Advancing acoustics for integrated population assessment

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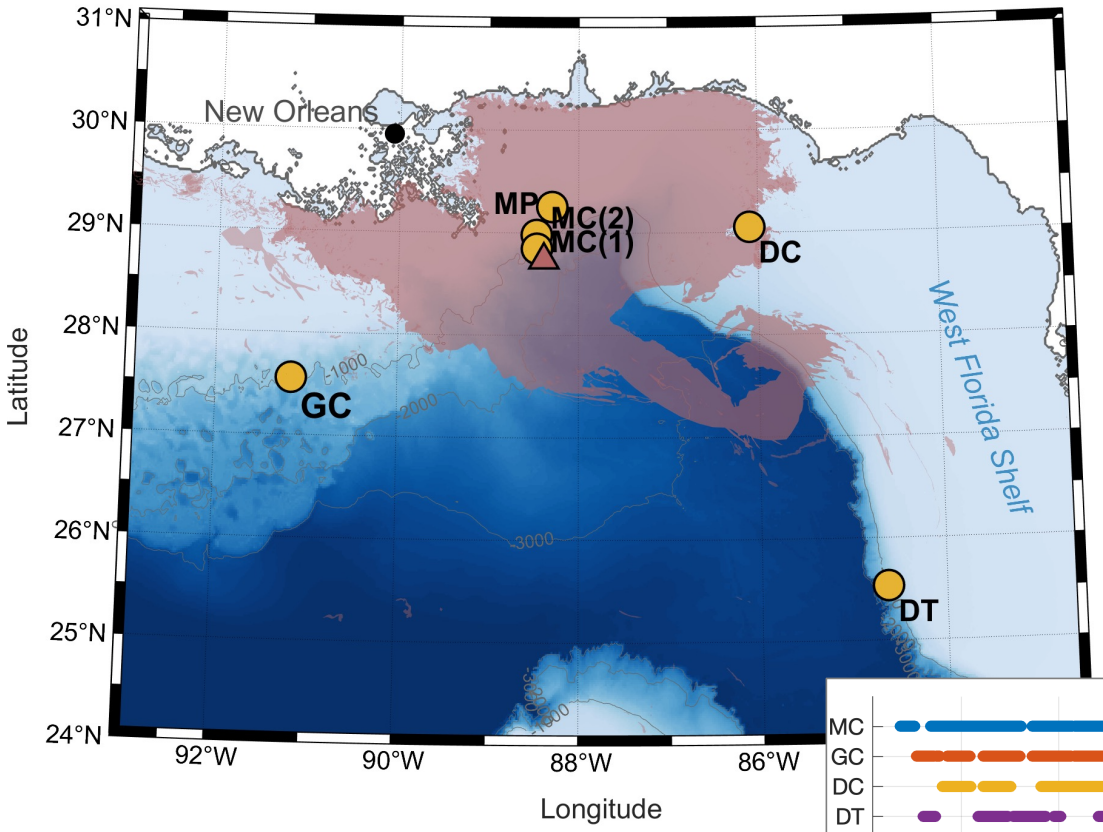
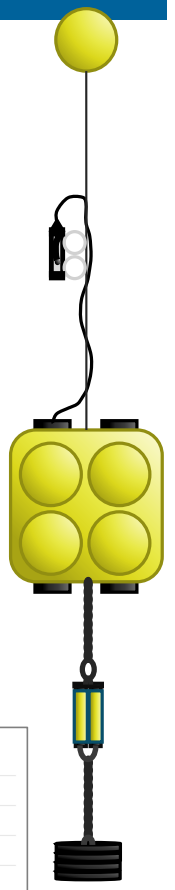
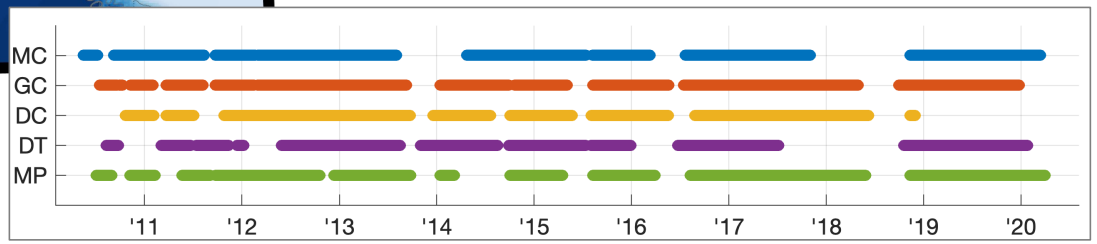
Where we've been: Passive acoustic monitoring post DWH
Long-term trends in odontocete densities 2010-2020



- 5 sites
- Near-continuous passive acoustic recording
- 10 Hz - 100kHz effective bandwidth





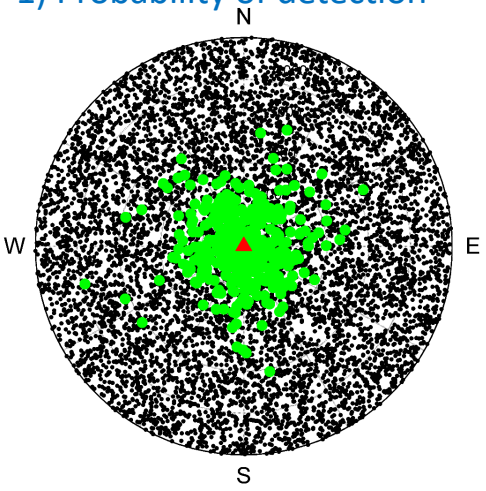
Density Estimation from Echolocation Clicks

Common units between acoustic and visual methods: individuals per unit area

Point transect approach including:

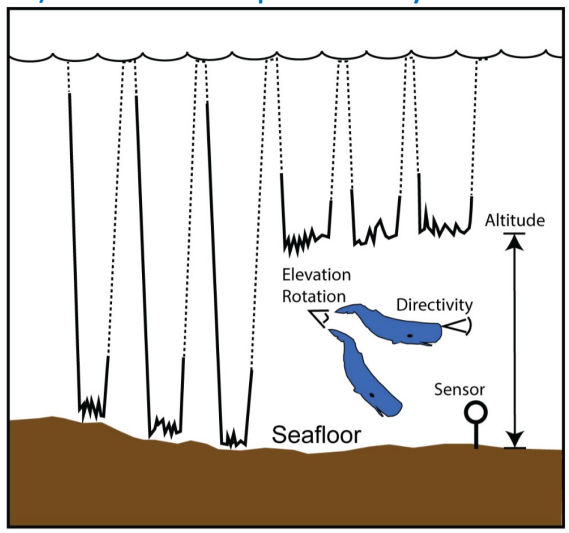
- Probability of detection
  - from simulations and acoustic tracking
- Vocalization probability from tag data
- Group size from visual surveys and/or acoustic tracking
- Detector/classifier error rates

1) Probability of detection



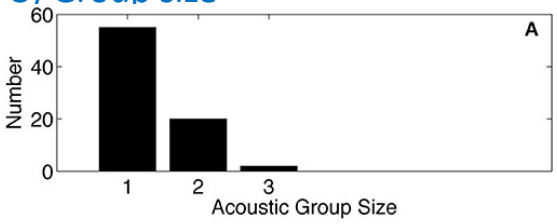
Frasier et al 2016: Dolphins

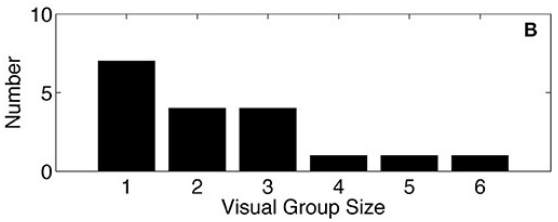
2) Vocalization probability



Solsana Berga et al 2021: Sperm whales

3) Group size

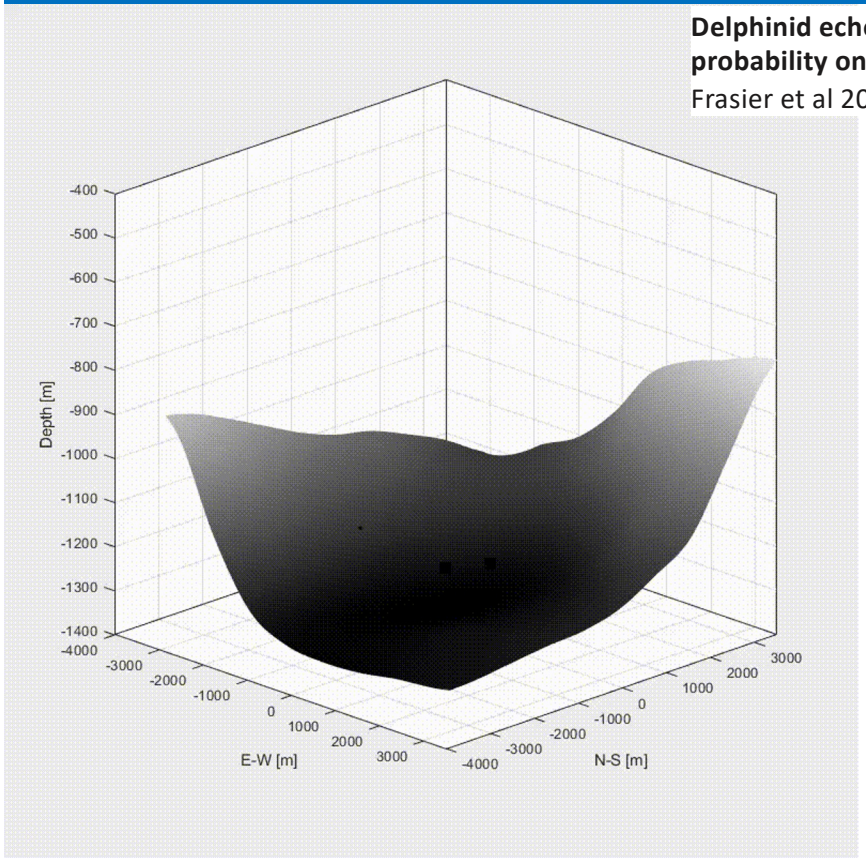




Hildebrand et al 2018: *Kogia* spp.

