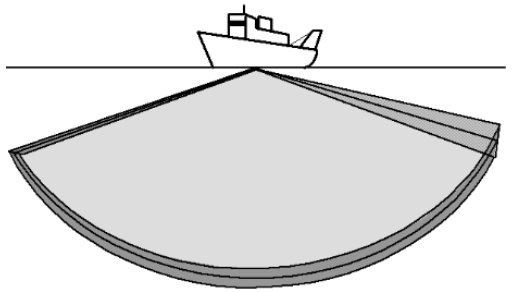
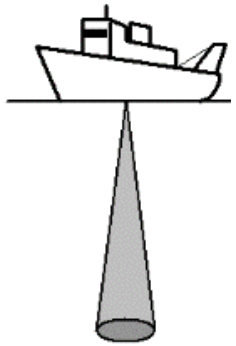
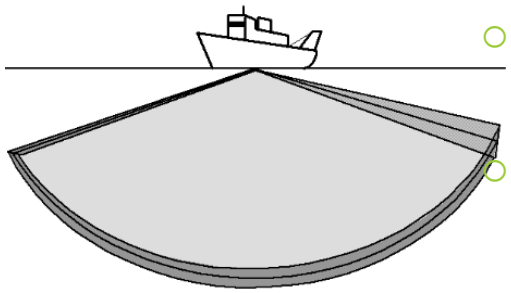
What is the impact of MBES sound on the marine acoustic environment and marine life?

Presented by Dr. Hilary Kates Varghese



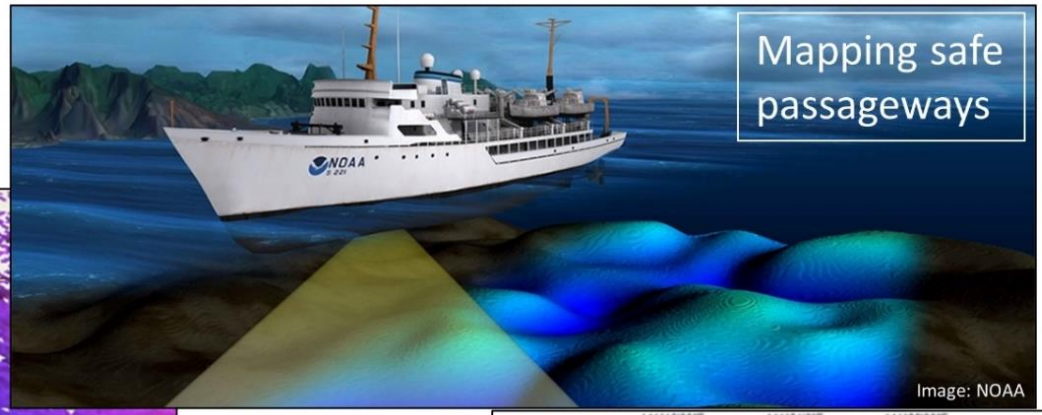
What do we know about the interaction of (multibeam) echosounders and marine life?

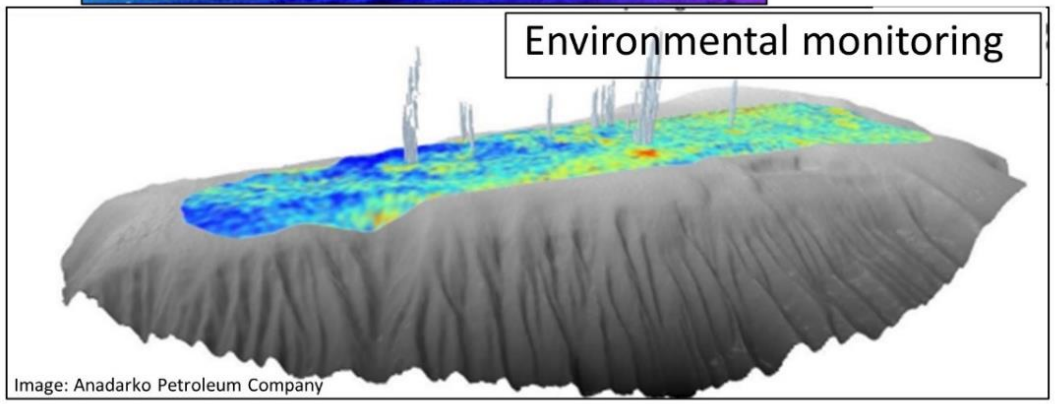


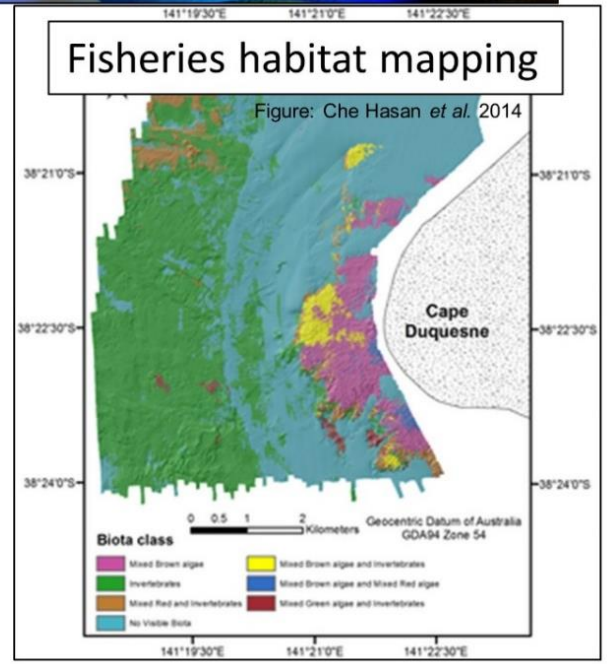


- Mass stranding of melon-headed whales in Madagascar in 2008, raised suspicion about MBES. (Southall et al. 2013)
- Harmonics exist: significantly lower sound level than nominal operating frequency, but in range of hearing of some marine mammals. Captive grey seals respond to MBES signals in a tank setting. (Deng *et al.* 2014, Hastie et al. 2014)
- Marine mammal behavioral response to *single beam echosounder* signals (38-200 kHz) in the wild are context and species-dependent; biological significance unclear.
  - Vires 2011 - no change in foraging behavior of beaked whales
  - Quick *et al.* 2017 – no change in foraging behavior of short-finned pilot whales, change in heading variance
  - Cholewiak *et al.* 2017 – beaked whales did not leave the area; number of foraging clicks detected decreased
- Risk of direct ensonification from MBES that can lead to auditory damage is low. (Lurton and DeRuiter 2011; Lurton 2016)
- Studies of foraging wild marine mammals near deep-water MBES (12 kHz) surveys show no clear adverse impact of MBES. (Kates Varghese et al. 2020, 2021)

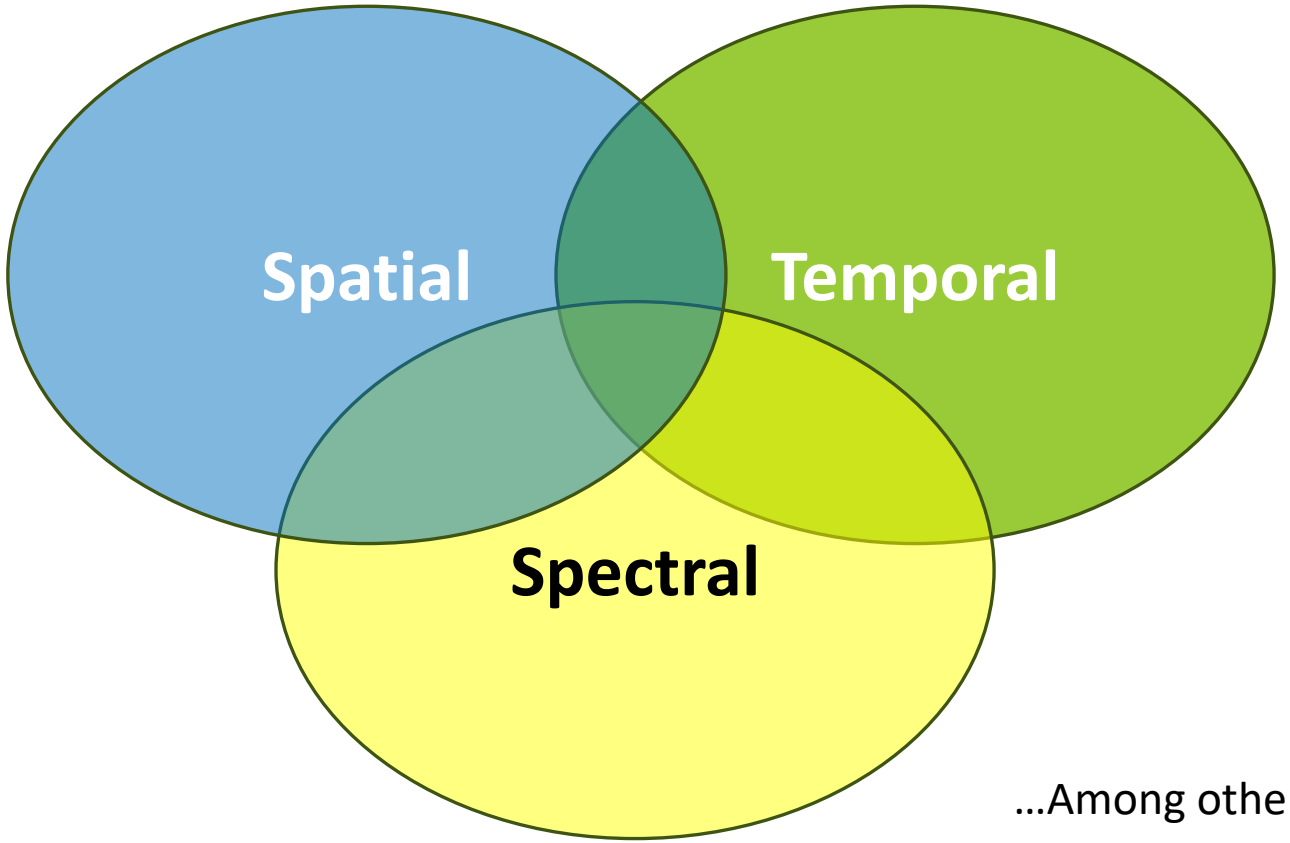
Different applications require different MBES systems.
Not all MBES are the same.







