









GOOS BioEco EOVs

Microbial: Biomass and Diversity Corals: Cover and Composition

October 10th 2025

A series supported by:



In collaboration with:







Why observe the ocean?

Climate action Blue economy Today's Beach Condition Forecasts & early warnings Community Ocean health adaptation Carbon strategies But the ocean is so vast,

no one country can observe it effectively on its own.

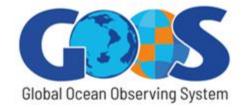


The Global Ocean Observing System (GOOS)

Leading and supporting a community of international, regional and national ocean observing programmes, governments, UN agencies, research organisations and individual scientists.

















A truly global ocean observing system that delivers the essential information needed for our sustainable development, safety, wellbeing and prosperity.

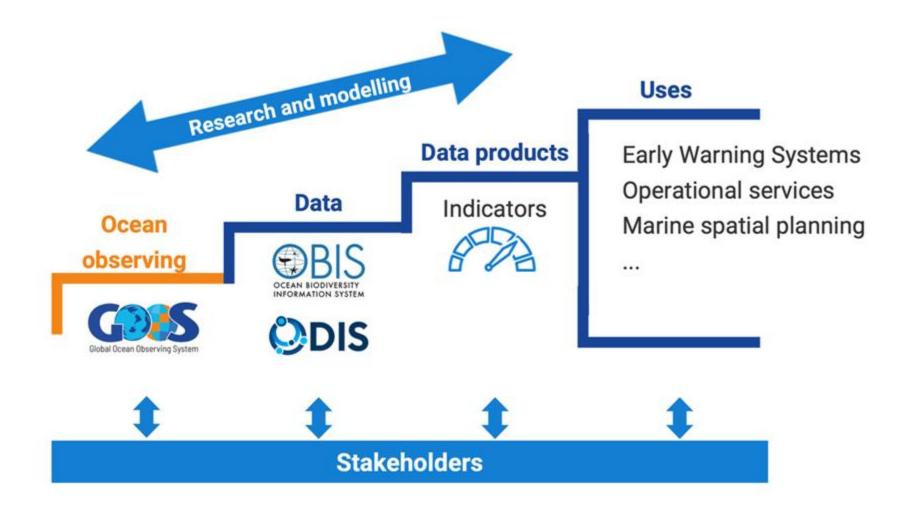
Mission

To lead the ocean observing community and create the partnerships to grow an integrated, responsive and sustained observing system.





From observations to impact





GOOS Essential Ocean Variables (EOVs)

the minimum set of ocean variables
needed to assess ocean state and
variability for important global ocean
phenomena, and to provide essential data
for applications that support societal
benefit.

EOVs make it easier to measure and compare ocean data from all corners of the world!



EOVs focus on three main delivery areas:



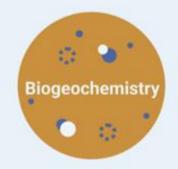




EOVs are grouped by discipline and are overseen by three GOOS expert panels:







EOVs can be described by three key elements:



Basic measurements for estimating the main EOV (e.g., counting marine turtles)



Additional measurements
offering context (e.g., measuring
water temperature for
understanding environmental
conditions affecting turtles)



Outputs calculated from the sub-variables and other relevant information (e.g., visible changes in turtle population using turtle count and water condition)



