Environmental assessment of offshore wind power generation near Rhode Island: Acoustic and electromagnetic effects on marine animals.

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James H. Miller
University of Rhode Island

Gopu R Potty
University of Rhode Island

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Environmental assessment of offshore wind power generation near Rhode Island: Acoustic and electromagnetic effects on marine animals

James H. Miller, Gopu R. Potty, Kathleen Vigness Raposa, David Casagrande, Lisa Miller, Steven Crocker, Robert Tyce, Jonathan Preston, and Brian Roderick
University of Rhode Island

Jeffrey Nystuen, University of Washington

Peter Scheifele, University of Cincinnati

THINK BIG WE DO℠

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Outline

- Offshore Wind Farm off Rhode Island
- Noise Budgets
- Passive Acoustic Listeners
- Wind Turbine Noise Measurements (Europe)
- Measured Noise Budget (RI)
- Transmission Loss Measurements (RI)
- Right Whale Abundance (RI)
- Predicted Effect of Wind Turbines on Noise Budget

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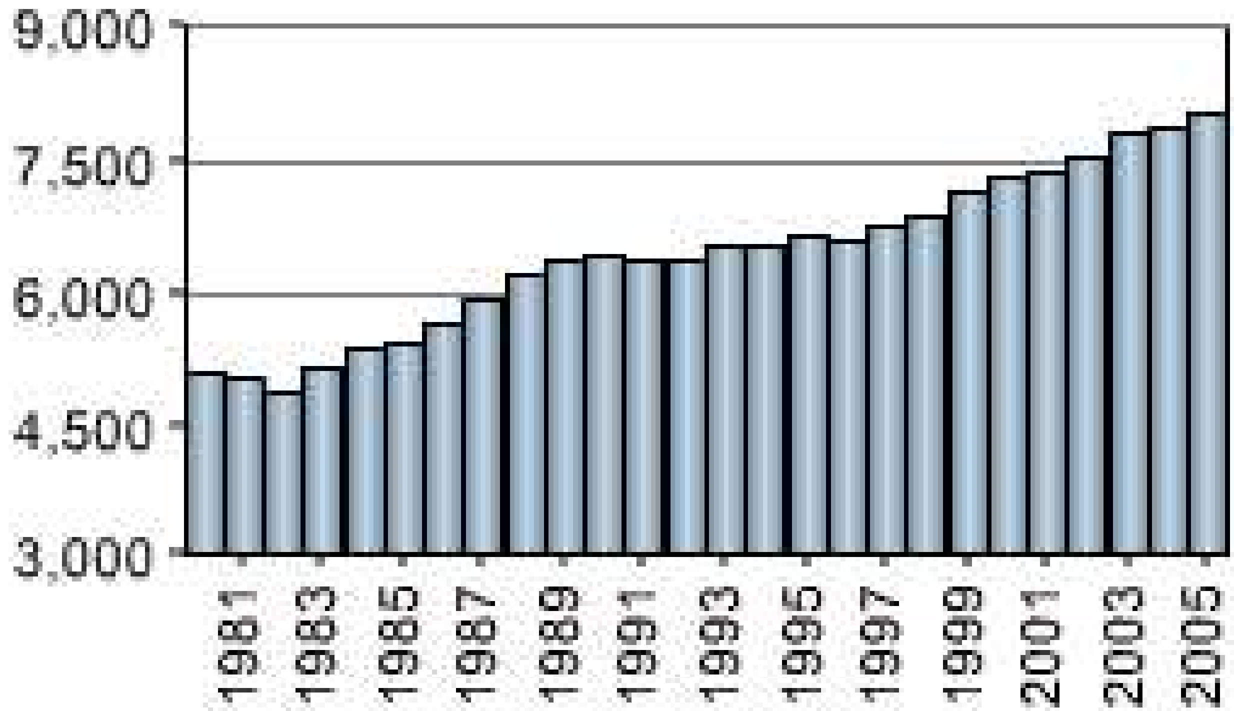
Offshore Wind Power

- Interior Secretary Salazar said ocean winds along the East Coast can generate 1 million megawatts of power, roughly the equivalent of 3,000 medium-sized coal-fired power plants, or nearly five times the number of coal plants now in the United States.
- Offshore wind has the potential to supply a significant fraction of Rhode Island’s electric power needs. (Goal: 15% in 2020)
- The state selected URI to assist in the planning for an offshore wind farm
- Our team is responsible for the acoustic and EM impact assessment

Total Electricity Consumption in Rhode Island 1980 – 2005

(million kWh)

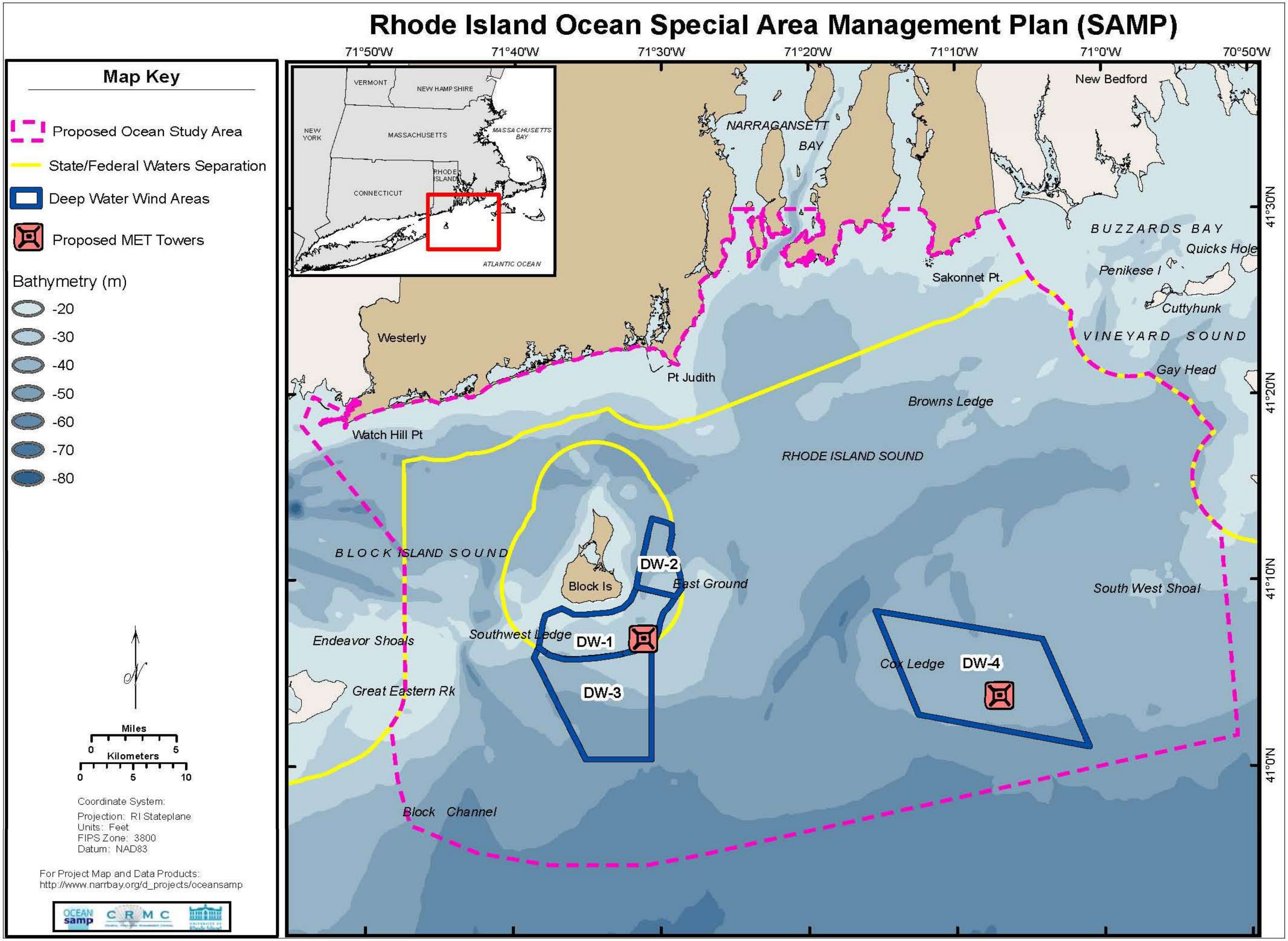


108 3.6 MW
Wind turbines
50% utilization
=1700 million kWh

http://apps1.eere.energy.gov/states/electricity.cfm/state=ri#total

Rhode Island Ocean Special Area Management Plan (SAMP)

- Examine current and potential uses and natural assets of Rhode Island's offshore;
  - Zone offshore waters;
  - Make Rhode Island the first state in the U.S. to zone its offshore waters for renewable energy development;
  - Protect current uses and habitats: fish, marine animals, birds, marine transport, etc.


Rhode Island Ocean Special Area Management Plan (SAMP)
Map Key
Proposed Ocean Study Area
State/Federal Waters Separation
Deep Water Wind Areas
Proposed MET Towers
Bathymetry (m)
-20
-30
-40
-50
-60
-70
-80
Miles
0
5
Kilometers
0
5
10
Coordinate System:
Projection: RI Stateplane
Units: Feet
FIPS Zone: 3800
Datum: NAD83
For Project Map and Data Products:
http://www.narrbay.org/d_projects/oceansamp
71°50'W
71°40'W
71°30'W
71°20'W
71°10'W
71°0'W
70°50'W
41°30'N
41°20'N
41°10'N
41°0'N
VERMONT
NEW HAMPSHIRE
NEW YORK
MASSACHUSETTS
MASSACHUSETTS BAY
CONNECTICUT
RHODE ISLAND
ATLANTIC OCEAN
New Bedford
NARRAGANSETT BAY
BUZZARDS BAY
Quicks Hole
Penikese I
Sakonnet Pt.
Cuttyhunk
VINEYARD SOUND
Westerly
Gay Head
Pt Judith
Browns Ledge
Watch Hill Pt
RHODE ISLAND SOUND
BLOCK ISLAND SOUND
DW-2
Block Is
East Ground
South West Shoal
Endeavor Shoals
Southwest Ledge
DW-1
Cox Ledge
DW-4
Great Eastern Rk
DW-3
Block Channel

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Objectives for Offshore Wind Farm Noise Study

- Perform a detailed analysis of the atmospheric and underwater noise conditions presently existing in the candidate locations.
- Predict the atmospheric and underwater noise levels during and after construction of the wind facility in the candidate locations.
- Estimate the effects of the added noise on marine mammals, turtles, and other animals native to the region.

