Passive Acoustic Monitoring Overview- Applications for Marine Mammals and Fishes

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Passive acoustic program lead

Northeast Fisheries Science Center

What is Passive Acoustic Monitoring? (PAM)

Routine recording of underwater sounds in the marine environment over long time periods

Graphic: NOAA Fisheries

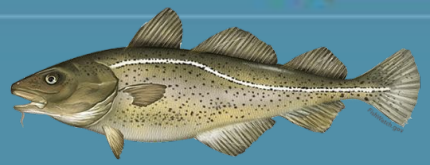
All light is absorbed within 200 m of the ocean's surface

10 meters

20 meters

30 meters

40 meters



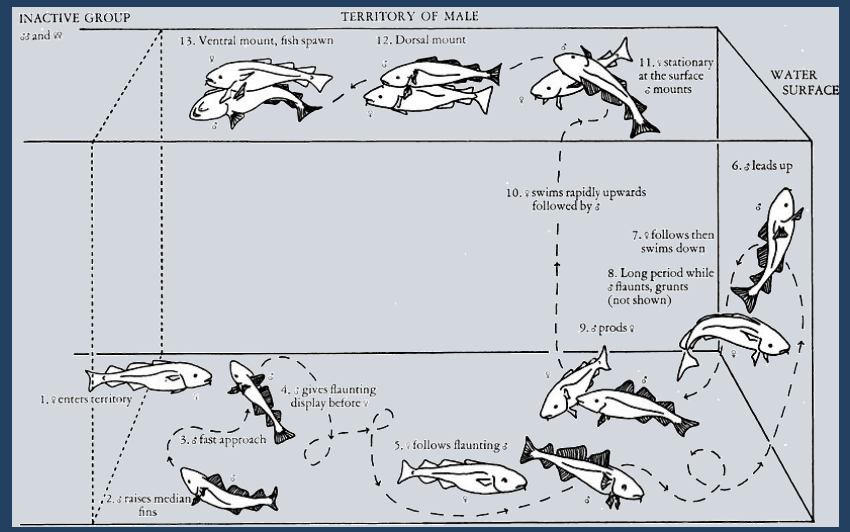
Sound travels 5 times faster in water (1500m/s) than in air (340m/s)

Graphics adapted from: René Swift
Illustrations : Pieter Folkens

Marine Animal Sounds

Communication

- Identification between individuals
- Find mates
- Maintain group structure
- Establish territories or spawning aggregations
- Mother – calf contact
- Aggressive interactions



Graphics adapted from: René Swift
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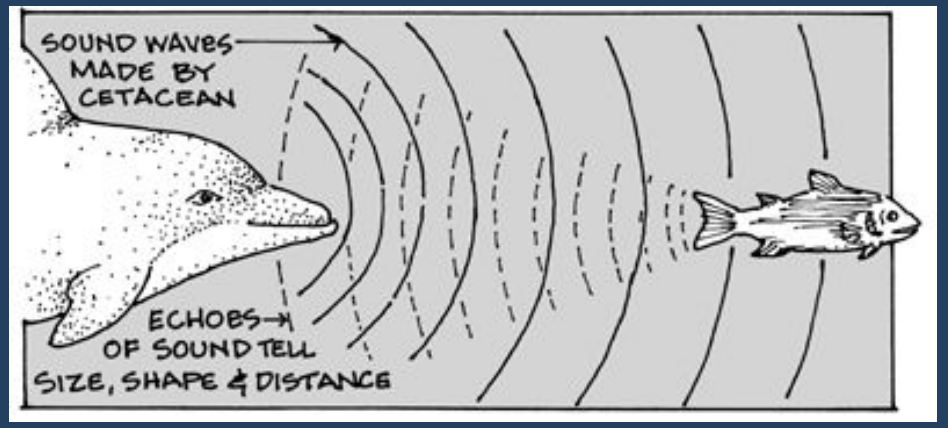
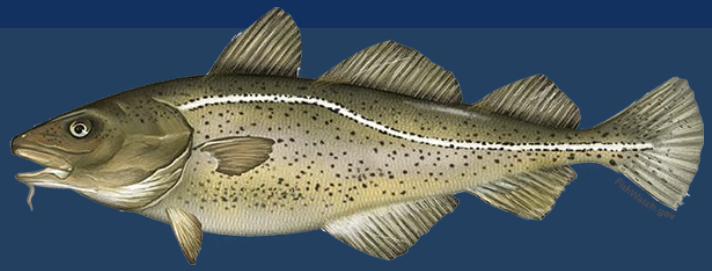
Marine Animal Sounds

Echolocation/Foraging/Navigation

- Detect, localize, and characterize objects
- sharing information about food
- startling prey to aid capture
- Jaw clapping/swim bladder changes



Conventional Techniques



Benefits

Marine mammals visual sightings provide species presence, number of animals, health and ID

Trawl surveys for fish provides species presence, extrapolation of the number of animals, health condition, genetic and growth samples

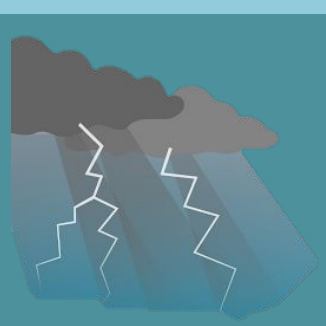
Limitations

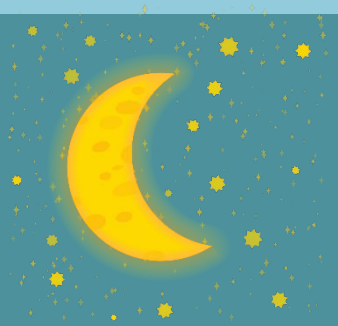
Limited due to bad weather, light and cost.

You only see what is on the surface or is caught in a trawl.

WHY PASSIVE ACOUSTIC MONITORING? (PAM)

- Provides a non-invasive, valuable alternative or addition to traditional survey methods





+ Benefits +

- Can detect animals at night and in bad weather
- Can do long-term monitoring with reduced field effort and cost
- Can cover wide spatial range

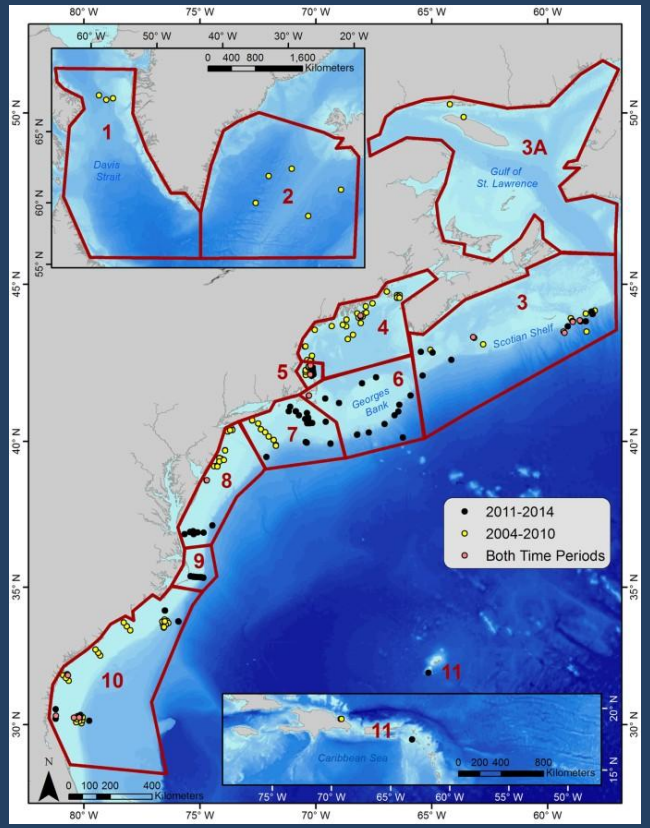
- Limitations -

- Presence only: cannot tell when animals are NOT around
- For most species, difficult to determine number of individuals present
- Many sounds are still unknown

Graphic: NOAA Fisheries

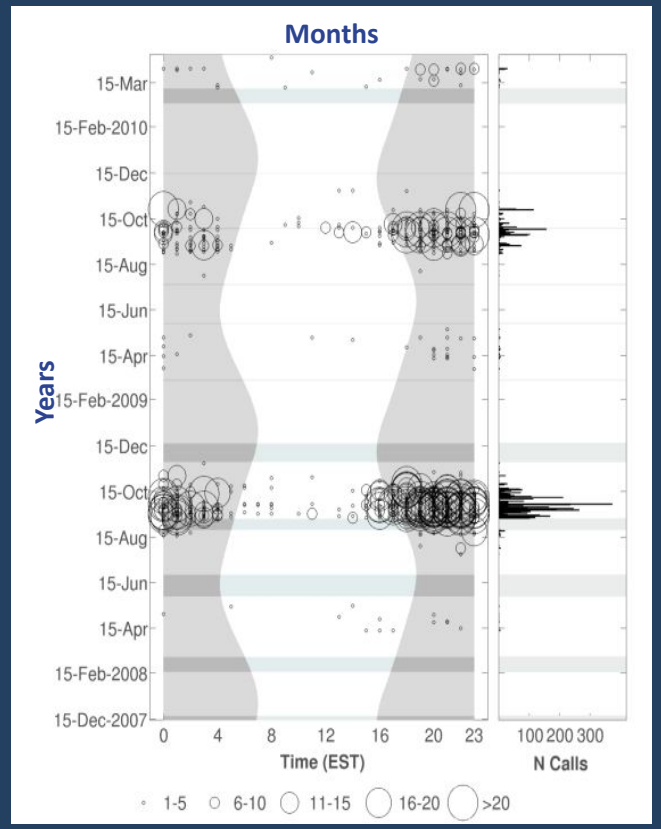
WHY PAM?

Spatial Coverage



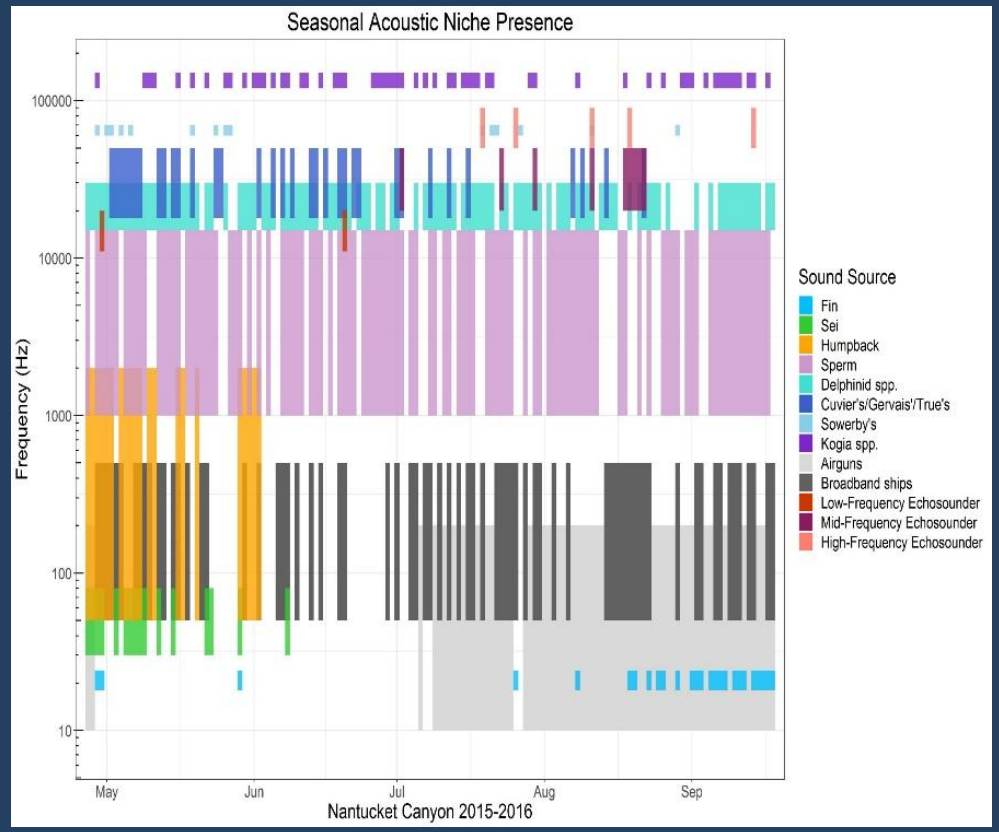
Davis et al. 2017

Long Time Periods



Risch et al. 2014

Species Ecology/Soundscape



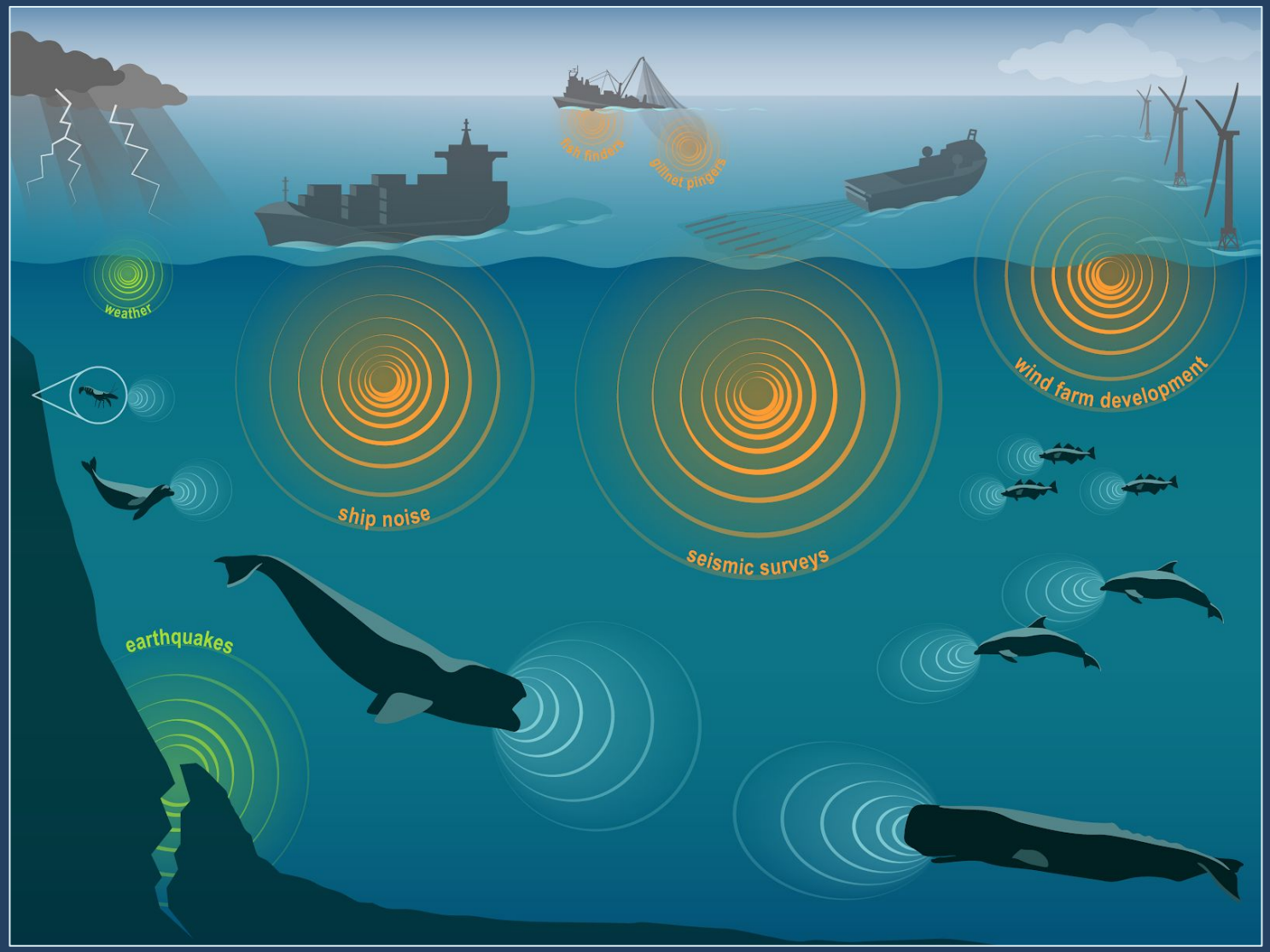
Weiss et al. *submitted*

Questions to Consider when using PAM

1. **What are your Species of Interest?**
2. What are your PAM Recording Technologies ?
3. What are your PAM System Requirements?
4. What is your PAM Design?
5. What information does your PAM Data provide?
6. How will you Report and Archive your PAM data?

