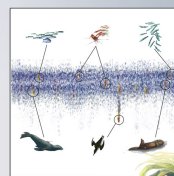
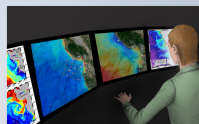
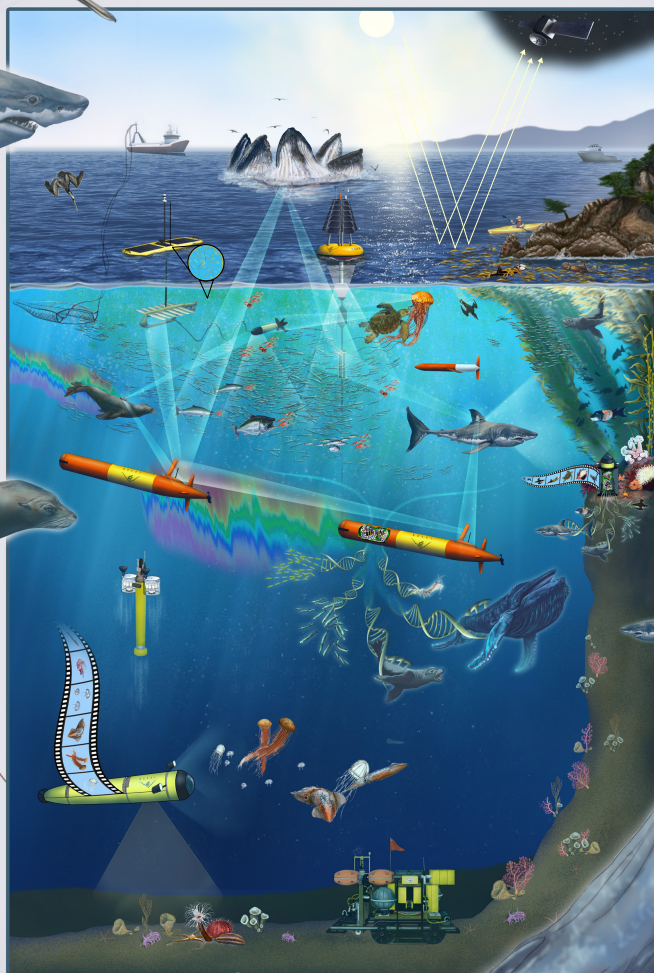
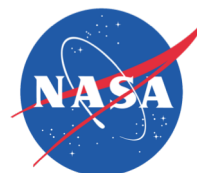


Observing Life in the Sea



Washington, DC
April 2018



MBON

Marine Biodiversity
Observation Network

Sanctuaries MBON

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

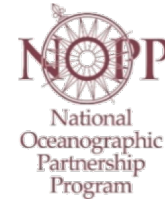
Principal Investigators:
Frank Muller-Karger (USF)
Francisco Chávez (MBARI)



Partners: M. Breitbart/A. Djurhuus/N.

April 27, 2018

Sawaya¹, K. Pitz/R. Michisaki², S. Gittings/M.
Tartt⁴, K. Thompson⁴, M. Howard/
B.Kirkpatrick⁵, M. Buchman⁶, A.
DeVogelaere⁷, J. Brown⁷, J. Field⁸, S. Bograd⁸,
E. Hazen⁸, A. Boehm⁹, K. O'Keefe¹⁰, G.
Graettinger¹¹, J. Lamkin¹², E. (Libby) Johns/C.
Kelble/C. Sinigalliano/J. Hendee¹³, M. Roffer¹⁴



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

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

¹ College of Marine Science, Univ. of South Florida (USF), St Petersburg, FL;

² MBARI/CenCOOS, CA;

³ Woods Hole Oceanographic Institution (WHOI), Woods Hole, MA;

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;

¹⁴ Roffer's Ocean Fishing Forecasting Service (ROFFS™), Melbourne, FL.



Matthew K. Howard

**We mourn the tragic loss of
Dr. Howard on Feb 8, 2018**

*Research Scientist
Physical Oceanography: Data
Management Systems for
Oceanography.*

MBON GCOOS Partner and co-PI

*A great friend and wonderful
individual, Matt demonstrated that
serving biological data by IOOS
ERDDAP and enrolling into Darwin
Core/OBIS is easy*



Develop a community of practice...

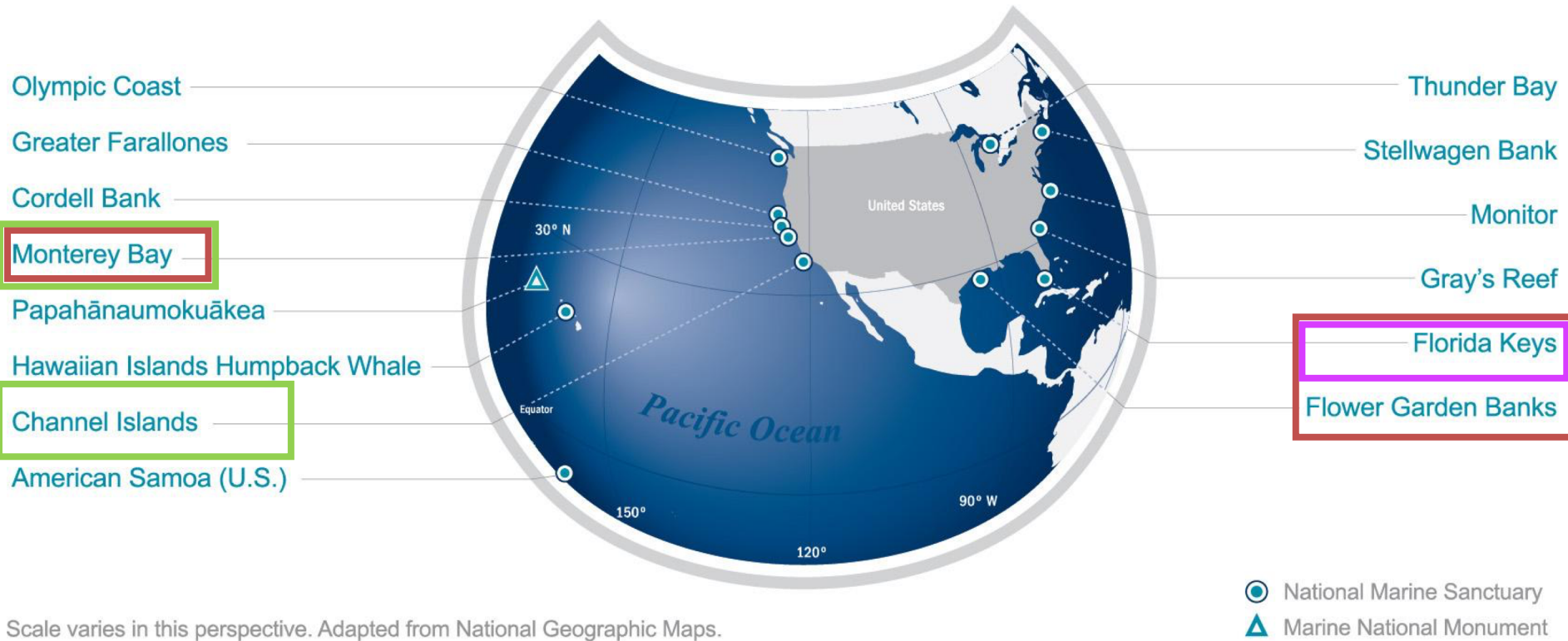
...to understand marine biodiversity
and how it changes over time

...for fundamental ecology studies
and ensure sustainable development

Addressing Sanctuary Needs: data & tools

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

NATIONAL MARINE SANCTUARY SYSTEM



Collaboration of IEA with



MBON

Marine Biodiversity Observation Network

U.S. MBON PORTAL

Smithsonian MarineGEO Partnership

Our infrastructure is people



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



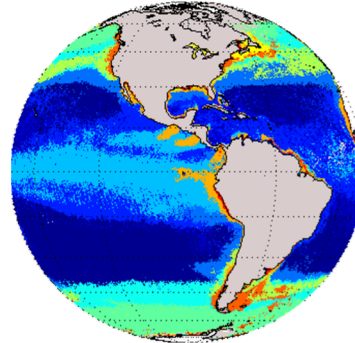
Main activities

- Field data collection
- Identify, obtain other biological data
- New approaches:
 - Seascapes (biogeographic areas from satellite obs.)
 - Environmental DNA (eDNA)
- Adopting and improving data schema for NOAA IOOS operational applications
 - Darwin Core / OBIS
- Development of a global MBON

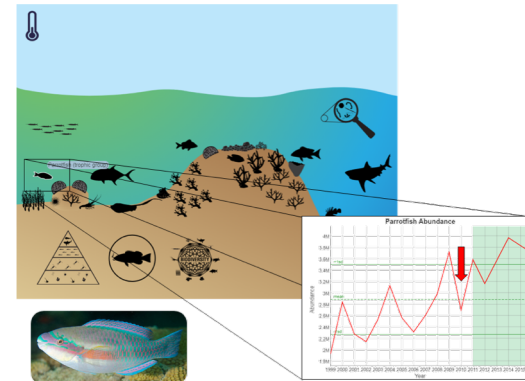
The Sanctuaries MBON pilot concept



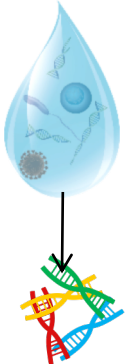
Seascapes



Data Integration



eDNA



Informs



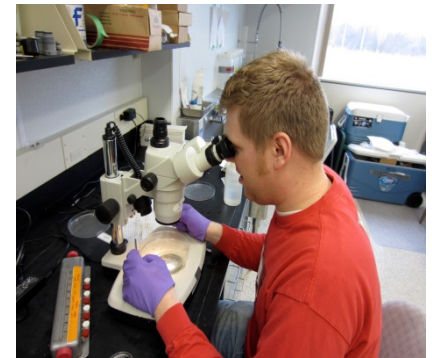
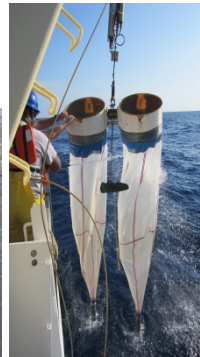
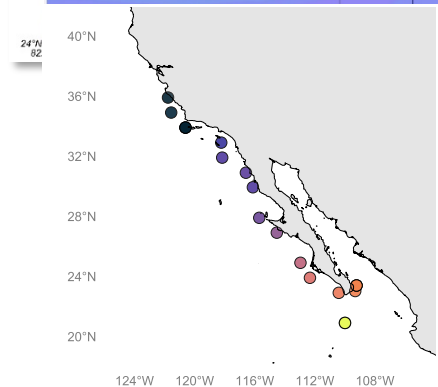
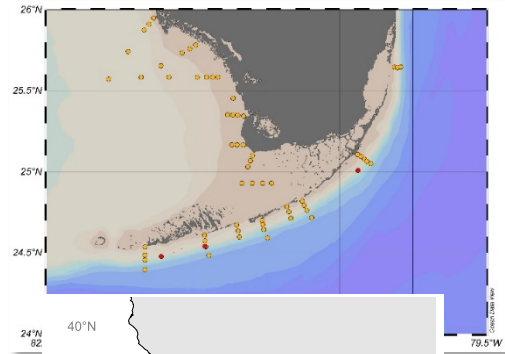
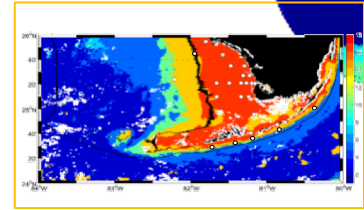
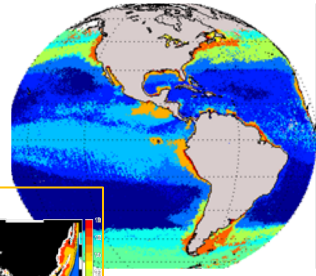
Ocean literacy