SAMP, 2009

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PORTSMOUTH HIGH SCHOOL WIND TURBINE
PORTSMOUTH, RHODE ISLAND

NRC 2003 Finding

- **A proper accounting of the global ocean noise budget must include both the background ambient component and the contributions from identifiable sources.**

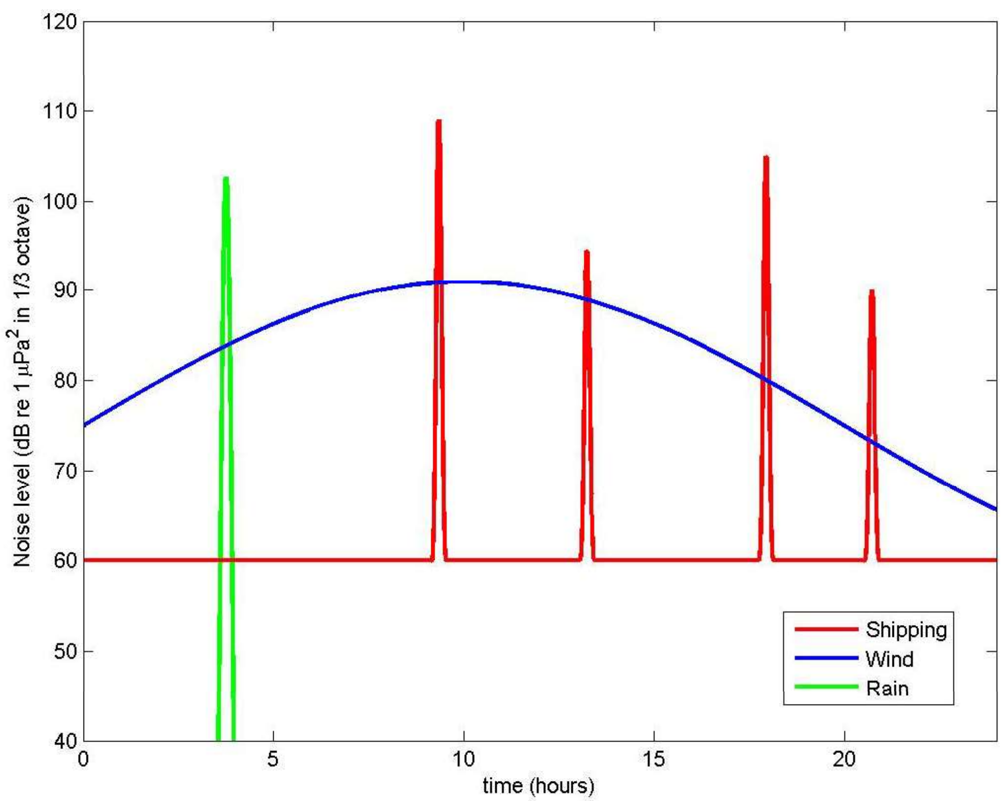
G. Frisk, D. Bradley, J. Caldwell, G. D'Spain, J. Gordon, M. Hastings, D. Ketten, J. Miller, D. L. Nelson, A. N. Popper, and D. Wartzok, *Ocean Noise and Marine Mammals*, National Academy Press, (2003).

Why Noise Budgets?

- Provides a listing of the sources of noise
- Allows for comparison between sources and context for a potential additional source
- May be biologically relevant, e.g. quantifying masking
- May be useful for outreach to media and public

A Day in a Hypothetical Noise Environment

How can we compare the relative contributions to the ambient noise field?



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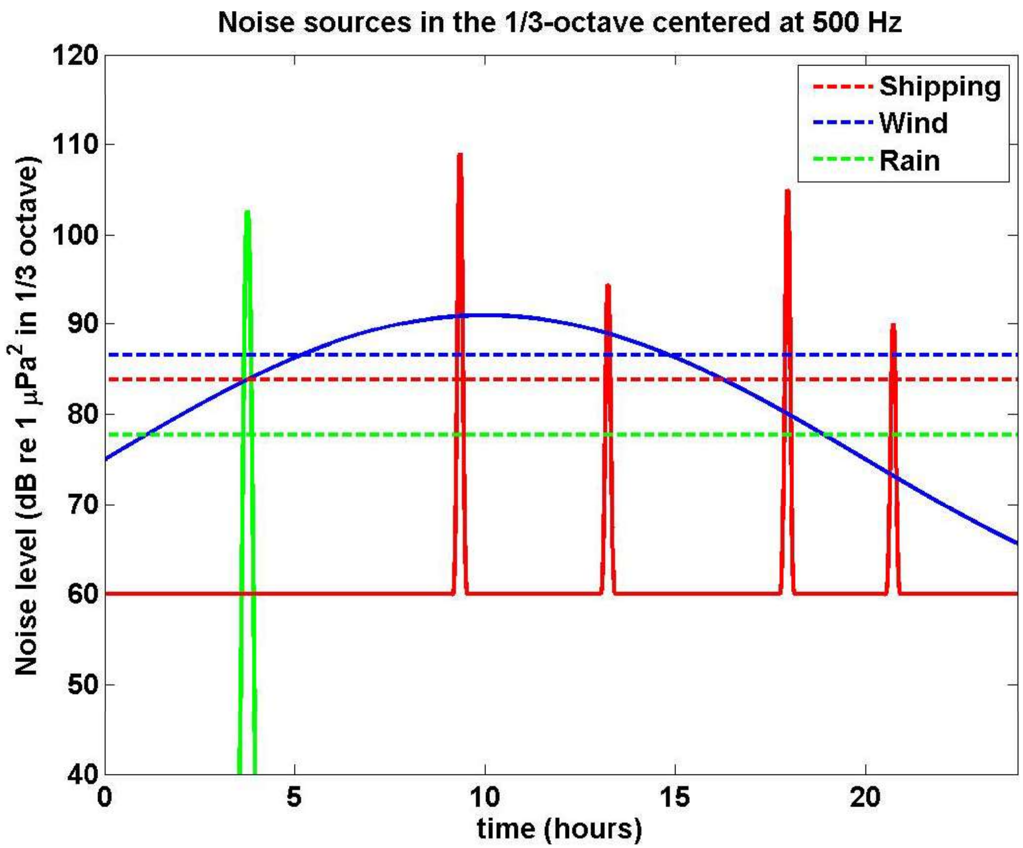
Budget Currency: Average Intensity from nth Source

$$\langle I_n(f) \rangle = \frac{1}{T \rho c} \int_0^T \left| \widetilde{p}_n(f,t) \right|^2 dt$$

where T is the averaging time, a biologically significant duration such as a day, season, etc. over a frequency band (e.g. 1/3 octave) of the nth source (e.g. wind, rain, shipping, seismic, biologics, etc.)

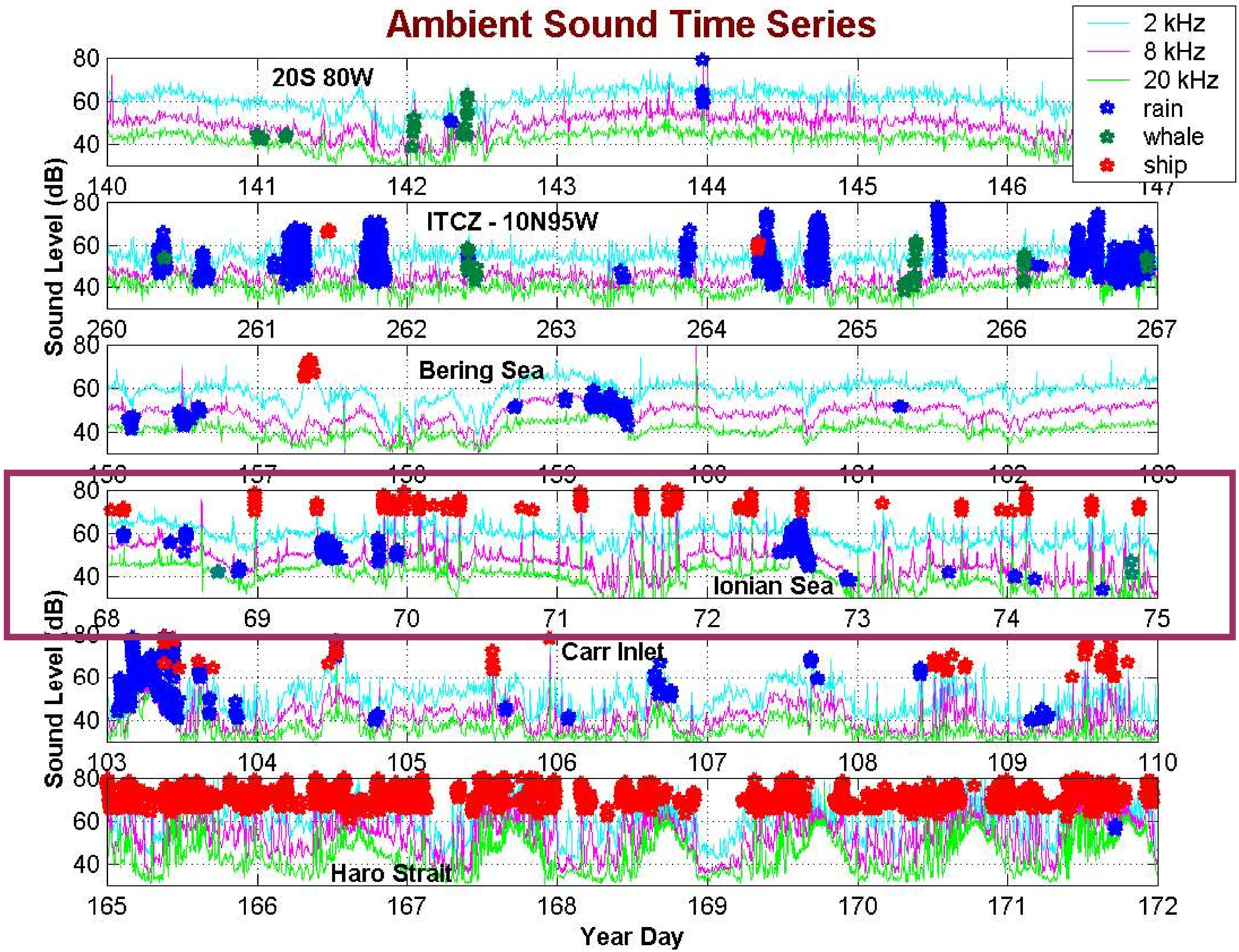
A Day in a Hypothetical Noise Environment



