May 24, 2019

MBON

Marine Biodiversity Observation Network

Sanctuaries MBON

Monterey Bay,
Florida Keys, and
Flower Garden Banks
National Marine Sanctuaries

Principal Investigators:
Frank Muller-Karger (USF)
Francisco Chávez (MBARI)

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[2] MBARI/CenCOOS, CA;
[3] Oregon State University, Corvallis, OR;
[4] NOAA Office of National Marine Sanctuaries (ONMS), Washington, DC;
[5] Texas A&M University (TAMU/GCOOS), College Station, TX;
[6] NOAA Florida Keys National Marine Sanctuary (FKNMS), Key West, FL;
[7] NOAA Monterey Bay National Marine Sanct. (MBNMS), Monterey, CA;
[8] NOAA SW Fisheries Science Center (SWFSC), La Jolla, CA,
[9] Center for Ocean Solutions, Stanford University, Pacific Grove, CA;
[10] Florida Fish and Wildlife Research Institute (FWRI), St Petersburg, FL;
[11]NOAA Office of Response and Restoration (ORR), Seattle, WA;
[12]NOAA SE Fisheries Science Center (SEFSC), Miami, FL;
[13]NOAA Atlantic Oceanographic and Meteorol. Lab. (AOML), Miami, FL;
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MBON
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The MBON vision:

Good and timely information on marine biodiversity sustains the long-term health and use of marine ecosystems

Huge investments have gone into ocean observing systems — but there is no systematic effort to observe life in the sea

MBON Goal: Enable the effort to characterize how marine biodiversity is changing and how it affects us

The NOPP Sanctuaries MBON Pilot:
Primary Goals of Cooperative Agreement

- Integrate, synthesize, augment biodiversity information from ongoing programs
- Develop technologies for biodiversity assessments through:
  - Emerging environmental DNA (*eDNA*) molecular methods and autonomous sample collection;
  - Application of remote sensing to evaluate biogeographic *Seascapes*
- Bring biodiversity and environmental data together and serve it using international standards
- Use advanced analyses to link the mean and fluctuating components of biodiversity and ecosystem function to environmental conditions
- Relate information to social-economic context and provide information rapidly to stakeholders
- Seek to do this as an operational system
- Work with other US MBON demonstration projects to develop network concept
- Export the MBON concept globally

NOPP
National Oceanographic Partnership Program

Addressing User Needs

Sanctuary sites engaged with California Current IEA, MBON demonstration projects and Gulf of Mexico IEA

Collaboration of IEA with MBON Marine Biodiversity Observation Network

U.S. MBON PORTAL

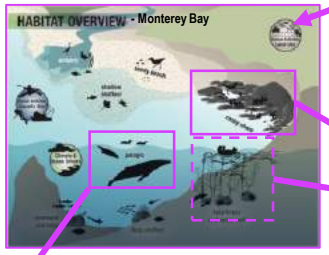
The NOPP Sanctuaries MBON Pilot: Integration of information using international standards

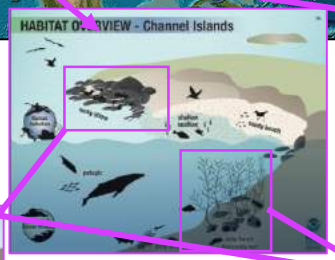
- Multiple, multi-agency, international satellite and in situ datasets
- State data sets
  - GCOOS (FL, Alabama, Mississippi, Louisiana, Texas)
  - CenCOOS (CA)
- Augmented Monterey Bay Time series (eDNA)
- Augmented the South Florida Program (eDNA, plankton)
- NOAA/State Fisheries and Reef surveys
  - Reef Visual Surveys, Rockfish Recruitment & Ecol Assessment, Coral Reef
  - Physical and chemical oceanographic data
- Beach Strandings data
- Many different environmental data
- Contributed to developing the MBON Portal (IOOS) and open source information tools

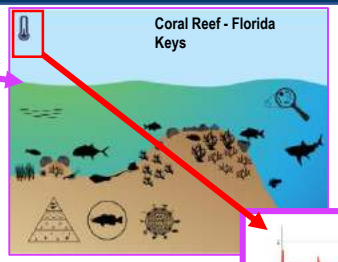
Addressing Sanctuary Needs: data tools

Processes and products being shared across programs and regions

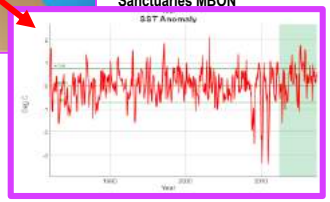
Collaboration between sanctuaries, IEA, MBON expanding to Gulf of Mexico

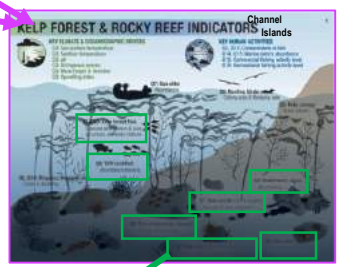


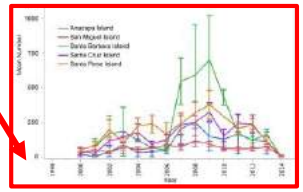




Currently conceptual models and data products under Development by Sanctuaries MBON

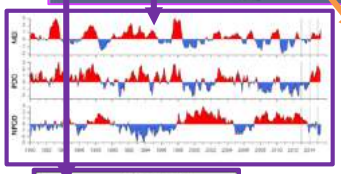


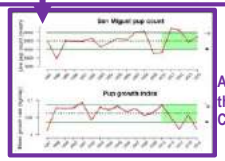




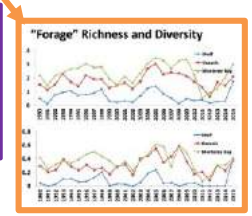
MARINe long-term monitoring data

Gulf of Mexico IEA meeting with FKNMS, including Sanctuaries MBON partners, to expand collaboration apply IEA products and processes to the sanctuary.

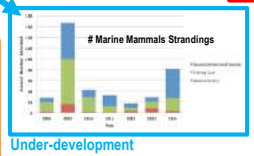




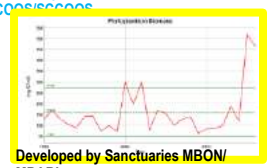
Available through CCIEA



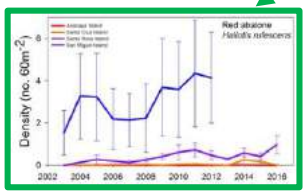
Developed by Sanctuaries MBON



Under-development CeNCOOS/SCCOOS



Developed by Sanctuaries MBON/ MBARI



PISCO / CINP / LTER data

FKNMS Demo: https://marinebon.github.io/info-fk/corals.html

MBNMS Demo: https://marinebon.github.io/info-mb/pelagic.html

Collaboration of

MBON Marine Biodiversity Observation Network

U.S. MBON PORTAL

https://mbon.ioos.us/

Inventories and "Curated data views"!

Outcomes in Information Management:

- Established a framework for operational biological observations, data management, communications
  - Biodiversity Information Standards (TDWG; Taxonomic Databases WG)
  - Darwin Core / Event Core: data standard; Publish/Harvest data: ERDDAP
  - Framework adopted by US IOOS and broadly discussed at NOAA
- Developed pathways for incorporation of eDNA into national and international repositories
- International: Bon in a Box: Contributing IOC Best Practices, OBIS

MBON Marine Biodiversity Observation Network

NOPP National Oceanographic Partnership Program

In memory of Matt Howard, whose leadership demonstrated the MBON framework for IOOS

The NOPP Sanctuaries MBON Pilot:
Primary Goals of Cooperative Agreement

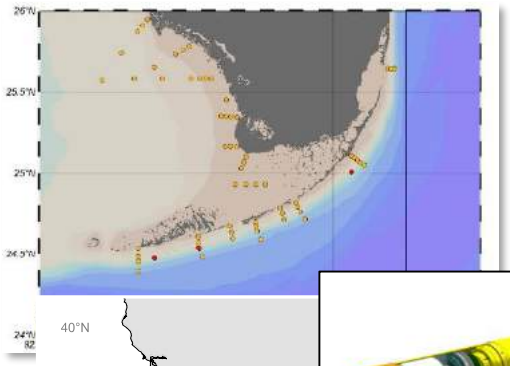
- Develop technologies for biodiversity assessments through:
  - Emerging environmental DNA (*eDNA*) molecular methods and autonomous sample collection;
  - Application of remote sensing to evaluate biogeographic *Seascapes*

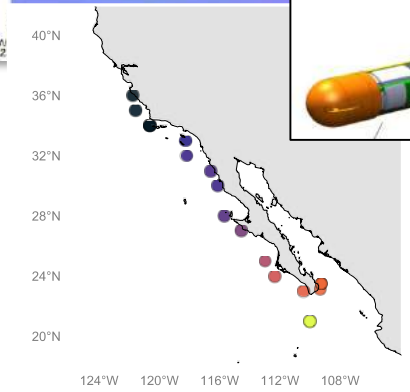
National Oceanographic Partnership Program

MBON
Marine Biodiversity Observation Network

Active Biodiversity Field Programs

Gulf of Mexico / South Florida, Northern Gulf
Monterey Bay / Southern California
Sampling Sanctuaries with big and small boats,
and automated devices (AUVs, etc.)

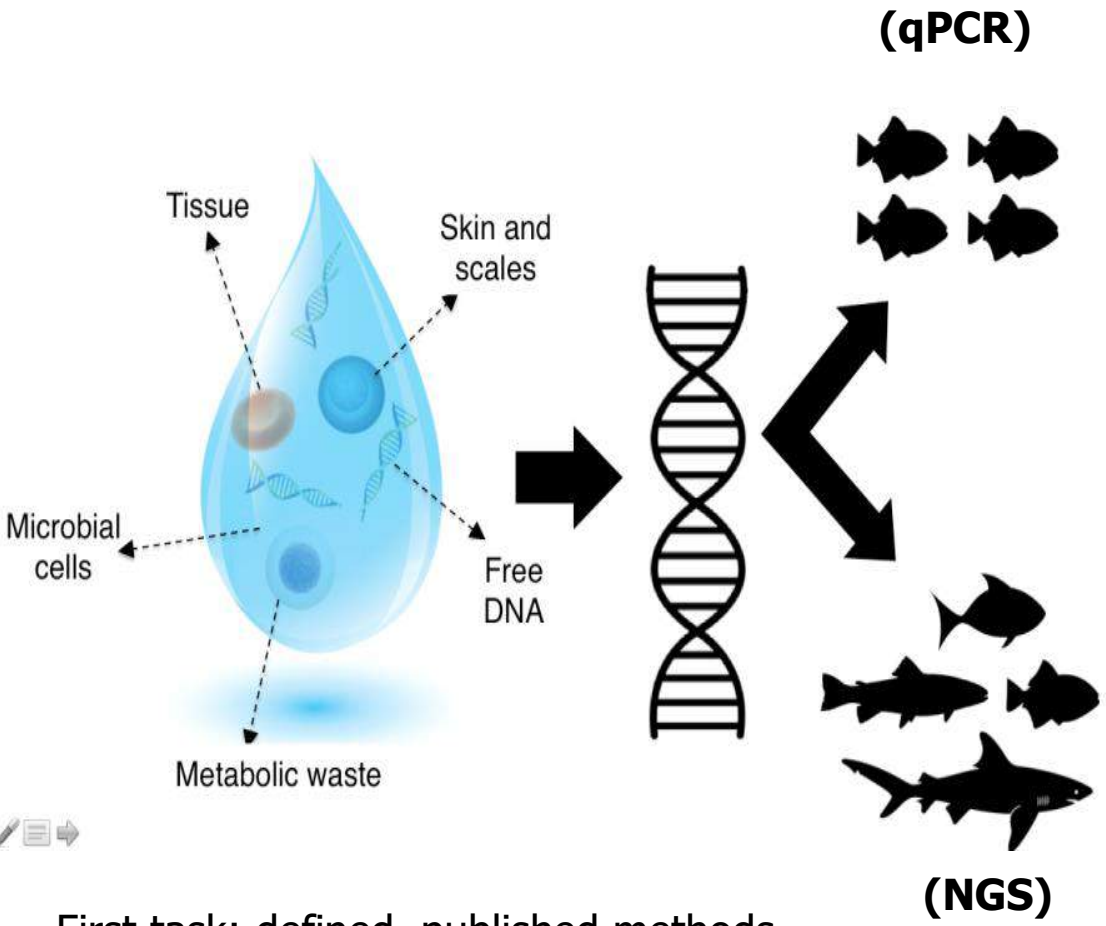




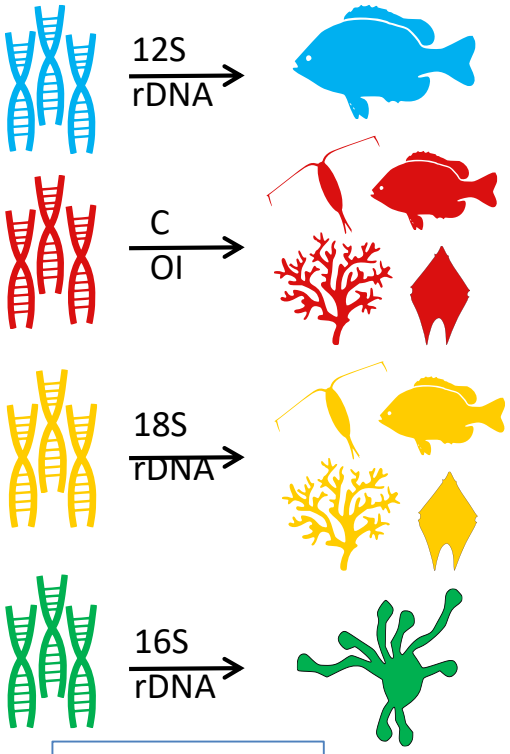
Over 45 expeditions in each FL Keys & MB

Marine environmental DNA (MBON)

A cheaper, less invasive and larger scale strategy to monitor species diversity – two approaches: next generation sequencing (NGS) and species specific primers



Target Gene Markers



Djurhuus et al. 2017

Each marker targets a different group of organisms.