Biogeochemical

EOVs

Physical EOVs

Global Ocean Observing System

Biology &

Ecosystems EOVs









Disaster Risk Reduction



Weather forecasting and hazard warnings



Safety at sea, optimised routing, energy optimisation



Convention on Biological Diversity 30x30, Global Biodiversity **Framework**



Plastics Treaty



Biodiversity Beyond National Jurisdiction

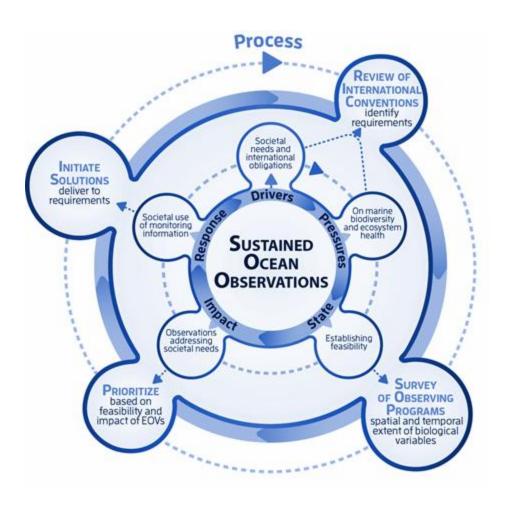




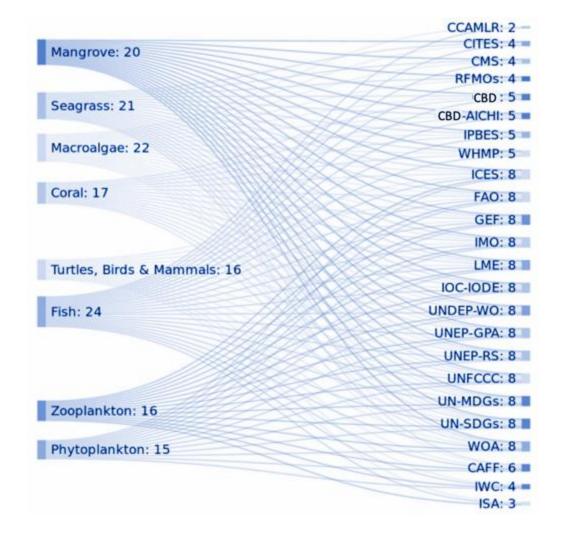
SDG14 / Sustainable Ocean **Management**



BioEco EOVs



Miloslavich et al. (2018)





Functional Groups



Microbe
Diversity and biomass



*Phytoplankton
Diversity and biomass



*Zooplankton
Diversity and biomass



Benthic invertebrates
Abundance and distribution



Cross

panel



Abundance and distribution



Abundance and distribution



Seabirds
Abundance and distribution



Abundance and distribution

Habitat State



*Seagrass
Cover and composition



*Macroalgal canopy
Cover and composition



Cover and composition



Cover and composition



*Essential Climate Variable



GOOS Biology and Ecosystems EOVs

BioEco EOVs are the minimum set of ocean variables for biology and ecosystems identified to help understand and forecast marine life.

They provide a framework for coordinating ocean observations, ensuring globally comparable and combinable data.



Phytoplankton Diversity and biomass



Zooplankton Diversity and biomass



Fish Abundance and distribution



Sea Turtles Abundance and distribution



SeaBirds Abundance and distribution



Marine mammal Abundance and distribution



Ocean sound Cross-disciplinary



Coral Cover and composition



Seagrass Cover and composition



Macroalgal canopy Cover and composition



Mangrove Cover and composition



Microbe Diversity and biomass (Pilot)



Benthic invertebrates Abundance and distribution (Pilot)



Ocean colour Cross-disciplinary



Partners in strategic alliance



Foster and coordinate a global community of practice for collecting, curating, analyzing, good management, and communicating marine biodiversity data and related services to the scientific community, policymakers, the public, and other stakeholders.

Framework for coordination: Essential Biodiversity Variables



Build and maintain a global alliance that collaborates with scientific communities to facilitate free and open access to, and application of, biodiversity and biogeographic data and information on marine life.

FAIR and open biodiversity data













Microbial Biomass and Diversity Spec Sheet



Alejandra Prieto Davó Julie Robidart

A series supported by:

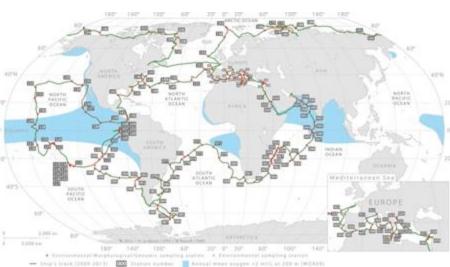


In collaboration with:



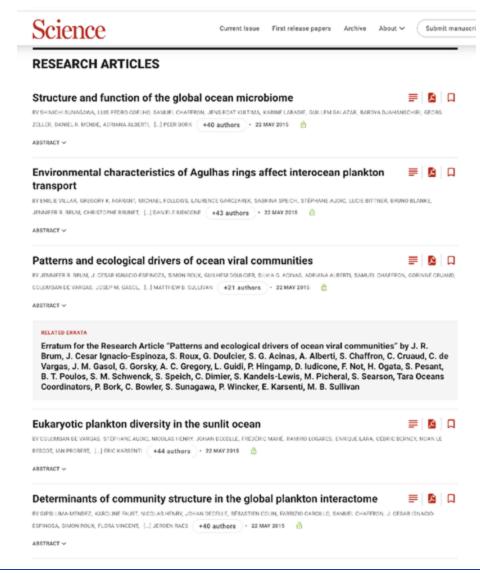


The impact of coordinated observations



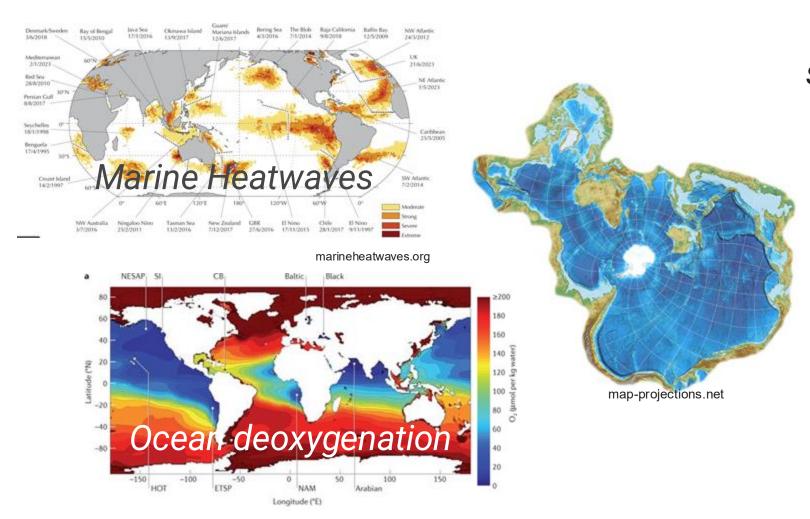
Pesant, S., et al. Open science resources for the discovery and analysis of *Tara* Oceans data. *Sci Data* **2**, 150023 (2015). https://doi.org/10.1038/sdata.2015.23



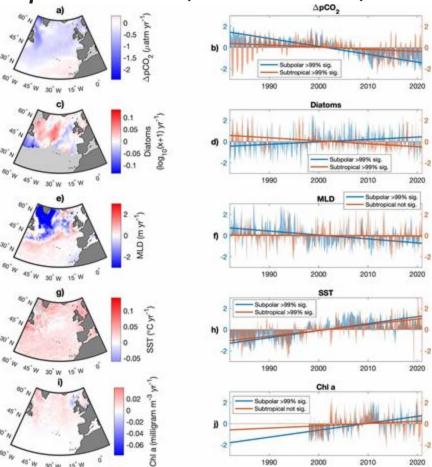




Coordinated networks to address ocean challenges



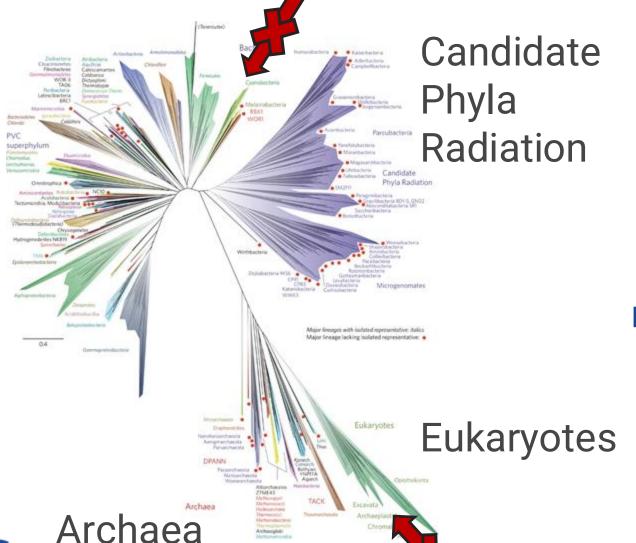
Effects on carbon sequestration, food webs, etc.

