Overview of Marine BON activities, EBVs and EOVs

http://www.marinebon.org/

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Vision and Goal

Develop a community of practice to understand changes in marine biodiversity

Focus:
- US Integrated Ocean Observing System
- National Marine Sanctuaries
- Intergovernmental Oceanographic Commission (IOC/UNESCO: GOOS, OBIS, Ocean Best Practices)
- GEO BON: help develop EBVs
OBIS – THE Ocean Biogeographic Information System

>50 million records

+8600 records daily in 2017

120,000 marine species

>2500 datasets

>600 institutions

33 OBIS nodes
Present SURFACE OCEAN (upper 20 m) OBIS records
2/3 of our knowledge is in the upper layer (5% of the ocean)

Same issues of lack of coverage and minimal biodiversity observations in coastal areas:

- wetlands
- estuaries
- rocky shores
- beaches
Linking Essential Biodiversity Variables (EBVs) and Essential Ocean Variables

Based on the Framework for Ocean Observing (OceanObs ‘09):

- Essential Biodiversity Variables (EBVs)
- Essential Climate Variables (ECVs, GCOS)
- Essential Ocean Variables (EOVs, GOOS)
- EBV complement the EOV
Essential Biodiversity Variables (EBV)

Scenarios for biodiversity & ecosystem services (e.g. for IPBES)

High-level indicators of biodiversity & ecosystem services (e.g. for CBD)

Ancillary attributes (slow changing)

Ecosystem-service valuation & other data

Observations of drivers & pressures

Essential Biodiversity Variables

Genetic composition

Community composition

Species populations

Ecosystem structure

Species traits

Ecosystem function

Primary observations of change in state of biodiversity

In-situ monitoring

Remote sensing

Observations of policy & management responses

<table>
<thead>
<tr>
<th>PHYSICS</th>
<th>BIOGEOCHEMISTRY</th>
<th>BIOLOGY AND ECOSYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea state</td>
<td>Oxygen</td>
<td>Phytoplankton biomass and diversity</td>
</tr>
<tr>
<td>Ocean surface stress</td>
<td>Nutrients</td>
<td>Zooplankton biomass and diversity</td>
</tr>
<tr>
<td>Sea ice</td>
<td>Inorganic carbon</td>
<td>Fish abundance and distribution</td>
</tr>
<tr>
<td>Sea surface height</td>
<td>Transient tracers</td>
<td>Marine turtles, birds, mammals abundance and distribution</td>
</tr>
<tr>
<td>Sea surface temperature</td>
<td>Particulate matter</td>
<td>Hard coral cover and composition</td>
</tr>
<tr>
<td>Subsurface temperature</td>
<td>Nitrous oxide</td>
<td>Seagrass cover</td>
</tr>
<tr>
<td>Surface currents</td>
<td>Stable carbon isotopes</td>
<td>Macrolgal canopy cover</td>
</tr>
<tr>
<td>Subsurface currents</td>
<td>Dissolved organic carbon</td>
<td>Mangrove cover</td>
</tr>
<tr>
<td>Sea surface salinity</td>
<td>Ocean colour (<em>Spec Sheet under development</em>)</td>
<td>Microbe biomass and diversity (<em>emerging</em>)</td>
</tr>
<tr>
<td>Subsurface salinity</td>
<td></td>
<td>Benthic invertebrate abundance and distribution (<em>emerging</em>)</td>
</tr>
<tr>
<td>Ocean surface heat flux</td>
<td></td>
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</tbody>
</table>
Conceptual, complementary relationship between EOVs and EBVs

(TBM: marine turtles, birds, and mammals)

Example EBVs: GC – Genetic composition; SP – Species populations; ST – Species traits; CC – Community composition; ES – Ecosystem structure; EF – Ecosystem function.

Building a global ocean biodiversity observing system: Use what already exists: 15 GOOS Regional Alliances + LTER, etc.
Scales of variation and observation

- Physical processes at different scales affect different biological processes

- Different technologies are suited for different observations

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Table 1. Main ranges of spatial, temporal, and spectral resolutions used in the terrestrial and global environment, including marine and atmospheric domains.