Passive Aquatic Listeners (PALs)

- PALs, developed by Jeff Nystuen, can sort out the and classify noise sources
- PALs can provide the data to compute the average intensity budget

Ambient Sound Time Series



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Mean Sound Levels (dB re 1 $\mu Pa^2/Hz$)

	20 S 85 W	10 N 95 W	Bering Sea	Ionian Sea	Carr Inlet	Haro Strait
2 kHz	61.0 ± 4.9	52.9 ± 5.0	58.7 ± 7.9	60.3 ± 5.8	53.4 ± 8.7	68.2 ± 8.4
8 kHz	50.1 ± 4.7	46.8 ± 7.1	47.7 ± 7.3	47.4 ± 8.3	45.9 ± 8.3	58.6 ± 8.4
20 kHz	42.4 ± 4.5	43.0 ± 8.2	40.9 ± 4.9	39.2 ± 8.6	43.5 ± 9.6	49.2 ± 8.6

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Dominant Sound Sources

Percentage of time present

	20 S 85 W	10 N 95 W	Bering Sea	Ionian Sea	Carr Inlet	Haro Strait
Wind	93%	86%	90%	74%	80 %	21 %
Rain	-	8 %	3 %	3 %	8 %	5 %
Ships	0.5 %	1.5 %	1 %	20 %	2 %	59 %
Whale*	1.8 %	0.6 %	-	0.5 %	-	-
Other	5 %	4 %	6 %	2 %	10 %	15 %

*30 kHz click detected – no visual confirmation

Temporal Detection (TD) Noise Budget

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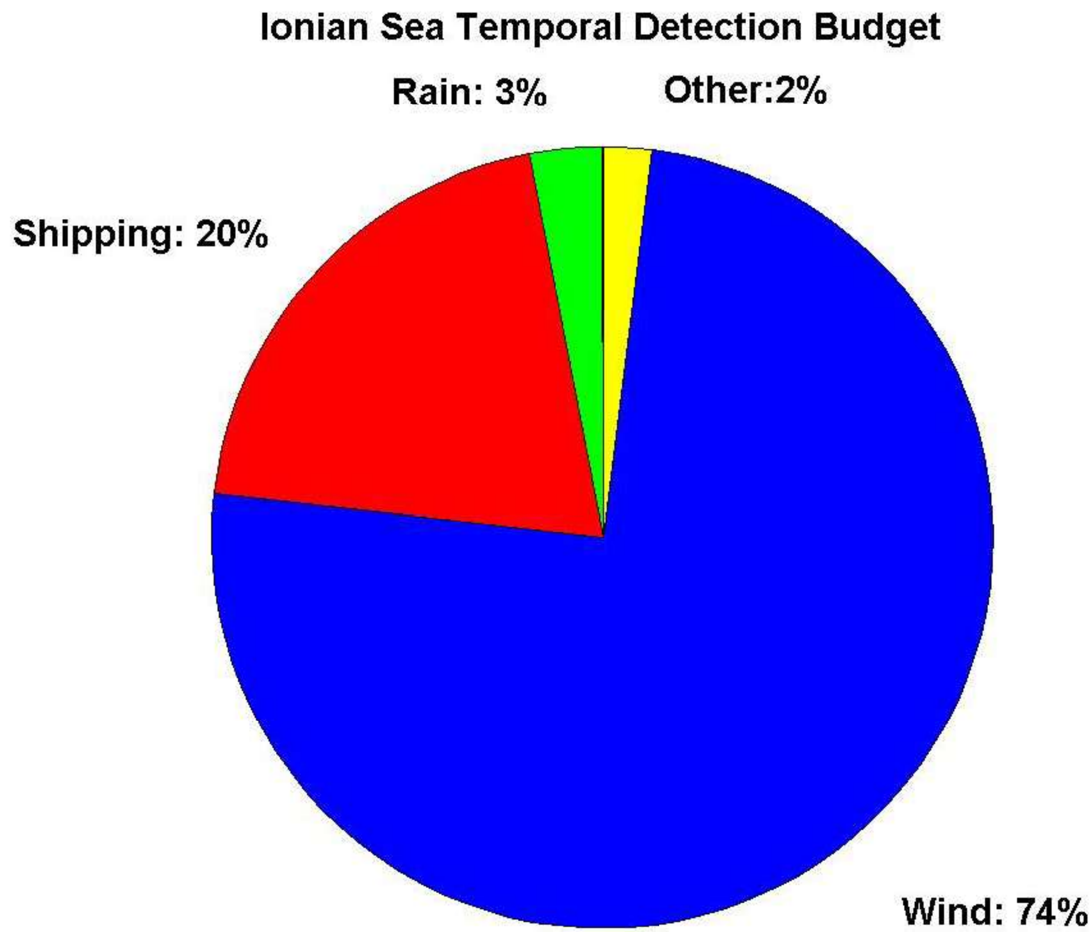
Temporal Detection Budget



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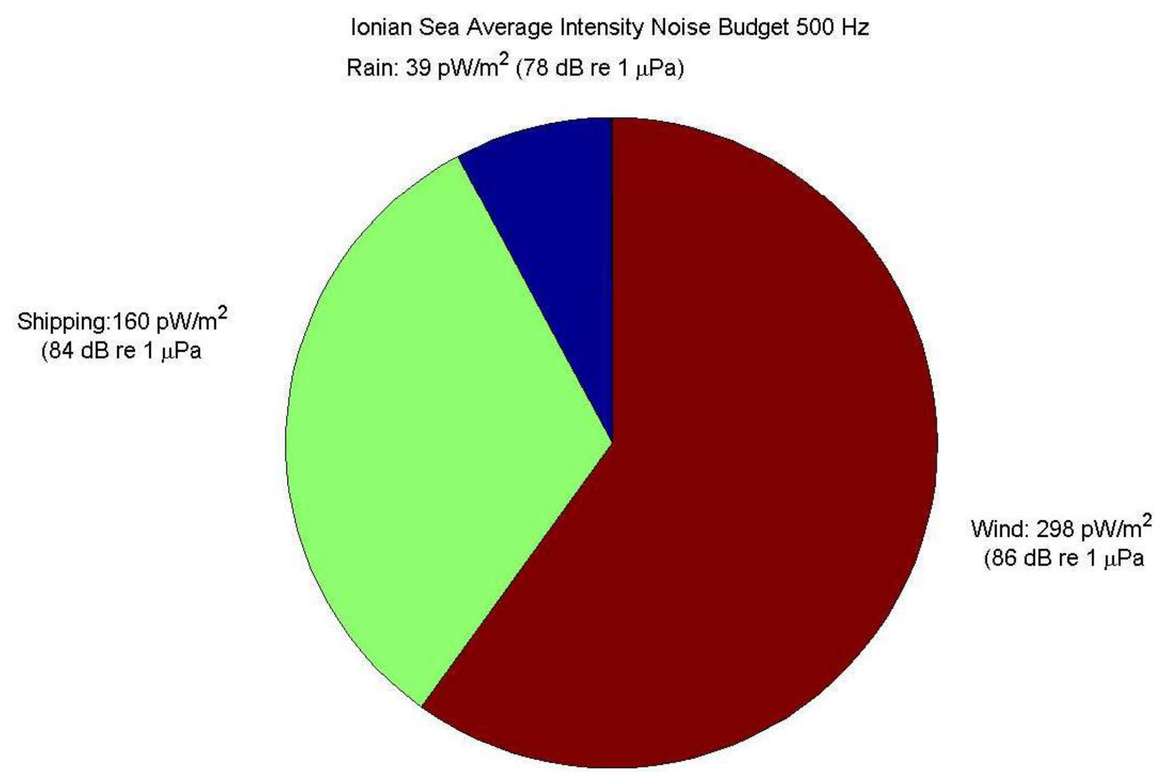
Average Intensity Budget



RI Ocean SAMP: Progress To Date

- Two Passive Acoustic Listener (PAL) systems deployed south and southwest of Block Island from October 6 to November 14, 2008.
- Data collection was successful and analysis complete and budget computed
- Two additional PALs deployed October 17 for a 6 to 12 month deployment, attached to two meteorological buoys