1. Multi-Species & Ecological Focus

- ESA listed large whales (sei, fin, blue, sperm, right whales)
- Other marine mammals
- Soniferous Fish
- Invertebrates



Graphic: NOAA Fisheries

- Anthropogenic Sounds
- Environmental

1. What Are your species of interest?

Killer Whale

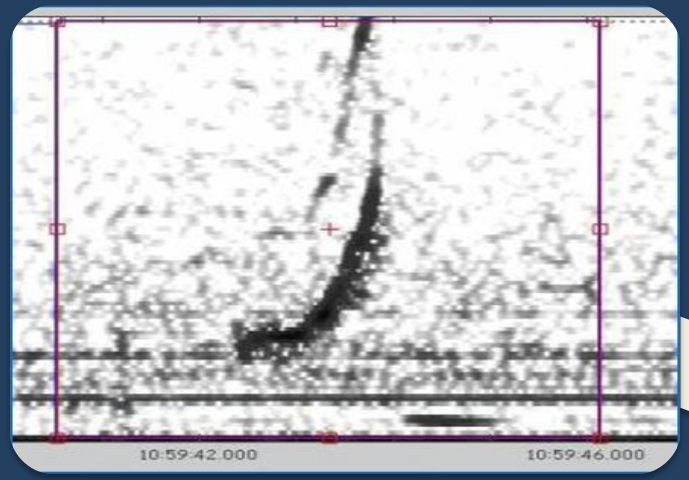
Ross Seal

Haddock

Humpback Whale

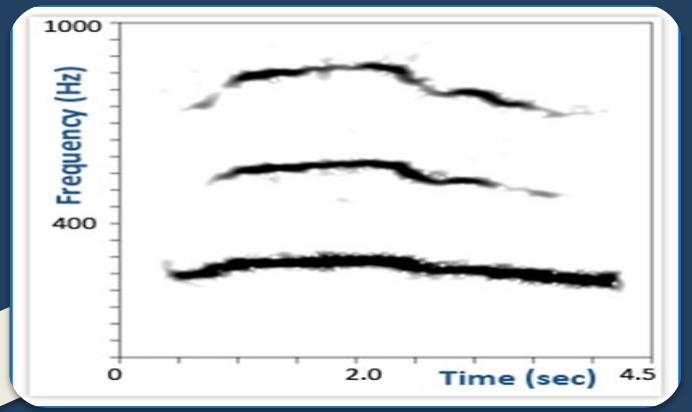
Minke Whale

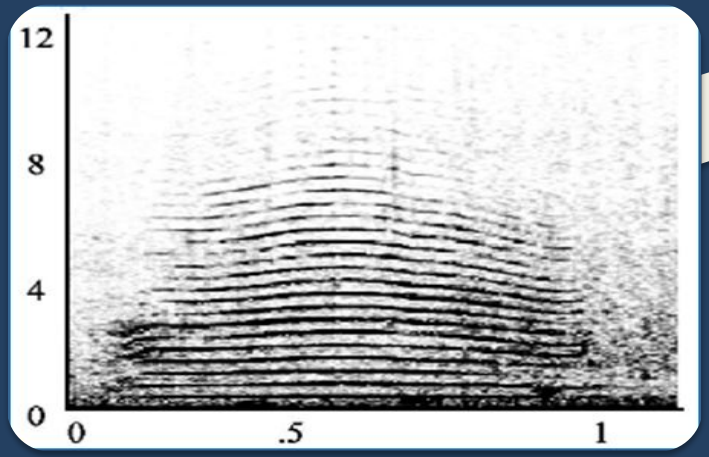
1. What Are your call types of interest?



Upcall

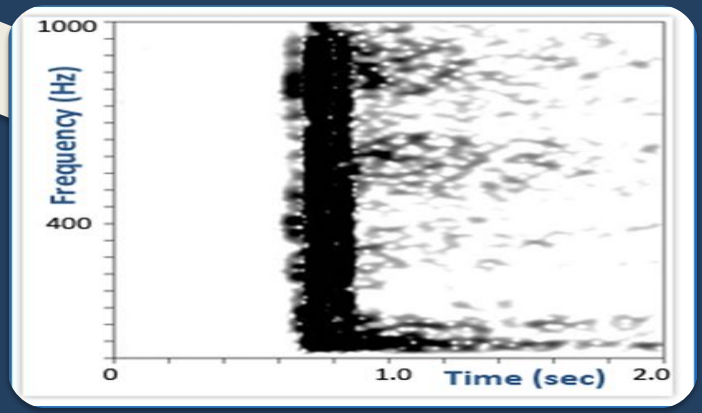
Moan





Scream

Gunshot



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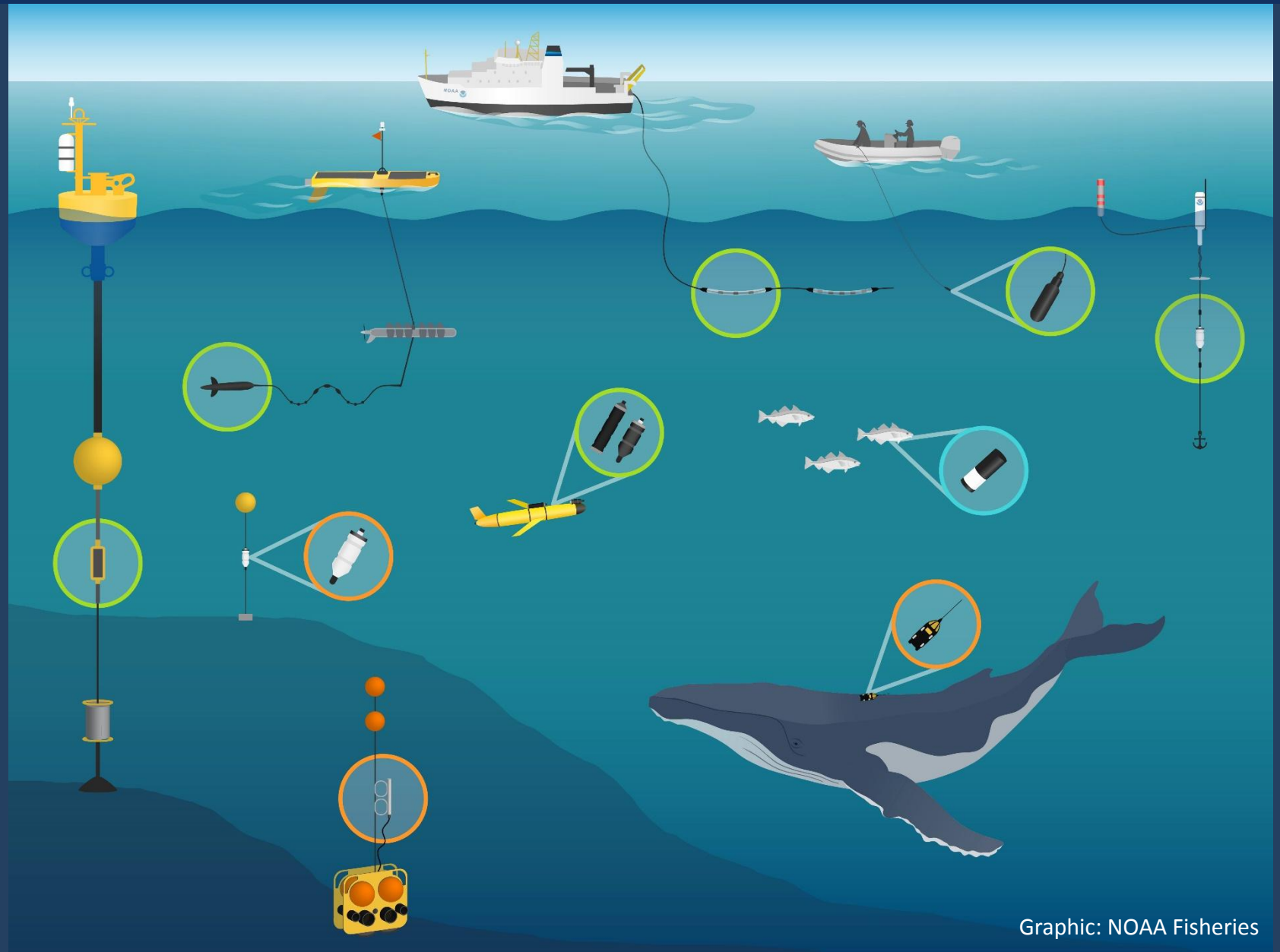
6. How will you Report and Archive your PAM data?

2. PAM Data Collection: technologies

ARCHIVAL

- Bottom-mounted recorders
- Acoustic tags
- Telemetry tags (active)



Graphic: NOAA Fisheries

REAL TIME

- Moored buoys
- Gliders
- Towed Arrays
- Drop hydrophones
- Drifting buoys

Questions to Consider when using PAM

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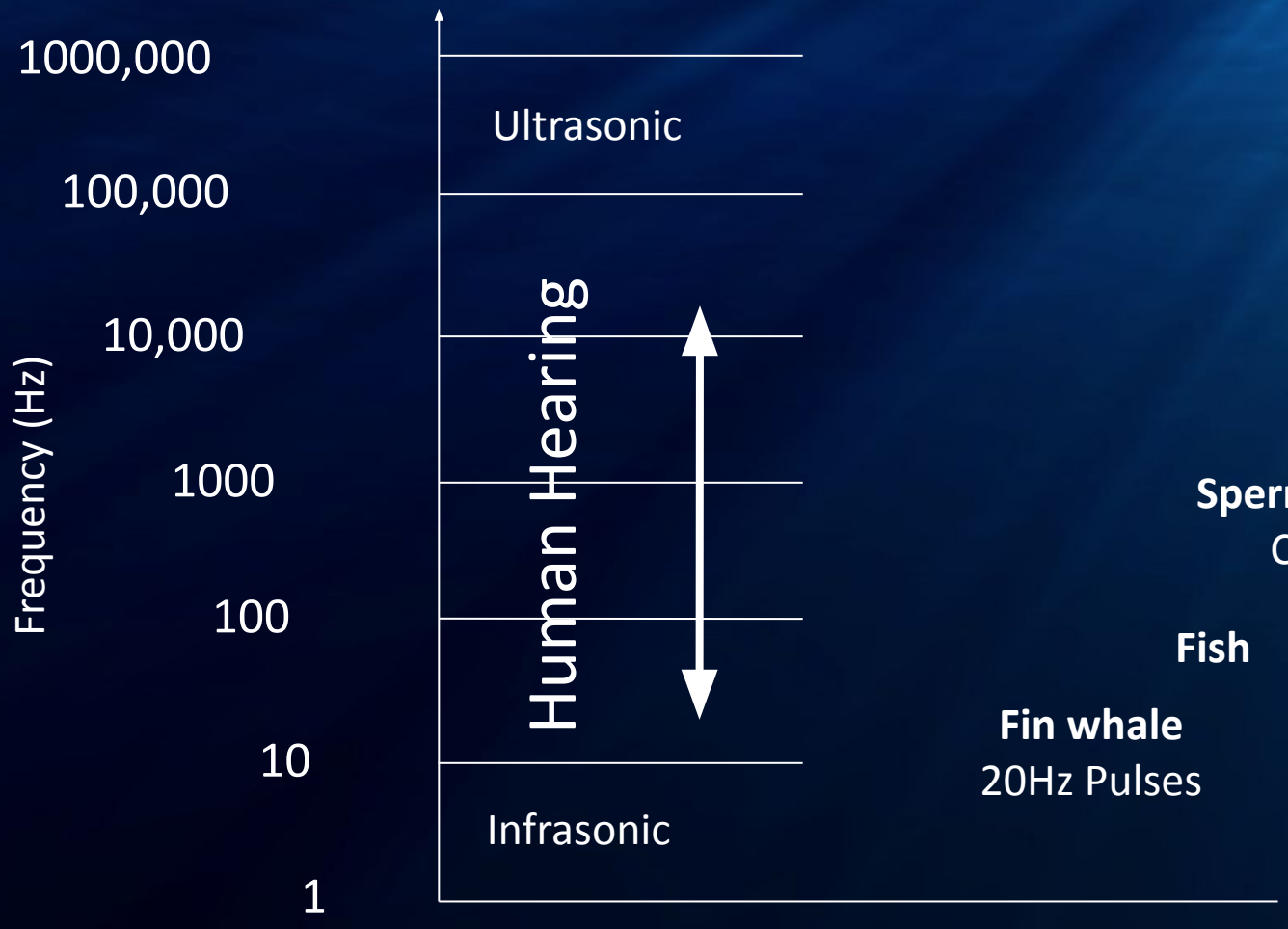
4. Species Frequency Range



Harbor porpoise
Ultrasonic clicks

Dolphins
Whistles & clicks

Sperm whale
Clicks

Fish

Fin whale
20Hz Pulses

Graphics courtesy of R. Swift

Questions to Consider when using PAM

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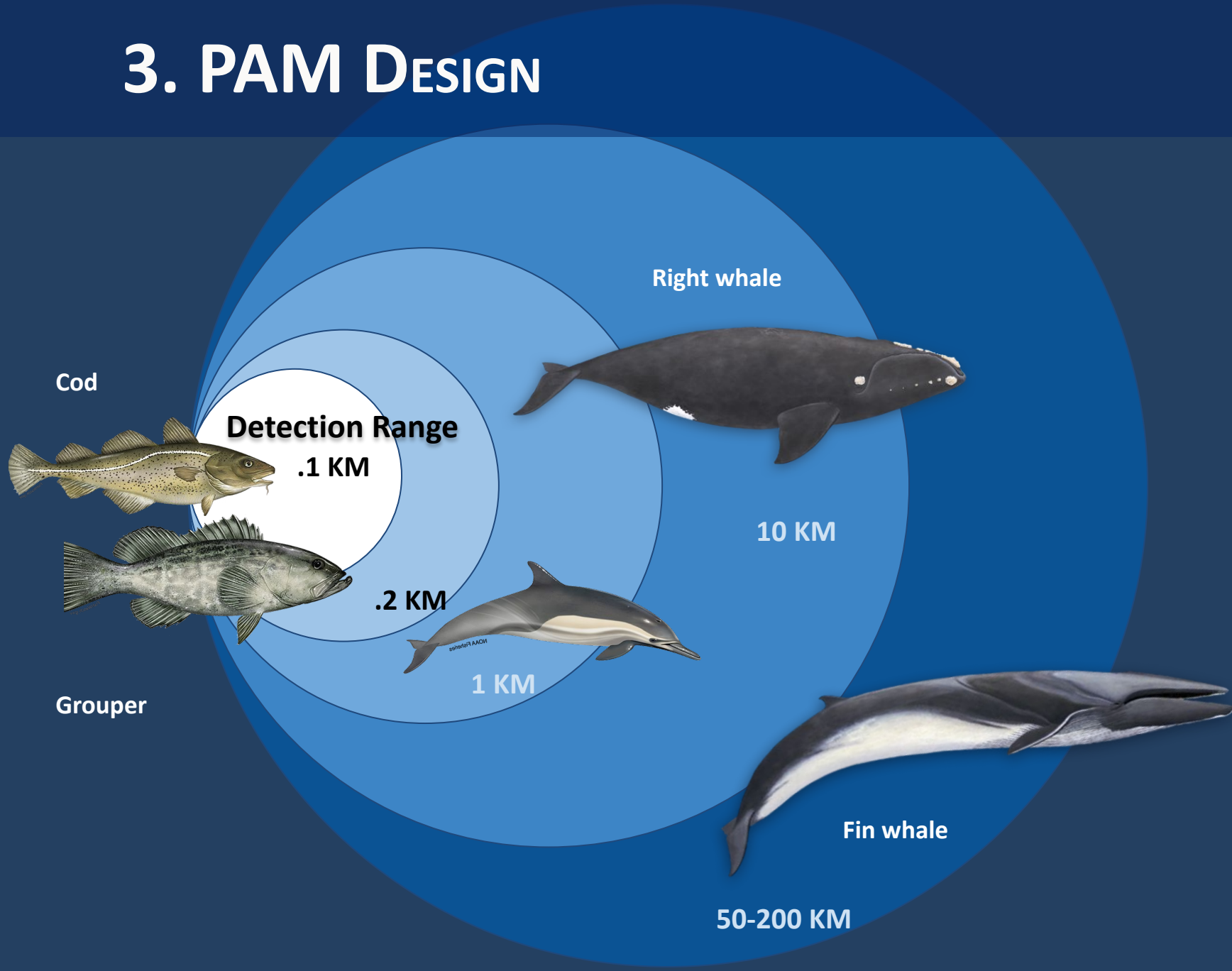
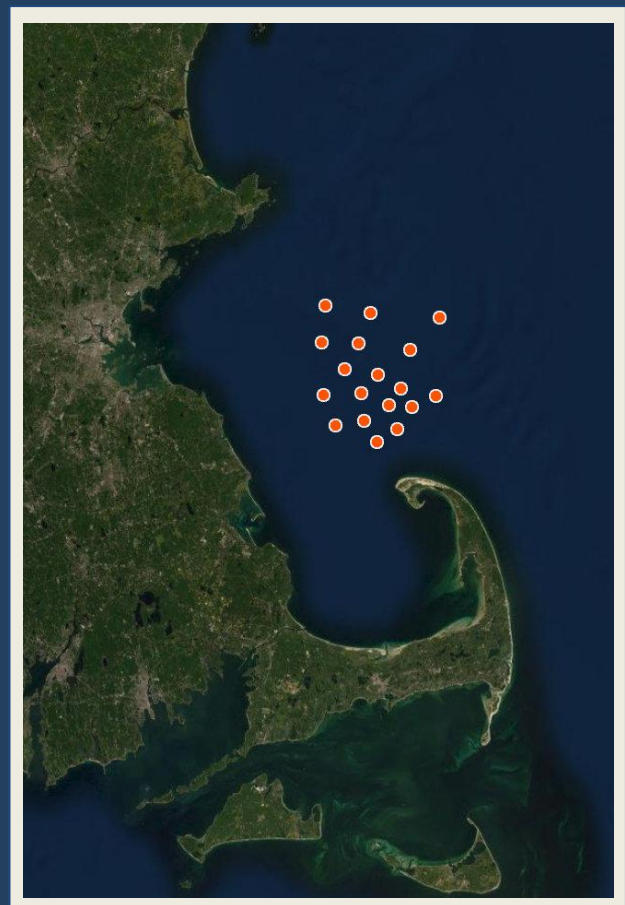
3. PAM Design

How far can your species be heard on average?

