Research Ideas and Outcomes 11: e163815
doi: 10.3897/rio.11.e163815

Workshop Report

Expanding the scale and scope of the Marine Biodiversity Observation Network Pole to Pole of the Americas: Merging rocky intertidal biodiversity surveys with environmental DNA and plankton imaging applications

Gonzalo Bravo[‡], Gregorio Bigatti[‡,§], Mariana Lozada[‡], Luke R. Thompson[|], Juan P. Livore[‡], María M. Mendez[‡], Lorena P. Arribas[‡], Lino Bigatti[¶], Tyler Christian[#,¤], Erasmo C. Macaya[«], Edgardo Londoño-Cruz[»], Nicolas Moity[^,˅], Juan J. Cruz-Motta[¦], Augusto A. V. Flores[ʔ], Gabriela M. Vélez-Rubio[ʕ], Maria G. Palomo[¢], Cesar A. M. M. Cordeiro[ℓ], Franciane M. Pellizzari[ϑ], Maritza Cárdenas-Calle[P,₳], La Daana Kanhai[ƨ], Ivonne A. Vivar Linares[₣], Patricia Gil-Kodaka[₮], Linsey Martinez[₦], Pablo Sugliano[₭], Agostina B. Trigo[₭], Juan Zottola[₭], Dulce M. Blanco[₲], Matias Tricase[₲], Nadia Bravo[₲], Mariana Degrati[₹], Camila E. F. Tavano Formigo[₹], Frank Muller-Karger[₩], Enrique Montes[#,¤]

‡ Instituto de Biología de Organismos Marinos (IBIOMAR-CCT CONICET-CENPAT), Puerto Madryn, Argentina
§ Universidad Espíritu Santo, Samborondón, Ecuador
| Northern Gulf Institute, Mississippi State University, Starkville, United States of America
¶ Computer Science student, Universidad de Buenos Aires, Buenos Aires, Argentina
# Atlantic Oceanographic and Meteorological Laboratory, National Oceanic and Atmospheric Administration, Miami, United States of America
¤ Cooperative Institute for Marine and Atmospheric Studies, University of Miami, Miami, United States of America
« Laboratorio de Estudios Algales (ALGALAB), Departamento de Oceanografía, Universidad de Concepción, Concepción, Chile
» Grupo de Investigación en Ecosistemas Rocosos Intermareales y Submareales Someros (LITHOS). Departamento de Biología, Facultad de Ciencias Naturales y Exactas, Universidad del Valle, Cali, Colombia
^ Charles Darwin Research Station, Charles Darwin Foundation, Santa Cruz, Galápagos, Ecuador
˅ Department of Biological Sciences, University of New Hampshire, Durham, United States of America
¦ University of Puerto Rico, Department of Marine Sciences, Mayagüez, Puerto Rico
ʔ Center for Marine Biology, University of São Paulo, São Sebastião, SP, Brazil
ʕ Sección de Oceanografía y Ecología Marina. Instituto de Ciencias Ambientales, Facultad de Ciencias, Universidad de la República, Montevideo, Uruguay
¢ Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” (MACN, CONICET), Buenos Aires, Argentina
ℓ Laboratório de Ciências Ambientais, Universidade Estadual do Norte Fluminense (UENF), Campos dos Goytacazes, Rio de Janeiro, Brazil
ϑ Laboratório de Ficologia e Qualidade de Água Marinha (LAQUAMAR), Paraná State University (UNESPAR) campus Paranaguá, Comendador Correia Jr. Centro, Paranaguá, Paraná, Brazil
P Faculty of Chemical Engineering, University of Guayaquil, Guayaquil, Ecuador
₳ Fundacion Bioelite, Guayaquil, Ecuador
ƨ Department of Life Sciences, Faculty of Science and Technology, The University of the West Indies, St. Augustine, Trinidad and Tobago
₣ Universidad Nacional Agraria La Molina, Lima, Peru
₮ Facultad de Pesquería, Universidad Nacional Agraria La Molina, Lima, Peru
₦ Universidad Nacional Autónoma de Honduras, Tegucigalpa, Honduras

₭ Administración de Parques Nacionales (APN), CABA, Argentina
₲ Subsecretaría de Conservación y Áreas Protegidas, Chubut, Rawson, Argentina
₹ Centro Para el Estudio de Sistemas Marinos (CESIMAR-CCT-CONICET-CENPAT), Puerto Madryn, Argentina
₩ College of Marine Science, University of South Florida, St Petersburg, United States of America

Corresponding author: Gonzalo Bravo (gonzalobravoargentina@gmail.com), Enrique Montes (enrique.montes@noaa.gov)

Reviewable v 1

Received: 01 Jul 2025 | Published: 18 Jul 2025

Citation: Bravo G, Bigatti G, Lozada M, Thompson LR, Livore JP, Mendez MM, Arribas LP, Bigatti L, Christian T, Macaya EC, Londoño-Cruz E, Moity N, Cruz-Motta JJ, Flores AAV, Vélez-Rubio GM, Palomo MG, Cordeiro CAMM, Pellizzari FM, Cárdenas-Calle M, Kanhai LD, Vivar Linares IA, Gil-Kodaka P, Martinez L, Sugliano P, Trigo AB, Zottola J, Blanco DM, Tricase M, Bravo N, Degrati M, Tavano Formigo CEF, Muller-Karger F, Montes E (2025) Expanding the scale and scope of the Marine Biodiversity Observation Network Pole to Pole of the Americas: Merging rocky intertidal biodiversity surveys with environmental DNA and plankton imaging applications. Research Ideas and Outcomes 11: e163815. https://doi.org/10.3897/rio.11.e163815

