

Presentation at the First Plenary Meeting  
of the Advisory Committee on Acoustic  
Impacts on Marine Mammals

3-5 February 2004

Bethesda, Maryland

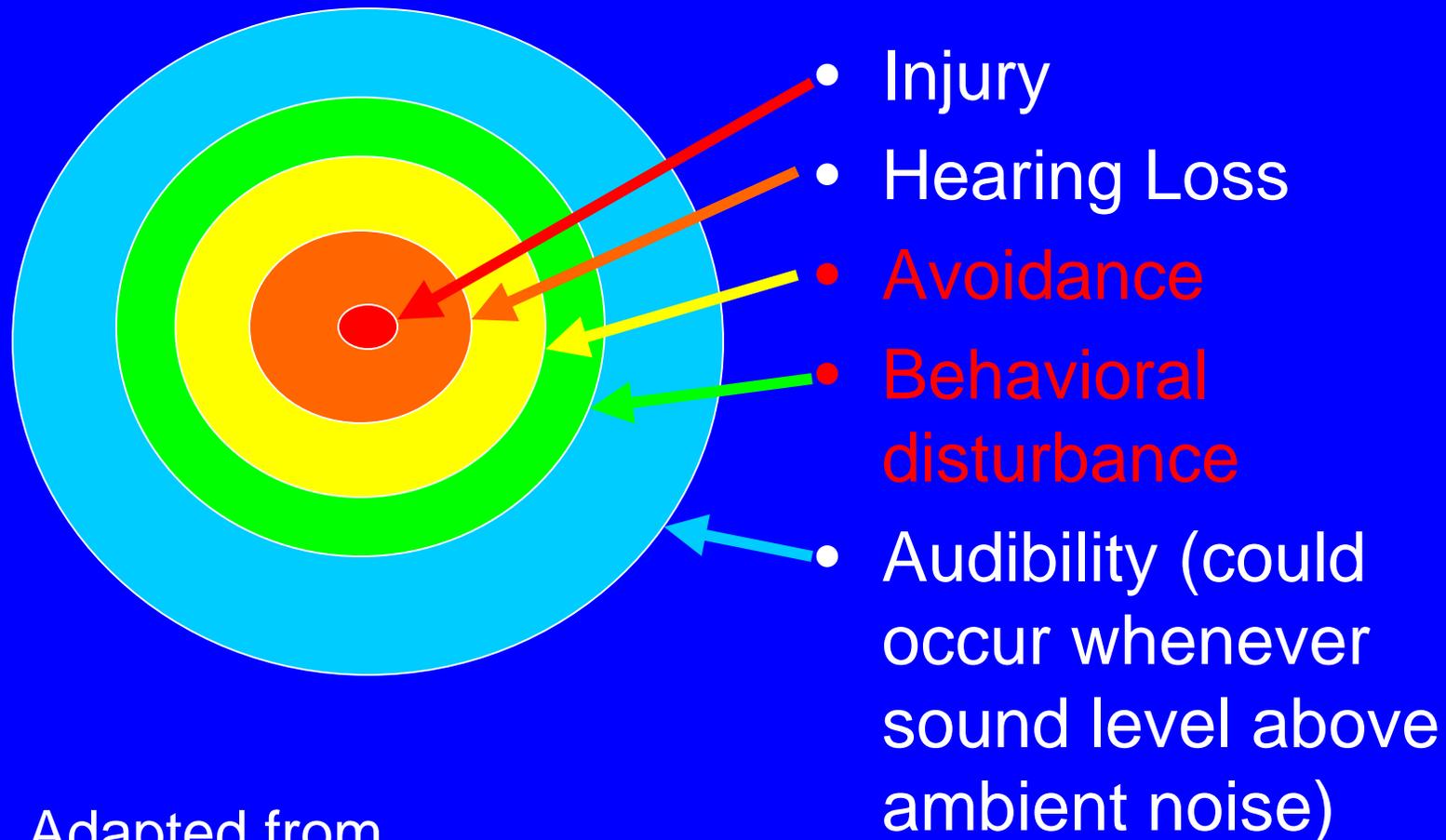
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# Behavioral Impacts of Sound on Marine Mammals

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MMC Advisory Committee on Anthropogenic Sound and Marine  
Mammals, Wed 4 Feb 2004

# Zones of Noise Influence

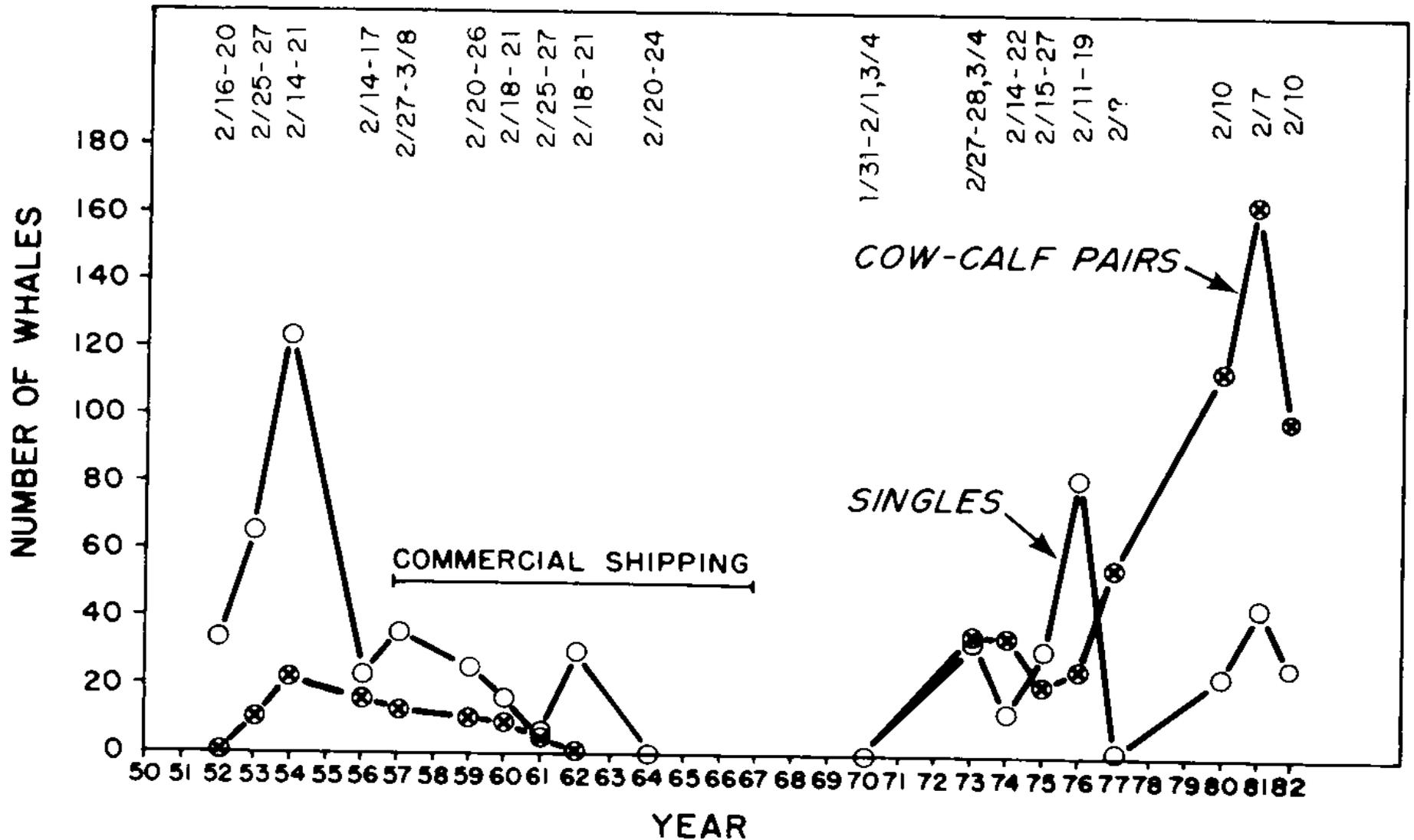


Adapted from  
Richardson and  
Malme 1995

# Time Scales for Avoidance

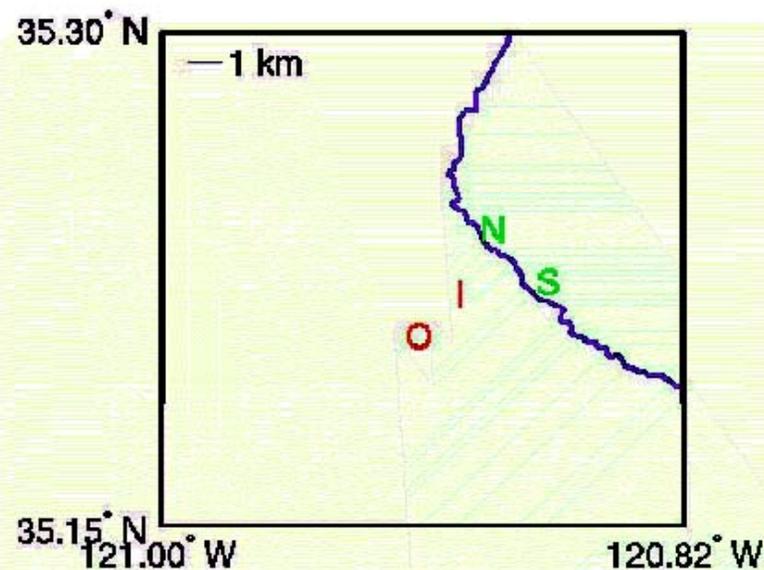
- Permanent Abandonment
- Avoidance during experimental exposure of several hours
- Very few experiments designed to study habituation – often need days to weeks with same subjects

# Gray whales abandon breeding lagoon during shipping/dredging



# Measuring Avoidance Responses of Migrating Gray Whales

- 8-27 Jan 1998, Paired Playback/Control Design
- One moored LFA source, 160-330 Hz, transmit 42 s every 6 min
- 1200 whales observed migrating past source