Factors to consider when assessing the likelihood of a sound to affect marine life

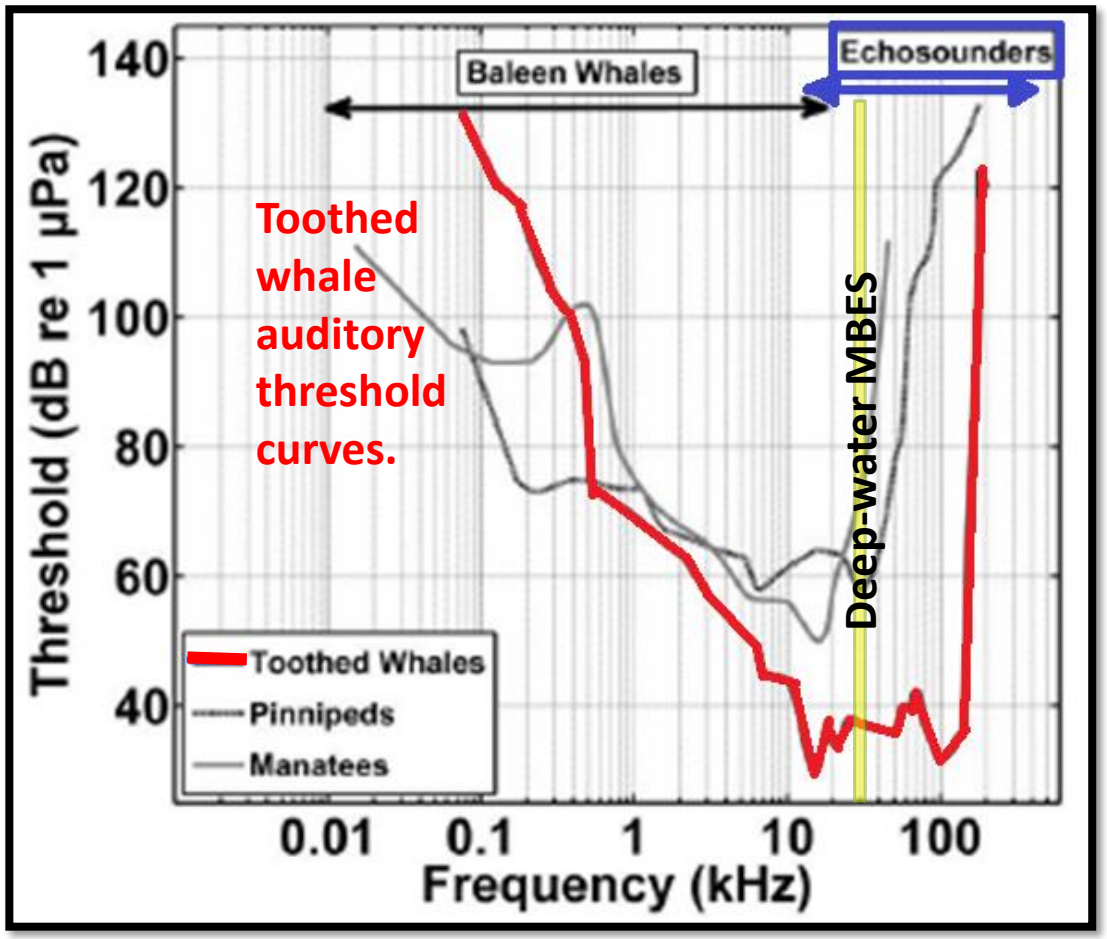


…Among other factors

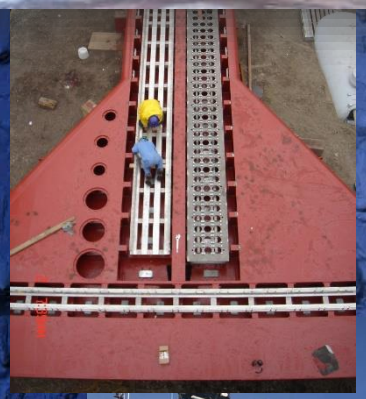
Empirical studies looking at the effect of a 12 kHz deep-water mapping survey on beaked whale foraging behavior

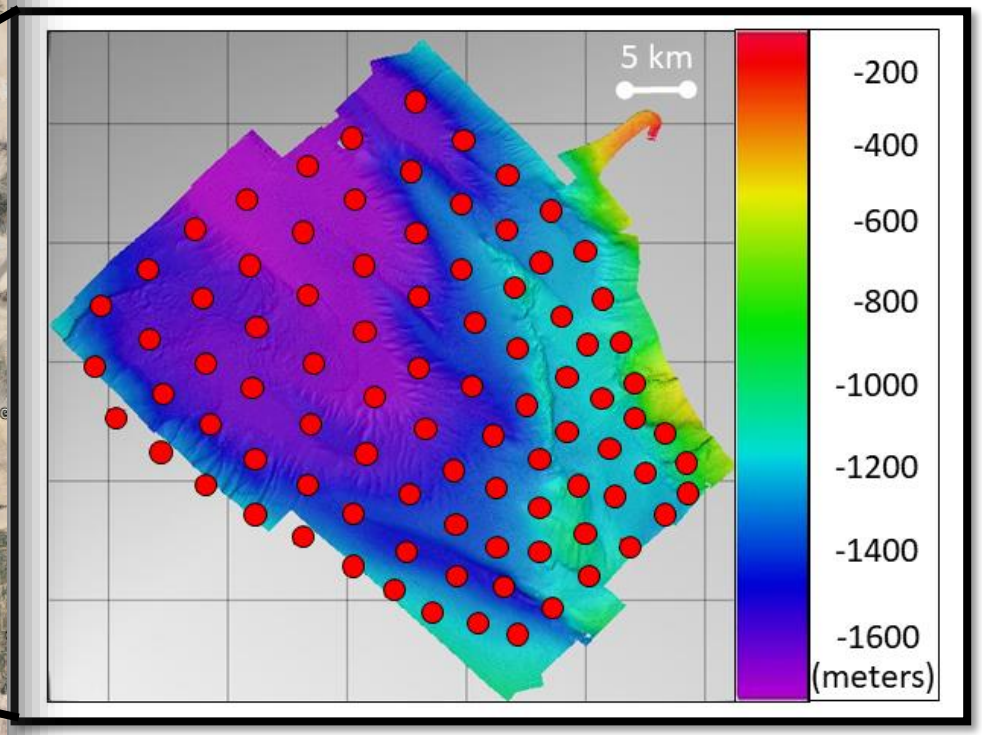
POTENTIAL SPATIAL-TEMPORAL-SPECTRAL OVERLAP

- ✓ 12 kHz system has largest acoustic footprint of any MBES.
- ✓ Species sensitive to other sounds, like mid frequency active sonar (MFAS).
- ✓ Hearing range of species overlaps with 12 kHz deep-water MBES signal.
- ✓ Animals found in deep waters where this MBES would be appropriate to use.
- ✓ Biologically important behavior.

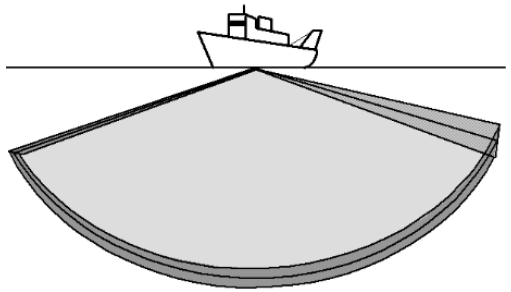


Two deep-water MBES mapping surveys conducted over the Southern California Antisubmarine Warfare Range (SOAR)



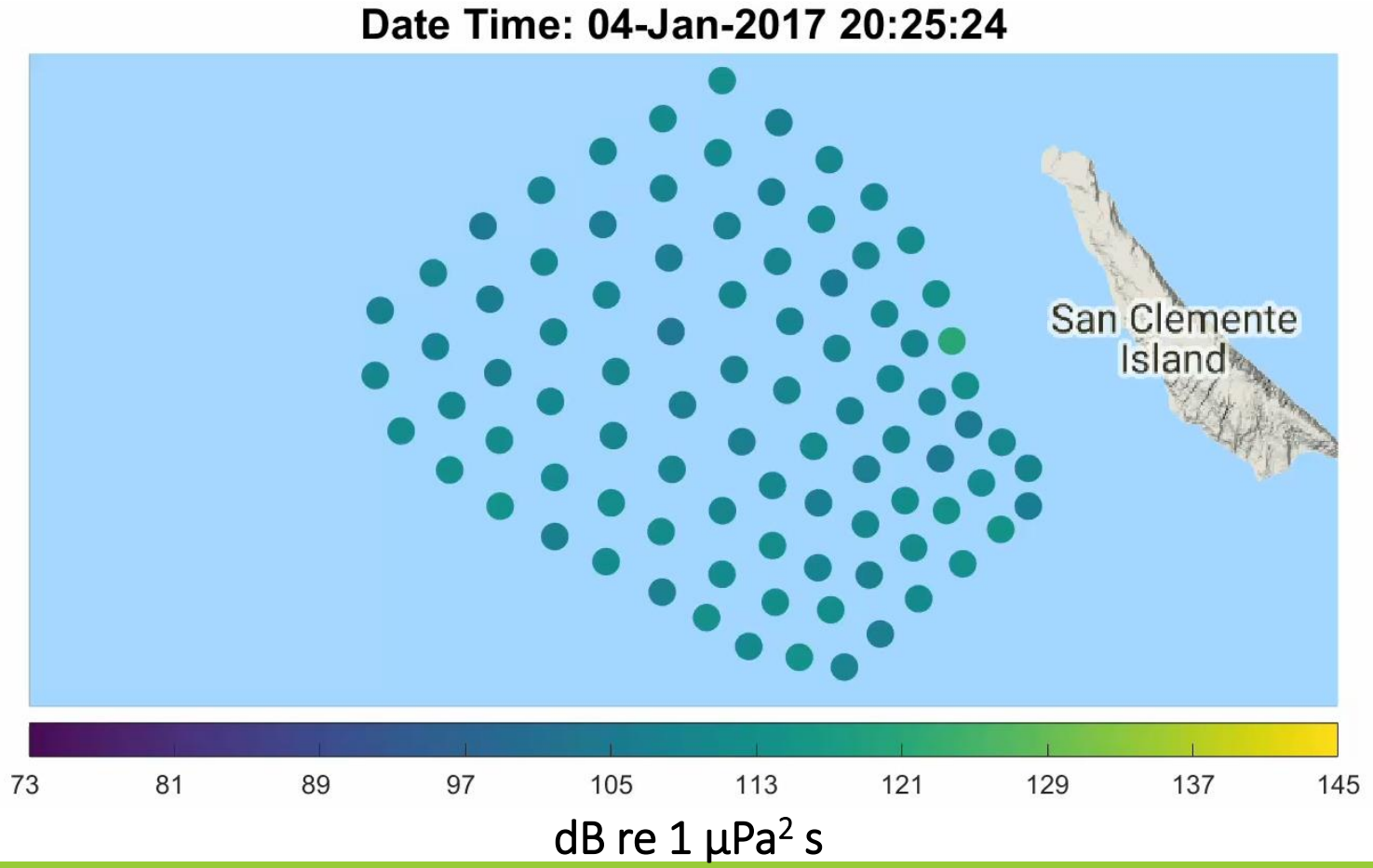


How does an MBES survey manifest in the marine acoustic environment?