Abstract

The Marine Biodiversity Observation Network Pole to Pole of the Americas (MBON Pole to Pole) brought together 30 participants from 10 countries in Patagonia, Argentina, to strengthen observing capacity of coastal biodiversity across the Americas. The network held a five-day workshop focused on three core components: standardized rocky intertidal photo-quadrat surveys, low-cost environmental DNA (eDNA) sampling, and affordable plankton imaging tools. Participants included researchers, park rangers, and conservation practitioners fostering a collaborative and inclusive environment. Key outcomes included field validation of protocols, identification of context-specific methodological adaptations (e.g., for low tidal amplitude areas), adoption of novel tools for monitoring marine life, and strategies for broader participation and data harmonization. The workshop highlighted the potential of simple, replicable methods to support long-term monitoring, and emphasized the value of shared protocols, tools, and open data for building a more connected and resilient regional observation network.

Keywords

rocky shores, benthos, marine biodiversity, integrative taxonomy, AI, MPAs, molecular tools

Date and place

March 31st-April 4th, 2025, Puerto Madryn and Puerto Pirámides, Chubut, Argentina

List of workshop contributors

Workshop lead:

- Dr. Enrique Montes (U. Miami CIMAS / NOAA AOML)
- Dr. Gregorio Bigatti (IBIOMAR-CONICET)
- Dr. Gonzalo Bravo (IBIOMAR-CONICET).

Workshop supporters, moderators and facilitators:

- Dra. Mariana Lozada (IBIOMAR-CONICET)
- Dr. Luke R. Thompson (Mississippi State University NGI / NOAA AOML)
- Dr. Juan Pablo Livore (IBIOMAR-CONICET)
- Dra. María (Pitu) Mendez (IBIOMAR-CONICET)
- Dra. Lorena P. Arribas (IBIOMAR-CONICET)
- Tyler Christian (U. Miami CIMAS / NOAA AOML)
- Dr. Erasmo Macaya H. (Universidad de Concepción / Centro IDEAL)
- Dr. Mariana Degrati (CESIMAR-CONICET)
- Lic. Camila Tavano (CESIMAR-CONICET)
- Lino Bigatti (Computer Science student, Universidad de Buenos Aires)
- Dra. Gabriela Vélez-Rubio (Facultad de Ciencias, Universidad de la República)
- Juan Zottola (Administración de Parques Nacionales, APN)
- Pablo Sugliano (Administración de Parques Nacionales, APN)
- Agostina Trigo (Administración de Parques Nacionales, APN)

Workshop participants:

A total of 30 individuals participated in the workshop in Puerto Madryn and Puerto Pirámides, Patagonia, Argentina (Fig. 1). All participants contributed to the development of this work and are listed as co-authors. The group included representatives from universities, research centers, non-governmental organizations (NGOs), and institutions from both national and provincial parks. The complete list of participants, including their country of origin and institutional affiliation, is available in the supplementary material.

Figure 1. doi

a: Coastal landscapes and some of the intertidal species observed during fieldwork in Península Valdés, Argentina. From left to right: *Dictyota dichotoma* (brown algae), *Spheniscus magellanicus* (Magellanic penguin), *Otaria flavescens* (South American sea lion), and an unidentified intertidal sea anemone.

b: Group photo of the MBON Pole to Pole workshop participants during field activities.

c: Terrestrial environments adjacent to the intertidal zone, featuring native wildlife such as a large hairy armadillo (*Chaetophractus villosus*) and a guanaco (*Lama guanicoe*).

Photo credits: Luke R. Thompson, Gabriela Vélez-Rubio, Erasmo C. Macaya, Edgardo Londoño-Cruz, and Gonzalo Bravo.

Introduction

Rocky shores are key habitats that occupy extensive areas along the coasts of the Americas. Organisms living on rocky shores are sensitive indicators of broader ecosystem changes (Barry et al. 1995, Sagarin et al. 1999, Helmuth et al. 2006, Hawkins et al. 2008, Mieszkowska et al. 2014, Mieszkowska et al. 2021), highlighting the importance of rocky shore ecosystems as sentinel sites for tracking long-term environmental change. Monitoring Essential Ocean Variables (Miloslavich et al. 2018) such as macroalgal coverage and distribution, and benthic invertebrate diversity is therefore crucial to understanding how coastal biodiversity responds to both local and global drivers, and helps make decisions about the management of resources in a particular region (Thompson et al. 2002, Joseph and Cusson 2015, Mieszkowska et al. 2019). In recognition of the importance of sustained observation efforts, the United Nations Decade of Ocean Science for Sustainable Development (Claudet et al. 2020, Guan et al. 2023) and Sustainable Development Goal 13 (Climate Action) and 14 (Life Below Water) emphasize the need for inclusive, coordinated, and long-term monitoring systems to support the conservation and sustainable use of marine resources (Estes et al. 2021).

