Illustration courtesy of F. Chavez/K. Lance (Monterey Bay Research Institute/MBARI)

NASA · NOPP National Oceanographic Partnership Program · NOAA · BOEM Bureau of Ocean Energy Management

IOOS Integrated Ocean Observing System · NOAA Ocean Exploration and Research · National Marine Sanctuaries · NOAA FISHERIES

CLIVAR

MBON
Marine Biodiversity Observation Network

Integration of biology into observing systems: why, how, and when

Frank Muller-Karger
carib@usf.edu

USF University of South Florida College of Marine Science

Conversation topics:

MBON
Marine Biodiversity Observation Network

- What have we learned from in situ data?
- What technologies are available to make biological observations operational?
- The need:
  - better organization and integration & multidisciplinary observing

In situ programs

- Are extremely numerous around the world
    - (research, resource monitoring, water quality, etc.)

- Often provide
    - High quality data
    - Resolution in depth

- ***Very few*** provide:
    - high temporal and (3D) spatial resolution
    - Integration and coordination with everything else
    - Data organized in common formats or available

What has been the focus of in situ ocean observation efforts?

For the past 70-80+ years *(in general):*

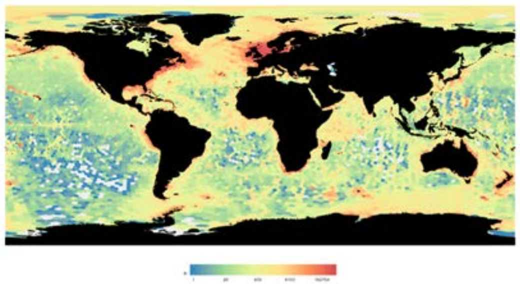
- "Salt", Carbon, nutrients, trace elements: indicators of ocean biogeochemical state
- Bulk indicators for biology
  - Chlorophyll
  - Particulate and dissolved organic / inorganic matter
  - Many but disconnected observations on microbes to whales
    - Mammals, birds, fish (biomass, abundance), plankton, etc.

Issues:

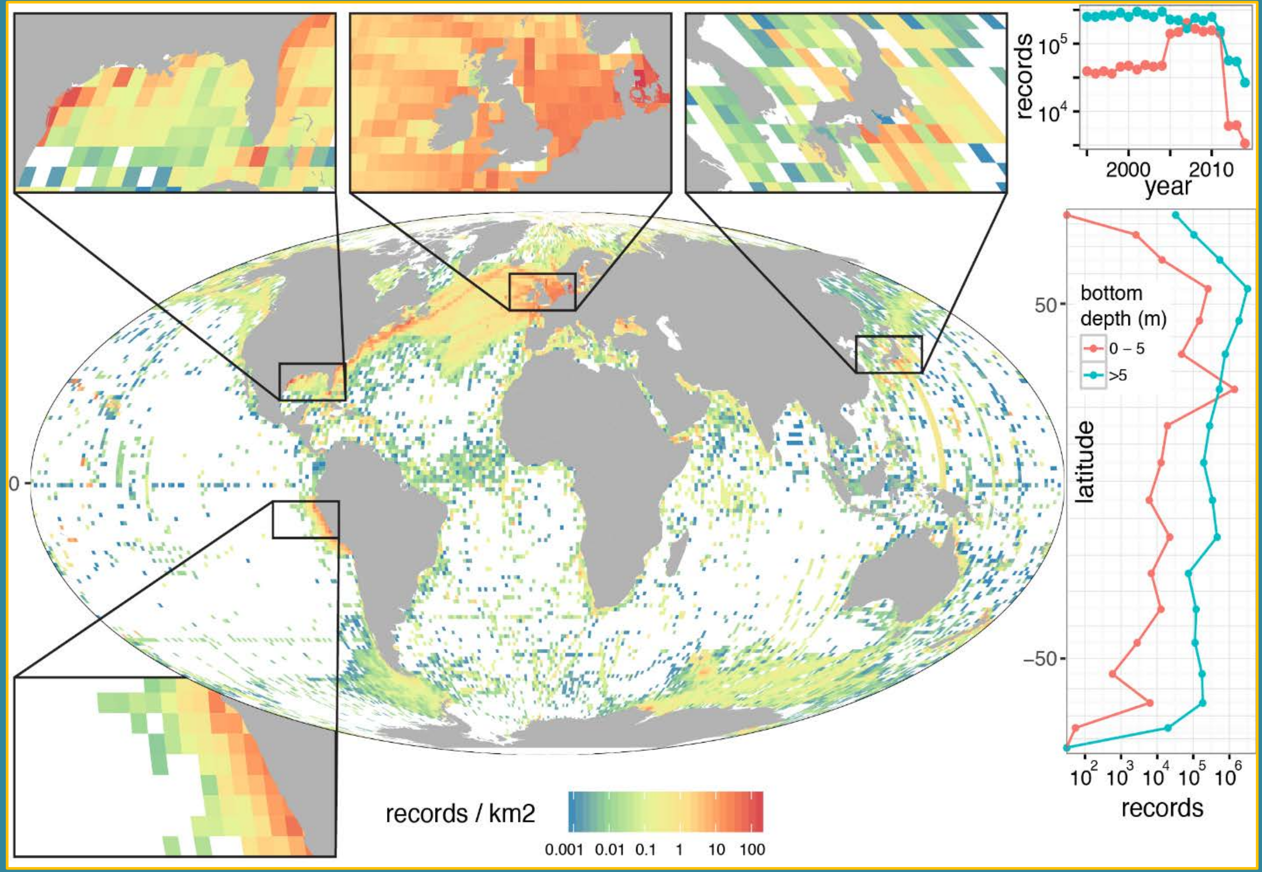
- Hard to characterize variation in fluxes with just bulk observations:
  - Primary productivity
  - Fluxes to the deep ocean
  - Cycling of nutrients
- Little to no info on spatial distribution and abundance of species

The state of marine biodiversity monitoring

OBIS
OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM



OBIS: 47 million records (water column to benthos)



<u>Near-surface</u> taxonomic records (<20 m)

→Many areas have no records

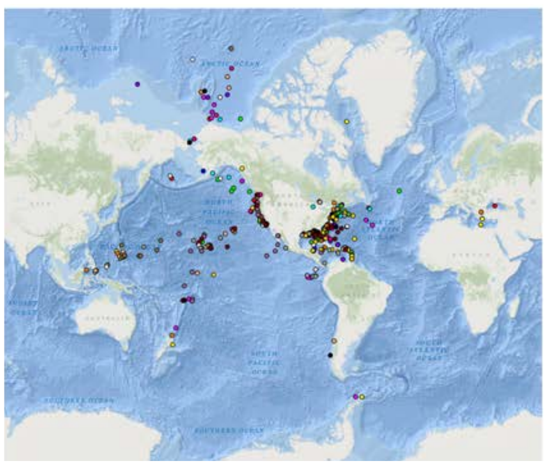
→Fewer records in last 10 years!

(Lag in reporting data to OBIS? Sharing?)

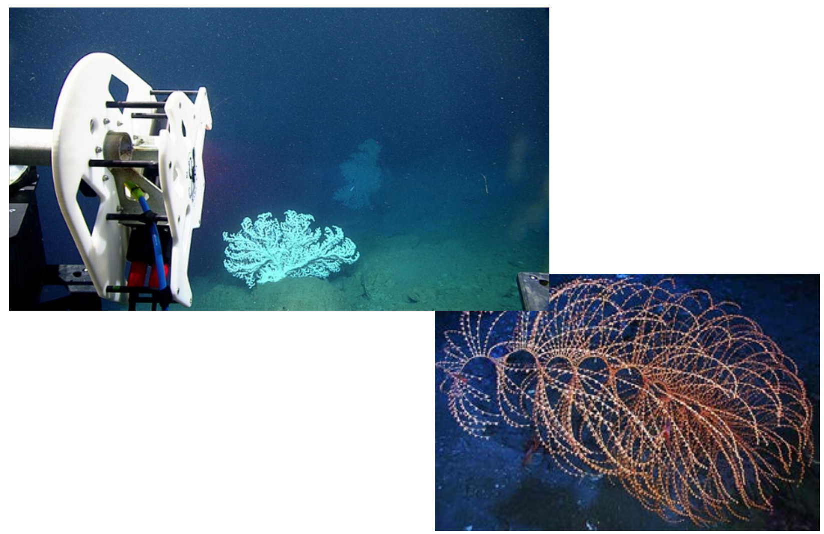
The Deep Ocean

Is still a mystery to us, with very few observations …

….but we're going mining and fishing!



Locations visited by
NOAA Ocean Exploration



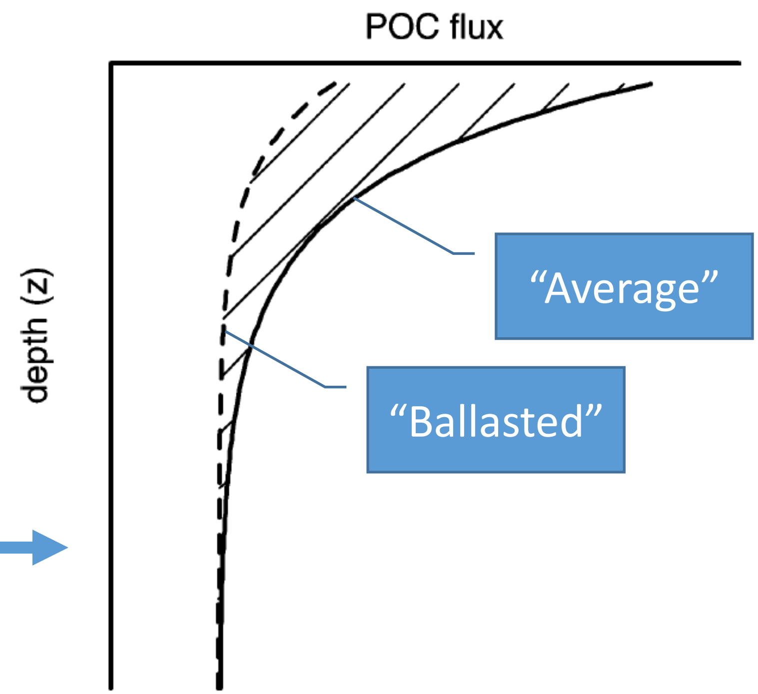
DEEP OCEAN OBSERVING STRATEGY

The Carbon Cycle: How much "C" is sequestered to the ocean bottom?

In situ data have given great insights:

- New and regenerated production
- The microbial loop
- Particulate Organic Carbon flux

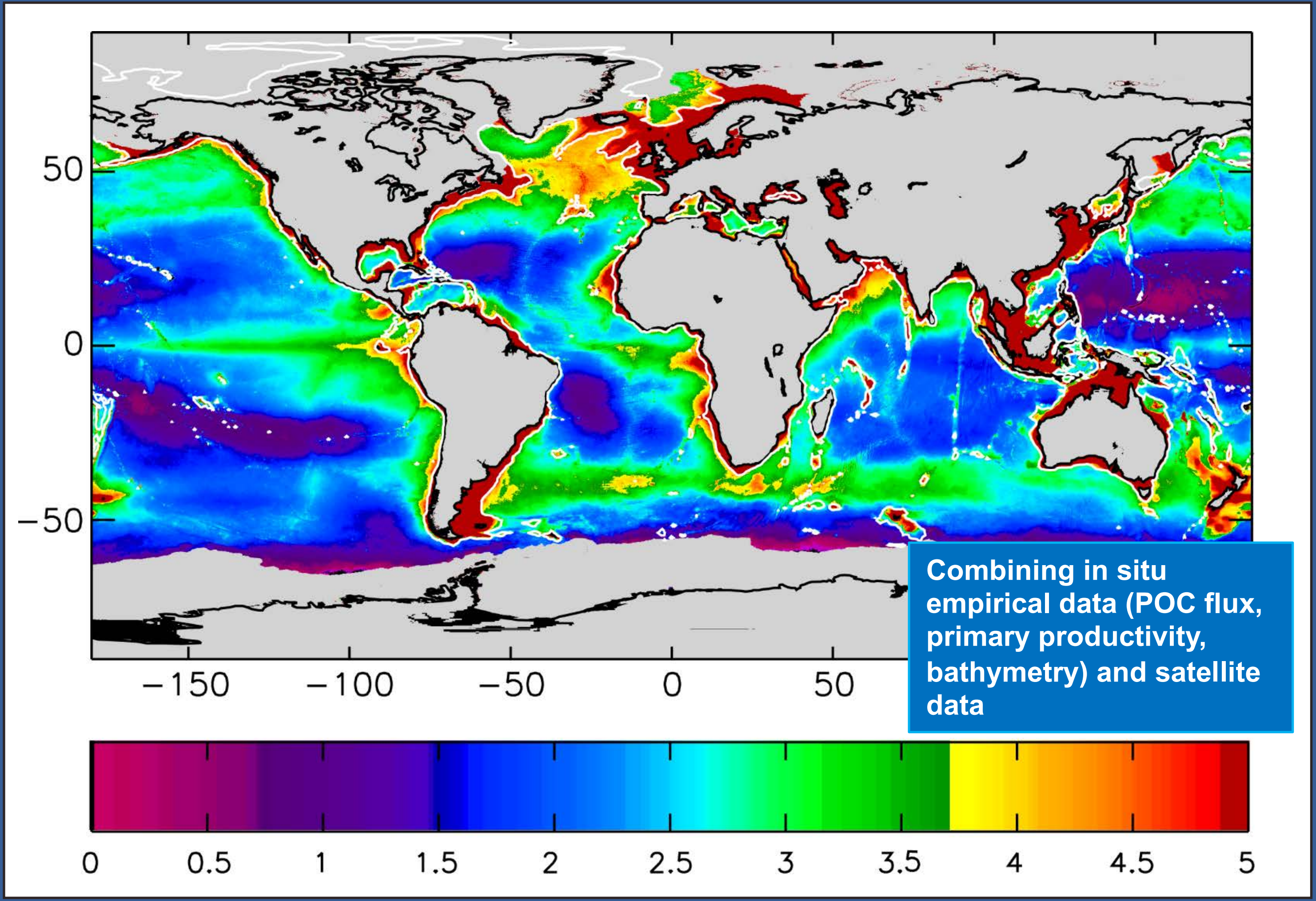
But…there is *lots* of variability in time and space



Armstrong et al., 2002. Deep-Sea Research II 49:219–236

Average annual POC flux [g C m^{-2} y^{-1}] to bottom of the ocean (1998 – 2001)

Muller-Karger et al. 2005. The importance of continental margins in the global carbon cycle. GRL, Vol. 32.