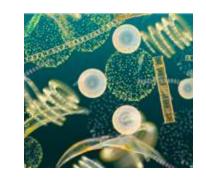


Wright et al., 2012 Nature Reviews Microbiology



"Microbes" operational definition





"For the sake of this specification sheet, "microbes" include microscopic Eukaryotes, Bacteria and Archaea but only touch on phytoplankton and viruses.

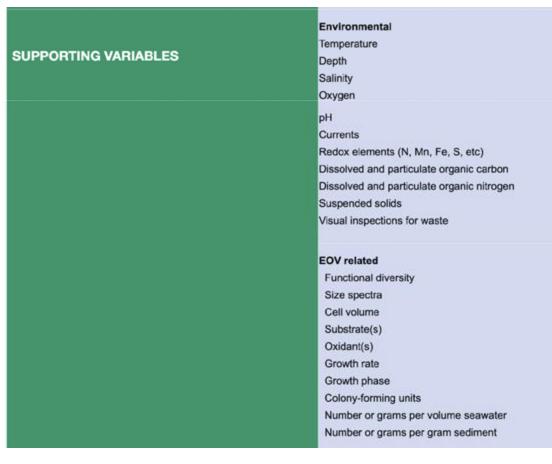
Cyanobacteria and Eukaryotic phytoplankton are well-covered in the Phytoplankton EOV specification sheet."

Bacteria

Specification sheets - Definition and variables

1. EOV information

ESSENTIAL OCEAN VARIABLE (EOV)	Microbial Biomass and Diversity
DEFINITION	The operational definition of microbes for the purpose of this specification sheet includes Bacteria, Archaea and Eukaryotic microbes, but exclude viruses. As phytoplankton, cyanobacteria are more thoroughly addressed in the Phytoplankton specification sheet, though genetic methodologies can be applied. Microbial biomass refers to: - weight (mass as the concentration per unit area/volume), - abundance or quantity of organisms (number of individuals per unit area or volume, or per mass of sediment). Microbial diversity refers to: - variability of microbes from all sources; including diversity within and
EOV SUB-VARIABLES key measurements that are used to estimate the EOV	between species (genetic diversity, functional diversity, etc.) Microbial concentration (biomass / abundance)
osumate the EOV	* Diversity
*bare minimum	Genomic and genetic diversity Phenotypic diversity Functional diversity
	Presence of fecal indicator bacteria



DERIVED PRODUCTS Describe EOV using sub-variables and relating to supporting variables

Microbial community composition (concentrations of all types of microbes in a sample), microbial community function, richness, phylogeny, participation (role) of microbes in global biogeochemical cycles. Biogeography of important microbial groups. Changes in microbial community related or due to anthropogenic actions

Specification sheets- Phenomena

2. Phenomena to observe - what we want to observe with this EOV

This section presents examples of priority phenomena for GOOS that can be (partly) characterised by this EOV's sub-variables. This list is not exhaustive but serves to provide general guidance on how observation efforts can structure their planning and implementation to observe certain phenomena.

