

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

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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

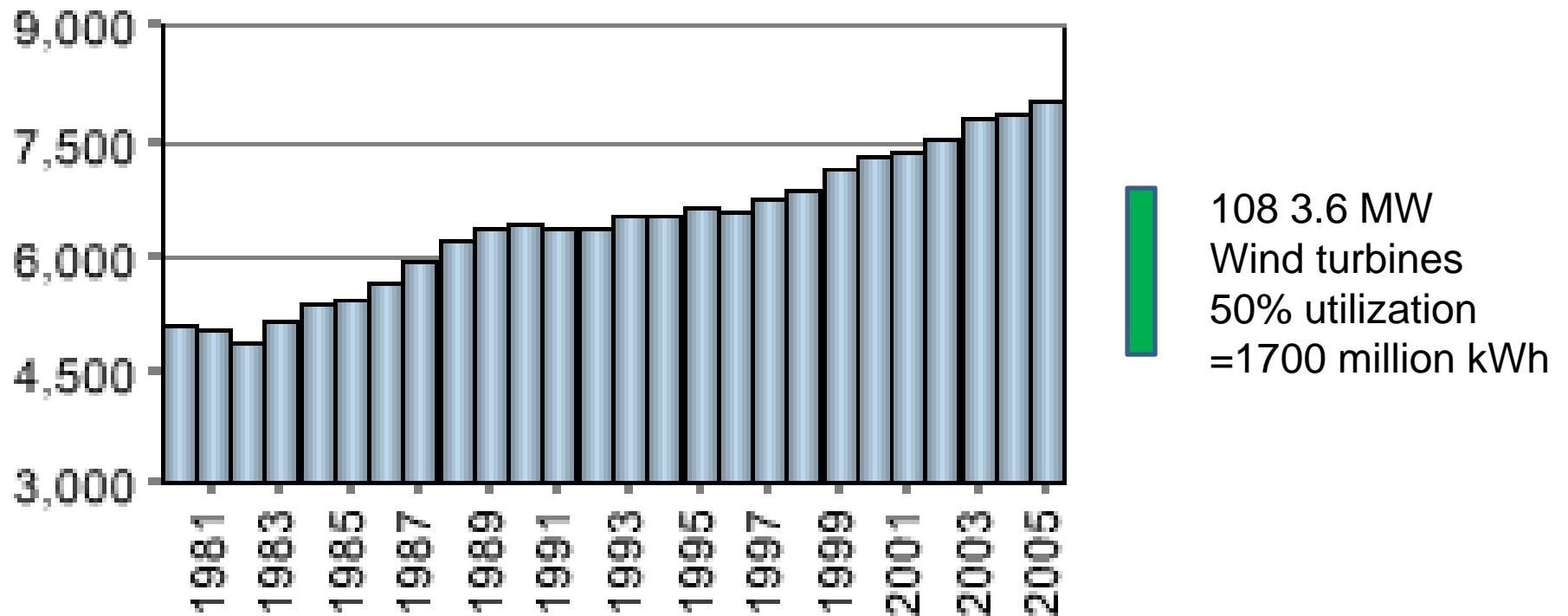
Offshore Wind Power

- 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)



<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)


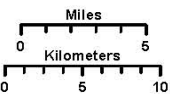
71°50'W 71°40'W 71°30'W 71°20'W 71°10'W 71°0'W 70°50'W

Map Key

-  Proposed Ocean Study Area
-  State/Federal Waters Separation
-  Deep Water Wind Areas
-  Proposed MET Towers


Bathymetry (m)

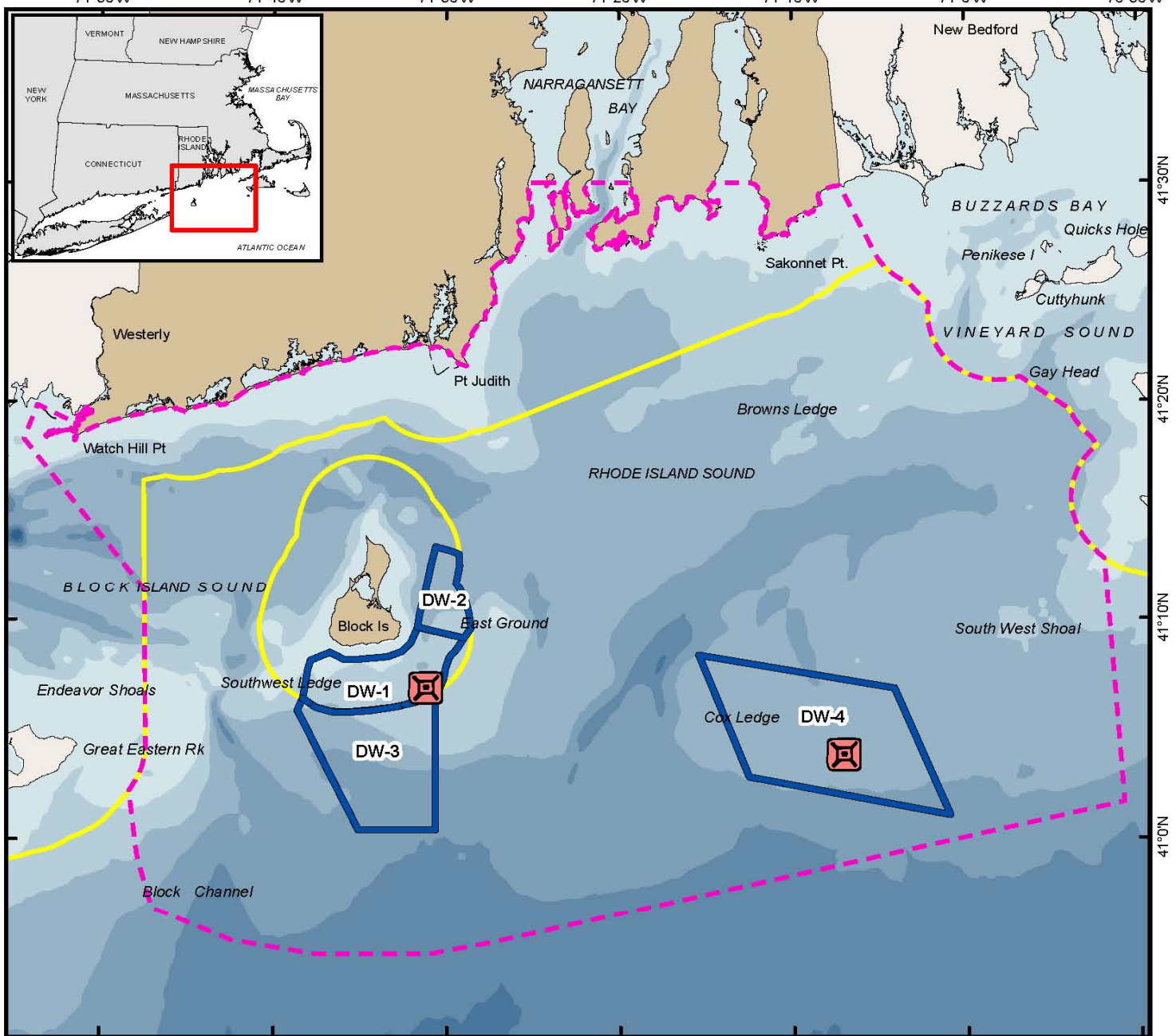
-  -20
-  -30
-  -40
-  -50
-  -60
-  -70
-  -80

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





41°30'N
41°20'N
41°10'N
41°0'N

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.



