Seismic surveys: Potential impacts and ideas for mitigation, monitoring and management

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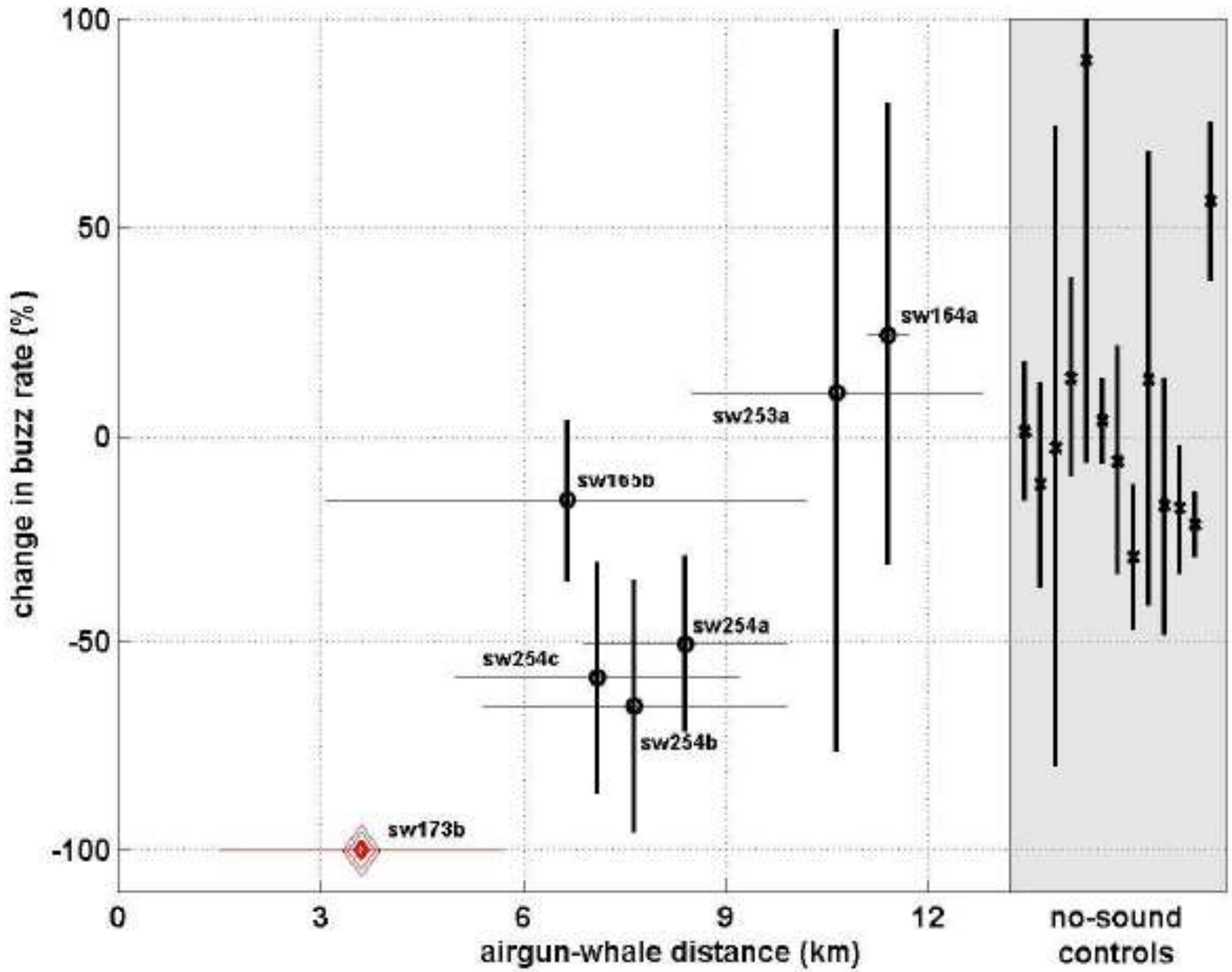
Take home messages

- Demonstrated effects
  - Including those that can be incorporated into population level impact calculations
  - Important to consider turtles and fish
- Mitigation
  - Numerous options ranging from observing animals to alternative gear
  - Feedback on effectiveness
  - The next generation of managing noise
- PSSAs, e.g., Cape Hatteras Point
  - Almost complete lack of information about animal use
  - PAM is great, but not without cue rates

Change in sperm whale foraging rate vs distance to seismic survey

Change in Foraging Rate
(% compared to control)



