The Passive Aquatic Listener (PAL): An Adaptive Sampling Passive Acoustic Recorder

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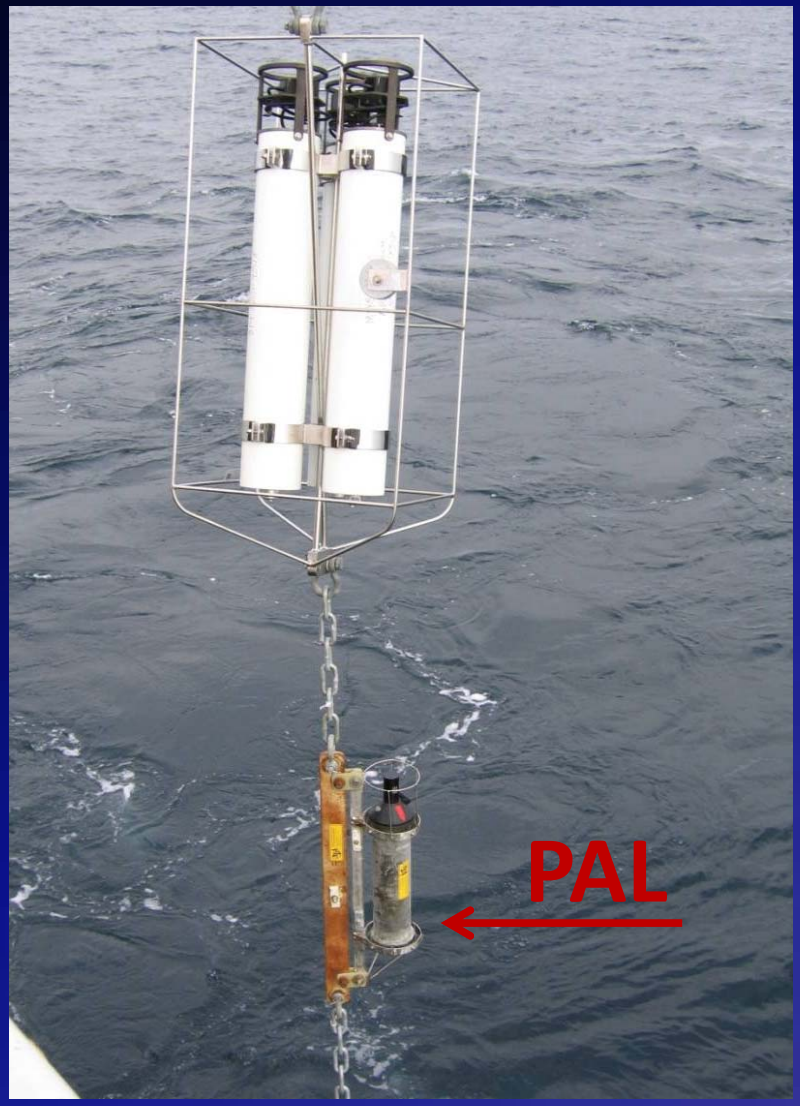
Passive Acoustic Monitoring

- Popular in monitoring and mitigation of vocalizing animals (marine mammals)
- Advantages
  - Non-invasive
  - Large spatial coverage
  - Data collection is not labor intensive
- Limitations/challenges
  - Only detects vocalizing animals
  - Tradeoffs: size vs deployment duration, power vs storage, storage vs bandwidth
  - Post-processing is labor intensive

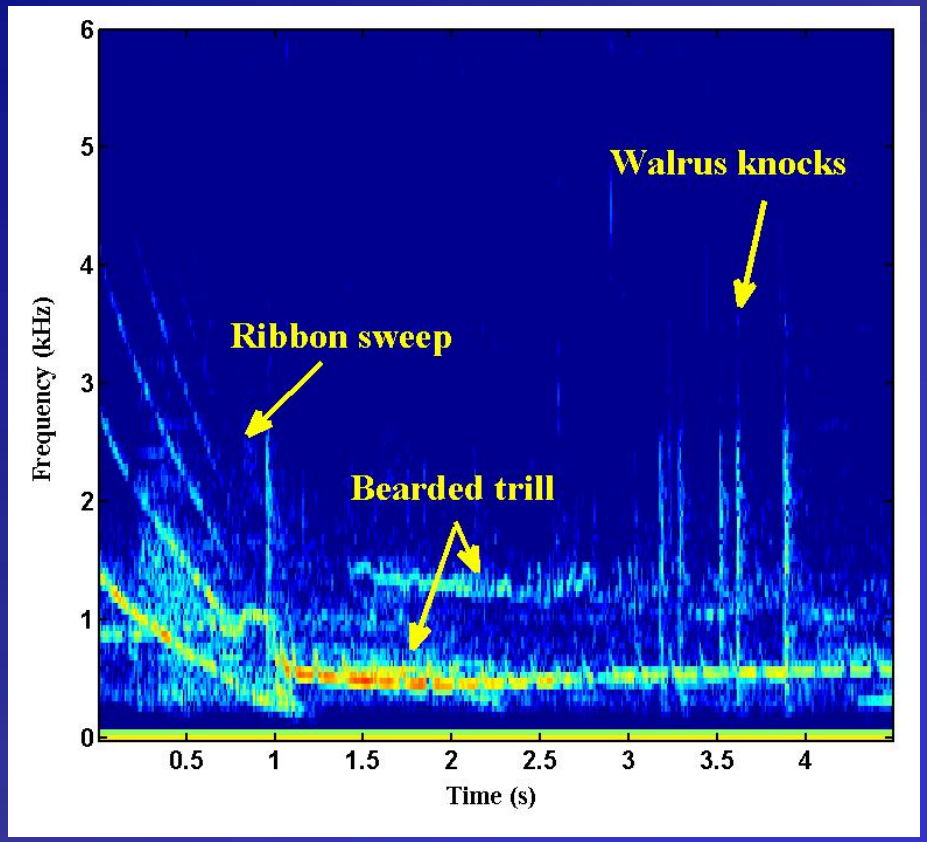
Passive Aquatic Listener (PAL)



- 100 kHz sampling rate
- 20 Hz-50 kHz usable frequency range
- Adaptive, sub-sampling protocol (onboard processing)
- Year deployments
- Stored data
  - Spectra
  - 4.5 sec time series, “soundbites”

Passive Aquatic Listener (PAL)

- Passive acoustic time series of spectra and sound bites
  - Marine mammal detections
  - Environmental sound levels
  - Ocean wind and precipitation
  - Sea Ice dynamics
  - Detections of human activity



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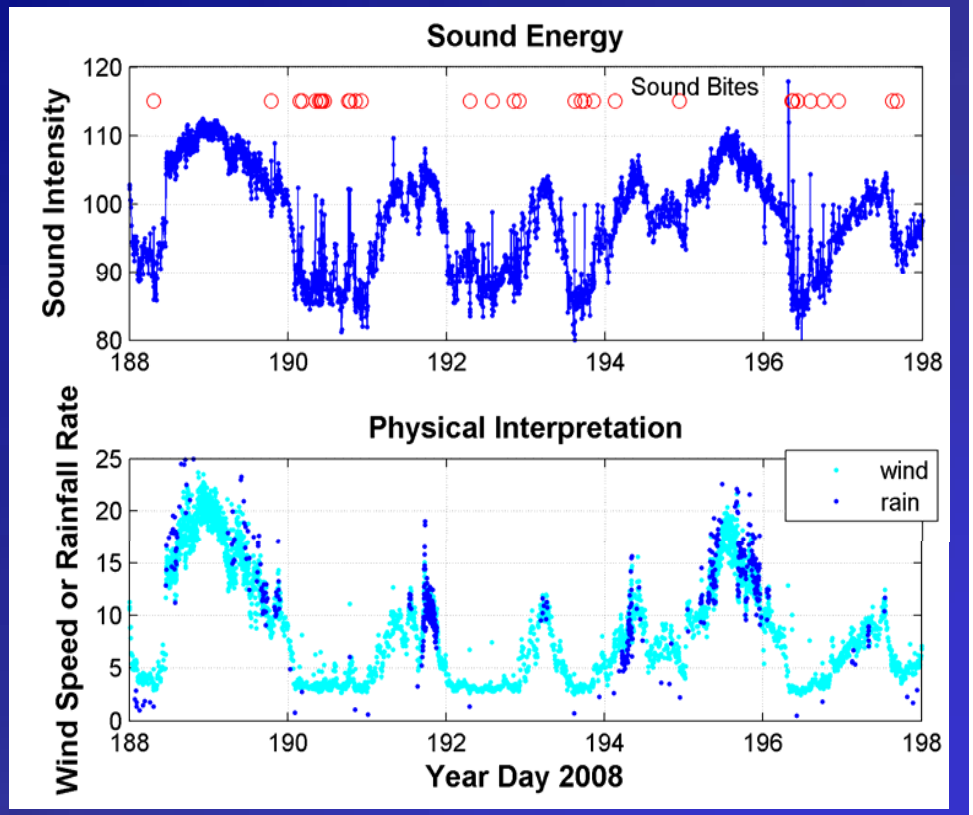

