Controlled exposure experiments (CEEs) with full-scale military mid-frequency active sonars (MFAS) in four cetacean species

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Photos taken under U.S. NMFS permits #14534; 19116

Overview and Objectives

- Valid concerns about sonar effects on marine mammals have been informed by recent research (see: Southall *et al*, 2016)
    - *Potential stranding issues, but also non-lethal disturbance*

- Increasing evidence that key contextual variables mediate behavioral response type and probability

    (Ellison *et al*, 2012; Goldbogen *et al*, 2013; Friedlaender *et al*, 2016; DeRuiter *et al*, 2013; 2017)

- CEEs enable independent evaluation of specific variables not possible with observational methods

- Need to directly evaluate the most powerful MFAS systems

OBJECTIVES

➢ *Safely apply proven CEE methods using full-scale, operational sources*

➢ *Evaluate CEE results relative to those with simulated MFAS*

➢ *Provide results directly applicable to management decisions*

Experimental Methods
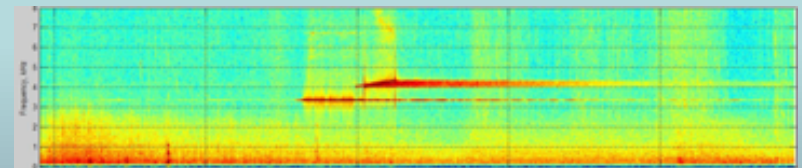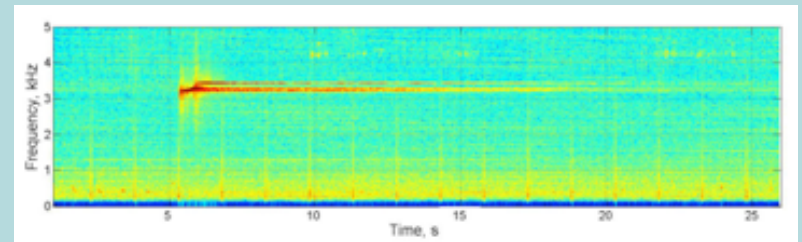

High-resolution archival tags

Short-duration (hours) archival acoustic, dive sensors (DTAG)

Med-duration (weeks) archival acoustic, dive, GPS (see: Szesciorka et al. poster – group A, Bay 4.5)

Controlled Exposure Experiments (CEEs)

coordinated with real operations - speed, orientation, and desired RL controlled (*2 source types*)

AN-SQS-53C

AN-AQS-22

Response Analyses:

Quantitative, cluster-based statistical methods with synoptic behavioral metrics (**Mahalanobis distance** (MD)) to inform **expert evaluation of response severity**

(based on Southall et al. (2007) adapted by Miller et al., 2012)

Photos taken under U.S. NMFS permits #14534; 19116

CEEs Conducted and Known Incidental Exposures to Operational Sonar Sources

| SUBJECT SPECIES	CEEs AN-SQS 53C tactical sonar (hull-mounted)	CEEs AN/AQS-22 tactical sonar (helicopter-dipped)	Incidental (source type)
BLUE WHALE (*Balaenoptera musculus*)	8	3	**3** (53C) **1** (unknown ~1 kHz)
FIN WHALE (*Balaenoptera physalus*)	2		
CUVIER'S BEAKED WHALE (*Ziphius cavirostris*)	1		**1** (53C)
RISSOS DOLPHIN (*Grampus griseus*)	2		
TOTAL	13	3	5

Categories of Behavioral Responses Identified

- No behavioral response identified

- Behavioral response identified, but not scored as having potential adverse effects (*e.g.*, onset of foraging)

- Behavioral response identified and scored as having potential adverse effects of variable severity based on type, duration, other factors (as in Southall et al., 2007; Miller et al., 2012)