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Environment</th>
<th>Low resolution</th>
<th>Medium resolution</th>
<th>High resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial</td>
<td>Terrestrial</td>
<td>30 – 1000 m</td>
<td>4 – 30 m</td>
<td>0.4 – 4 m</td>
</tr>
<tr>
<td></td>
<td>Marine</td>
<td>10 – 50 km</td>
<td>2 – 10 km</td>
<td>≤ 1 km</td>
</tr>
<tr>
<td>Temporal</td>
<td>Terrestrial</td>
<td>&gt; 16 d</td>
<td>4 – 16 d</td>
<td>1 – 3 d</td>
</tr>
<tr>
<td></td>
<td>Marine</td>
<td>&gt; 5 d</td>
<td>1 – 5 d</td>
<td>≤ 1 d</td>
</tr>
<tr>
<td>Spectral</td>
<td>–</td>
<td>1 channel (e.g. panchromatic)</td>
<td>3 – 10 channels</td>
<td>≥ 10 channels (hyperspectral)</td>
</tr>
</tbody>
</table>
Remote sensing elements for Earth Observation

**Other constellations:**
- European Commission / ESA
- Russia
- China
- India
- Japan / JAXA
Ocean covers large area of our planet (>70%)  
Coastal zones are critical for humans and biodiversity
Remote Sensing of Aquatic Essential Biodiversity Variables (EBV):
More could be achieved with $H4*$ sensors (orange boxes)

*$H4$: High spectral  High spatial  High Temporal  High quality

<table>
<thead>
<tr>
<th>EBV class</th>
<th>EBV</th>
<th>Wetland Vegetation</th>
<th>Benthic Communities</th>
<th>Pelagic Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic composition</td>
<td>Population genetic diversity</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Species populations</td>
<td>Distribution</td>
<td></td>
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<tr>
<td></td>
<td>Abundance</td>
<td></td>
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<tr>
<td></td>
<td>Size/vertical distribution</td>
<td></td>
<td></td>
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<tr>
<td>Species traits</td>
<td>Pigments</td>
<td></td>
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<tr>
<td></td>
<td>Phenology</td>
<td></td>
<td></td>
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<tr>
<td>Community composition</td>
<td>Taxonomic diversity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecosystem structure</td>
<td>Functional type</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Fragmentation/ heterogeneity</td>
<td></td>
<td>ROUTINE USE FOR OPEN OCEAN</td>
<td></td>
</tr>
<tr>
<td>Ecosystem function</td>
<td>Net primary production</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Net ecosystem production</td>
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</tbody>
</table>

Legend:

- Unproven
- Demonstrated limited cases
- Routine use
- Habitat model required

Rapid changes in nuisance cyanobacteria (*phycocyanin pigment index*)

In situ measurements every 15 minutes daily with hand-held spectrometer used to identify the organism in Upper Mantua Lake (Italy).

16 days: grey vertical bars
3-day: Orange vertical bars

From Hestir et al 2015
Many examples of rapid change in aquatic cyanobacteria and harmful algae concentrations.

Identification of cyanobacteria using spectral info from the ground.

(graph: Kudela et al. 2015).
HICO shows *Mesodinium rubrum* bloom because it has fluorescence information provided by hyperspectral data.
MODIS 1 km pixel grid on 30 m Landsat-8 OLI image

Figure 5: Three-band water-leaving reflectance composite image from OLI at the location where the Potomac River enters Chesapeake Bay. MODIS Aqua scan pixel boundaries for the same date are overlaid to demonstrate the sub-pixel variability revealed by the higher spatial resolution of OLI. The $R_{rs}(\lambda)$ were retrieved using standard NASA ocean color processing in SeaDAS, and red, green, and blue reflectances at $\lambda = (655, 561, 443$ nm) were combined to form the image.
Fig. 3. Effects of increasingly coarser resolution on spatial representation of an example wetland. Shown is an inset of a rasterized layer from polygon data mapped in Fig. 2 for the Estuarine and Marine Wetland type (see the double-line box in Fig. 2).

From Turpie et al 2015
Coastal / Great Lakes aquatic remote sensing priorities

- High temporal
  - At some representative locations: twice weekly or more

- High spatial (~30-90 m)
  - Global + regional intensive
  - Consistency with Landsat history and global coverage

- High spectral (VIS and SWIR)
  - VIS can be ~5 nm except higher (~2 nm or better) in key areas such as around chlorophyll fluorescence (~685 nm) and O2 absorption bands

- Radiometric/geolocation: high quality
  - High SNR (ocean color class), high digitization/quantitization, minimal polarization sensitivity, minimal cross-talk or other out-of-band, atmospheric correction scheme (including adjacency), sun-glint avoidance, cloud screening/masking, etc.
  - High geolocation accuracy

- Robust and data processing and distribution
IOOS/NASA/BOEM/NSF/SI
MBON Demonstration

- Florida Keys
- Monterey Bay
- Channel Islands
- Chukchi Sea

US MBON stations
Tennenbaum/MarineGEO stations (Smithsonian)
The US MBON demonstration program