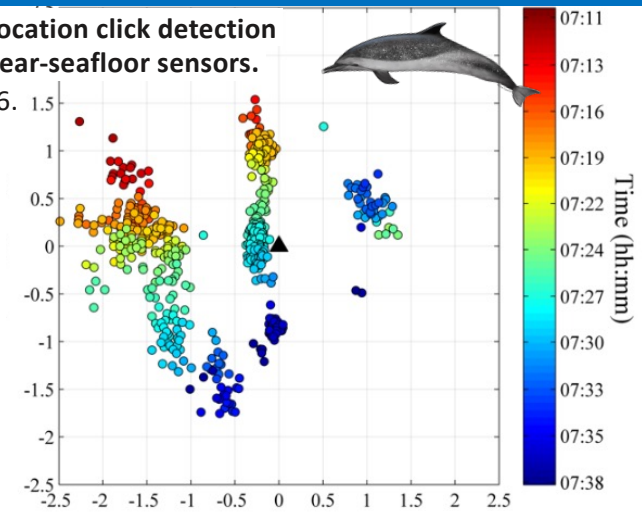
Methods after Marques et al 2009: Estimating cetacean population density using fixed passive acoustic sensors: An example with Blainville's beaked whales

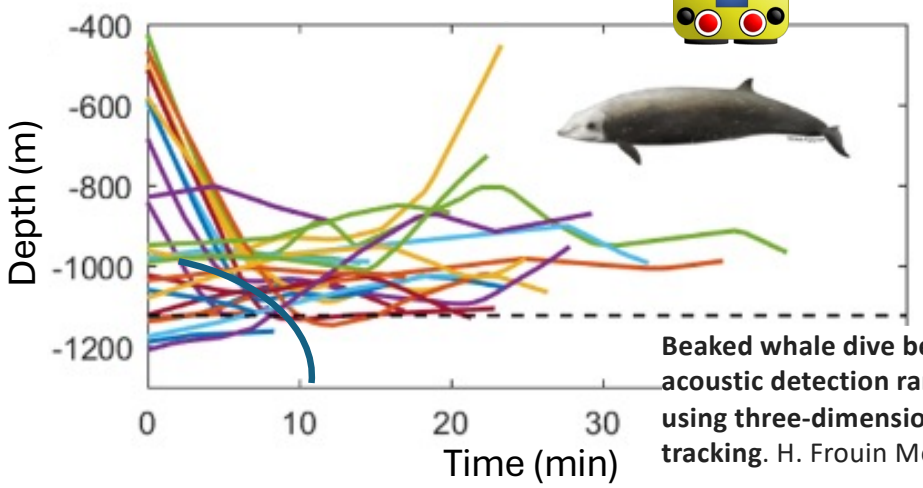
Acoustic tracking for detection probability estimation

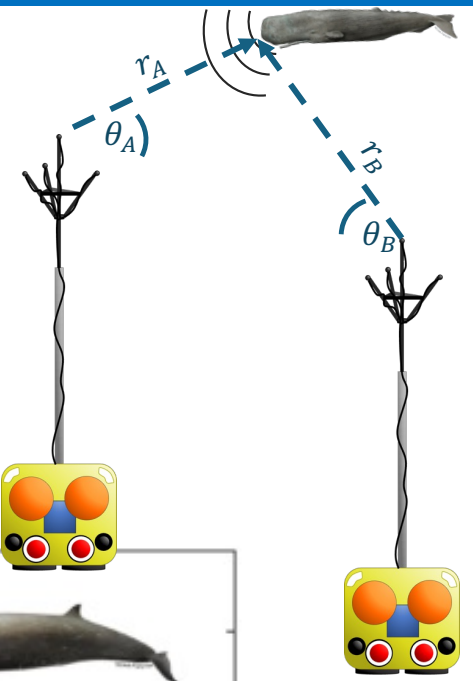


Long-term monitoring of *Ziphius cavirostris* behavior using 3D tracking from fixed hydrophone arrays off Southern California. L. Baggett et al, in review.

Delphinid echolocation click detection probability on near-seafloor sensors.
Frasier et al 2016.

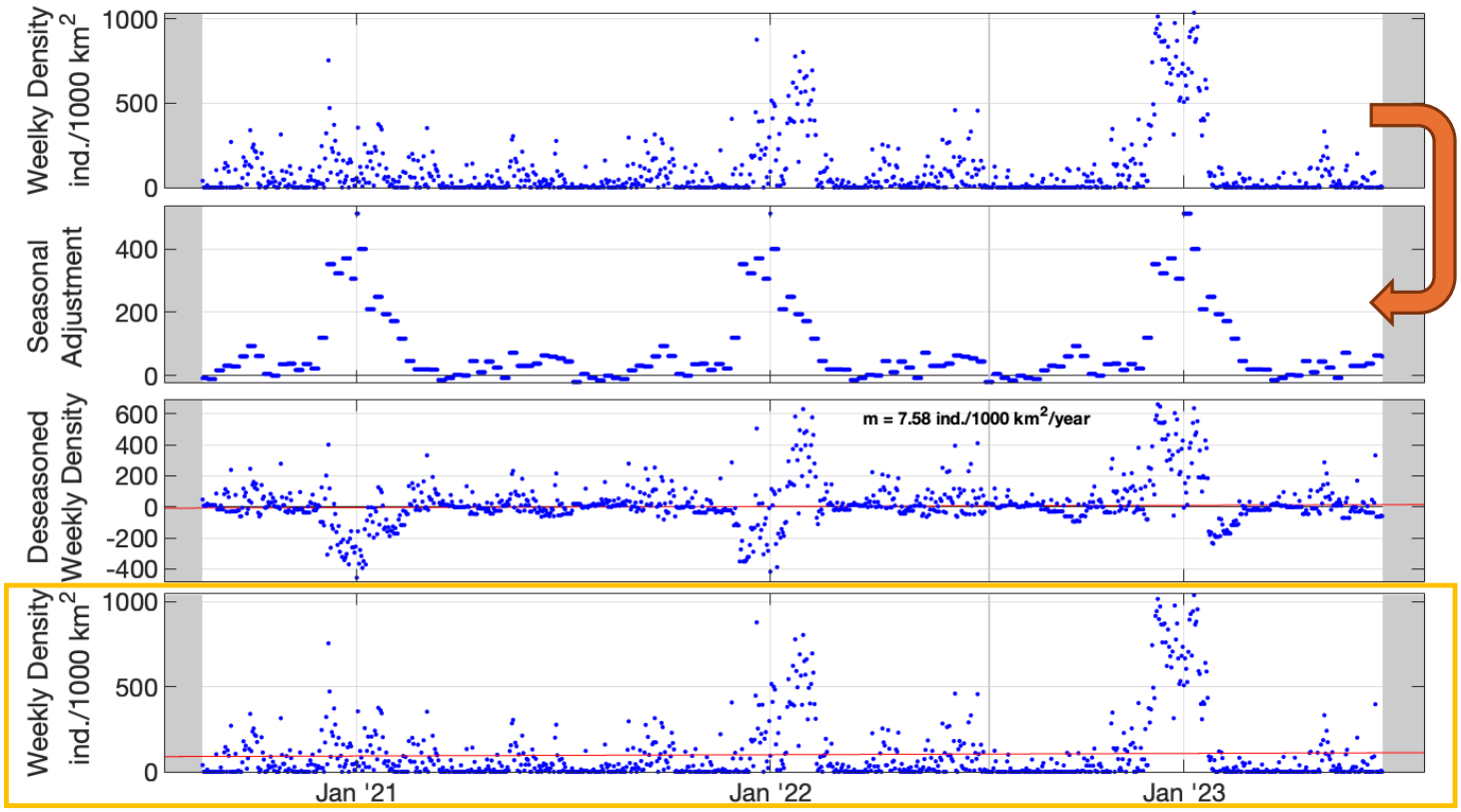




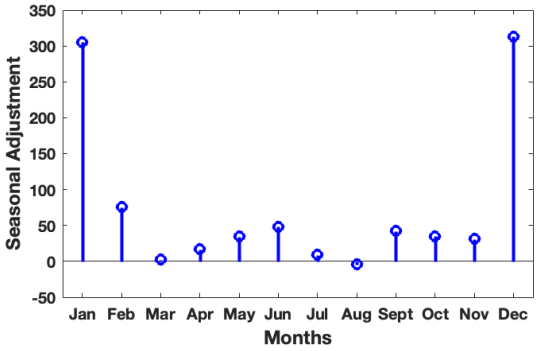


Beaked whale dive behavior and acoustic detection range off Louisiana using three-dimensional acoustic tracking. H. Frouin Mouy et al in review.

Trend Analysis – Current Method



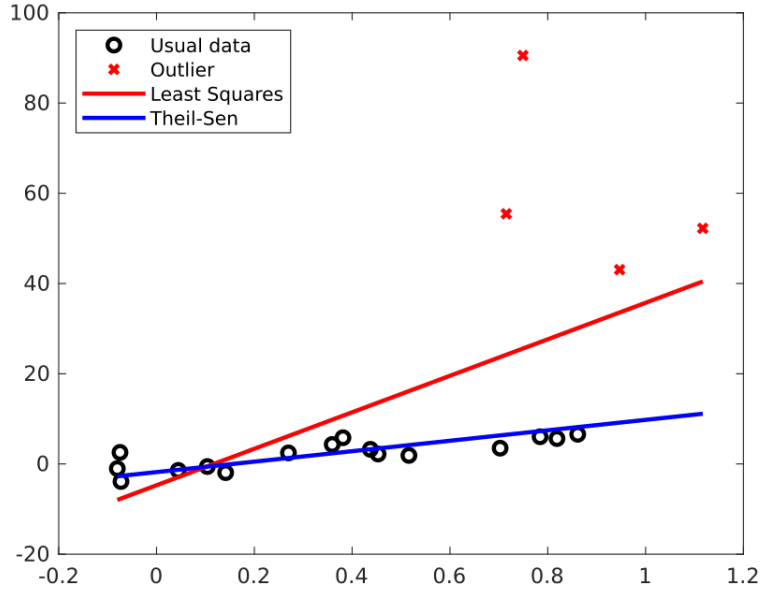
Time (Month/Year)

