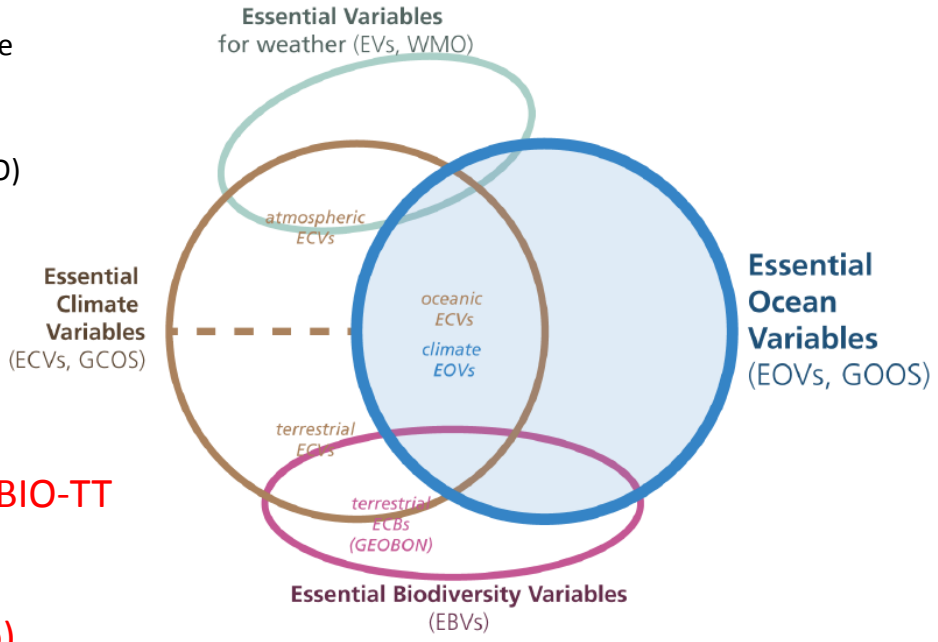
Global Marine Biodiversity Monitoring

- **Biodiversity observations need to advance basic science and applications (need to have a customer)**
  - People health and well-being
  - Ecological balance and health
  - Understanding the formation of species and how organisms occupy existing or new niches
- Concepts for assessments outlined by:
  - Convention on Biological Diversity (CBD)
  - Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES)
  - World Ocean Assessment (UN General Assembly 2014)
  - Marine protected area / resource management agencies

Marine Biodiversity Monitoring

- **Several groups are working to define requirements for ocean biology, ecology and biodiversity; including:**
  - Group on Earth Observations (GEO):
    - GEOSS, GEOWOW, GEOBON – Marine Ecosys. Change
  - GOOS
    - GOOS Panel for Integrated Coastal Observation (PICO)
    - GOOS Bio/Eco Panel
  - I-OBIS
  - U.S. Interagency Working Group on Ocean Partnerships Ad Hoc Group on Biodiversity
  - Interagency Ocean Observation Committee BIO-TT
  - US Marine Biodiversity Obs. Network (BON)
  - Smithsonian Tennenbaum Obs. (Marine Geo)
  - OBIS + IOOS

USA



- Tiered approach:

National → regional → global

Strategy should follow DPSIR (developed by the Organisation for Economic Co-operation and Development/OECD 1994)
(Driver. Pressure, State, Impact, Response)

The U.S. Interagency Ocean Observation Committee (IOOC): Biological Integration and Observation (BIO) Task Team

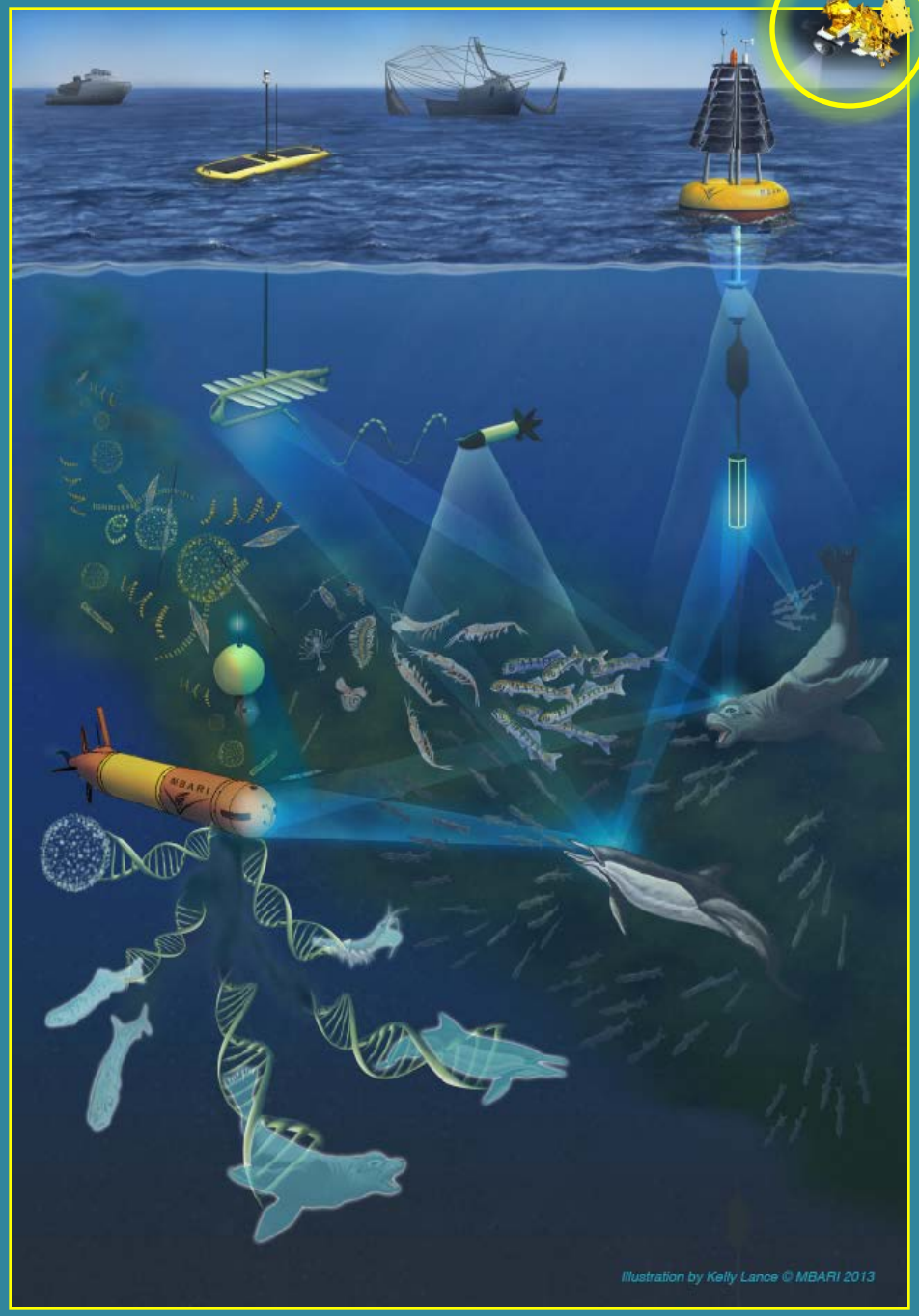
BIO Task Team and non-governmental experts surveyed U.S. agency needs for monitoring living organisms in the ocean, coasts, and Great Lakes as part of IOOS

RECOMMENDATIONS:

To ensure stewardship of these areas we must consider interactions (spatial and temporal) among climate, physics, chemistry, **and biology.**

Need to observe these biology/ecology core variables:

- **Species and abundance** of core functional groups (highest priority)
- **Biological vital rates (BVRs)** included as IOOS core variables
  - Include: production, recruitment, mortality, fecundity, growth, feeding rates
- **Nekton diet**
- **Sound**



(2010-2013 –) U.S. Interagency Working Group on Ocean Partnerships Ad Hoc Group on Biodiversity:

A Marine Biodiversity Observation Network (MBON)

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

(2014)


NASA


NOPP
National
Oceanographic
Partnership
Program


BOEM
Bureau of Ocean Energy Management


NOAA


ATLANTIC OCEANOGRAPHIC & METEOROLOGICAL LABORATORY
NOAA


IOOS
INTEGRATED OCEAN OBSERVING SYSTEM


NATIONAL MARINE
SANCTUARIES


NOAA FISHERIES


OFFICE OF OCEAN EXPLORATION AND RESEARCH

Four US Pilot MBON's

PIs: F. Muller-Karger (USF)
F. Chavez (MBARI)
Katrin Iken (UAK)

Pilot MBON projects designed to answer specific needs of government and industry 'customers':

- *NOAA:*
    - * *National Marine Sanctuaries*
    - * *Fisheries trends and impacts*
    - * *Invasive species monitoring*
- *Bureau of Ocean Energy Management and Oil industry:*
    - * *Environmental Impact Assessments*

Primary goals

- Implement a demonstration MBON
- Integrate, synthesize and augment information from ongoing programs
- Develop environmental DNA technology and autonomous sample collection methods for conducting biodiversity assessments
- Bring biodiversity measurements together in a relational database with links to national and international databases
- Develop a plan to transition the demonstration MBON into an operational system

Example: National Marine Sanctuary 'Condition Report' questions that require biodiversity observation

Water Quality

1) What is the eutrophic condition of sanctuary waters and how is it changing?
2) Do sanctuary waters pose risks to human health and how are they changing?
3) Have recent changes in climate altered water conditions and how are they changing?
4) Are other stressors, individually or in combination, affecting water quality, and how are they changing?