R/V Endeavor

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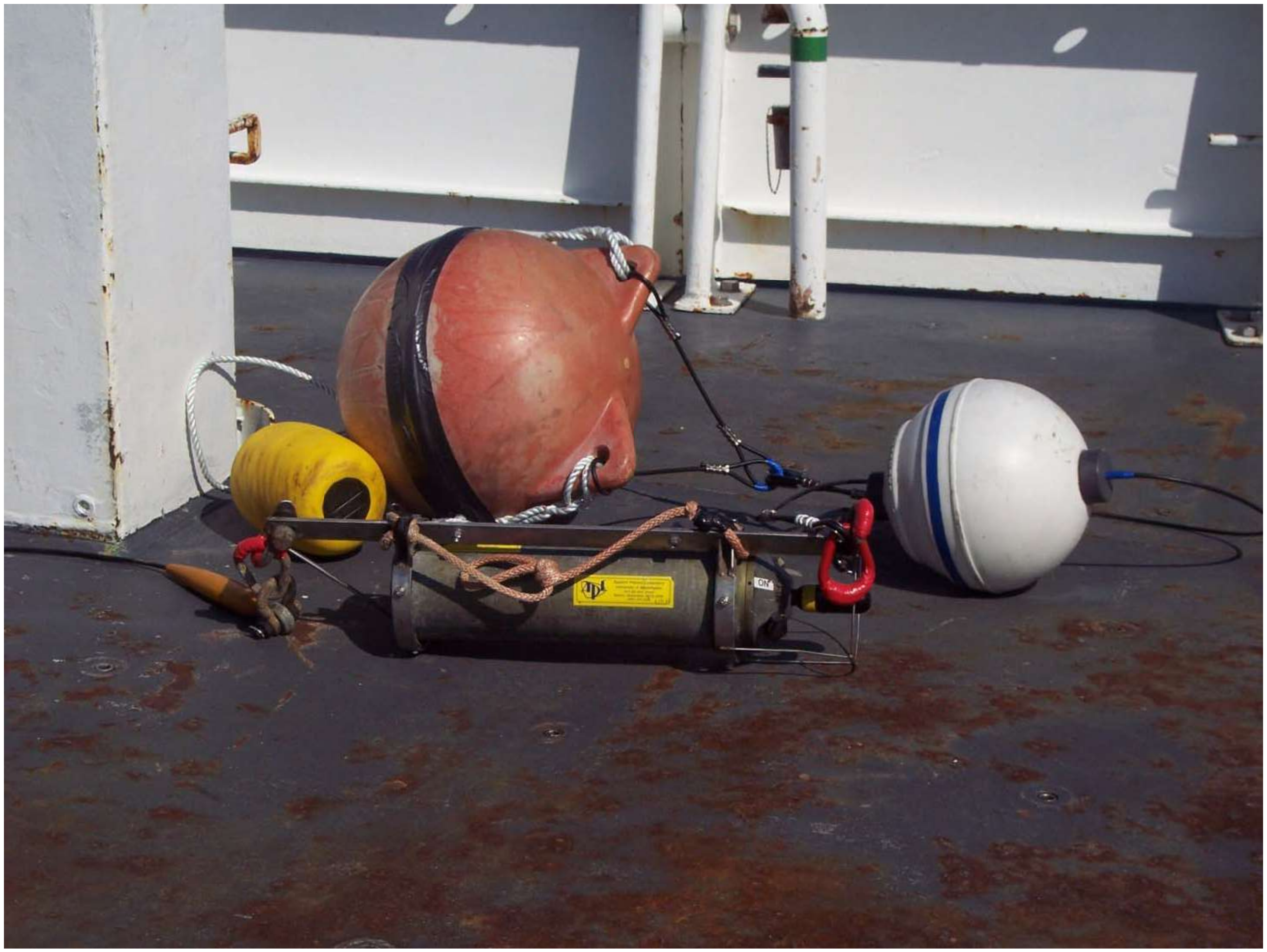
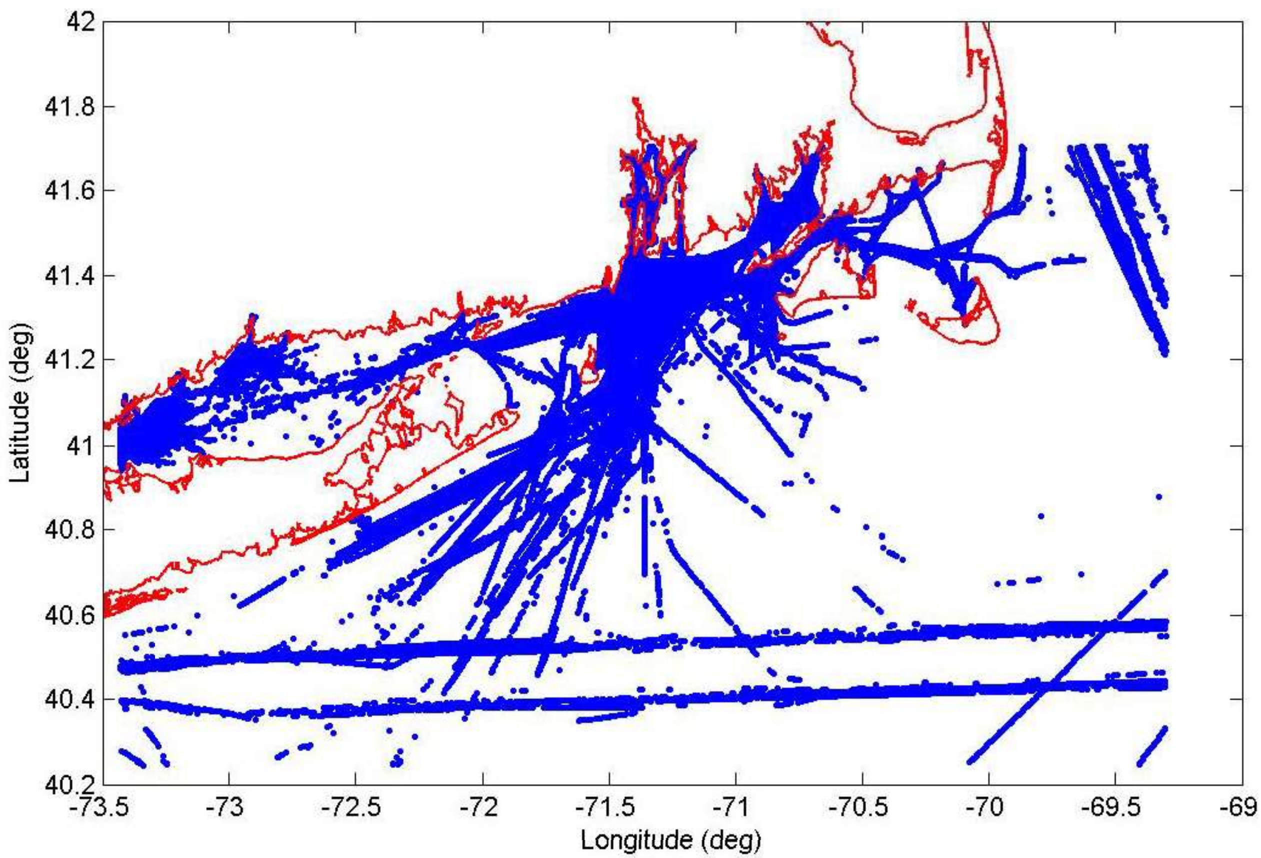
Passive Acoustic Listener System and Mooring Equipment



Shipping Positions from Automated Identification System (AIS)



Data from the AIS for the period from October 6 to November 14 is shown and will be used to analyze the acoustic noise data.

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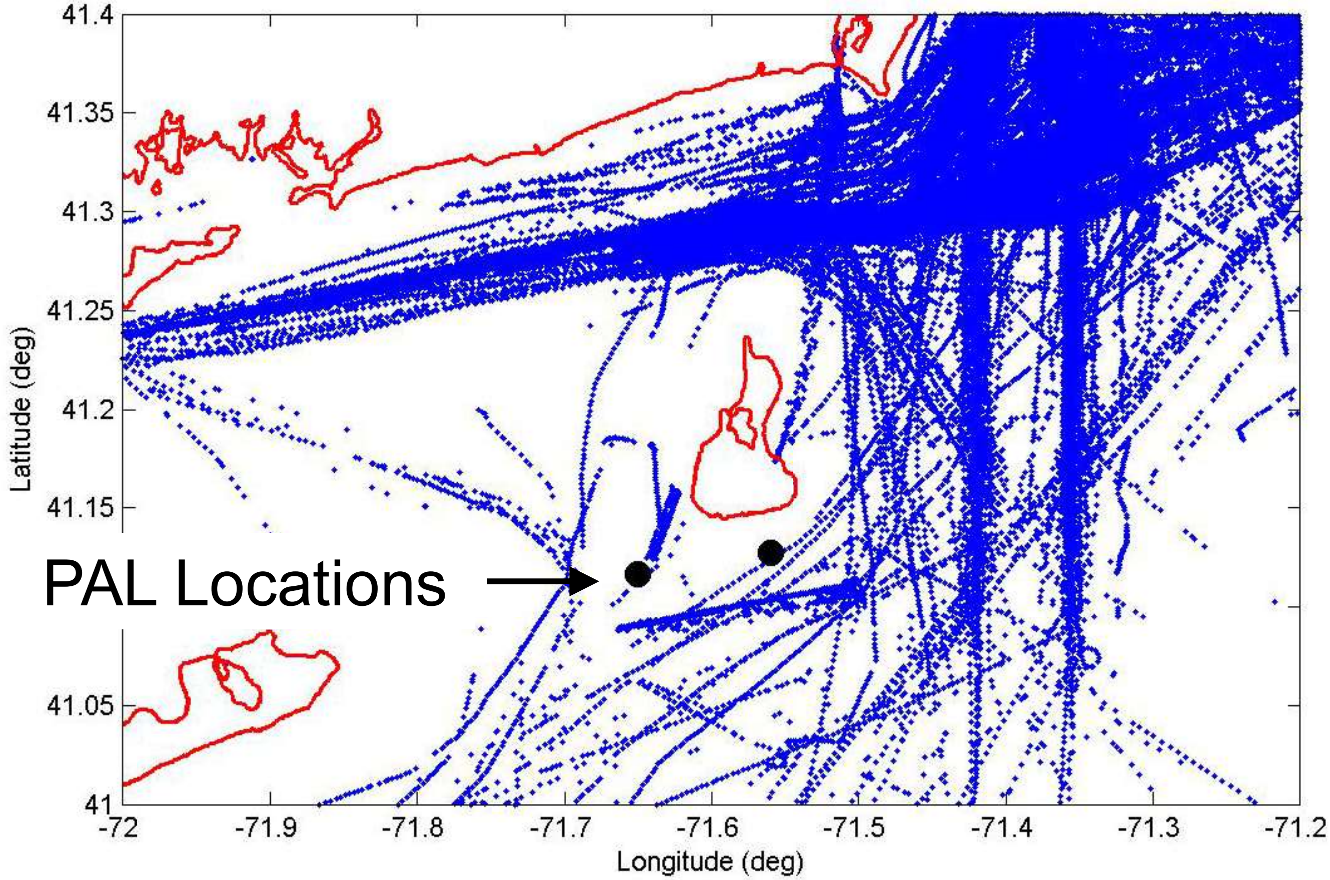
AIS-Derived Ship Positions Near Block Island



