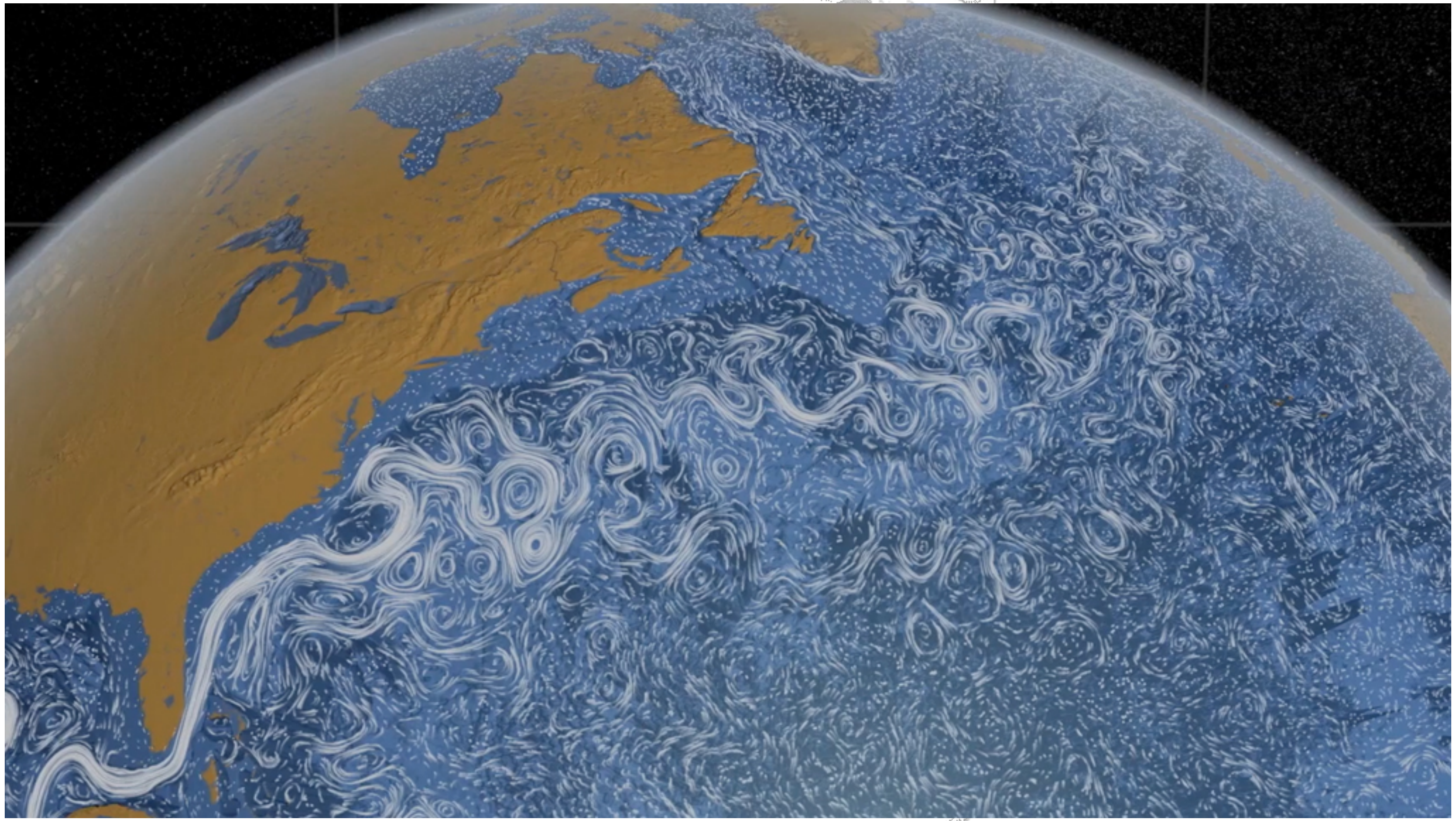
Migratory Connectivity of the Ocean (MiCO) and the Sargasso Sea



Sargasso Sea Commission

1st Intergovernmental Conference

March 13th, 2019

Patrick N. Halpin

Daniel Dunn & the MiCO team

Marine Geospatial Ecology Lab

Duke University

MiCO Migratory Connectivity in the Ocean

Marine Geospatial Ecology Lab Duke University

GOBI Global Ocean Biodiversity Initiative

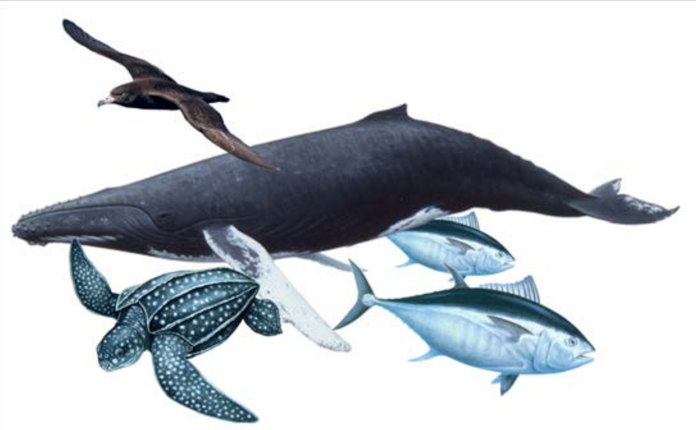
Supported by:

Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

based on a decision of the German Bundestag

Topics

- Introduction
- Analyzing destinations and corridors
- MiCO – Migratory Connectivity of the Ocean
- Synthesis & future trends



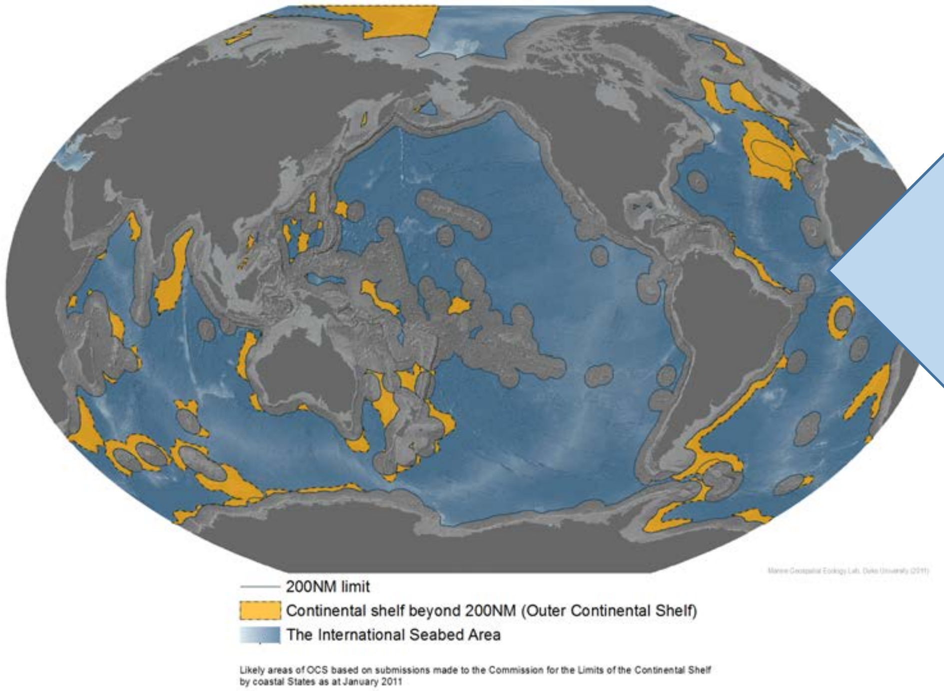
Marine Geospatial Ecology Lab
Duke University

Migratory marine animals move great distances both within and beyond national jurisdictions

MiCO
Migratory Connectivity in the Ocean

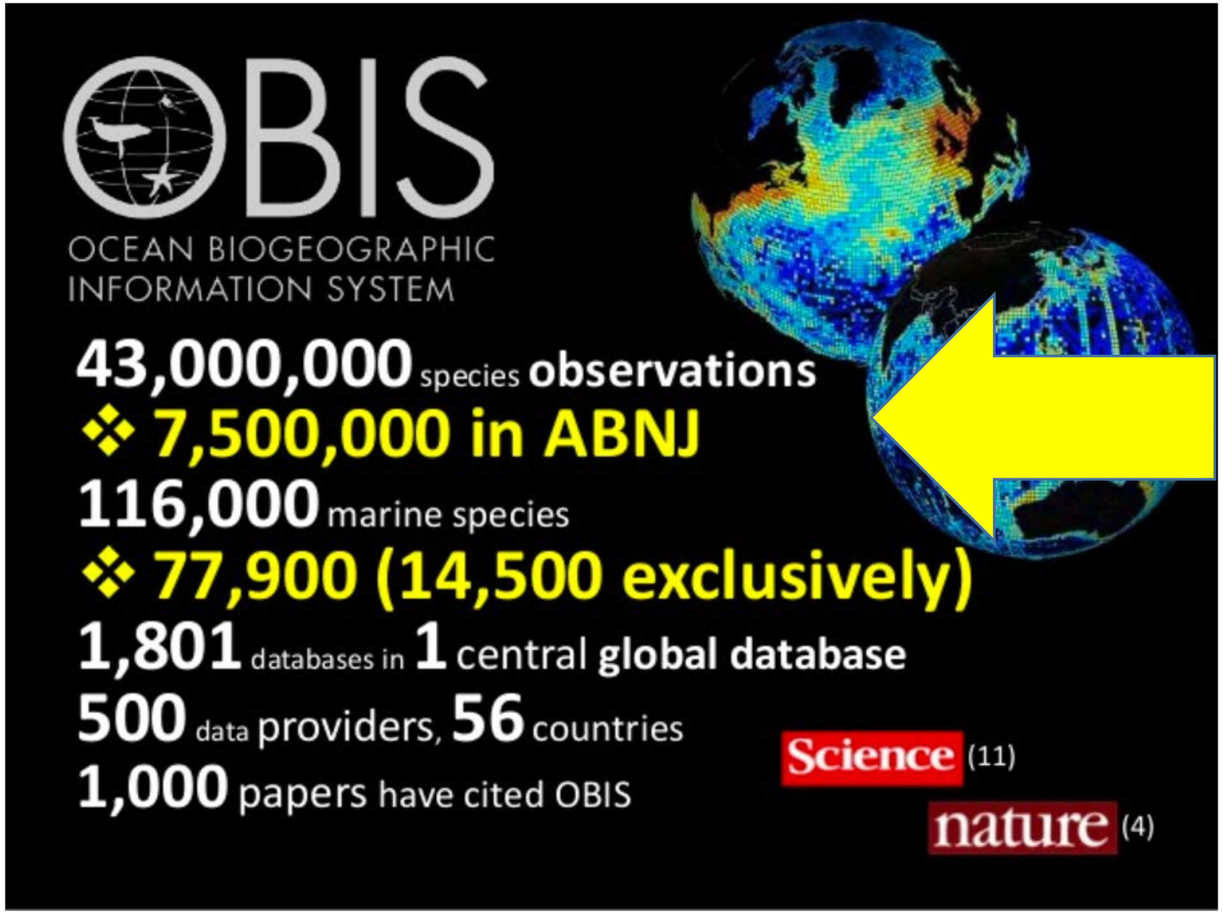
The Migratory Connectivity of the Ocean (MiCO) initiative is working to identify these corridors and connections

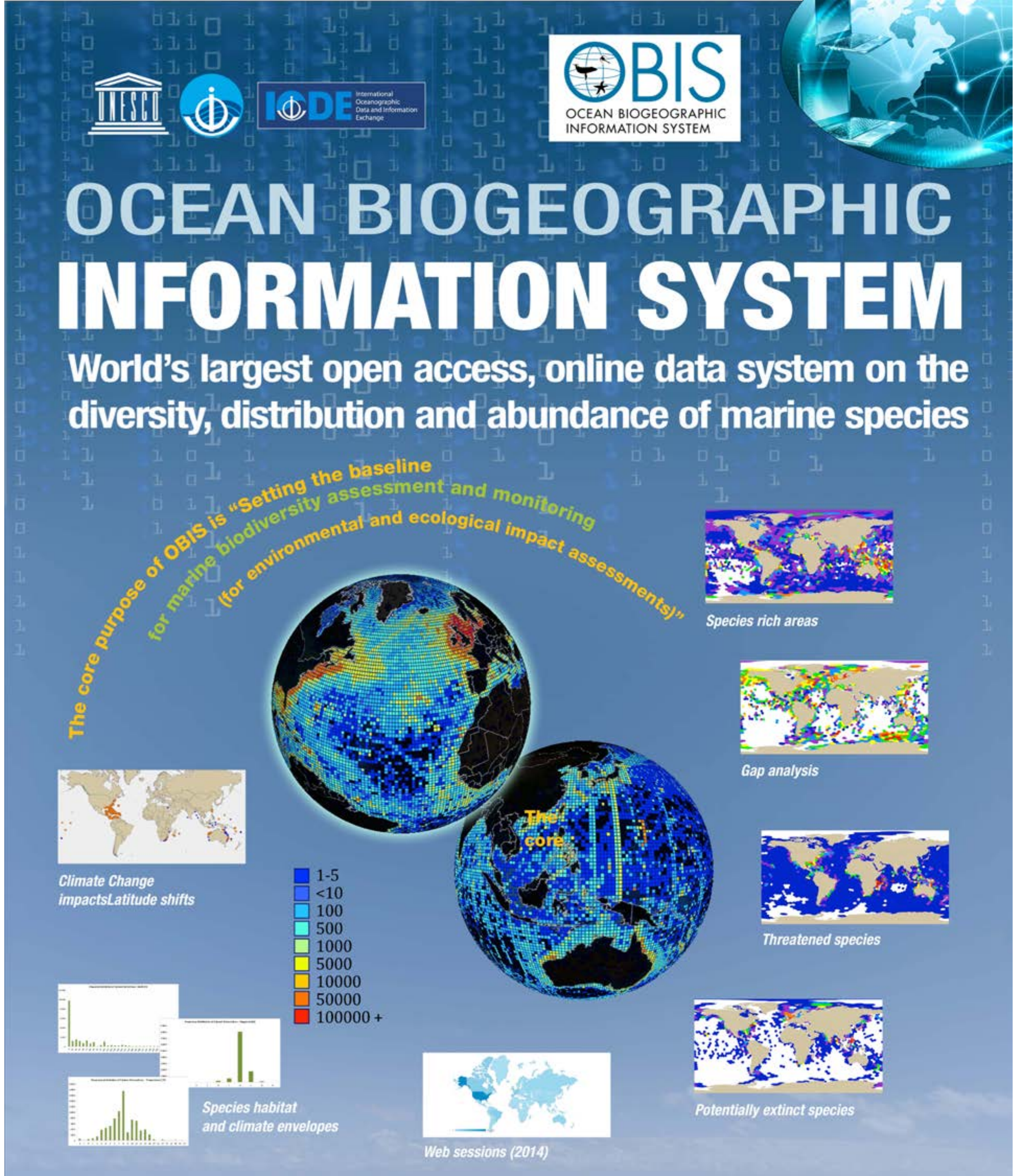
Many marine species migrate long distances through both ***national*** and ***international waters***.



Effective management of these wide-ranging species requires ***shared information*** and ***international cooperation***.

Open-access marine biodiversity data is the necessary starting point for managing ABNJ



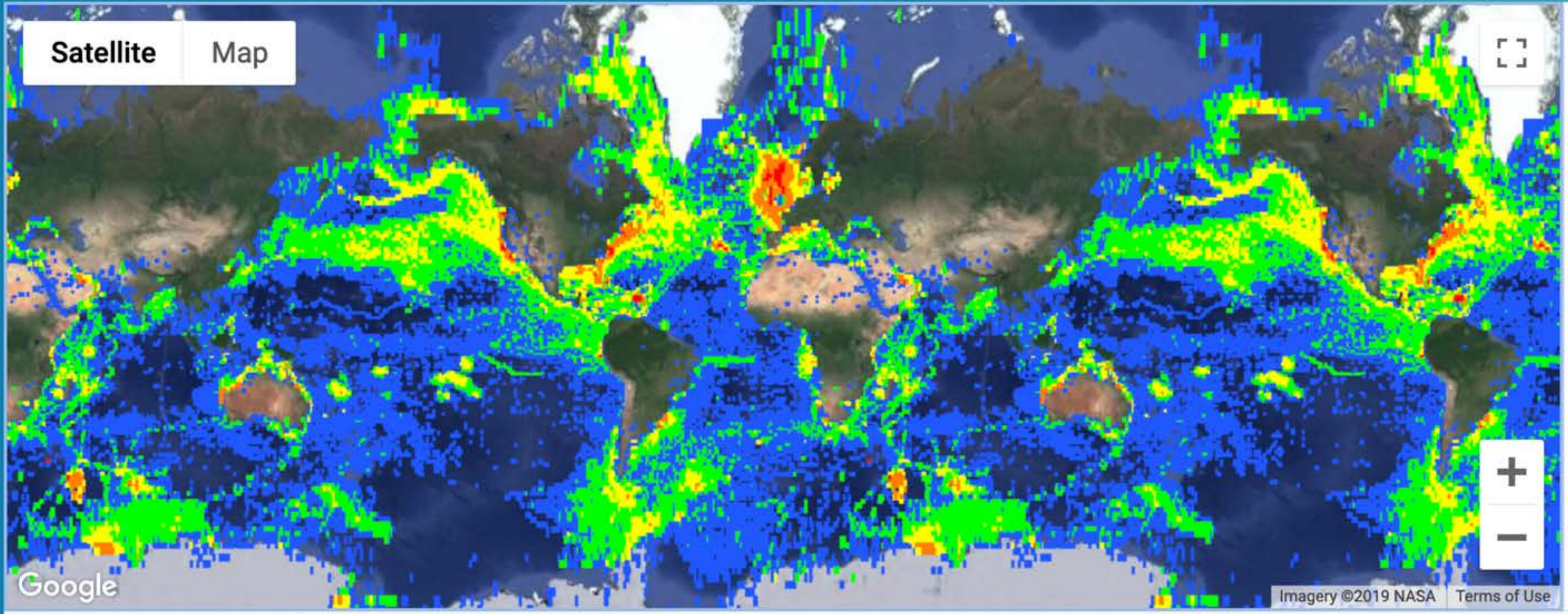


http://seamap.env.duke.edu

OBIS SEAMAP

Terms of Use Help Contact us Log in

Home | Contribute | Services | About



OBIS-SEAMAP, Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations, is a spatially referenced online database, aggregating marine mammal, seabird, sea turtle and ray & shark observation data from across the globe.

Map Summary
#records: 5,928,475
#datasets:1,096 #species:711 / 892

Visit Species or Dataset Page via Quick Search

Species/dataset/provider name or ITIS TSN/Da

Records by 1 ° cells
- 1-10
- 11-100
- 101-1,000
- 1,001-10,000
- >10,000

Explore more with Advanced Search

Browse Datasets | **Browse Contributors** | **Browse Species**

~6,000,000 migratory animal observations
> 1,000 datasets

Applications
- SERDP SDS
- SWOT The
- MABDC Pho
- CDOC Calif
- GoMDIS Gulf of Mexico Dolphin ID System (login required)
- Black Sea Cetaceans Photo ID Catalog
- PREDIS Pearl River Estuary Dolphin Identification System (login required)
- WIDECAST Wider Caribbean Sea Turtle Nesting Sites
- MWBD Marine Wildlife Behavior Database

Green Turtles

eb 20, 2019

- Zakynthos Nesting Turtles
  Judith Zbinden, Nov 06, 2018

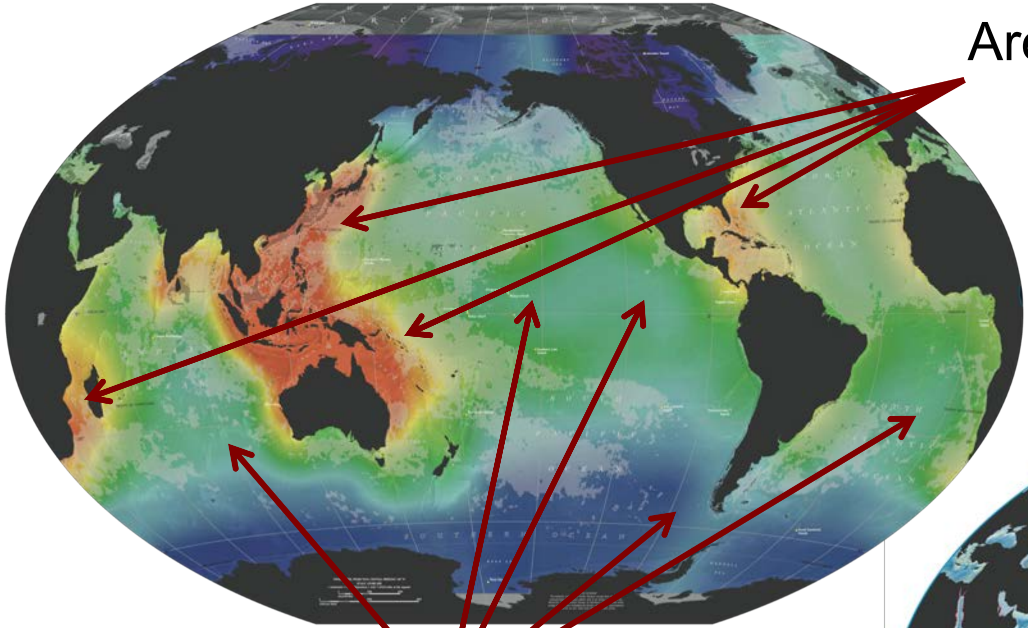
Improvements / Issues / Announcements
- Oceano data are unavailable, Feb 15, 2019
- Quicker download of SWOT site locations will be available soon, Jan 31, 2019
- Transfer of the STAT data from seaturtle.org is temporarily paused, Apr 19, 2018

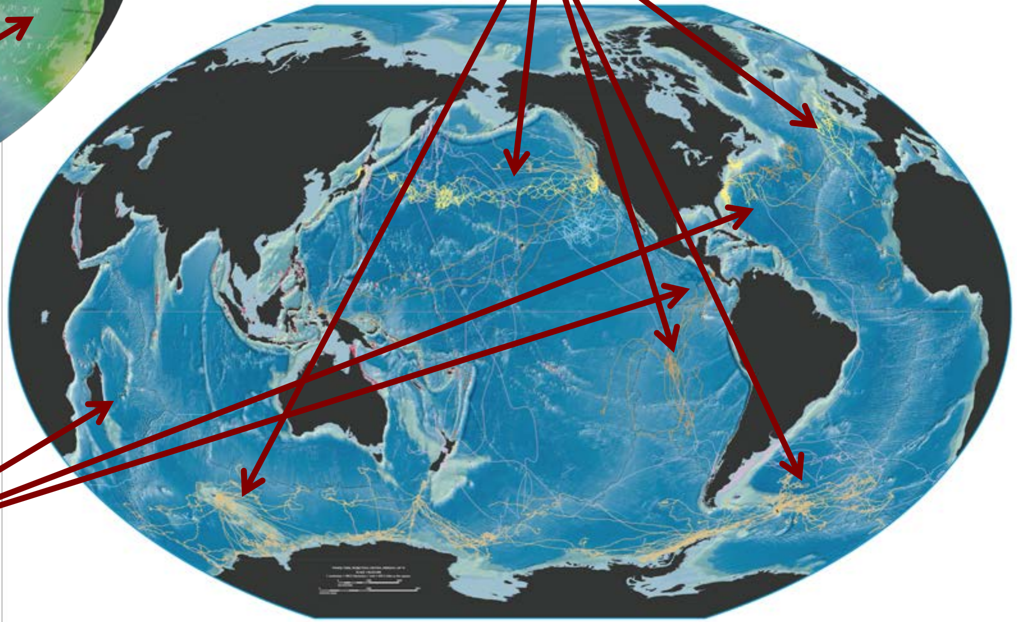
CBD criteria for ecologically or biologically significant areas (EBSAs) (annex I, decision IX/20)

1. Uniqueness or Rarity
2. Special importance for life history stages of species
3. Importance for threatened, endangered or declining species and/or habitats
4. Vulnerability, Fragility, Sensitivity, or Slow recovery
5. Biological Productivity
6. Biological Diversity
7. Naturalness