The GOOS application area(s) the phenomena are relevant for are depicted as follows: Climat



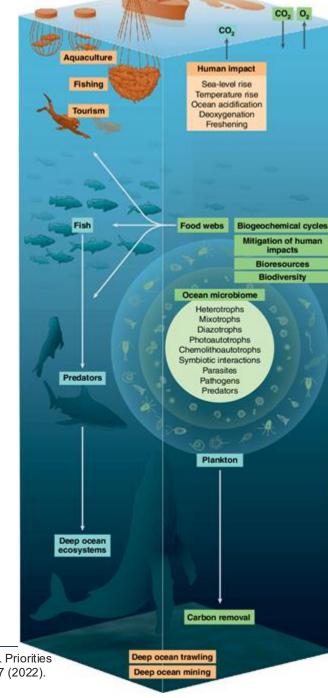
, ocean health



operational services



PHENOMENA TO OBSERVE		Geographic variation in diversity / composition	Role in transport/cycling of elements	Detection and enumeration of fecal indicator bacteria (Escherichia coli) in bathing waters	Oil spill degradation by microbial community	
			Amount of carbon, nitrogen.			
PHENOME NA EXTENT	HORIZONTAL	/ functional gene markers or full metagenomic sequencing tracked locally, regionally, or globally (meters to 1000's of kilometers) depending on the application	redox intermediates or gases taken up or released over scales of meters to kilometers, at regional and basin-scale; biomass imported or exported from a location by advection or biological processes	metres to kilometres, regional	Local to regional can be tracked by high throughpu sequencing of targeted taxonomic/functional genes or full shotgun sequencing	
	VERTICAL	Vertical stratification of the same sequence identifications over meters to kilometers, depending on the applications	Fluxes in terms of nitrogen fixation rates, greenhouse gas production or uptake, redox cycling, exopolysaccharide production, respiration of dissolved and particulate organics, ballast characteristics, within and below the photic zone	Photic zone; can settle to benthos	m.	



Maritime transport



Tara Ocean Foundation., Tara Oceans., EMBL, EMBRC. Priorities for ocean microbiome research. *Nat Microbiol* **7**, 937–947 (2022). https://doi.org/10.1038/s41564-022-01145-5

Specification sheets- Links to observatory design

This section outlines long-term system to	s ideal measure observe key p sd, the combin	ements for phenomena ed efforts o	an optimal ob related to the of various obs	oserving system e EOV. These vi erving systems	for this Essential	Ocean Varia	Requirem able (EOV). It offers guida: nis expectals. Observations at differ	nce on creating a ted to meet all	EOV SUB-VARIABLE	Presence of	fecal indica	ator bacteria	
EOV	Microbe Bi	omass and	Diversity								Resolution	1	
PHENOMENA	geographic v		diversity/comp of elements	position;						Spatial Horizontal	Spatial Vertical	Temporal	Timel
EOV SUB-VARIABLE	Microbial div	versity			DEFINITION		identifying microbial tax sequencing, qPCR, mic	ra /functional groups by croscopy (e.g. FISH)		0.5m from bathers:	photic		daily if hazardo (polluteo
	Spatial Horizontal	Resolution Spatial Vertical	Temporal	Timeliness	Uncertainty Measurement	Stability	Sampling approach	References	IDEAL	within and 0.5m from area at greatest risk of pollution	zone; 5-10m from shore	4 times monthly (if high risk)	condition present (36-72h analysis case of hazardo condition
	Co-located plankton and environment al observations (if known,	Depth-re solved at standard oceanogr aphic sampling	Depending on question or problem: day-night variations, weekly, monthly or	depends on the purpose: near-real-time for harmful			Bottle samples, nets, filters for biomass, chemical composition of particulates, genetic (eDNA and other), microscopy. Samples preserved for	Hawaii Ocean Time-series Program, Time-series sampling strategy Oxygen minimum zone	DESIRABLE	0.5m from bathers; 0.5m from area at greatest risk of pollution	photic zone; 5-10m from shore	2 times monthly	2 weeks
IDEAL	within the decorrelation is scale of the data) Sample similar / same	depths for deep water or higher resolutio n for euphotic zone.	revery few months (e.g., seasonal). Similar timing if building climatologie	organisms; monthly for long time-series	Depends on method		preserved for subsequent taxonomic analyses, or frozen (liquid nitrogen/-80C) Platforms: ships, small boats, autosamplers, marine snowcatchers, sediment traps	time-series design Continental-scale marine microblome time-series: Australian Marine Microbiome Initiative	MINIMUM	0.5m from bathers	photic zone	1 sample pre-bathing- season; 1 sample per month during the bathing season	1 month