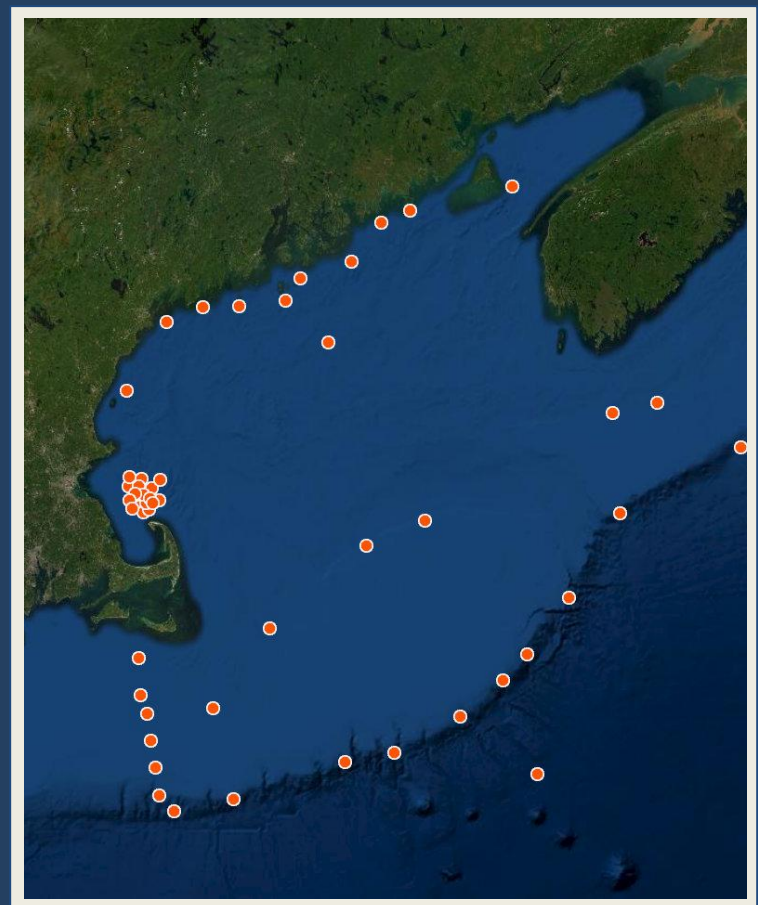


3. PAM Design

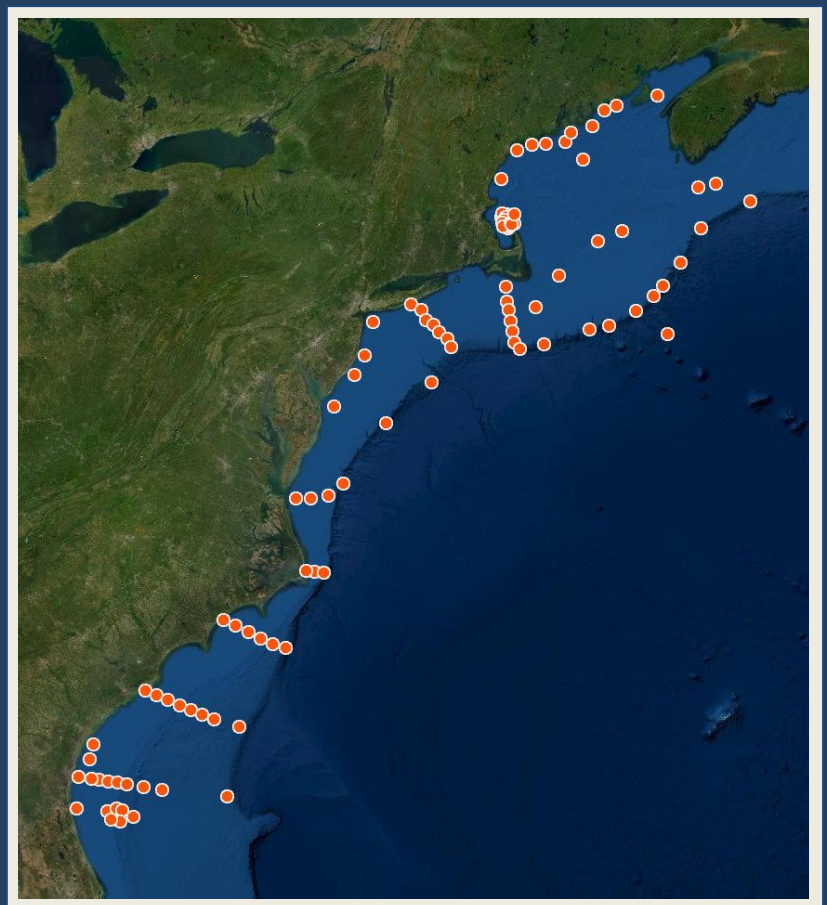
Site



Regional



Ocean



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Archival Vs Real Time

ARCHIVAL

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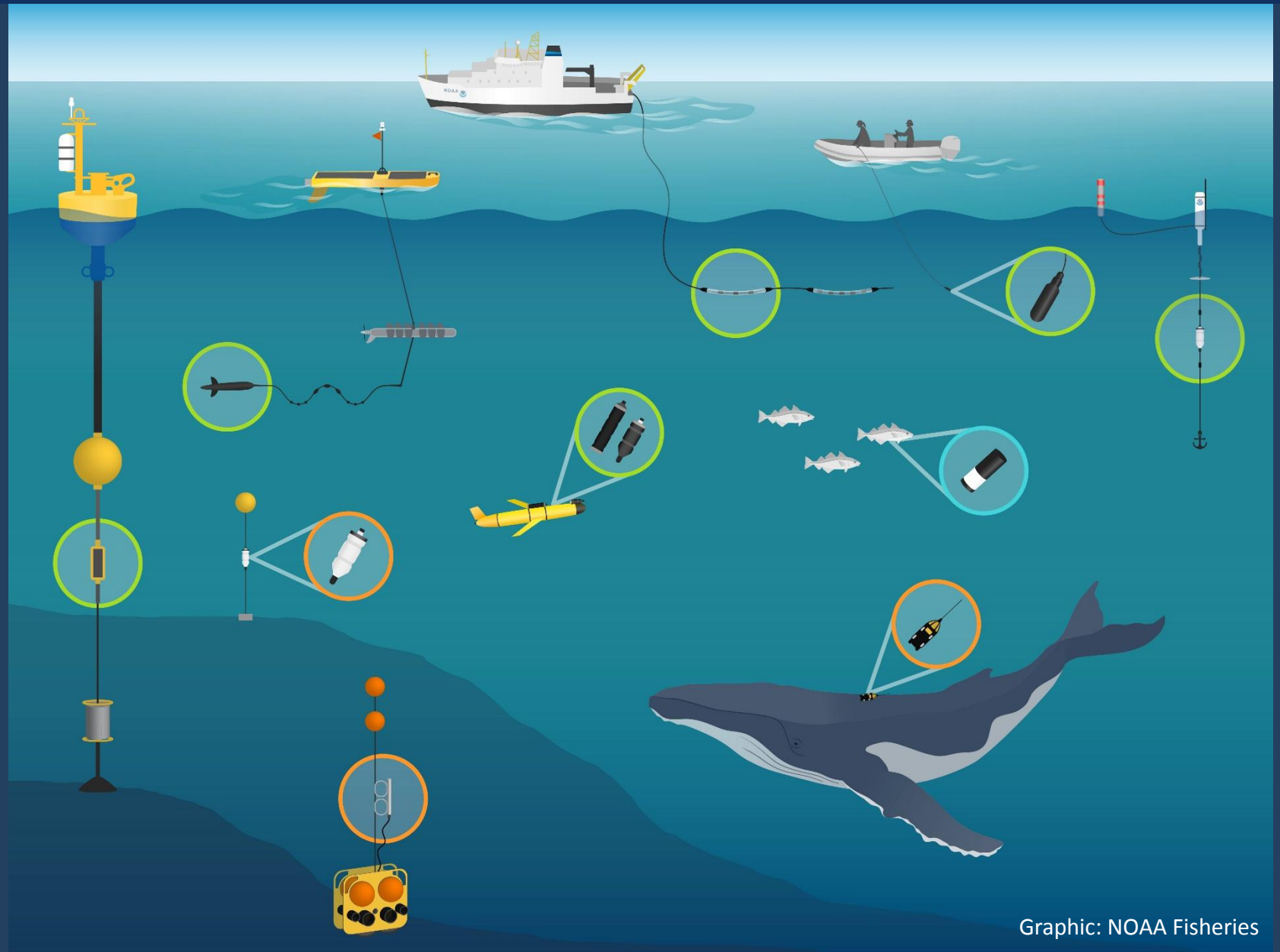

Graphic: NOAA Fisheries

REAL TIME

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- Drop hydrophones
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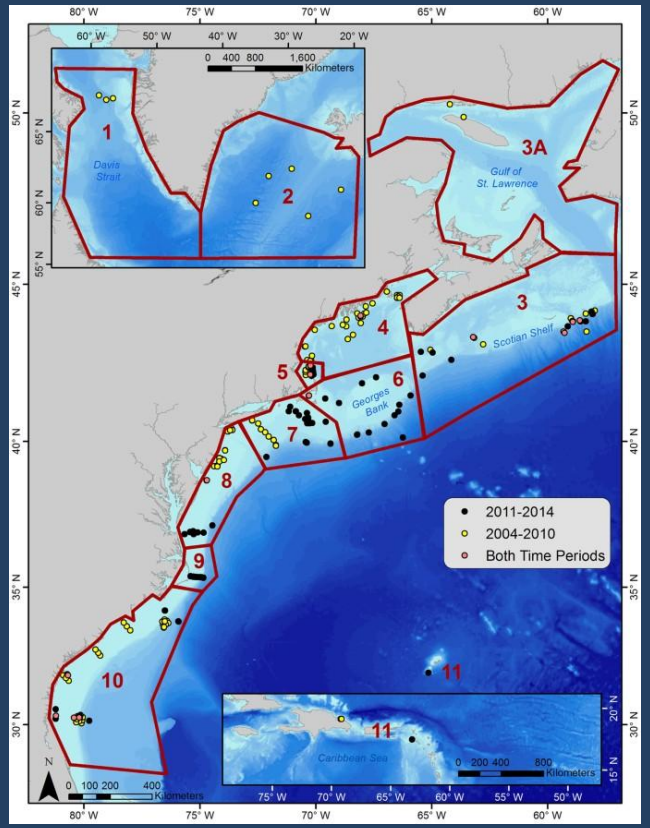
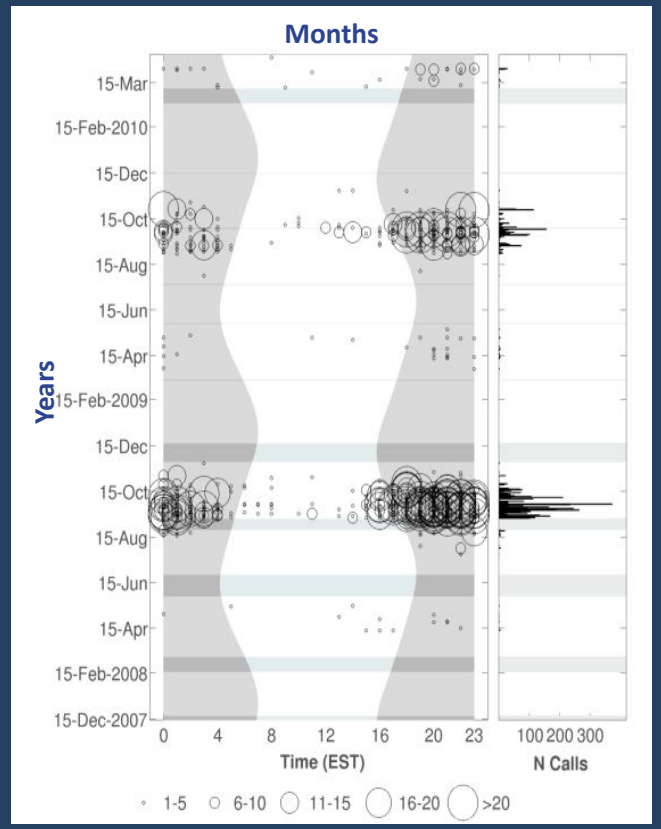
PAM Data

Spatial Coverage



Davis et al. 2017

Long Time Periods



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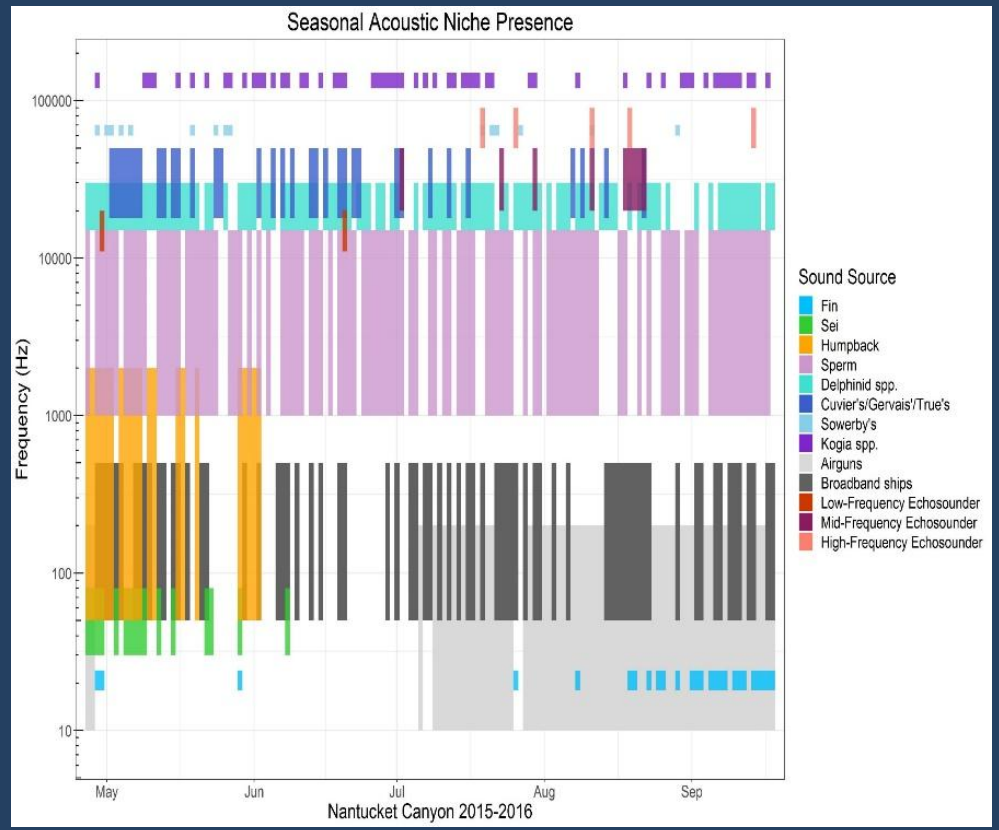
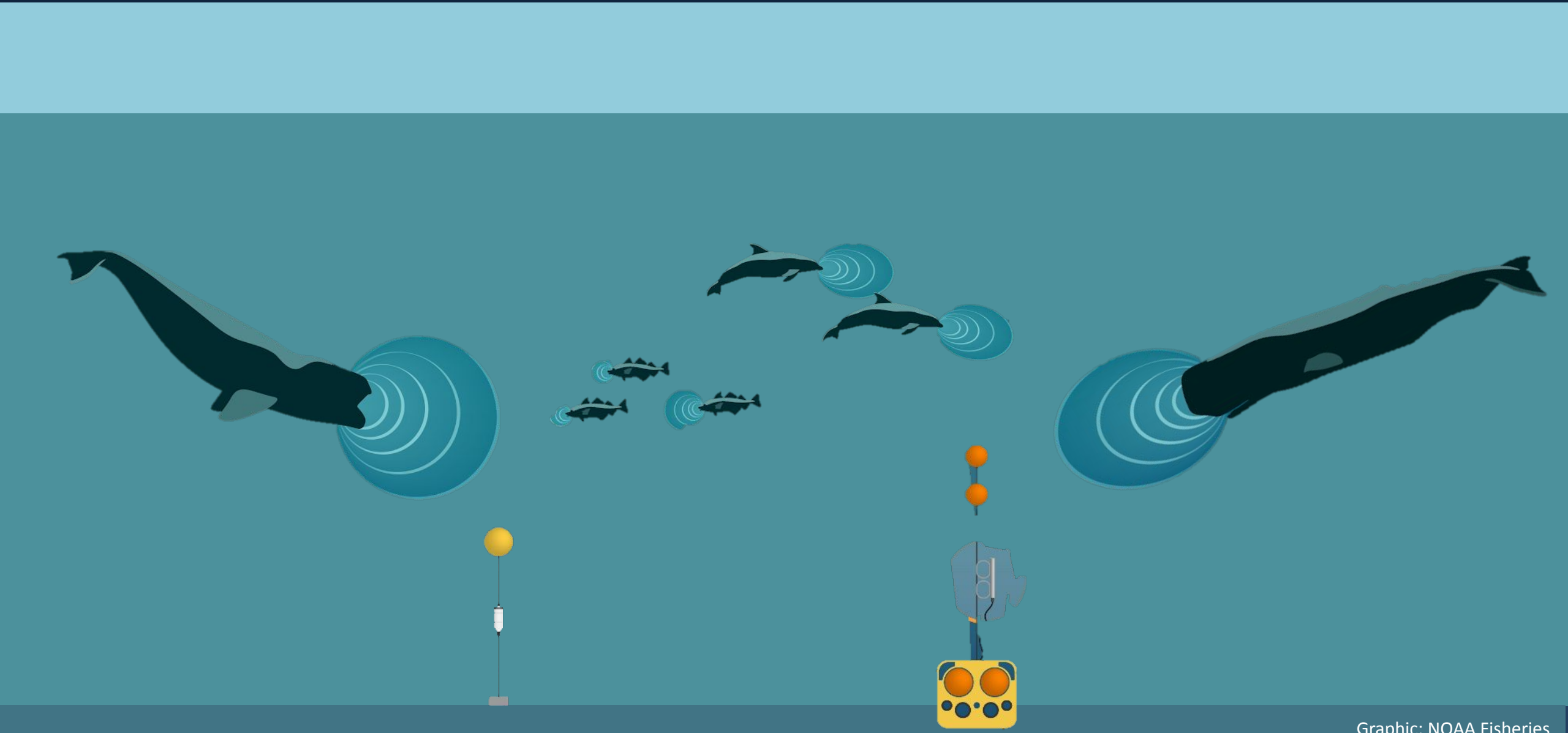
Species Ecology/Soundscape