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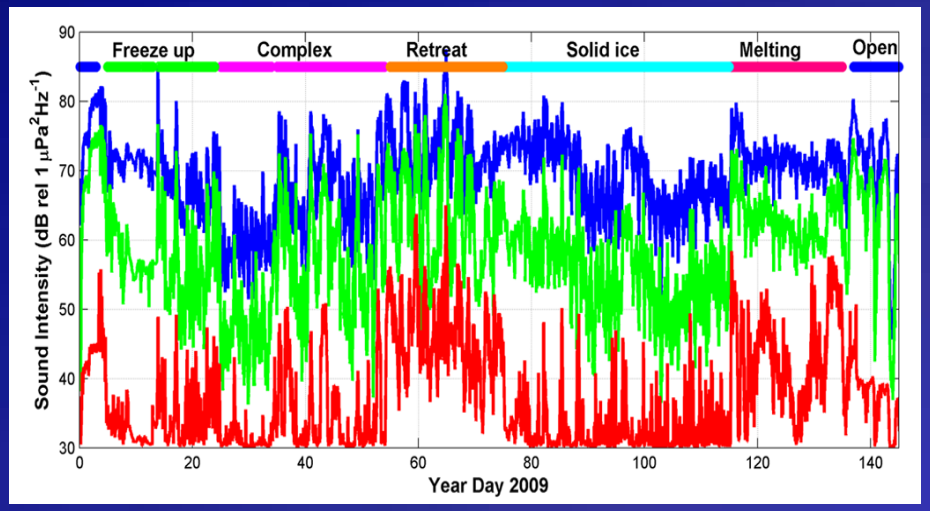

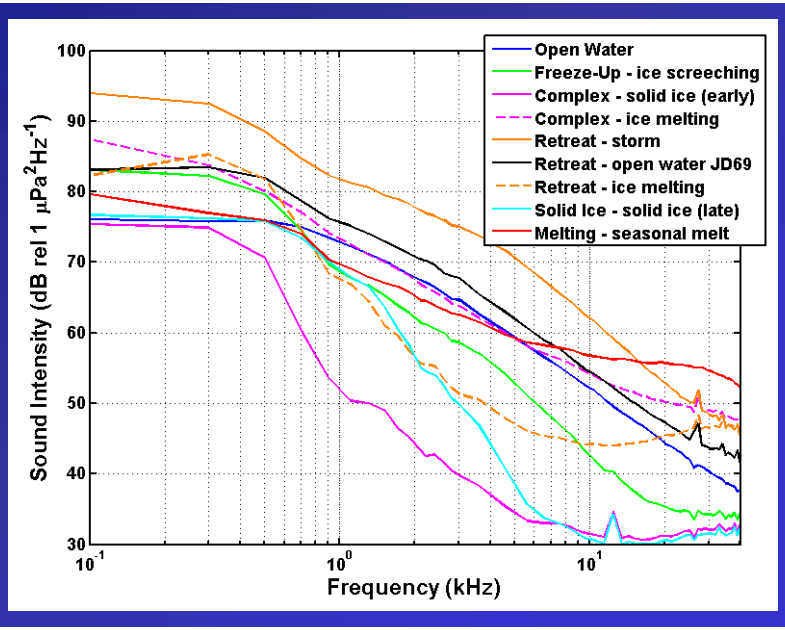

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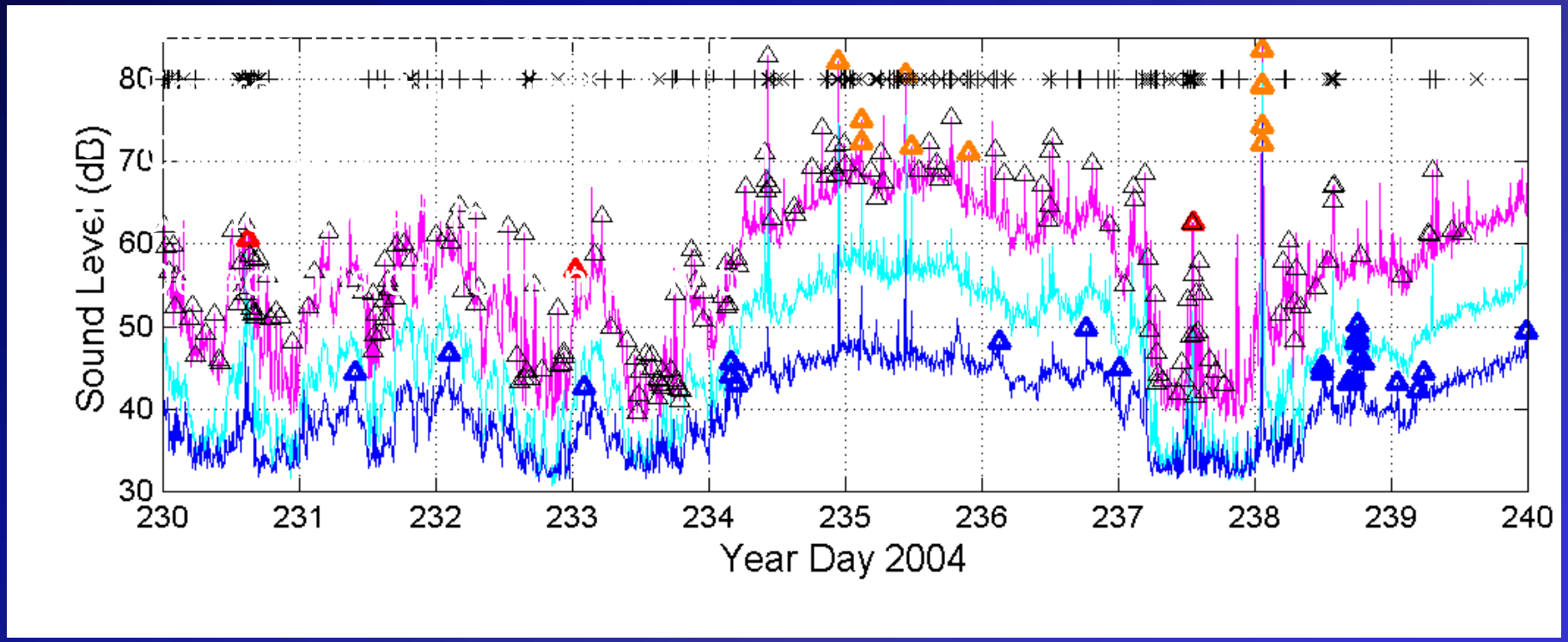
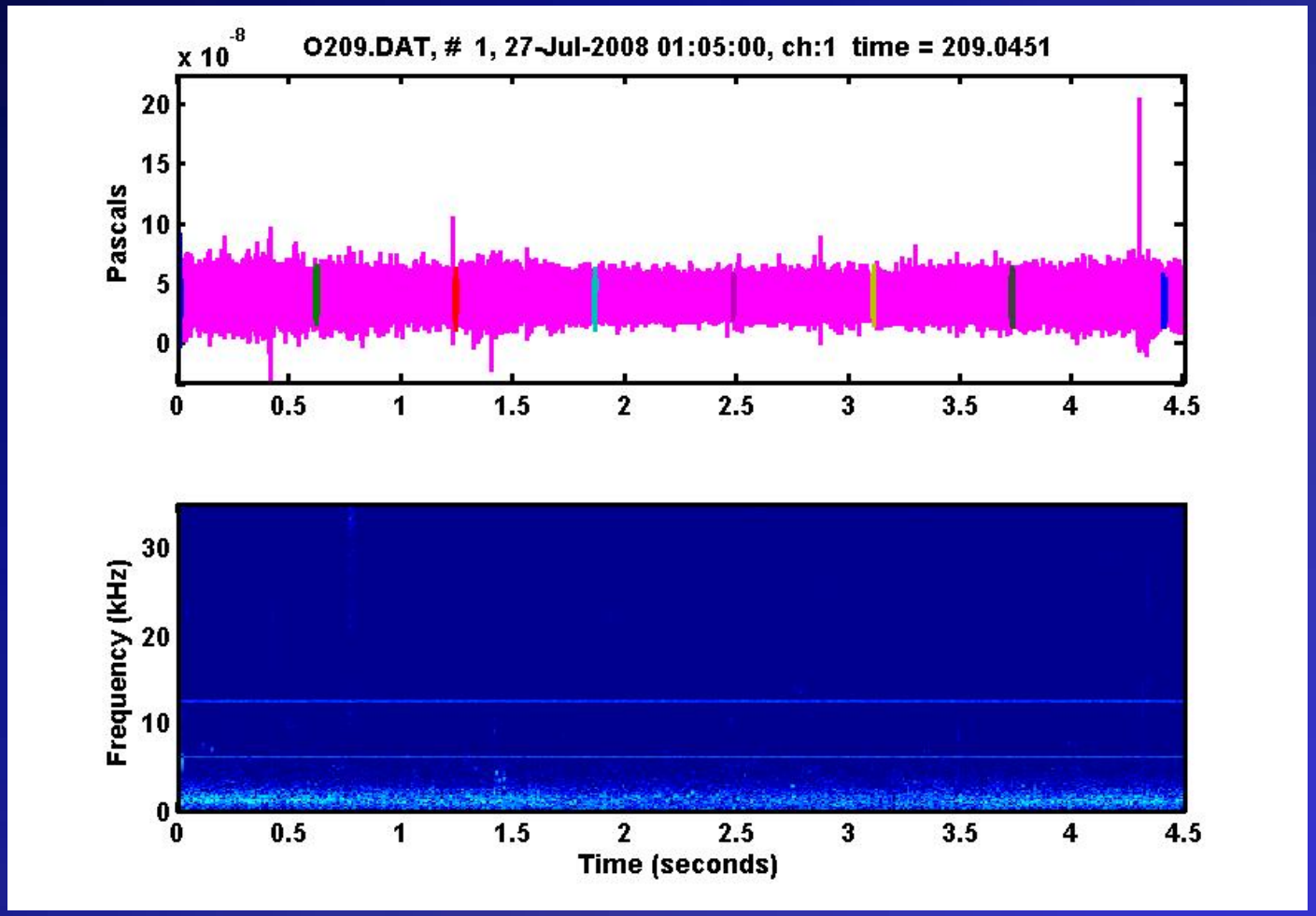


