

# Cues, creaks, and decoys (oh my!)

Using underwater sound as a tool to study sperm whale depredation

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Many thanks to the Sitka fishing fleet (Kendall Folkert, Stephen Rhoads, Dan Falvey,  
Brad von Wichman) .

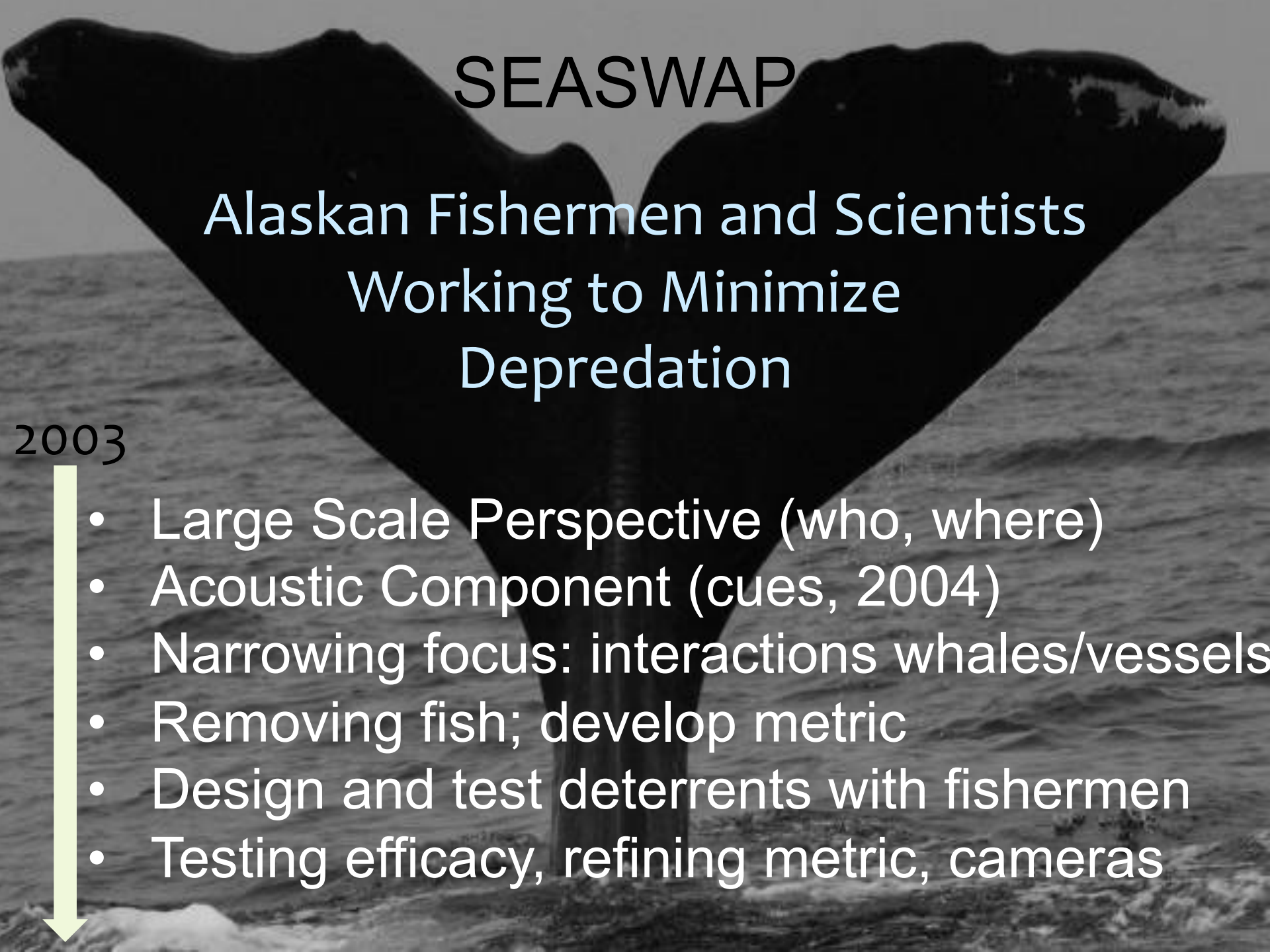
# A collaborative project between regulators, fishermen, and scientists

- \* University of Alaska Southeast
- \* Alaska Longline Fishermen's Association
- \* Alaska Department of Fish and Game
- \* Scripps Institution of Oceanography
- \* University of Texas-ARL
- \* Southwest Fisheries Science Center
- \* North Pacific Research Board and National Geographic Society

# SEASWAP

## Alaskan Fishermen and Scientists Working to Minimize Depredation

2003

- 
- Large Scale Perspective (who, where)
  - Acoustic Component (cues, 2004)
  - Narrowing focus: interactions whales/vessels
  - Removing fish; develop metric
  - Design and test deterrents with fishermen
  - Testing efficacy, refining metric, cameras

# Using passive acoustics to study depredation has been a sound decision

- \* Background: SEASWAP, acoustic recorders, spectrograms, sperm whale sounds.
- \* Cues: initial role
  - \* study of acoustic cues that attract whales
  - \* detection of sperm whale presence
- \* Creaks: Expanded application
  - \* The use of 'creak' sounds as metrics for depredation rates.
  - \* Evidence from tagging, statistical analysis of federal surveys.
- \* Decoys: Bringing it all together
  - \* Using sound to attract animals *away* from fishing activity.
  - \* Both the deterrent and the experimental design acoustics-based.
  - \* Preliminary example from July 14, 2013.
- \* Acoustic tracking a subject in itself; not covered here.



## Depredation : removal or damage of fish from longlines

- First reported in Alaska in the 70's, became problematic in 90's.



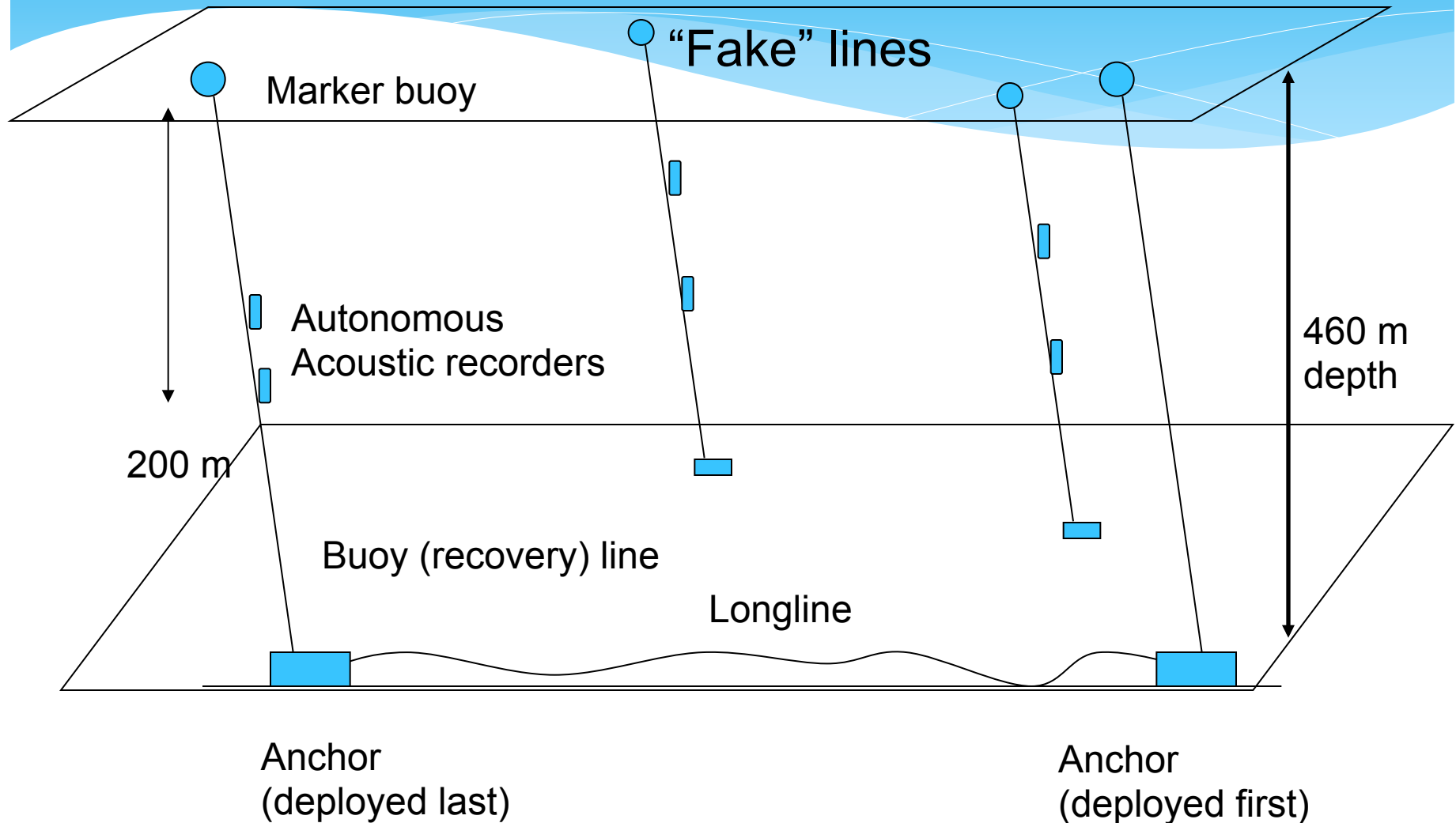
- Whale depredation on commercial sablefish longline gear increases harvesting costs and presents marine mammal entanglement issues.
- Whale depredation affects federal sablefish stock assessment survey.





2013-128 Gb flash memory, 100 kHz sampling rate  
“fishermen friendly” attachments (Falvey fasteners) and activation.  
Five MIA during program. (Hint: don’t give recorders names).

# Anchorlines converted into listening posts



# What a sperm whale looks like to most people

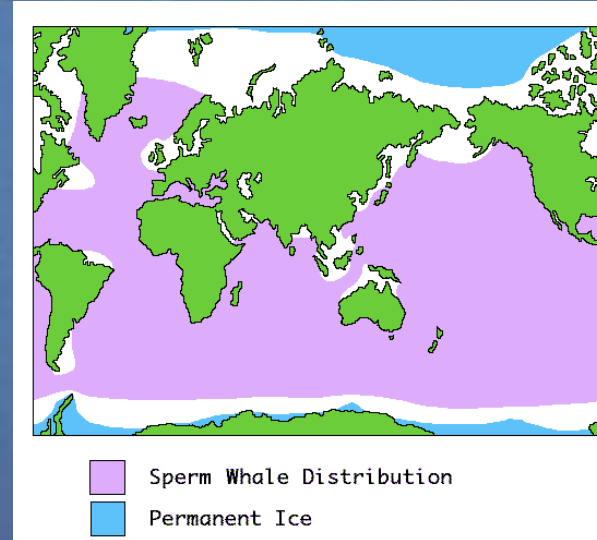
➤ Hunted until the early 1980's – listed as endangered

➤ **Habitat :**

mostly found near continental shelf regions,  
in waters deeper than 800 m.

➤ **Sexual dimorphism :**

- in size : 17 m for males, <12 m for females ;
- in habitat : only males travel into the higher latitudes,  
females and calves stay near the equator.



➤ **Natural foraging behavior :**

alternate long (~45 mins) and deep (>300m) dives  
with surface rest intervals (~ 15 mins).

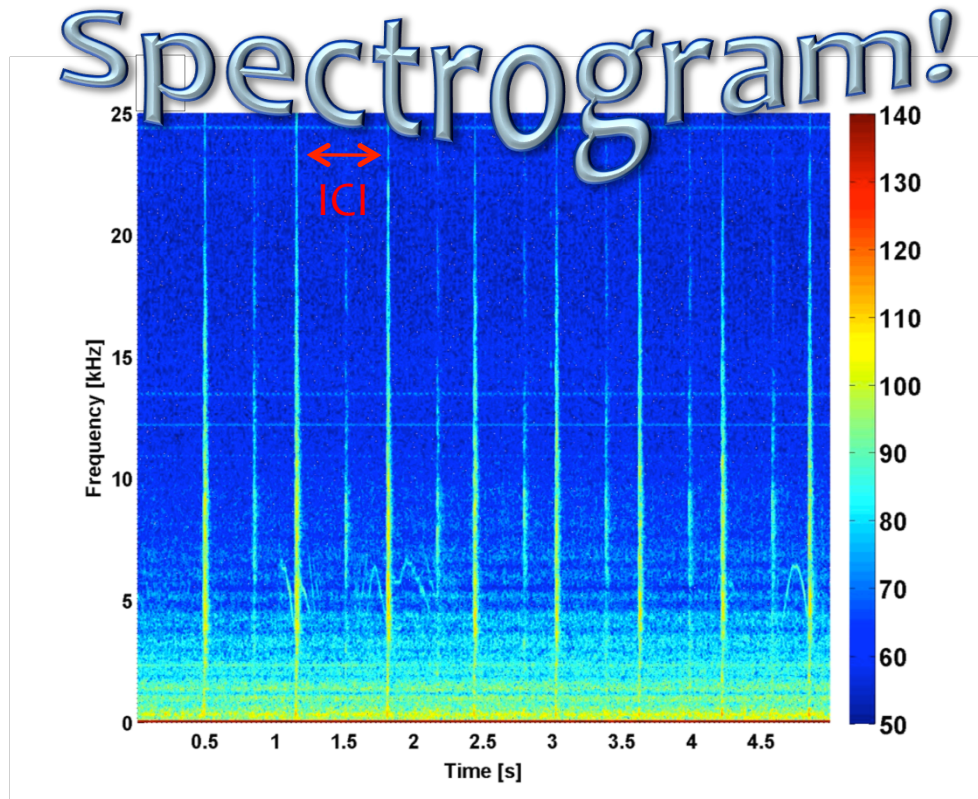
➤ **Diet :**

feed on a wide variety of mesopelagic and  
bathypelagic preys : mostly squid , but also  
invertebrates and fish.