Weiss et al. *submitted*

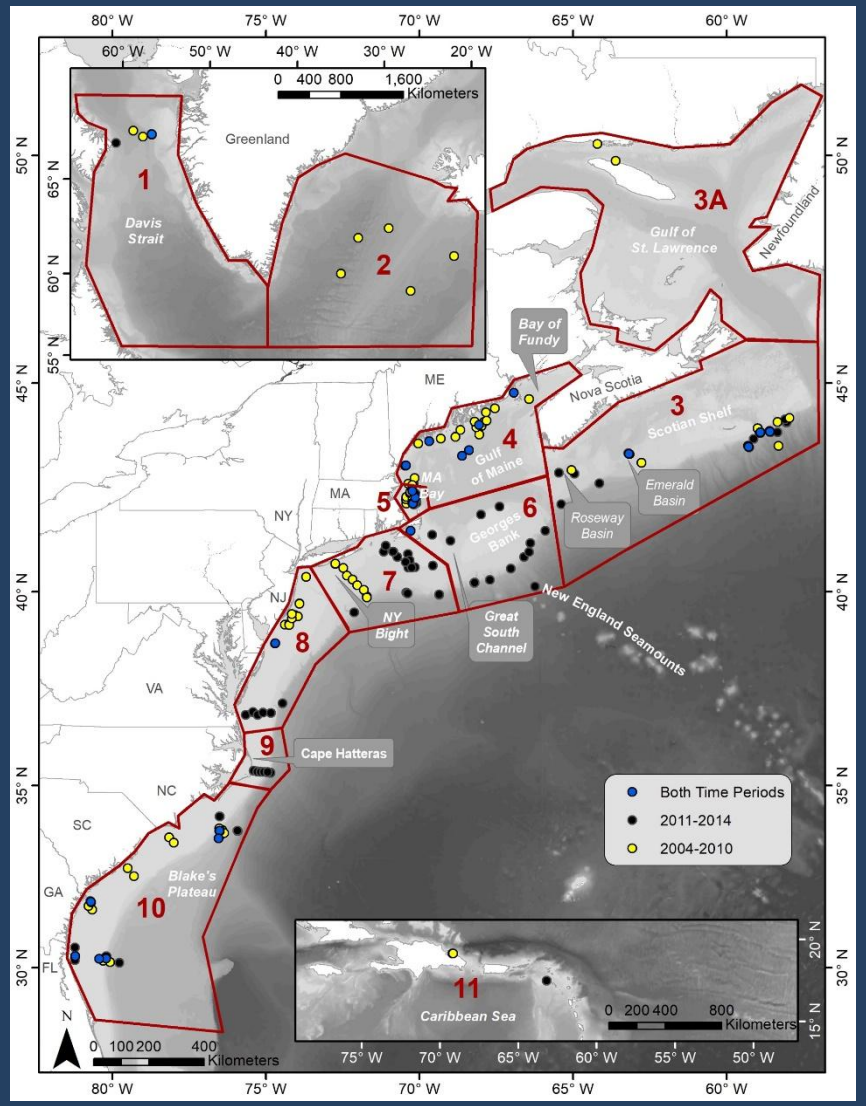
Archival Passive Acoustics



Graphic: NOAA Fisheries

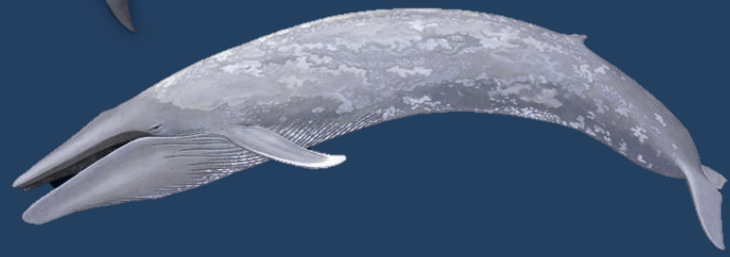
Changing Distributions - Baleen Whales

2004 – 2014



North Atlantic right whales

fin whales



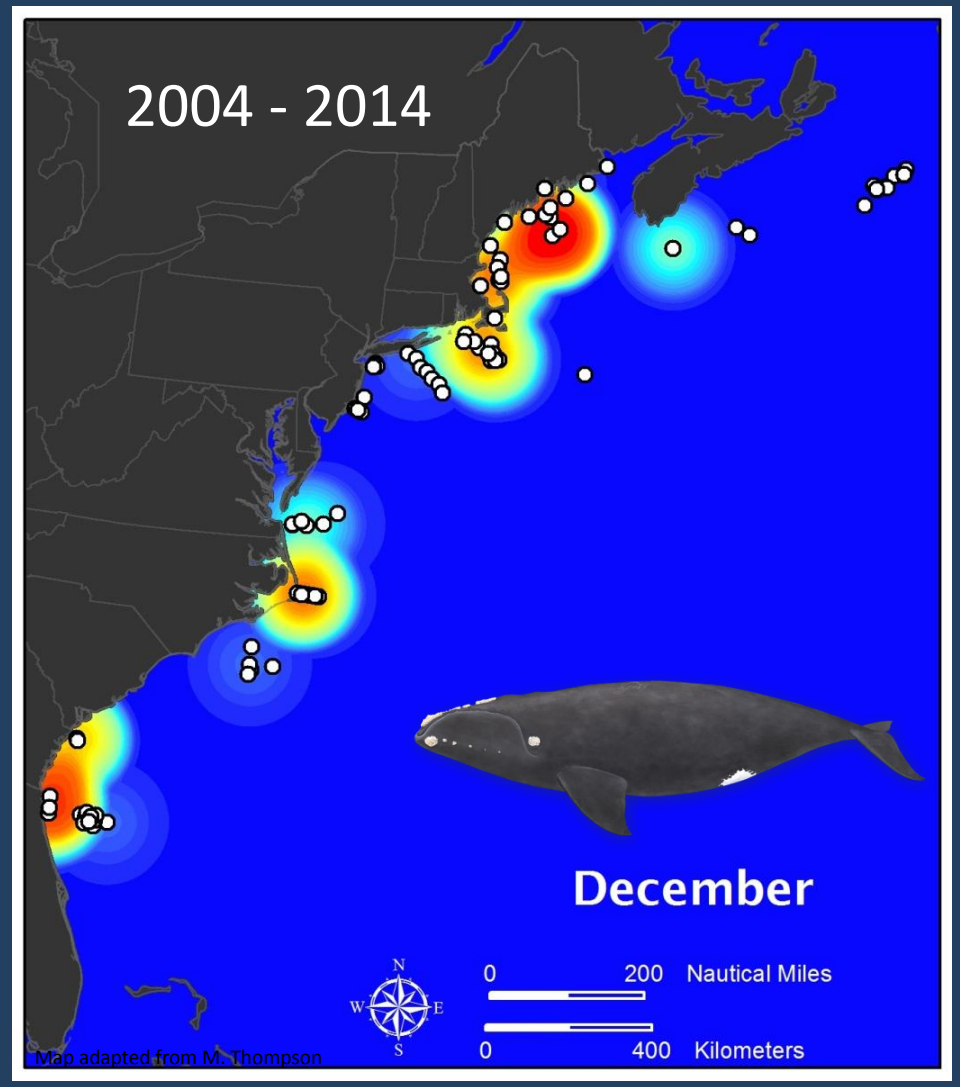
blue whales

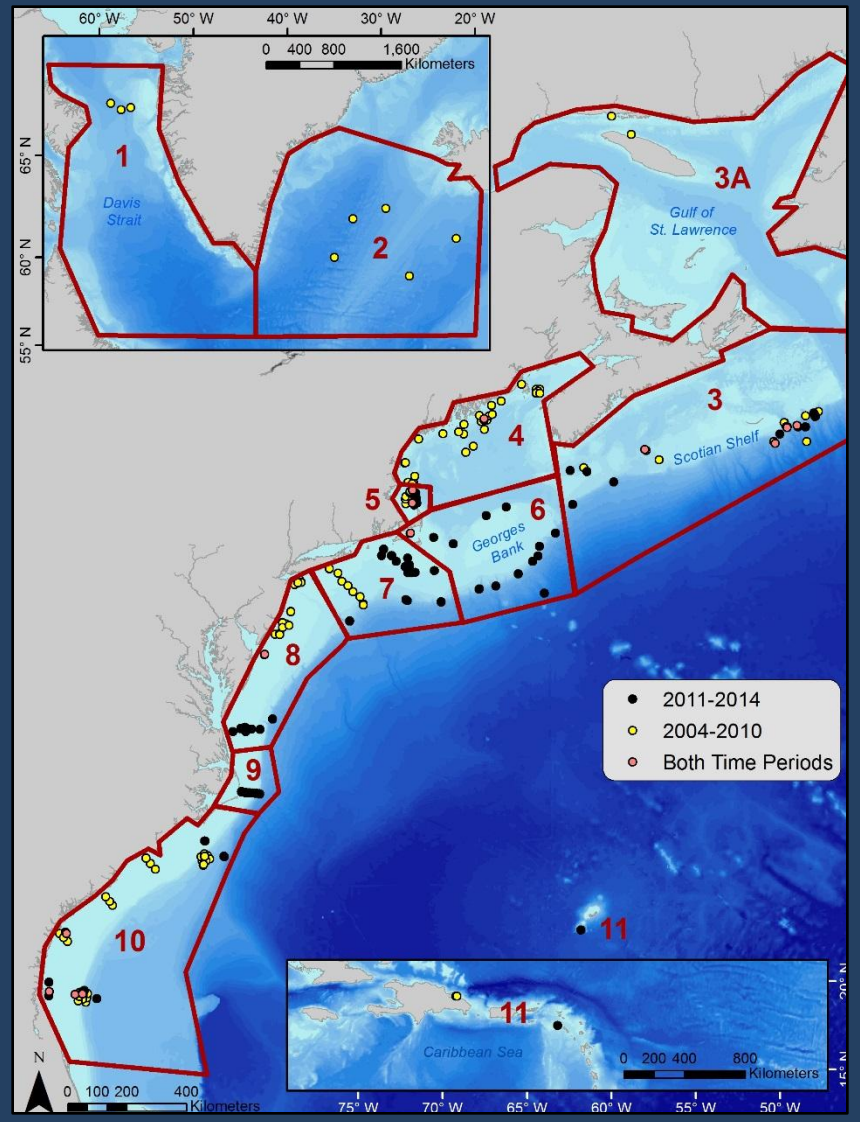
humpback whales

sei whales

Davis et al. 2020. Exploring movement patterns and changing distributions of baleen whales in the western North Atlantic using a decade of passive acoustic data. Global Change Biology 26: 4812-4840

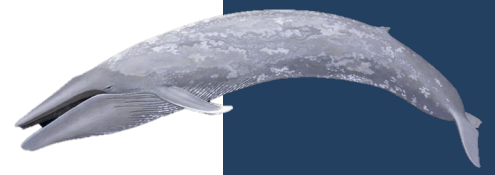
NARW Long Term Changes: Spatial



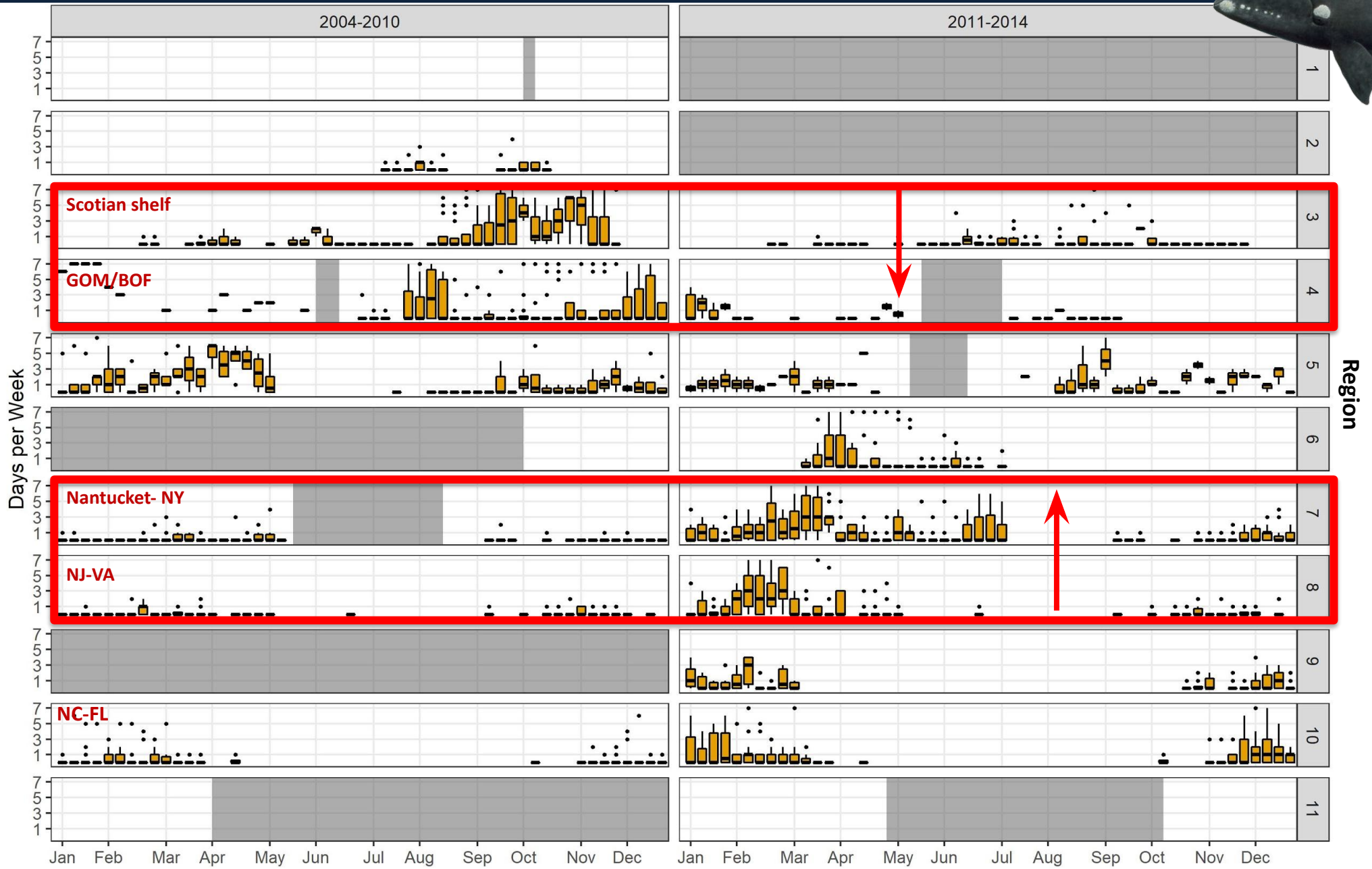


Davis et al. 2017. Long-term passive acoustic recordings track the changing distribution of North Atlantic right whales. Scientific Reports 7: 13460.

Baleen Whales: Temporal



NARW Shifts Across Time

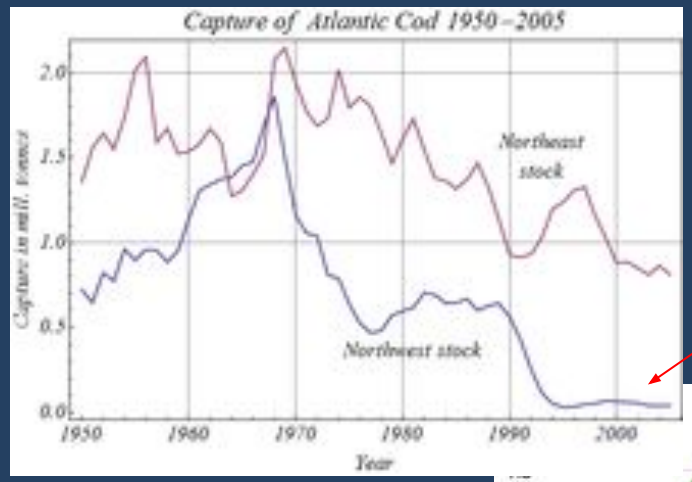


Davis et al. 2017. Scientific Reports

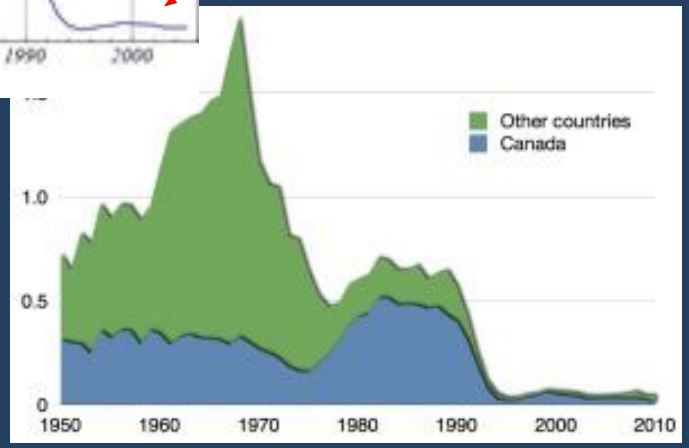
THE POWER OF ARCHIVAL PAM

- Collaboration is *essential*
  (33+ scientists, 19+ organizations contributed data)
- Although not collected for the same purpose data still very valuable at a broad scale
- Detailed records over long time and spatial scales on species we knew very little about
- Able to detect major shifts in movement patterns and distribution.

