The Global Ocean Observing System

GCOS

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Essential Ocean Variable Specification Sheet

Macroalgal Cover and Composition

Global Ocean Observing System (2024). Essential Ocean Variable Specification Sheet: Macroalgal canopy cover and composition. GOOS Reference No; DOI: [to be assigned]

EOV Specification Sheet curated by:

Biology and Ecosystems Panel

The Global Ocean Observing System

DETAILED INFORMATION ON HOW TO READ THE SPECIFICATION SHEET CAN BE FOUND IN THIS GUIDE

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Background and justification

Macroalgae forms the foundation of coastal ecosystems around the world, providing essential services for ocean ecosystems and humanity. Macroalgal forests and intertidal provide habitat, food, shoreline protection, nurseries, food for many global communities, and more. Kelp forests alone provide $500 billion USD in services per year (Eger et al. 2023). Intertidal algal canopies are valued roughly $5 million USD per mile of intertidal habitat (Hall et al. 2008).

Macroalgal habitats face serious threats from global, regional, and local stressors. Ocean warming, pollution, habitat degradation, the spread of invasive species, release of grazers due to overfishing, and more all weaken macroalgal systems and can lead to shifts and population collapse.

Macroalgal canopy cover and composition provides a strong measurement of ecosystem health and environmental change. Further, they are easy to measure, enabling scientists to monitor macroalgal changes, range shifts, and responses to broader environmental trends at multiple scales. Macroalgae make visible changes in ecosystems that would otherwise be difficult to measure. Their health and stability are essential not only for biodiversity, but also for supporting sustainable coastal economies.

Integration with Global Observation Frameworks

The Global Climate Observing System (GCOS) developed the Essential Climate Variable (ECV) framework to define necessary observations for monitoring Earth's climate (Bojinski et al., 2014). Some EOVs, including ocean physics, biogeochemistry, and biology/ecosystems variables (GCOS, 2022a; GCOS, 2022b), are also ECVs.

The Essential Biodiversity Variables (EBVs) defined and curated by the Group on Earth Observations Biodiversity Observation Network (GEO BON) complement the GOOS biological and ecosystem (BioEco) EOVs (Muller-Karger et al., 2018; Bax et al., 2019). The EOVs represent the basic observations of a particular parameter or process. EBVs are time series of biodiversity observations across genes, species populations, communities, or ecosystems. Thus, EOVs may be seen as the building blocks for GEO BON EBVa. The EOVs can be used to synthesise the EBVs as time series of BioEco EOV sub-variables at one location, or as time series of gridded, mapped, or modelled EOVs (Jetz et al., 2019).

The GOOS Biology and Ecosystems Panel collaborates with the Physics and Climate and Biogeochemistry Panels to advance EOVs, advocating for the need for biological observations, information management, and applications. GOOS, MBON, GEO BON, and OBIS work together to standardise guidelines and data management for EOVs, EBVs, and ECVs.

Current observing networks and coordination

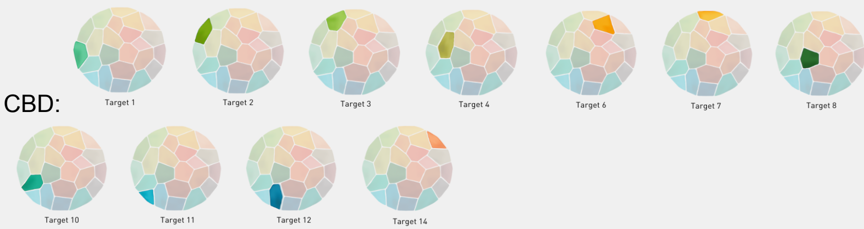
Diverse networks and communities are collecting observations of biology and ecosystems EOVs at different scales and in different regions. An initial baseline survey conducted in 2019/20 identified 203 active, long-term (>5 years) observing programs systematically sampling marine life. These programs spanned about 7% of the ocean surface area, mostly concentrated in coastal regions of the United States, Canada, Europe, and Australia (Satterthwaite et al 2021). This information can be found in the GOOS BioEco Metadata Portal, which is continually updated. To consult the latest information, please visit: https://bioeco.goosocean.org