First task: defined, published methods

eDNA summary statistics

Monterey Bay (2013-2019)

- >50 cruises
- Samples collected: >1500

Florida Keys (2015-2019)

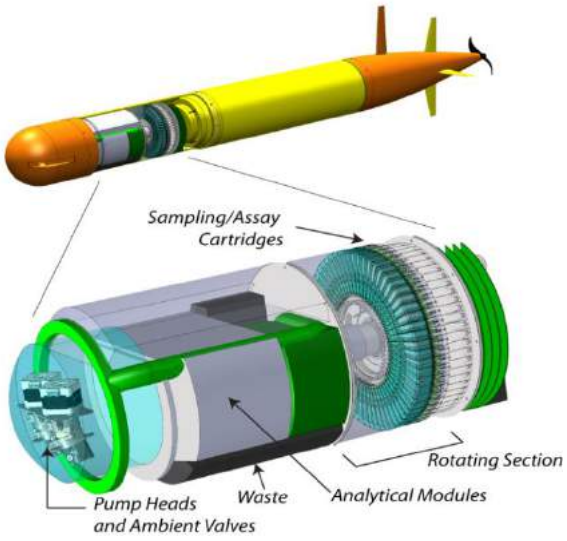
- >20 cruises
- Samples collected: >1300

Santa Barbara (2015-2017)

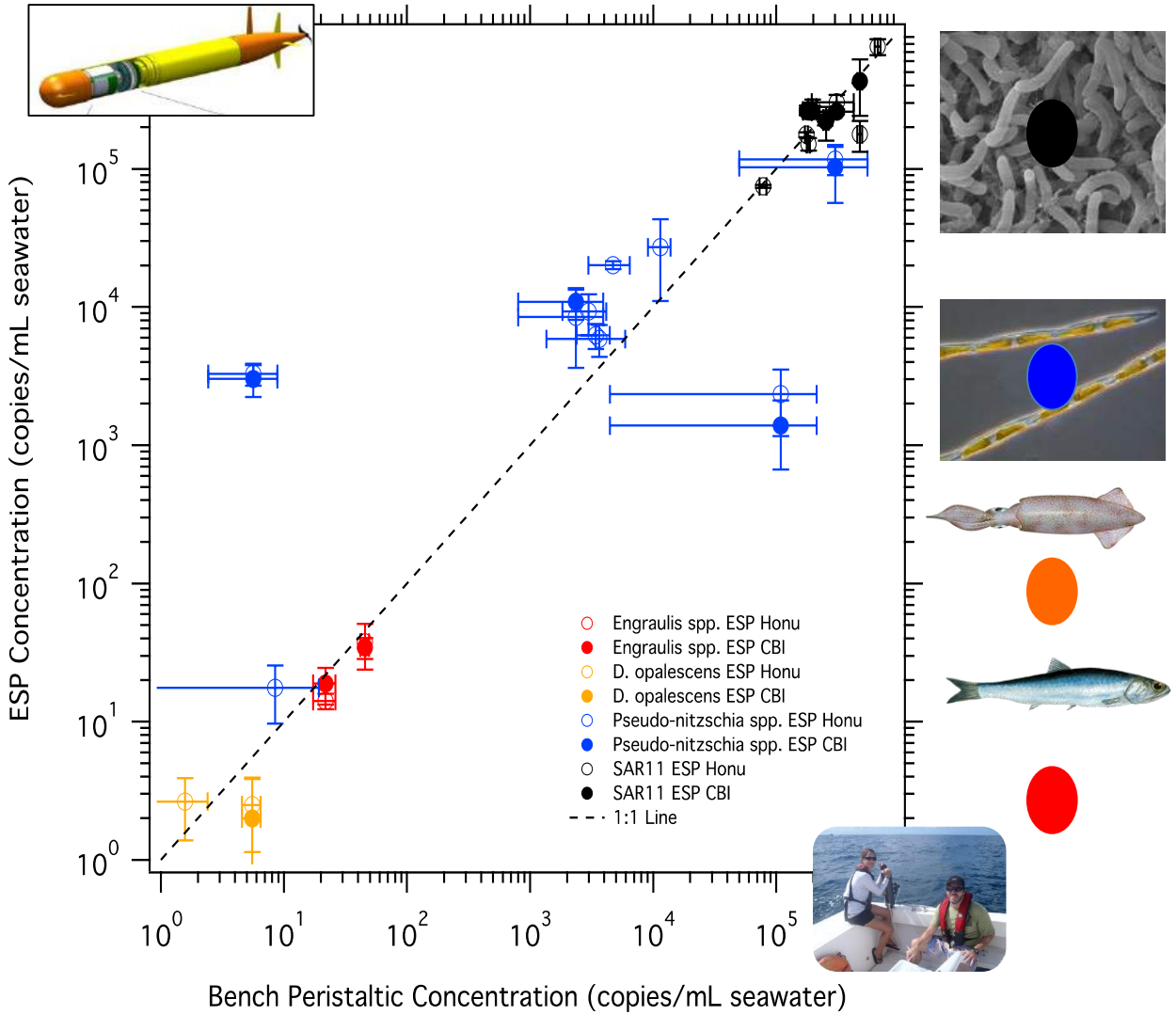
- 11 Diver surveys

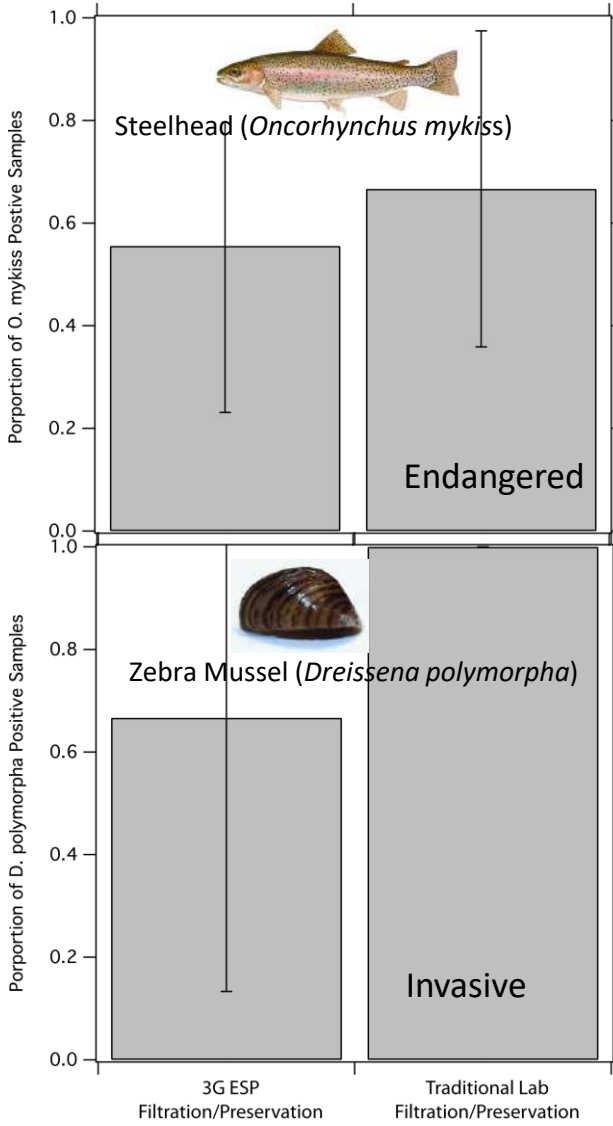
AUV (2015-2018)

- 26 missions
- Autonomous eDNA samples collected: 366
  - Sequenced for 18S: 5
  - Sequenced for COI: 19



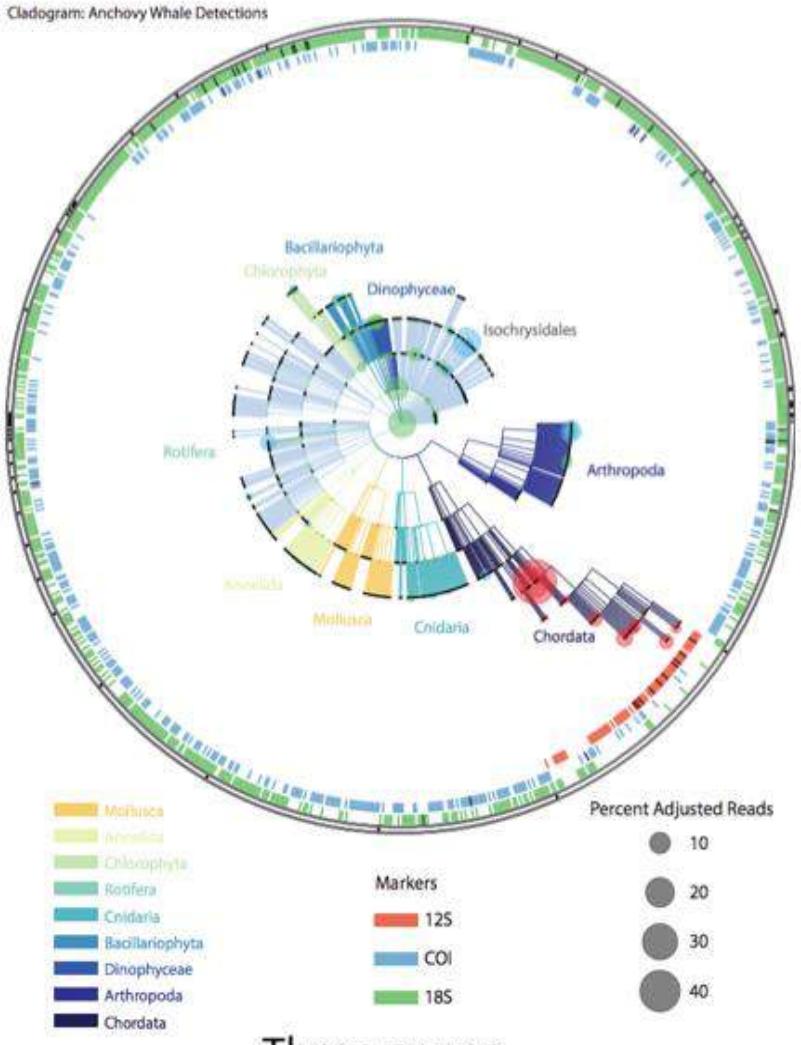
ESP vs Traditional Laboratory Methods





Yamahara et al., submitted

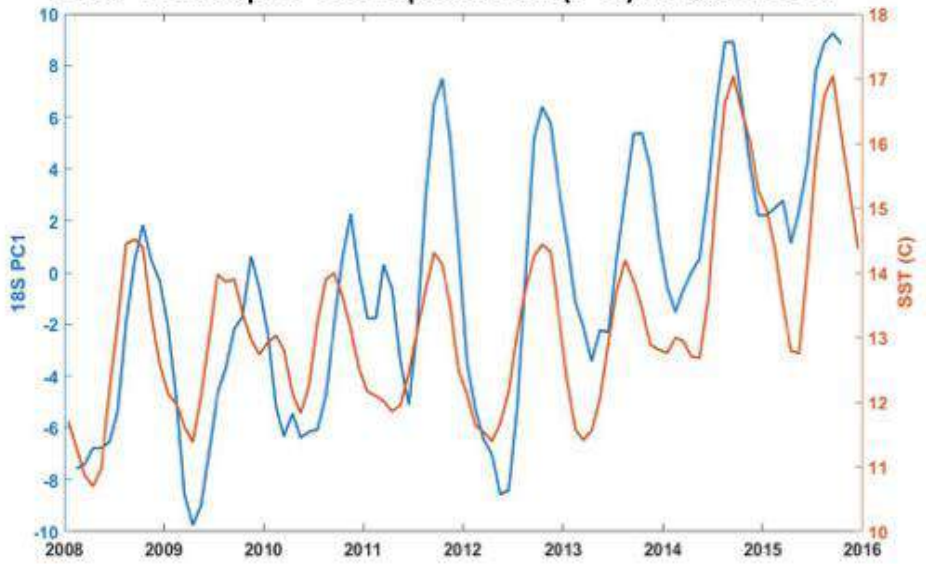
Marine biodiversity monthly over 8 years from eDNA