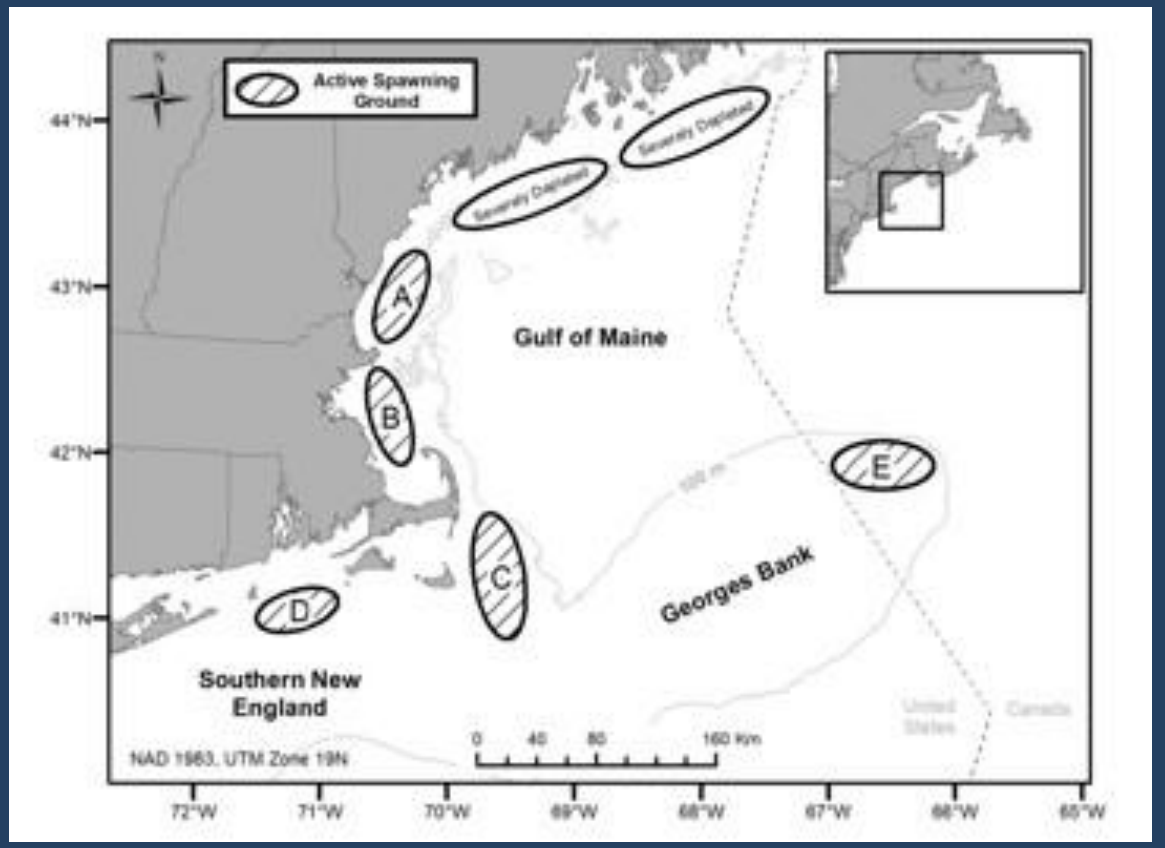
Protecting Spawning aggregations - Fish



North West Atlantic Stock

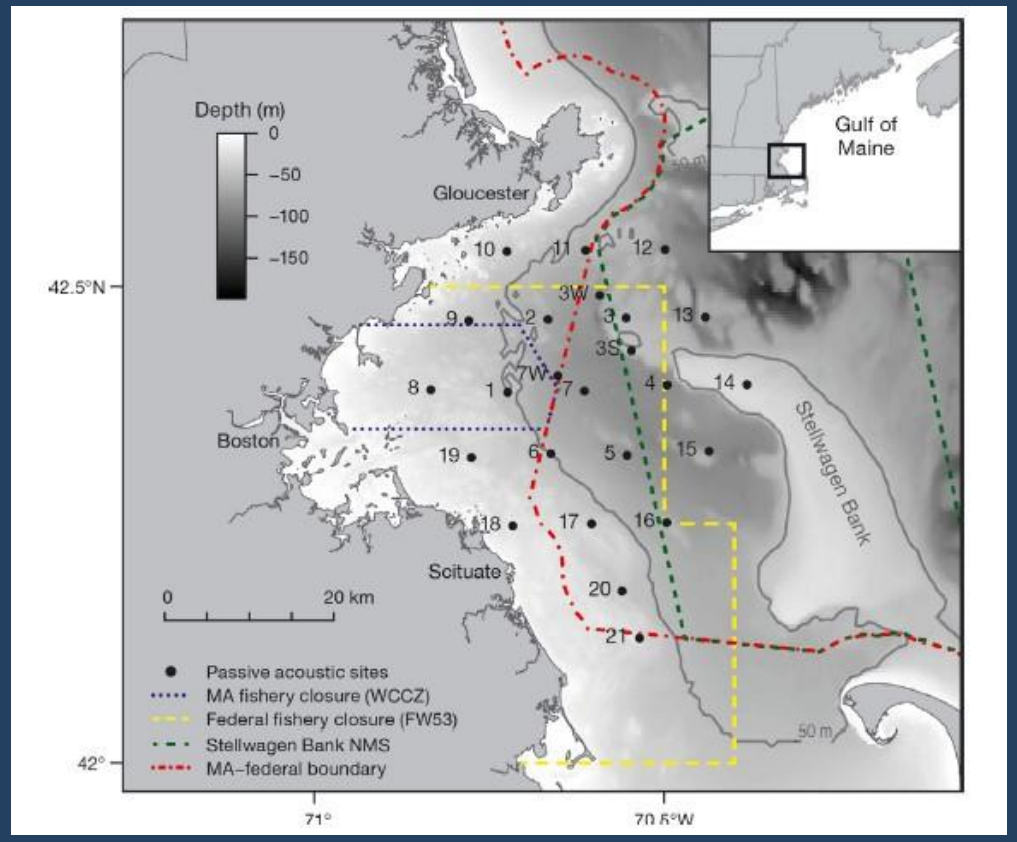


Drastic decrease in catch rate



Zemeckis et al. 2017. *ICES Journal of Marine Science*, *74*(6), 1780-1796.

PAM for Fish Spawning



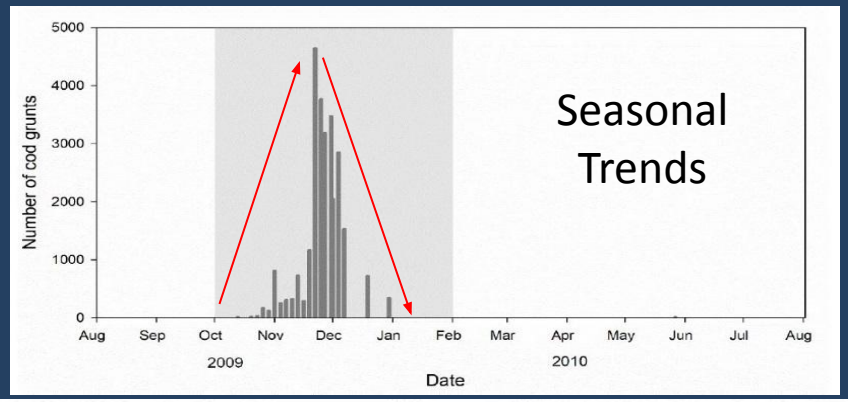
- Form dense aggregations in localized areas
- Strong spawning site fidelity
- Spawning groups are distinct = vulnerable to trawling
- Cod
-

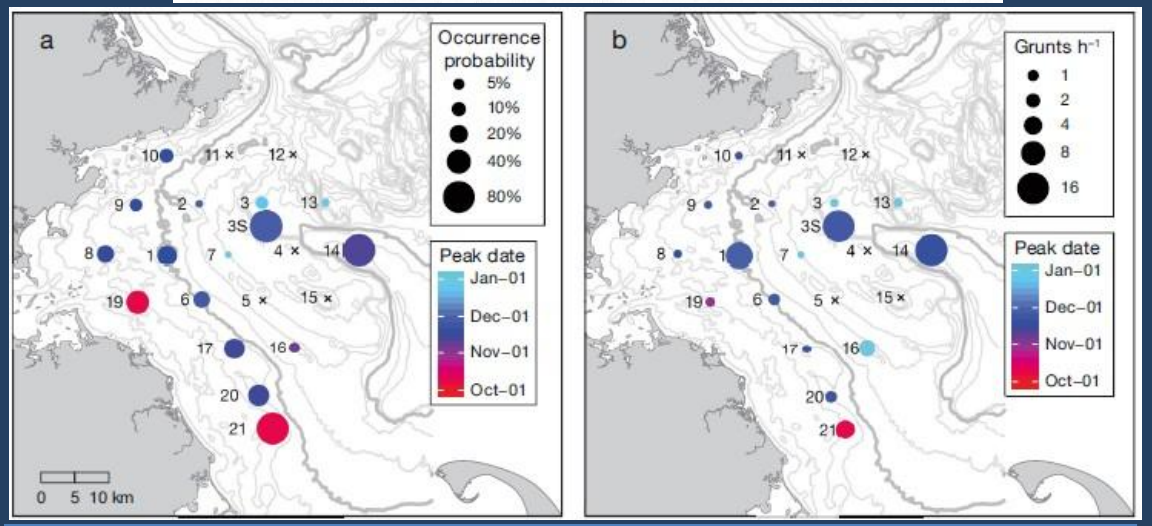
Massachusetts Bay: 2011 - 2018

Haystack formations

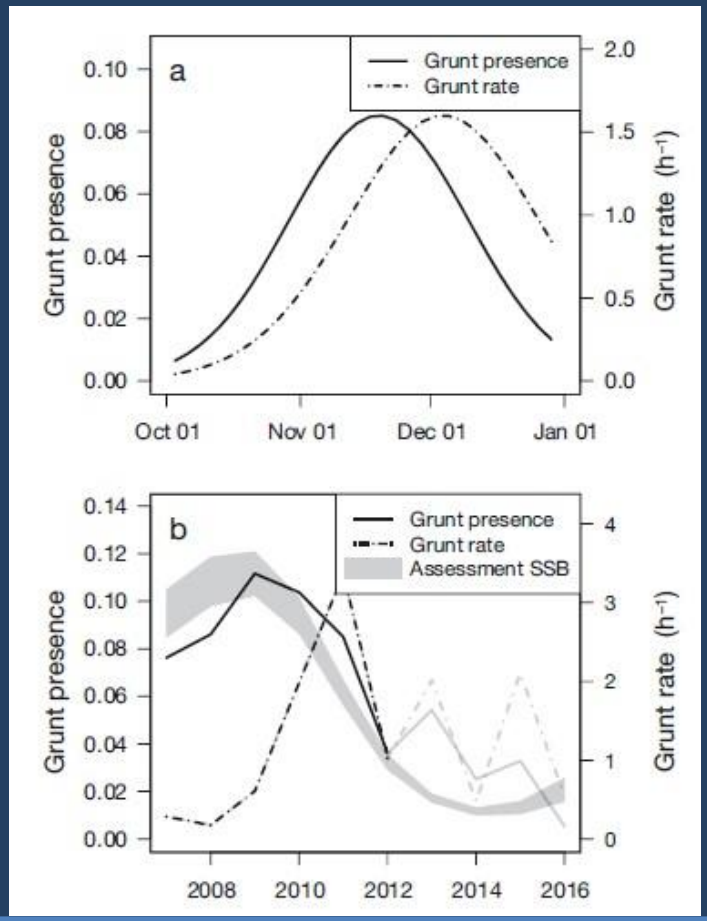
Spawning aggregations – Temporal

2011 - 2018

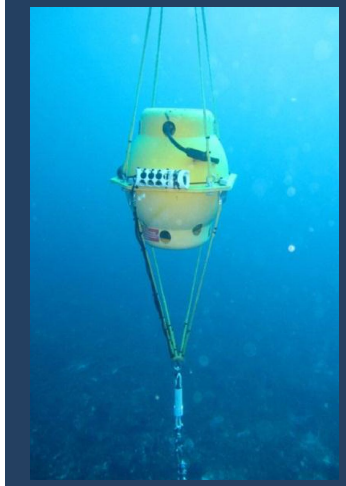




Seasonality and peak spawning

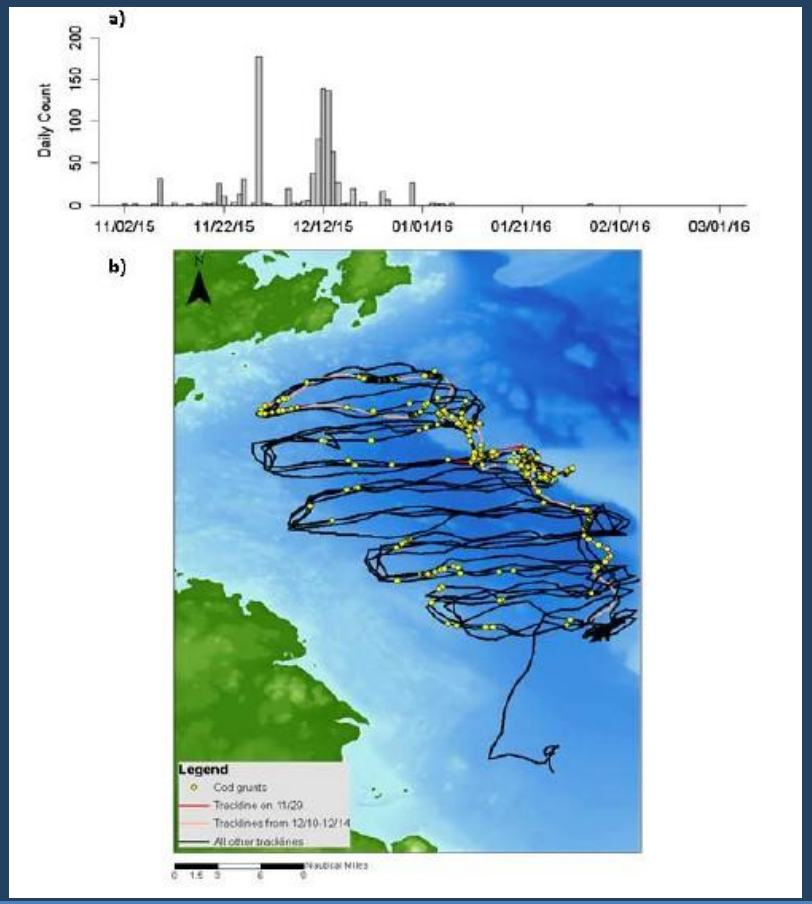


Grunt rate tracks assessment model of population

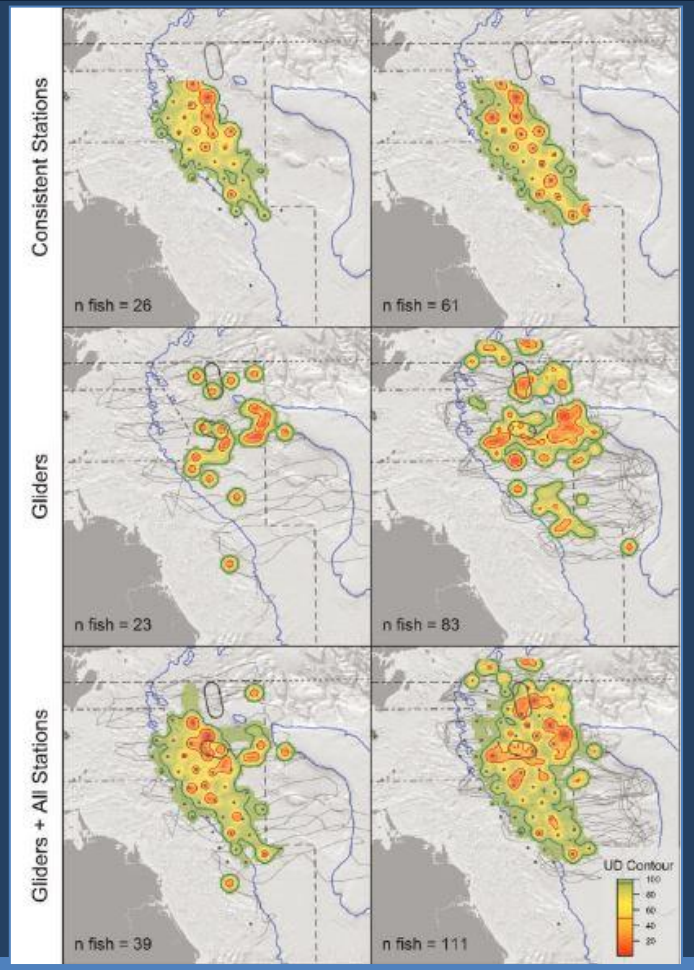


Caiger et al. 2020. Marine Ecology Progress Series, 635, 89-103.

