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℠

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)
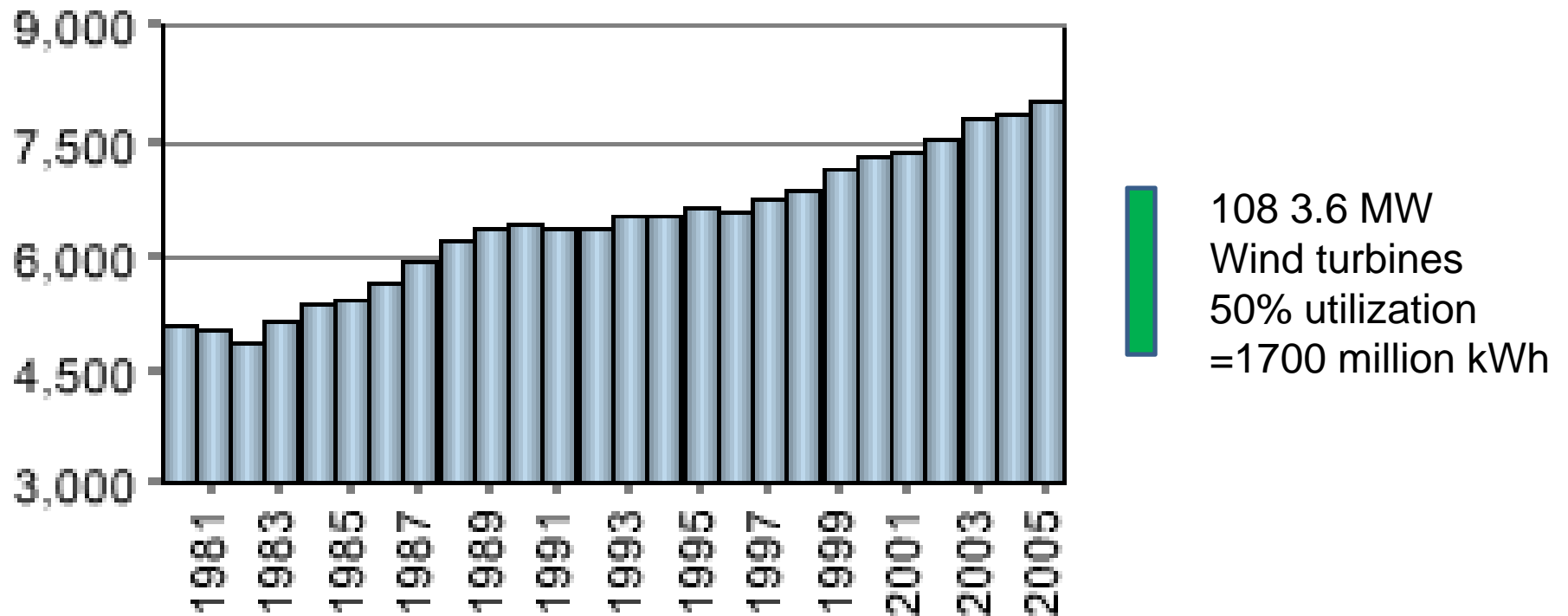- Predicted Effect of Wind Turbines on Noise Budget

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)

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

OCEAN samp   C R M C

NARRAGANSETT BAY

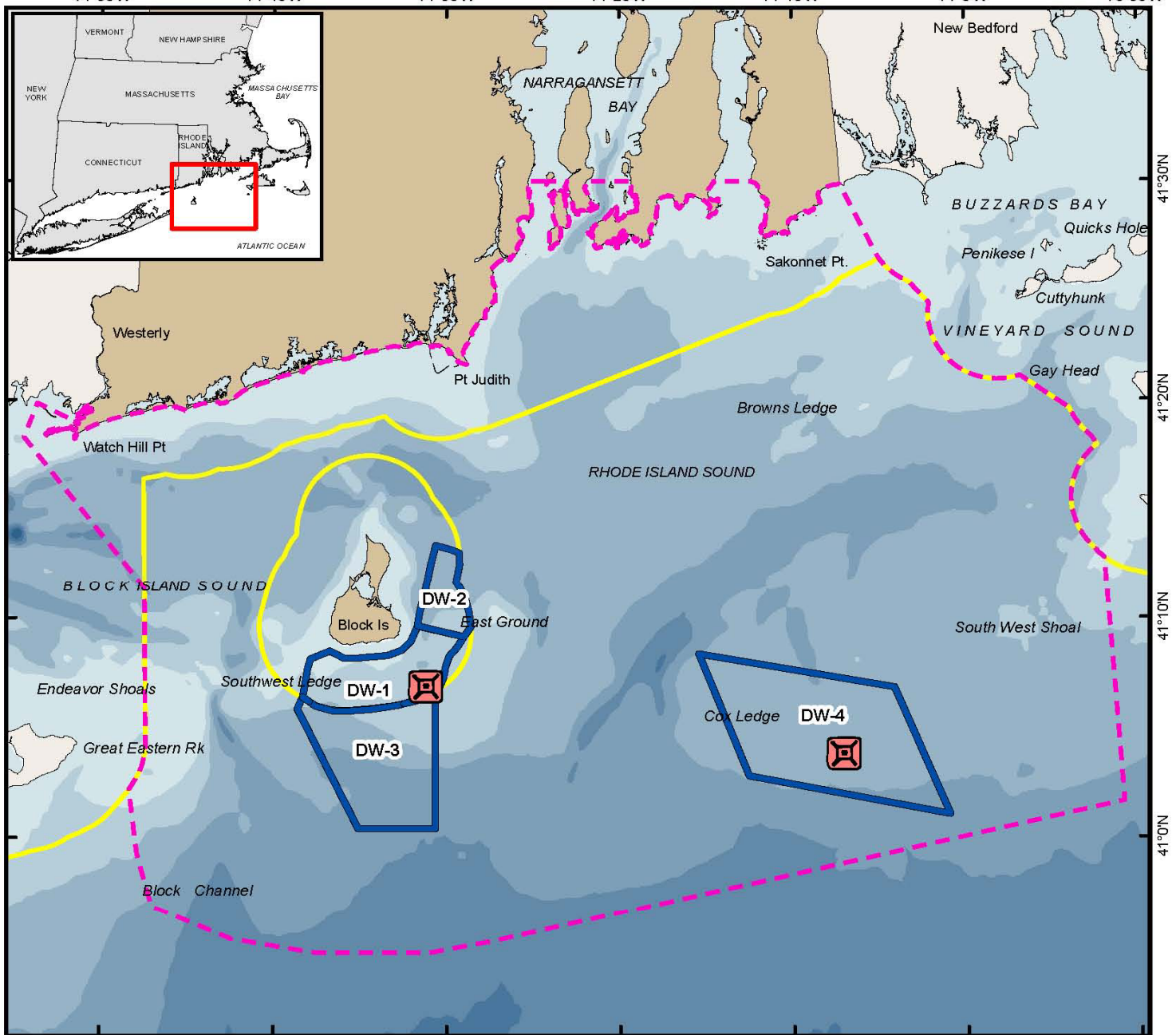BUZZARDS BAY

New Bedford

Quicks Hole

Penikese I

Cuttyhunk

VINEYARD SOUND

Gay Head

Sakonnet Pt.

Westerly

Pt Judith

Browns Ledge

RHODE ISLAND SOUND

Watch Hill Pt

South West Shoal

BLOCK ISLAND SOUND

DW-2

East Ground

Block Is

Endeavor Shoals

Southwest Ledge

DW-1

Cox Ledge   DW-4

Great Eastern Rk

DW-3

Block Channel

VERMONT   NEW HAMPSHIRE

NEW YORK   MASSACHUSETTS

MASSACHUSETTS BAY

CONNECTICUT   RHODE ISLAND

ATLANTIC OCEAN

Ambient Noise   6

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.
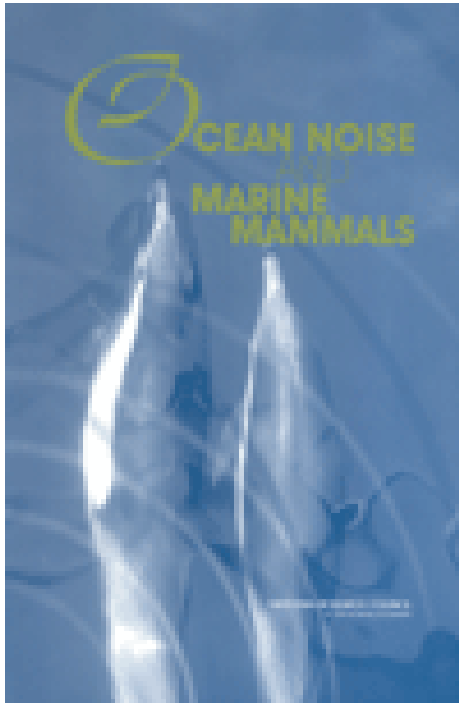