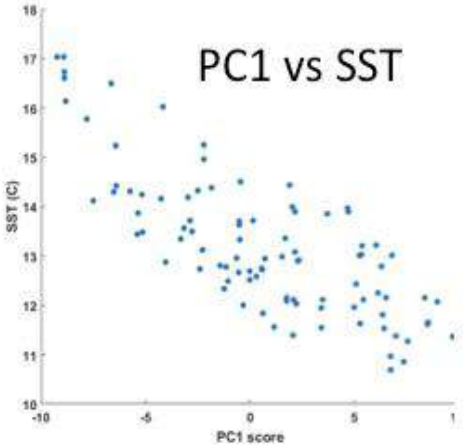
Three genes

(Pitz et al. in prep)

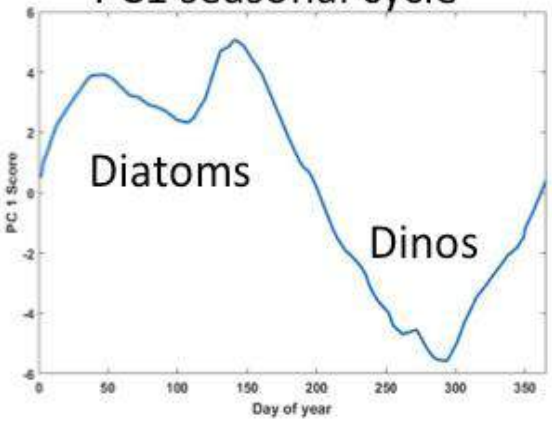
18S Principal Component (PC) 1 and SST



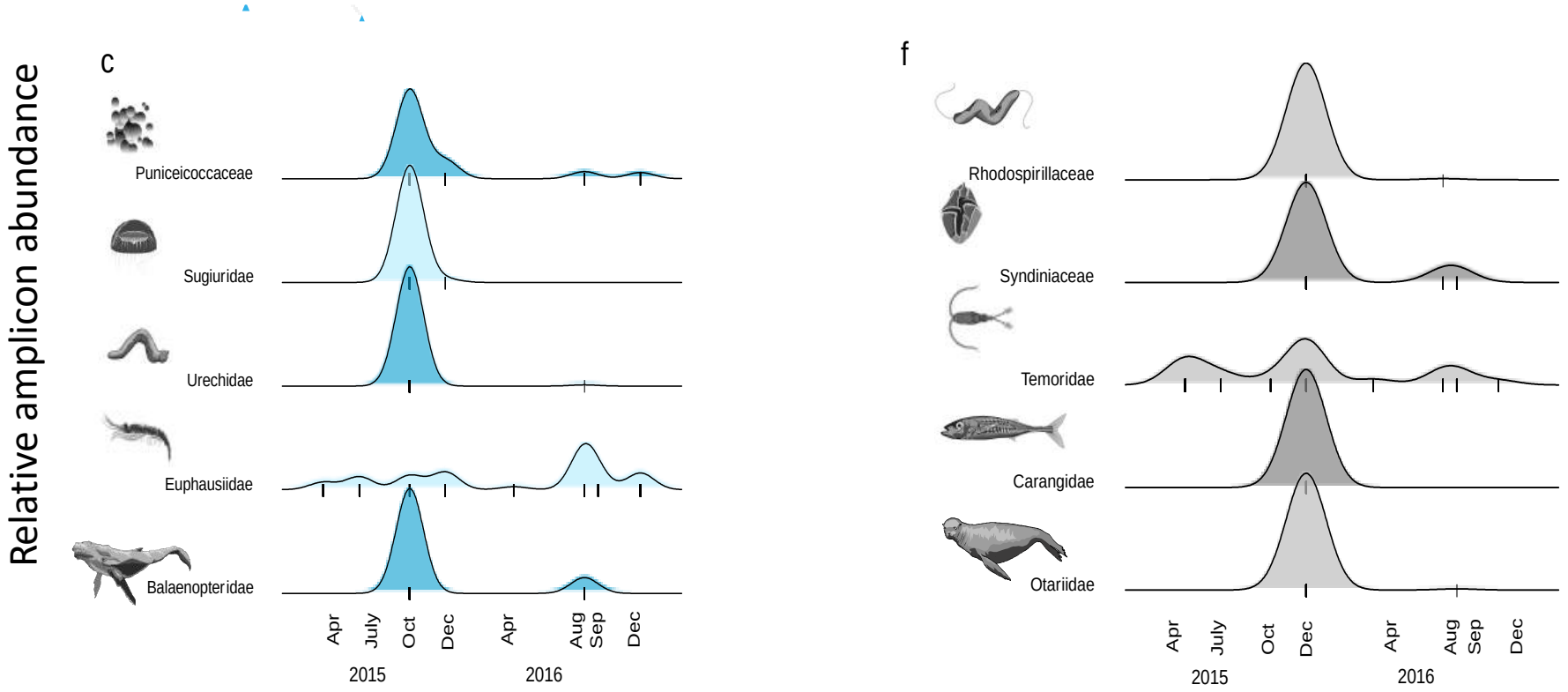
PC1 vs SST



PC1 seasonal cycle

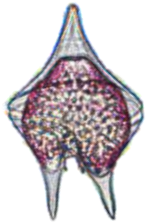


eDNA: Microbes to whales



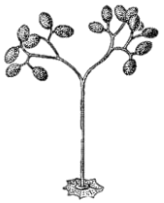
Balaenoptera

Rhodospirillaceae

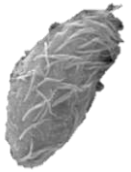


Protoperidinium

Peronosporales



Doliolidae

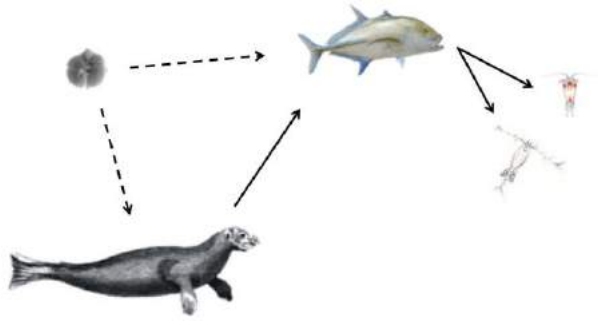


Marynidae

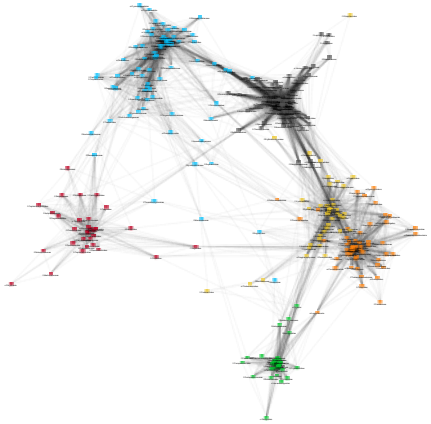
adjurhuus@mail.usf.edu

What information does eDNA provide?

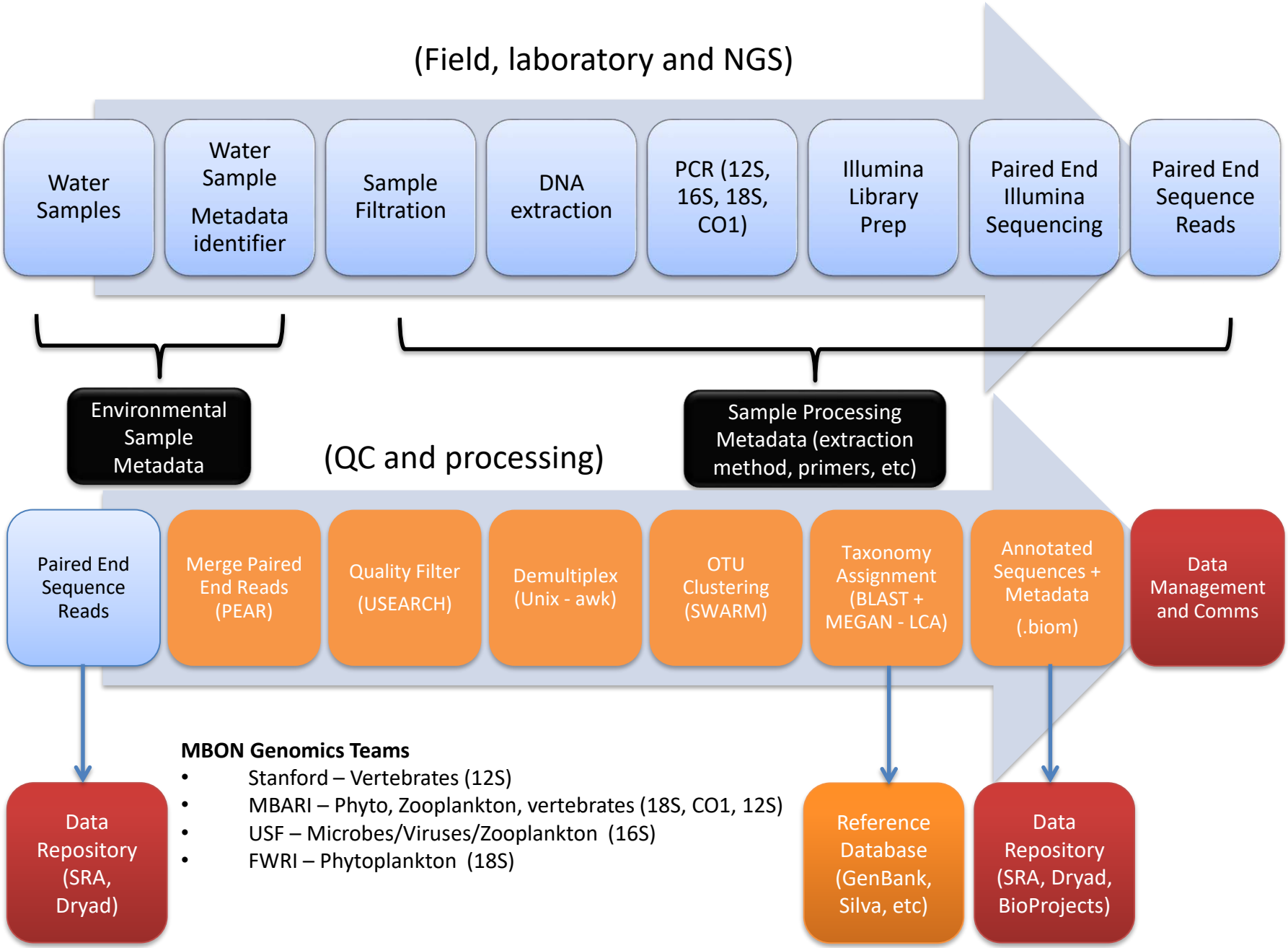
1. Interactions between trophic levels



2. Total biodiversity and indicator species over time



Bioinformatics - MBON Sequencing Work and Data Flow



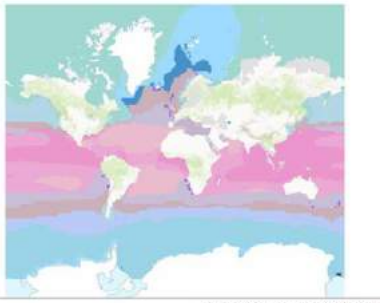
Satellite-derived Seascapes

Kavanaugh (OSU), Doney (UVa), Grebmeier (UMCES), Wright (ESRI), Otis, Montes, Djurhuus, Muller-Karger (USF)