October 6 – November 14, 2008

Wind Turbine Noise

- Utgrunden (Sweden): 1.5 MW
- Moderate-strong ws: 12 m/s
- 1/3 Octave Leq:
  120 - 142 dB re 1 μPa at 1m
- Main frequency 50 / 150 Hz

(Thomsen et al. 2006)

The main source of underwater noise from these GE wind turbines seems to be gear noise

Measurements of Underwater Noise from Wind Turbines in Utgrunden Wind Farm, Sweden

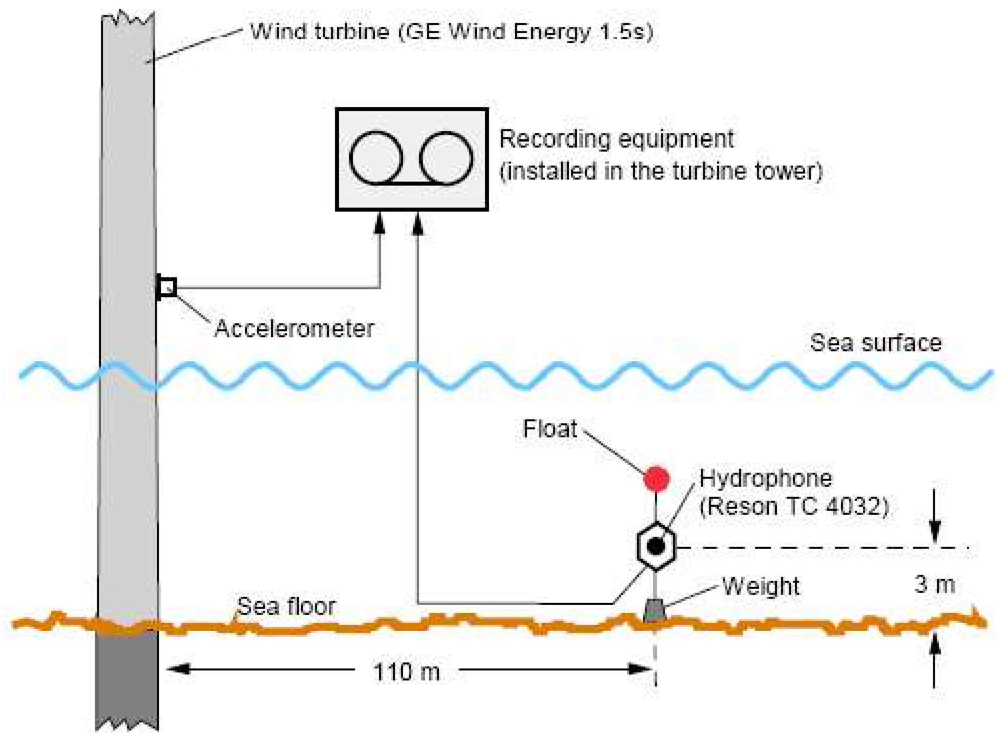
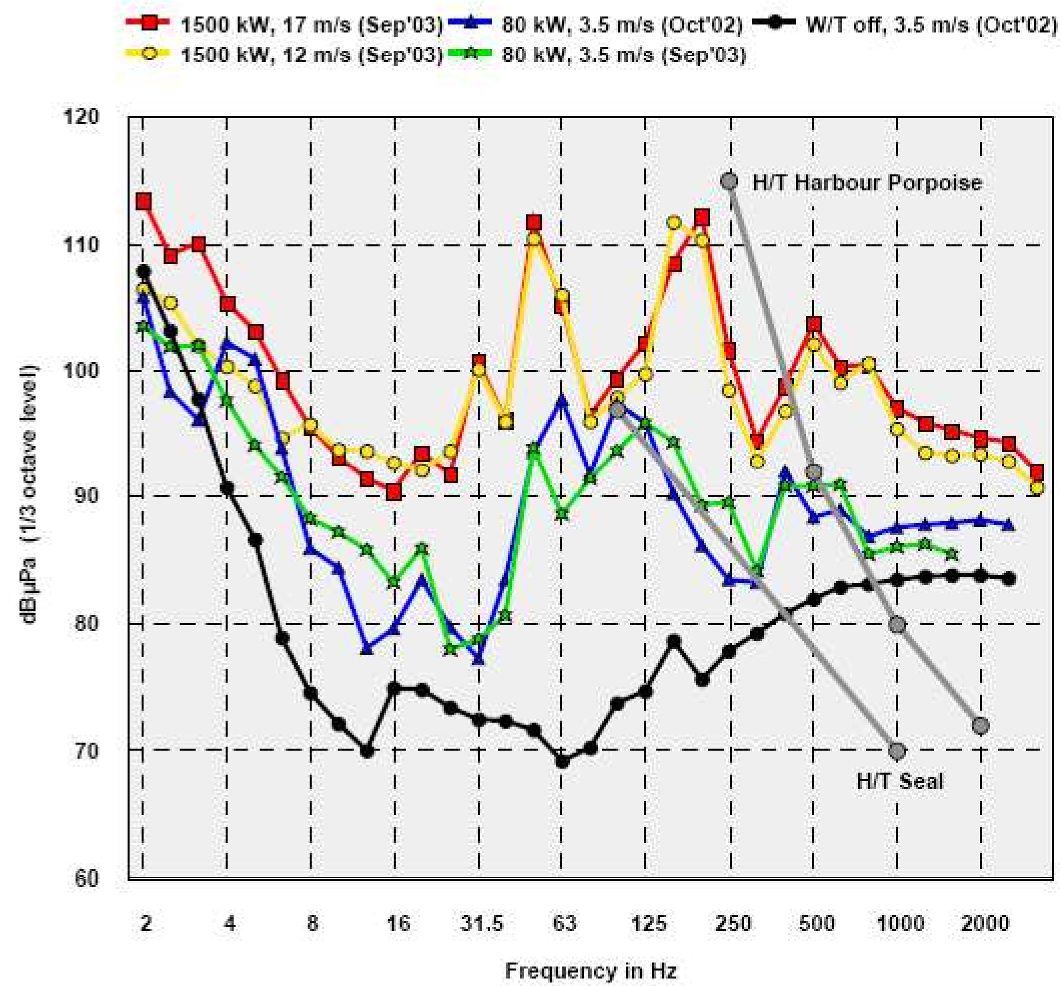


Figure 2: Measurement setup for monitoring underwater noise induced by an offshore wind turbine. Water depth was about 10 m.

(from Betke, 2004)

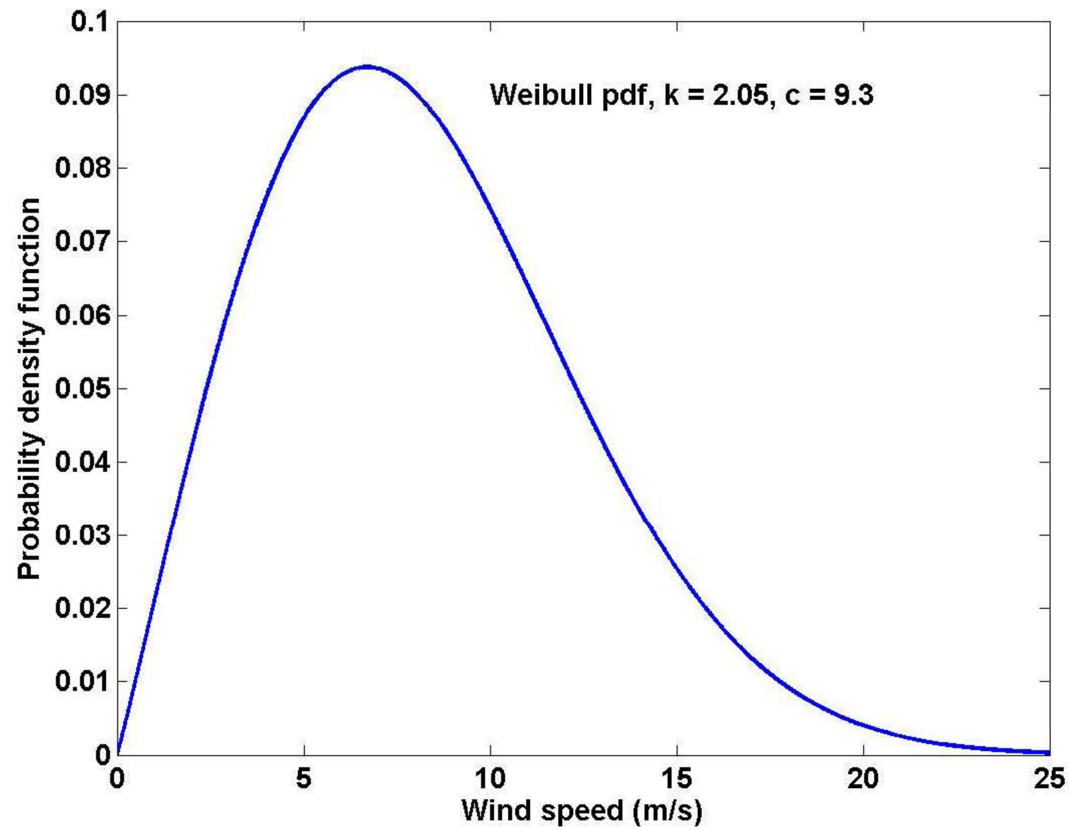
Measurements of Underwater Noise from Wind Turbines in Utgrunden Wind Farm, Sweden

Figure 3: Underwater sound pressure levels (1/3rd octave spectra) recorded at 110 m distance from the turbine for different turbine states. Wind speeds refer to hub height (nacelle anemometer). Low frequency parts of hearing thresholds for two marine mammals are shown for comparison.