Habitat Quality

5) What is the integrity of major habitat types and how are they changing?
6) What are the contaminant concentrations in sanctuary habitats and how are they changing?

Living Resources

7) What is the status of keystone and foundation species and how is it changing?
8) What is the status of other focal species and how is it changing?
9) What is the status of non-indigenous species and how is it changing?
10) What is the status of biodiversity and how is it changing?

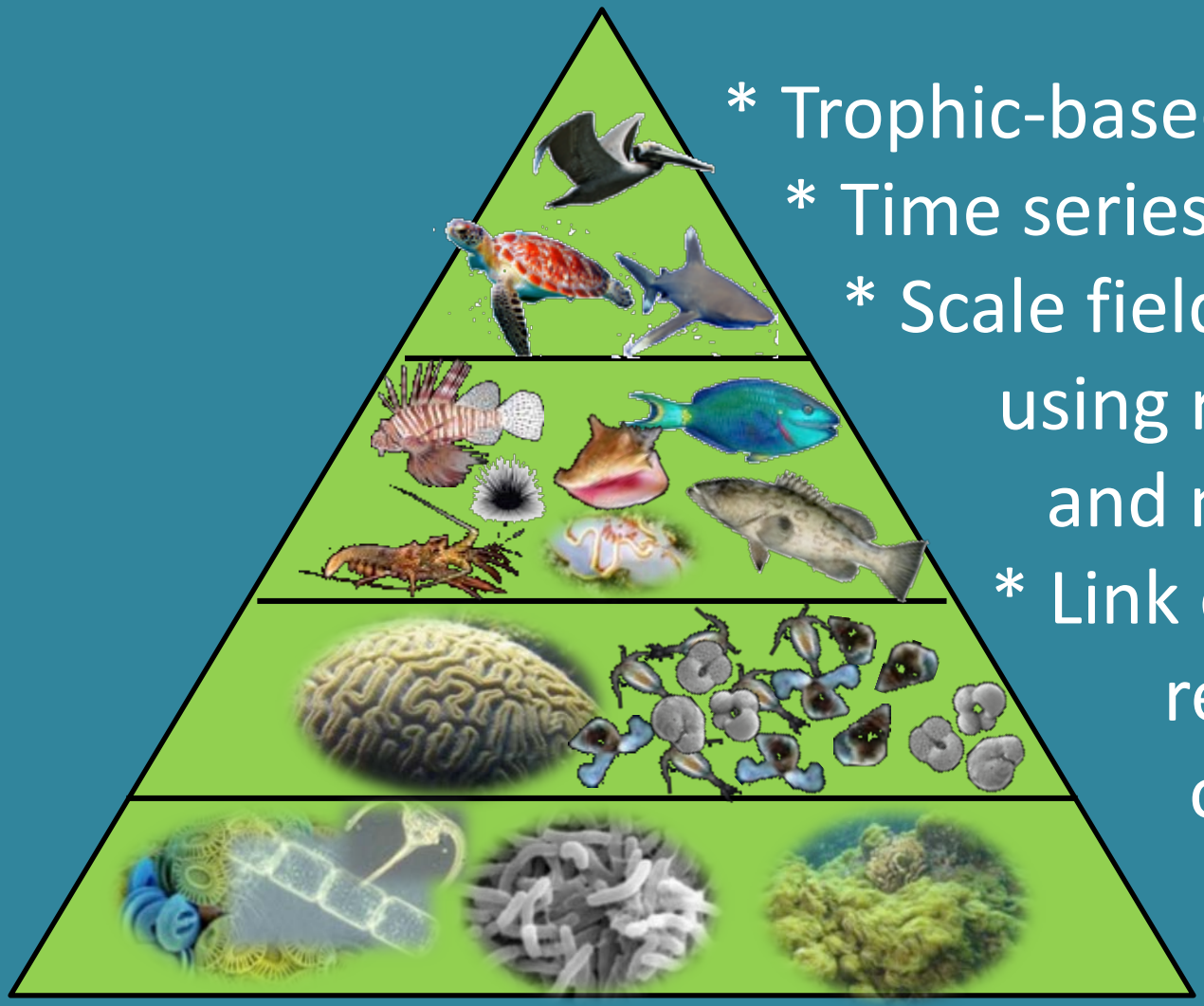
Maritime Archaeological Resources

11) What is the archaeological integrity of known maritime archaeological resources and how is it changing?
12) Do known maritime archaeological resources pose an environmental hazard and how is this threat changing?

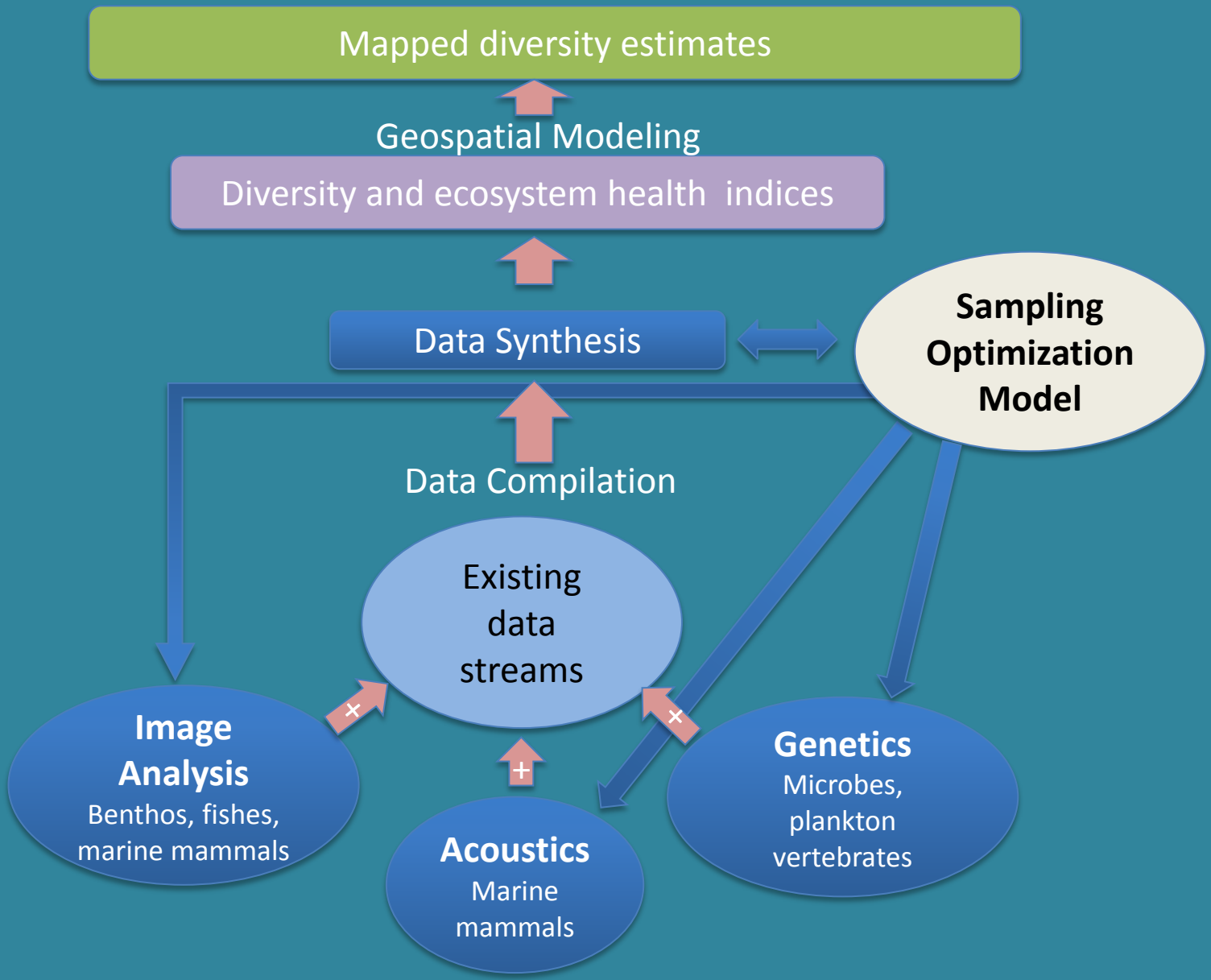
Human Dimensions

13) What are the levels of human activities that may adversely influence water quality and how are they changing
14) What are the levels of human activities that may adversely influence habitats and how are they changing?
15) What are the levels of human activities that may adversely influence living resources and how are they changing?
16) What are the levels of human activities that may adversely influence maritime archaeological resources and how are they changing
17) What are the states of influential human drivers and how are they changing?