Miller et al 2009

Change in humpback whale singing behavior in the presence of seismic

Seismic Surveys Affect Humpback Whale Singing

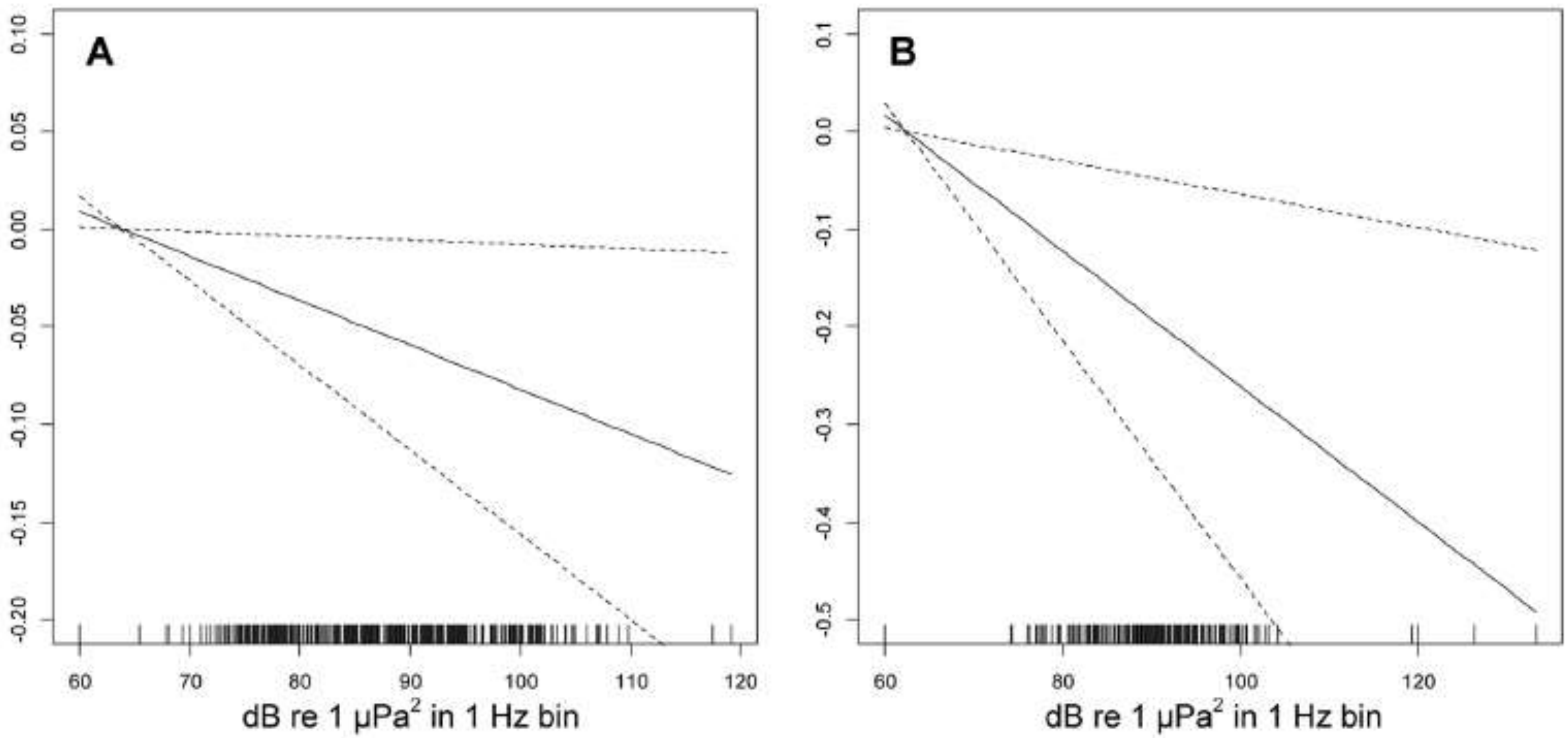


Figure 4. Impact of seismic survey pulse RL on humpback whale singing activity for the full dataset. Generalized Additive Mixed Models of the number of humpback whale singers with smooth terms for the dependence on Survey Day, Hour, Moon Phase and Peak Power fitted for each of the MARUs; plots show the estimated conditional dependence of humpback whale singer numbers on Peak Power for (**A**) MARU 1 and (**B**) MARU 2. The x-axis in each plot shows Peak Power, describing received level of seismic survey pulse (in dB re: 1 μPa^2 in a 1 Hz frequency bin) with a rug plot (short vertical bars) indicating the Peak Power values of observations. The y-axis, with scale selected optimally for each plot, shows the contribution of the smooth of Peak Power to the fitted values of singer number. Estimates (solid lines) are shown with 95% confidence bands (dashed lines), indicating a significant downward trend in singer number with increasing pulse RL.

doi:10.1371/journal.pone.0086464.g004

Cerchio et al 2014

Right whale mother-calf counter-calling

Effects on cetaceans, fish and turtles(?)

Species	Location	Response/ Effect	Received Level	Reference
Bowhead whale	Arctic	Change surface-respiration; Avoidance	120-130 dB re 1 µPa RMS	Richardson et al. 1999; Robertson et al. 2013
Sperm whale	Gulf of Mexico	Buzz (feeding) rate decline	135-147 dB re 1 µPa RMS	Miller et al. 2009
Harbor porpoise	North Sea	Temporary displacement	145–151 dB re 1 $\mu Pa^2 s^{-1}$	Thompson et al. 2013
Humpback whale	Angola	Singing and singers declined	120-150 dB re 1 µPa peak	Cerchio et al. 2014
Fin whale	Mediterranean	Altered singing and abandon habitat	ca. 15 dB 1 µPa above background	Castellote et al. 2012
Fish (herring, blue whiting)	Norway	Displacement, horizontal and vertical	Unknown	Slotte et al. 2004
Fish (Cod, Pollock)	Scotland	Short-term startle, no long term effects	variable	Wardle et al. 2001
Fish (Pink snapper)	Captive	Hearing system damage	Variable 150-180 dB re 1 µPa RMS	McCauley et al. 2003

Responsible Practices for Minimizing and Monitoring Environmental Impacts of Marine Seismic Surveys with an Emphasis on Marine Mammals

