

The Golden Age of Marine Mammal Behavioral Response Studies: Recent Progress and Paradigm Shifts in Evaluation and Mitigation

DOSITS Webinar – 16 March 2016

Brandon L. Southall, Ph.D.

Southall Environmental Associates, Inc.



UC Santa Cruz – Long Marine Laboratory
Duke University Marine Laboratory



Presentation Outline

- * Historical Studies of Marine Mammal Behavioral Responses to Noise*
- * New Technologies - New Capabilities*
- * Recent Progress in Marine Mammal Behavioral Response Studies*
- * New Paradigms - Exposure Context & Broader Perspectives on Behavioral Disturbance*

Conventional regulatory view

Single sound source



2-D sound “isopleths” with impacts based solely
on exposure level “thresholds”



In reality, the ocean is full of many overlapping natural and human sound sources

THE BIG IDEA | OCEAN NOISE

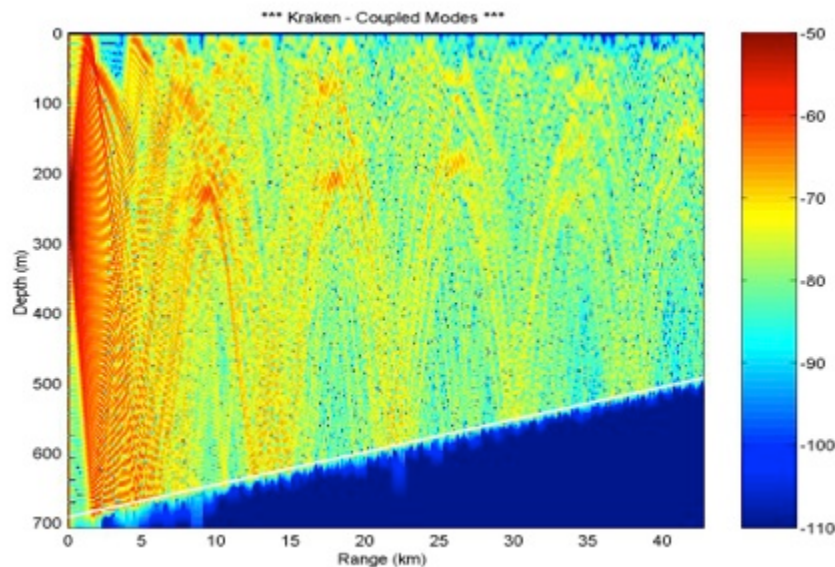
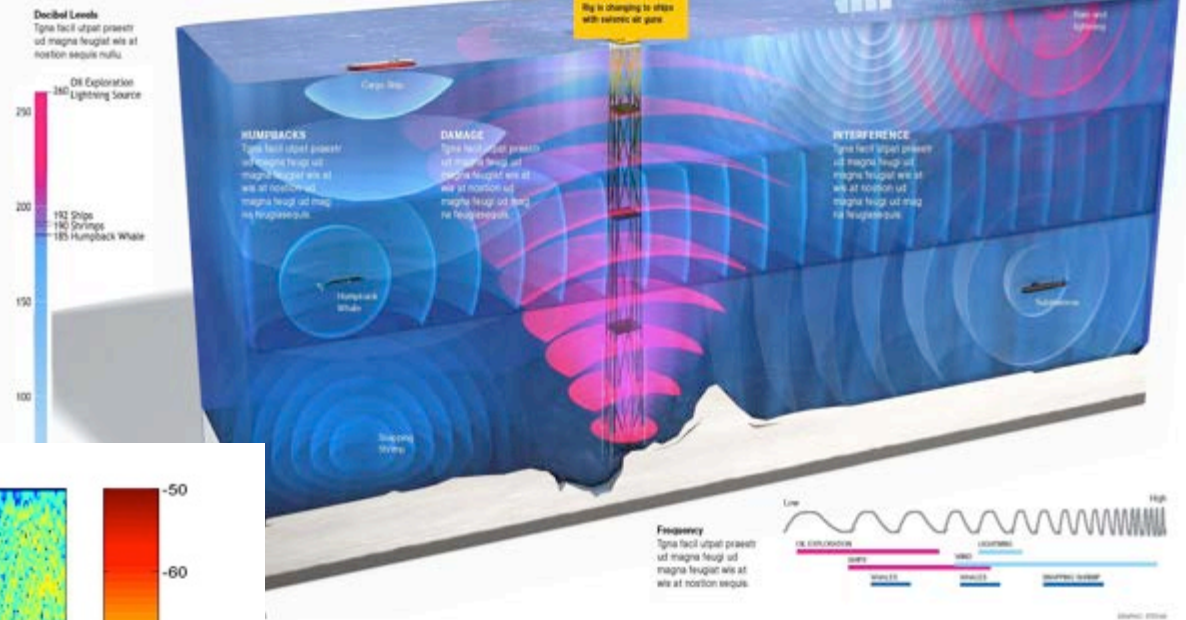
Waves of Sound

The sea is a noisy place. Understanding how it works means something.