Rocky intertidal areas are generally easy to access and inexpensive to study, making them ideal for long-term ecological monitoring. Large-scale efforts in these habitats have historically generated important insights on how a region changes (Miloslavich et al. 2019, Satterthwaite et al. 2021, Kaplanis 2023). Initiatives such as MarClim (Mieszkowska et al. 2019) in Europe, the Multi-Agency Rocky Intertidal network (MARINe; Gilbane et al. 2022), the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO; Carr and Bergen 2012) in the United States, and the South American Research Group on Coastal Ecosystems (SARCE; Miloslavich et al. 2016, Cruz-Motta et al. 2020) in South America have all generated valuable time-series data. However, comparing these datasets remains challenging due to differences in sampling design, methodologies, financial resources and data formats (Duffy et al. 2019, Miloslavich et al. 2019). These inconsistencies in monitoring protocols may compromise standardization, scalability, and long-term feasibility. In this context, the Natural Geography in Shore Areas (NaGISA) project (Rigby et al. 2007), part of the Census of Marine Life, played a pivotal role by establishing standardized protocols for rocky intertidal surveys, which was later expanded across South America through the SARCE program (Miloslavich et al. 2016).

Building upon these foundations, the Marine Biodiversity Observation Network Pole to Pole of the Americas (MBON Pole to Pole) emerged as an international network that fosters standardized and participative biodiversity monitoring across coastal ecosystems (Moity et al. 2025). Since 2016, the network has promoted a standard methodology by adopting photo-quadrats as the primary data collection tool, promoting non-extractive, repeatable, and cost-effective monitoring practices (MBON Pole to Pole 2019). This transition to standardized protocols has enabled broader participation, improved data interoperability, and strengthened alignment with global organizations like the Global Ocean Observing System (GOOS) and the Ocean Data and Information System (ODIS).

Additionally, MBON Pole to Pole is broadening the adoption of GOOS Essential Ocean Variables (EOVs) like macroalgal coverage and benthic invertebrate abundance (Miloslavich et al. 2018, Canonico et al. 2019).

Following a training workshop hosted by IBIOMAR-CONICET in Camarones, Argentina, in March 2023, the MBON Pole to Pole project implemented regionally coordinated, image-based surveys. This activity led to the development of a standardized protocol to guide users in collecting high-quality photo-quadrat images (Montes Herrera et al. 2024). Such methodological consistency enables the effective application of machine learning tools to efficiently and reliably analyze rocky shore photographs (Bravo et al. 2021). The streamlined, non-extractive approach not only facilitates large-scale monitoring but also enhances accessibility, allowing participation from a broad range of contributors across regions. The MBON Pole to Pole actively engages conservation practitioners and citizen scientists, who are trained through regional workshops organized by the network to support the collection of benthic imagery (Bravo et al. 2024).

This report summarizes the fifth MBON Pole to Pole workshop, held in Patagonia, Argentina, with participants from 10 countries: Chile, Uruguay, Brazil, Argentina, Peru, Trinidad and Tobago, Puerto Rico, Ecuador (continental and Galapagos Islands), Colombia, and Honduras. This event marked a significant step towards expanding the monitoring network to the northern countries of the Americas and strengthening regional capacity for long-term biodiversity monitoring in coastal ecosystems. To broaden the scope of coastal monitoring, the workshop introduced two complementary techniques to the existing photo-quadrat protocol: seawater environmental DNA (eDNA) sampling and coastal plankton analysis using imaging methods. These additions aim to enhance biodiversity assessments by offering accessible, scalable methodologies and promoting data availability through open access platforms.

Workshop objectives

General Objective of the MBON Pole to Pole workshop:

- Expand regional surveying stations across the Americas by training new network participants capable of implementing and disseminating the rocky shore photo-quadrat protocol in their respective countries, and testing the integration of simplified methods for eDNA sample collection and coastal plankton analysis into the existing monitoring framework.

Specific Objectives:

- Engage and provide theoretical and hands-on training to park rangers, scientists and managers of Marine Protected Areas (MPAs) in techniques for capturing standardized photo-quadrats and selecting suitable monitoring sites in rocky intertidal habitats.

- Conduct field demonstrations in intertidal areas to reinforce practical skills and ensure consistency in image quality and data collection across participants.
- Introduce participants to machine learning tools for classification and analysis of photo-quadrats via the CoralNet platform (Beijbom et al. 2015, Chen et al. 2021).
- Test the inclusion of a protocol tailored for coastal habitats utilizing a low-cost sampling kit for the collection and preservation of eDNA seawater samples. Expose participants to the use of eDNA-derived species observation data for biodiversity monitoring.
- Demonstrate a basic protocol for nearshore plankton sampling, through net-towing, and analysis using the Planktoscope, an open-source and low-cost plankton imaging application. This component aimed to broaden the understanding of connections between benthic and planktonic components of coastal ecosystems.
- Co-develop and refine standardized, easy-to-adopt monitoring protocols that integrate optional photographic, eDNA, and plankton data, promoting broader regional adoption.
- Strengthen regional capacity in coastal biodiversity monitoring, literacy, and conservation through collaborative learning and interdisciplinary exchange.

Workshop design and implementation

The workshop was designed as an immersive, five-day experience that combined theoretical instruction with hands-on fieldwork and peer-to-peer exchange. The workshop kick-off took place in Puerto Madryn, Argentina, at the National Patagonian Centre of the National Scientific and Technical Research Council (Centro Nacional Patagónico of the Consejo Nacional de Investigaciones Científicas y Técnicas [CENPAT-CONICET], Fig. 2a). The kick-off was a full day dedicated exclusively to theoretical training on rocky shore monitoring and photo-quadrat sampling methods as foundational elements of the MBON Pole to Pole rocky shore monitoring protocol.