Combining in situ empirical data (POC flux, primary productivity, bathymetry) and satellite data

Global POC flux analysis

Muller-Karger et al. 2005. GRL, Vol. 32.

Estimate:

Margins account for ~40% C stored annually below thermocline

and

40% buried in global ocean sediments from settling POC

Distinct spatial patterns in flux to the bottom

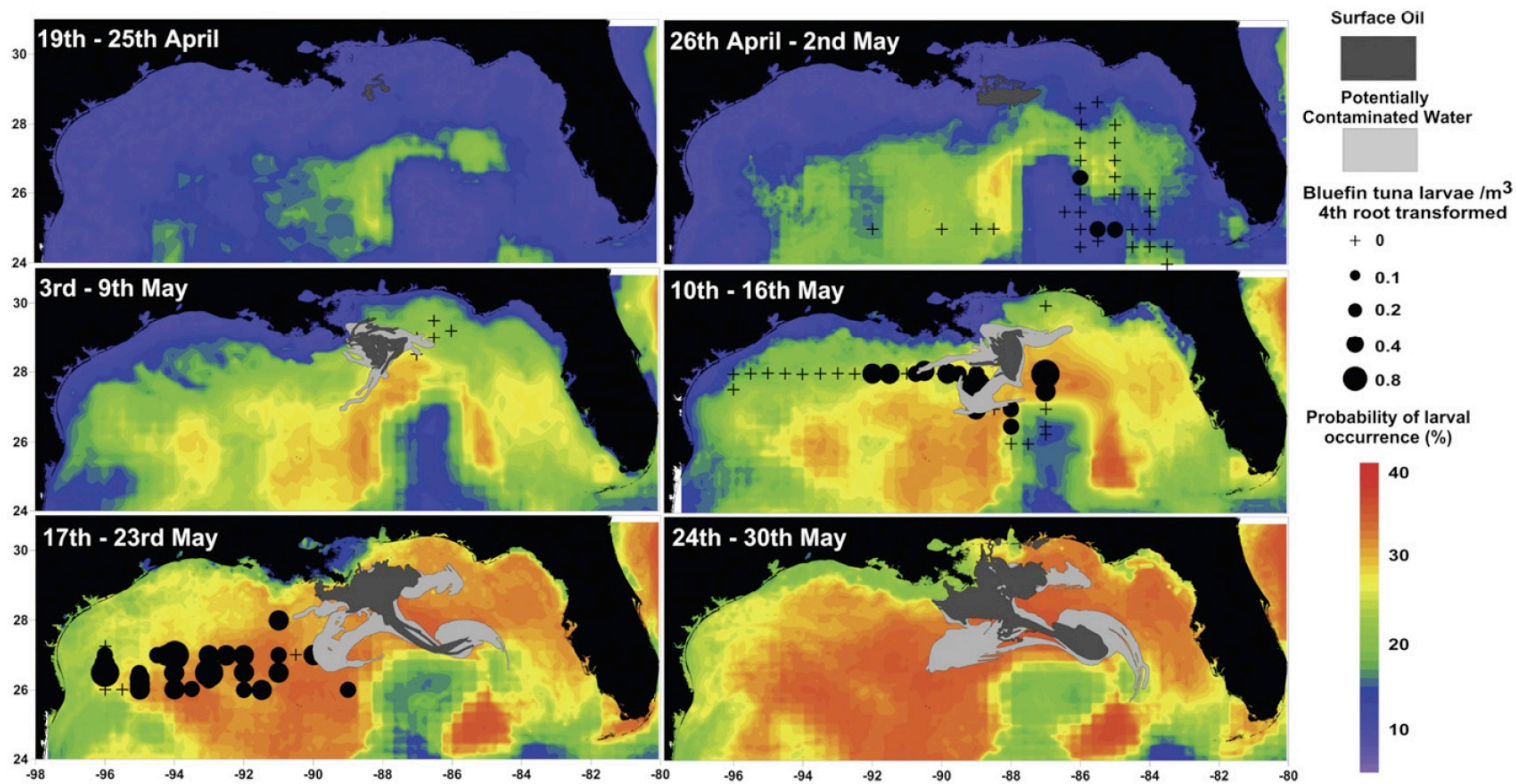


Fig. 5. Predicted probabilities of occurrence for larval bluefin tuna in the northern Gulf of Mexico on a weekly basis during spring 2010. Probabilities were derived from a neural network model trained using archival larval collection data. Oil extents are derived from satellite products. Catches of larval bluefin tuna from spring 2010 (April 19th–May 23rd), are also shown.

Less than 10% of Bluefin tuna spawning habitat was predicted to have been covered by surface oil, and less than 12% of larval BFT were predicted to be within contaminated waters in the northern Gulf of Mexico during the Deepwater Horizon disaster

In situ has undergone a small revolution in the last 10-20 years

- Ecology concepts and methods become important again
- Realization that diversity of life is important!
  - Biogeochemistry (carbon, nutrients)
  - Ecosystem resilience
  - Human health

    (Production of food and water quality)

- Linking in situ observations, remote sensing and simulations is critical

Community production is higher with higher biodiversity
(Aquatic & terrestrial environments)

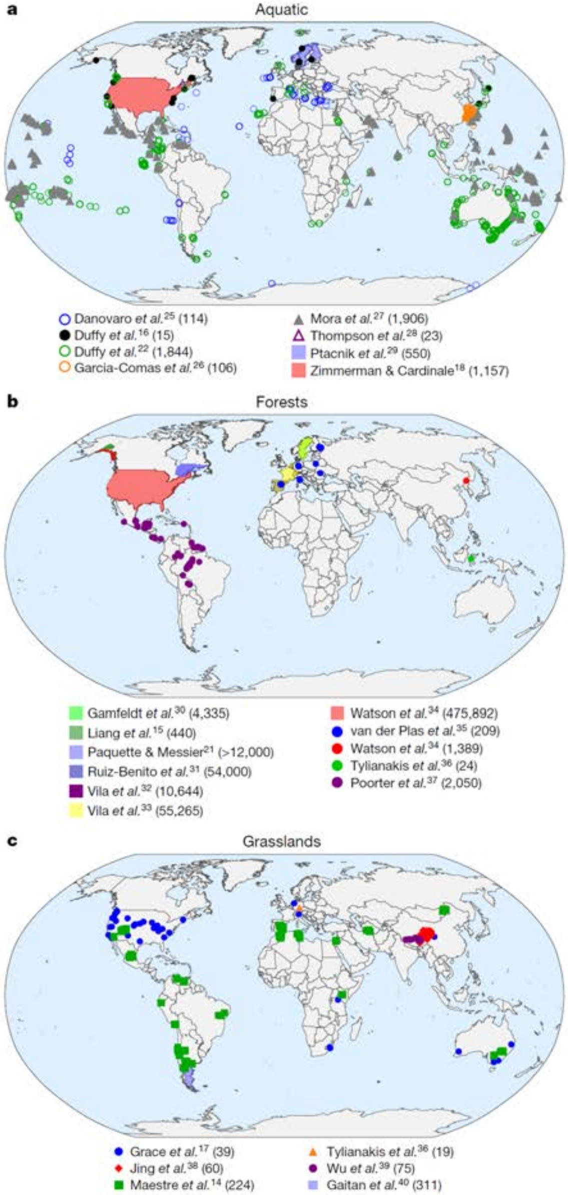


Figure 1 | Distribution of observational field studies used in our analysis. a–c, Studies focused on algal and consumer diversity in freshwater and marine ecosystems (**a**), tree diversity in forests (**b**) or herbaceous plant diversity in grasslands (**c**). These three categories encompass 63 out of 67 studies analysed. The number in parentheses after each study is the number of sites that the study included. The studies[25–40] are listed in Supplementary Table 1 and are shown as symbols for individual or closely neighbouring sites, and as shaded regions where numerous sites are located within a limited geographic area.

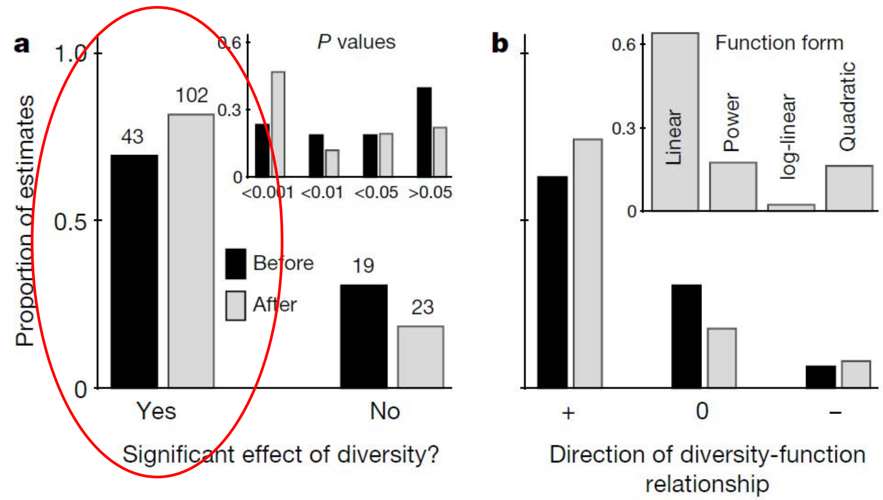
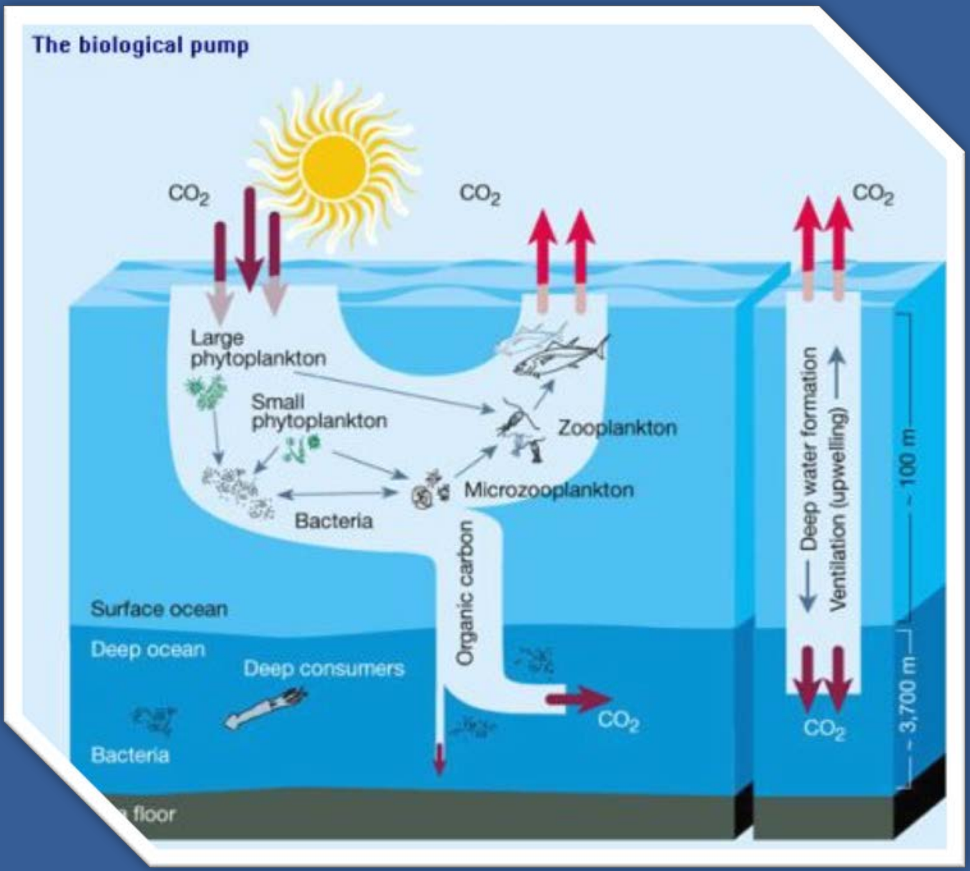


Figure 2 | Biodiversity effects on community biomass production are widespread in nature, and more robust when covariates are accounted for. a, Proportions of field studies in which the effect of diversity on biomass was significant ($P < 0.05$) before (black) and after (grey) accounting for environmental covariates. Inset, distribution of studies by P value. Numbers above bars denote the number of studies in each category. **b**, Proportions of studies with positive, neutral or negative diversity effect when covariates were not (black) and were (grey) accounted for. Inset, proportions of studies with different forms of the richness–productivity relationship.

Duffy, James Emmett, Godwin, Casey M. and Cardinale, Bradley J. (2017). **Biodiversity effects in the wild are common and as strong as key drivers of productivity.** *Nature,* (549) , 261-264. http://dx.doi.org/10.1038/nature23886

Plankton functional groups (PFGs): Important in Biogeochemistry

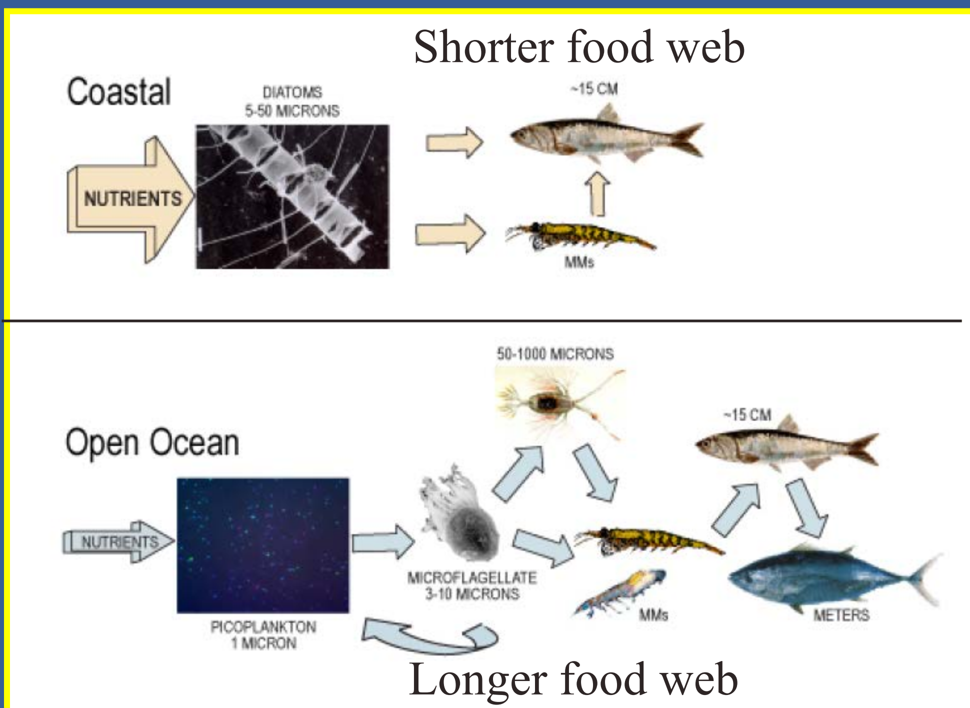


Chisholm, 2000

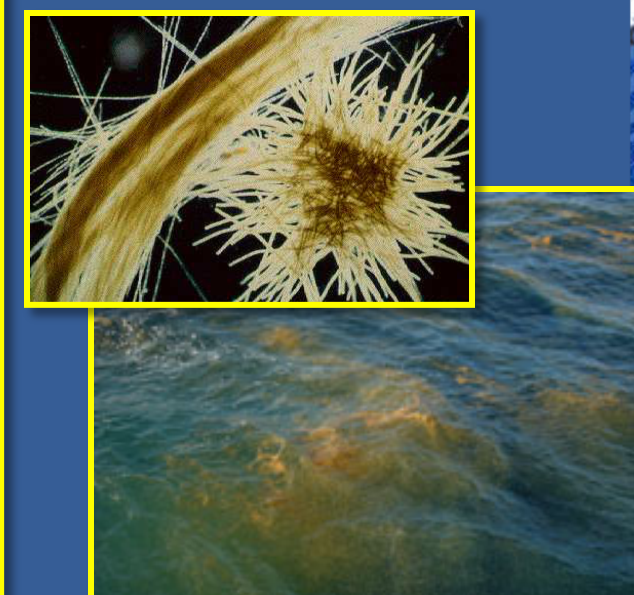
- PFG's have similar biology & biogeochemical roles, e.g.:
  - physiology
  - sinking
  - CO_2 sequestration
  - DMS production
  - silicate drawdown
- Cell SIZE
  - is a characteristic feature of PFT's
  - determines structure and function of pelagic ecosystems
- Observations of the PFT's is needed

Plankton functional groups (PFGs): important in ecosystem-based management

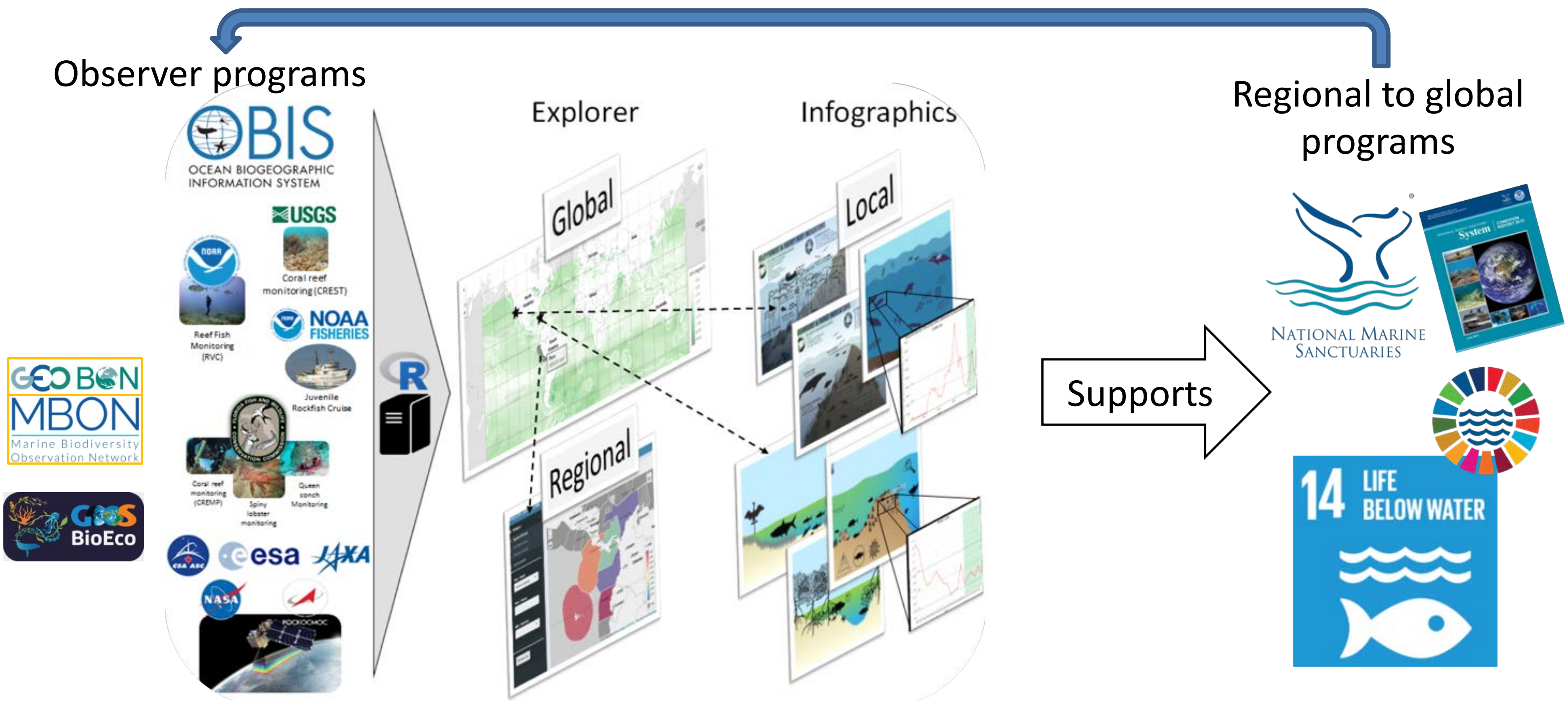
Diatoms, dinoflagellates, other microplankton, picoplankton



Nitrogen fixation (*Trichodesmium* sp.)



The need for an observing framework: **Integration** of programs, technologies, data types

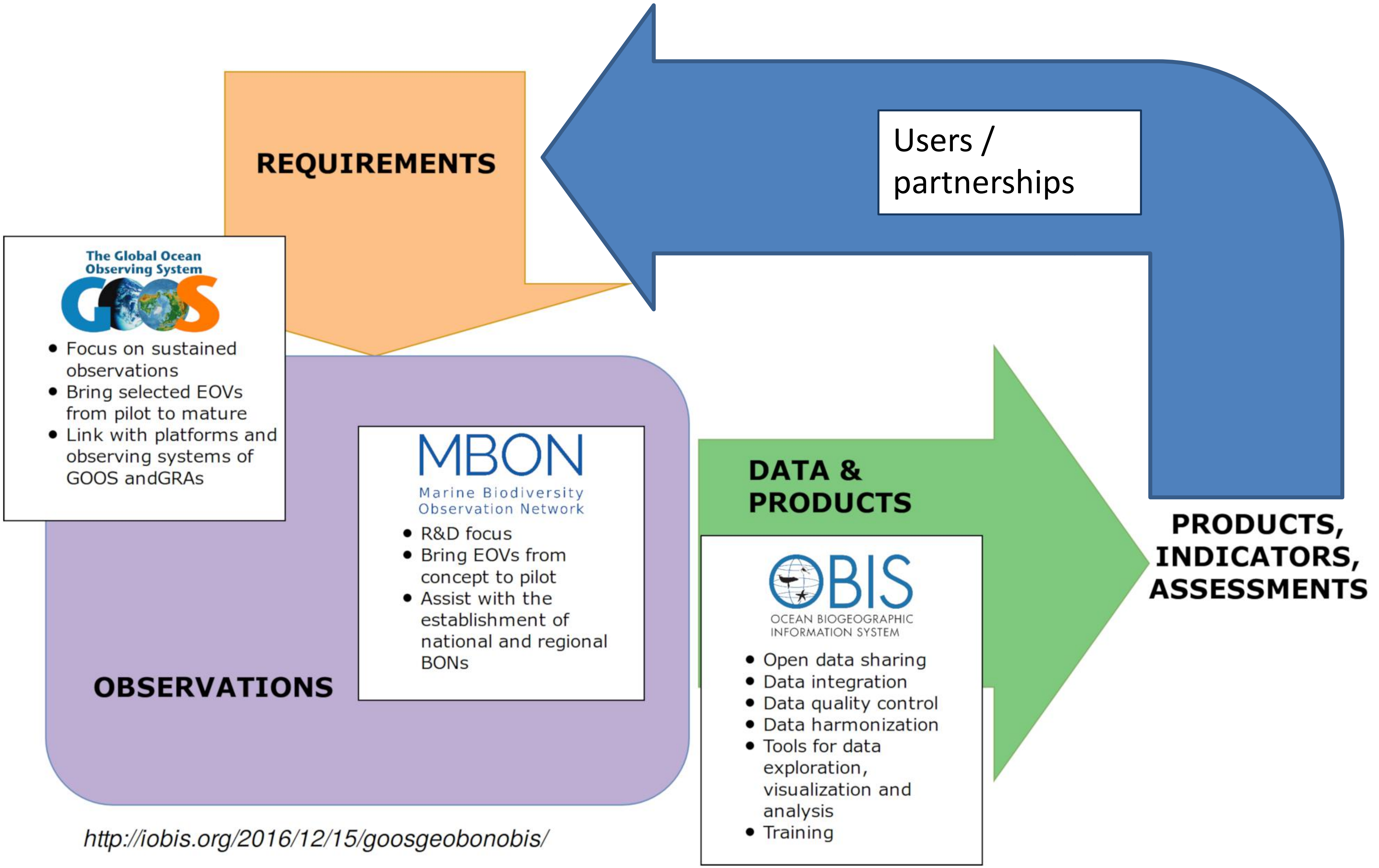


Explorer (global) **Infographic** (local)

https://mbon.ioos.us/

MBON Portal: Interactive Tools

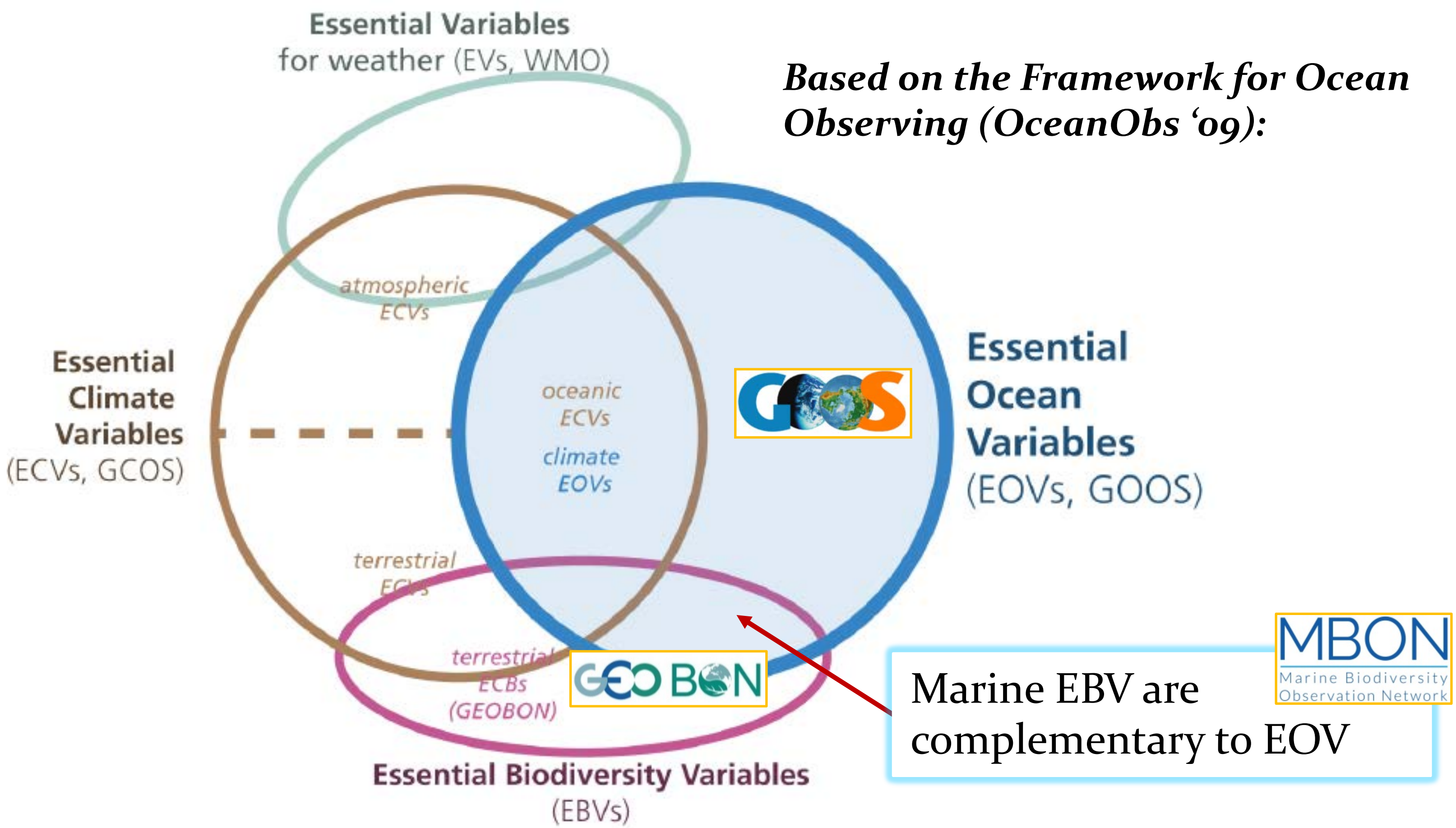
Framework for Ocean Observing (FOO; 2012)



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

Linking Essential Biodiversity Variables (EBVs) and Essential Ocean Variables (EOVs)

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



EOVs are central to GOOS strategic planning and implementation
EBVs are central to GEO BON strategic planning and implementation

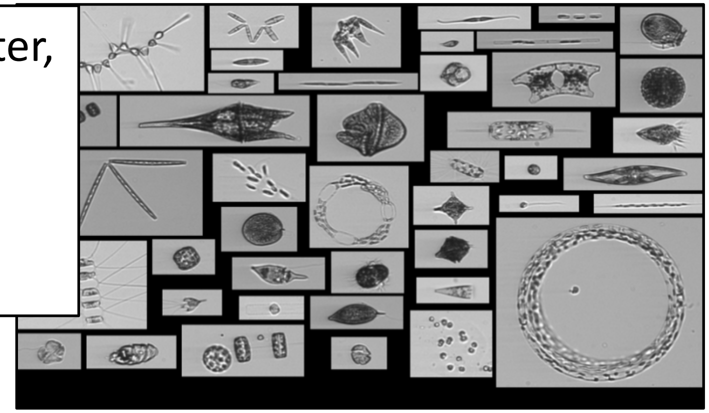
Evolving technology matrix for in situ observations

	Microbes/ Phyto	Zooplankton	Fish	Top Predators	Benthos, habitat forming
Optics/Imaging	X	X	X Benthic		X
Animal tracking (satellite, underwater)			X	X	
Acoustics		X active	X Active, passive	X Tags, passive	X Active, passive (noise)
Genomics	X	X	X	X	X
Platforms with samplers	AUVs, floats, moorings, satellites	AUVs, moorings	AUVs, moorings	AUVs, moorings, tags	AUVs, moorings, satellites
Data and visualization	X	X	X	X	X

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

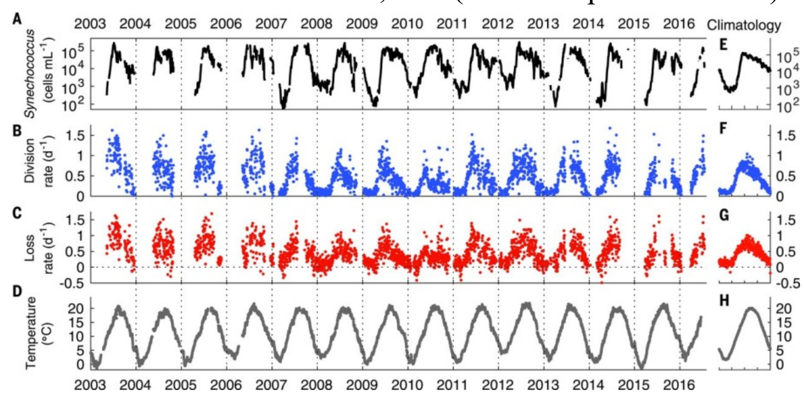
Weight	32 kg
Diameter	26 cm
Height	102 cm
Max Depth	40 m
Duration	Up to 6 mo.
Frequency	5 mL/20 min
Power	35W, 18-36VDC
Comms	10/100/1000-BaseT Ethernet

Automated flow cytometer, *FlowCytobot* (FCB): Phytoplankton taxa, size, abundance (moored, flow-through)

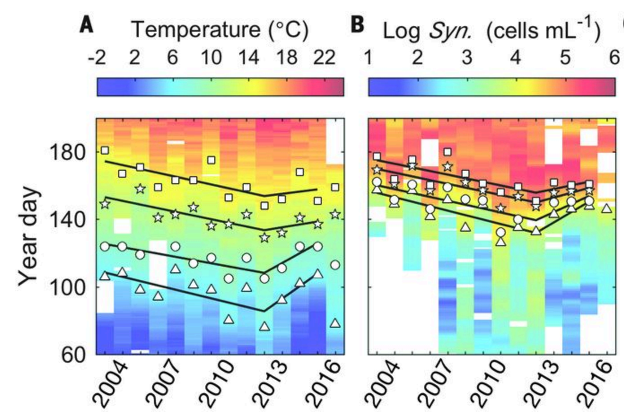


Phytoplankton cells automatically identified and categorized by the IFCB analysis software, from samples collected at Port Aransas, TX. (Lisa Campbell - TAMU)

Daily time series at MVCO from 2003 to 2016



Hunter-Cevera et al. 2016. Science. Vol. 354, Issue 6310, pp. 326-329 DOI: 10.1126/science.aaf8536



Changes in phenology with changes in temperature

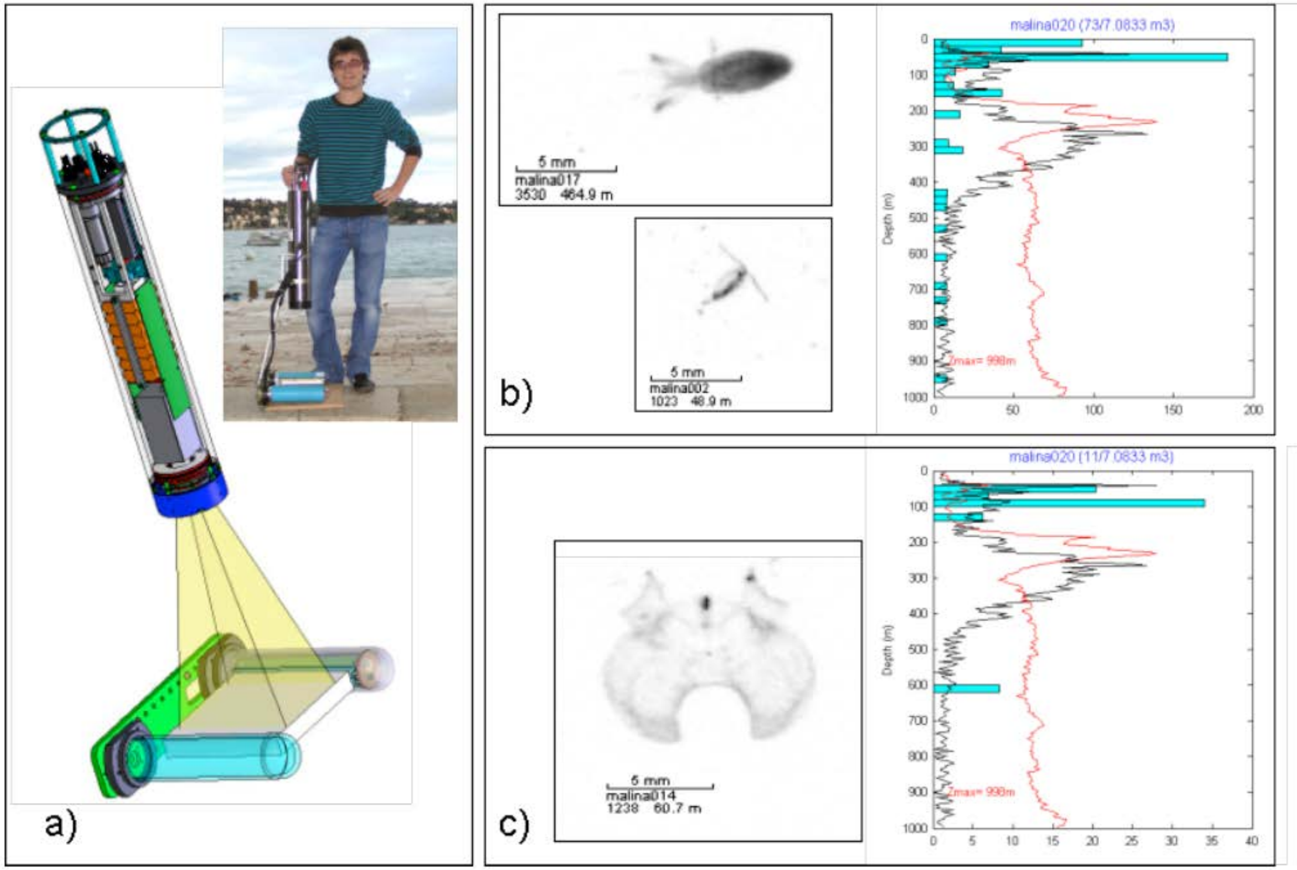
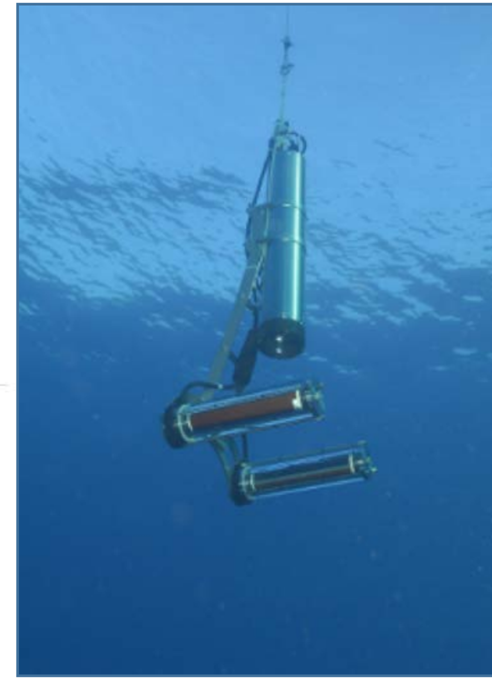
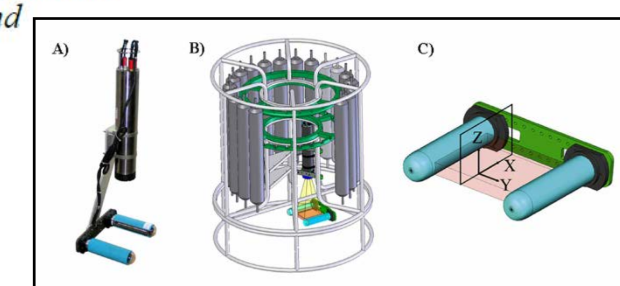


Figure 1: a) UVP5, b) specimens and vertical distribution of copepods (blue), particles below 200 µm (black) and particles above 500 µm (red) at station 20 of Malina cruise, c) specimen and vertical distribution of appendicularia (blue), particles below 200 µm (black) and particles above 500 µm (red)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



http://www.hydroptic.com/index.php/public/Page/product_item/UVP5-DEEP

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

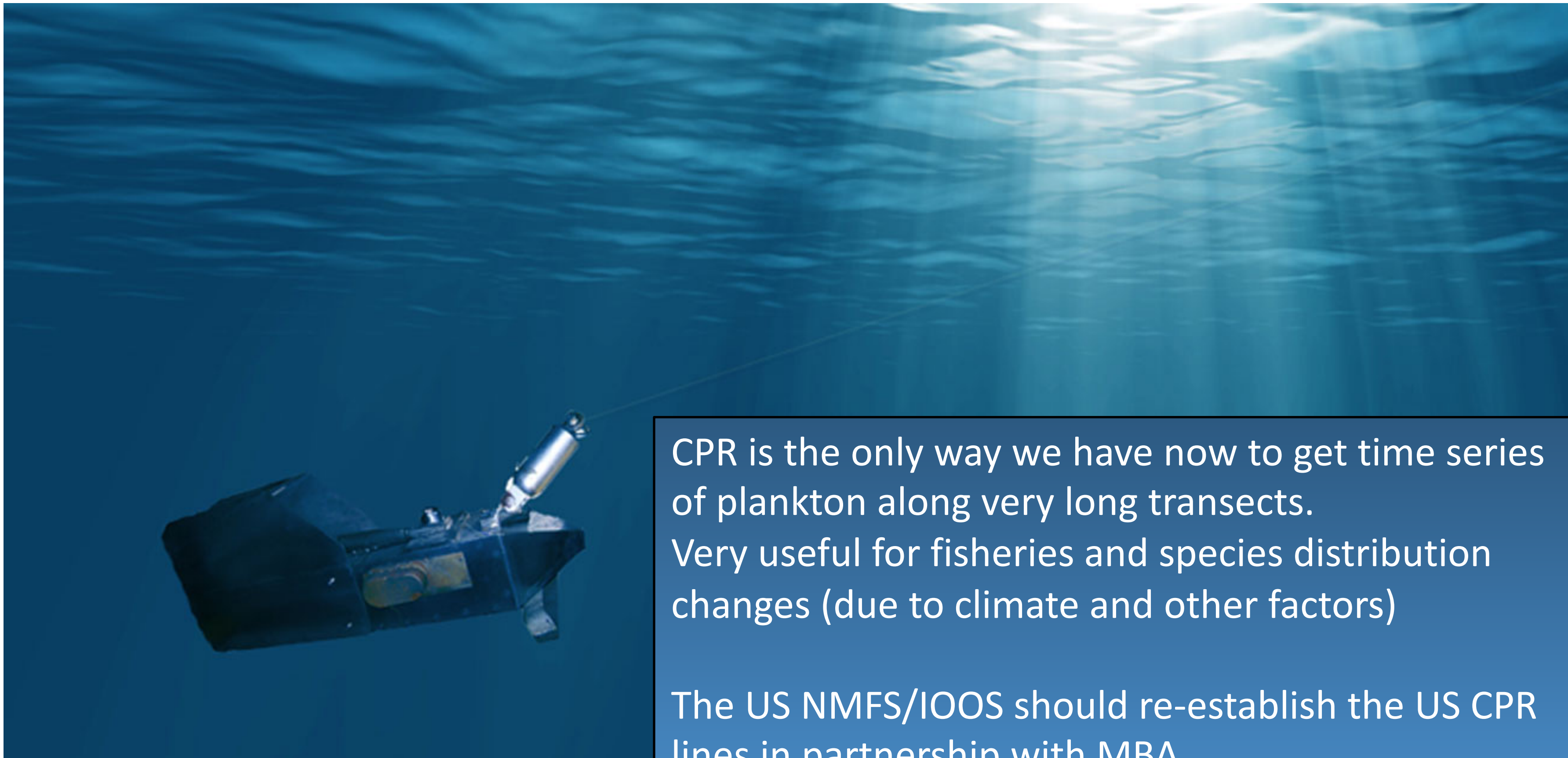


Picheral et al., 2010. Limnol. Oceanogr.: Methods 8, 2010, 462–473

THE CONTINUOUS PLANKTON RECORDER (CPR)

The Marine Biological Association of the UK

https://www.mba.ac.uk/fellows/cpr-survey

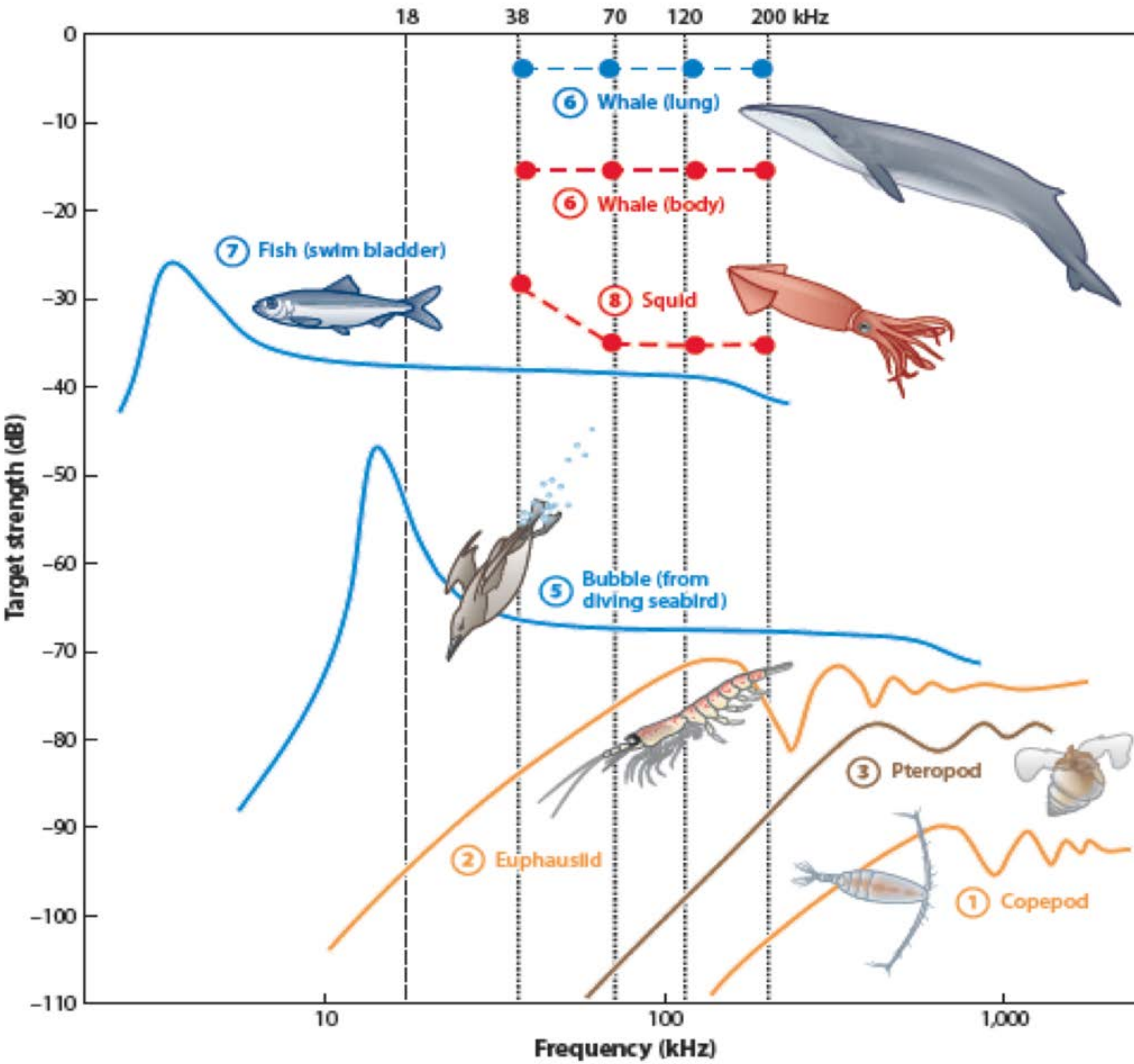


CPR is the only way we have now to get time series of plankton along very long transects.
Very useful for fisheries and species distribution changes (due to climate and other factors)

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

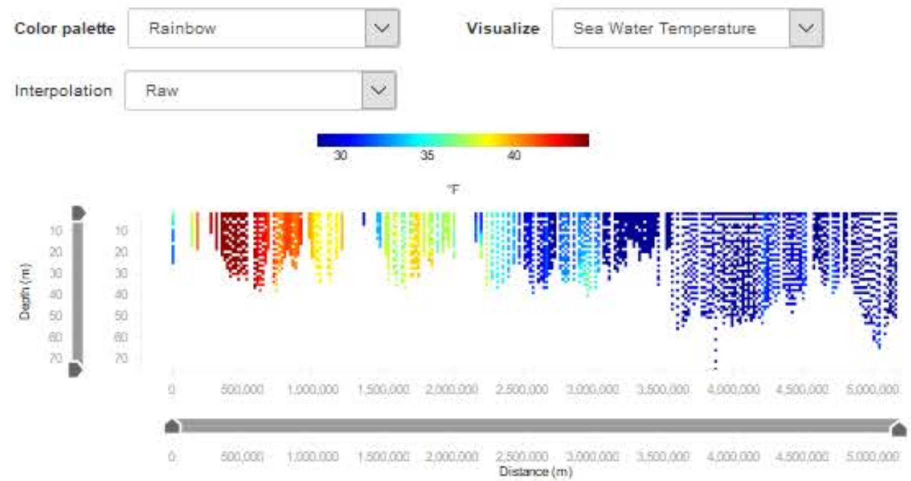


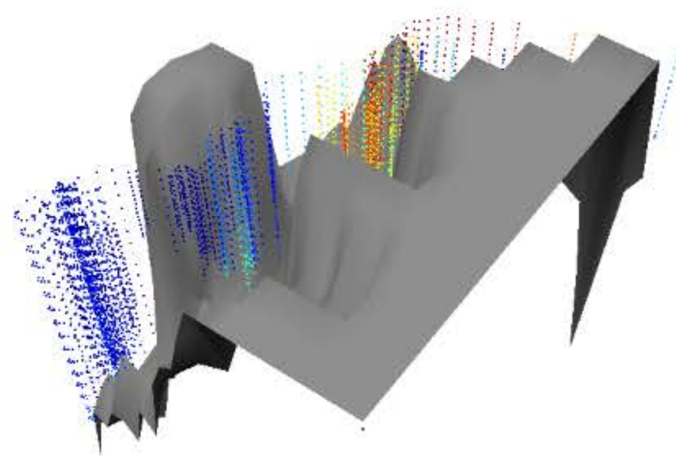
Animal borne sensors and telemetry

Animal Telemetry Network: IOOS Integrated Ocean Observing System ***ATN***
https://atn.ioos.us

eb03-061-15

Date range	Sep 11, 2015 07:26 (EST) - Feb 22, 2016 04:02 (EDT)
Depth range	2 (m) - 75 (m)
Points	4,149
Institution	MARES
Authority	uk.ac.st-andrews.smru

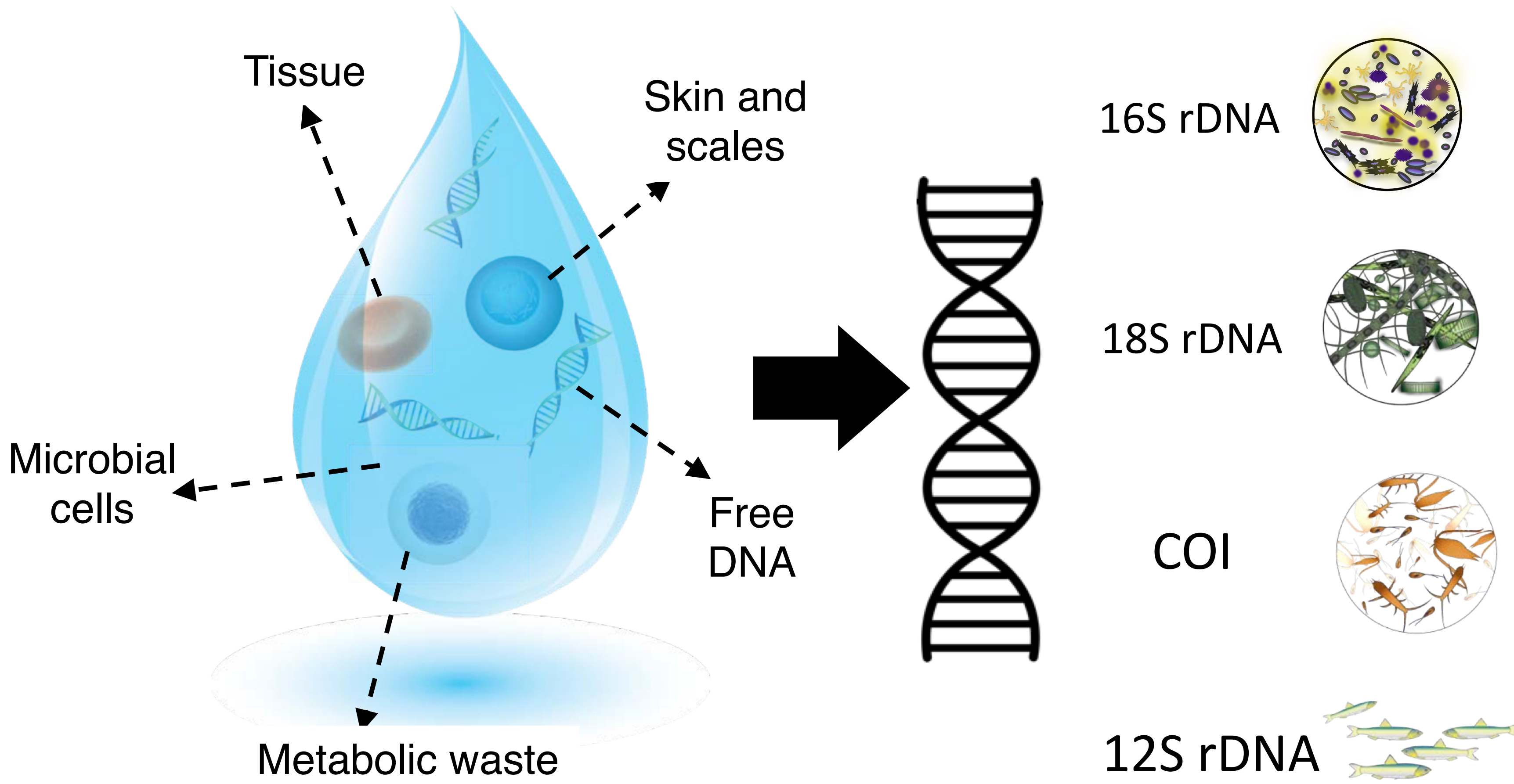




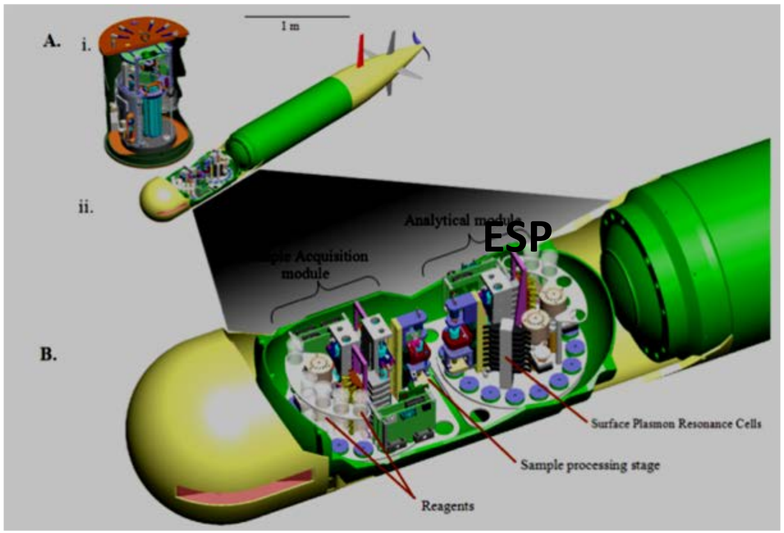
Many other things can be learned about marine animal movement and behavior using telemetry capabilities:
-migration corridors
-breeding behavior
-feeding behavior
-biodiversity hotspots

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



A revolution of autonomous platforms and sensors (biogeochemical, optical, genomic) is underway.

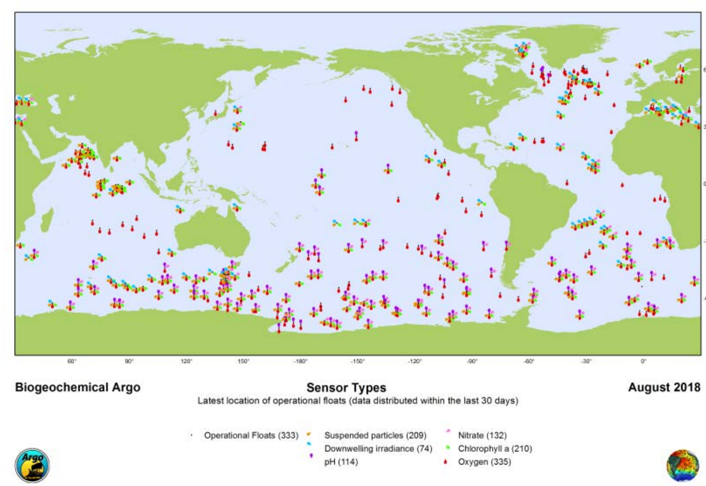


Long range AUV

(Courtesy of MBARI ESP and LRAUV teams)

Biogeochemical Argo

Oxygen
Nitrate
pH
Chlorophyll fluorescence
Suspended particles
Downwelling irrandiance
Zooplankton images



http://biogeochemical-argo.org/#

Satellite-derived Seascapes

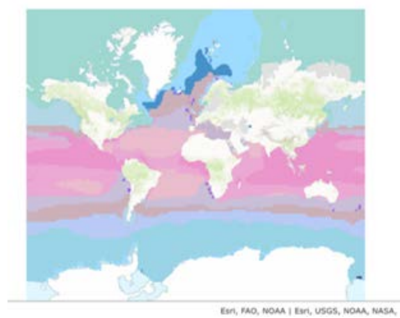
Kavanaugh (OSU), Doney (UVa), Grebmeier (UMCES),
Wright (ESRI), Otis/Montes/Djurhuus/Muller-Karger (USF),
Trinanes/DiGiacomo (NESDIS CoastWatch)

Collaboration:

- MBON sites
- NOAA NESDIS
- US IOOS
- NASA

Static+3D

Global classification



Ecological Marine Units

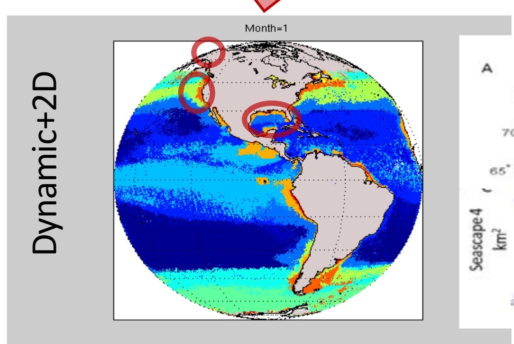
Regional downscaling

Arctic MBON; Distributed Biological Observatory

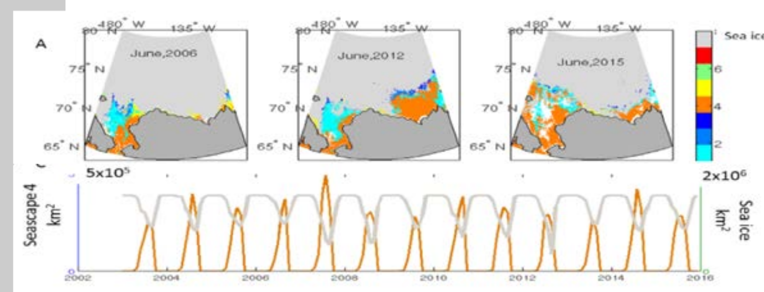
Ongoing efforts

- Global classification of dynamic seascapes
- EMU intercalibration
- Case Study: Arctic (polar, temperate, subtropic)
- Habitat –species relationships
- Operational multiscale products

Dynamic+2D



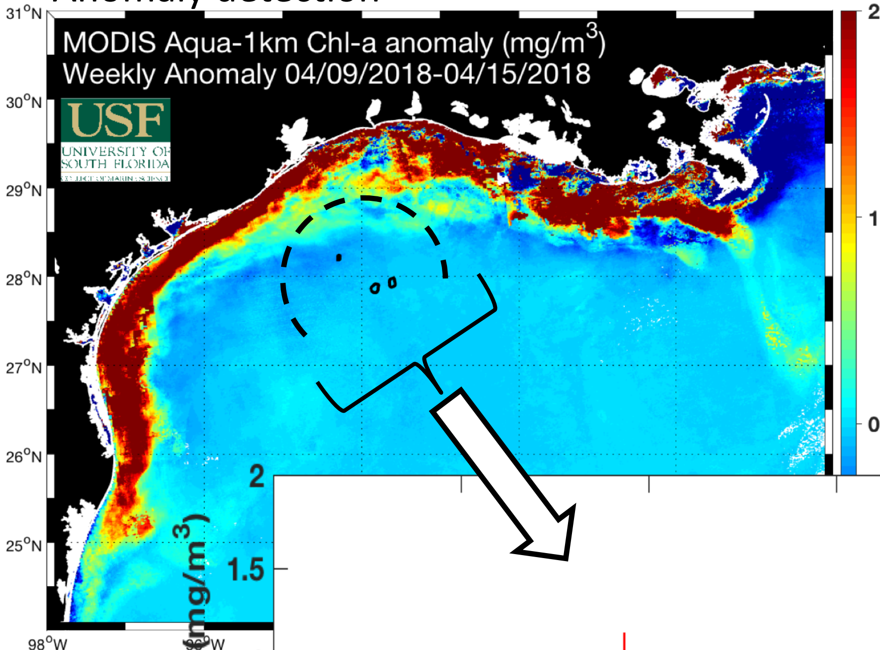
Dynamic Seascapes



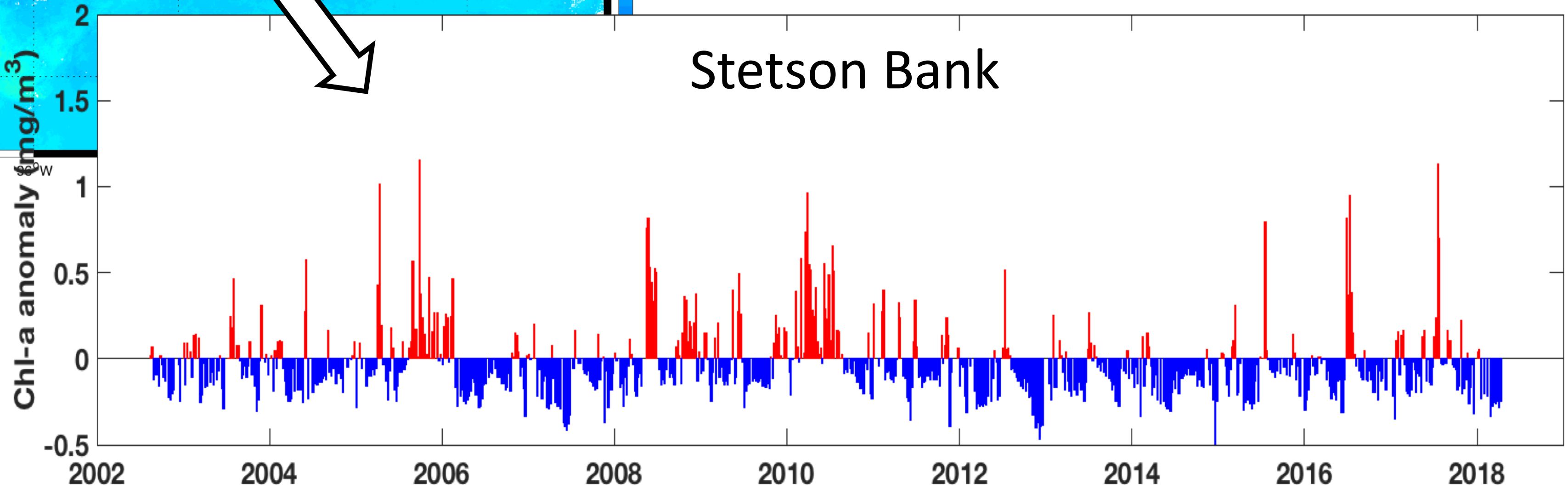
Dynamic habitat maps

Early warning and alert system (US Sanctuaries)

Anomaly detection

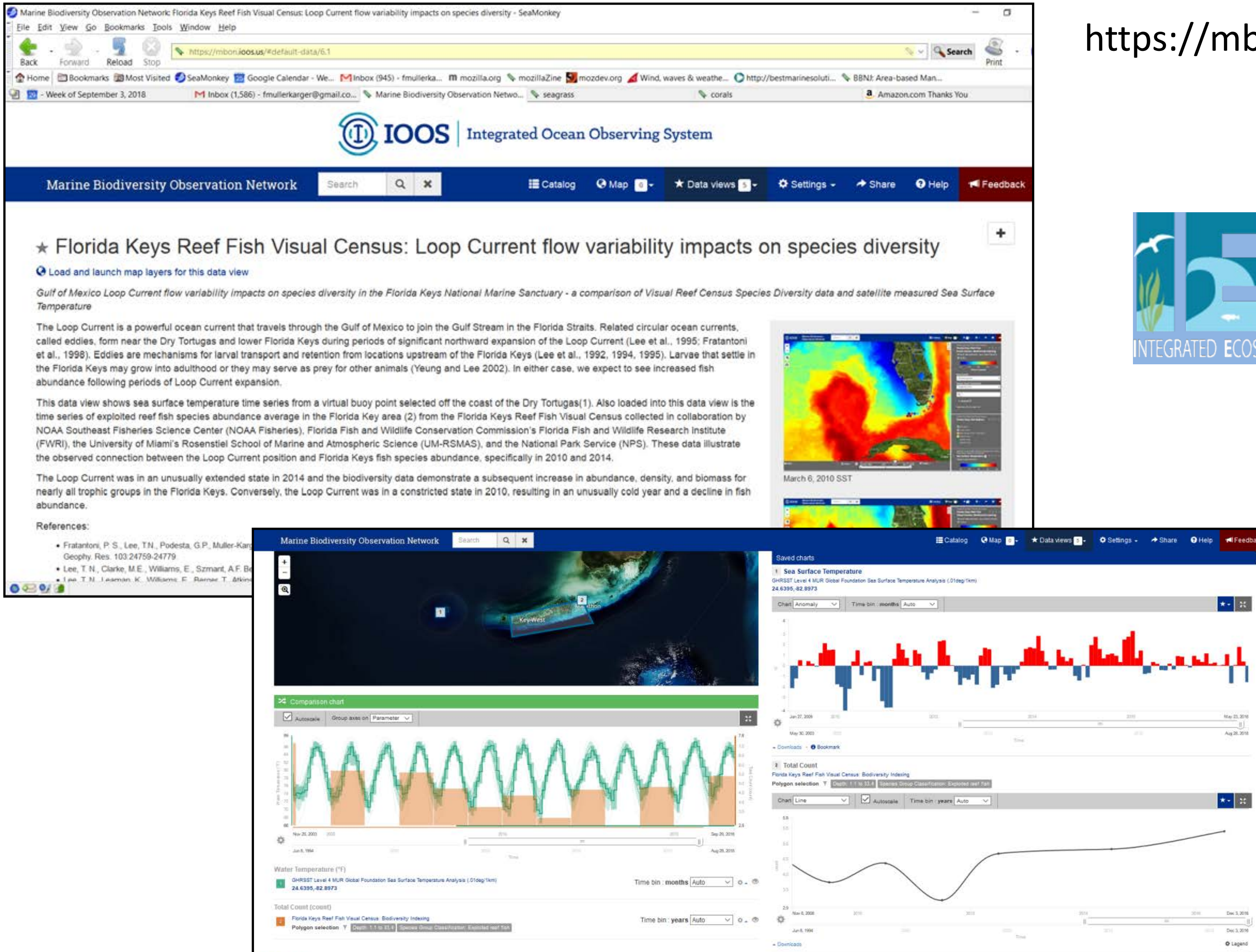


- Detection of anomalies in CHL, SST, Turbidity
- FGBNMS, FKNMS, others
- Dashboard and email alerts in real time



Dynamically updating status and trends:

https://mbon.ioos.us/



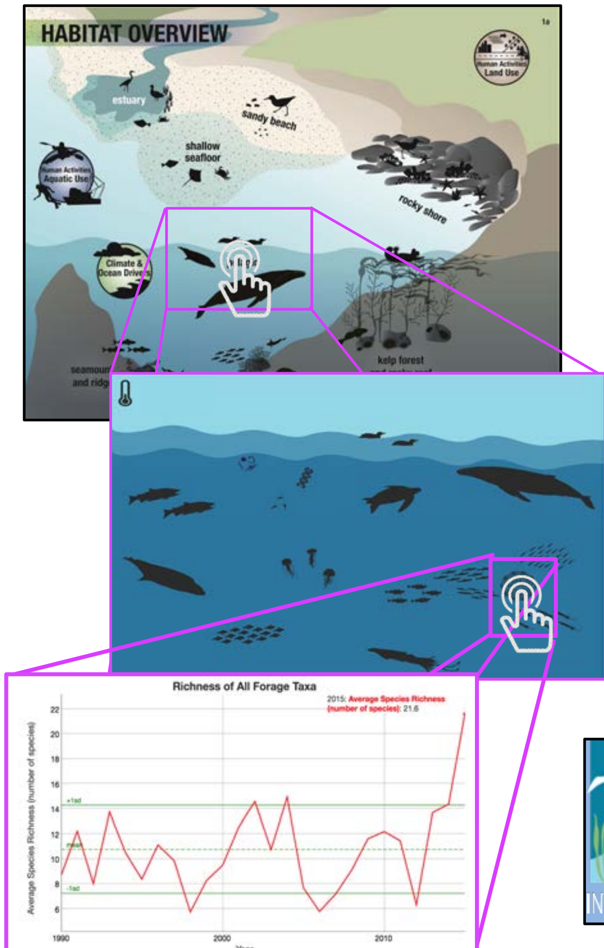
INTEGRATED ECOSYSTEM ASSESSMENT

https://mbon.ioos.us/#default-data/6.1

Dynamically updating status and trends

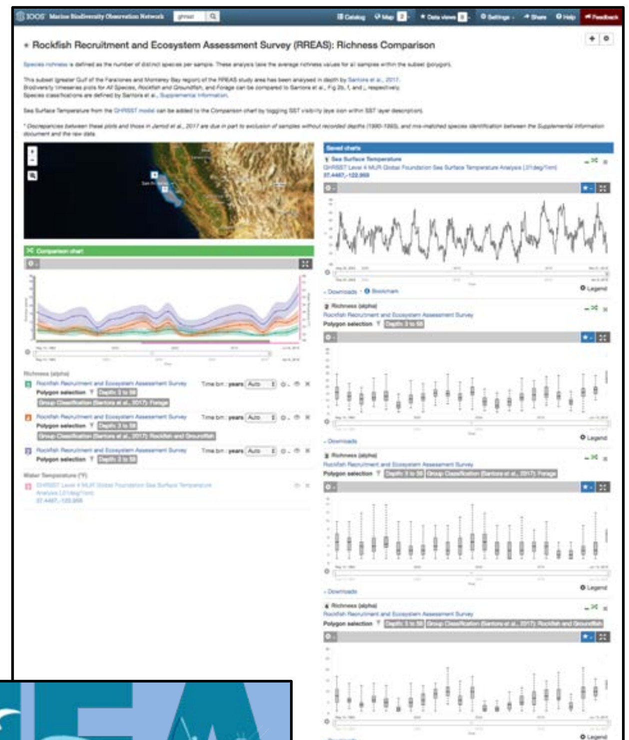
Infographics

Audience:
Public, managers, educators



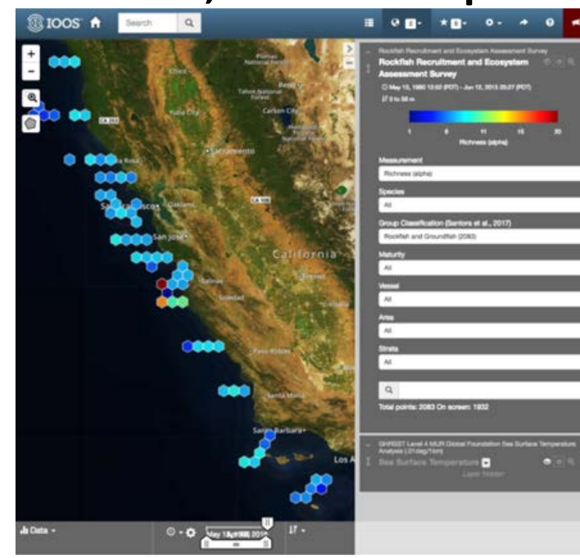
Curated Data Views

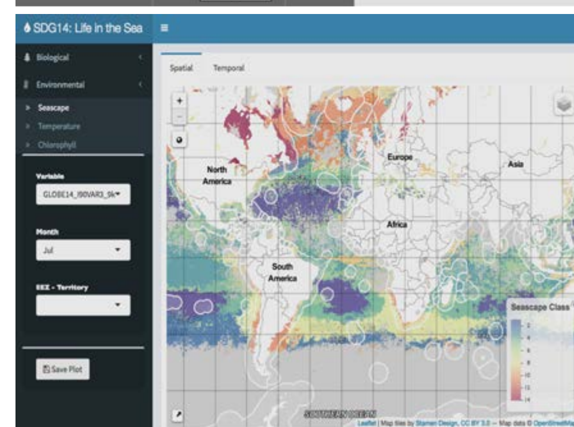
Audience:
Advisory groups, researchers, teams



Data portals

Audience:
Scientists, technical experts





What programs address the need for biological data?

- Multiple research programs
- Many resource management programs

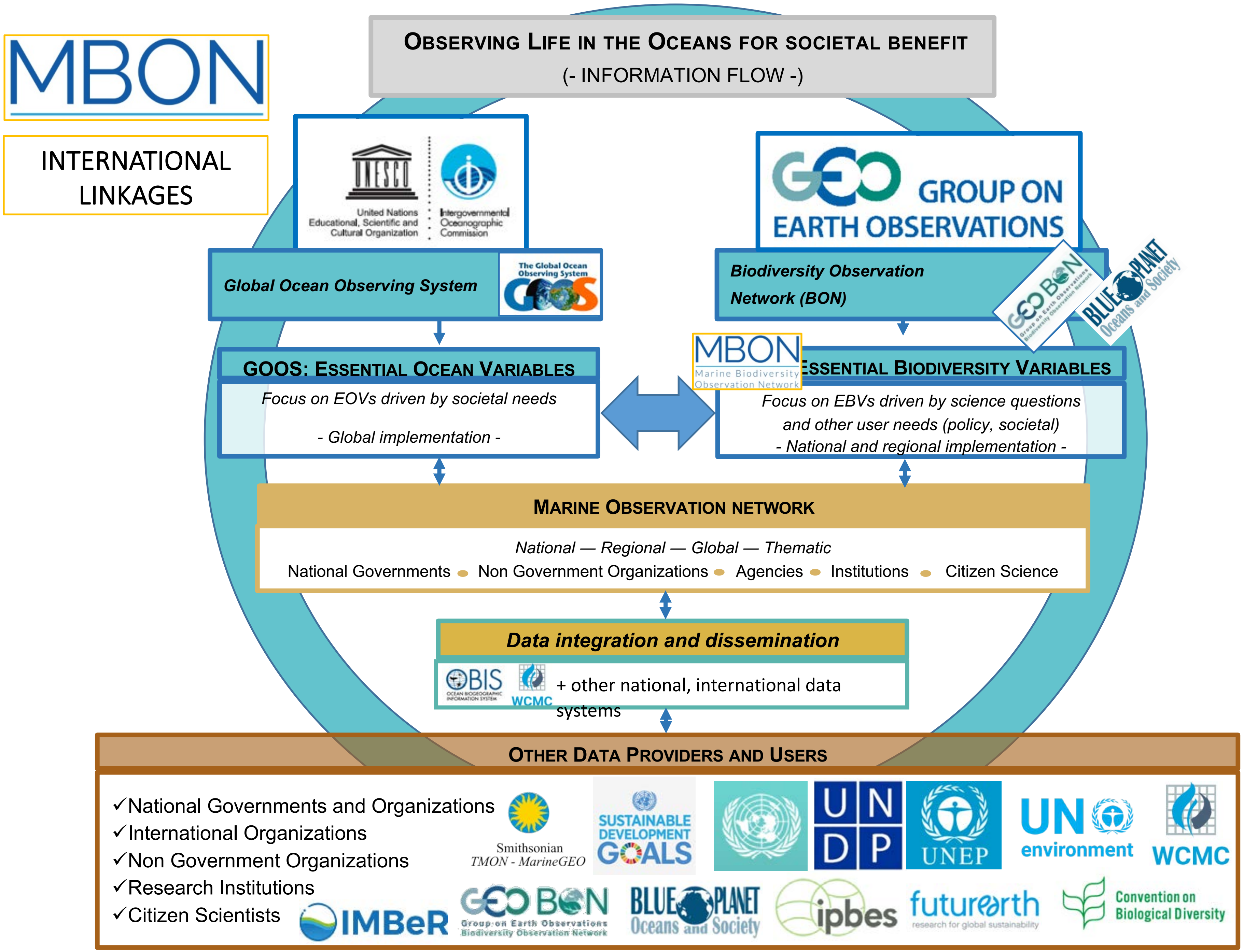
- None are coordinated
- Few store data in common format
- Few share data

Coordination efforts

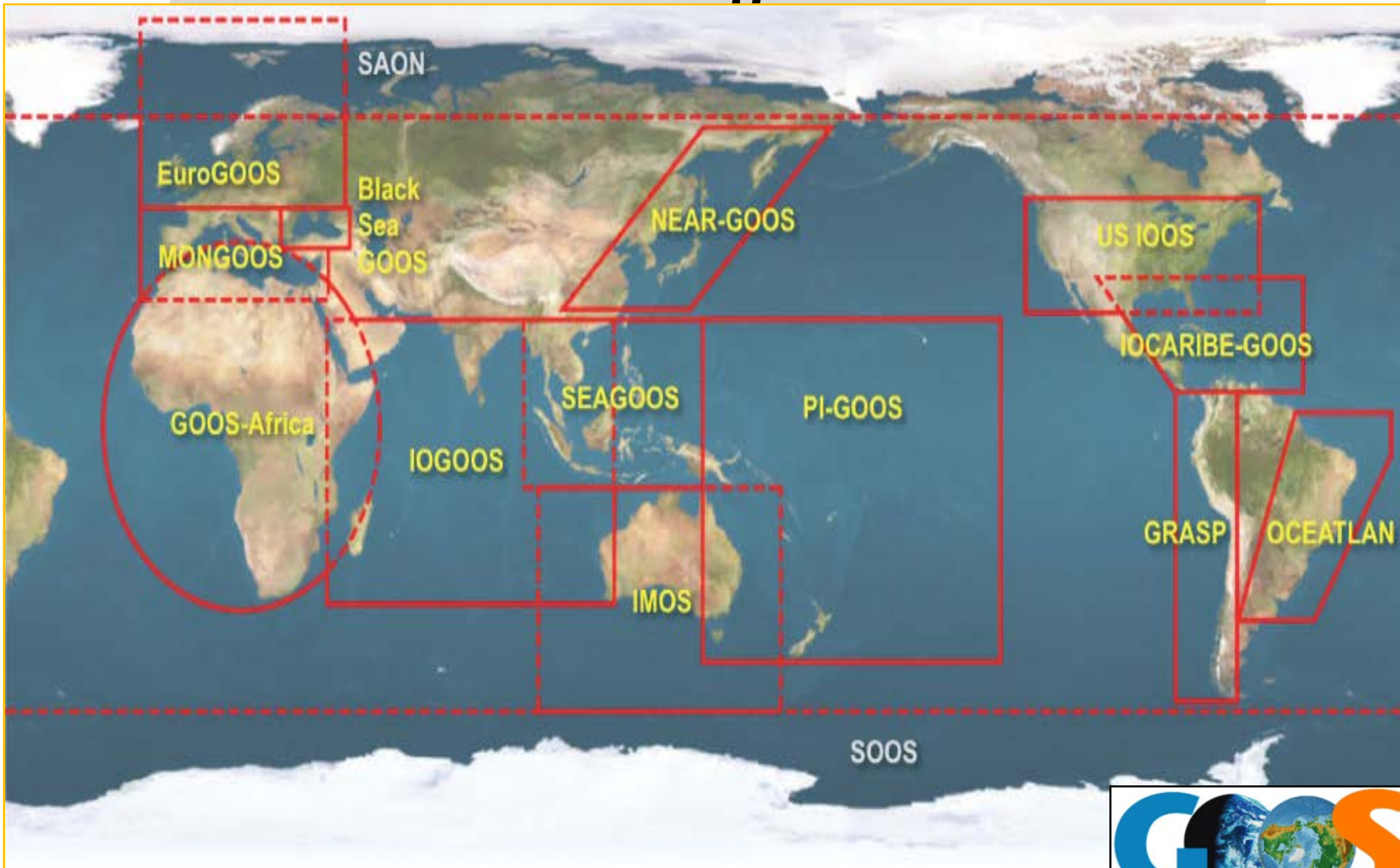
- Intergovernmental Oceanographic Commission
  - Global Ocean Observing System (GOOS)

    + OBIS, OTGA, **Ocean Best Practices System**
- NSF OceanObs Research Coordination Network (RCN)
- Marine Biodiversity Observation Network (MBON)
- MarineGEO (Smithsonian Institution)
- OceanObs ‘19 Conference (SEP 16-20, Honolulu, HI)

- UN Sustainable Development Goals
  - UN Decade of Ocean Science for Sustainable Development (2021-2030)
  - UN Decade for Ecosystem Restoration
- Convention on Biological Diversity
  - Aichi Targets and post-2020 agenda
- Etc.


MBON
INTERNATIONAL LINKAGES
OBSERVING LIFE IN THE OCEANS FOR SOCIETAL BENEFIT
(- INFORMATION FLOW -)
United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
GEO GROUP ON EARTH OBSERVATIONS
Global Ocean Observing System
The Global Ocean Observing System
Biodiversity Observation Network (BON)
GOOS: ESSENTIAL OCEAN VARIABLES
Focus on EOVs driven by societal needs
- Global implementation -
MBON Marine Biodiversity Observation Network
ESSENTIAL BIODIVERSITY VARIABLES
Focus on EBVs driven by science questions and other user needs (policy, societal)
- National and regional implementation -
MARINE OBSERVATION NETWORK
National — Regional — Global — Thematic
National Governments
Non Government Organizations
Agencies
Institutions
Citizen Science
Data integration and dissemination
OBIS
WCMC
+ other national, international data systems
OTHER DATA PROVIDERS AND USERS
✓National Governments and Organizations
✓International Organizations
✓Non Government Organizations
✓Research Institutions
✓Citizen Scientists
Smithsonian TMON - MarineGEO
SUSTAINABLE DEVELOPMENT GOALS
UNDP
UNEP
UN environment
WCMC
IMBeR
GEO BON Group on Earth Observations Biodiversity Observation Network
BLUE PLANET Oceans and Society
ipbes
futurearth research for global sustainability
Convention on Biological Diversity

Goal: Integrate biological observing into 15 GOOS Regional Alliances



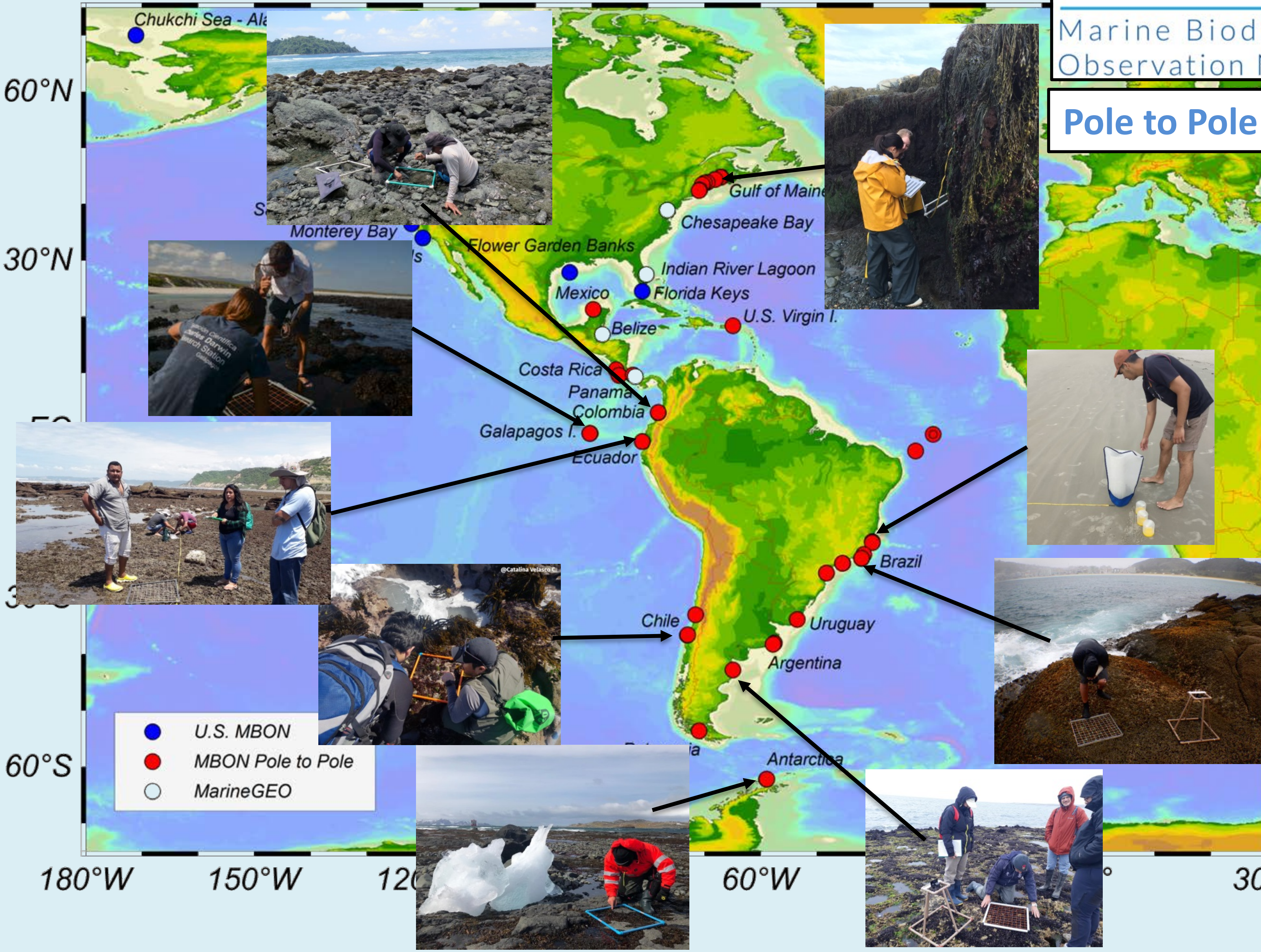
MBON
Marine Biodiversity Observation Network

- Address a number of Issues:
  - Integrating biology into operational observing systems
  - Space, time resolution
  - Data latency
  - Data management: curation, archiving
  - Products and services
  - Sharing data!
  - Cost
  - Capacity building and tech transfer

Capacity Building – Field sampling

MBON
Marine Biodiversity Observation Network

Pole to Pole MBON



Recommendations for CLIVAR

- Carefully define specific user needs
- Integrate biological observations into ocean observing
    - *Ships, moorings, buoys, gliders, animals*
- Expand collaborations / partnerships to access/collect bio data
- Engage in defining linked in situ and satellite remote sensing systems
- Develop integrated biological-physical coupled models designed for purpose

Recommendations for CLIVAR (2)

- Biological/biogeochemical data management strategy:
  - Promote best practices for operational data collection (EOVs)
  - Promote common data formatting and archiving (Darwin Core/ERDDAP)
  - Promote use of OBIS
  - Initiate Data Archaeology (a la Syd Levitus / NODC 1980’s):
    - National (and provide leadership for international effort)
  - National to Regional to Global product integration
  - Use infographics and user-defined data views and regional scenarios

Let’s work together to measure life in the sea

Image courtesy of Francisco Chavez / MBARI

NASA

NOPP National Oceanographic Partnership Program

NOAA

IOOS Integrated Ocean Observing System

Ocean Exploration and Research

National Marine Sanctuaries

NOAA FISHERIES

GEO BON

MBON

Marine Biodiversity Observation Network

FRANK MULLER-KARGER
carib@usf.edu
College of Marine Science
Saint Petersburg, Florida, USA

USF UNIVERSITY OF SOUTH FLORIDA