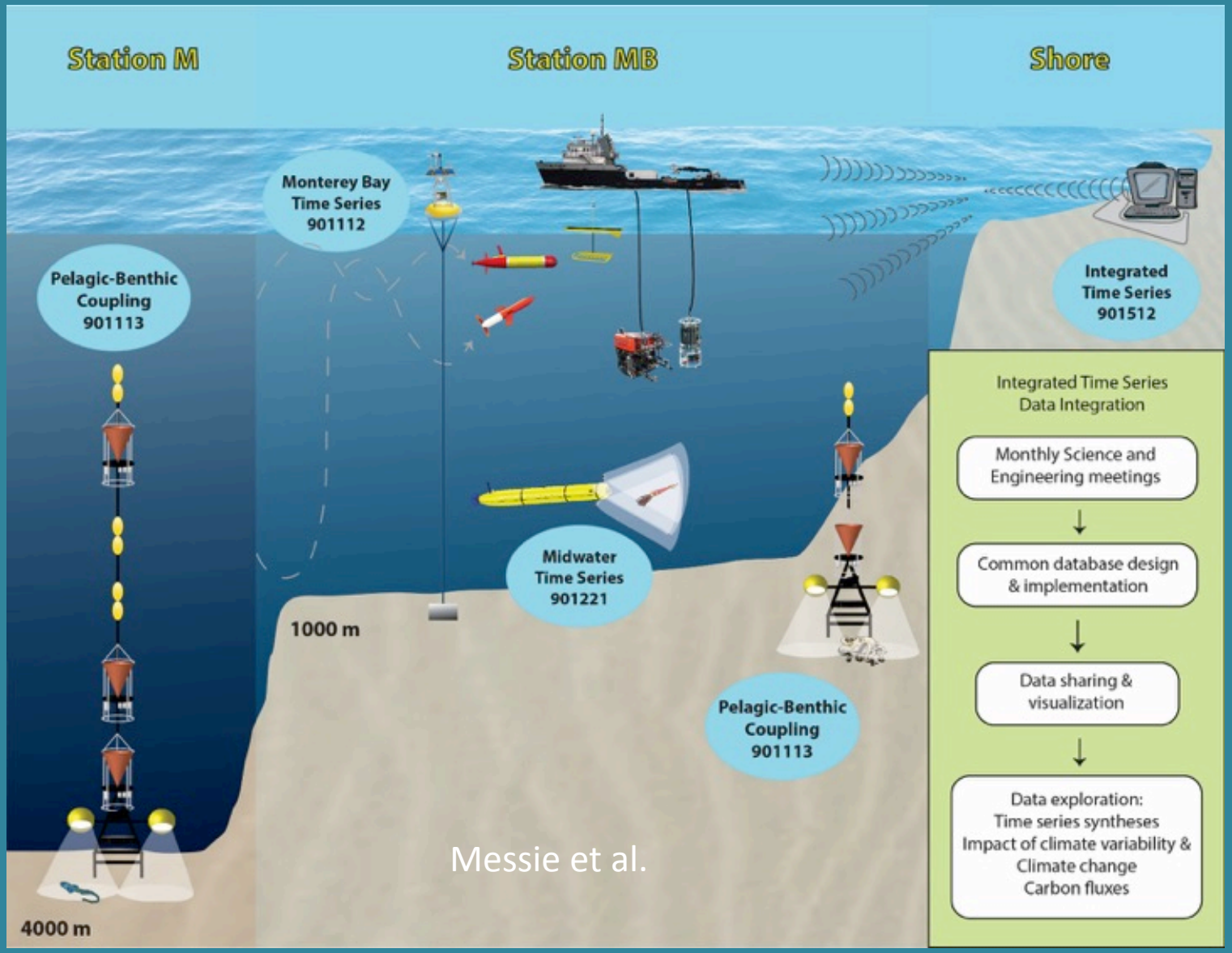
MBON Strategy



* Trophic-based biodiversity
* Time series metrics
* Scale field observations using remote sensing and models
* Link existing research and operational programs


Mapped diversity estimates
Geospatial Modeling
Diversity and ecosystem health indices
Data Synthesis
Sampling Optimization Model
Data Compilation
Existing data streams
Image Analysis
Benthos, fishes, marine mammals
Acoustics
Marine mammals
Genetics
Microbes, plankton vertebrates
+
+
+

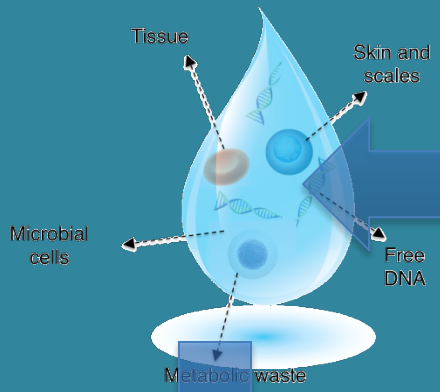
Each program builds on 20+ years of ongoing time series



Messie et al.

MBON Start-up (2014)

eDNA testing

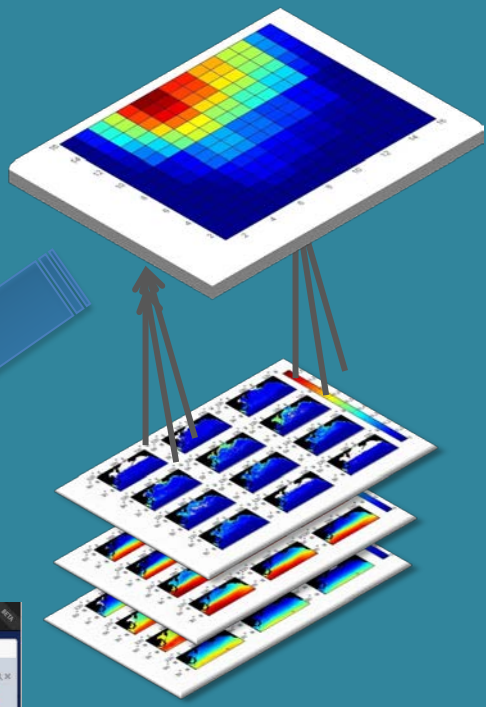


Case Studies

- Integration of environmental and biological datasets
- In situ data collection

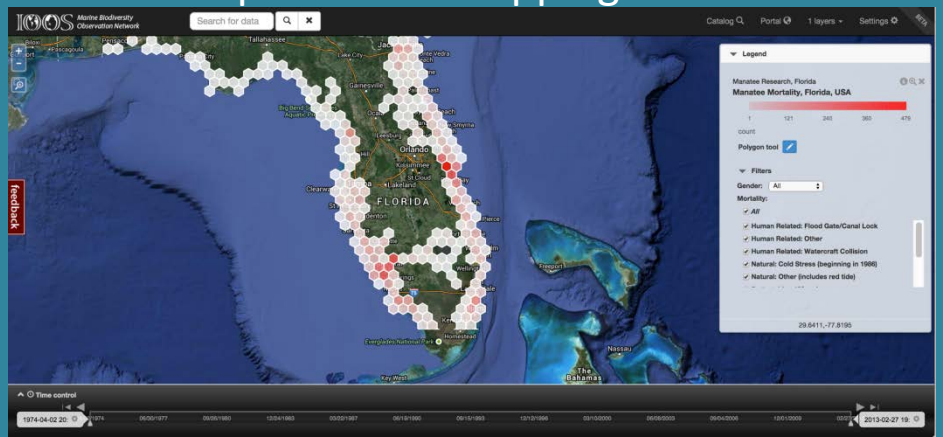
- E&O
- Socio-economics
- Ecosystem Valuation