On the second day, participants were transported to Puerto Pirámides in the MPA and UNESCO Heritage Site Península Valdés to continue training activities at the Municipal Hall "La Nona" Fig. 2b. Participants were introduced to the theoretical concepts of eDNA and its applications, the use of eDNA in marine biodiversity monitoring, and an overview of bioinformatics data analysis and visualization methods. This session included practical demonstrations of simple and replicable sampling techniques suitable for coastal environments and hands-on exploration of eDNA-derived biodiversity data from global repositories.

The third day was devoted entirely to fieldwork, with a visit to Estancia San Lorenzo near Puerto Pirámides Fig. 2c, d). This site was selected for its pristine rocky intertidal habitats

and exuberant and diverse wildlife (e.g., penguins, sea lions, seabirds). The activity provided moments of contemplation and connection with a place of spectacular natural settings and wildlife, which enhanced the reason and justification for monitoring biodiversity. The immersive fieldwork provided participants an opportunity to build a deep connection with the coastal and marine biodiversity of the Argentinian Patagonia, which is key to catalyzing action and championing marine biodiversity monitoring efforts in their respective countries.

Figure 2.

Workshop locations.

a: CCT CONICET-CENPAT facilities in Puerto Madryn where the first day of theoretical training on photo-quadrat sampling was conducted. doi
b: Municipal Hall "La Nona" in Puerto Pirámides, which hosted the theoretical sessions and demonstrations on eDNA and coastal plankton sampling. doi
c: Fieldwork conducted at Estancia San Lorenzo, a site selected for its rich intertidal. doi
d: Indoor facilities at Estancia San Lorenzo used for processing water samples and training activities during the workshop. doi

The fourth day returned to theoretical learning, this time focusing on coastal plankton sampling and analysis using the PlanktoScope technology. The PlanktoScope is a modular, community-supported, quantitative imaging platform, developed with the aim of lowering the threshold for the collection, processing, and analysis of plankton observations throughout the world's ocean in a standardized fashion (Pollina et al. 2022).

On the fifth and final day, participants presented findings, reflections, and proposed next steps for applying what they had learned in their respective countries. The presentations fostered dialogue, mutual support, and the strengthening of a collaborative network committed to advancing coastal biodiversity monitoring across the Americas.

Recommendation and strategies identified

Several key recommendations emerged during workshop discussions. Emphasis was on the strengthening and expansion of the photo-quadrat protocol for rocky intertidal monitoring for regional operational and comparable biodiversity surveys, with the options of incorporating eDNA and plankton imaging into biodiversity monitoring efforts:

- **Adapting the protocol for low tidal amplitude regions**: A need was identified to modify certain aspects of the protocol to ensure its applicability in areas with minimal tidal variation. This is the case with the Caribbean Basin. Given that much of the current protocol is based on experiences from high-amplitude tidal zones like Patagonia (Argentina and Chile), adjustments will help broaden its use across different geographical contexts.

- **Continued engagement of conservation practitioners, educators, and resource managers**: Participants emphasized the importance of involving park rangers, local conservation agents, and trained citizens in the monitoring process. Their long-term presence and familiarity with the sites are key to carry out activities in the long run and enhance local ownership of monitoring efforts and the subsequent use of data. The group recommended creating a series of short video tutorials as training resources for participating individuals and groups.

- **Development of a species-grouping reference document**: A recurring challenge identified in past and current workshops is the classification of organisms—particularly macroalgae—within CATAMI categories (Althaus et al. 2015). Participants agreed on the need to co-develop a standardized document detailing which species, including diverse morphofunctional groups of seaweeds, are grouped under each CATAMI category. This tool will be essential for harmonizing analyses and reducing misclassifications, especially when working with photographs taken out of water, where algal morphology can be difficult to discern.

Conclusions and future steps

As part of the conclusions, the sampling methodologies developed during the MBON workshop show strong potential for collaborative networks aiming to improve primary data collection through non-extractive, repeatable, and cost-effective monitoring practices and for future scientific initiatives that go beyond participatory approaches. These methodologies open the door to community-engaged projects involving park rangers,

local schools and other non-scientific stakeholders, fostering inclusive and collaborative knowledge generation.

While inexpensive and easy-to-apply methodologies are being widely adopted by biodiversity monitoring efforts throughout the region, sustained financial and institutional support continues to emerge as a key challenge. Individual commitment has supported such efforts. Nonetheless, the inclusion of other stakeholders, such as park rangers and citizen scientists, the MBON Pole to Pole has strengthened its ability to sustain monitoring of coastal habitats, showing a large potential for expansion as a model along the Americas. This way, further steps may focus on

1. ensuring local engagement and financial support,
2. promoting those simple protocols as basic monitoring solutions for coastal protected areas,
3. putting into practice a standardized workflow linking data collection to integrated analysis at multiple scales.

This workshop consolidated the MBON Pole to Pole network as a robust and collaborative platform for generating marine biodiversity data using standardized protocols across diverse regions. The network has demonstrated its scalability and stands as a global example of how coordinated, science-based monitoring can inform marine conservation and management. Moving forward, key priorities include securing sustained funding to maintain momentum, expanding monitoring coverage and stakeholder participation, and developing simplified and affordable protocols to integrate emerging tools like environmental DNA and plankton imaging into network activities. Implementing these innovations as proof-of-concept initiatives will be essential to further enhance the network's capacity to support biodiversity assessments and ecosystem-based management at regional and global scales.