FAR FROM THE 'SILENT DEEP' of lore, oceans are rich and complex soundscapes. Sound travels many times faster and further in water than light does; not surprisingly, whales and other marine mammals, fish, and even some invertebrates depend on sound to find food and mates,

navigate, communicate, and avoid predators. But now a fast-rising barrage of human-created noise is transforming marine soundscapes in ways that scientists are just beginning to understand.

Hundreds of naval vessels use submarine-hunting sonar systems whose intense sound pulses have triggered several high-profile mass whale strandings during training exercises. Round-the-clock bursts from airplanes (Continued on next page)



Real sound propagation highly variable

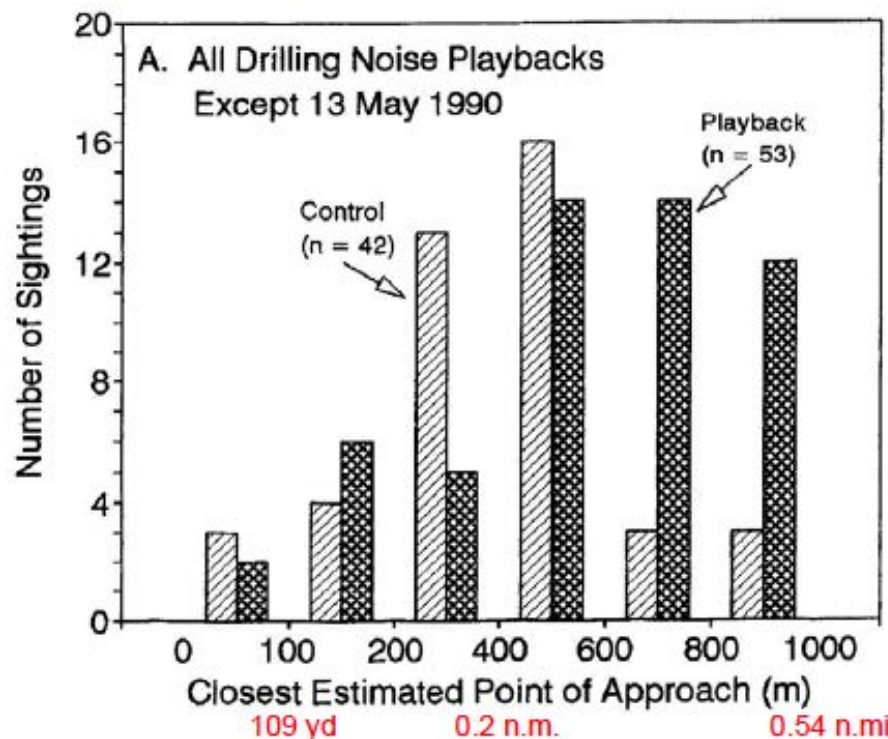
Measuring Marine Mammal Behavior

- Experimental Methods
 - *Controlled Exposure Experiments (CEEs)* with FIELD and LAB BRS Approaches
- Observational/Opportunistic Methods
 - *Behavioral Monitoring* during ongoing activities (uncontrolled)