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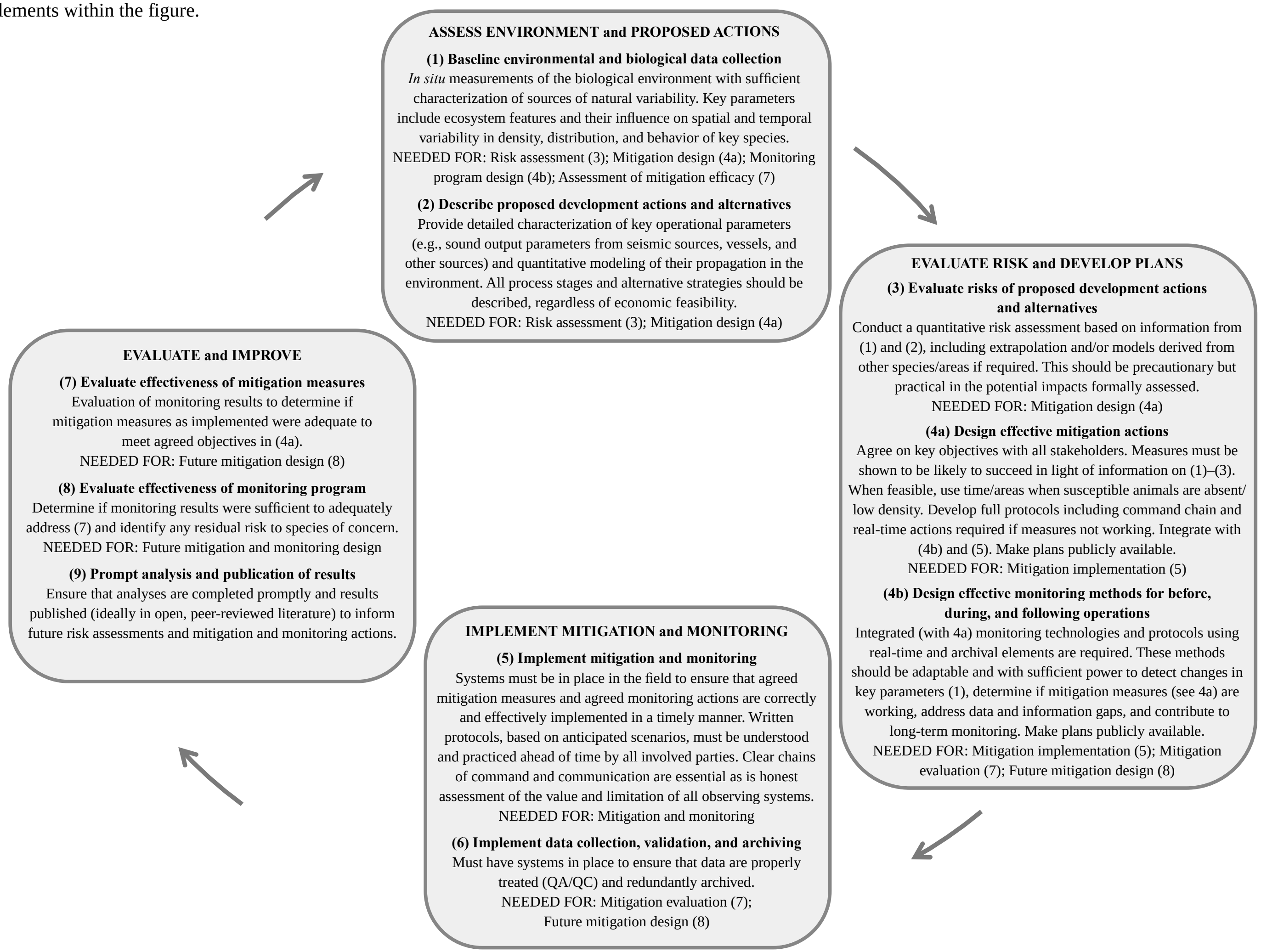
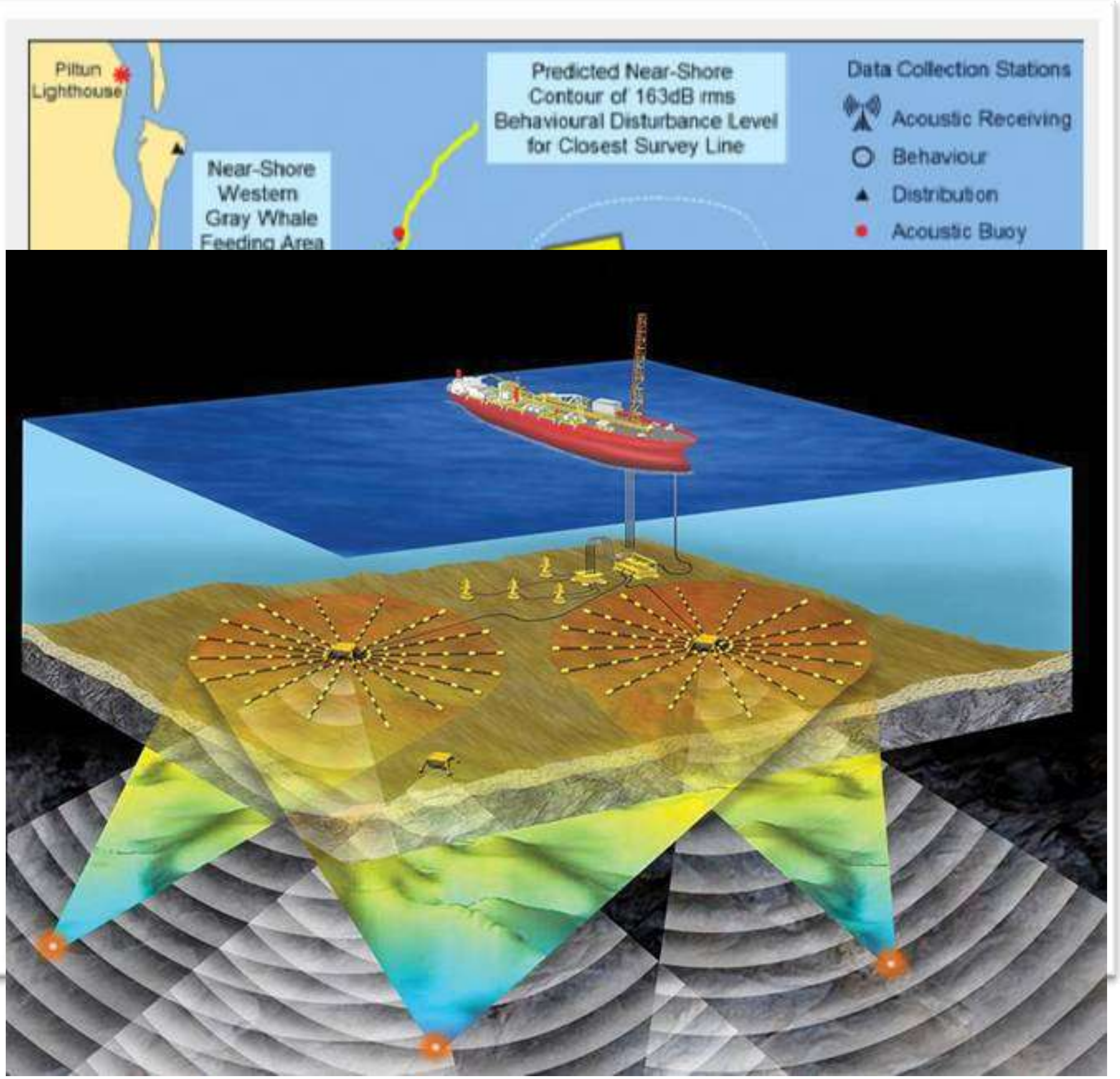
Douglas P. Nowacek, Christopher W. Clark, David Mann, Patrick J.O. Miller, Howard C. Rosenbaum, Jay S. Golden, Michael Jasny, James Kraska and Brandon L. Southall – In Press *Frontiers in Ecology and Env*