WARNING! Next three slides contain flashing animations!

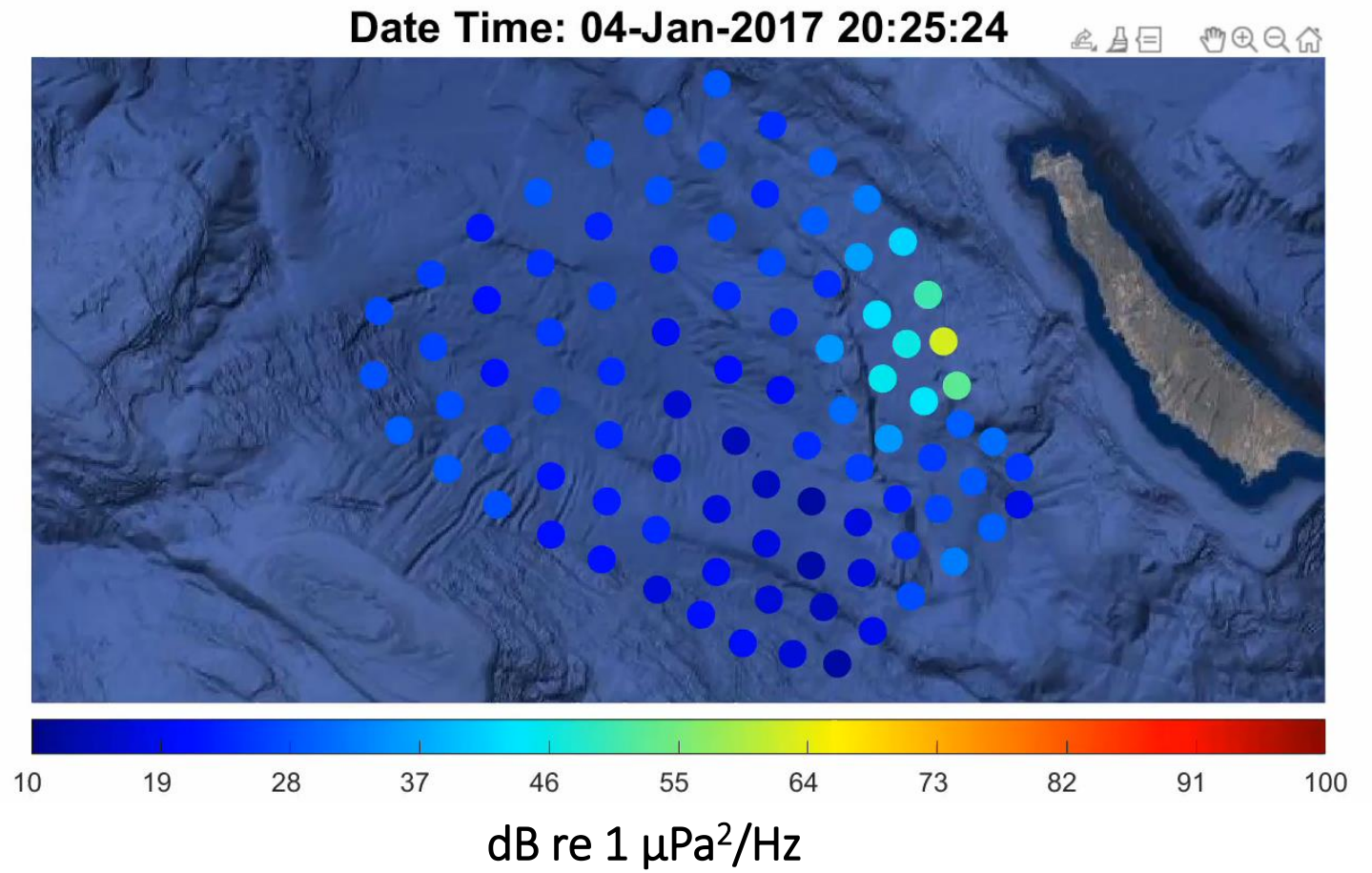
Array-wide sound exposure levels during MBES survey



- SEL of each 1 minute of the dataset
- SEL inclusive of the n=-13 to 16 decidecade bands

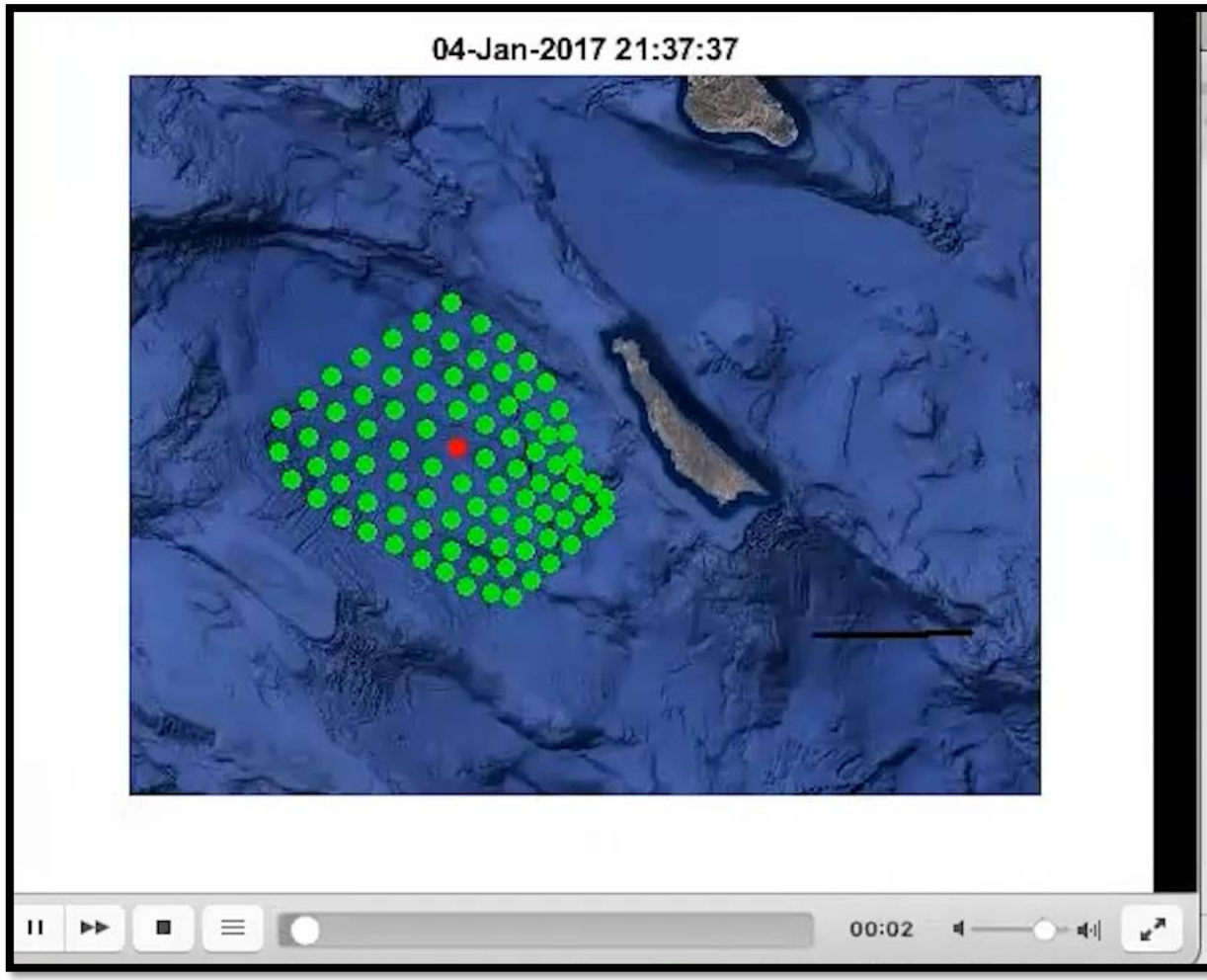
(per Ainslie et al. 2017. ADEON Soundscape and Modeling Metadata Standard)

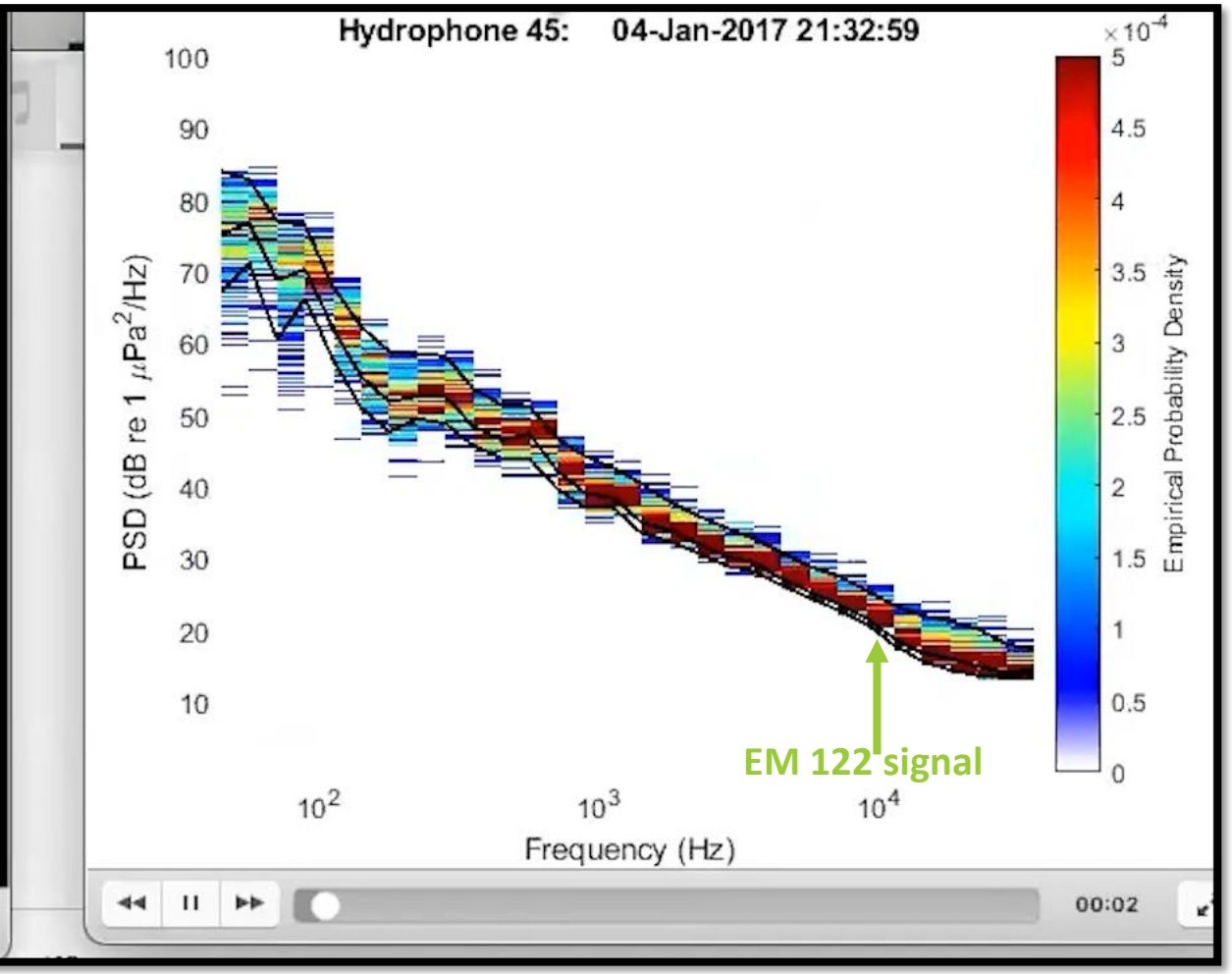
Array-wide 12.5 kHz decidecade band levels during MBES survey