PAL Operation

Default Sampling Strategy



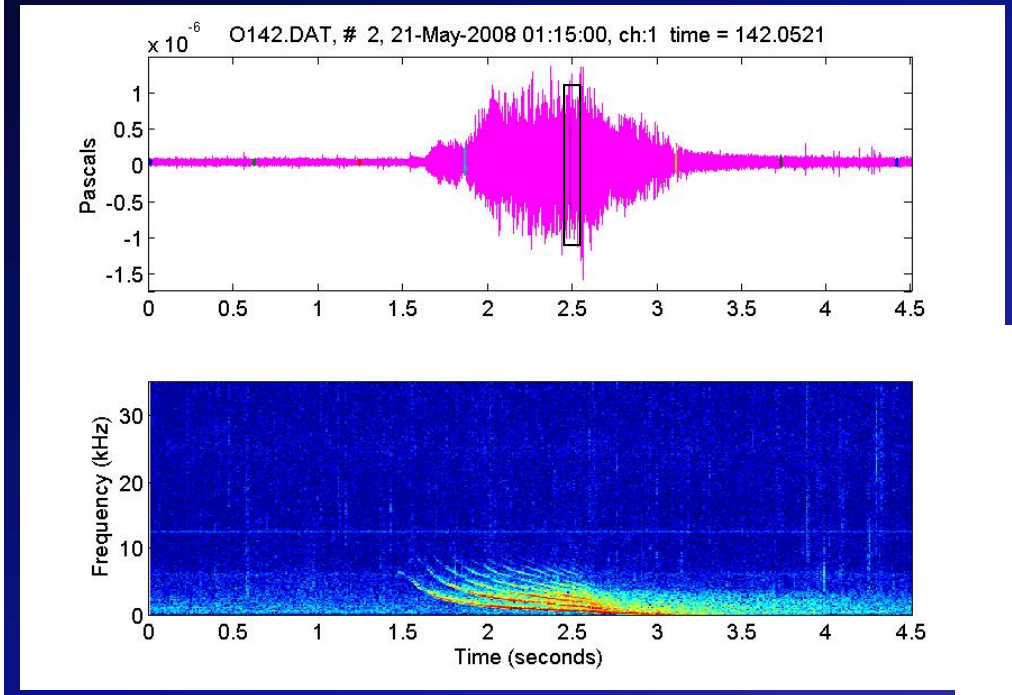
PAL Operation

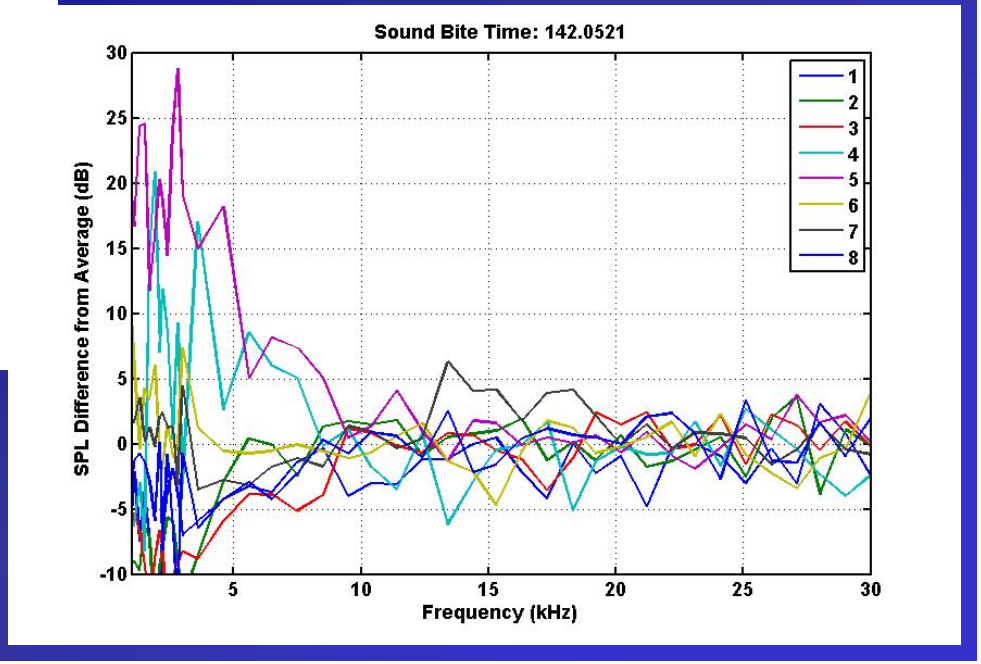
Alternate Sampling Strategy

- Triggers (user spcified)
  - Exceeding a defined dB threshold level between sequential sub-samples indicating a **transient source**
  - Matching of spectrum characteristics to known spectra (rain, vocalizations, etc)
  - Matching of predefined peaks (e.g. 300 Hz- 3 kHz) indicating possible tonal or click vocalization

PAL Operation

Triggered Soundbite





PAL Operation

Alternate Sampling Strategy

- Wake up
- Record 4.5 sec time series (100 kHz)
- Sub-sample time series (Eight 40 ms samples)
- Fourier transform (0-50 kHz)
- Identify sound source characteristics
- Quantify source
- Store individual spectra AND time series
- Reduce time in “deep sleep” mode before next sampling period