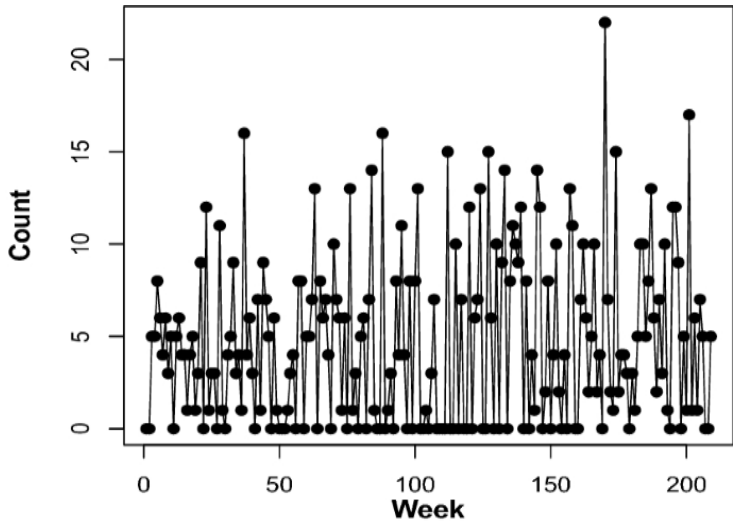


Trend Analysis – Current Method

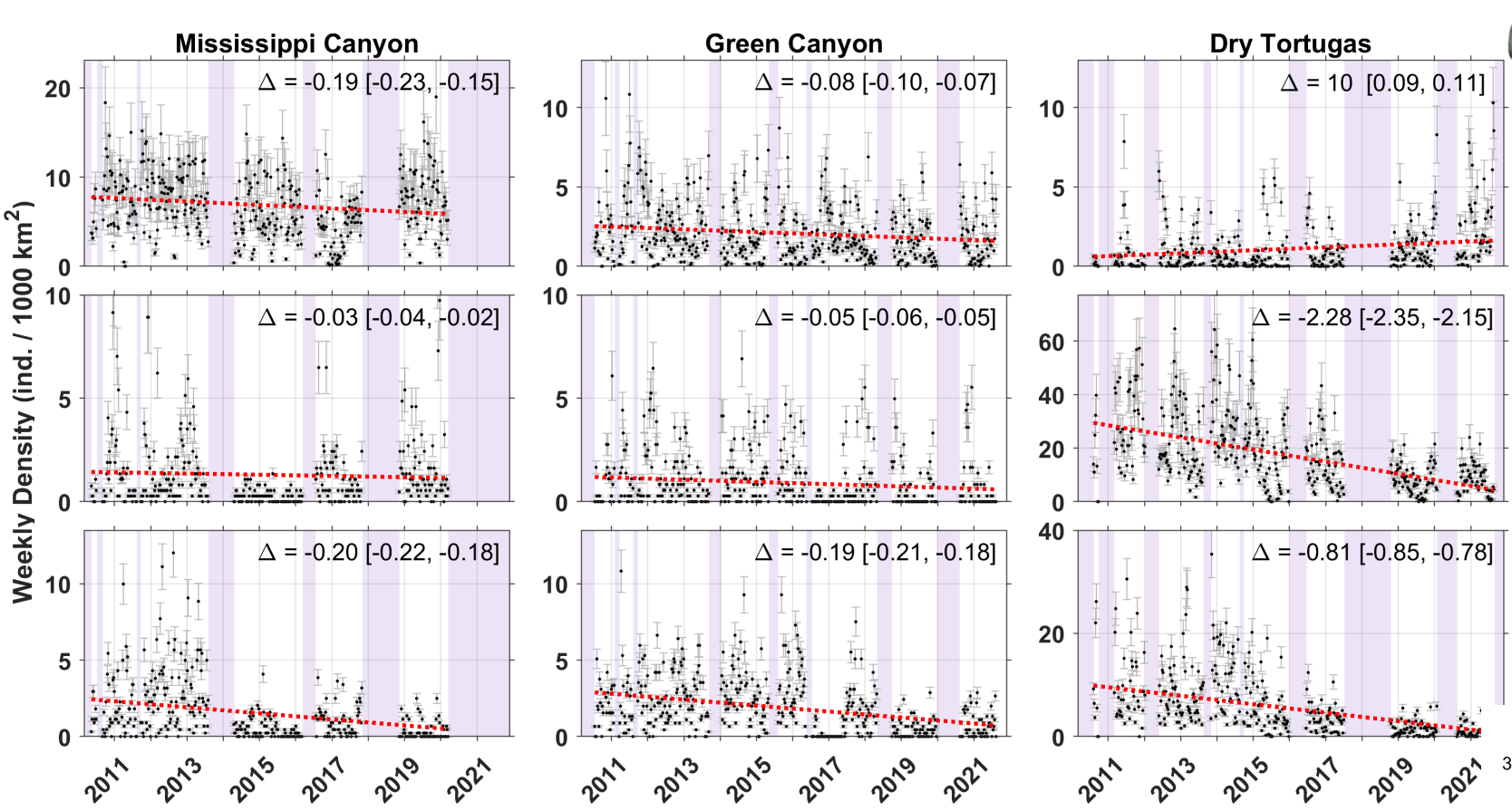
Theil-Sen regression

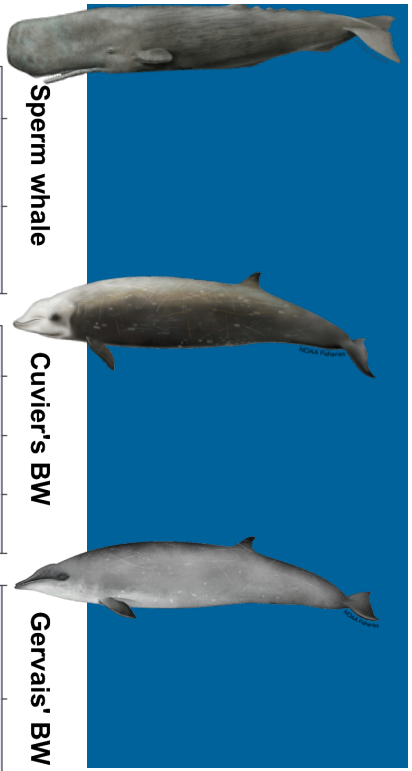
- Conservative trend estimation by averaging the slope between every pair of points.
- Simple, linear, does not assume data normality.
- Rare species trend estimation is challenging.

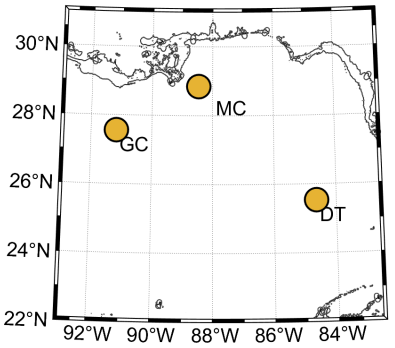




https://gitlab.ub.uni-giessen.de/jkeyser/theil-sen-matlab







A decade of declines in toothed whale densities following the *Deepwater Horizon* oil spill. Frasier et al. 2024

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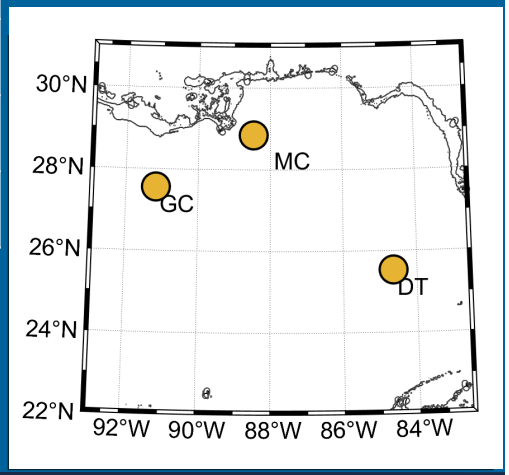
Species	Site	Mean density (ind./ 1000 km²) 2010	2020	Decadal % Change	Change Type (D/I/N)
Sperm whale 	MC	4.1	3.0	-28	D
	GC	1.3	0.9	-32	D
	DT	0.3	0.7	153	I
Cuvier's BW 	MC	1.4	1.1	-23	D
	GC	1.2	0.7	-45	D
	DT	30.0	7.4	-76	D
Gervais' BW 	MC	2.4	0.5	-80	D
	GC	2.9	1.0	-67	D
	DT	10.1	1.9	-81	D



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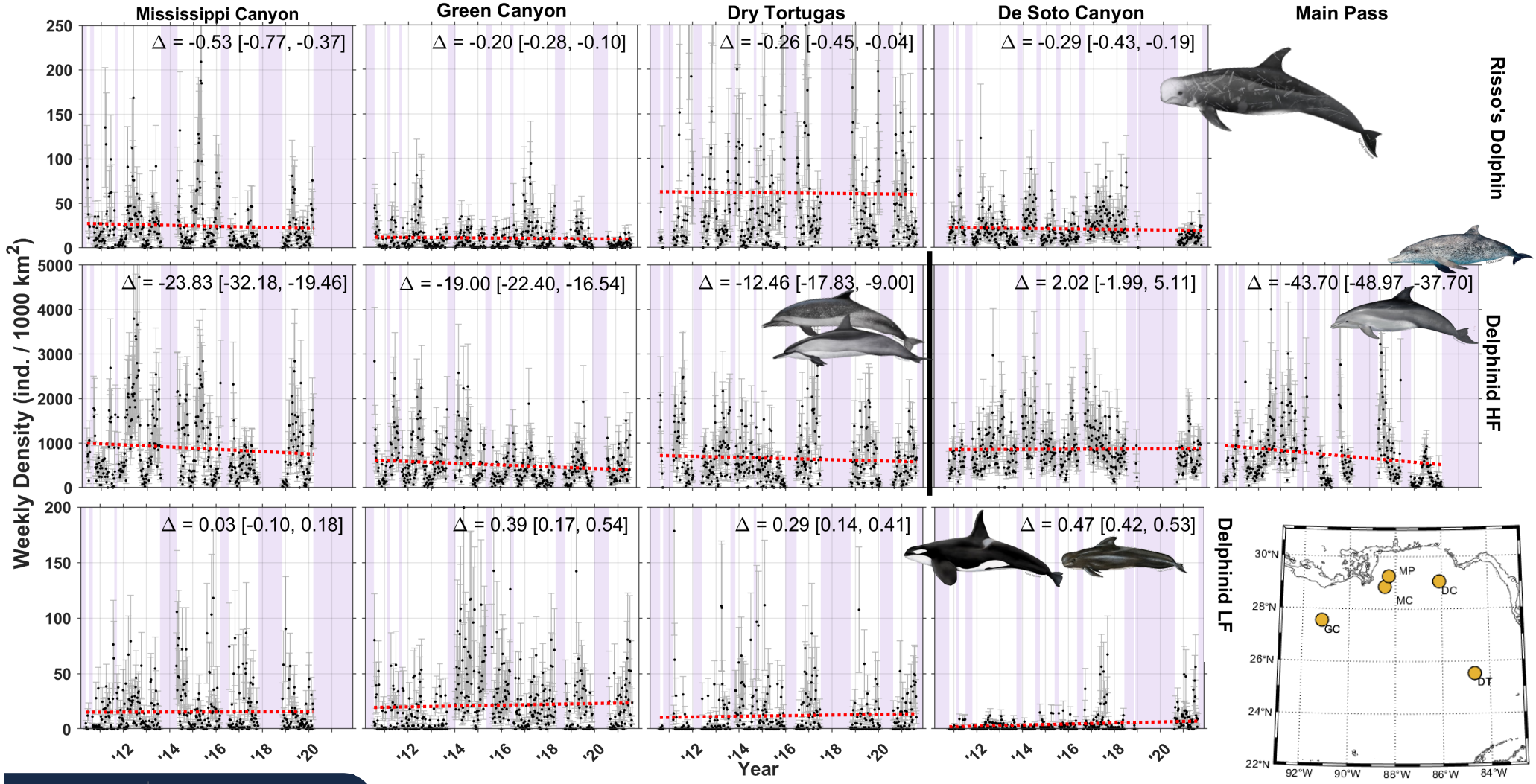
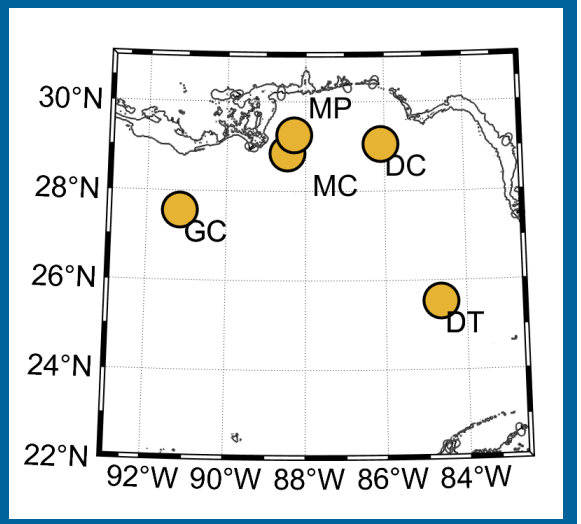
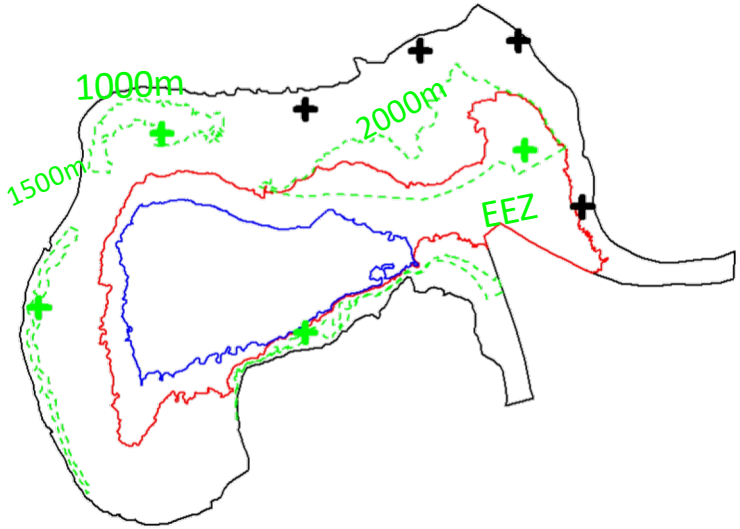

