Behavioral Response of Blainville's Beaked Whales (*Mesoplodon densirostris*) to U.S. Navy Training Activity

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- Four Blainville's beaked whales whales were tagged with Wildlife Computers satellite tags at PMRF
  - Tag durations of 8.2 – 24.3 days with positional data
    - Dive data for only two tags (MdTag020 and MdTag021)
  - Whale tracks smoothed and interpolated every 5-min with *crawl* in R
  - Two of the animals remained together for at least 9 days on or near range (MdTag020 and MdTag021)
  - One whale left area before training, three animals remained in area during and after training, moved off range
- Sources of MFAS included hull-mounted ship sonar, active sonobuoys, and helicopter-dipping sonar
- **Received levels of MFAS** were estimated using Peregrine parabolic equation propagation model developed by Oasis Ltd (Heaney and Campbell 2016)
  - Median estimated received levels from ship sonar ranging from 120 - 147 dB re 1 μPa
  - Median estimated received levels from sonobuoys and dipping sonar were significantly lower at 110 - 120 dB re 1 μPa
- **Dive behavior** was quantified for baseline and MFAS exposure periods
  - 24 deep foraging dives linked to periods of Blainville's beaked whale foraging clicks from range hydrophone data
  - Dive metrics: deep and intermediate dive depths and durations, inter-deep dive interval (IDDI) durations, and number of intermediate dives per IDDI
  - Percentiles compared between baseline and MFAS exposure dives
- **Movement behavior** was quantified for baseline, Phase A (training with no MFAS), Phase B (before MFAS), during MFAS exposures in Phase B, and equal duration periods after exposures
  - Periods with Argos or GPS updates longer than 6 hours apart were removed from the analysis (reduce false smoothing)
  - Track step length, speed, bearing, and directionality were estimated for all other periods
  - Conducted ANOVA and multiple comparison analyses for metrics within individuals across training periods
  - Training periods were Before, Phase A (no MFAS), Phase B (before MFAS), During MFAS, After MFAS
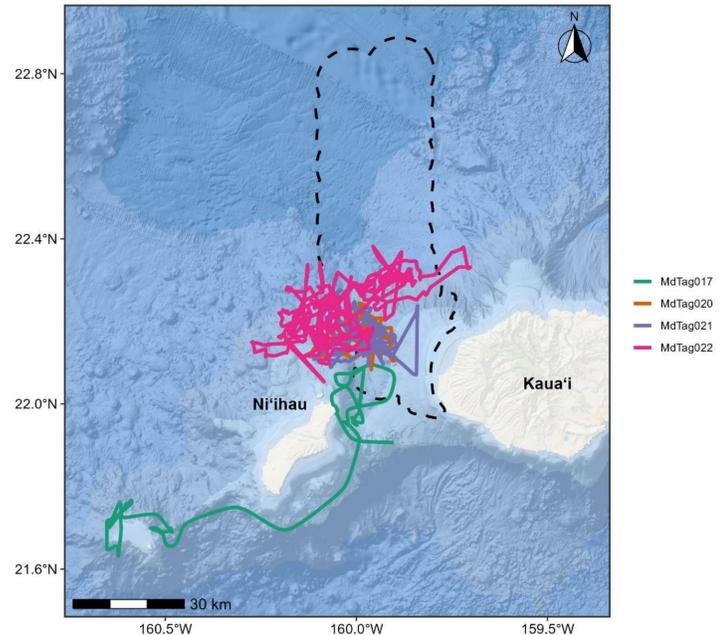
Satellite tag tracks of four Blainville's beaked whales tagged at the Pacific Missile Range Facility in Hawai'i