Trigger identified

PAL Operation

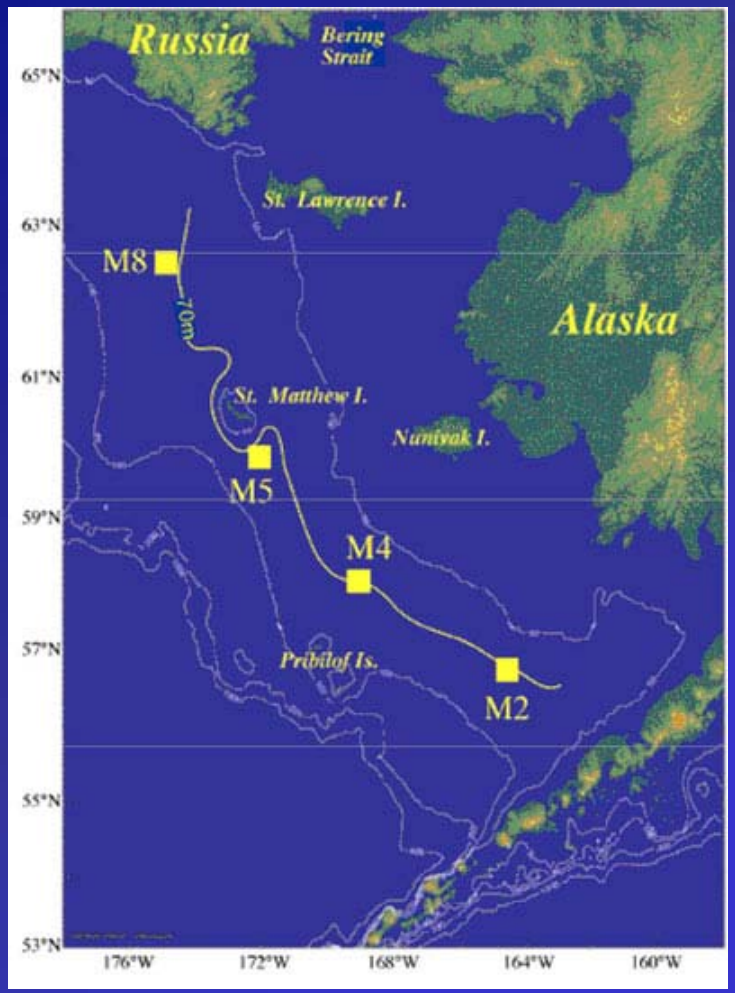
Duty Cycle Example

- Default (Low Duty Cycle)
  - 10 minute sampling interval
  - 0.75% duty cycle
  - Average spectrum saved
- Triggered (High Duty Cycle)
  - 30 second sampling interval
  - 15% duty cycle
  - Time series saved
  - NOTE: only a limited number of time series can be saved each day. User specified

PAL Performance

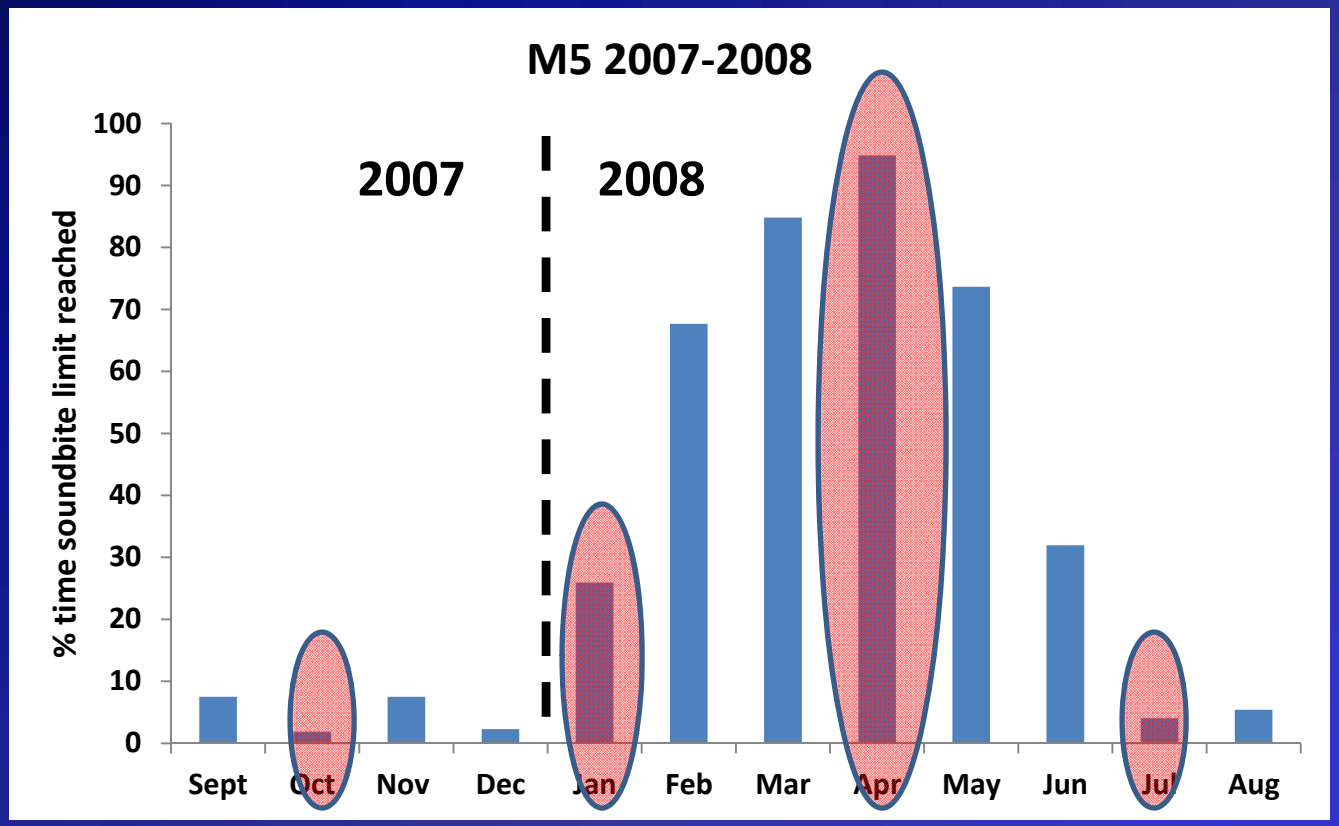
Bering Sea Case Study

- Two mooring locations
  - M2: SE Bering Sea
  - M5: Central Bering Sea
- Sampling Parameters
  - Default: 10 min interval
  - Trigger: 2 min interval
  - 16-20 soundbites/day



PAL Performance

- Spectral data: full coverage at 10 min intervals
- Soundbites: Variable coverage by month



M5 soundbite triggers

Oct 2007 (n=73)

Echolocation	28%
Wind	20%
Humpback	20%
Gray whale	8%
Mooring	7%
Precipitation	7%

Jan 2008 (n=239)

Bowhead	89%
Echolocation	5%
Unknown	3%
Beluga	1%
Wind	1%
Precipitation	

Apr 2008 (n=240)

Bearded seal	70%
Ribbon seal	8%
Bowhead	5%
Walrus	5%
Precipitation	4%
Low clicks	2%
Echolocation	

Jul 2008 (n=133)

Wind	26%
Echolocation	21%
Low clicks	14%
Mooring	11%
Ship	10%
Precipitation	6%
Gray whale	2%

M5 soundbite triggers and incidental detections

PENNSTATE 1855

Oct 2007 (n=73)

Echolocation	28%	5%
Wind	20%	
Humpback	20%	20%
Gray whale	8%	1%
Mooring	7%	5%
Precipitation	7%	7%

Jan 2008 (n=239)

Bowhead	89%	5%
Echolocation	5%	12%
Unknown	3%	
Beluga	1%	
Wind	1%	
Precipitation		25%

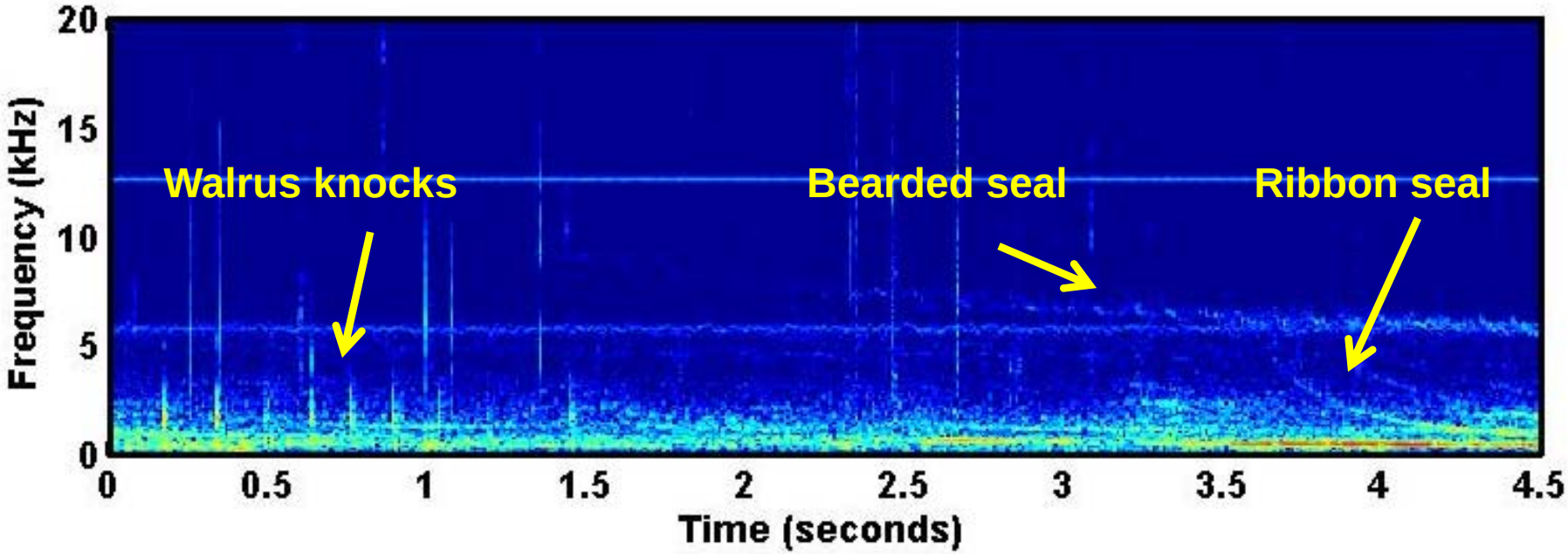
Apr 2008 (n=240)