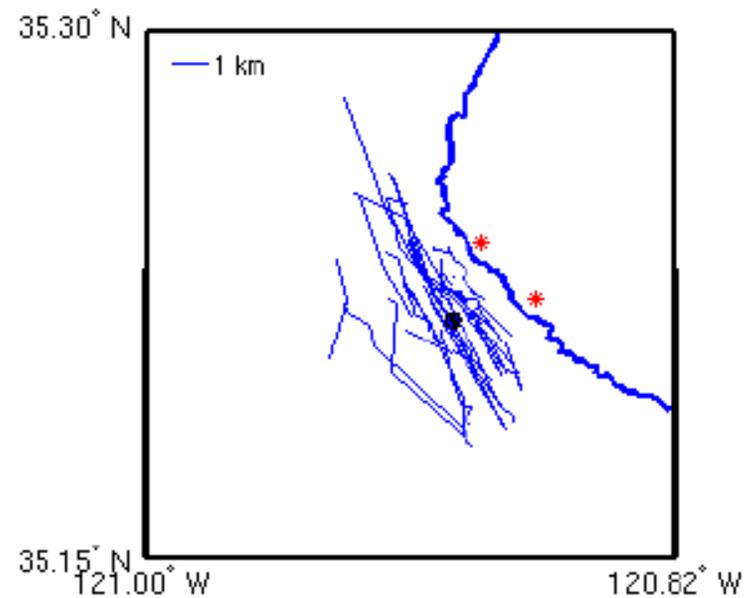
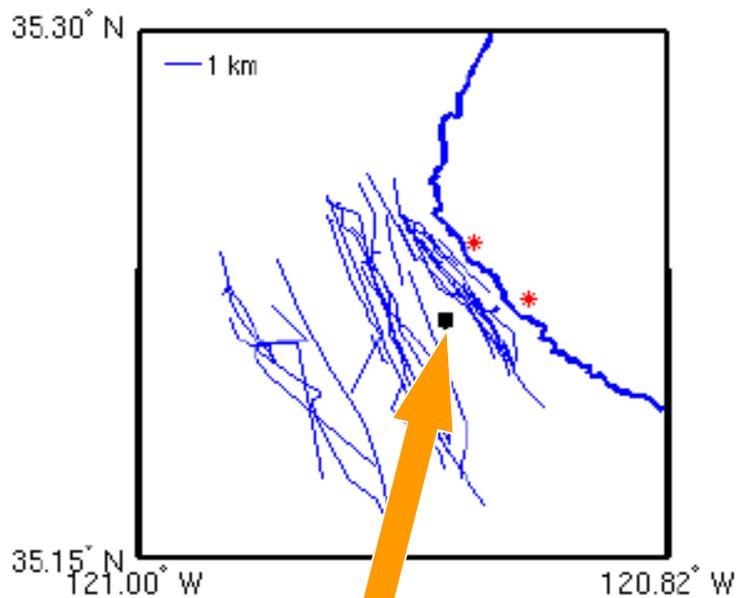


# LFA Inshore

Source Level = 185 dB re 1  $\mu$ Pa @ 1m

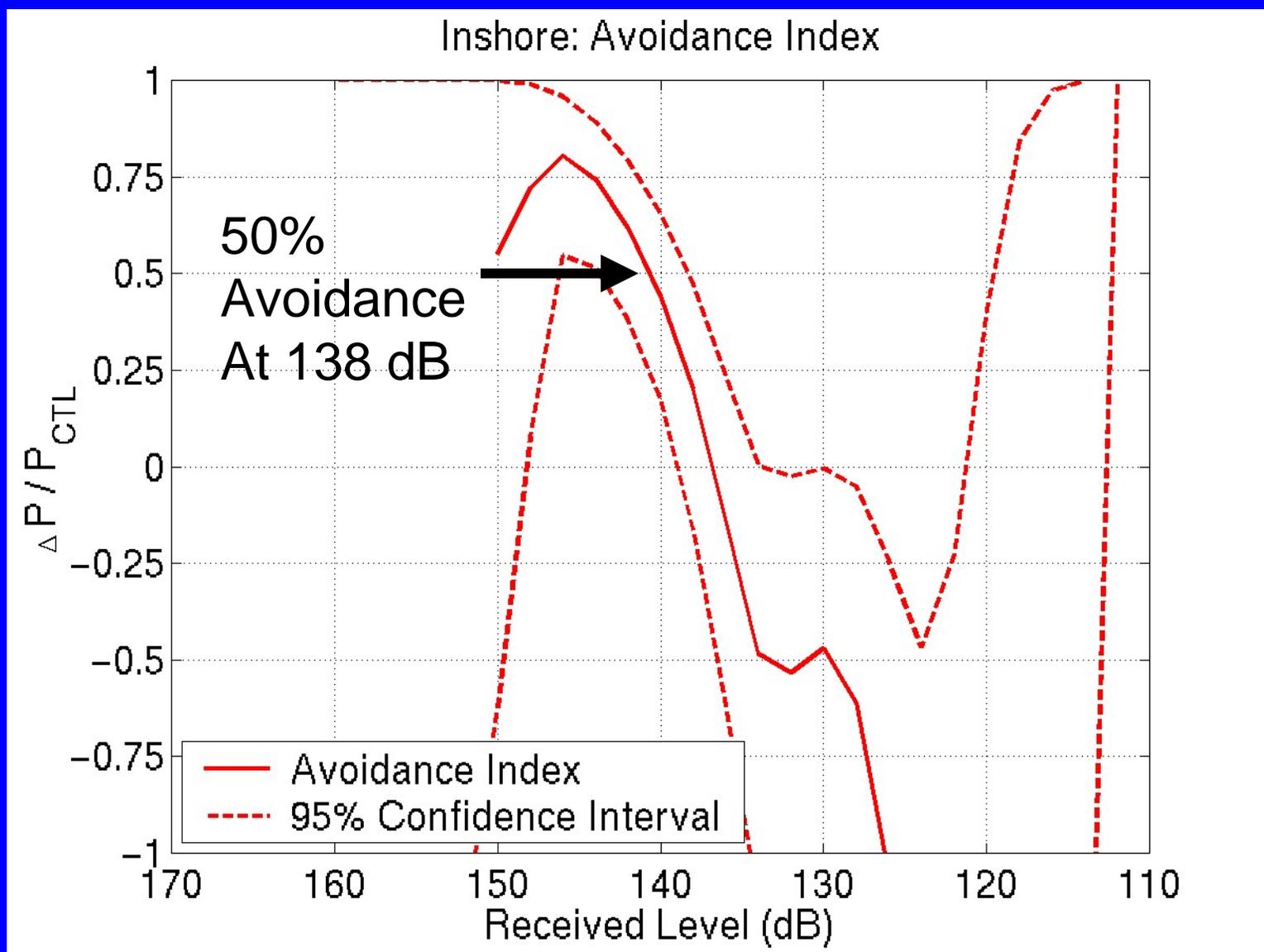
Playback

Control



Whales avoid  
area near source

# Avoidance of gray whales to LFA sonar increases at higher received levels



# Responses of *Phocoena* to 145 dB pinger

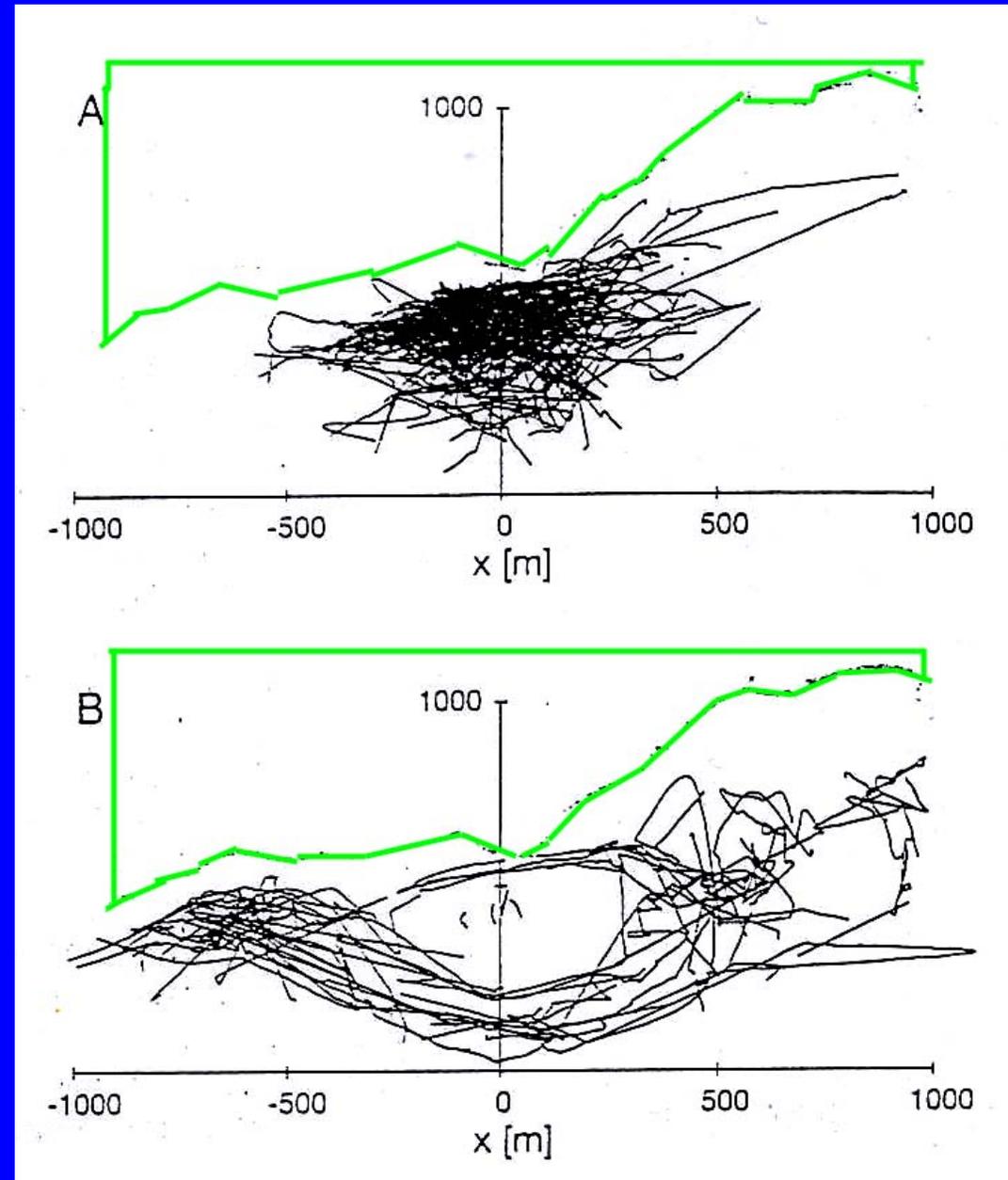


Control

50% avoidance of 100 dB  
assuming 15 log r  
Spreading Loss

Effect reduced by 50%  
after 3 days of transmit

Transmit



# Habituation of Phocoena to Pingers

Trial	# Days	Mean Distance (m)	Time to 50% Avoid
Control 1	15	217	
Trial 1	28	736	2.8 days
Control 2	15	225	
Trial 2	13	338	8.5 days