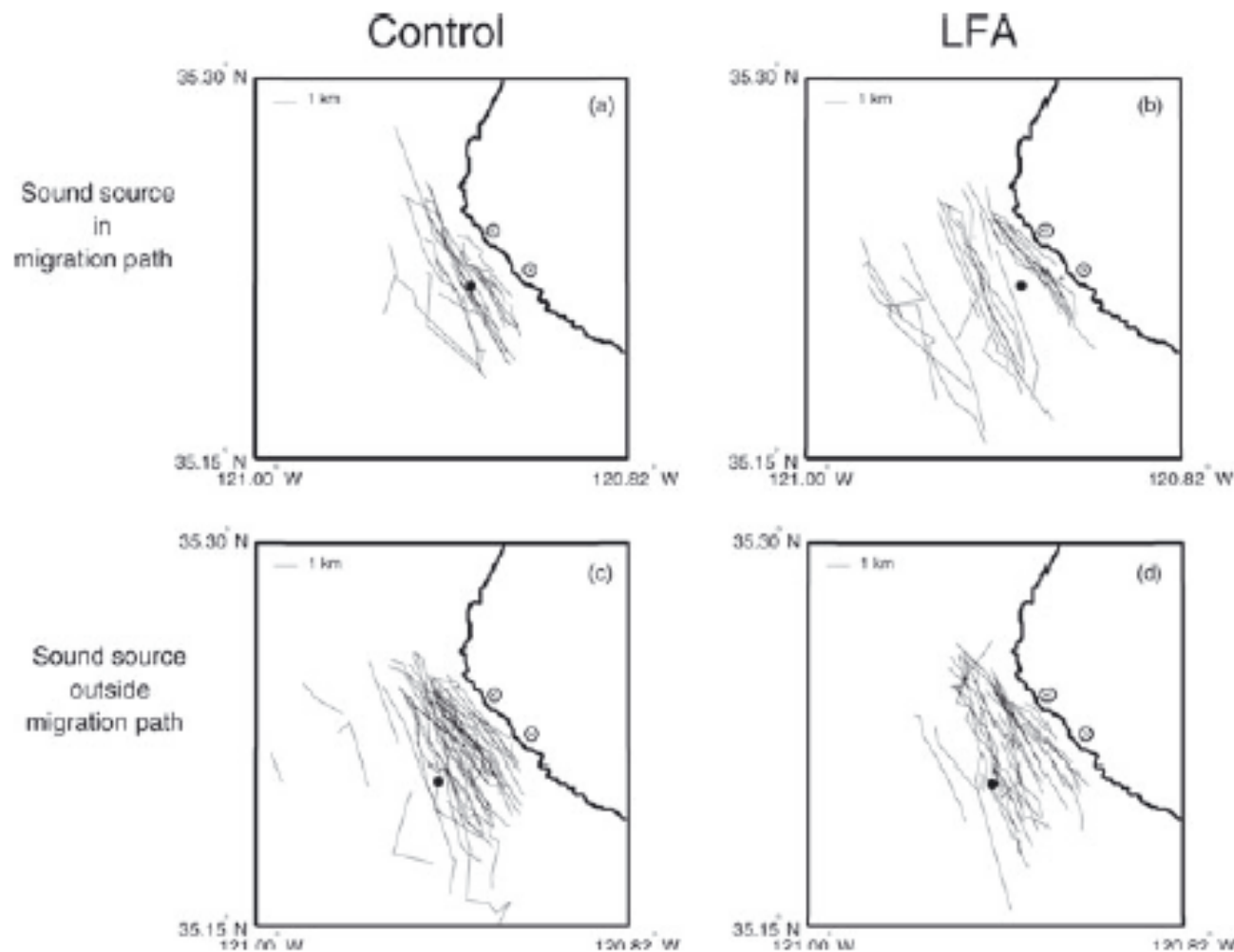
Historical Experimental Studies of Marine Mammal Behavioral Response

Closest Approach of Bowheads to Sound Projector, Drilling Noise Playbacks vs. Silent Control



During playbacks, bowheads tended to remain 400+ m (0.2 n.mi.) from projector. At that distance, received level ~115 dB re 1 μ Pa.

Historical Experimental Studies of Marine Mammal Behavioral Response



Courtesy: J. Buck,
P. Tyack

Field Behavioral Response Studies: Key Technological Innovation

Evolution of **non-invasive, remote-deployed, archival tags** to obtain high-resolution, multivariate individual data

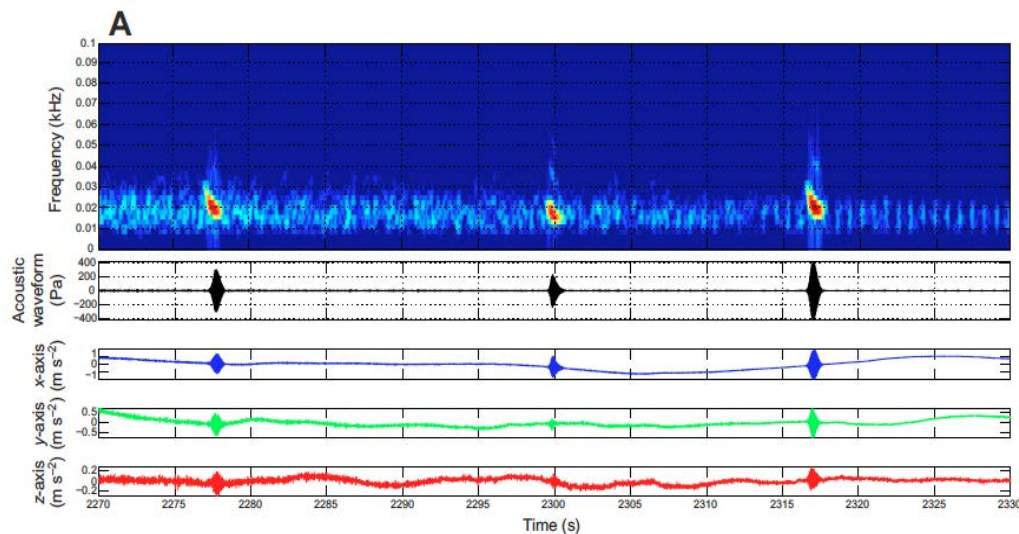
- Depth (pressure sensors)
- 3D movement (accelerometers, magnetometers)
- Light (photo sensors)
- High-sampling rate acoustics (up to 512 kHz; multiple hydrophones)
- Lat/Lon position



