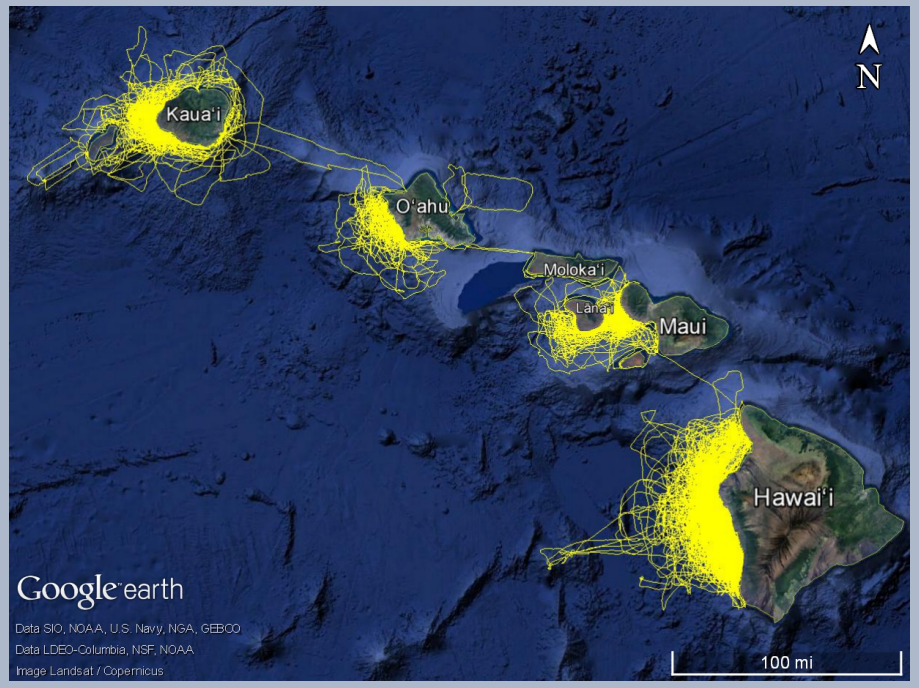
Effects of Navy sonar on whales and dolphins in the Hawaiian Islands: some data, some speculation, some gaps

Robin W. Baird
Cascadia Research Collective
rwbaird@cascadiaresearch.org

Presentation to the Hawaiian Islands Humpback Whale National Marine Sanctuary Sanctuary Advisory Council, 15 September 2020

Cascadia Research Collective Hawai‘i research program

- Long-term multi-species effort using a variety of methods (photo-ID, genetics, satellite tagging, drone use)
- Collaborative effort with researchers from NMFS, Navy, universities, other non-profits
- Photo-ID catalogs of 11 species of odontocetes and 2 species of mysticetes, satellite tag data from ~320 individuals of 12 species
- Questions include population structure & size, spatial use, responses to Navy sonar
- Primary funding by NOAA Fisheries, US Navy (Office of Naval Research, Living Marine Resources, Pacific Fleet) with support from a number of foundations and other organizations



Effort from 2000-2020

1,161 days (>8,000 h)

>147,000 km effort

>3,000 odontocete sightings

18 odontocete species

3 baleen whale species

Potential effects of noise on marine mammals

- None observable
- Interference with communication or foraging
  - Auditory masking (loss of acoustic “habitat”)
  - Temporary or permanent hearing damage
- Behavioral responses
  - Orientation, increased alertness, vocal changes
  - Effects on feeding, social activity, risk of predation
  - Habitat abandonment: temporary or permanent
- Physiological effects
- Death or stranding

Generally Increasing Severity

but

Generally Decreasing Occurrence

Modified from Southall 2020

Military mid-frequency active sonar (MFAS)

Highest source level
AN/SQS-53C

- Center frequencies 2.6 and 3.3 kHz
- Nominal source level 235 dB re: 1 µPA root mean square

Recording orcasound.net

Hull-mounted

Other source levels:

- Humpback whale ~174 dB
- Supertanker ~190 dB

Helicopter-dipping
AN/AQS-22, 4.1 kHz, source level 217 dB

DICASS sonobuoy
Directional Command-Activated Sonobuoy System

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Diving behaviour of Cuvier's beaked whales exposed to two types of military sonar

Erin A. Falcone[1], Gregory S. Schorr[1], Stephanie L. Watwood[2], Stacy L. DeRuiter[3], Alexandre N. Zerbini[1,4,5], Russel D. Andrews[1,6], Ronald P. Morrissey[2] and David J. Moretti[2]

[1]Marine Ecology and Telemetry Research, 2420 Nellita Rd NW, Seabeck, WA 98380, USA
[2]Naval Undersea Warfare Center Division, Code 74, Newport, RI 02840, USA
[3]Department of Mathematics and Statistics, Calvin College, 1740 Knollcrest Circle SE, Grand Rapids, MI 49546, USA
[4]Marine Mammal Laboratory, Alaska Fisheries Science Center, NMFS-NOAA, 7600 Sand Point Way NE, Seattle, WA 98115, USA
[5]Cascadia Research Collective, 218 ½ W 4th Avenue, Olympia, WA 98501, USA
[6]College of Fisheries and Ocean Sciences, University of Alaska Fairbanks,

Research

Cite this article: Falcone EA, Schorr GS, Watwood SL, DeRuiter SL, Zerbini AN, Andrews RD, Morrissey RP, Moretti DJ. 2017 Diving behaviour of Cuvier's beaked whales exposed to two types of military sonar. *R. Soc. open sci.* **4**: 170629.
http://dx.doi.org/10.1098/rsos.170629

Received: 12 June 2017
Accepted: 2 August 2017

"Most responses intensified with proximity and were more pronounced during mid-power than high-power MFAS use at comparable distances within approximately 50 km, despite the significantly lower source level of mid-power MFAS."

Sources of information from Hawai‘i

- Studies using the acoustic array at the Pacific Missile Range Facility (PMRF) to track vocalizing individuals and MFAS

Aquatic Mammals 2019, *45*(6), 661-674, DOI 10.1578/AM.45.6.2019.661

Changes in the Spatial Distribution of Acoustically Derived Minke Whale (*Balaenoptera acutorostrata*) Tracks in Response to Navy Training

Catriona M. Harris,[1] Stephen W. Martin,[2] Cameron Martin,[3] Tyler A. Helble,[3] E. Elizabeth Henderson,[3] Charles G. M. Paxton,[1] and Len Thomas[1]

[1]*Centre for Research into Ecological and Environmental Modelling, Buchanan Gardens, University of St Andrews, St Andrews, Fife KY16 9LZ, UK*
E-mail: catriona.harris@st-andrews.ac.uk
[2]*National Marine Mammal Foundation, 2240 Shelter Island Drive, Suite 200, San Diego, CA 92106, USA*
[3]*Naval Information Warfare Center Pacific, 53560 Hull Street, San Diego, CA 92152, USA*

Aquatic Mammals 2016, *42*(4), 507-518, DOI 10.1578/AM.42.4.2016.507

Impacts of U.S. Navy Training Events on Blainville's Beaked Whale (*Mesoplodon densirostris*) Foraging Dives in Hawaiian Waters

Roanne Manzano-Roth,[1] E. Elizabeth Henderson,[1] Stephen W. Martin,[2] Cameron Martin,[2] and Brian M. Matsuyama[2]

[1]*SPAWAR Systems Center Pacific, 53560 Hull Street, San Diego, CA 92152, USA*
E-mail: Roanne.Manzano@navy.mil
[2]*National Marine Mammal Foundation, 2240 Shelter Island Drive, #200, San Diego, CA 92106, USA*

Quantifying the response of Blainville's beaked whales to Naval sonar exercises in Hawaii

Eiren K. Jacobson, E. Elizabeth Henderson, Cornelia S. Oedekoven, David L. Miller, Stephanie L. Watwood, David J. Moretti, Len Thomas

eiren.jacobson@st-andrews.ac.uk | @eirenkate

Naval Information Warfare Center PACIFIC

NAVSEA NAVAL SEA SYSTEMS COMMAND

Jacobson et al. Beaked Whale Risk Hawaii: eirenjacobson.github.io/JacobsonEtAl_WMMC2019.pdf

Sources of information from Hawai‘i

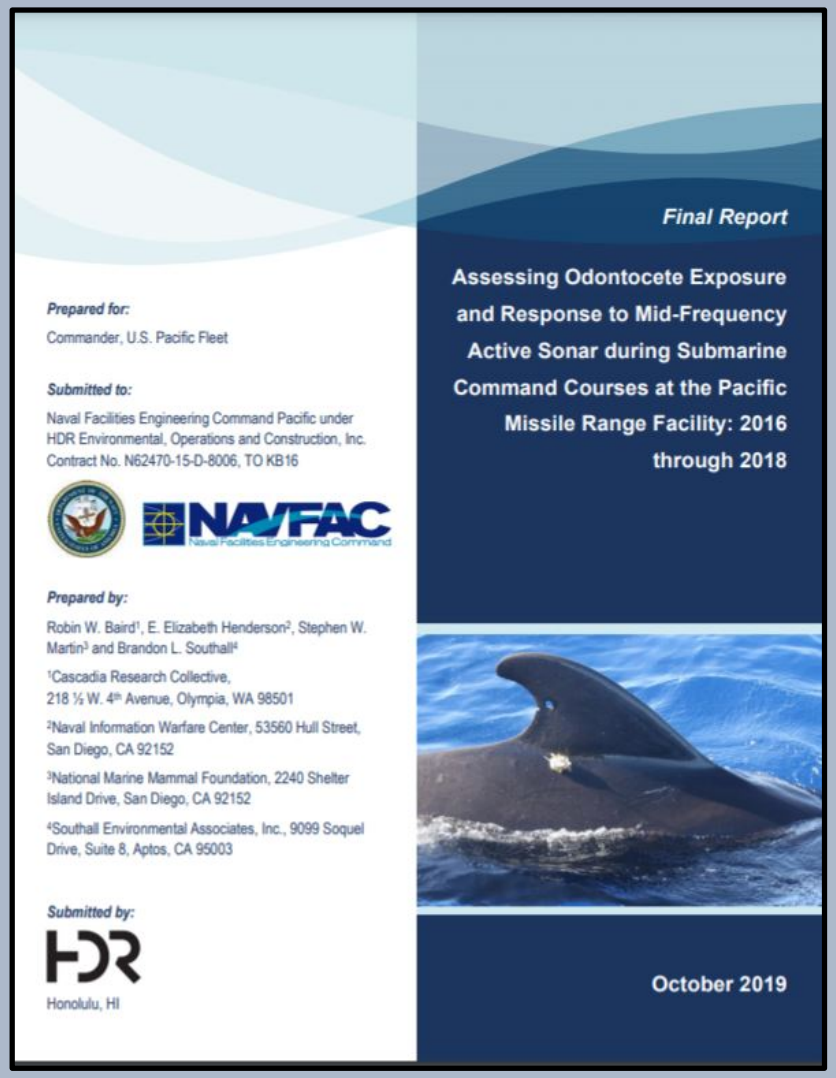
- Studies using a combination of tag data and sonar data from the acoustic array at PMRF

Aquatic Mammals 2019, *45*(6), 612-631 DOI 10.1578/AM.45.6.2019.612

Quantifying the Behavior of Humpback Whales (*Megaptera novaeangliae*) and Potential Responses to Sonar

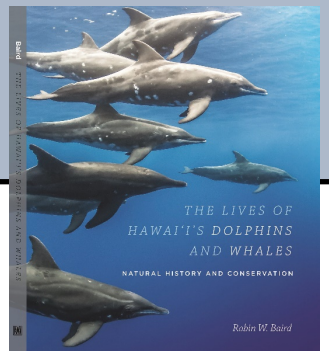
E. Elizabeth Henderson,[1] Jessica Aschettino,[2] Mark Deakos,[3] Gabriela Alongi,[4] and Tara Leota[5]

[1]*NIWC Pacific, 53560 Hull Street, San Diego, CA 92152, USA*
E-mail: ehenders@spawar.navy.mil
[2]*HDR, 4144 Hermitage Point, Virginia Beach, VA 23455, USA*
[3]*HDR, 305 S. High Street, Suite 101, Wailuku, HI 96793, USA*
[4]*National Marine Mammal Foundation, 2240 Shelter Island Drive, Suite 200, San Diego, CA 92106, USA*
[5]*Kaua‘i Sea Rider Adventures, PO Box 643, Kalaheo, Kaua‘i, HI 96741, USA*



Sources of information from Hawai‘i

- Stranding events coincident in time & space with Navy MFAS use



Hawaiian Melon-headed Whale *(Peponacephala electra)*
Mass Stranding Event of July 3-4, 2004

Brandon L. Southall, Robert Braun, Frances M.D. Gulland, Ashley D. Heard, Robin W. Baird, Sarah M. Wilkin, and Teri K. Rowles

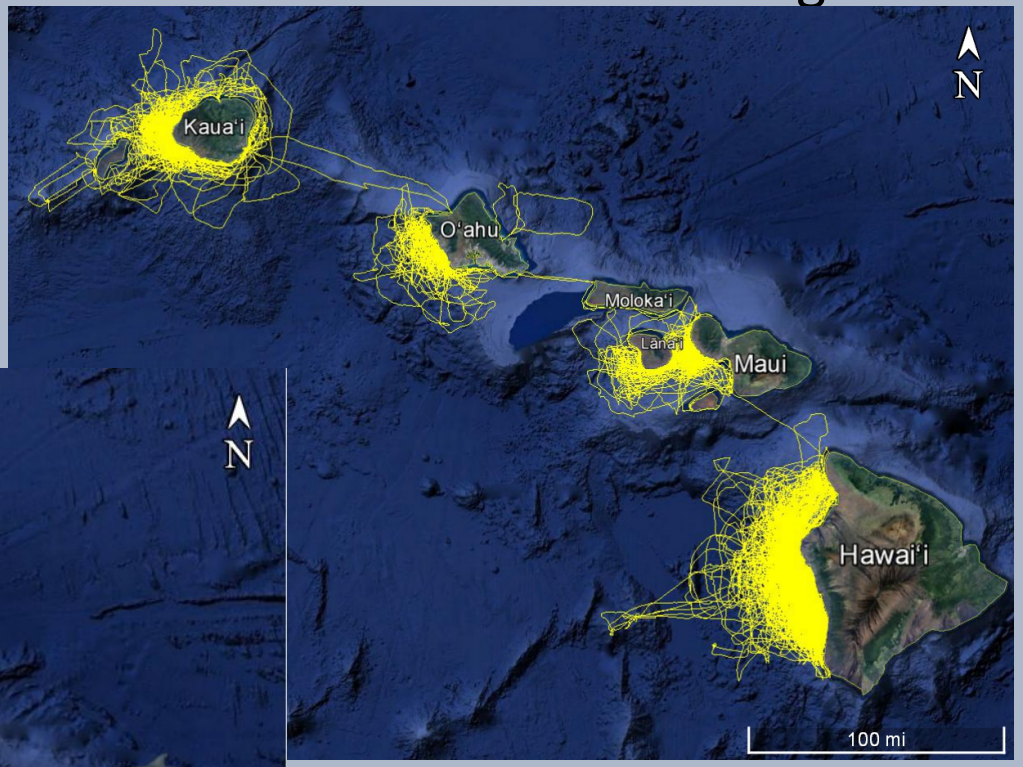
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OPR-31
April 2006

A dwarf sperm that live stranded at the mouth of the Kilauea Stream, Kaua'i, August 27, 2009, the same morning that a U.S. Navy Submarine Commanders Course had started about 50 km to the northwest. The individual, an adult male, had a full stomach, and the necropsy showed it was in good condition with no obvious abnormalities. Photo by Kim Steutermann Rogers.

Sources of information from Hawai‘i

- Comparisons of species composition and abundance from high- and low-MFAS use areas



Effort from 2000-2020

1,161 days (>8,000 h)
>147,000 km effort
>3,000 odontocete sightings
18 odontocete species
3 baleen whale species

Sources of information from elsewhere

Behavioral response studies (Controlled Exposure Experiments)

- Cuvier's beaked & short-finned pilot whales –North Carolina
- Blainville's beaked whales – Bahamas
- Humpback, minke, killer, long-finned pilot, sperm & northern bottlenose whales - Norway
- Cuvier's beaked, Baird's beaked, & blue whales, common, bottlenose & Risso's dolphins - California

Strandings or behavioral changes concurrent with MFAS use

- Cuvier's beaked whales – Greece, Bahamas, CNMI
- Blainville's beaked whales – Bahamas, Canary Islands
- Short-finned pilot whales – North Carolina
- Pygmy killer whale - Taiwan
- Dwarf sperm whale – North Carolina
- Killer whales – Washington state

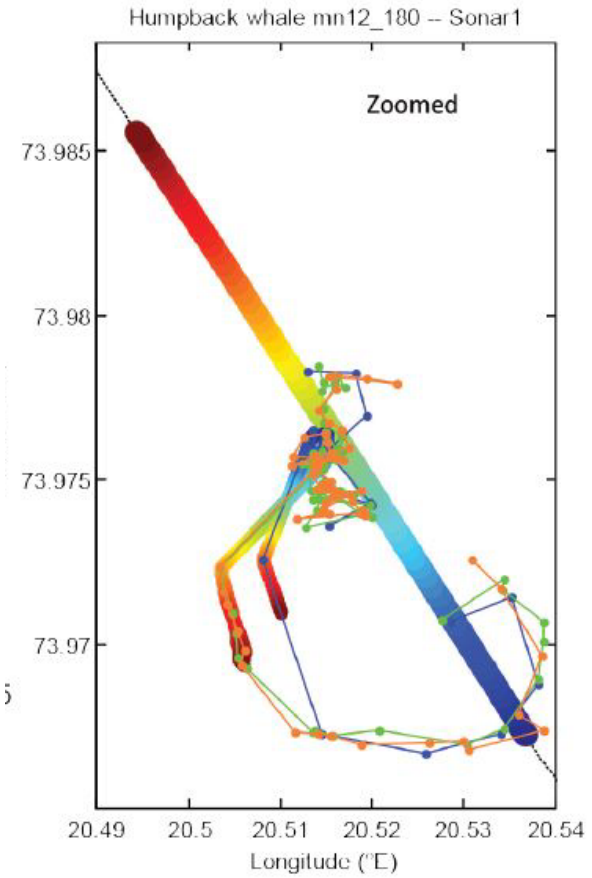
research-repository.st-andrews.ac.uk/handle/10023/9942

Aquatic Mammals 2015, *41*(4), 469-502, DOI 10.1578/AM.41.4.2015.469

Severity of Expert-Identified Behavioural Responses of Humpback Whale, Minke Whale, and Northern Bottlenose Whale to Naval Sonar

Lise D. Sivle,[1] Petter H. Kvadsheim,[2] Charlotte Curé,[7] Saana Isojunno,[3] Paul J. Wensveen,[3] Frans-Peter A. Lam,[4] Fleur Visser,[5,6] Lars Kleivane,[2] Peter L. Tyack,[3] Catriona M. Harris,[8] and Patrick J. O. Miller[3]

- Most common response was avoidance, some changes in diving behavior
- Responses less severe than minke whale or northern bottlenose whale exposed to same source, and less responsive than killer whales, sperm whales, long-finned pilot whales



Aquatic Mammals 2019, *45*(6), 612-631 DOI 10.1578/AM.45.6.2019.612

Quantifying the Behavior of Humpback Whales (*Megaptera novaeangliae*) and Potential Responses to Sonar

E. Elizabeth Henderson,[1] Jessica Aschettino,[2] Mark Deakos,[3] Gabriela Alongi,[4] and Tara Leota[5]

Table 5. Propagation-modeled received levels of MFAS (estimated over 1 s and averaged in µPa) at the surface for each satellite tagged whale along with the distances to the closest ship

Tag ID	RL mean (dB re 1 µPa)	RL median (dB re 1 µPa)	RL max (dB re 1 µPa)	cSEL (dB re 1 µPa2s)	Mean distance (km)	Min/max distance (km)
173784	99.9	126.0	133.2	141.6	121.6	109/134
173786	129.1	136.9	151.4	162.8	59.8	27/107
173787	146.3	153.7	158.4	165.2	33.7	17/101
173788	109.2	104.3	137.4	138.8	202.0	62/253
173789	116.7	116.0	146.1	151.5	67.1	36/96

- Exposure during Submarine Command Course
- Small sample size (n=5)
- Distances from MFAS 17-253 km

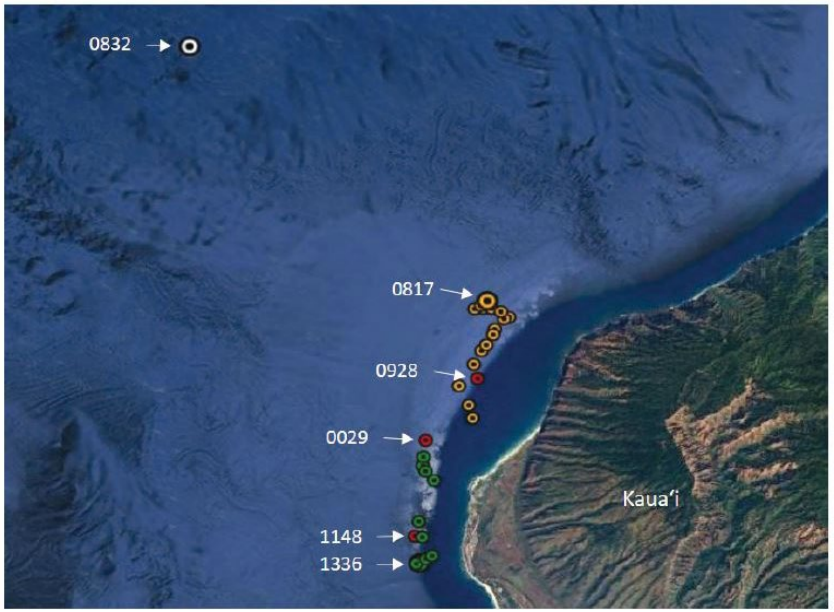


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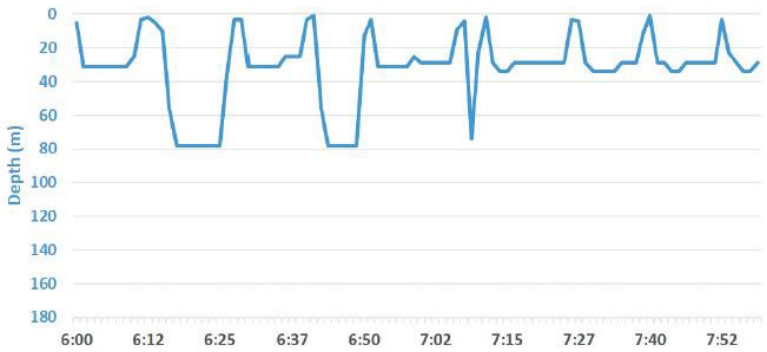
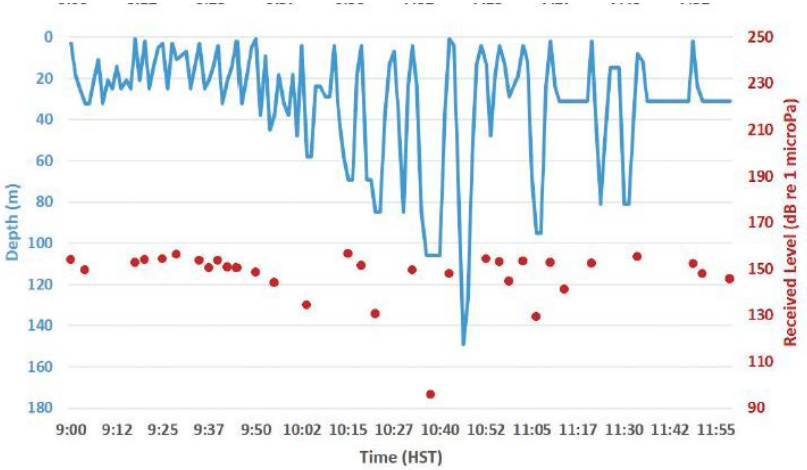
Table 6. Dive variables for which MFAS was a significant predictor and the associated coefficient estimate, standard error, *t* value, and *p* value from the GLMs for whale 173787

Whale 173787	Without MFAS	With MFAS	Coef.	SE	*t* value	*p* value
Dive count	138.0	15.0	--	--	--	--
Dive duration (min)	9.9	7.5	-0.27	0.13	-2.1	0.04
Descent rate (m/min)	3.9	6.1	-0.74	0.34	-2.2	0.03
Bottom distance (m)	8.0	37.6	1.55	0.32	4.9	< 0.001
Dive depth SD (m)	3.5	16.7	1.57	0.30	5.3	< 0.001
Maximum depth (m)	34.7	55.5	0.47	0.16	2.9	0.005

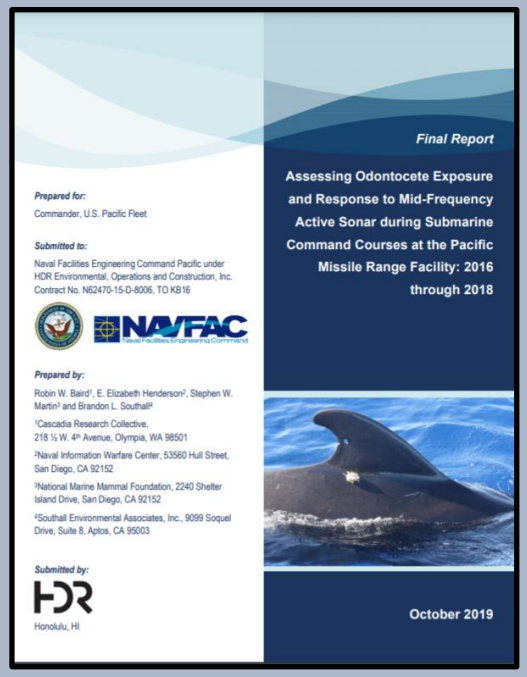


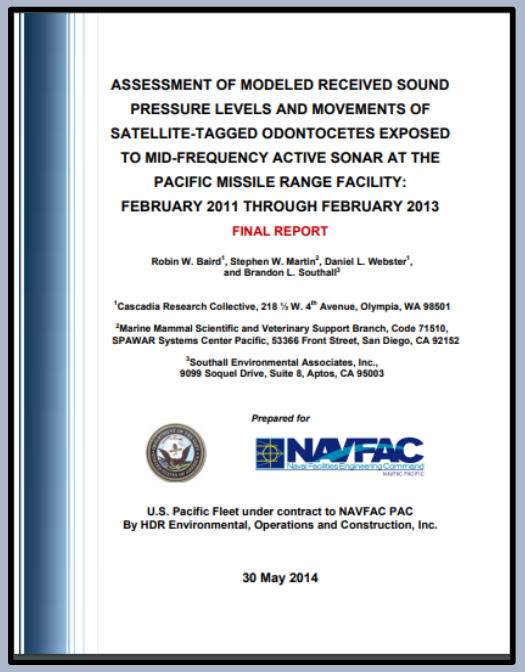
No MFAS exposure

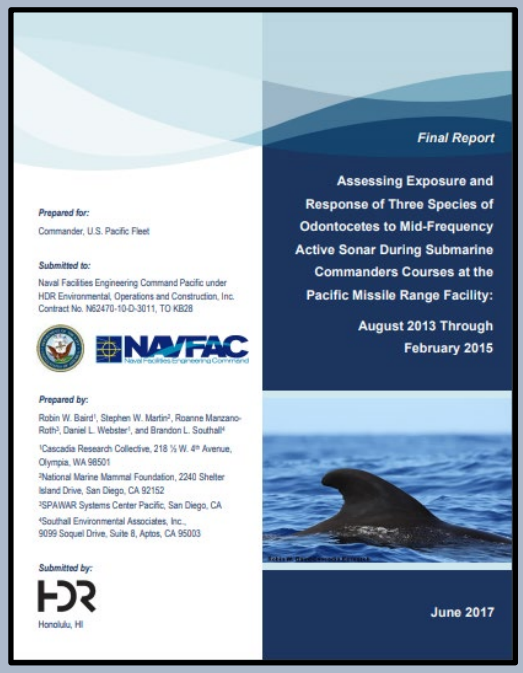


MFAS exposure

Assessing changes in spatial use and diving behavior of odontocetes exposed to MFAS off Kaua‘i







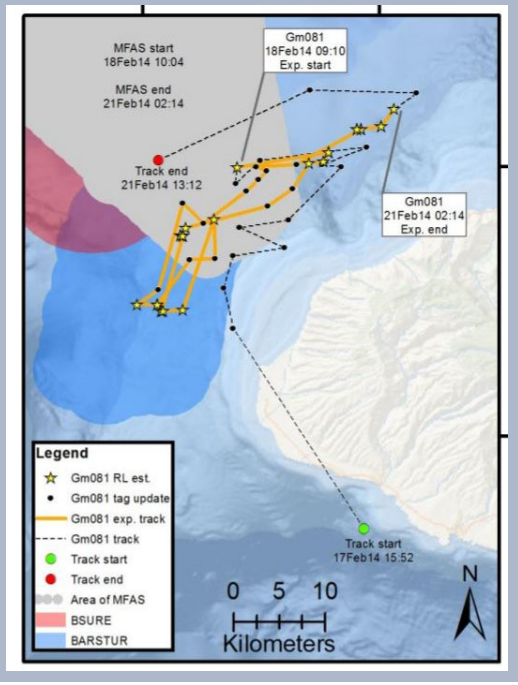
- Short-finned pilot whales n=13
- Rough-toothed dolphins n=7
- Common bottlenose dolphins n=3
- Melon-headed whale n=2
- False killer whale n=1

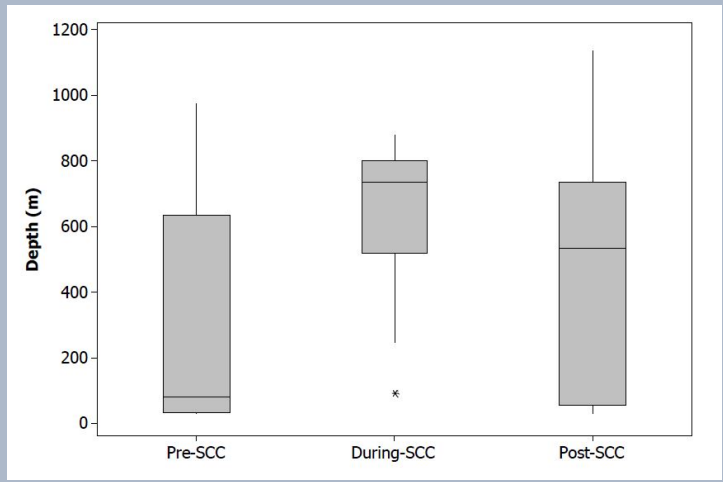
- Pilot whales & rough-toothed & bottlenose dolphins resident
- High use areas of all three overlap with PMRF
- Pelagic pilot whales also tagged
- False killers from NWHI population

www.cascadiaresearch.org/hawaiian-cetacean-studies/publications

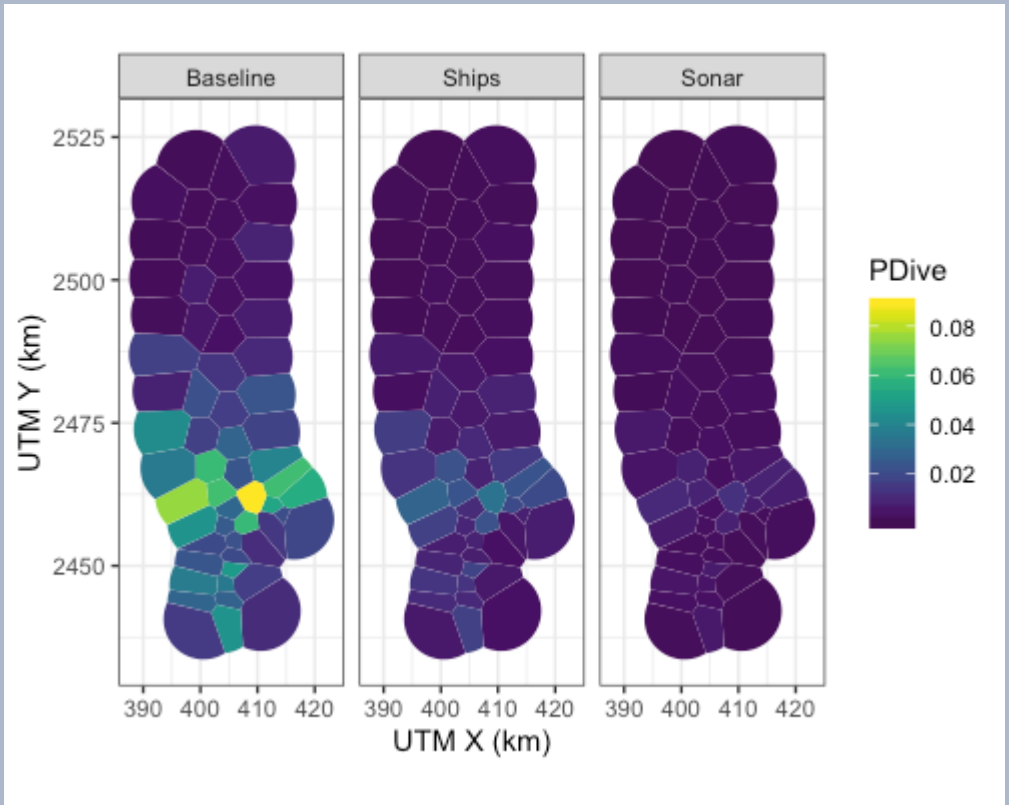
Assessing changes in spatial use and diving behavior of odontocetes exposed to MFAS off Kaua‘i