Bearded seal	70%	29%
Ribbon seal	8%	8%
Bowhead	5%	5%
Walrus	5%	19%
Precipitation	4%	4%
Low clicks	2%	20%
Echolocation		20%

Jul 2008 (n=133)

Wind	26%	
Echolocation	21%	9%
Low clicks	14%	4%
Mooring	11%	8%
Ship	10%	2%
Precipitation	6%	5%
Gray whale	2%	1%

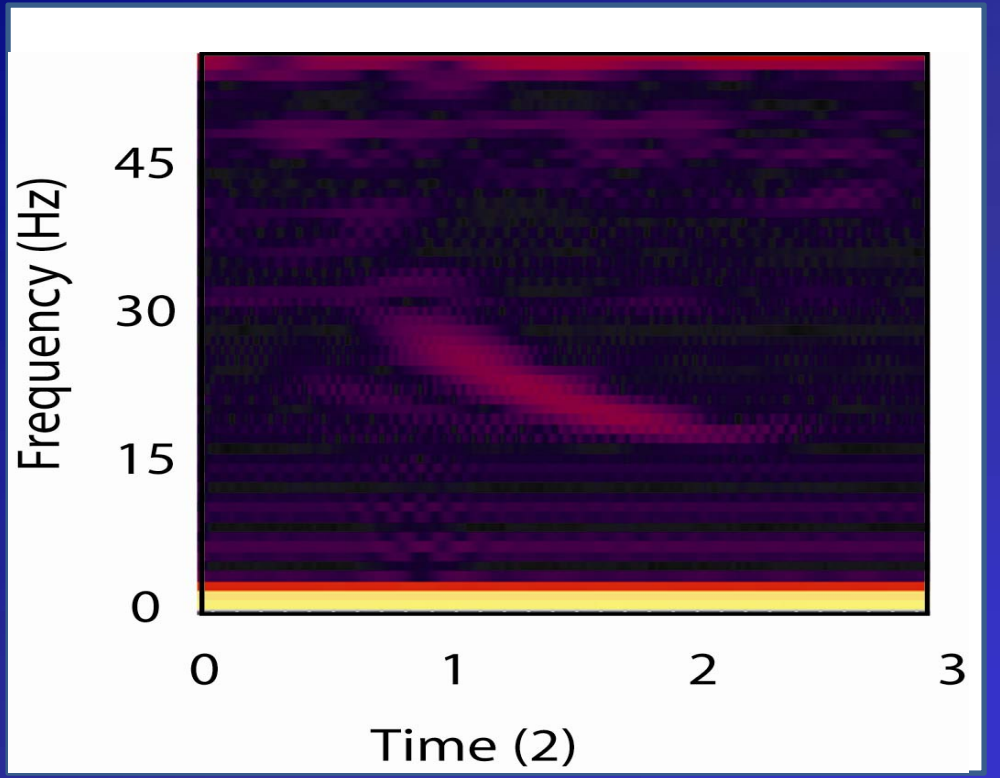
M5 Example
April 25, 2008



M2 soundbite triggers and **incidental** detections

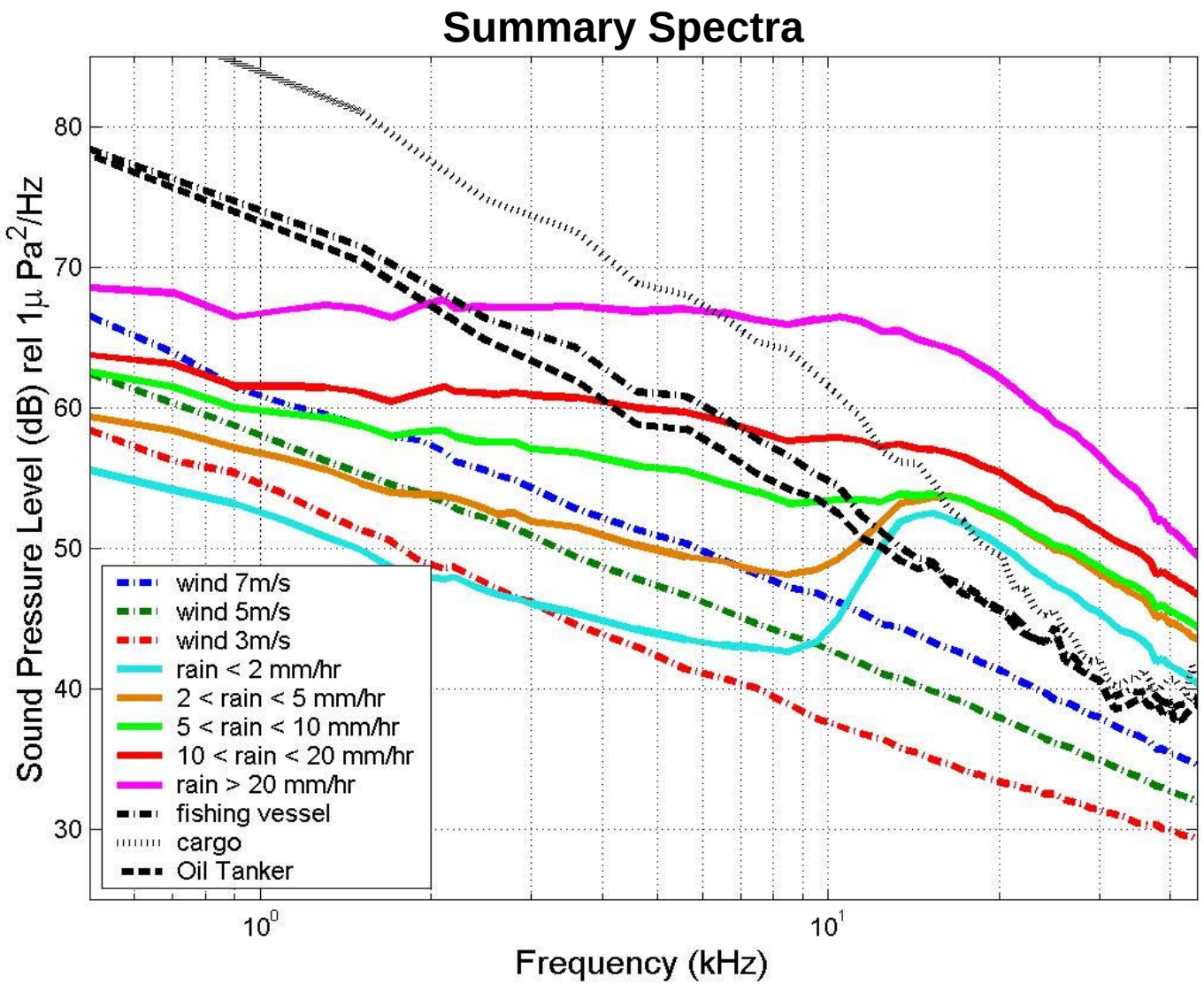
Oct 2008 (n=215)

Echolocation	36%	3%
Right whale	26%	1%
Ship	14%	12%
Mooring	12%	10%
Humpback	3%	4%
Killer whale	3%	1%
Precipitation	2%	8%
Wind	2%	
Fin whale		60%