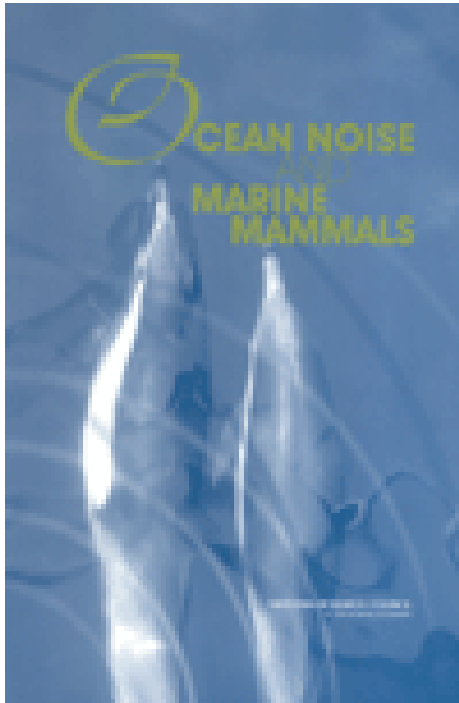
SAMP, 2009

PORTSMOUTH HIGH SCHOOL WIND TURBINE
PORTSMOUTH, RHODE ISLAND



October 13, 2009

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.**

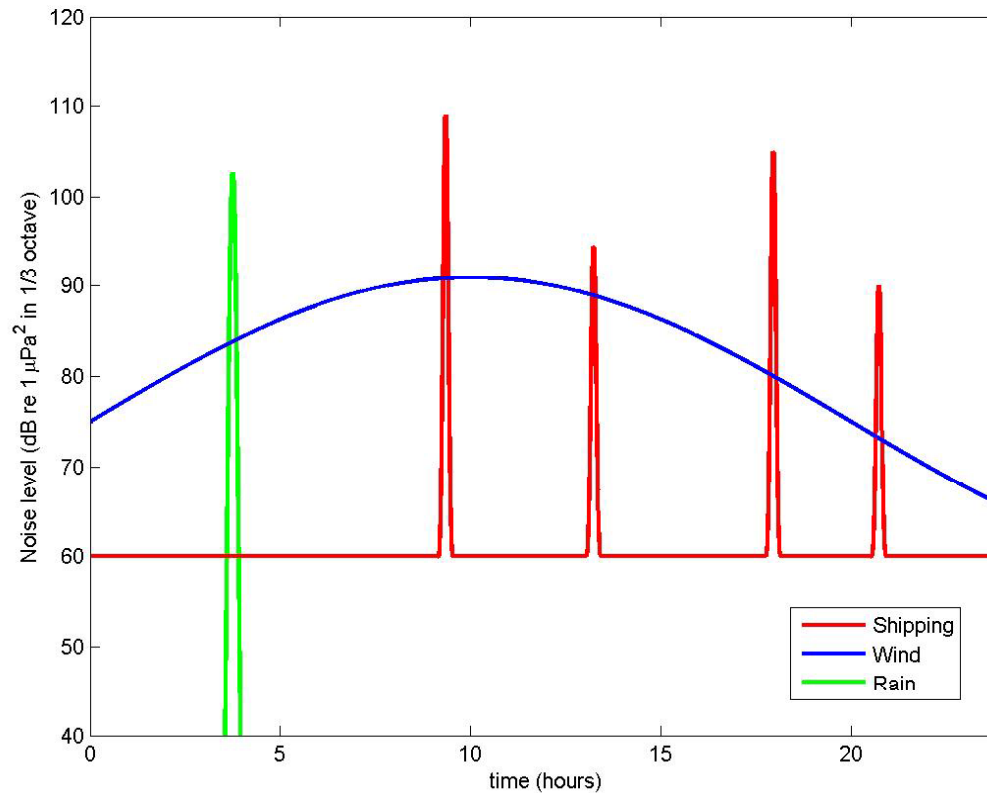
G. Frisk, D. Bradley, J. Caldwell, G. D'Spain, J. Gordon, M. Hastings, D. Ketten, J. Miller, D. L. Nelson, A. N. Popper, and D. Wartzok, *Ocean Noise and Marine Mammals*, National Academy Press, (2003).

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?



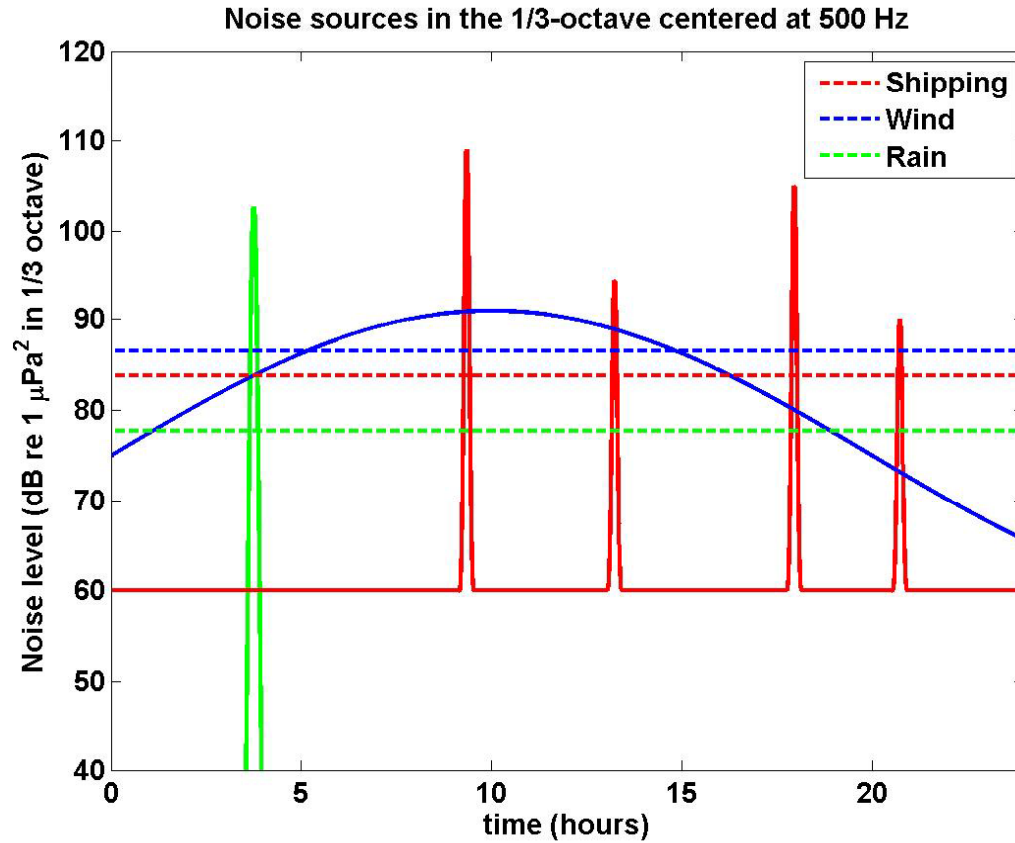
Budget Currency:

Average Intensity from n^{th} Source

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

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 n th source (e.g. wind, rain, shipping, seismic, biologics, etc.)