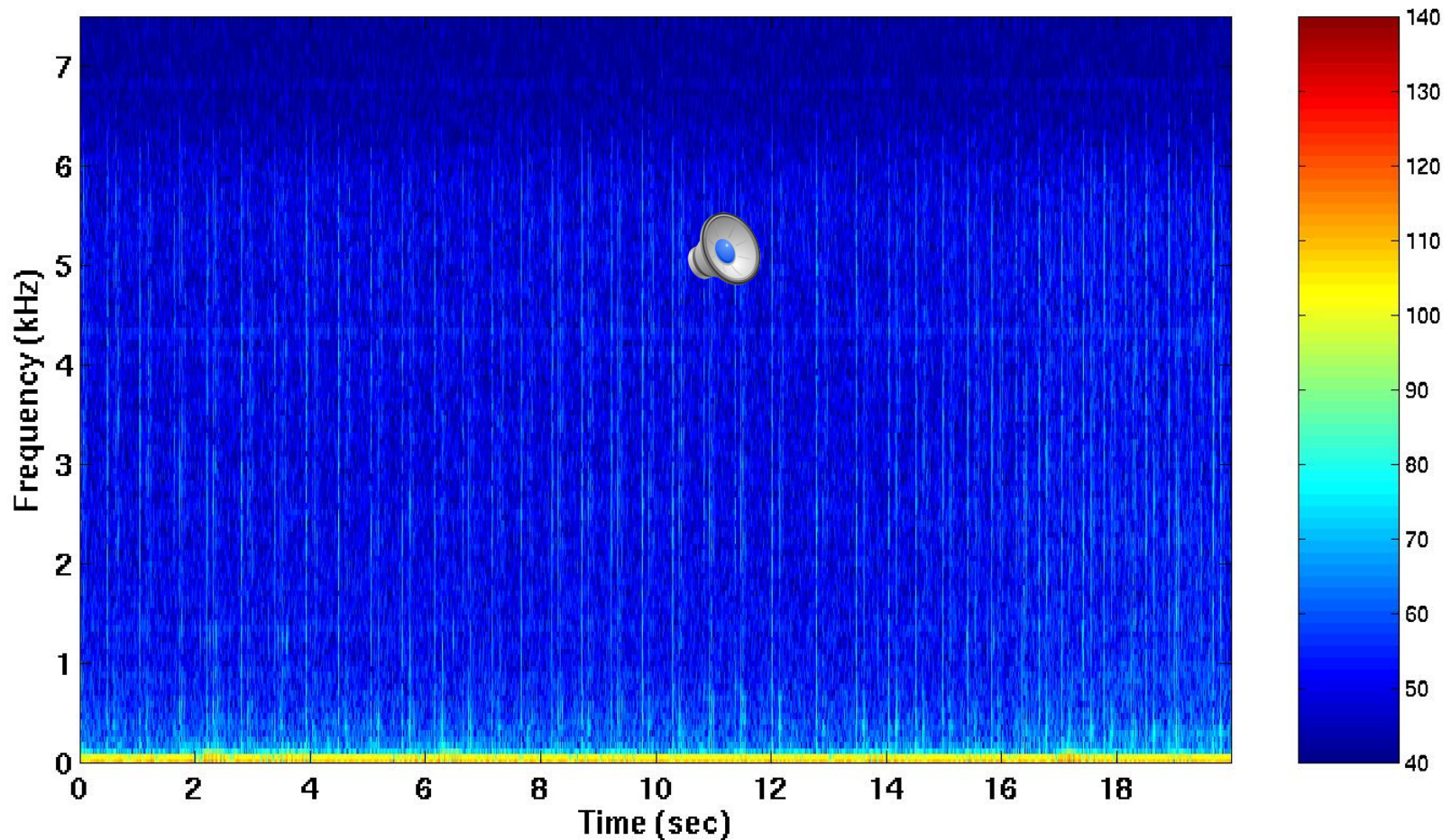
# What a sperm whale looks like to me

- Sperm whales produce 25-30 ms sounds called “clicks” used for communication and echolocation purposes.
- Clicks have energy between 100Hz and at least 20 kHz. Very convenient!
- The inter-click interval (ICI) is the time difference of arrival between 2 successive clicks.
- “Usual” clicks ICI : 0.5s - 1s



**Sperm whale click:**  
One of most powerful biosonars  
in the world  
(~210 dB rms re. 1uPa)

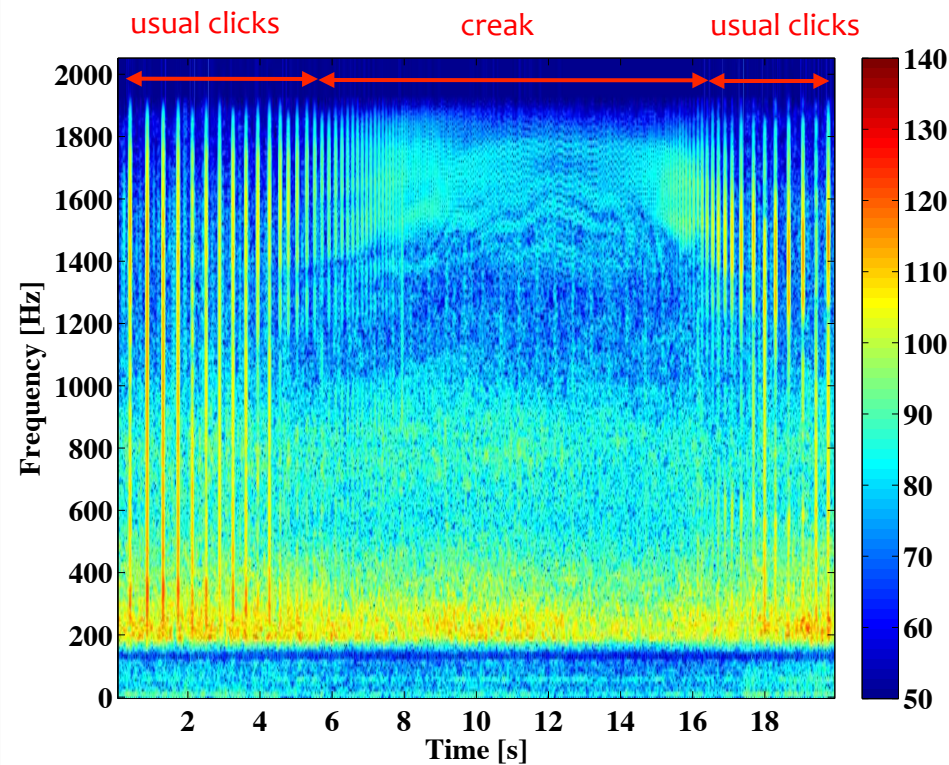
# Sperm whale “clicks” change rhythm over time: exciting!



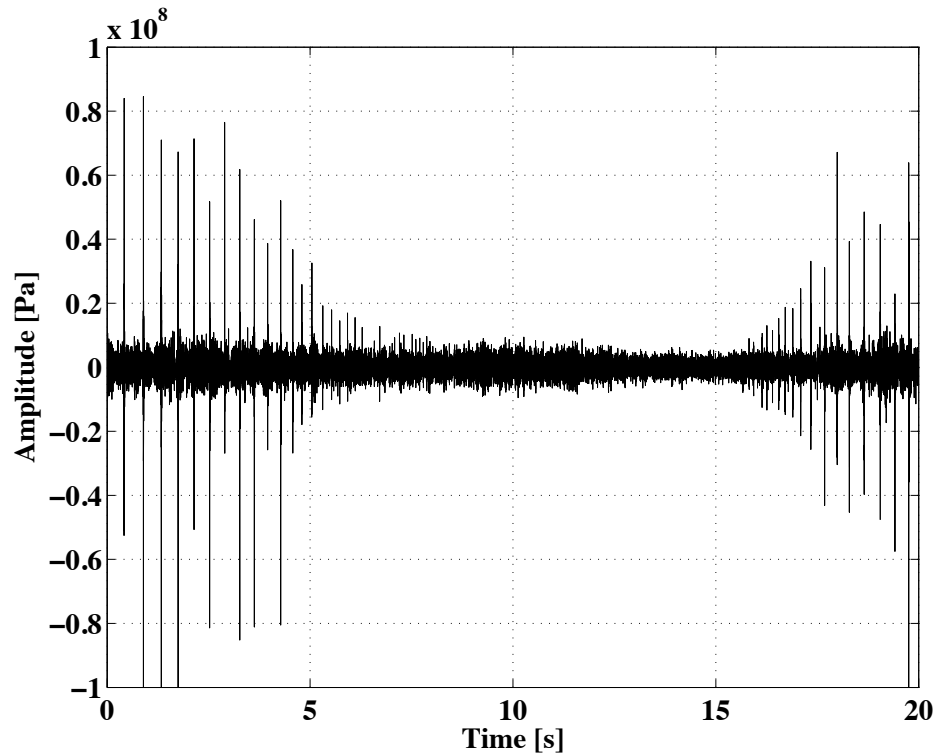
# “Creak” sounds are associated with prey capture attempts.

(Miller *et al.*, 2004 – Watwood *et al.*, 2006)

- The inter-click interval (ICI) decreases during a creak sequence ( $ICI < 0.2s$ ).

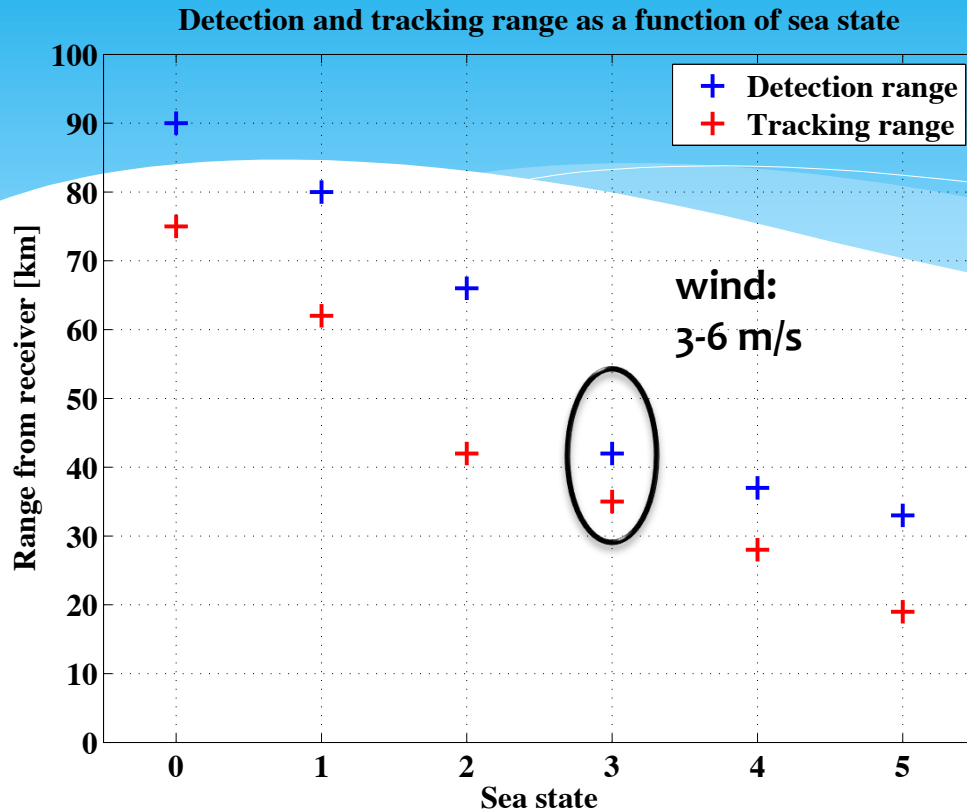


Spectrogram of a creak  
recorded on a tag



Time series of a creak  
recorded on a tag

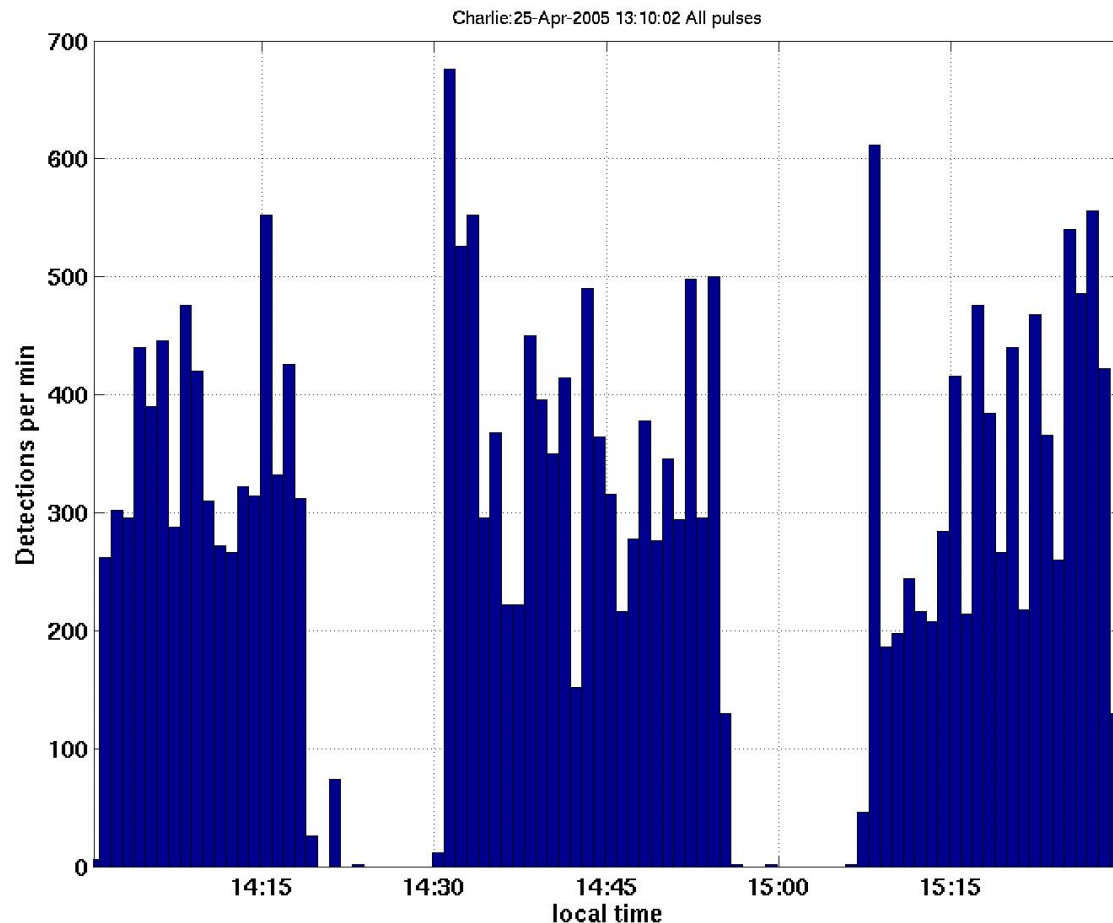
# How far can you hear a sperm whale?—answer is blowin' in the wind