Marine Seismic Surveys and Ocean Noise: Time for coordinated and prudent planning

Figure 1. A practical roadmap for planning, executing, evaluating, and improving the design of a responsible seismic survey; the numbers in parentheses throughout the figure refer to other elements within the figure.



Nowacek et al. 2013



Acoustic Zoom: The Future of Offshore Exploration

- Mitigation measures
  - Baseline data
  - Minimize survey area
  - Minimize airgun array
  - Propagation modeling
  - Exposure criteria
  - Real time acoustic monitoring
  - Visual monitoring
  - Timing survey to separate from animals
  - Multi-client surveys
  - Provisions for poor visibility conditions
  - Shut-downs
  - Dissemination of results
  - Alternative sources

Time for planning

- Appropriate impact thresholds
    - Managing with a single number…currently regulated to avoid exposure >180 dB for injury and 160 dB for behavioral disruption…needs to be revisited
    - Revisions to impact criteria are underway
    - Probabilistic risk function
- The need for baseline data
    - Lessons from DWH
- Cumulative effects
    - Inherent and pragmatic challenges
    - Still, need to press ahead, tools are improving
        - Estimating health, e.g., PCOD
        - Estimating masking, e.g., Clark et al. 2009
        - Risk assessment frameworks, e.g., value of individual habitats
- A way forward…

A Way Forward…

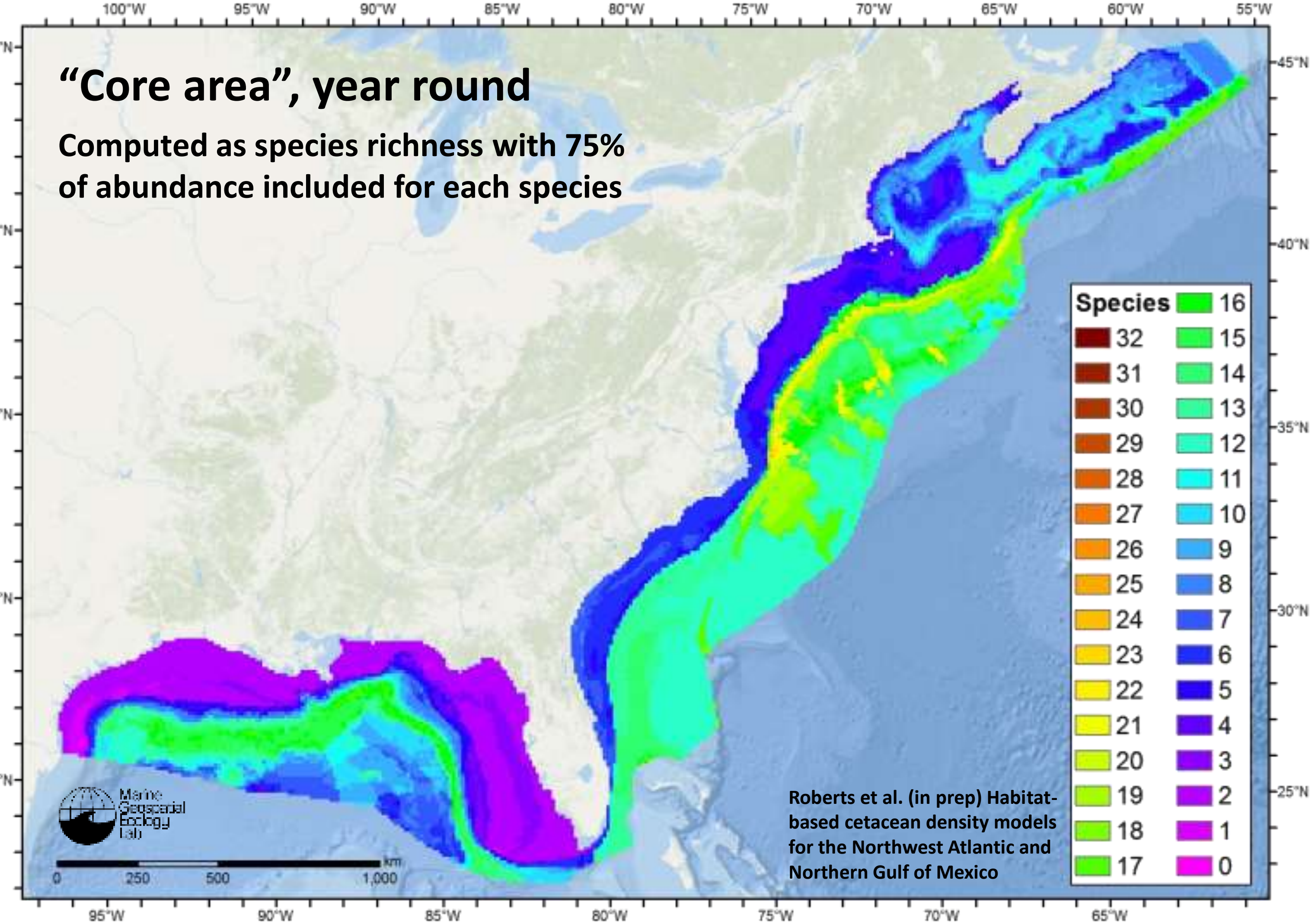
- Precedents for international and trans boundary ‘pollutants’
  - Cartegena Protocol for Biosafety (UN 2000)
  - Convention on Long-range Transboundary Air Pollution (UN ECE 1979)
  - EU, CBD, CMS, etc., all recognize noise as a problem or even a pollutant
- Options??
  - IMO member states could pursue a new annex to MARPOL 73/78 through Marine Env Protection Comm
    - » Definition of ‘harmful substances’? Maybe use ‘discharge’
  - New Convention regulating all non-military noise sources