Convention on Biological Diversity

Criteria often related to migratory species





Areas of high biodiversity

Areas of special importance for the life history of a species

Areas of significant naturalness

Areas of uniqueness or rarity

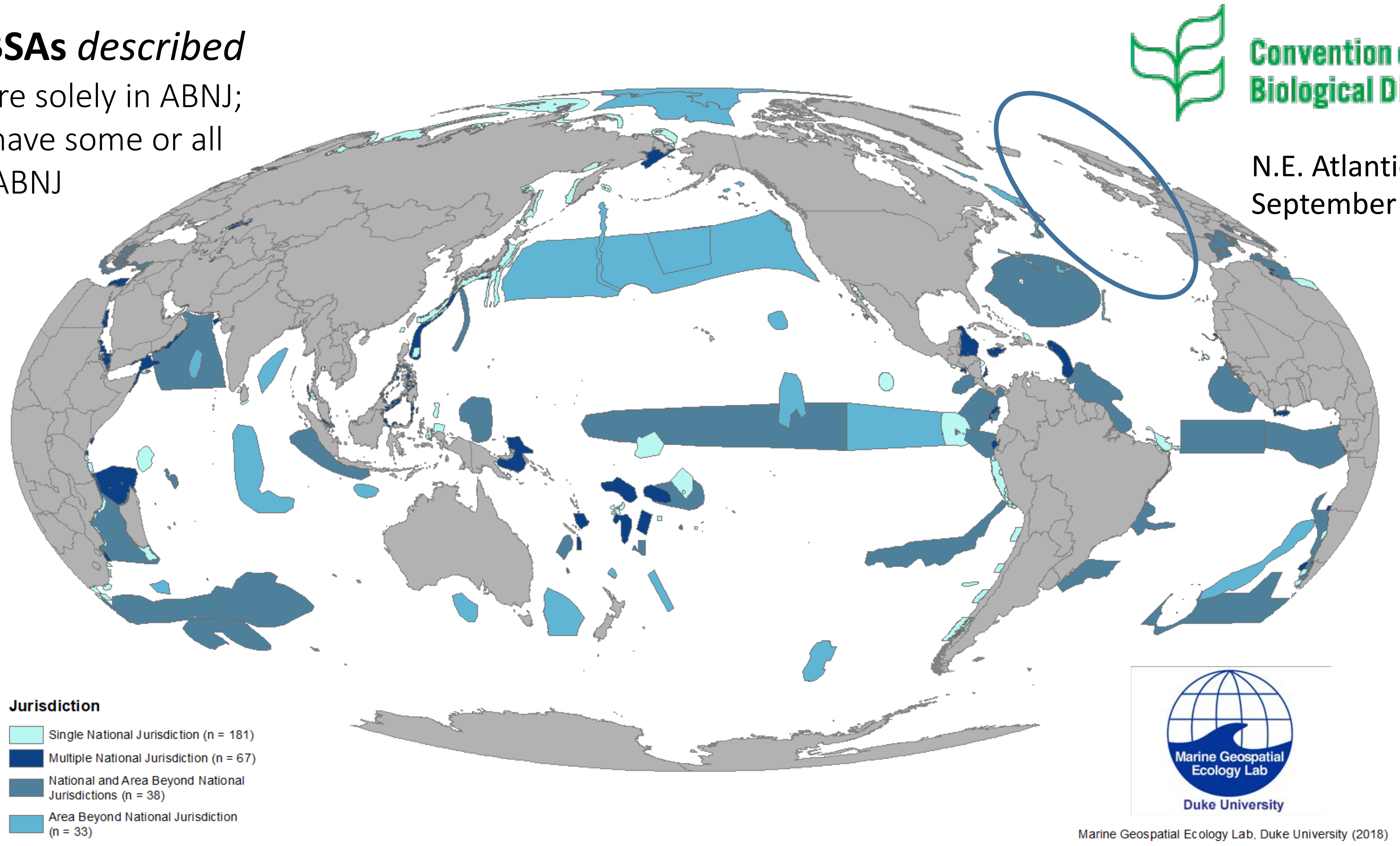
Current distribution of Ecologically or Biologically Significant Areas

321 EBSAs ***described***

10.3% are solely in ABNJ;
22.3% have some or all area in ABNJ

Convention on Biological Diversity

N.E. Atlantic
September 2019



Ecologically or Biologically Significant Marine Areas

Special places in the world's oceans

Search

HOME ABOUT EBSAs MEETINGS RESOURCES COLLABORATORS

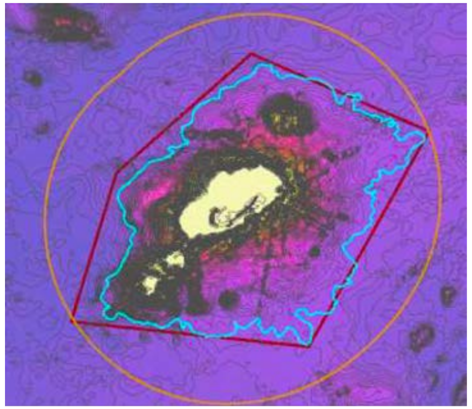
View Areas Meeting the EBSA Criteria

- All Regions
- Arctic
- Baltic Sea
- Black and Caspian Seas
- East Asian Seas
- Eastern Tropical and Temperate Pacific
- Mediterranean
- North Pacific
- North-East Indian Ocean
- North-west Atlantic
- North-West Indian Ocean and Adjacent Gulf Areas
- South-Eastern Atlantic
- Southern Indian Ocean
- Western South Pacific
- **Wider Caribbean and Western Mid-Atlantic**

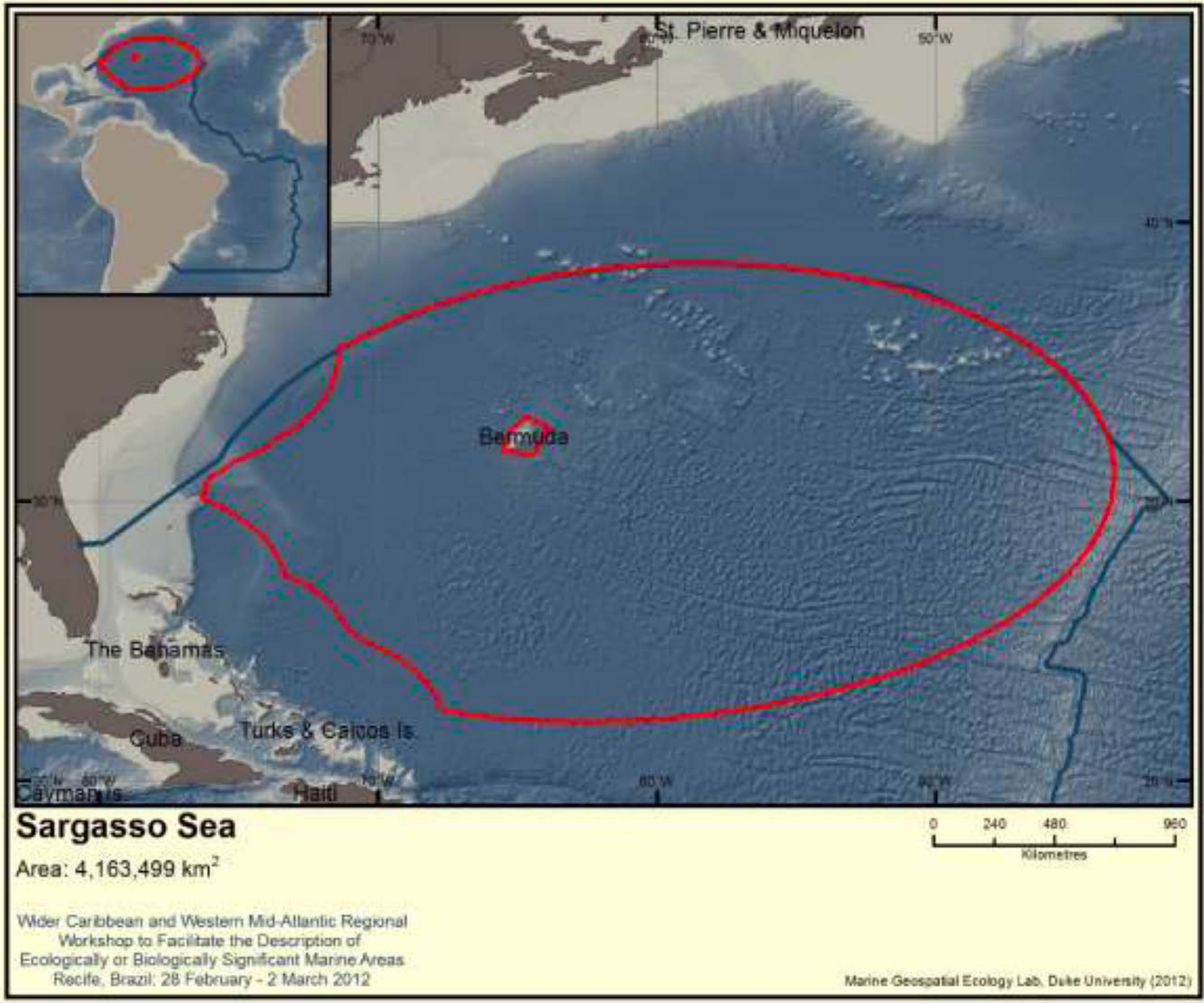
Convention on Biological Diversity

DISCLAIMER: The designations employed and the presentation of material in this map do not imply the expression of any opinion whatsoever on the part of the

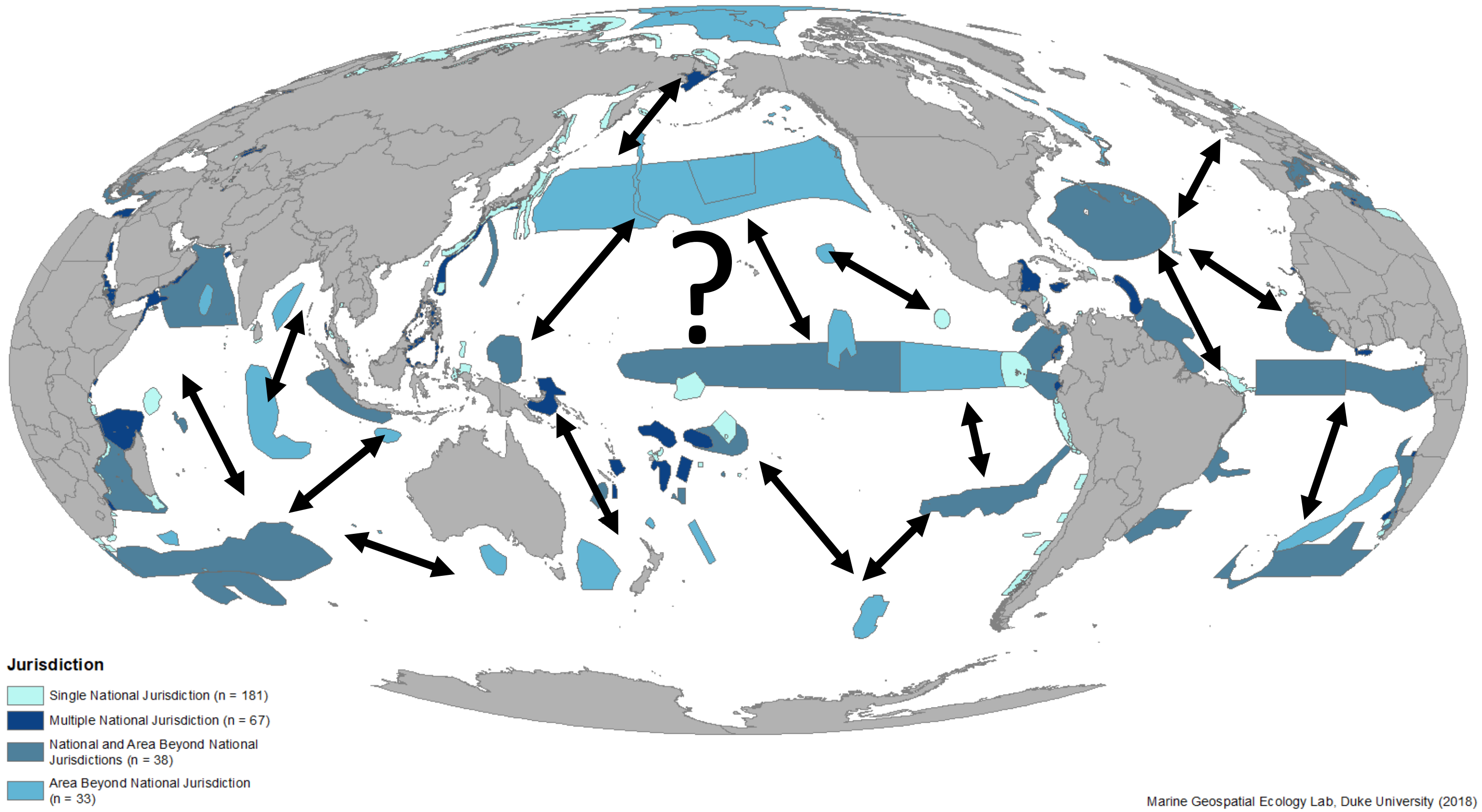
Sargasso Sea EBSA



Inner boundary of the Sargasso Sea area meeting EBSA criteria (red polygon). This was a simplification of the 4350 isobath (light blue) at the base of the rise to the Bermuda Platform. Previously a 50 nm buffer around Bermuda had been used as a provisional inner boundary (orange).

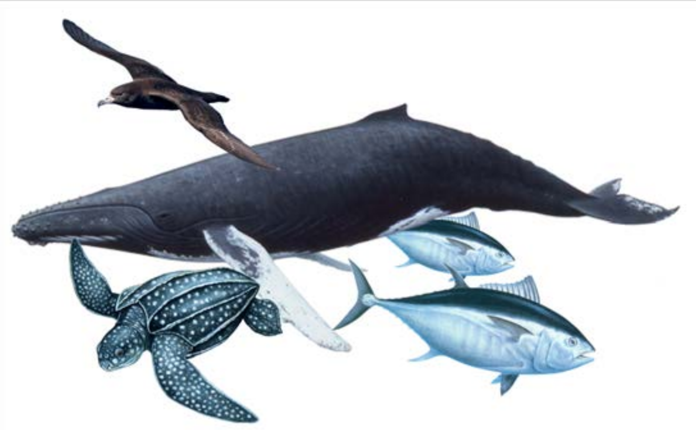


The EBSA process describe ecologically important areas but we need a robust network of of ecologically important area ***nodes*** and the ***corridors*** that connect them



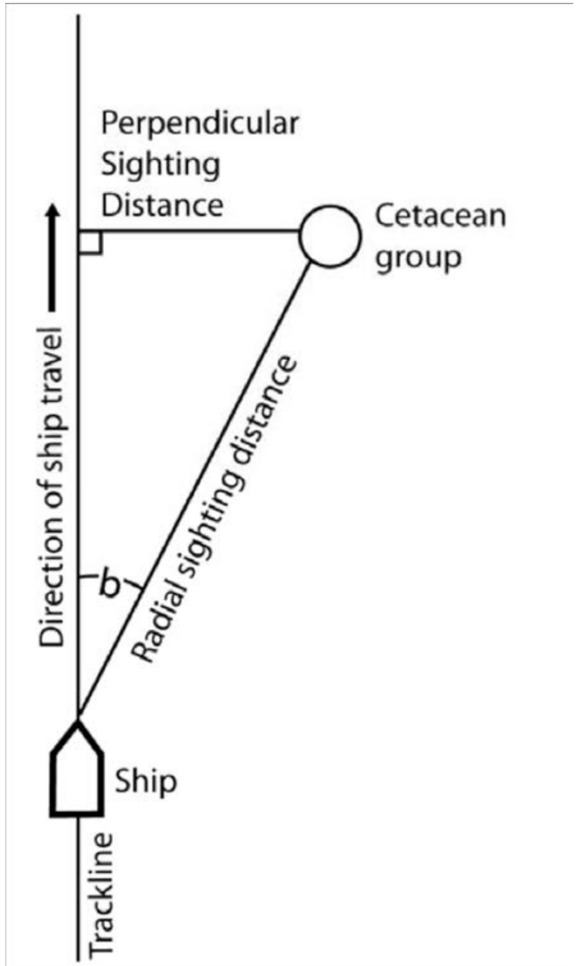
Topics

- Introduction
- Analyzing destinations and corridors
- MiCO – Migratory Connectivity of the Ocean
- Synthesis & future trends

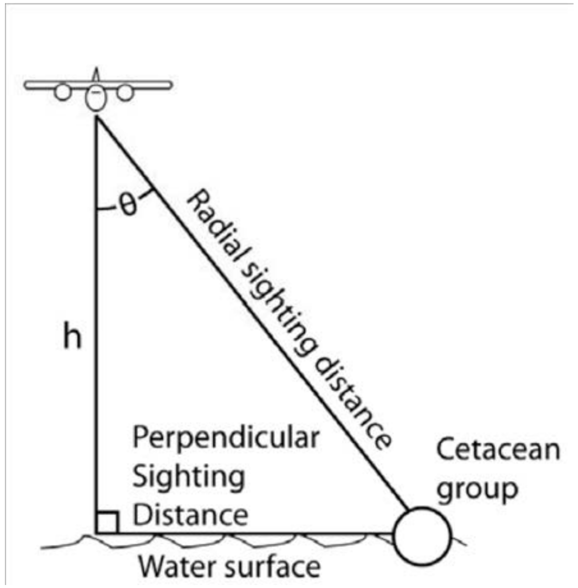


So how do we model the abundance and density of marine animals?

Forecasting Process

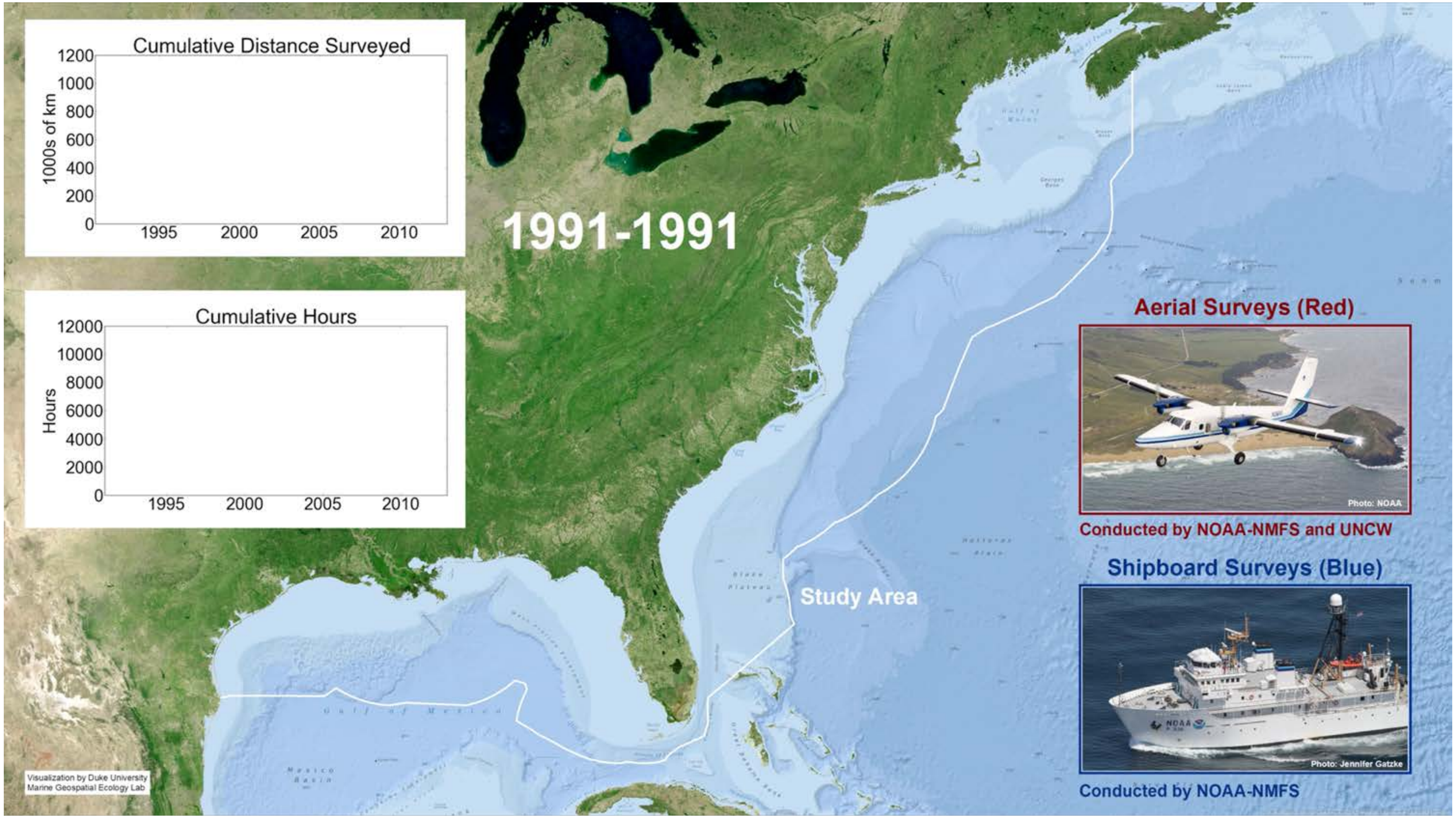


http://nefsc.noaa.gov



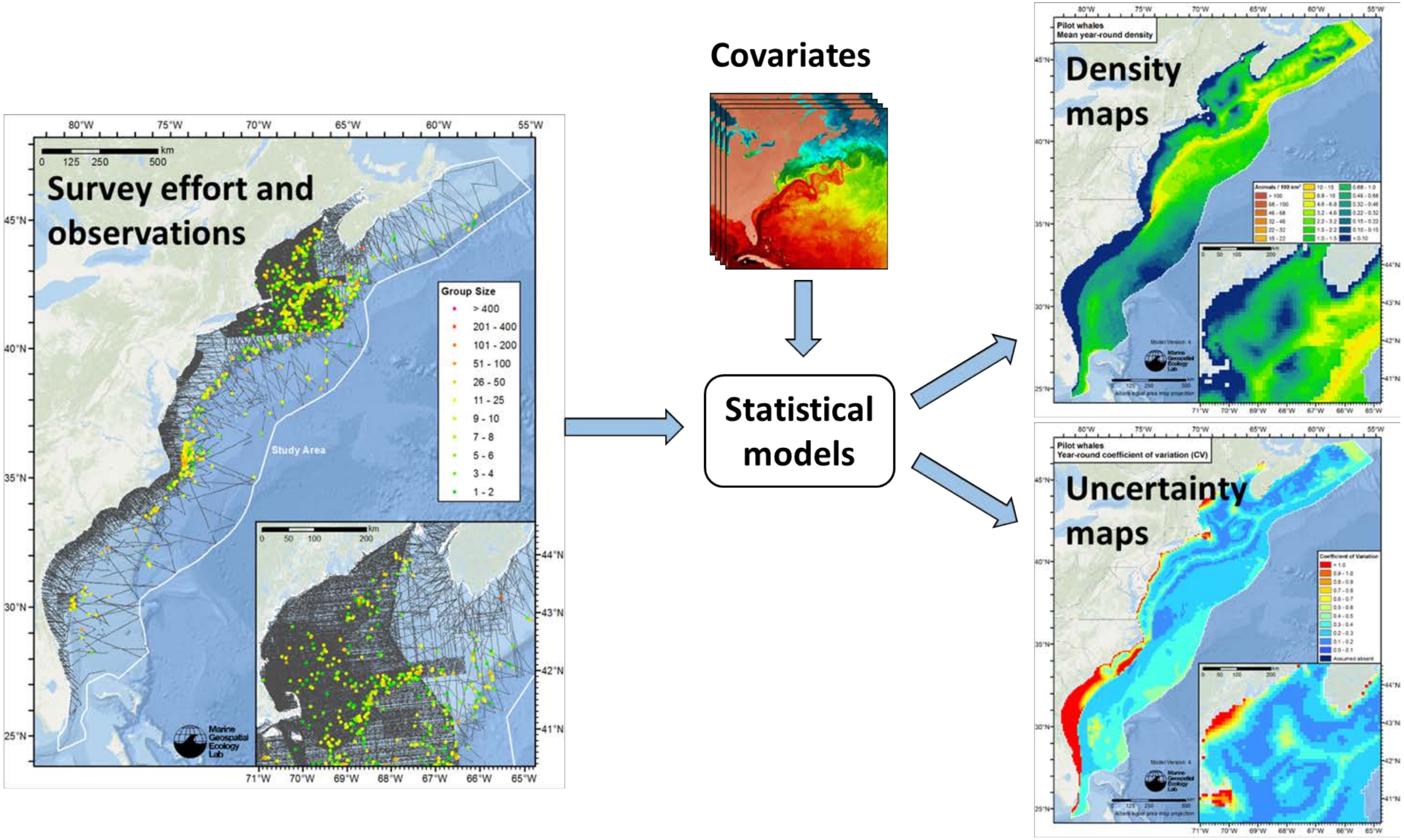
Marine mammal aggregation data overview

Marine Geospatial Ecology Lab
Duke University



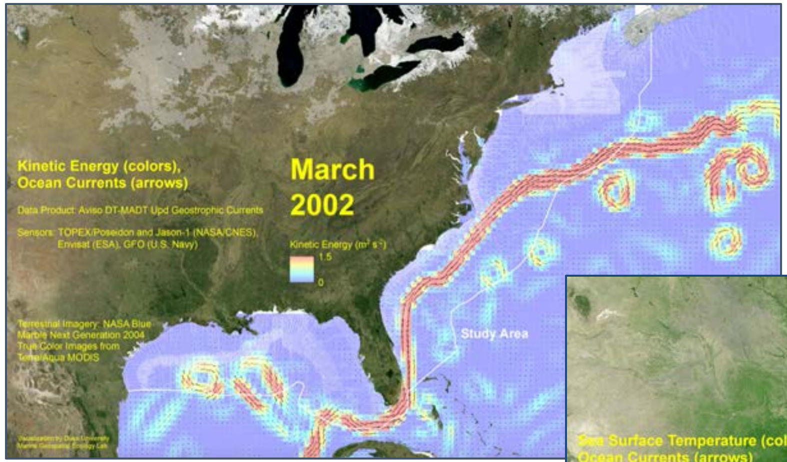

Detection probability
?
How many animals are also underwater?
Photo: Scott and Mary Flanders