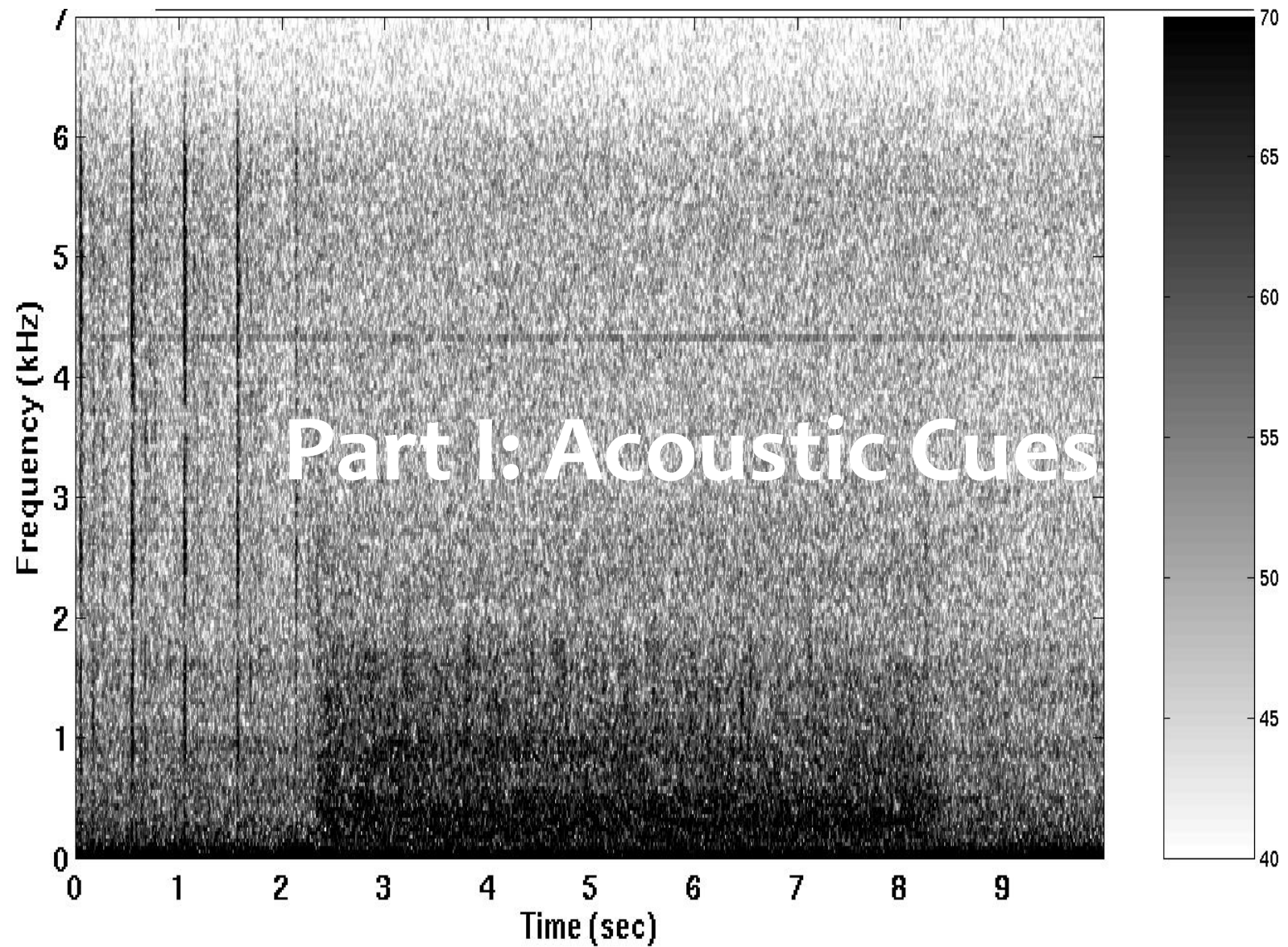


- **Detection range** predicted to be up to 90 km in calm sea conditions and up to 35 km in high wind conditions.
- **Tracking range** predicted to be up to 75 km in calm sea conditions and up to 19 km in high wind conditions.
- **The sonar equation and Wenz curves predict that for a sea state of 3, the tracking range should be 35 km**
  - Matches empirical 35 km range tracking limit

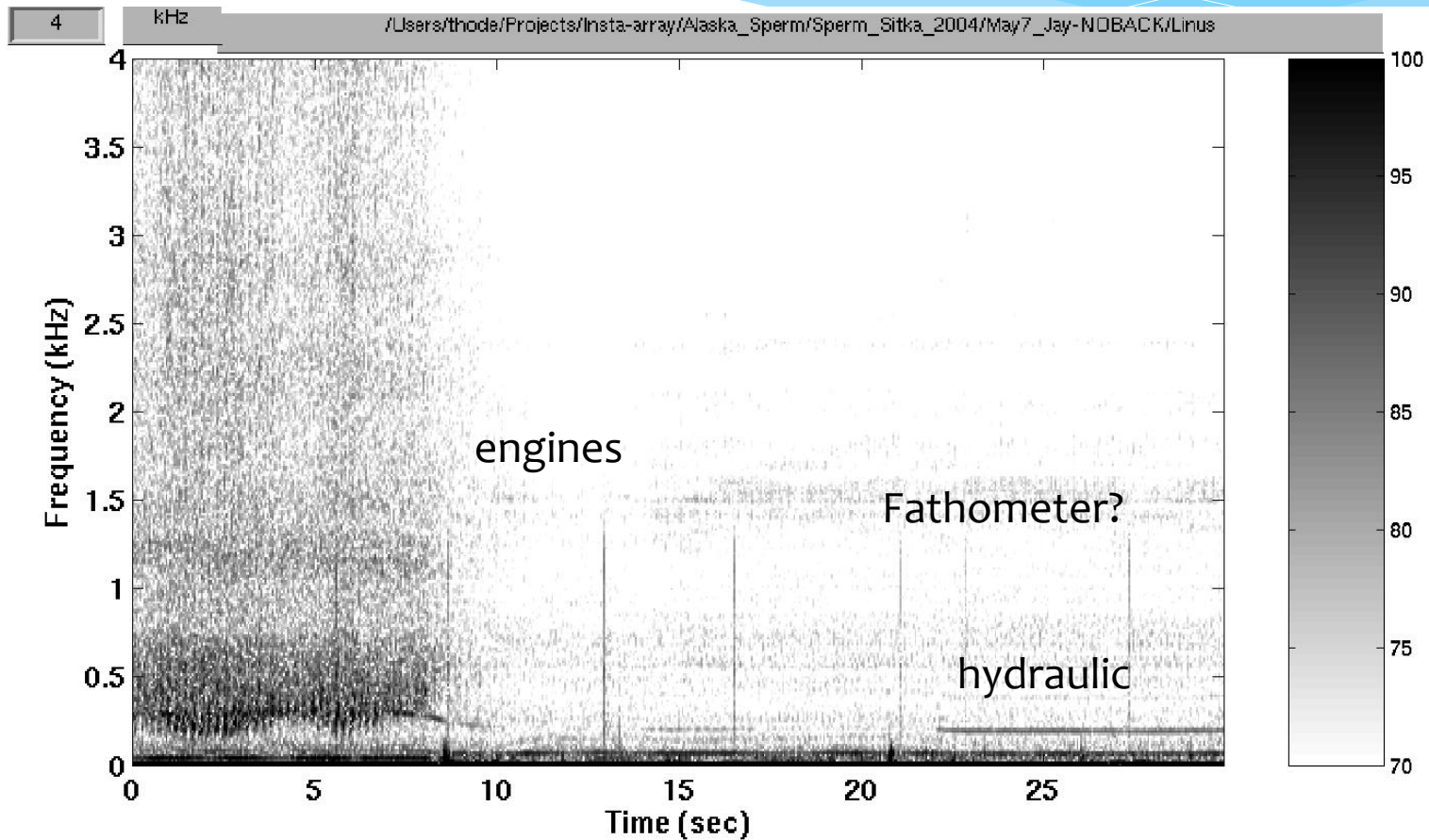


# Natural dive cycles consistent with whales elsewhere (Apr 25, 2005)-- useful diagnostic tool





# Initial application: Acoustic cues recorded from Jay Skordahl's vessel in 2004

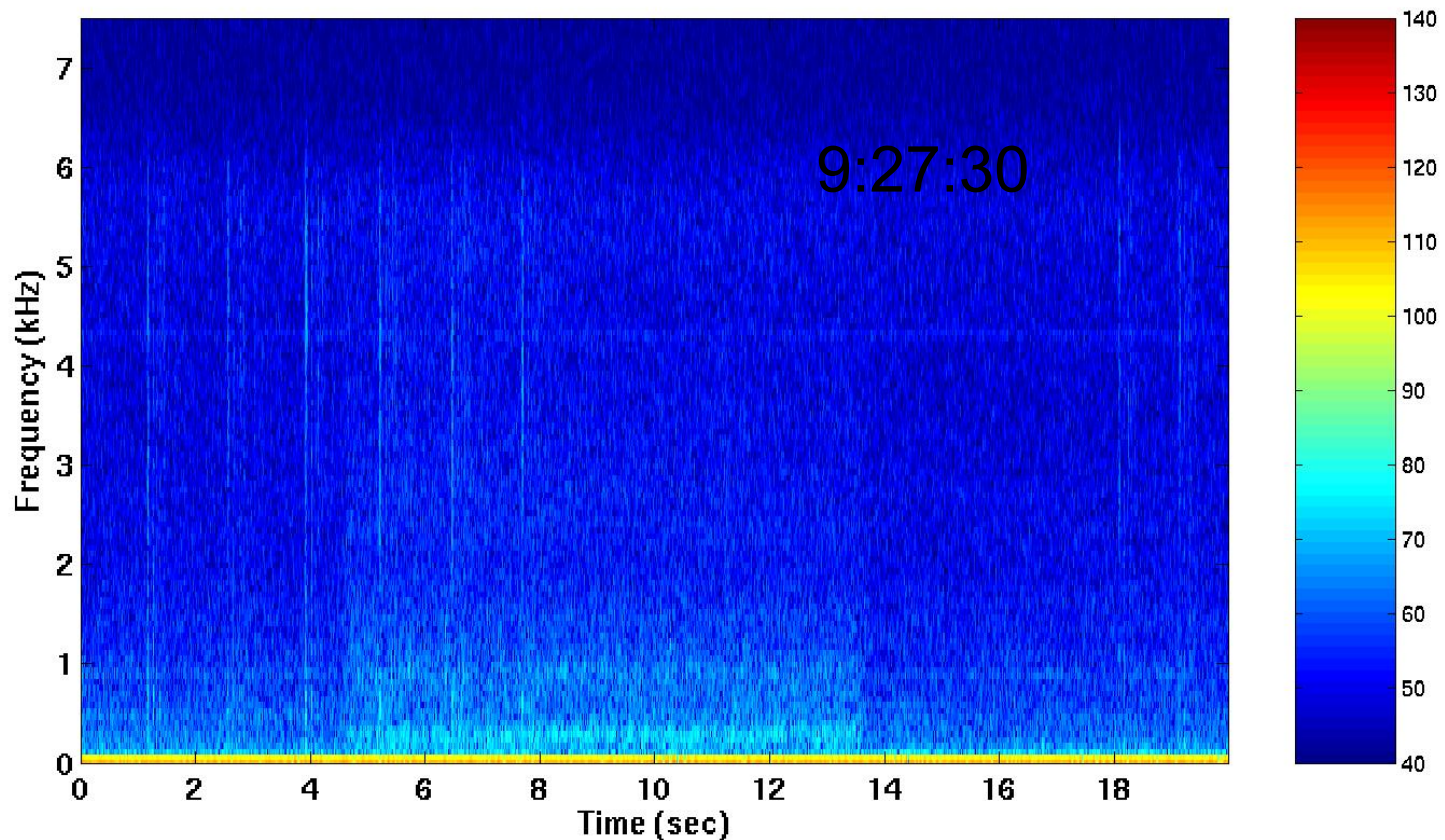




# Vessel makes distinctive sound when hauling longline

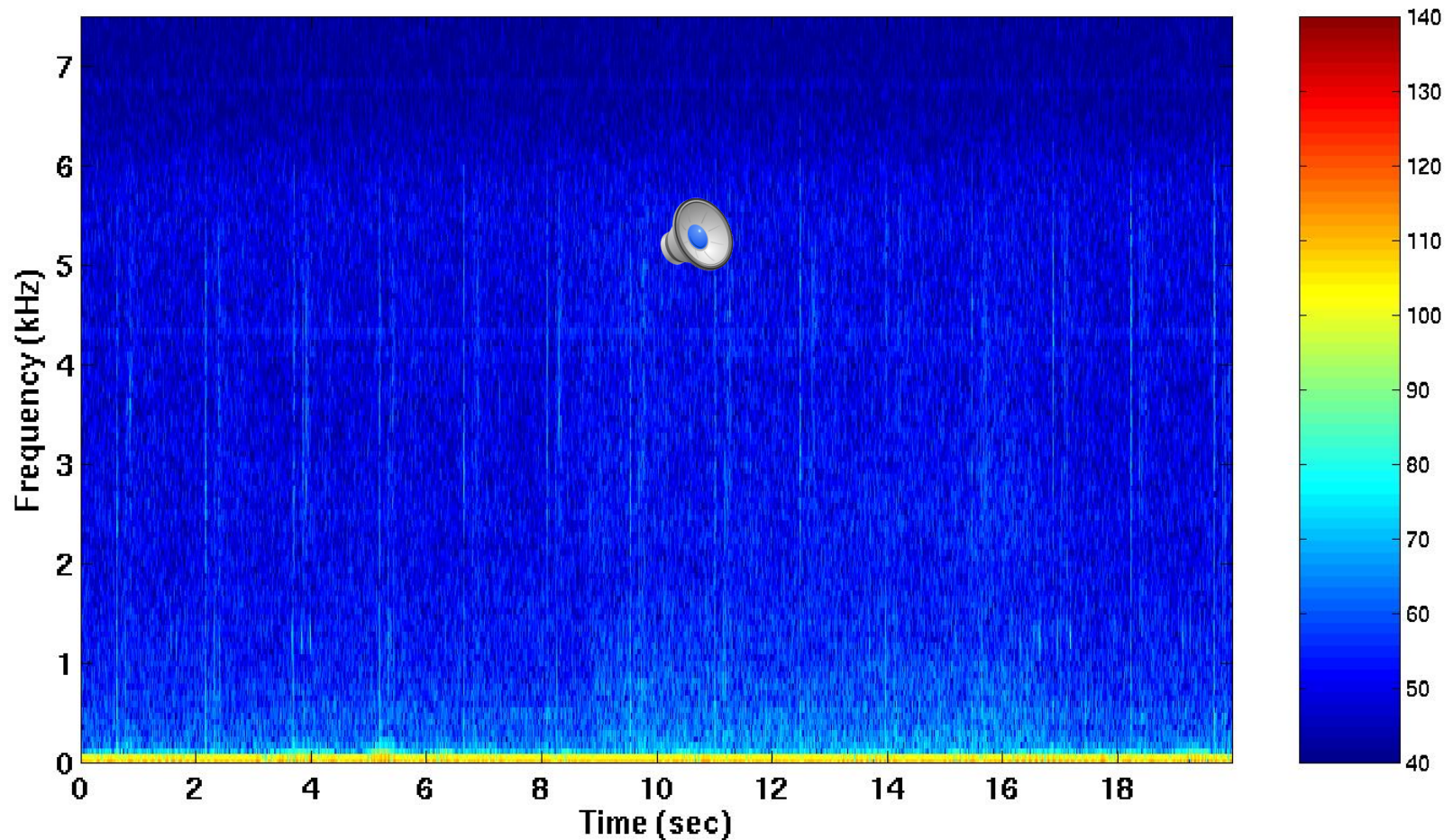
Not hydraulics, but cavitation from engaging engine

20 dB above ambient background at 1.2 km range

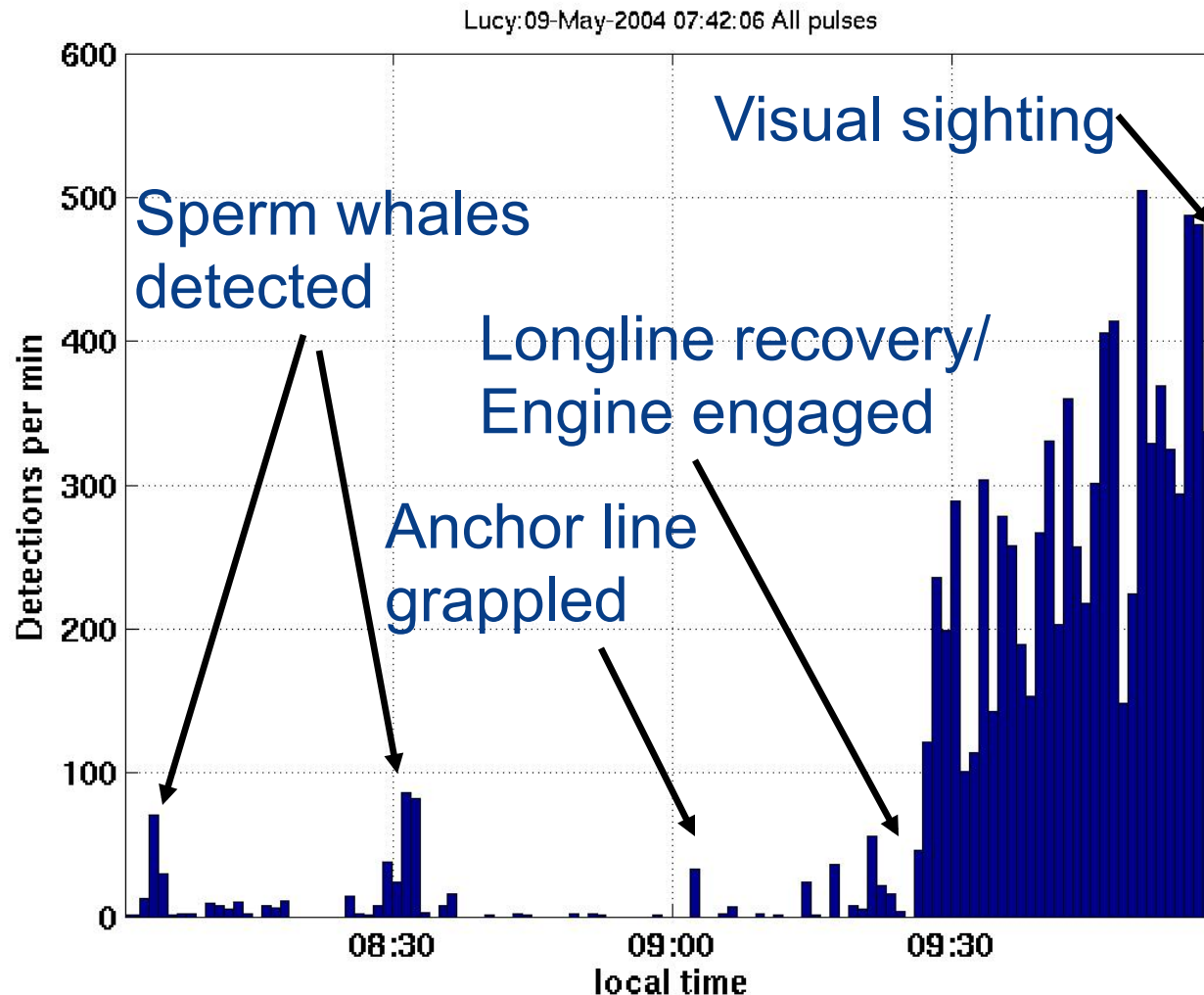




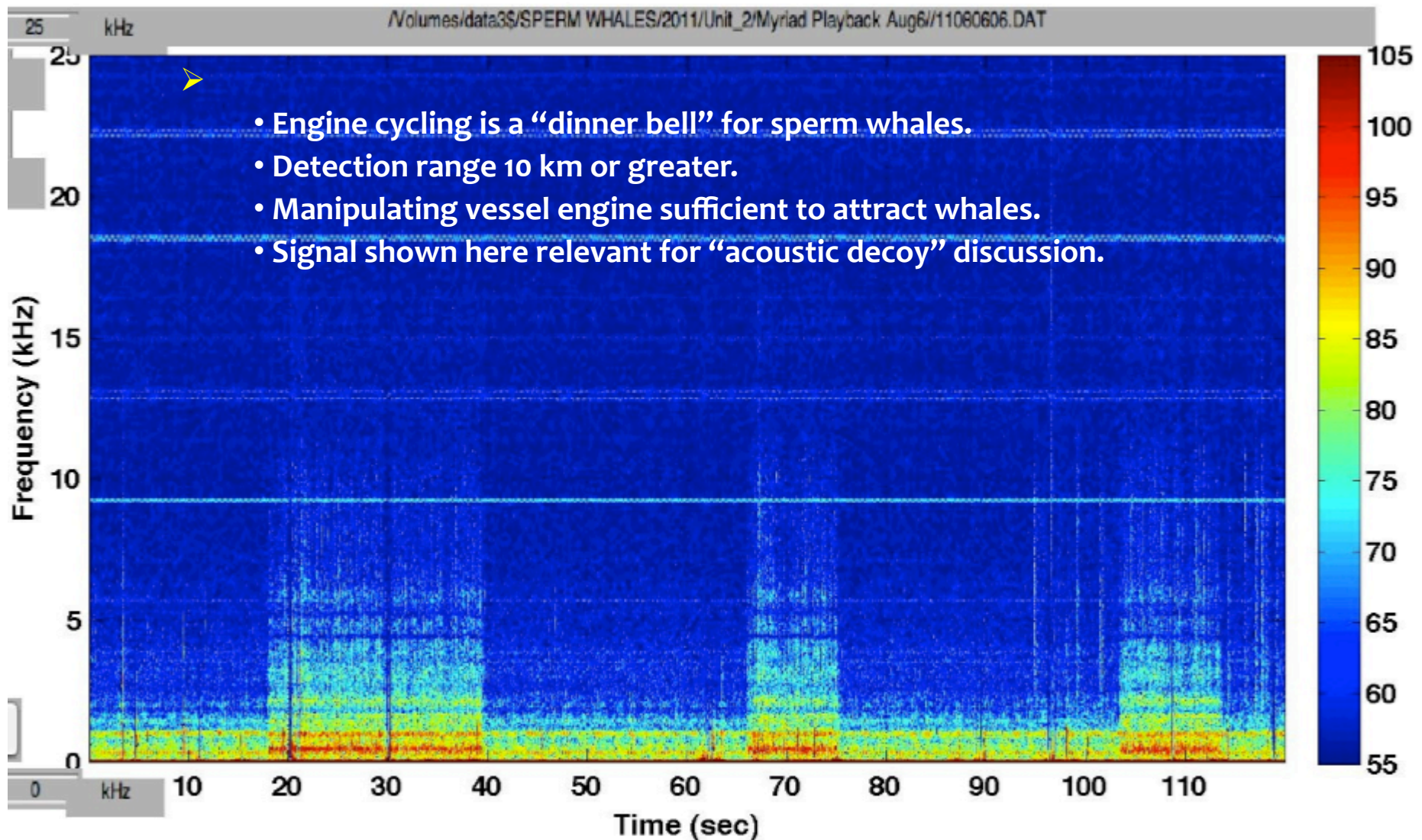
Can you find the sperm whale,  
humpback whale, and fishing boat?



# Whale activity increases rapidly once haul begins



# Sperm whales use acoustic cues (engine noise) to detect fishing activity. (Thode et al., 2007)





# Cue conclusions: circa 2007

- \* Dive cycle analysis and acoustic tracking permit hypothesis testing of acoustic cues
- \* Only strong evidence for one long-range cue
  - \* Changes in engine speed, particularly engine cycling while hauling--can be detected for miles.
  - \* Hydraulic activation has no effect on acoustic behavior
  - \* No sounds of fishing gear strum (except on video)
  - \* Visual cues not confounding
- \* Fake anchorlines show some success



# Part II: Creaks-remotely estimating depredation rates

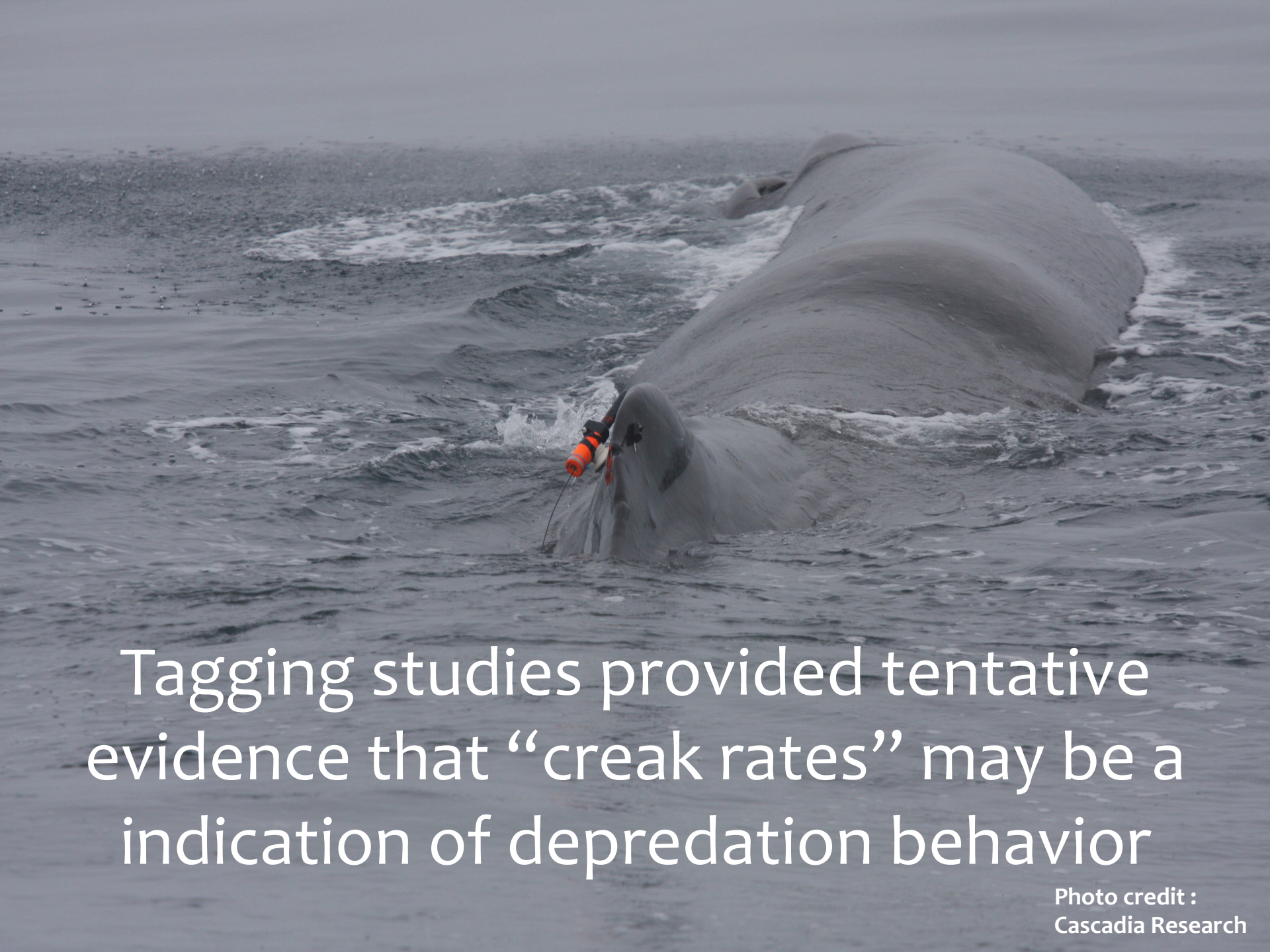
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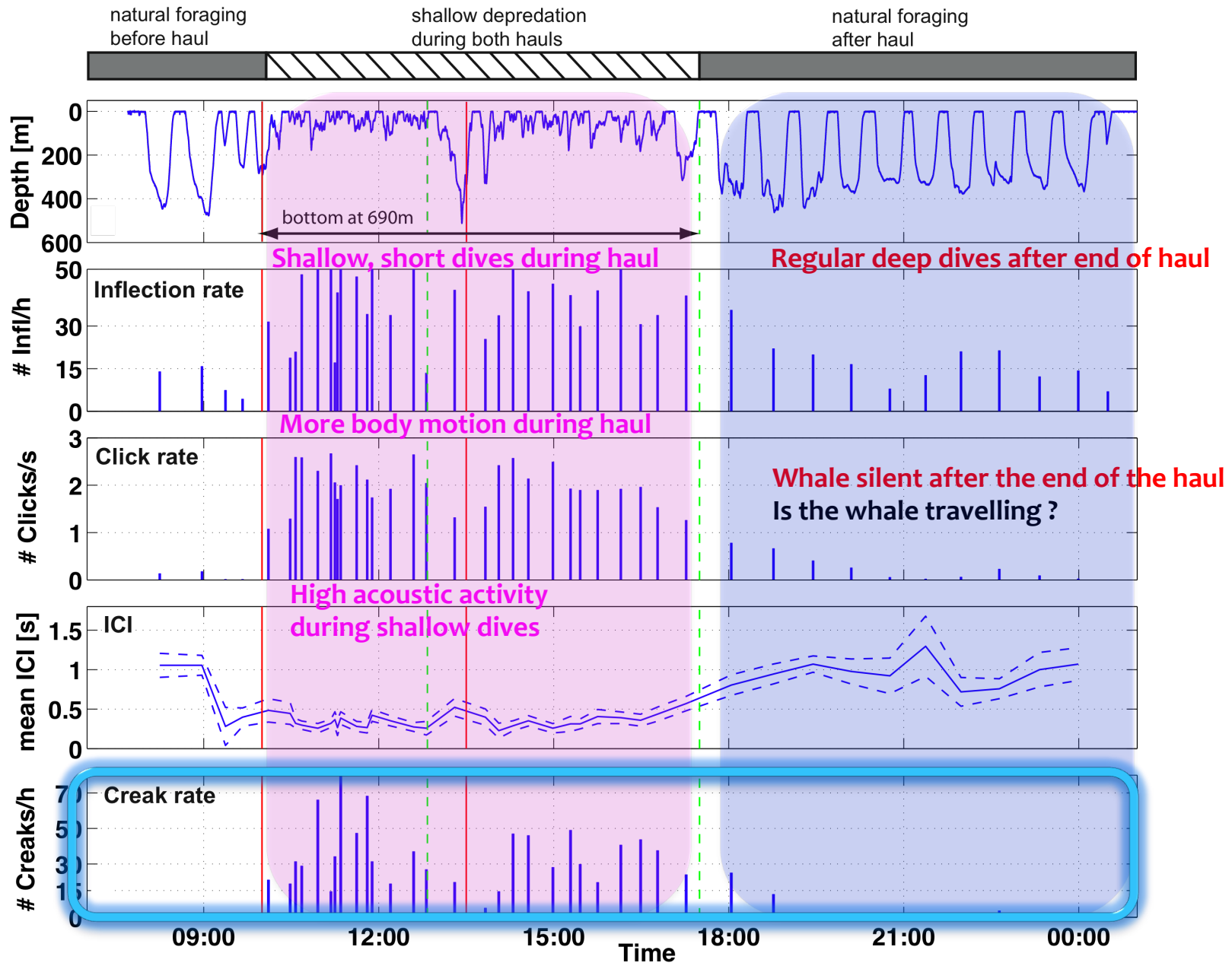


Tagging studies provided tentative evidence that “creak rates” may be a indication of depredation behavior

Photo credit :  
Cascadia Research

# During depredation behavior creak rates become very high.

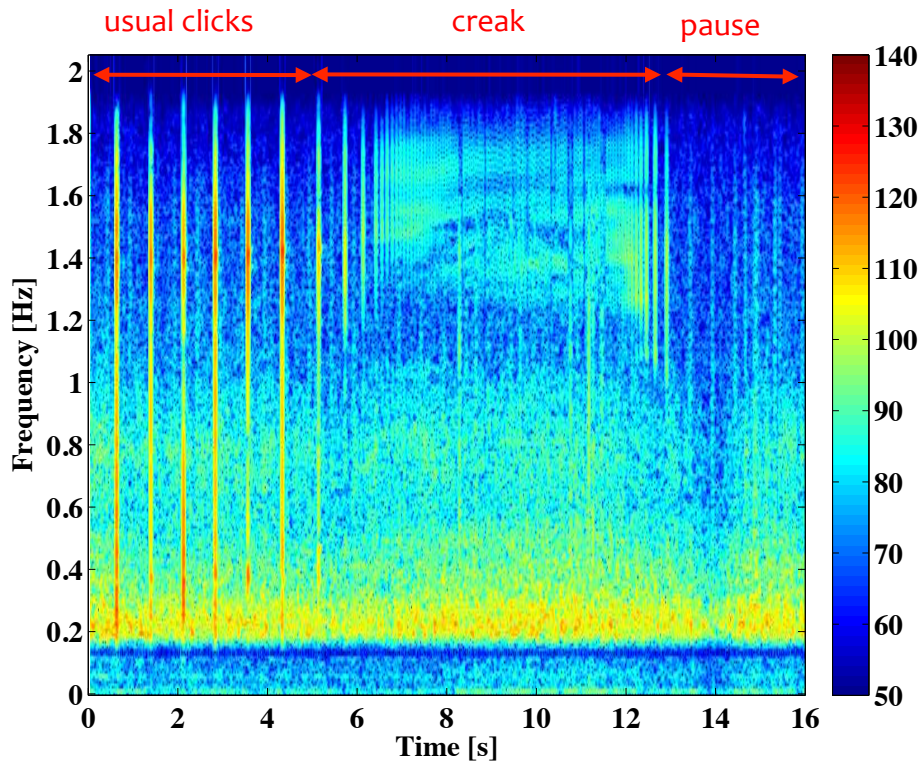
July 2007, F/V Ocean Prowler, 155 feet





Creaks with a pause are interesting because....  
....evidence of prey capture?