Contributes to (please click on the symbol for more information):

Essential Biodiversity and Climate Variables

SDG:

CBD:



1. EOV information

ESSENTIAL OCEAN VARIABLE (EOV)	Macroalgal canopy cover and composition
DEFINITION	A measure of cover, abundance, and diversity of algae that provides habitat and shelter for understory species.
EOV SUB-VARIABLES - key measurements that are used to estimate the EOV	Canopy percent cover Macroalgal stipe density Canopy species diversity Areal extent
SUPPORTING VARIABLES - other measurements that are useful to provide scale or context to the sub-variables of the EOV	**Environmental :** Nutrients, Sea surface temperature, Subsurface temperature, Sea surface salinity, Subsurface salinity, Dissolved organic carbon, Ocean colour and derived products
	EOV related: Photosynthetic biomass, Canopy height, Plant size classes, Algal decomposition rate, Photosynthetic efficiency, Algal condition (e.g., signs of necrosis, fouling, and/or grazing), Extent of alternative habitats (e.g., barrens and turf beds), Species composition and abundance of understory assemblages
DERIVED PRODUCTS - outputs calculated from the EOV and sub-variables, often in combination with the supporting variables	Habitat extent, Canopy health indices, Global geographical distribution, Primary production

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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: Climate , ocean health , operational services

PHENOMENA TO OBSERVE		Status and trends in macroalgal canopy cover	Severe events/ population collapse/ regime shift	Recovery/Resilience	Range Shifts
PHENOMENA EXTENT	HORIZONTAL	Local to regional	Local to regional	Local to regional	Regional to continental
	VERTICAL	Photic zone	Photic zone	Photic zone	Photic zone
	TEMPORAL	Decadal	Annual to decadal	Annual to decadal	Annual to decadal
RESOLUTION TO OBSERVE PHENOMENA	HORIZONTAL	10m – 1000km	100m – 100 km	100m – 100km	100 – 1000km
	VERTICAL	0.5m – 30m	0.5m – 30m	0.5m – 30m	0.5m – 30m
	TEMPORAL	3-10 years	1-2 years	3-10 years	1-5 years
SIGNAL TO CAPTURE		20% Change	40% Loss	40% Gain	20% Range Movement
SUB-VARIABLES NEEDED TO MEASURE		Canopy percent cover Macroalgal stipe density Canopy species diversity	Canopy percent cover Macroalgal stipe density Canopy species diversity Areal extent	Canopy percent cover Macroalgal stipe density Canopy species diversity	Areal extent
SUPPORTING VARIABLES NEEDED					

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3. GOOS Observing Specifications or Requirements

This section outlines ideal measurements for an optimal observing system for this Essential Ocean Variable (EOV). It offers guidance on creating a long-term system to observe key phenomena related to the EOV. These values are not mandatory, and no single system is expected to meet all requirements. Instead, the combined efforts of various observing systems should aim to meet these goals. Observations at different scales are also valuable contributions to global ocean observation if shared openly.

EOV	Macroalgal canopy cover and composition
PHENOMENA	Status and trends in macroalgal canopy cover Severe events/population collapse/regime shift Recovery/Resilience

EOV SUB-VARIABLE	Canopy percent cover	**DEFINITION**	The percent of a single sample unity covered by macroalgal canopy species.