- Subset of potential responses when incomplete data available or limited exposure data (uncontrolled incidental)
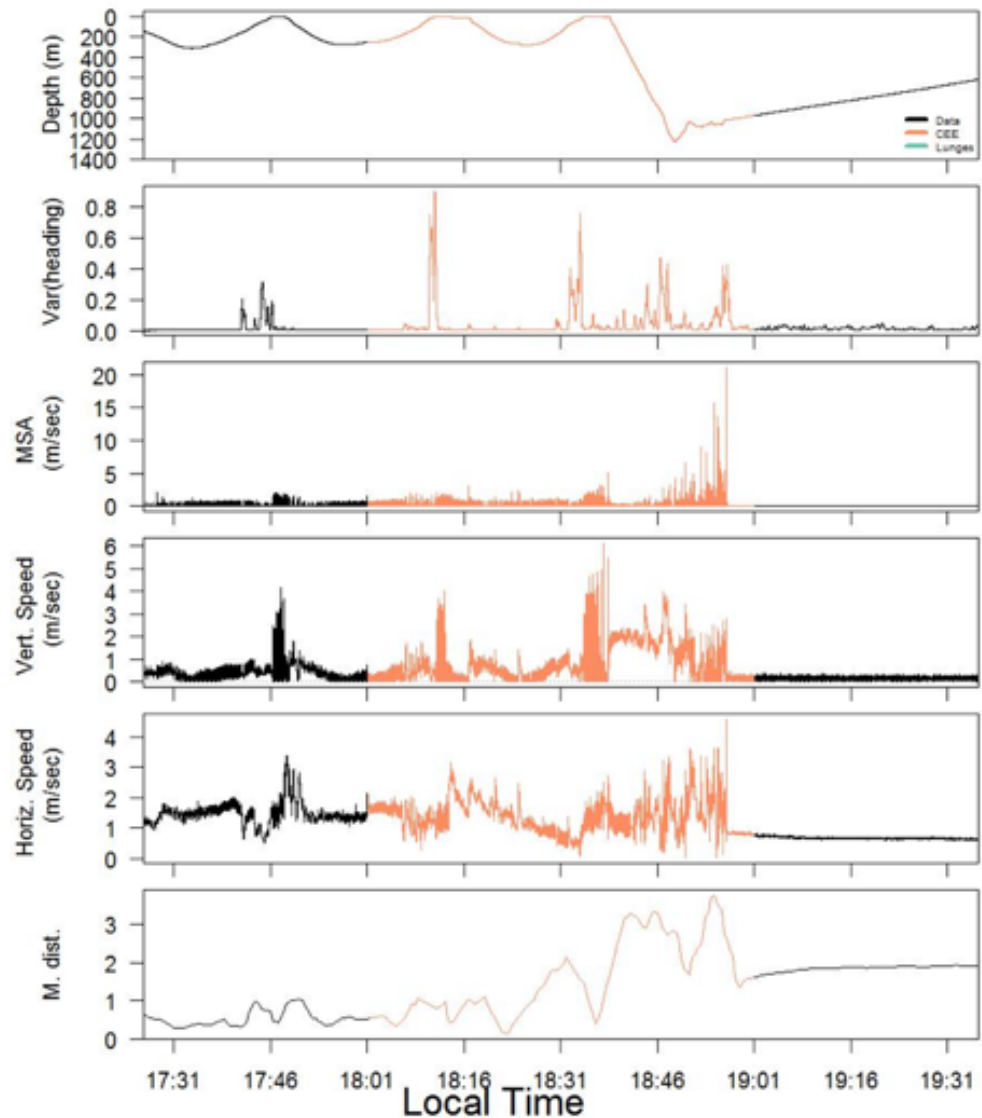