The *absence* of clicking (listening for silence) may be a remote means for measuring depredation.



Gregory (Scotland Yard detective): "Is there any other point to which you would wish to draw my attention?"

Holmes: "To the curious incident of the dog in the night-time."

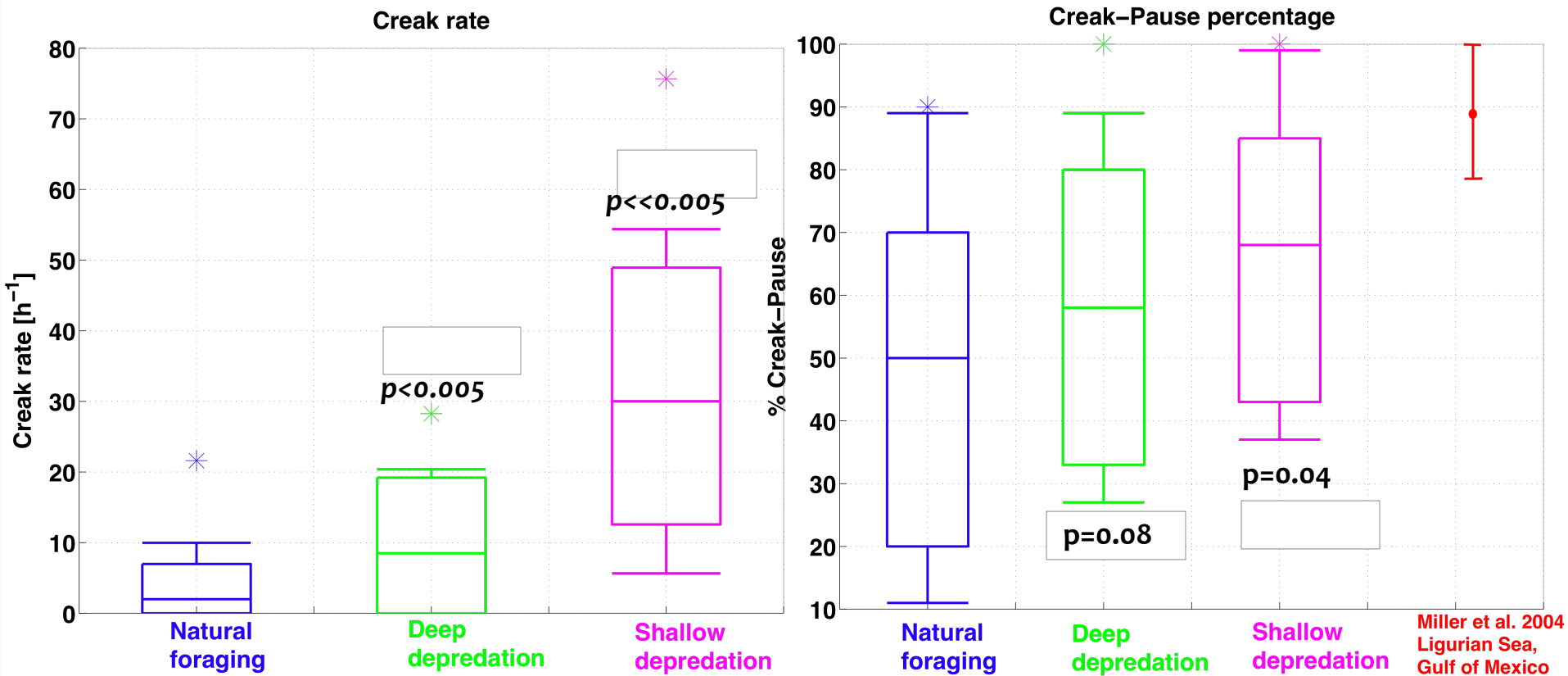
Gregory: "The dog did nothing in the night-time."

Holmes: "That was the curious incident."

-A. Conan Doyle (Silver Blaze)

Spectrogram of a creak followed by a 6s silence recorded on a tag

# Higher creak rates during depredation, but creak-pause hypothesis inconclusive



- Creak rate distribution is significantly different between depredation and natural behavior
  - Creak rate is as much as three times higher during shallow depredation
- Fraction of creak-pause events doesn't increase significantly with depredation state
  - however, Alaska creak-pause fraction much smaller than reported in Miller et al. (2004) study.
- Fish in AK versus squid at lower latitude
  - more feeding opportunities, but not more efficient ? (same effort per prey item)

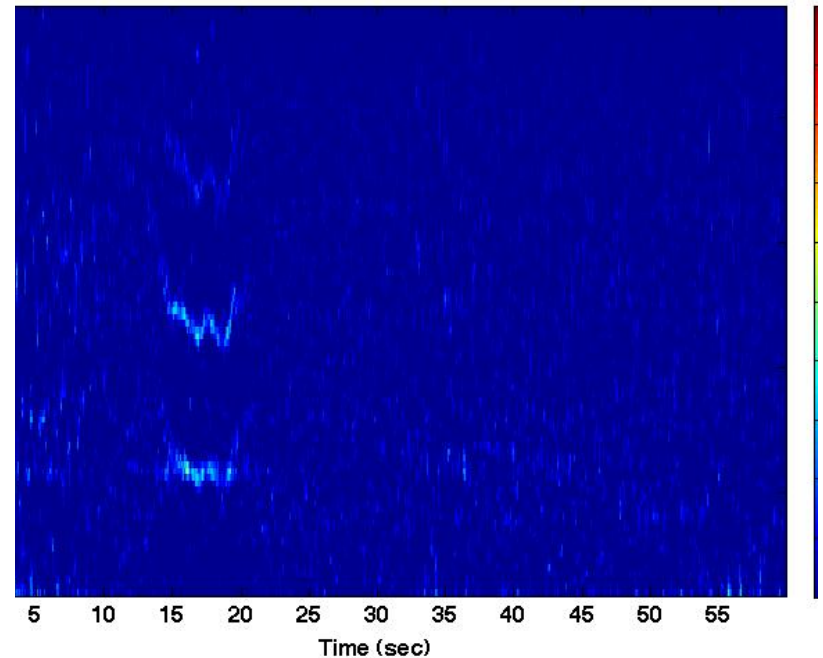
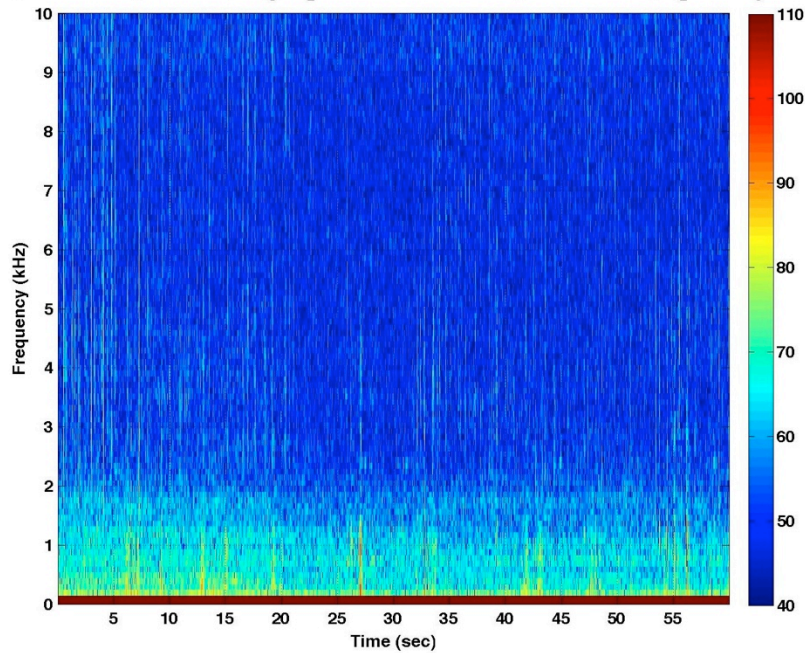
**Green:** acoustic recorders deployed.  
**Dot:** whale present.



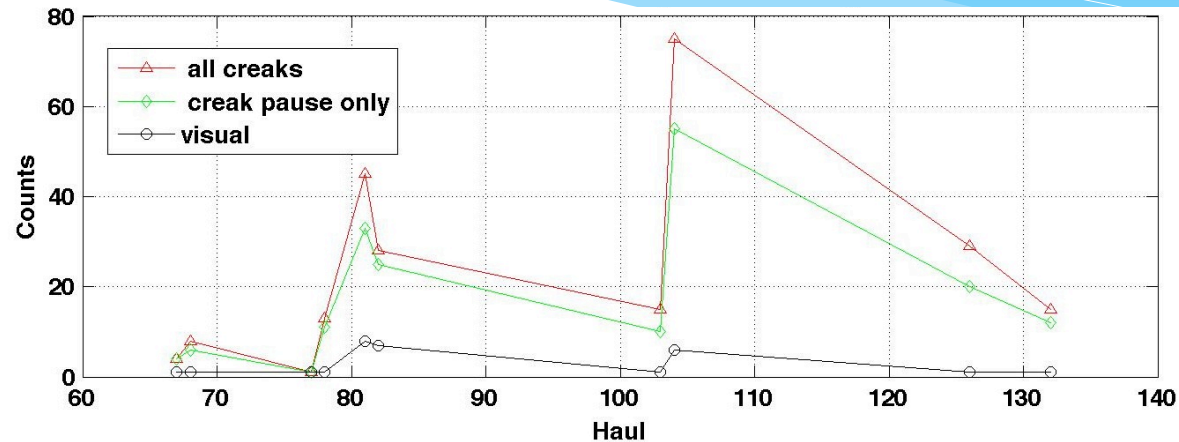


# Creaks manually flagged using “correlograms”

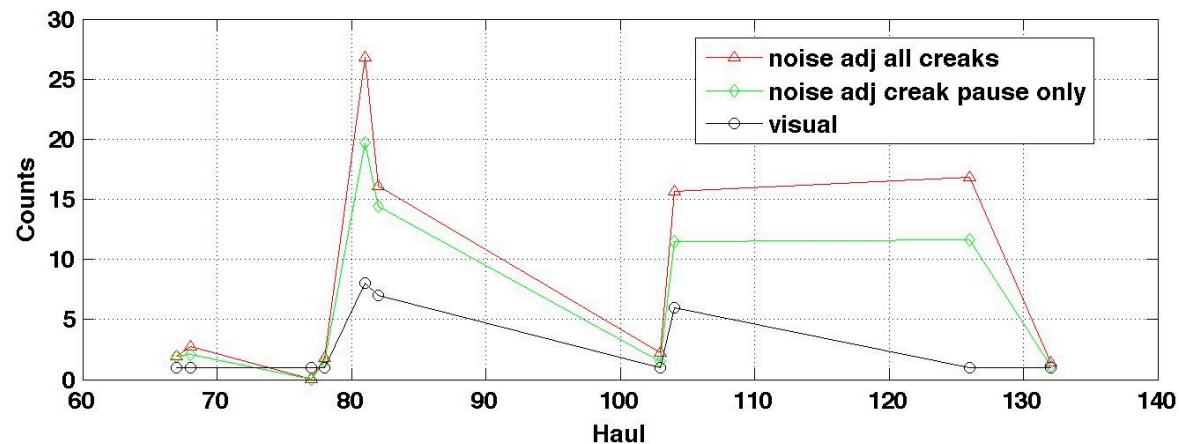
SpermWhaleDepredation/Sperm\_itka\_2011/CreakDetectorTesting.dir/Data.dir/July28\_2011/Unit\_3\_/1107:



# Relationship between detected creak rate and shredded lip count: 2012



Raw acoustic counts



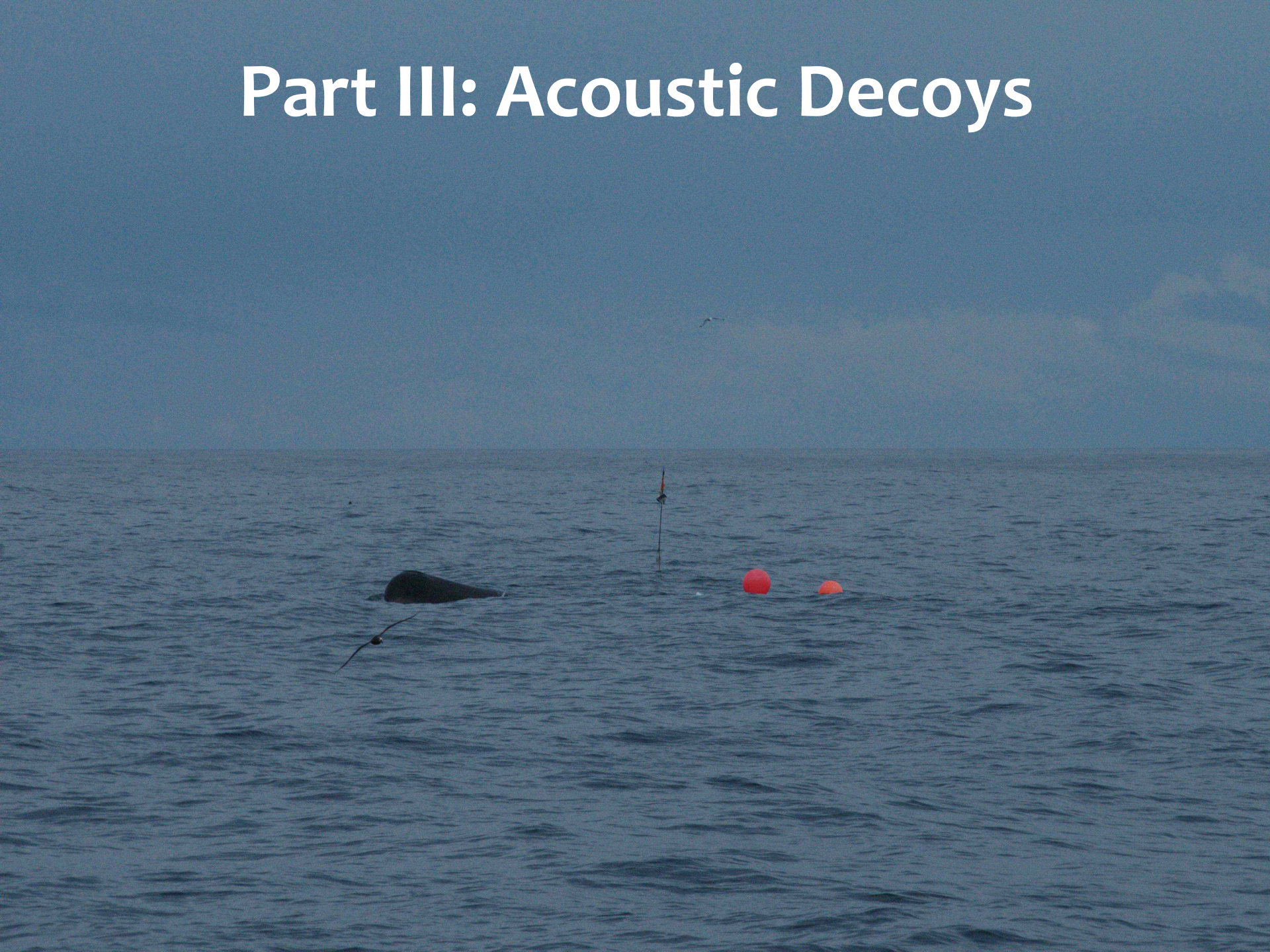
Counts adjusted for background noise (visual count Same as above).