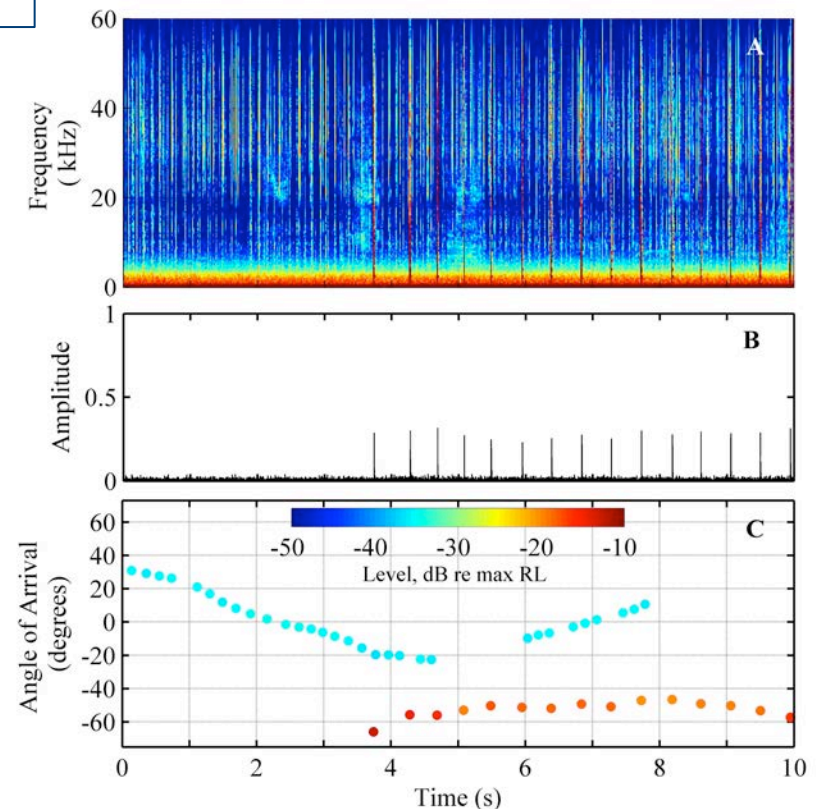
Quantifying Behavior & Responses: Technological Innovations

Identifying Vocalizing Individuals (Response, Density Estimates)

Accelerometers to identify
calling fin whales
(Goldbogen et al., 2014)



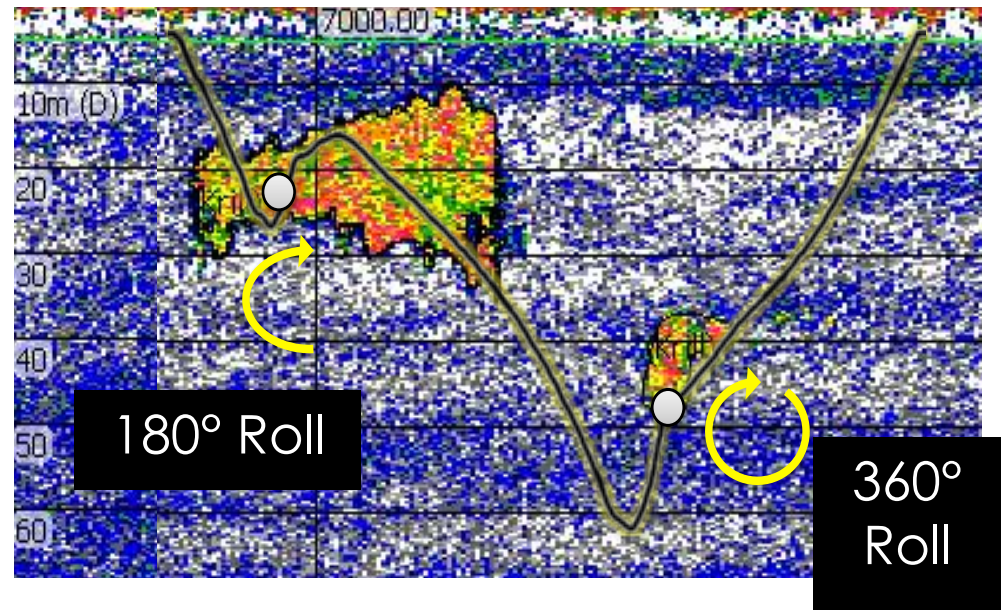
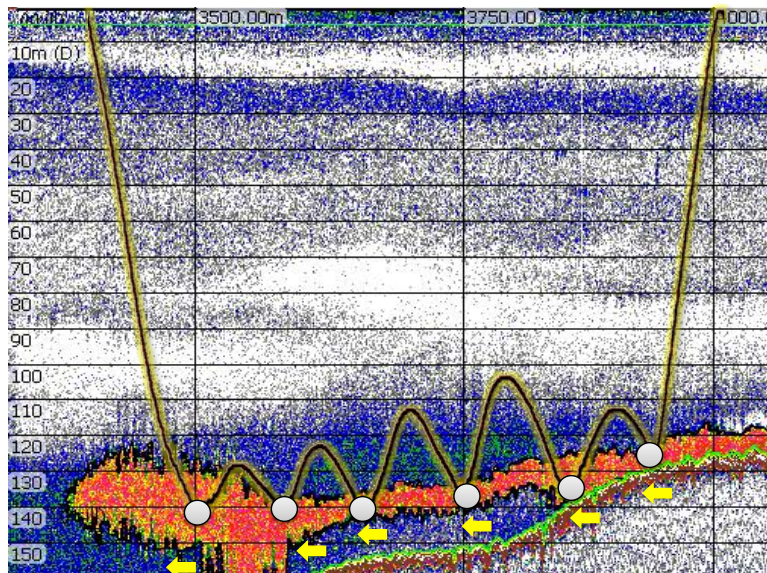
Time of arrival differences to
identify clicking Risso's dolphins
(Arranz et al., in review)



