# Why observe the ocean?



Climate action

Blue economy

Forecasts & early warnings

Community adaptation

Ocean health

Carbon strategies

But the ocean is so vast, no one country can observe it effectively on its own.
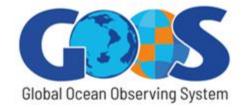
# The Global Ocean Observing System (GOOS)

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

# Vision

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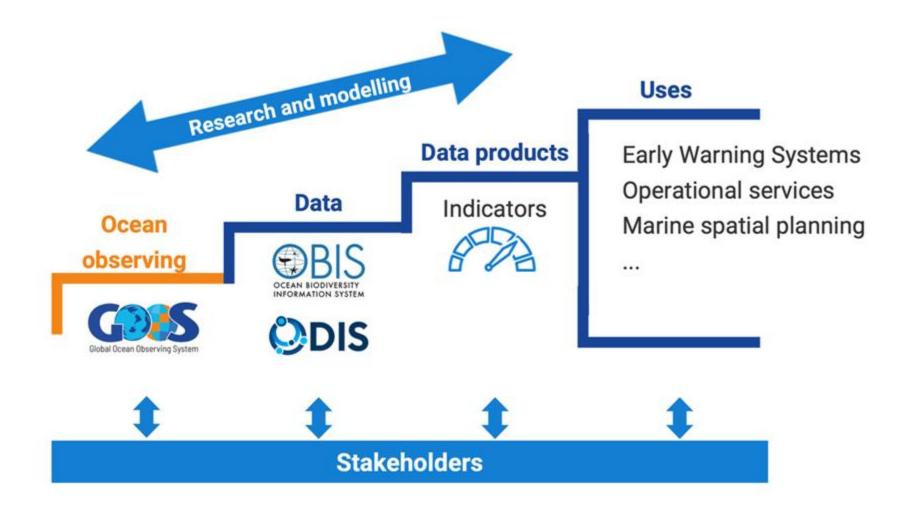
# Mission

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!
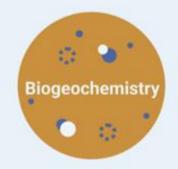
EOVs focus on **three** main delivery areas:

**Climate**

**Operational Services**

**Ocean Health**

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

**Physics and Climate**

**Biology and Ecosystems**

**Biogeochemistry**

EOVs can be described by **three** key elements:

**Sub-variables**

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

**Supporting Variables**

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

**Derived Products**

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

**CLIMATE**

United Nations Climate Change — **Paris Agreement**

**OPERATIONAL SERVICES**

SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION 2015-2030 — **Disaster Risk Reduction**

WORLD METEOROLOGICAL ORGANIZATION — **Weather forecasting and hazard warnings**

IMO INTERNATIONAL MARITIME ORGANIZATION — **Safety at sea, optimised routing, energy optimisation**

**OCEAN HEALTH**

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

UN environment programme — **Plastics Treaty**

THE LAW OF THE SEA — **Biodiversity Beyond National Jurisdiction**
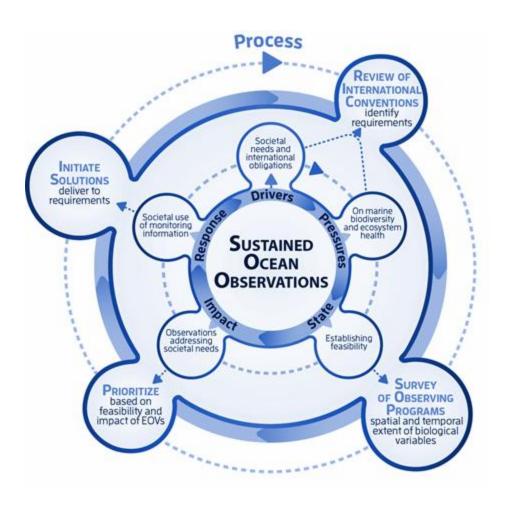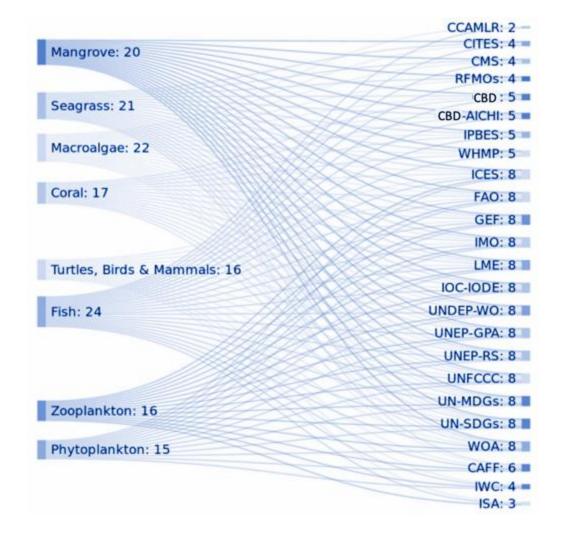
14 LIFE BELOW WATER — **SDG14 / Sustainable Ocean Management**