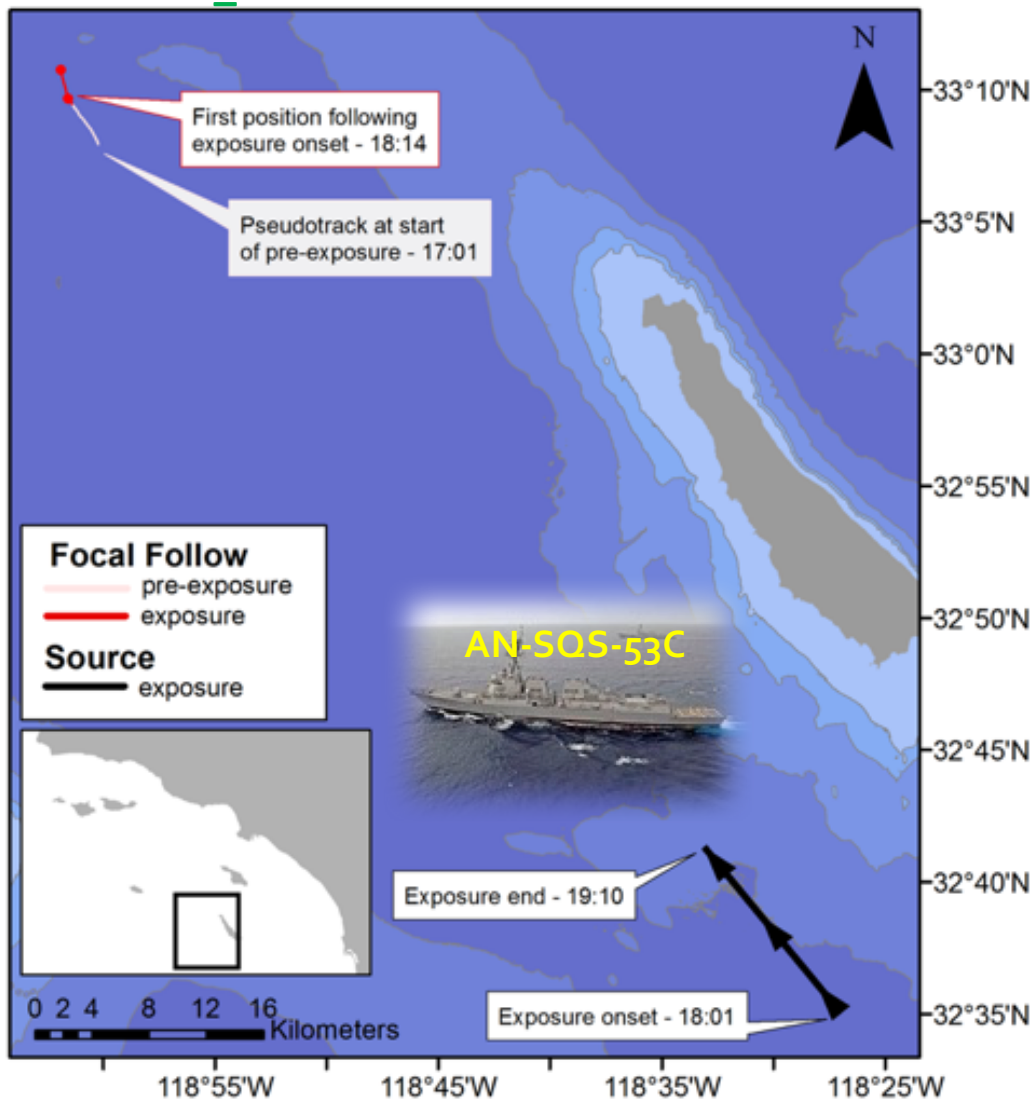
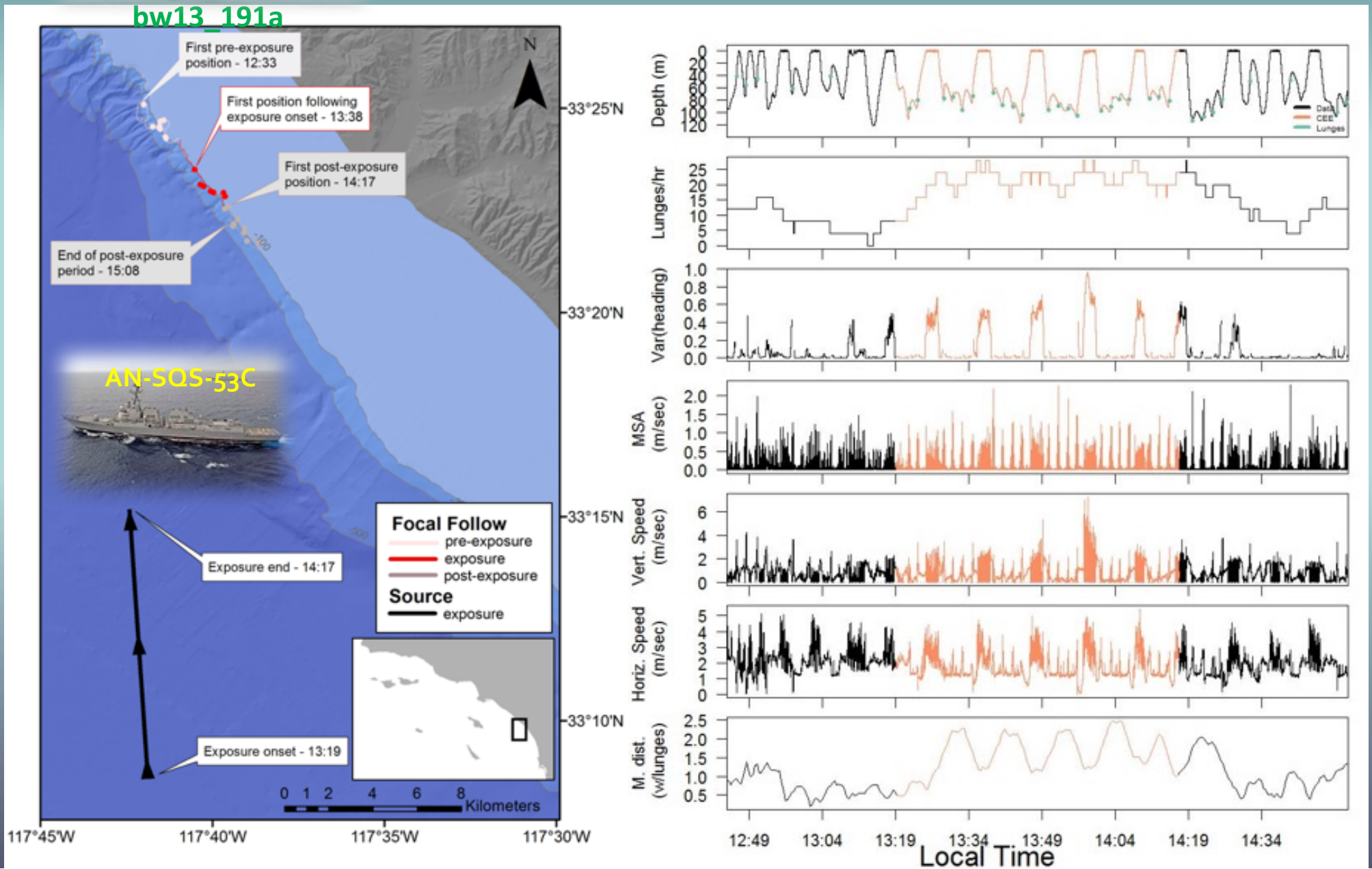# *RESULTS*: NO BEHAVIORAL CHANGE IDENTIFIED