Mississippi Canyon
Green Canyon
Dry Tortugas
De Soto Canyon
Main Pass
Δ = -0.53 [-0.77, -0.37]
Δ = -0.20 [-0.28, -0.10]
Δ = -0.26 [-0.45, -0.04]
Δ = -0.29 [-0.43, -0.19]
Risso's Dolphin
Δ = -23.83 [-32.18, -19.46]
Δ = -19.00 [-22.40, -16.54]
Δ = -12.46 [-17.83, -9.00]
Δ = 2.02 [-1.99, 5.11]
Δ = -43.70 [-48.97, -37.70]
Delphinid HF
Δ = 0.03 [-0.10, 0.18]
Δ = 0.39 [0.17, 0.54]
Δ = 0.29 [0.14, 0.41]
Δ = 0.47 [0.42, 0.53]
Delphinid LF
Weekly Density (ind. / 1000 km2)
Year
'12
'14
'16
'18
'20
MP
MC
DC
GC
DT
30°N
28°N
26°N
24°N
22°N
92°W
90°W
88°W
86°W
84°W

Species	Site	Mean density (ind./ 1000 km²) 2010	2020	Decadal % Change	Change Type (D/I/N)
Risso's **dolphin** 	MC	27.7	21.7	-21	D
	GC	11.7	9.7	-17	D
	DT	62.8	60.0	-5	N
	DC	22.7	19.6	-13	D
Delphinid HF 	MC	993.3	756.9	-23	D
	GC	618.2	427.2	-31	D
	DT	721.9	599.7	-16	D
	DC	853.5	869.3	2	N
	MP	952.2	512.4	-47	D
Delphinid LF 	MC	15.3	15.8	5	N
	GC	19.9	22.9	16	I
	DT	10.4	13.5	32	I
	DC	1.9	6.6	256	I

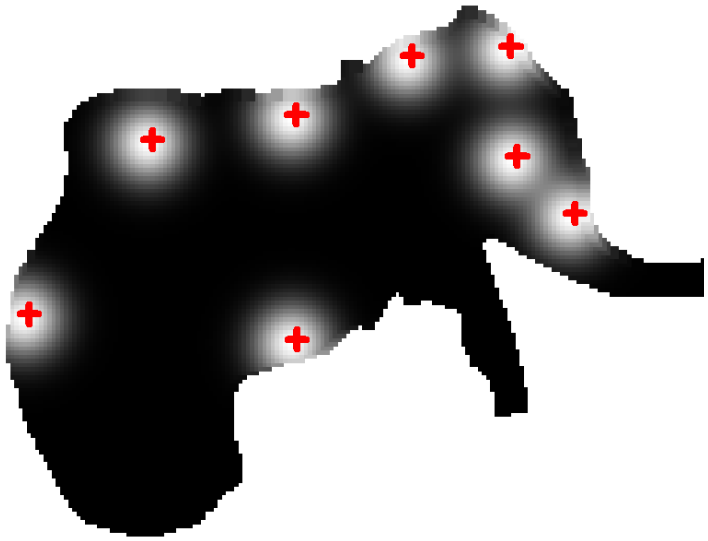


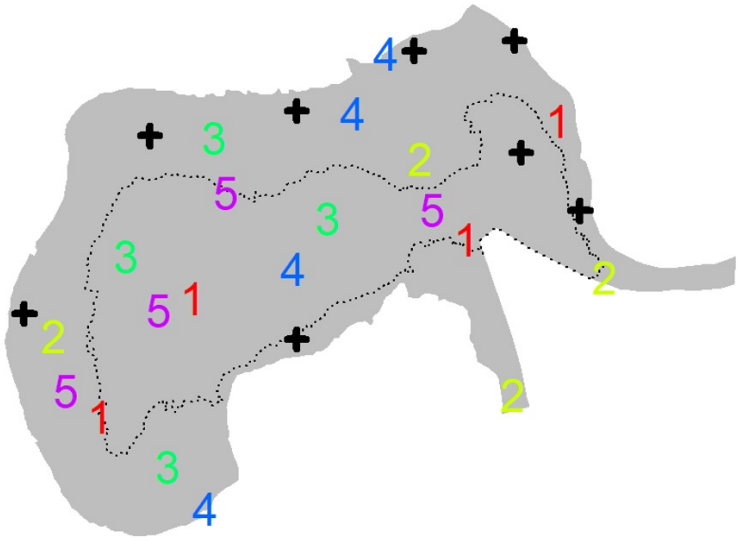
Where we are: Expanding passive acoustic monitoring effort Gulf-wide



3000m isobath
3500m isobath
200m isobath
New long-term site zones

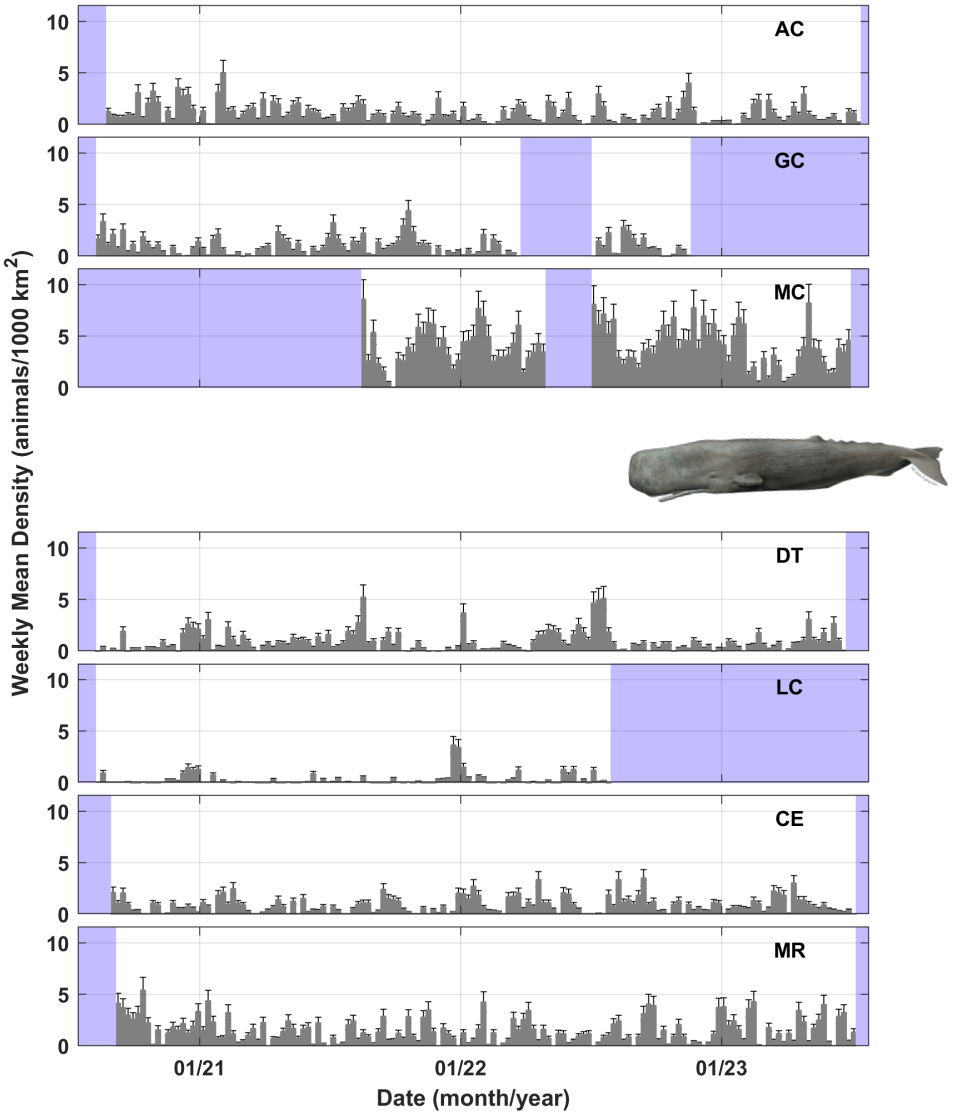
- Original historic sites +
- Added 4 comparable long-term sites around the Gulf +
- How do we cover the remaining space?
  Idea: Short-term sites moved annually

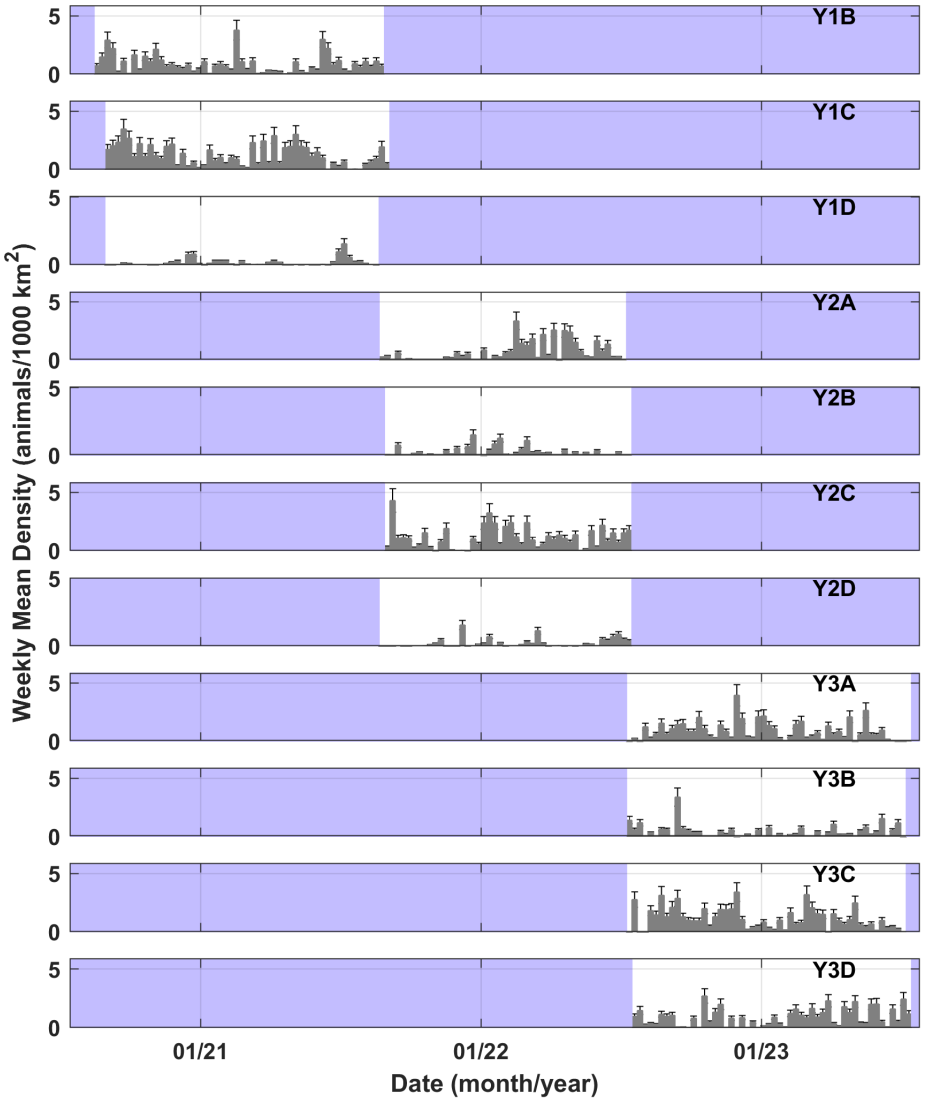




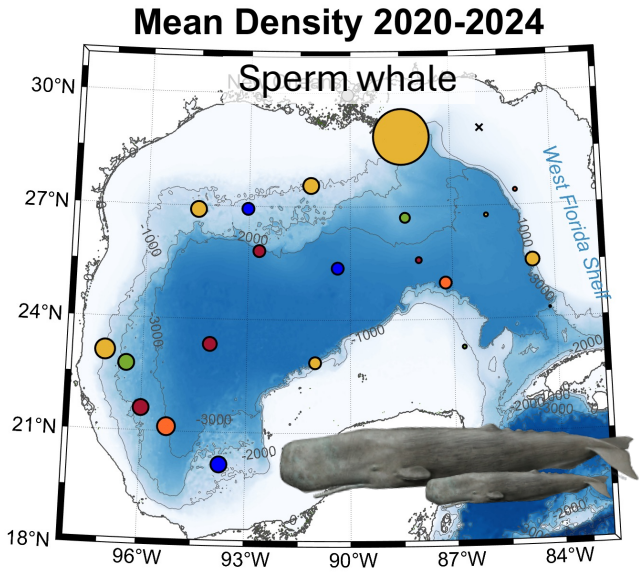
Frasier et al in prep.