Abundance & density surface modeling



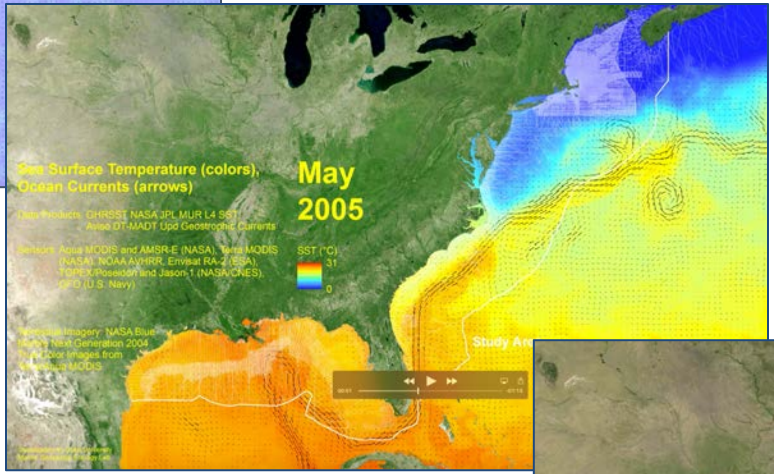
dynamic oceanographic predictor variables

currents, eddys & kinetic energy

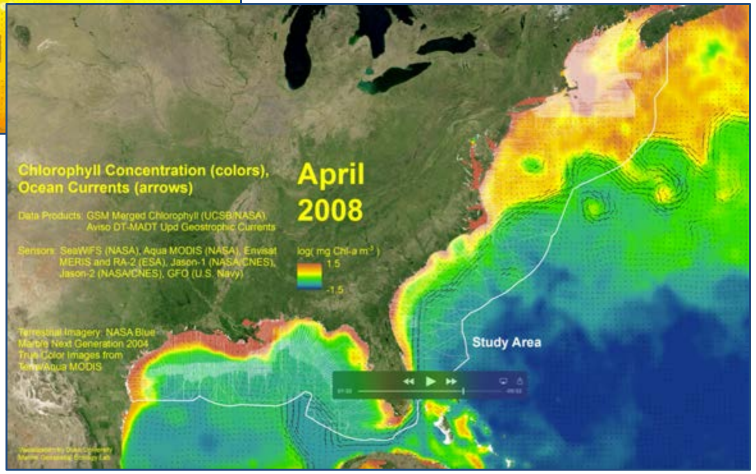


The challenge is modeling species distributions at relevant time scales that capture seasonal migratory behaviors

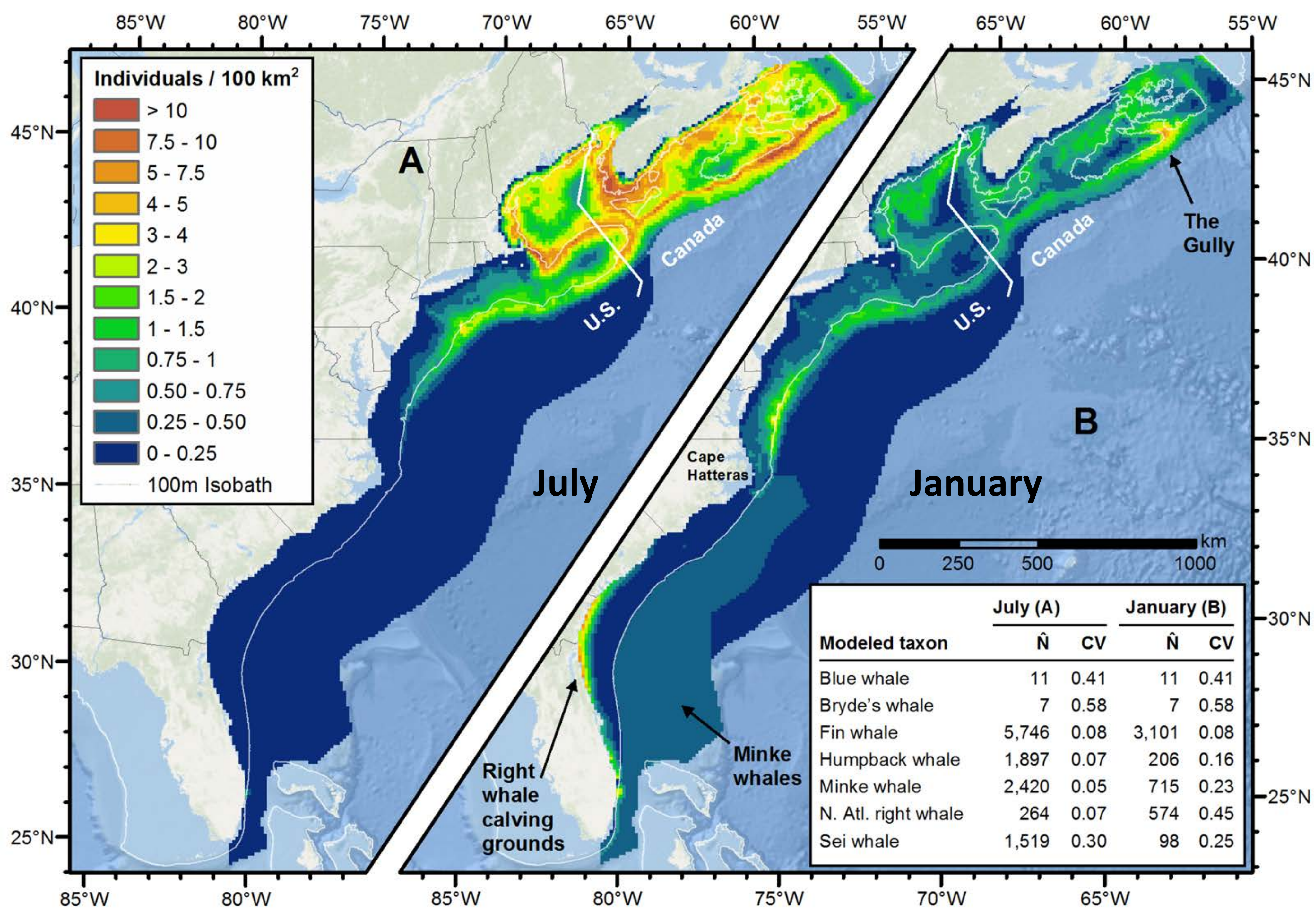
sea surface temperature



chlorophyll a

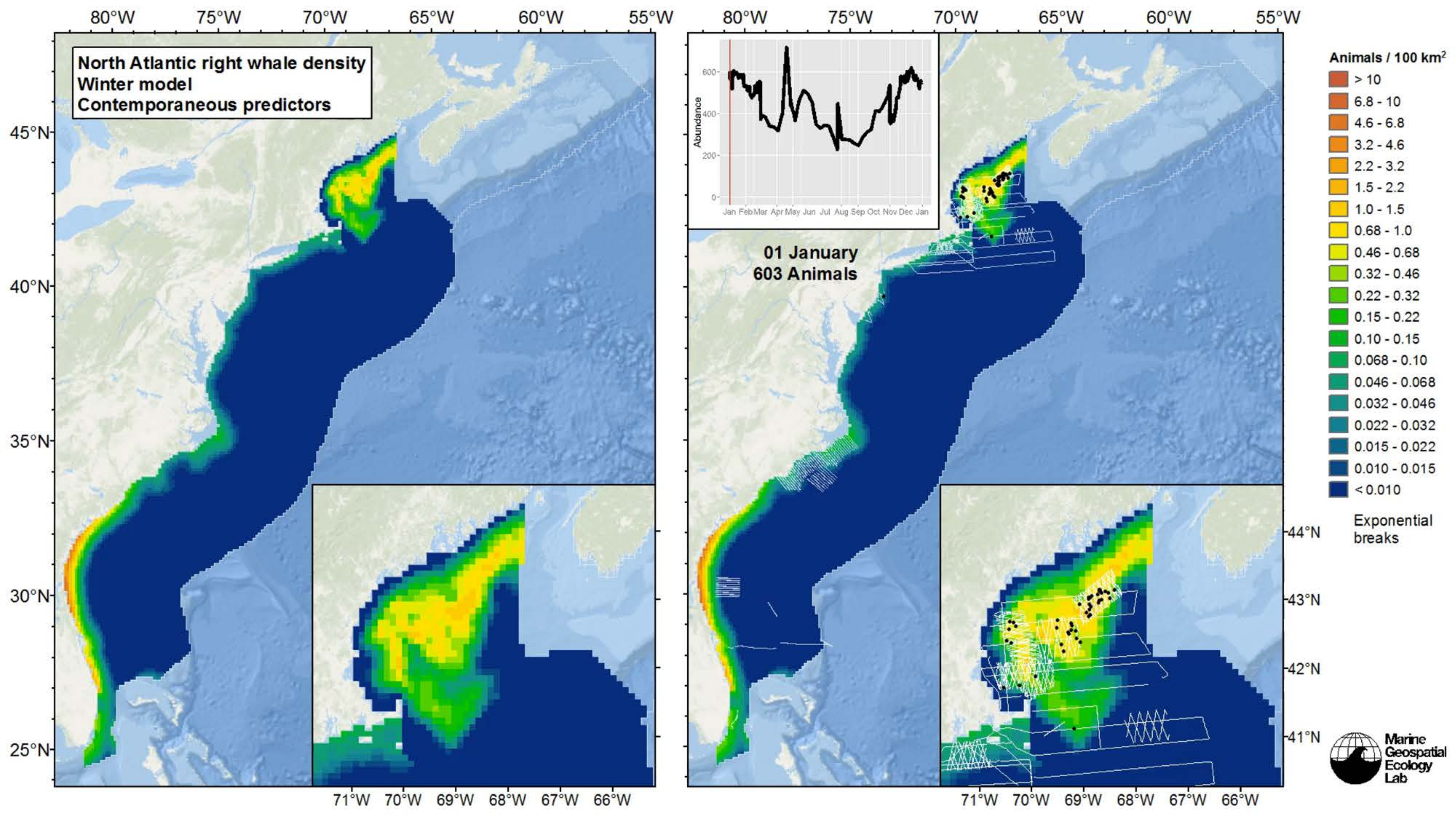


Aggregate density of baleen whales



Modeled taxon	July (A) N̂	July (A) CV	January (B) N̂	January (B) CV
Blue whale	11	0.41	11	0.41
Bryde's whale	7	0.58	7	0.58
Fin whale	5,746	0.08	3,101	0.08
Humpback whale	1,897	0.07	206	0.16
Minke whale	2,420	0.05	715	0.23
N. Atl. right whale	264	0.07	574	0.45
Sei whale	1,519	0.30	98	0.25

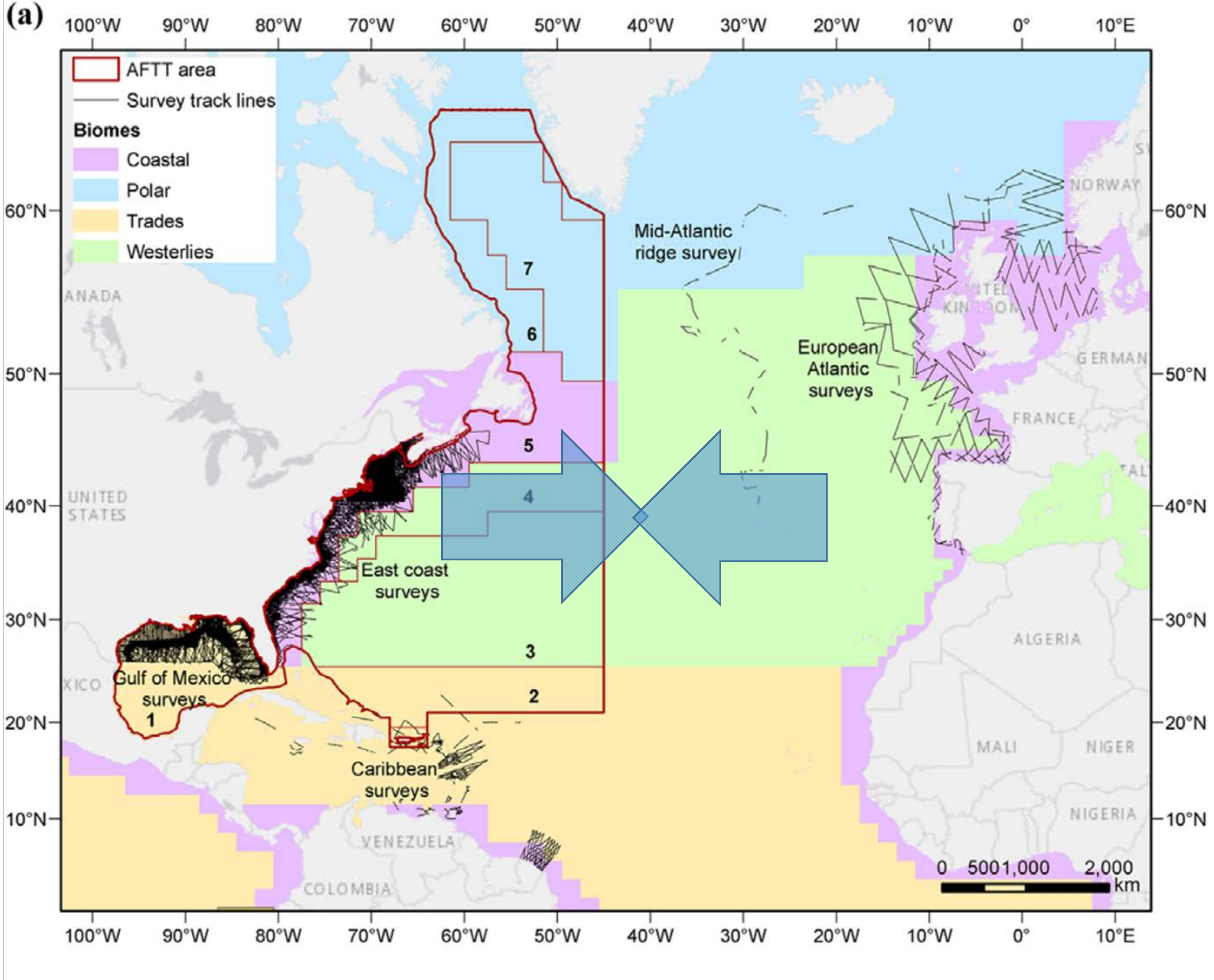
Roberts et al. (2016)


North Atlantic right whale density
Winter model
Contemporaneous predictors
01 January
603 Animals
Abundance
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Animals / 100 km²
> 10
6.8 - 10
4.6 - 6.8
3.2 - 4.6
2.2 - 3.2
1.5 - 2.2
1.0 - 1.5
0.68 - 1.0
0.46 - 0.68
0.32 - 0.46
0.22 - 0.32
0.15 - 0.22
0.10 - 0.15
0.068 - 0.10
0.046 - 0.068
0.032 - 0.046
0.022 - 0.032
0.015 - 0.022
0.010 - 0.015
< 0.010
Exponential breaks
Marine Geospatial Ecology Lab

Modeling animal abundance

We are working towards an North Atlantic Basin scale modeling domain

This is forcing us to extrapolate beyond the environmental range of existing observation data

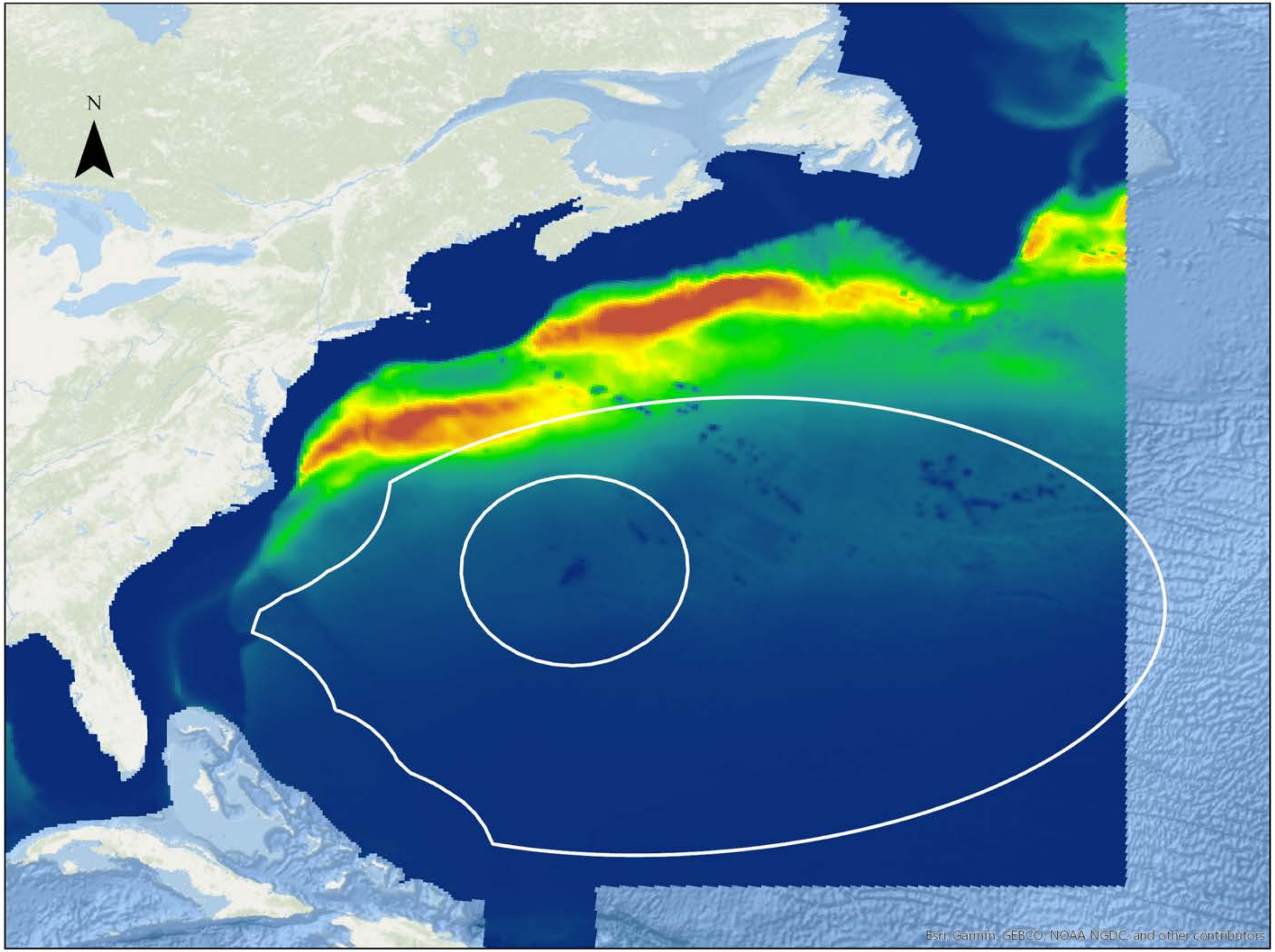


Mannocci et al 2017

Striped dolphin

Annual model

Mannocci et al 2017

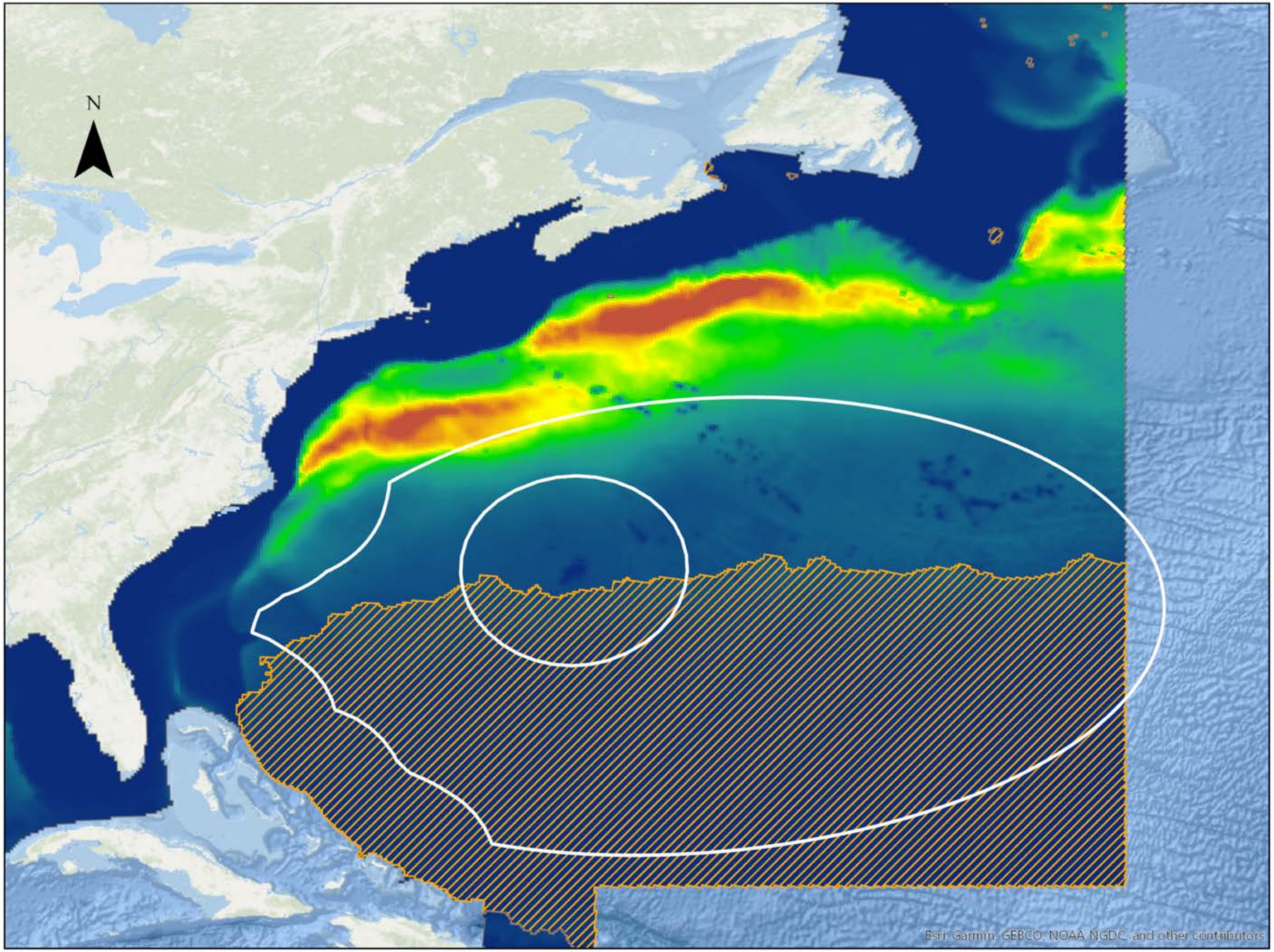


Striped dolphin

Annual model

Hatched area is extrapolated beyond the environmental range of existing observation data