- Power spectral density level of the n = 11 decidecade band (Ainslie et al. 2017) centered at 12.5 kHz for each minute of the data set
- Frequency band contains energy from the 12 kHz MBES

Single hydrophone spectral levels during MBES survey



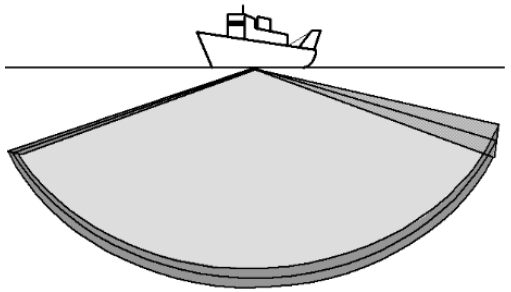


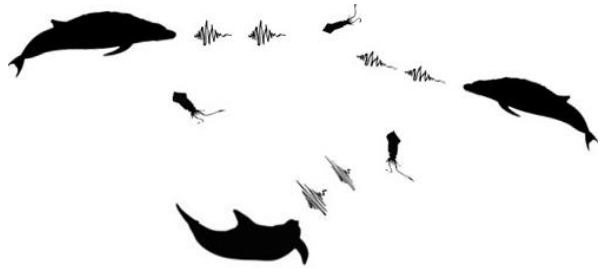
Manifestation of 12 kHz MBES survey in the marine acoustic environment

- MBES signal detectable within a finite distance of the survey vessel (~17 km).
- MBES signal manifests most clearly as elevated sound levels around the nominal operating frequency of the MBES, 12 kHz.
- MBES activity is loud, but temporally and spatially intermittent, and not broadband.

Kates Varghese, H., X. Lurton, M. Smith, J. L. Miksis-Olds, and L. Mayer. (2024). "Soundscape Assessment of a Deepwater (12 kHz) Multibeam Mapping Survey," A. N. Popper et al. (eds.), *The Effects of Noise on Aquatic Life*, https://doi.org/10.1007/978-3-031-10417-6_76-1

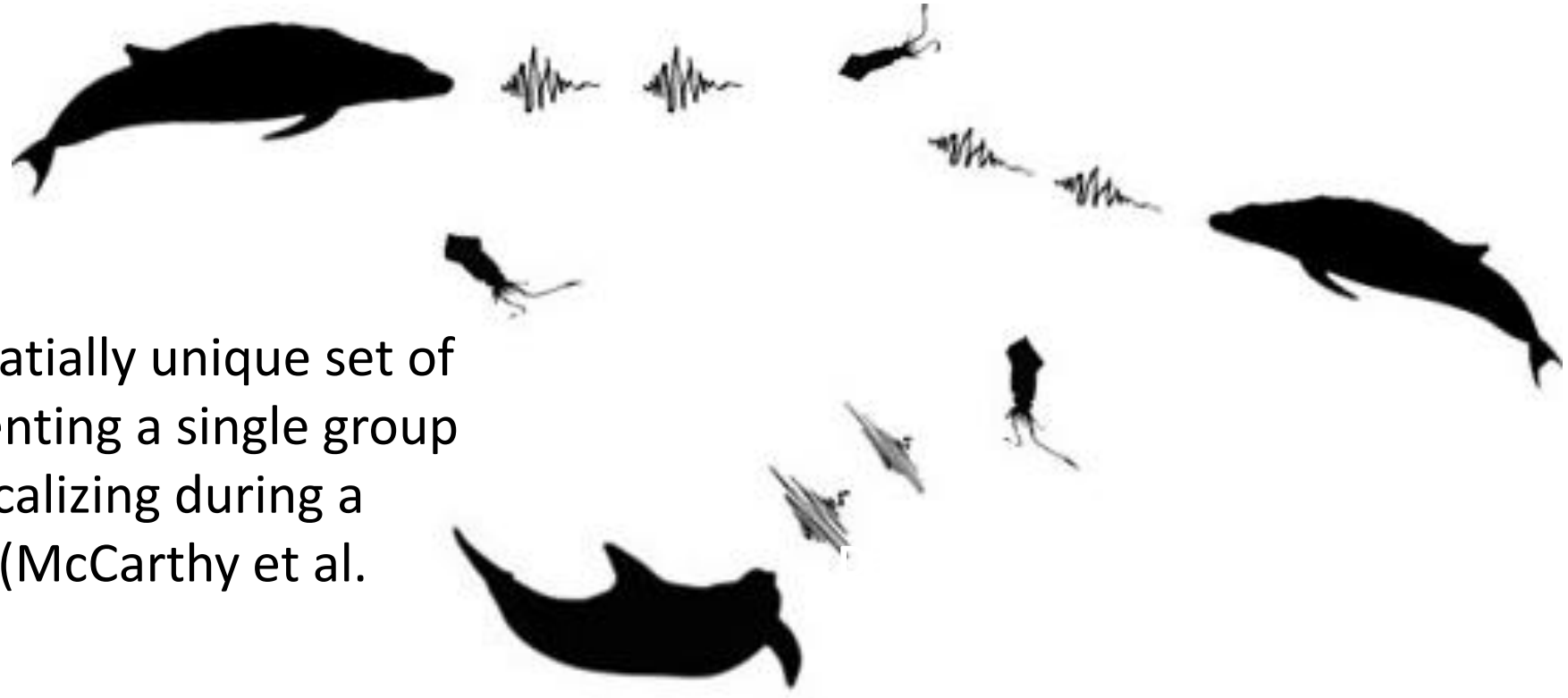
What is the impact of MBES sound on foraging beaked whales?





Does beaked whale foraging behavior change before-during-after a deep-water mapping survey?

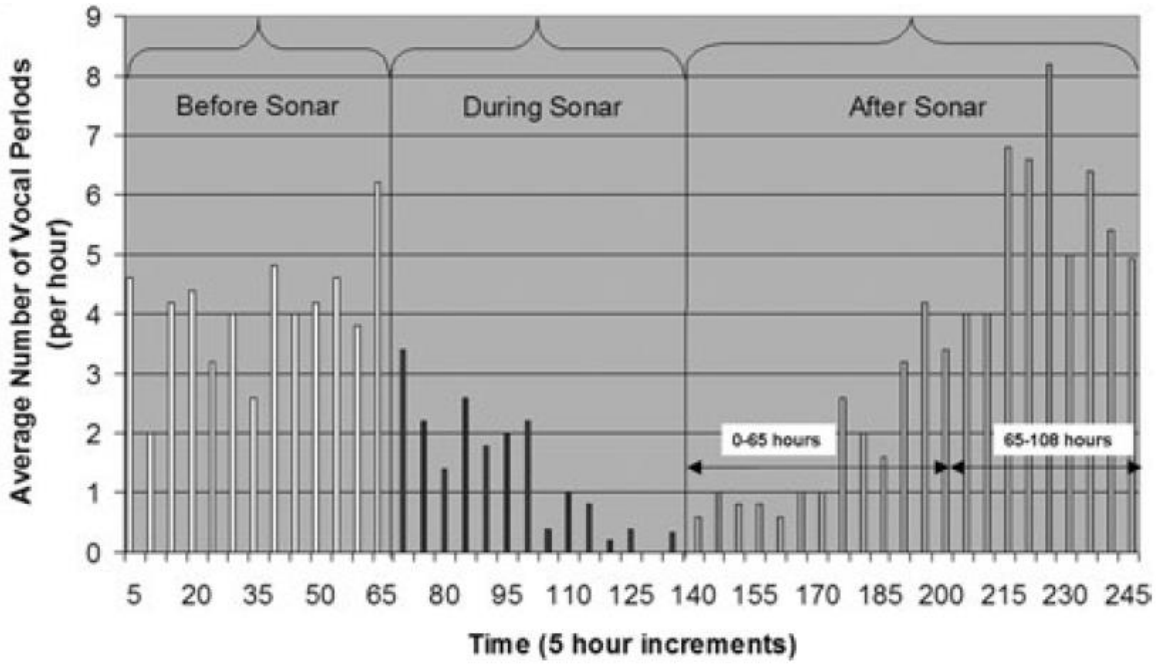
Group Vocal Periods (GVPs)



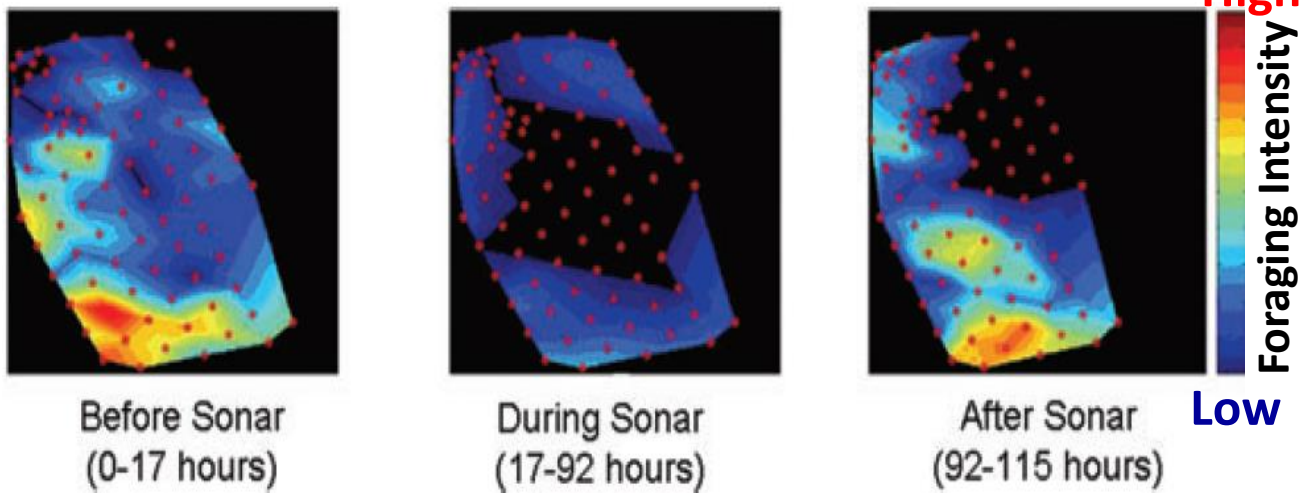
"a temporally and spatially unique set of vocalizations representing a single group of beaked whales vocalizing during a deep foraging dive" (McCarthy et al. 2011)

Effect of Navy MFAS (3-8 kHz) on beaked whale foraging

Foraging Events Before-During-After MFAS



***Spatial* Foraging Intensity Before-During-After MFAS**



- **Reduction in foraging activity AND animals leave the range during MFAS exercises.**
  - **Analogous study design used to assess MBES effect on beaked whales.**

WARNING! Next slide contains flashing animation.