PHENOMENA	Detection an	d enumera	tion of fecal in	dicator bacteria	a (Escherichia coli)					
EOV SUB-VARIABLE	Presence of	fecal indica	ator bacteria		DEFINITION		culture-based enumeration of Escherichia coll for water quality assessment in bathing waters			
	Resolution						_			
	Spatial Horizontal	Spatial Vertical	Temporal	Timeliness	Uncertainty Measurement	Stability	Sampling approach	References		
IDEAL	0.5m from bathers; within and 0.5m from area at greatest risk of pollution	photic zone; 5-10m from shore	4 times monthly (if high risk)	daily if hazardous (polluted) conditions are present (36-72h for analysis), in case of hazardous conditions 2 weeks	Can be >30% based on difficulty collecting a representative sample; and		100ml water is collected at each site, early morning to ensure time	Review of bathing water recommendations in England Uncertainties in stormwater E. coil levels		
DESIRABLE	0.5m from bathers; 0.5m from area at greatest risk of pollution	photic zone; 5-10m from shore	2 times monthly		2 weeks	analytical variation associated with culturing and counting E. coli ddPCR has 9.6%		to finalise the protocol that day; samples are refrigerated during	Droplet digital PCR (ddPCR) assay for Enterococcus and human associated fecal indicators	
MINIMUM	0.5m from bathers	photic zone	1 sample pre-bathing- season; 1 sample per month during the bathing season		uncertainty relative to EPA approved reference methods		transport to the lab	Application of droplet digital PCR in coastal water quality monitoring		



Specification sheets- Links to protocols

4. Observing approach, platforms and technologies

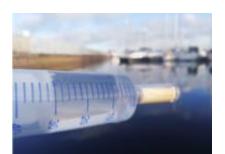
APPROACH / PLATFORM eDNA and Sequencing **Cultivation dependent Bacterial counts EOV SUB-VARIABLE(S)** Taxonomic diversity Taxonomic diversity Microbial abundance MEASURED cultivation on seawater agar + High throughput sequencing **TECHNIQUE / SENSOR TYPE** microscopy, cytometry nutrients media Marine Microbiome Initiative microbial sampling, section 5.5.9: Sample processing and storage. Bacterioplankton abundance, Chapter section 6.7; metadata collection, section 8.2, 8.3 Direct counts by microscopy: Sediment sampling for marine Marine microscopy image analysis: Zobell Marine Agar: microbes: Fluorescent in situ hybridisation Extraction of DNA from seawater: Culturing marine bacteria: SUGGESTED METHODS AND (FISH) for microbes in marine Library preparation for sequencing: **BEST PRACTICES** sediments: Microscopy: Morphological feature High throughput sequencing Colony-Forming Units*: identification (Illumina): Bacteria counts by flow cytometry DNA and RNA analytical workflows (for amplicon, metagenomic, * restricted to enumeration of metatranscriptomic sequences); culturable microbes Intercomparison of marine microbiome sampling protocols Temperature Temperature Temperature Depth Depth Depth SUPPORTING VARIABLES Salinity Salinity Salinity **MEASURED** Oxygen Oxygen Oxygen pH



Inter-comparisons of SOPs and mock communities



www.nature.com/ismecomms

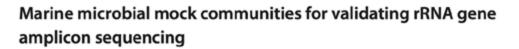


ARTICLE OPEN

Inter-comparison of marine microbiome sampling protocols

Francisco Pascoal (a) 1-2, Maria Paola Tomasino 3, Roberta Piredda 3, Grazia Marina Quero 4, Luís Torgo 5, Julie Poulain 6, Pierre E. Galand (a) 7, Jed A. Fuhrman (a) 8, Alex Mitchell 7, Tinkara Tinta 10, Timotej Turk Dermastia 10, Antonio Fernandez-Guerra (a) 11, Alessandro Vezzi (a) 12, Ramiro Logares (a) 13, Francesca Malfatti 114, Hisashi Endo (a) 15, Anna Maria Dabrowska (a) 16, Fabio De Pascale (a) 12, Pablo Sánchez (a) 13, Nicolas Henry (a) 17.18, Bruno Fosso 19, Bryan Wilson 10, Stephan Toshchakov (a) 11, Gregory Kevin Ferrant 12, Ivo Grigorov 13, Fabio Rocha Jimenez Vieira 14, Rodrígo Costa (a) 25.26, Stéphane Pesant (a) 288 and Catarina Magalhães (a) 1.288