Quantifying Behavior & Responses: Technological Innovations

BEHAVIORAL CONTEXT: Synoptic, Direct Measurements of Prey for Feeding Animals

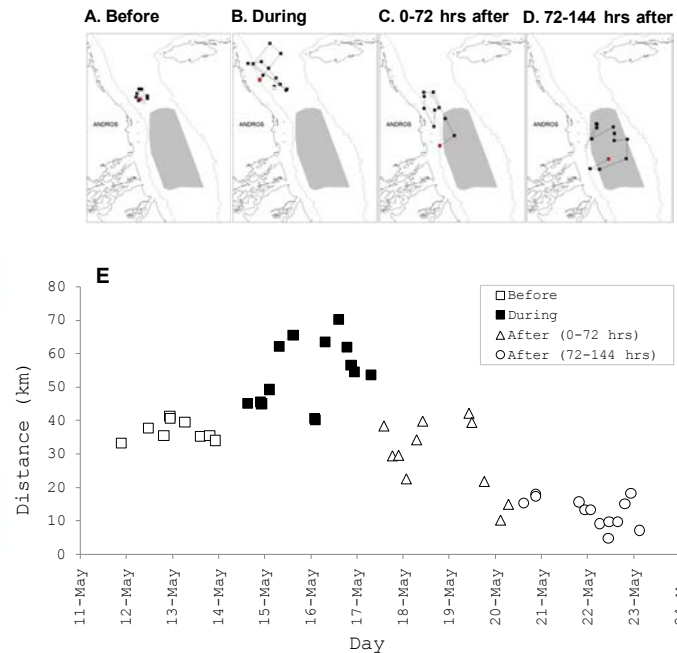
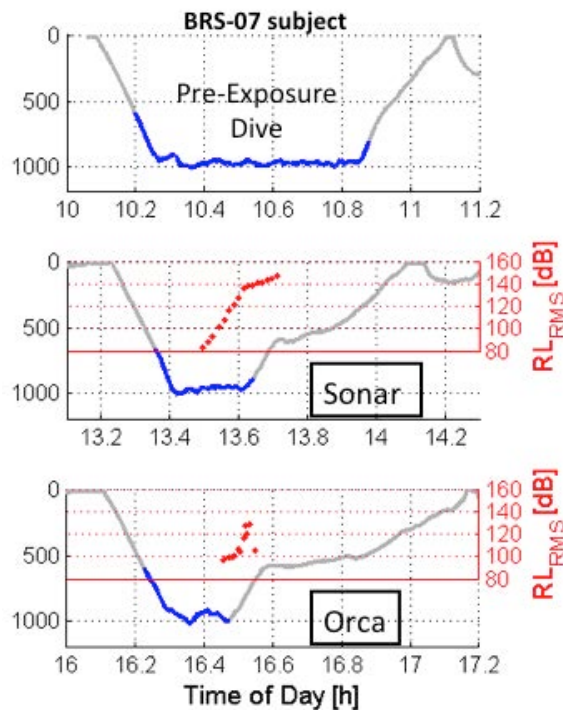
- *Five-fold increase in ability to describe variance in behavior in CEEs*



Recent Progress in Marine Mammal Behavioral Response Studies

Bahamas (AUTECH): 2007-2008

- US Navy/NOAA coordinated BRS to obtain direct data on responses of cetaceans (including beaked whales) to the tactical mid-frequency sonars involved in previous stranding events