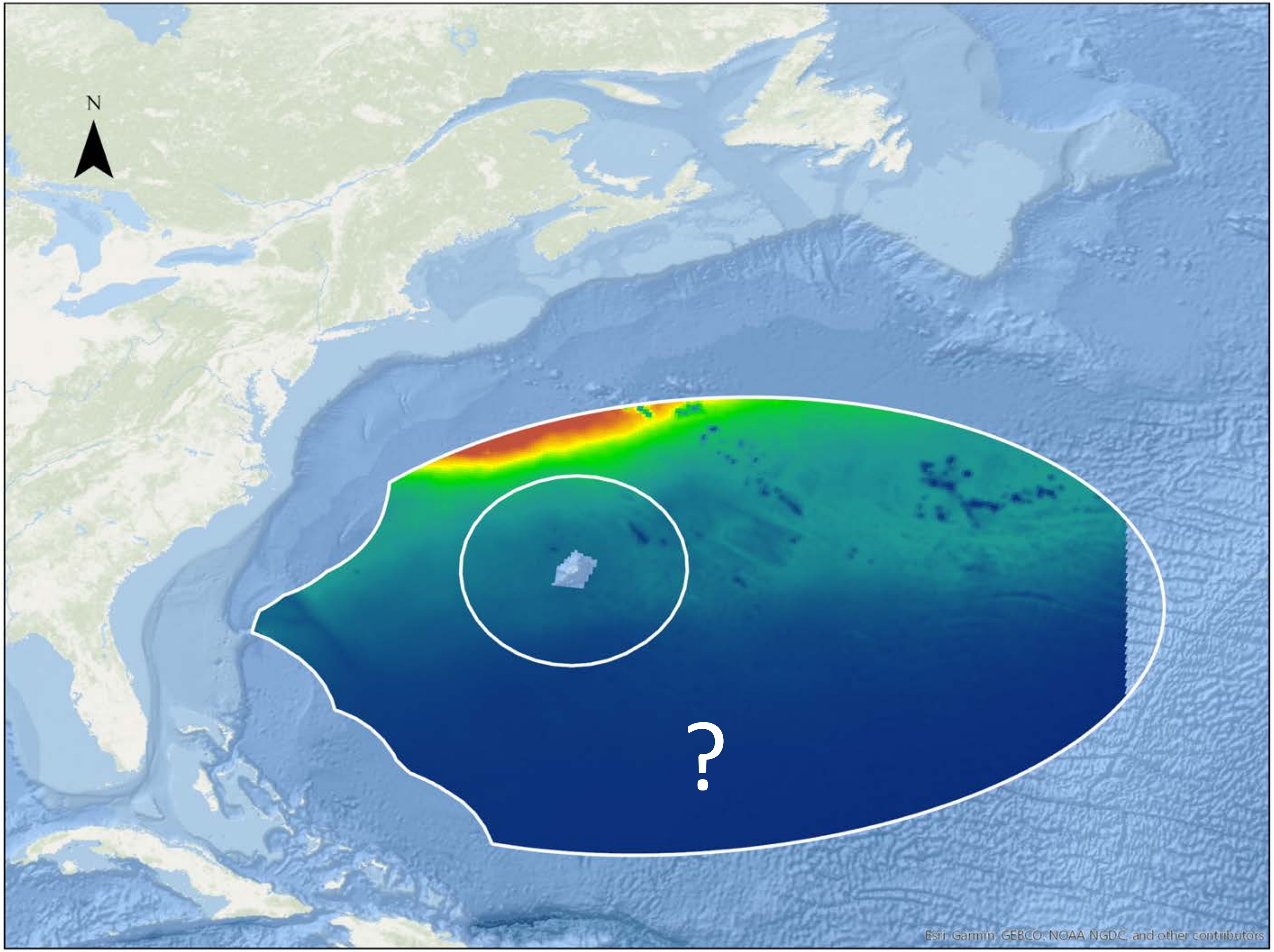
Mannocci et al 2017



Striped dolphin

Annual model

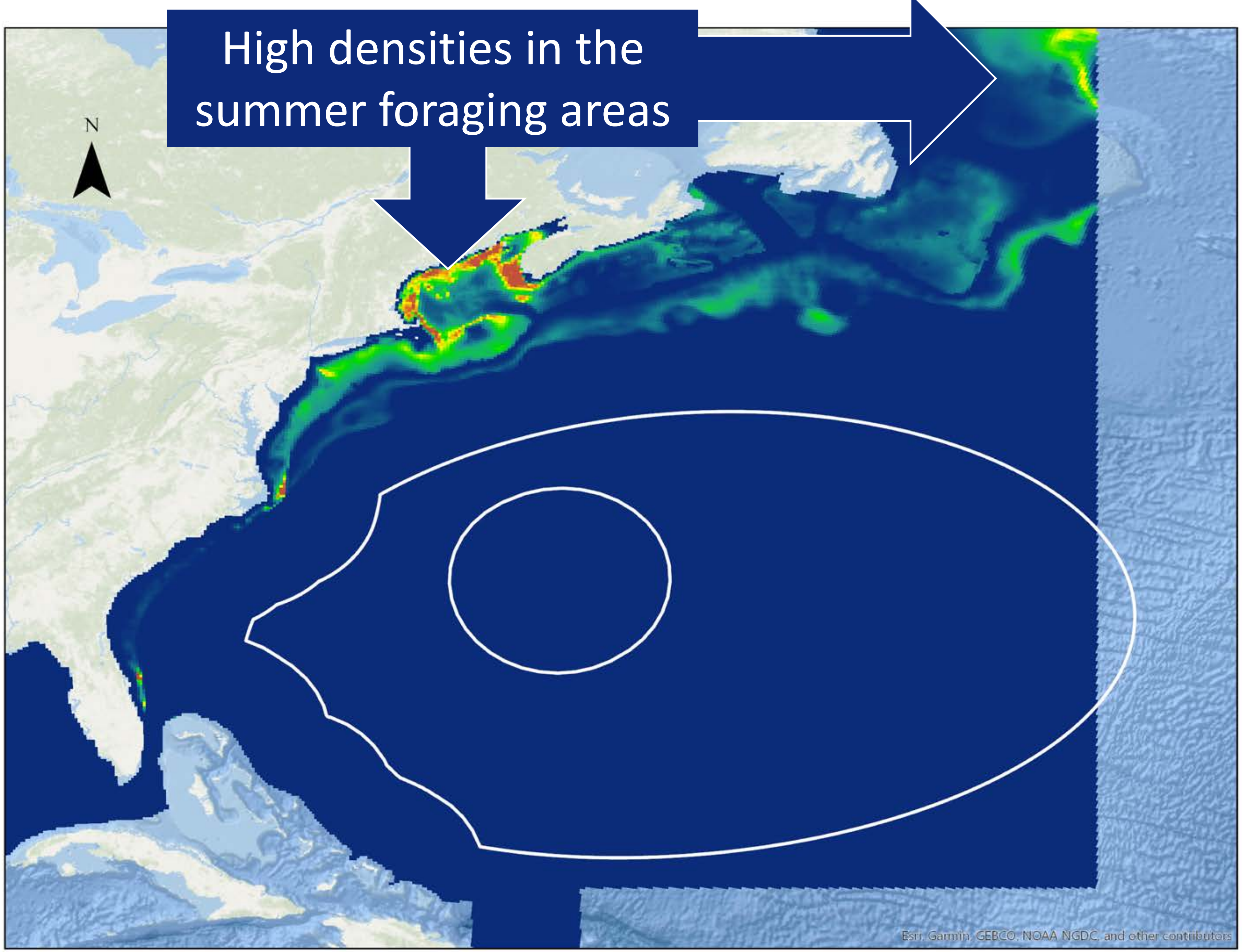
Mannocci et al 2017



Humpback Whale

summer season model

Mannocci et al 2017

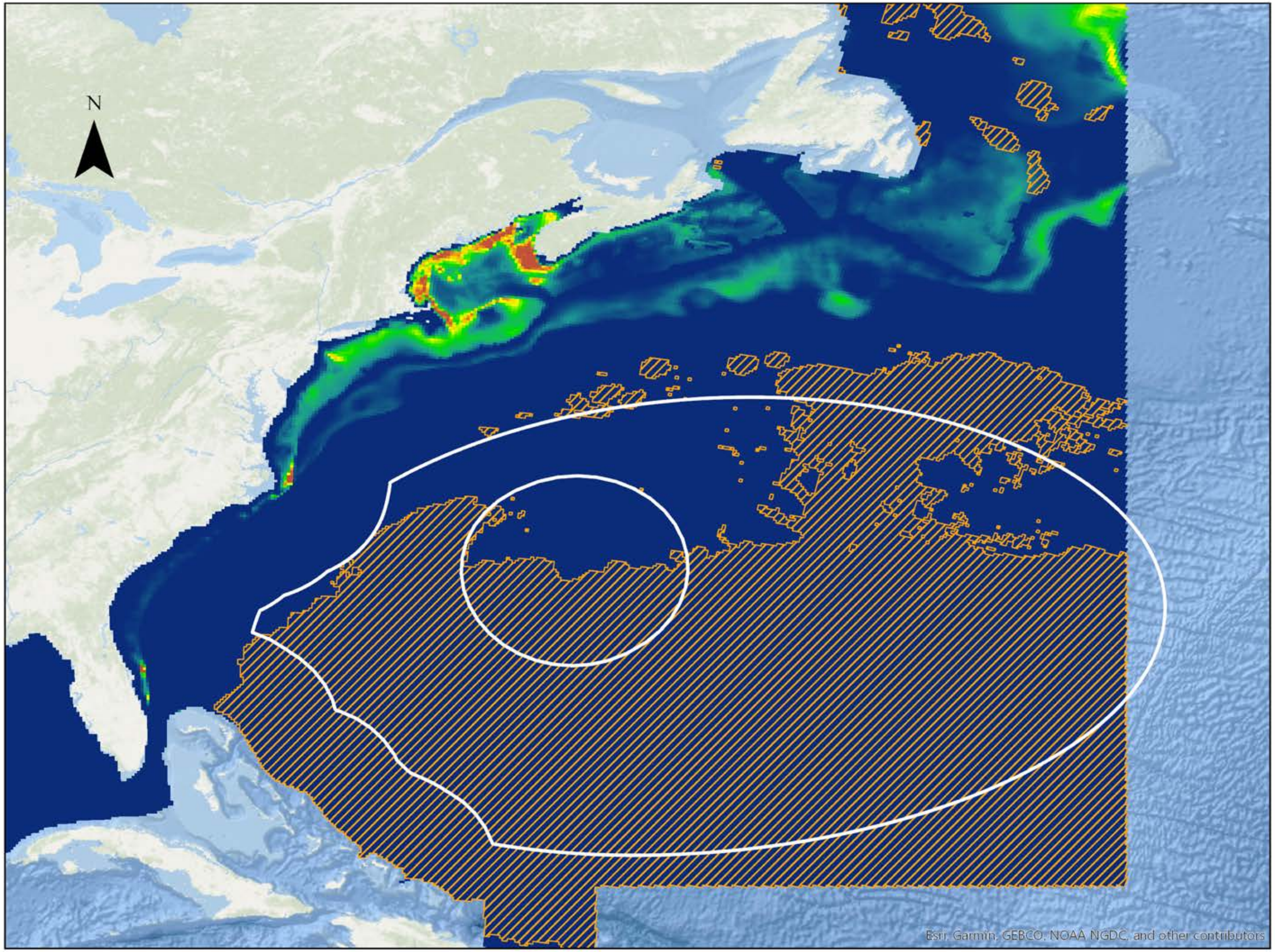


Humbpack Whale

summer season model

Hatched area is extrapolated beyond the environmental range of existing observation data

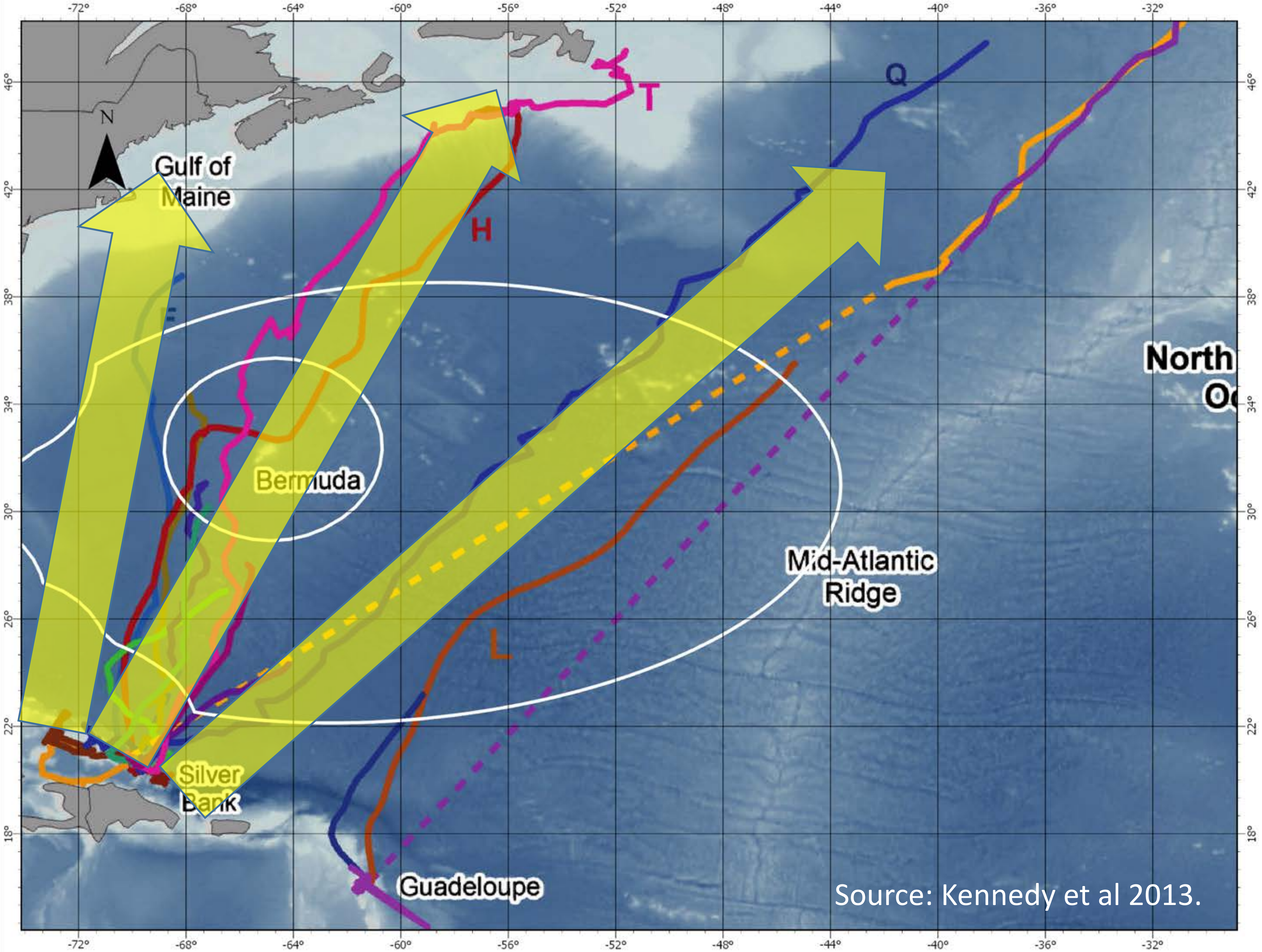
Mannocci et al 2017



Humpback Whale

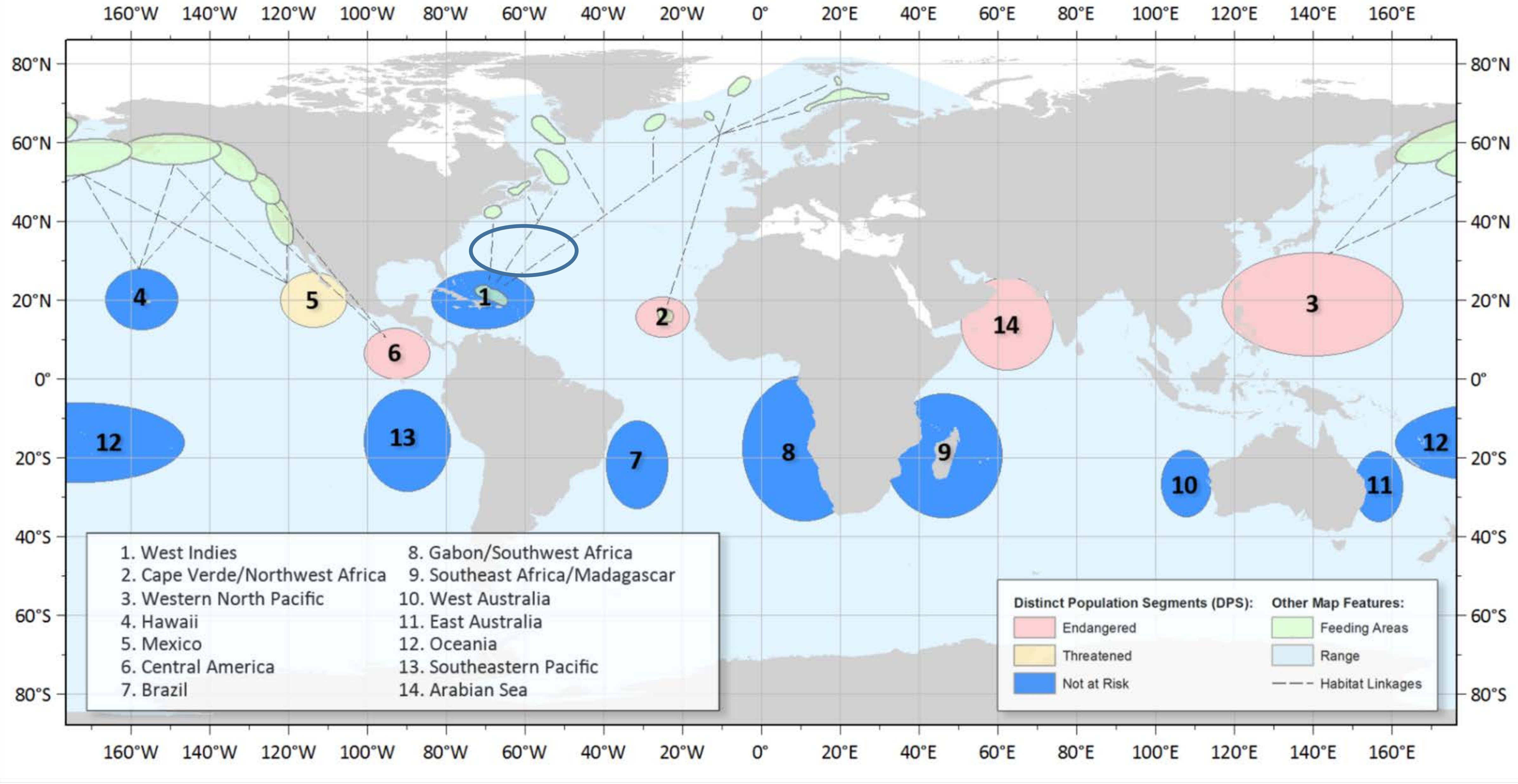
telemetry tracking

Satellite telemetry tracking indicates that humpback whale travel through the Sargasso Sea region in route to seasonal foraging areas



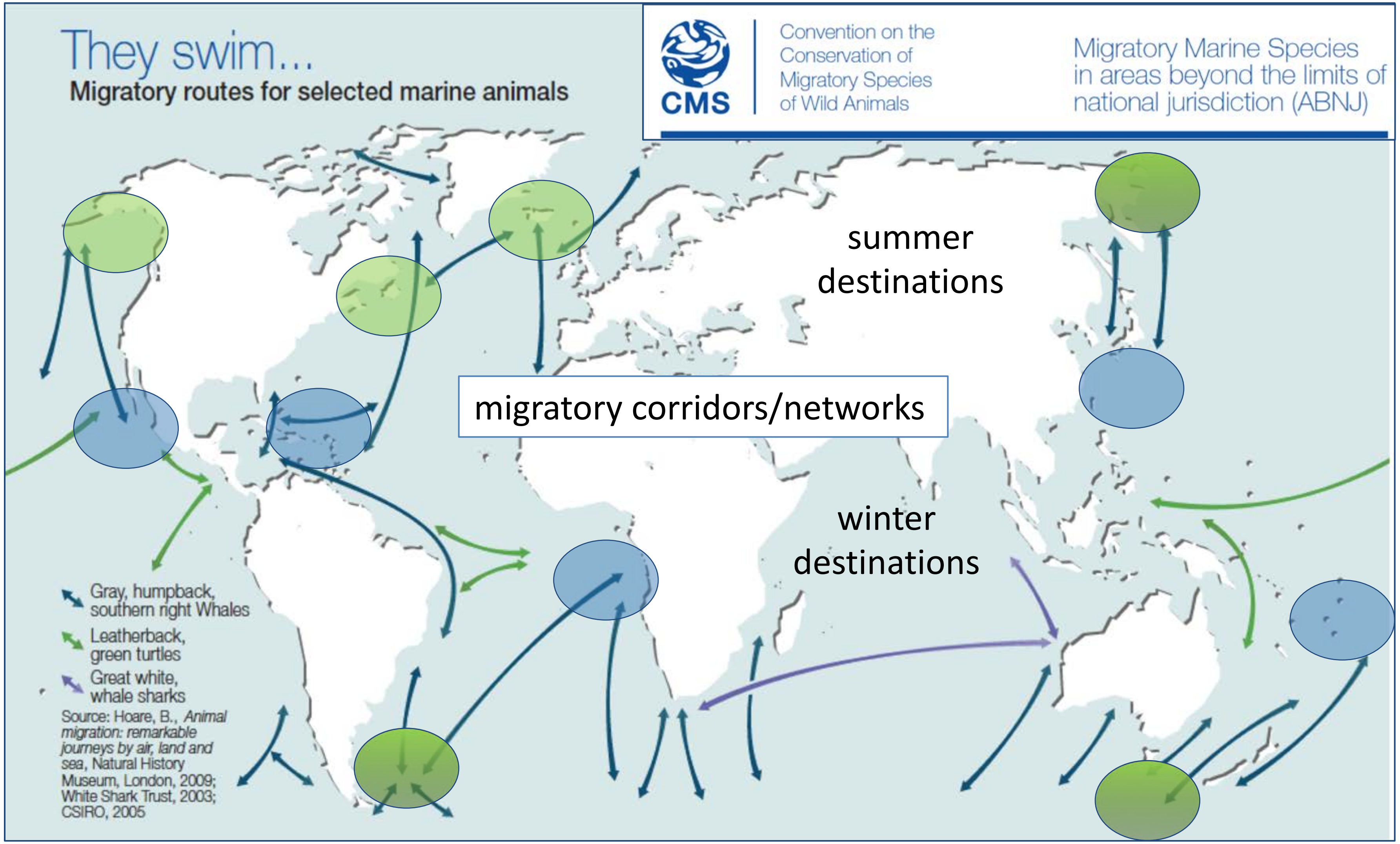
Source: Kennedy et al 2013.

Humpback whale populations



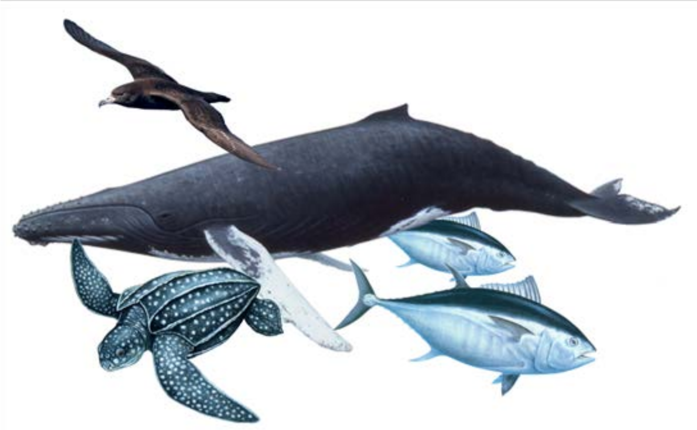
Source: NOAA/NMFS

We may have **observation data** and **environmental relationships** to model destinations… but often not for migratory corridors

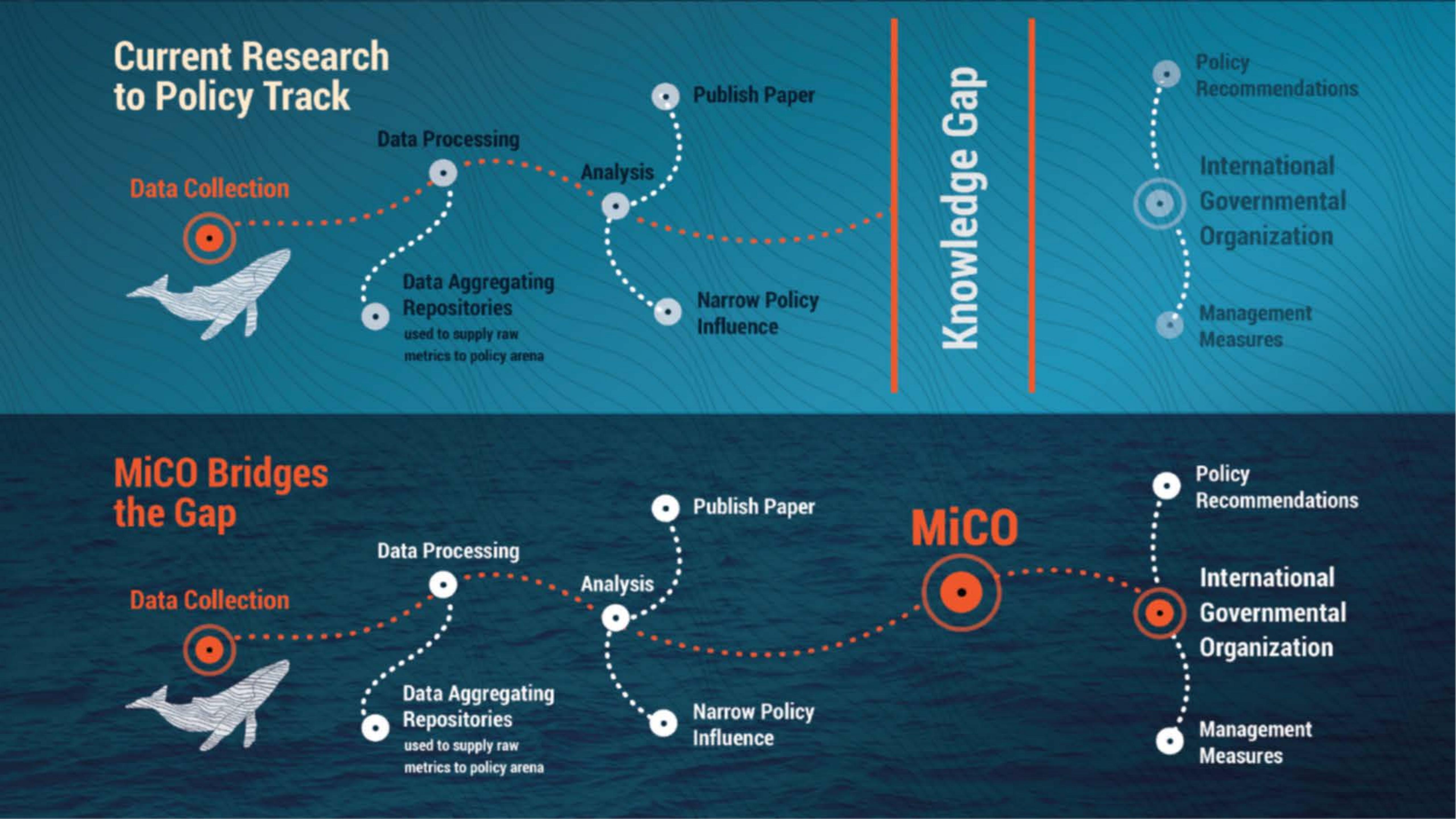


Topics

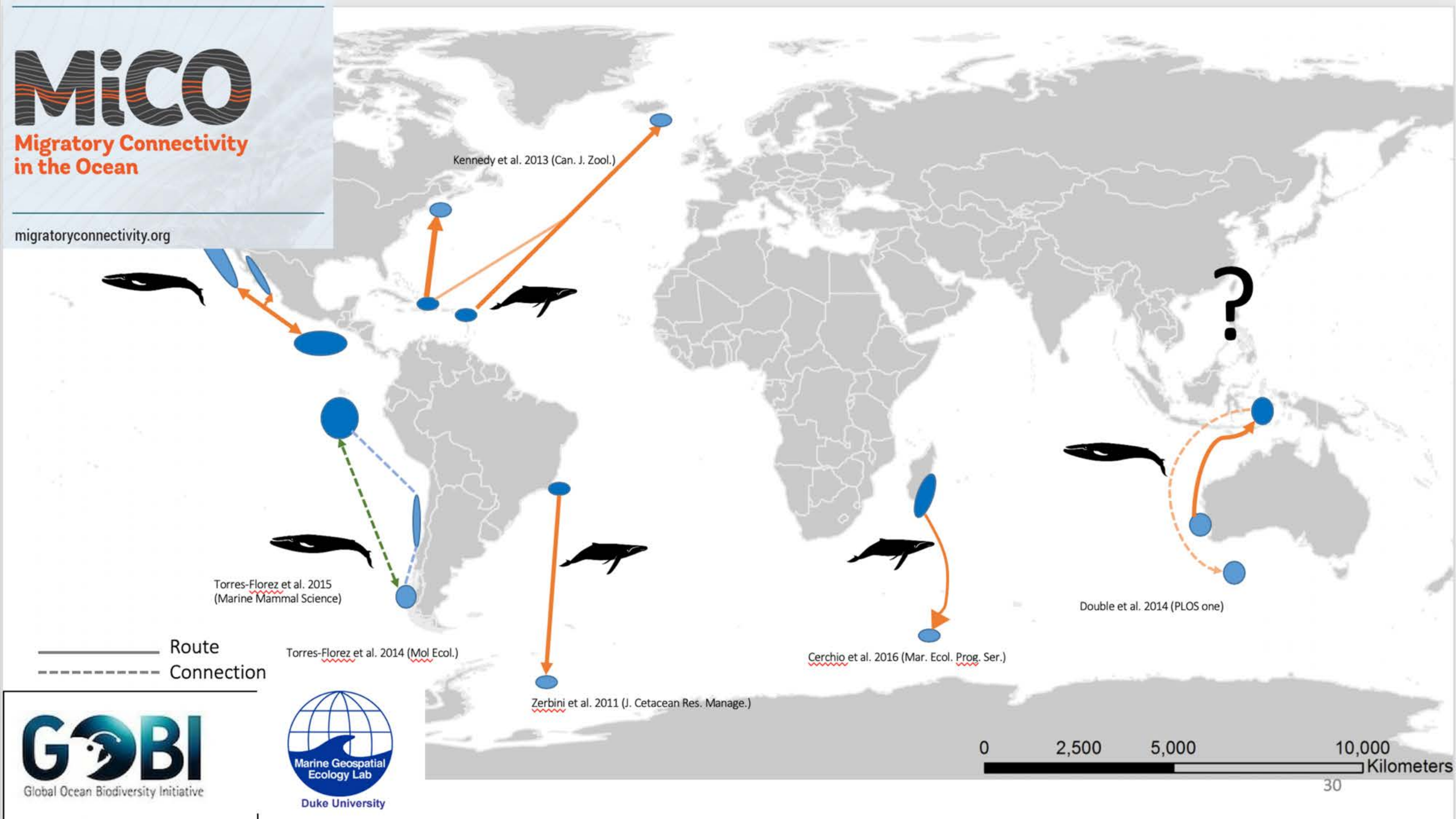
- Introduction
- Analyzing destinations and corridors
- MiCO – Migratory Connectivity of the Ocean
- Synthesis & future trends



http://mico.eco



Current Research to Policy Track
Data Collection
Data Processing
Data Aggregating Repositories
used to supply raw metrics to policy arena
Analysis
Publish Paper
Narrow Policy Influence
Knowledge Gap
Policy Recommendations
International Governmental Organization
Management Measures
MiCO Bridges the Gap
Data Collection
Data Processing
Data Aggregating Repositories
used to supply raw metrics to policy arena
Analysis
Publish Paper
Narrow Policy Influence
MiCO
Policy Recommendations
International Governmental Organization
Management Measures