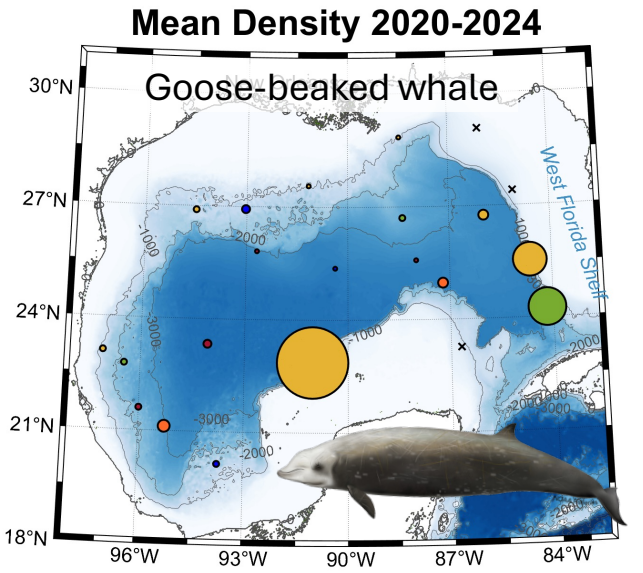
Method developed with Dr. Len Thomas, University of St. Andrews

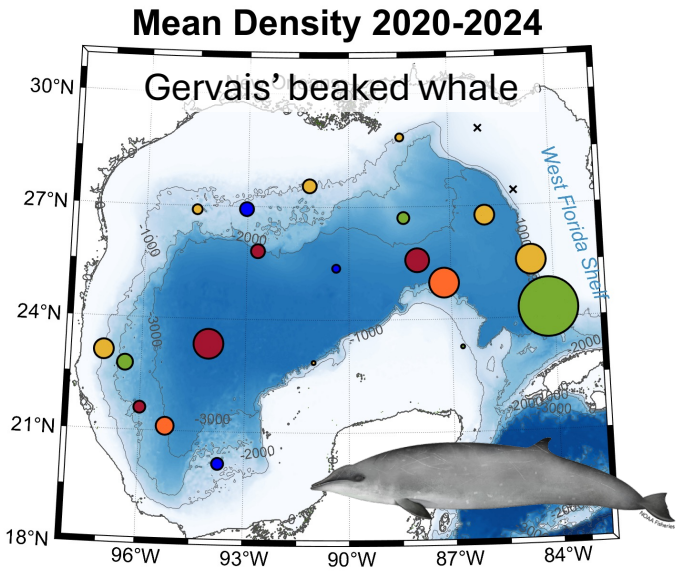


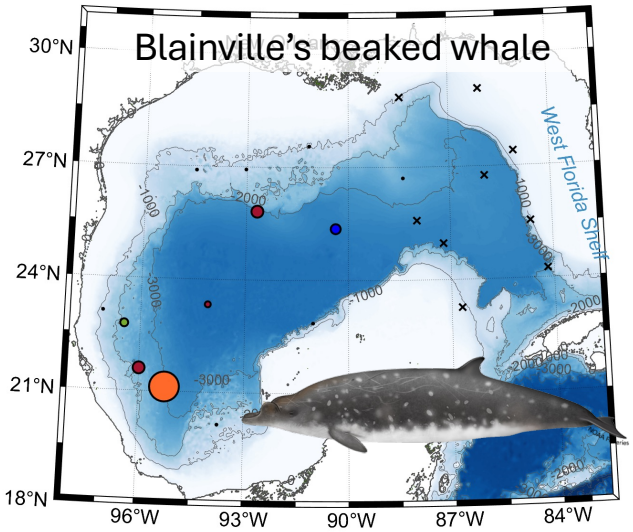


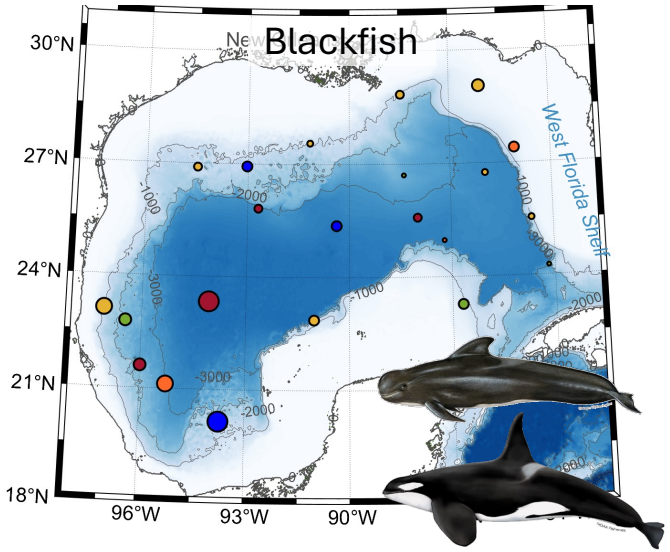
Frasier et al. (2024) *LISTEN GoMex: 2020-2023 - Long-term Investigations into Soundscapes, Trends, Ecosystems, and Noise in the Gulf of Mexico*