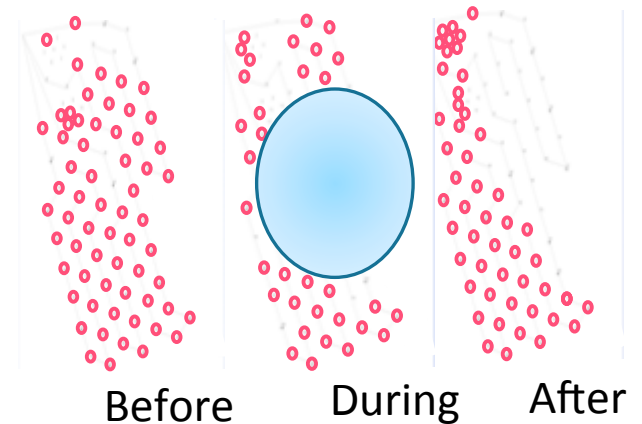


OPEN ACCESS Freely available online

PLoS one

Beaked Whales Respond to Simulated and Actual Navy Sonar

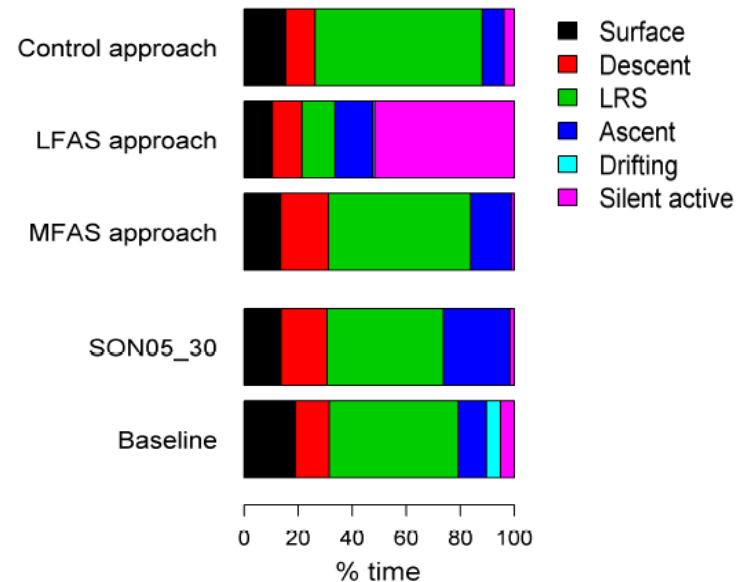
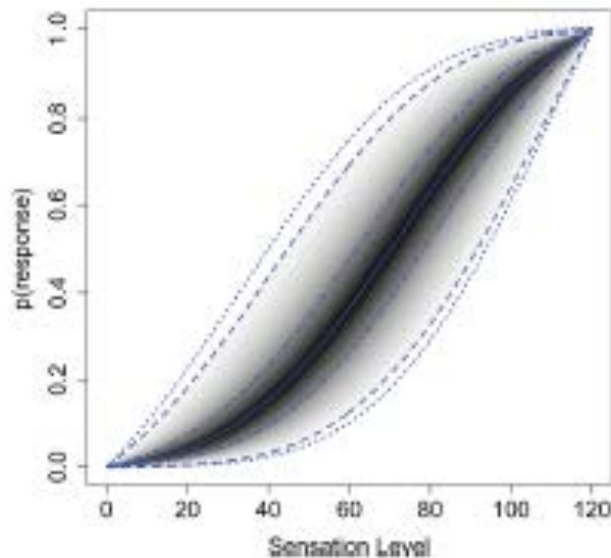
Peter L. Tyack^{1,2}, Walter M. X. Zimmer³, David Moretti⁴, Brandon L. Southall^{1,5}, Diane E. Claridge⁶, John W. Durban⁷, Christopher W. Clark⁸, Angela D'Amico⁹, Nancy DiMarzio⁵, Susan Jarvis¹, Elena McCarthy⁹, Ronald Morrissey⁹, Jessica Ward¹, Ian L. Boyd^{1,9}



Recent Progress in Marine Mammal Behavioral Response Studies

3S Program (Norway): 2007-present

- Dutch/Norwegian collaboration to measure responses operational Navy sonars
- Operational, mobile sources approach subjects to increase dose



Miller et al., 2012; 2014; Cure et al., 2013; Wensveen et al., 2015; Isojunno et al., 2016

Recent Progress in Marine Mammal Behavioral Response Studies

BRAHHS Program (Australia): 2010-present

- Australian collaboration to measure potential behavioral responses and significance for migrating humpback whales to seismic airgun surveys
- High sample sizes, careful controls, different exposure conditions (small airgun, ramp-up, full airgun array)