	Resolution			**Timeliness**	**Uncertainty Measurement**	**Stability**	**Sampling approach**	**References**
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	0.25m^2	NA	Monthly	Monthly data deposition	±1%	10 years	Visual sampling via in-person transects, quadrats, or photo/video monitoring. For larger spatial scales, drone or aerial imagery can be useful. For surface canopies, remote sensing at a 50m^2 or lower resolution.	Multi-Agency Rocky Intertidal Network Sampling Protocols Partnership for Interdisciplinary Studies of Coastal Oceans Kelp Forest Sampling Protocols Reef Life Survey Methods Santa Barbara Coastal LTER Kelp Forest Community Structure Methods - Percent Cover of Algae, Invertebrates and Bottom Substrate
DESIRABLE	1m^2	NA	Annual	Semi-annual data deposition	±3%	5 years		
MINIMUM	50m^2	NA	Bi-annual	Annual data deposition	±5%	3 years		

PHENOMENA	Status and trends in macroalgal canopy cover Severe events/population collapse/regime shift Recovery/Resilience

EOV SUB-VARIABLE	Macroalgal stipe density				**DEFINITION**		The number of algal stipes per unit area. Some algae have single stipes (e.g., *Saccharina latissima*) while some have multiple (e.g., *Macrocystis pyrifera*).	
	Resolution			**Timeliness**	**Uncertainty Measurement**	**Stability**	**Sampling approach**	**References**
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	0.25 m^2	NA	Monthly	Monthly data deposition	±1%	10 years	Visual sampling via in-person transects, quadrats. Photo/video monitoring only useful if algae can be individuated.	SBC LTER Kelp Forest Community Structure Methods - Density of algae and invertebrates SBC LTER SBC LTER Kelp Forest Community Structure Methods - Density of giant kelp Multi-Agency Rocky Intertidal Network Sampling Protocols Partnership for Interdisciplinary Studies of Coastal Oceans Kelp Forest Sampling Protocols
DESIRABLE	1 m^2	NA	Annual	6 months	±3%	5 years		
MINIMUM	50 m^2	NA	Bi-annual	Annual	±5%	3 years		

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PHENOMENA	Status and trends in macroalgal canopy cover Severe events/population collapse/regime shift Recovery/Resilience

<table>
<tr><td>EOV SUB-VARIABLE</td><td colspan="4">Canopy species diversity</td><td colspan="2">DEFINITION</td><td colspan="2">The number of algal species (i.e, richness) or an abundance adjusted estimate of the number of algal species (e.g., Hill Numbers).</td></tr>
<tr><td rowspan="2"></td><td colspan="3">Resolution</td><td rowspan="2">Timeliness</td><td rowspan="2">Uncertainty Measurement</td><td rowspan="2">Stability</td><td rowspan="2">Sampling approach</td><td rowspan="2">References</td></tr>
<tr><td>Spatial Horizontal</td><td>Spatial Vertical</td><td>Temporal</td></tr>
<tr><td>IDEAL</td><td>0.25 m^2</td><td>NA</td><td>Monthly</td><td>Monthly data deposition</td><td>±1%</td><td>10 years</td><td rowspan="3">Visual sampling via in-person transects, quadrats. Photo/video monitoring only useful if algae can be individuated. Hyperspectral techniques might be used in the future for remote sensing approaches</td><td rowspan="3">See references for above two subvariables.</td></tr>
<tr><td>DESIRABLE</td><td>1 m^2</td><td>NA</td><td>Annual</td><td>6 months</td><td>±3%</td><td>5 years</td></tr>
<tr><td>MINIMUM</td><td>50 m^2</td><td>NA</td><td>Bi-annual</td><td>Annual</td><td>±5%</td><td>3 years</td></tr>
</table>

PHENOMENA	Severe events/population collapse/regime shift Recovery/Resilience

EOV SUB-VARIABLE	Areal extent				**DEFINITION**		The spatial area of occupancy of macroalgal canopy.	
	Resolution			**Timeliness**	**Uncertainty Measurement**	**Stability**	**Sampling approach**	**References**
	Spatial Horizontal	**Spatial Vertical**	**Temporal**					
IDEAL	Global		Monthly	Real-time	±1%	10 years	Remote sensing approaches and large-scale biogeographic presence-absence surveys using either visual or eDNA methods.	Giant Kelp and Bull Kelp Canopy Dynamics from the Landsat Satellite Sensors (TM, ETM+, OLI), Santa Barbara Coastal LTER 2020 A DNA mini-barcode for marine macrophytes
DESIRABLE	Continental		Annual	6 months	±3%	5 years		
MINIMUM	Regional		Bi-annual	Annual	±5%	3 years		