SAMP, 2009

THE
UNIVERSITY
OF RHODE ISLAND

**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?
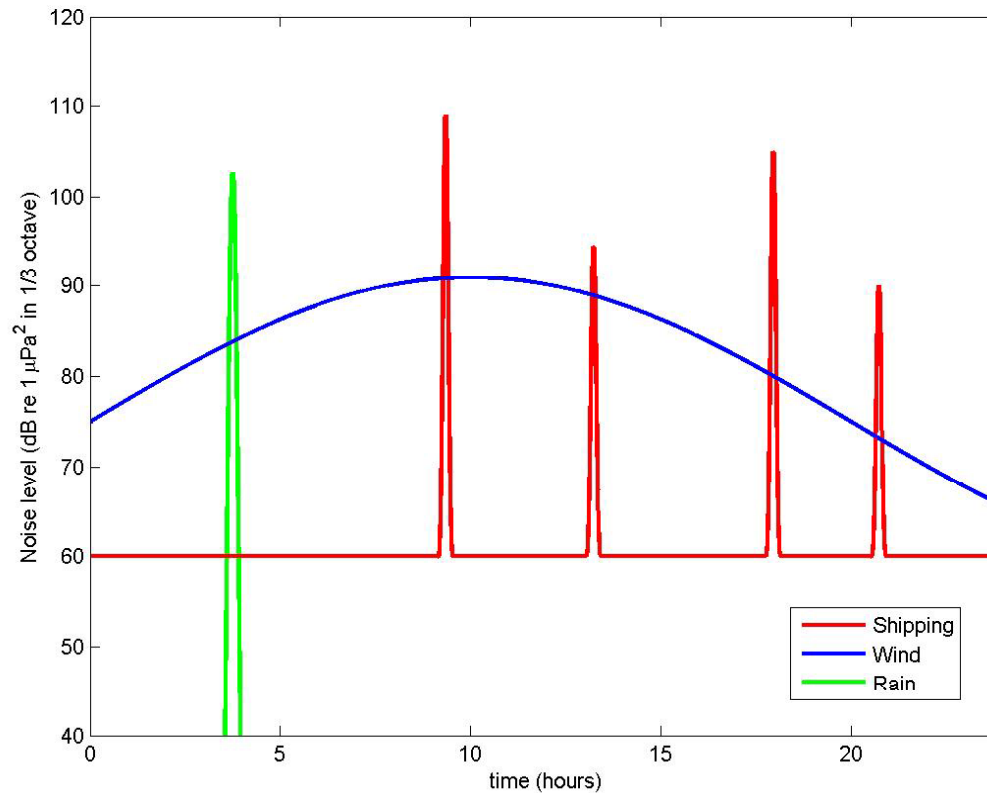
Budget Currency:
Average Intensity
from n$^{\text{th}}$ Source

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

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

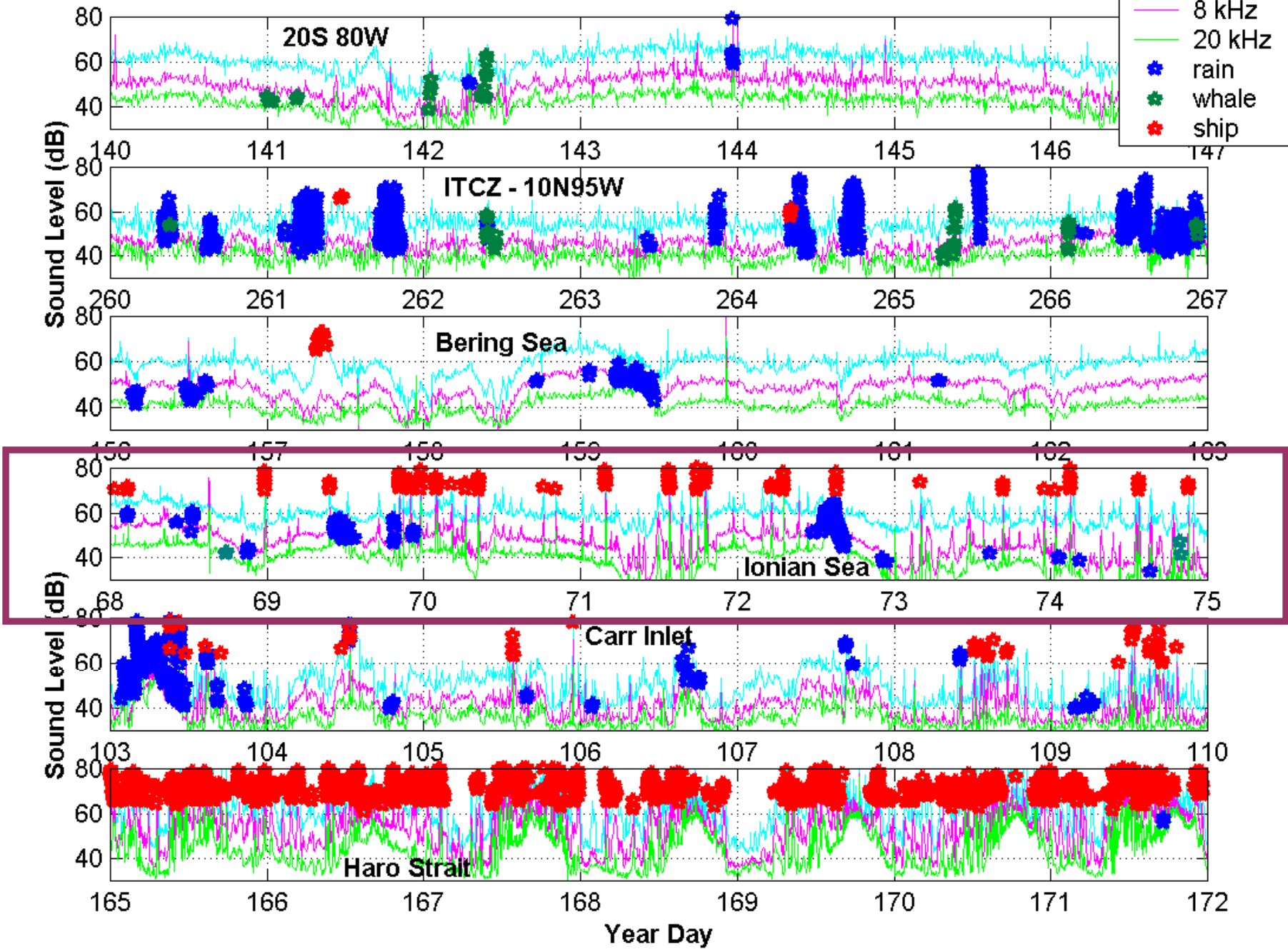Noise sources in the 1/3-octave centered at 500 Hz
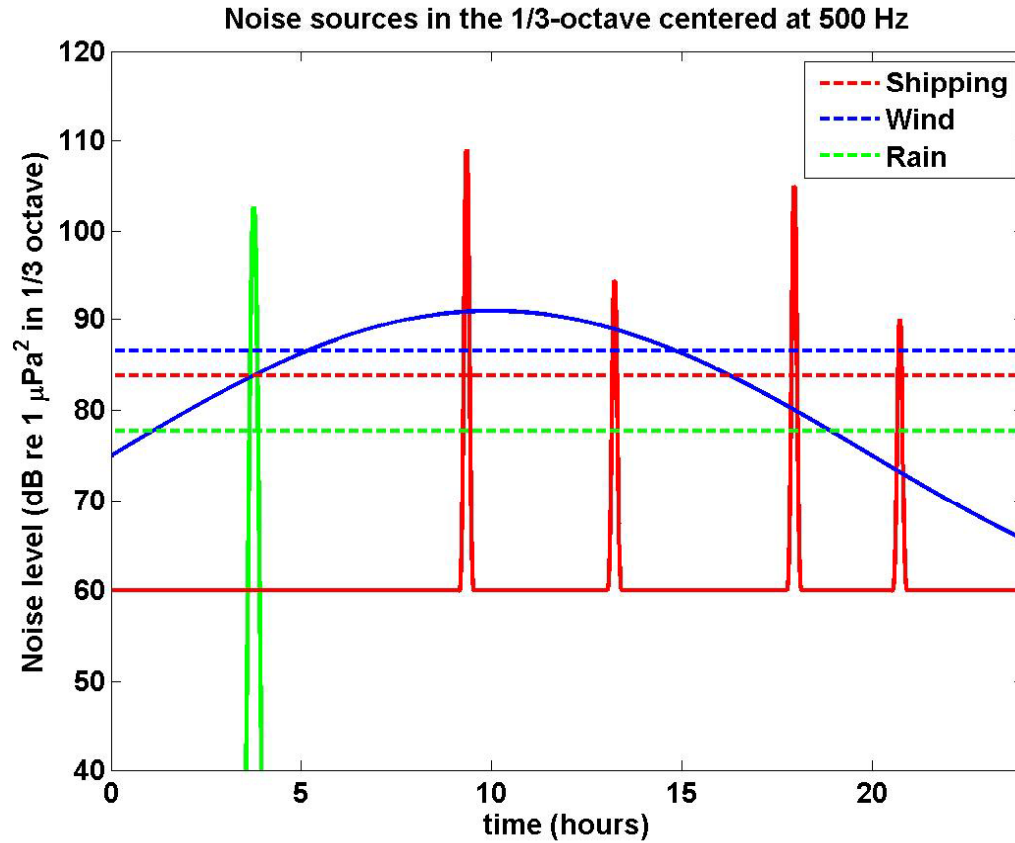
Passive Aquatic Listeners (PALs)