A Day in a Hypothetical Noise Environment

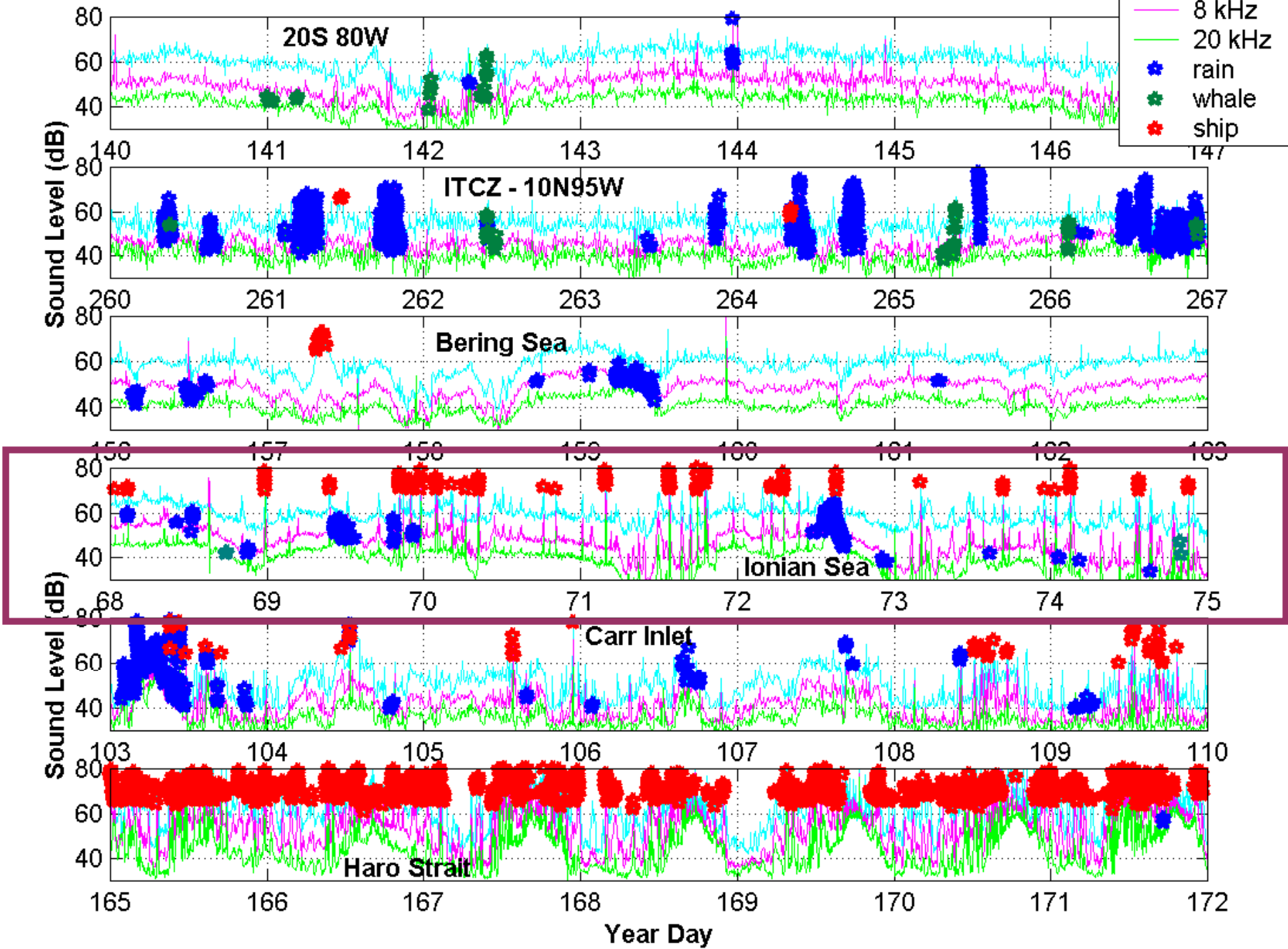
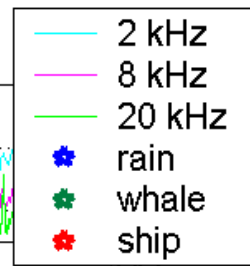


Passive Aquatic Listeners (PALs)



- 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



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

	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

Dominant Sound Sources

Percentage of time present

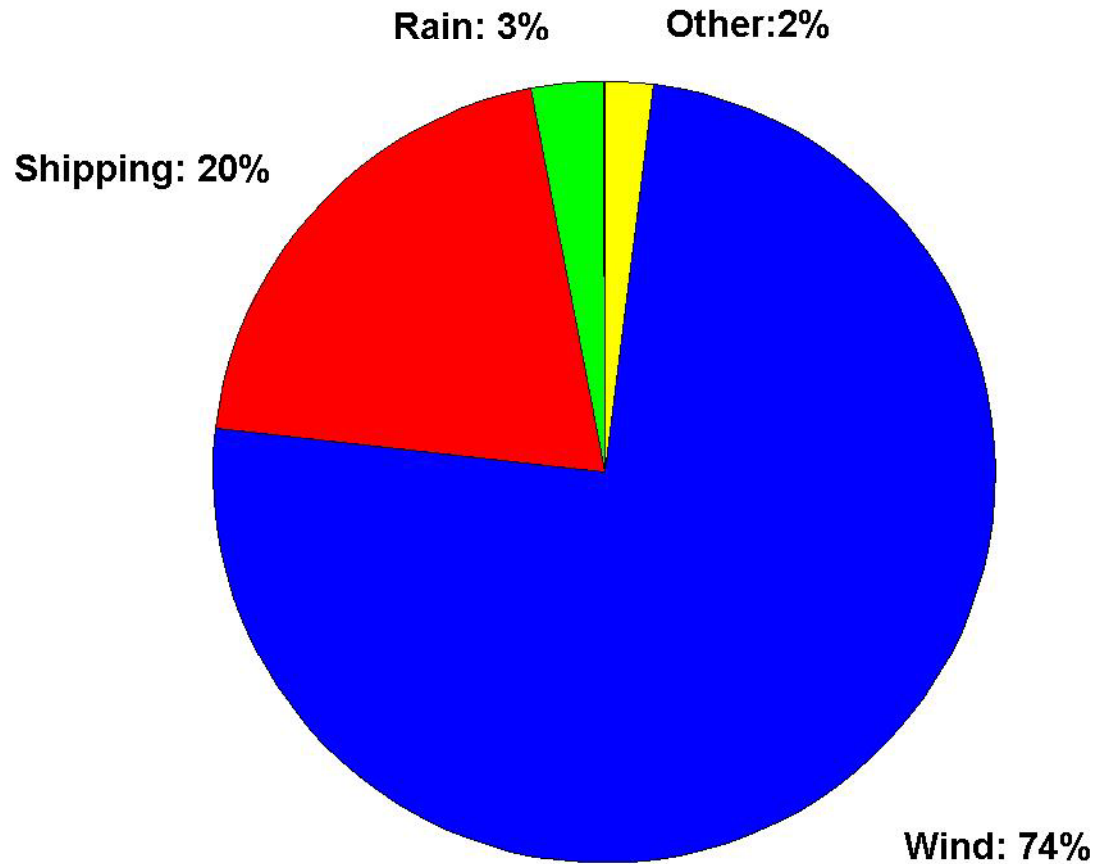
	20 S 85 W	10 N 95 W	Bering Sea	Ionian Sea	Carr Inlet	Haro Strait
Wind	93%	86%	90%	74%	80 %	21 %
Rain	-	8 %	3 %	3 %	8 %	5 %
Ships	0.5 %	1.5 %	1 %	20 %	2 %	59 %
Whale*	1.8 %	0.6 %	-	0.5 %	-	-
Other	5 %	4 %	6 %	2 %	10 %	15 %

*30 kHz click detected – no visual confirmation

Temporal Detection (TD) Noise Budget

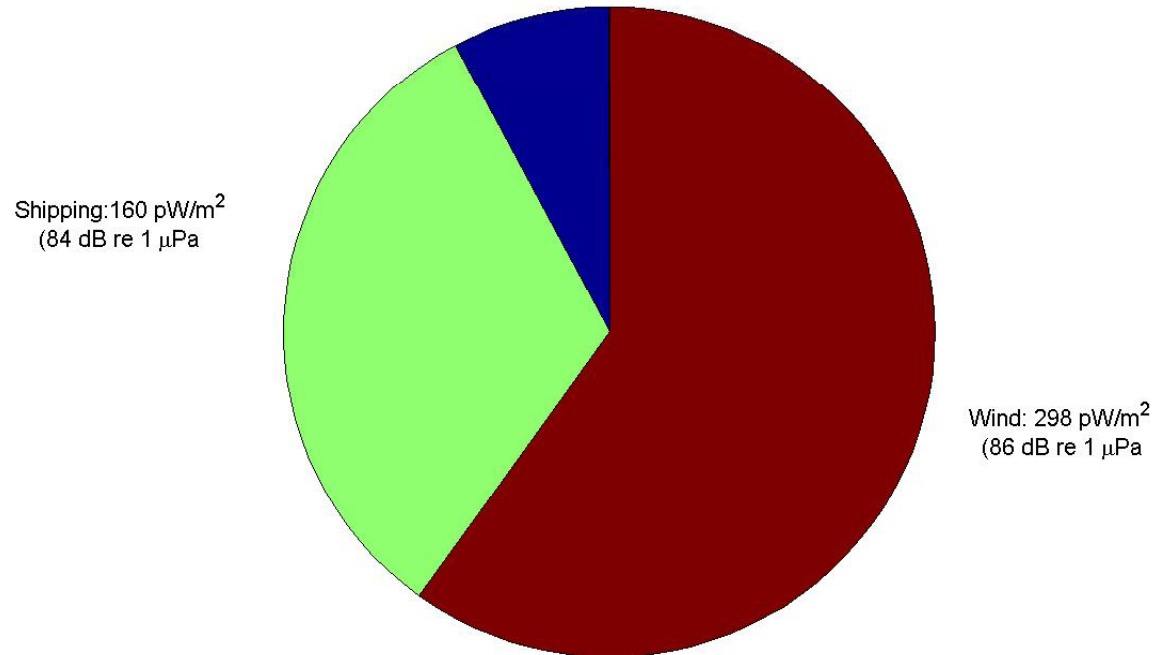
Temporal Detection Budget

Ionian Sea Temporal Detection Budget



Average Intensity Budget

Ionian Sea Average Intensity Noise Budget 500 Hz
Rain: 39 pW/m² (78 dB re 1 μPa)