Satellite Seascapes

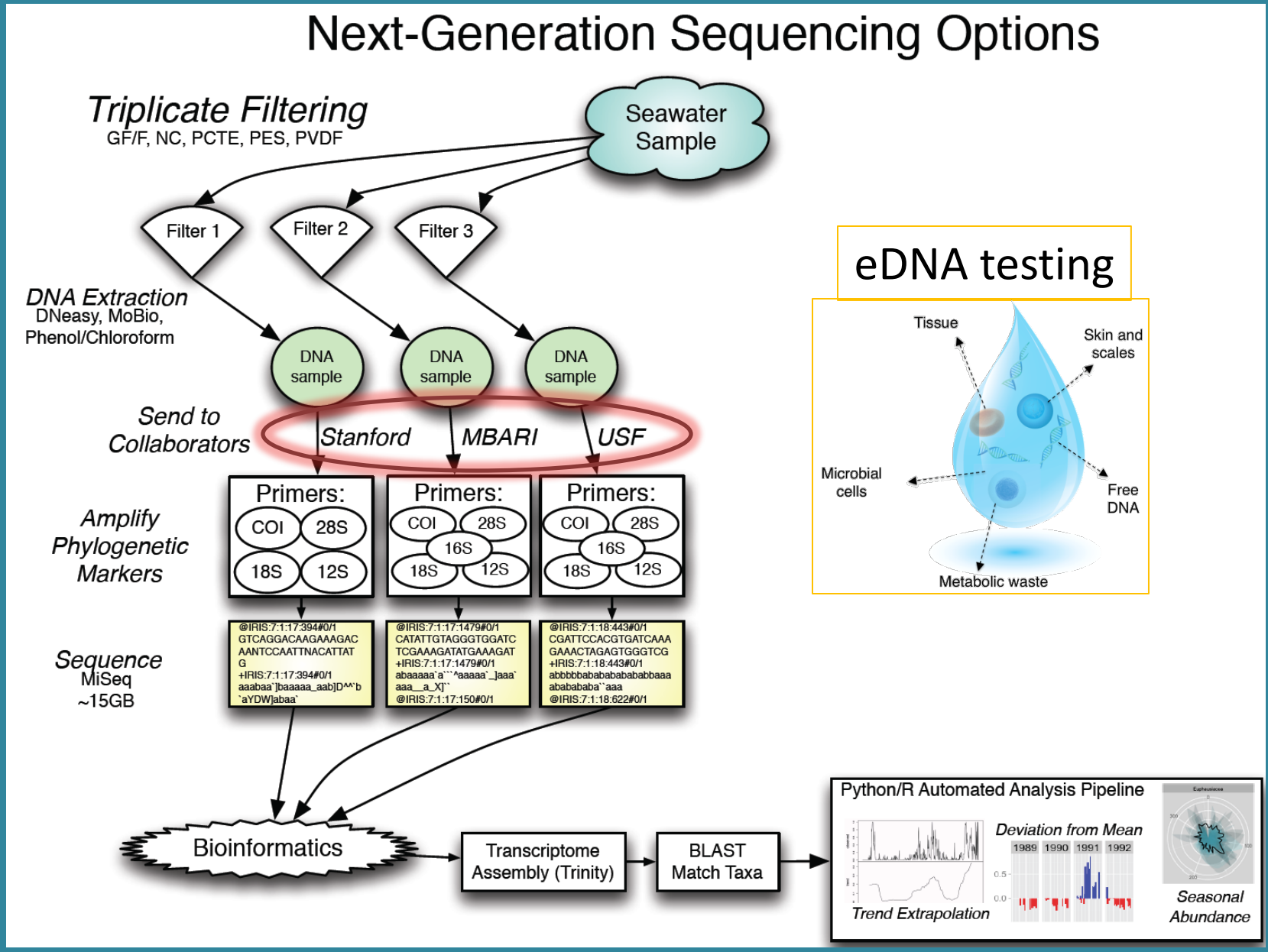


Autonomous eDNA sensor

MBON data portal and mapping tool

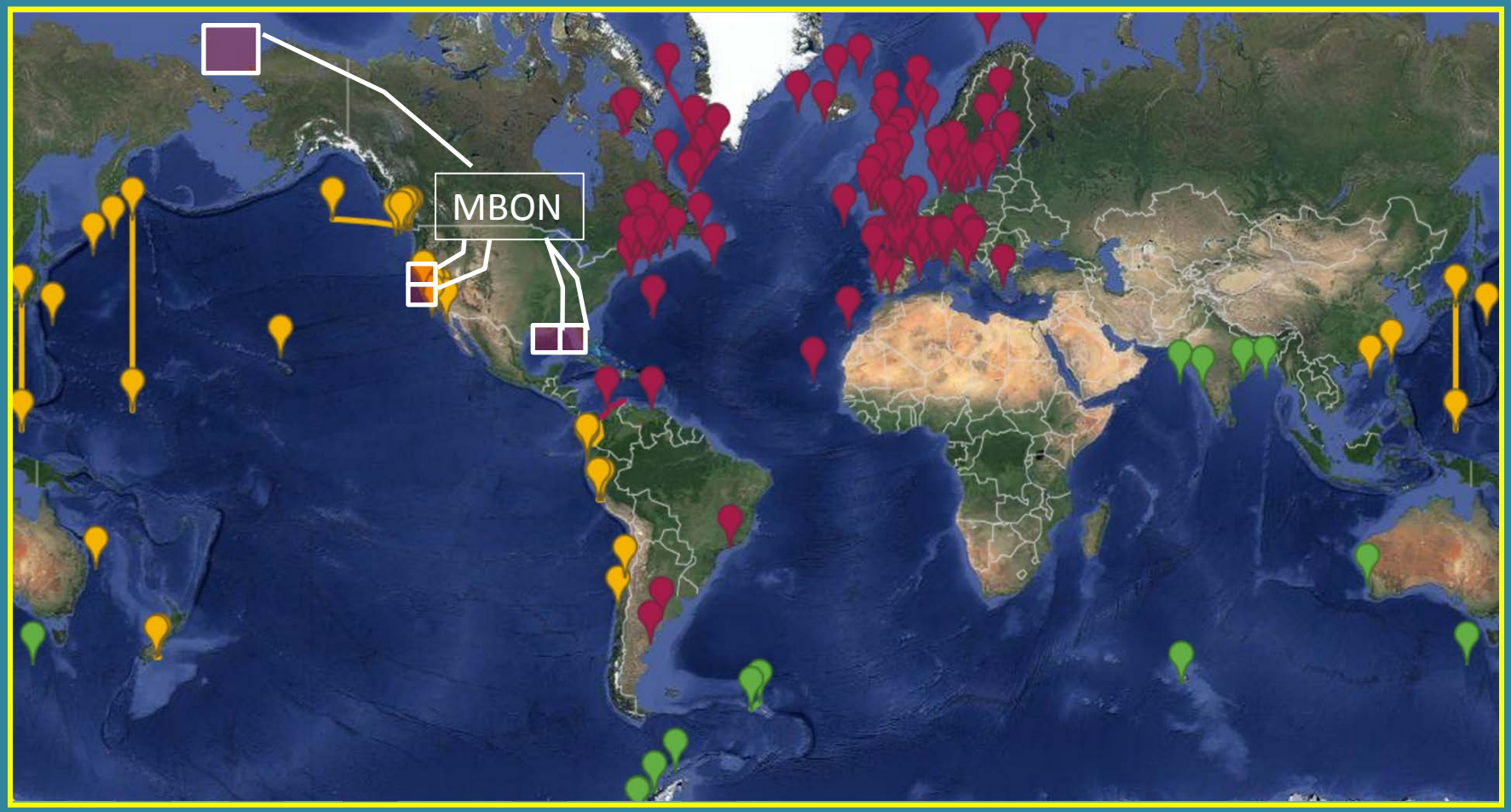


Test new high-risk methods for monitoring

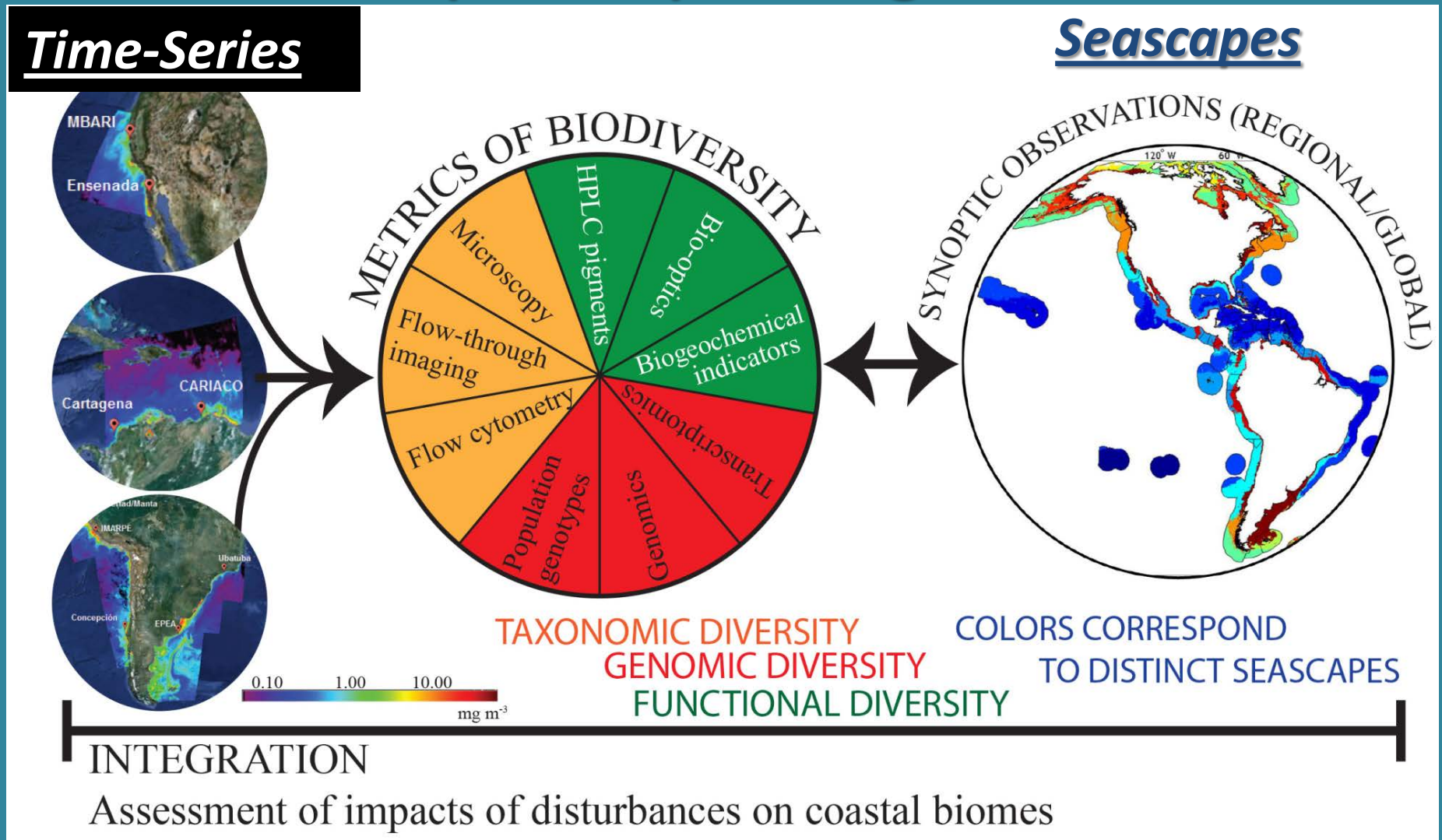


Can we do this at larger scales?

Ocean biogeochemistry (OCB) and ecology time series + U.S. MBON



Marine Biodiversity Observation Network (MBON) strategies



F.E. Muller-Karger, M. Kavanaugh, E. Montes, W.M. Balch, M. Breitbart, F.P. Chavez, S.C. Doney, E.M. Johns, R.M. Letelier, M.W. Lomas, H.M. Sosik, A.E. White. A framework for a Marine Biodiversity Observation Network within changing continental shelf seascapes. In press. Oceanography. September 2014.

Draft Guiding Principles for MBON

(Draft)

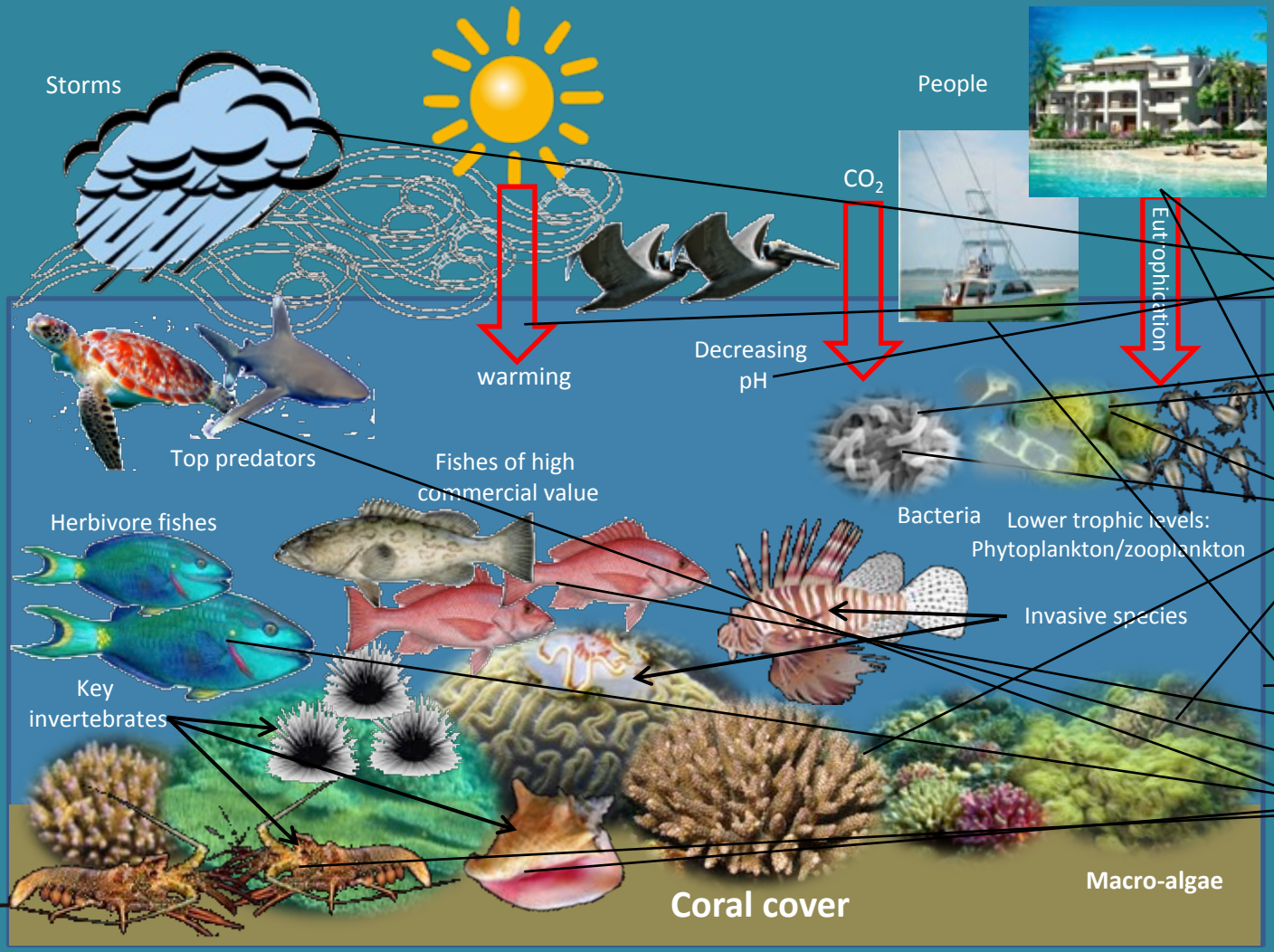
- **Ownership: the MBON should have stakeholders.**
- **Sustainability: build on existing monitoring infrastructure and management structures**; MBONS should meet the needs of the present without compromising future capability.
- **Stewardship:** balancing different uses of resources for the continued benefit of organisms and also of people that use or are related to the area covered.
- **Ocean–Land–Atmosphere Connections:** recognize that the oceans, land, and atmosphere are inextricably intertwined and that actions that affect one component are likely to affect another.
- **Ecosystem-based Management**: resources should be managed to reflect the relationships among all ecosystem components, including humans. This will require defining relevant geographic management areas based on ecosystem, rather than political, boundaries.
- Multiple Use Management: The many potentially beneficial uses should be acknowledged and managed in a way that balances competing uses while preserving and protecting the overall integrity of the ocean and coastal environments.
- Preservation of Marine Biodiversity: Downward trends in marine biodiversity should be reversed where they exist, with a desired end of maintaining or recovering natural levels of biological diversity and ecosystem services.
- **Best Available Science and Information**: Integrate the best available understanding of the natural, social, and economic processes. An MBON should help and support decision makers; these should be able to obtain and understand quality science and information
- Adaptive Management: programs should meet clear goals and provide new information to continually improve the scientific basis for future management. Allow for periodic reevaluation of the goals and management measures by incorporation of new information
- Understandable governance: governance should be clear, coordinated, and accessible to the various management bodies whose jurisdiction may overlap in an MBON. Decisions and reasoning behind them should be clear and available to all stakeholders.
- Participatory Governance: Governance should ensure widespread participation by all citizens/stakeholders on issues that affect them.
- Timeliness: Information should be available efficiently and openly.
- **Accountability:** MBON management should be accountable for the actions they take that affect ocean and coastal resources.
- **International Responsibility**: Nations should act cooperatively in developing and implementing MBONS, reflecting connectivity of marine ecosystems and anticipating changes in the marine environment.

Challenges and Recommendations

- Develop ‘lessons learned’ and ‘best practices’ from U.S. MBON projects
- Move from ‘talking’ to ‘measuring’ Essential X Variables – EXV’s
- Nudge existing programs and methods toward ocean biodiversity observation:
  - International Ocean Biogeochemistry (OCB) ship-based time series, op’s. surveys
- Converge to measure specific variables within trophic levels:
  - Microbes and phytoplankton
    - hard to get to species, but focus on funct. groups, abundance, production, fluxes
  - Fish
    - Can’t measure everything: build on operational surveys (counts, distribution, diet)
  - Higher trophic levels
    - Use ongoing species counts
  - eDNA
- Remote sensing and modeling
  - Need better spatial and spectral resolution satellite sensors
- Link terrestrial and marine communities: Land-ocean interface studies
- Coordinate among investigators /countries to integrate databases
  - Include people collecting the data when doing assessments

Backup

Dynamic support for Condition Reports through MBON



Condition Report Questions

WATER:

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

HABITAT:

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

LIVING RESOURCES:

- Q10: Biodiversity status
- Q17: Fishing status
- Q9: Invasive species
- Q7: Keystone species
- Q8: Focal species
- Q17: Human impacts

Good	Good/Fair	Fair	Fair/Poor	Poor	Undet.

Focus: Address ‘user’ needs

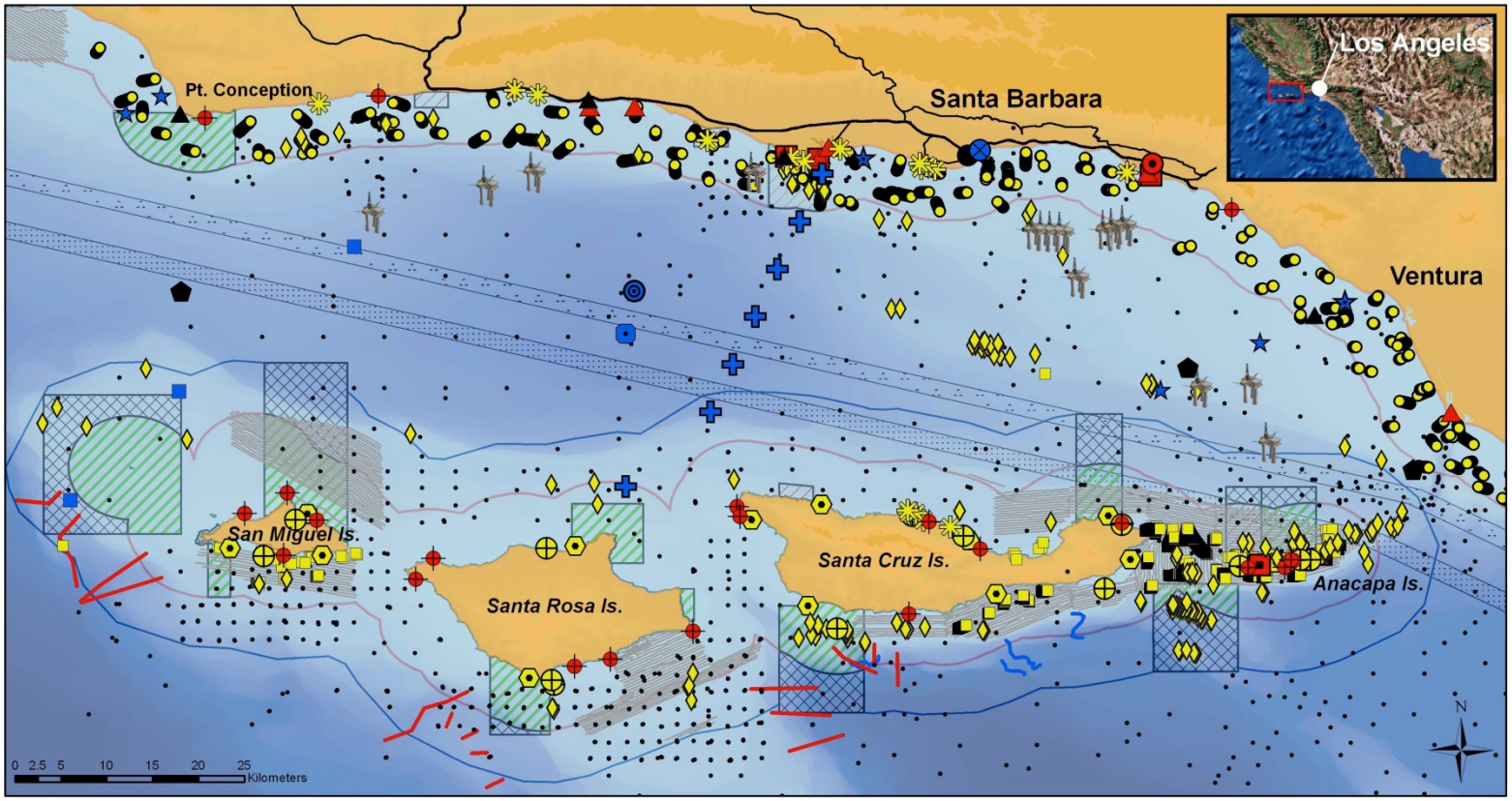
- National Marine Sanctuary MBON:
  - Sanctuary ‘Condition Report’ Questions:
    - Water Quality
    - Habitat Quality
    - Living Resources
    - Maritime Archaeological Resources
    - Human Dimensions
- AK MBON
  - Environmental impacts assessments on industry activities
- Santa Barbara MBON
  - LTER
  - Industry / resource management

Santa Barbara Channel (SBC) BON

Marine Science Institute, University of California Santa Barbara

Existing Monitoring Partners

Santa Barbara Channel, California



Legend

- CalCOFI
- CalCOFI / SCCOOS
- NOAA NMFS Midwater Trawls
- Mark VI Sediment Trap
- SIO Whale Acoustics
- SCCOOS HAB Monitoring
- Plumes and Blooms
- SCCOOS CDIP Buoy
- SCCOOS HF Radar
- SCCOOS Manual Shore Station
- SCCOOS Automated Shore Station
- LiMPETS Rocky Intertidal
- LiMPETS Beach
- SONGS Estuary Monitoring
- CINP/MARINe Rocky Intertidal
- Love Submersible Survey
- SBC LTER
- CNIP Kelp Forest
- CINMS OB Moorings
- USGS ROV Video
- USGS Scuba-ROV Surveys
- Love Oil Platform Survey
- USGS Sediment Samples
- USGS Survey Tracks
- CINMS Deep Sea Coral Transects
- CINMS OE Transects
- CA State Water
- Federal MPA
- CINMS Boundary
- Shipping North
- Shipping South
- SMCA
- SMCA (No-Take)
- SMP
- SMR
- SMRMA
- Special Closure