bw16_264b
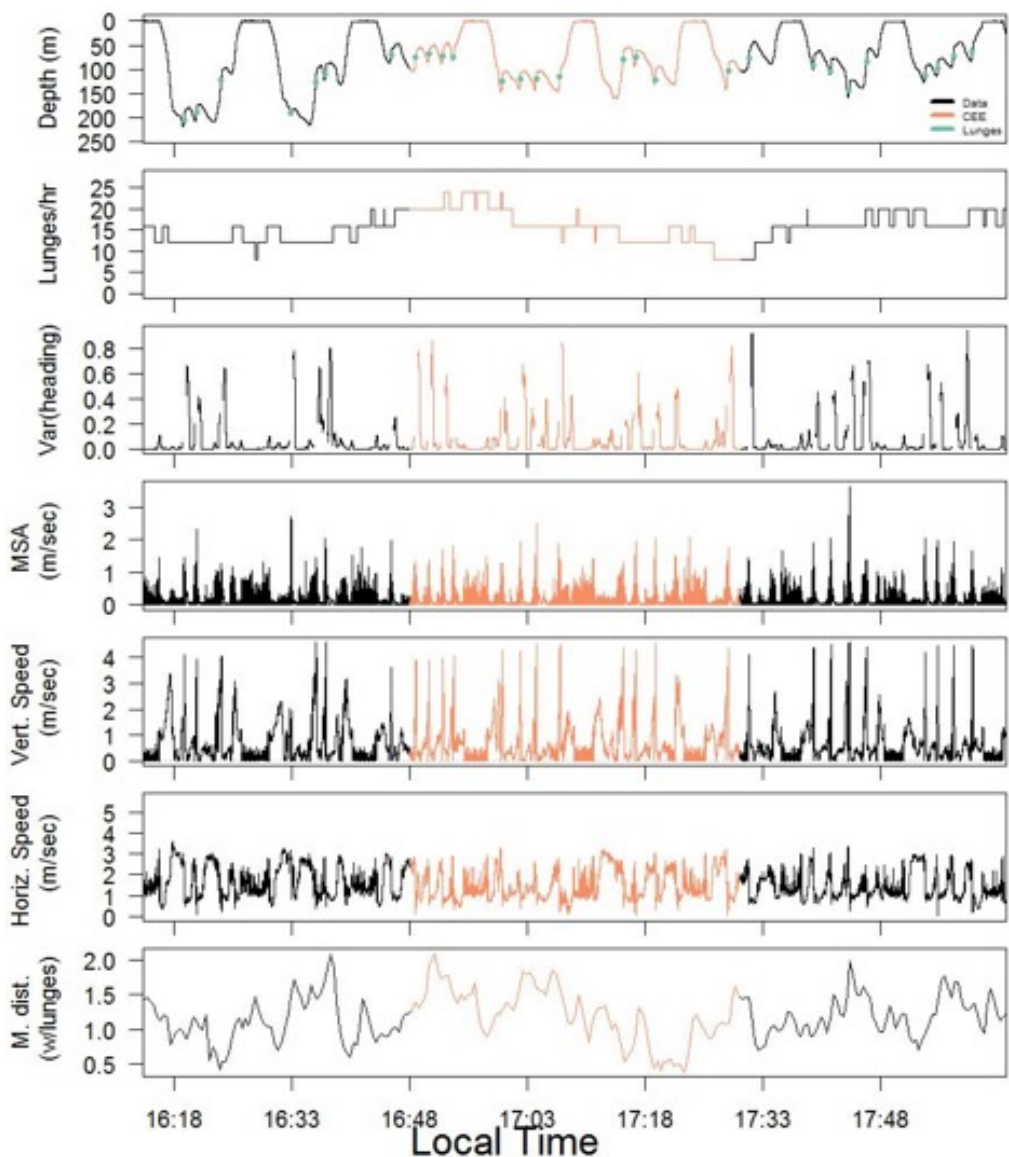