- 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 μPa^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

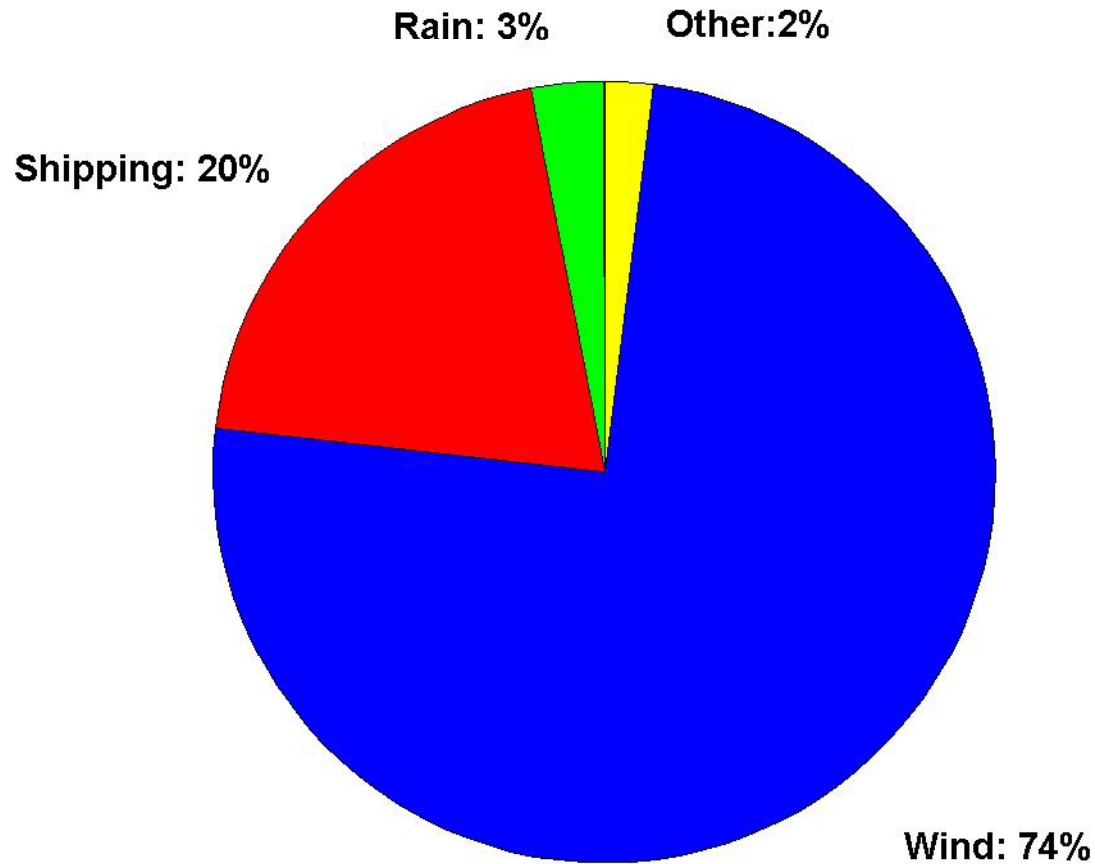# Dominant Sound Sources
Percentage of time present

	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

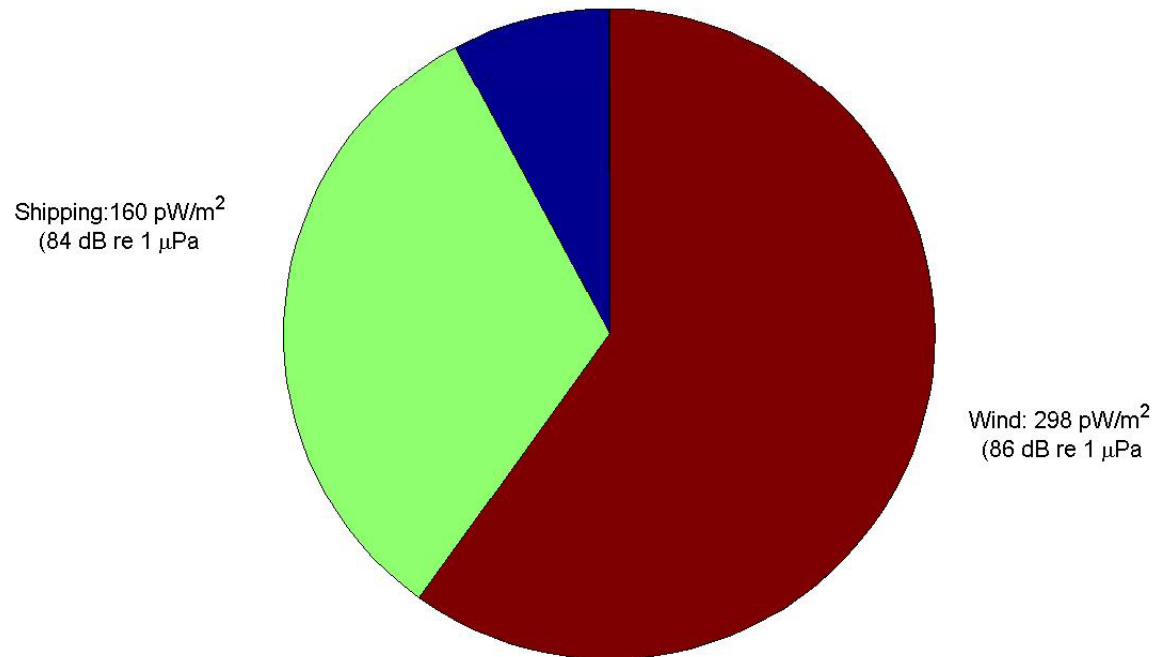Temporal Detection (TD) Noise Budget

Temporal Detection Budget

Ionian Sea Temporal Detection Budget

Average Intensity Budget

Ionian Sea Average Intensity Noise Budget 500 Hz

Rain: 39 pW/m^2 (78 dB re 1 μPa)