MiCO
Migratory Connectivity in the Ocean
migratoryconnectivity.org
Kennedy et al. 2013 (Can. J. Zool.)
?
Torres-Florez et al. 2015 (Marine Mammal Science)
Torres-Florez et al. 2014 (Mol Ecol.)
Zerbini et al. 2011 (J. Cetacean Res. Manage.)
Cerchio et al. 2016 (Mar. Ecol. Prog. Ser.)
Double et al. 2014 (PLOS one)
Route
Connection
0
2,500
5,000
10,000
Kilometers
GOBI
Global Ocean Biodiversity Initiative
Marine Geospatial Ecology Lab
Duke University

Scaling up Data to Knowledge

DATA

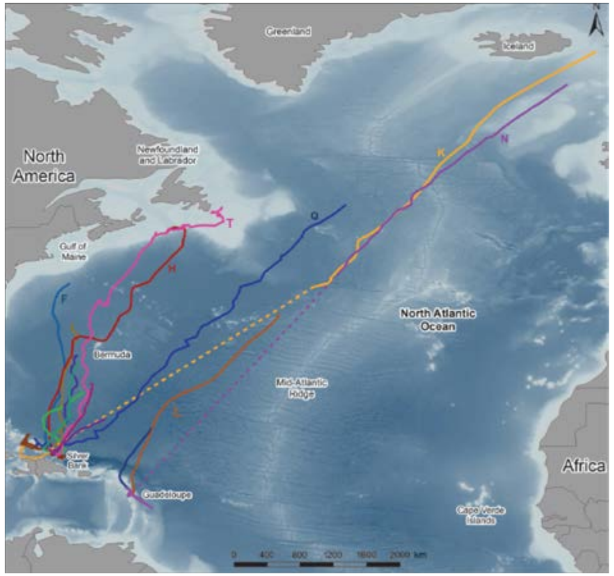
- Sites
- Routes

ANALYSIS

KNOWLEDGE

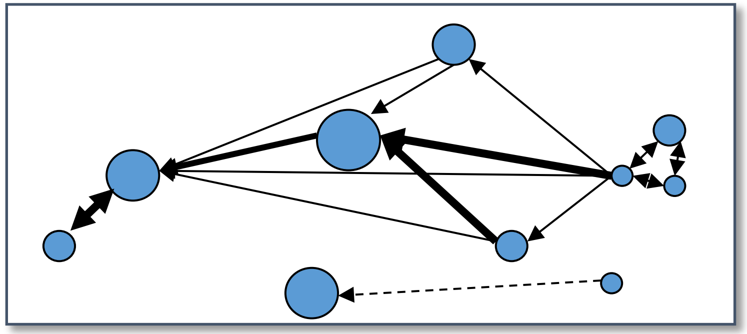
- Nodes
- Corridors

“Raw” observations,
Geographic representation



Kennedy *et al.* (2014) Can. J. Zool

Interpreted patterns,
Functional representation



Communicating Knowledge with New Tools

KNOWLEDGE

- Nodes
- Corridors

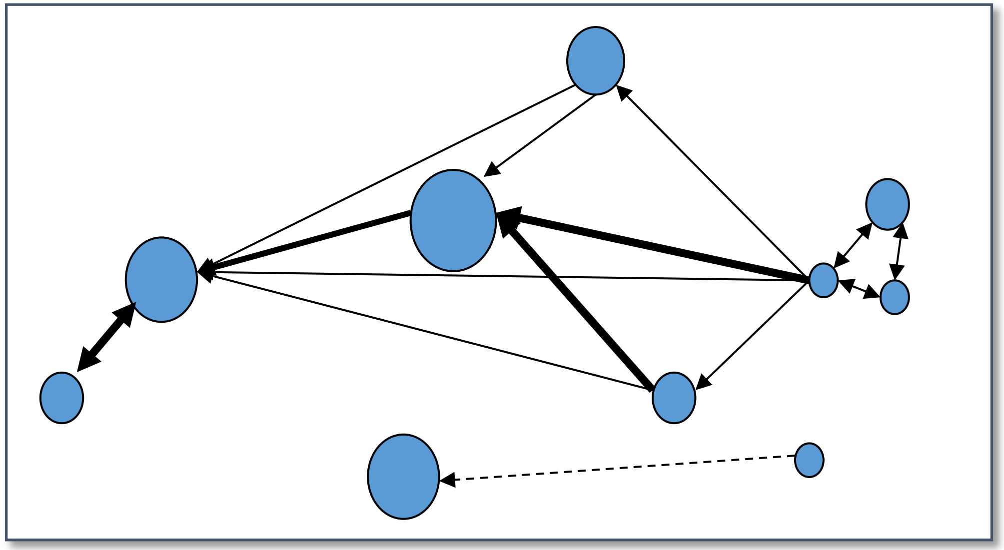
RESULTS

FRAMEWORK to assess

to explain:

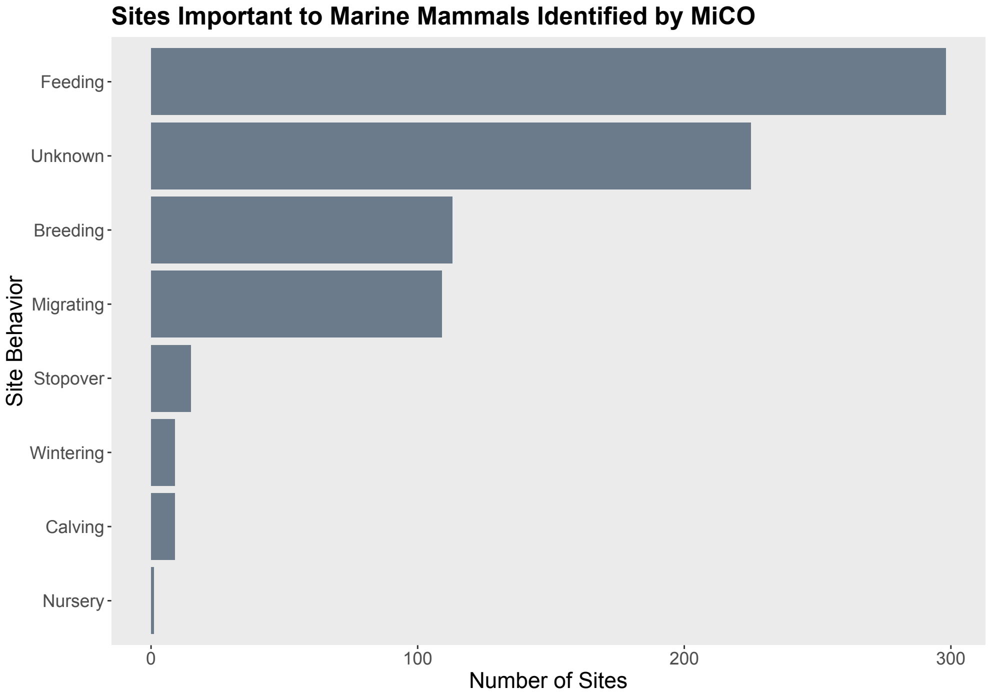
- Function
- Relative importance
- Interconnections
- Alternative pathways

Interpreted patterns,
Functional representation

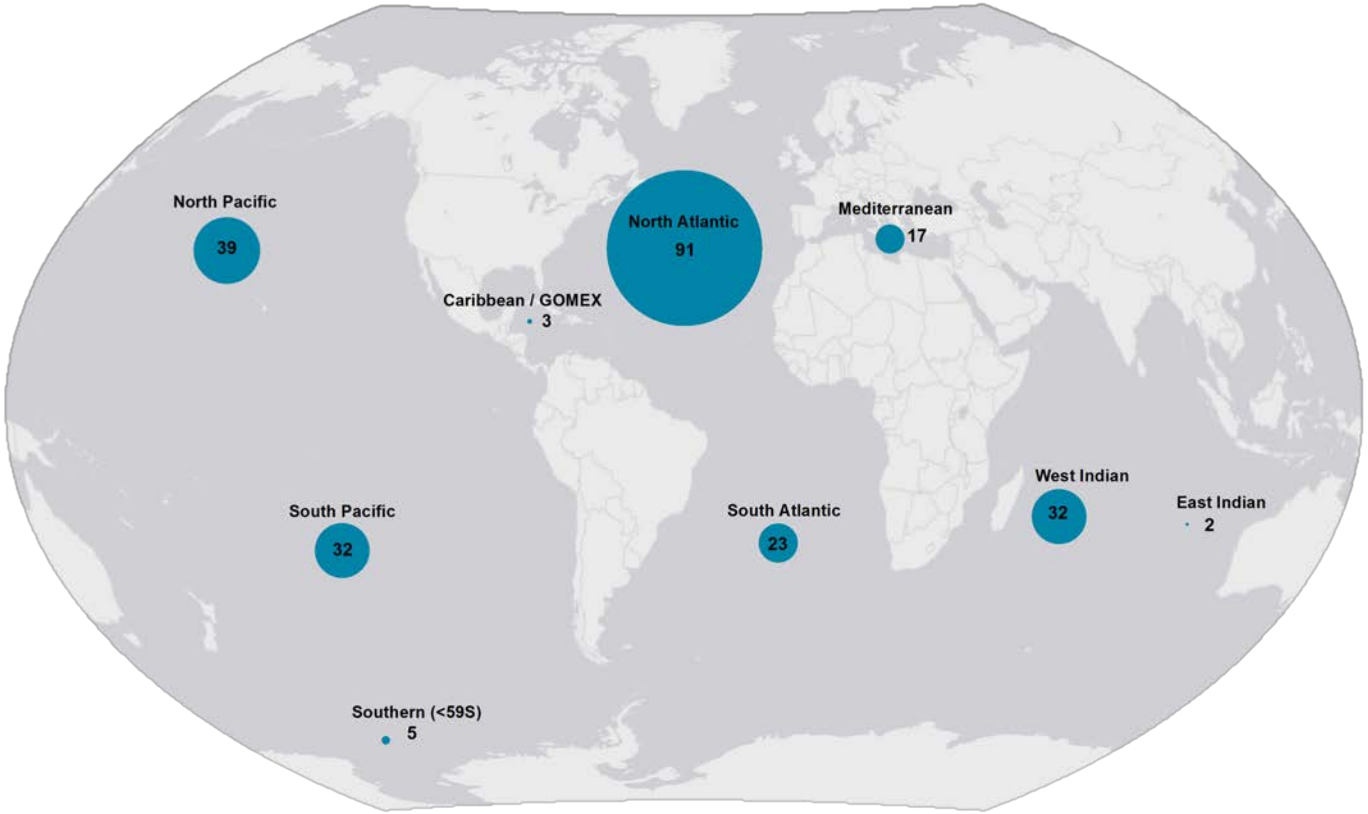


MiCO is a knowledge aggregation project

marine mammal
sites & corridors



779 MARINE MAMMAL SITES TO DATE

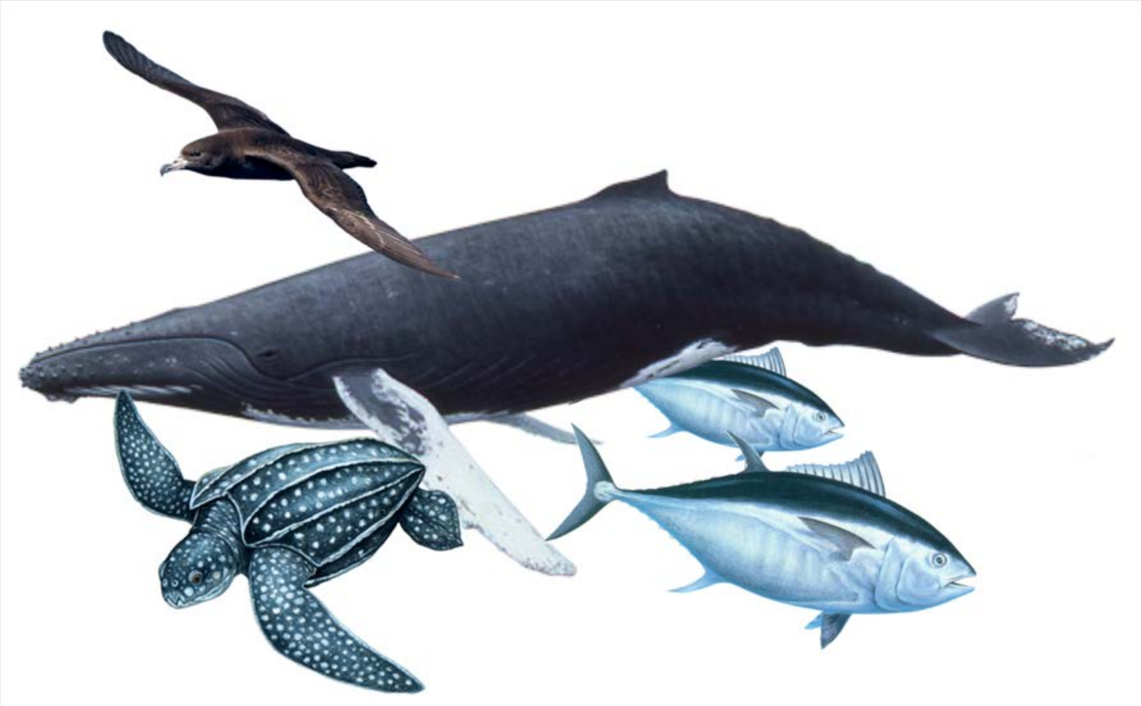


Development of collaborations and literature interpretation is intensive and time consuming…

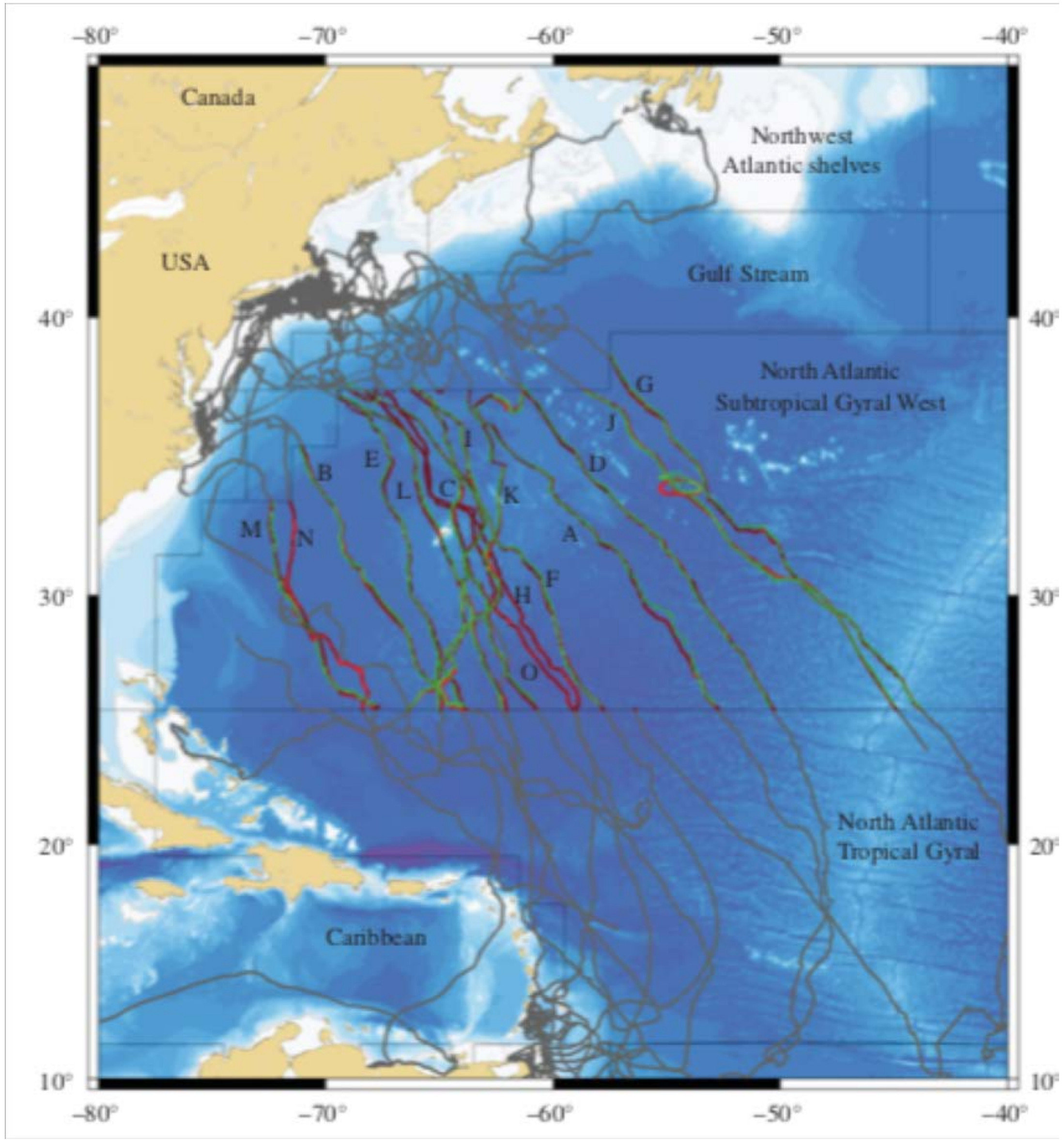
Taxa

- Cetaceans
- Sea turtles
- Sea birds
- Migratory fish
- Sharks & rays
- Pinnipeds