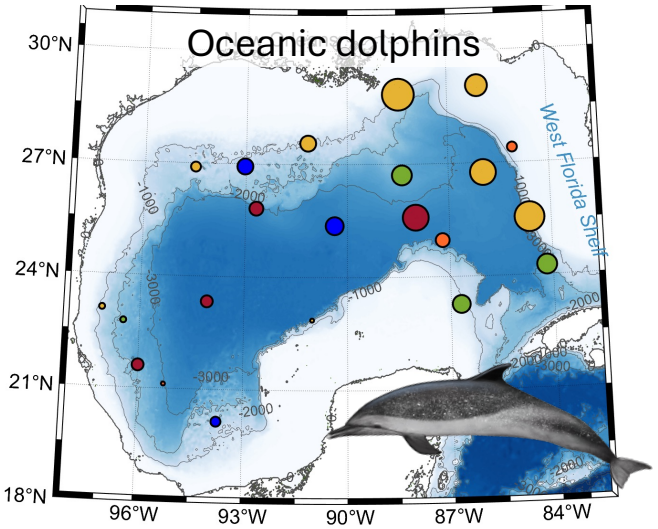




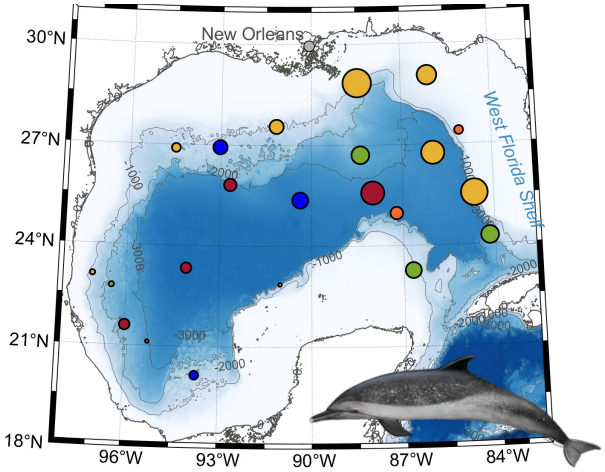




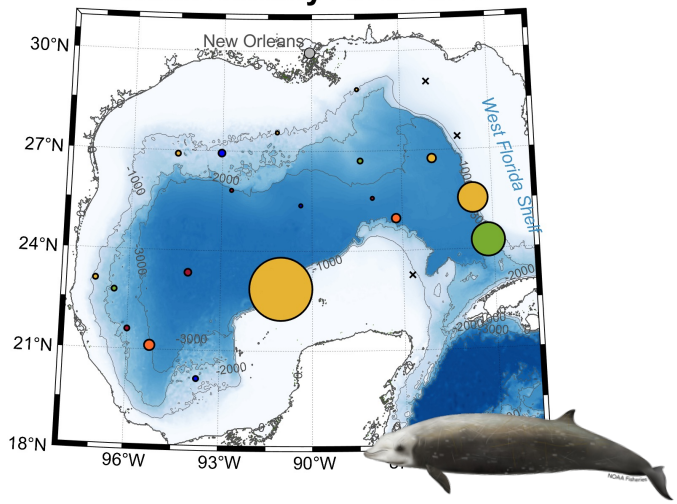




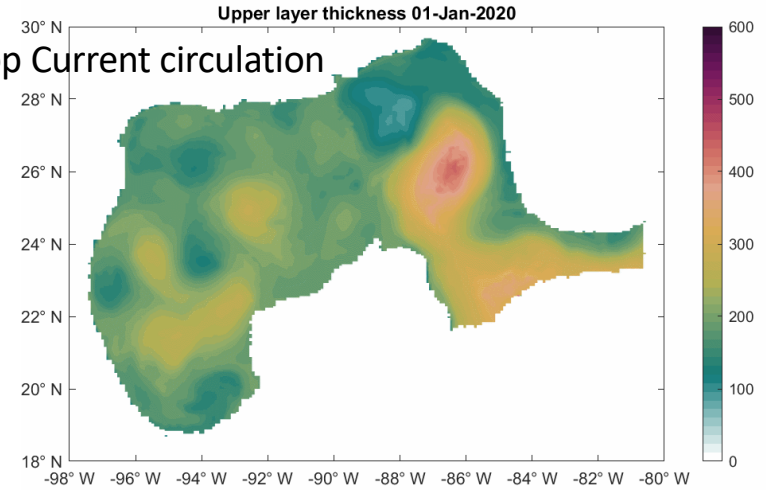
Frasier et al in prep



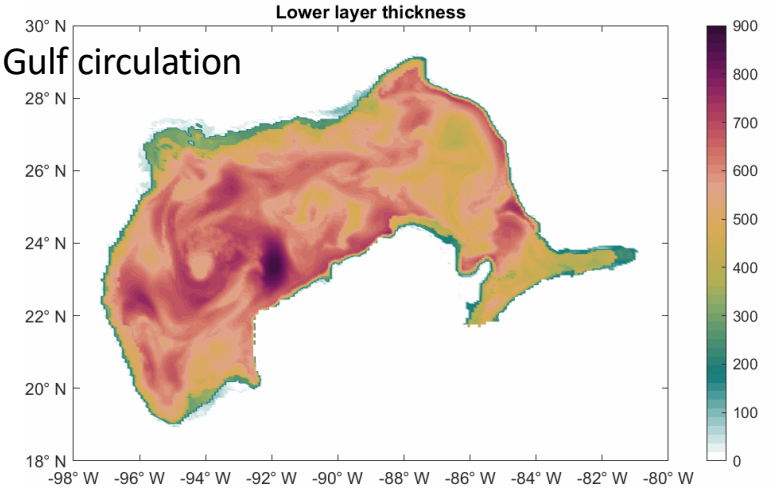
Mean Density 2020-2024



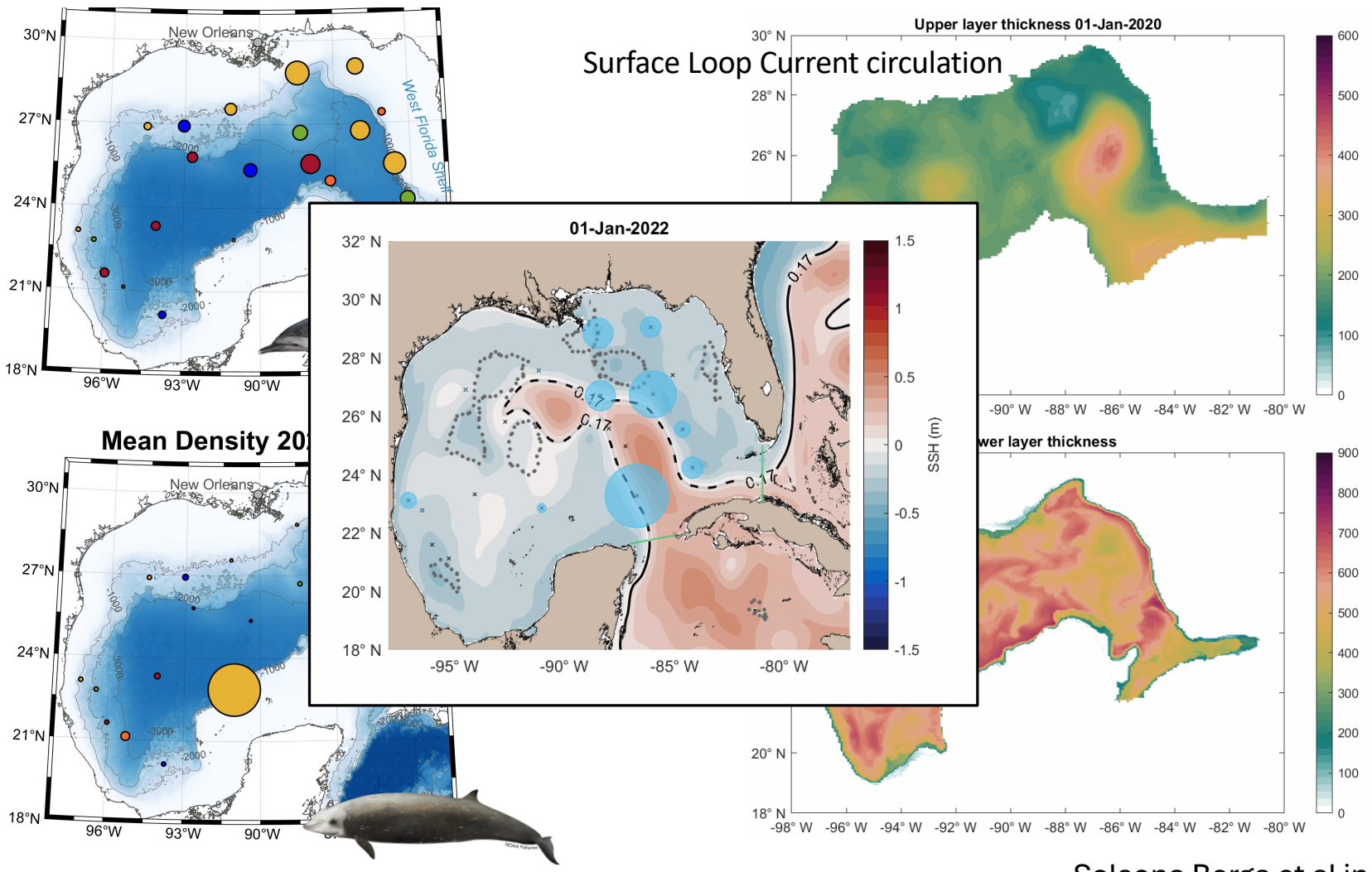
Surface Loop Current circulation



Deep Gulf circulation

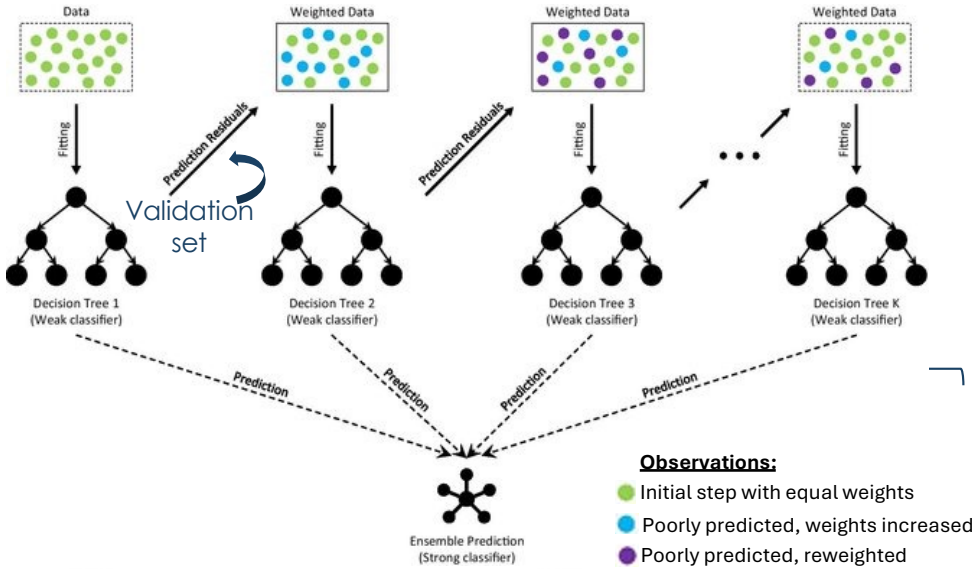


Solsona Berga et al in prep



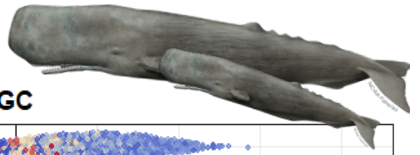
Solsona Berga et al in prep

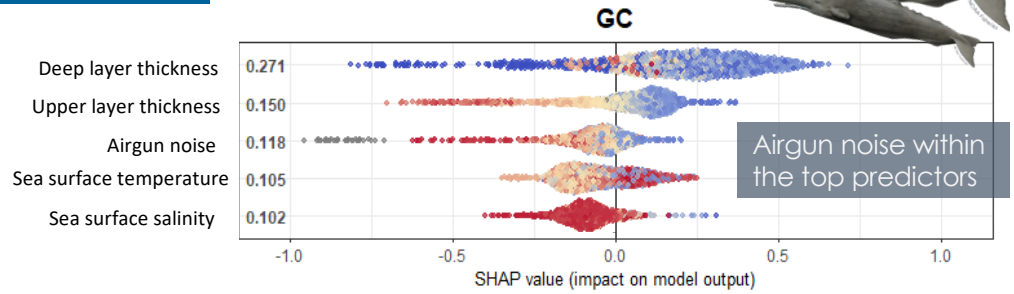
Understanding influence of local-to-regional predictors



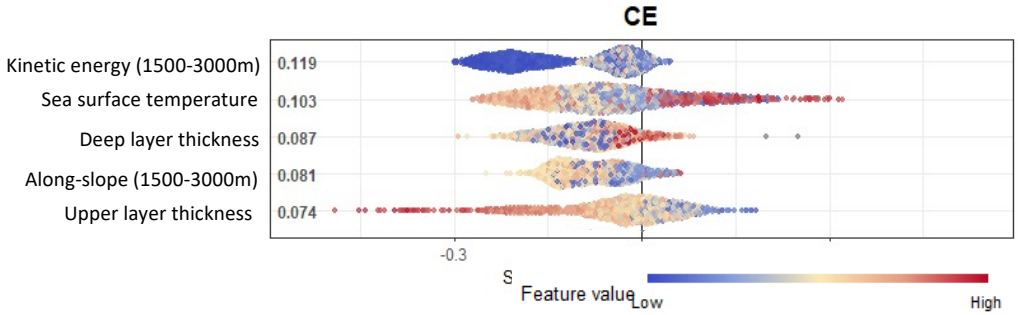
Observations:

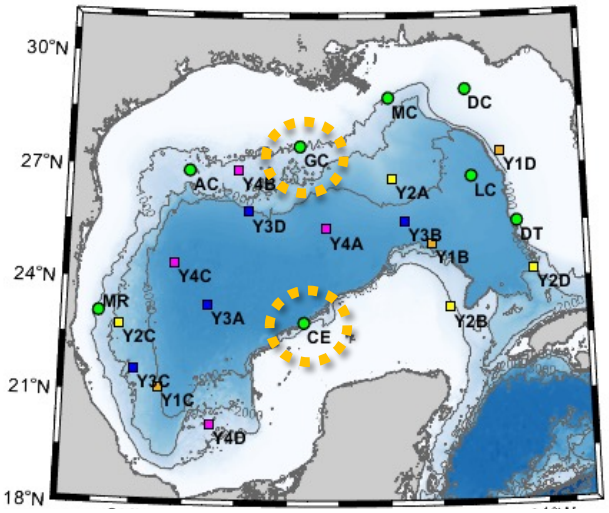
- Initial step with equal weights
- Poorly predicted, weights increased
- Poorly predicted, reweighted