Measures to include in a convention

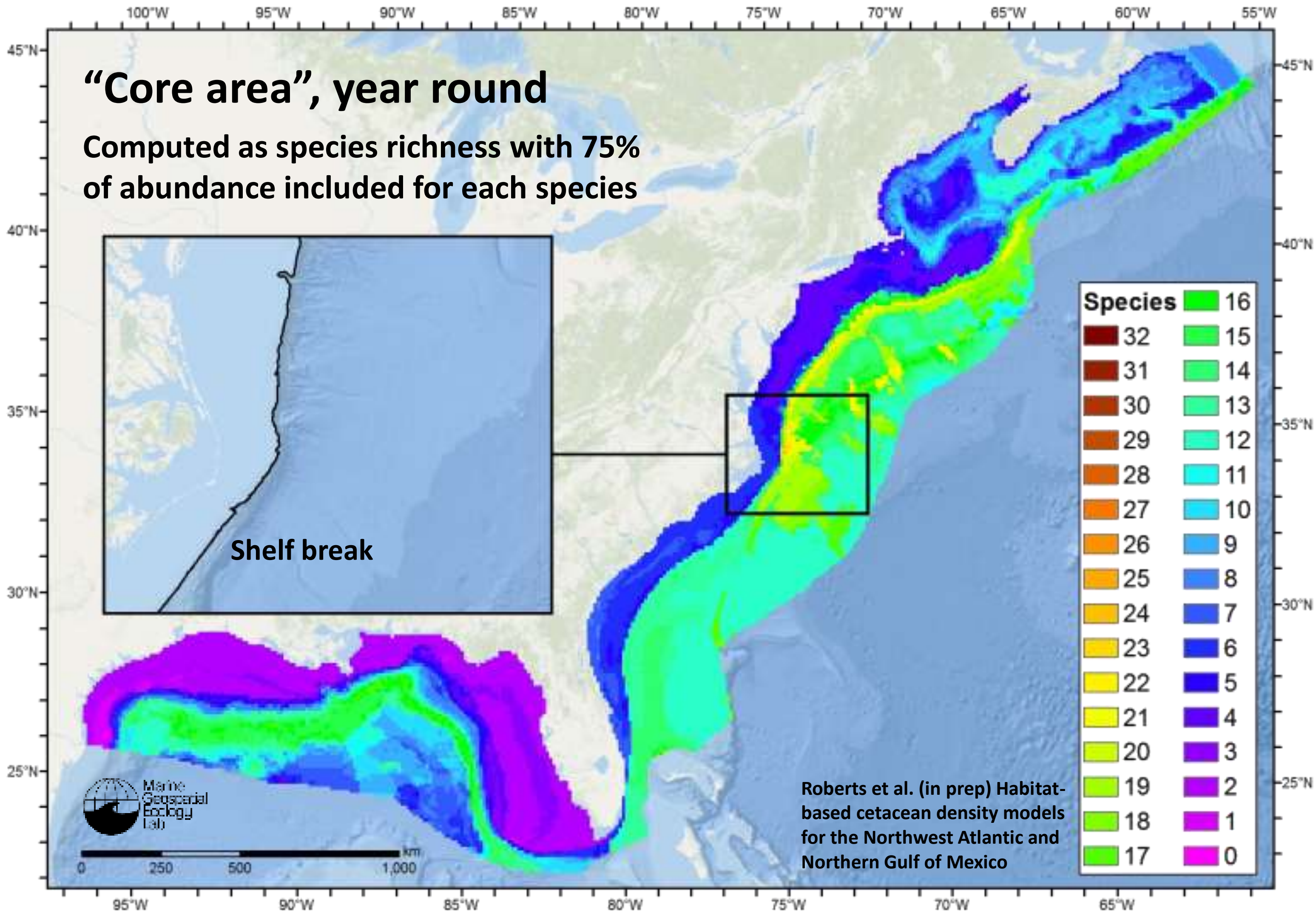
1. Empirically-based restrictions on time, duration and/or area of activities in biologically important habitats
2. Require sustained monitoring of acoustic habitat indicators, including establishing limits and targets
3. Promote development and requiring use of methods and technologies that reduce acoustic footprints
4. Creation of intergovernmental science organization to coordinate, promote and advance efforts to improve assessment of impacts
5. Requirements for preparation of EISs and ‘strategic’ or ‘programmatic’ EAs that meaningfully analyze cumulative effects