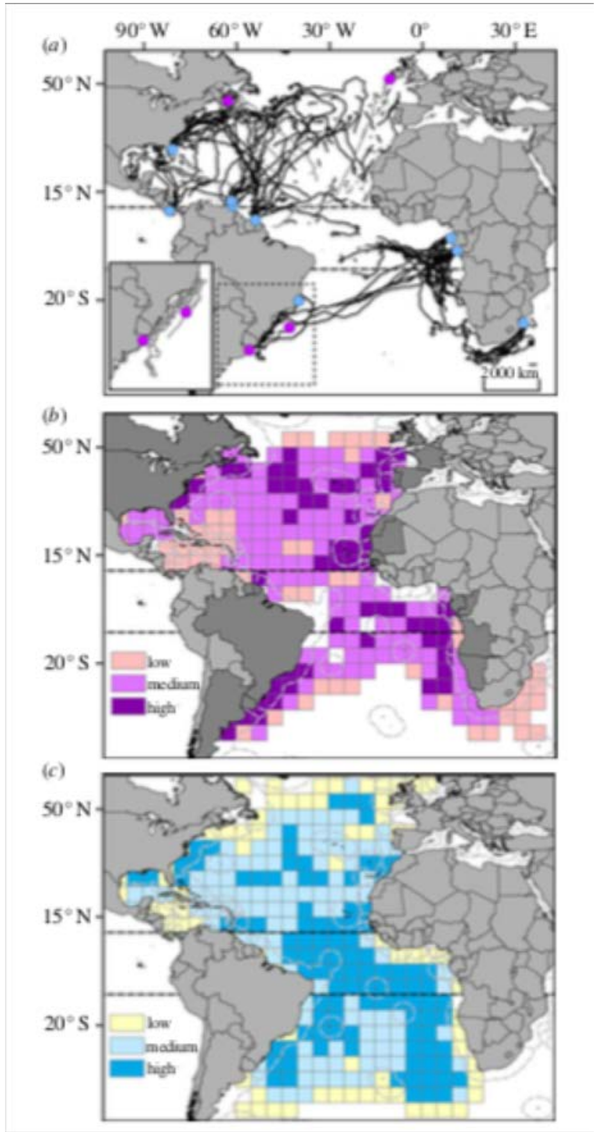
...Eels



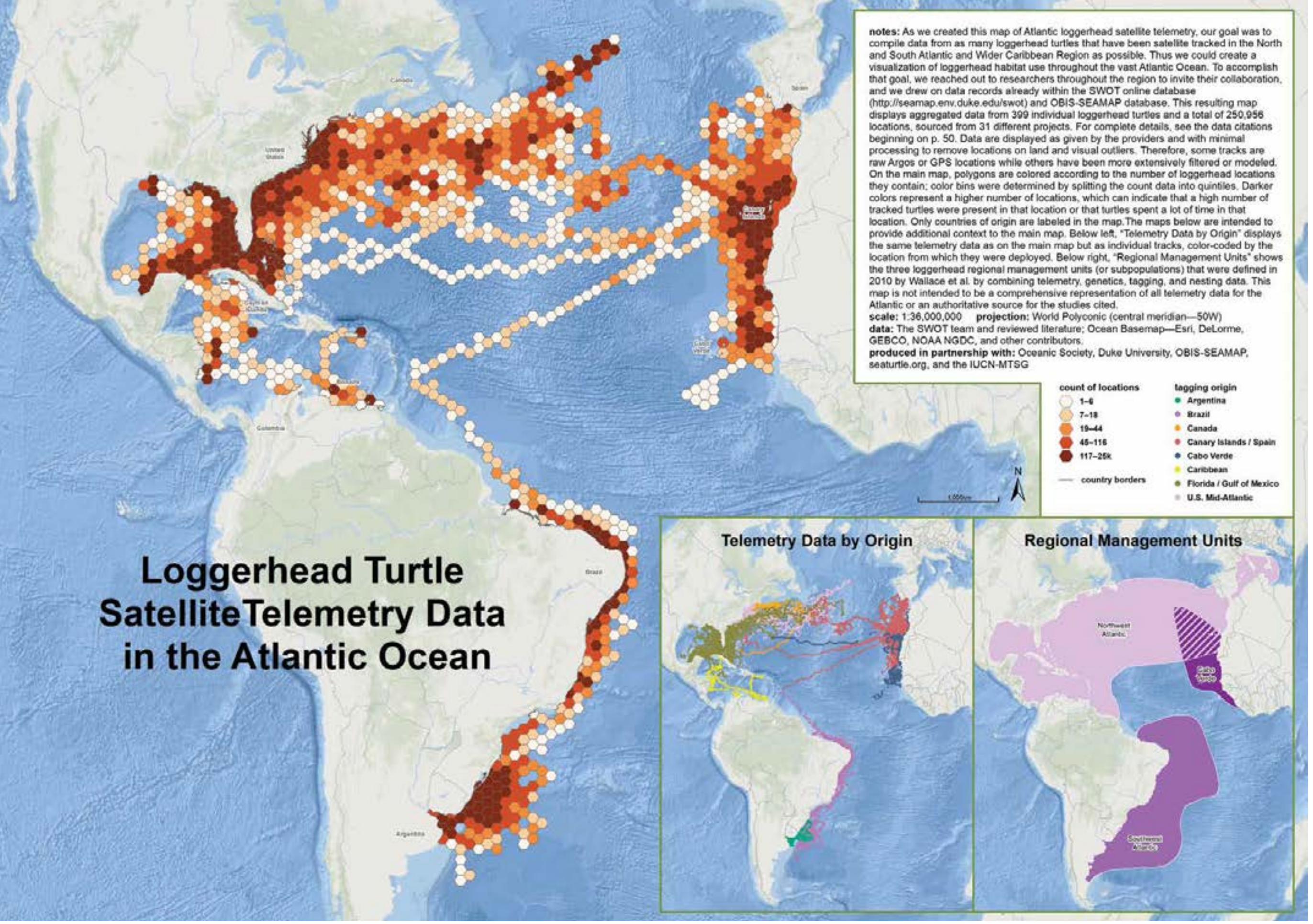
Leatherback Data in the Sargasso Sea



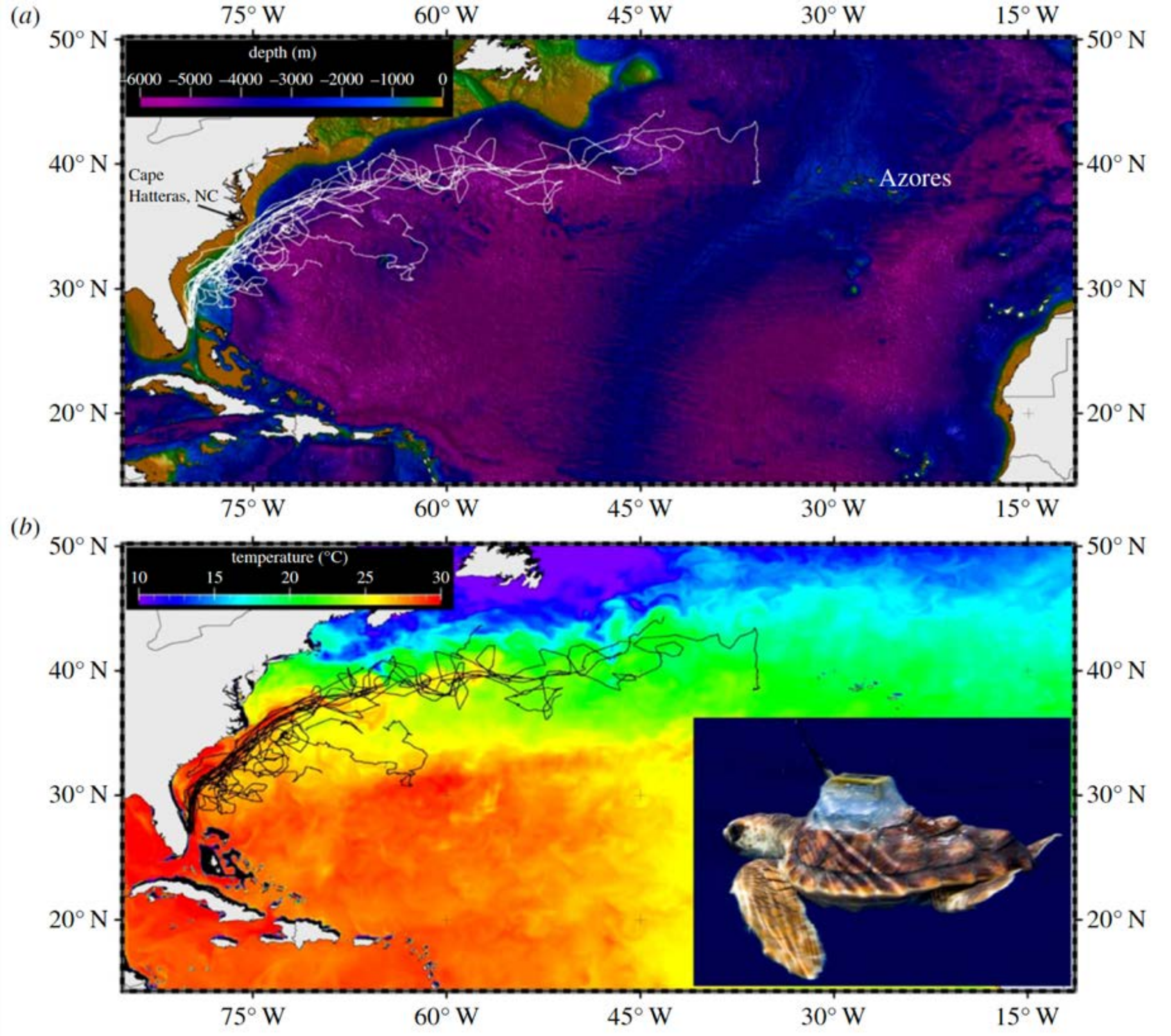
Dodge et al. 2015



Fossette et al. 2014, Hays 2018, unpublished



The "lost years" neonate Loggerhead seaturtles
Mansfield et al. 2013



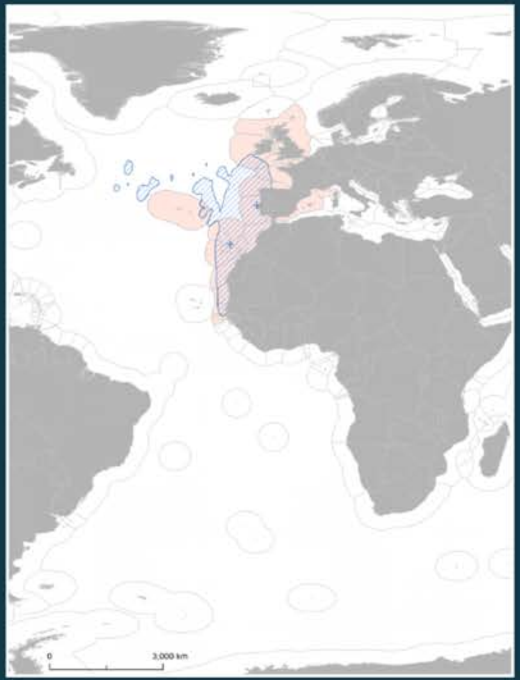
MiCO analysis tool

Corey Shearwater –Sargasso Sea example

Corey Shearwater

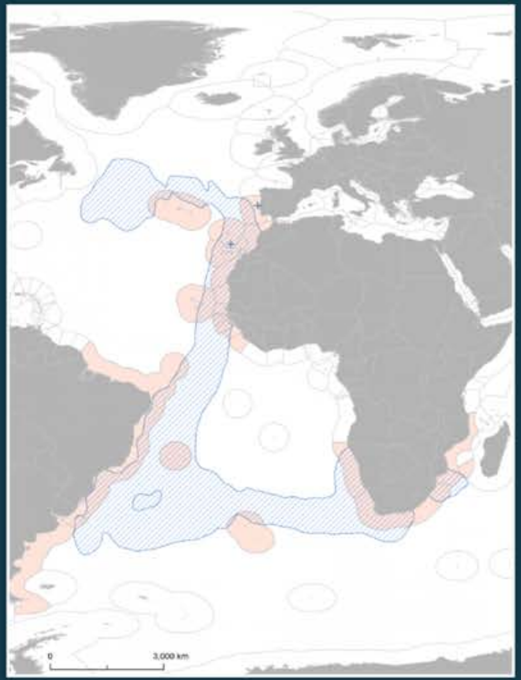
MIGRATION MAPS

Hatched blue areas demonstrate the distribution of Cory's shearwaters, based on a 90% utilization distribution. Exclusive Economic Zones that Cory's shearwaters pass through during each stage of their annual cycle are highlighted in light red. Breeding colonies where birds were tagged are represented by blue plus signs: Berlengas (n=23) and Selvagens(n=103).



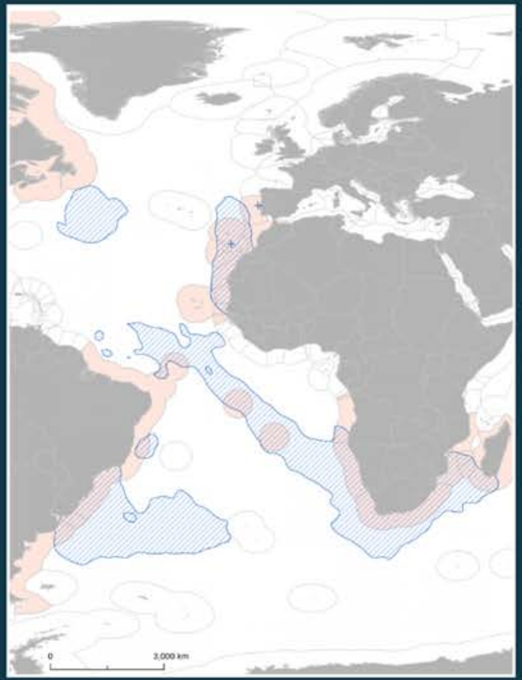
Breeding Season (~April to October)

During the breeding season, Cory's shearwaters move through the waters of many European and African countries to forage and find food for their chicks.



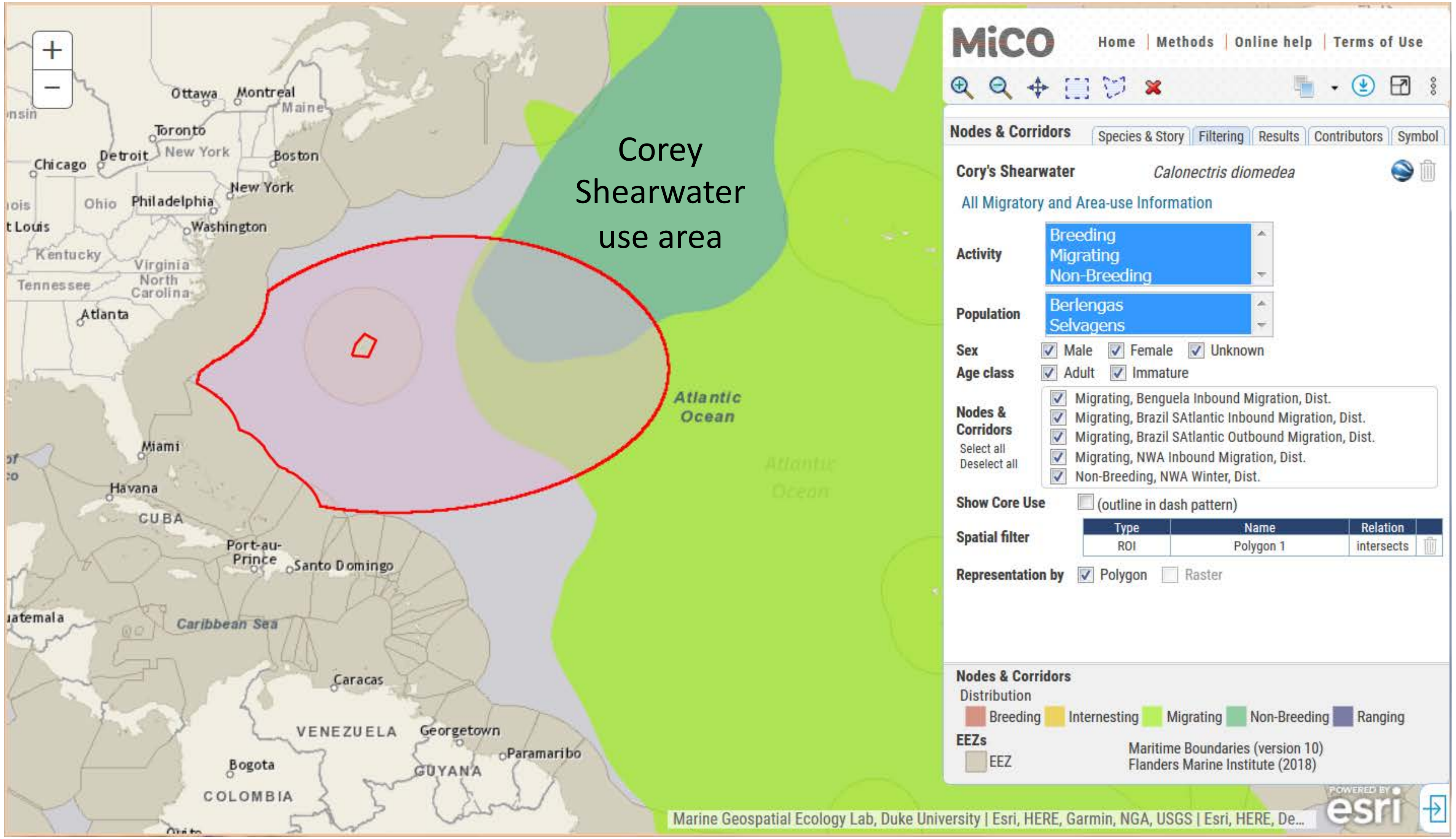
Outbound Migration and Wintering Sites

In November and December, Cory's shearwaters commence a long migration to their wintering areas in waters off South America and southern Africa.



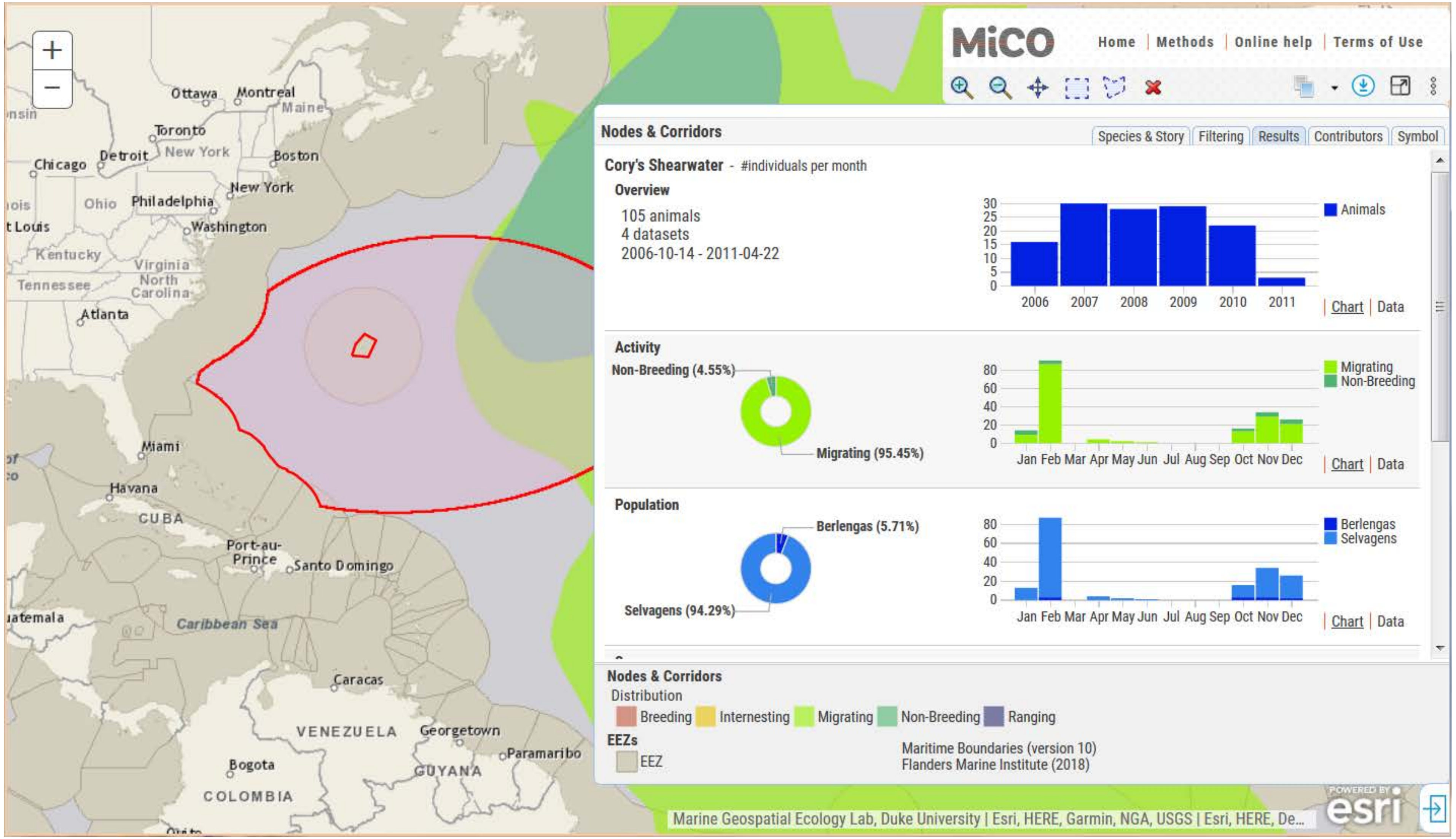
Return Migration from Wintering Sites to Colonies

Following dominant wind patterns, Cory's shearwaters move back across the Atlantic to their nesting colonies, with some birds looping through the northwest Atlantic along the way.



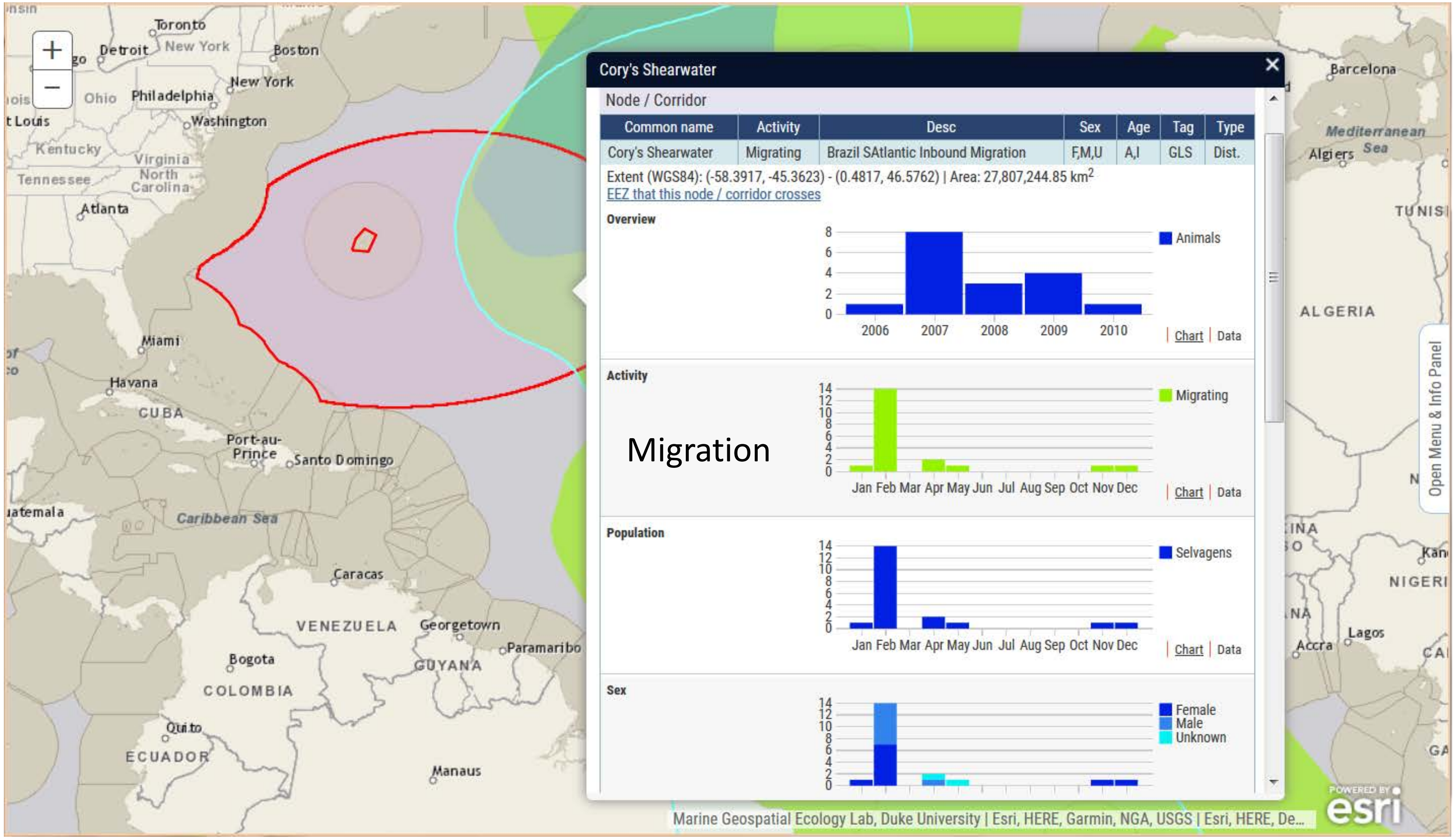
Notes

- Then, add distributions of Cory's Shearwater to see how the species intersects with the Sargasso Sea.
- You see the species cross the Sargasso Sea while they are “Breeding”, “Migrating” or “Non-Breeding”.



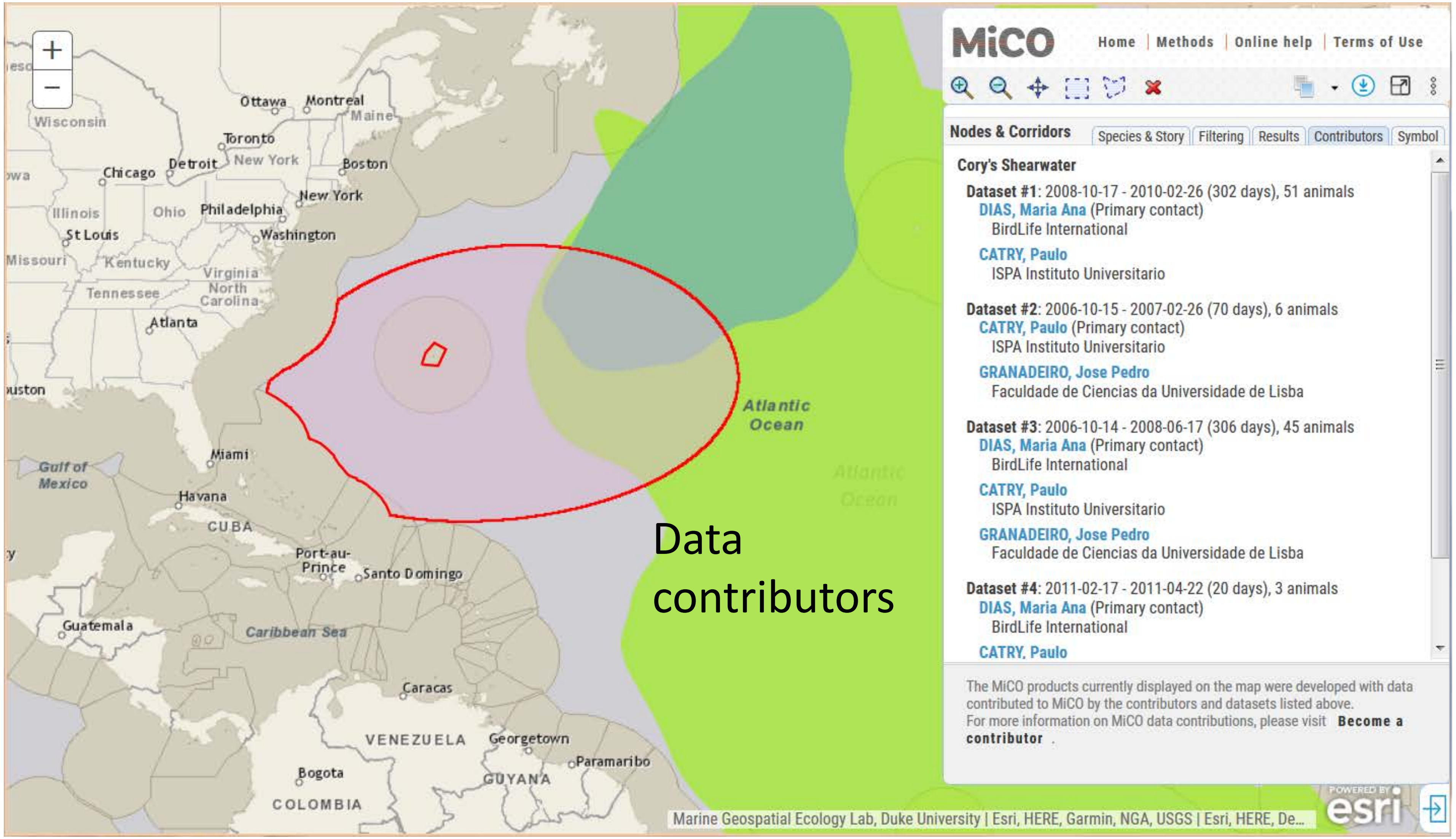
Notes

- For more details of Cory's Shearwater’s interaction with the Sargasso Sea, summary statistics are available in charts.
- For example, the migrating Shearwater crosses the Sargasso Sea mainly in fall through winter.