Shipping:160 pW/m^2
(84 dB re 1 μPa

Wind: 298 pW/m^2
(86 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
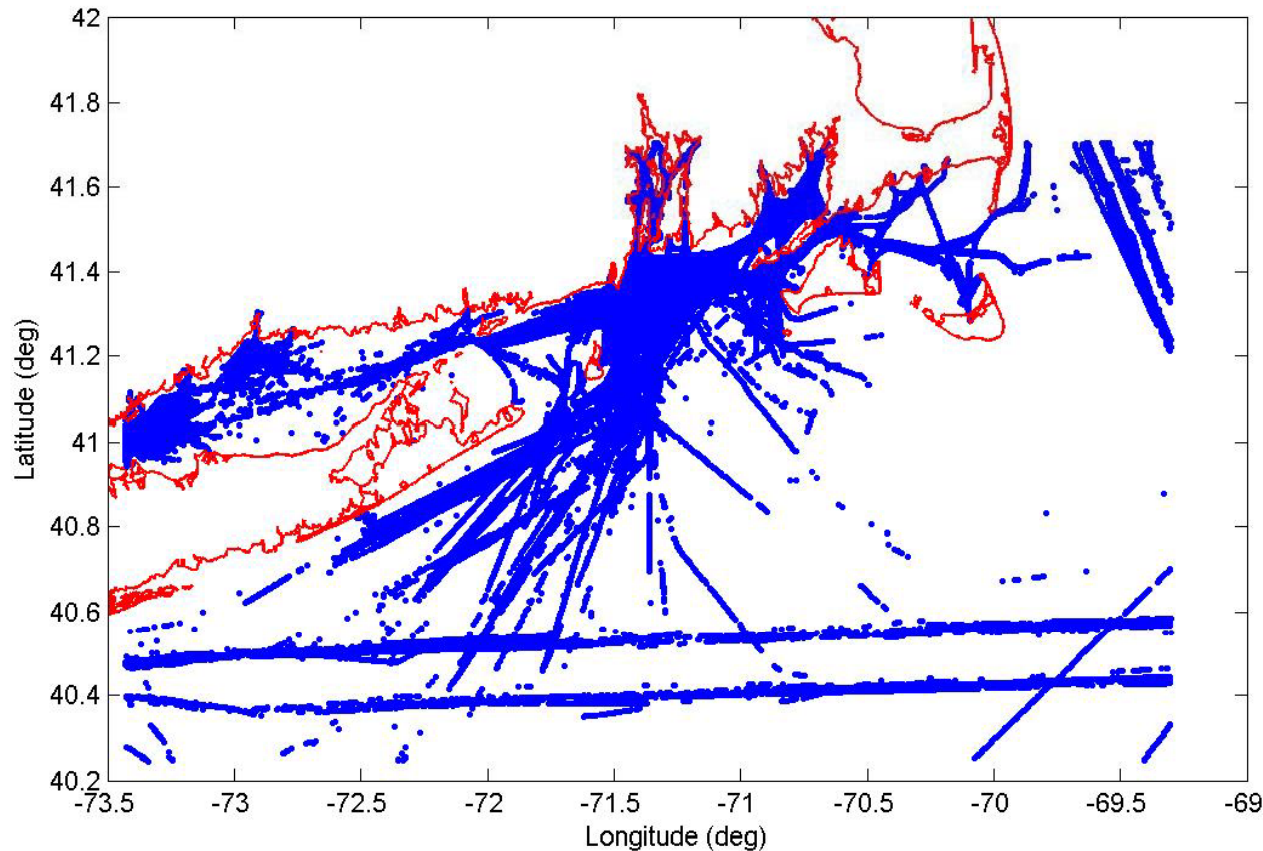
R/V Endeavor

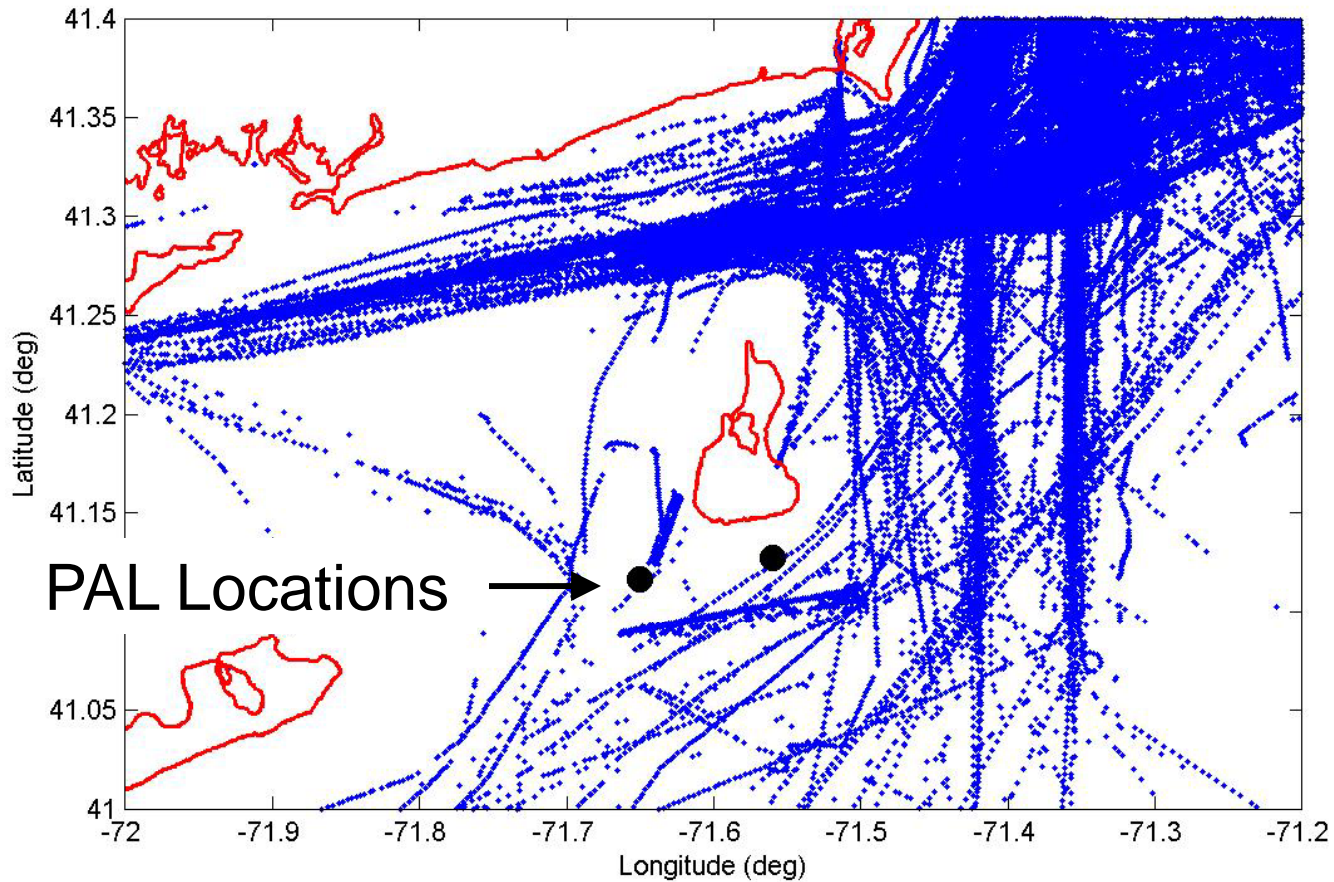# Passive Acoustic Listener System and Mooring Equipment
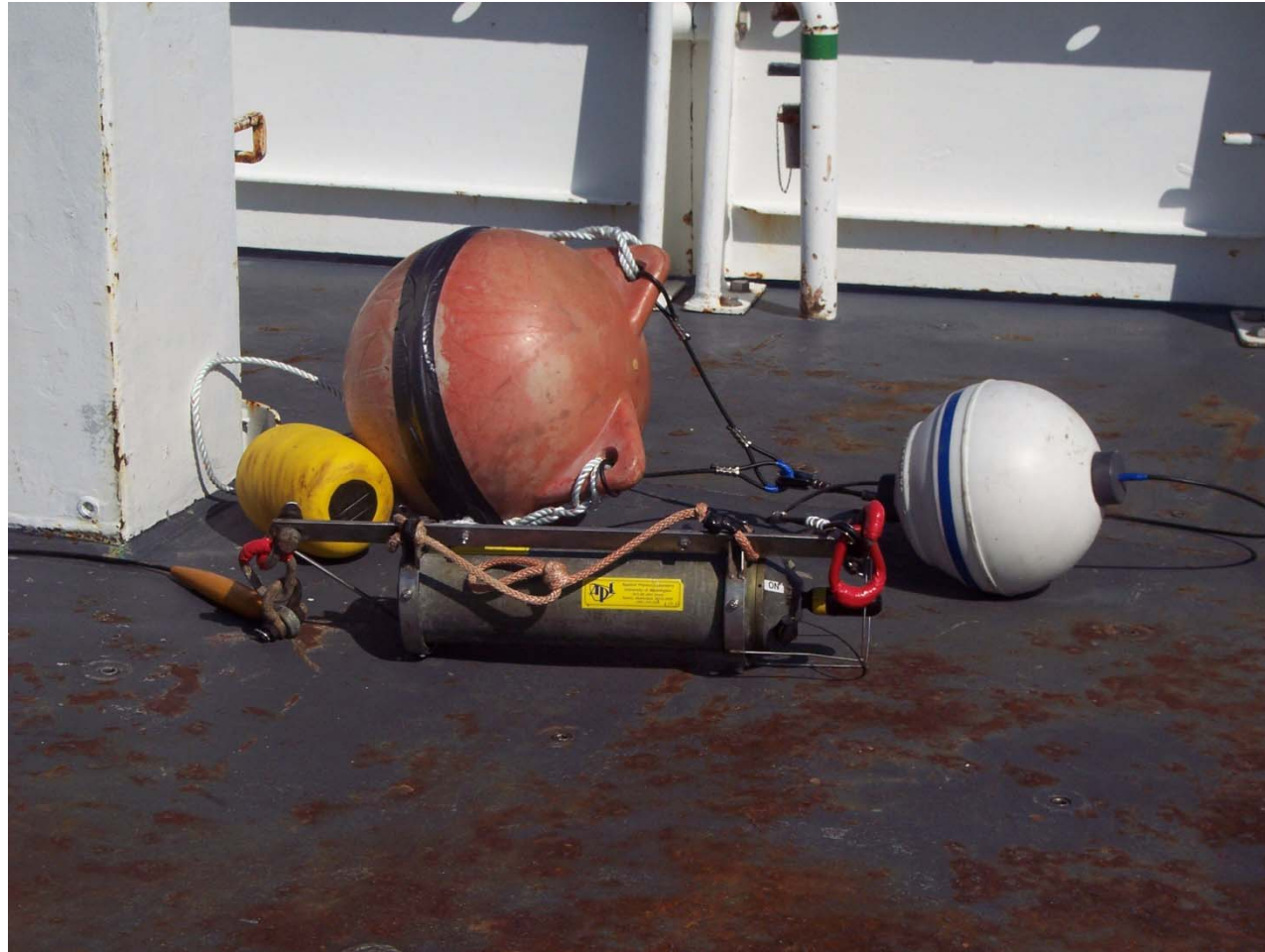
Shipping Positions from Automated Identification System (AIS)