NATIONAL MARINE
SANCTUARIES



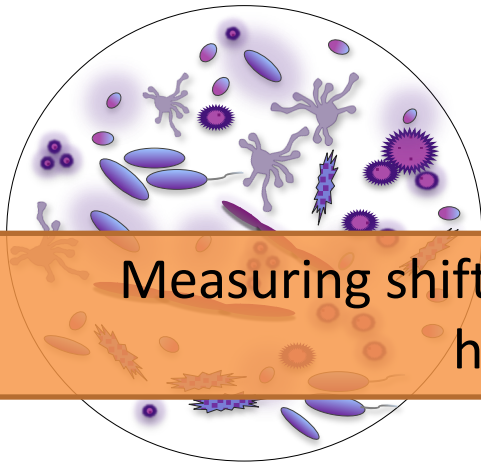
*People are at the core
of our effort*



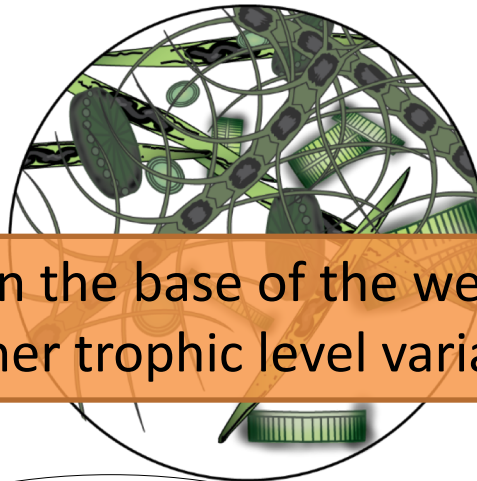
Over 30 expeditions in each FL Keys & MB 2015-2018

eDNA genetic markers give snapshots of biodiversity across various groups that are difficult to capture through other methods

16S rDNA



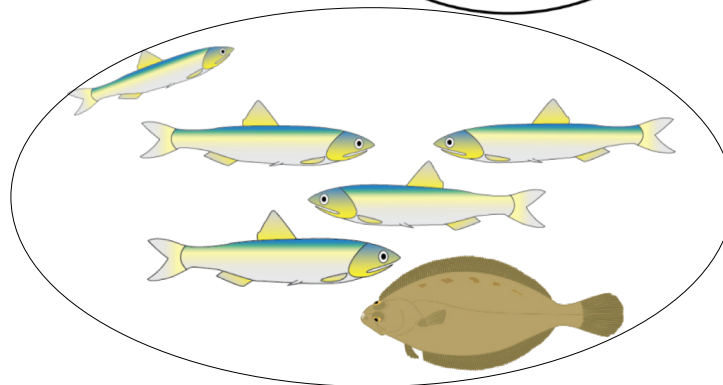
18S rDNA



COI



Measuring shifts in the base of the web gives insights into higher trophic level variability



12S rDNA

Each marker is most sensitive towards detecting different groups of organisms

eDNA summary statistics

Monterey Bay (2013-2018)

- 42 cruises
- Samples collected: 1448

Florida Keys (2015-2018)

- 15 eDNA cruises, 12 small boat
- Samples collected: 1285

Sequenced for 12S: 297

16S: 454

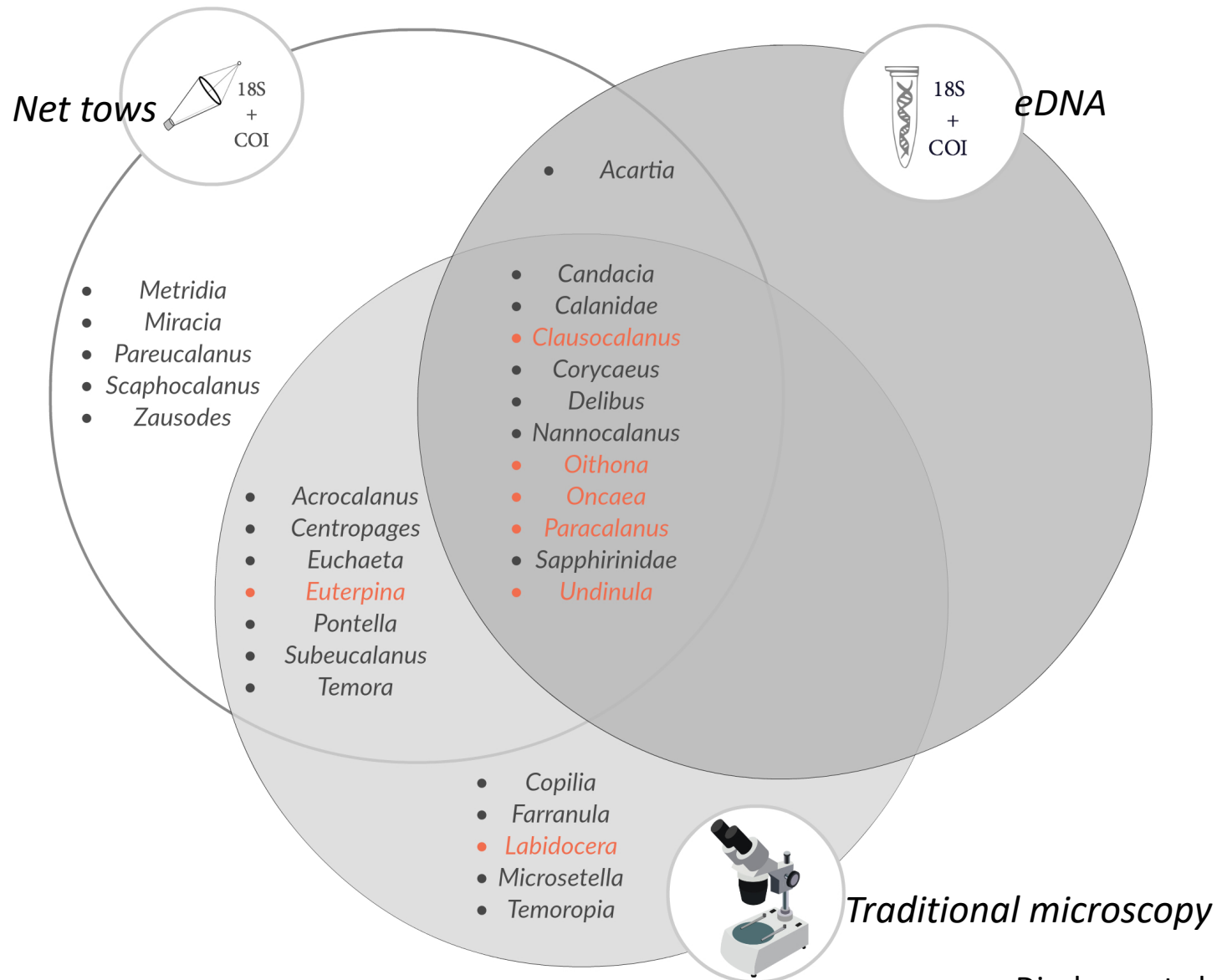
18S: 639

COI: 417

AUV (2015-2018)

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

Zooplankton Methods Comparison (Florida)

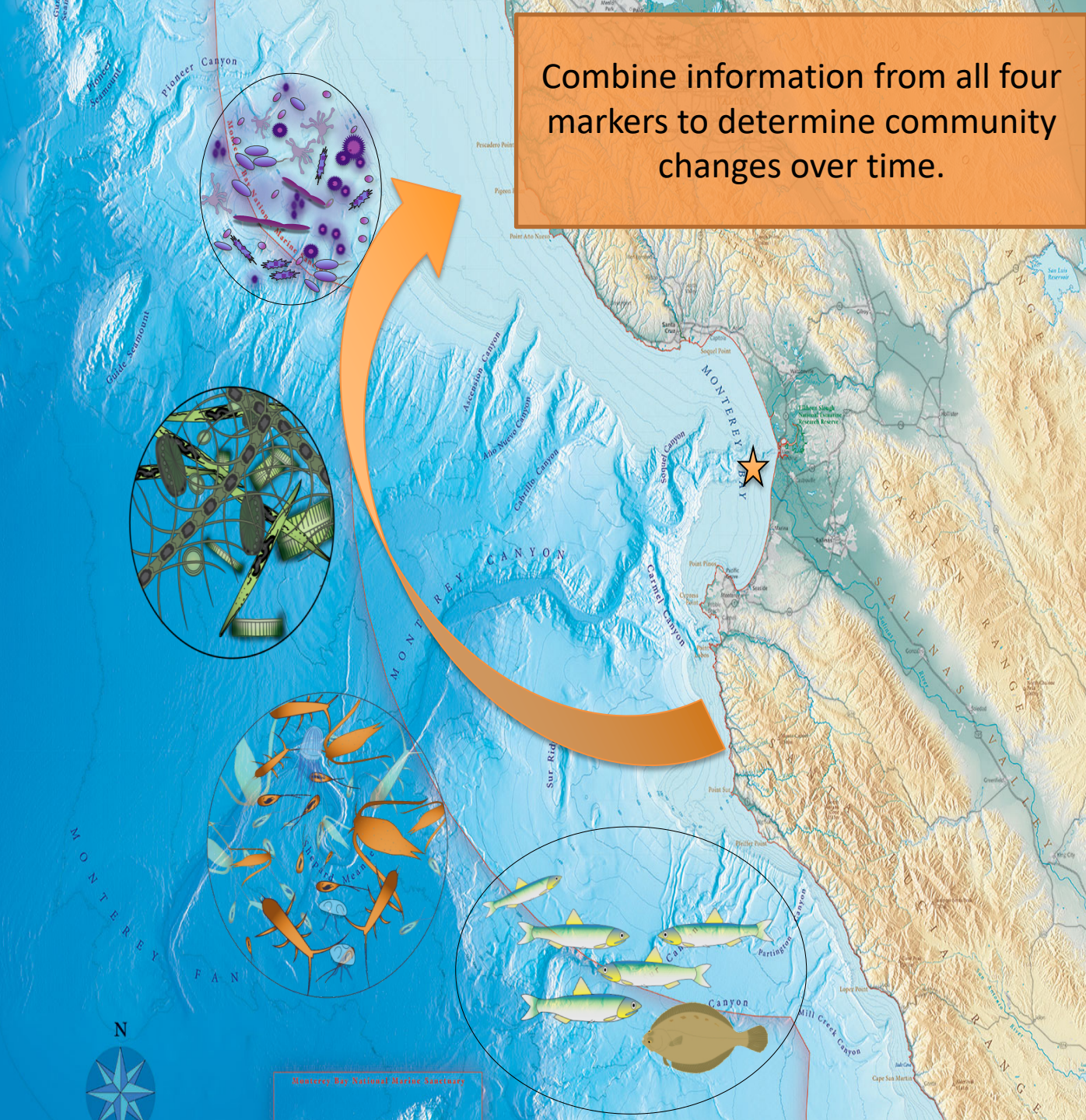


Monterey Bay National Marine Sanctuary:

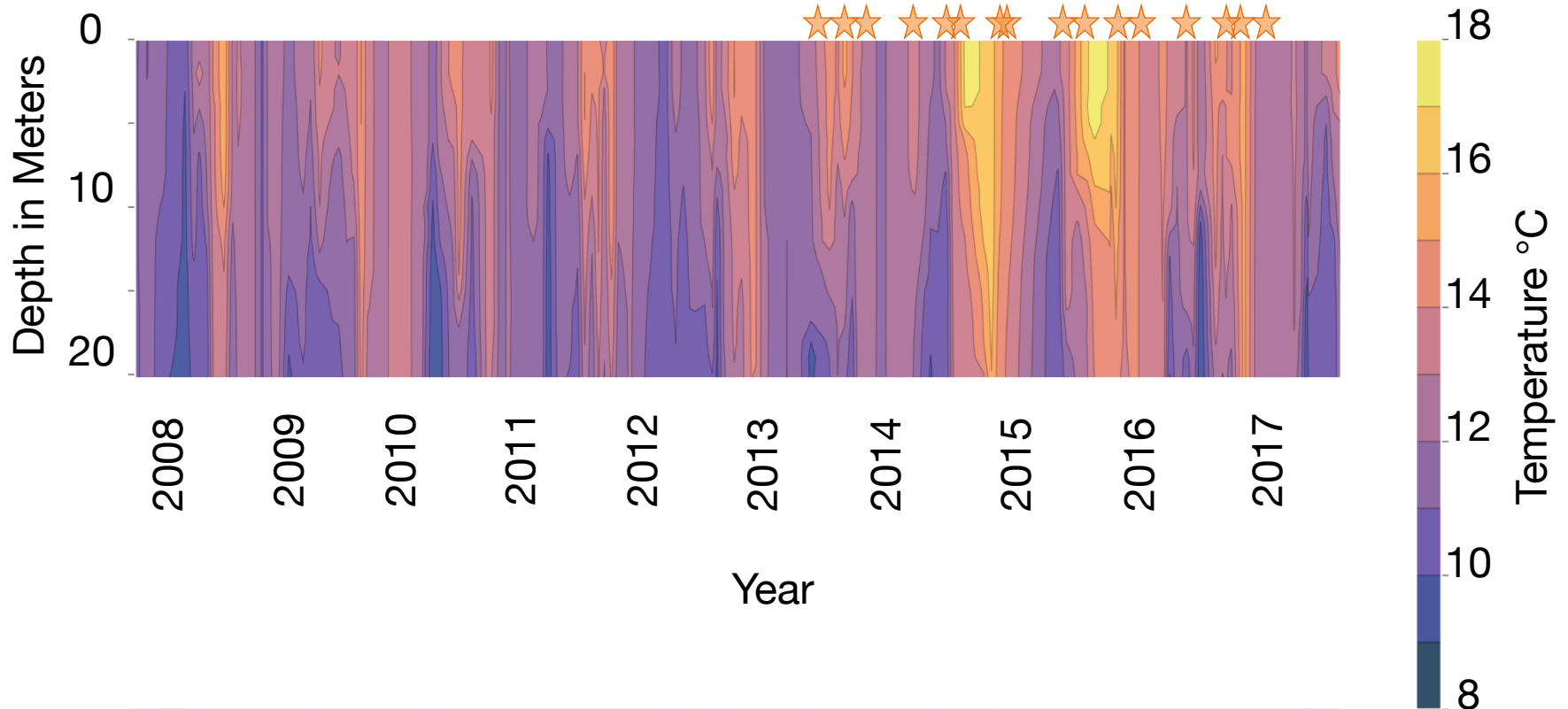
eDNA Monitoring

Combine information from all four markers to determine community changes over time.

- Monthly cruises to stations within Monterey Bay
- Build on long-standing time series

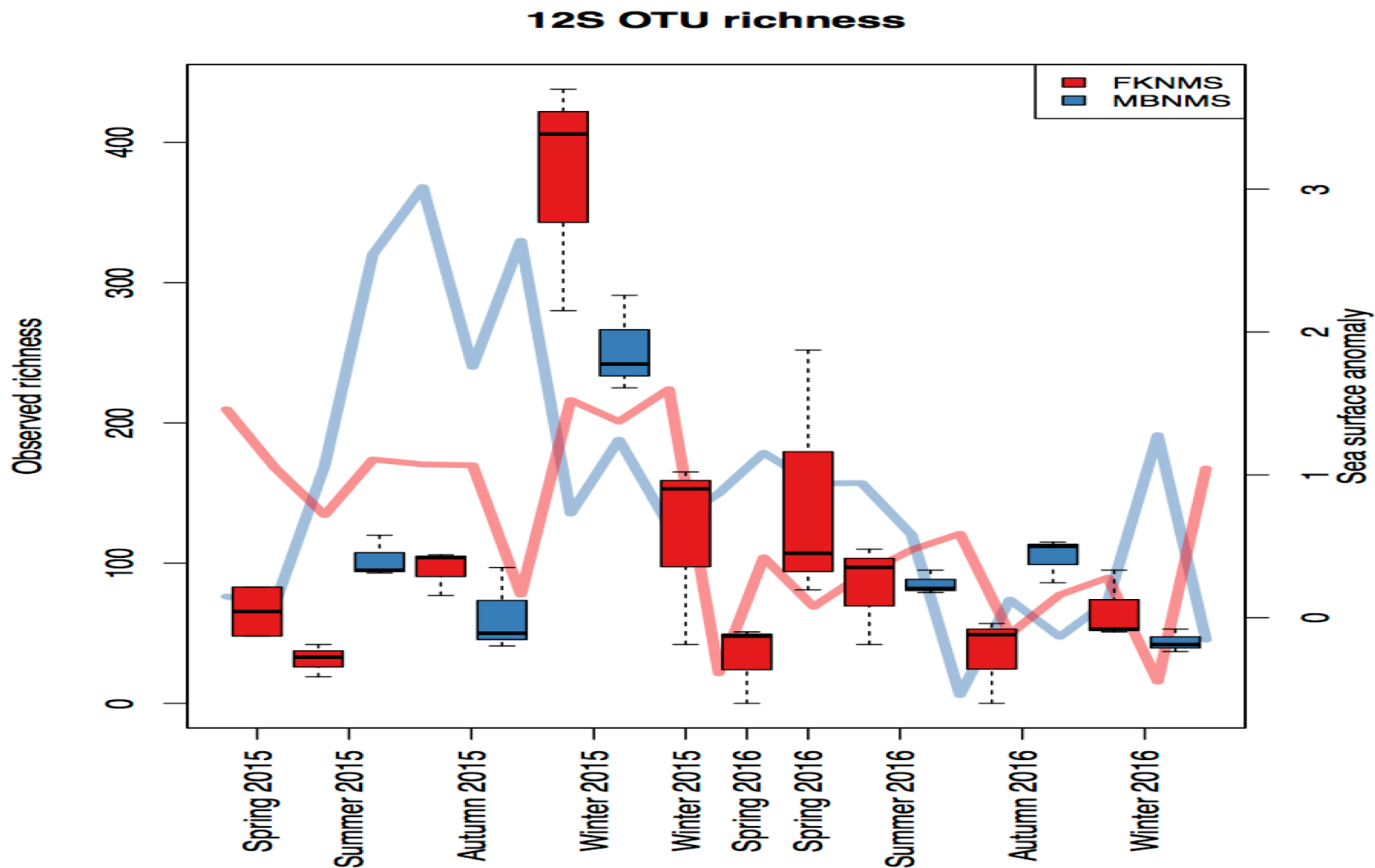


When did we sample?
Samples captured different ocean conditions



Upper water temperature
changes in Monterey Bay

Higher Phytoplankton & Vertebrate diversity seen by eDNA with warmer conditions in FL and MB



MBON eDNA 2017-18 Products

Peer-Reviewed Publications

1. Djurhuus, et al. (2018) Evaluation of marine zooplankton community structure through environmental DNA metabarcoding. *Limnol. Oceanogr. Methods*. doi:10.1002/lom3.10237*
2. Chavez, et al. (2017) Climate variability and change: Response of a coastal ocean ecosystem. *Oceanography*, doi:10.5670/oceanog.2017.429.
3. Djurhuus, et al. (2017) Evaluation of Filtration and DNA Extraction Methods for Environmental DNA Biodiversity Assessments across Multiple Trophic Levels. *Frontiers in Marine Science*, doi:10.3389/fmars.2017.00314*
4. Andruszkiewicz, et al. (2017) Biomonitoring of marine vertebrates in Monterey Bay using eDNA metabarcoding. *PLOS One*. doi:10.1371/journal.pone.0176343*
5. Kelly, et al. (2017) Genetic and Manual Survey Methods Yield Different and Complementary Views of an Ecosystem. *Frontiers in Marine Science*, doi:10.3389/fmars.2016.00283*

* = sequences submitted to SRA

Public Submissions

1. SDG14 MBON Tool: Infographics & eDNA Viewer
2. Pitz, et al. (2017) Rewards and Challenges of eDNA Sequencing with Multiple Genetic Markers for Marine Observation Programs. *Proceedings of TDWG*, doi:10.3897/tdwgproceedings.1.20548
3. Closek & Djurhuus, et al. (2018) Environmental DNA (eDNA) extraction using Qiagen DNeasy blood and tissue kit. dx.doi.org/10.17504/protocols.io.mvzc676
4. Closek & Djurhuus, et al. (2018) Environmental DNA (eDNA)...metabarcoding Illumina MiSeq NGS
16S: dx.doi.org/10.17504/protocols.io.m3ec8je
18S: dx.doi.org/10.17504/protocols.io.mv2c68e
COI: dx.doi.org/10.17504/protocols.io.mwnc7de
12S: dx.doi.org/10.17504/protocols.io.m3bc8in

Satellite data

NASA MODIS (2000-present)

Daily, monthly, annual, climatology, anomalies:

- Sea Surface Temperature
- Ocean color

Seascapes

- Regional (Gulf of Mexico, US W coast, Arctic Ocean)
- Global

NOAA VIIRS (2011-present)

Daily, monthly, annual, climatology, anomalies:

- Sea Surface Temperature
- Ocean color

Seascapes

- Regional (Gulf of Mexico, US W coast, Arctic Ocean)
- Global

Landsat, Commercial (WorldView 2, 3)

Individual images, mosaics

- Wetland land-cover classification
- Bathymetry
- Coral reef, seagrass

Satellite-derived Seascapes

Kavanaugh (OSU), and all

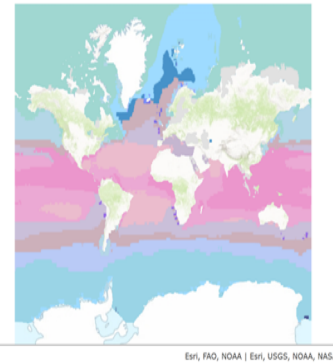
Global classification

Regional downscaling

Ongoing efforts

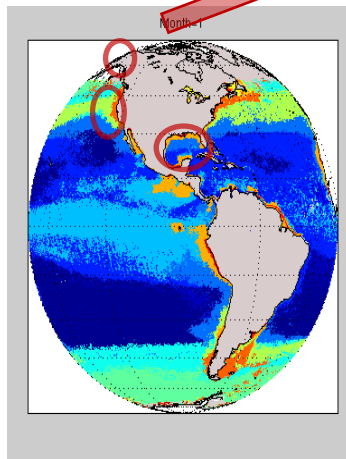
- Global
- EMU intercalibration
- Case Studies:
 - Arctic
 - Temperate
 - Subtropical
- Habitat –species relationships
- Operational
 - NOAA NESDIS
 - NASA COVERAGE

Static+3D

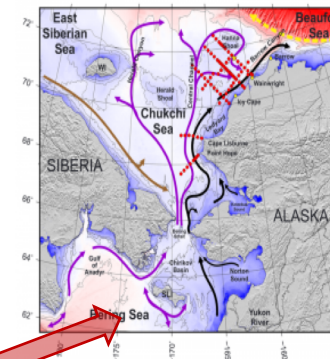


Ecological Marine Units

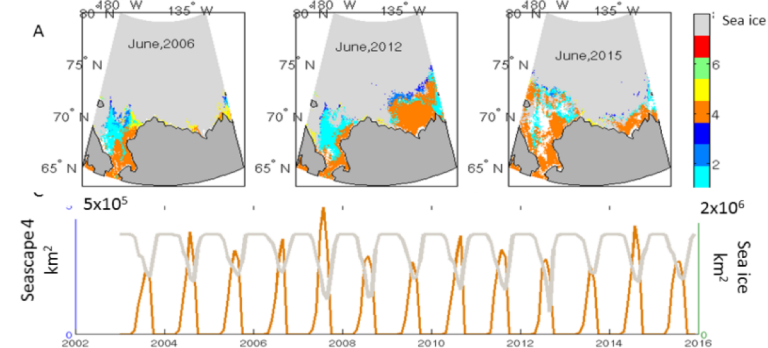
Dynamic+2D



Dynamic Seascapes



Arctic MBON; Distributed Biological Observatory



Dynamic habitat maps

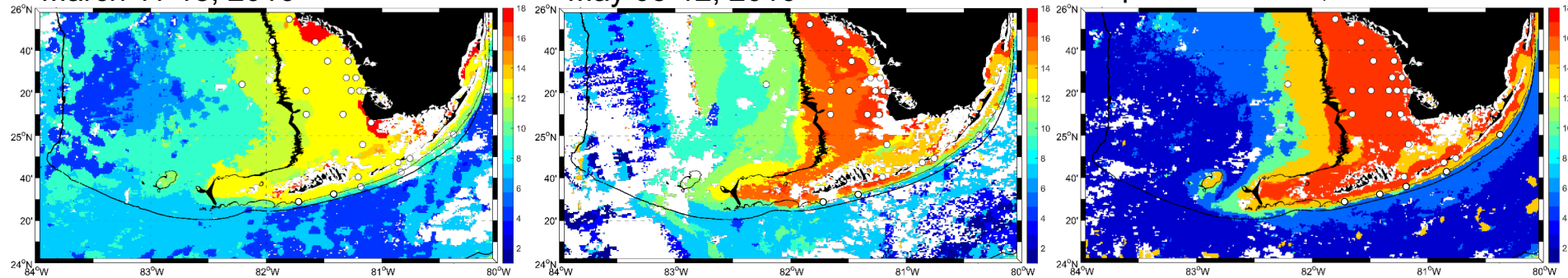
Arctic MBON

Seascape validation: south Florida

March 11-18, 2016

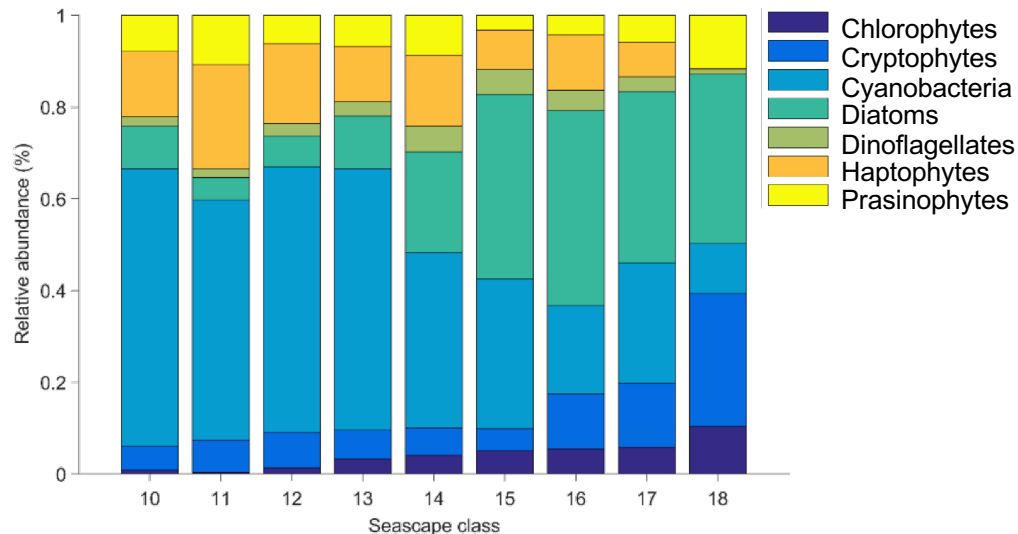
May 05-12, 2016

September 12-19, 2016



Seasonal shifts of
phytoplankton
assemblages

Also validating:
eDNA,
zooplankton



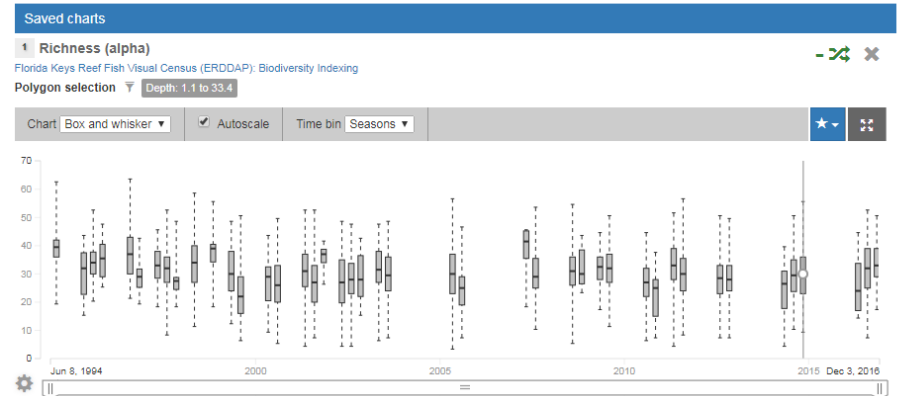
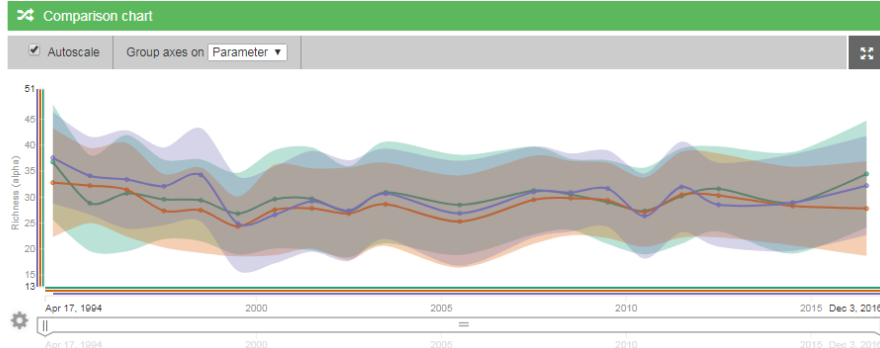
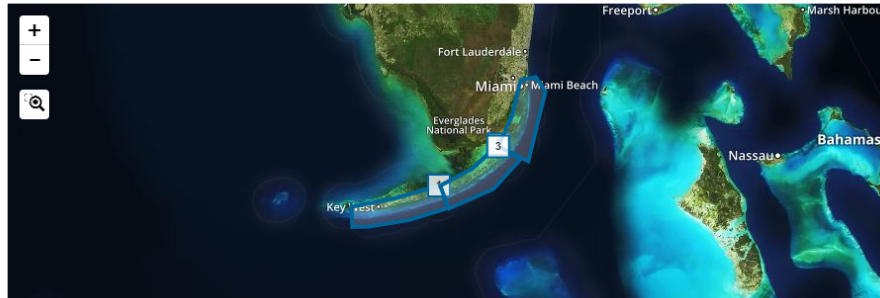
In prep: Dynamic satellite seascapes as predictors of seasonal shifts of phytoplankton assemblages in south Florida waters.
Enrique Montes, Anni Djurhuus, Christopher R. Kelble, Daniel Otis, Frank E. Muller-Karger, and Maria T. Kavanaugh

Addressing Sanctuary and Other User Needs

- Data tools:
 - development of interactive data tools using ecosystem conceptual models (e.g., Integrated Ecosystem Assessment)
 - Curated views of the MBON Portal for Sanctuaries:
 - Taxa aggregations – fishes
 - Areas of interest:
 - Sanctuary Preservation Areas, Ecological Reserves, benthic layers, others.
 - Early warning systems for detection of anomalous conditions in the Sanctuaries
- Satellite products:
 - High-res imagery for disaster response (i.e. Irma impacts in the FKNMS)
 - Time series data for detection of anomalous conditions (FK, FGB, MB).
- Local to global scaling

★ Florida Keys Reef Fish Visual Census: Species richness in the Upper, Middle, and Lower Key

Species richness is defined as the number of distinct species per sample. These analysis take the average richness values for all samples within the subset (polygon).



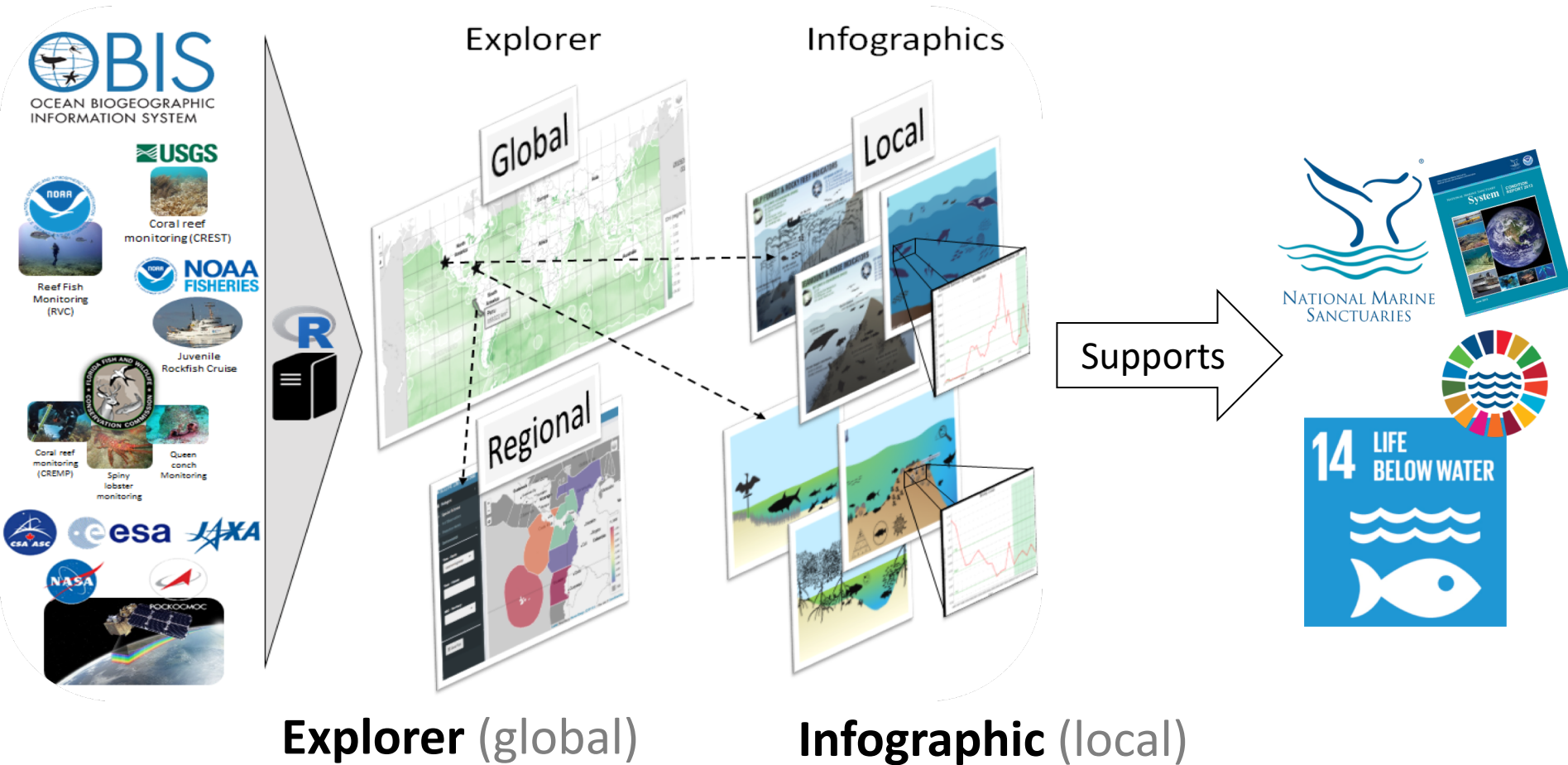
- Beta version is live

<https://mbon.ioos.us/>

Data Integration

MBON Portal: Interactive Tools

for data storytelling



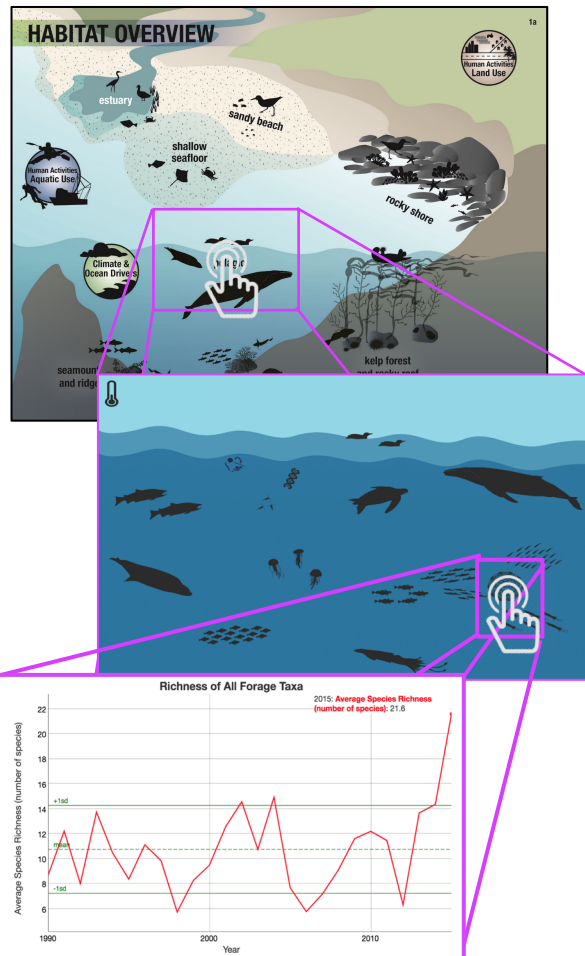
<https://mbon.ioos.us/>

Dynamically updating sanctuary status and trends

Infographics

Audience:

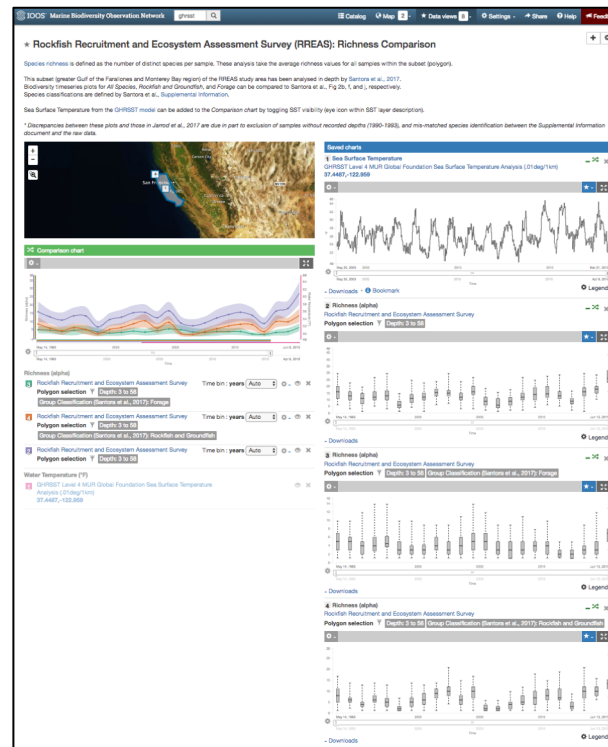
Public, managers, educators



Curated Data Views

Audience:

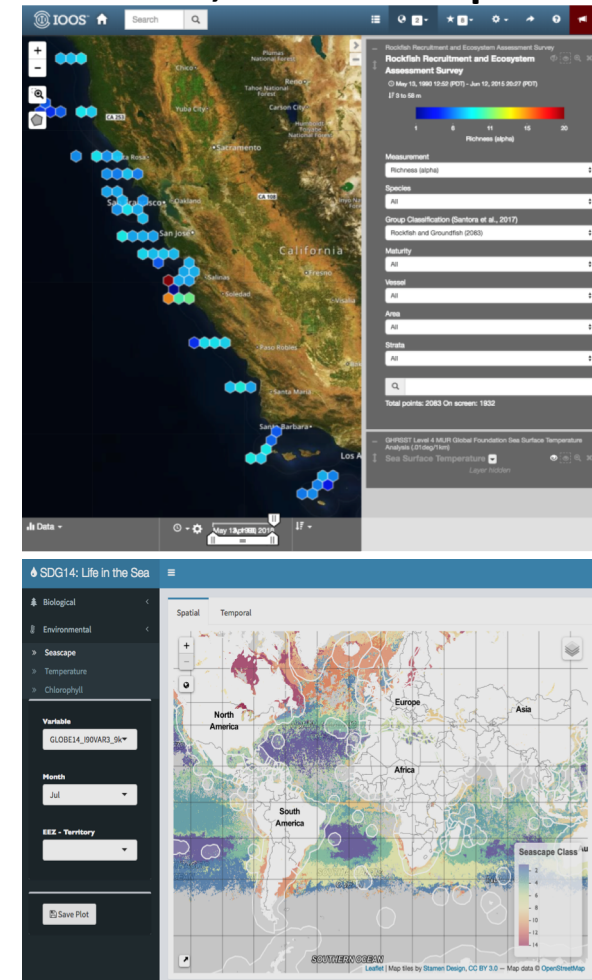
Advisory groups,
researchers, teams



Data portals

Audience:

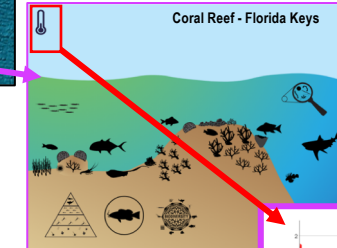
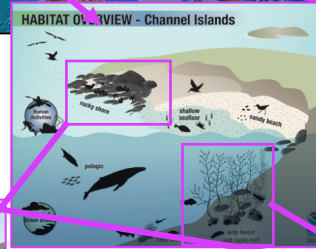
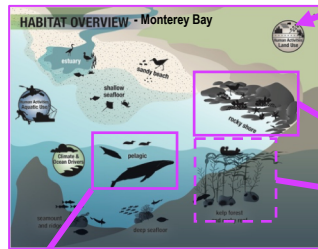
Scientists, technical experts



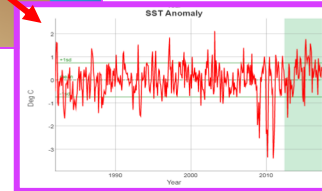
Addressing Sanctuary Needs: data tools

Processes and products being shared across programs and regions

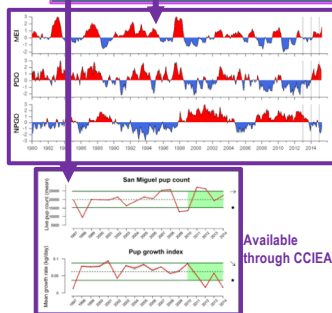
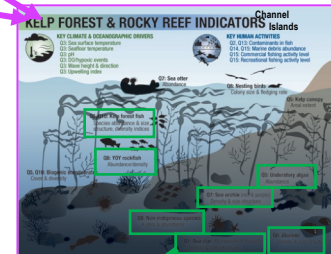
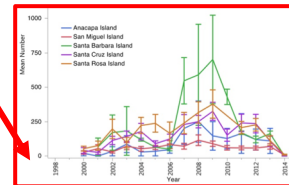
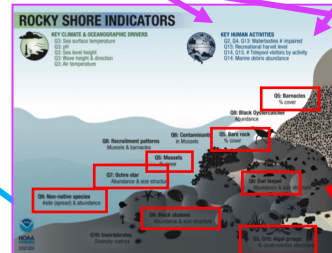
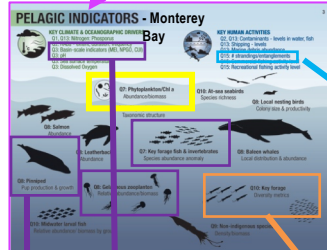
Collaboration between sanctuaries, IEA, MBON expanding to Gulf of Mexico



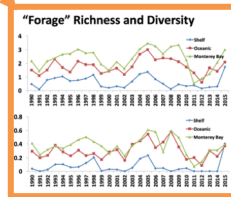
Currently conceptual models and data products under Development by Sanctuaries MBON



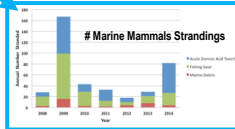
Gulf of Mexico IEA meeting with FKNMS, including Sanctuaries MBON partners, to expand collaboration apply IEA products and processes to the sanctuary.



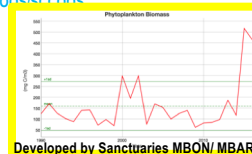
Available through CCIEA



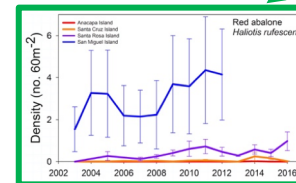
Developed by Sanctuaries MBON



Under-development CeNCOOS/SCOOS



Developed by Sanctuaries MBON/ MBARI



PISCO / CINP / LTER data

U.S. MBON PORTAL

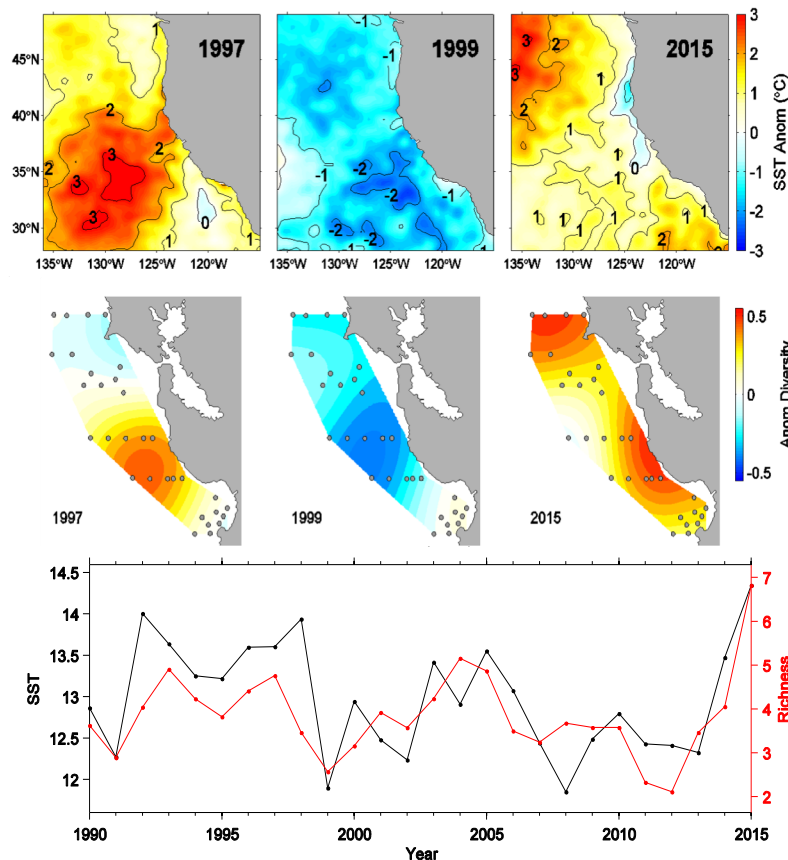
Collaboration of IEA with

MBON

Marine Biodiversity Observation Network

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

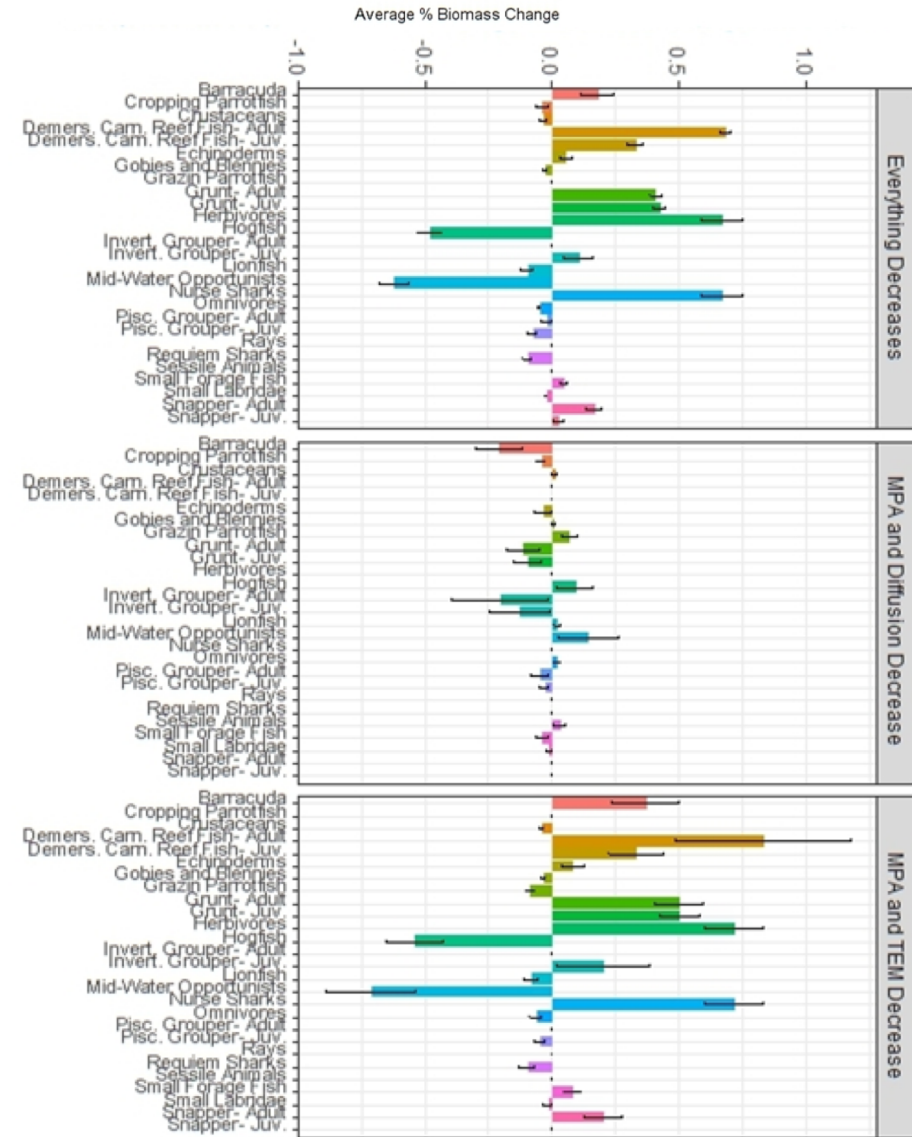


- 1995-97 and 2015 heat waves (ENSO) show high diversity.
- Affects fisheries and coastal water quality.

Ecosystem Modeling: Conservation Planning - Florida Keys



Ecospace Biomass Change 1994-2012 Given MPA Size, Fishing Effort (TEM), and Diffusion (Movement)

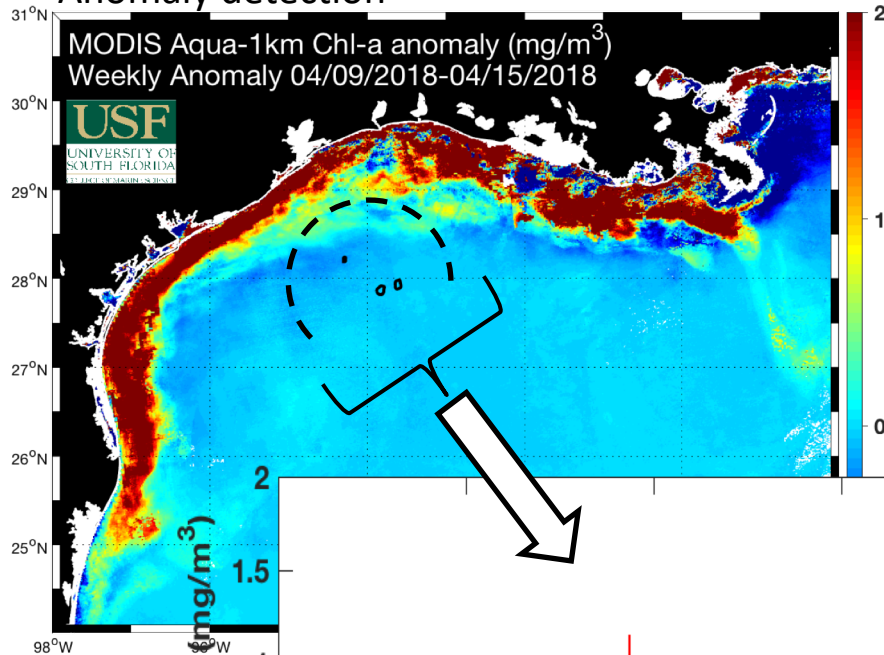


Ecospace scenarios:
Fish biomass variation
with Marine Protected
Area (MPA) size, fishing
effort, and movement

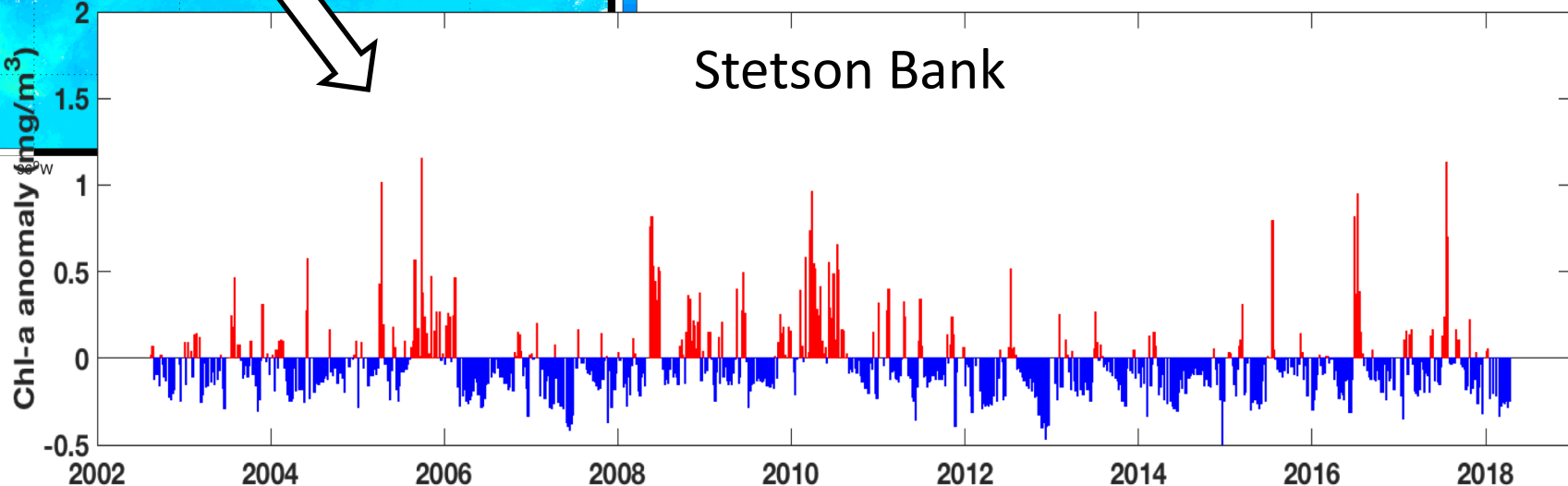
**Fishing effort: larger effect on
biomass than MPA size**

Early warning and alert system for Sanctuaries

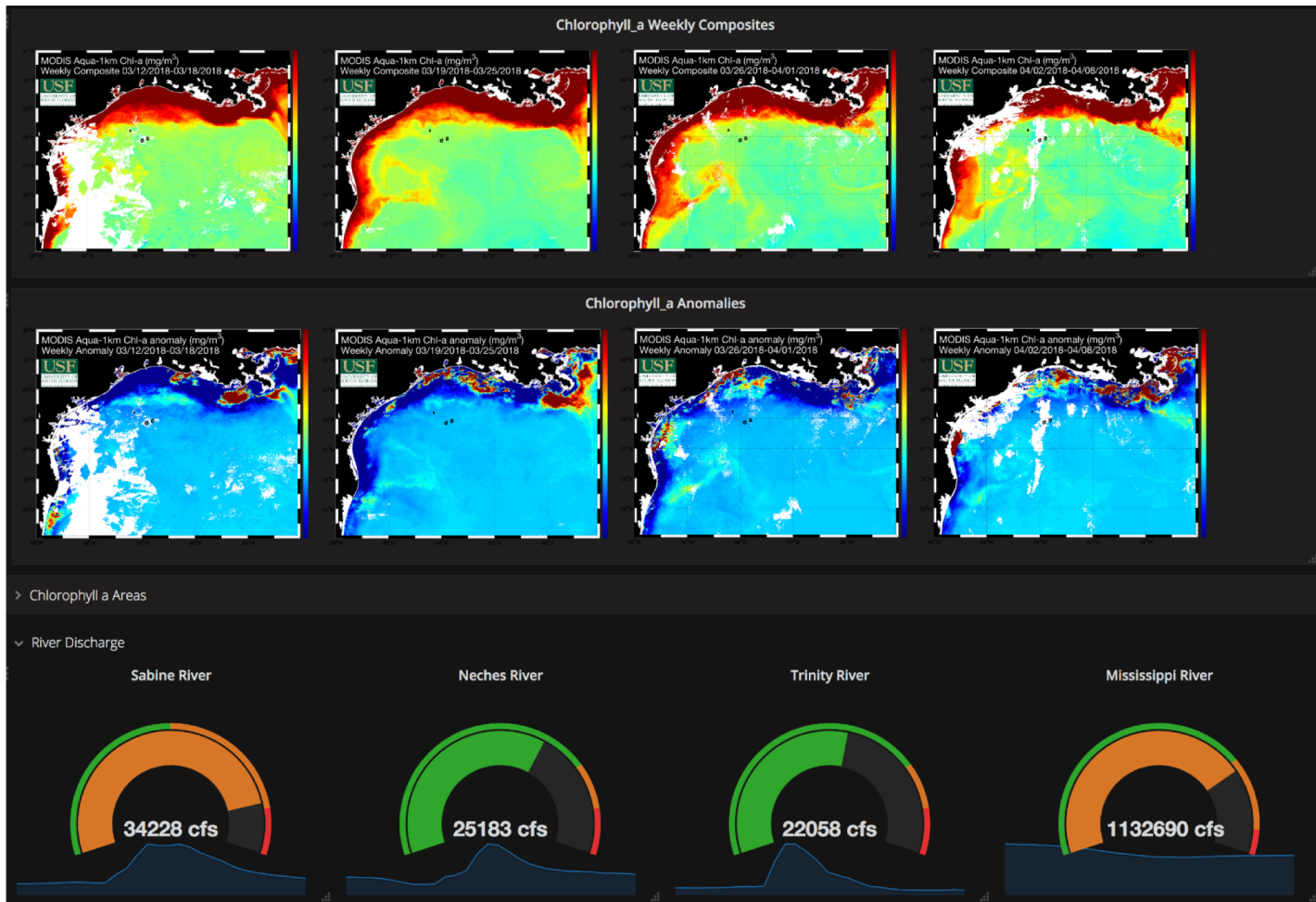
Anomaly detection



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



Early warning alerts for Sanctuaries



User dashboard for FGBNMS is live.

<https://usf-imars.github.io/img-dash/index.html?date=2018-04-10T19:15:51.513Z>

Florida Youth Outreach

- St. Pete Science Fest Oct. 20-21, 2017
 - 175+ 4th & 5th graders and 800+ “kids of all ages”
 - Activities teach about reef biodiversity, led by Simonello, supported by GCOOS, SECOORA and IMARS
- Stewart Middle Magnet School, Tampa, FL Nov-Dec activities
 - 60 students “lunch and learn” with FMK on remote sensing and biodiversity
 - USF CMS Campus Visit -- 50 students learn about MBON, conduct research with Keys Infographic, interact with AUVs, tour the R/V *Weatherbird*.
 - Featured on [USF Facebook](#), [Twitter](#) and [Hillsborough County School District website](#)
- [USF CMS awareness FMK interview](#)



Students learn how to assess diversity on coral reef transects at Sci Fest



Successes of the Sanctuaries

MBON

Successes:

- Well-defined conceptual framework for a collaborative MBON, national, international
- eDNA: collection and extraction methods tested and validated (i.e. zooplankton)
- Satellite-based, dynamic seascape products automated pipeline co-developed with CoastWatch
- Biodiversity field monitoring program fully implemented in both Sanctuaries
- Expanding links: NOAA *ocean acidification* program, *NOAA Omics*, State and Federal fisheries & environmental monitoring, NSF LTER (Everglades), IOOS and other observation programs
- 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

2018-2019 Plans

- Microbes-to-Whales (M2W) eDNA
- Biodiversity indicators for SDG14
- Operational Seascapes data via NOAA NESDIS / CoastWatch
- Early Warning System
- MBON Portal: Infographics/Explorer
- Global MBON (GEO BON MBON, Pole-to-Pole, Marine GEO-TMON/Smithsonian)
- X-MBON

MBON

Marine Biodiversity
Observation Network

Working with and supporting
other US and international
MBON projects



The First U.S. IOOS Biological Data Training Workshop

February 8-9, 2018
Seattle, WA.



MBON / OBIS Portals

Enrolling data

Web services:
Darwin Core /
WoRMS,
rOBIS and ERDDAP

Partnership



OCEAN BIOGEOGRAPHIC
INFORMATION SYSTEM

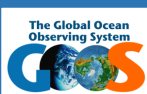
MBON

INTERNATIONAL
LINKAGES

OBSERVING LIFE IN THE OCEANS FOR SOCIETAL BENEFIT
(- INFORMATION FLOW -)



Global Ocean Observing System



GOOS: ESSENTIAL OCEAN VARIABLES

Focus on EOVS driven by societal needs

- Global implementation -

**GROUP ON
EARTH OBSERVATIONS**

**Biodiversity Observation
Network (BON)**



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



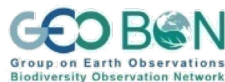
+ other national, international data systems