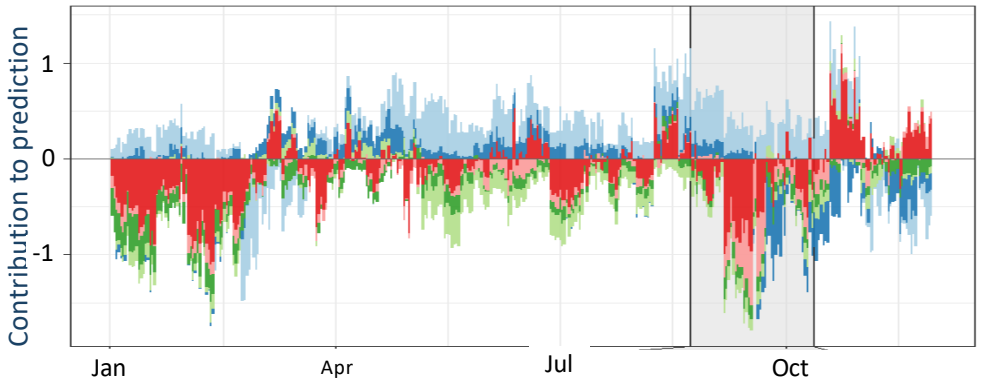




Airgun noise within the top predictors







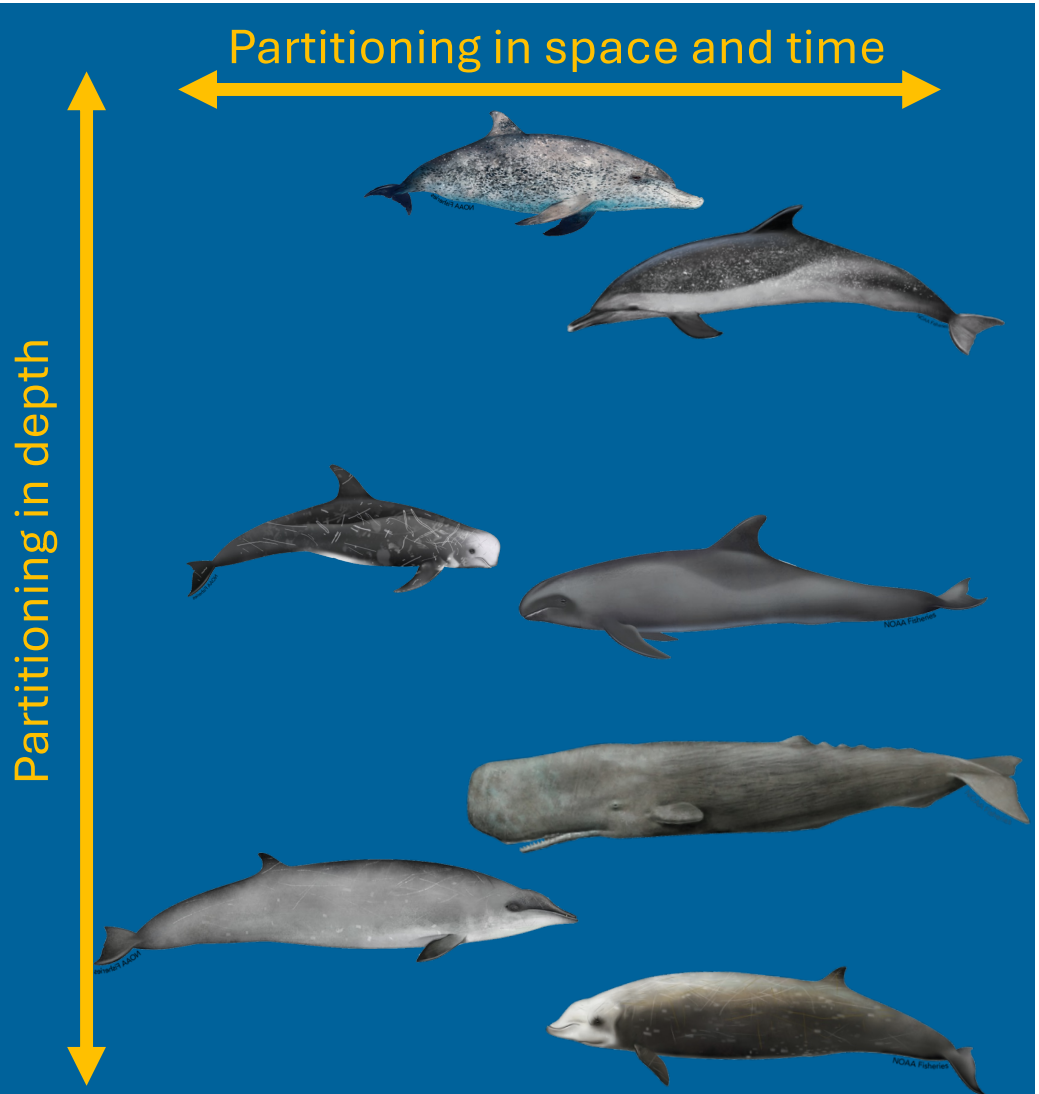
A. Solsona Berga et al., in prep.

Predictors

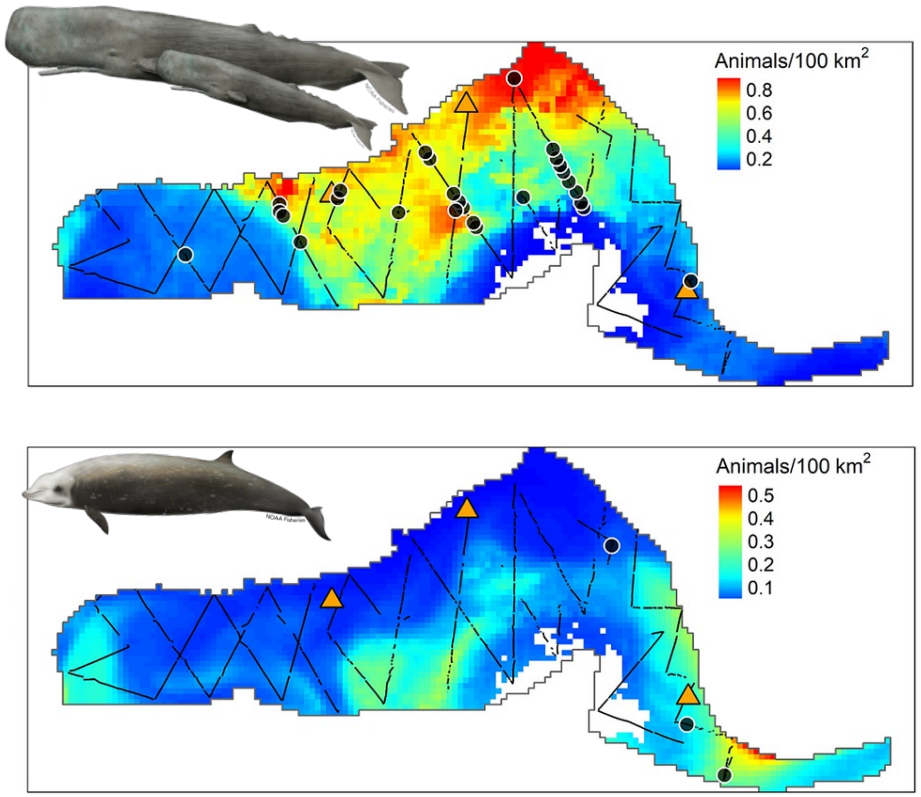
- Deep layer thickness
- Upper layer thickness
- SST
- Salinity
- Airgun noise
- Remaining predictors

Takeaways

- Densities declined for 7 of 8 marine mammal species/groups at long-term monitoring sites from 2010-2020.
- Marine mammals are not uniformly distributed across the Gulf.
- Hotspots differ between species.
- Patterns in occurrence are complex, driven by oceanography, mediated by prey.
- Major drivers differ regionally.



Where we're going: Combining datatypes to enhance explainability

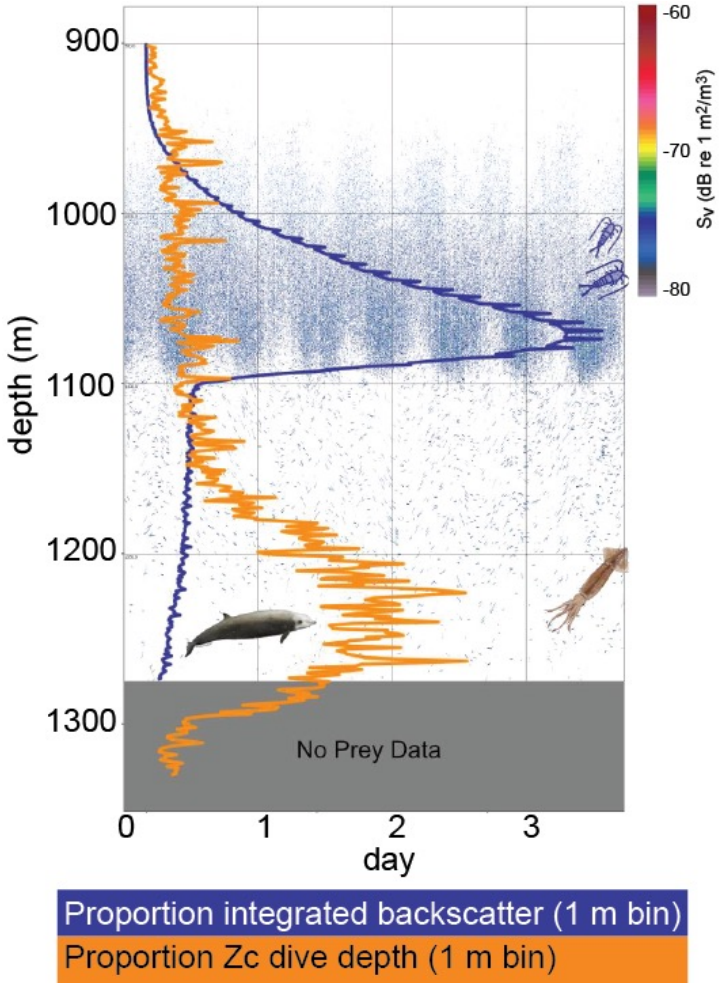


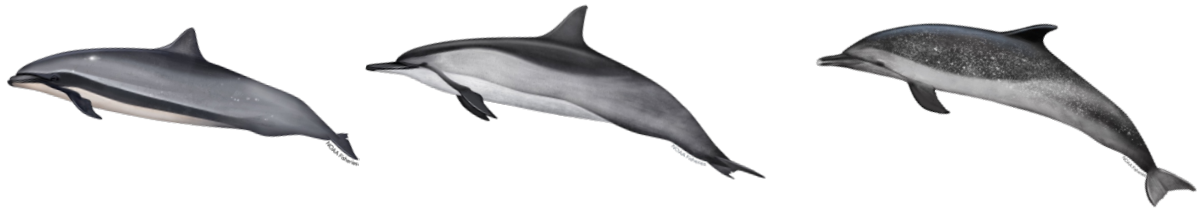
Frasier et al. 2021

Visual + Acoustic observations to:

- Reduce uncertainty in cryptic species abundance.
- Improve year-round estimates.
- Account for spatial shifts.
- Understand oceanographic drivers for model prediction fine-tuning.

Where we're going: Combining datatypes to enhance explainability



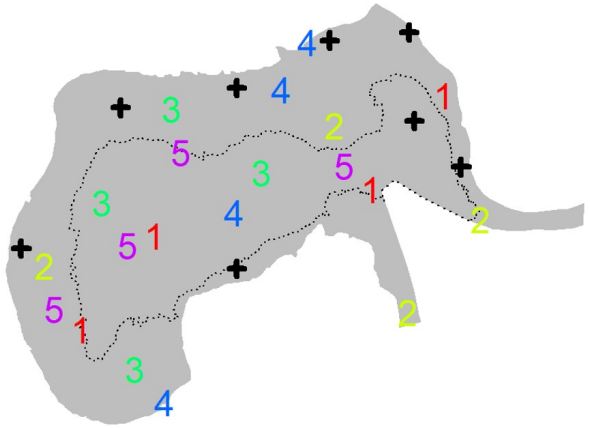


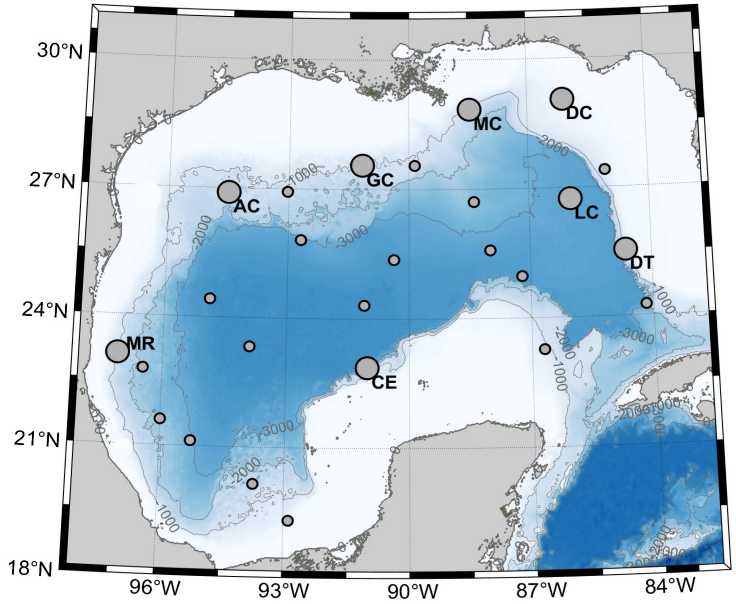
Needs:

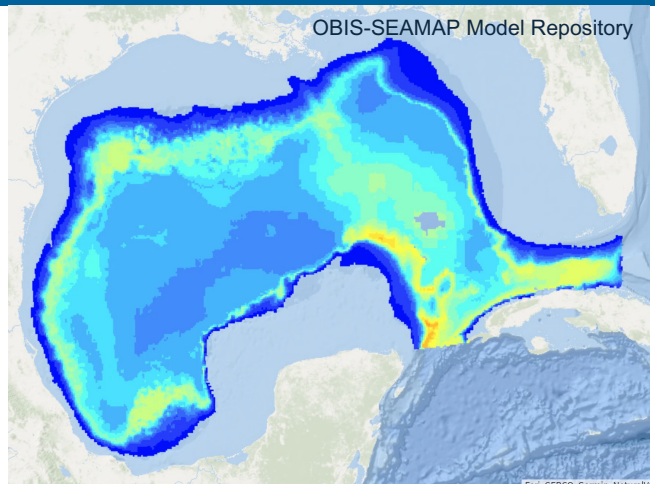
- Improved acoustic separation of small odontocete species.
- Tracking for more species to improve detection probability estimates.
- Understanding the missing link – prey.