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

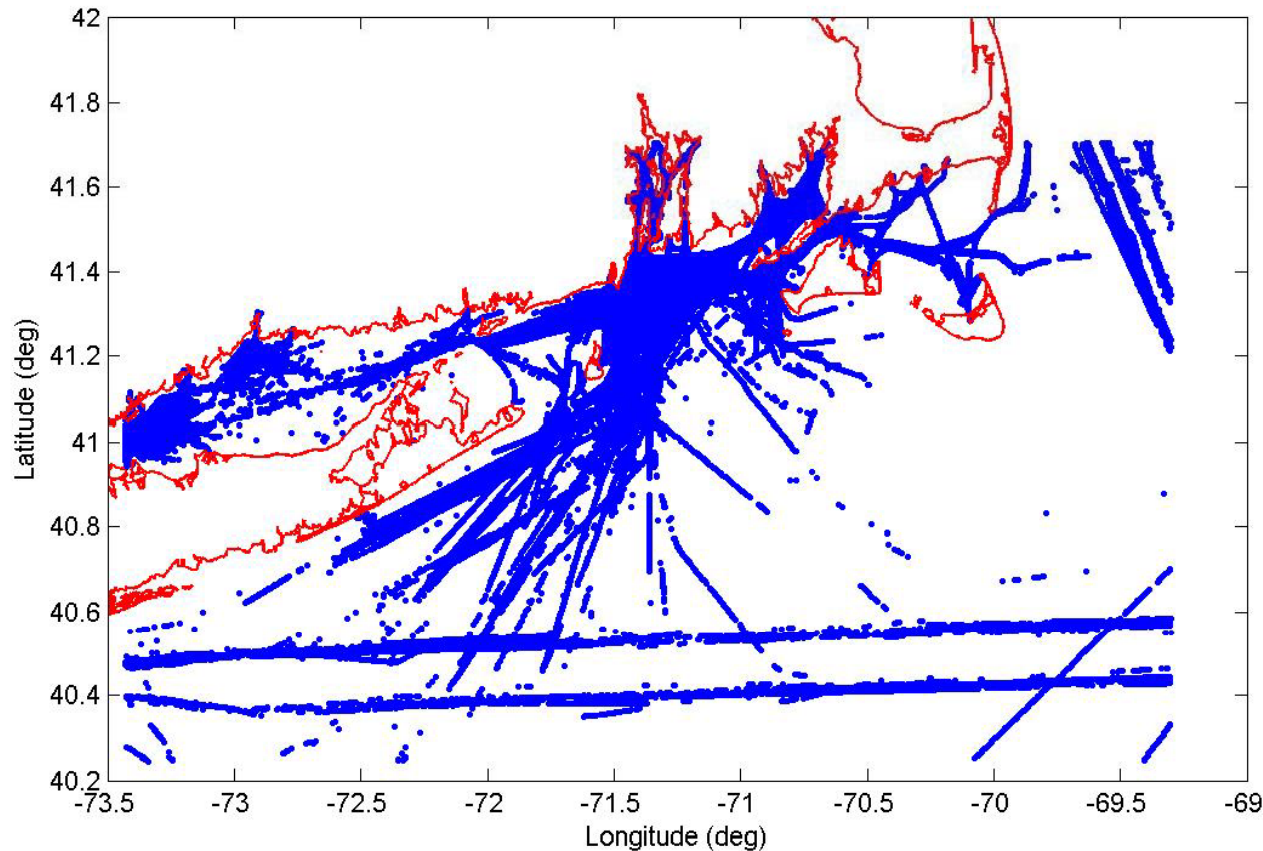


R/V Endeavor

Passive Acoustic Listener System and Mooring Equipment

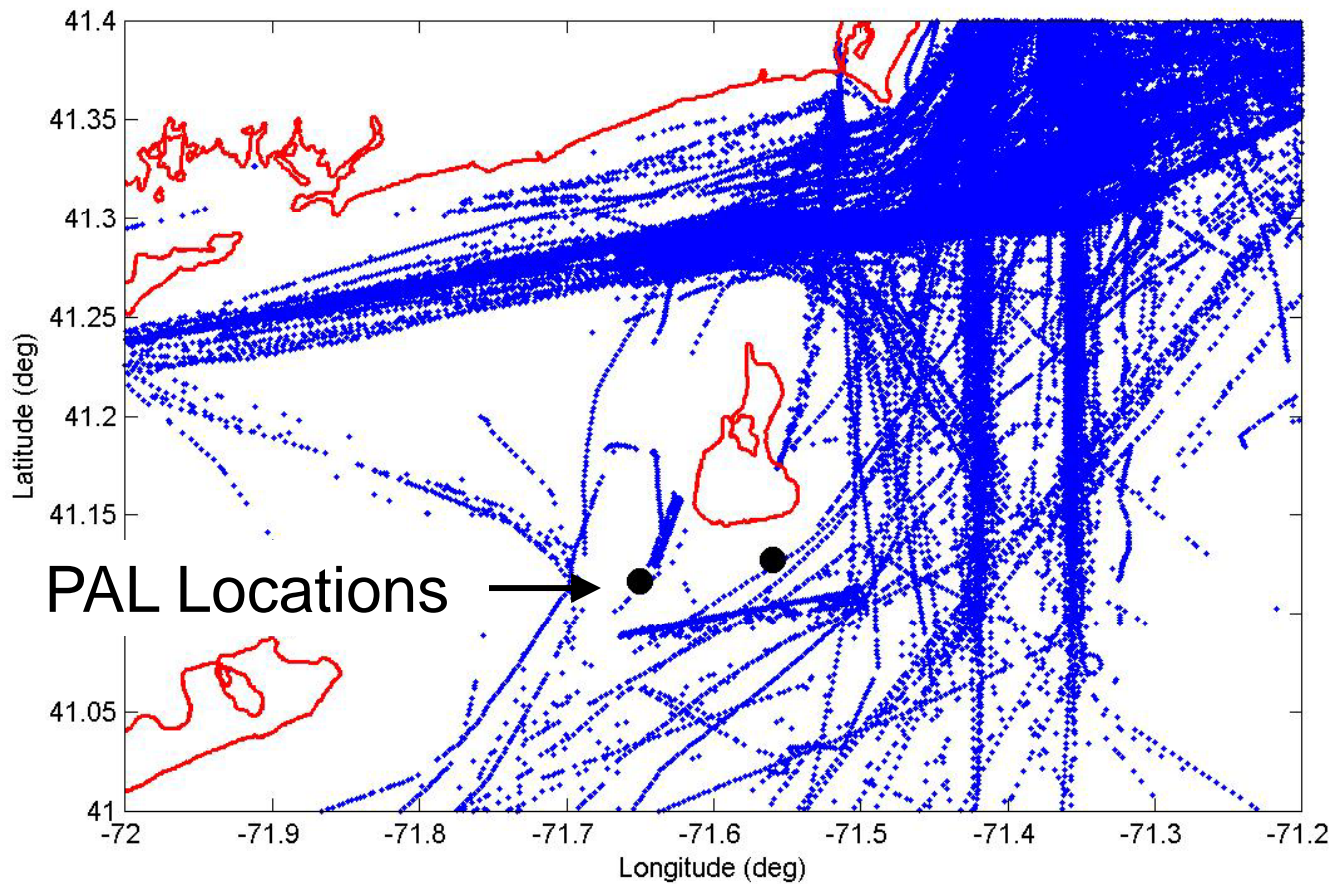


Shipping Positions from Automated Identification System (AIS)



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.