OTHER DATA PROVIDERS AND USERS

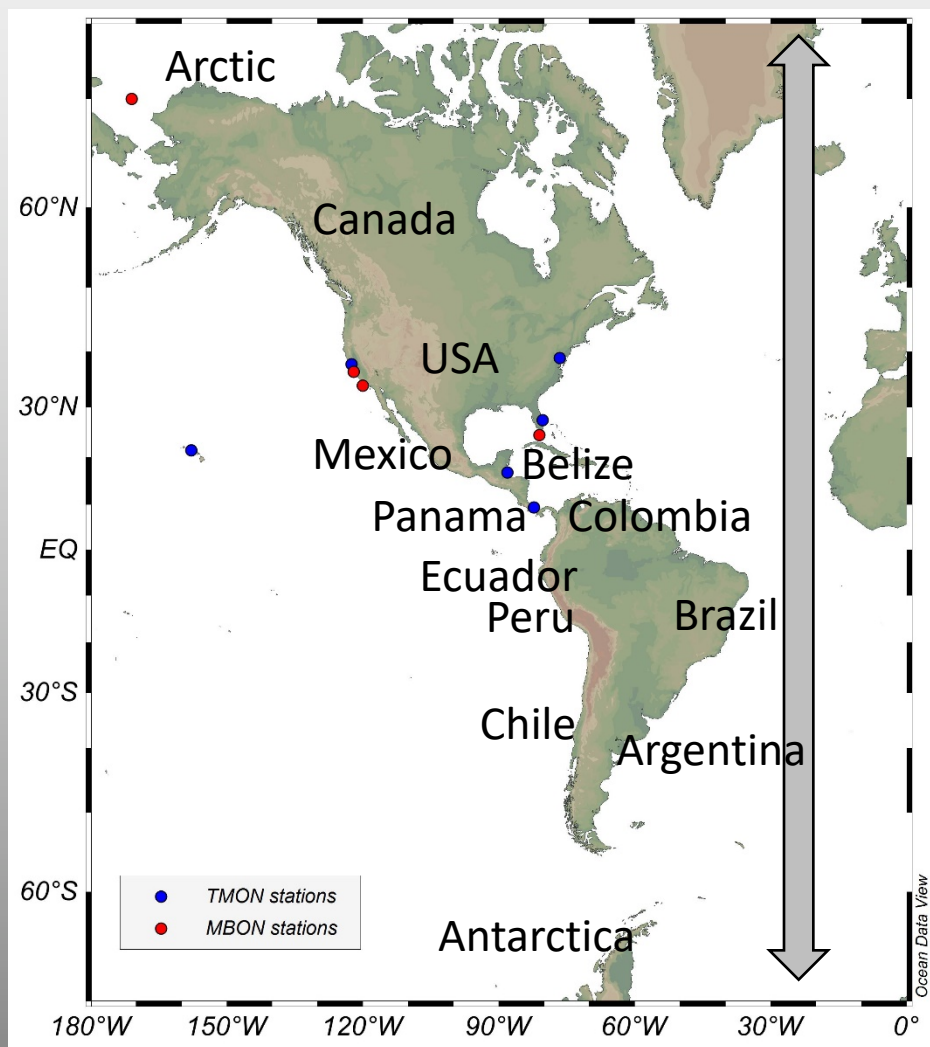
- ✓ National Governments and Organizations
- ✓ International Organizations
- ✓ Non Government Organizations
- ✓ Research Institutions
- ✓ Citizen Scientists



Smithsonian
TMON - MarineGEO



MBON beyond the US: GEO, GOOS, CBD, UN SDG

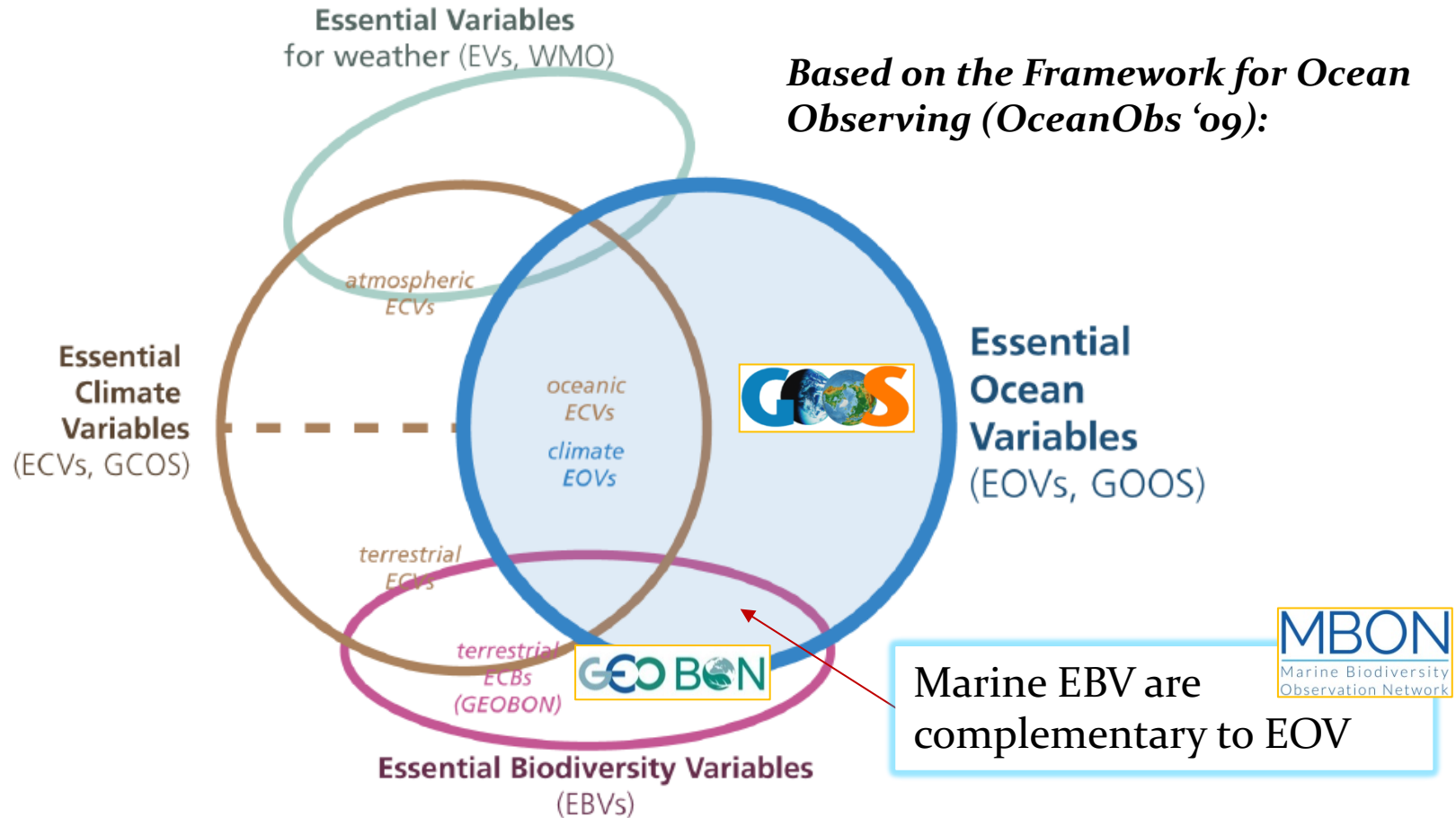


- **Pole-to-Pole MBON pilot**
 - the Americas
- **BON in a Box**
- **UN Sustainable Development Goal 14**

Outreach and planning

- MBON presentation at the GEO Plenary (Washington, DC, 2017)
- Monthly Webinars
- Pole-to-Pole in the Americas Workshop (Brazil, Aug 9-15, 2018)

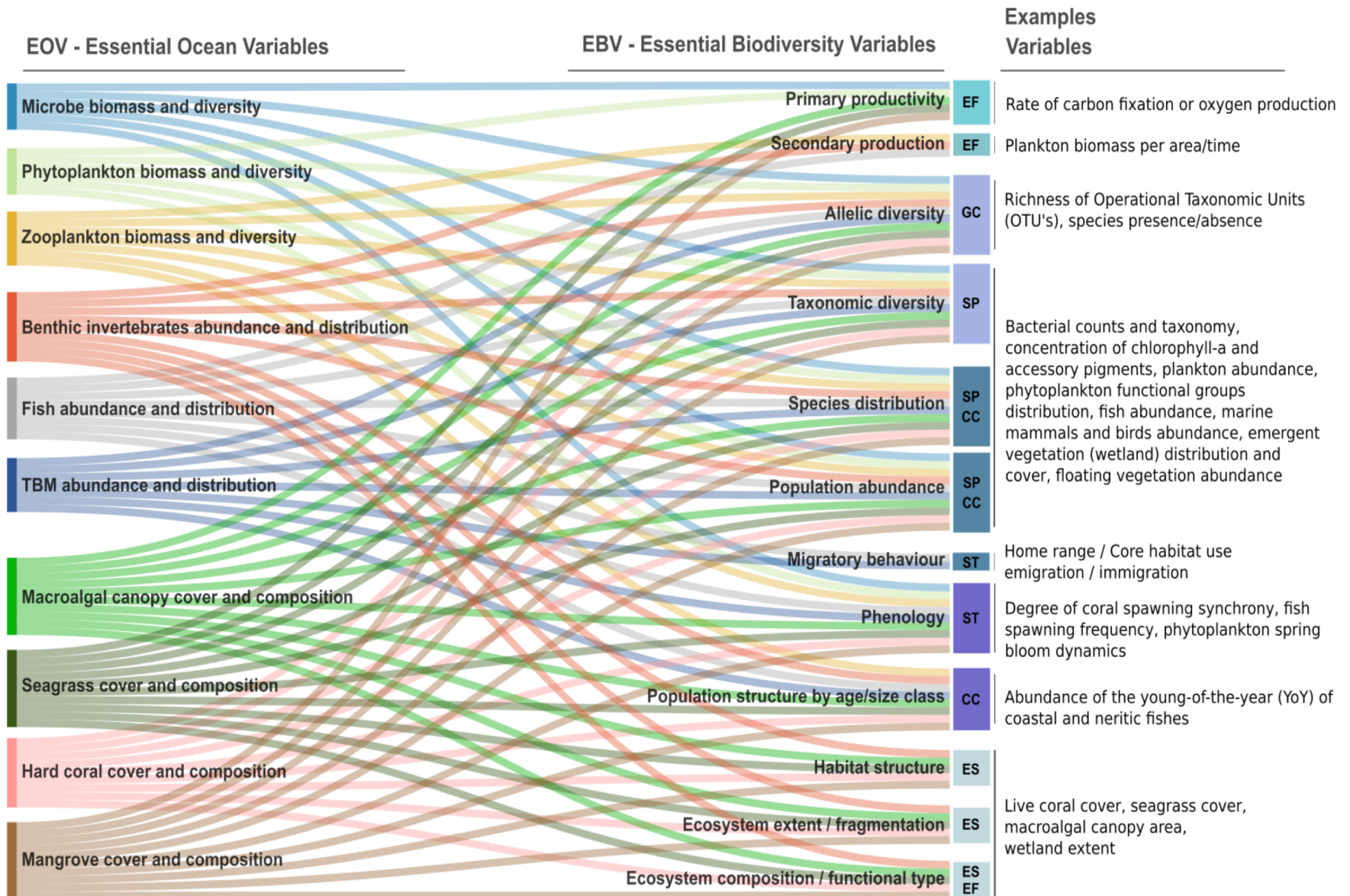
Linking Essential Biodiversity Variables (EBVs) and Essential Ocean Variables (EOVs)



EOVs are central to GOOS strategic planning and implementation

EBVs are central to GEO BON strategic planning and implementation

EBV and EOV are Complementary



MBON beyond the US: – In Progress

- GOOS Bio-Eco Panel and RNC
- OBIS and IOOS – IOOS adopts DarwinCore + training efforts
- MBON Portal development (X-MBON, IOOS)
- Indicator development for SDG14 in progress
- Global 'omics observatories
- WCMB in Montreal on May 17 (prototype to demo to CBD officials)
- GOOS Regional Alliances Meeting, June 12, Santa Marta, Colombia
- SBSTTA in Montreal on July 27 (promote the polished prototype)
- CBD in Egypt November 2018 (unveiling the tool/portal international)
- OceanObs 19
- SCOR P-OBS Working Group: Integration of Plankton-Observing Sensor Systems to Existing Global Sampling
- CMAR corridor: MBON is working with Ecuador, Panama, Colombia and Costa Rica to help define research needs in this EBSA.
- NOAA Ocean Exploration Research

Smithsonian MarineGEO Partnership

Our infrastructure is people



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





Seascapes



Satellite-derived Seascapes

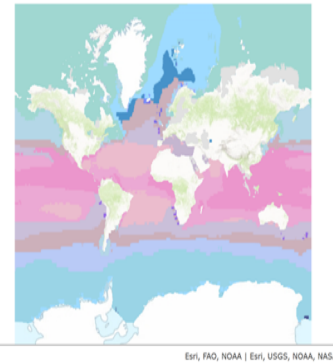
Kavanaugh (OSU), and all

Ongoing efforts

- Global classification of dynamic seascapes
- EMU intercalibration
- Case Studies:
 - Arctic
 - Temperate
 - Subtropical
- Habitat –species relationships
- Operational, multiscale products
- Collaboration:
 - NOAA NESDIS
 - NASA COVERAGE