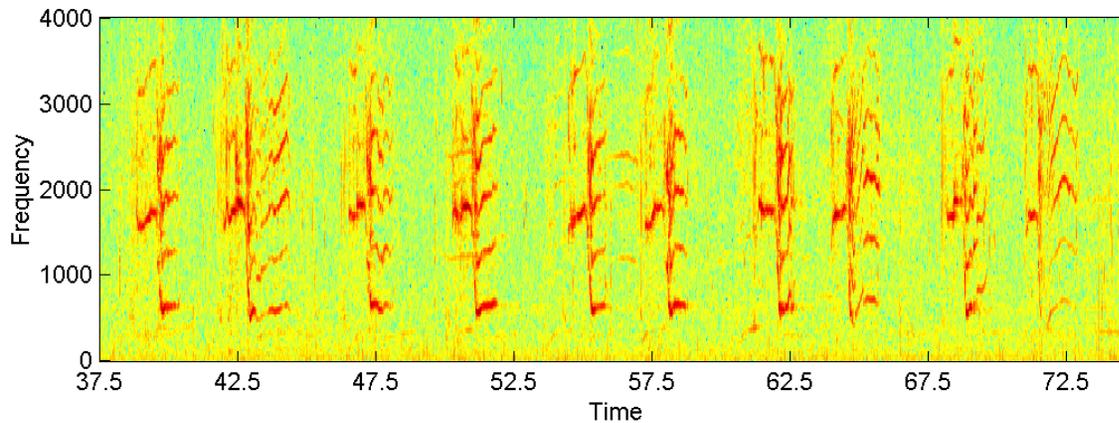
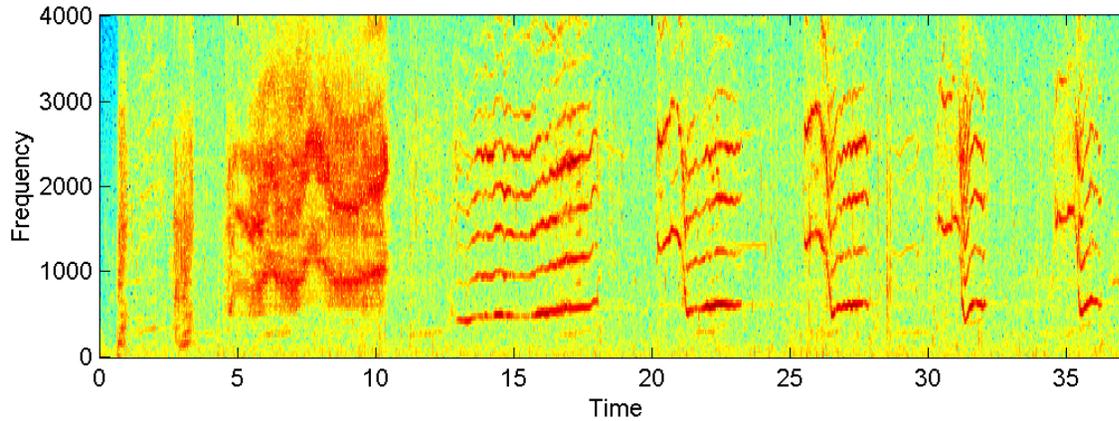
Cox et al. (2001) J Cet Res Manage 3:81-86

# Effects of Avoidance Responses

- Can be used positively to stimulate animals to avoid harm – weak pingers on nets can reduce entanglement in nets
- Must be used carefully – intense noise over long time can cause animals to abandon habitat
- If animals habituate, does this constitute abandonment, does it pose other risks?

# Behavioral Disturbance: Disruption of Biologically Significant Activities

- Basic issues are demographic – effects on growth, survival, and reproduction
  - Reproduction: mating behavior
  - Survival: strandings, separation of calf
  - Growth: Feeding and energetics



# Hump- back Whale Song

- Performed by lone males during breeding season

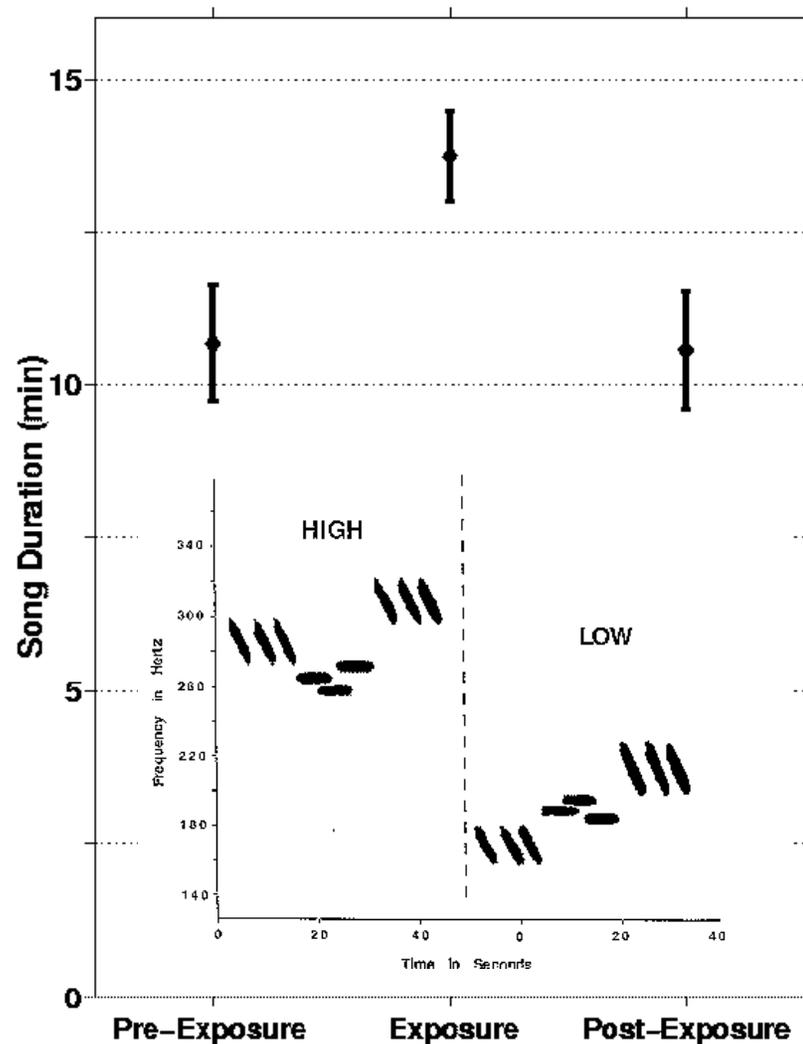


# Possible Functions of Humpback Song

- Reproductive advertisement display
  - Attract females
  - Assist in location of singer by females
- Mediate interactions among males
  - Male-male spacing

Disruption of song  
could interfere with  
reproduction





Humpback  
whales  
lengthen  
songs during  
LFA exposure

Nature (2000)  
405:903

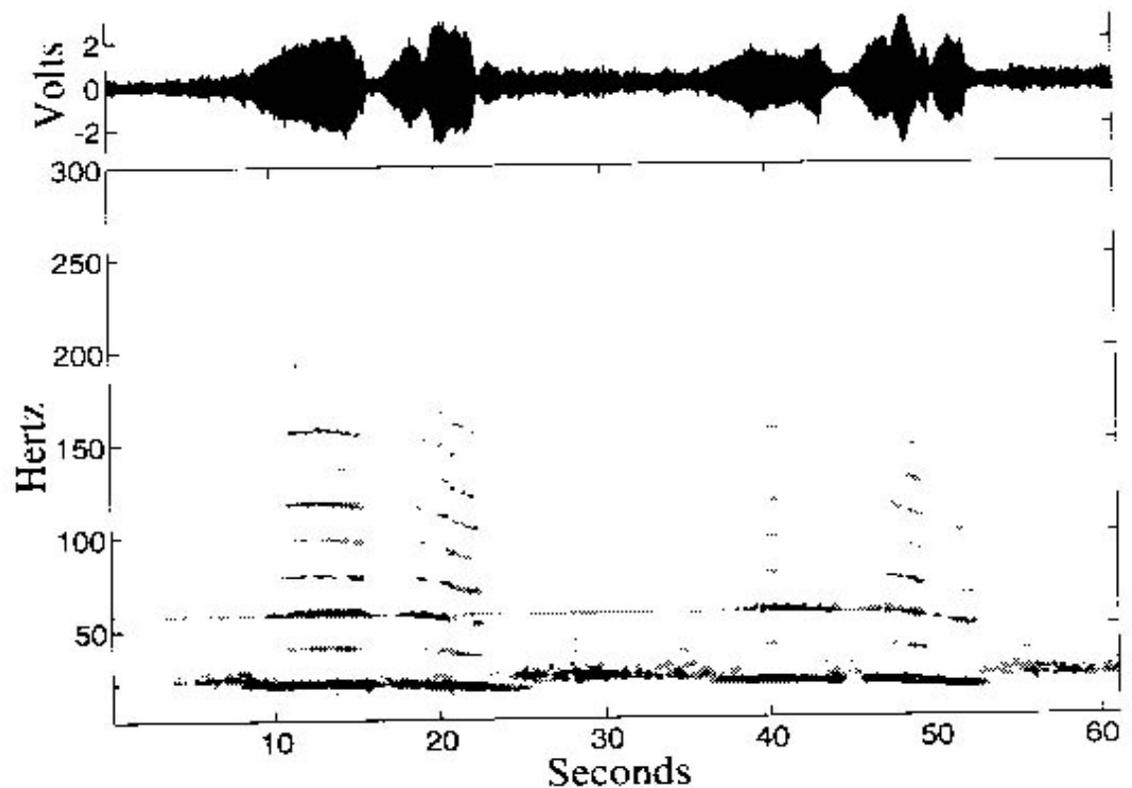
# What is impact of increase in song length?