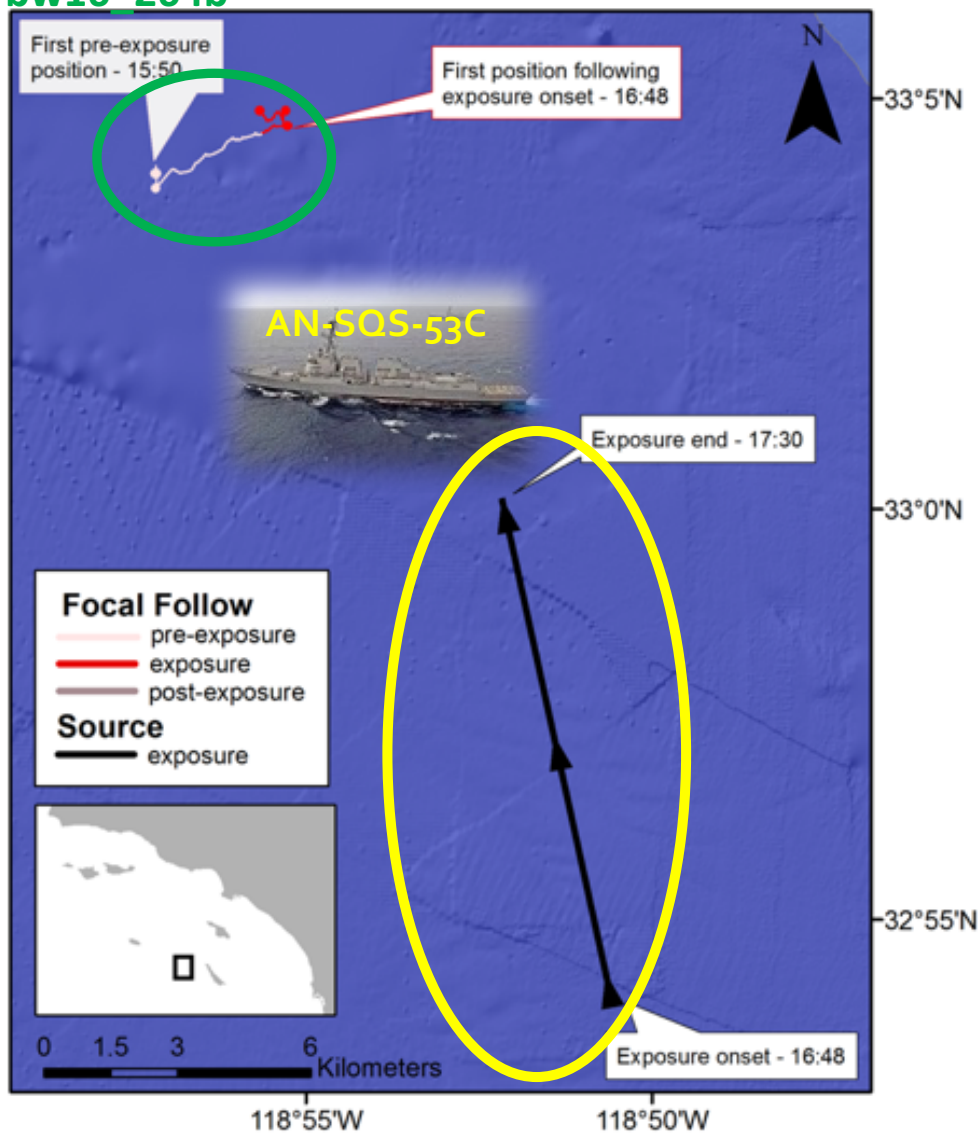
NO BEHAVIORAL CHANGE IDENTIFIED