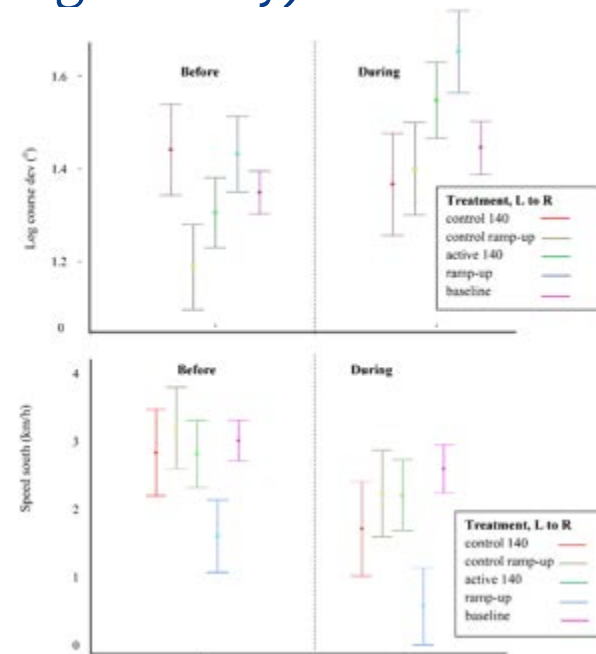


Behavioural Response of
Australian Humpback whales
to Seismic Surveys

<http://www.brahss.org.au/>

Single airgun BRS

- Decreases in dive time and southbound migration during exposure
- Effect not correlated with source distance, RL, source direction, or exposure time
- Orienting responses to source vessel



**Airgun
Ramp-Up**

Recent Progress in Marine Mammal Behavioral Response Studies



Southern California (SOCAL) BRS: 2010-present

- > 175 tags deployed on 10 species; 80 CEEs using simulated and **actual Navy sonar**
- Variables (beyond received level): Behavioral state, prey distribution, spatial orientation/movement
- Responses: avoidance; changes in diving, feeding, social
- Certain species (beaked whales) appear particularly sensitive; other species are more tolerant but variable depending on exposure context

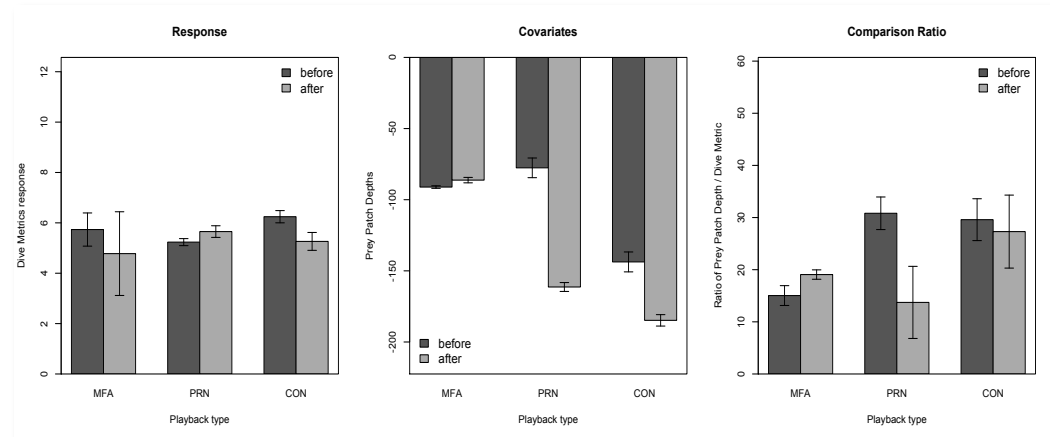
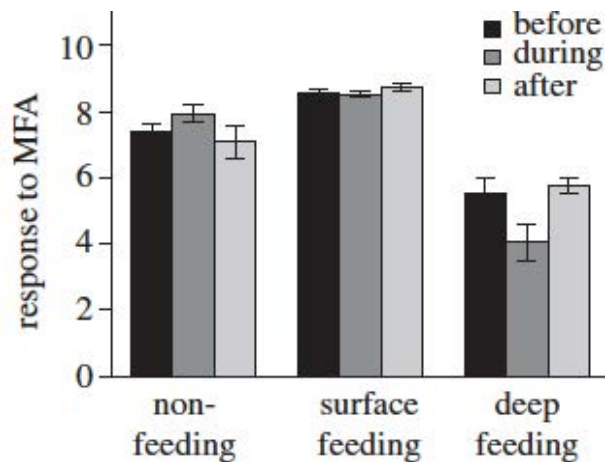
www.socal-brs.org

Recent Progress in Marine Mammal Behavioral Response Studies

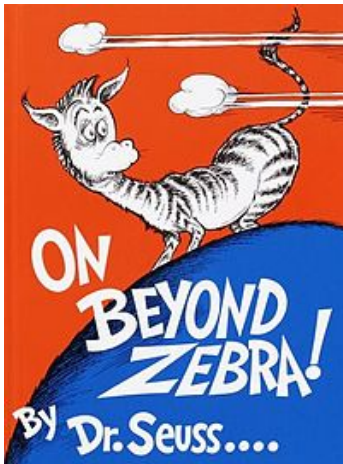
Southern California (SOCAL) BRS: 2010-present



www.socal-brs.org



Contextual aspects of exposure (e.g., behavioral state, prey distribution, relative proximity) can be as or more important than received level



On beyond thresholds...