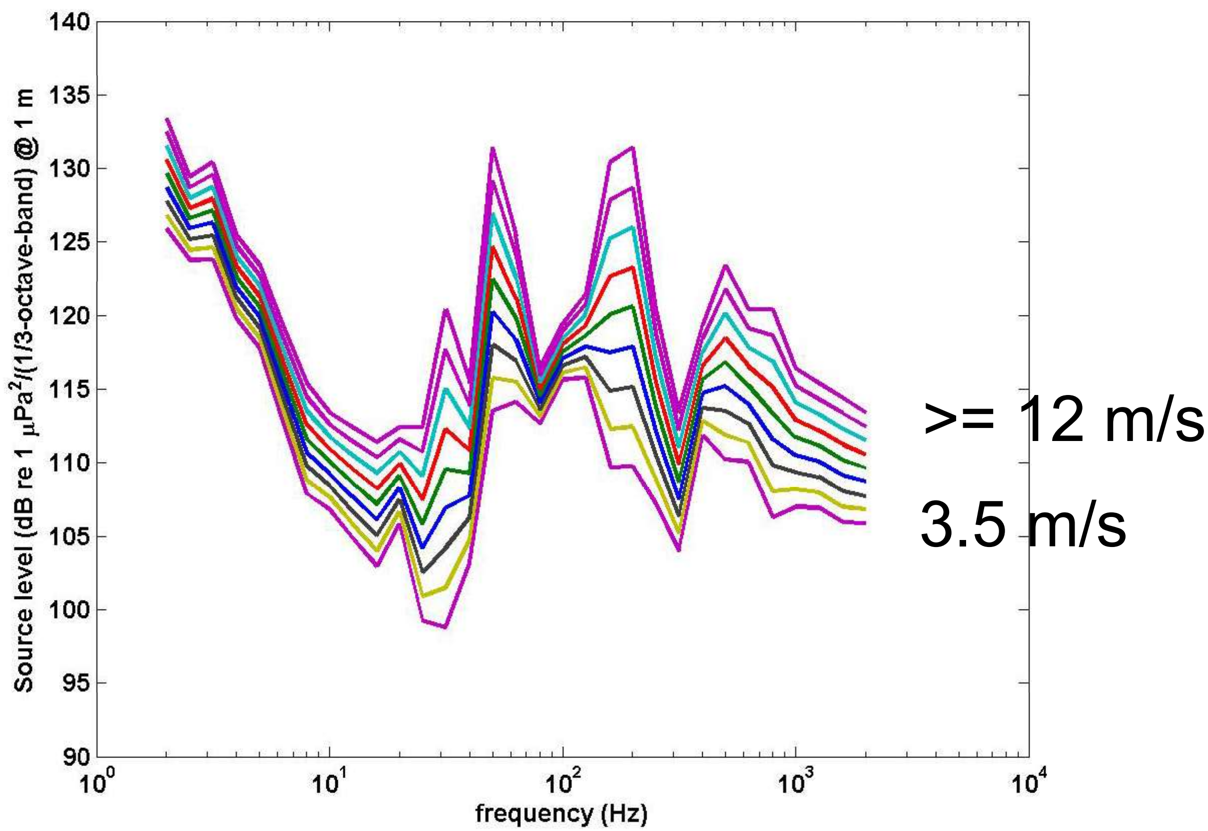


(from Betke, 2004)

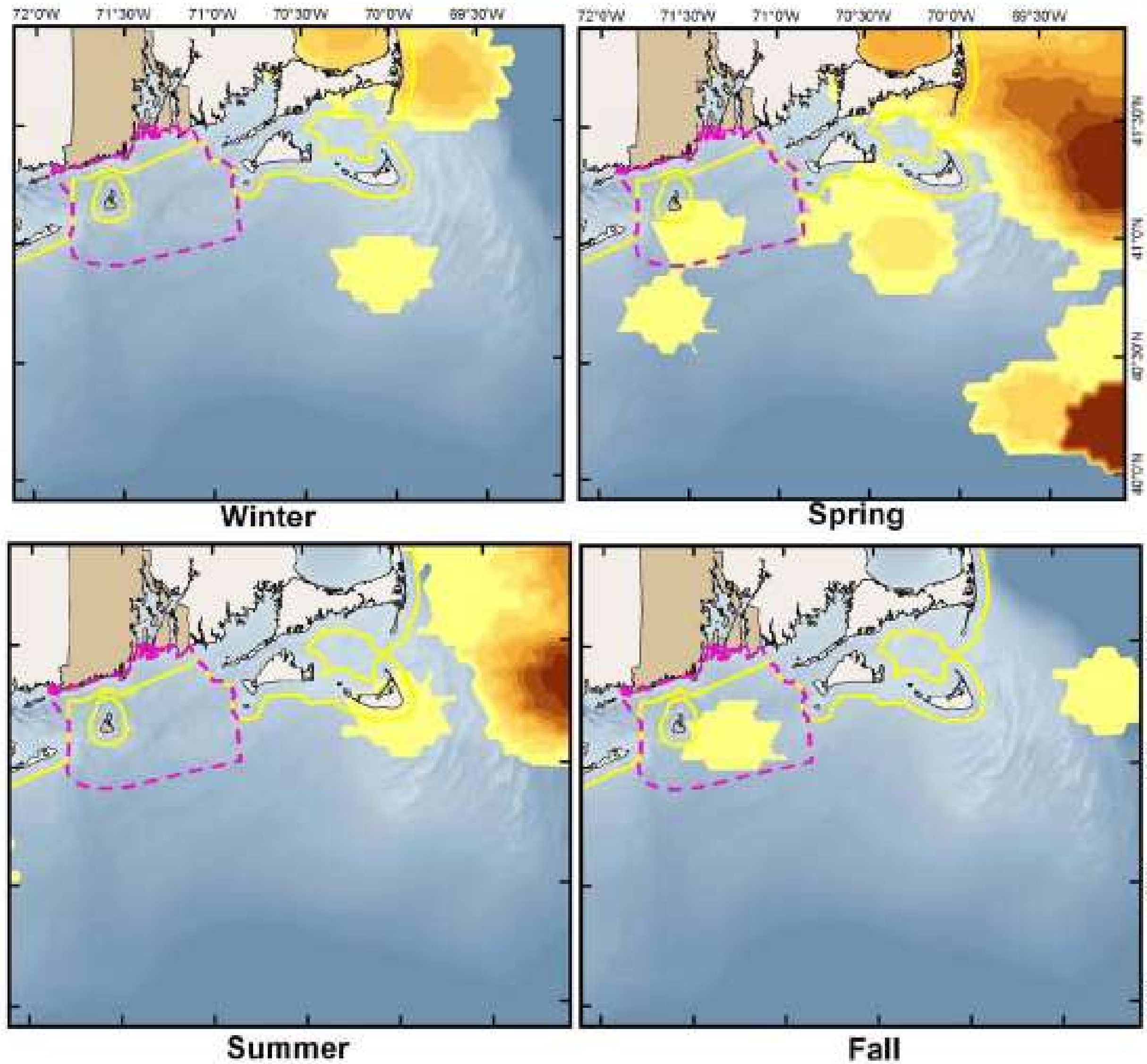
Wind Speed PDF



Interpolated Underwater Noise from a Wind Turbine



Northern right whale relative abundance



Kenney, 2009

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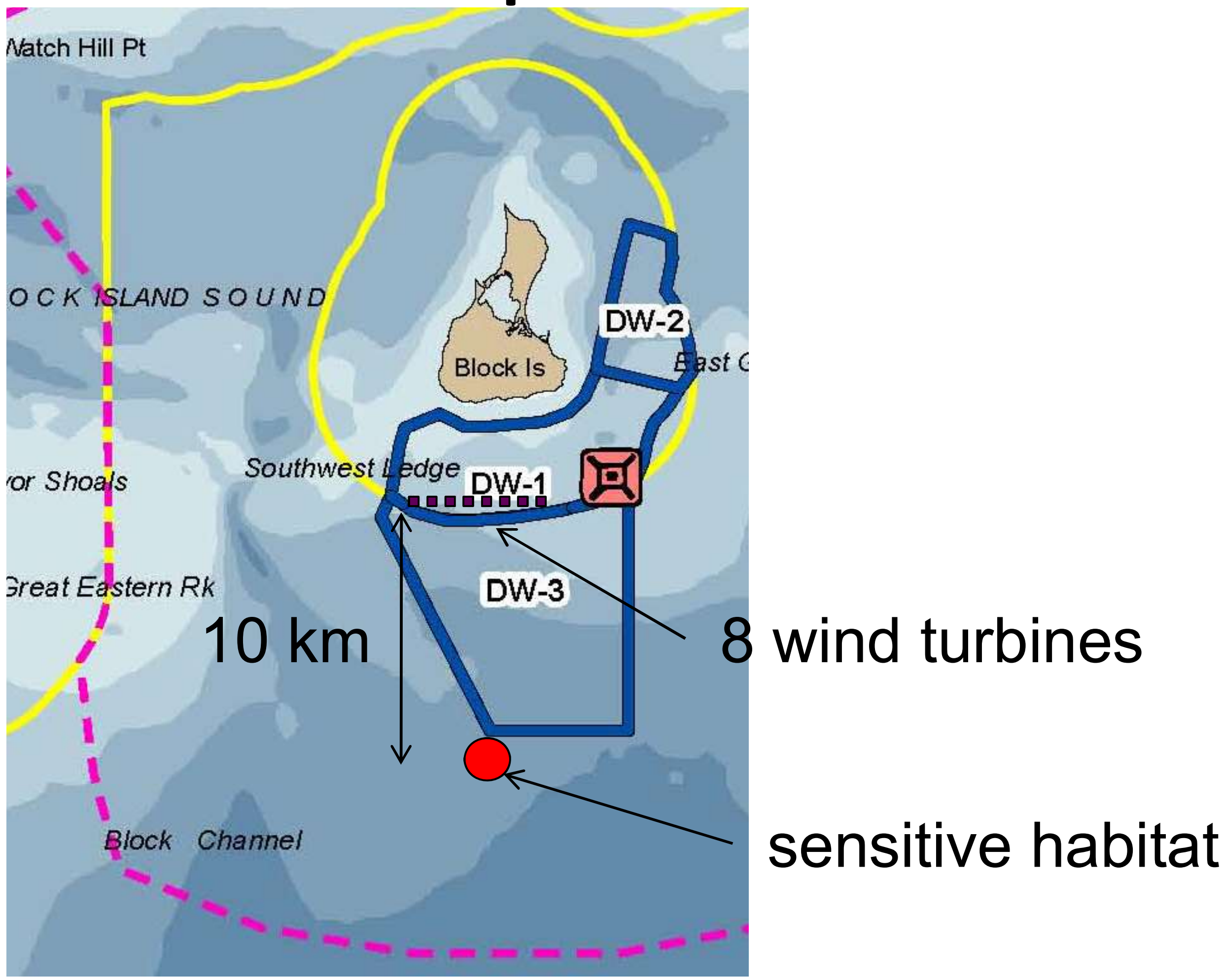
Wind Farm Example Scenario