MdTag020 – August 2021

MdTag021 – August 2021

MdTag022 – August 2022
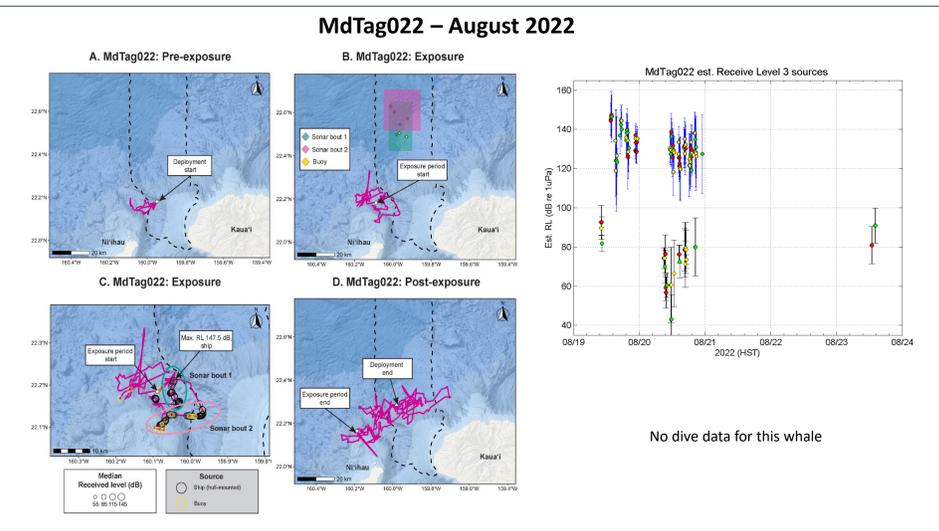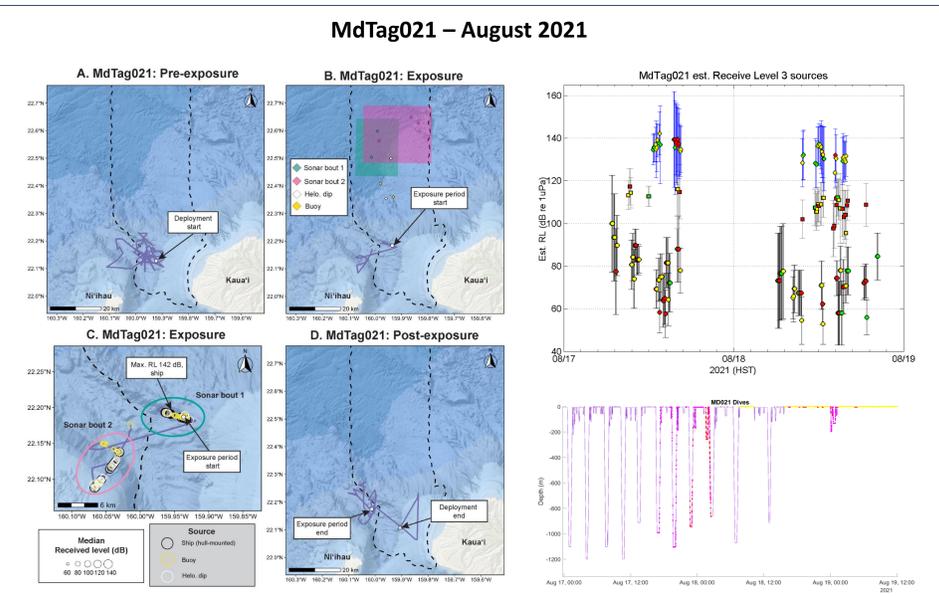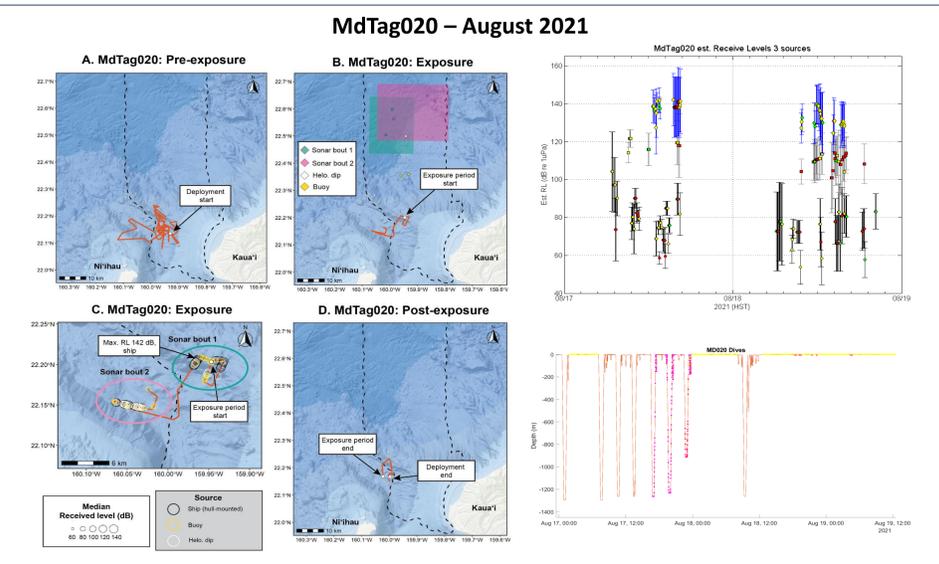
FIGURE KEY

- **Received level plots**
  - Circles are the median estimated RL per 5-min bin
  - Circle color indicates amount of MFAS per bin (green – low, yellow – medium, red – high);
  - blue bars are 2*SE for hull-mounted MFAS, black bars are 2*SE for helicopter-dipping/sonobuoy MFAS
- **Dive plots**
  - Pink dots are 5-min bins with helo-dipping/sonobuoy MFAS, red dots are 5-min bins with ship MFAS
  - Yellow bar on the top indicates periods of missing dive data

Dive Behavior Analysis

Baseline		Deep dive duration (min)	Deep dive depth (m)	IDDI duration (min)	# Int. dives following	Mean int. dive duration (min)	Mean int. dive max depth (m)	IDDI max depth (m)
2.5%	MdTag020	17.3	349.7	3.2	0.0	4.0	56.7	62.0
	MdTag021	35.9	830.5	39.0	0.0	4.9	51.3	51.3
25%	MdTag020	47.4	955.5	74.7	2.0	8.3	97.5	119.5
	MdTag021	46.8	991.5	81.4	1.5	8.7	76.5	107.1
50%	MdTag020	51.1	1263.5	108.6	3.0	10.3	110.3	135.5
	MdTag021	50.3	1103.5	110.6	3.0	10.3	101.5	123.5
75%	MdTag020	54.6	1327.5	137.8	4.0	11.2	130.8	163.5
	MdTag021	53.0	1231.5	132.1	4.0	11.4	117.5	147.5
97.5%	MdTag020	59.2	1389.9	256.9	7.7	15.9	193.8	225.8
	MdTag021	61.3	1327.5	237.1	8.4	14.1	140.3	209.0