First look at beaked whale detections on SOAR hydrophones during 2017 survey.

= hydrophone

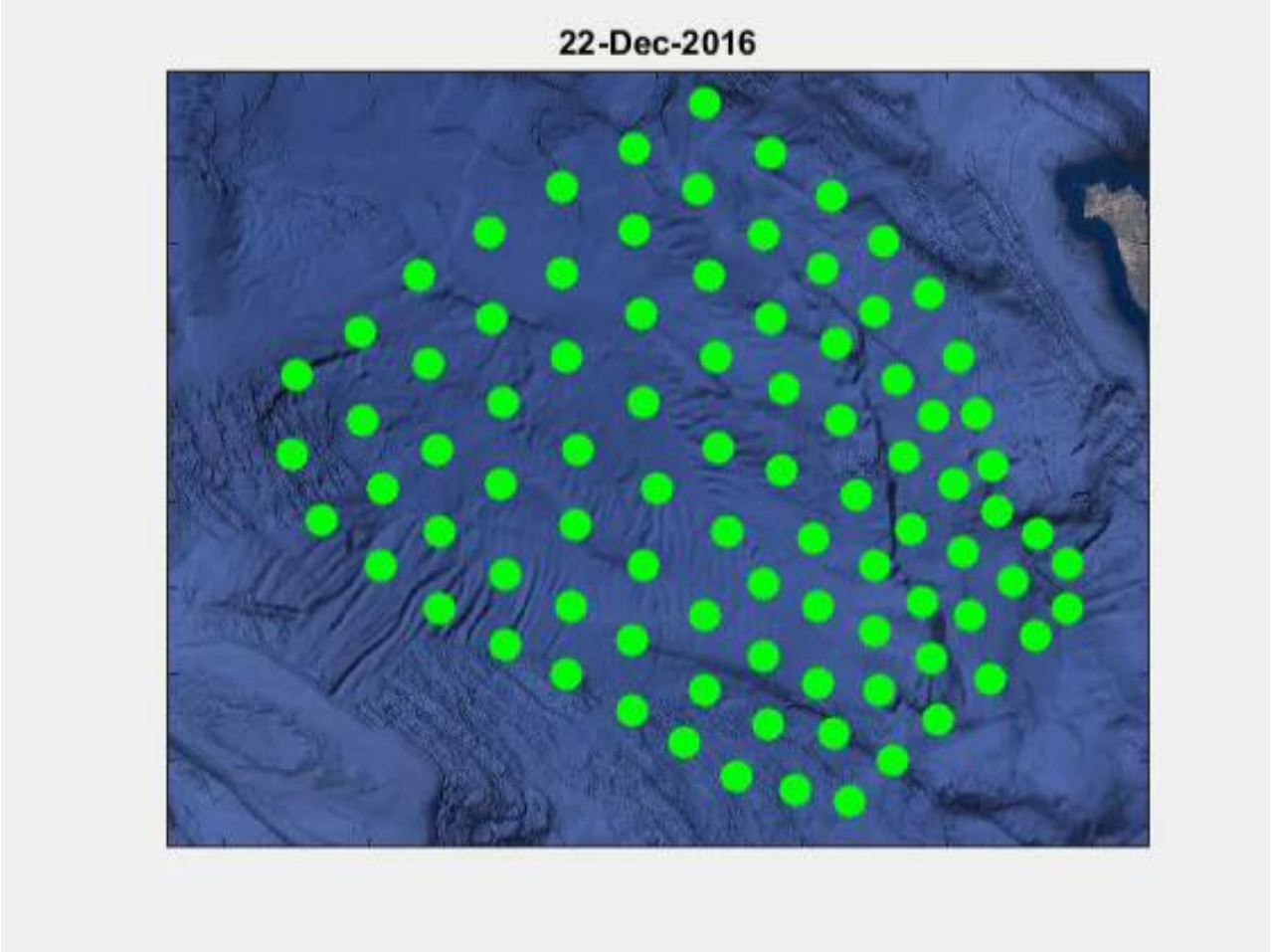
Hydrophone = when one or more detections are made on it during the respective time interval.

Ship track-lines = black line.

Recreation of detections before-during-after the 2017 mapping survey.

Take-aways:

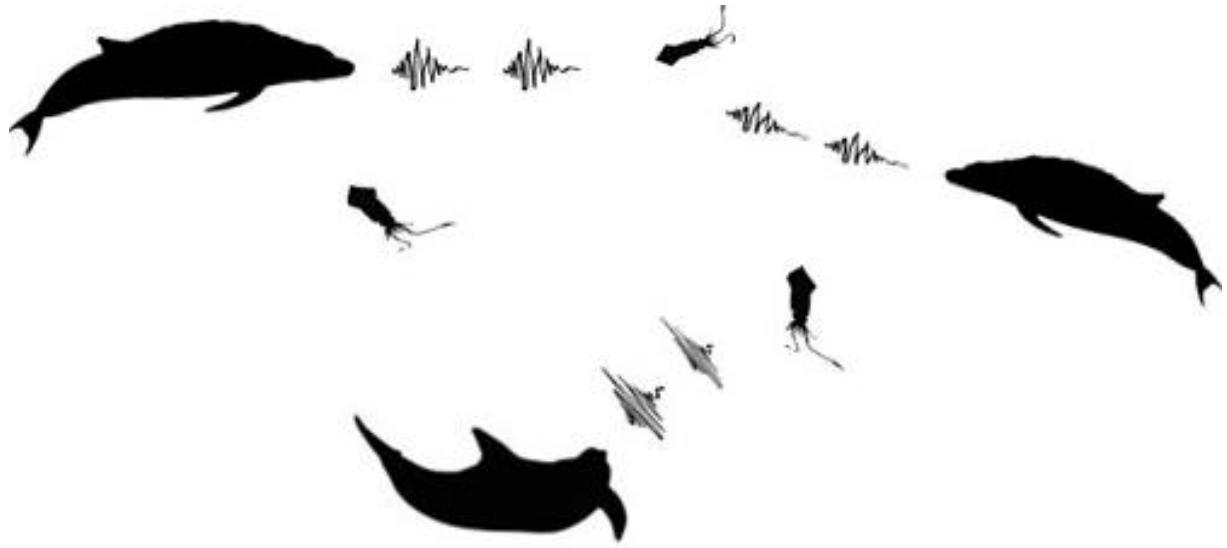
1) Foraging continues on the range throughout the survey.
2) No visually discernable change in where foraging takes place.



Methodology

Four GVP characteristics used as proxies of foraging behavior:

- Number of GVPs per hour
- Number of clicks per GVP
- GVP duration
- Click rate per GVP

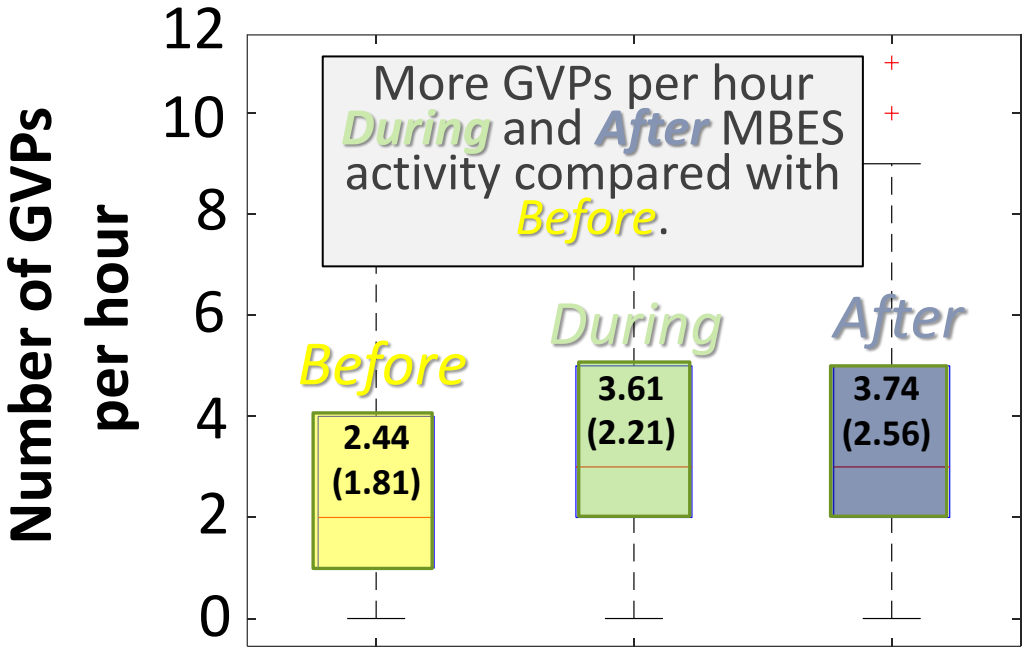


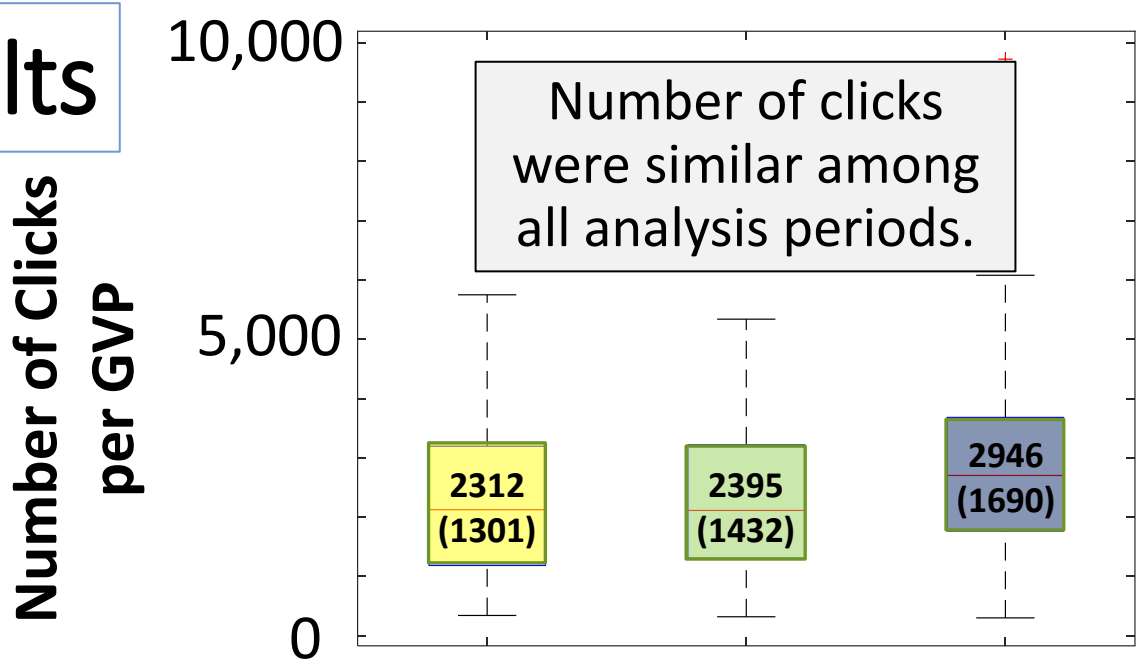
◦ GVPs partitioned into three analysis periods:

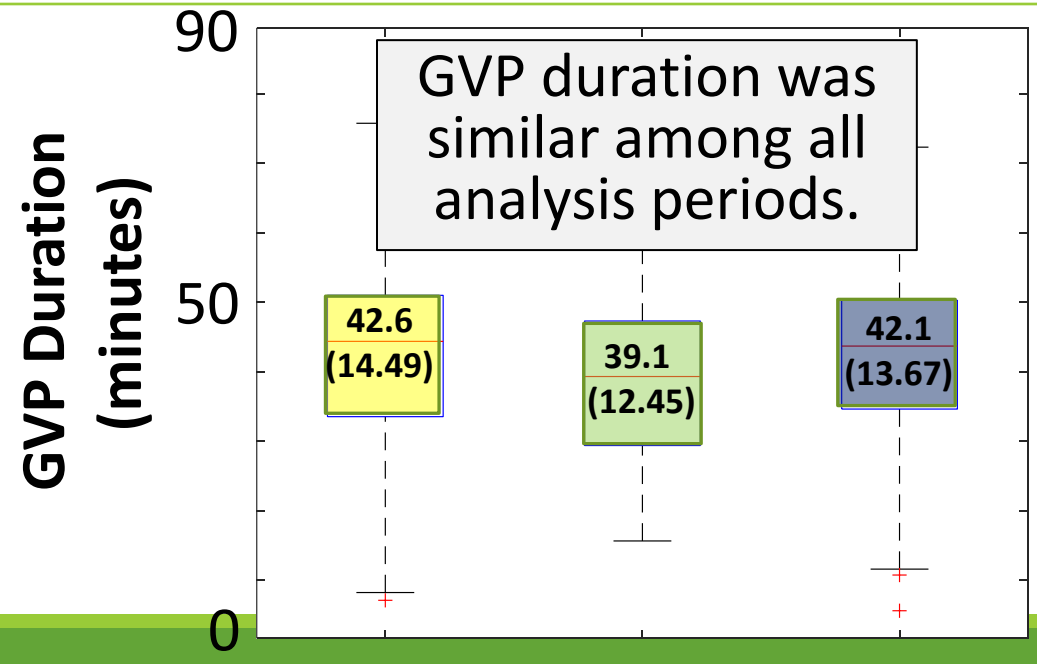
- *Before*
- *During*
- *After*

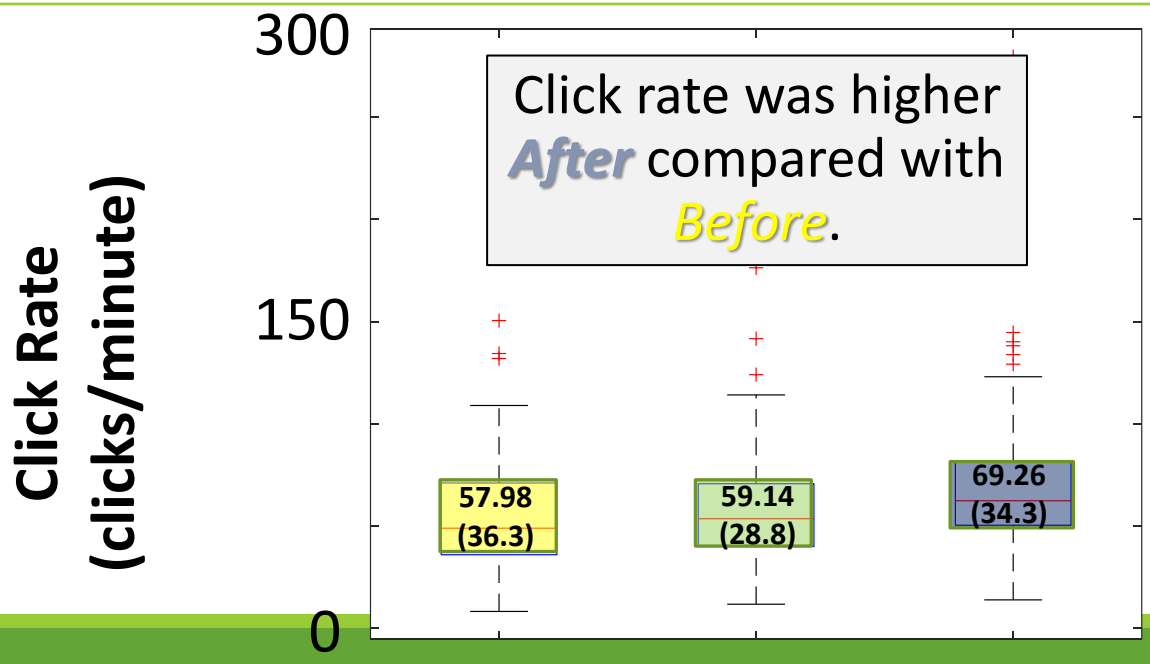
◦ GVP observations pooled from the two mapping surveys.

Results


Number of GVPs per hour
12
10
8
6
4
2
0
More GVPs per hour During and After MBES activity compared with Before.
Before
During
After
2.44 (1.81)
3.61 (2.21)
3.74 (2.56)


Number of Clicks per GVP
10,000
5,000
0
Number of clicks were similar among all analysis periods.
2312 (1301)
2395 (1432)
2946 (1690)


GVP Duration (minutes)
90
50
0
GVP duration was similar among all analysis periods.
42.6 (14.49)
39.1 (12.45)
42.1 (13.67)


Click Rate (clicks/minute)
300
150
0
Click rate was higher After compared with Before.
57.98 (36.3)
59.14 (28.8)
69.26 (34.3)

Summary: Does beaked whale foraging behavior change before-during-after a deep-water mapping survey?

No change in 3 of 4 GVP characteristics between MBES and non-MBES periods.

More GVPs *During* MBES surveys than *Before*, suggests an increase in foraging effort.

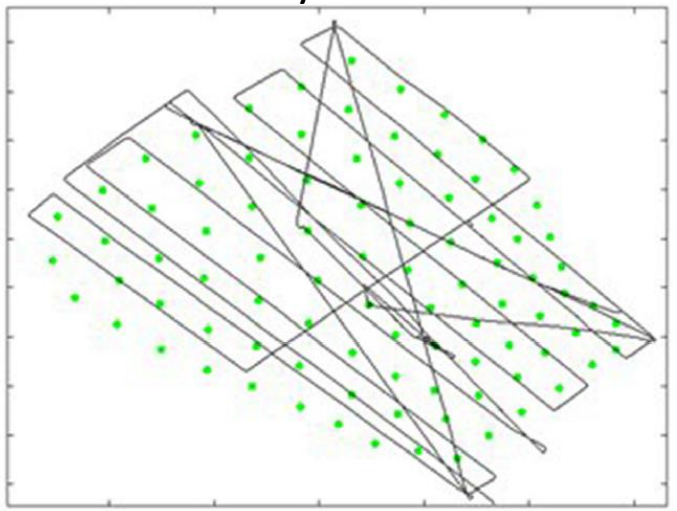
Differences between non-MBES periods in two of four GVP characteristics.

Does a deep-water ocean mapping survey affect *where* beaked whales forage?

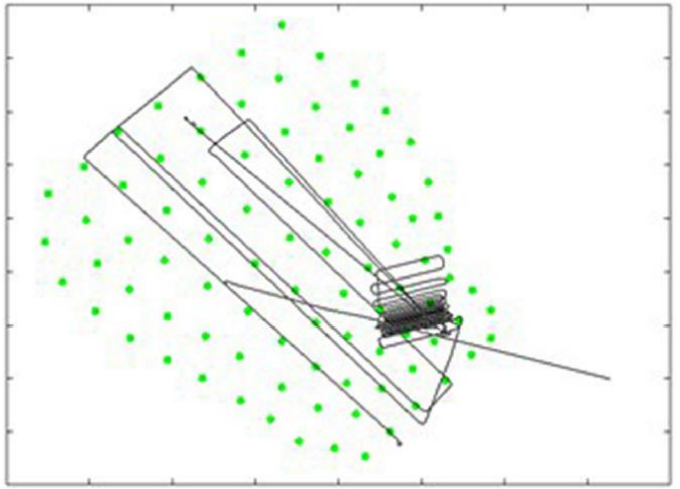
Methodology

- Same deep-water MBES mapping surveys
- Same *Before*-*During*-*After* design
- Same beaked whale GVP data sets
- Observations are now temporally static; spatial dimension considered here
- *Two years analyzed separately*
- *Only # of GVPs examined*

2017 Survey track lines:

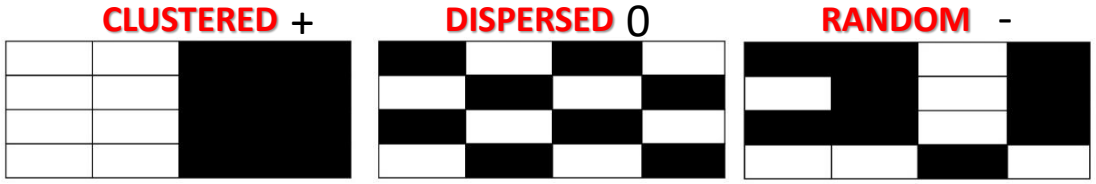


2019 Survey track lines:

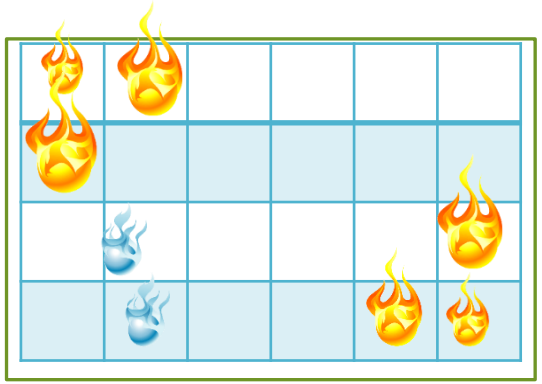


Metrics for assessing large-scale spatial change

GLOBAL: Is foraging effort spatially clustered, dispersed, or random across the ENTIRE range?