Biogeochemical EOVs

Biology & Ecosystems EOVs

Physical EOVs

GOOS — Global Ocean Observing System

# 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

**Fish**
Abundance and distribution

**Sea turtles**
Abundance and distribution

**Seabirds**
Abundance and distribution

**Marine mammal**
Abundance and distribution

# Habitat State

**\*Seagrass**
Cover and composition

**\*Macroalgal canopy**
Cover and composition

**\*Mangrove**
Cover and composition

**\*Coral**
Cover and composition

# Cross panel

**\*Ocean Colour**

**Ocean Sound**

\*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

## MBON
### Marine Biodiversity Observation Network

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

## OBIS
### OCEAN BIODIVERSITY INFORMATION SYSTEM

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

# The impact of coordinated observations
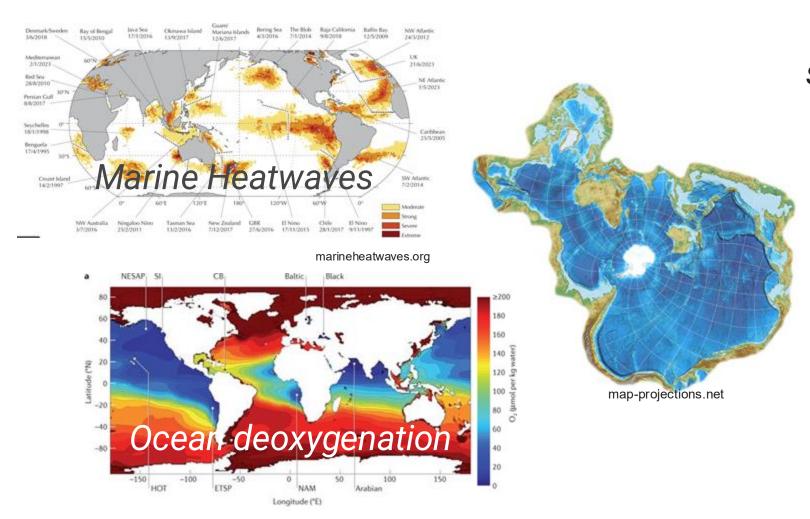


Pesant, S., *et al*. Open science resources for the discovery and analysis of *Tara* Oceans data. *Sci Data* **2**, 150023 (2015). https://doi.org/10.1038/sdata.2015.23
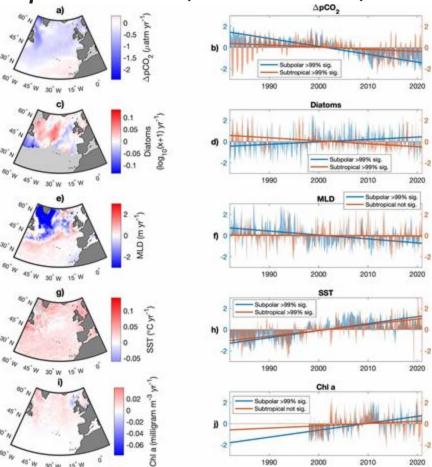
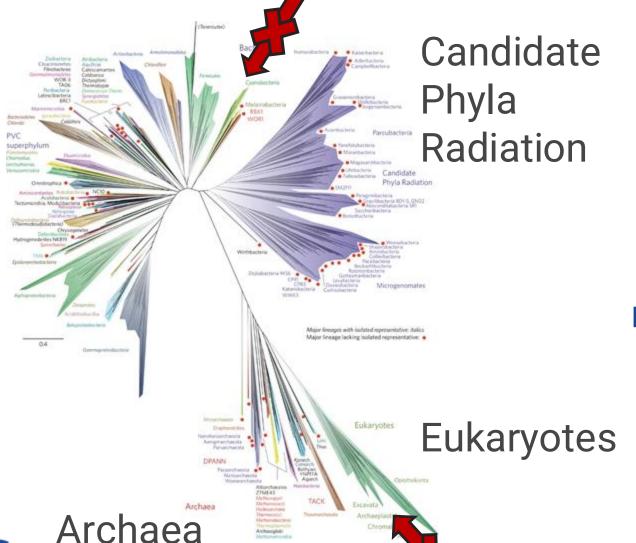# Coordinated networks to address ocean challenges