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 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
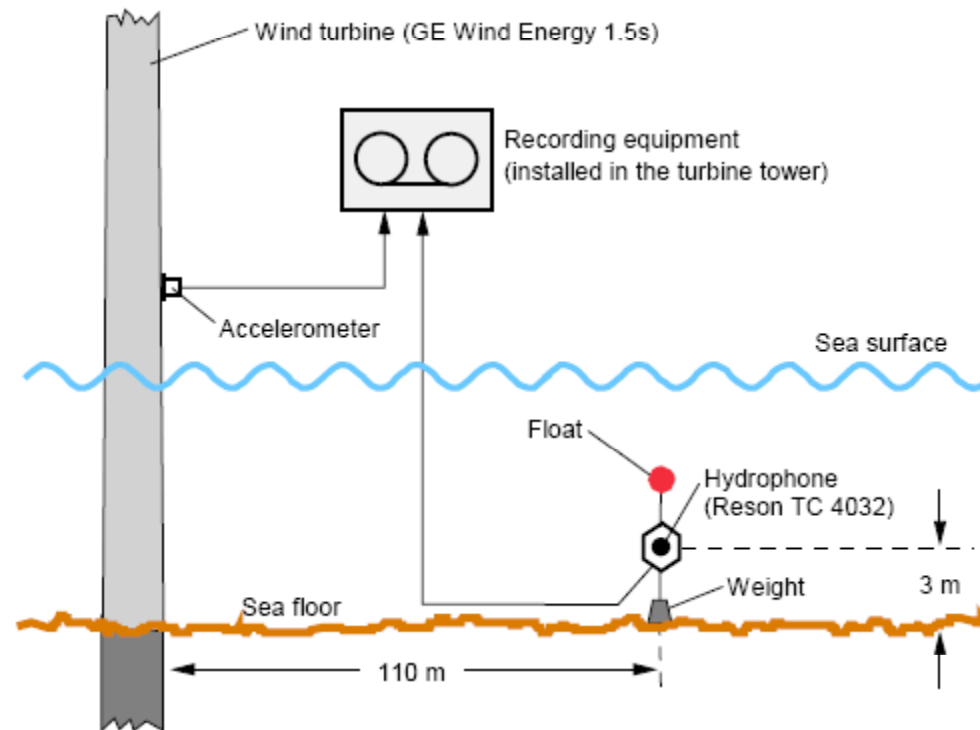

Figure 2: Measurement setup for monitoring underwater noise induced by an offshore wind turbine. Water depth was about 10 m.