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4. Observing approach, platforms and technologies

This table provides examples of approaches and technologies used to collect this EOV to help observe priority phenomena

APPROACH / PLATFORM	Visual Sampling	Photo Sampling	Satellite/Aerial Remote Sensing
EOV SUB-VARIABLE(S) MEASURED	Canopy percent cover Macroalgal stipe density Canopy species diversity	Canopy percent cover Canopy species diversity	Areal extent
TECHNIQUE / SENSOR TYPE	*In situ* observations	Photographic camera with post-processing using labelling tools or trained computer vision classifiers.	Satellite or aerial sensor.
SUGGESTED METHODS AND BEST PRACTICES	Costello et al. 2017	Reef Life Survey 2015, Bravo et al. 2021, Costello et al. 2017	Cavanaugh et al. 2010, Cavanaugh et al 2021
SUPPORTING VARIABLES MEASURED	Photosynthetic biomass Canopy height Plant size classes Algal condition Species composition and abundance of understory assemblages	Plant size classes Algal condition Species composition and abundance of understory assemblages Extent of alternative habitats	Photosynthetic biomass

APPROACH / PLATFORM	Remote Underwater Video	Remote/Autonomous Underwater Vehicle	eDNA
EOV SUB-VARIABLE(S) MEASURED	Canopy percent cover Canopy species diversity	Canopy percent cover Canopy species diversity	Areal extent Canopy species diversity
TECHNIQUE / SENSOR TYPE	Video camera with post-processing using labelling tools or trained computer vision classifiers.	Camera mounted on AUV/ROV with post-processing using labelling tools or trained computer vision classifiers.	Water or sediment samples used for molecular analysis.
SUGGESTED METHODS AND BEST PRACTICES	Reef Life Survey 2015, Monk et al. 2018	Monk et al. 2018	Djurhuus et al. 2017, Ortega et al. 2020
SUPPORTING VARIABLES MEASURED	Plant size classes Algal condition Species composition and abundance of understory assemblages Extent of alternative habitats	Plant size classes Algal condition Species composition and abundance of understory assemblages Extent of alternative habitats	Extent of alternative habitats Species composition of understory assemblage

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:

1. As a **minimum**, you must ensure information describing your EOV data (i.e. metadata) are visible in the Ocean Data and Information System (ODIS)[2]. Regardless of where the actual data is stored, evidence of its existence must be findable within ODIS.
2. 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.
3. If data is published to OBIS[3], 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

[1] Wilkinson et al. 2016 https://doi.org/10.1038/sdata.2016.18
[2] 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.
[3] 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.

Not all steps may be relevant for you, but **Step 1 is the minimum required** to ensure your data contributes to EOVs. .

TO CONTRIBUTE DATA AND METADATA TO THE GLOBAL OBSERVING SYSTEM, PLEASE GO TO: https://iobis.github.io/eov-data-management/

Figure 2. Map of OBIS Nodes. See https://obis.org/contact/ for a complete list.

Contact the OBIS Secretariat (helpdesk@obis.org) for help setting up your data workflows. To publish BioEco EOV data from systems like NCEI or ERDDAP to OBIS, consider becoming an OBIS node or collaborating with one. The OBIS Secretariat can help guide you through the process of becoming a Node, or connect you with an appropriate OBIS node (Figure 2).