- Regional to global classification of dynamic seascapes
- EMU intercalibration (R. Sayre/USGS, D Wright/Esri)
- Case Studies: Arctic, West Coast, Florida
- Habitat –species relationships
- Operational multiscale products: collaboration with NOAA NESDIS (P DiGiacomo, J Trinanes, G Goni)

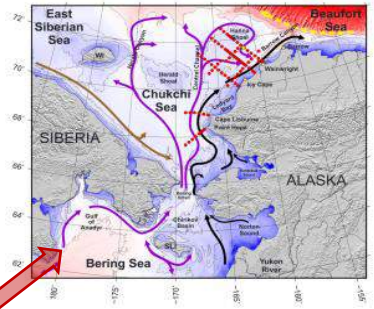
Global classification

Static+3D



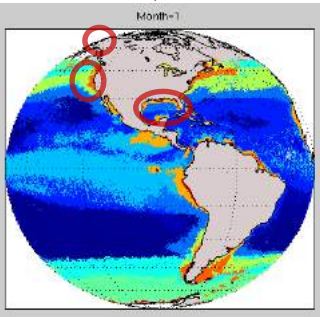
Ecological Marine Units

Regional downscaling

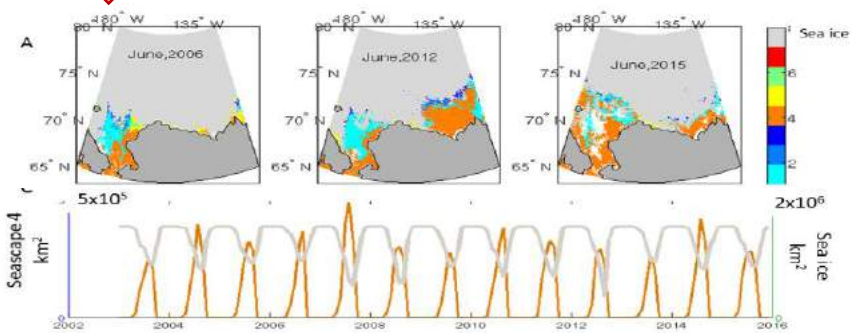


Arctic MBON; Distributed Biological Observatory

Dynamic+2D



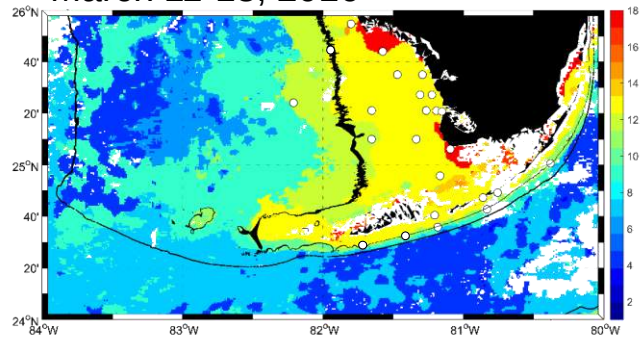
Dynamic Seascapes



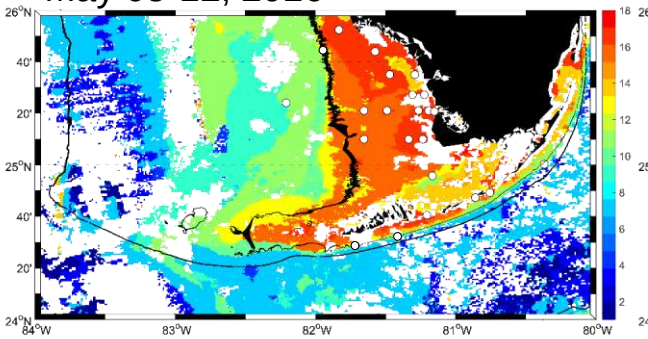
Dynamic habitat maps

Seascape validation in south Florida

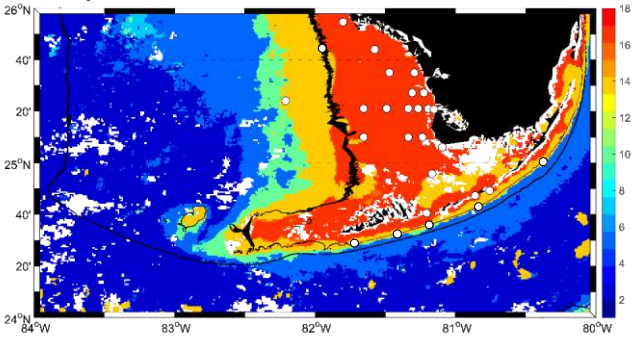
March 11-18, 2016

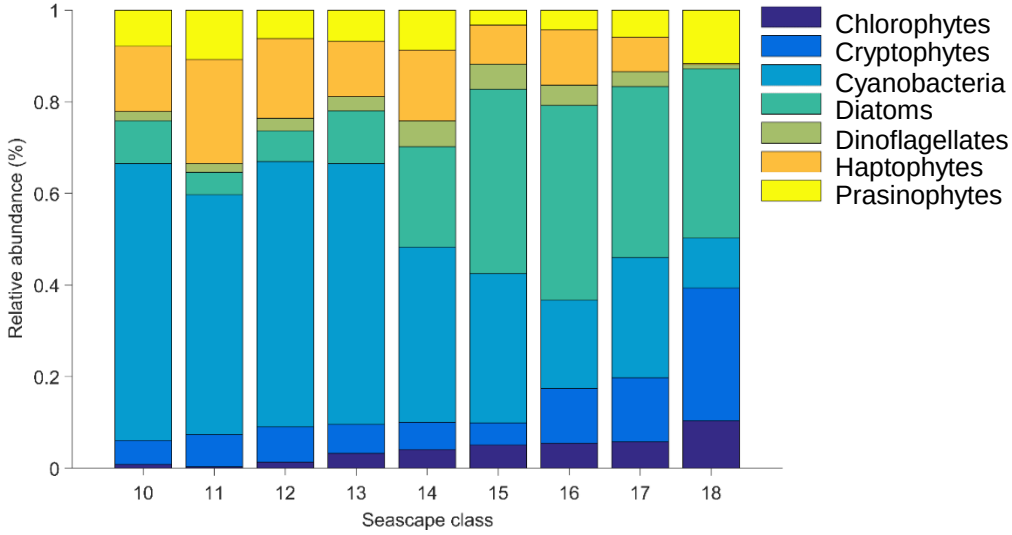


May 05-12, 2016



September 12-19, 2016





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

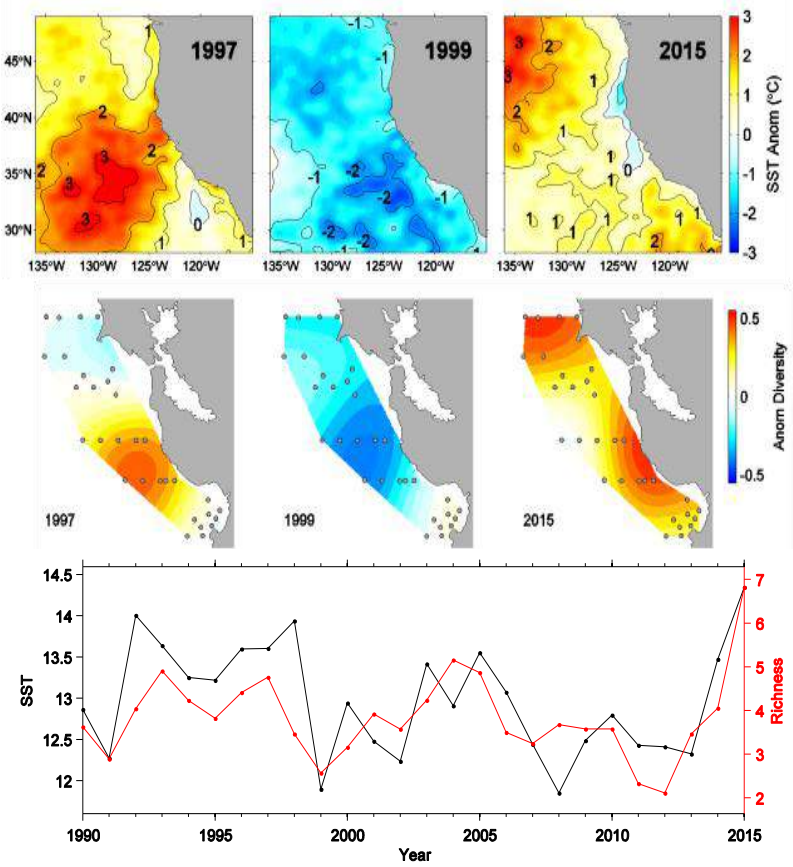
The NOPP Sanctuaries MBON Pilot:
Primary Goals of Cooperative Agreement

- Use advanced analyses to link the mean and fluctuating components of biodiversity and ecosystem function to environmental conditions

National Oceanographic Partnership Program

Ocean climate and biodiversity of pelagic fish (forage species)

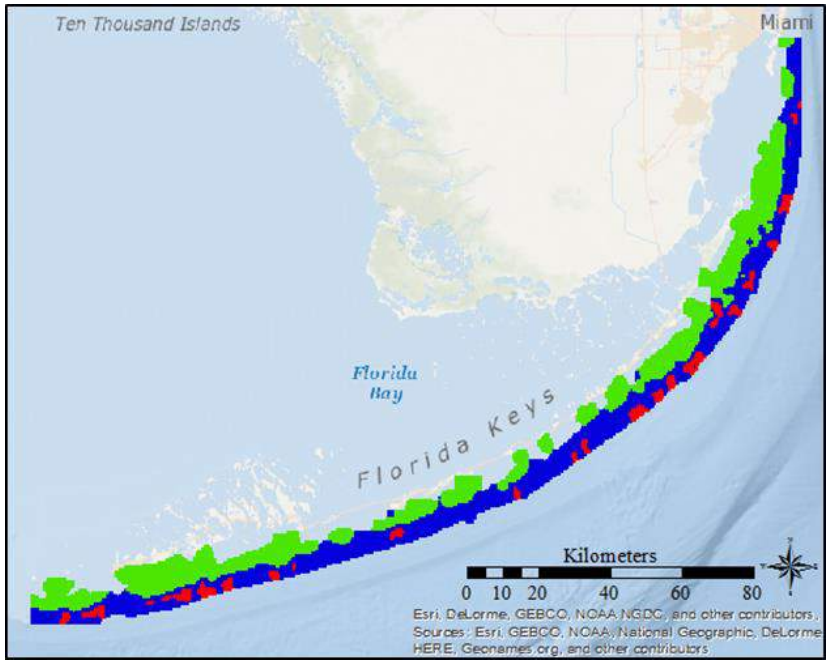
J.A. Santora, E.L. Hazen, I.D. Schroeder, S.J. Bograd, K.A. Sakuma, J.C. Field (2017)
MEPS Vol 580: 205-220, DOI: 10.10.3354/meps12278