# Conclusions: Part II (in review)

- \* Acoustic creak rates and partial fish counts significantly correlated when  $< 2$  whales.
  - \* In 2011 correlation better for creak-pauses, in 2012 no difference.
  - \* Correcting for background noise levels important.
- \* Creak rates predict higher depredation rates than visual evidence.
- \* Correlations break down when many whales present.
  - \* Creak rates much higher than visual depredation evidence (can't discount empty hooks).



# Part III: Acoustic Decoys

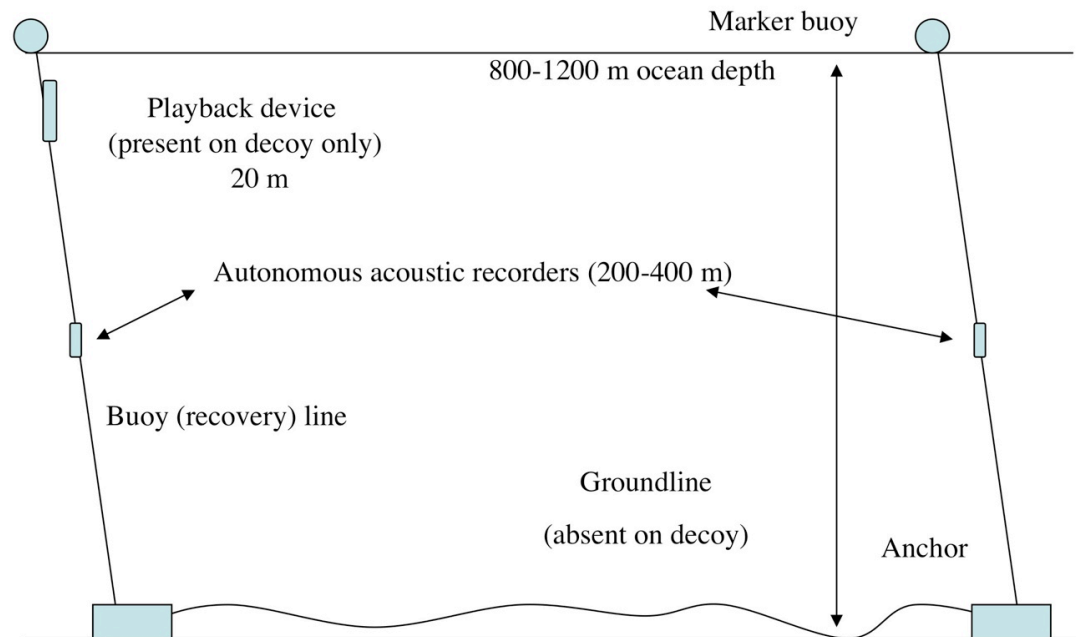




# Playing back acoustic cues to attract animals away from an area

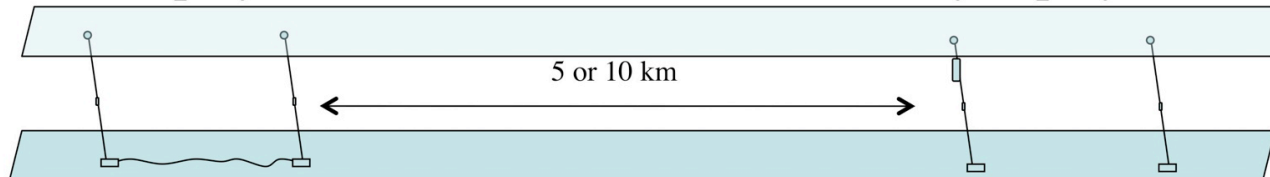
- \* Acoustic playbacks to deter (2009) not promising.
- \* Advantages:
  - \* Fewer fidelity problems:
    - \* Signal expected to be detected at a distance, low signal-to-noise ratio. (Cruddy signal expected)
  - \* Habituation (pseudo replication) issues reduced due to larger sample sizes.
    - \* Many different hauling sounds by different boats.
  - \* Potential for behavioral modification.
    - \* Make a whale “think twice” before responding to hauling sounds.
- \* Issues:
  - \* Convenience for fishermen
  - \* Detection range

# Decoy deployed at least 10 km away from planned activity (5 knot swimming speed)



True deployment

Decoy deployment

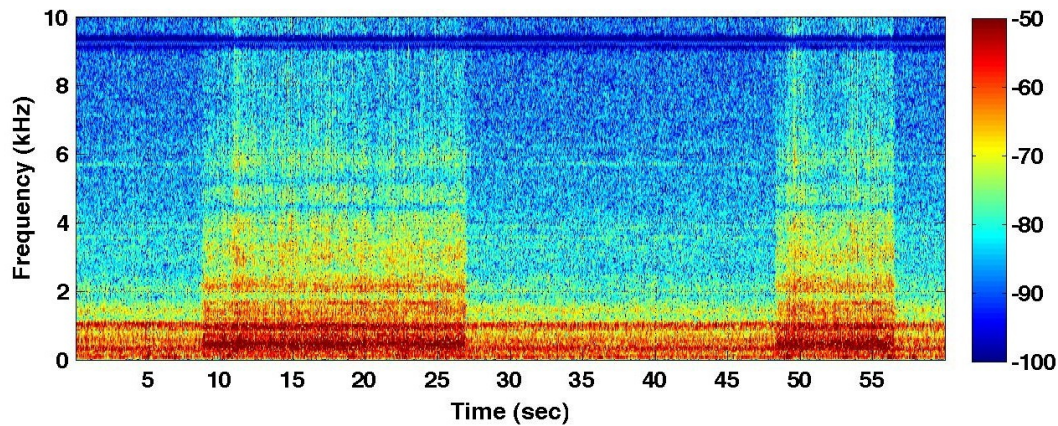




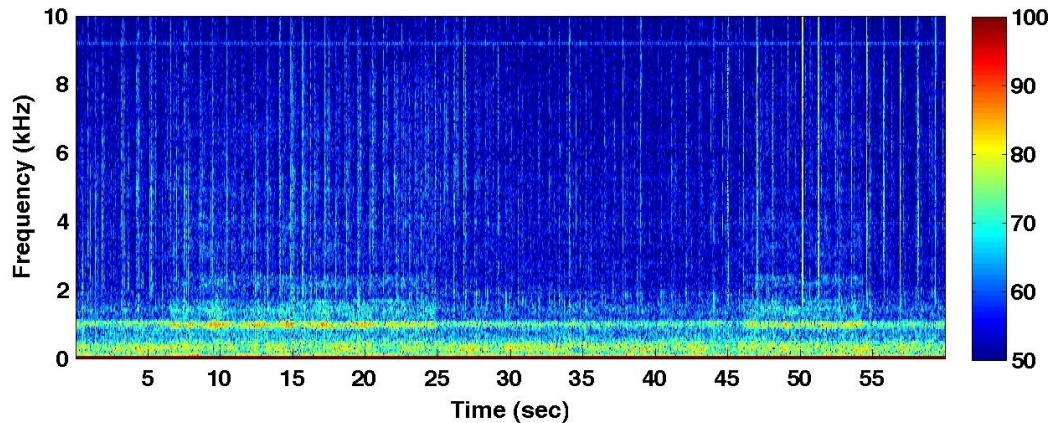
# Radio-activated acoustic decoy at 6 nautical mile ranges



# Sample of acoustic decoy



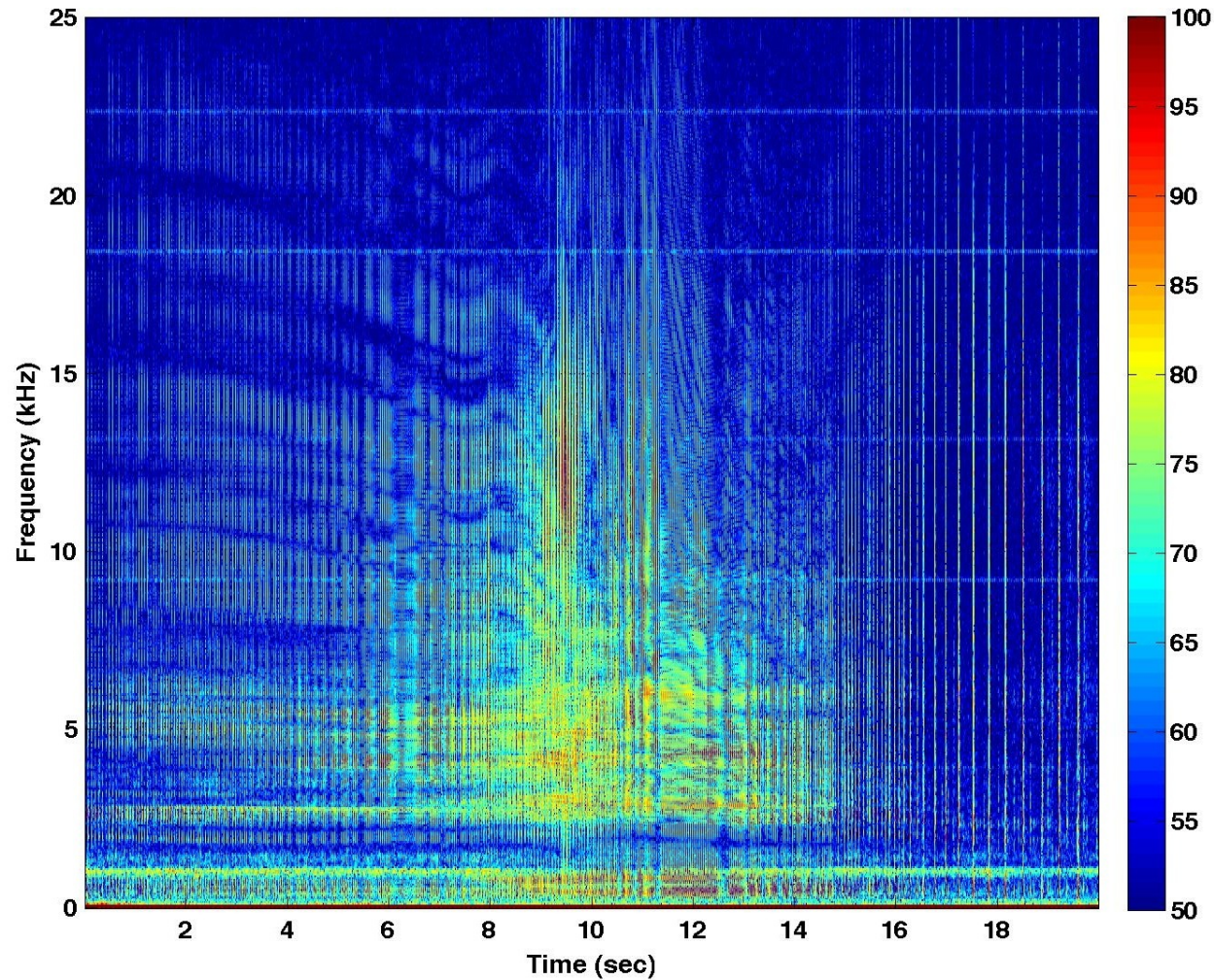
Recording



Playback detected at 380 m

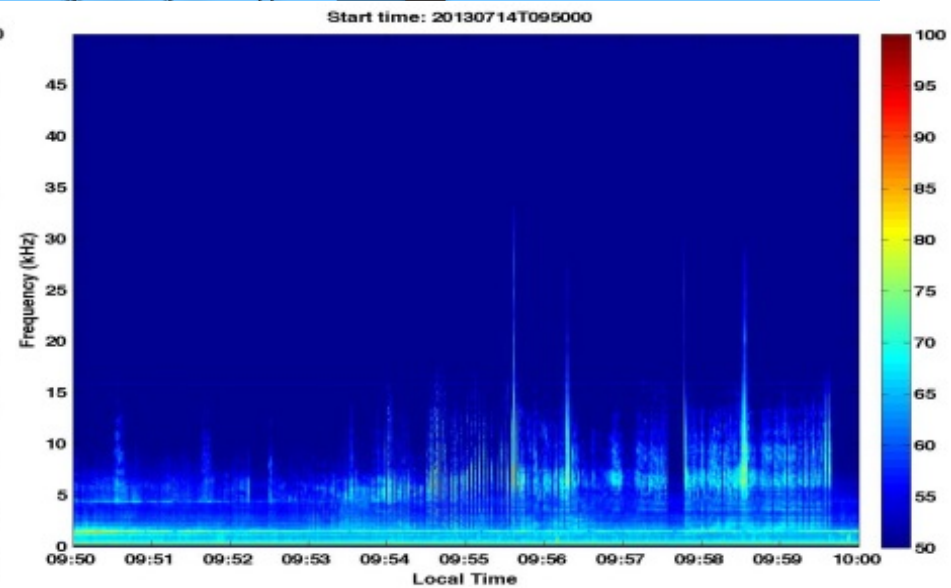
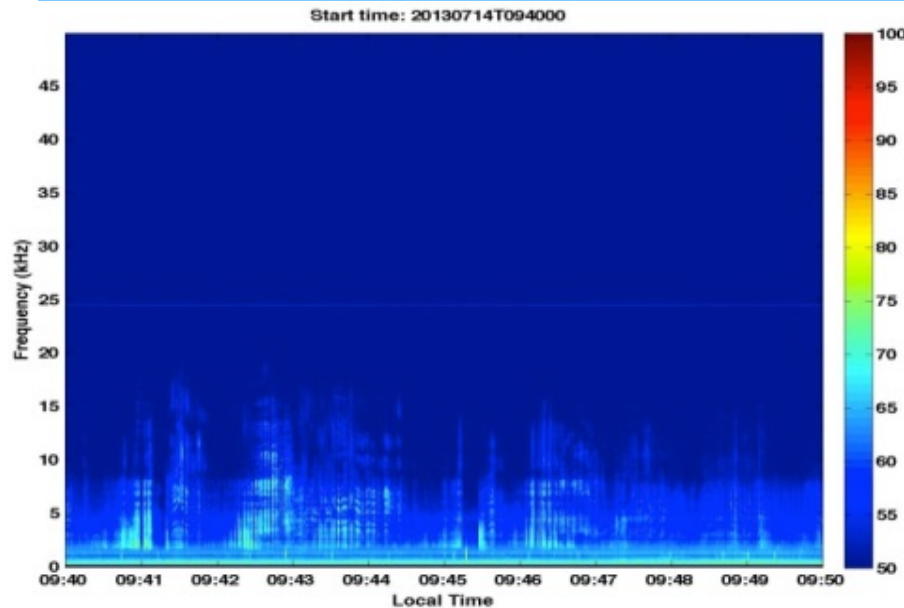
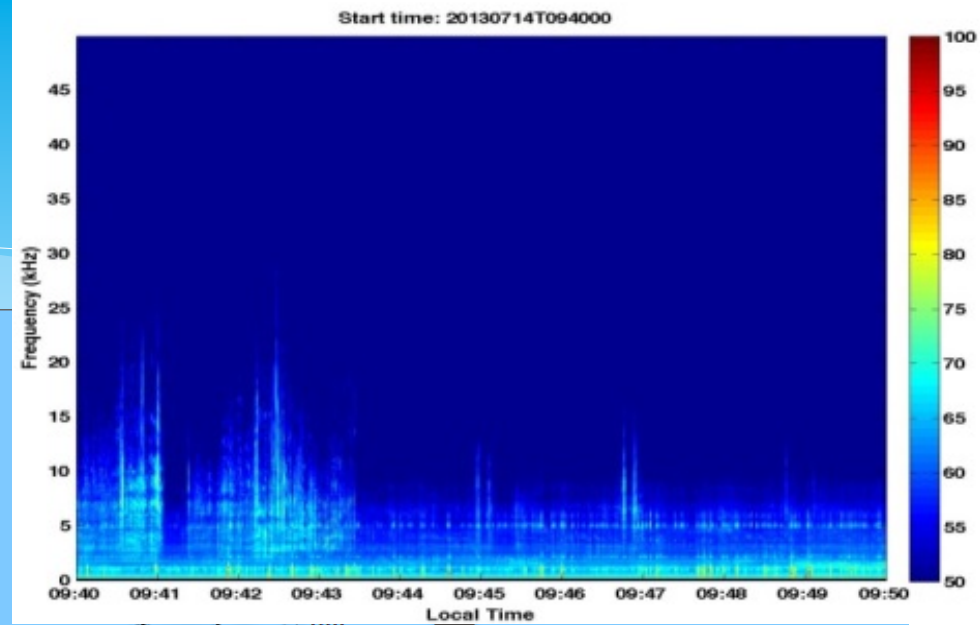