Key outcomes and workshop achievements

1- Rocky intertidal sampling with photo-quadrats

The workshop provided an opportunity to advance and improve the standardized rocky intertidal monitoring protocol co-developed and refined during the previous two workshops in Argentina (Bravo et al. 2024, Montes Herrera et al. 2024), including advances in automated sample cropping and preprocessing using an AI model for object recognition (Kirillov et al. 2023). A key highlight of this edition was the participation of researchers previously involved in the SARCE project. This allowed revisiting and discussing the benefits of nested sampling designs — with multiple sites within each locality — to strengthen the statistical robustness of intercomparisons across sampling localities and spatial scales. This activity included the participation of national park rangers and provincial wildlife wardens from Chubut, Argentina, who contributed field-based insights to further improve the feasibility and adaptability of the protocol. Their

firsthand monitoring experiences, in a variety of field conditions, provided critical feedback to produce a refined and straightforward protocol.

Fieldwork in the rocky intertidal zone was conducted in small teams of 4–5 participants, with each group using the standard quadrat frame and camera to practice the setup and image capture protocols. This hands-on experience ensured that all participants became familiar with the methodology and were able to troubleshoot common challenges (Fig. 3b, d, f).

Finally, a dedicated session was held to identify potential new monitoring sites and countries that could be incorporated into the expanding MBON network. As a result, four complete photo-quadrat kits — including cameras and frame structures — were provided to participants from Colombia, continental Ecuador, Perú, and Trinidad and Tobago. Additionally, five extra quadrat structures were also delivered to countries already equipped with suitable cameras, facilitating further expansion of the protocol's geographic reach.

2- eDNA

Collection and analysis of eDNA has become a powerful technology for biodiversity monitoring, but its use in the Global South is currently limited by technical capacity, financial constraints, limited in-country sequencing facilities, budget limitations, and difficulties in access to remote areas (Sahu et al. 2023). This workshop provided an opportunity to share state-of-the-art eDNA methods with participants while discussing solutions to overcome the technical and financial constraints preventing wider adoption of eDNA technology. A low-cost sampling system was discussed, including low-cost filters, a pump-less design (e.g., using gravity to push water through the filter), and buffers to preserve DNA without freezing or refrigeration. Second, we discussed the tradeoffs between DNA metabarcoding and quantitative or digital PCR. The former provides relative abundance of whole communities at sequence-level resolution but requires more expensive DNA sequencers and/or a DNA sequencing facility, whereas the latter provides absolute abundance of single or few taxa, but is possible to run with simpler equipment and data analysis. For some monitoring efforts, quantitative PCR of keystone, critical or invasive species may be sufficient. Finally, the group of biodiversity researchers and park rangers tested the accessibility of eDNA data published on biodiversity platforms like the Global Biodiversity Information Facility (GBIF). Participants used both the graphical user interface and R application program interface (API) from GBIF (Chamberlain et al. 2022) to find eDNA-based species records and DNA sequences, while providing valuable feedback for developers to improve the utility of these interfaces.

3- Assessing and monitoring planktonic communities with affordable imaging tools

A new MBON Pole to Pole training module with focus on affordable plankton imaging applications was introduced to workshop participants. The goal was to expand the scope

of coastal biodiversity monitoring efforts. In this full-day session, foundational concepts of plankton ecology, traditional sampling methods, and emerging technologies for plankton monitoring were presented. This included an active discussion on the value of linking plankton EOV observations to better understand the ecological processes shaping rocky intertidal benthic communities, as well as the challenges and opportunities of implementing plankton monitoring at survey sites.

Figure 3.

Field activities carried out during the workshop.

a: Collection of coastal water samples using a Niskin bottle. doi
b: Rocky intertidal exploration to determine suitable monitoring areas. doi
c: Manual, electricity-free filtration system for collection and preservation of environmental DNA (eDNA) samples. doi
d: Photo acquisition in the rocky intertidal zone using the standardized quadrat method. doi
e: PlanktonScope unit during the plankton imaging demonstration. doi
f: Quadrat structure (25 × 25 cm) and Olympus TG-7 camera setup used to capture images. doi

The training session included a demonstration of the use of dedicated equipment for the collection of plankton samples, net tows, the use of flowmeters, and selection of net mesh sizes for targeting specific size classes of phytoplankton and zooplankton. The training included sample splitting and preservation methods, including safe procedures to handle formalin and ethanol solutions. Subsequently, participants were split into two groups to run preserved plankton samples in PlanktoScope units and the open-source platform that operates the images via the instrument's WiFi hotspot and its graphical unit interface (Fig. 3e). Participants became familiar with the equipment, learning about its practical advantages as a compact, easy-to-assemble, affordable, and user-friendly device suitable for both laboratory and field applications. Also, participants learned to adjust PlanktoScope parameters like microscope focus, sample flow rate, and total volume processed, to input sample information such as station ID, geographic coordinates, date and time, mesh size, and to initiate built-in image processing algorithms for object detection and segmentation. The final component of this training session was focused on uploading segmented images and associated metadata to EcoTaxa (Irisson et al. 2022), building a training model for predicting classifications, and annotating sets of images for validation. As follow-up steps after the workshop, participants will compile a list of available equipment for plankton sample collection and requirements for obtaining a PlanktoScope at their respective institutions with the support of instructors.