Help Resources

- EOV Metadata Submission tool: https://eovmetadata.obis.org/

ODIS

- General help https://book.odis.org/index.html
- Connecting to ODIS https://book.odis.org/gettingStarted.html
- ODIS Catalogue of Sources: https://catalogue.odis.org/
- Ocean Info Hub: https://oceaninfohub.org/
- Schema.org framework https://schema.org/

OBIS

- OBIS Manual: https://manual.obis.org/
- OBIS YouTube data formatting and publishing videos: https://www.youtube.com/playlist?list=PLlgUwSvpCFS4TS7ZN0fhByj_3EBZ5IXbF
- Darwin Core term reference list: https://dwc.tdwg.org/terms/
- WoRMS taxonomy: https://www.marinespecies.org/
- Spreadsheet template generator https://www.nordatanet.no/aen/template-generator/config%3DDarwin%20Core
- BioData Guide with example code for transforming datasets to DwC: https://ioos.github.io/bio_data_guide/

GOOS BioEco Portal

- Documentation https://iobis.github.io/bioeco-docs/
- Access https://bioeco.goosocean.org/

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Background information

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Acronyms and Abbreviations

CBD: Convention on Biological Diversity

EBV: Essential Biodiversity Variables

ECV: Essential Climate Variables

EOV: Essential Ocean Variables

GCOS: Global Climate Observing System

GEO BON: Group on Earth Observations Biodiversity Observation Network

GOOS: Global Ocean Observing System

IOCCP: International Ocean Carbon Coordination Project

MBON: Marine Biodiversity Observation Network

OBIS: Ocean Biodiversity Information System

ODIS: Ocean Data Information System

OCG: Observation Coordination Group

OOPC:Ocean Observations Physics and Climate Panel

SDG: Sustainable Development Goals

Glossary of terms

Derived products: outputs calculated from the EOV and sub-variables, often in combination with the supporting variables, that contribute to evaluating change in phenomena. For example, evaporation can be determined from sea surface temperature measurements; air-sea fluxes of CO2 can be derived from inorganic carbon EOV; fish stock productivity can be determined from fish abundance.

Indicators: An indicator can be defined as a 'measure based on verifiable data that conveys information about more than just itself'. This means that indicators are purpose dependent - the interpretation or meaning given to the data depends on the purpose or issue of concern. (BIP definition)

Measurement Uncertainty: the parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand (GUM)1. It includes all contributions to the uncertainty, expressed in units of 2 standard deviations, unless stated otherwise

Phenomena: properties (e.g., of a species such as distribution), processes (e.g., of the ocean such as surface ocean heat flux), or events (e.g., such as algal blooms) that have distinct spatial and temporal scales, and when observed, inform evaluations of ocean state and ocean change

Stability: The change in bias over time. Stability is quoted per decade.

Supporting variables: other measurements that are useful to provide scale or context to the sub-variables of the EOV (e.g., pressure measurements to provide information on the depth at which subsurface currents are estimated, sea temperature to understand dissolved inorganic carbon, water turbidity to support estimations of hard coral cover).

Sub-variables: key measurements that are used to estimate the EOV (e.g., counts of individuals to provide an estimate of species abundance (such as fish, mammals, seabirds or turtles), partial pressure of carbon dioxide (pCO_2)to estimate ocean inorganic carbon, or wave height to estimate sea state).

Timeliness: The time expectation for availability of data measured from the data acquisition time.

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Appendix - Additional information

A1. Applications

This table provides examples of applications of this EOV, including, contribution to other essential variable frameworks, multilateral environmental agreements, contribution to indicators and GOOS applications

EOV		
CORRESPONDING ESSENTIAL VARIABLES	ECV	
	EBV	
GLOBAL INDICATORS EOV CAN CONTRIBUTE	**SDG**	
	CBD	
	CLIMATE	
	OTHER	
GOOS APPLICATIONS		

A2. Additional supporting material and literature

Suggested literature

Other material

A3. Readiness level assessment

Essential Ocean Variable Specification Sheet

Sponsored by: