Integrating biological and environmental time series to understand and manage changing marine ecosystems

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OCB Summer Workshop

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IOOS | EYES ON THE OCEAN™

What is U.S. IOOS?

U.S. IOOS is a cooperative, coordinated network of federal and non-federal observing networks since 2009.

Thousands of observing data sets gathered every day by public and private programs

Integrated, made accessible, & supported U.S. IOOS

Supporting weather forecasting, maritime safety, and public and ecosystem health

11 Regional Associations
17 Federal agencies
Local to Regional to Global

Advancing Observing Communities

HF Radar:

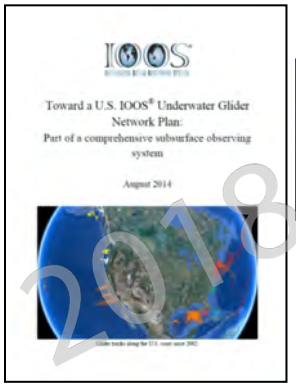
Biological Data and Biological Variables:

OBIS
OCEAN BIOGEOGRAPHIC INFORMATION SYSTEM

MBON
Marine Biodiversity Observation Network

WORKSHOP REPORT
Biological and Ecosystem Observations within U.S. Waters:
A Workshop to Inform Priorities for the U.S. Integrated Ocean Observing System®
Convened by the Interagency Ocean Observation Committee (IOOC) Biological Integration and Observation (BIO) Task Team

Gliders:



Marine Biodiversity Observation Network (MBON):

Animal Telemetry:

Wave Measurements:

IOOS Core Variables

Core observing variables required to detect and predict changes in the oceans, coasts, and Great Lakes:

- **Physics**: Bathymetry, Bottom character, Currents, Heat flux, Ice distribution, Salinity, Sea level , Surface waves, Stream flow, Temperature, Wind speed and direction;
- **Biogeochemistry**: Acidity, Colored dissolved organic matter, Contaminants, Dissolved nutrients, Dissolved Oxygen, Ocean color, Optical properties, Pathogens, Partial pressure of CO2, Total suspended matter;
- **Biology & Ecosystems**: Biological vital rates, Coral species and abundance, Fish species/abundance, Invertebrate species and abundance, Marine mammal species/abundance, Microbial species/abundance/activity, Nekton diet, Phytoplankton species/abundance, Seabird species/abundance, Sea turtles species/abundance, Submerged aquatic vegetation species/abundance, Sound, and Zooplankton species/abundance.

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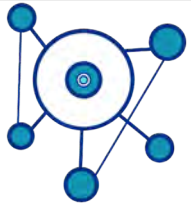

Core Variables

Ocean observing measurements required to detect & predict changes in the Ocean

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Biology and Ecosystem Essential Ocean Variables (EOVs)

The Global Ocean Observing System

FUNCTIONAL GROUPS

Phytoplankton
Diversity and Biomass

Zooplankton
Diversity and Biomass

Fish
Distribution and Abundance

Turtle-Bird-Mammal
Distribution and Abundance

HABITAT STATE

Hard Coral
Cover and Composition

Macroalgal Canopy
Cover and composition

Seagrass
Cover and composition

Mangrove
Cover and composition

Emerging EOVs: *Microbial diversity and biomass*
Benthic invertebrate distribution and abundance

Courtesy: P. Miloslavich

Examples of networks that observe biology

RESPONSIBLE	"NETWORK"	Global spatial scale	Temporally sustained	Globally coordinated	International data standards / open access	Contributing to (EXV) requirements	Clear mission, targets	Agreed best practices / QC	Technological readiness
ICRI	Coral GCRMN	Pilot	Pilot	Pilot	Concept	Pilot	Pilot	Pilot	Pilot
MBA (SAHFOS)	Zooplankton e.g. GACs	Pilot	Mature	Mature	Pilot	Mature	Mature	Mature	Mature
UTAS	RLS (Reef Life Survey)	Pilot	Pilot	Pilot	Pilot	Mature	Mature	Mature	Mature
IOC	Phytoplankton e.g. TRENDS-PO	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot
IOC	GlobalHAB	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot
IOCCG	Ocean colour	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature
IOC	IGMETS	Mature	Mature	Mature	Mature	Mature	Mature	Mature	Mature
OTN, ATN, ETN, ARGOS	Animal Tracking	Mature	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot	Pilot

Concept	Pilot	Mature

Courtesy: P. Miloslavich

…but cross-reference with our lists of variables and there are gaps.

Time Series…

- Collectively represent how a system, process, or behavior changes over time - rate and extent
- Enable us to track conditions, see anomalies, forecast change
- Work at multiple scales - from remote sensing to in situ and traditional survey methods …and plenty in between (eg technology-supported obs)
- Can be layered into existing observing networks
- Should be integrated across disciplines for best understanding of changes to marine life and ecosystems

We have abiotic time series fairly well in hand - much work remains to establish and make accessible biological time series.

Addressing a critical observing gap

- Huge investment in biodiversity monitoring and ocean observing systems
- ...but no systematic effort to observe life in the sea

COML ends 2010 → MBON workshop 2010 → Projects launched 2014 → GEO BON Thematic Node 2016 → MBON-OBIS-GOOS Partnership 2016

Attaining an Operational Marine Biodiversity Observation Network (BON) Synthesis Report

http://www.nopp.org/wp-content/uploads/2010/03/BON_SynthesisReport.pdf

US MBON Demonstrations

- MBON: A long-term, multi-sector network to observe marine life and ecosystem interactions – what is changing and how it affects us.
- 5-year demos 2014-2019:
  - Santa Barbara Channel
  - Arctic/Chukchi Sea
  - Sanctuaries (Florida Keys, Flower Garden Banks, Monterey Bay)
- ~17M - NASA, NOAA, BOEM, NSF, Shell
- USGS, Smithsonian, LTER partnerships
- USG planning for 2019 and beyond

Courtesy: MBARI

MBON Commitment

- Integrating existing monitoring, filling gaps
- Advancing technologies (eDNA, imagery, remote sensing)
- Serving users, building tools
- Expanding access to marine biological data and information
- Sharing best practices and protocols
- Building capacity

Smithsonian Marine Global Earth Observatory

MarineGEO
THE TENNENBAUM
MARINE OBSERVATORIES NETWORK

Smithsonian Institution

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

Satellite data

NASA MODIS (2002-present)

Daily, monthly, annual, climatology, anomalies:

- Sea Surface Temperature
- Ocean color

Seascapes

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

NOAA VIIRS (2011-present)

Daily, monthly, annual, climatology, anomalies:

- Sea Surface Temperature
- Ocean color

Seascapes

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

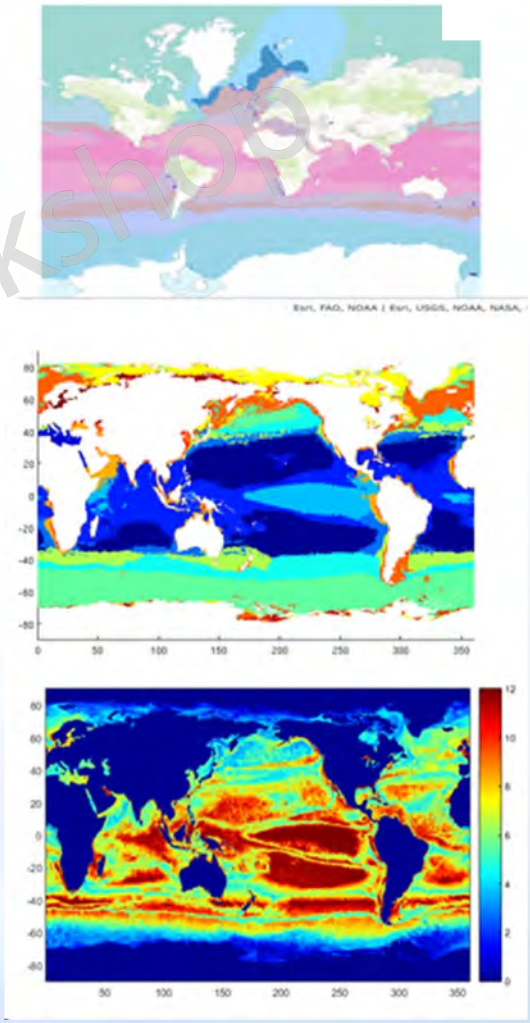
Landsat, Commercial (WorldView 2, 3)

Individual images, mosaics

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

MBON Seascapes: Global, regional, operational

- Classification of dynamic seascapes from satellite variables: SST, chl-a, SSS, tau, SSH, nFLH, CDOM
- Soon to be produced operationally by NOAA/CoastWatch, NASA COVERAGE
- Local to global
- Applications for cruise planning, feature tracking
- Also fisheries management, OA, HABS, characterizing Arctic habitat



Environmental DNA

- MBON is advancing methods for water sample collection, filtering, extraction and sequencing
- Comparing results with existing time series, across trophic levels, and regions
- Peer-reviewed, documented best practices
- MBON eDNA efforts are helping:
  - Florida improve screening for toxic algae,
  - Monterey Bay partners assess vertebrate diversity at oceanographic stations, and
  - Flower Garden Banks scientists detect diversity of corals, sponges, and brittle stars from spawning events.

CENTER FOR OCEAN SOLUTIONS

USF UNIVERSITY OF SOUTH FLORIDA

MBARI

MBON Marine Biodiversity Observation Network

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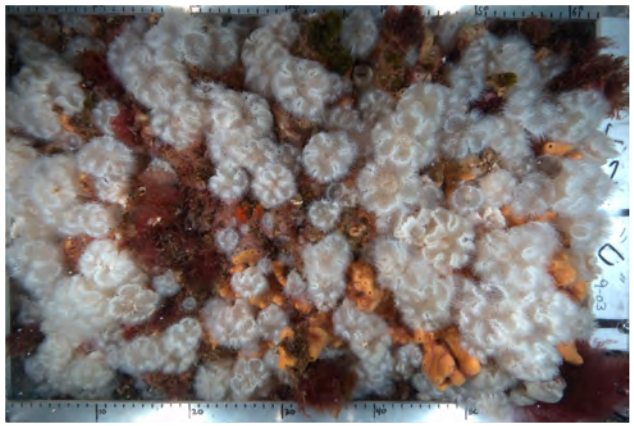
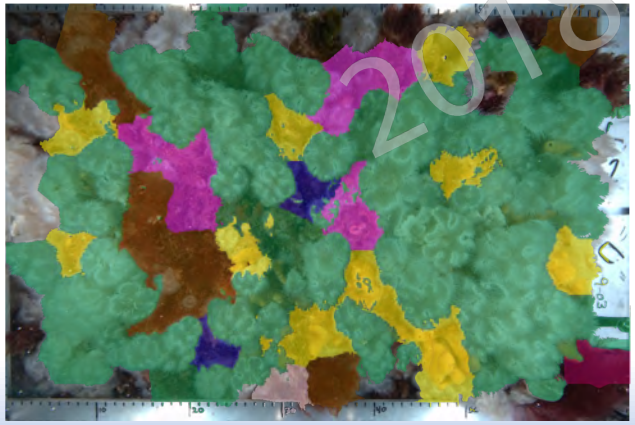
Deep learning for image analysis



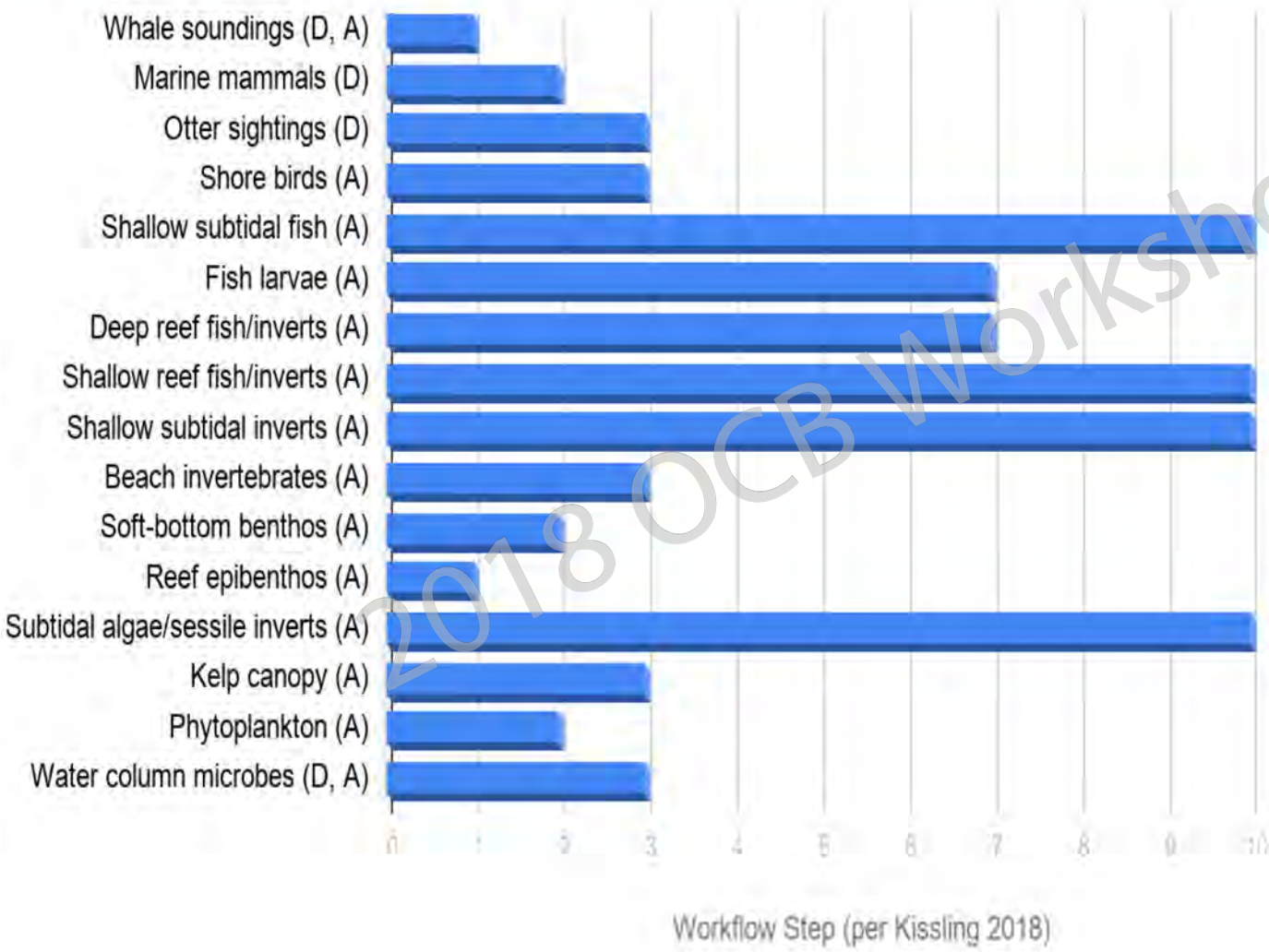


- Using Seabed AUV imagery from NOAA Fisheries
- Refining process for automated species identification
- Benefits: Generalizes to your data, Fully automated - no feature selection, High accuracy

MARINE BIODIVERSITY OBSERVATION NETWORK
SANTA BARBARA CHANNEL

BisQue

Example of MBON data available



Key - measurement type:

D: Occurence (EBV class “distribution”)

A: abundance or density (EBV class “abundance”)

Delivery Mechanisms Tested:

DwC-A in repository
NSF EDI/DataONE

EML-to-ERDDAP
IOOS - SCCOOS

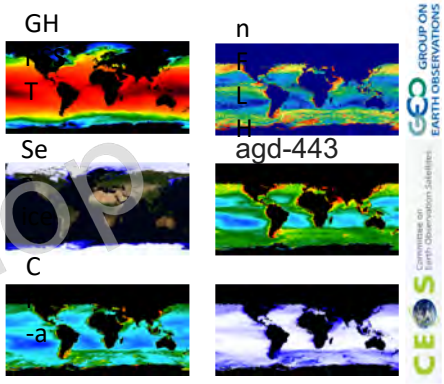
Manual contributions
OBIS

Workflow input to research community formats
NSF EDI

Societally-relevant products need linked data pipelines

At least 5 pipelines need to be linked:

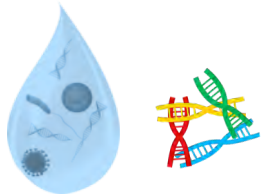
Satellite data (space agencies)



COVERAGE

In situ environmental data (NODCs)

Genetic (GenBank/NCBI, RefSeq, Gene Home, SRA, etc.)



Biodiversity (OBIS, GBIF, others)

Socio-economic data

Maps, jurisdictions, census, economy

Courtesy: Frank Muller-Karger

Advancing Biological Data Management

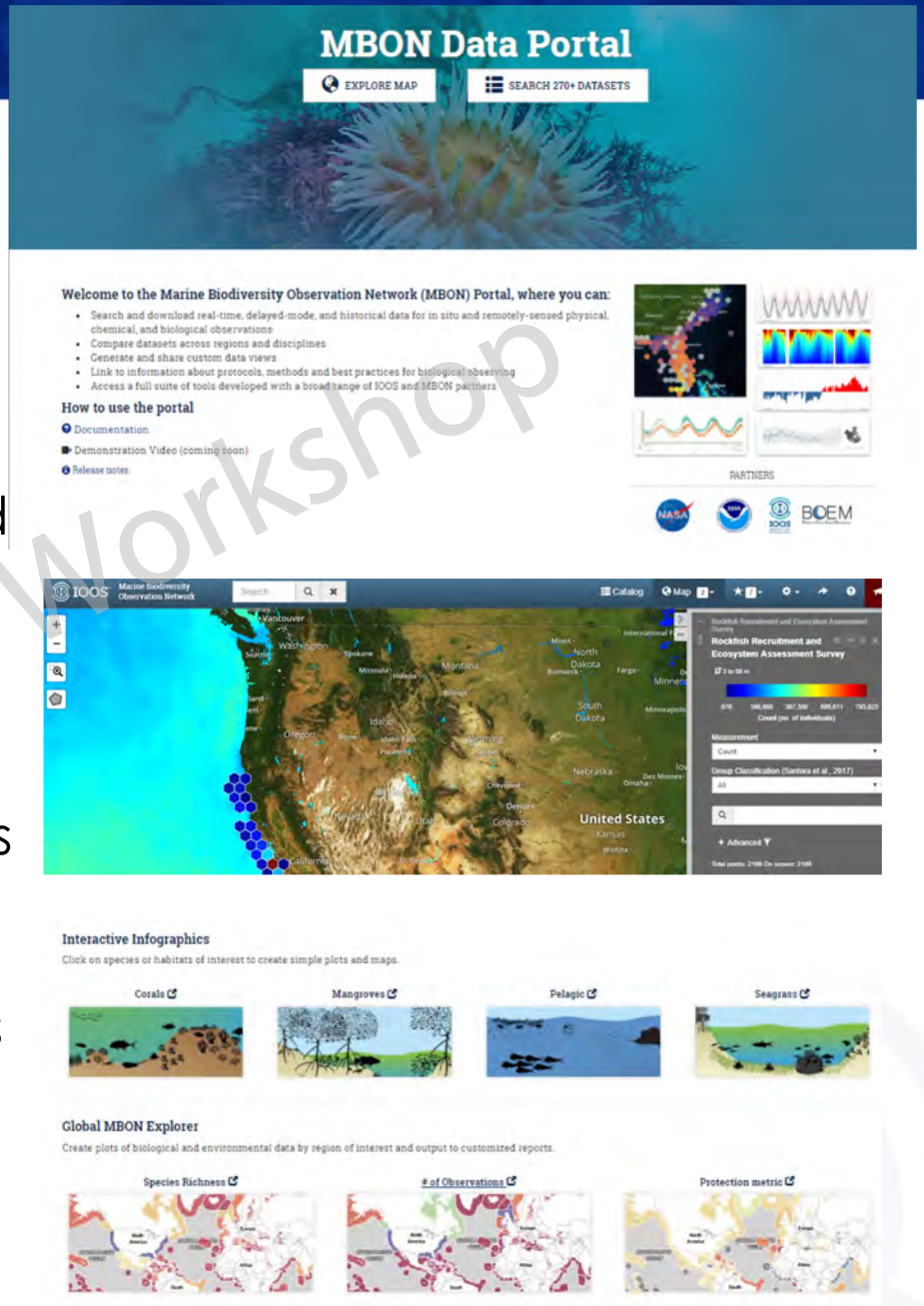
- Advocating standards-based data and metadata
- Feb 2018 Biological Data Training
- ERDDAP and similar web services to provide a simple, consistent way to download datasets or ingest them into other platforms
- Accessible via MBON Portal, OBIS

MBON Portal V 2.0

- https://mbon.ioos.us/

US MBON Portal

- Discover, visualize time series and other data
- Search, download real-time, delayed-mode, and historical data - in situ and remotely-sensed physical, chemical, and biological obs
- Compare datasets across regions and disciplines
- Generate and share custom data views and time series plots
- Link to protocols, methods and best practices
- Access interactive infographics and Global MBON Explorer



https://mbon.ioos.us/

Example: Rockfish Data View

- Scientists at the NOAA Southwest Fisheries Science Center are examining natural variability of biodiversity of pelagic forage fish off California. (Santora et al 2017)
- NMFS Rockfish Recruitment and Ecosystem Assessment Survey (RREAS) data in the MBON portal allows for analysis of biodiversity and climate episodes (El Nino,La Nina, 2015 warm blob)

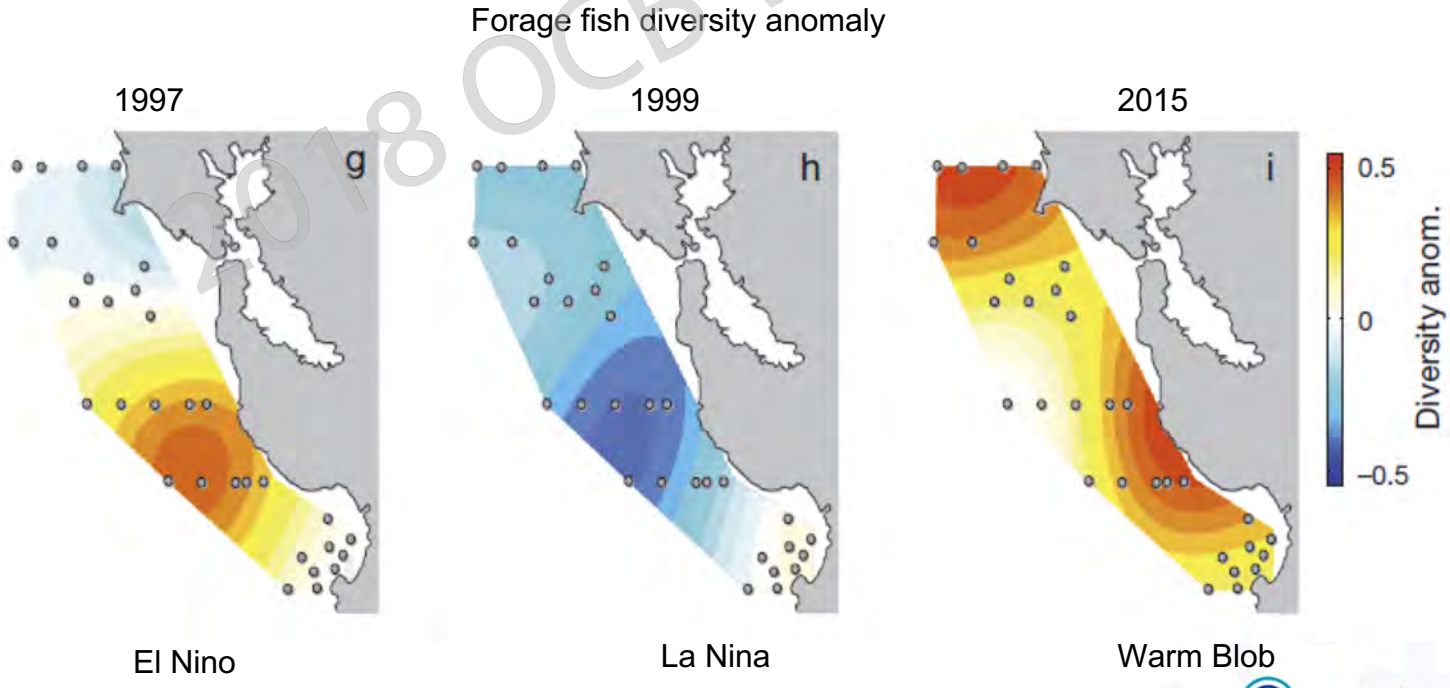
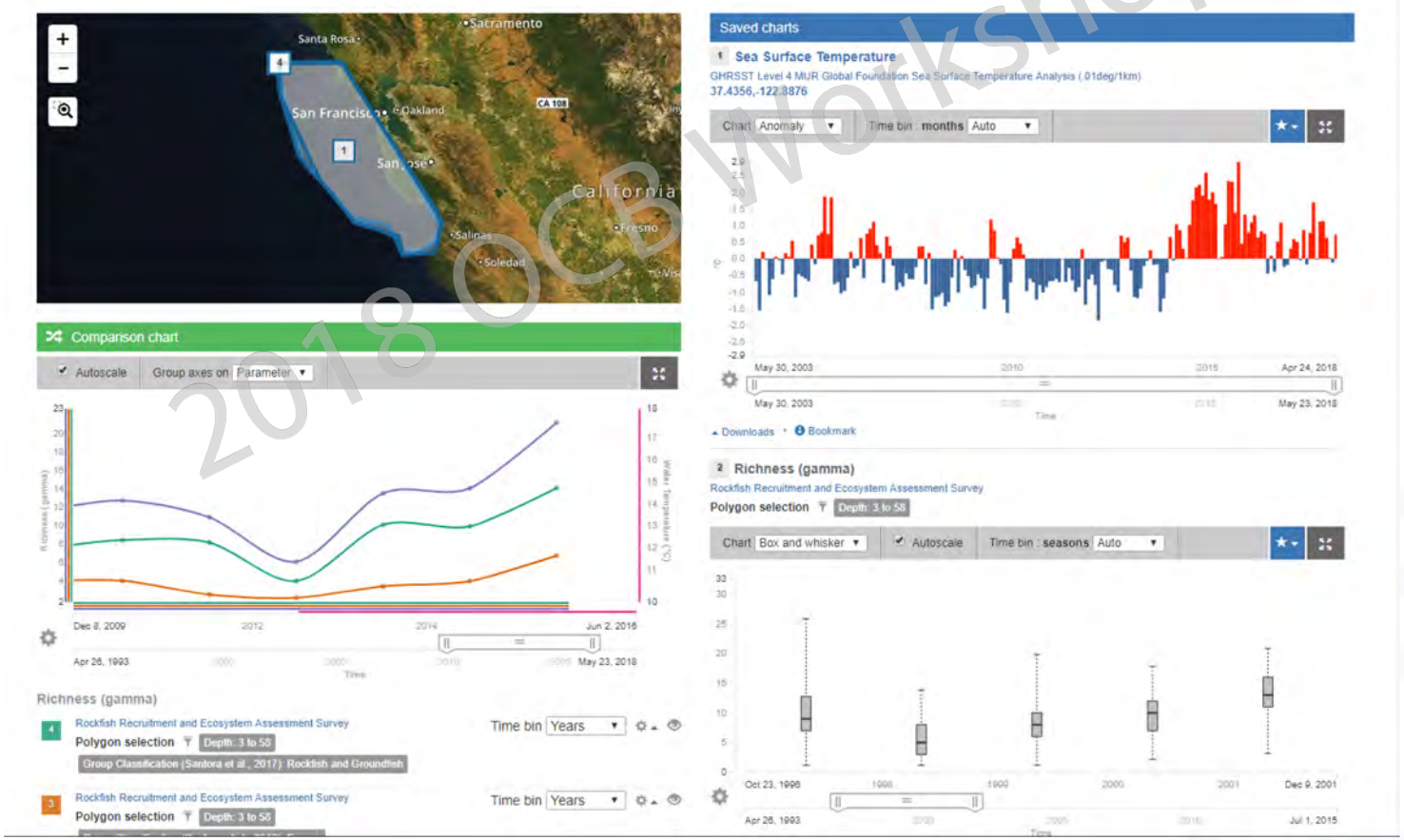


Figure 6 Santora et al. 2017

MBON Portal: Rockfish Data View

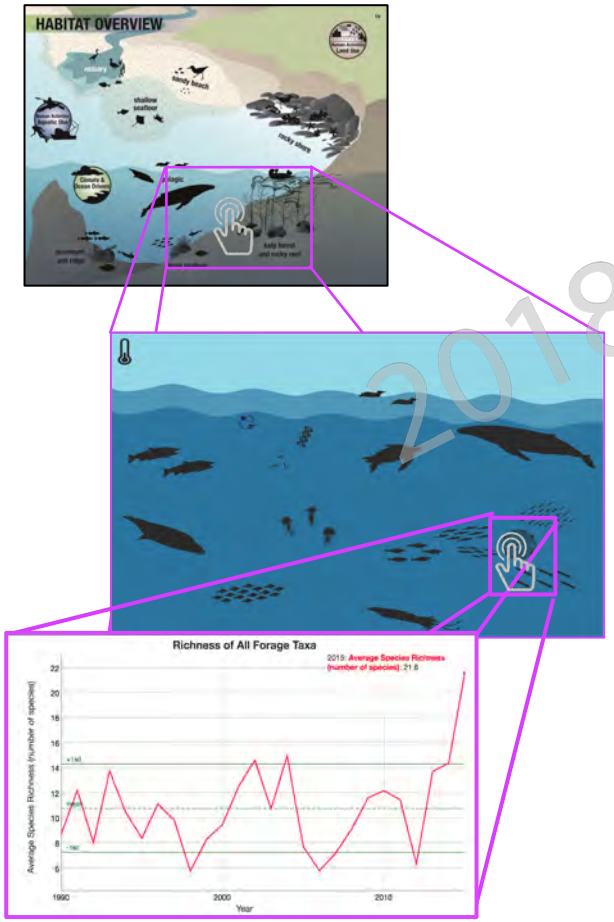
- Map of data polygons
- On the right are time series plots of data loaded into the data view
- On left below the map is a comparison chart of the data
- Below comparison chart is the list of data sets loaded.



MBON Suite of Tools

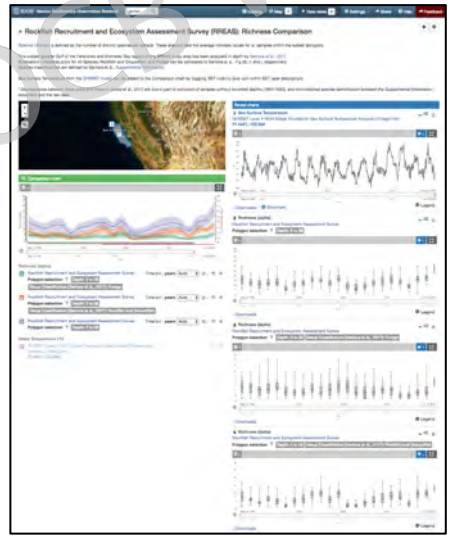
Infographics

Audience:
public, managers, educators



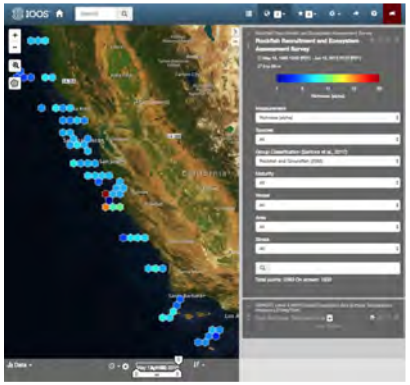
MBON Curated Data Views

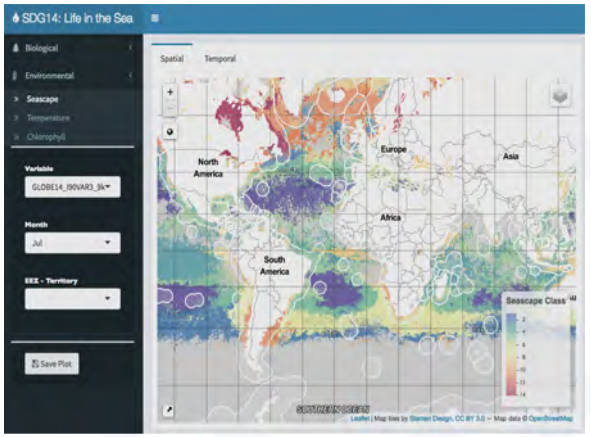
Audience:
Advisory groups, researchers, teams



MBON Data portal

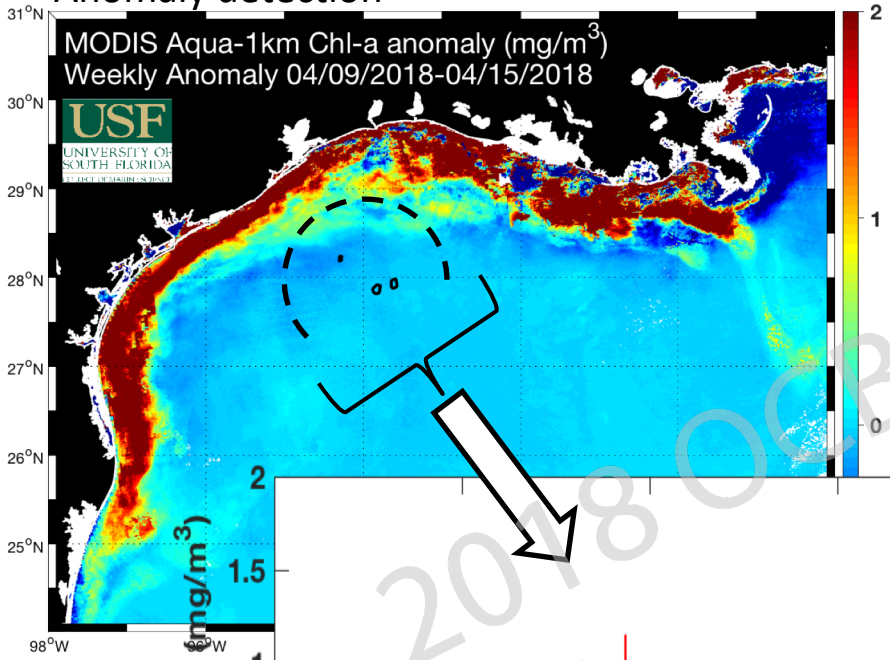
Audience:
Scientists, technical experts



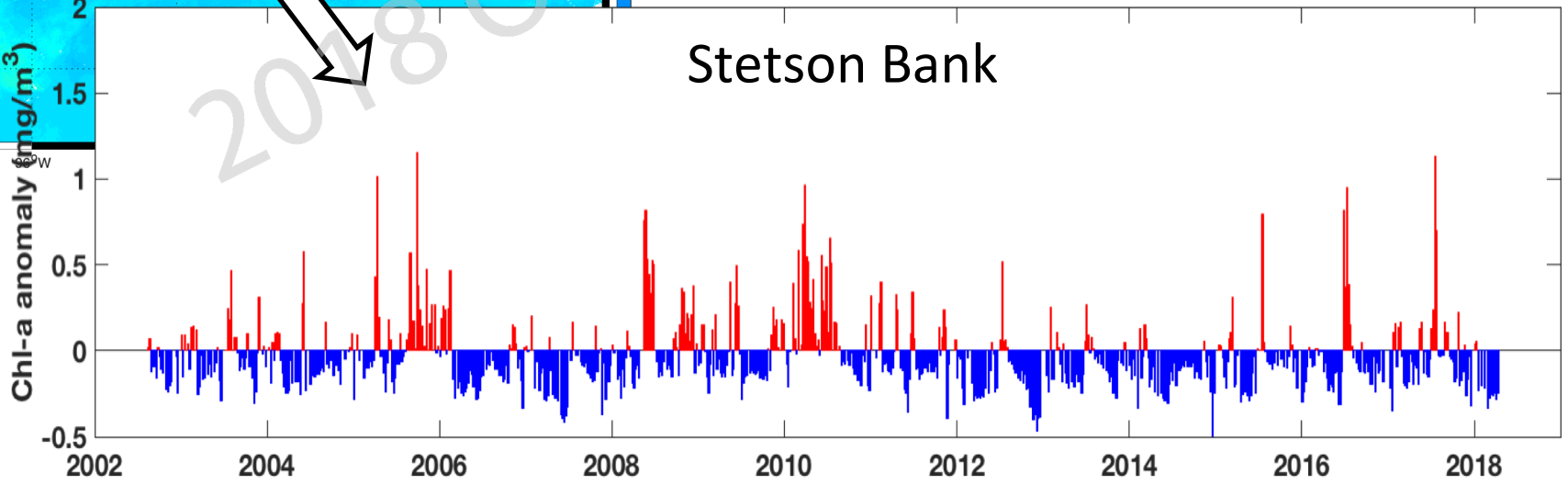


Early warning and alert system for Sanctuaries

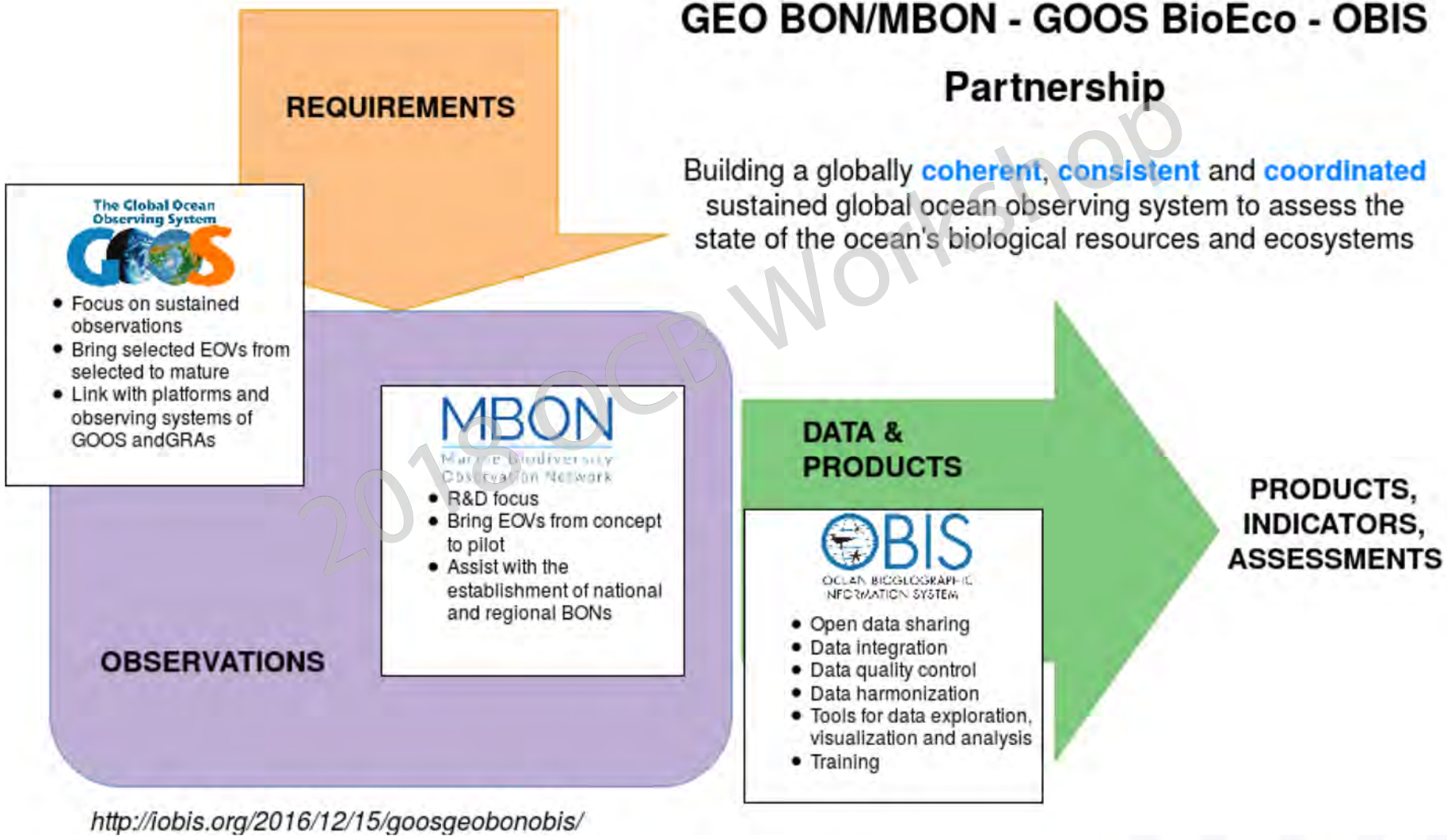
Anomaly detection



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

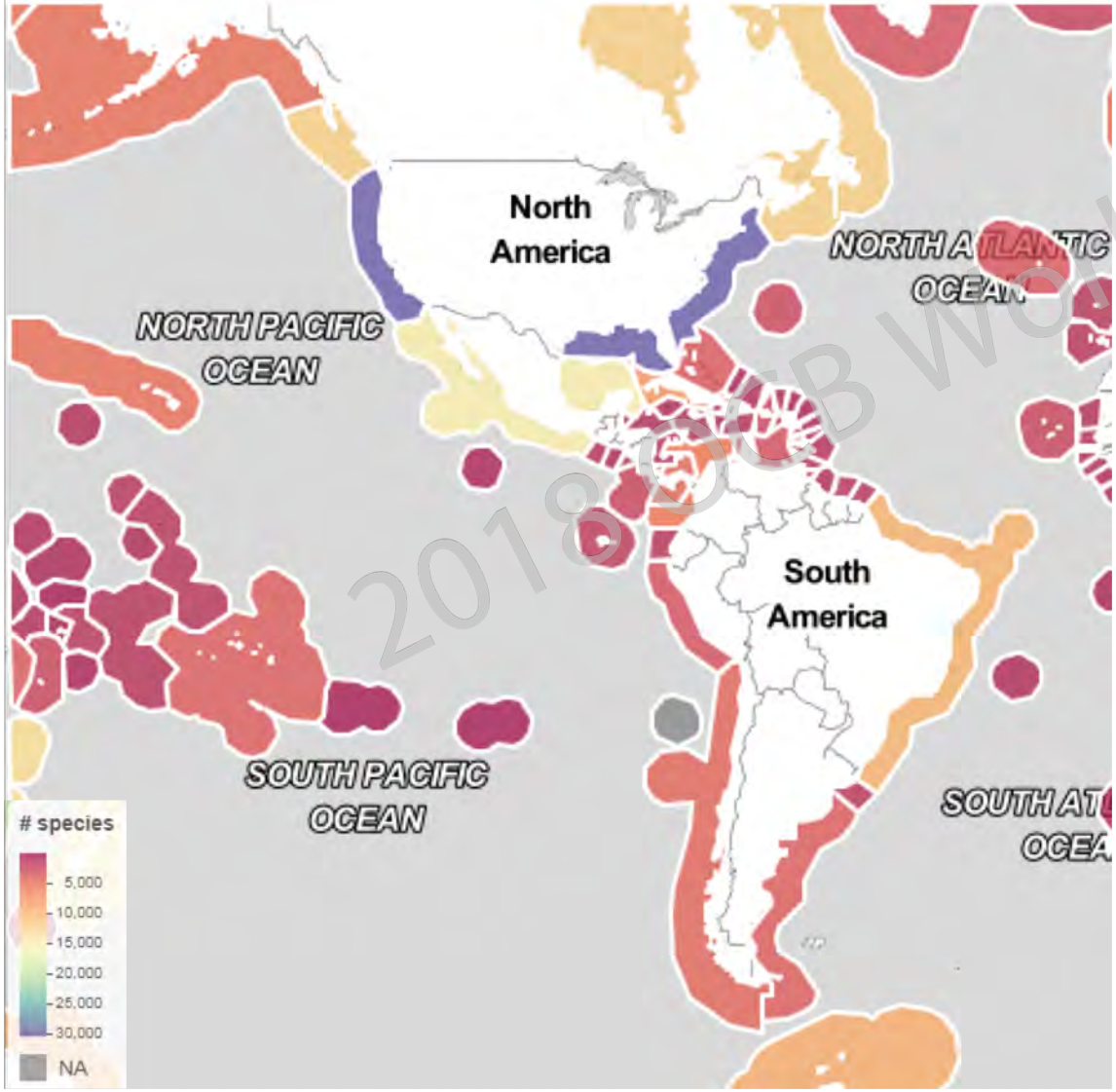


Global Community of Practice



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

Pole to Pole MBON - Americas



AmeriGEOSS

… and all others that want to join.

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Globally, MBON members agree to:

- Support development of a Community of Practice on the observation of marine biodiversity;
- Contribute to the IOC/IODE Best Practices repository for standardized field, laboratory and analysis methods and metadata;
- Advance partnerships with existing monitoring efforts in your country or region;
- Publish data into open-access databases such as the IOC-UNESCO Ocean Biogeographic Information System; and
- Promote integration of biological observations with other environmental parameters at the relevant scales (eg with GOOS)

[Montréal, 2018]

Time Series - Challenges

- Emphasis on discrete research effort vs. operational monitoring and activities that yield long time series
- Shifting priorities of government agencies impact long-term monitoring - US and globally
- Difficulty prioritizing variables to focus long term monitoring investments
- Infrastructure, maintenance of time series databases - time-series data accumulates quickly

Science can advance new methods but if results cannot be intercompared, and if data are not shared, then we cannot measure change across regions and the globe.

Questions?

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https://mbon.ioos.us/
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