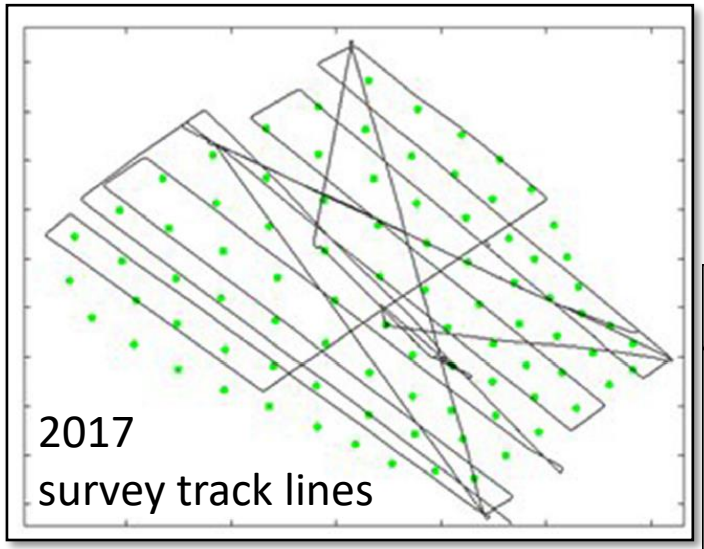


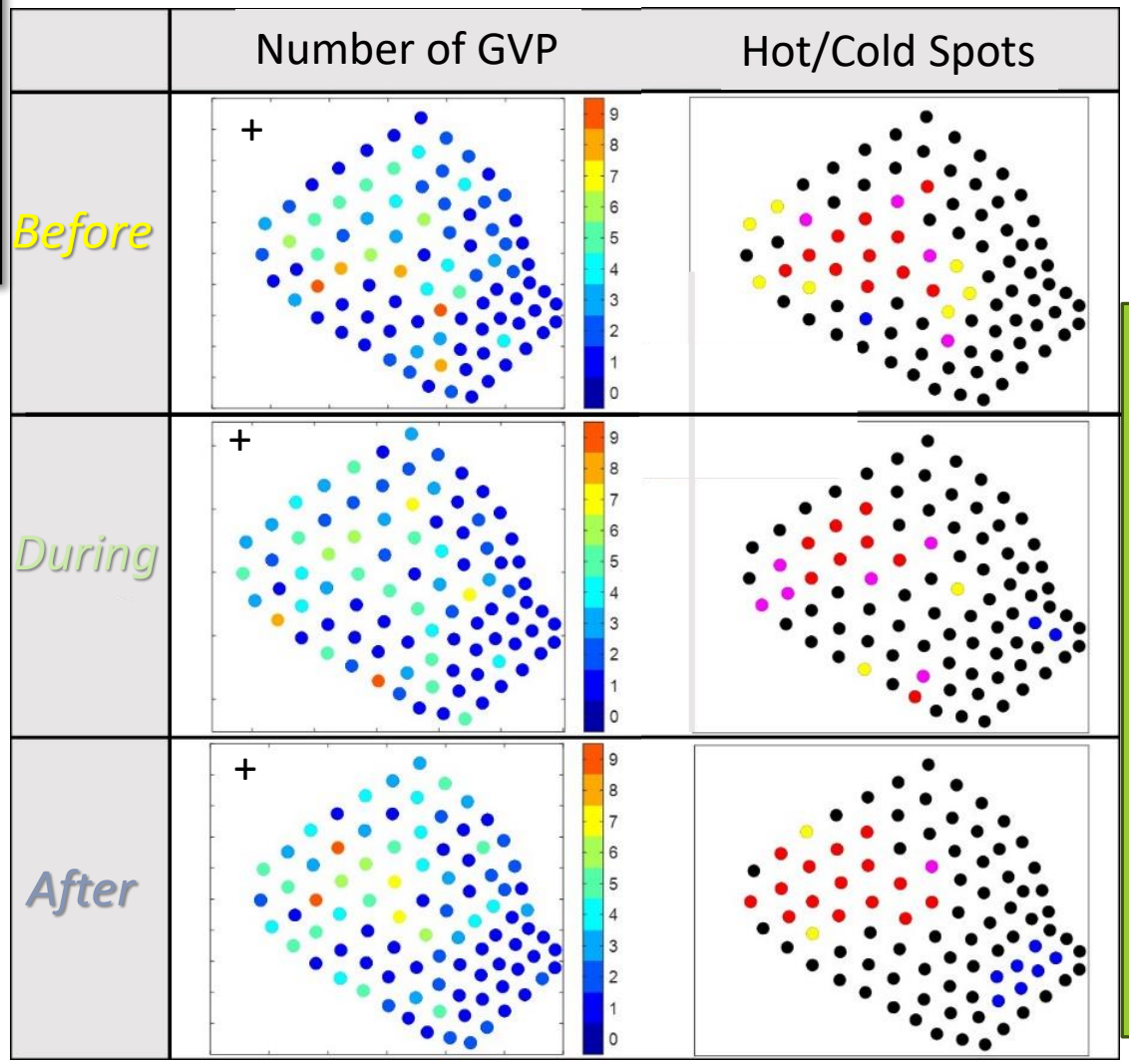
LOCAL: Where are relative hot🔥and cold🥶spots of foraging effort?



COMPARISON: Is the magnitude of foraging effort similar among analysis periods?

2017 Results





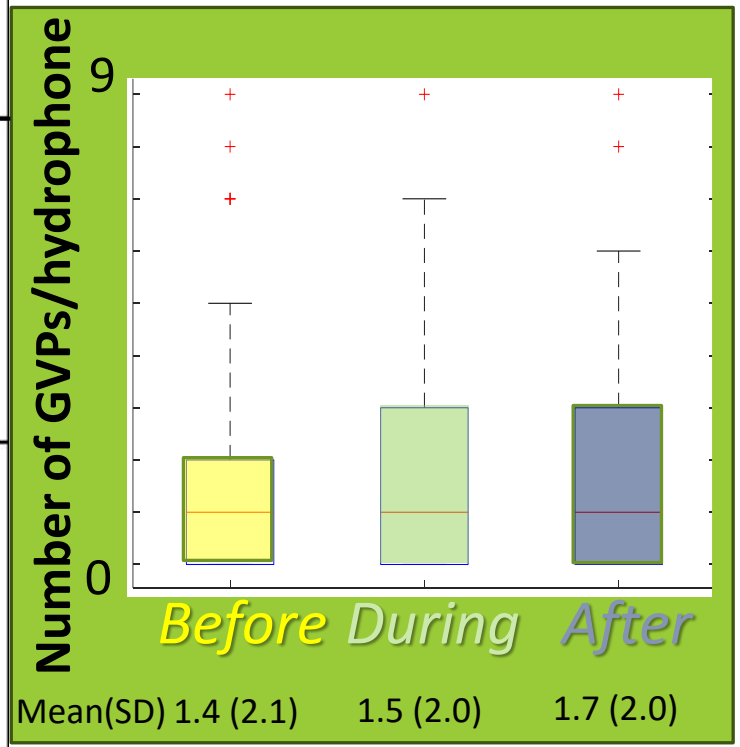
N
W
E
S

Key:
Foraging hot spots
Foraging cold spots
\+ Clustered
\- Dispersed
0 Random

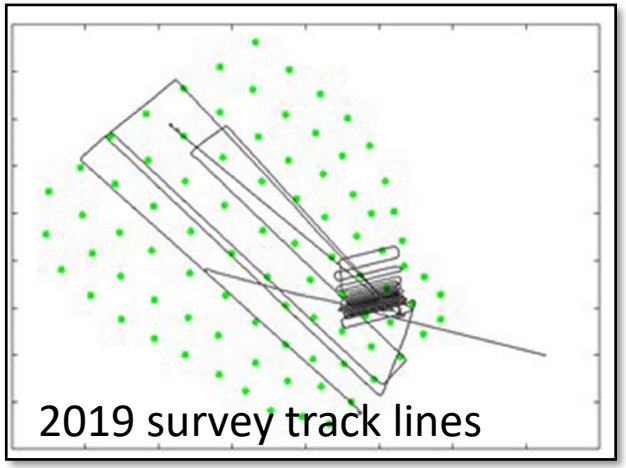
Foraging effort:

- **remained clustered**
- **remained in the northwest corner of the array**
- **magnitude remained similar**

across all analysis periods.

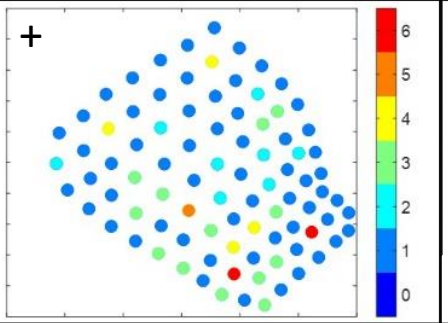
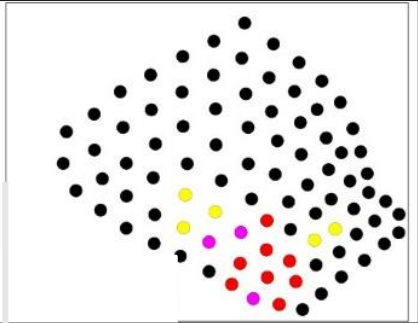
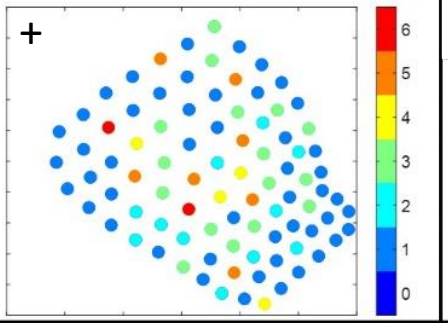
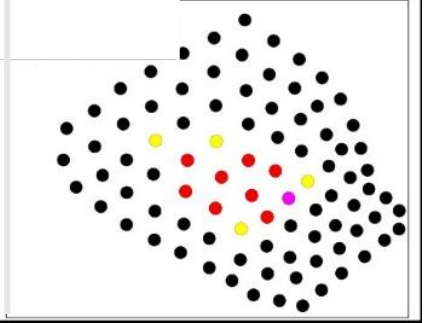
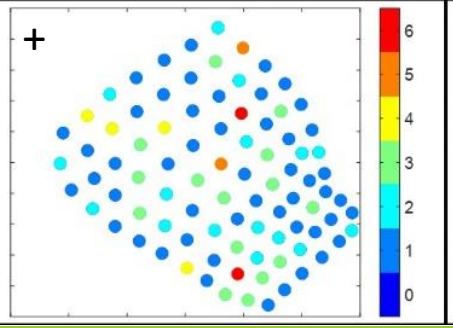
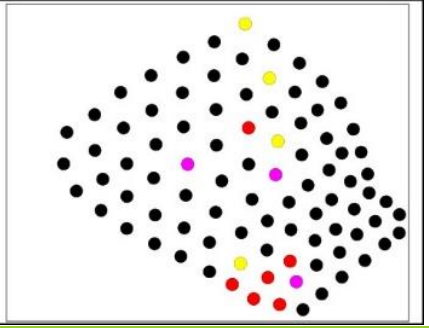