Shannon Dolan & Simone Baumann-Pickering, in prep.

Closing the loop: What sampling design is practical and effective?





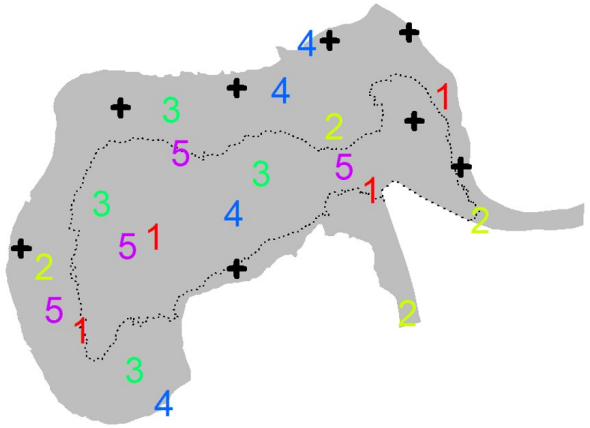


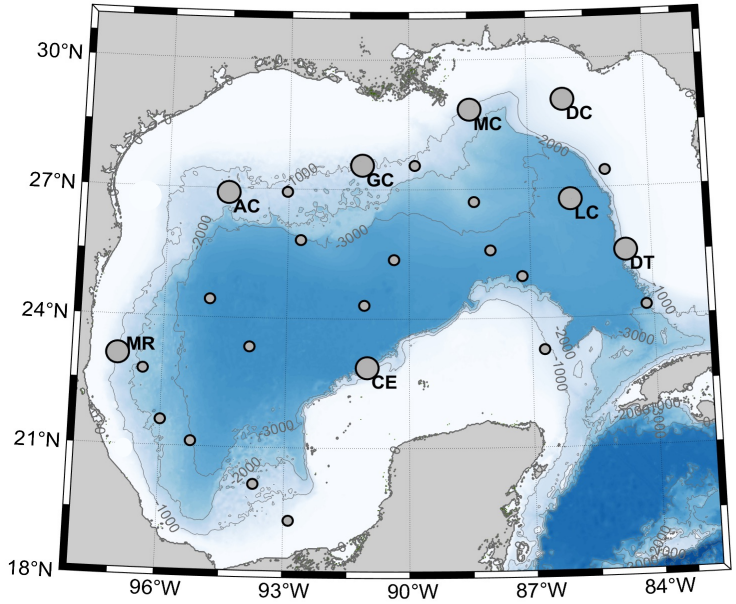
What is the minimum number of sensors needed to

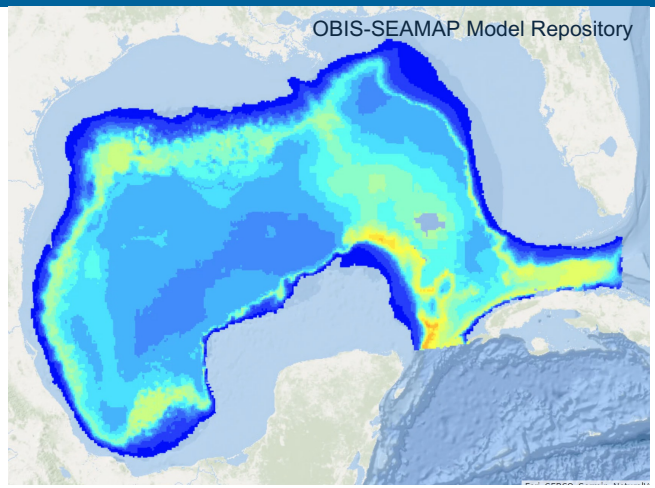
- Characterize actual spatial distributions?
- Improve abundance estimates?
- Detect change?

Based on: Species priorities, confidence and sensitivity requirements

Closing the loop: What sampling design is practical and effective?





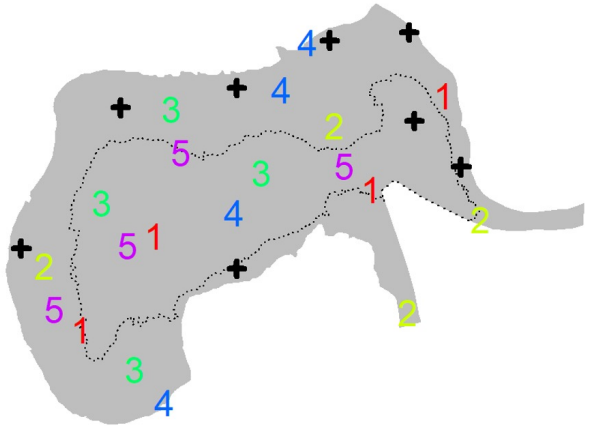


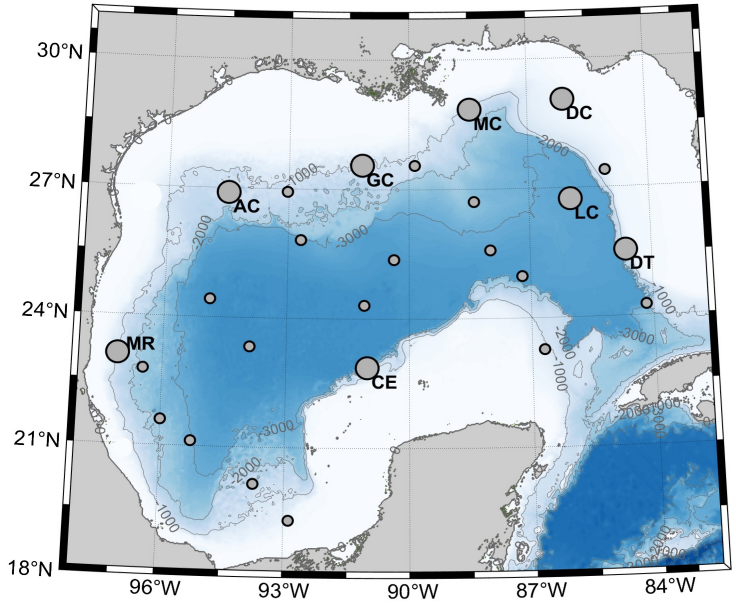
What is the minimum number of sensors needed to

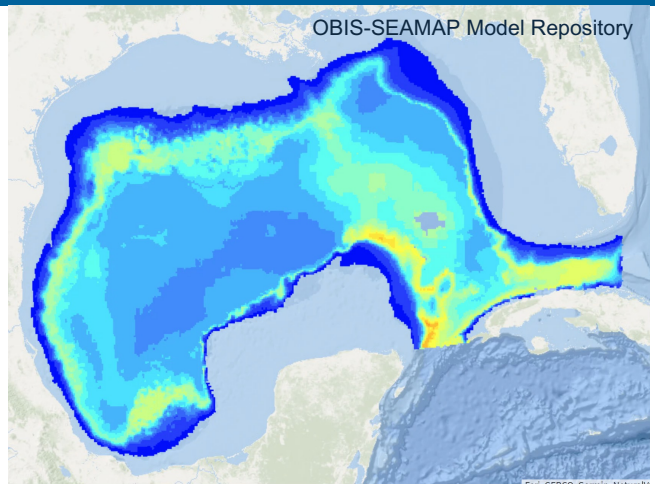
- Characterize actual spatial distributions? <- Short-term sites
- Improve abundance estimates?
- Detect change? <- Long-term sites

Based on: Species priorities, confidence and sensitivity requirements

Closing the loop: What sampling design is practical and effective?







What is the minimum number of sensors needed to

- Characterize actual spatial distributions? <- Short-term sites
- Improve abundance estimates? <- May need a mix
- Detect change? <- Long-term sites

Based on: Species priorities, confidence and sensitivity requirements

Acknowledgements

LISTEN project partners: Adolfo Gracia, Arturo Serrano, Matthieu Le Hénhaff, Carrie Wall-Bell

Bruce Thayre, Itzel Pérez Carballo, Kieran Lenssen, Isabel Catalina Barrera Diaz, John Hurwitz, Sean Wiggins, Gabrielle Arrieta, Ashley Cook, Héloïse Frouin-Mouy, Eva Hildalgo Pla, Gania Figueroa, Josh Jones, Kristen Rosier, Natalie Posdaljian, Ryan Pierson, Sam Wagner, and Vanessa ZoBell assisted with building, deploying and recovering of HARPs. Erin O'Neill, Diego Majewski, and Shelby Bloom processed the acoustic data.

Vanessa ZoBell, Jenny Trickey and Kieran Lenssen assisted with data analysis, Morgane Dackiw with statistical analysis. Captain Tad Berkey and the crew of the R/V Pelican made the field work possible. Len Thomas assisted with the LISTEN GoMex survey design.

Research also made possible by Adolfo Gracia, Arturo Serrano Solis, Tony Martinez, Jesse Wicker Keith Mullin, the crews of the R/V Gordon Gunter and R/V Pisces, Ocean Alliance, and many, many others.

Funding Sources Include:

- NOAA's RESTORE Science Program
- The Deepwater Horizon Open Ocean Trustee Implementation Group
- Office of Naval Research Task Force Ocean
- Deepwater Horizon Natural Resource Damage Assessment program
- The Gulf of Mexico Research Initiative through C-IMAGE at USF (Steve Murawski and Sheryl Gilbert)
- NOAA NMFS' Office of Science and Technology (Mridula Srinivasan)
- NOAA's Southeast Regional Office (Laura Engleby)
- National Oceanic and Atmospheric Administration's RESTORE Science Program
- Deepwater Horizon Open Ocean Trustee Implementation Group's "Reduce Impacts of Anthropogenic Noise on Cetaceans" project

NOAA FISHERIES Southeast

MARINE BIOACOUSTICS RESEARCH COLLABORATIVE

RESTORE SCIENCE PROGRAM

UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY

Universidad Veracruzana

Instituto de Ciencias del Mar y Limnología

CIMAS

C-IMAGE Center for Integrated Modeling and Analysis of Gulf Ecosystems

GULF OF MEXICO RESEARCH INITIATIVE

NSF GRFP

NATIONAL ACADEMIES Sciences Engineering Medicine

GULF RESEARCH PROGRAM

National Centers for Environmental Information

U.S. NAVY TASK FORCE OCEAN — OCEANUM SUPERIORIS SCIENTIAE