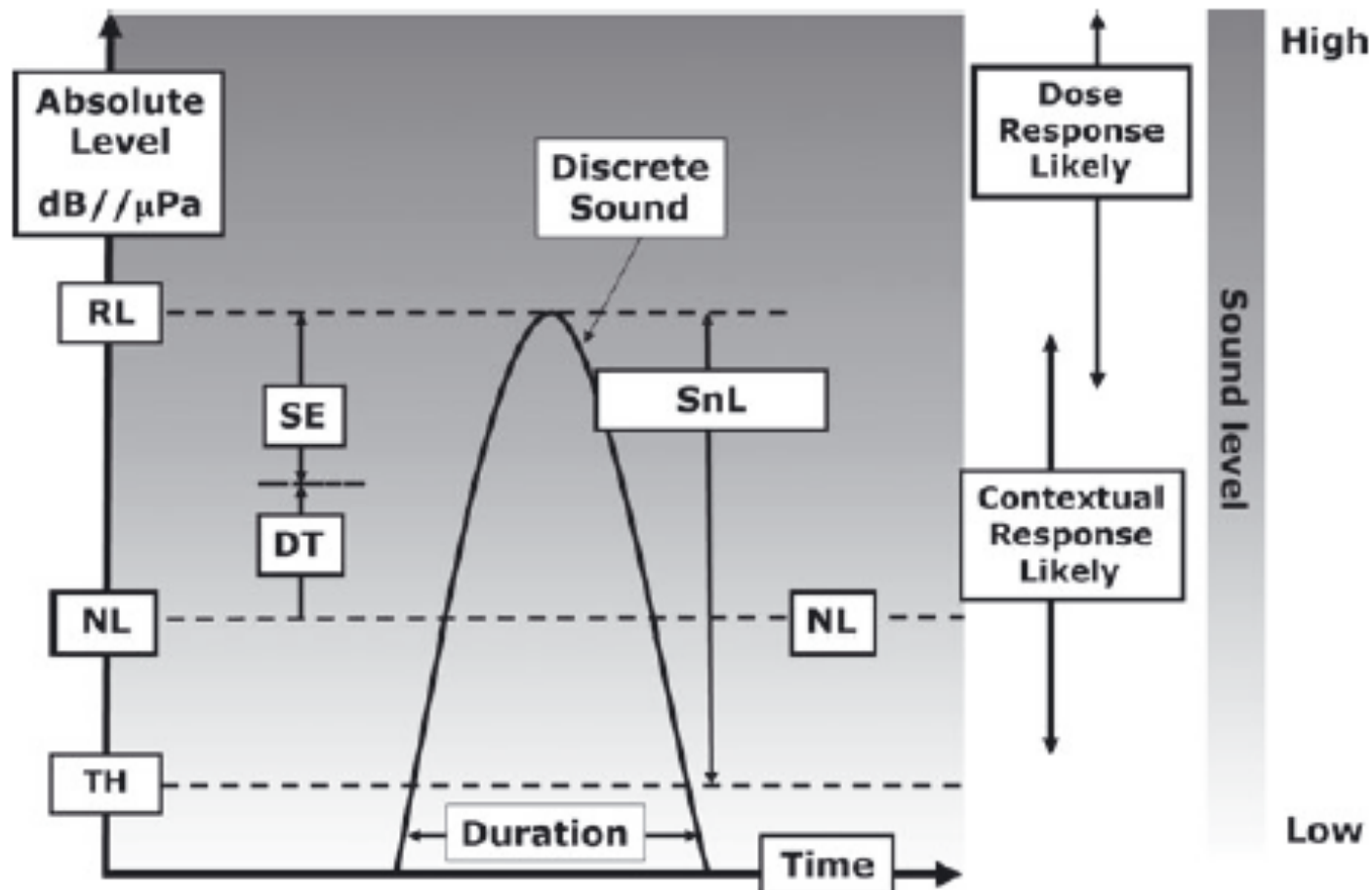
Conservation Biology



Conservation Practice and Policy

A New Context-Based Approach to Assess Marine Mammal Behavioral Responses to Anthropogenic Sounds

W.T. ELLISON,* B.L. SOUTHALL,†‡ C.W. CLARK,§ AND A.S. FRANKEL*



New Paradigms - Exposure Context & Broader Perspectives on Behavioral Disturbance

- Species differences in response probability exist, with some particularly sensitive species (*e.g.*, beaked whales, harbor porpoise, melon-headed whales)
- Received level is one of many exposure contextual factors (behavioral state, exposure-animal proximity)
 - Don't have to measure every possible contextual combination
- Quantitative exposure estimates can be improved using probabilistic movement models that incorporate behavior

New Paradigms - Exposure Context & Broader Perspectives on Behavioral Disturbance

- Ultimately the severity and consequences of response matter most, not just exposure or discrete response (PCOD)
- Exposure (“take”) estimates must be put into biologically-meaningful, real-world context – risk assessment
- Exposure-response analyses in regulatory processes must incorporate new paradigms of response complexity and consequence; mitigation measures must remain simple

ACKNOWLEDGMENTS



RESEARCH PROGRAMS