- Compensation Mechanism? Whales increase redundancy of song when noise increases
- How sure can we be about whether this change might affect reproduction?

# Low frequency calls of blue whales

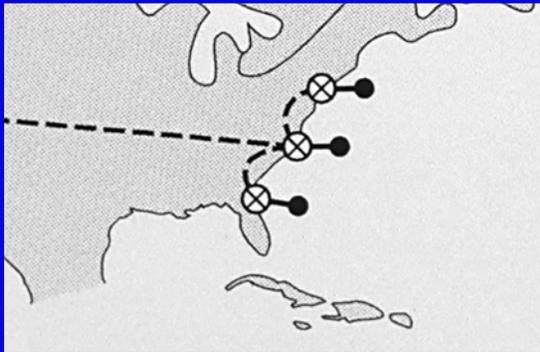


- Duration 10-20 sec
- Frequency 8-15 Hz strong harmonics
- Varies with geographical region

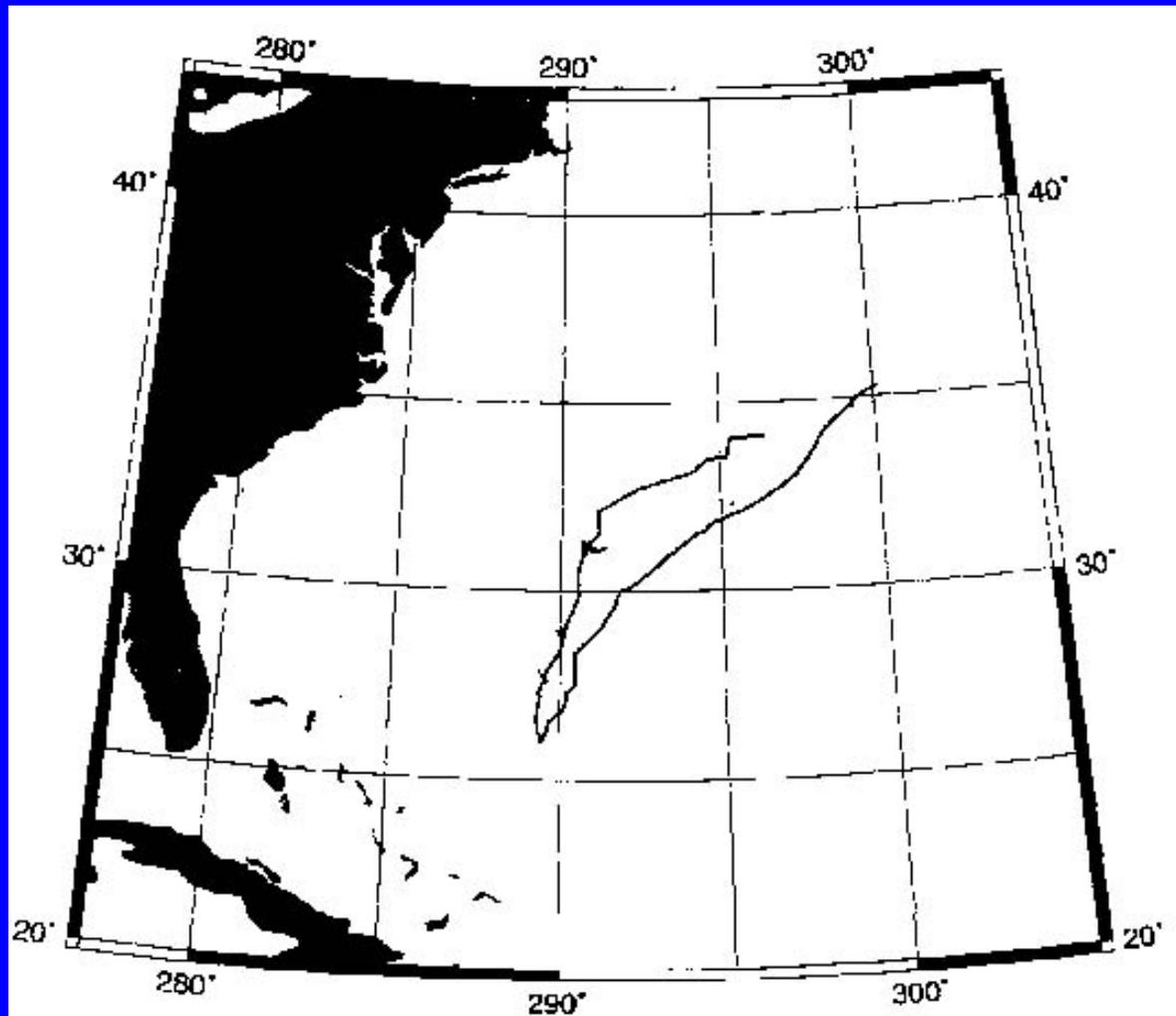


# Example of long range detection of blue whale call

Tracked by US Navy SOSUS array

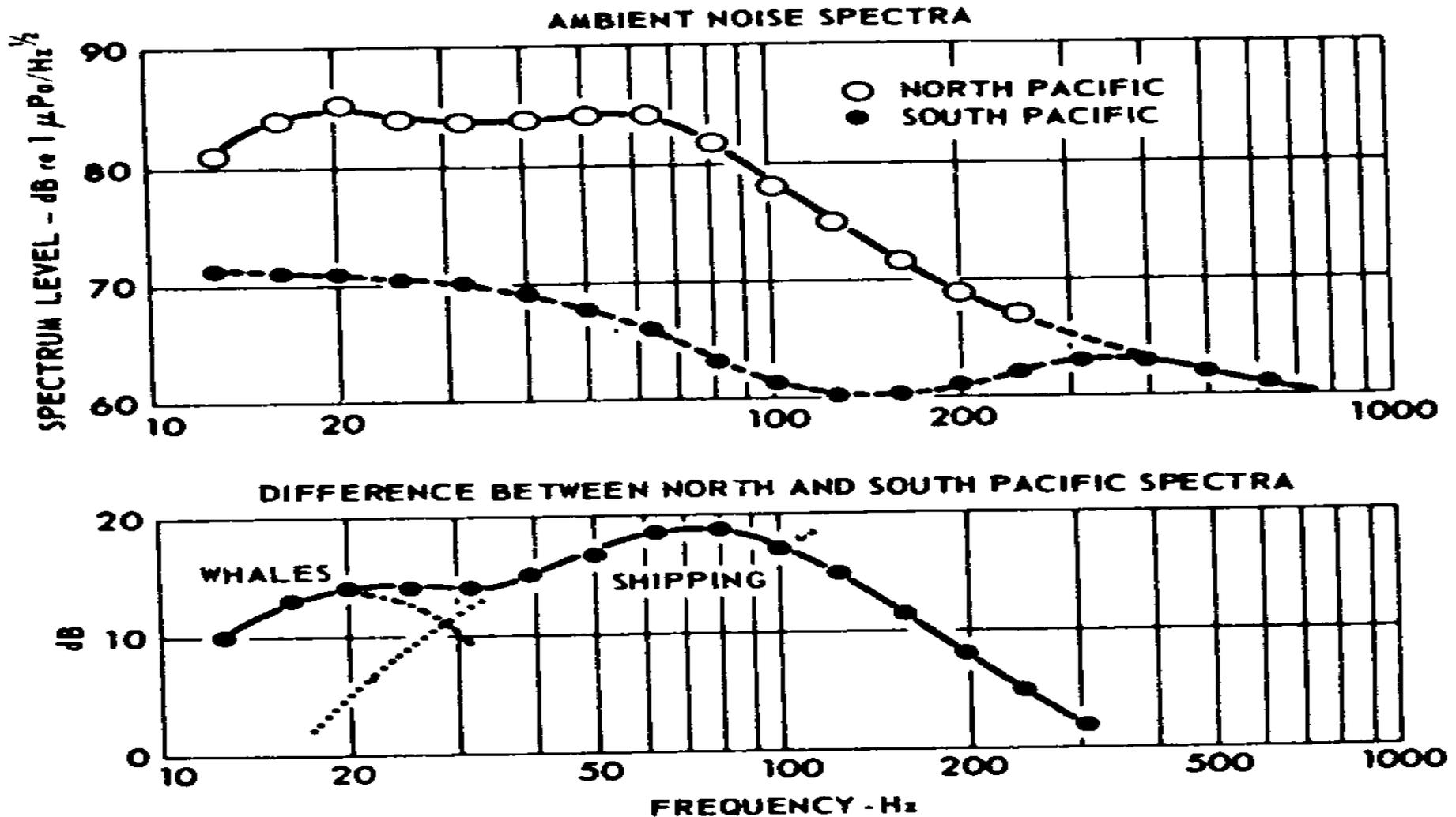


- Whale tracked for 43 days as it swam > 1700 km

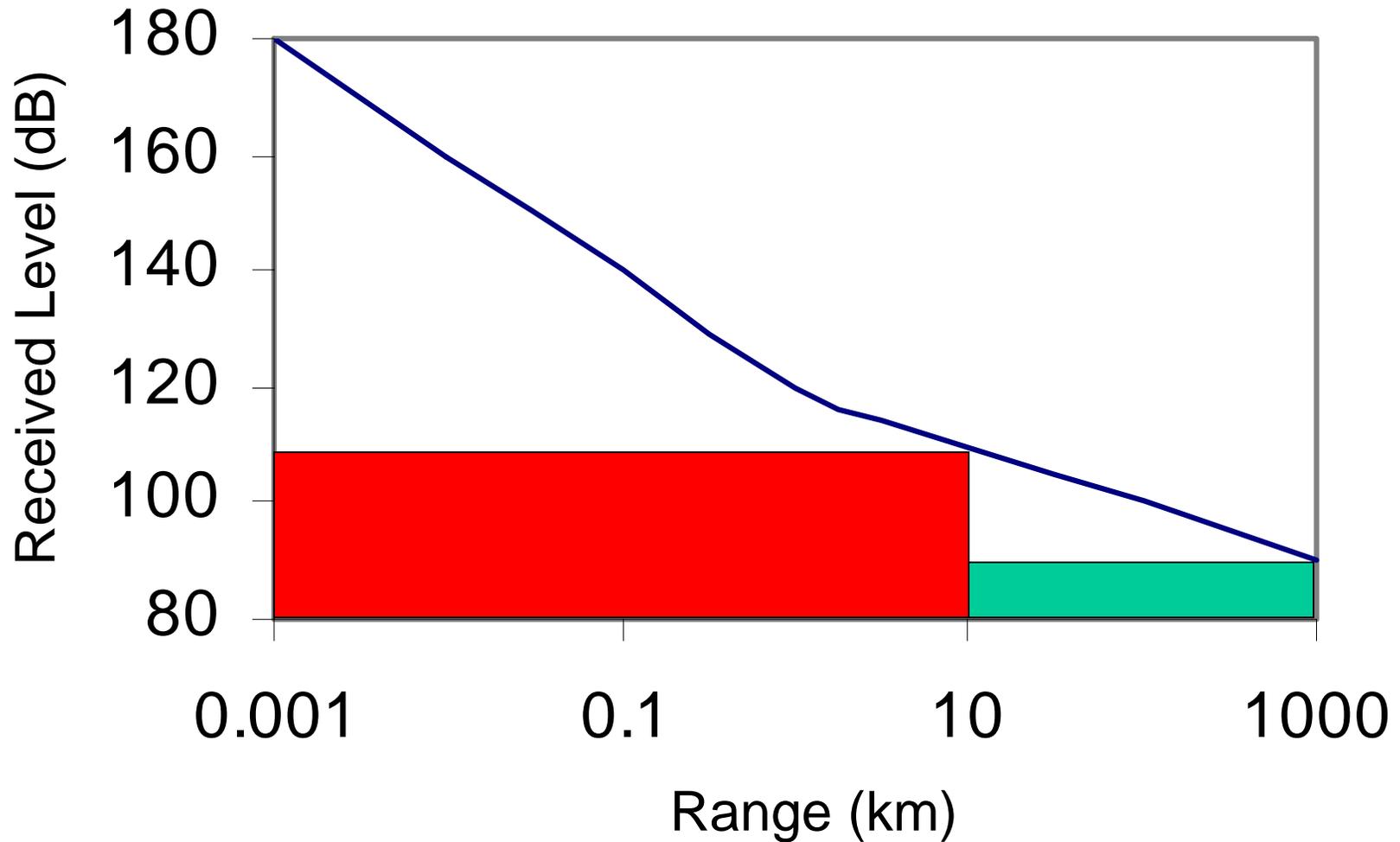


Courtesy C. Clark

# The aggregate sound of thousands of ships dominates average ambient low frequency noise in N. hemisphere



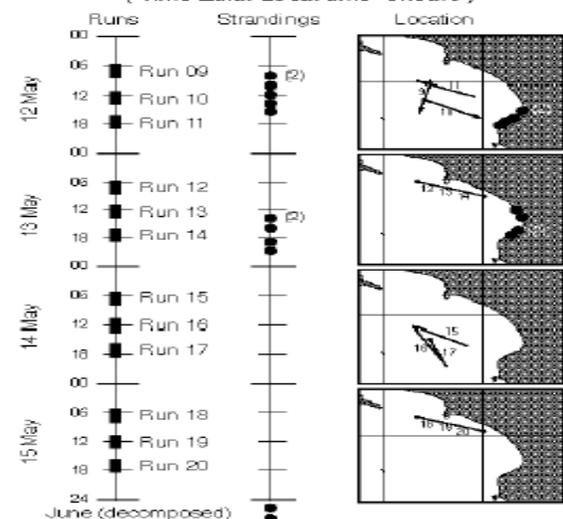