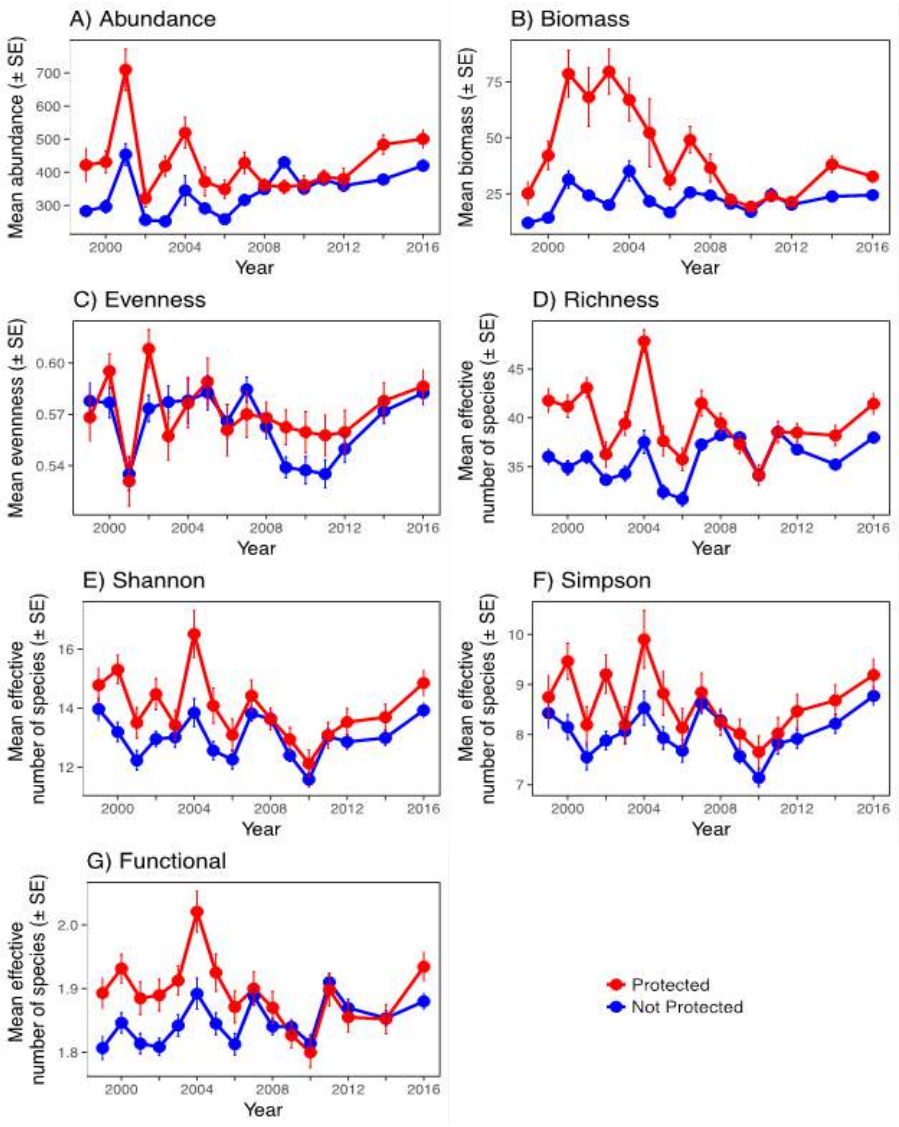
- 1995-97 and 2015 heat waves (ENSO) show high diversity.
- Affects fisheries and coastal water quality.

NOAA FISHERIES
National Oceanic and Atmospheric Administration

Reef Fish Biodiversity by No-Take Marine Zones and Habitat Strata in the Florida Keys National Marine Sanctuary: 1999 – 2016

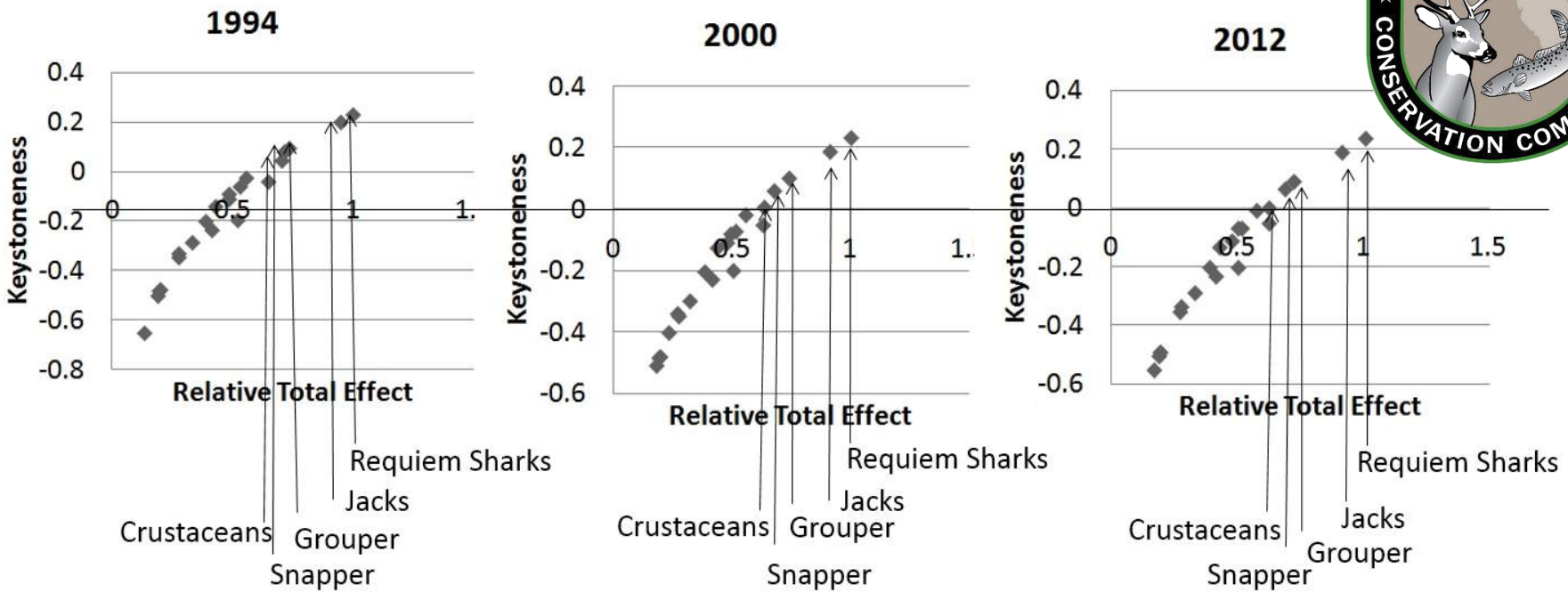


Recommendation: Species biomass and diversity can be enhanced with network of no-take marine reserves



Megan Hepner et al (thesis and paper in prep)

Ecosystem Modeling Highlights: Planning for Conservation in the Florida Keys



Keystone species assessment over time:

Requiem sharks are likely “keystone”:

broad diet, low occurrence, no predators

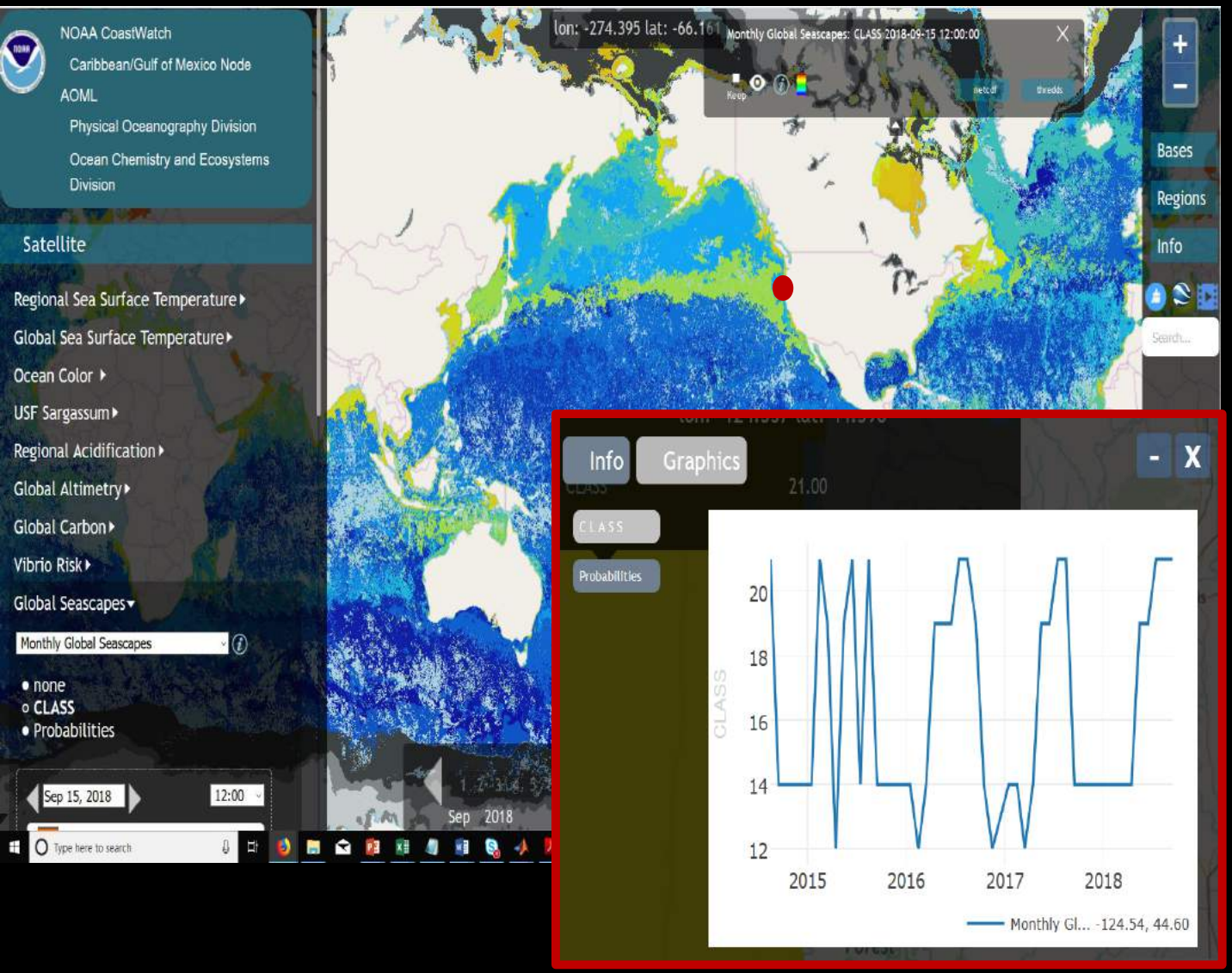
The NOPP Sanctuaries MBON Pilot:
Primary Goals of Cooperative Agreement

- Seek to do this as an operational system

- Seek to do this as an operational system
  - Strong partnerships have led to operational MBON elements:
    - US IOOS and RA's are fully engaged in MBON pilot program
      - Established a framework for management of biological ocean observations
      - Training in DMAC framework to all IOOS RA's
      - Early warning tool development
      - Links to DoI USGS / US OBIS program
    - NOAA NESDIS: Global Seascapes now served via CoastWatch
    - Integrated Ecosystem Assessment (CA, FL Keys): indicators, infographics, data visualizations; MBON Portal development
    - National Marine Sanctuaries: Condition Reports
    - Worked with NOAA NMFS to develop eDNA srategy
  - Heavy input to US OSTP ocean policy vision

NOAA CoastWatch: Operational Global Coverage

Seascape Identity: visualization and analysis



EBVs

Ecosystem Structure Class

- Habitat Structure
- Habitat Extent
- Habitat Function (time dynamics of seascape identity)

Other Classes:
Community Composition
Ecosystem Structure

The NOPP Sanctuaries MBON Pilot: Primary Goals of Cooperative Agreement

- Work with other US MBON demonstration projects to develop network concept

  - *Sanctuaries MBON*
  - *Santa Barbara Channel MBON*
  - *Arctic MBON*
  - *MarineGEO/Smithsonian*
  - *Animal Telemetry Network (ATN-IOOS)*

Work with other US MBON

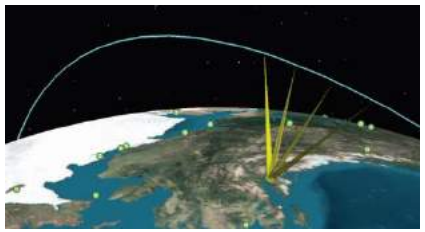
- Substantial In-Reach Effort & Activities
  - eDNA augmentation of SB MBON
  - Seascapes –M. Kavanaugh engaged actively with all MBON pilots and beyond
  - Data Management and Communications (many exchanges)
  - Papers:
    - eDNA
    - Remote Sensing of Biodiversity
    - EOV and EBV
- Discussed new joint research efforts




Water Quality Wetland Disturbance Ecosystem Services

Observing and Understanding Aquatic Boundary Habitats

- **Provided substantial input to NAS Decadal Survey process**
- Published community consensus on **<u>H4</u>** from LEO
  - (sensible/needed alternative to bio from GEO)
  - High: temporal, spatial, spectral, radiometric observations



Concept of a LEO H4 sensor

Science requirements for EBV with H4 remote sensing

EBV class	EBV	Habitat Type								
		Wetland Vegetation	*Benthic Communities*			*Pelagic Organisms*				
		Mangrove/ salt marsh	Seagrass	Macroalgae	Coral	Phytoplankton	HAB		Fish, Zoo-plankton	Apex predator
Genetic composition	Population genetic diversity									
Species populations	Distribution									
	Abundance									
	Size/vertical distribution									
Species traits	Pigments								NA	NA
	Phenology									
Community composition	Taxonomic diversity									
Ecosystem structure	Functional type									
	Fragmentation/ heterogeneity					ROUTINE USE FOR OPEN OCEAN				
Ecosystem function	Net primary production								NA	NA
	Net ecosystem production						NA		NA	NA

Legend
Unproven
Demonstrated limited cases
Routine use
Habitat model required

Today!