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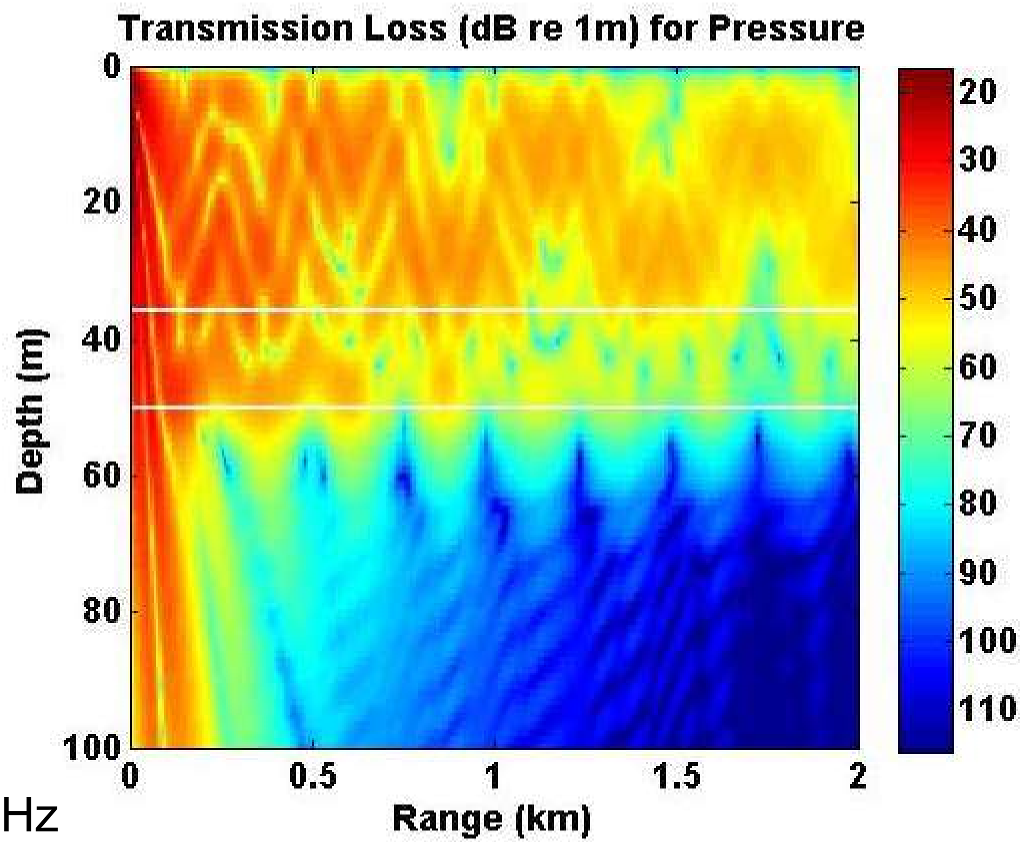
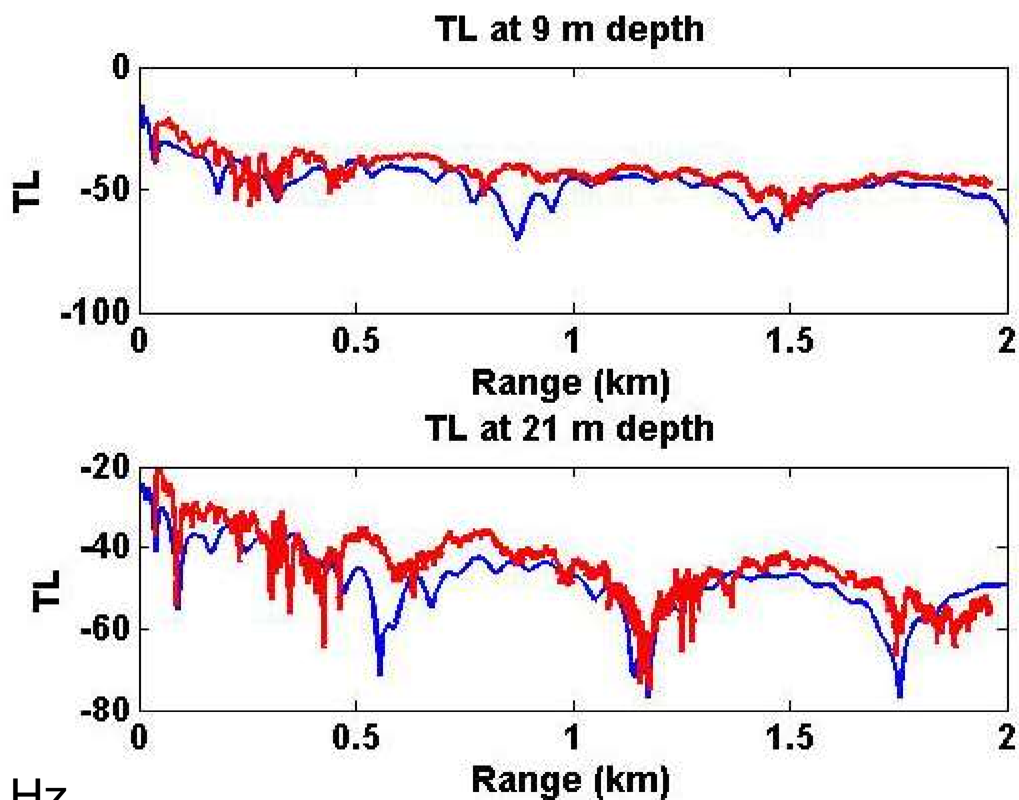


Frequency 200 Hz
bathymetry: 35 m
Top sediment layer 15 m thick
Sediment speed- 1590 m/s
Basement speed - 1770 m/s



Frequency 200 Hz
bathymetry: 35 m
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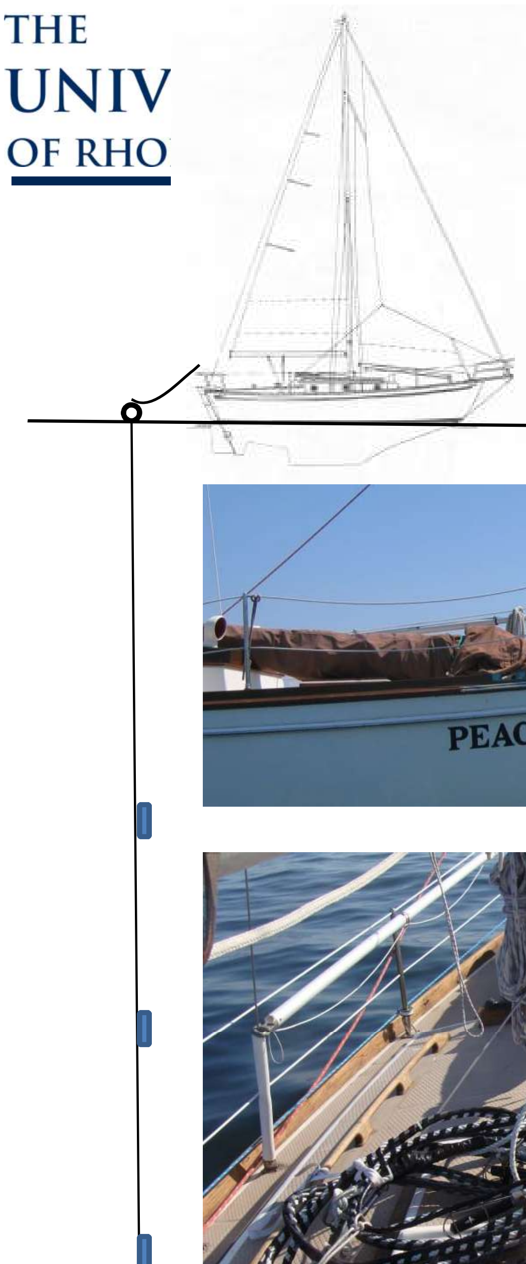
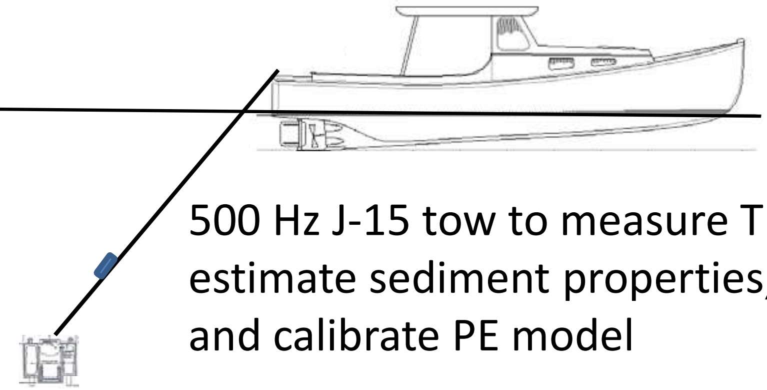
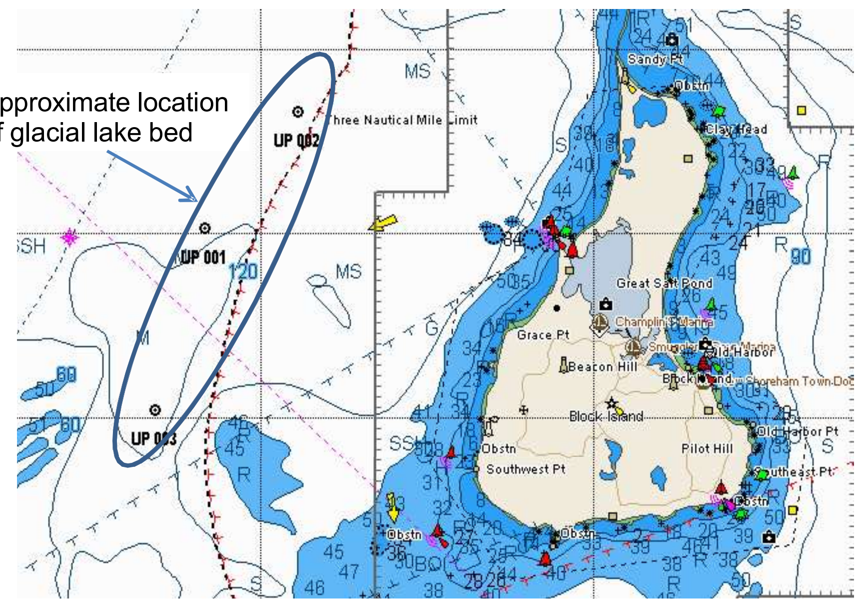
TL Measurement