Acknowledgements

Special thanks to Administración de Parques Nacionales (APN), Ministerio de Turismo y Áreas Protegidas de la Provincia del Chubut, Municipalidad de Puerto Pirámides. Thanks to the CCT CONICET-CENPAT for hosting the workshop and technicians Andrés Morales, Julio Rúa, Fabián Quiroga and Hugo Insaurralde for logistics support. Fundación ProyectoSub supported the logistics and organization of the workshops. We are deeply grateful to Dr. Daniel Otis of the University of South Florida, College of Marine Science, for the administrative and logistical support provided for the organization of this activity. NM thanks the Galapagos National Park and the Charles Darwin Foundation for their institutional support. This publication is contribution number 2736 of the Charles Darwin Foundation for the Galapagos Islands.

Funding program

This workshop and collaborative effort was made possible by the Marine Biodiversity Observation Network (MBON) including support from NASA (grants NNX14AP62A; 80NSSC20K0017, 80NSSC22K1779), and NOAA (IOOS grant NA19NOS0120199).

Hosting institution

This workshop was hosted by the Instituto de Biología de Organismos Marinos (IBIOMAR-CONICET) at CCT CONICET-CENPAT and carried out thanks to the following

institutions: CONICET, U Miami, USF, NOAA, National Parks Administration (APN), ProyectoSub Foundation, and NASA.

Conflicts of interest

The authors have declared that no competing interests exist.

References

- Althaus F, Hill N, Ferrari R, Edwards L, Przeslawski R, Schönberg CL, Stuart-Smith R, Barrett N, Edgar G, Colquhoun J, Tran M, Jordan A, Rees T, Gowlett-Holmes K (2015) A standardised vocabulary for identifying benthic biota and substrata from underwater imagery: The CATAMI Classification Scheme. PLoS ONE 10 (10). https://doi.org/10.1371/journal.pone.0141039
- Barry JP, Baxter CH, Sagarin RD, Gilman SE (1995) Climate-related, long-term faunal changes in a California rocky intertidal community. Science 267 (5198): 672-675. https://doi.org/10.1126/science.267.5198.672
- Beijbom O, Edmunds P, Roelfsema C, Smith J, Kline D, Neal B, Dunlap M, Moriarty V, Fan T, Tan C, Chan S, Treibitz T, Gamst A, Mitchell BG, Kriegman D (2015) Towards Automated Annotation of Benthic Survey Images: Variability of Human Experts and Operational Modes of Automation. PLoS ONE 10 (7). https://doi.org/10.1371/journal.pone.0130312
- Bravo G, Moity N, Londoño-Cruz E, Muller-Karger F, Bigatti G, Klein E, Choi F, Parmalee L, Helmuth B, Montes E (2021) Robots versus humans: Automated annotation accurately quantifies Essential Ocean Variables of rocky intertidal functional groups and habitat state. Frontiers in Marine Science 8 https://doi.org/10.3389/fmars.2021.691313
- Bravo G, Bigatti G, Bagur M, Macaya E, Valdivia N, Rodriguez A, Gauna M, Walker I, Livore JP, Mendez M, Nieto Vilela R, Lima F, Seabra R, Montes E (2024) Implementing biodiversity monitoring of rocky shores using photo-quadrats and artificial intelligence in support of data-driven decision-making of marine living resources. Research Ideas and Outcomes 10 https://doi.org/10.3897/rio.10.e126660
- Canonico G, Buttigieg PL, Montes E, Muller-Karger F, Stepien C, Wright D, Benson A, Helmuth B, Costello M, Sousa-Pinto I, Saeedi H, Newton J, Appeltans W, Bednaršek N, Bodrossy L, Best B, Brandt A, Goodwin K, Iken K, Marques A, Miloslavich P, Ostrowski M, Turner W, Achterberg E, Barry T, Defeo O, Bigatti G, Henry L, Ramiro-Sánchez B, Durán P, Morato T, Roberts JM, García-Alegre A, Cuadrado MS, Murton B (2019) Global observational needs and resources for marine biodiversity. Frontiers in Marine Science 6 https://doi.org/10.3389/fmars.2019.00367
- Carr M, Bergen L (2012) PISCO: A Collaborative Model for Informing Nearshore Policy. In: Magoon O, Converse H, Baird B, Jines B, Miller-Henson M (Eds) California and the World Ocean'02: Revisiting and Revising California's Ocean Agenda. Santa Barbara, California. [ISBN 9780784407615]. https://doi.org/10.1061/9780784407615
- Chamberlain S, Oldoni D, Geffert L, Desmet P, Barve V, Ram K, Blissett M (2022) ropensci/rgbif: rgbif v3.7.0. Zenodo. DOI: 10.5281/zenodo.6023735. https://doi.org/10.5281/zenodo.6023735