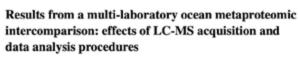
3 | Environmental Microbiology | Announcement



Robert H. Lampe, 1,2 Ariel J. Rabines, 1,2 Bryce A. Ellman, 1,2 Hong Zheng, 2 Andrew E. Allen 1,2







Mak A. Saito¹, Jaclyn K. Saunders^{1,2}, Matthew R. McIlvin², Erin M. Bertrand², John A. Breier³, Margaret Mars Brisbin³, Sophie M. Colston², Jaimee R. Compton³, Tim J. Griffin³, W. Judson Hervey⁴, Robert L. Hettich⁹, Pratik D. Jagtap², Michael Janech⁷, Red Johnson⁹, Rick Keil⁹, Hugo Kickiamp¹⁰, Dagmar Leary⁴, Lennart Martens^{5,1,8}, J. Scott P. McCain^{2,1,1}, Ei Moore^{2,2}, Subina Mehta², Dawn M. Moran³, Jaqui Neibauer², Benjamin A. Neely¹³, Michael V. Jakuba¹, Jim Johnson^{5,4}, Megan Duffy⁷, Gerhard J. Herndil¹, Richard Giannone⁶, Ryan Mueller¹⁵, Brook L. Nunn⁹, Martin Pabst⁹, Samantha Peters⁹, Andrew Rajczewski⁷, Elden Rowland³, Brian Searle¹⁶, Tim Van Den Bossche^{17,18}, Gary J. Vora⁴, Jacob R. Waldbauer¹⁹, Haiyan Zheng²⁰, and Zihao Zhao¹⁴

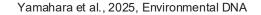


The Global Omics Observatory Network

Mission

Our mission is to federate omically enabled observatories and create an integrated, global system of multi-omic monitoring to enhance our capacity to understand, investigate, and monitor the biosphere. <u>Join us</u>





The specification sheet is a living document.
It should be updated with linked SOPs from intercomparison exercises.



Specification sheets- Data

5. Data and information management

Access to data and information is at the core of an ocean observing system. This section provides essential information on how to contribute data to the GOOS

GOOS approach to data management is aligned with open data and FAIR (Findable, Accessible, Interoperable, Reusable)¹ practices. All EOV data and information is valuable, thus effective data management practices are essential to ensure it remains accessible and (re)usable for future generations.

In this section you will be directed to resources that explain how you can contribute data to global ocean observing and ensure your data and information is accessible, interoperable and sustained. This resource has instructions for different scenarios: an individual submitting data, or existing data centres connecting to the system.

Please follow these practices carefully, as BioEco EOV data FAIRness relies on compliance with these guidelines.

Before proceeding, please note these important points:

- As a minimum, you must ensure information describing your EOV data (i.e. metadata) are visible in the <u>Ocean Data and Information System (ODIS)</u>². Regardless of where the actual data is stored, evidence of its existence must be findable within ODIS.
- BioEco EOV data is successfully managed if it is discoverable in the GOOS BioEco Portal. The BioEco Portal is the central point of access and coordination of BioEco EOV observing programmes. Data visible in ODIS will automatically be visible in the BioEco Portal and vice versa.
- If data is published to OBIS³, it will also be visible in ODIS and the BioEco Portal. You do not need to also add it elsewhere, unless there is extra
 information you would like to include.