(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.
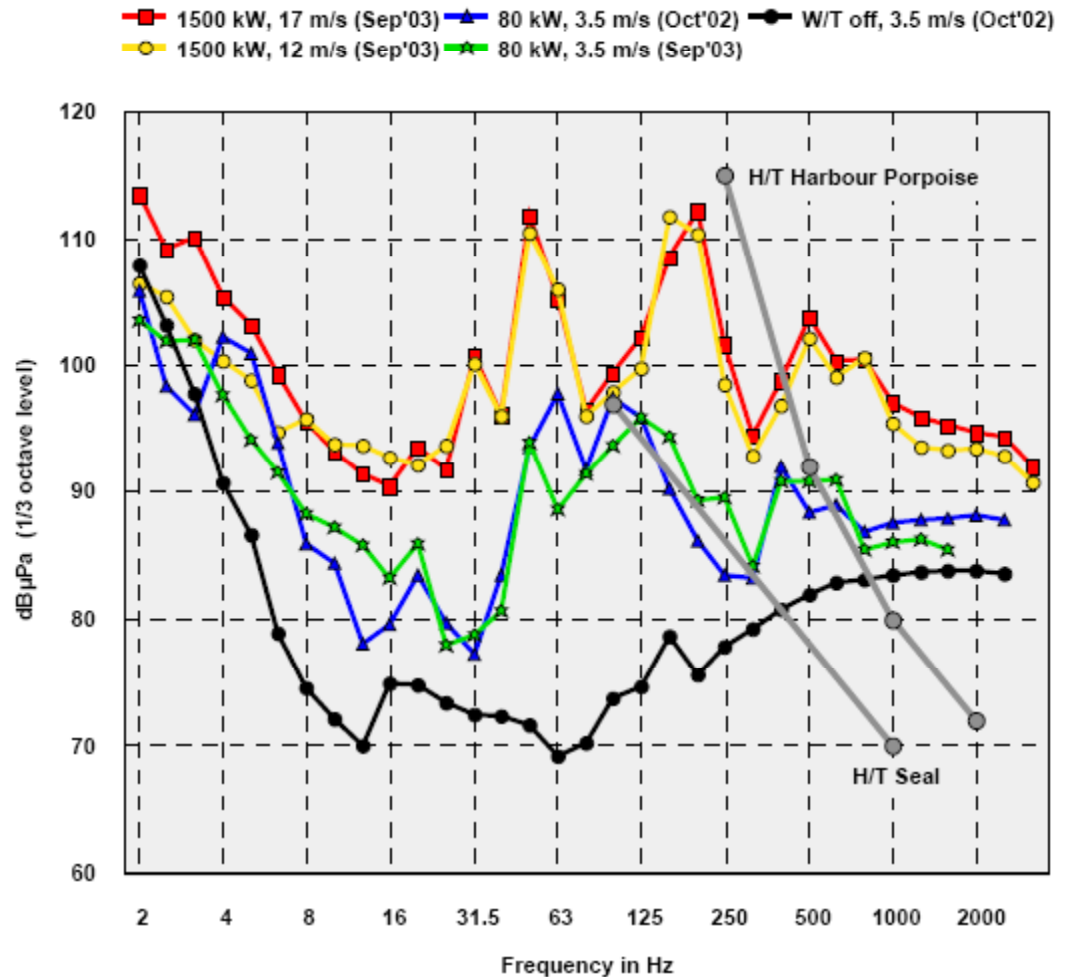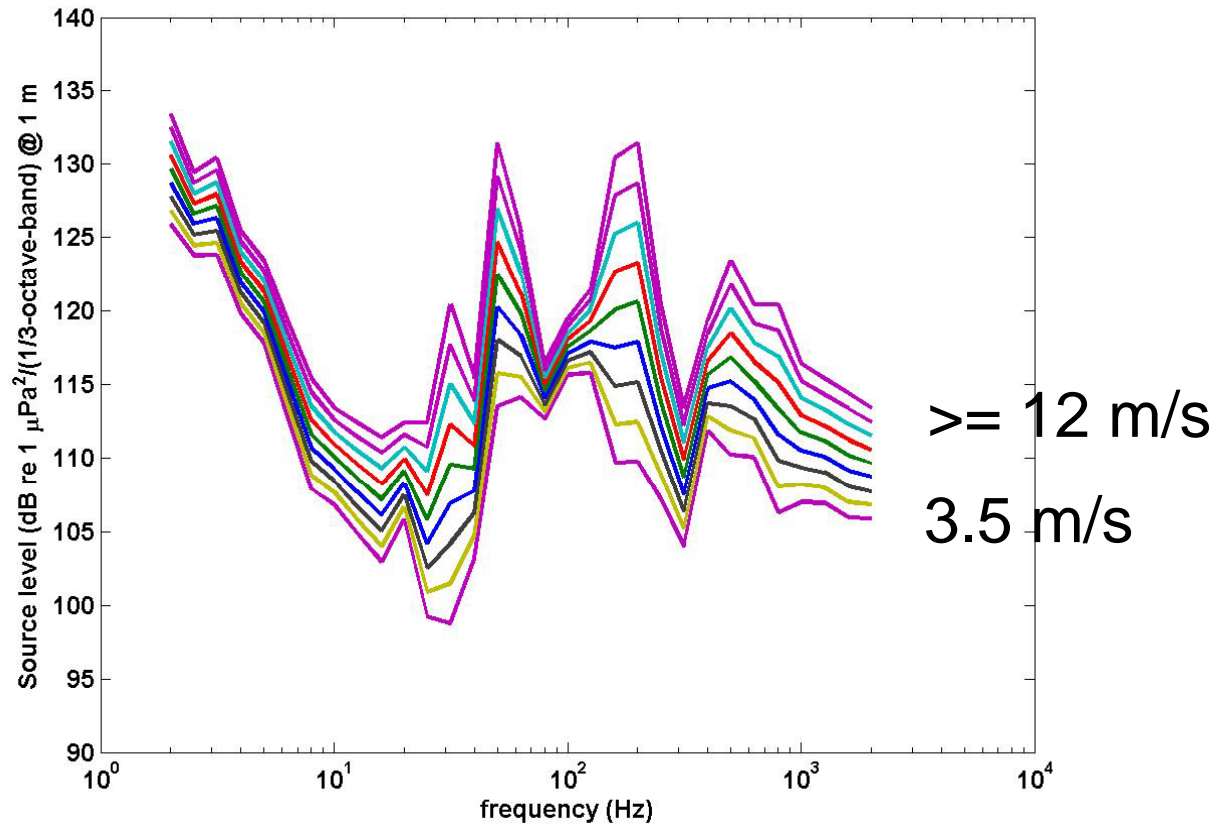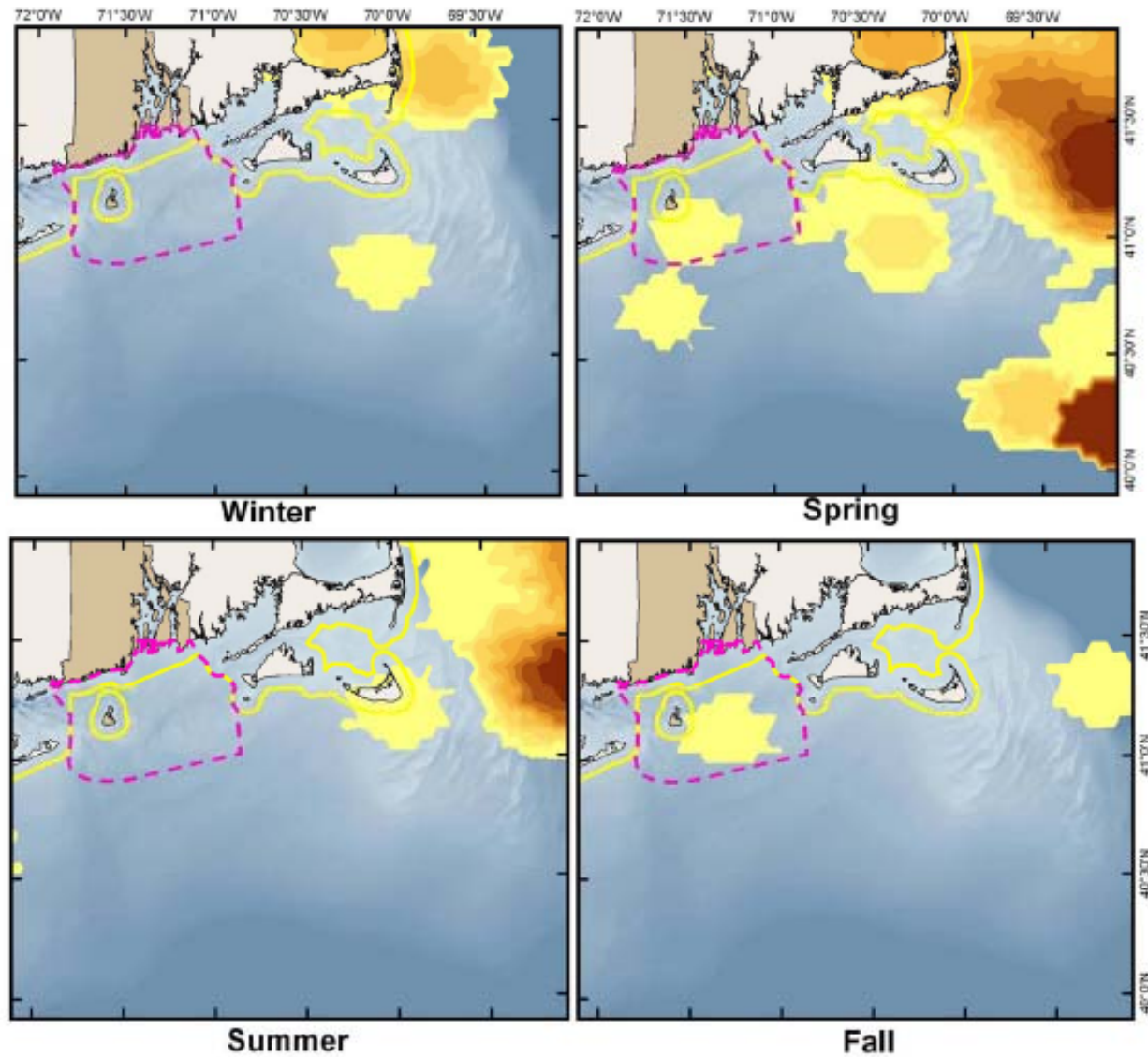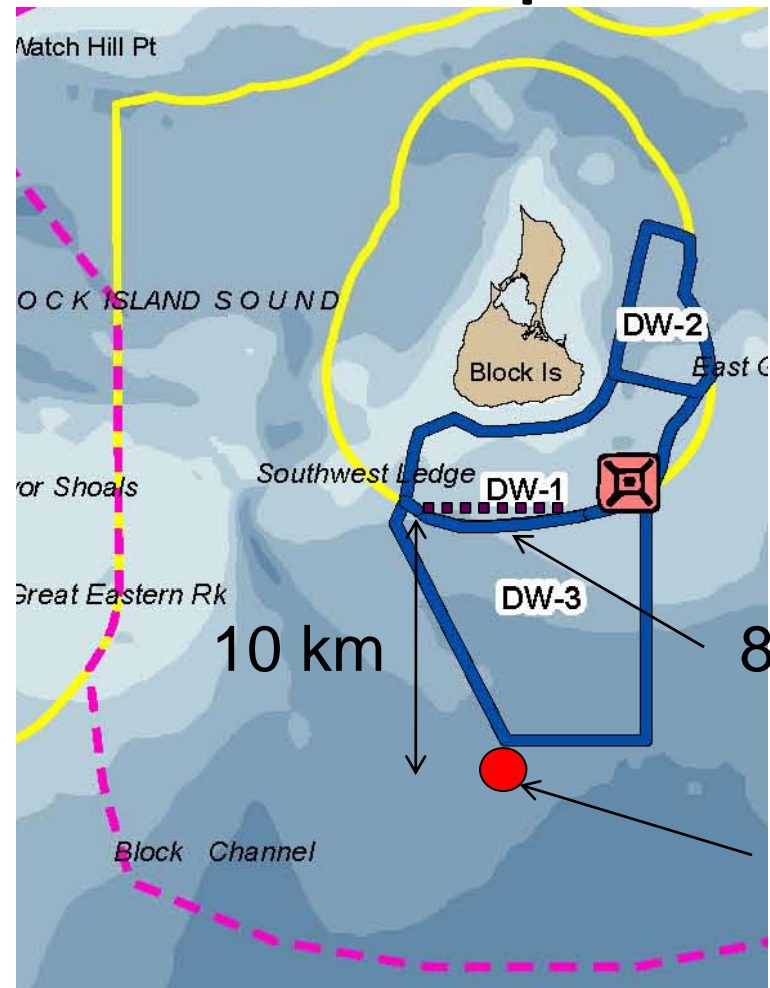
(from Betke, 2004)