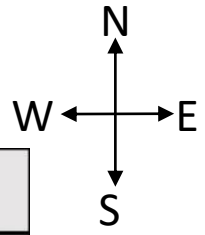
2019 Results



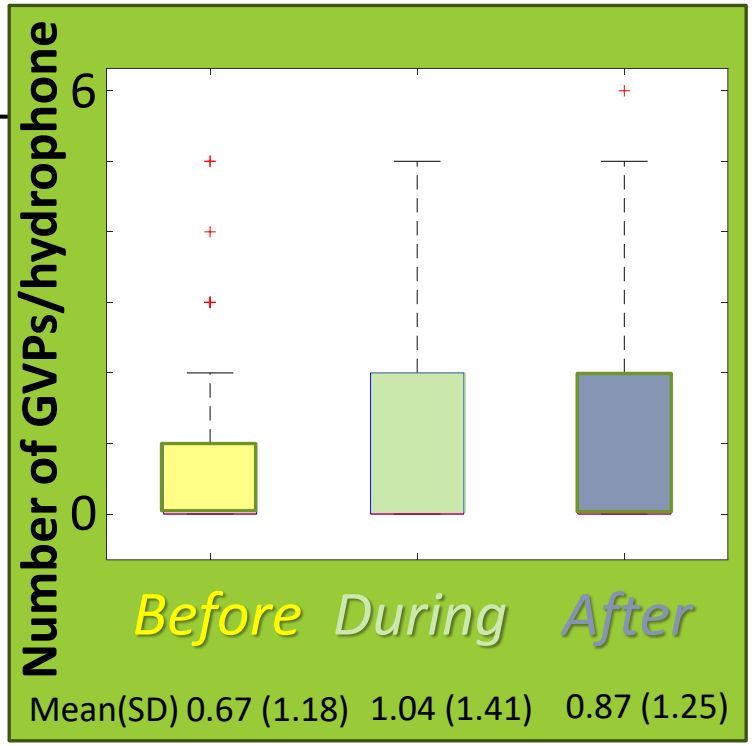
Foraging effort:

- **remained clustered across analysis periods**
- **shifted from the southern corner *Before*, to center *During*, and dispersed across center of array *After***
- **magnitude remained similar across all analysis periods.**

	Number of GVP	Hot/Cold Spots
Before		
During		
After		



Key:
- Foraging hot spots
- Foraging cold spots
- \+ Clustered
- \- Dispersed
- 0 Random



Kates Varghese et al. 2021. Spatial Analysis of Beaked Whale Foraging. *Front. Mar. Sci.* 8:654184. doi: 10.3389/fmars.2021.654184

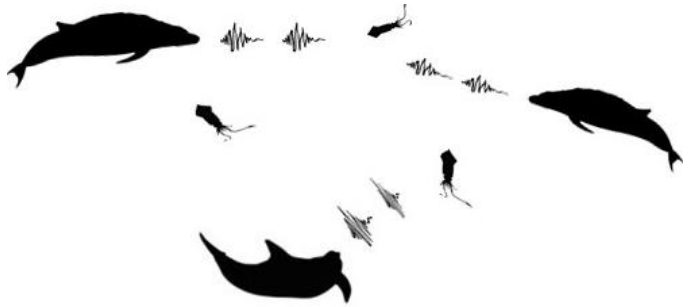
Summary: Does a deep-water ocean mapping survey affect *where* beaked whales forage?

No change in spatial foraging effort during 2017 survey.

No global or order-of magnitude change in 2019. Local shift in where animals foraged within the array.

- Shift toward array center ***During*** survey - NOT indicative of avoidance.
- Foraging remained in area historically well-utilized by goose-beaked whales (Falcone et al. 2009).

Kates Varghese, H., Lowell, K., Miksis-Olds, J., DiMarzio, N., Moretti, D., and Mayer, L. (2021). Spatial Analysis of Beaked Whale Foraging During Two 12 kHz Multibeam Echosounder Surveys. *Frontiers in Marine Science* 8:654184. DOI: 10.3389/fmars.2021.654184.



Summary of empirical studies

Animals didn't leave the range and continued to forage during both MBES surveys.

No change in 3 of 4 temporal metrics of foraging behavior examined.

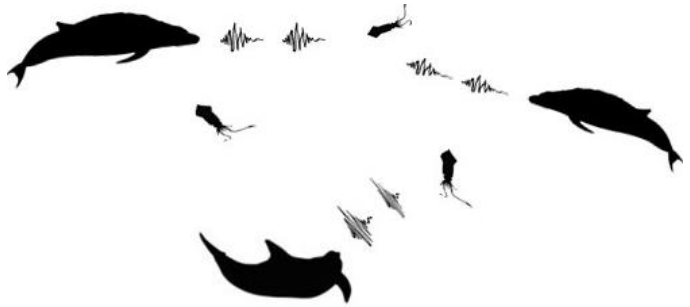
Increase in the number of foraging events observed during the survey.

- Stark contrast from other studies of sounds with known adverse effects on whales.

No change in spatial use of the array during one survey, localized change during the other.

- Shift toward center of array

No adverse change observed in foraging goose-beaked whales.



Conclusions

Likelihood of direct ensonification leading to auditory injury is low.

12 kHz MBES contributes substantially to local soundscape, but spatially and temporally intermittent on broad scale.

Empirical assessment of sensitive species performing a biologically-important behavior during a deep-water mapping survey shows no adverse effect; no clear response to MBES.

12 kHz MBES represents largest MBES acoustic footprint, goose-beaked whales - a sensitive species to other anthropogenic sounds; **effects observed here should represent an upper bound.**

Questions?

THANK YOU FOR YOUR ATTENTION

References and Resources

Ainslie, MA, Miksis-Olds, JL, Martin, B, Heaney, K, de Jong, CAF, von Benda-Beckman, AM, and Lyons, AP (2017) ADEON Soundscape and Modeling Metadata Standard. Version 2.0 DRAFT. Technical report by TNO for ADEON Prime Contract No. M16PC00003. Retrieved from: https://adeon.unh.edu/sites/default/files/user-uploads/ADEON%20Soundscape%20Specification%20Deliverable%20v1.0%20FINAL%20Submission.pdf

Cholewiak, D., DeAngelis, A., Palka, D., Corkeron, P., Van Parijs, S. (2017). Beaked whales demonstrate a marked acoustic response to the use of shipboard echosounders. *Royal Society Open Science* 4, 170940. doi: 10.1098/rsos.170940

Deng, Z.D., Southall, B.L., Carlson, T.J., Xu, J., Martinez, J.J., Weiland, M.A., Ingraham, J.M. (2014). 200 kHz Commercial Sonar Systems Generate Lower Frequency Side Lobes Audible to Some Marine Mammals. *PLoS ONE* 9(4), e95315.

Hastie, G., Donovan, C., Gotz, T. and Janik, V.S. (2014). Behavioral responses by grey seals (*Halichoerus grypus*) to high frequency sonar. *Marine Pollution Bulletin* 79, 205-210.

Kates Varghese, H., X. Lurton, M. Smith, J. L. Miksis-Olds, and L. Mayer. (2024). "Soundscape Assessment of a Deepwater (12 kHz) Multibeam Mapping Survey," A. N. Popper et al. (eds.), *The Effects of Noise on Aquatic Life*, https://doi.org/10.1007/978-3-031-10417-6_76-1

Kates Varghese, H.S.C. 2021. "The Effect of Deep-Water Multibeam Mapping Activity on the Foraging Behavior of Cuvier's Beaked Whales and the Marine Acoustic Environment." *Doctoral Dissertations*. 2648. Retrieved from: https://scholars.unh.edu/dissertation/2648

Kates Varghese, H., Lowell, K., Miksis-Olds, J., DiMarzio, N., Moretti, D., and Mayer, L. (2021). Spatial Analysis of Beaked Whale Foraging During Two 12 kHz Multibeam Echosounder Surveys. *Frontiers in Marine Science* 8:654184. DOI: 10.3389/fmars.2021.654184.

Kates Varghese, H., Miksis-Olds, J., DiMarzio, N., Lowell, K., Linder, E., Mayer, L., and Moretti, D. (2020). The effect of two 12 kHz multibeam mapping surveys on the foraging behavior of Cuvier's beaked whales off of southern California. *The Journal of the Acoustical Society of America* 147(6), 3849-3858. DOI: 10.1121/10.0001385.

Kates Varghese, H., Smith, M.J., Miksis-Olds, J.L., and Mayer, L. (2019). Regulation Consideration of Ocean Mapping Multibeam Echo Sounders: A Square Peg in a Round Hole. *Journal of Ocean Technology* 14(3), 40-46.

Lurton, X. (2016). Modelling of the sound field radiated by multibeam echosounders for acoustical impact assessment. *Applied Acoustics* 101, 201-211.

Lurton, X. and DeRuiter, S. (2011). Sound radiation of seafloor-mapping echosounders in the water column, in relation to the risks posed to marine mammals. *International Hydrographic Review* 7-17.
Mayer, L.A. (2006). Frontiers in seafloor mapping and visualization. *Marine Geophysical Research* 27, 7-17. doi: 10.1007/s11001-05-0267-x

Mayer, L., Jakobsson, M., Allen, G., Dorschel, B., Falconer, R., Ferrini, VS, Lamarche, G., Snaith, H., and Weatherall, P. (2018). The Nippon Foundation-GEBCO Seabed 2030 Project: The Quest to See the World's Oceans Completely Mapped by 2030. *Geosciences* 8(63). Doi: 10/3390/geosciences8020063.

Smith, M.J. (2019). Analysis of the radiated sound field of a deep-water multibeam echo sounder using a navy hydrophone array. M.S. thesis, University of New Hampshire, https://unh.idm.oclc.org/login?url=https://search.proquest.com/docview/2273838102?accountid=14612.

Quick, N., Scott-Hayward, L., Sadykova, D., Nowacek, D., and Read, A. (2017). Effects of a scientific echo sounder on the behavior of short finned pilot whales (*Globicephala macrorhynchus*). *Canadian Journal of Fisheries and Aquatic Sciences* 74(5), 716-726.

Vires, G. (2011). Echosounder effects on beaked whales in the Tongue of the Ocean, Bahamas. Master's Thesis. Duke University, Durham, N.C.