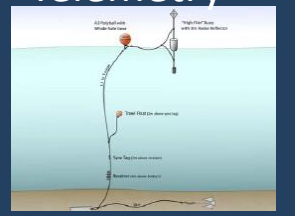
Spawning aggregations - Spatial



Glider tracks and presence of grunts



Telemetry



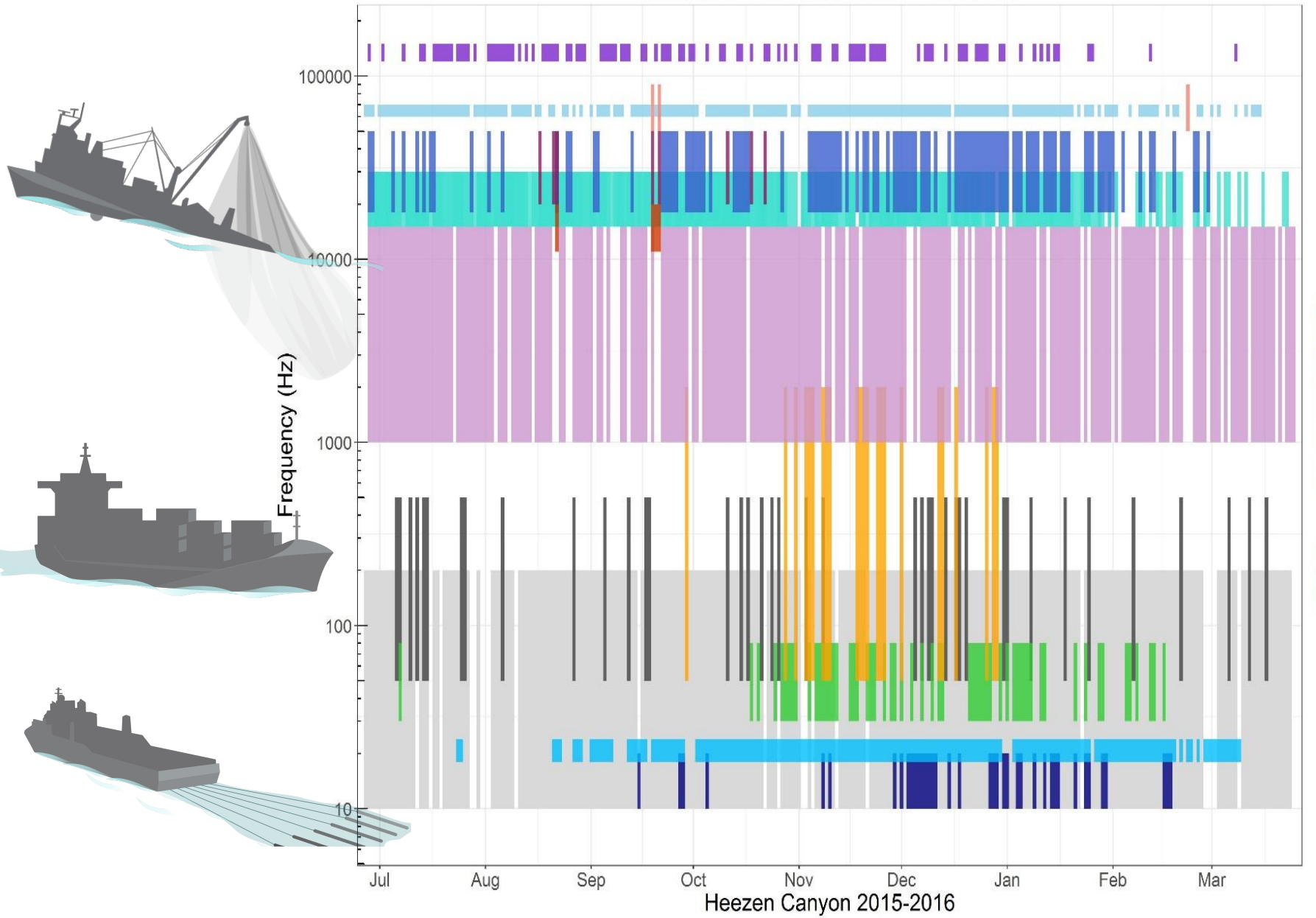
PAM glider

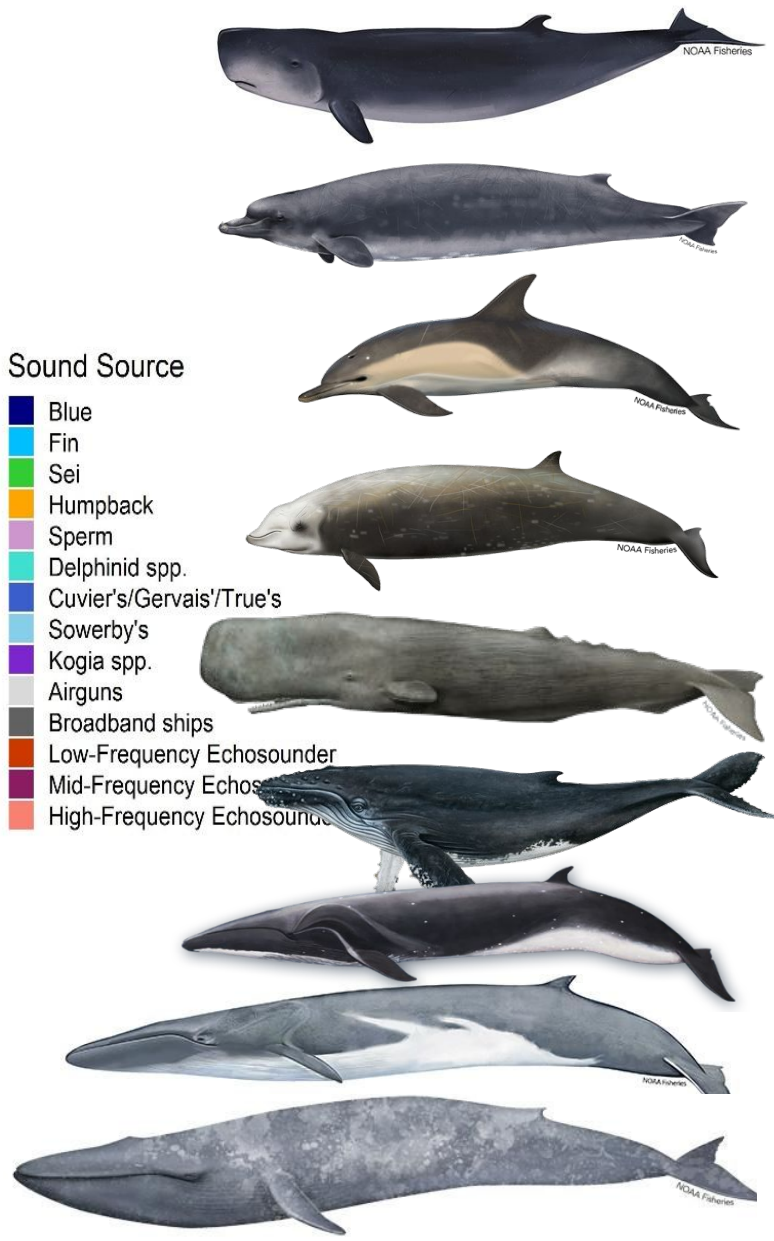
Both

Combining Telemetry + Acoustics !

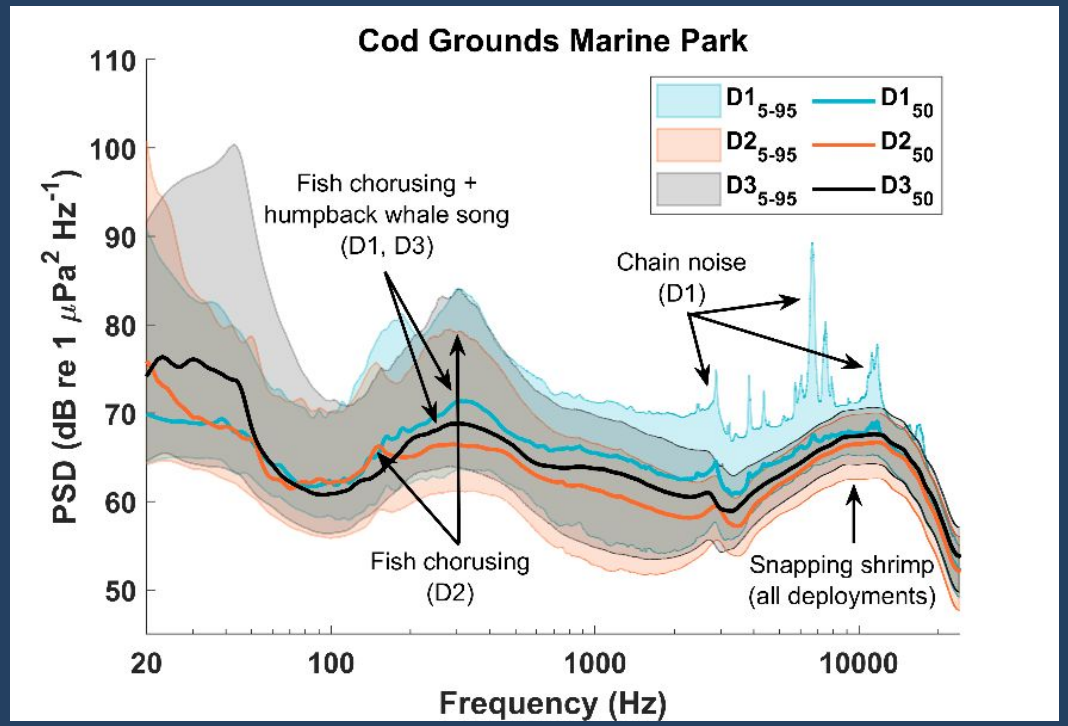
Zemeckis et al. 2019. ICES Journal of Marine Science, 76(6), 1610-1625.

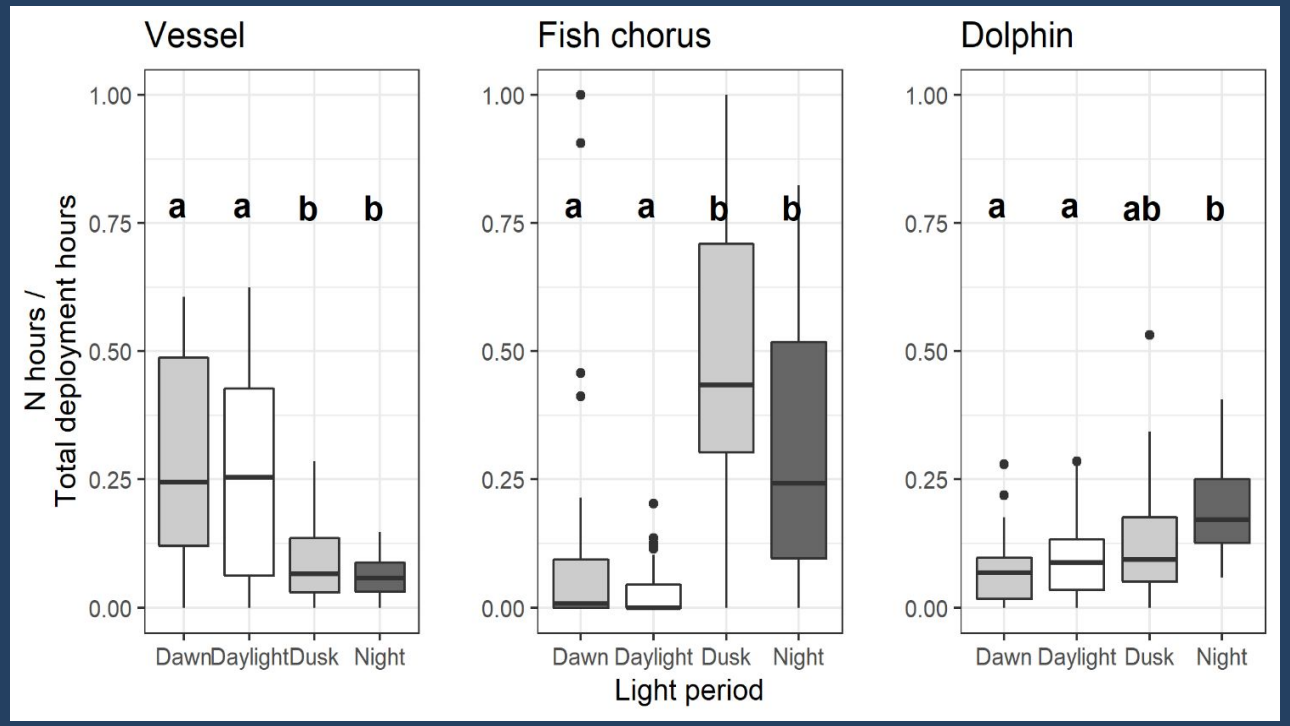
Soundscape Patterns – Species Ecology





Soundscape Patterns – Temporal & Amplitude



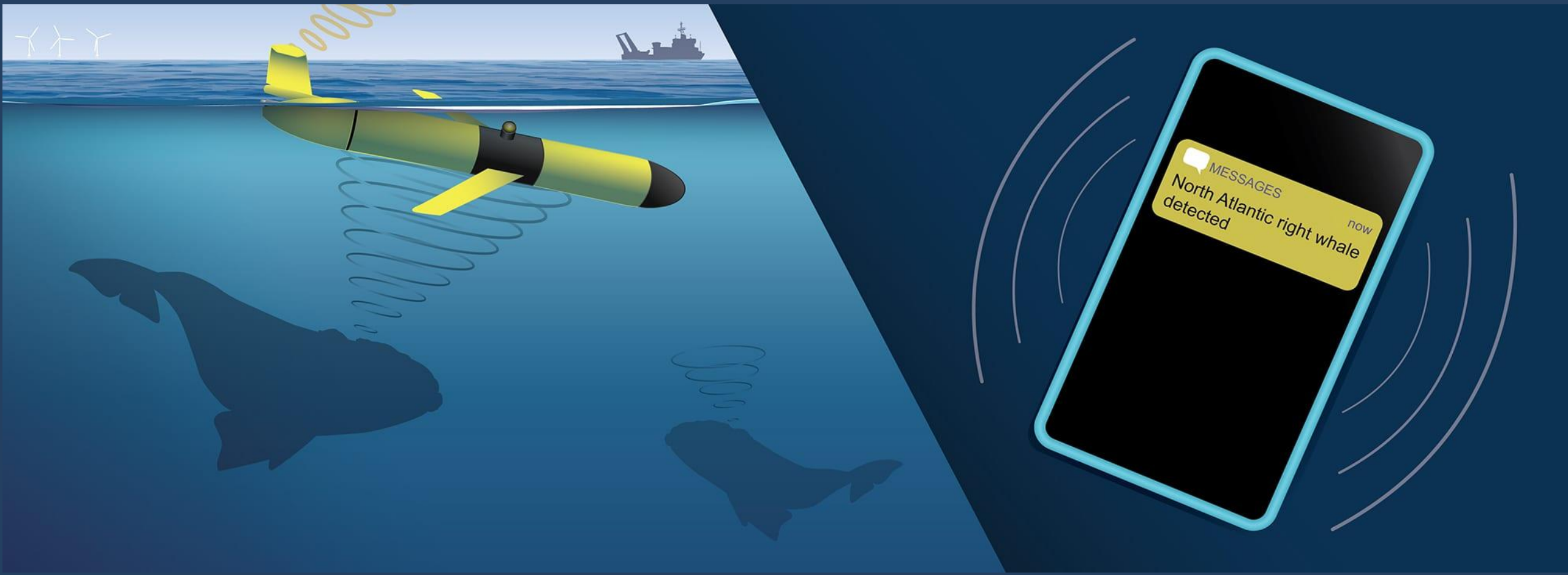


Amplitude presence

Temporal presence

Tracking long term health and changes to a marine ecosystem

Real-Time Passive Acoustics



Graphic: Woods Hole Oceanographic Institution

Real-Time Monitoring & Mitigation

Iridium satellite

Shore-side server

dcs.whoi.edu

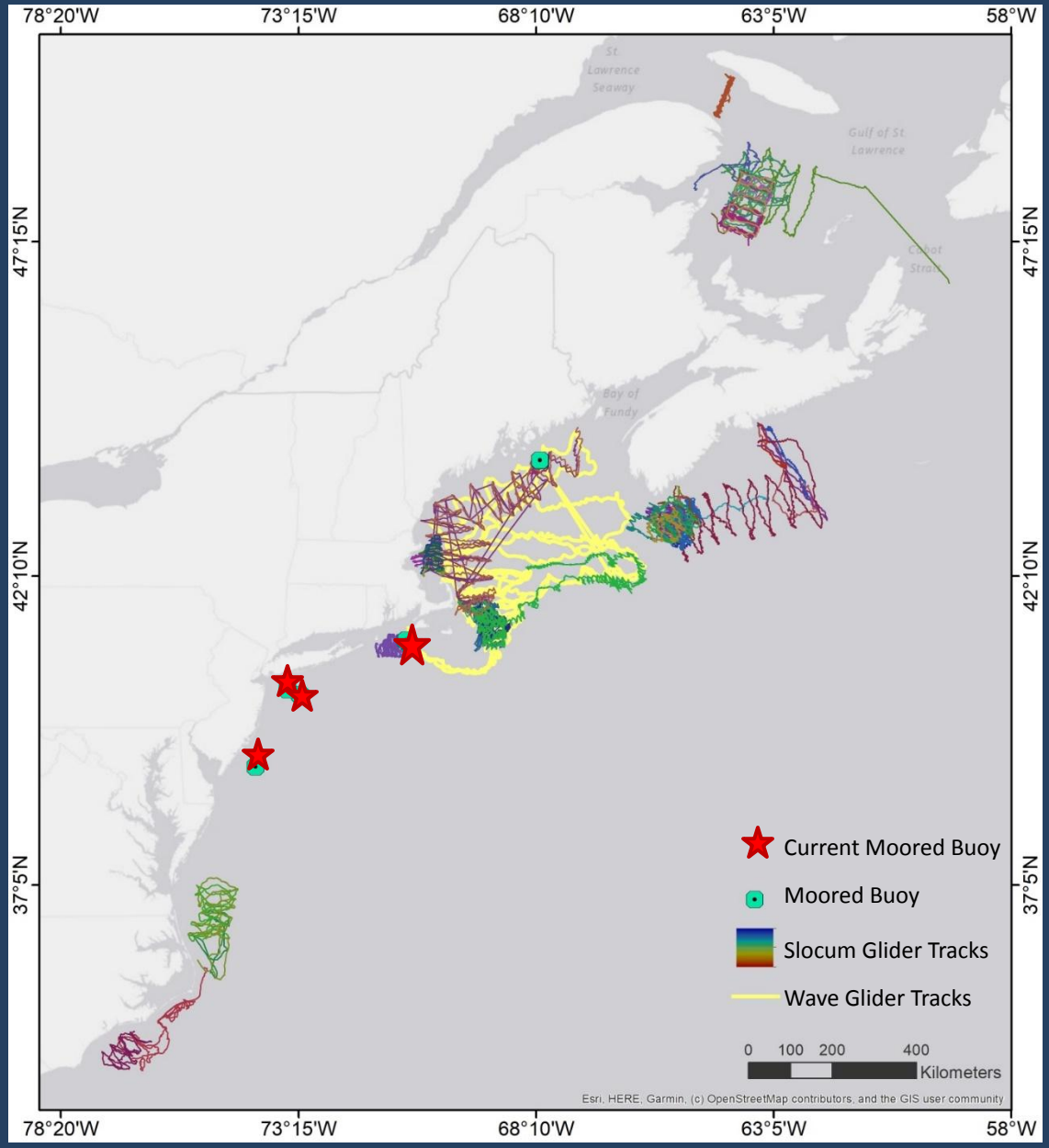
Slocum glider

Moored buoy

Wave glider

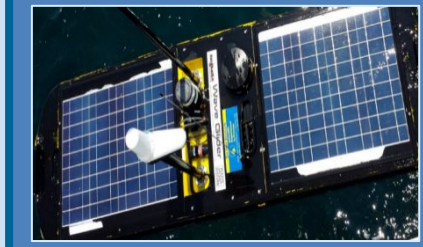
Graphic: WHOI

From Developing Capacity to Operational



U.S. & Canada Real-Time deployments since 2012

Platform	Total # deployments	Total # of days monitored
Slocum Glider	55	2436
Moored Buoy	12	2461
Wave Glider	3	326