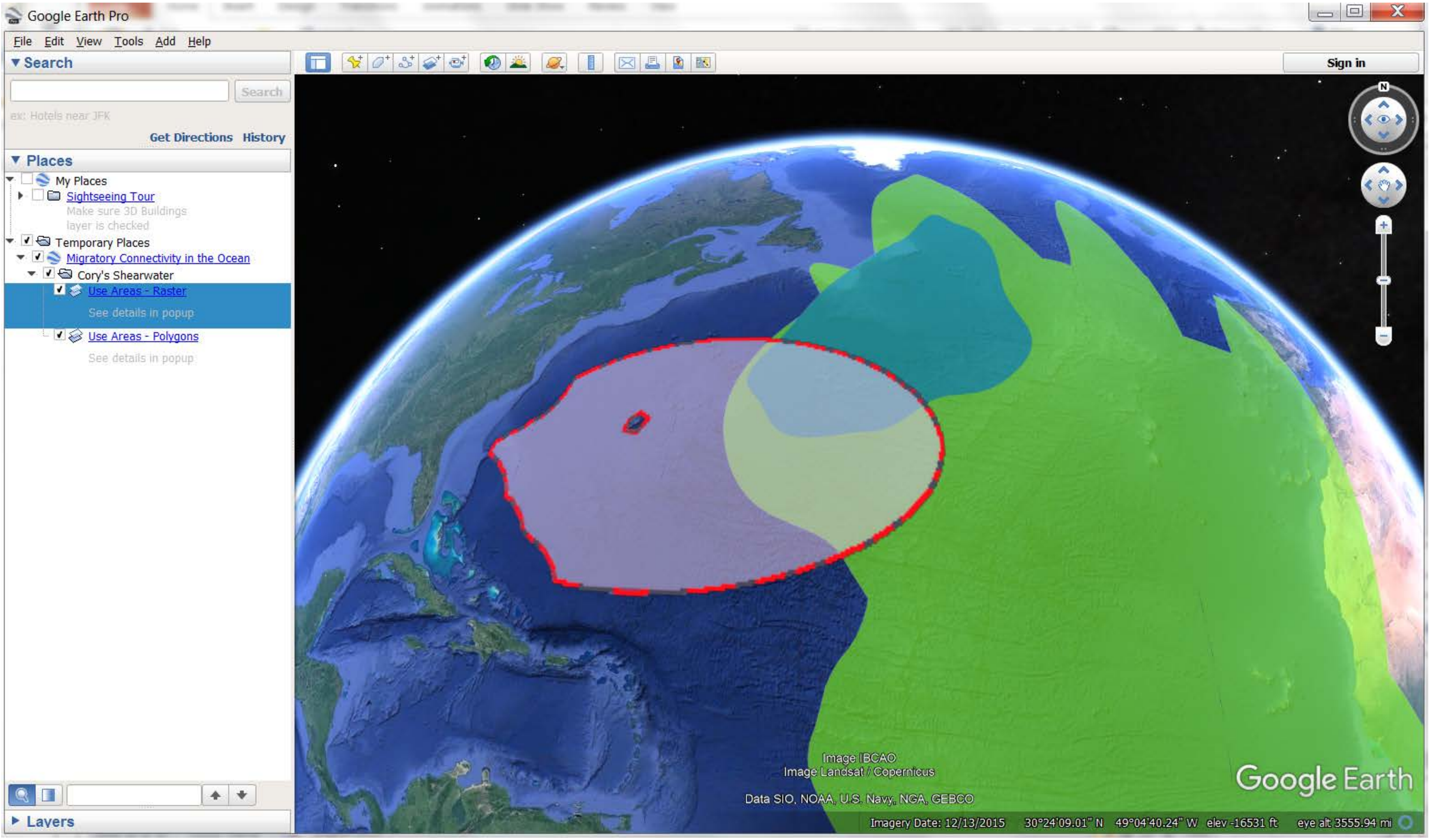
Notes

- As there are multiple activities of Cory’s Shearwater happening around the Sargasso Sea, you might want to pick one of them (clicking on the distribution polygon; e.g. Migrating).
- Then, the summary statistics for that particular activity are shown in charts.



Notes

- You can also see who contributed data to MiCO for this species.

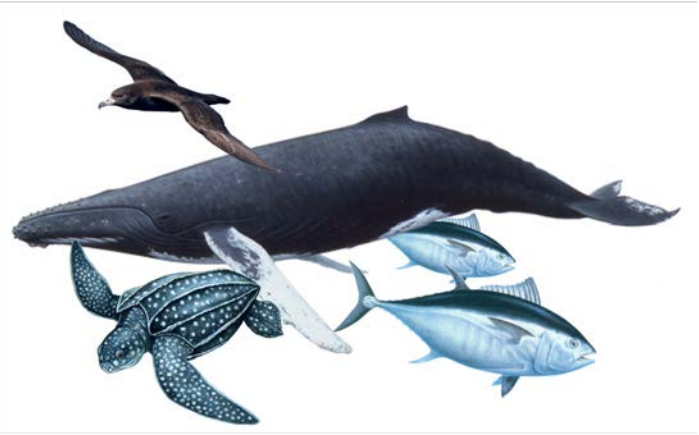


Notes

- You can explore the species distributions on Google Earth.

Topics

- Introduction
- Analyzing destinations and corridors
- MiCO – Migratory Connectivity of the Ocean
- Synthesis & future trends

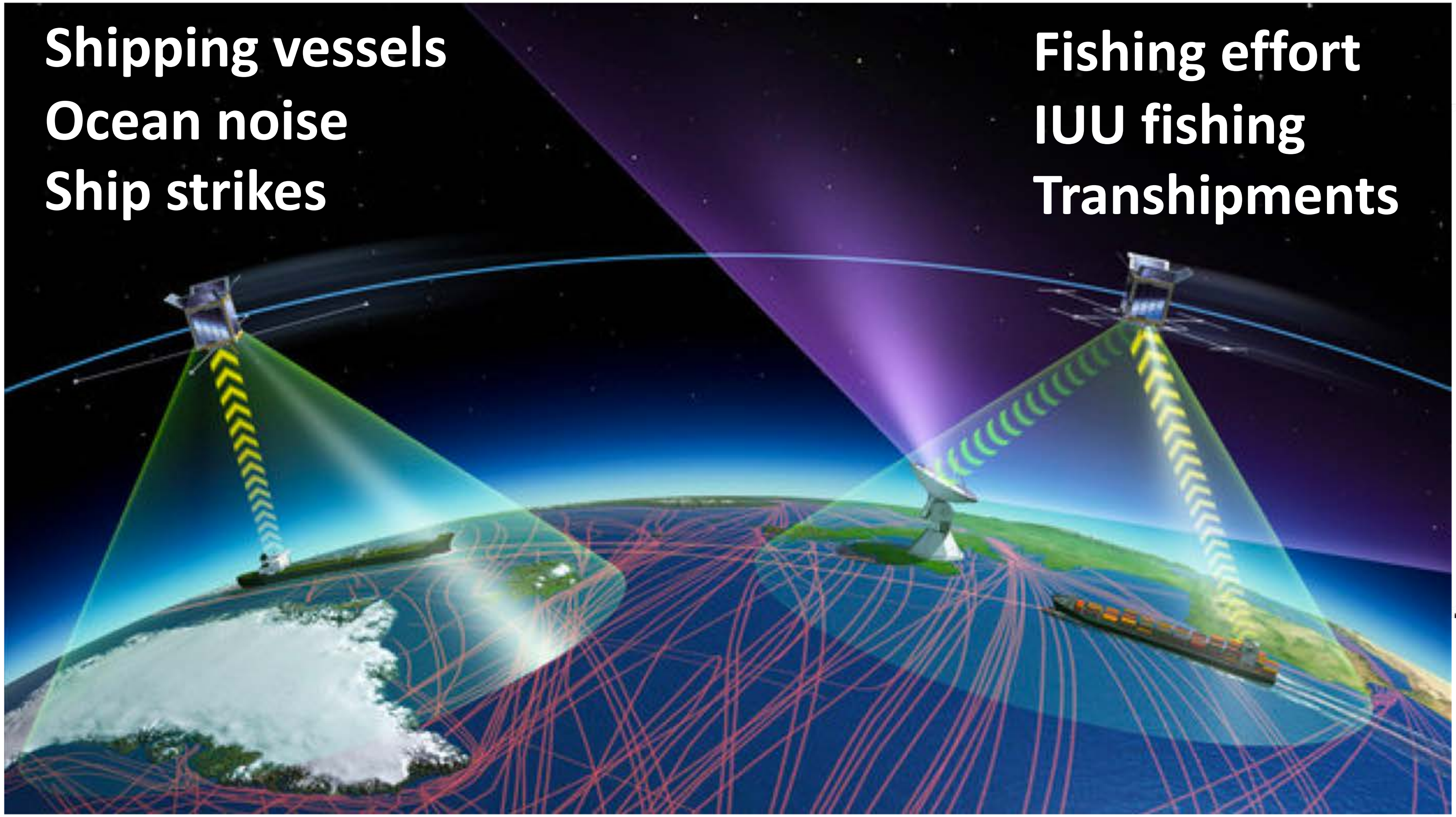


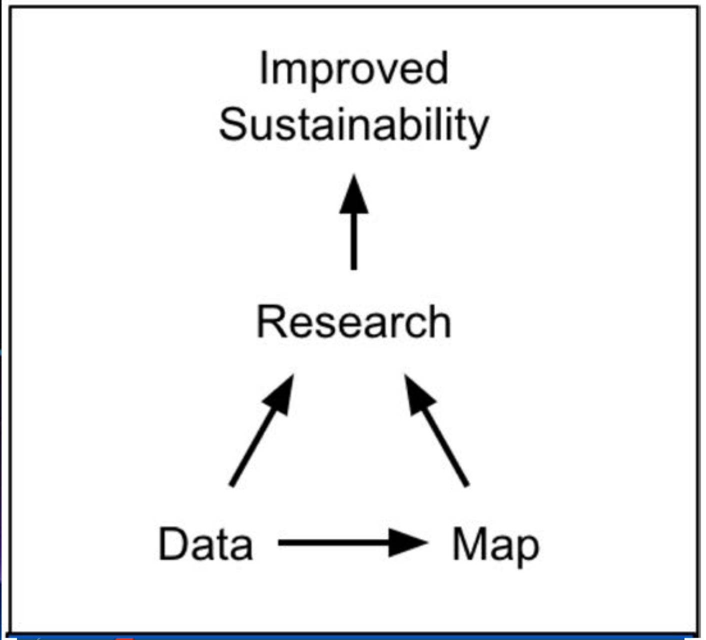
Management implications

Migratory species interactions with human activities:

- Shipping
  - ship strikes
  - ocean noise
- Fisheries
  - bycatch
- Deep Sea mining

Tracking vessels using satellite-based AIS data





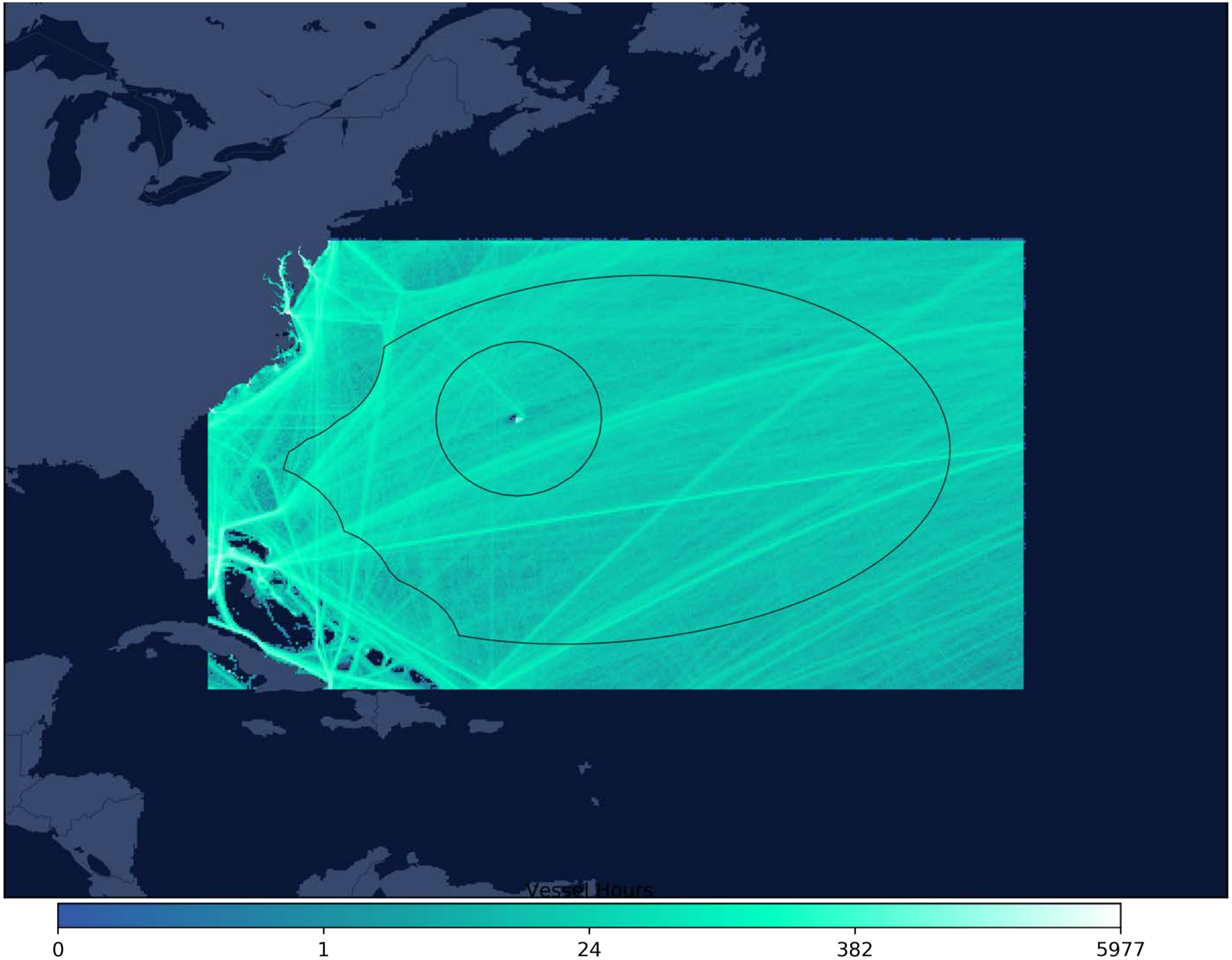
GLOBAL FISHING WATCH
Sustainability through Transparency

Vessel traffic

Vessels > 100 m and moving faster than 8 knots (2018)

Source: P. Woods 2019

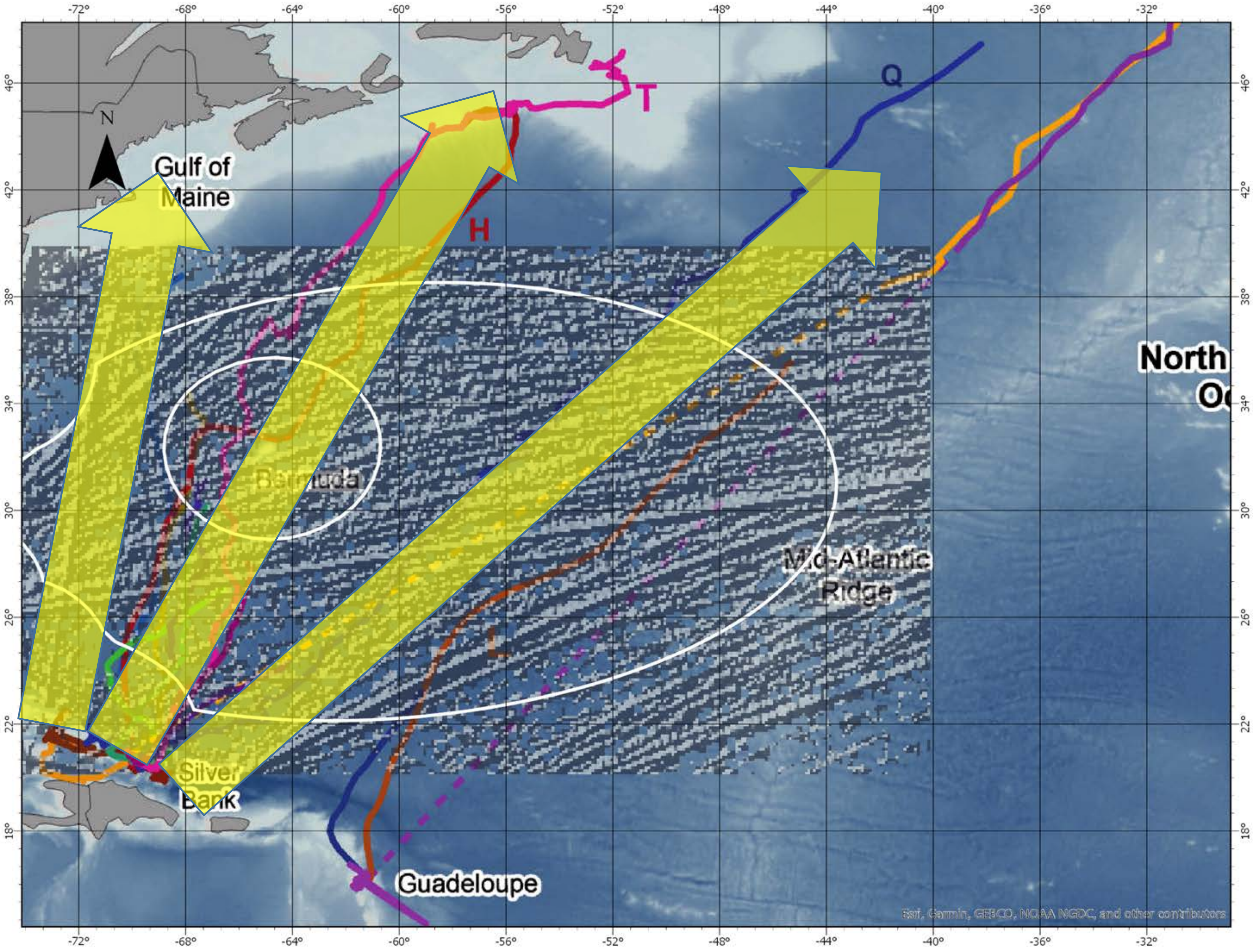
GLOBAL FISHING WATCH
Sustainability through Transparency



Humpback Whale

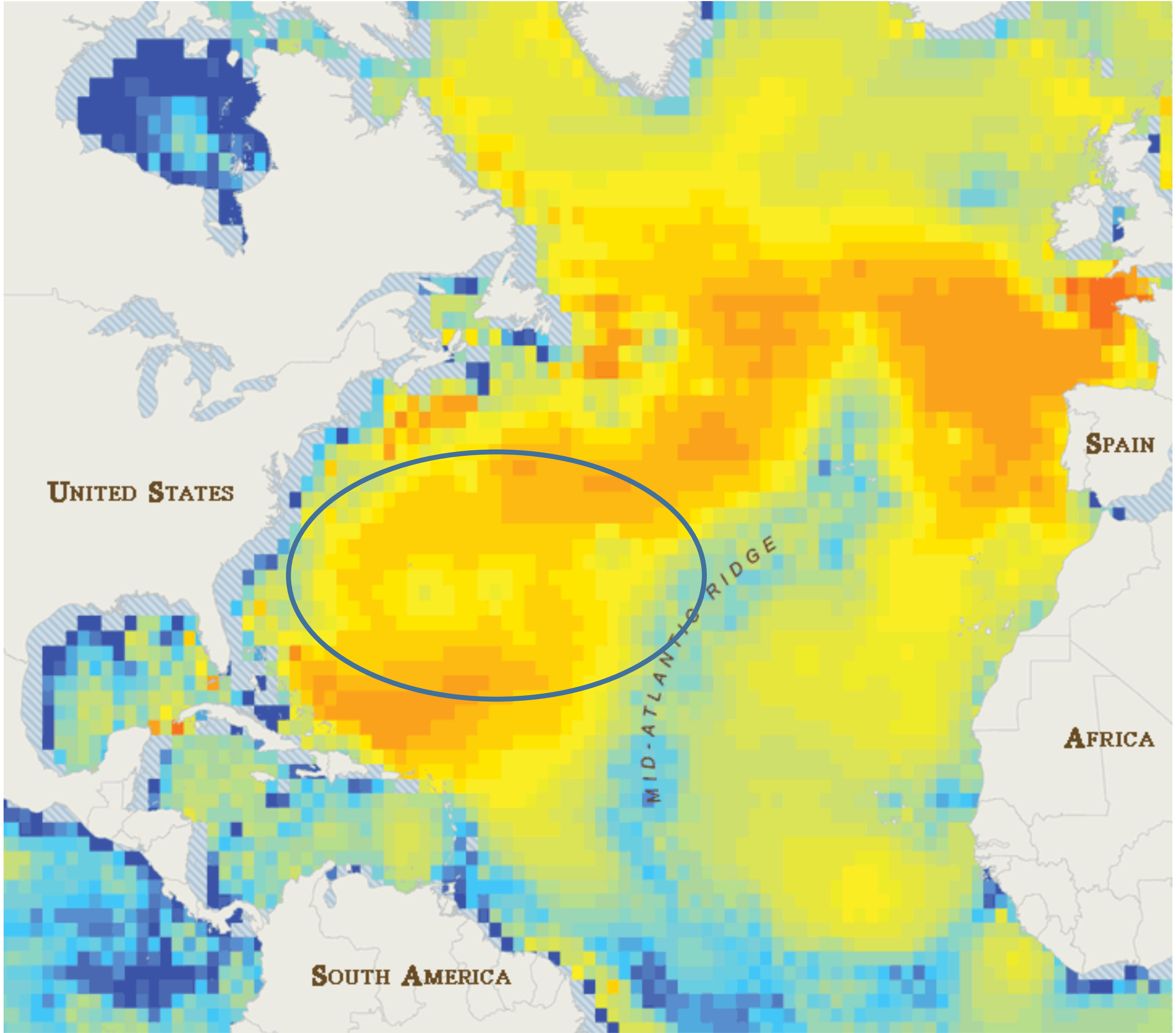
Humpback whale corridors overlaid with large vessel tracks from GFW. Potential interactions with spring migrations.

Note: vessels > 100 m and moving faster than 8 knots (2018)

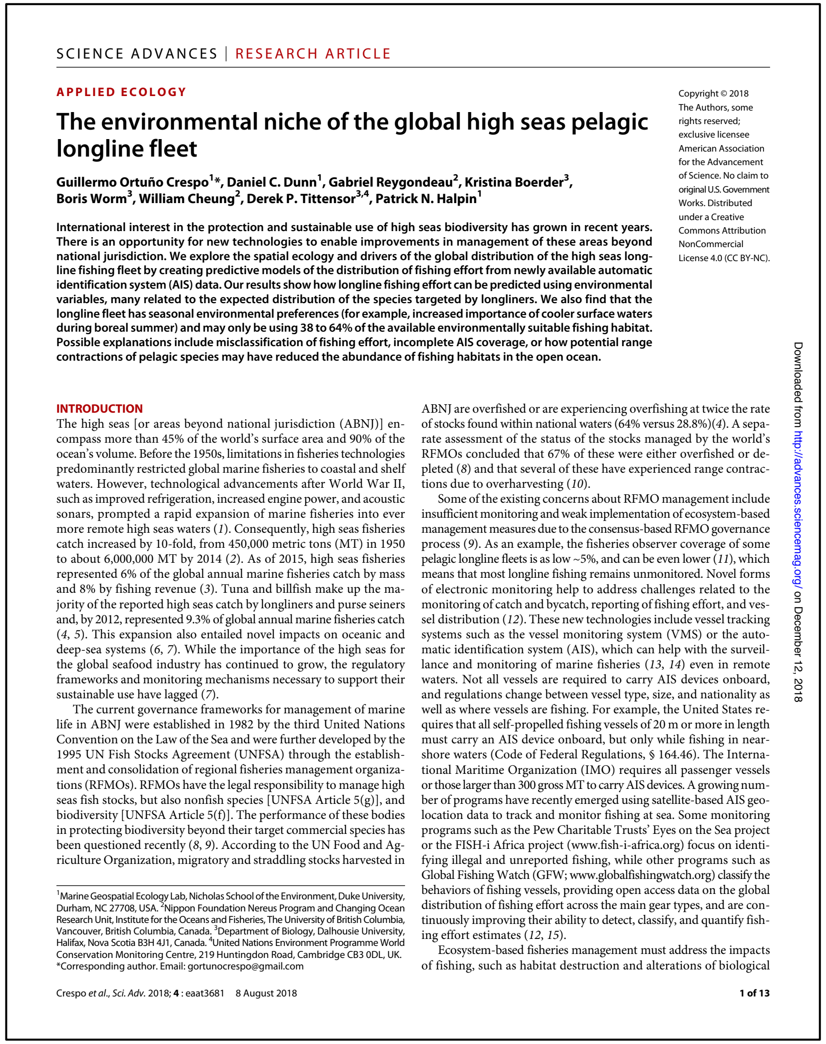


Ocean noise

Chronic ocean noise from vessels impacts marine mammals through sound masking



Fisheries interactions with migratory species



SCIENCE ADVANCES | RESEARCH ARTICLE

APPLIED ECOLOGY

The environmental niche of the global high seas pelagic longline fleet

Guillermo Ortuño Crespo[1]*, Daniel C. Dunn[1], Gabriel Reygondeau[2], Kristina Boerder[3], Boris Worm[3], William Cheung[2], Derek P. Tittensor[3,4], Patrick N. Halpin[1]

International interest in the protection and sustainable use of high seas biodiversity has grown in recent years. There is an opportunity for new technologies to enable improvements in management of these areas beyond national jurisdiction. We explore the spatial ecology and drivers of the global distribution of the high seas longline fishing fleet by creating predictive models of the distribution of fishing effort from newly available automatic identification system (AIS) data. Our results show how longline fishing effort can be predicted using environmental variables, many related to the expected distribution of the species targeted by longliners. We also find that the longline fleet has seasonal environmental preferences (for example, increased importance of cooler surface waters during boreal summer) and may only be using 38 to 64% of the available environmentally suitable fishing habitat. Possible explanations include misclassification of fishing effort, incomplete AIS coverage, or how potential range contractions of pelagic species may have reduced the abundance of fishing habitats in the open ocean.