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 μ Pa 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

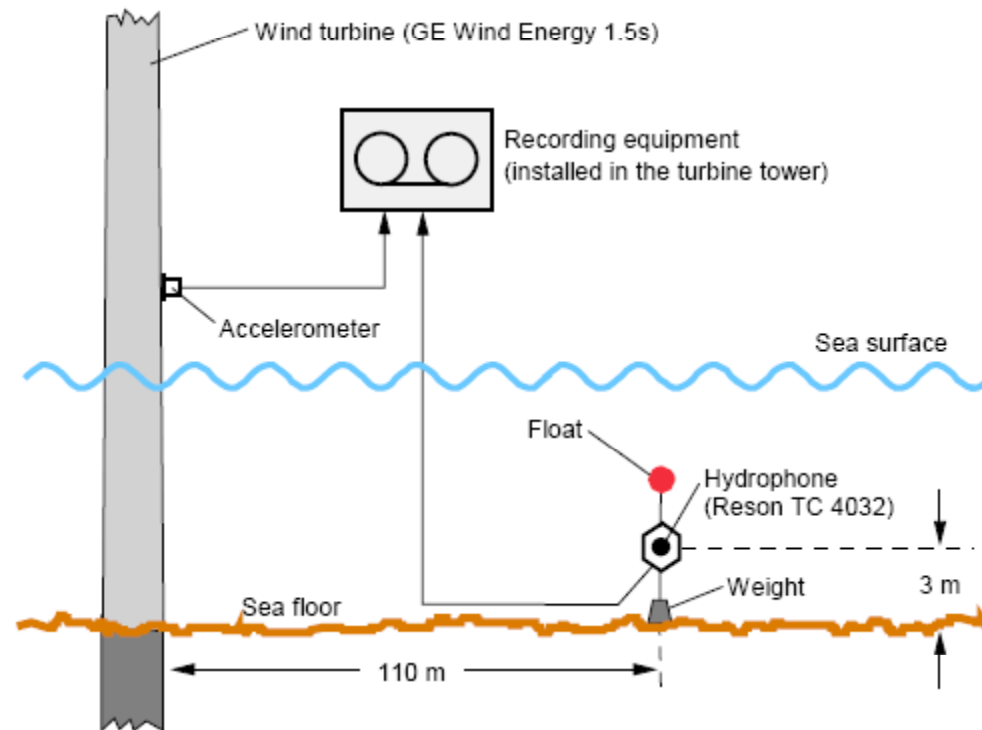
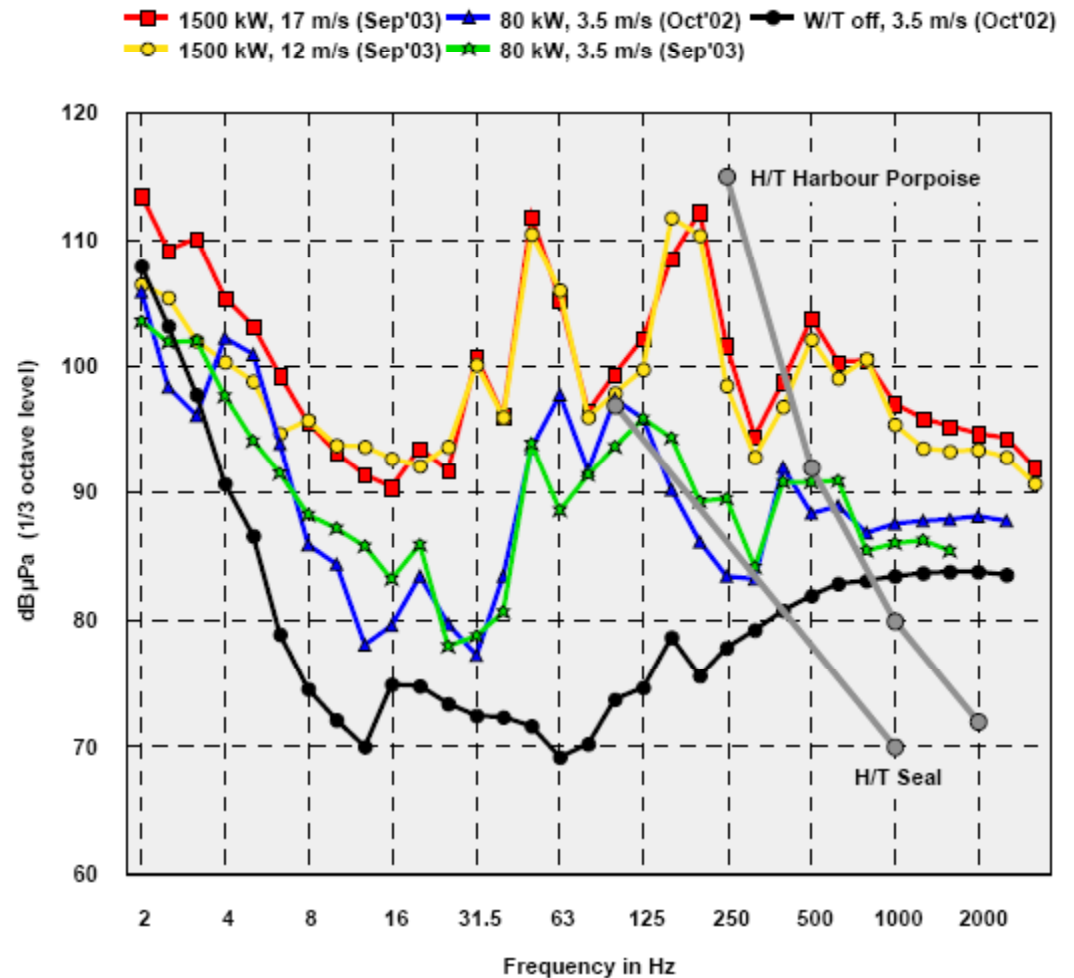


Figure 2: Measurement setup for monitoring underwater noise induced by an offshore wind turbine. Water depth was about 10 m.

(from Betke, 2004)

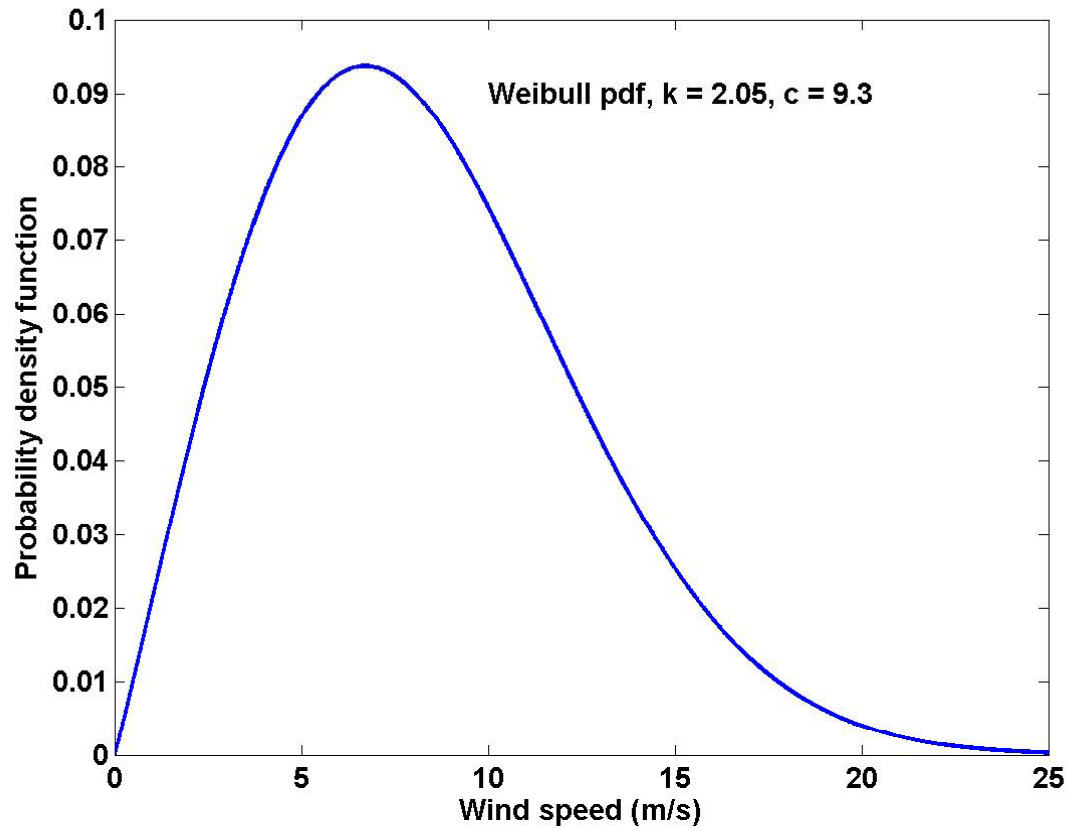
Measurements of Underwater Noise from Wind Turbines in Utgrunden Wind Farm, Sweden