- Monterey Bay
- Florida Keys
- Channel Islands
- Flower Garden Banks

**Sanctuaries MBON**

**Data Integration:**
- IOOS/GOOS
- I-OBIS
- GEO BON

**Multivariate seascape analysis**

**eDNA**

**Web-based information system**

- Sanctuary Condition Reports
- Resource managers and policy makers
- Scientists and educators

**Supports**
Pole to Pole MBON

Image: Mean surface Chl-a from SeaWIFS. Black line shows Large Marine Ecosystems.
## Evolving technology matrix: *Biology ‘beyond fluorescence’*

<table>
<thead>
<tr>
<th>Data archaeology, data management <em>(Darwin Core)</em>, Products/indicators</th>
<th>Microbes/Phyto</th>
<th>Zooplankton</th>
<th>Fish</th>
<th>Top Predators</th>
<th>Benthos, habitat forming</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</table>

### Optics/Imaging

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<th>Microbes/Phyto</th>
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<tbody>
<tr>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Benthic</td>
<td>X</td>
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</table>

### Animal tracking (satellite, underwater)

<table>
<thead>
<tr>
<th>Animal tracking (satellite, underwater)</th>
<th>Microbes/Phyto</th>
<th>Zooplankton</th>
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</table>

### Acoustics

<table>
<thead>
<tr>
<th>Acoustics</th>
<th>Microbes/Phyto</th>
<th>Zooplankton</th>
<th>Fish</th>
<th>Top Predators</th>
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<tbody>
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### Genomics

<table>
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<th>Microbes/Phyto</th>
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<tbody>
<tr>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</tbody>
</table>

### Platforms with samplers

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<th>Fish</th>
<th>Top Predators</th>
<th>Benthos, habitat forming</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUVs, floats, moorings, satellites</td>
<td>AUVs, moorings</td>
<td>AUVs, moorings</td>
<td>AUVs, moorings, tags</td>
<td>AUVs, moorings, satellites</td>
<td></td>
</tr>
</tbody>
</table>

### Biological-physical / ecological *models*

<table>
<thead>
<tr>
<th>Biological-physical / ecological <em>models</em></th>
<th>Microbes/Phyto</th>
<th>Zooplankton</th>
<th>Fish</th>
<th>Top Predators</th>
<th>Benthos, habitat forming</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>X?</td>
<td>X??</td>
<td>X??</td>
<td>X??</td>
<td>X??</td>
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</tbody>
</table>
Societally-relevant products need linked data pipelines

At least 5 pipelines need to be linked:

- Satellite data (space agencies)
- In situ environmental data (NCEI, DataOne, GOOS)
- Genetic (GenBank/NCBI, RefSeq, Gene Home, SRA, etc.)
- Biodiversity (OBIS, GBIF, others)
- Socio-economic data

The Imaging Flow Cytobot (above) and basic specs (below). (Heidi Sosik – WHOI)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>32 kg</td>
</tr>
<tr>
<td>Diameter</td>
<td>26 cm</td>
</tr>
<tr>
<td>Height</td>
<td>102 cm</td>
</tr>
<tr>
<td>Max Depth</td>
<td>40 m</td>
</tr>
<tr>
<td>Duration</td>
<td>Up to 6 mo.</td>
</tr>
<tr>
<td>Frequency</td>
<td>5 mL/20 min</td>
</tr>
<tr>
<td>Power</td>
<td>35W, 18-36VDC</td>
</tr>
<tr>
<td>Comms</td>
<td>10/100/1000-BaseT Ethernet</td>
</tr>
</tbody>
</table>

Phytoplankton cells automatically identified and categorized by the IFCB analysis software, from samples collected at Port Aransas, TX. (Lisa Campbell - TAMU)

Daily time series at MVCO from 2003 to 2016


Changes in phenology with changes in temperature
Figure 1: a) UVP5, b) specimens and vertical distribution of copepods (blue), particles below 200 µm (black) and particles above 500 µm (red) at station 20 of Malina cruise, c) specimen and vertical distribution of appendicularia (blue), particles below 200 µm (black) and particles above 500 µm (red) at station 20 of Malina cruise.

Underwater Vision Profiler (UVP): Zooplankton taxonomy, size, and counts

THE CONTINUOUS PLANKTON RECORDER (CPR)
The Marine Biological Association of the UK
https://www.mba.ac.uk/fellows/cpr-survey

CPR is the only way we have now to get time series of plankton along very long transects. Very useful for fisheries and species distribution changes (due to climate and other factors)

The US NMFS/IOOS should re-establish the US CPR lines in partnership with MBA

...with a commitment to process the data (zooplankton and phytoplankton), release it to Darwin Core
Active Acoustics
Many other things can be learned about marine animal movement and behavior using telemetry capabilities:
- migration corridors
- breeding behavior
- feeding behavior
- biodiversity hotspots