Muller-Karger, Frank E., et al., 2018. Ecological Applications. DOI: 10.1002/eap.1682.

Communications & Outreach

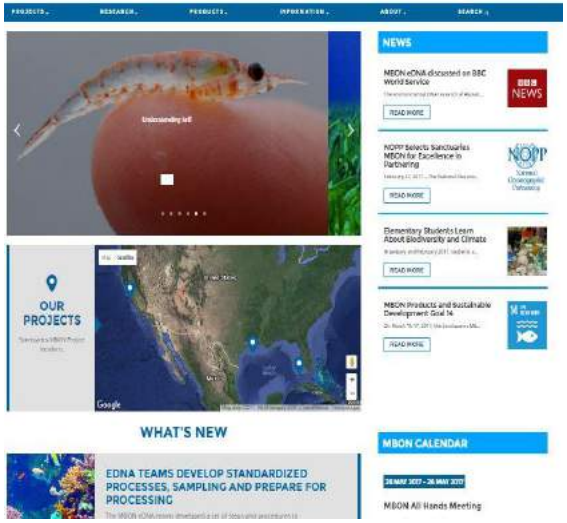
CJ Reynolds, Jennifer Brown, Chris Simoniello, Mitch Roffer

MBON
Marine Biodiversity Observation Network

Engage users and support Products

- Quarterly Updates,
- Short videos,
- Pod casts,
- Sanctuaries MBON website,
- User oriented webinars and tutorials

Coming soon: Sanctuaries.marinebon.org



CENTER FOR OCEAN SOLUTIONS

eDNA Video

Other outreach

- Project Ocean Watch (Around the Americas)
- Local Science Fairs
- Local schools
- Smithsonian Institute, Ft. Pierce, FL
- Gulf of Mexico IOOS (GCOOS) E&O Committee
- Southeast US IOOS (SECOORA) Webinar
- Support and engagement from:
  - NASA
  - NOAA
  - US IOOS
  - BOEM
  - NSF
  - GEO / GEO BON / Blue Planet / GEO Wetlands
  - IOC (GOOS, OBIS)

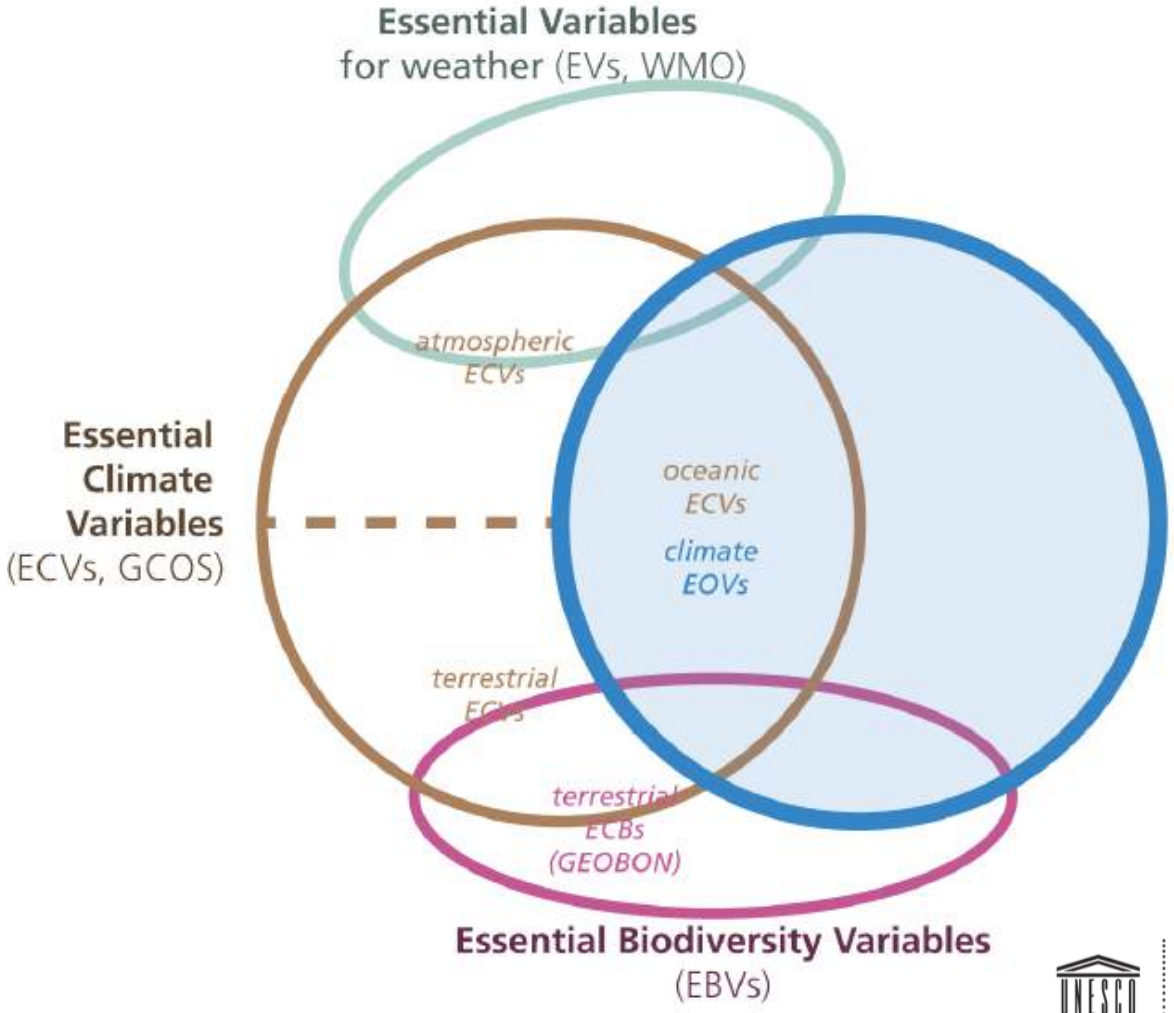
The NOPP Sanctuaries MBON Pilot:
Primary Goals of Cooperative Agreement

- Export the MBON concept globally

Our Approach:

Networking networking networking

- Building a community of practice
- Standard and best practices
- Respecting/enhancing identity of observer groups and stakeholders



GEO BON

MBON
Marine Biodiversity Observation Network

BLUE PLANET
Oceans and Society

UNESCO
United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

Ocean best practices

The Global Ocean Observing System
GOOS

OBIS
OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM

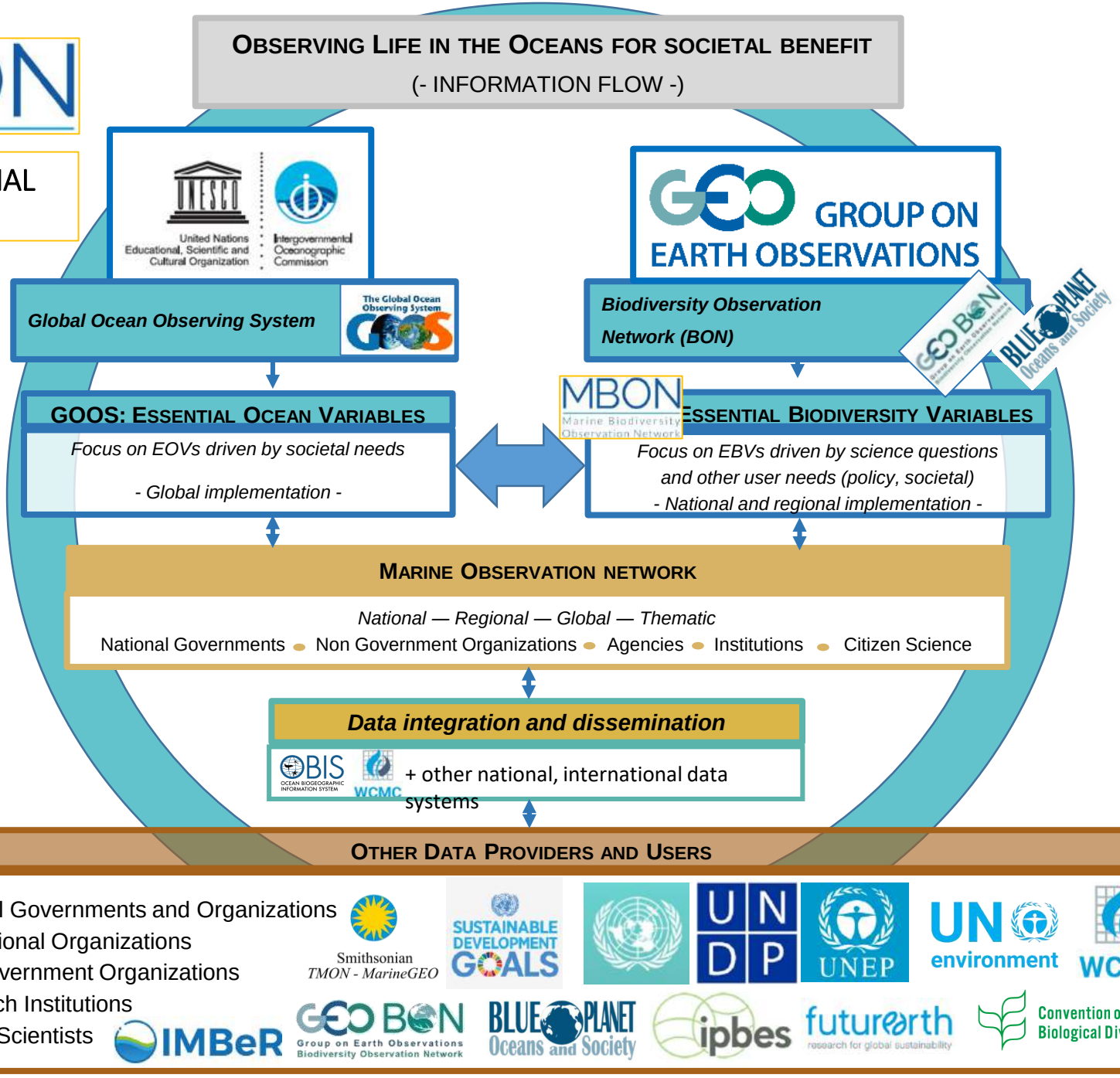
Concept: 'global' coverage of EBVs means integrated land and ocean information
(e.g. Radeloff + Oliver exploration of joint Dynamic Habitat Indices (DHI))

MBON

INTERNATIONAL LINKAGES

OBSERVING LIFE IN THE OCEANS FOR SOCIETAL BENEFIT

(- INFORMATION FLOW -)



Smithsonian MarineGEO Partnership

Our infrastructure is people

MarineGEO
THE TENNENBAUM
MARINE OBSERVATORIES NETWORK
Smithsonian Institution

- **Vital signs**:
  coastal seabed focus
  diversity time series
- **Diagnostic tests**:
  Coordinated exp'ts
- **Capacity building**