Photos: Mark Baumgartner

robots4whales.whoi.edu

Real-Time Acoustics

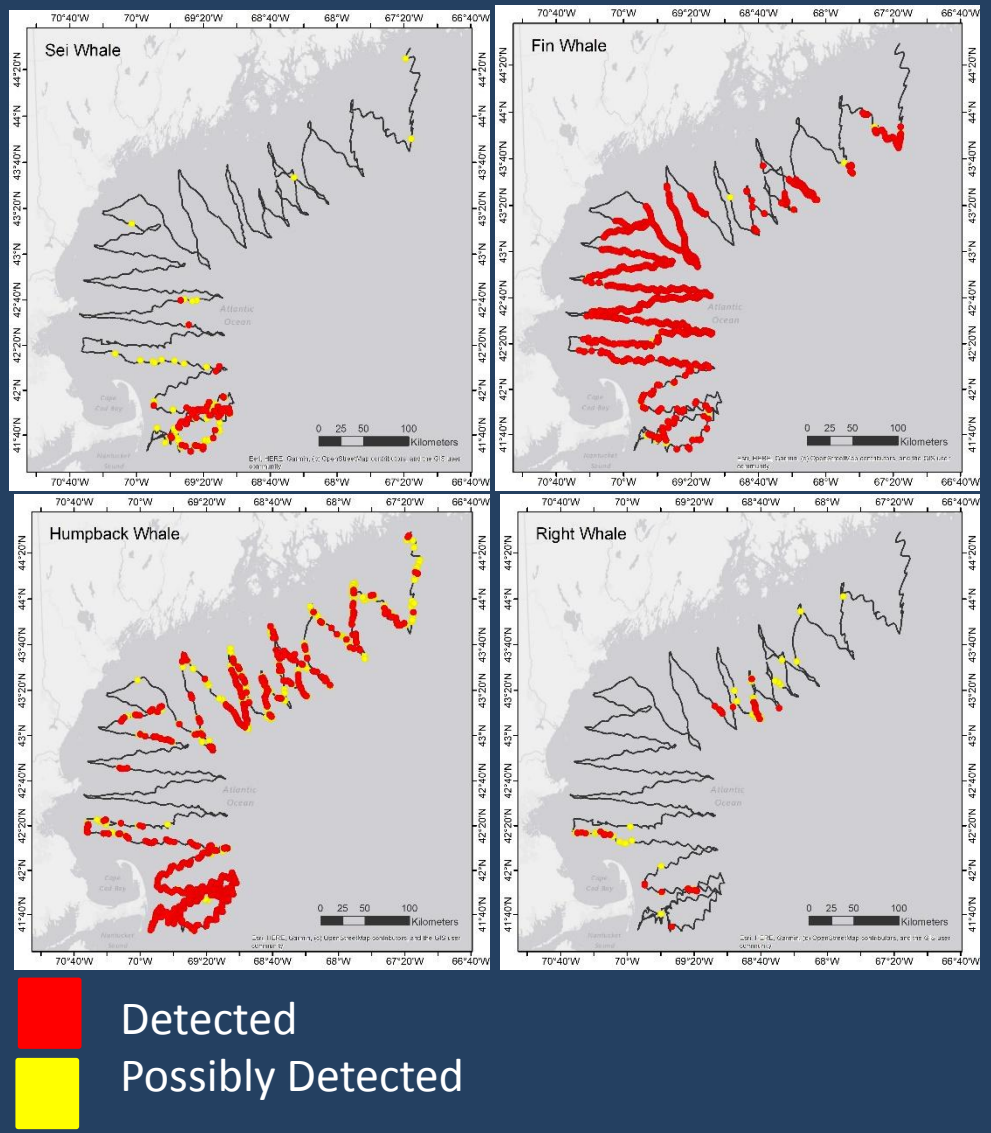
Live now at: robots4whales.whoi.edu

Monitoring:

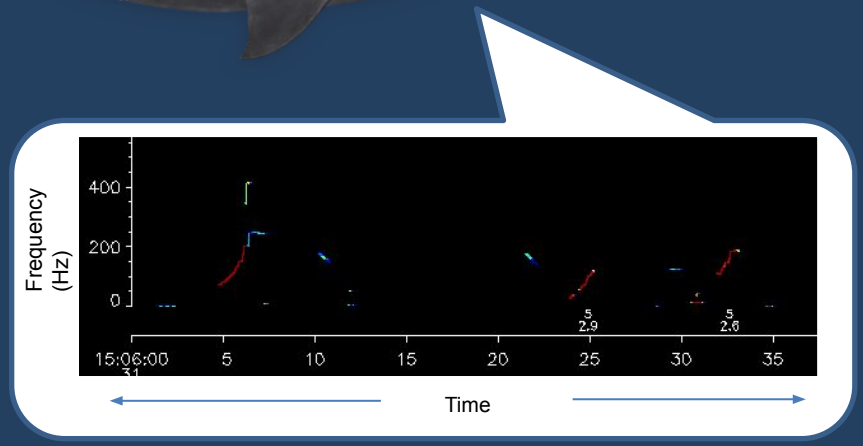
- When and where are they?
- Reduce aerial/vessel survey time spent looking for whales

Mitigation:

- Reduce ship strike risk
- Creation of NMFS ‘Slow Zones’
- Inform operations e.g. wind

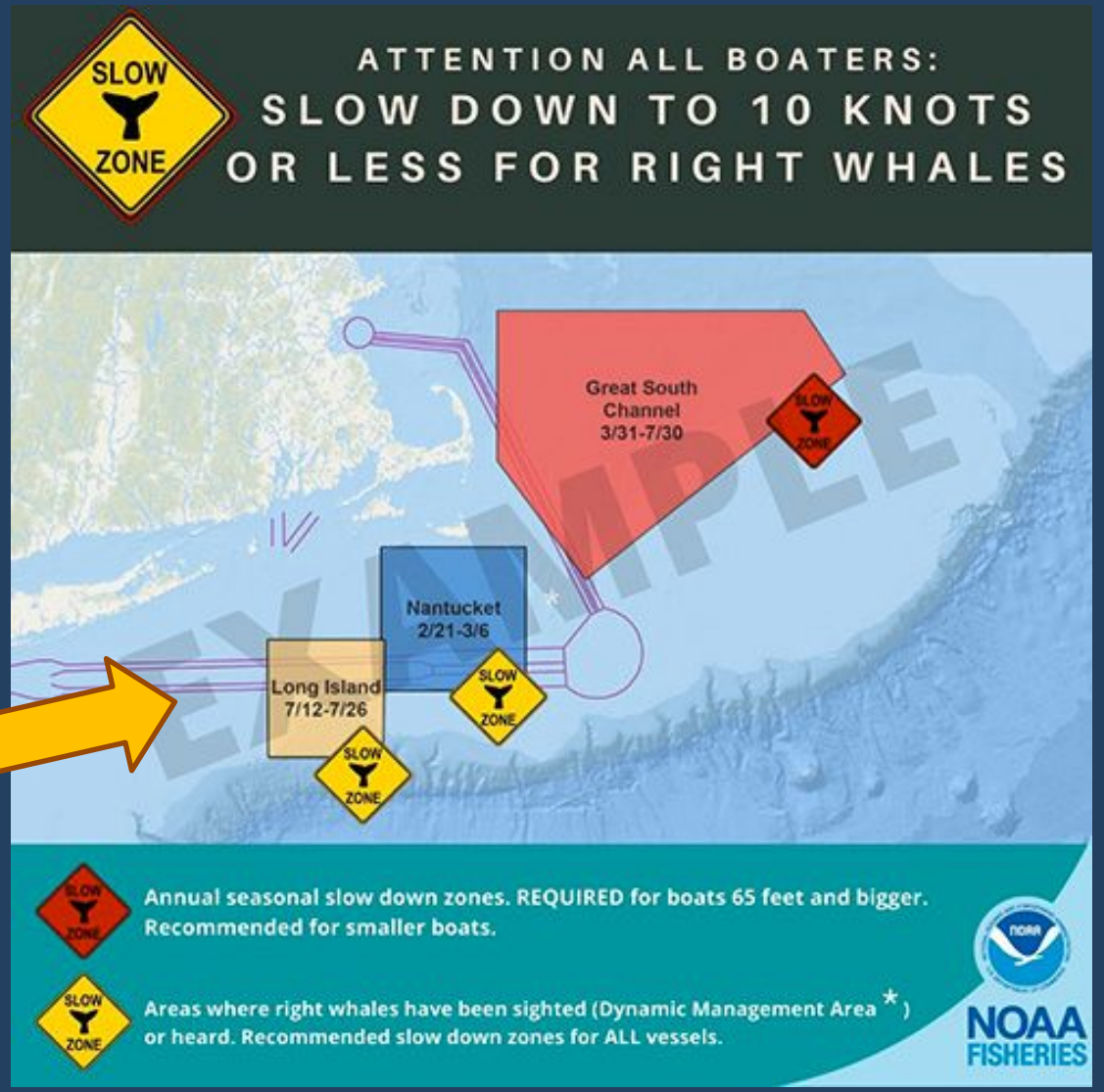


Right Whale Slow Zones



Date	Right whale
04/01/2015	Detected

robots4whales.whoi.edu

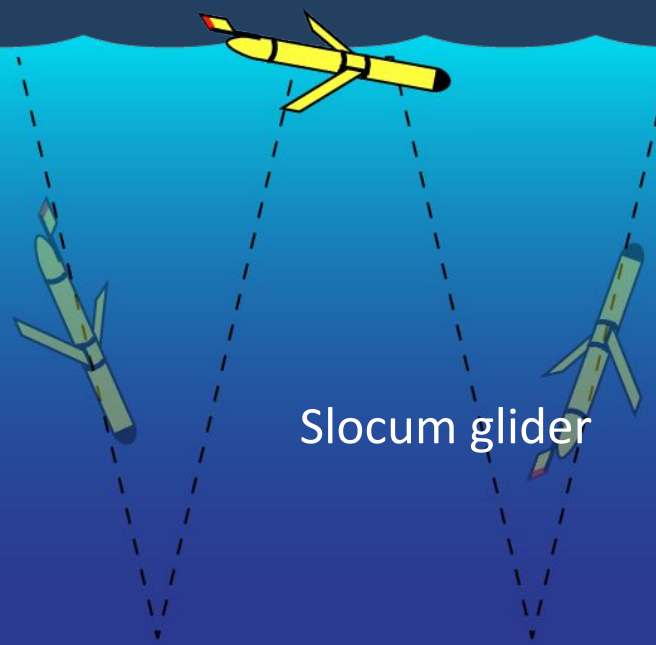


Real-Time PAM - Fish

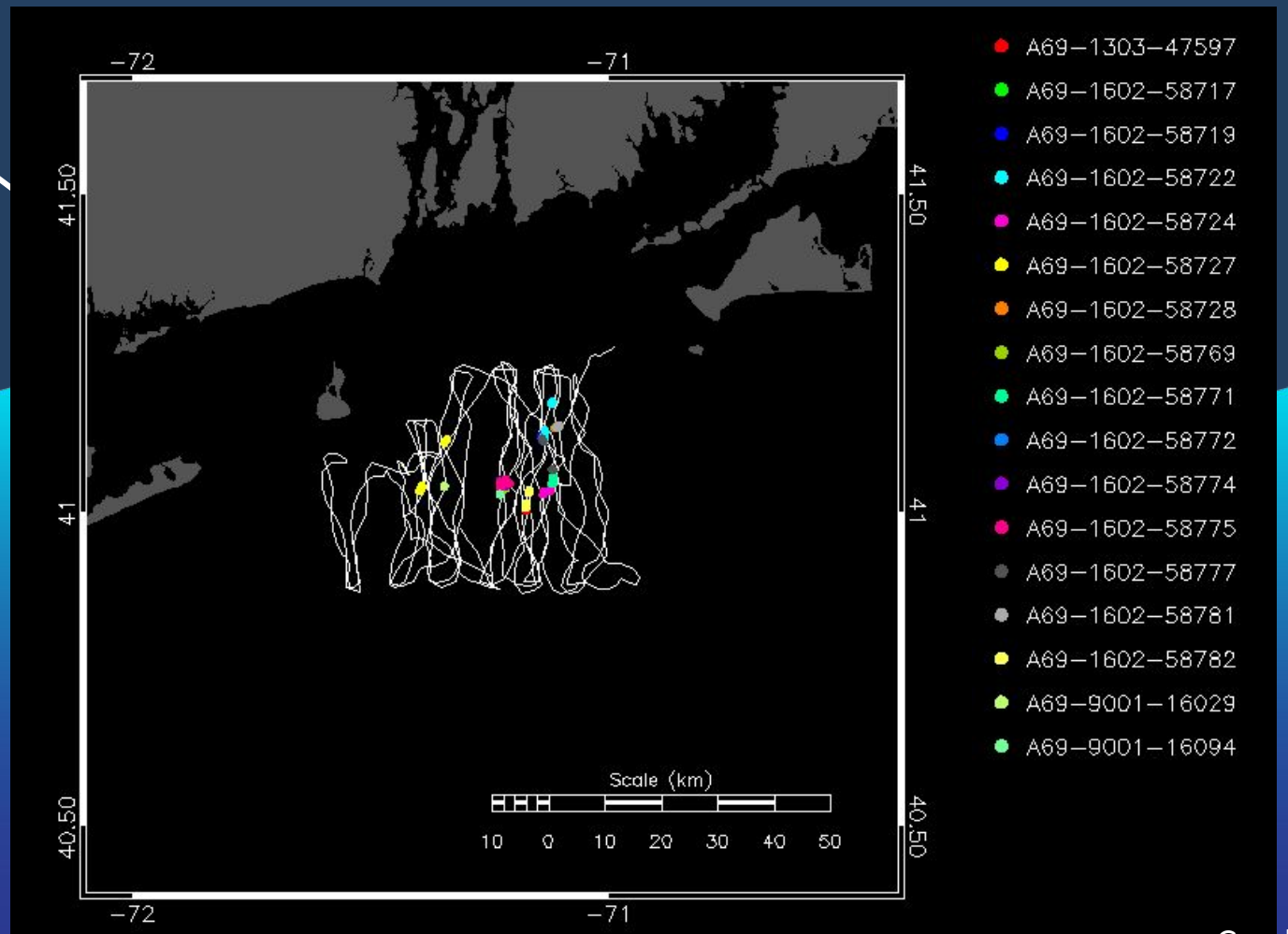
Iridium satellite

Shore-side server

dcs.whoi.edu



Slocum glider



Graphic: WHOI

Real-Time Monitoring & Mitigation

Distribution of Information

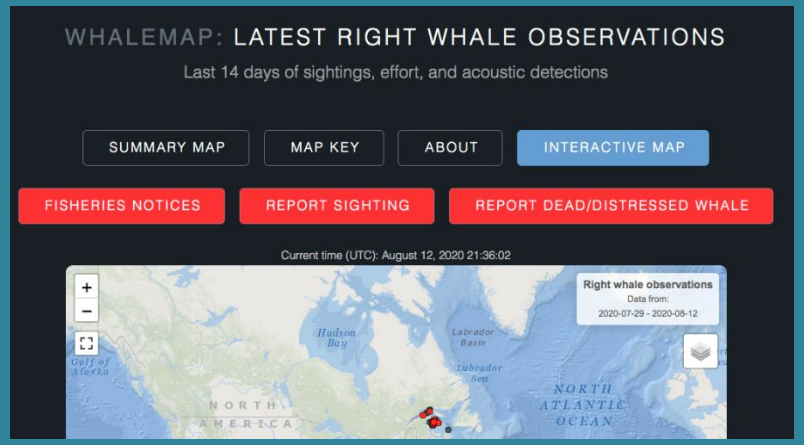
Web Platforms

robots4whales.whoi.edu

Daily analyst review:

Date	Sei whale	Fin whale	Right whale	Humpback whale
09/04/2015				
09/03/2015				
09/02/2015				
09/01/2015				
08/31/2015				
08/30/2015				
08/29/2015				
08/28/2015				

WHALEMAP(DFO/Dalhousie)



Notifications

Email message

Mark Baumgartner
To: undisclosed-recipients:;
Fin whales detected on the Nomans Land buoy

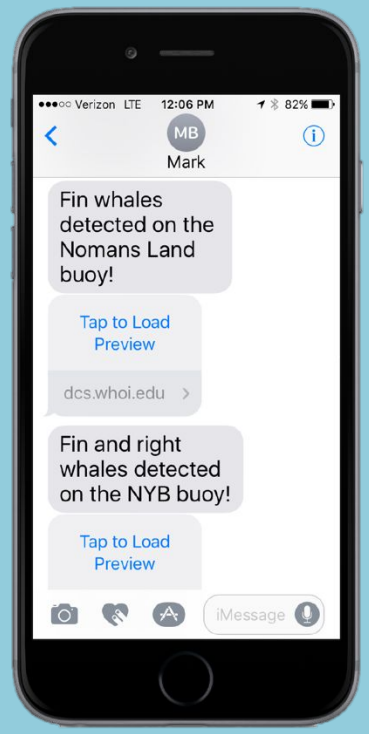
Time now: 12/13/16 12:00 EST

Fin whales detected on the Nomans Land buoy! Latest detections: 2.8 hours ago.