Marine Heatwaves

marineheatwaves.org



Ocean deoxygenation

Wright et al., 2012 Nature Reviews Microbiology



map-projections.net

*Effects on carbon sequestration, food webs, etc.*



Ostle et al., 2022 Environmental Research Letters

# "Microbes" operational definition



Candidate Phyla Radiation

Bacteria

Eukaryotes

Archaea

"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."
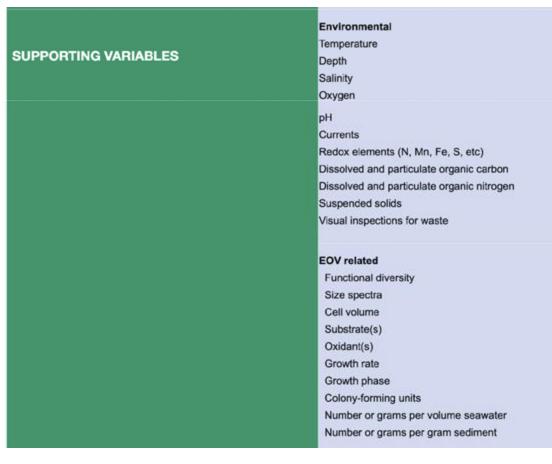
Hug, L.A., Baker, B.J., et al., 2016. A new view of the tree of life. *Nature microbiology*, *1*(5), pp.1-6.

# 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.<br><br>Microbial biomass refers to:<br>- weight (mass as the concentration per unit area/volume),<br>- abundance or quantity of organisms (number of individuals per unit area or volume, or per mass of sediment).<br>Microbial diversity refers to:<br>- variability of microbes from all sources; including diversity within and between species (genetic diversity, functional diversity, etc.) |
| EOV SUB-VARIABLES key measurements that are used to estimate the EOV<br><br>*bare minimum | * Microbial concentration (biomass / abundance)<br>* Diversity<br>- Genomic and genetic diversity<br>- Phenotypic diversity<br>- Functional diversity<br><br>Presence of fecal indicator bacteria |

**SUPPORTING VARIABLES**

**Environmental**
Temperature
Depth
Salinity
Oxygen

pH
Currents
Redox elements (N, Mn, Fe, S, etc)
Dissolved and particulate organic carbon
Dissolved and particulate organic nitrogen
Suspended solids
Visual inspections for waste

**EOV related**
Functional diversity
Size spectra
Cell volume
Substrate(s)
Oxidant(s)
Growth rate
Growth phase
Colony-forming units
Number or grams per volume seawater
Number or grams per gram sediment

| 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 |
|---|---|

https://goosocean.org/document/36264

# 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.

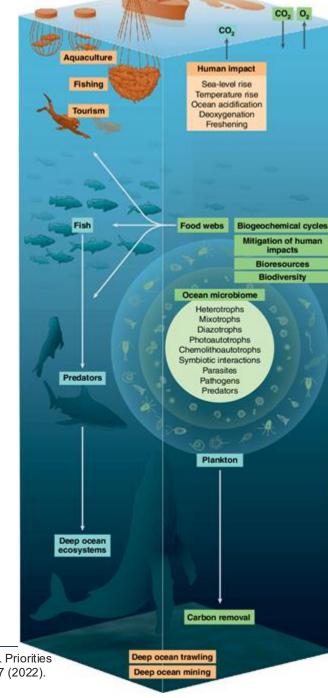The GOOS application area(s) the phenomena are relevant for are depicted as follows: Climate [icon], ocean health [icon], operational services [icon]

| 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 |
|---|---|---|---|---|---|
| PHENOMENA EXTENT | HORIZONTAL | Sequences of taxonomic / functional gene markers or full metagenomic sequencing tracked locally, regionally, or globally (meters to 1000's of kilometers) depending on the application | Amount of carbon, nitrogen, 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 throughput 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 |

