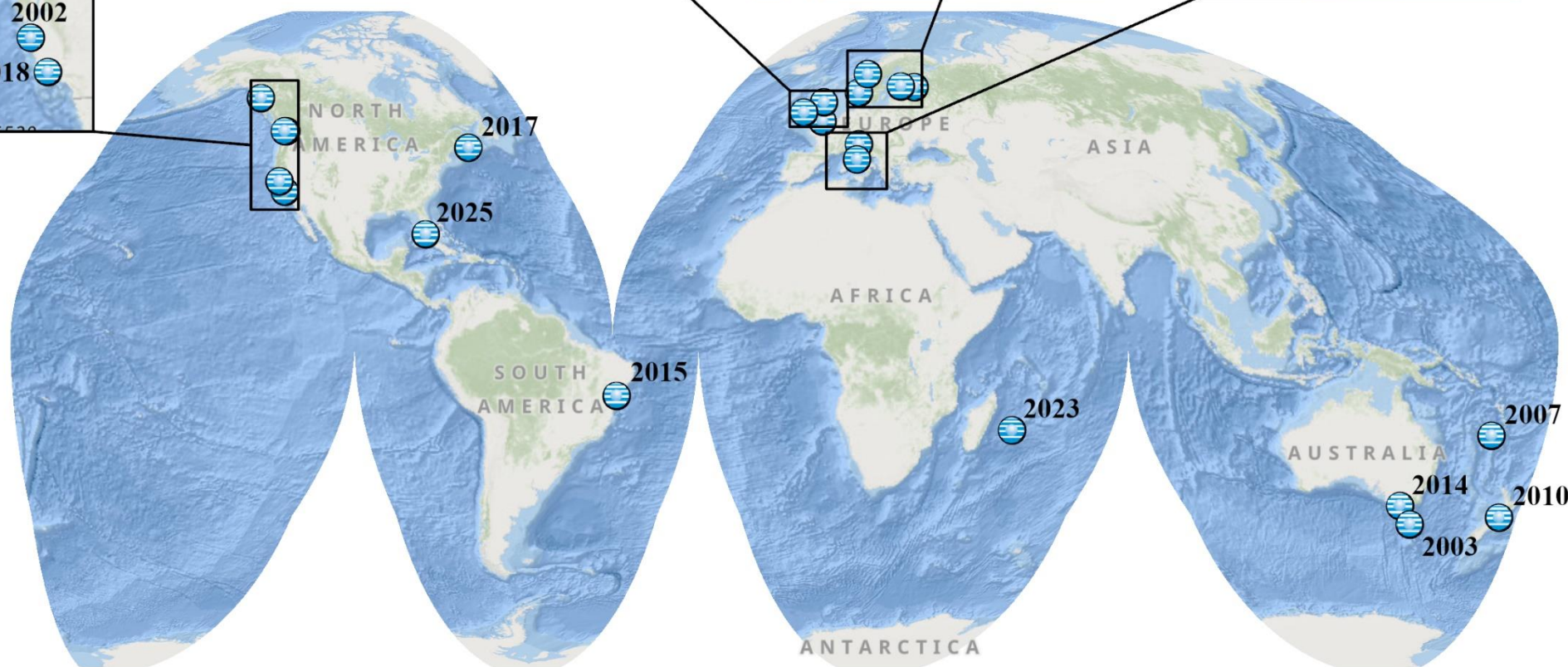
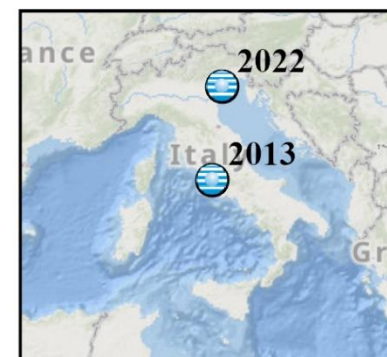
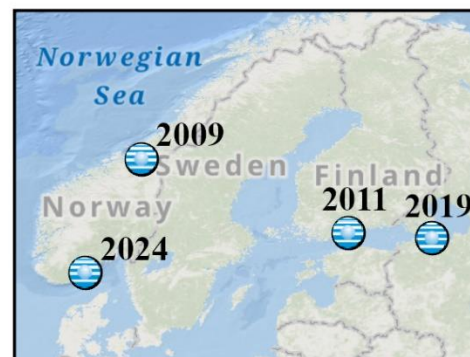
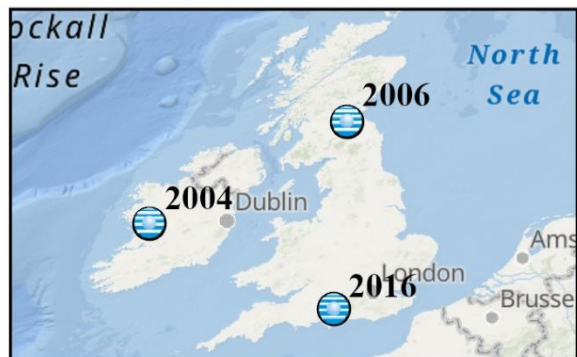
Appendix E: GeoHab Conferences 2002-2025