INTRODUCTION

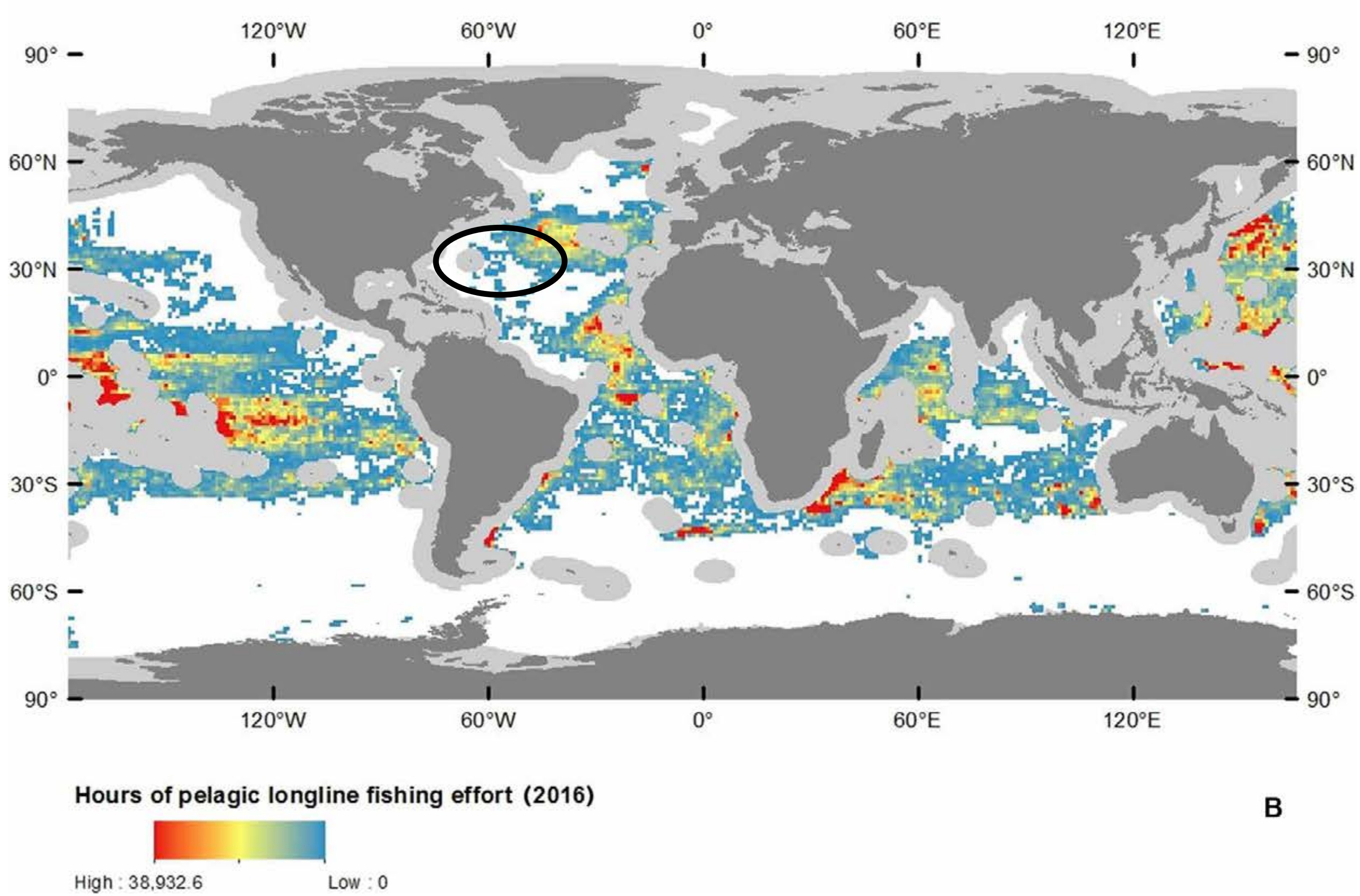
The high seas [or areas beyond national jurisdiction (ABNJ)] encompass more than 45% of the world's surface area and 90% of the ocean's volume. Before the 1950s, limitations in fisheries technologies predominantly restricted global marine fisheries to coastal and shelf waters. However, technological advancements after World War II, such as improved refrigeration, increased engine power, and acoustic sonars, prompted a rapid expansion of marine fisheries into ever more remote high seas waters (*1*). Consequently, high seas fisheries catch increased by 10-fold, from 450,000 metric tons (MT) in 1950 to about 6,000,000 MT by 2014 (*2*). As of 2015, high seas fisheries represented 6% of the global annual marine fisheries catch by mass and 8% by fishing revenue (*3*). Tuna and billfish make up the majority of the reported high seas catch by longliners and purse seiners and, by 2012, represented 9.3% of global annual marine fisheries catch (*4*, *5*). This expansion also entailed novel impacts on oceanic and deep-sea systems (*6*, *7*). While the importance of the high seas for the global seafood industry has continued to grow, the regulatory frameworks and monitoring mechanisms necessary to support their sustainable use have lagged (*7*).

The current governance frameworks for management of marine life in ABNJ were established in 1982 by the third United Nations Convention on the Law of the Sea and were further developed by the 1995 UN Fish Stocks Agreement (UNFSA) through the establishment and consolidation of regional fisheries management organizations (RFMOs). RFMOs have the legal responsibility to manage high seas fish stocks, but also nonfish species [UNFSA Article 5(g)], and biodiversity [UNFSA Article 5(f)]. The performance of these bodies in protecting biodiversity beyond their target commercial species has been questioned recently (*8*, *9*). According to the UN Food and Agriculture Organization, migratory and straddling stocks harvested in ABNJ are overfished or are experiencing overfishing at twice the rate of stocks found within national waters (64% versus 28.8%)(*4*). A separate assessment of the status of the stocks managed by the world's RFMOs concluded that 67% of these were either overfished or depleted (*8*) and that several of these have experienced range contractions due to overharvesting (*10*).

Some of the existing concerns about RFMO management include insufficient monitoring and weak implementation of ecosystem-based management measures due to the consensus-based RFMO governance process (*9*). As an example, the fisheries observer coverage of some pelagic longline fleets is as low ~5%, and can be even lower (*11*), which means that most longline fishing remains unmonitored. Novel forms of electronic monitoring help to address challenges related to the monitoring of catch and bycatch, reporting of fishing effort, and vessel distribution (*12*). These new technologies include vessel tracking systems such as the vessel monitoring system (VMS) or the automatic identification system (AIS), which can help with the surveillance and monitoring of marine fisheries (*13*, *14*) even in remote waters. Not all vessels are required to carry AIS devices onboard, and regulations change between vessel type, size, and nationality as well as where vessels are fishing. For example, the United States requires that all self-propelled fishing vessels of 20 m or more in length must carry an AIS device onboard, but only while fishing in near-shore waters (Code of Federal Regulations, § 164.46). The International Maritime Organization (IMO) requires all passenger vessels or those larger than 300 gross MT to carry AIS devices. A growing number of programs have recently emerged using satellite-based AIS geolocation data to track and monitor fishing at sea. Some monitoring programs such as the Pew Charitable Trusts' Eyes on the Sea project or the FISH-i Africa project (www.fish-i-africa.org) focus on identifying illegal and unreported fishing, while other programs such as Global Fishing Watch (GFW; www.globalfishingwatch.org) classify the behaviors of fishing vessels, providing open access data on the global distribution of fishing effort across the main gear types, and are continuously improving their ability to detect, classify, and quantify fishing effort estimates (*12*, *15*).

Ecosystem-based fisheries management must address the impacts of fishing, such as habitat destruction and alterations of biological

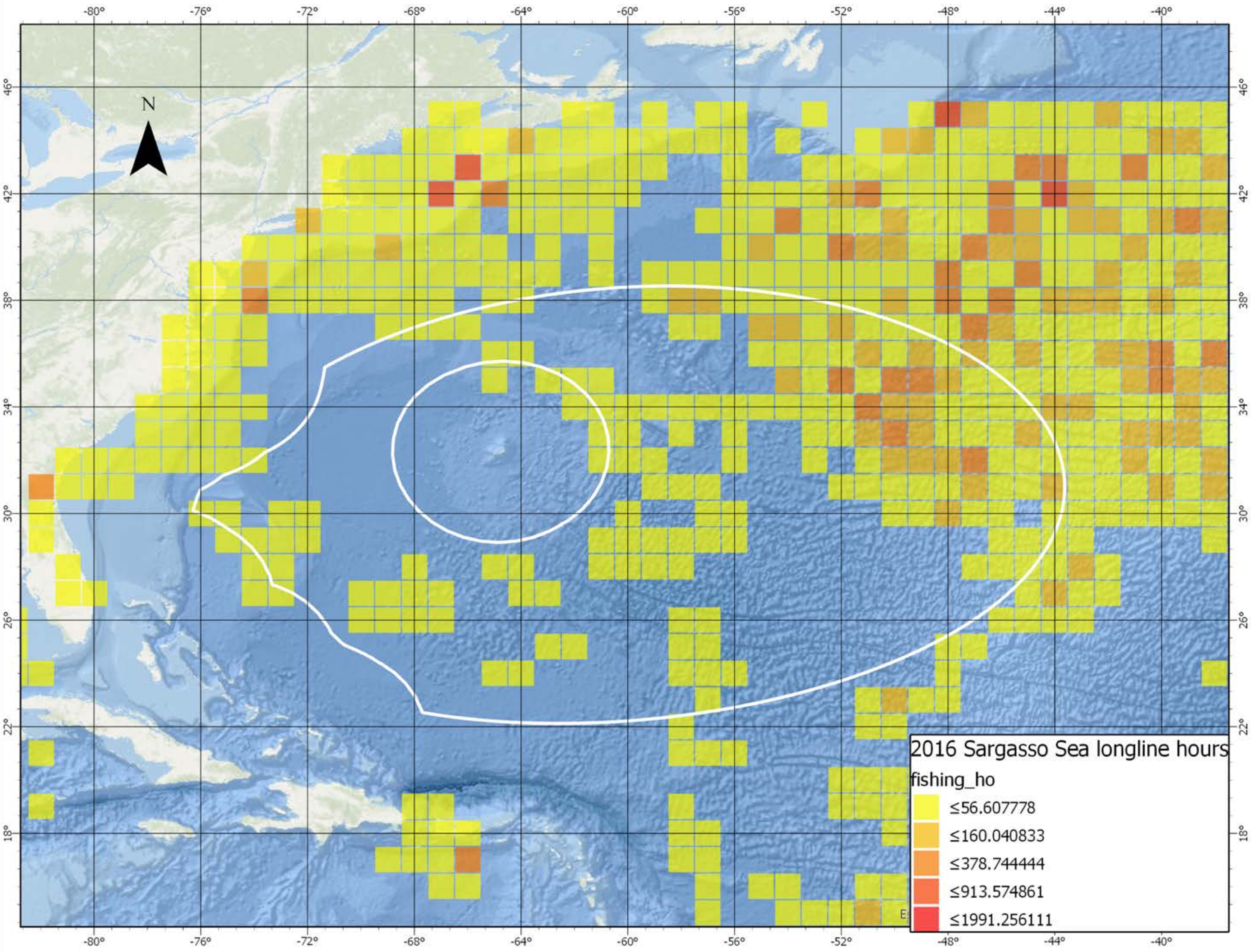
[1]Marine Geospatial Ecology Lab, Nicholas School of the Environment, Duke University, Durham, NC 27708, USA. [2]Nippon Foundation Nereus Program and Changing Ocean Research Unit, Institute for the Oceans and Fisheries, The University of British Columbia, Vancouver, British Columbia, Canada. [3]Department of Biology, Dalhousie University, Halifax, Nova Scotia B3H 4J1, Canada. [4]United Nations Environment Programme World Conservation Monitoring Centre, 219 Huntingdon Road, Cambridge CB3 0DL, UK.
*Corresponding author. Email: gortunocrespo@gmail.com



Longline fishing hours

Forecast model of fishing hours based on fishing vessel tracking data and environmental predictors

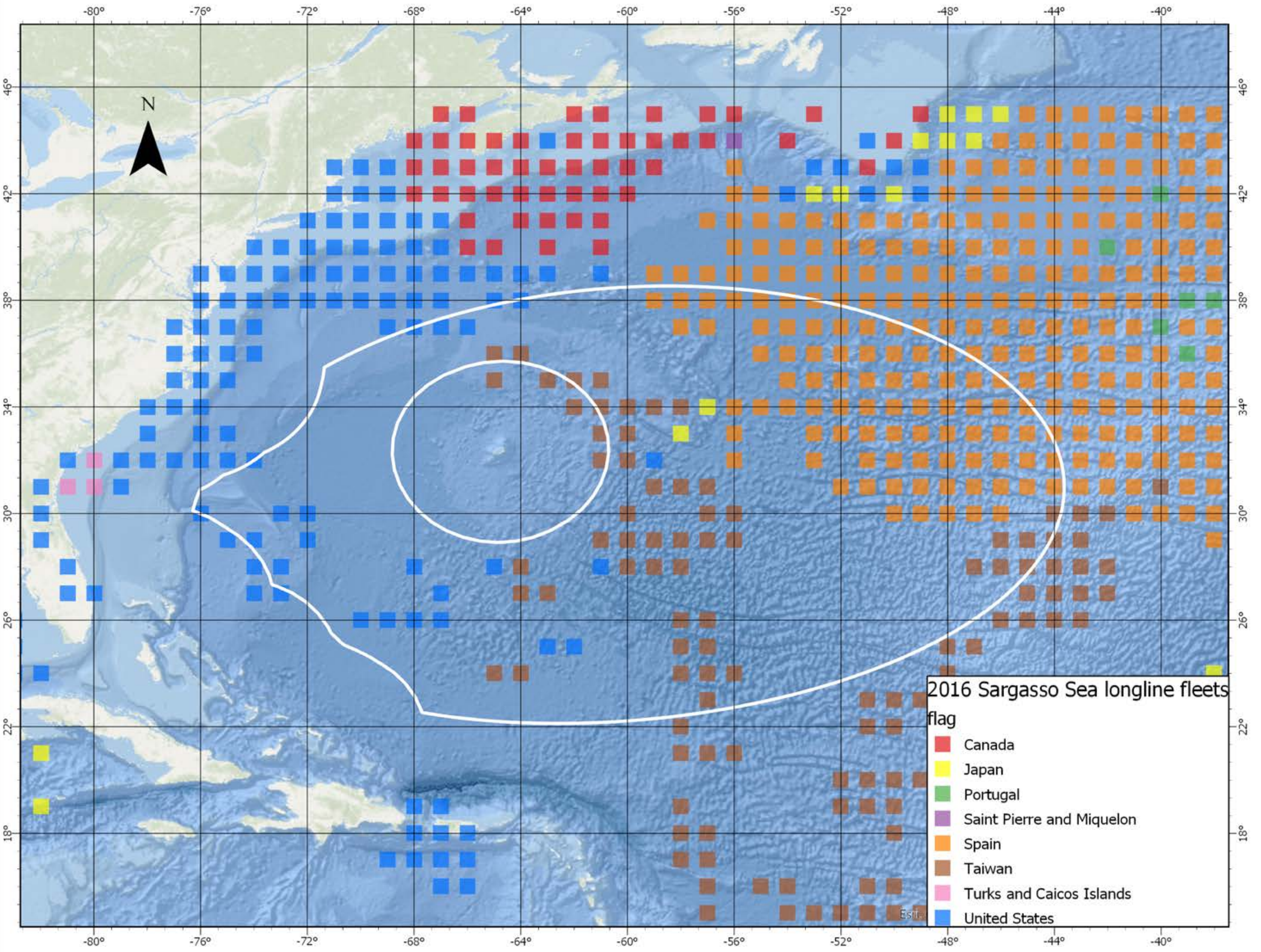
Crespo et al. 2018



Longline fishing flag fleets

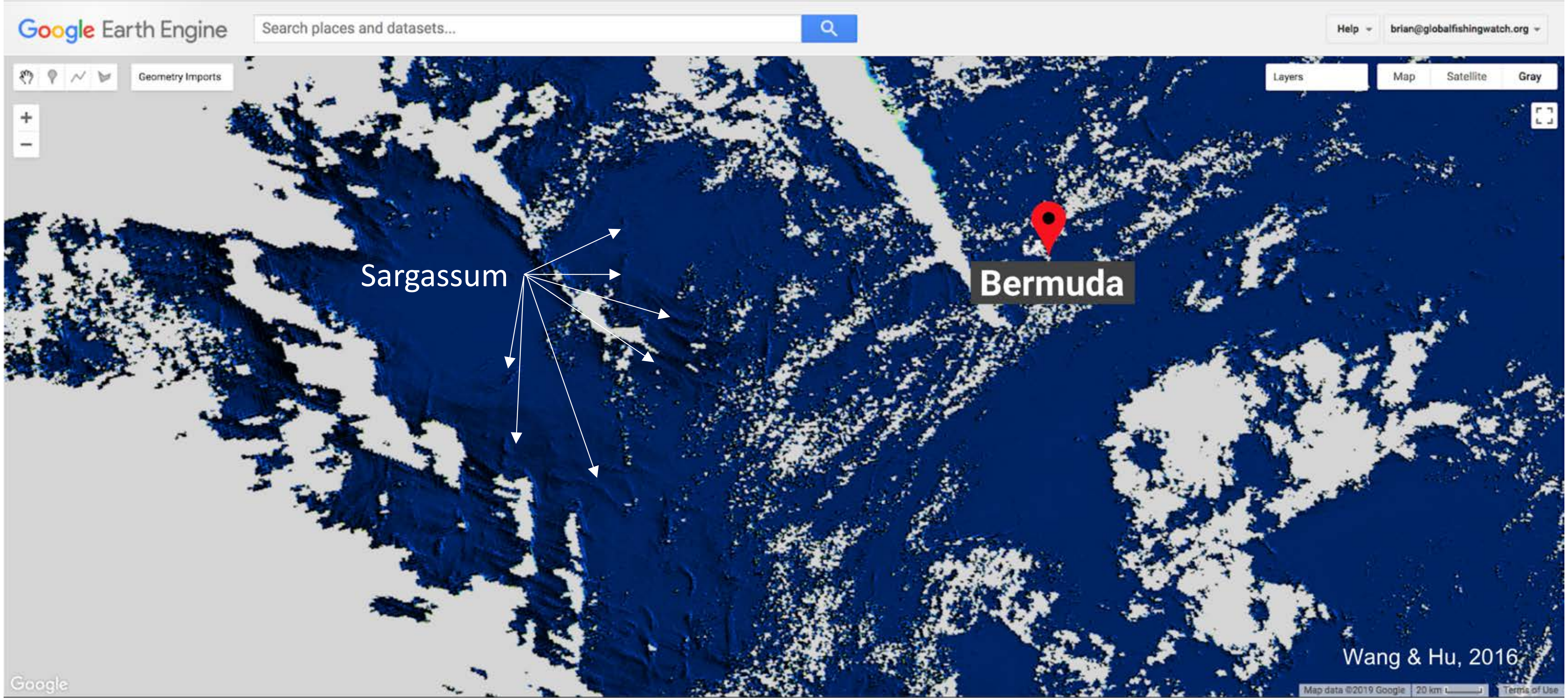
Forecast model of fishing flag state based on fishing vessel tracking data and environmental predictors

Crespo et al. 2018



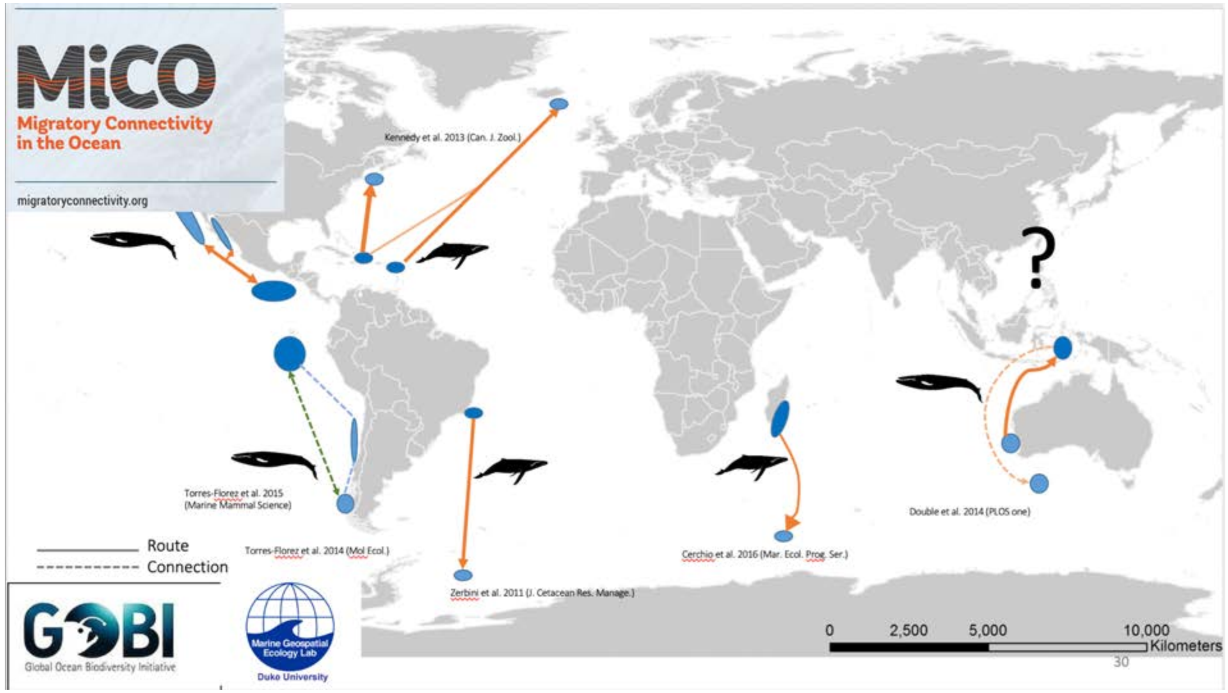
Ongoing Research:

Times series of sargassum tracking, migratory species and human uses…



Future – next steps

- Initial public roll-out of MiCO at the UN BBNJ negotiations in NY (March 2019)
- Continued development of MiCO database & decision support tools
- New science applications
- Exploratory development of management implications



MiCO IS A CONSORTIUM

This project is a collective effort between the Marine Geospatial Ecology Lab (MGEL) of Duke University and a growing number of international partner organizations.

Consortium Partners →

Consortium Data Contributors →

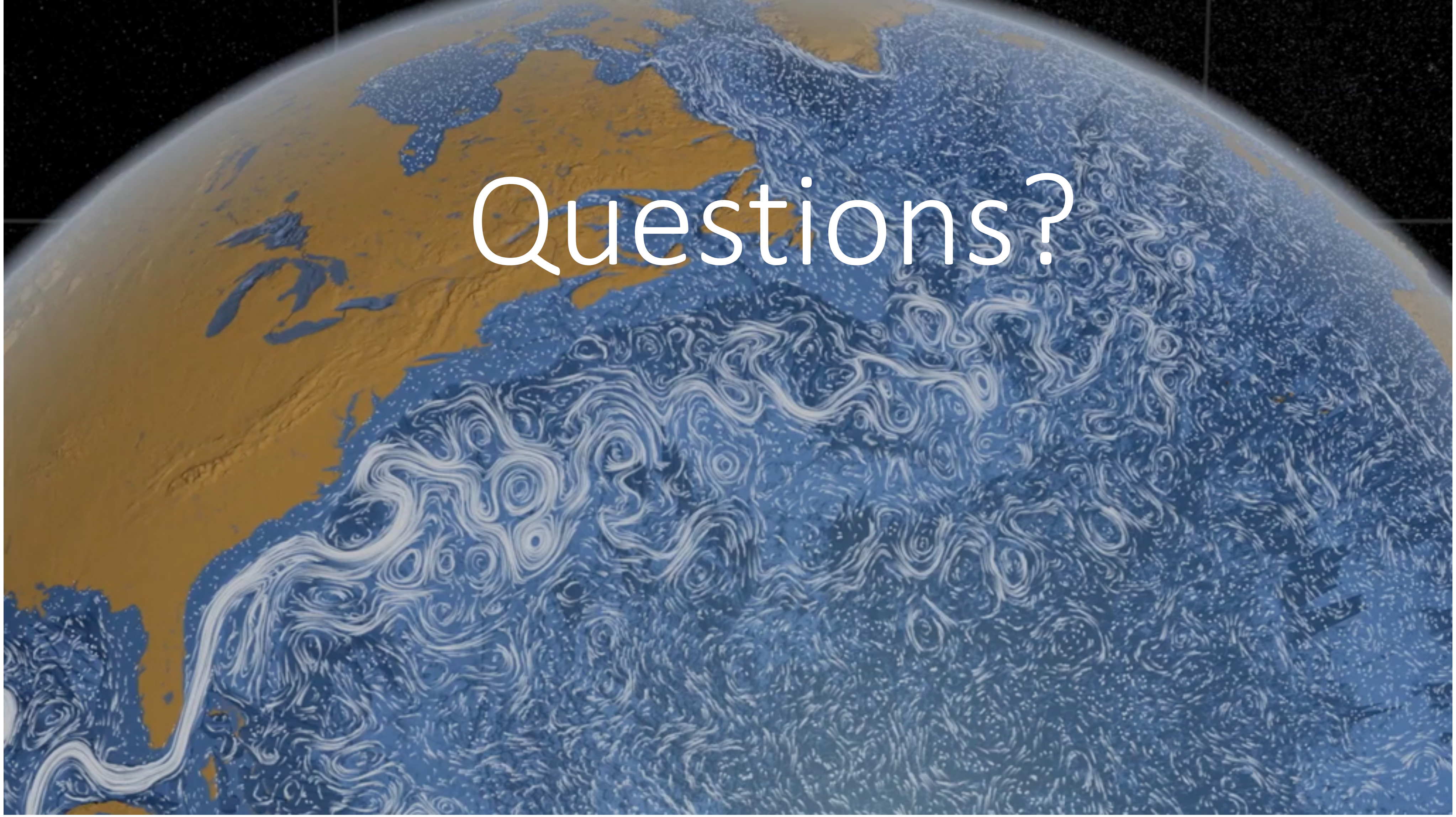
MiCO is guided by a steering committee with three advisory panels:

Project Structure →

BECOME A DATA PARTNER

The success of MiCO, and its ability to influence conservation outcomes, depends on our network of data holders. Learn more about how your data can further the project.

PUT YOUR DATA TO WORK SIGN UP



Supported by:

Federal Ministry
for the Environment, Nature Conservation, Building and Nuclear Safety

based on a decision of the German Bundestag

GOBI
Global Ocean Biodiversity Initiative

MiCO
Migratory Connectivity in the Ocean

Marine Geospatial Ecology Lab
Duke University

Duke | NICHOLAS SCHOOL OF THE ENVIRONMENT
DUKE UNIVERSITY MARINE LAB