"Core area", year round

Computed as species richness with 75% of abundance included for each species



Roberts et al. (in prep) Habitat-based cetacean density models for the Northwest Atlantic and Northern Gulf of Mexico


"Core area", year round
Computed as species richness with 75% of abundance included for each species
Shelf break
Species
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Roberts et al. (in prep) Habitat-based cetacean density models for the Northwest Atlantic and Northern Gulf of Mexico
Marine Geospatial Ecology Lab
km
0
250
500
1,000
100°W
95°W
90°W
85°W
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N

“Core area”, year round

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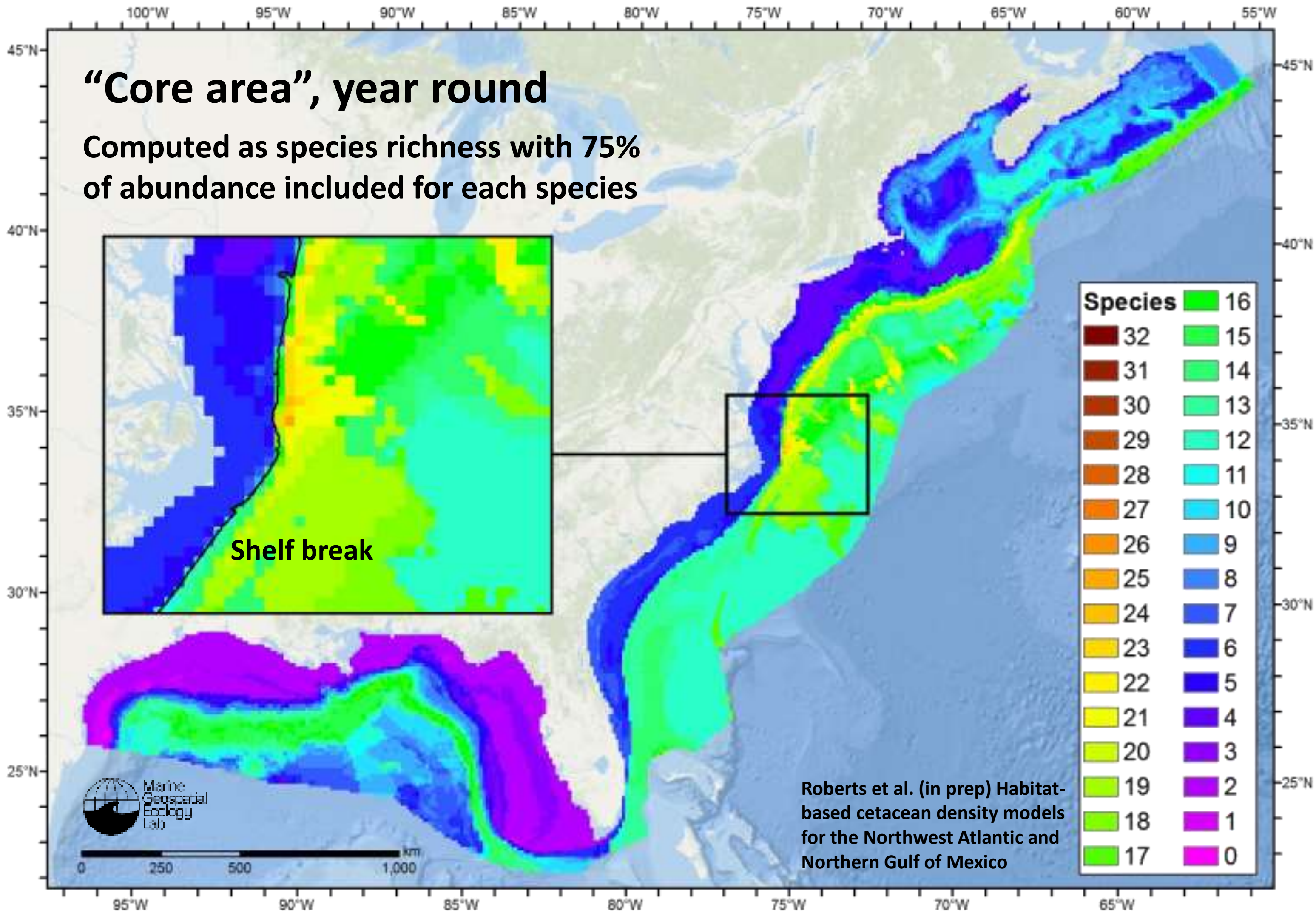