Bathymetry
Depth (m)
0
-1939

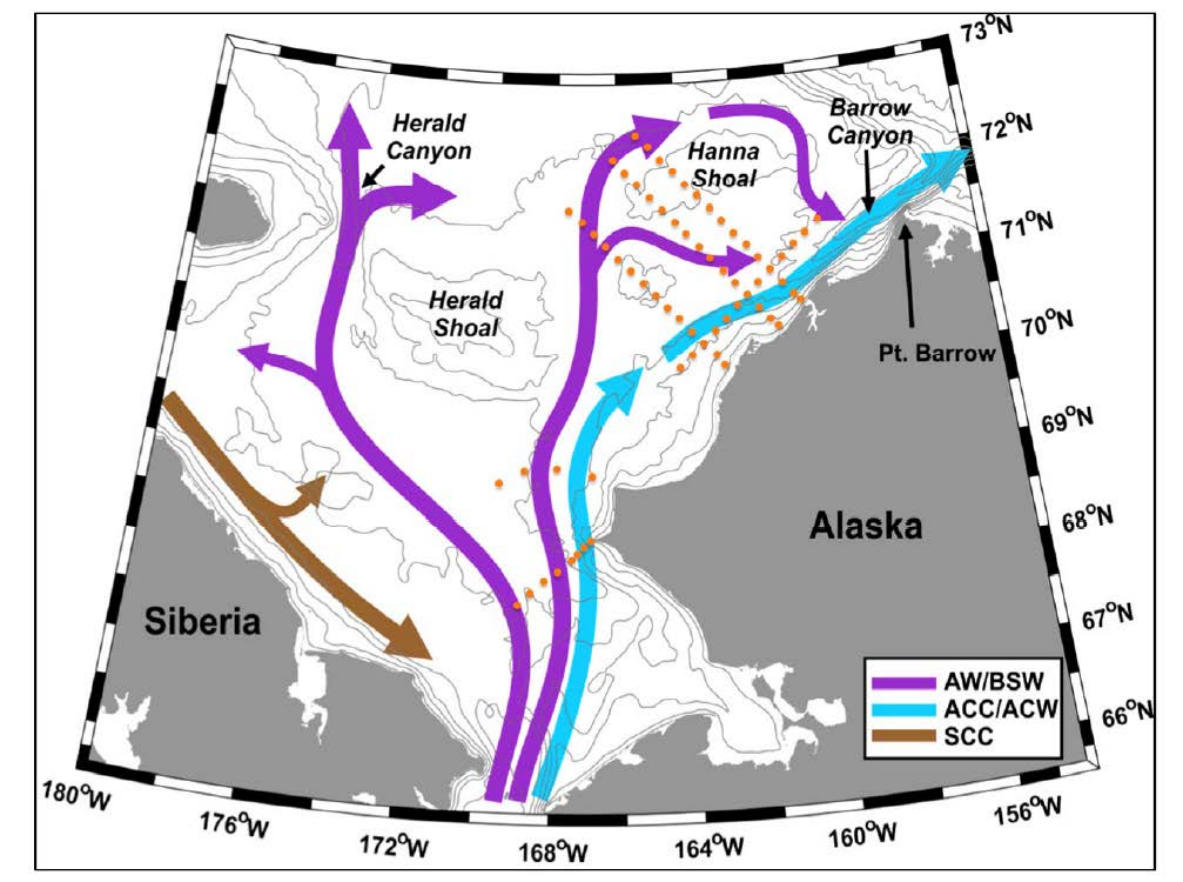
Projection: NAD 1983

Blue = Pelagic, Black = Oceanography, Red = Intertidal, Yellow = Benthic/Subtidal

CalCOFI - California Cooperative Oceanic Fisheries Investigations
SCCOOS - Southern California Coastal Ocean Observing System
NOAA - National Oceanic & Atmospheric Administration
NMFS - National Marine Fisheries Service
SIO - Scripps Institute of Oceanography
HAB - Harmful Algal Blooms
CDIP - Coastal Data Information Program
HF - High Frequency
LIMPETS - Long-term Monitoring Program & Experimental Training for Students
SONGS - San Onofre Nuclear Generating Station
SBC LTER - Santa Barbara Coastal Long-term Ecological Research
CNIP - Channel Islands National Park
MARINe - Multi-Agency Rocky Intertidal Network
CINMS - Channel Islands National Marine Sanctuary
ROV - Remotely Operated Vehicle
USGS - United States Geologic Survey
MPA - Marine Protected Area
SMCA - State Marine Conservation Area
SMP - State Marine Park
SMR - State Marine Reserve
SMRMA - State Marine Recreational Management Area

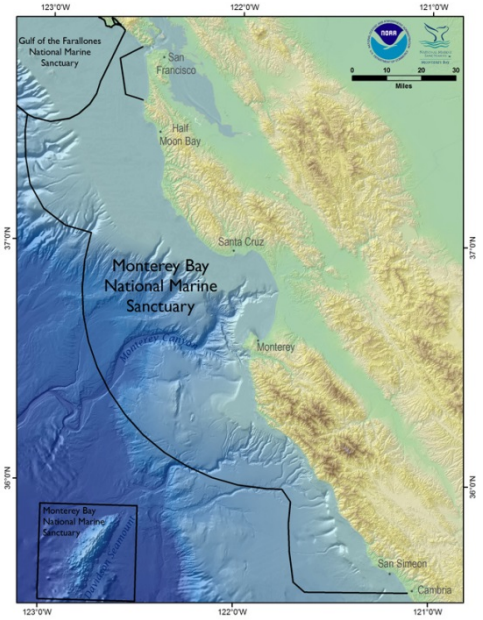
AMBON

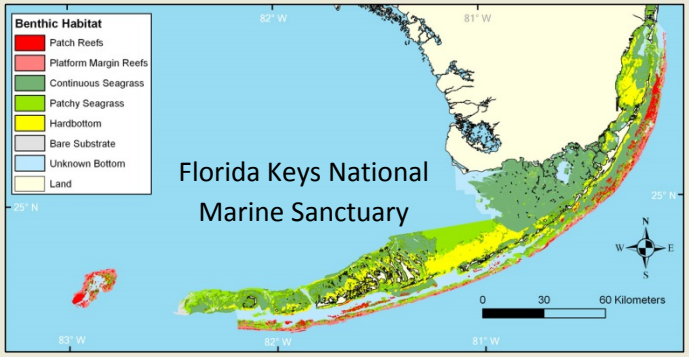
Arctic Marine Biodiversity Observing Network



SANCTUARY MARINE-BON

University of South Florida
Monterey Bay Aquarium Research Institute





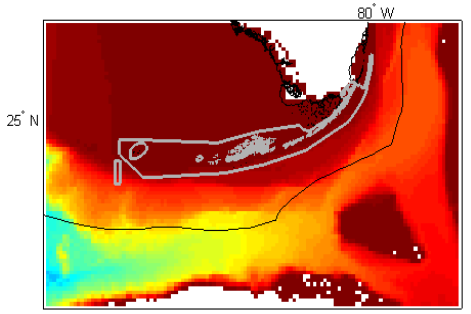
NOAA South Florida Program: 20 y of observations
April 13-17, 2015: R/V Walton Smith cruise

- Chl-a
- HPLC
- CDOM
- Phytoplankton
- Zooplankton
- Remote-sensing reflectance (R_{RS})

April 13-17, 2015, Walton Smith cruise to the FKNMS: eDNA samples

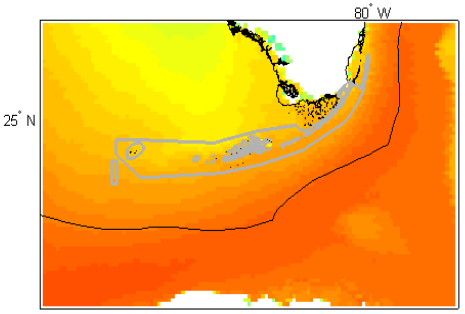
16S (microbial), 18S (eukaryotes), and 12S (vertebrates) rRNA genes analyses

MBON Seascape Classifications



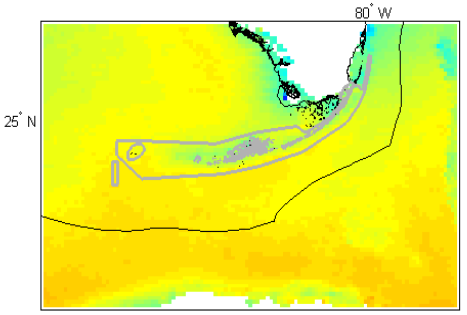
bathy

-4000 -2000 0



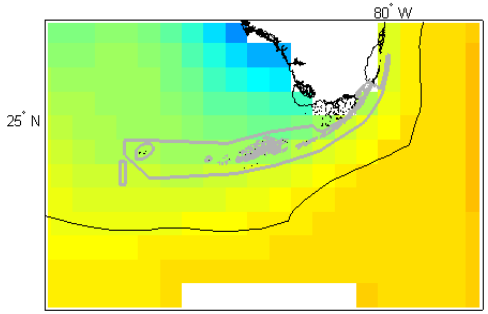
SST

20 25 30



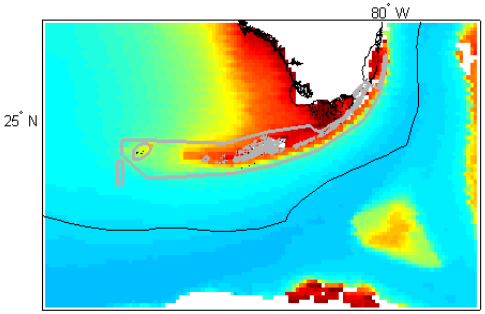
PAR

30 40 50



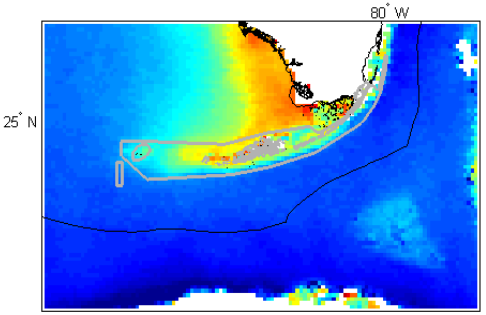
SSS

34 35 36 37



CHL

-2 -1 0 1



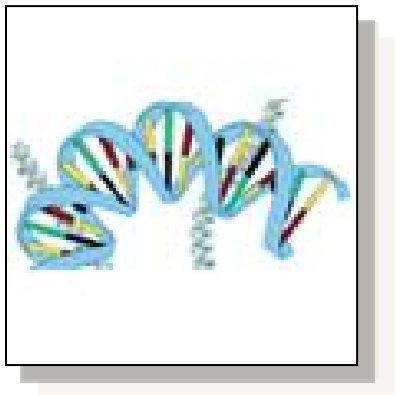
FLH

-3 -2 -1

What is Biodiversity

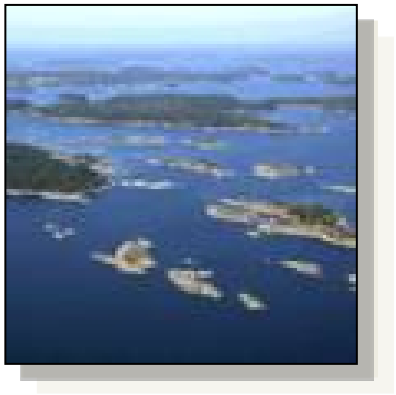
"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