Ambient Noise

Wind Speed PDF

Weibull pdf, k = 2.05, c = 9.3
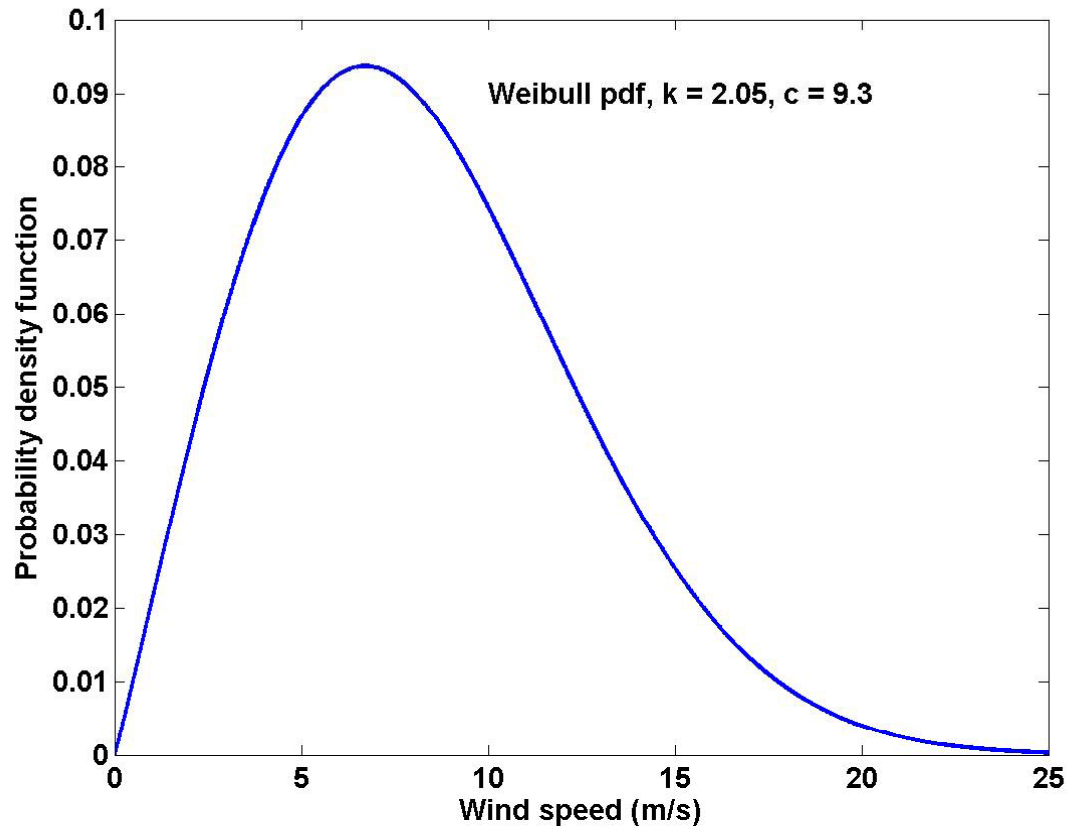
Interpolated Underwater Noise from a Wind Turbine

>= 12 m/s

3.5 m/s

Northern right whale relative abundance

Winter

Spring

Summer

Fall
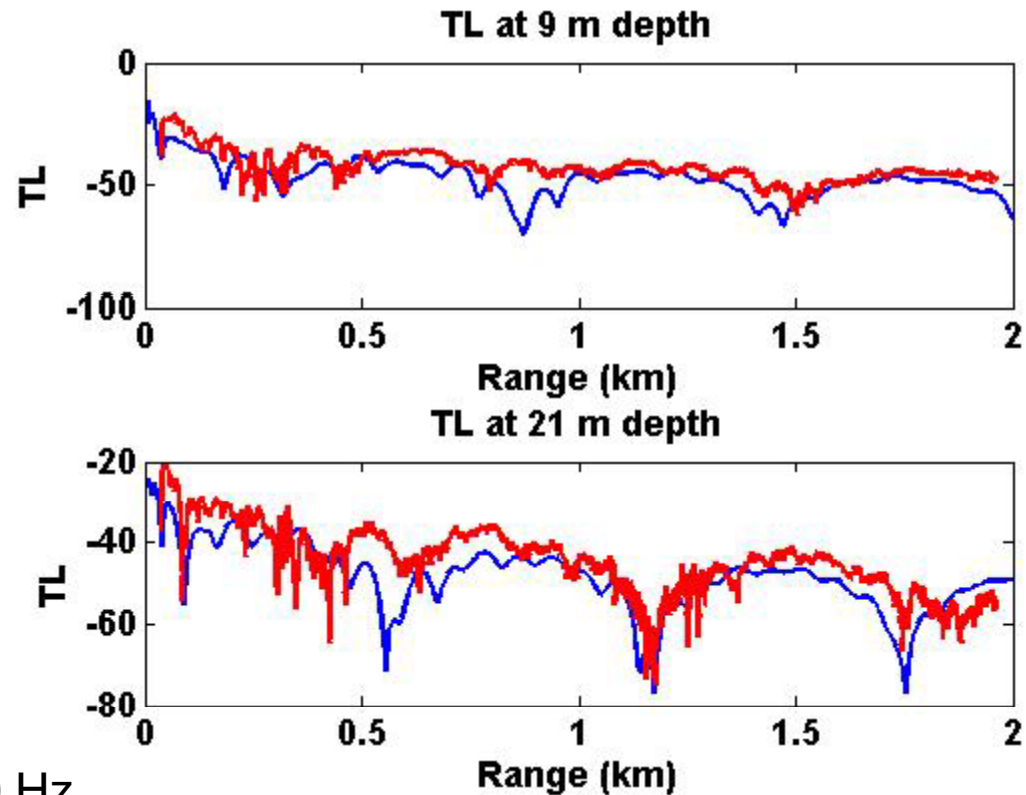
Wind Farm Example Scenario
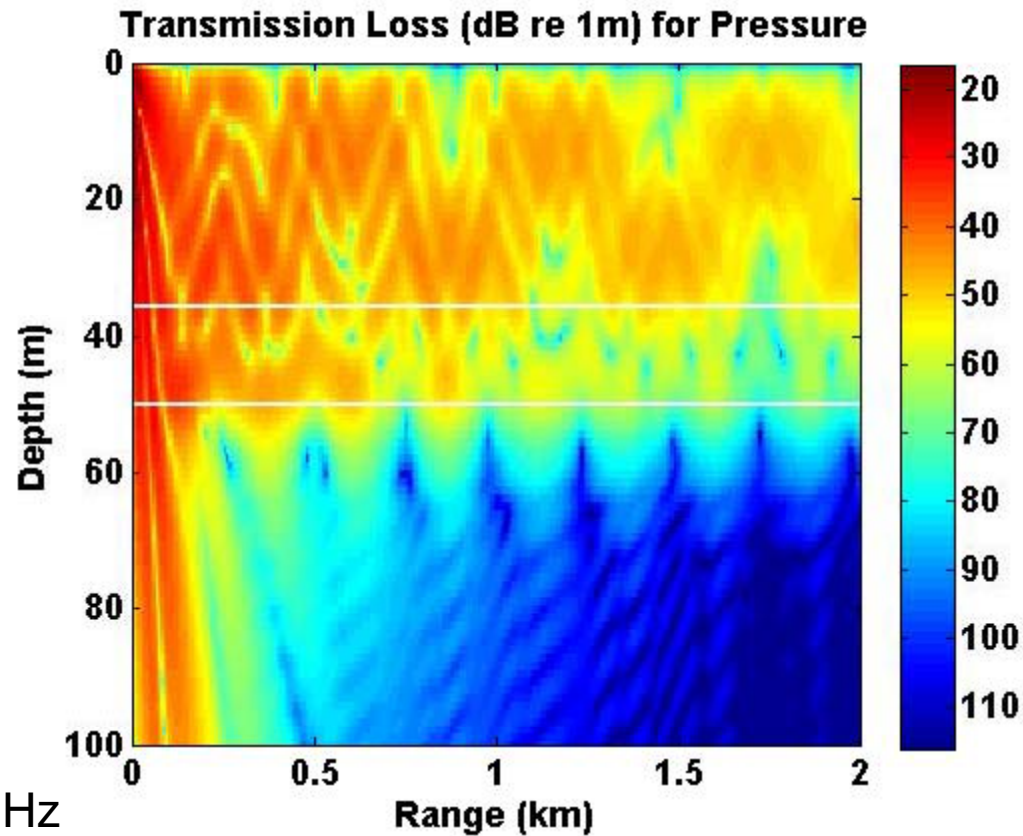
SAMP