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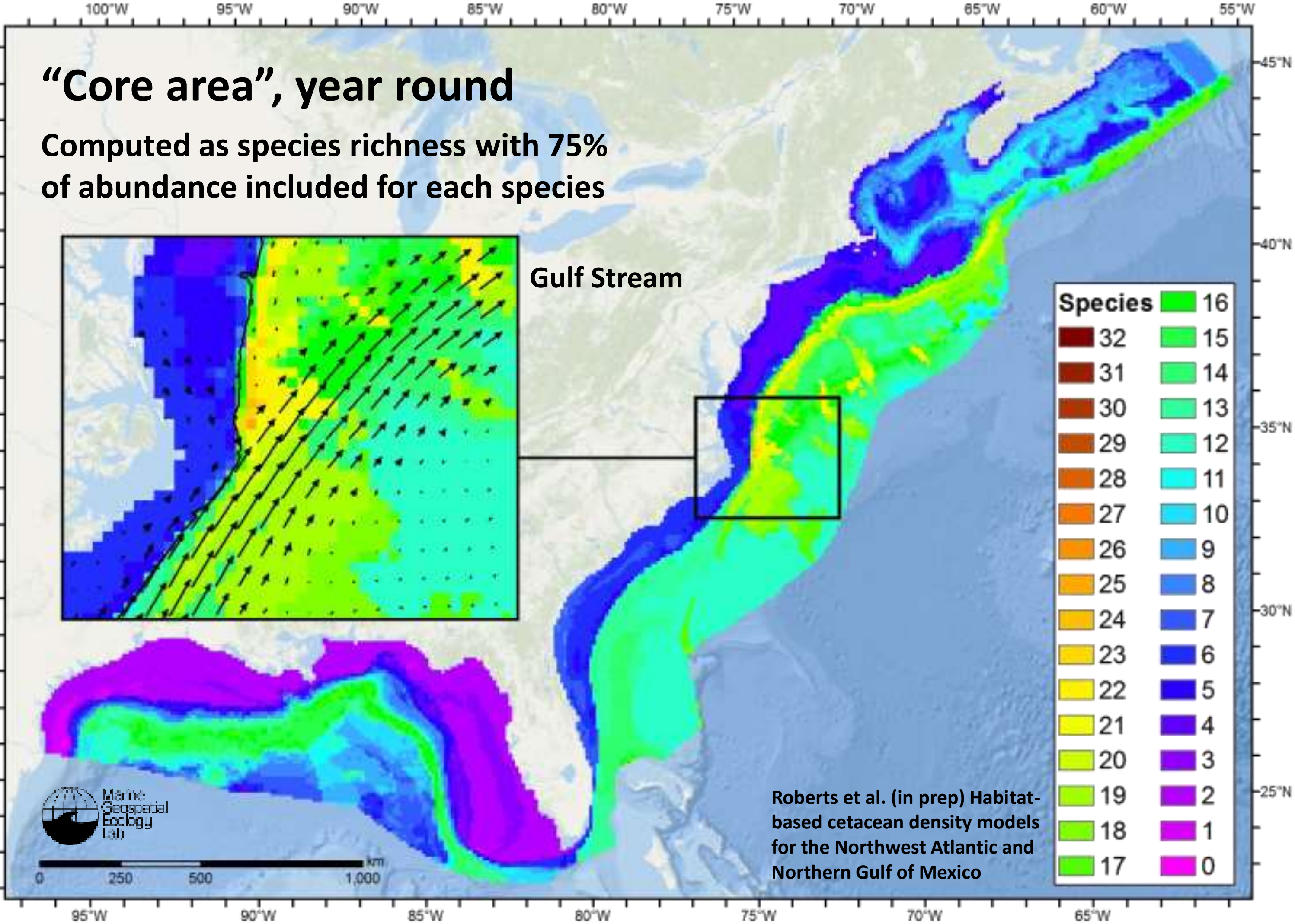

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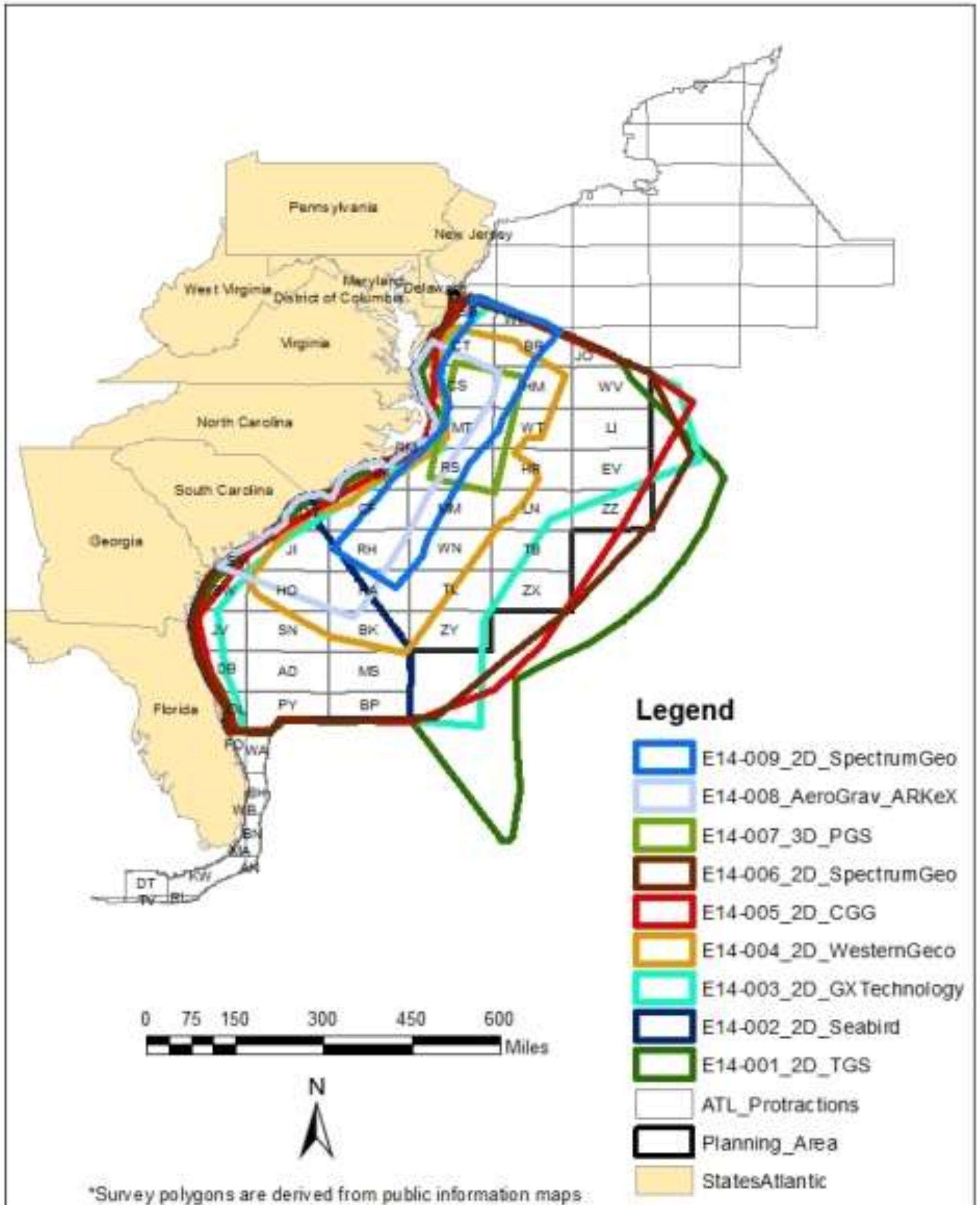
Atlantic Pending Surveys