- Convention on Biological Diversity



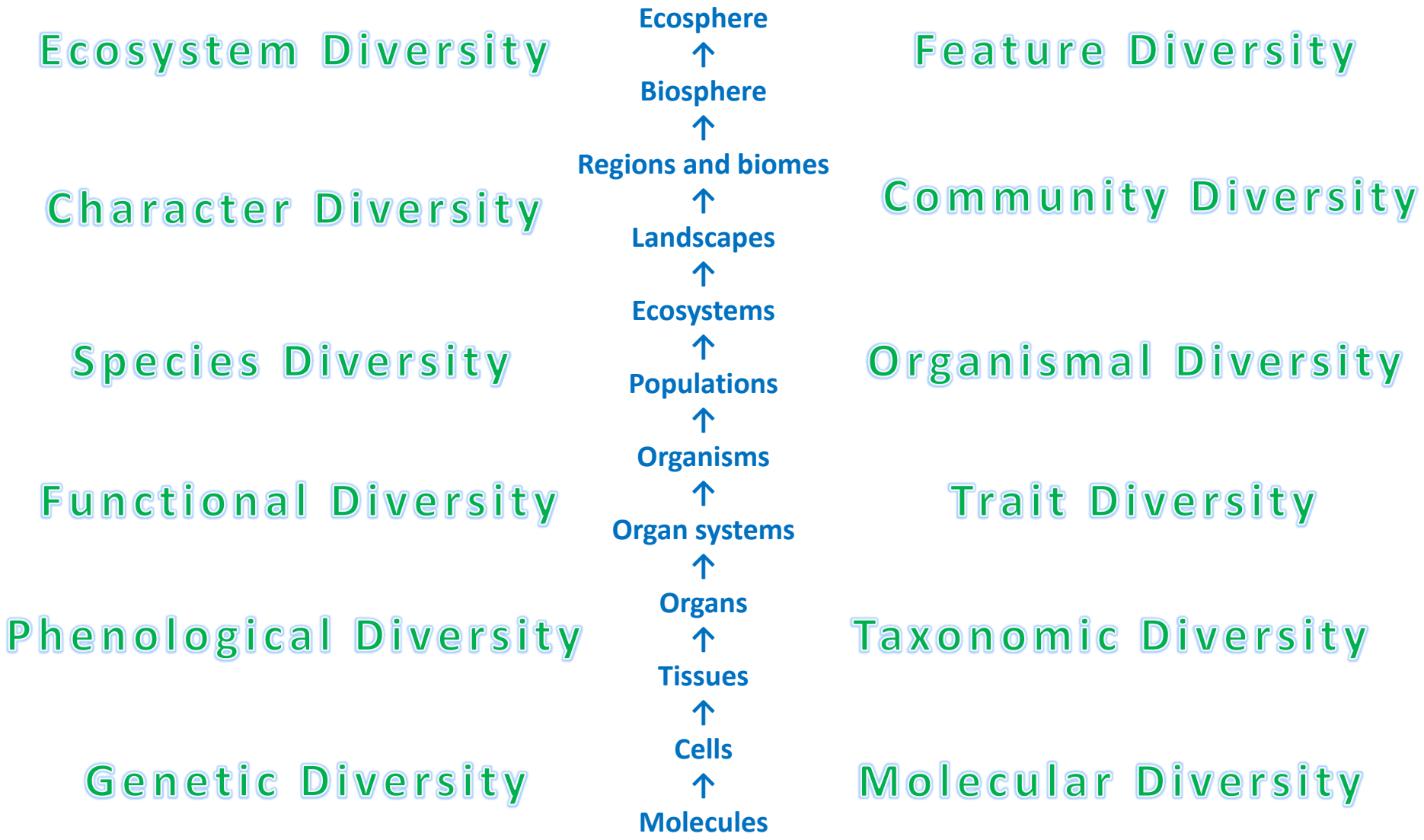
Genetic Diversity

Species Diversity



Ecosystems Diversity

Different Measures of Biodiversity



Ecosystem Services

Provisional Services	Supporting Services	Cultural Services	Regulating Services
Food, fuel, fiber	Primary production	Spiritual and religious values	Invasive resistance
Genetic resources	Provision of habitats	Education and inspiration	Pollination and seed dispersal
Freshwater	Nutrient and water cycling	Recreational values	Pest and disease regulation
Biochemicals	Soil formation and retention	Aesthetic values	Climate regulation
		Sense of place	Natural hazard protection
			Water purification

Millennium Ecosystem Assessment, 2005. *Ecosystem and Human Well-being: Biodiversity Synthesis.*

Metrics

- **Richness Metrics**
  - Margalef diversity
  - Menhinick diversity
  - Chao estimated diversity
- **Diversity Metrics**
  - Shannon Diversity
  - Simpson Diversity
  - Hulbert Diversity
- **High Rarity Metrics**
  - LogSkew
  - PctRare1%
- **Functional Diversity Metrics**
  - EcoSim
  - Fdiversity
  - EstimateS
- **Dominance Metrics**
  - Absolute dominance
  - Relative dominance
  - McNaughton dominance
- **Evenness Metrics**
  - Shannon evenness
  - Simpson evenness
  - Camargo evenness
  - Smith Wilson evenness

Thoughts…

- Should we place weight on species or traits?
  - Option value
- What are the indicator species in the ecosystem?
  - Krill? Starfish? Herbivores? Etc.
- How should we include abiotic factors?
  - Temperature, currents, winds, sediment type, tides, disturbances in these, etc.
- Which measures should we use?
  - Species richness? species evenness? species abundance? functional diversity? etc.

Outreach and Education

- We need to understand from the beginning:
  - how different groups of people use the Sanctuaries
  - How users interact with existing portals/products relevant to MBON

- Who exactly are all of the users?
- What do users want?
  - Are there “high priority” users?
  - How does it add value to their job/decision making processes
  - What is their preferred level of interaction
    - push a button to see a prepackaged report?
    - Upload their data and develop customized analysis? Both?
- We need to make sure the MBON O&E effort, web site content, etc. meets user needs

Outreach and Education

- We are working with ONMS and the IOOS DMAC to review current NOAA Sanctuary, IOOS, and other portals
- Create a list of sites, key reports and data sets, and “decisions made” which relate or have influence on biodiversity
- Contact program managers in various agencies and other users to explore perspectives and needs

- Developing a list of questions to define top priorities for products
- Develop recommendations MBON to inter-connect to various NOAA sites
- Develop a plan to implement an MBON website with MBON ‘products’ and content

- IOOS DMAC to develop action plan for team
  - schedule meetings, calls, product timetable
- Use existing NOAA websites:
  - CRW: Coral Reef Watch
    - http://coralreefwatch.noaa.gov/satellite/index.php
  - CREMP: Florida Keys Coral Reef Evaluation and Monitoring Project (CREMP)
    - http://ocean.floridamarine.org/FKNMS_WQPP/pages/cremp.html

Florida Keys Biological and Environmental Monitoring Programs

1. Geospatial Assessment of Marine Ecosystems (FWRI GAME)
2. Gulf of Mexico Alliance (GOMA)
3. South Florida Program (NOAA SFP)
4. Florida Harmful Algal Bloom monitoring (FWRI HAB group)
5. Coral Reef Ecosystem Monitoring Program (FWRI CREMP; 1996 - present)
6. Coral Reef Ecosystem Studies (CREST – USGS; 2008 - present)
7. Water Quality Protection Program (EPA)
8. Southeast Environmental Research Center (SERC) water quality program
9. Florida Fish and Wildlife Specimen Information Systems
10. Florida SE Fisheries Independent Monitoring (FIM - Florida's DEP)
11. NOAA's SE Fisheries Science Center (SEFSC)
12. Florida Reef Resilience Program (FRRP)
13. Etc.