Capacity Building – Field sampling

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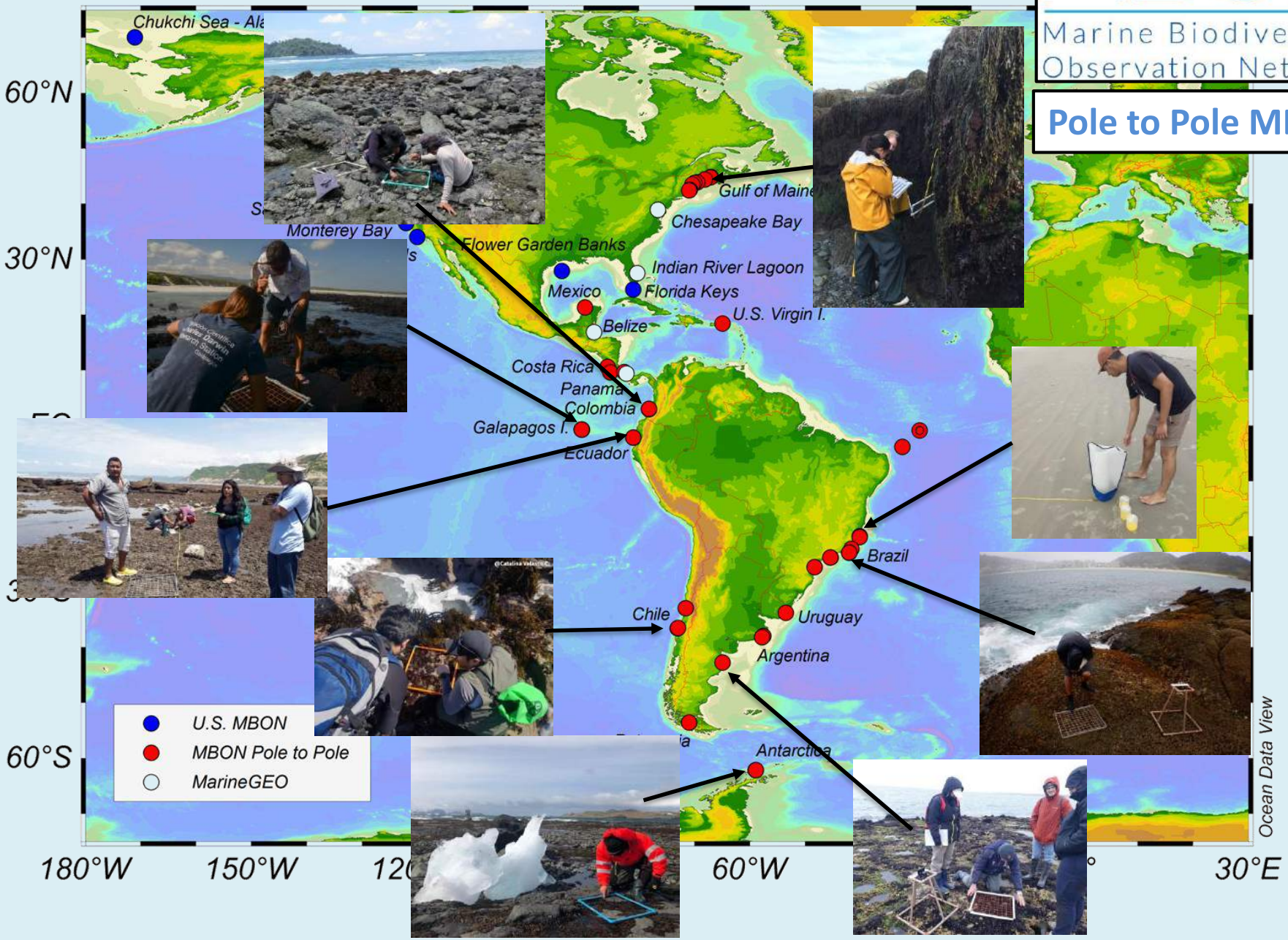
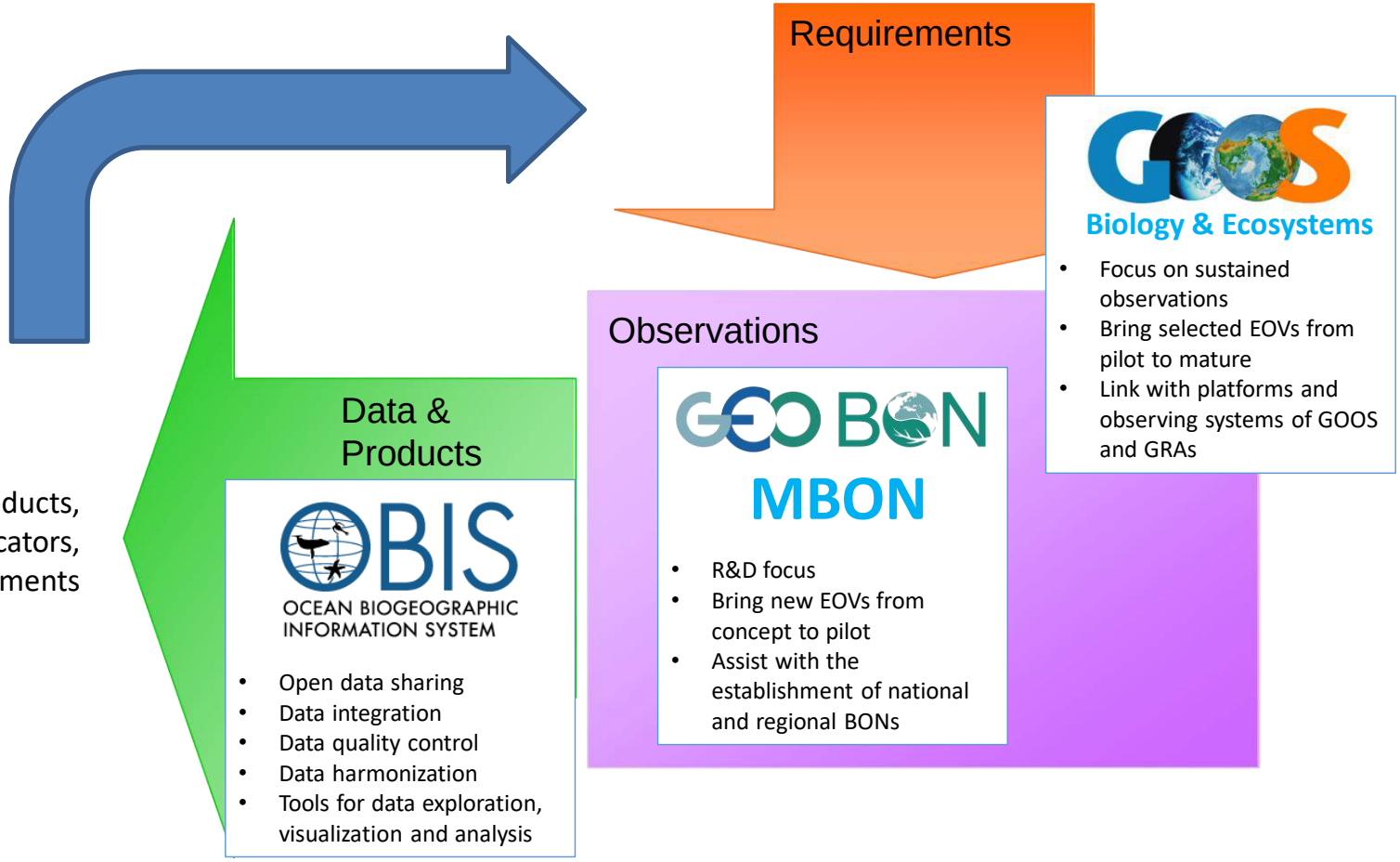
Pole to Pole MBON

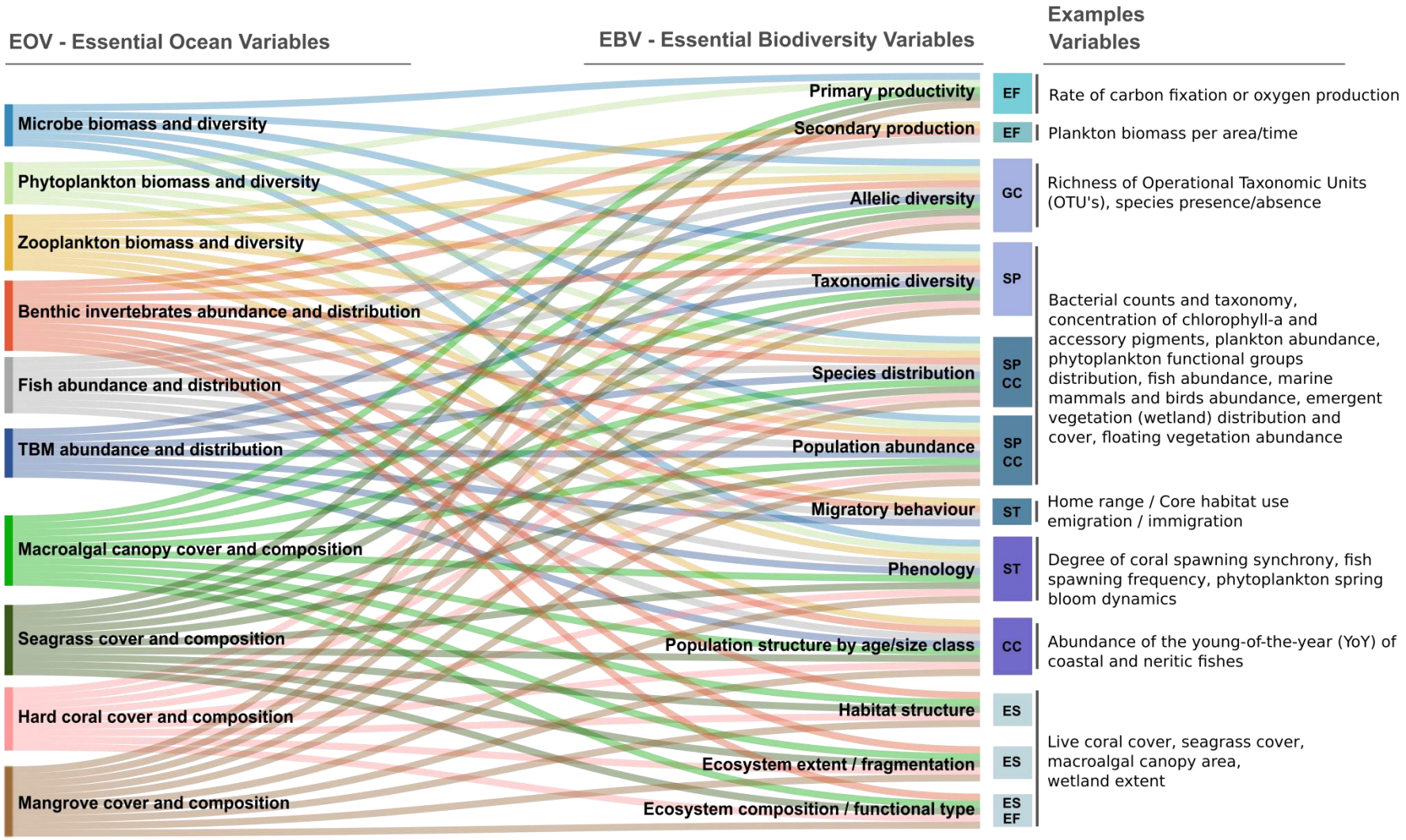


A Global Collaboration: OBIS + GOOS (IOC) and MBON



e.g.: http://iobis.org/2016/12/15/goosgeobonobis/

Complementarity between EOV and EBV



Muller-Karger, et al., 2018. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2018.00211

Honolulu, Hawaii

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The Global Ocean Observing System
GOOS

BLUE PLANET
Oceans and Society

Substantial MBON involvement

In partnership with

NSF OceanObs RCN:

- ***Intellectual sponsor***
- ***Program Committee***
- Participation:
  - Speakers and panelists
  - Breakout sessions
- **Post OO19 activities** planned
  - AGU fall Meeting
  - Ocean Sci. Meeting

SUSTAINABLE DEVELOPMENT GOALS

2030 AGENDA

UN Decade of Ocean Science forSustainable Development (2021-2030)

Biological Diversity/Aîchi Biodiversity targets (CBD)

Law of the Sea (UNCLOS + BBNJ + UNFSA)

SIDS Action (SAMOA Pathway)

Disaster Risk Reduction SENDAI Framework

Climate Change/Paris Agreement (UNFCCC)

A global framework that will ensure Ocean Science can help governments and societies achieve the major goals of our generation