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.

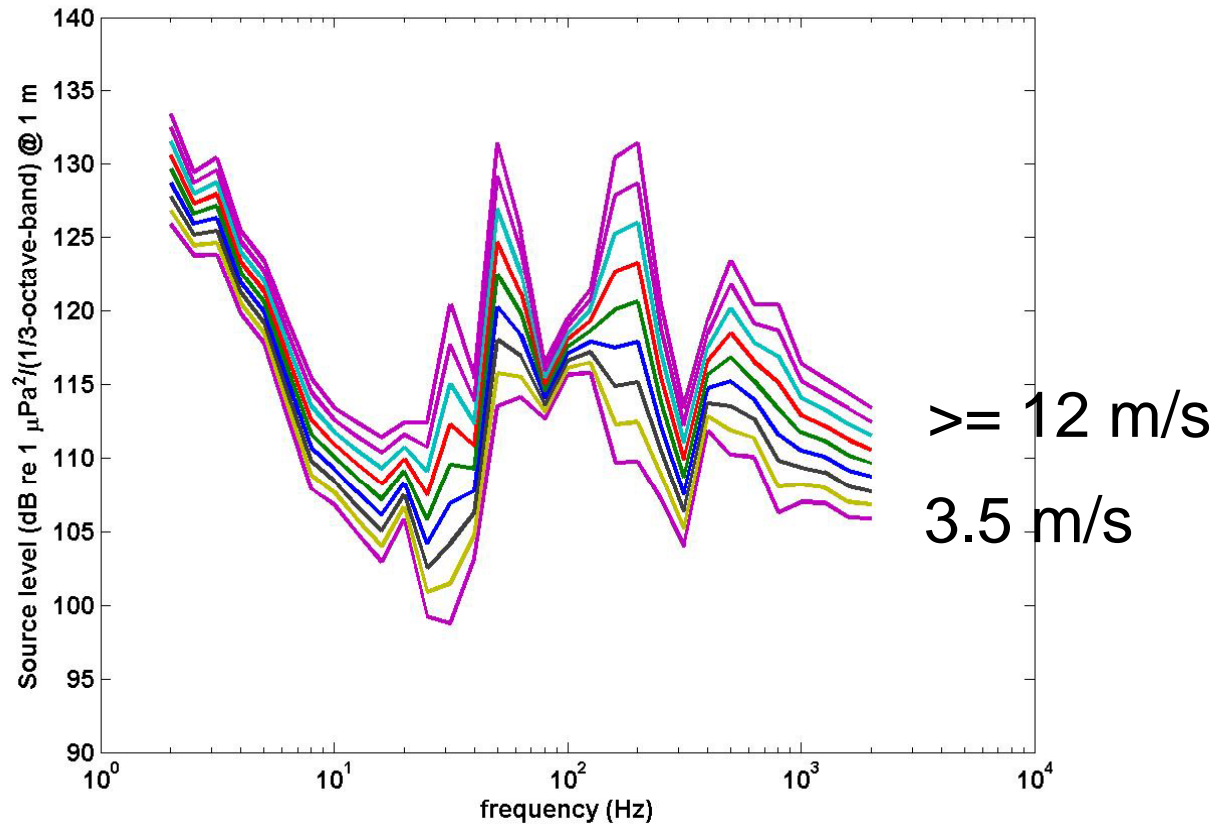


(from Betke, 2004)
Ambient Noise 27

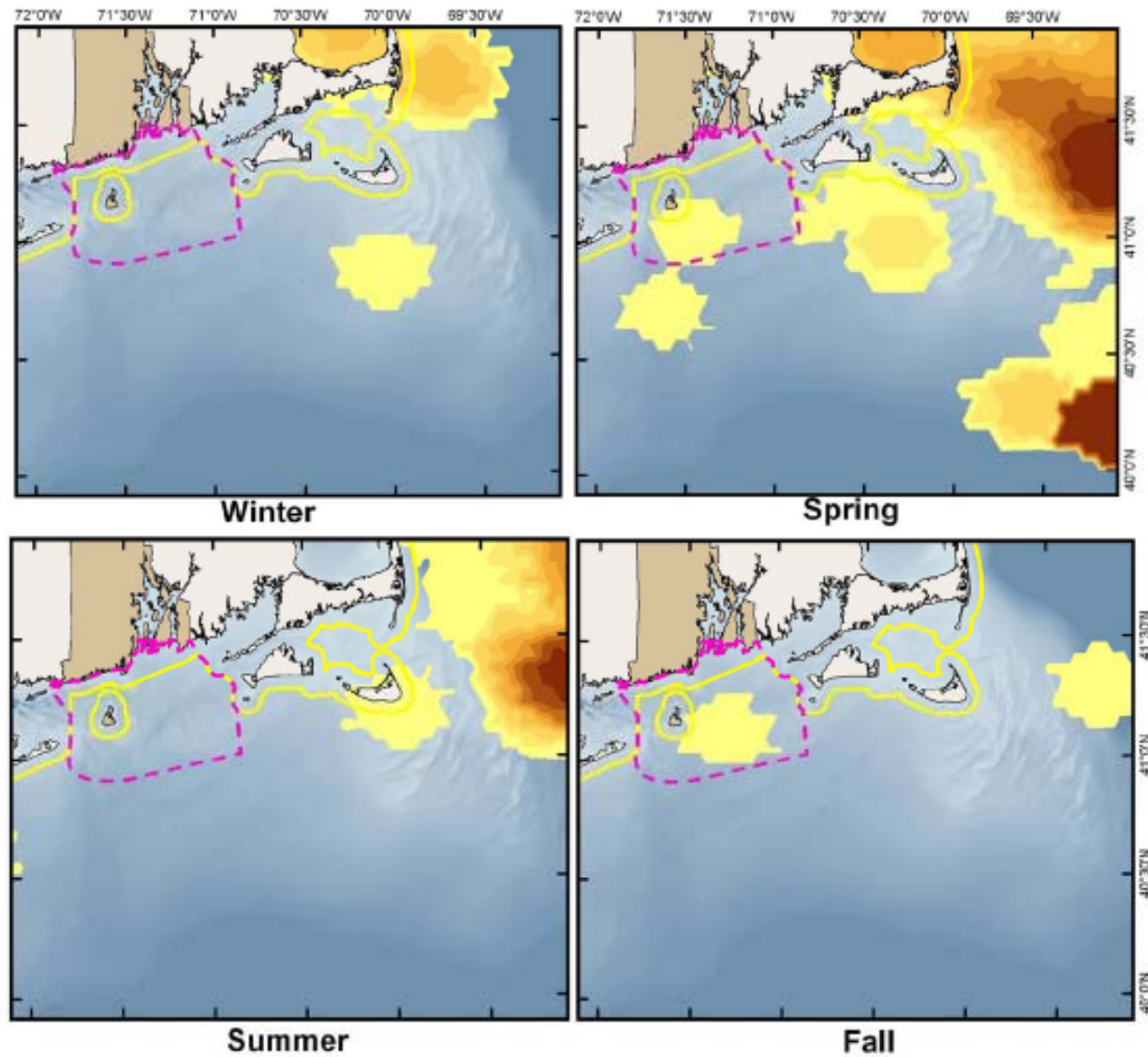
Wind Speed PDF



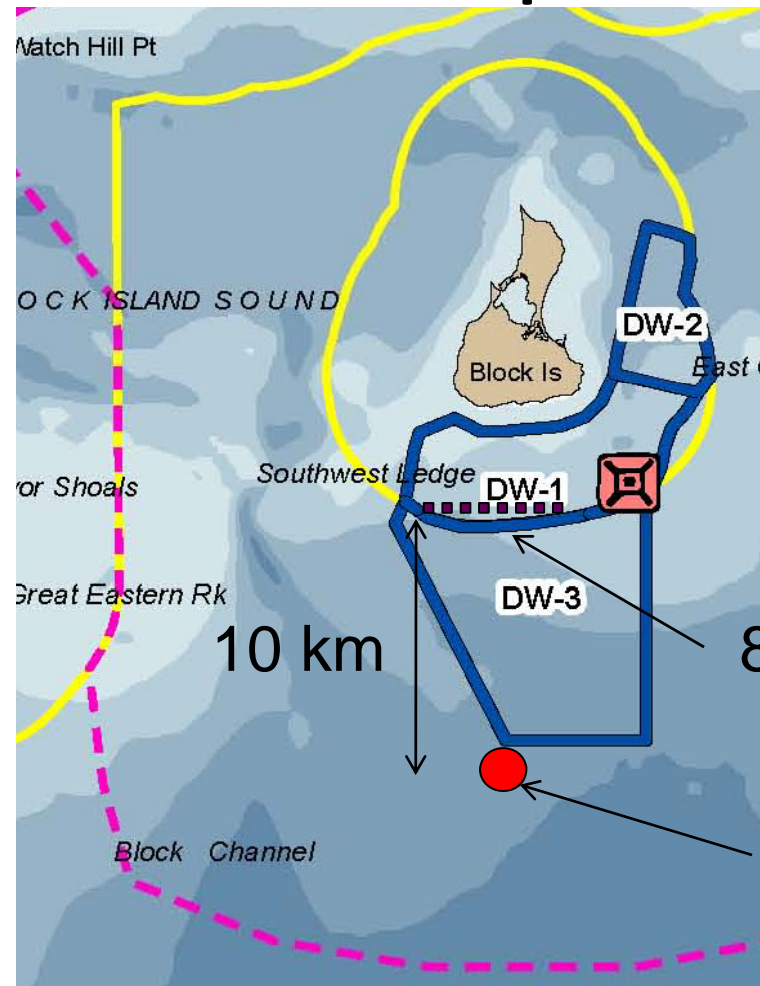
Interpolated Underwater Noise from a Wind Turbine