Animal borne sensors and telemetry

Animal Telemetry Network: ATN
https://atn.ioos.us
Environmental DNA (eDNA)

A cheaper, less invasive and larger scale approach to monitor species diversity - Each marker is most sensitive towards detecting different groups of organisms

- Skin and scales
- Tissue
- Free DNA
- Metabolic waste
- Microbial cells

Markers:
- 16S rDNA
- 18S rDNA
- COI
- 12S rDNA
Global and regional satellite-derived environmental fields (weekly, monthly, seasonal climatologies)

Sea Surface Temperature

Phytoplankton fluorescence

Sea ice

Dissolved org. C index

Chlorophyll-a

+ other fields…
Dynamic seascapes: biogeographic framework for global and regional MBONs

**Multiple biophysical synoptic datasets**

**Global classification**

- Dynamic+2D

**Regional relevance**

**Objectives**

- Multiscale classification
- Case Studies: polar, temperate, subtropic
- Habitat –species relationships: plankton to fish
- Operational products: NOAA CoastWatch, Axiom, NASA COVERAGE

**Biology: Ocean Color**

Physics: e.g. SSS, SST, winds, SSHa

Regional downscaling

High resolution, local validation

**Area (km²)**

“Anchovy habitat”

Dynamic habitat maps: forage fish community, NOAA SWFSC

Maria Kavanaugh (OSU)
mkavanau@ceoas.oregonstate.edu

J. Grebmeier (U. MD), D. Otis, E. Montes, F. Muller Karger (USF), D. Wright (ESRI), R. Sayre (USGS), G. Canonico (NOAA), V. Tsontos & J. Vasquez (NASA JPL)
Seascape validation in south Florida waters

- March 14-18, 2016
- May 9-13, 2016
- September 12-19, 2016

In situ variables:
- Pigments (HPLC)
- Bio-optics ($a_{phy}$)
- eDNA
- Zooplankton (64, 200, 500 um)
- Phytoplankton taxa (microscopy)
- Environmental variables (nits, temp., salinity, etc)
Seasonal shifts of phytoplankton assemblages
Also validating: eDNA, zooplankton

*In prep:* Dynamic satellite seascapes as predictors of seasonal shifts of phytoplankton assemblages in south Florida waters. Enrique Montes, Anni Djurhuus, Christopher R. Kelble, Daniel Otis, Frank E. Muller-Karger, and Maria T. Kavanaugh
Information for Sanctuary Condition Reports

**Condition Report Questions**

**WATER:**
- Q1: Eutrophication
- Q2: Human health risks
- Q4: Stressors

**HABITAT:**
- Q5: Habitat dist. / health
- Q14: Human impacts

**LIVING RESOURCES:**
- Q7: Keystone species
- Q9: Invasive species
- Q8: Focal species
- Q10: Biodiversity status
- Q17: Fishing status
- Q17: Human impacts
NCEAS Global Marine Ecosystems layers:

- Beach
- Coral Reefs
- Deep Hard Bottom
- Deep Soft Benthic
- Deep Waters
- Hard Shelf
- Hard Slope
- Intertidal Mud
- Kelp
- Mangroves
- Rocky Intertidal
- Rocky Reef
- Salt Marsh
- Seagrass
- Seamounts
- Soft Shelf
- Soft Slope
- Sub-tidal Soft Bottom
- Surface Waters
- Suspension-Feeder Reef

Note: Abyssal-Hadal layers to be created

NASA, other regional/global data

Infographic of local habitats (EEZ, LME)

Local data/time series

Collaborators:
B. Best, J. Brown, L. McEachron, E. Montes
Web-based interactive tools for Pole to Pole MBON

www.marinebon.org

Number of species (OBIS)

Redlist protection level (OBIS)

Chl-a

Explorer

Infographics

Chlorophyll for Argentina
Dynamically updating status and trends:

https://mbon.ioos.us/
Dynamically updating status and trends

Infographics
Audience: Public, managers, educators

Curated Data Views
Audience: Advisory groups, researchers, teams

Data portals
Audience: Scientists, technical experts
Key messages

• MBON is developing a community of practice to monitor life in the sea with GEO BON IOC (GOOS, OBIS, Ocean Best Practices)

• Biodiversity Observing System need to focus on:
  – Promote standards for a manageable number of variables
  – Integrate biodiversity, physical, chemical, geological obs.
  – Sensor development for biodiversity (beyond fluorescence)
  – Deliver data to linked databases (use DarwinCore schema)

• Product development: Scale ancillary data matrices, offer in a format accessible to many applications in addition to RS product

• Integrate land, ocean and other aquatic areas in truly ‘global’ biodiversity cover and trends / maps

• Continue to integrate land/aquatic communities