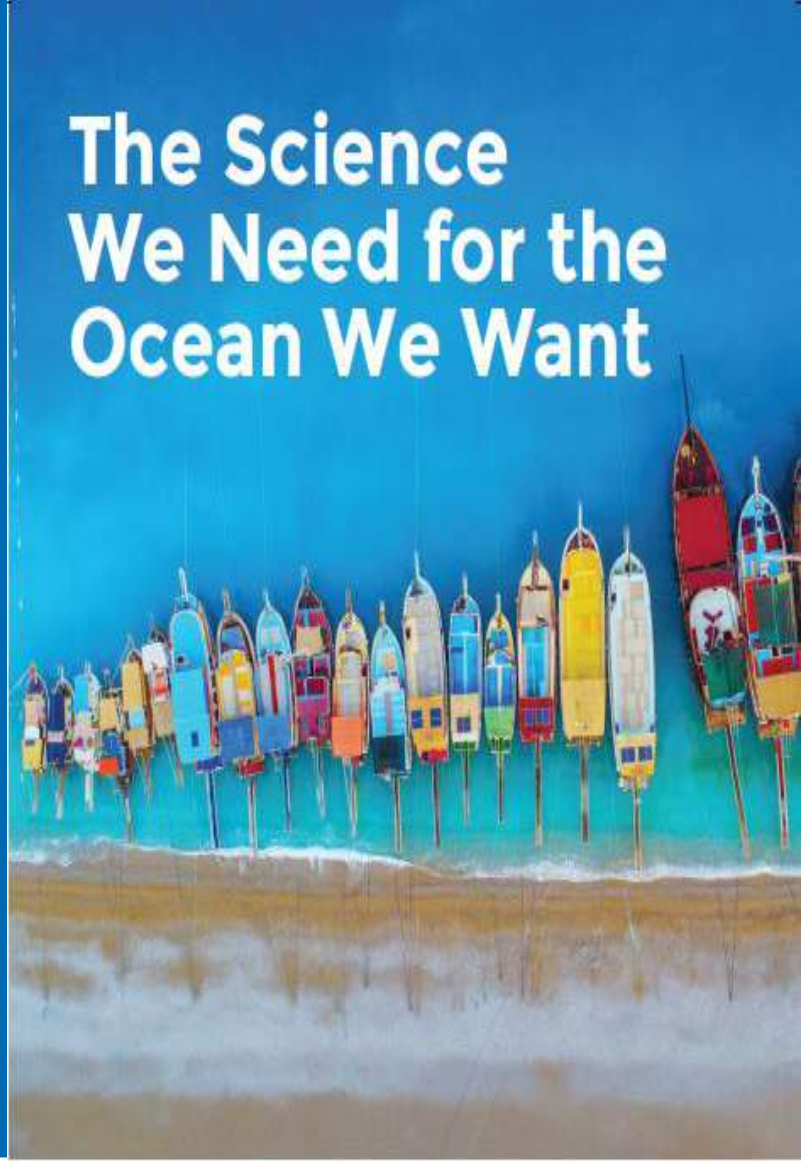
Get in touch

Write to:
oceandecade@unesco.org

Follow all Decade news:
http://oceandecade.org

Social media:

IocUnesco IocUnesco ioc_unesco



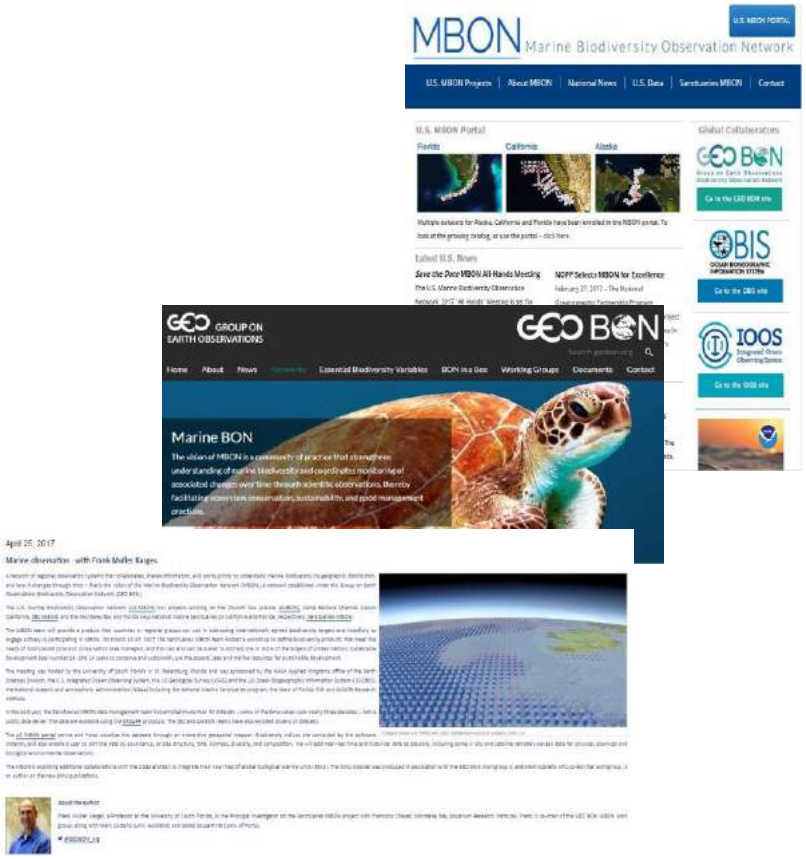
United Nations Educational, Scientific and Cultural Organization · Intergovernmental Oceanographic Commission · 2021 2030 United Nations Decade of Ocean Science for Sustainable Development

The United Nations Decade of Ocean Science for Sustainable Development (2021-2030)

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

International Outreach

- Monthly GEOBON MBON webinars/telecon
  - Videos, recorded webinars
  - https://geobon.org/about/events/web-conferences/
- Constant communication with MBON co-chairs (M. Costello and I Sousa Pinto)
- Collaborate with GEO staff, support GEOBON MBON workgroup -- targeted engagement in key countries, expand webinar outreach



Peer-reviewed Publications

MBON
Marine Biodiversity Observation Network
Sanctuaries

39 publications

- Topics:
  - eDNA
  - Essential Ocean Variables and Essential Biodiversity Variables
  - Biodiversity changes over time and causes
  - Recommendations for coastal and ocean biodiversity observations from space (H4)
  - Mapping coastal wetlands
  - Harmful algae blooms
  - Capacity building and education strateges

Successes of the Sanctuaries MBON

- MBON is now known nationally and internationally
- Established a framework for biological observations; IOOS adopted
- eDNA: collection and extraction methods tested and validated
- Satellite-based, dynamic seascape products automated pipeline co-developed with NOAA NESDIS CoastWatch
- Biodiversity field monitoring program fully implemented in both Sanctuaries
- Expanding links: NOAA *ocean acidification* program, *NOAA Omics*, State and Federal fisheries & environmental monitoring, Animal Telemetry Network, NSF LTER (Everglades), IOOS and other observation programs
- Connected to international policy bodies
- MBON continues to support GEO BON's WG and TF

Challenges of the Sanctuaries MBON

Challenges:

- Development and maintenance of data system / visualization tool:
  - The amount of work is staggering – many details
  - How to transition to a sustainable model?
- Curation and permanent archive of biological datasets from various sources:
  - Identifying and understanding datasets is an ongoing effort
  - How do these data transition into a permanent archive? How do we maintain access needed for operational & research utility?
  - How do we engage monitoring programs to enroll data?
- Operationalization of eDNA to monitor biodiversity
- Communications flow on news and outreach
- Integrating the MBON observations into Condition Reports
- Coordination of myriad moving parts with partners and X-MBON projects
- Building critical international partners and linkages for Pole-to-Pole
- Operational MBON
  - Developing path to sustainability

Tracing a Path Forward: Key Recommendations

X-MON pilot efforts made tremendous progress

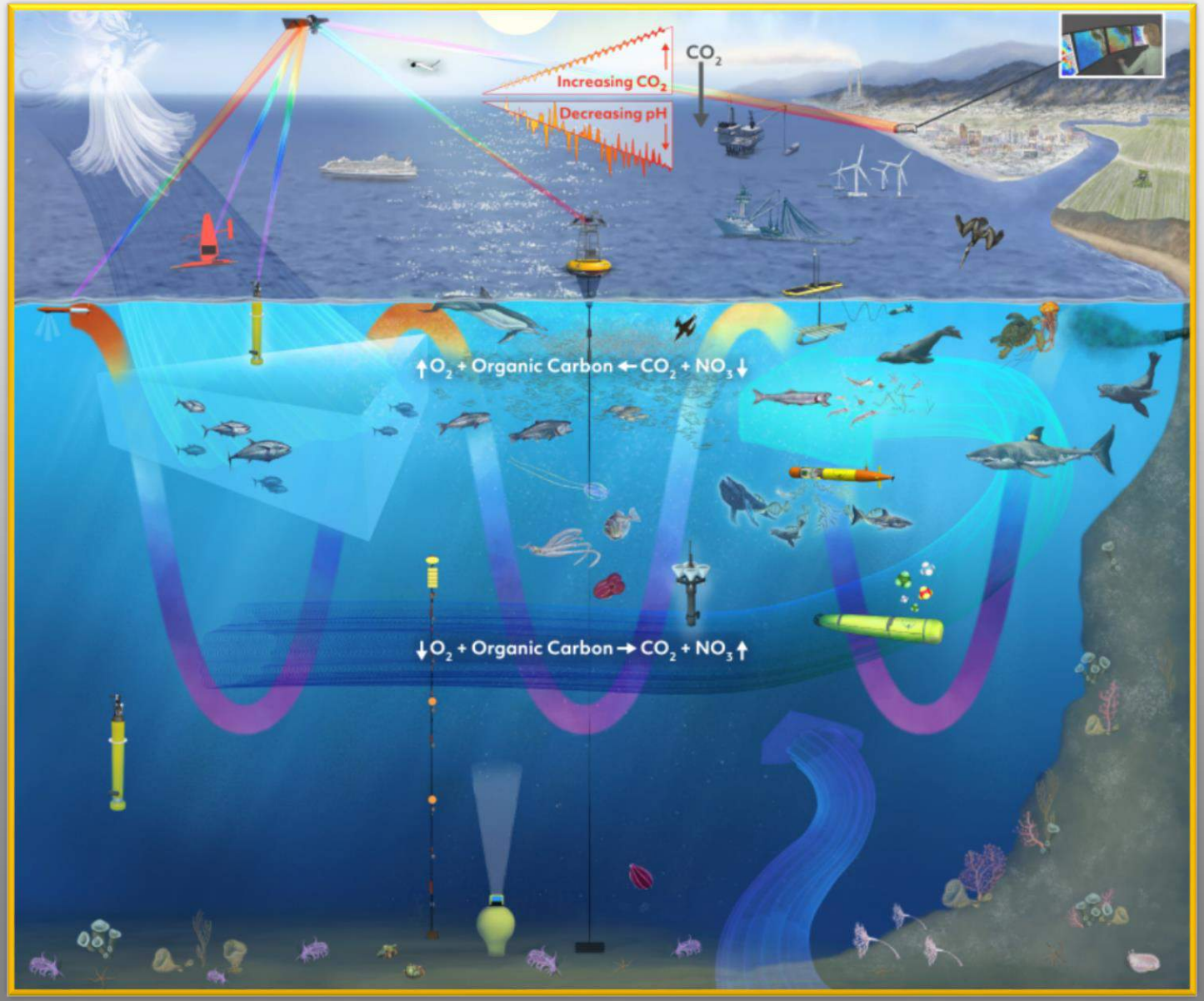
- Now: Continue focus on the development of a national + international MBON
- Program managers need to provide direction and vision, and
- Provide support for community organization efforts
- Provide support to improve the 'translators' to complement the OBIS / GBIF Integrated Publishing Toolkit (IPT), which uses Ecological Metadata Language (EML) as a standard to capture Darwin Core/Event Core data
- Work with agency hierarchy to provide budget lines for operation elements

– Integration of observing technologies: seascapes, remote sensing, in situ, eDNA, documentation of best practices
– Seascapes evolution:
- Taxonomic and Functional groups, higher spatial resolution and global coverage, coastal land cover and nearshore benthic habitats, water quality
- Global wetlands, including mangroves, seagrasses, macroalgae, corals

– Further operational biological data archaeology
– Promote biodiversity measurements, remote sensing and image processing
– Engage internationally : Integration with IOOS, GOOS, OTGA, OBIS/GBIF, ++

Addressing the need for sustained observations of marine ecosystems

MBON
Marine Biodiversity Observation Network



NASA

NOAA
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Backup

15 GOOS Regional Alliances