- Chen Q, Beijbom O, Chan S, Bouwmeester J, Kriegman D (2021) A New Deep Learning Engine for CoralNet. 2021 IEEE/CVF International Conference on Computer Vision Workshops (ICCVW). [ISBN 978-1-66540-191-3]. https://doi.org/10.1109/ICCVW54120.2021.00412
- Claudet J, Bopp L, Cheung WL, Devillers R, Escobar-Briones E, Haugan P, Heymans J, Masson-Delmotte V, Matz-Lück N, Miloslavich P, Mullineaux L, Visbeck M, Watson R, Zivian AM, Ansorge I, Araujo M, Aricò S, Bailly D, Barbière J, Barnerias C, Bowler C, Brun V, Cazenave A, Diver C, Euzen A, Gaye AT, Hilmi N, Ménard F, Moulin C, Muñoz NP, Parmentier R, Pebayle A, Pörtner H, Osvaldina S, Ricard P, Santos RS, Sicre M, Thiébault S, Thiele T, Troublé R, Turra A, Uku J, Gaill F (2020) A Roadmap for Using the UN Decade of Ocean Science for Sustainable Development in Support of Science, Policy, and Action. One Earth 2 (1): 34-42. https://doi.org/10.1016/j.oneear.2019.10.012
- Cruz-Motta J, Miloslavich P, Guerra-Castro E, Hernández-Agreda A, Herrera C, Barros F, Navarrete S, Sepúlveda R, Glasby T, Bigatti G, Cardenas-Calle M, Carneiro PM, Carranza A, Flores AV, Gil-Kodaka P, Gobin J, Gutiérrez J, Klein E, Krull M, Lazarus J, Londoño-Cruz E, Lotufo T, Macaya E, Mora C, Mora E, Palomo G, Parragué M, Pellizzari F, Retamales R, Rocha R, Romero L (2020) Latitudinal patterns of species diversity on South American rocky shores: Local processes lead to contrasting trends in regional and local species diversity. Journal of Biogeography 47 (9): 1966-1979. https://doi.org/10.1111/jbi.13869
- Duffy JE, Benedetti-Cecchi L, Trinanes J, Muller-Karger F, Ambo-Rappe R, Boström C, Buschmann A, Byrnes J, Coles R, Creed J, Cullen-Unsworth L, Diaz-Pulido G, Duarte C, Edgar G, Fortes M, Goni G, Hu C, Huang X, Hurd C, Johnson C, Konar B, Krause-Jensen D, Krumhansl K, Macreadie P, Marsh H, McKenzie L, Mieszkowska N, Miloslavich P, Montes E, Nakaoka M, Norderhaug KM, Norlund L, Orth R, Prathep A, Putman N, Samper-Villarreal J, Serrao E, Short F, Pinto IS, Steinberg P, Stuart-Smith R, Unsworth RF, Van Keulen M, Van Tussenbroek B, Wang M, Waycott M, Weatherdon L, Wernberg T, Yaakub SM (2019) Toward a Coordinated Global Observing System for Seagrasses and Marine Macroalgae. Frontiers in Marine Science 6 https://doi.org/10.3389/fmars.2019.00317
- Estes M, Anderson C, Appeltans W, Bax N, Bednaršek N, Canonico G, Djavidnia S, Escobar E, Fietzek P, Gregoire M, Hazen E, Kavanaugh M, Lejzerowicz F, Lombard F, Miloslavich P, Möller K, Monk J, Montes E, Moustahfid H, Muelbert MC, Muller-Karger F, Peavey Reeves L, Satterthwaite E, Schmidt J, Sequeira AM, Turner W, Weatherdon L (2021) Enhanced monitoring of life in the sea is a critical component of conservation management and sustainable economic growth. Marine Policy 132 https://doi.org/10.1016/j.marpol.2021.104699
- Gilbane L, Ambrose RF, Burnaford JL, Helix ME, Miner CM, Murray S, Sullivan KM, Whitaker SG (2022) Long-term sustainability of ecological monitoring: perspectives from the Multi-Agency Rocky Intertidal Network. In: Auad G, Wiese F (Eds) Partnerships in Marine Research. Elsevier, 109-129 pp. [In English]. [ISBN 978-0-323-90427-8]. https://doi.org/10.1016/C2020-0-01694-4
- Guan S, Qu F, Qiao F (2023) United Nations Decade of Ocean Science for Sustainable Development (2021-2030): From innovation of ocean science to science-based ocean governance. Frontiers in Marine Science 9 https://doi.org/10.3389/fmars.2022.1091598
- Hawkins S, Moore P, Burrows M, Poloczanska E, Mieszkowska N, Herbert R, Jenkins S, Thompson R, Genner M, Southward A (2008) Complex interactions in a rapidly changing

world: responses of rocky shore communities to recent climate change. Climate Research 37 (2-3): 123-133. https://doi.org/10.3354/cr00768