Northern right whale relative abundance



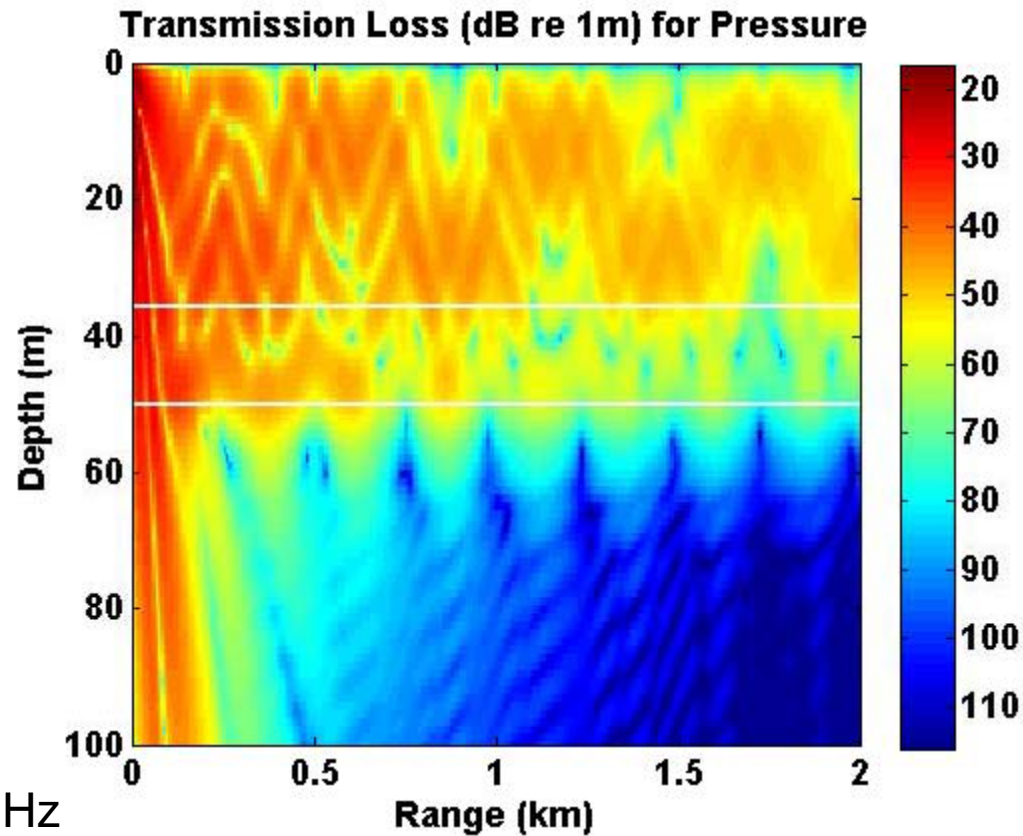
Wind Farm Example Scenario



8 wind turbines

sensitive habitat

SAMP



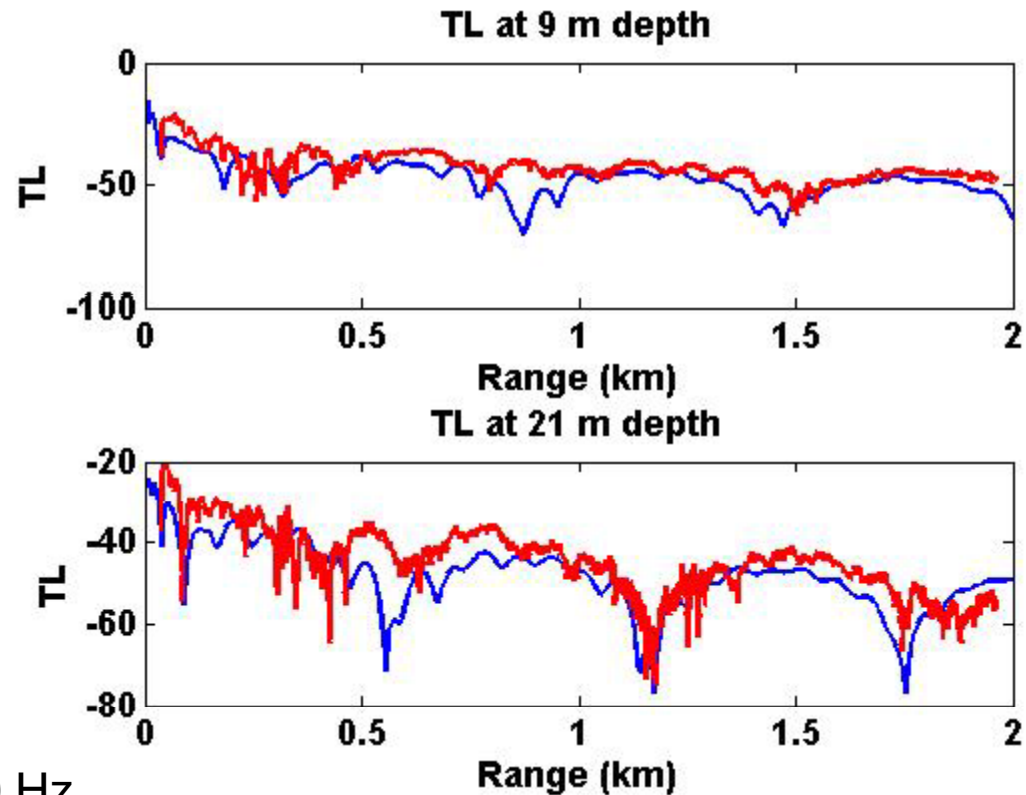
Frequency 200 Hz

bathymetry: 35 m

Top sediment layer 15 m thick

Sediment speed- 1590 m/s

Basement speed - 1770 m/s

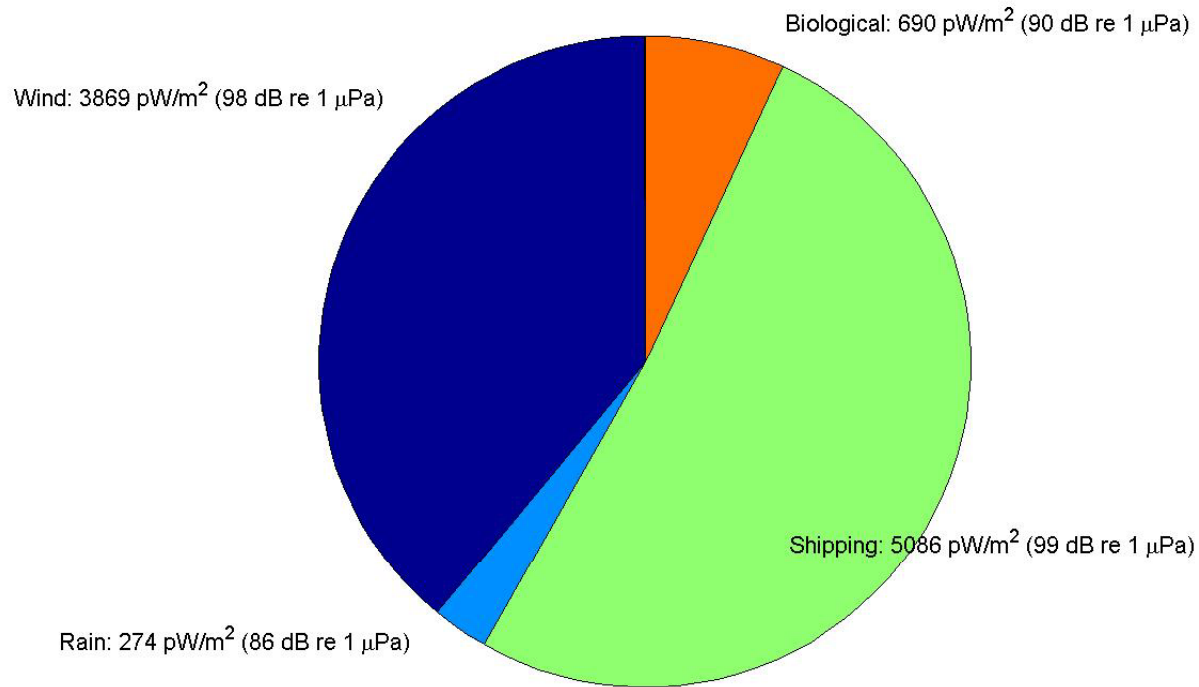


Frequency 200 Hz
bathymetry: 35 m
Top sediment layer 15 m thick
Sediment speed- 1590 m/s
Basement speed - 1770 m/s

1/3 Octave Noise Budget for Block Island

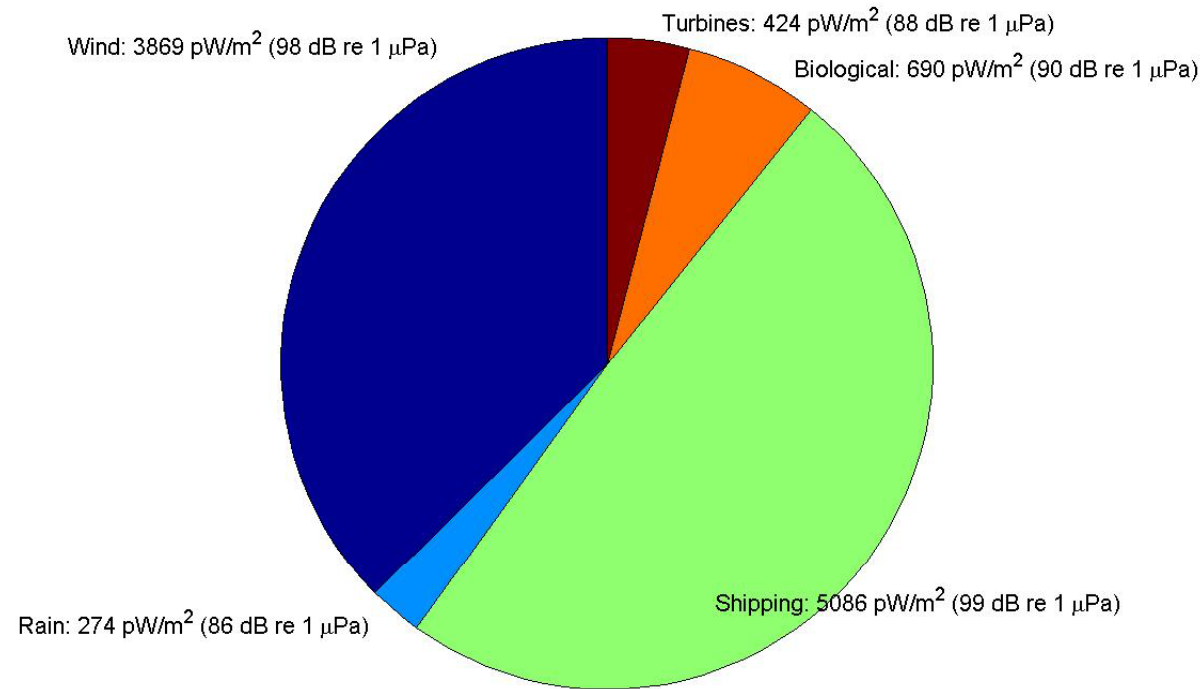
Sound Without Turbine Noise