- Some individuals move away from PMRF prior to MFAS start
- Resident pilot whales and a bottlenose dolphin have shown no large-scale movements away from high exposure (~168-169 dB) areas
- Changes in pilot whale diving behavior documented
- Some rough-toothed dolphins moved from area of low to higher exposure (~155 dB)
- False killer whale moved from area of low (~91 dB) to higher exposure (~160 dB)





Short-finned pilot whale GmTag081



Quantifying the response of Blainville's beaked whales to Naval sonar exercises in Hawaii

Eiren K. Jacobson, E. Elizabeth Henderson, Cornelia S. Oedekoven, David L. Miller, Stephanie L. Watwood, David J. Moretti, Len Thomas

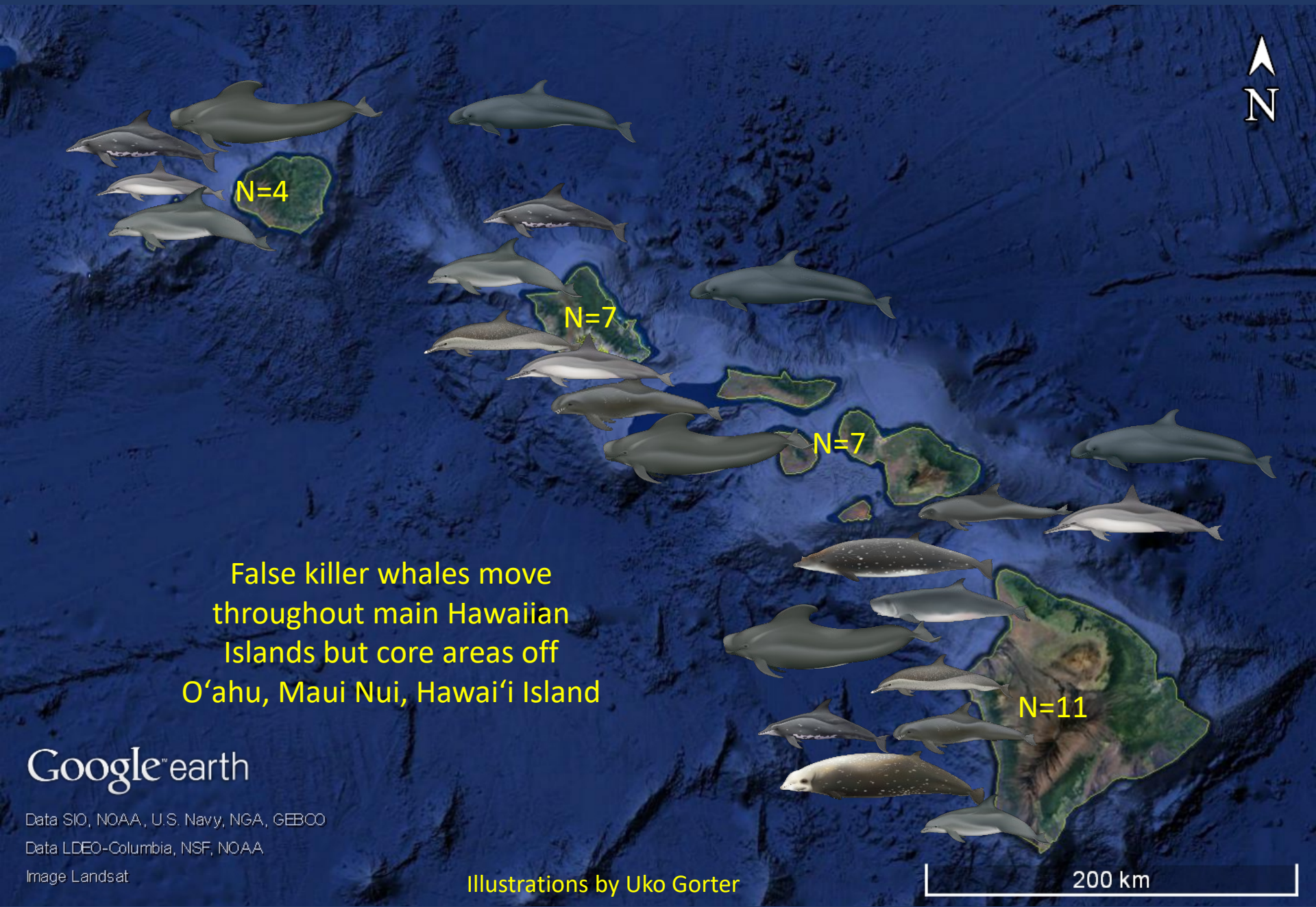
eiren.jacobson@st-andrews.ac.uk | @eirenkate

Jacobson et al. Beaked Whale Risk Hawaii: eirenjacobson.github.io/JacobsonEtAl_WMMC2019.pdf