# Specification sheets- Links to observatory design

# Specification sheets- Links to protocols



## 4. Observing approach, platforms and technologies

This table provides examples of approaches and technologies used to collect this EOV to help observe priority phenomena.
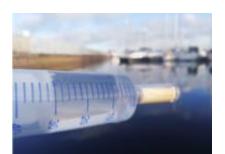
| APPROACH / PLATFORM | eDNA and Sequencing | Cultivation dependent | Bacterial counts |
|---|---|---|---|
| EOV SUB-VARIABLE(S) MEASURED | Taxonomic diversity | Taxonomic diversity | Microbial abundance |
| TECHNIQUE / SENSOR TYPE | High throughput sequencing | cultivation on seawater agar + nutrients media | microscopy, cytometry |
| SUGGESTED METHODS AND BEST PRACTICES | Marine Microbiome Initiative microbial sampling, section 5.5.9; Sample processing and storage, section 6.7; metadata collection, section 8.2, 8.3 Sediment sampling for marine microbes; Extraction of DNA from seawater; Library preparation for sequencing; High throughput sequencing (Illumina); DNA and RNA analytical workflows (for amplicon, metagenomic, metatranscriptomic sequences); Intercomparison of marine microbiome sampling protocols | Zobell Marine Agar; Culturing marine bacteria; Microscopy; Morphological feature identification | Bacterioplankton abundance, Chapter 18 Direct counts by microscopy; Marine microscopy image analysis; Fluorescent in situ hybridisation (FISH) for microbes in marine sediments; Colony-Forming Units*; Bacteria counts by flow cytometry * restricted to enumeration of culturable microbes |
| SUPPORTING VARIABLES MEASURED | Temperature Depth Salinity Oxygen pH | Temperature Depth Salinity Oxygen pH | Temperature Depth Salinity Oxygen pH |

# Inter-comparisons of SOPs and mock communities



Yamahara et al., 2025, Environmental DNA

*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:

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

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[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.
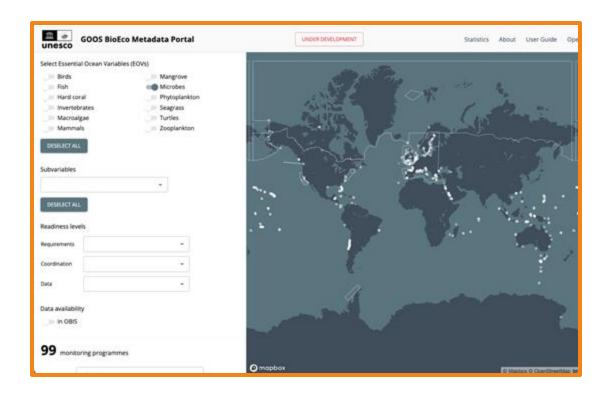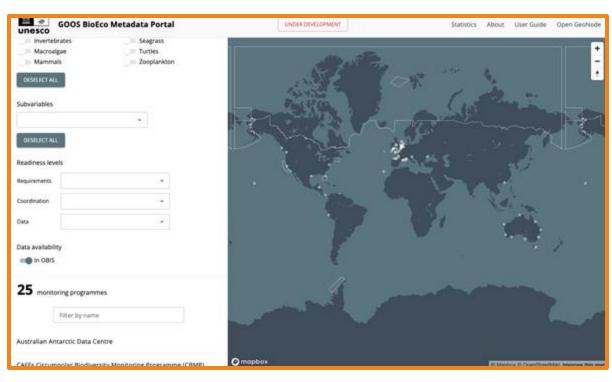
# Microbial Observatories

| | |
|---|---|
| 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
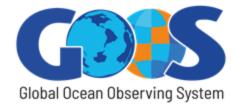


Julie Robidart

Alejandra Prieto-Davó

# Thank you

goosocean.org

Giiulia Wood

Dimitris Poursanidis / Ocean Image Bank