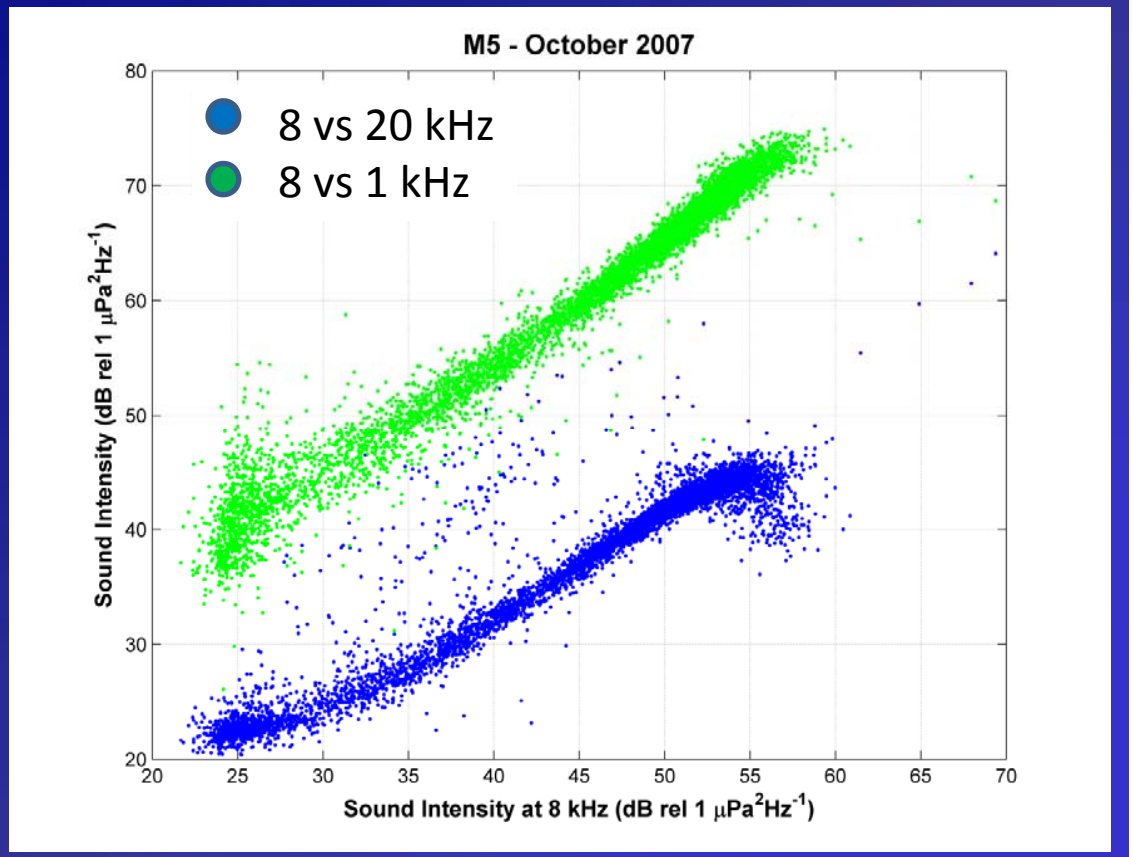
Fin whale
Oct. 15, 2008

Applications of PAL Data



Visual Representation of Sound Level and Variability

- Regional soundscapes generated from spectral patterns



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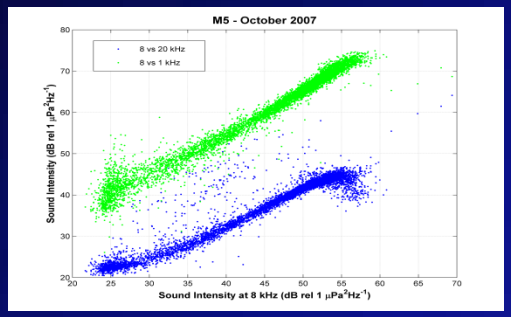

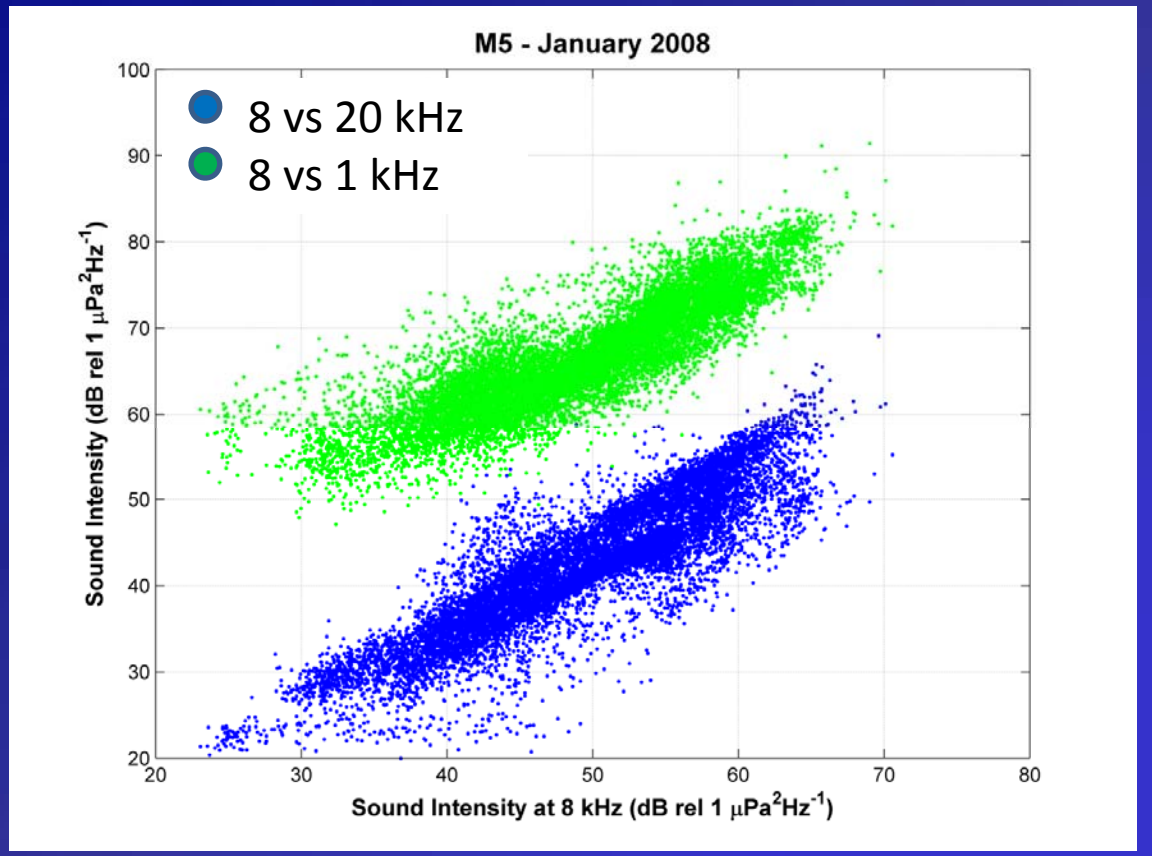

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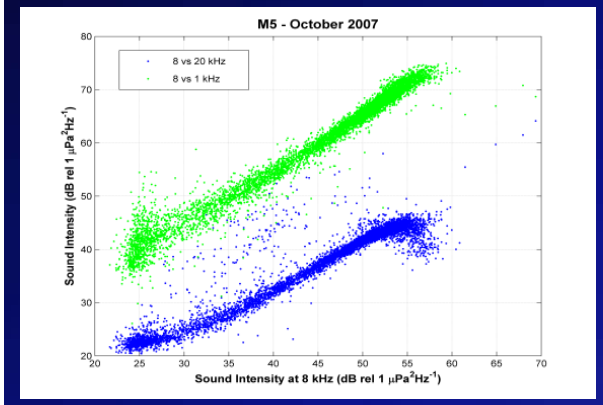