# Interrogating the decoy, 2011

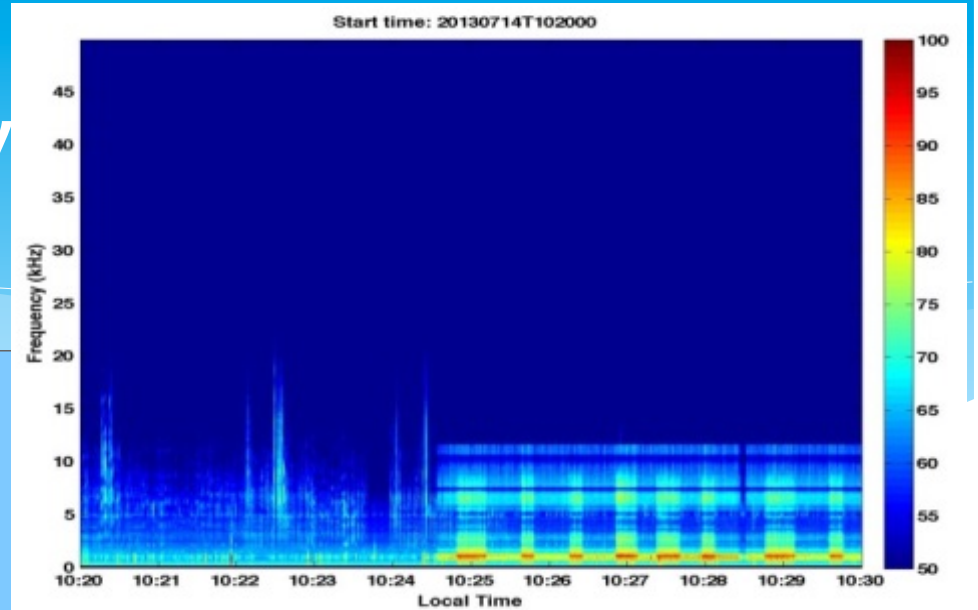




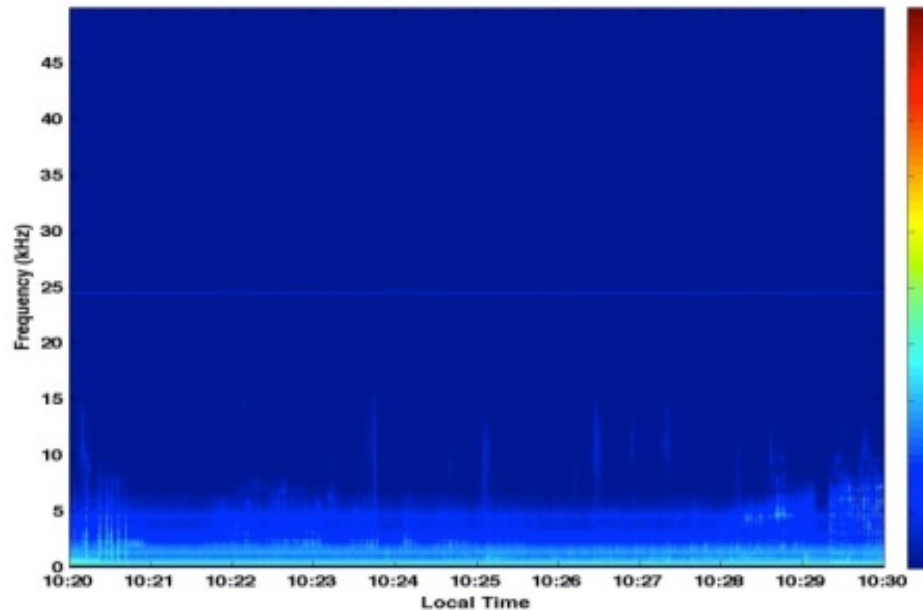
# Acoustic decoy



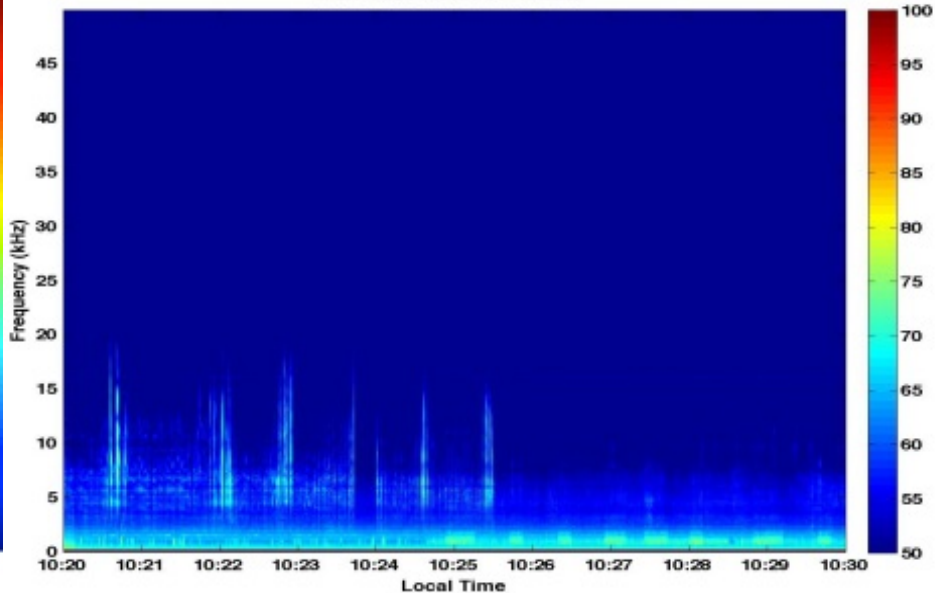
# Acoustic decoy



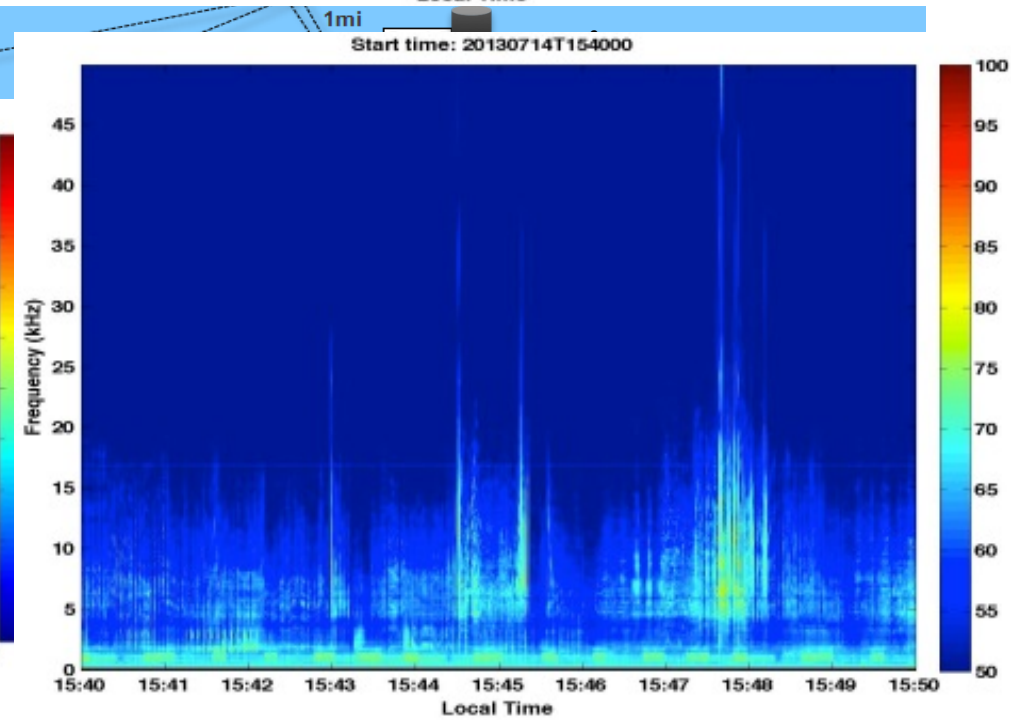
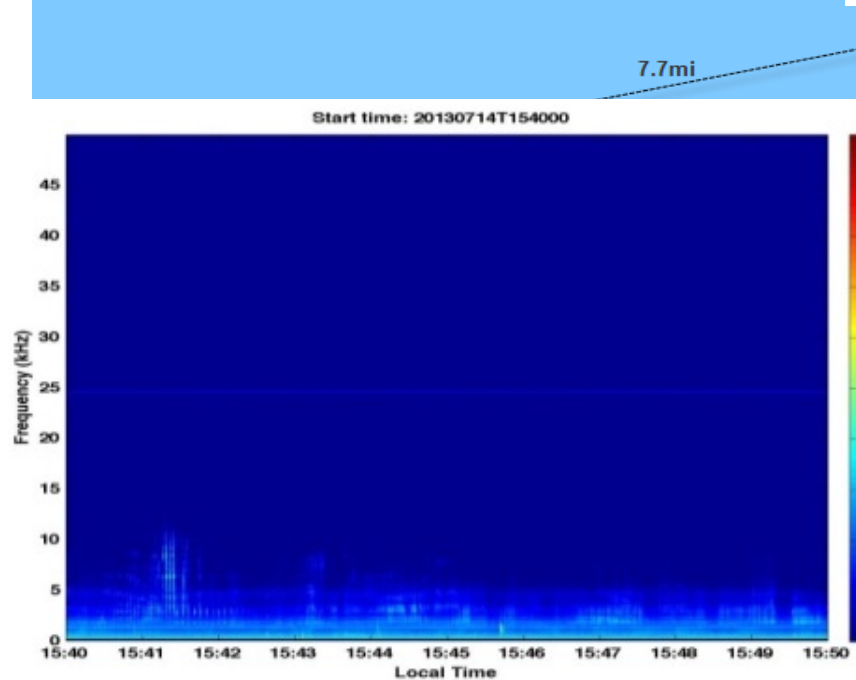
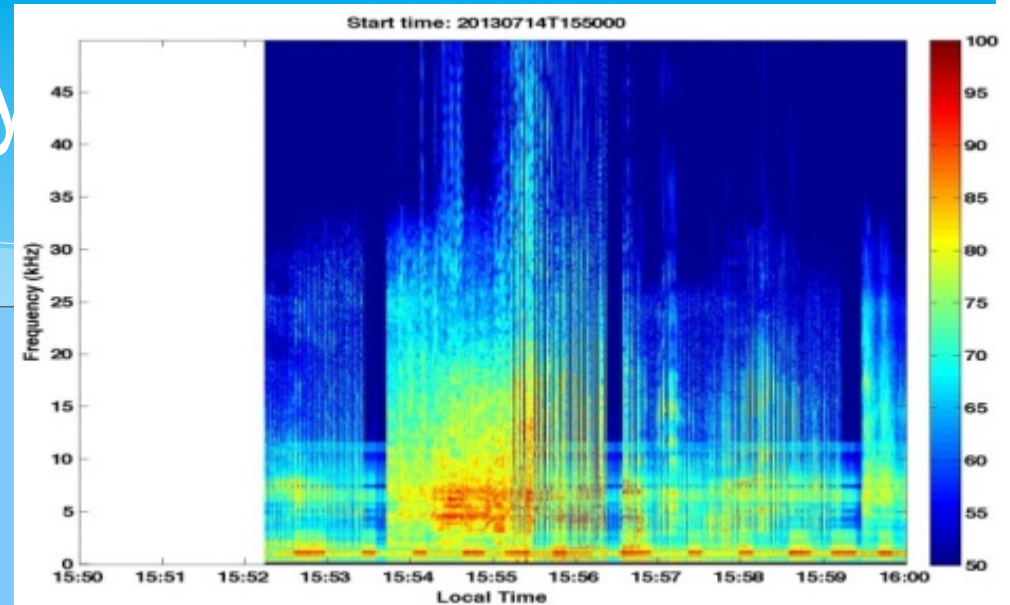
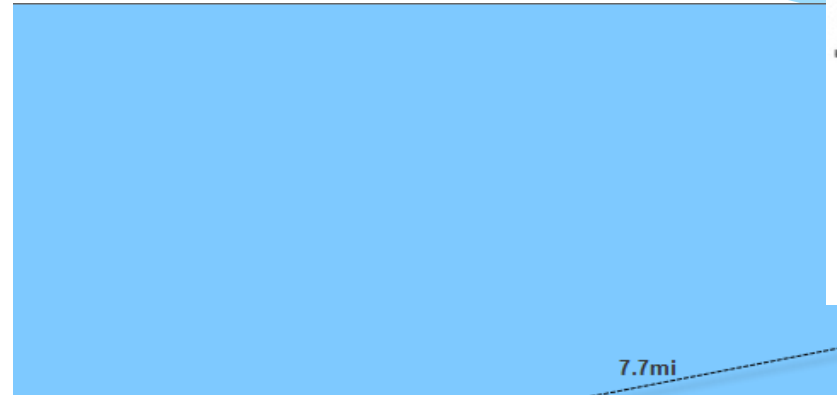
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Start time: 20130714T102000