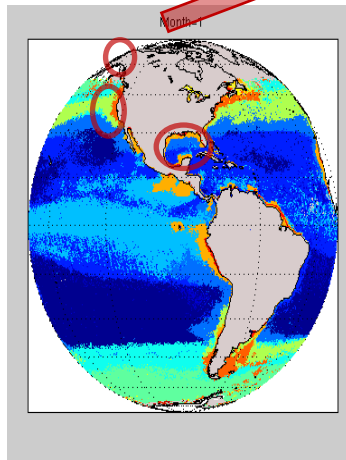
Global classification

Static+3D



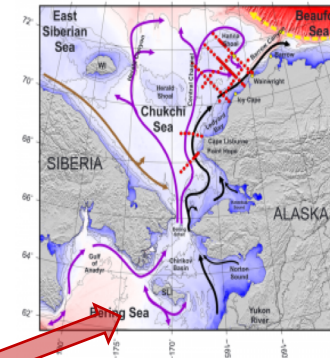
Ecological Marine Units

Dynamic+2D

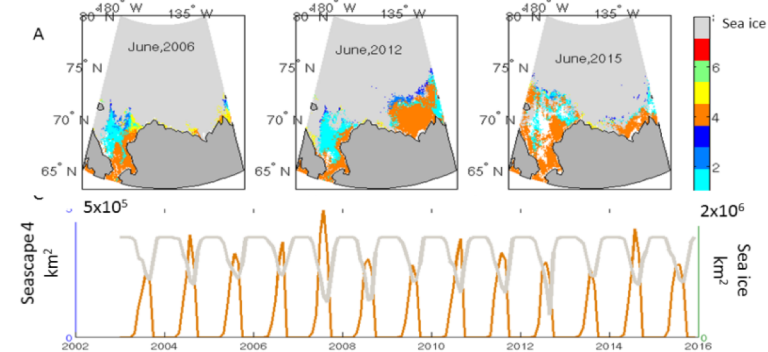


Dynamic Seascapes

Regional downscaling



Arctic MBON; Distributed Biological Observatory



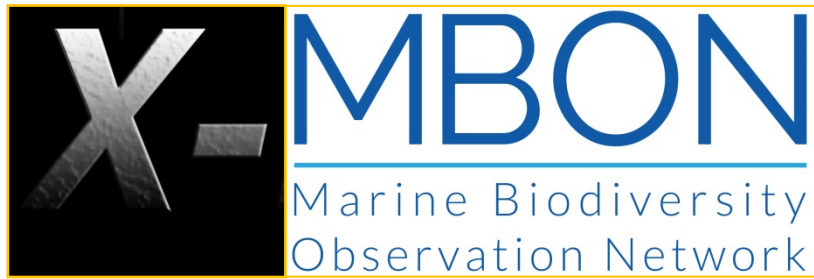
Dynamic habitat maps

Arctic MBON



eDNA





Comparing Visual Surveys and eDNA Detections in Temperate Rocky Reef Communities

Do environmental DNA (eDNA)
detections match classic visual
census records?

Data analysis performed by both
UC Santa Barbara and MBARI



UNIVERSITY OF CALIFORNIA
SANTA BARBARA



Monterey Bay Aquarium
Research Institute



NATIONAL SCIENCE FOUNDATION

LTER NETWORK
LONG TERM ECOLOGICAL RESEARCH

UCSB Postdocs: Thomas Lamy & Kathleen Pitz

Visual SCUBA survey

- 11 80 m² transects (11 rocky reefs)
- Classic Underwater Visual Census
- Water collection and filtering

eDNA pipeline

- Miseq runs for 3 markers: 12S (fish), 18S (phytoplankton, algae) and COI (zooplankton, inverts)
- MBARI eDNA analysis pipeline

Santa Barbara

Visual SCUBA survey

131 taxonomic units

- genus (N=16)
- species (N=91)
- coarse grouping (N=17)

eDNA pipeline

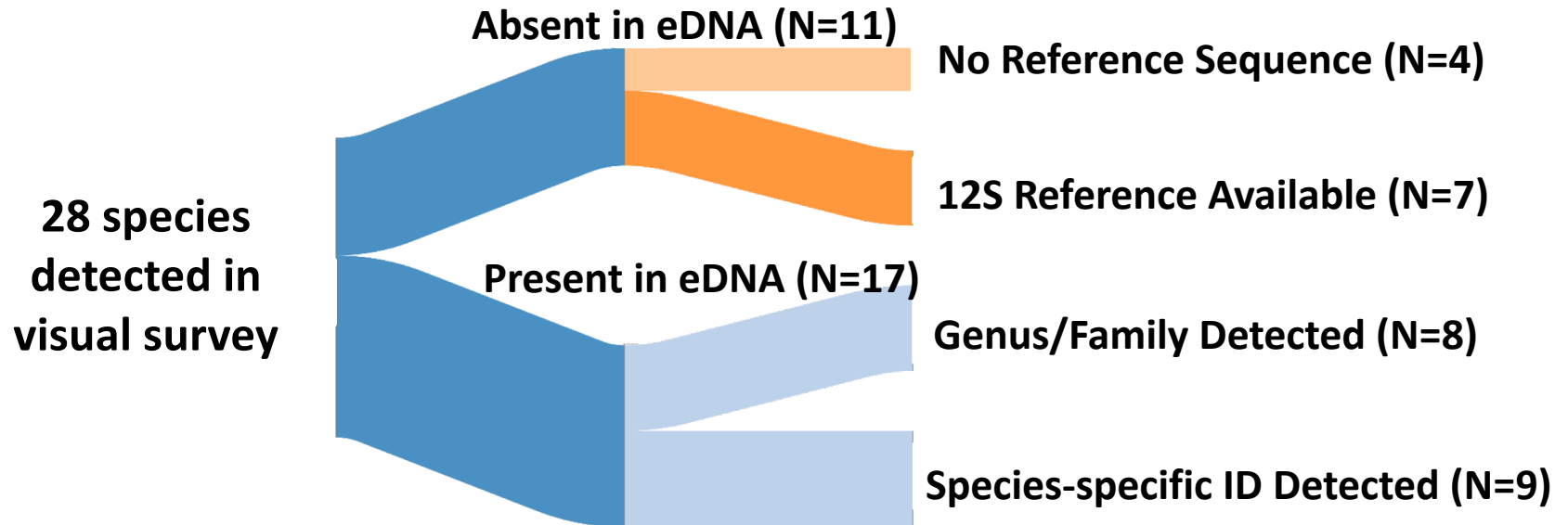
1710 unique taxonomies

- Classes (N=80)
- Orders (N=324)
- Families (N=686)
- Genera (N=963)
- Species (N= 1123)

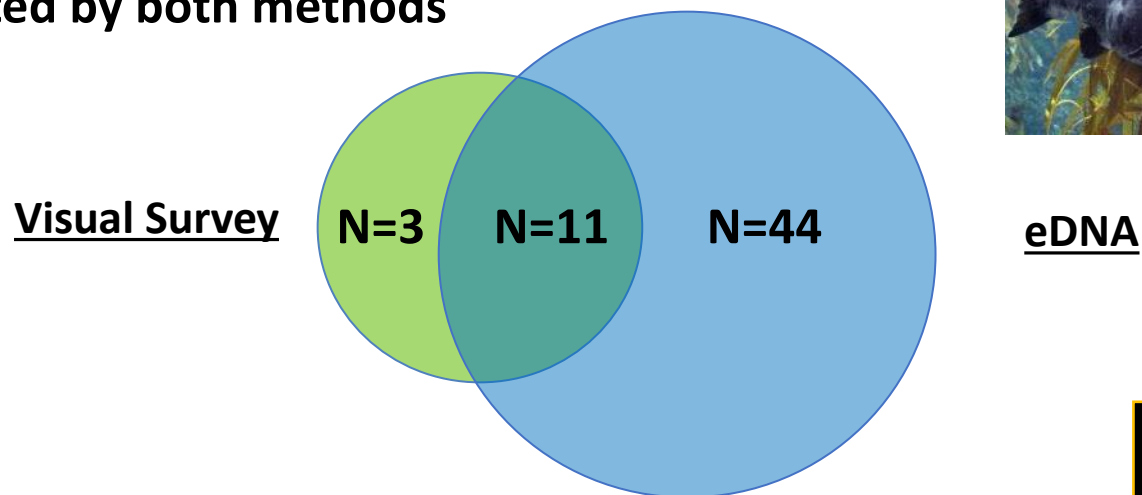
Sampling
Locations

Channel Islands National Park

A case study with bony fishes:



Comparing Bony Fish Families detected by both methods

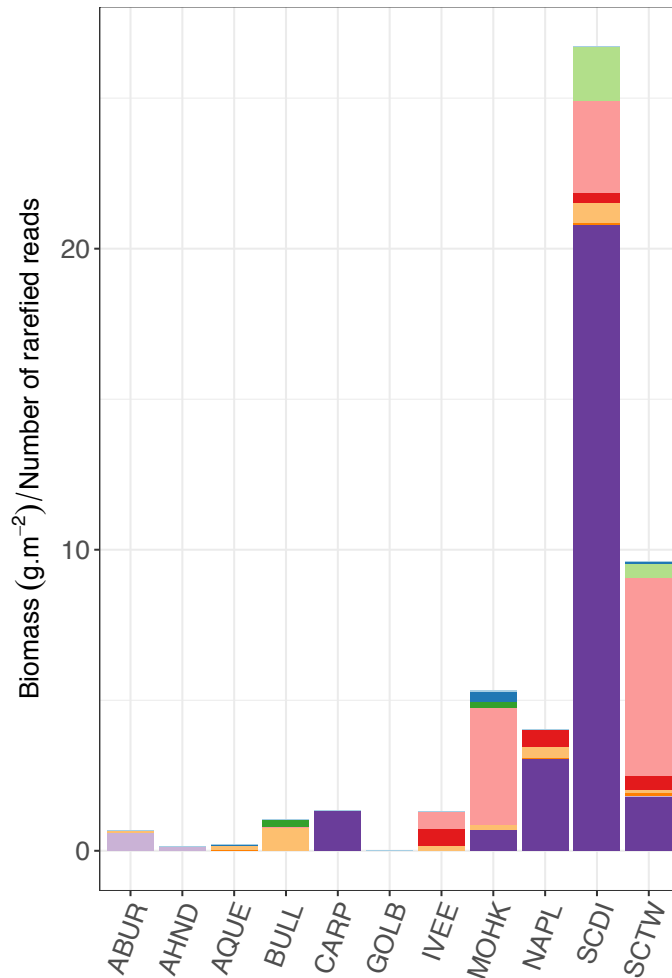


A case study with bony fishes:

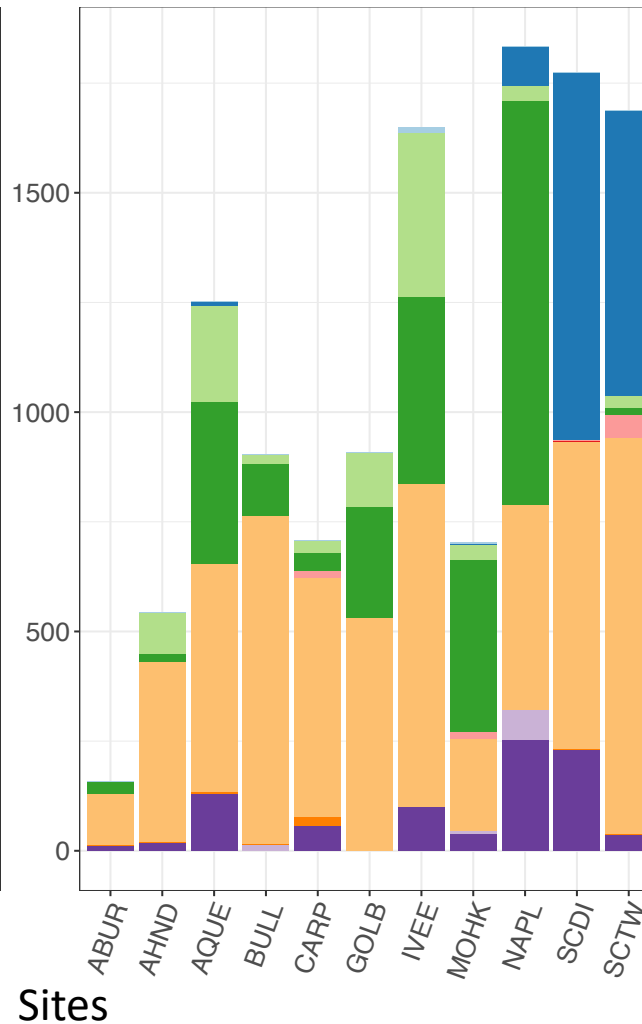


Species Detected by both Visual and eDNA methods

Visual Biomass



eDNA Relative Abundance



- Gibbonsia spp.
- Blacksmith
- Pile perch
- Black surfperch
- Garibaldi
- Rock wrasse
- Señorita
- Painted greenling
- Cabezon
- Sheephead



MBON

Marine Biodiversity
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