Year	Location	Host(s)	Affiliation(s)
2025	Key West, Florida, USA	Vincent Lecours	University of Florida & Université du Québec à Chicoutimi
2024	Arendal, Norway	Peter T. Harris Terje Thorsnes Margaret Dolan Lilja R. Bjarnadóttir	GRID-Arendal & University of Tasmania Geological Survey of Norway (NGU) Geological Survey of Norway (NGU) Geological Survey of Norway (NGU)
2023	Saint-Gilles-Les-Bains, La Réunion	Hayley C. Cawthra Rodolphe Devillers	Nelson Mandela University & Council for Geoscience Institut de recherche pour le développement
2022	Venice, Italy	Federica Foglini Fantina Madricardo	CNR-Institute of Marine Sciences
2021	Online, divided in three nodes (Americas, Asia/Pacific, Europe/Africa)	See organizing teams and affiliations here: https://geohab.org/geohab-2021/	
2020	No conference; postponed to 2022		
2019	St. Petersburg, Russia	Daria Ryabchuk Evgeny Petrov	A.P. Karpinsky Russian Geological Research Institute
2018	Santa Barbara, California, USA	Guy Cochran Donna Schroeder	United States Geological Survey Bureau of Ocean Energy Management
2017	Dartmouth, Nova Scotia, Canada	Craig J. Brown Brian J. Todd	Nova Scotia Community College Geological Survey of Canada
2016	Winchester, United Kingdom	Tim Le Bas Markus Diesing Heather Stewart Kerry Howell	National Oceanography Centre CEFAS British Geological Survey University of Plymouth
2015	Salvador, Bahia, Brazil	Alex Bastos Helenice Vital José Maria Dominguez Tereza Araújo	Federal University of Espirito Santo Federal University of Rio Grande do Norte Federal University of Bahia Federal University of Pernambuco
2014	Lorne, Victoria, Australia	Daniel Ierodiaconou Scott Nichol	Deakin University Geoscience Australia
2013	Rome, Italy	Andrea Fiorentino Silvana D'Angelo	Geological Survey of Italy (ISPRA)
2012	Orcas Island, Washington, USA	H. Gary Greene J. Vaughn Barrie	SeaDoc Society/Tombolo Geological Survey of Canada



2011	Helsinki, Finland	Aarno Kotilainen Anu Kaskela	Geological Survey of Finland (GTK)
2010	Wellington, New Zealand	Geoffroy Lamarche	National Institute of Water and Atmospheric Research (NIWA)
2009	Trondheim, Norway	Terje Thorsnes Kim Picard Margaret Dolan Pål Buhl-Mortensen Kari Nygaard Ingrid Bysveen	Geological Survey of Norway (NGU) Geological Survey of Norway (NGU) Geological Survey of Norway (NGU) Institute of Marine Research Institute for Water Research Directorate for Nature Management
2008	Sitka, Alaska, USA	Cleo Brylinski Tory O'Connell Jennifer Reynolds	Alaska Department of Fish and Game University of Alaska University of Alaska
2007	Nouméa, New Caledonia	Yves Lafoy	Direction de l'industrie, des mines et de l'énergie de Nouvelle-Calédonie
2006	Edinburgh, Scotland	Alan Stevenson Heather Stewart	British Geological Survey
2005	Sidney, British Columbia, Canada	J. Vaughn Barrie Kim Conway	Geological Survey of Canada
2004	Galway, Ireland	Anthony J. Grehan Colin Brown	National University of Ireland, Galway
2003	Hobart, Tasmania, Australia	Peter T. Harris Alan Butler	Geoscience Australia CSIRO Marine Laboratories
2002	Moss Landing, California, USA	H. Gary Greene Joe Bizzarro Isabelle Herbert	Moss Landing Marine Laboratories





Appendix F: Abstract Evaluation Process

Ahead of GeoHab 2025, all submitted abstracts were evaluated by at least two members of the international scientific committee. The reviewers were asked to follow the rubric below and provide a score between 0 and 3 for each of the four criteria: relevance to GeoHab, quality of the work, completeness, originality. Therefore, the maximum achievable score was 12.