# Increased Noise Can Reduce Effective Range of Communication



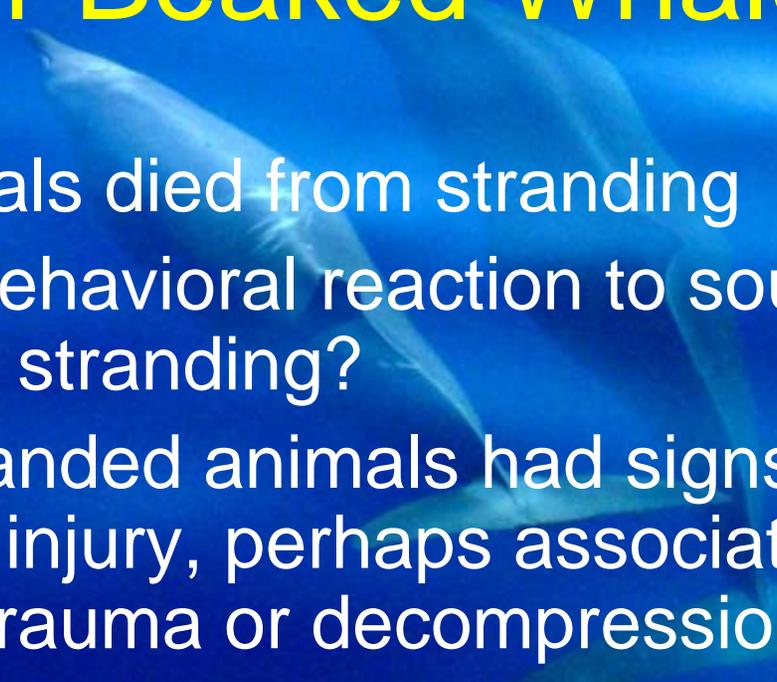
# Concern over strandings of deep-diving beaked whales

- Recent strandings in Bahamas, Greece, and Canary Islands
- >10 whales strand over tens of km
- Associated with naval maneuvers
- What caused the strandings?
- If sound, what exposures are safe?

Timeline 12-15 May 1996  
( Time Zulu: Local time -3 hours )

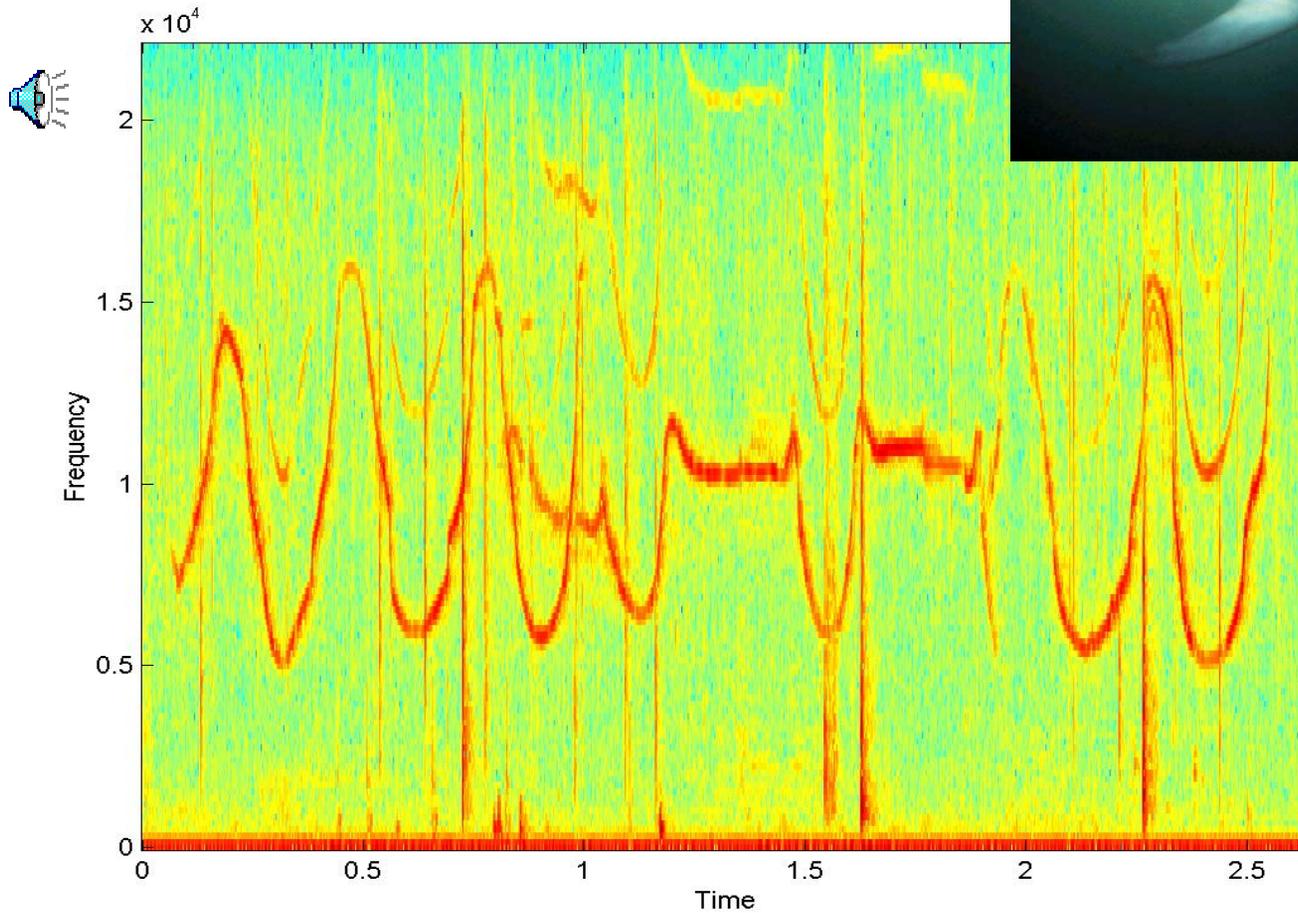


# Primary Behavioral Impact Issue for Beaked Whales

A photograph of a beaked whale swimming underwater. The whale is seen from a side profile, moving towards the left. Its long, pointed beak is prominent. The water is a deep blue, and the lighting creates a soft glow around the whale's body.