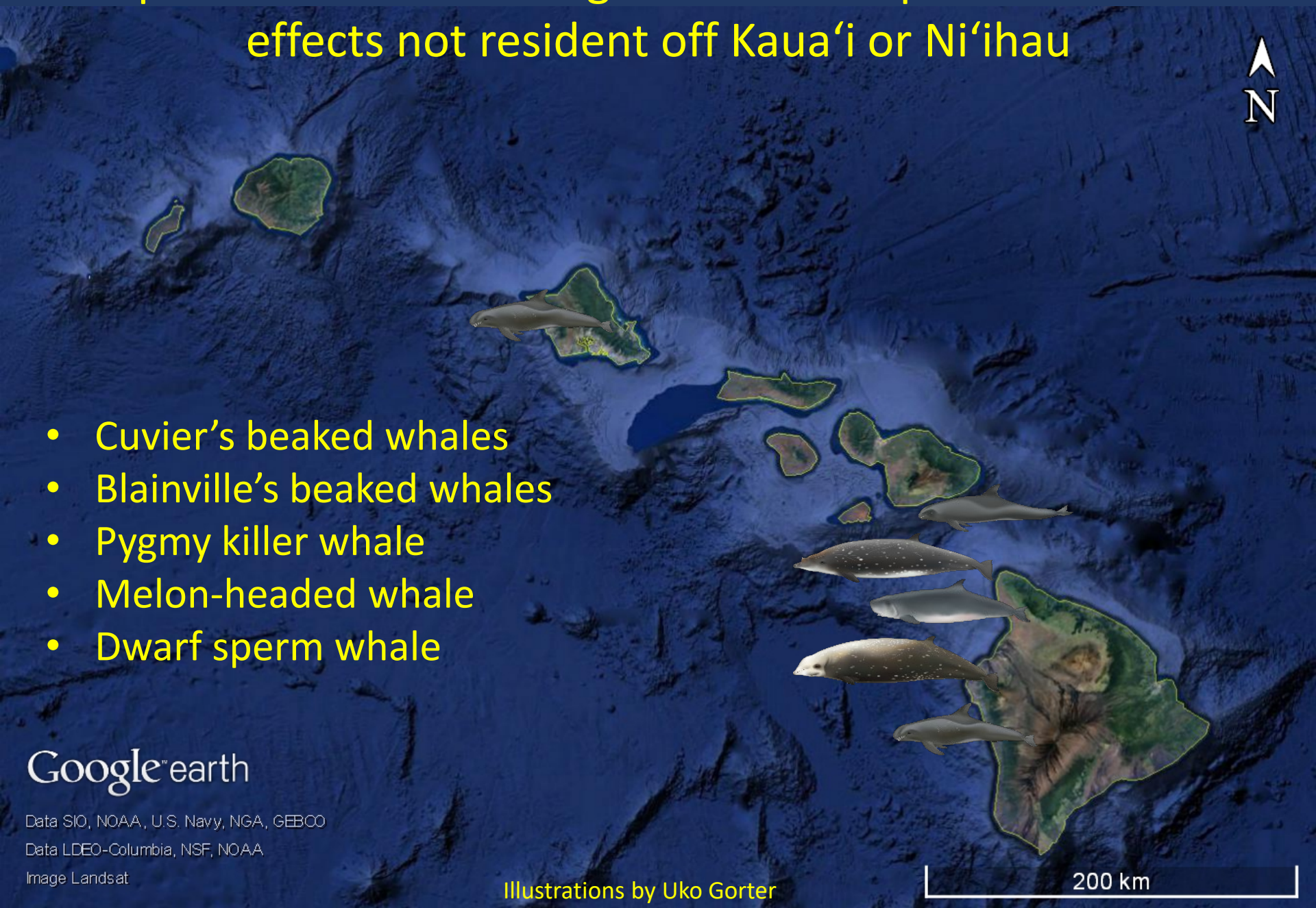
- Naval activity results in 64% reduction in probability of beaked whale detection relative to baseline

- Sonar received level of 150 dB re 1 µPa results in a 78% reduction relative to when Naval activity is present, but a **92% reduction relative to pre-activity period**

Number of resident odontocete species by island area



Species known or thought to be susceptible to MFAS effects not resident off Kaua‘i or Ni‘ihau



- Cuvier’s beaked whales
- Blainville’s beaked whales
- Pygmy killer whale
- Melon-headed whale
- Dwarf sperm whale

Mortality

Two primary mechanisms recognized:

- Gas and fat embolisms* caused by a behavioral response, particularly in long-diving species (e.g., beaked whales)
- Behavioral response to avoid sound resulting in animals stranding**

*www.cascadiaresearch.org/files/publications/BernaldodeQuirosetal2019.pdf

**www.cascadiaresearch.org/files/Projects/Hawaii/Southall_et_al_Peponocephala.pdf

Difficulties assessing MFAS-related mortality in Hawaiian waters

- Large proportion of animals that die are not found (~75% for California coastal bottlenose dolphins, ~95-98% of main Hawaiian Islands insular false killer whales)
- Assessing decompression sickness requires sampling animals shortly after death
- Limited access to MFAS data and incomplete data records in Navy's SPORTS database

www.cascadiaresearch.org/files/publications/BernaldodeQuirosetal2019.pdf

digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1533&context=usdeptcommercepub

Conclusions

- Sensitivity to sonar varies by species
- Responses to sonar varies by context (e.g., distance to source, source location relative to land, hull-mounted v. helicopter-dipping) and by prior exposure history
- MFAS used in Hawai‘i for ~50 years, current high-power systems for ~35 years, thus possible many changes occurred prior to any monitoring/research
- Incomplete or inaccessible data on when, where, and what type of MFAS is used in Hawaiian waters, making it impossible to conclusively rule out MFAS as a cause for many stranding events
- Population estimates and trend data lacking for many of the insular populations of species most likely to be susceptible (i.e., beaked whales, dwarf sperm whales, melon-headed whales, pygmy killer whales)

rwbaird@cascadiaresearch.org

www.cascadiaresearch.org/hawaiian-cetacean-studies/publications