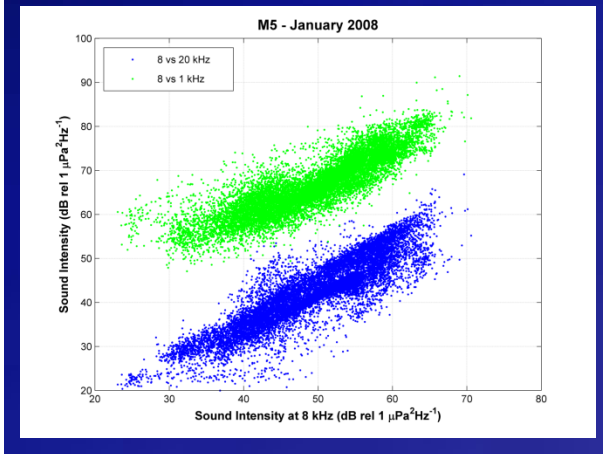

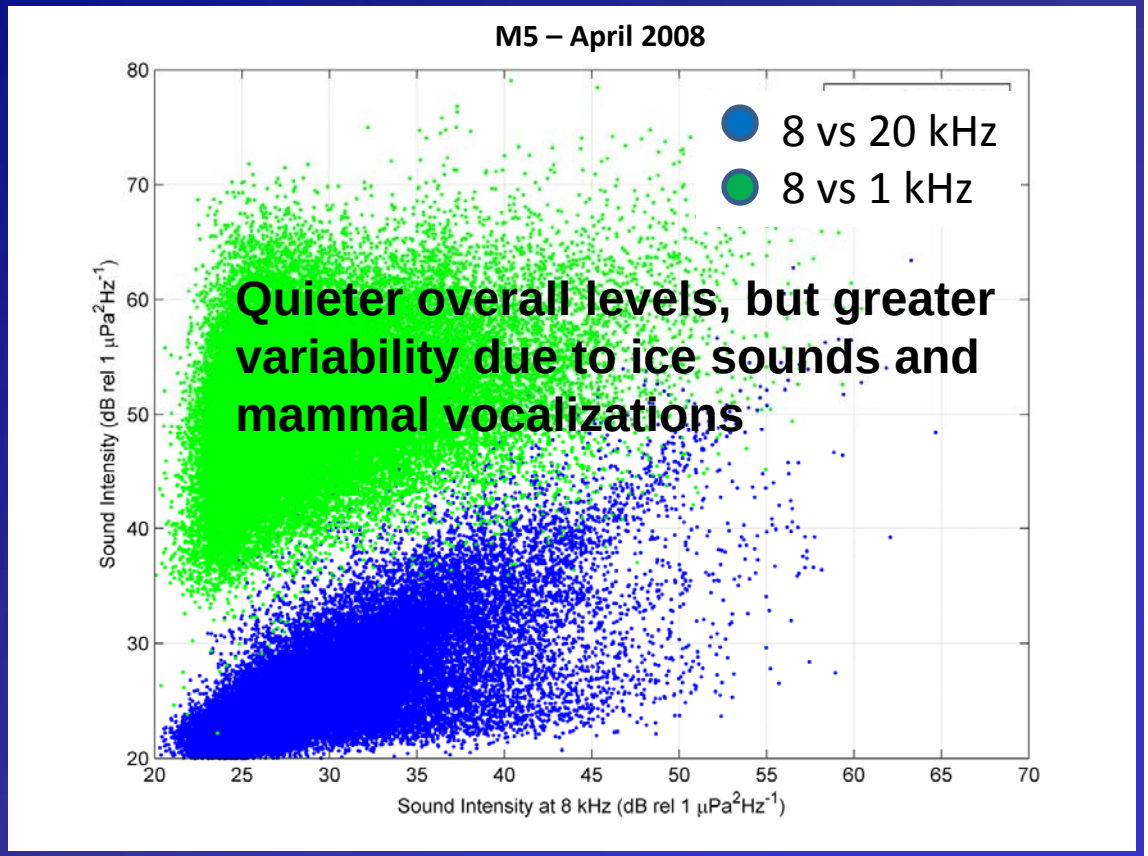

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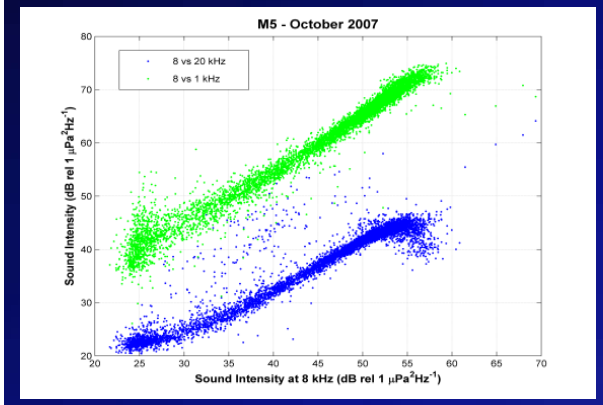
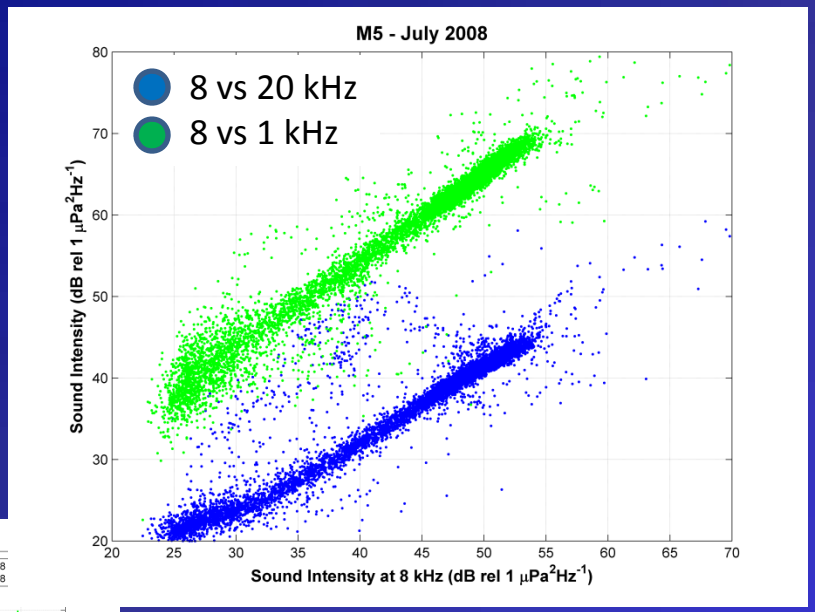
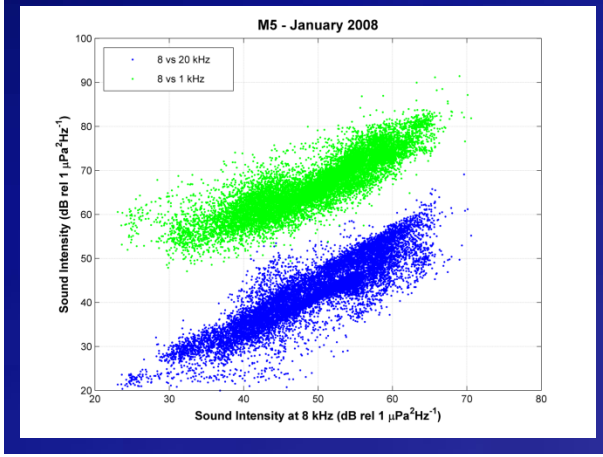
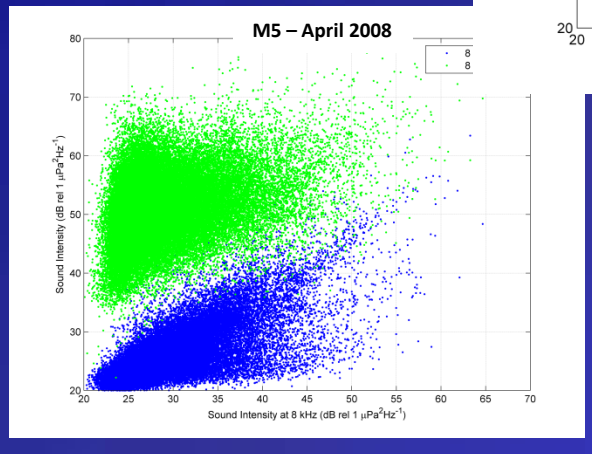