Measured Eider Noise Budget: 500 Hz



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

Measured Eider Noise Budget With Turbines: 500 Hz



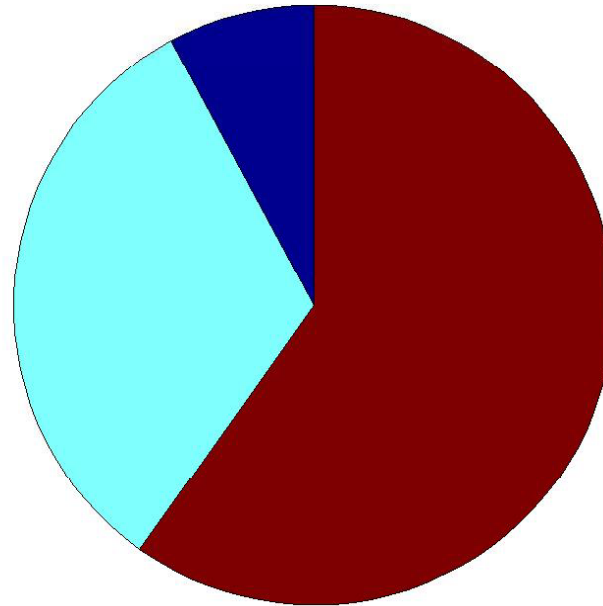
1/3 Octave Noise Budget with Ionian Sea Noise Without Turbine Noise

Example 1/3-Octave Noise Budget (No Turbines): 500 Hz

Rain: $39 \mu\text{W}/\text{m}^2$ (78 dB re 1 μPa)

Wind: $298 \mu\text{W}/\text{m}^2$
(86 dB re 1 μPa)

Shipping: $160 \mu\text{W}/\text{m}^2$
(84 dB re 1 μPa)



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

Example 1/3-Octave Noise Budget (with 8 Wind Turbines at 10 km): 500 Hz