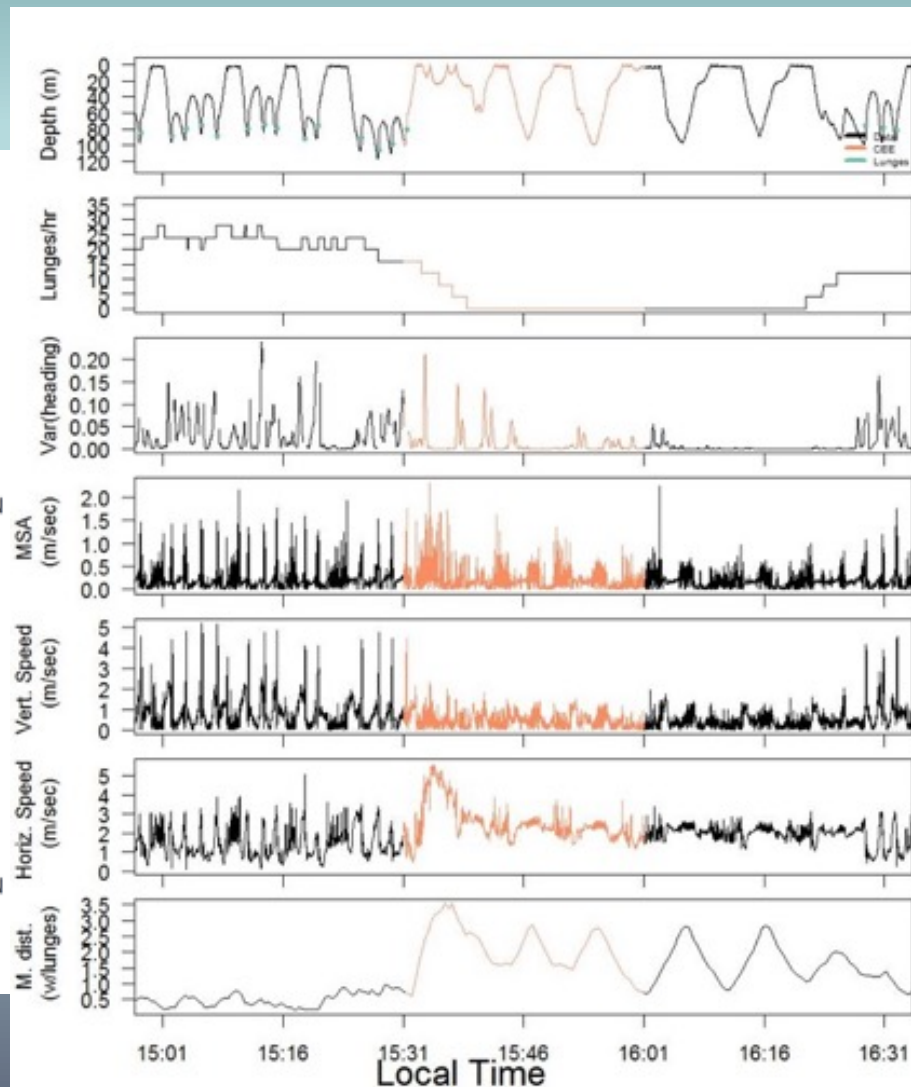
zc13_210a

BEHAVIORAL CHANGES IDENTIFIED
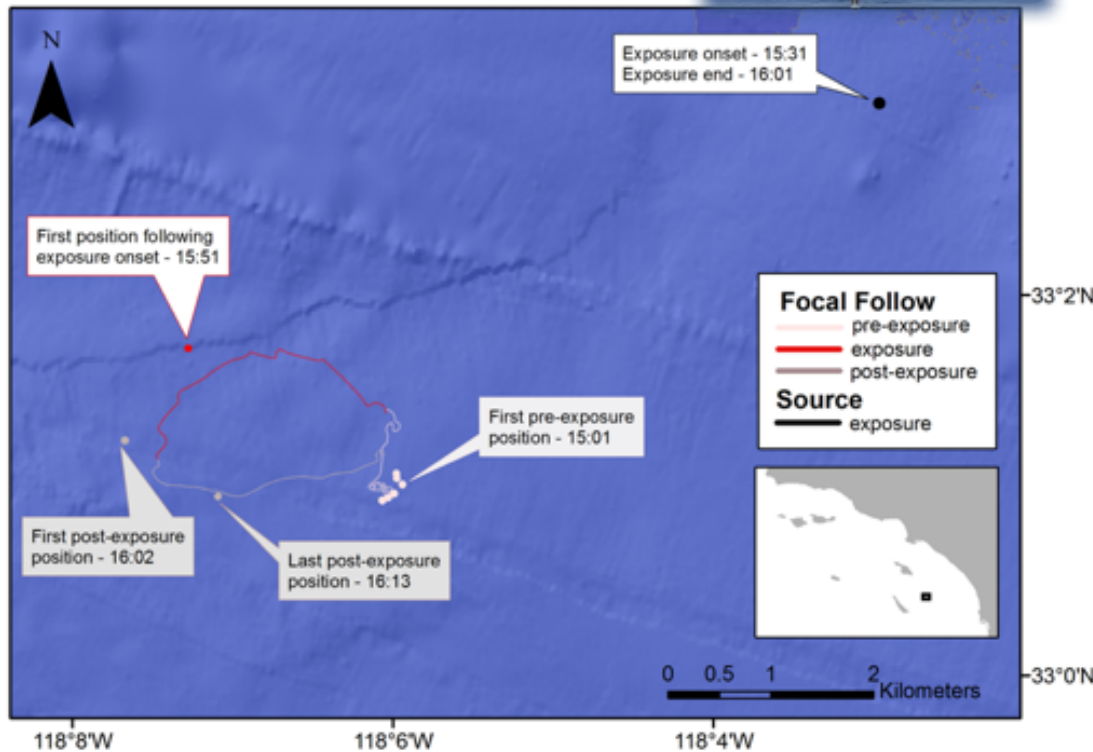## *(not scored adverse effect)*