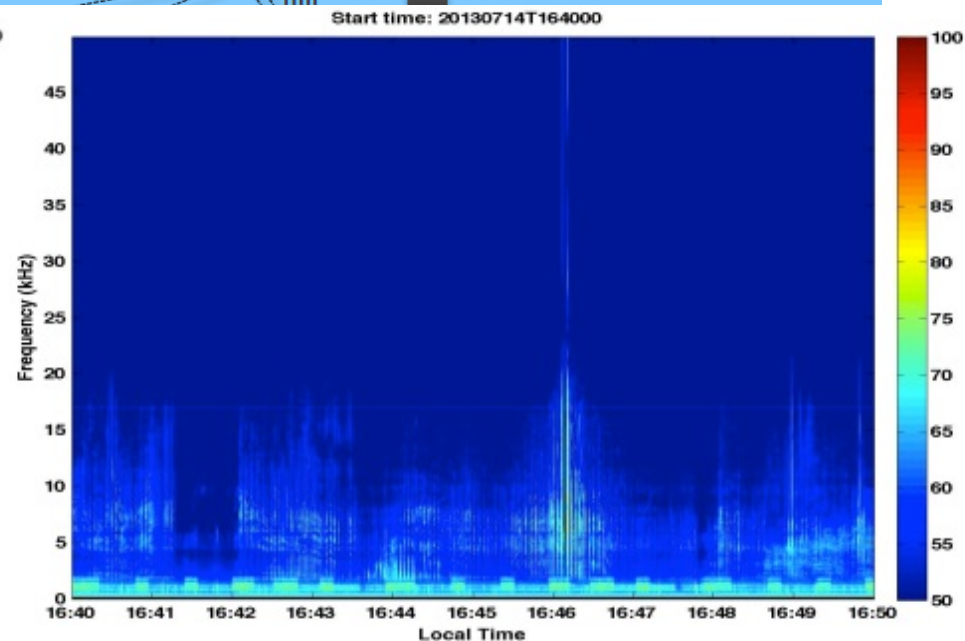
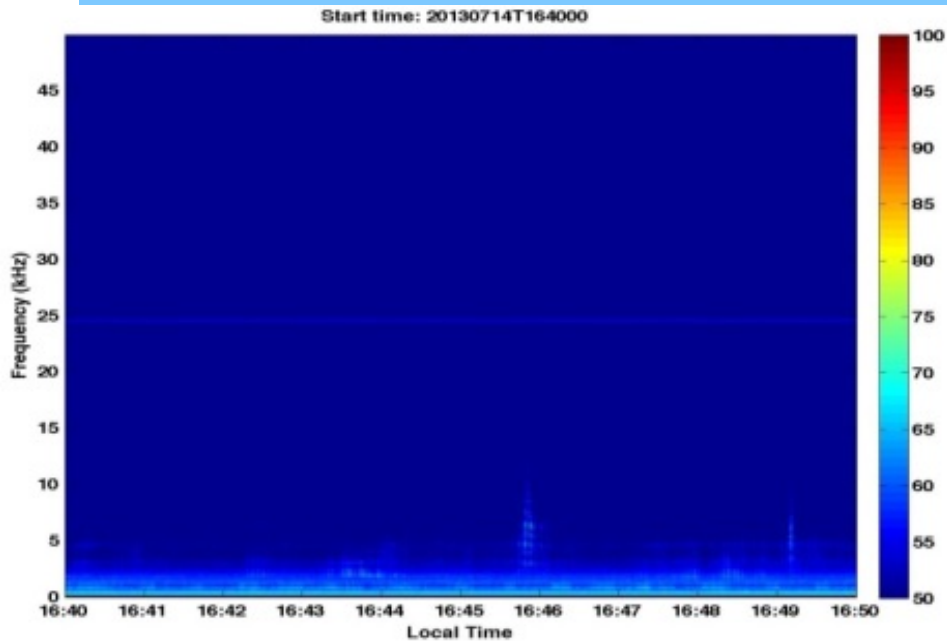
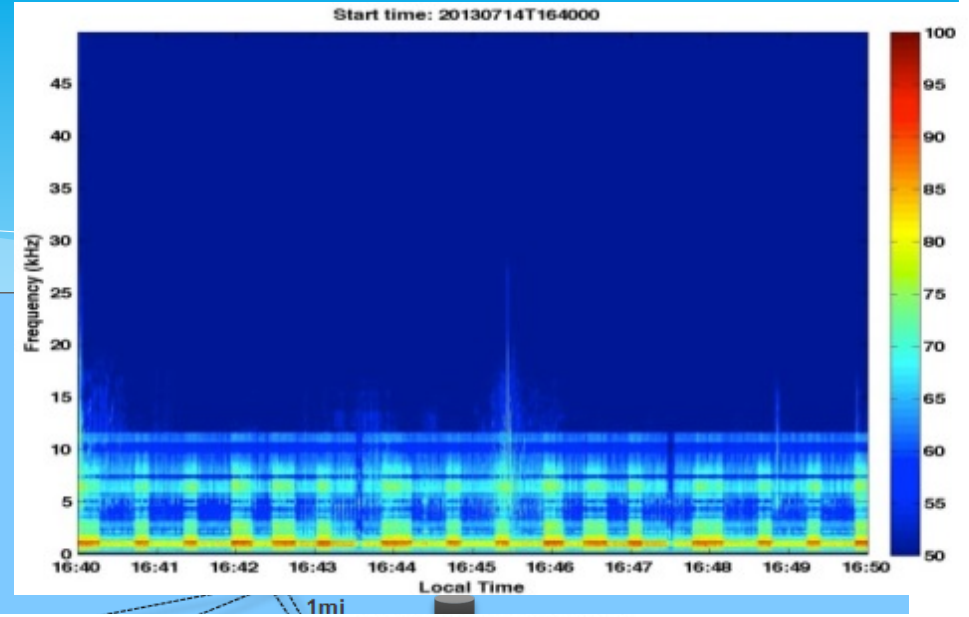


# Acoustic decoy





# Acoustic decoy



# Depredation and passive acoustic studies have been mutually advantageous

A. Thode, L. Wild, D. Mathias, J. Straley, C. Lunsford, "A comparison of acoustic and visual metrics of sperm whale longline depredation," J. Acoust. Soc. Am., in revision (2013).

D. Mathias, A.M. Thode, J. Straley, and R.K. Andrews. "Depth and range tracking of sperm whales in the Gulf of Alaska using a two-element vertical array, satellite and bioacoustic tags," J. Acoust. Soc. Am. **134**(3), Pt. 2, 2446-2461, (2013).

D. Mathias, A.M. Thode, J. Straley, J. Calambokidis, G.S. Schorr, K. Folkert, "Acoustic and diving behavior of sperm whales (*Physeter Macrocephalus*) during natural and depredation foraging in the Gulf of Alaska," J. Acoust. Soc. Am. **132**(1), 518-532, (2012).

A.M. Thode, J.S. Skinner, P. Scott, J. Roswell, J. Straley, and K. Folkert, "Tracking sperm whales with a towed acoustic vector sensor," J. Acoust. Soc. Am. **128**, 2681-2694 (2010).

D. Mathias, A. Thode, J. Straley, K. Folkert, "Relationship between sperm whale (*Physeter macrocephalus*) click structure and size derived from videocamera images of a depredating whale," J. Acoust. Soc. Am. **125**, 3444-3453 (2009).

A.M. Thode, J. Straley, C. Tiemann, K. Folkert, V. O'Connell, "Observations of potential acoustic cues that attract sperm whales to longline fishing in the Gulf of Alaska," J. Acoust. Soc. Am. **122**(2), 1265-1277 (2007).

C. Tiemann, A. Thode, J. Straley, K. Folkert, V. O'Connell, "Three-dimensional localization of sperm whales using a single hydrophone," J. Acoust. Soc. Am. **120** (4), 2355-65 (2006).

# Acknowledgements

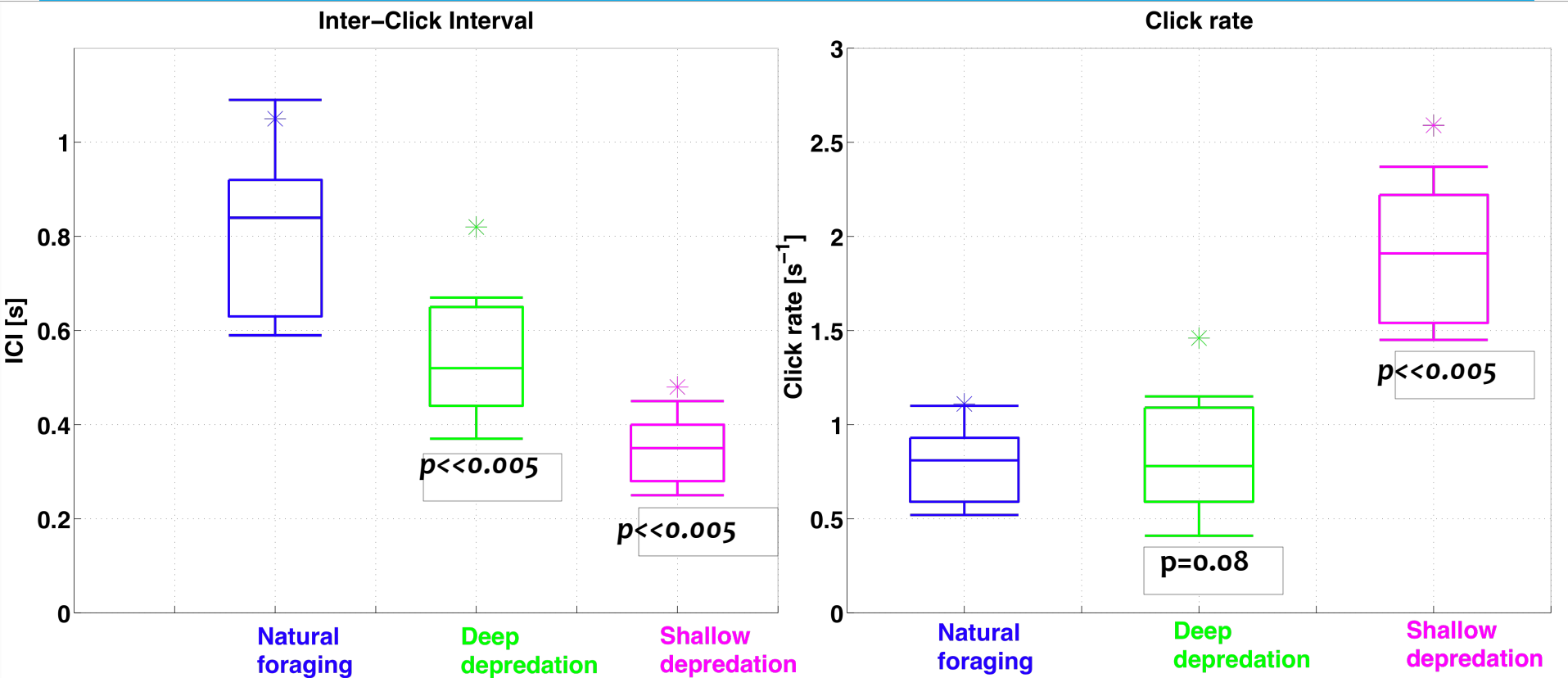
- \* Kendall Folkert, Stephen Rhoads, Dan Falvey, Linda Behnken
- \* Chris Tiemann, John Calambodkidas, Greg Shorr
- \* Steve Weissberg, Jay Skordahl, Carter Hughes, Jen Cedarleaf, Shane Walker, John Petraberg, Mike Sigler, Jim Hubbard, Valeria Teloni



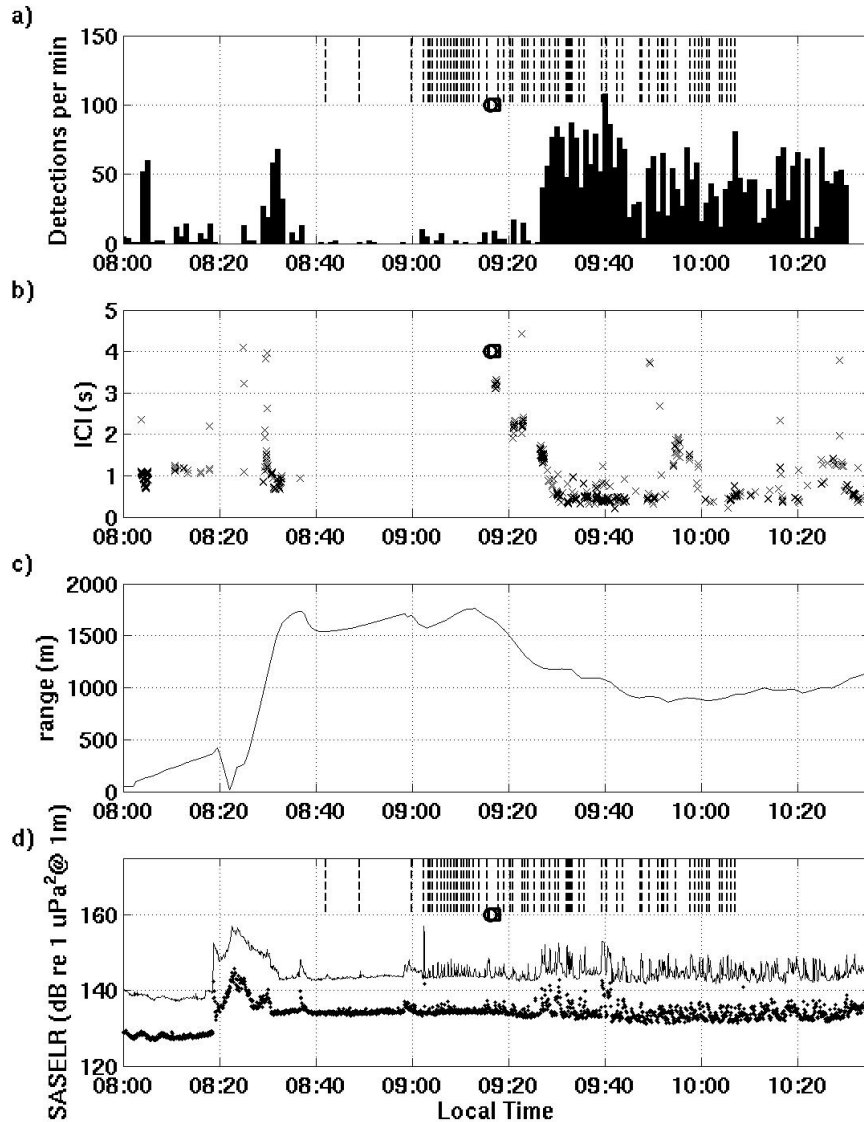
# Sperm whale acoustic behavior permits observation of potential acoustic cues

- \* Procedures
  - \* Portable acoustic recorders
  - \* Conversion of longline gear to listening posts
  - \* Review of a spectrogram-visual representation of sound
- \* Baseline measurements
  - \* Fishing vessel potential acoustic cues
  - \* Natural cycles of sperm whale sounds
  - \* How to track with sounds
- \* Observations
  - \* May 8, 2004-first encounter
  - \* May 7, 2005-fakery and hydraulic test
  - \* May 15, 2005-test of engine cycling
- \* Close-range acoustic cues
  - \* Combined video/acoustic analysis of underwater interaction
- \* Implications
- \* Future work

# Acoustics: whales click faster and more often during depredation



- **Deep depredation:** whales click significantly faster than during natural foraging.
- **Shallow depredation:** ICI interval twice as low and click rate twice as high than during natural foraging. Whales also start clicking earlier in the dive.
- Robust to individual variation (On same tag record, parameters change during natural and depredation states).



\* Sperm whale acoustic activity increased after engine cycling began.

\* Engine cycling leaves a distinctive acoustic signature in 250-1000 Hz band.