- Helmuth B, Mieszkowska N, Moore P, Hawkins S (2006) Living on the Edge of Two Changing Worlds: Forecasting the Responses of Rocky Intertidal Ecosystems to Climate Change. Annual Review of Ecology, Evolution, and Systematics 37 (1): 373-404. https://doi.org/10.1146/annurev.ecolsys.37.091305.110149
- Irisson J, Salinas L, Colin S, Complex T, Picheral M (2022) EcoTaxa: a tool to support the taxonomic classification of large datasets through supervised machine learning. SFEcologie URL: https://hal.science/hal-04026447/
- Joseph L, Cusson M (2015) Resistance of benthic intertidal communities to multiple disturbances and stresses. Marine Ecology Progress Series 534: 49-64. https://doi.org/10.3354/meps11359
- Kaplanis N (2023) Insight into best practices: a review of long-term monitoring of the rocky intertidal zone of the Northeast Pacific Coast. Frontiers in Marine Science 10 https://doi.org/10.3389/fmars.2023.1182562
- Kirillov A, Mintun E, Ravi N, Mao H, Rolland C, Gustafson L, Xiao T, Whitehead S, Berg AC, Lo W (2023) Segment anything. https://doi.org/10.25607/OBP-663
- MBON Pole to Pole (2019) Sampling protocol for assessment of marine diversity on rocky shores. (Modified from the SARCE South American Research Group on Coastal Ecosystems for sampling on rocky shores protocol). Marine Biodiversity Observation Network Pole to Pole of the Americas. DOI: http://dx.doi.org/10.25607/OBP-663.
- Mieszkowska N, Sugden H, Firth LB, Hawkins SJ (2014) The role of sustained observations in tracking impacts of environmental change on marine biodiversity and ecosystems. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 372 (2025). https://doi.org/10.1098/rsta.2013.0339
- Mieszkowska N, Benedetti-Cecchi L, Burrows M, Mangano M, Queirós A, Seuront L, Sarà G (2019) Multinational, integrated approaches to forecasting and managing the impacts of climate change on intertidal species. Marine Ecology Progress Series 613: 247-252. https://doi.org/10.3354/meps12902
- Mieszkowska N, Burrows M, Hawkins S, Sugden H (2021) Impacts of Pervasive Climate Change and Extreme Events on Rocky Intertidal Communities: Evidence From Long-Term Data. Frontiers in Marine Science 8 https://doi.org/10.3389/fmars.2021.642764
- Miloslavich P, Cruz-Motta JJ, Hernández A, Herrera C, Klein E, Barros F, Bigatti G, Cárdenas M, Carranza A, Flores A (2016) Benthic assemblages in South American intertidal rocky shores: biodiversity, services, and threats. Marine benthos: biology, ecosystems, functions and environmental impact83-137.
- Miloslavich P, Bax N, Simmons S, Klein E, Appeltans W, Aburto-Oropeza O, Andersen Garcia M, Batten S, Benedetti-Cecchi L, Checkley D, Chiba S, Duffy JE, Dunn D, Fischer A, Gunn J, Kudela R, Marsac F, Muller-Karger F, Obura D, Shin Y (2018) Essential ocean variables for global sustained observations of biodiversity and ecosystem changes. Global Change Biology 24 (6): 2416-2433. https://doi.org/10.1111/gcb.14108
- Miloslavich P, Seeyave S, Muller-Karger F, Bax N, Ali E, Delgado C, Evers-King H, Loveday B, Lutz V, Newton J, Nolan G, Peralta Brichtova A, Traeger-Chatterjee C, Urban E (2019) Challenges for global ocean observation: the need for increased human capacity. Journal of Operational Oceanography 12 (sup2). https://doi.org/10.1080/1755876X.2018.1526463

- Moity N, Bigatti G, Muller-Karger F, Montes E (2025) The Marine Biodiversity Observation Network Pole to Pole of the Americas: Building a Community of Practice for Detecting Rapid Changes in Coastal Biodiversity. Oceanography https://doi.org/10.5670/oceanog.2025.137
- Montes Herrera E, Bravo G, Bigatti G (2024) Sampling protocol for monitoring marine biodiversity on rocky shores. Marine Biodiversity Observation Network Pole to Pole of the Americas,. https://doi.org/10.25607/OBP-2014.2
- Pollina T, Larson A, Lombard F, Li H, Le Guen D, Colin S, De Vargas C, Prakash M (2022) PlanktoScope: Affordable Modular Quantitative Imaging Platform for Citizen Oceanography. Frontiers in Marine Science 9 https://doi.org/10.3389/fmars.2022.949428
- Rigby PR, Iken K, Shirayama Y (2007) Sampling biodiversity in coastal communities: NaGISA protocols for seagrass and macroalgal habitats. NUS Press
- Sagarin RD, Barry JP, Gilman SE, Baxter CH (1999) Climate-related change in an intertidal community over short and long time scales. Ecological Monographs 69 (4). https://doi.org/10.2307/2657226
- Sahu A, Kumar N, Pal Singh C, Singh M (2023) Environmental DNA (eDNA): Powerful technique for biodiversity conservation. Journal for Nature Conservation 71 https://doi.org/10.1016/j.jnc.2022.126325
- Satterthwaite E, Bax N, Miloslavich P, Ratnarajah L, Canonico G, Dunn D, Simmons S, Carini R, Evans K, Allain V, Appeltans W, Batten S, Benedetti-Cecchi L, Bernard AF, Bristol S, Benson A, Buttigieg PL, Gerhardinger LC, Chiba S, Davies T, Duffy JE, Giron-Nava A, Hsu A, Kraberg A, Kudela R, Lear D, Montes E, Muller-Karger F, O'Brien T, Obura D, Provoost P, Pruckner S, Rebelo L, Selig E, Kjesbu OS, Starger C, Stuart-Smith R, Vierros M, Waller J, Weatherdon L, Wellman T, Zivian A (2021) Establishing the Foundation for the Global Observing System for Marine Life. Frontiers in Marine Science 8 https://doi.org/10.3389/fmars.2021.737416
- Thompson RC, Crowe TP, Hawkins SJ (2002) Rocky intertidal communities: past environmental changes, present status and predictions for the next 25 years. Environmental Conservation 29 (2): 168-191. https://doi.org/10.1017/S0376892902000115