BEHAVIORAL CHANGE IDENTIFIED
(scored as adverse effect)

AN-AQS-22

20160817-B021-BM

Example CEEs or incidental exposures with partial data - *subset of response analyses*

bw15_232b

bw15_TDR10
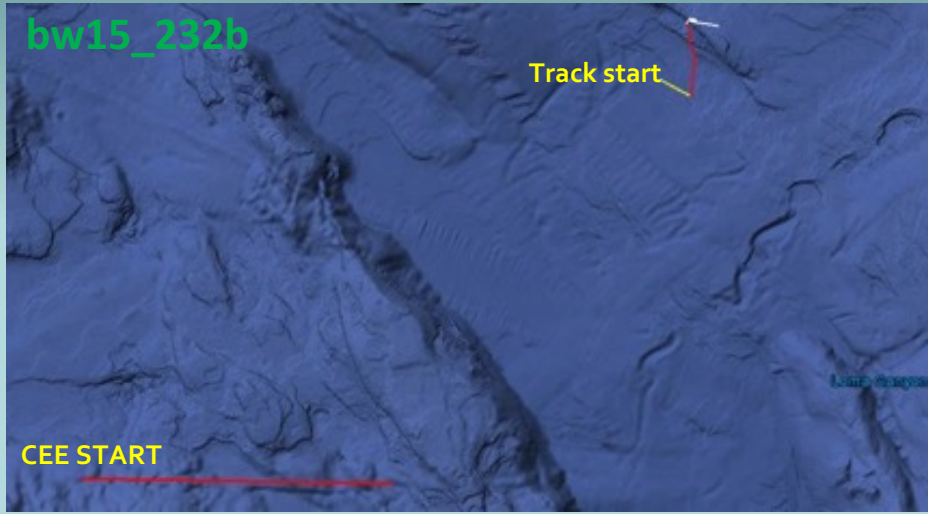
- **Focal follow only; tag lost**
- **Ship position and transmission known**
- **Evaluated potential avoidance; behavioral state**
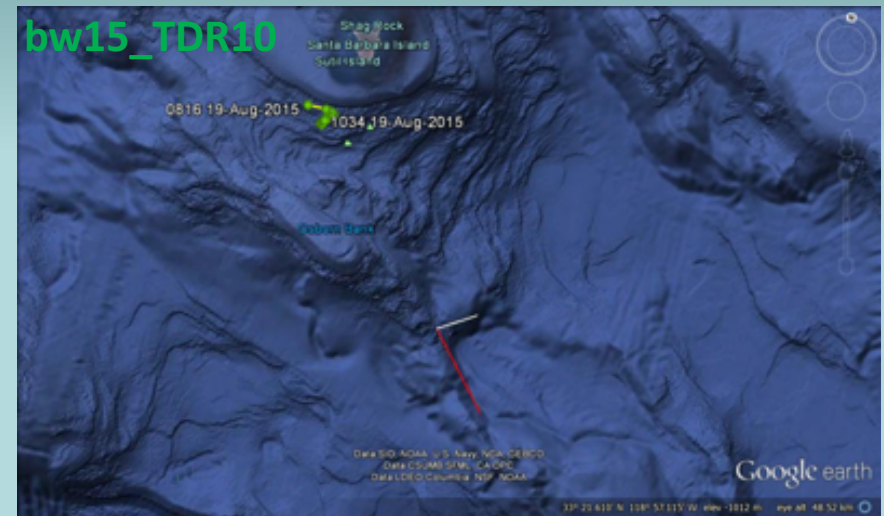
- **Archival tag with no acoustics; position known**
- **Ship position observed directly; MFAS transmission confirmed by other means**
- **Attempted to verify MFAS but Navy's SPORTS database incorrectly indicated no transmission**
- **Excluded from analysis given incorrect and misleading info on exposure (see: Falcone et al., 2017)**