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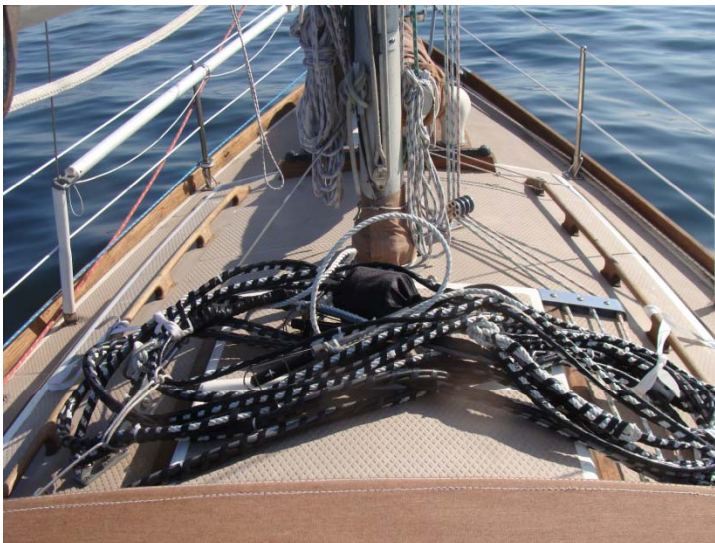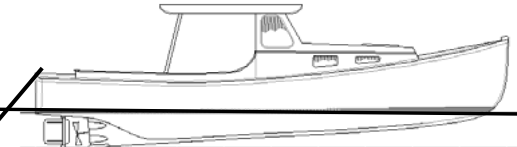bathymetry: 35 m
Top sediment layer 15 m thick
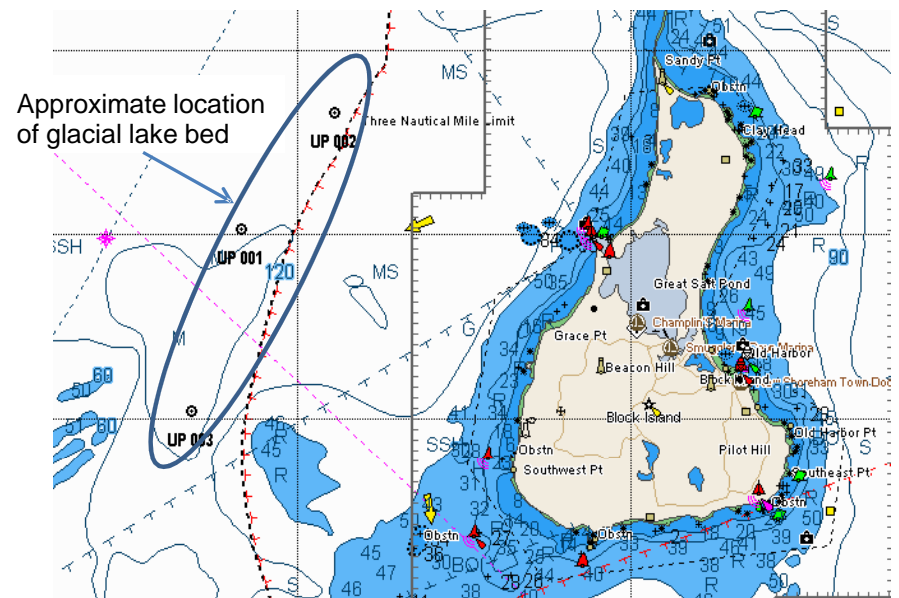Sediment speed- 1590 m/s
Basement speed - 1770 m/s

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

TL Measurement

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

Approximate location of glacial lake bed

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

Measured Eider Noise Budget: 500 Hz

Biological: 690 pW/m^2 (90 dB re 1 μPa)

Wind: 3869 pW/m^2 (98 dB re 1 μPa)

Shipping: 5086 pW/m^2 (99 dB re 1 μPa)

Rain: 274 pW/m^2 (86 dB re 1 μPa)

Measured Eider Noise Budget With Turbines: 500 Hz

Turbines: 424 pW/m^2 (88 dB re 1 μPa)

Biological: 690 pW/m^2 (90 dB re 1 μPa)

Wind: 3869 pW/m^2 (98 dB re 1 μPa)

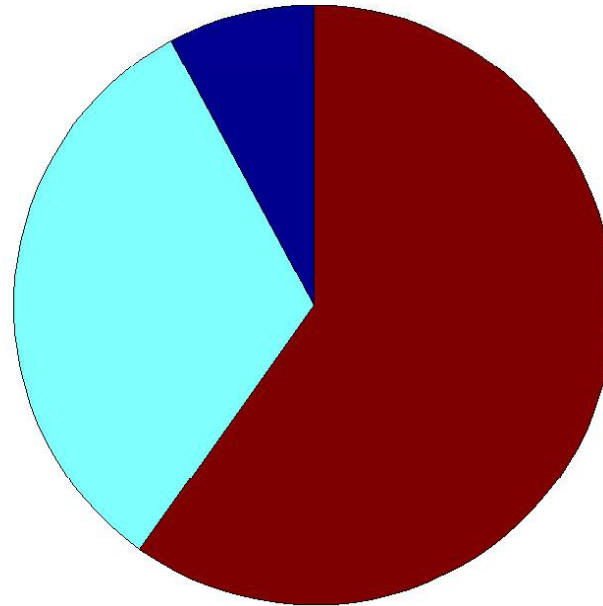Shipping: 5086 pW/m^2 (99 dB re 1 μPa)

Rain: 274 pW/m^2 (86 dB re 1 μPa)
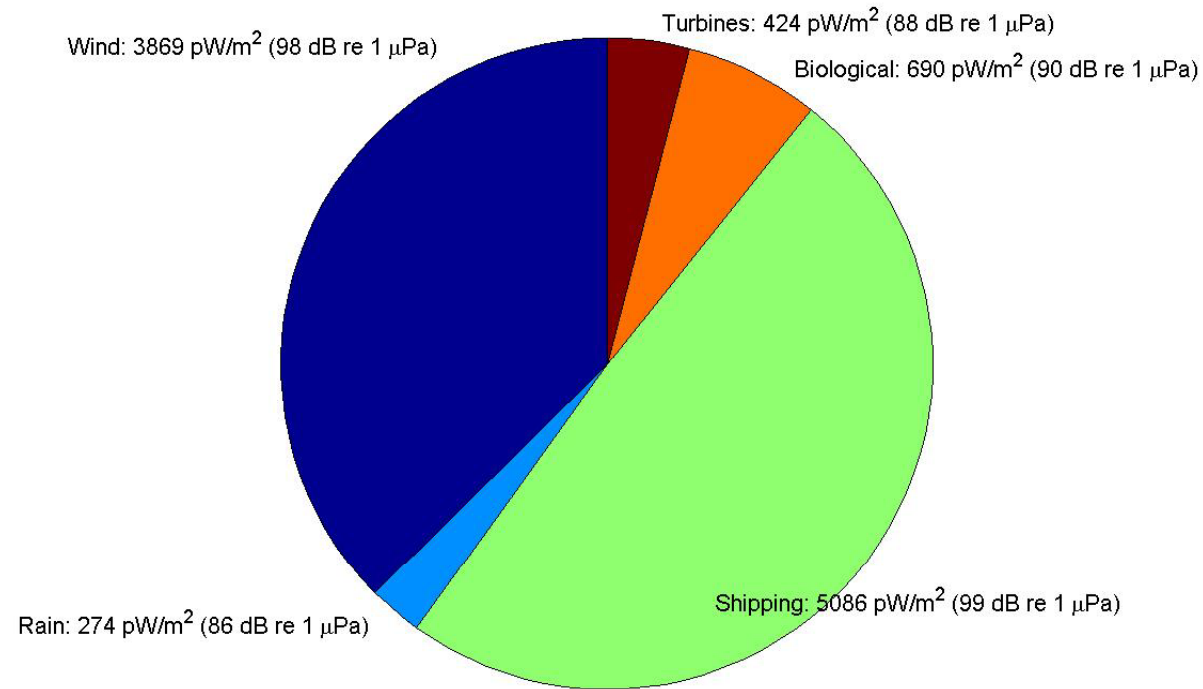
1/3 Octave Noise Budget with Ionian Sea Noise Without Turbine Noise

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

Rain: 39 μW/m^2 (78 dB re 1 μPa)

Wind: 298 μW/m^2 (86 dB re 1 μPa)

Shipping: 160 μW/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 Tubines at 10 km): 500 Hz

Rain: 39 μW/m^2 (78 dB re 1 μPa)

Shipping: 160 μW/m^2 (84 dB re 1 μPa)

Turbines: 424 μW/m^2 (88 dB re 1 μPa)

Wind: 298 μW/m^2 (86 dB re 1 μPa)