Fin whale detections:
12/12/16 18:09 EST (17.8 hr ago)
12/12/16 19:09 EST (16.8 hr ago)
12/12/16 20:09 EST (15.8 hr ago)
12/12/16 21:09 EST (14.8 hr ago)
12/12/16 23:09 EST (12.8 hr ago)
12/13/16 00:09 EST (11.8 hr ago)
12/13/16 01:09 EST (10.8 hr ago)
12/13/16 02:09 EST (9.8 hr ago)
12/13/16 02:24 EST (9.6 hr ago)
12/13/16 03:09 EST (8.8 hr ago)
12/13/16 05:09 EST (6.8 hr ago)
12/13/16 06:09 EST (5.8 hr ago)
12/13/16 07:09 EST (4.8 hr ago)
12/13/16 08:09 EST (3.8 hr ago)
12/13/16 09:09 EST (2.8 hr ago)

See http://dcs.whoi.edu/nomans0916/nomans0916.shtml for more information

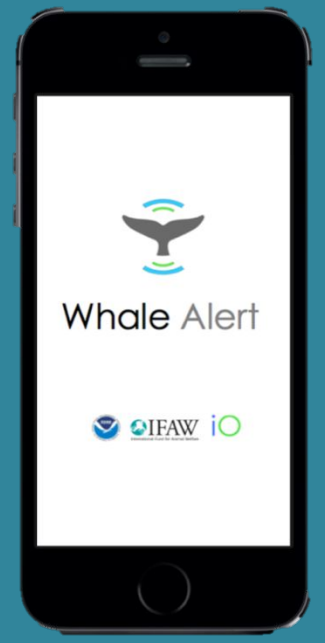
Text message



Applications

CG1View

Whale Alert app



Questions to Consider when using PAM

1. What are your Species of Interest?
2. What are your PAM Data Collection Types?
3. What are your PAM Recording Technologies ?
4. What is your PAM Design?
5. What information does your PAM Data provide?
6. **How will you Report and Archive your PAM data?**

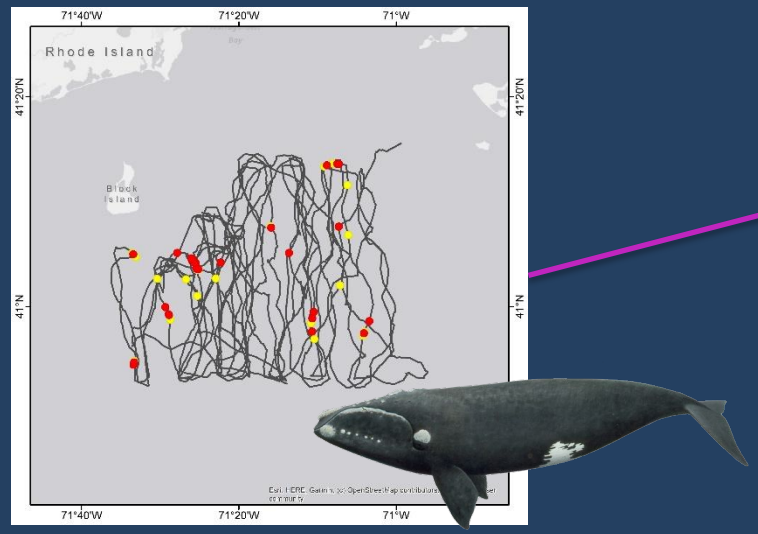
6. Explosion of Need

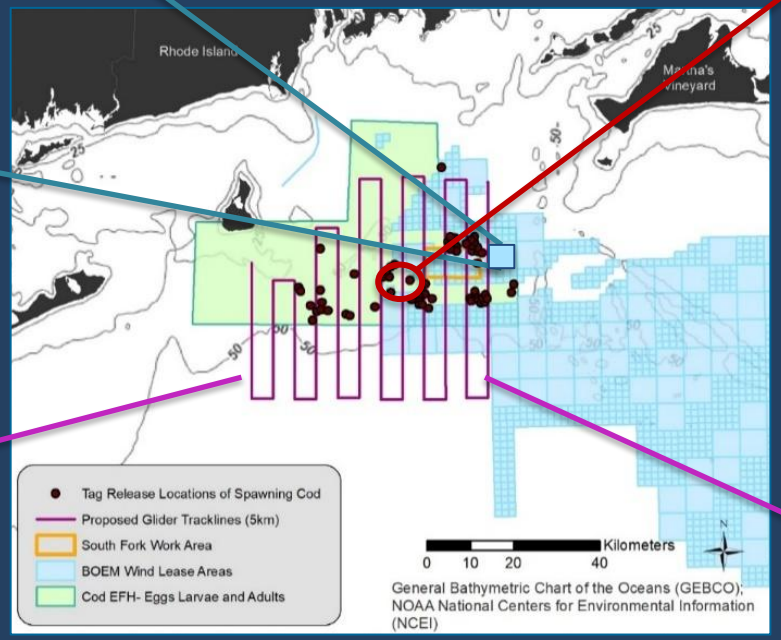
Whales and Fish

Wind Energy, Vessel Strike, Spawning Protection, Changing distributions and occurrence

Wind Energy Lease Areas

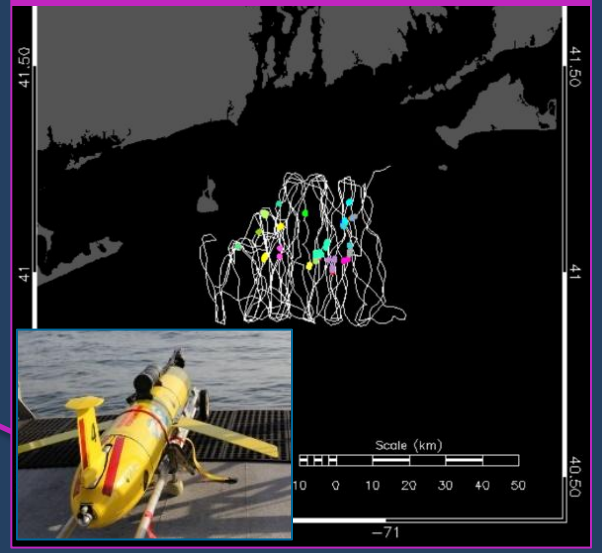
Detecting endangered whales





Finding Atlantic cod spawning: Acoustic Tags

Glider + Real Time Telemetry receiver



Program Funder: BOEM. Award #M19PG00015

6. Visualization & Accessibility

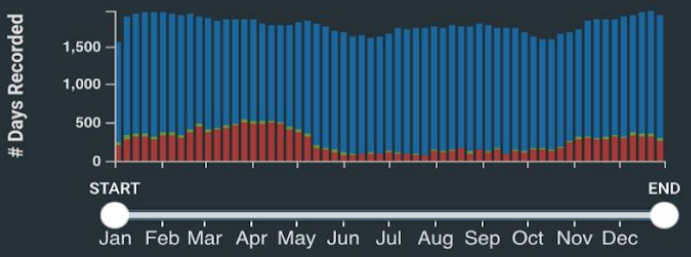
Select a species

North Atlantic Right Whale

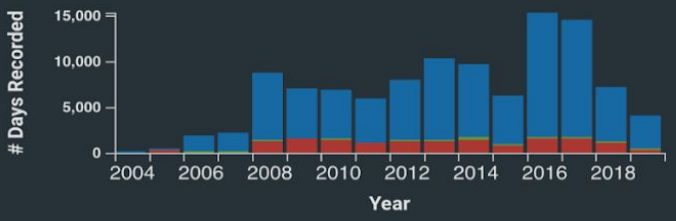
Select platform type(s)

Bottom Mooring | Glider | Surface Buoy | Towed Array

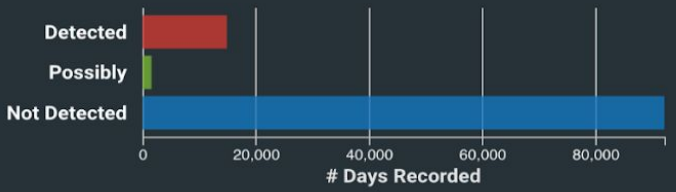
Season: Jan 1 to Dec 31

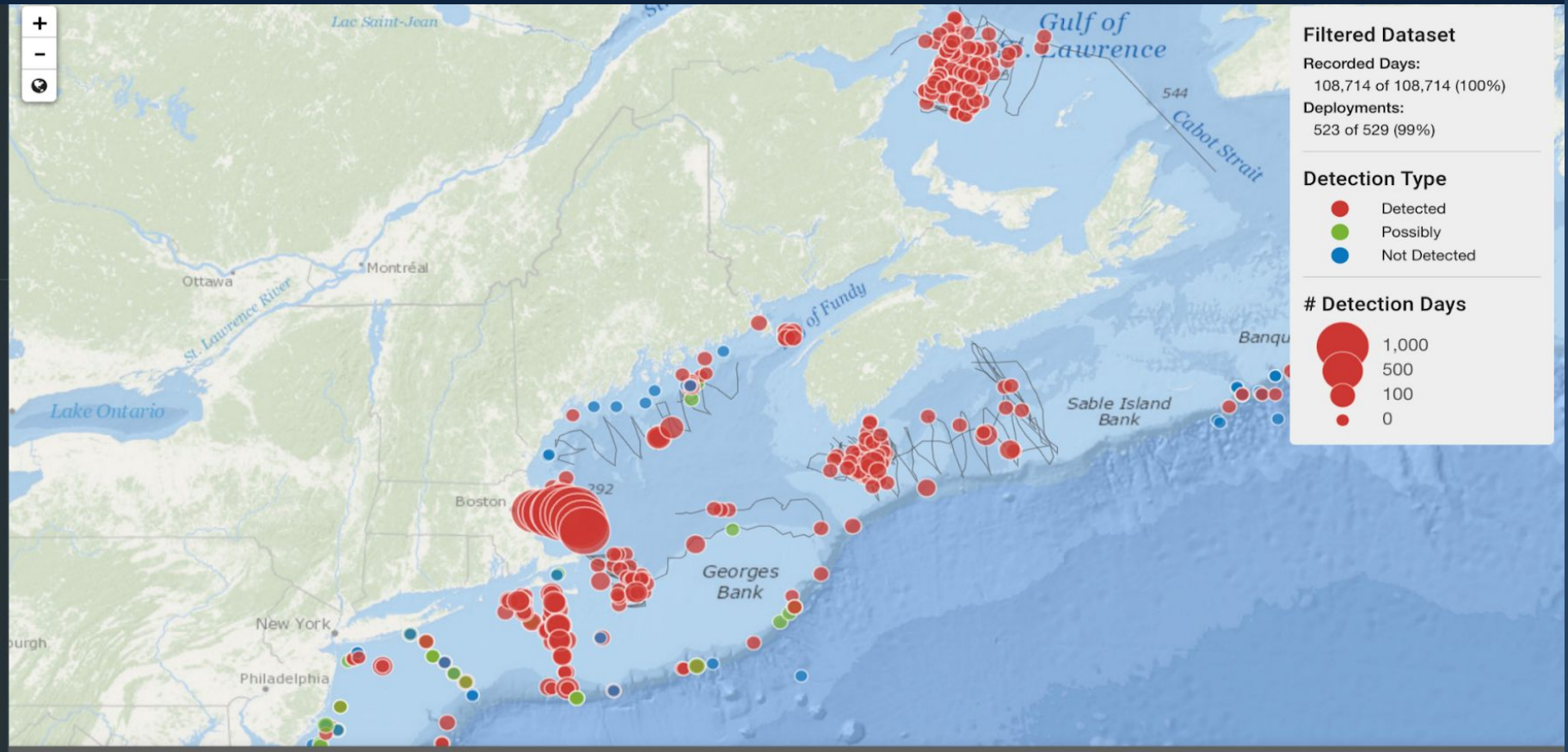


Years: 2004 to 2019



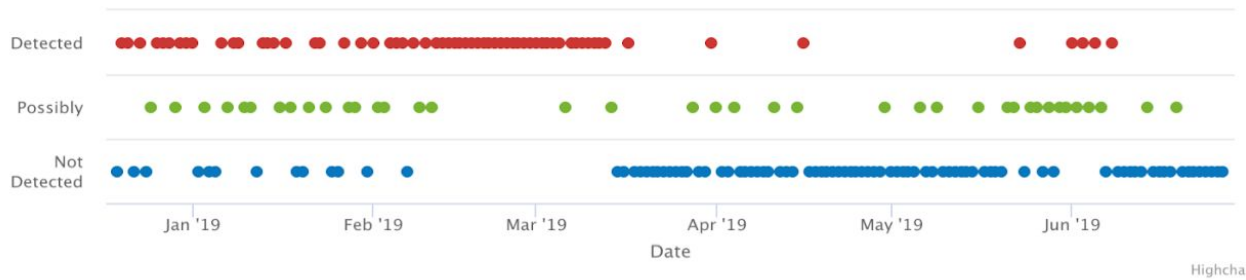
Total Detection Days





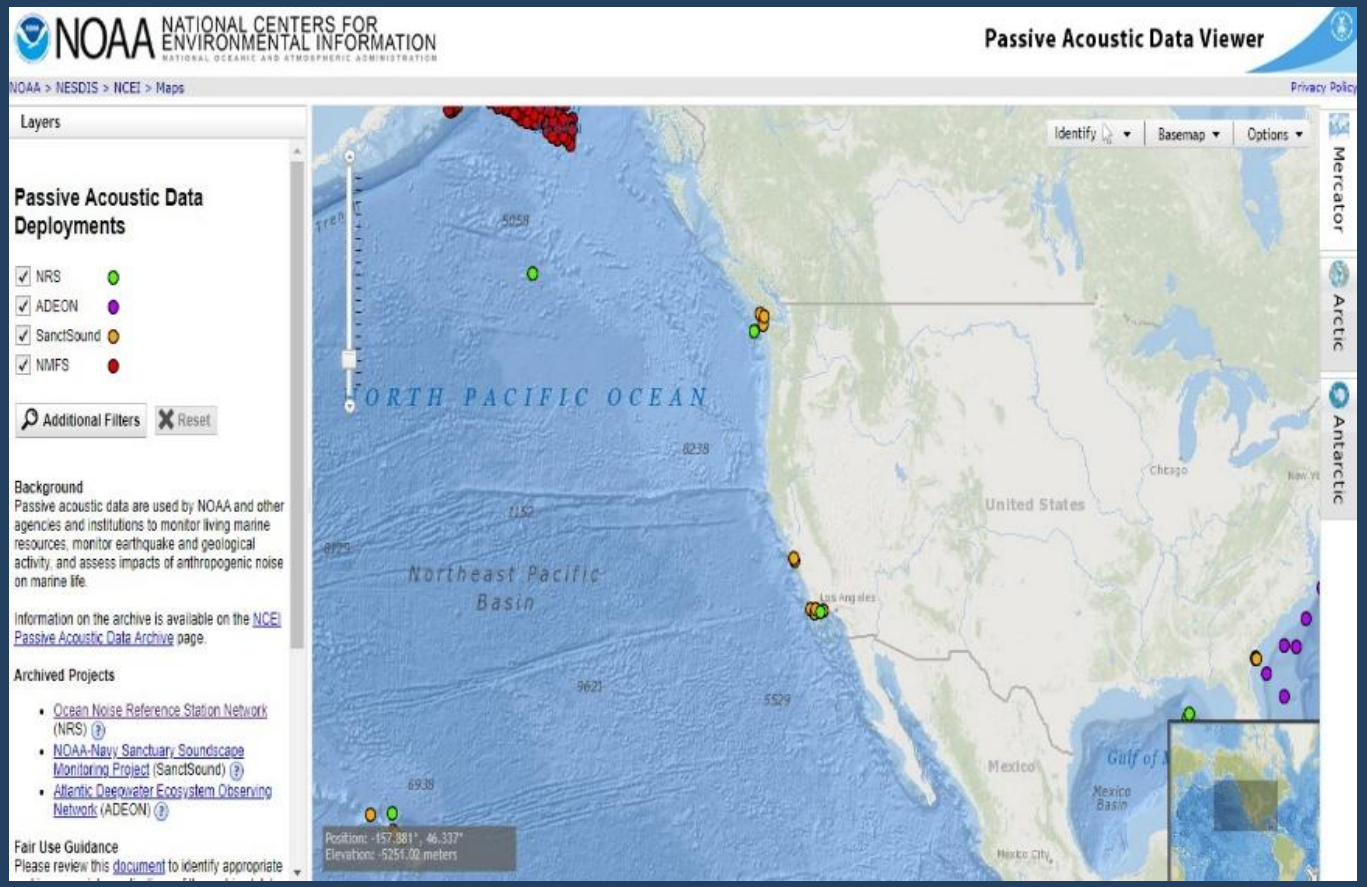
Project: NEFSC_MA-RI_201812_CH2

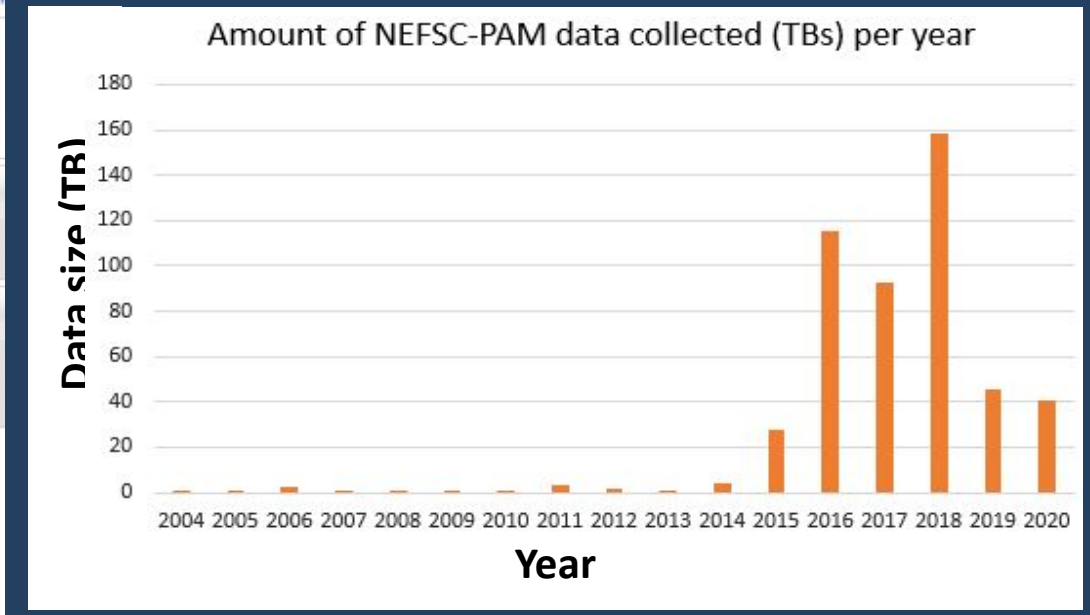
Site: **N4**
Platform: **Bottom Mooring**
Unit: **MARU**
Position: **40.6112, -70.2600**
Deployed: **Dec 20, 2018 to Jun 27, 2019**
Duration: **190 days**



6. PAM Databasing – NOAA NCEI

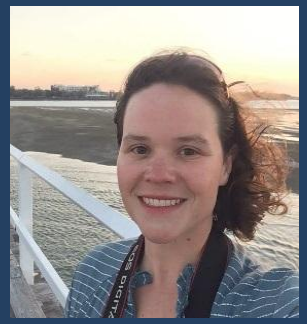
https://ngdc.noaa.gov/mgg/pad/





Total data storage size= 496 TB

Thanks to this group of smart, hard working scientists!


Check out our PA Group webpage!

fisheries.noaa.gov/new-england-mid-atlantic/endangered-species-conservation/passive-acoustic-research-atlantic-ocean

Sofie.VanParijs@noaa.gov