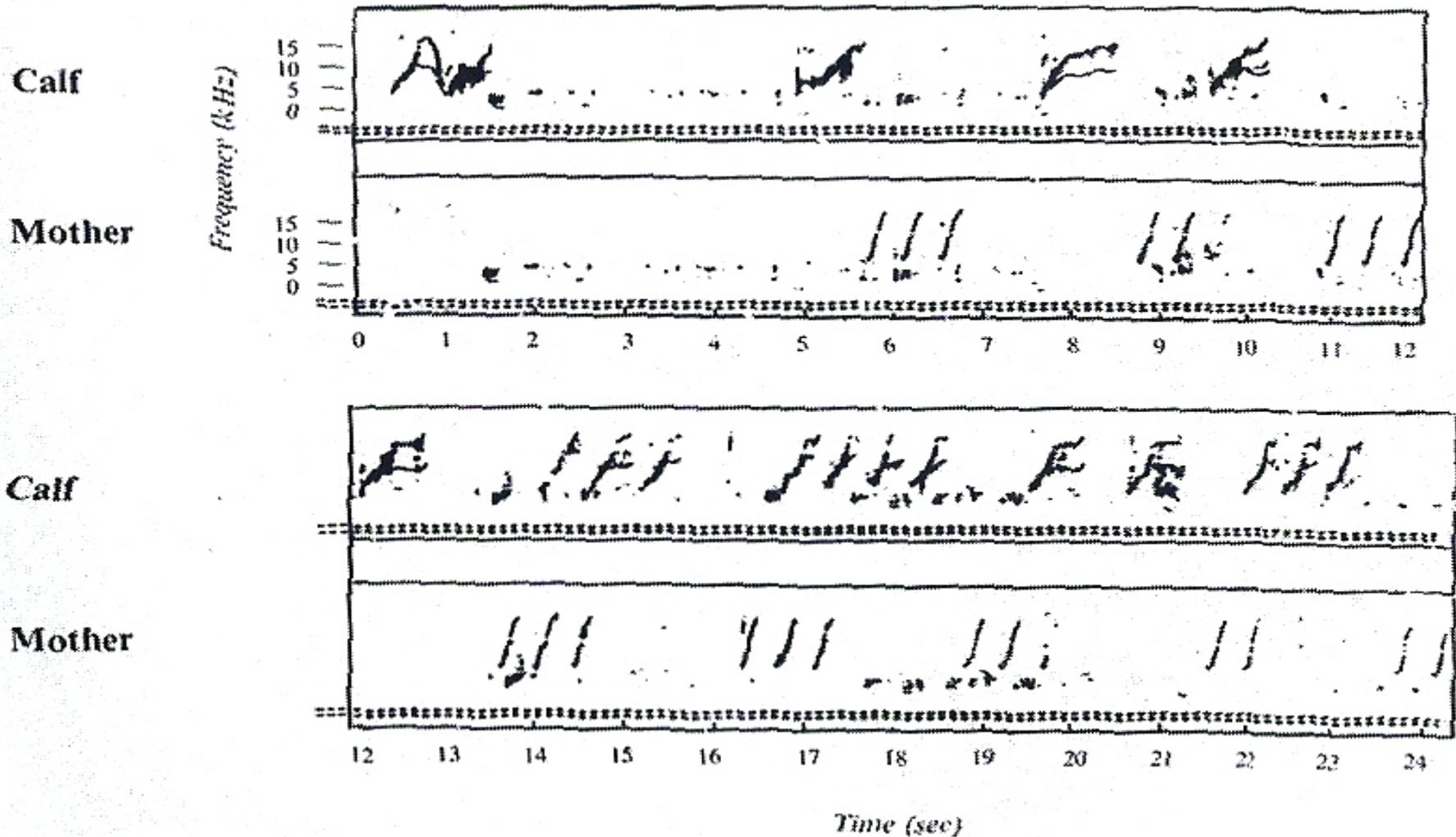
- The animals died from stranding
- Could a behavioral reaction to sound lead directly to stranding?
- Some stranded animals had signs of pre-stranding injury, perhaps associated with acoustic trauma or decompression-like syndrome
- Could a behavioral reaction to sound cause injuries that would make stranding more likely?
- How can we determine what exposures are safe?

# Dolphin Whistles



# Dolphins whistle to maintain contact

Whistle Exchange Between Bottlenosed Dolphins, *Tursiops Truncatus*

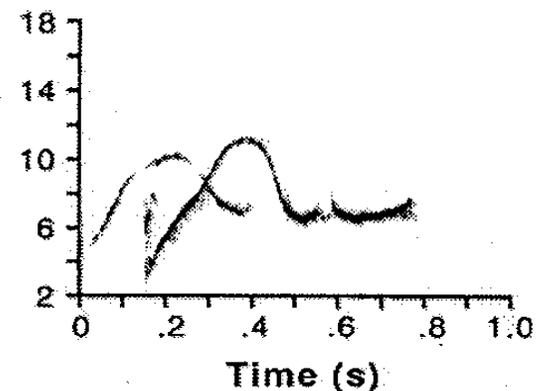
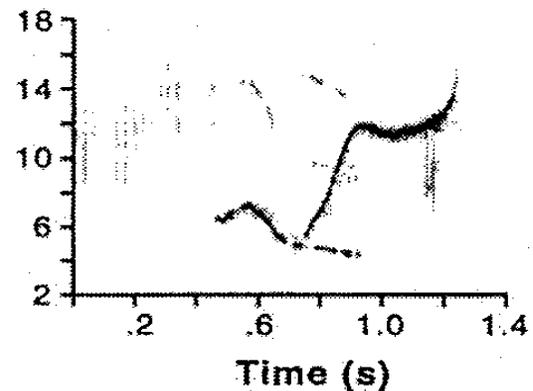
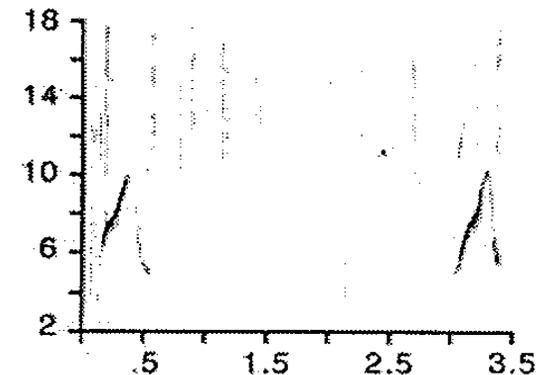
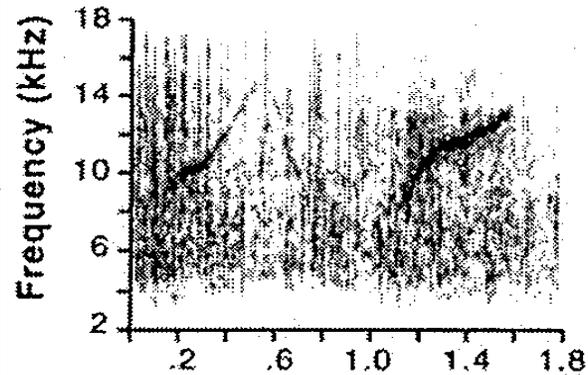
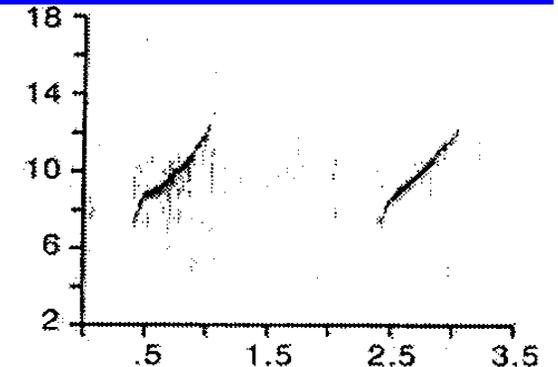
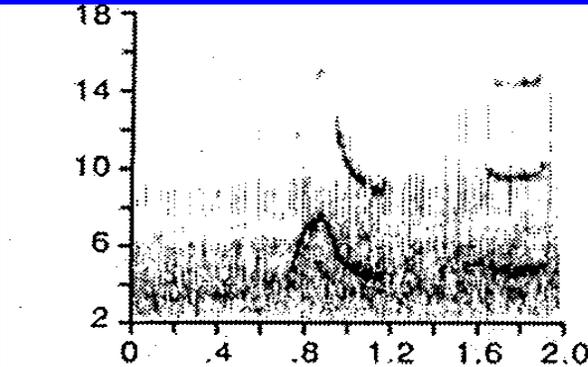


Wild dolphins respond to a whistle of a nearby conspecific by matching the whistle