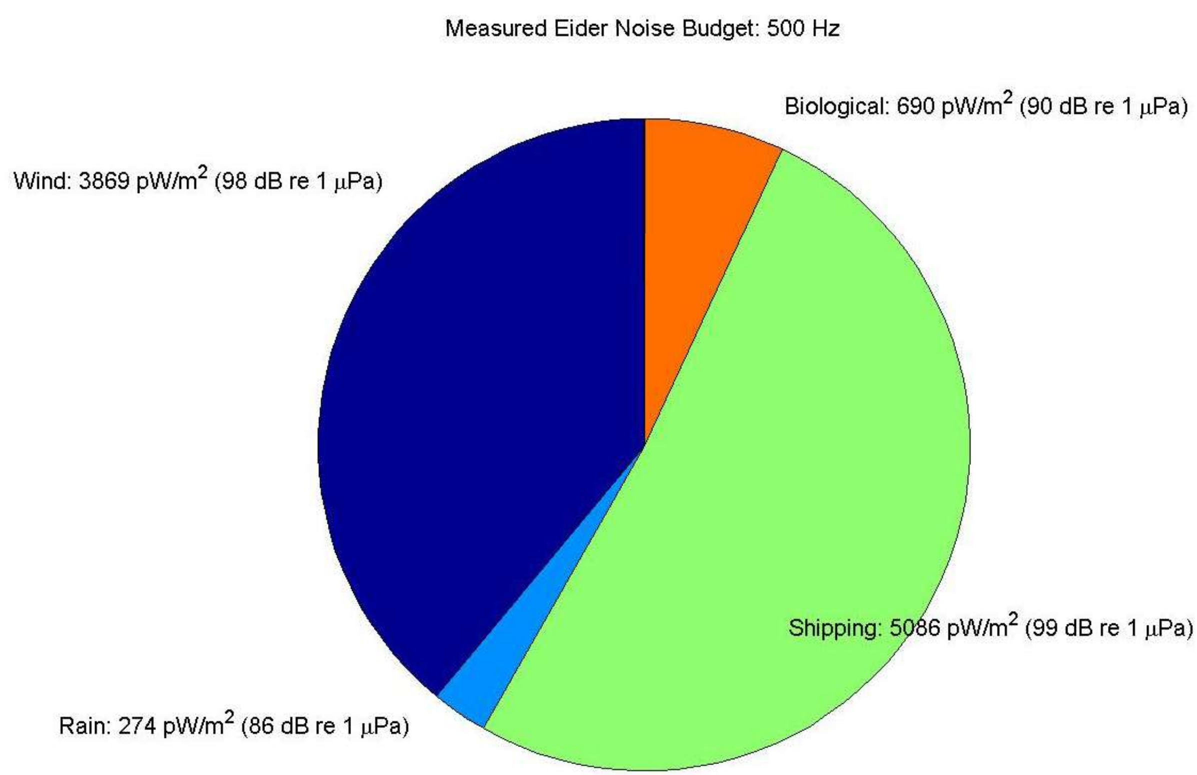




500 Hz J-15 tow to measure TL, estimate sediment properties, and calibrate PE model



1/3 Octave Noise Budget for Block Island Sound Without Turbine Noise



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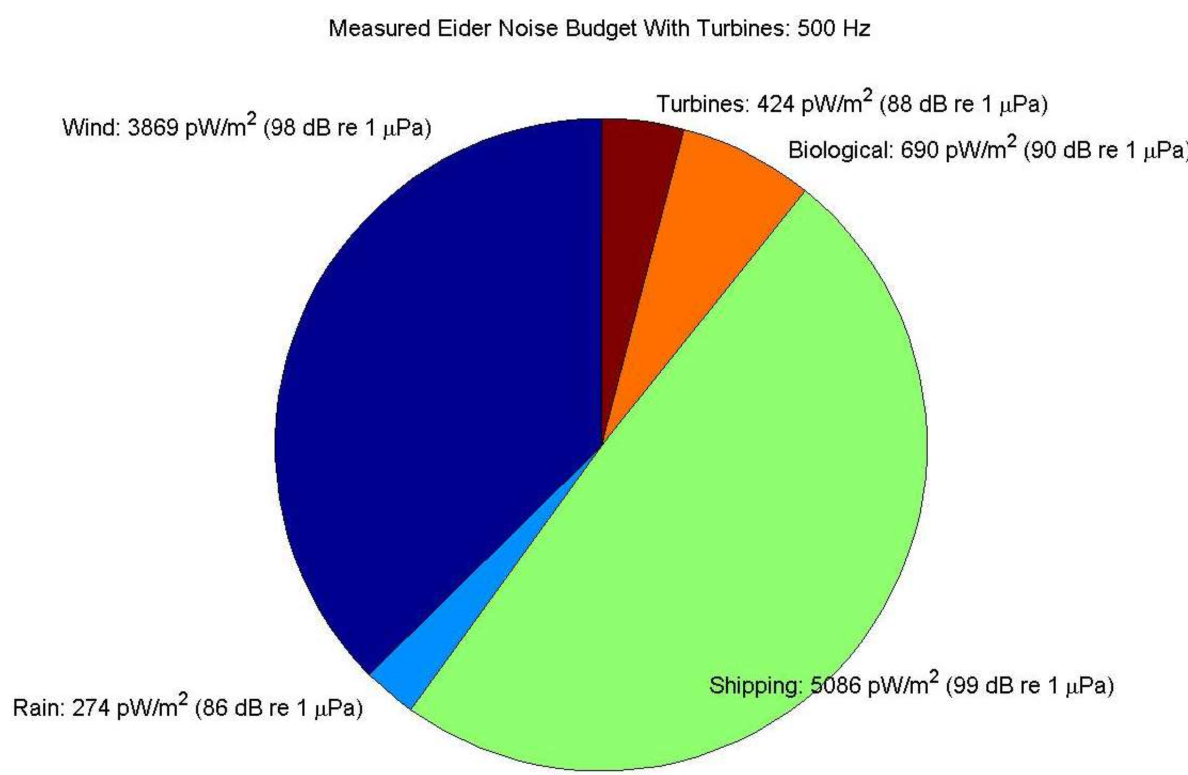
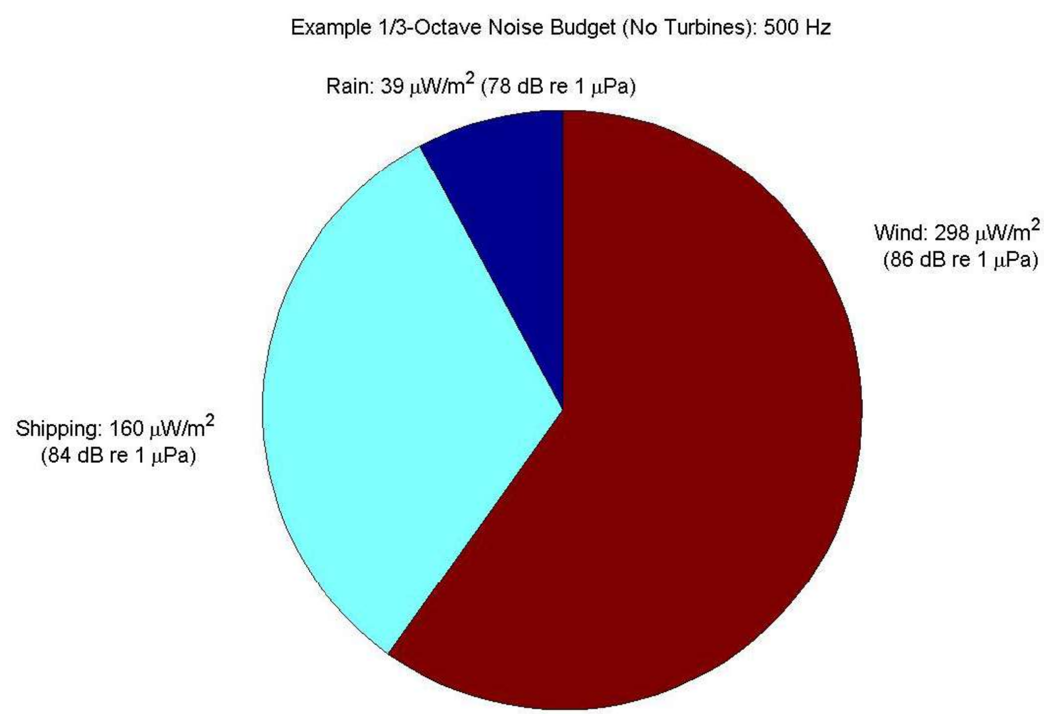
1/3 Octave Noise Budget for Block Island Sound With Turbine Noise



1/3 Octave Noise Budget with Ionian Sea Noise Without Turbine Noise



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1/3 Octave Noise Budget with Ionian Sea Noise With Turbine Noise