The main data management steps are as follow:

- 1. Become discoverable: ensure the data producers (e.g., organisation, programme, project, etc.) and datasets are visible in ODIS
- 2. Prepare the required metadata about the data producer and the datasets
- 3. Publish EOV data (e.g. OBIS)
- 4. Verify discoverability in ODIS

OBIS is a global biodiversity database and IOC-UNESCO IODE component, connecting +30 nodes, +1000 institutions, and 99 countries, interoperating with other major biodiversity hubs like GBIF and makes data visible in ODIS as an ODIS node.



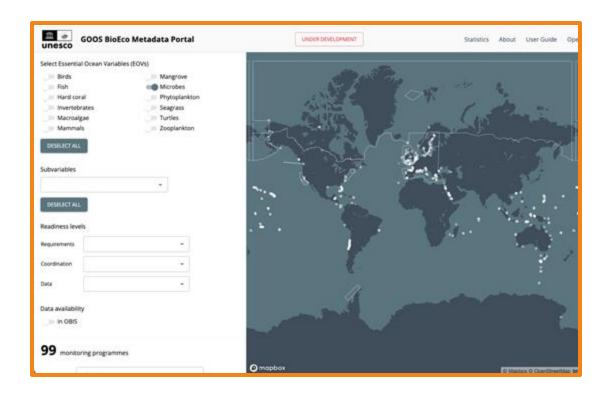
¹ Wilkinson et al. 2016 https://doi.org/10.1038/sdata.2016.18

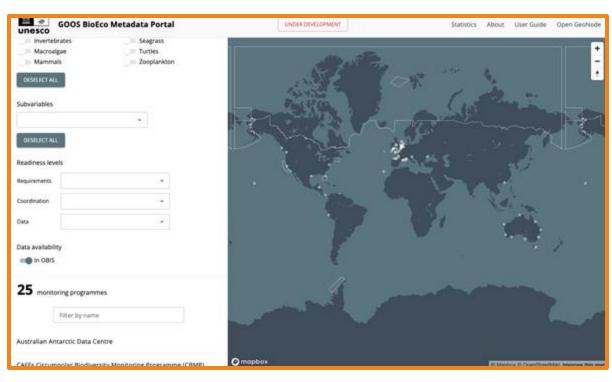
ODIS, part of IOC-UNESCO's International Oceanographic Data and Information Exchange (IODE), is a global federation of data systems sharing interoperable (meta)data about holdings, services, and other resources to enhance cross-domain data accessibility.

Microbial Observatories

MiCRO0	ESTOC
Bio-GO-SHIP	WCO (Station L4, E1)
European Marine Omics Biodiversity Observation Network (EMO BON)	Helgoland Land Roads
Aus Microbiome - IMOS Marine Microbiome	NEREA Augmented Observatory
Australian Microbiome	TARA
Hawai'i Ocean Times series (HOT)	Martha's Vineyard Coastal Observatory (MVCO)
Monterey Bay Time Series	Blanes Bay Microbial Observatory (BBMO)
Kāneʻohe Bay Time-series (KByT)	CeNCOOS MBON
HAUSGARTEN / FRAM	Bedford Basin Time-Series
South Florida Ecosystem Restoration (SFER)/Southeast US MBON	Saanich Inlet Time-Series
Boknis Eck	Arctic Marine Biodiversity Observation Network (AMBON)/Ecosystems & Fisheries Oceanography Coordinated Investigations (EcoFOCI)
Cabo Verde ocean Observatory (CVOO)	Linnaeus Microbial Observatory (LMO)
San Pedro Ocean Time Series (SPOT)	Microbial Observatory of the Laboratoire Arago
Ambon Bay Monitoring Programme	Blanes Bay Microbial Observatory
BATS	Northeast Shelf Long-Term Ecological Research (NES LTER)
	Northern California Current MBON

Microbial (meta)data in OBIS





Microbial

metadata

and

data



in OBIS

Global coordination is a collective and collaborative endeavour and many organisations contribute to the GOOS BioEco Panel and share GOOS vision





































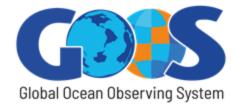


Julie Robidart





Alejandra Prieto-Davó



Thank you

goosocean.org