Janik (2000) Science

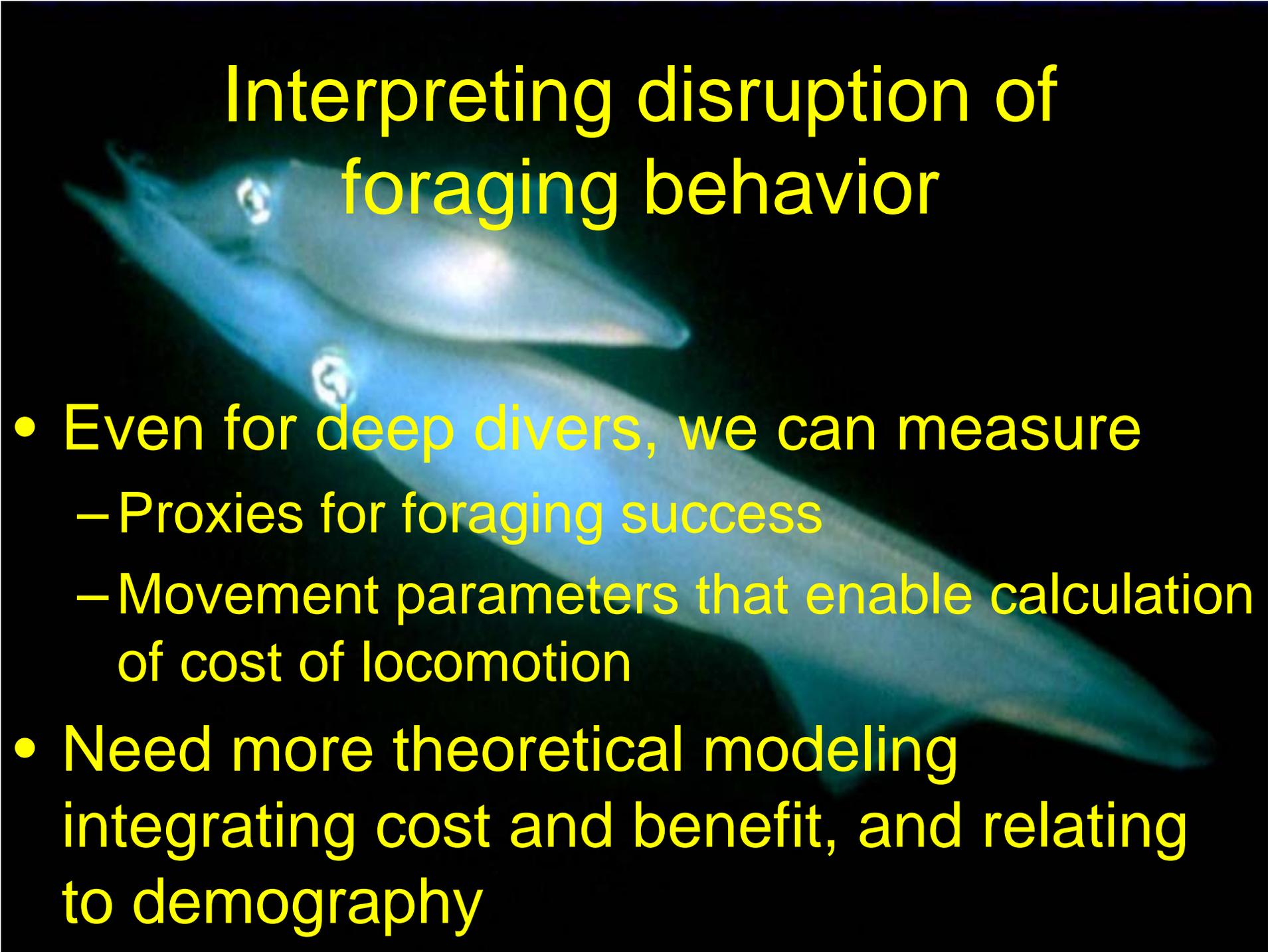
Non-Match

Match



# Effect of Noise on Contact Calls

- When might noise prevent dependent animals such as a mother and calf from maintaining contact?
  - Continuous Noise
  - Covering Frequency Band of Whistles
- When does noise interfere with more subtle communication such as vocal matching?
- We do not know the answers to these questions

Two blue dolphins are swimming in the dark ocean. They are positioned diagonally across the frame, with the one in the foreground slightly below and to the right of the one in the background. Both dolphins have small white circular markers on their heads, likely for tracking. The background is a deep, dark blue, suggesting a night or deep-sea environment.

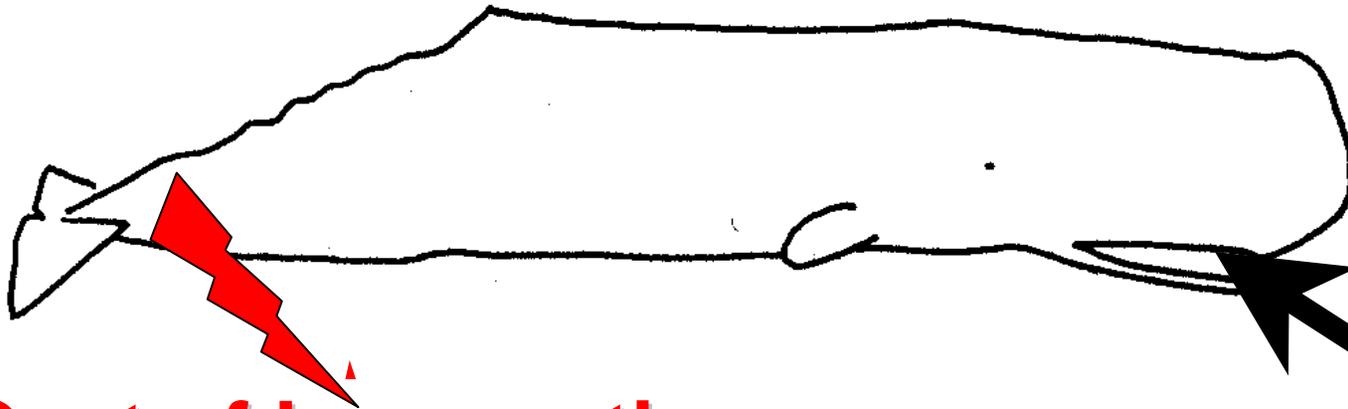
# Interpreting disruption of foraging behavior

- Even for deep divers, we can measure
  - Proxies for foraging success
  - Movement parameters that enable calculation of cost of locomotion
- Need more theoretical modeling integrating cost and benefit, and relating to demography

# Does exposure to noise cause enough disruption to significantly alter feeding success?

Energetic Model: Feeding whale needs to stay in the black.

It must take in more energy than it expends in order to build reserves for growth and reproduction



**Cost of Locomotion:**  
**Work to overcome drag,**  
**buoyancy, and inertia**

**Benefit:**  
**Creaks as**  
**metric of**  
**feeding**

# Example of Controlled Exposure Studies of Sperm Whales



- Tag, visual observation, and acoustic monitoring of behavior
- Concern about impact of airguns used for oil exploration
- Designed to evaluate effect of exposure on foraging

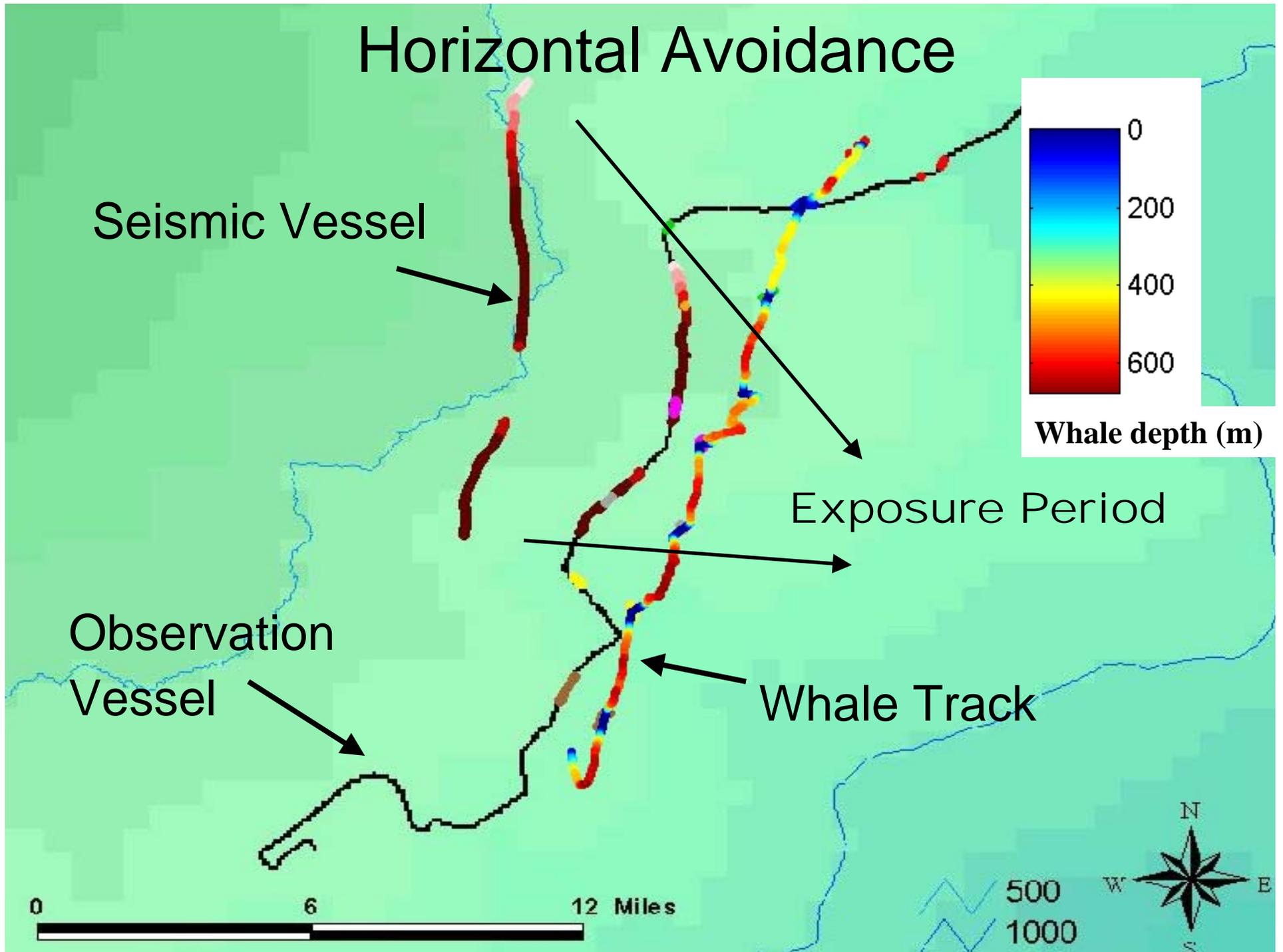


# Digital Acoustic Recording Tag

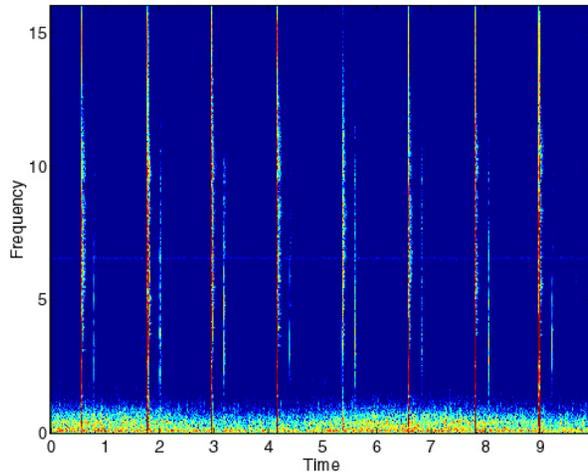
Developed by Mark Johnson, WHOI

- Measures received level of stimulus at whale while also measuring behavioral and physiological responses
- Tracks responses of marine mammals, especially deep divers, throughout their dives
- Improve understanding of functions and costs of behaviors in order to infer biological significance of behavioral disruption