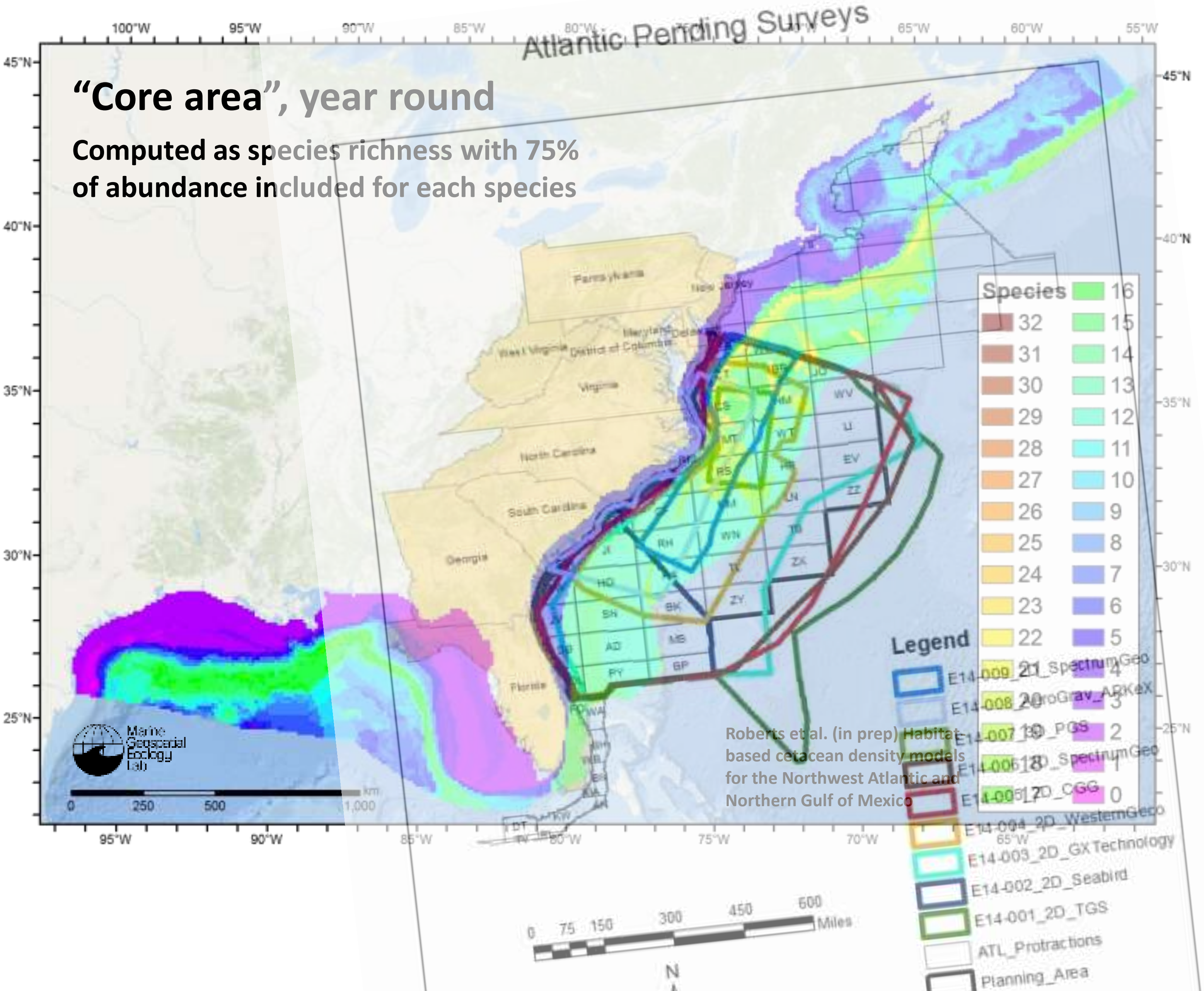


Seismic permit applications

- Speculative surveys – 2D
- 3D pre-production
- 4D during production

“Core area”, year round

Computed as species richness with 75% of abundance included for each species



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