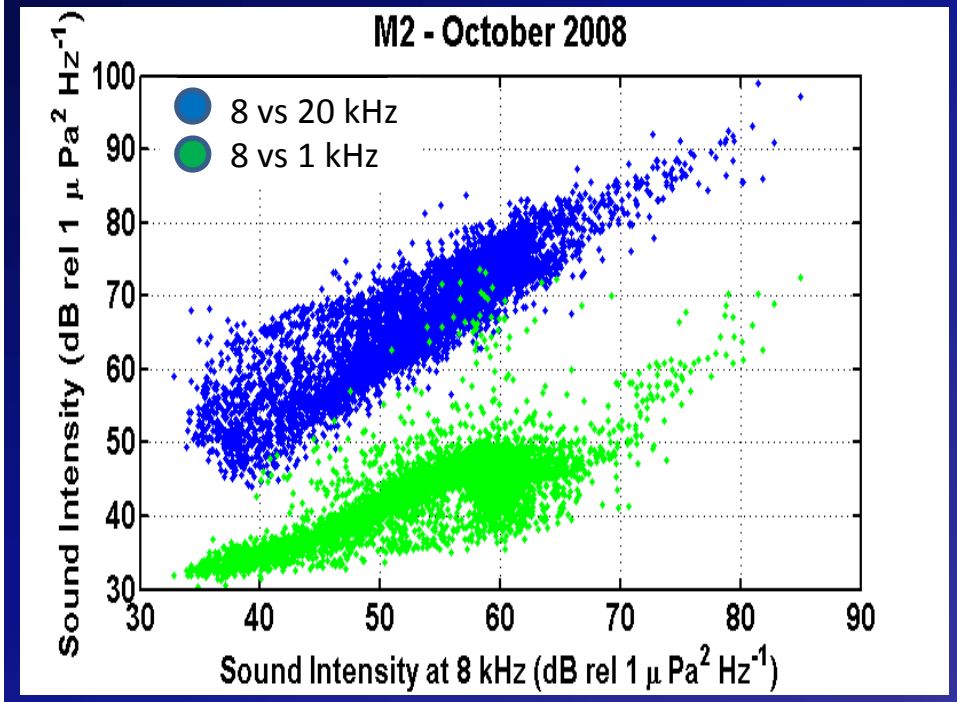


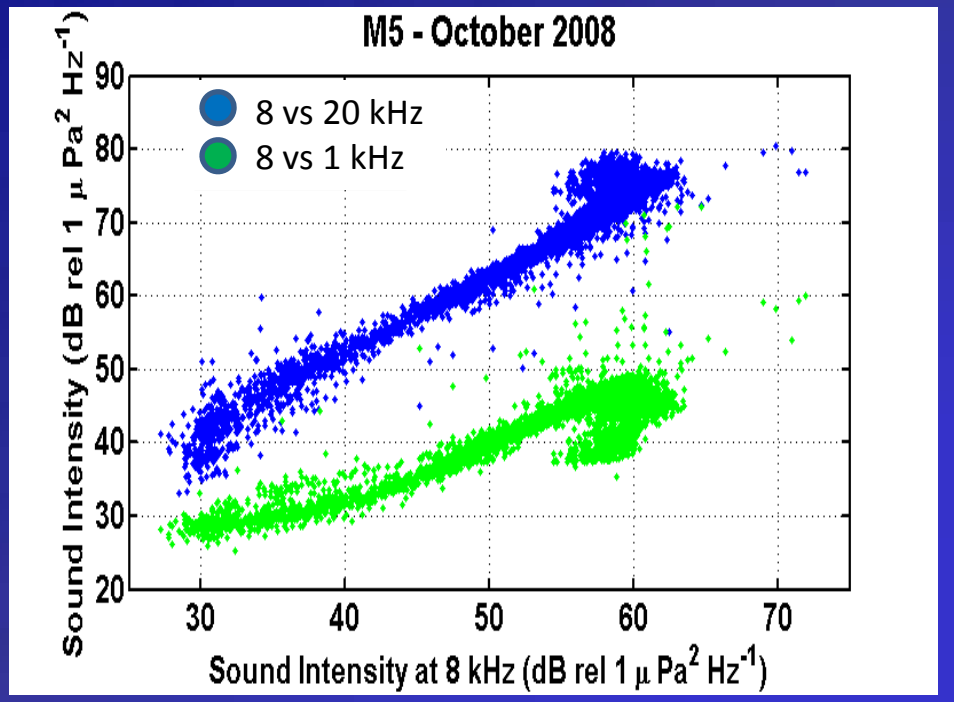




M2 vs M5

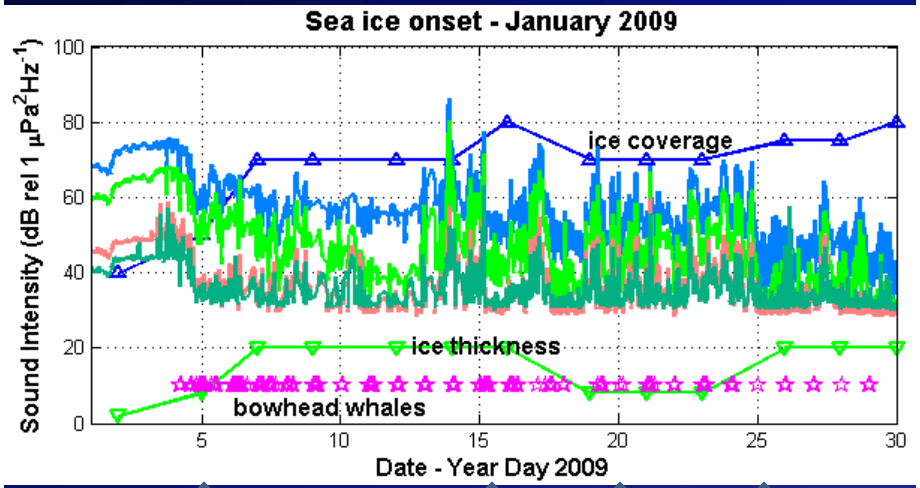
- **Greater sound level (note difference in axes) and variability at M2 due to vessels and vocalizations from large whales**

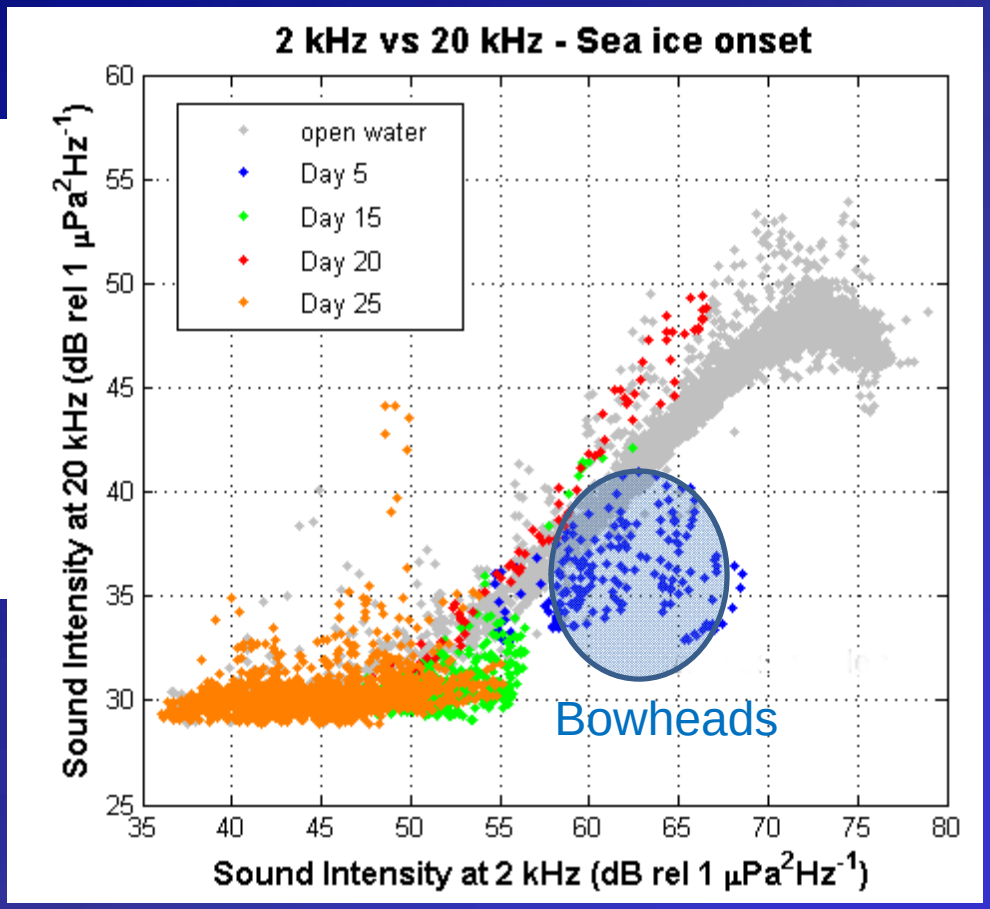




Miksis-Olds et al., 2012. What does ecosystem acoustics reveal about marine mammals in the Bering Sea? In: Effects of Noise on Aquatic Life.

Soundscapes





Conclusions

- Adaptive sub-sampling with PALs provides wide bandwidth (20Hz-50 kHz) acoustic data for year long deployments
  - Spectral data: soundscapes, source identification
  - Limited time series (soundbites): confirmation of source identification
    - Primary triggers
    - Incidental detections
- The PAL is appropriate for specific applications
  - Remote or hazardous areas with limited access
  - Questions related to species richness and co-occurring species
  - Questions related to temporal distribution

Future Goals

- Building representative spectra for different species
- Automated classification of spectral data
- Address ecosystem questions
  - Species richness
  - Temporal distribution/co-occurring species
  - Effects of background noise on signal detection
  - Population/regional response to environmental change

Acknowledgements

- NOAA PMEL: P. Stabeno, W. Floering, C. DeWitt

- Research funded by ONR Marine Mammal Program