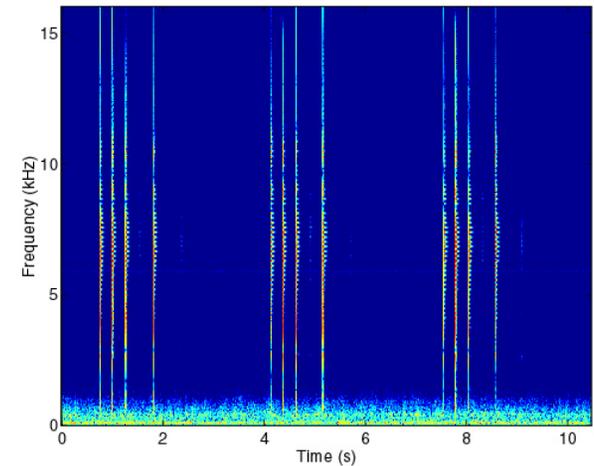
# Horizontal Avoidance



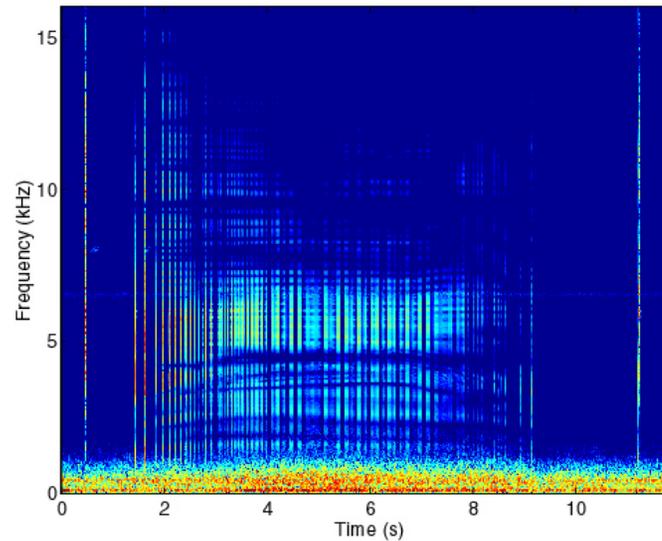
# Sperm whale vocalizations recorded on tag



Creak



Regular Clicks

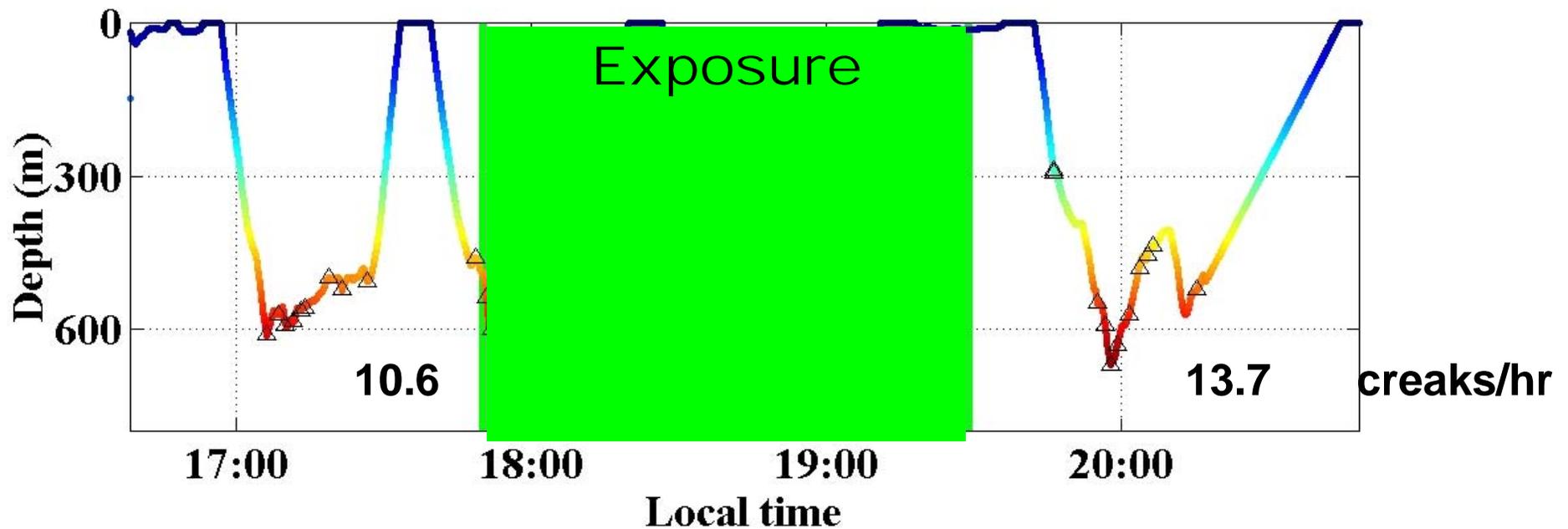


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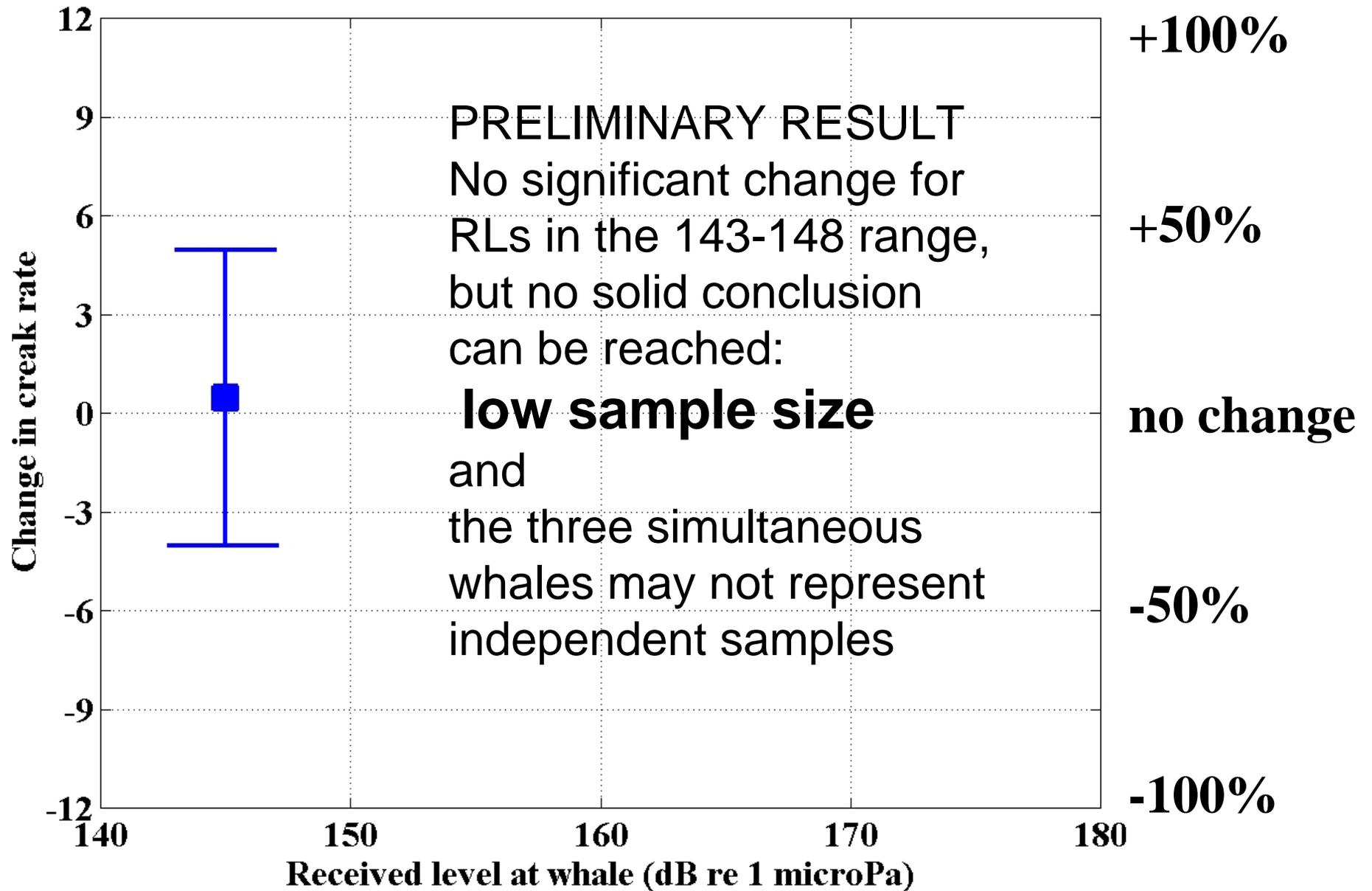


# Dive Pattern with Seismics and Creak Rates

Maximum Received Level = 143 dB<sub>rms</sub> re 1 μPa



# Mean (95% CI) of change in creak rates pre to exposure



# Key Issues for Future, Including Mitigation

	Policy Problem	Research Needed
Injury	Need Acoustic Exposure criteria for dif species, signals	
	Find area with low encounter rate	Map distribution, abundance, and dive patterns
	If rate too high, shutdown when detect	Improvement needed in detection capability, especially for submerged animals
Behavior	Treat profound disruption like risk of injury	Test most sensitive animals, e.g. beaked whales
	Habitat degradation	Test acoustic criteria for avoidance
	Lower benefit/higher cost for activity	Need models to frame cost/benefit in demographic terms