Behavioral Response Analyses
(vessel hull-mounted sonar)

AN-SQS-53C

Subject Species	CEE or Incidental	Behavioral Change Scored?	Received Level (dB re 1µPa RMS at change or max)
Blue whale (2013)	CEE	NO	146
Blue whale (2013)	CEE	NO	148
Blue whale (2015)	CEE	YES – mod. change speed; mod. avoidance	146 (max. modeled)
Blue whale (2015)	Incidental	*not scored – insufficient/misleading data*	-
Blue whale (2016)	CEE	NO	147
Blue whale (2016)	CEE	*not scored – insufficient data*	-
Blue whale (2016)	CEE	YES – minor change in dive behavior	<100
Blue whale (2016)	CEE	NO	<100
Blue whale (2016)	Incidental	NO	<100
Blue whale (2016)	Incidental	NO	<100
Fin whale (2013)	CEE	NO	110
Fin whale (2015)	CEE	NO	130
Cuvier's beaked (2013)	CEE	NO	125
Cuvier's beaked (2013)	Incidental	NO	115
Risso's dolphin (2013)	CEE	NO	128
Risso's dolphin (2013)	CEE	NO	131

Behavioral Response Analysis
(helicopter-dipping sonar)

AN-AQS-22

Subject Species	CEE or Incidental	Behavioral Change Scored?	Received Level (dB re 1µPa RMS at change or max)
Blue whale (2016)	CEE	YES – mod. avoidance, cessation of feeding, change in dive behavior	141
Blue whale (2016)	CEE	NO	142
Blue whale (2016)	CEE	YES – minor avoidance; minor cessation of feeding	146

Behavioral Response Analysis
(Unknown Sonar ~1 kHz tonal)

Subject Species	CEE or Incidental	Behavioral Change Scored?	Received Level (dB re 1µPa RMS at change or max)
Blue whale (2016)	Incidental	NO	< 110

Evaluation of CEE Exposure Context:
Deep-feeding blue whales – operational and simulated MFAS

| Subject Species	Source Type	Behavioral Change?	Source-Subject Range (km)	Received Level (dB re: 1uPa RMS at change or max)	Source Type Summary
Blue whale (2013)	SQS-53C (8 kt transit speed; 235 dB SL)	NO	28.1 (start) to 12	146	**Responses: 0/3** Range: 12-32.2 km RLs: 146-148
Blue whale (2013)		NO	32.2 (start) to 18	148	
Blue whale (2016)		NO	29 (start) to 12.5	147	
Blue whale (2016)	ASQ-22 (stationary from helo; 217 dB SL)	YES	8.1	141	**Responses: 2/3** Range: 7.9-8.1 km RLs: 141-146
Blue whale (2016)		NO	8.2	142	
Blue whale (2016)		YES	7.9	146	
Blue whale (2010)	Simulated SQS-53C (expt. source from stationary vessel; 212 dB SL)	YES	2.8	113	**Responses: 8/12** Range: 0.8-2.8 km RLs: 114-155 (at changes for responses) RLs: 159-161 (max RL where no response) (Southall *et al.*, in prep)
Blue whale (2010)		NO	1.5	159	
Blue whale (2010)		NO	1.3	161	
Blue whale (2011)		NO	1.2	161	
Blue whale (2011)		YES	0.8	117	
Blue whale (2011)		NO	1.0	160	
Blue whale (2011)		YES	1.3	155	
Blue whale (2011)		YES	1.2	121	
Blue whale (2014)		YES	0.7	126	
Blue whale (2014)		YES	1.1	131	
Blue whale (2014)		YES	0.8	111	
Blue whale (2014)		YES	1.4	123	

Summary and Conclusions

- First CEEs using most powerful operational MFAS for four cetacean species, including sensitive, endangered species

- Lower response probability at similar RLs for loudest sources (SQS-53C) at greater ranges than lower power (AQS-22) or simulated MFAS

- Simulated MFAS more similar to helicopter-dipping sonars than mobile, hull-mounted systems

- Additional studies of context and range-dependencies needed to inform contextual exposure-response functions

   o *Leverage large existing blue whale data set to systematically test additional far-loud and near-quiet treatments*

Acknowledgements

Sponsors: US Navy Living Marine Resources

Program & **ONR Marine Mammal Program**
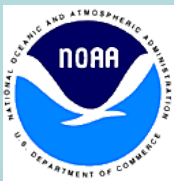
NOAA: NMFS Offices of Science & Technology, Protected Resources, and SWFSC; Channel Islands National Marine Sanctuary; SW Stranding Network

Thanks to the SOCAL-BRS field team and the crews of the *M/V Truth and M/V Conception* (Truth Aquatics)