Reviewers were also asked to make one of these recommendations based on their evaluation and what the authors requested: 1) Accept as 15-minute oral presentation, 2) Accept as 5-minute oral presentation, 3) Accept as poster presentation, 4) Reject (explain why). Similarly, reviewers had to make a recommendation of thematic session based on their assessment of the abstracts and the preferences of the authors.

Finally, all submitted abstracts were ranked based on their average total score. The available timeslots for oral presentations were assigned to the highest scoring abstracts that requested an oral presentation, until no more slots were available.

Rubric used by the international scientific committee to score submitted abstracts.

Criteria	Description	Rubric			
		Scores			
		3 points	2 points	1 point	0 point
Relevance to GeoHab	Is the abstract about habitat mapping?	Yes, it's about habitat mapping.	Well, it's only about mapping or only about habitat.	No, but it is about a closely-related topic that could be relevant to participants.	No, not at all.
Quality of the work	Scientific robustness.	The work that is presented is robust.	The work is good but has some flaws.	Some elements, such as the methodology, do not align with the stated objective(s) of the work.	The work has many flaws from a scientific standpoint.
Completeness	Are there results and a short discussion?	Yes, the abstract is complete with results and a discussion/conclusions.	Yes, there are results but little to no discussion/conclusions.	Yes, but the results are only preliminary.	No, there are no results.
Originality	Novelty and contribution to the field.	The work is innovative and significantly advances the field.	The work presents a new angle or builds on existing research in a meaningful way and offers valuable insights or new applications that are relevant to the field.	The work is on a familiar topic but contributes to the field.	The work does not offer new perspectives on the field.

Example of table that reviewers filled out for each abstract evaluated.

Abstract Info			Evaluation (score each criterion based on the rubric above - 0 to 3 points for each)					Recommendations		
Abstract	Lead author	Title	Relevance to GeoHab	Quality	Completeness	Originality	Total	Recommended talk type	Recommended session	Comments
1										
2										
...										
n										



Appendix G: About the 2025 GeoHab Logo

Our logo includes Florida icons: the American flamingo (*Phoenicopterus ruber*), also known as the Caribbean flamingo, and an ambiguous reptile that could either be an American alligator (*Alligator mississippiensis*) or an American crocodile (*Crocodylus acutus*), which are both present in Florida.

But did you know that flamingos are not that common in Florida? In fact, you are more likely to see them made of plastic on somebody's front lawn than in flesh wading in a pond. For a long time, the flamingo's status in Florida was debated. For some, they were deemed non-native as it was thought that flocks of flamingos in Florida were vagrants from the Bahamas and other Caribbean islands, sometimes blown into Florida by tropical storms and hurricanes. Now, it seems like the consensus is that flamingos were native to Florida before being overhunted in the 1800s for their feathers and food. Based on this, the Florida Fish and Wildlife Conservation Commission now considers them a native species, regardless of the origin of the individuals that can be seen today in the State.

If you want to see flamingos, you better come to GeoHab in the Florida Keys in 2025: according to The Nature Conservancy, your best bet to find flamingos in all of Florida is in the Keys in the Spring and Summer! If you're lucky, you might also see other great birds that wear shades of red or pink, such as roseate spoonbills, red knots, magnificent frigatebirds, and reddish egrets.

Alligators, on the other hand, are quite common. Emblem of the University of Florida, gators are found all across the State. There is a saying that says that if there is fresh water, chances are that there is an alligator. The Florida record for the longest alligator is more than 4.3 meters long and for the heaviest one, over 1,000 pounds. Gators can most often be seen basking in the sun by ponds or on golf courses, but are also occasionally seen crossing the road, in the middle of forests, or swimming rapidly after your boat. That said, do not let this prevent you from attending GeoHab in the Florida Keys, as serious injuries caused by alligators are rare in Florida, and there is very little fresh water in Key West.

And finally, crocodiles, a threatened species found in South Florida. Heavily hunted between 1930 and 1960, the American crocodiles' numbers have increased from less than 300 to more than 2,000 adults since 1975. They live in brackish or saltwater areas and are therefore found in the Florida Keys. They are relatively shy, so conflict with humans rarely occurs in Florida. When you visit Florida for GeoHab, I recommend you take some time to visit the Everglades National Park, where you might see the three icons from our logo!

Visit our conference website for pictures and resources to learn more about these species!

<https://geohab.org/2025-logo/>





GEOHAB

Marine Geological and Biological Habitat Mapping



Florida Keys, United States - 2025



www.GeoHab.org/KeyWest2025