Exposure		Deep dive duration (min)	Deep dive depth (m)	IDDI duration (min)	# Int. dives following	Mean int. dive duration (min)	Mean int. dive max depth (m)	IDDI max depth (m)
8/17/21 16:29	MdTag020	53.4	1263.5	122.2	3	8.2	96.8	151.5
	MdTag021	51.9	991.5	122.2	3	8.4	88.8	123.5
8/17/21 19:25	MdTag020	55.6	1231.5	128.4	2	10.8	136.5	223.5
	MdTag021	55.7	1103.5	128.3	2	13.7	117.5	183.5
8/17/21 22:29	MdTag020	50.0	911.5	30	2	11.1	171.5	175.5
	MdTag021	50.0	943.5	170.7	5	11.7	139.1	**255.5**
8/18/21 2:09	MdTag020	59.1	863.5	202.0	3	12.4	121.5	171.5
	MdTag021	--	--	--	--	--	--	--
8/19/21 0:04	MdTag020	--	--	--	--	--	--	--
	MdTag021	NA	NA	75.6	5	13.0	105.1	195.5
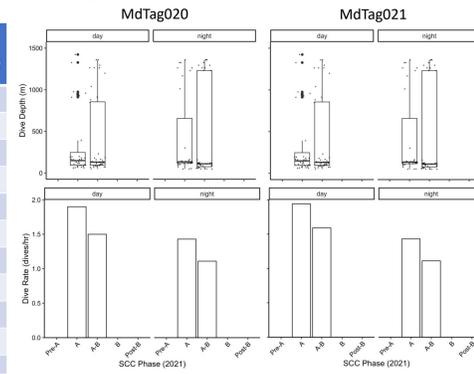
Key Results

- Only IDDI max intermediate dive depth during exposure fell outside 97.5% of baseline
- Continued foraging during helo-dipping/sonobuoy MFAS
- Changed dive behavior during 1st ship MFAS and left range
- Whales may have split up at that time (tracks split too)

Movement Behavior Analysis
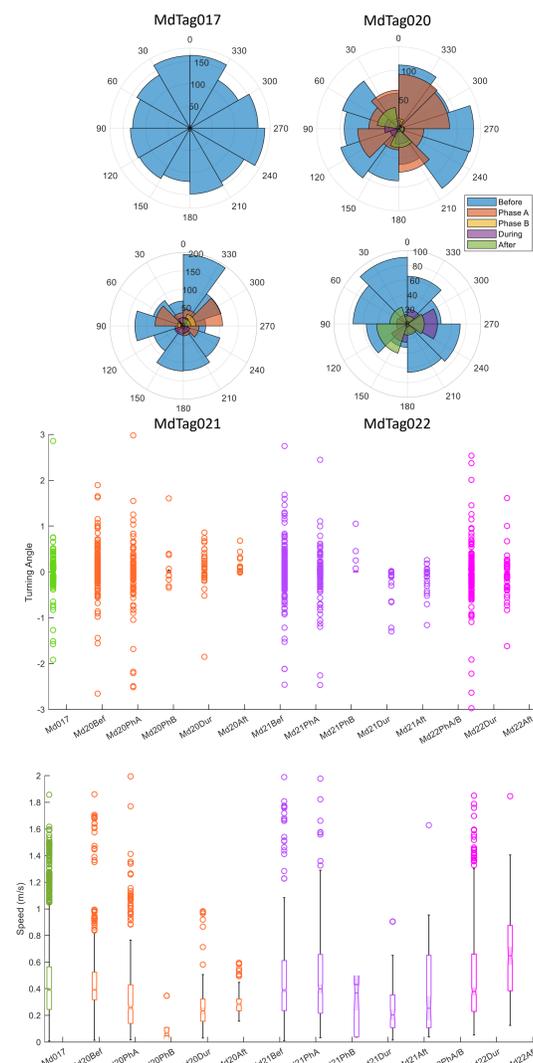
	MdTag020	MdTag021	MdTag022
Bearing (degree)	10.6	43.1	18.9
	0.031	<0.001	<0.001
Step Length (m)	250.2	36.6	24.0
	<0.001	<0.001	<0.001
Turning Angle (concentration)	9.58	27.8	6.18
	0.048	<0.001	0.046
Speed (m/s)	256.0	51.4	31.9
	<0.001	<0.001	<0.001

Statistics are Chi-square (top) and P-value (bottom)

Key Results

- Track headings became less broad, generally away from area of activity during/after MFAS
- Turning angle concentration approached zero – more directed travel
- Travel speeds for MdTag020 & MdTag021 were reduced once training activity began, and slowest during MFAS periods
- Travel speed for MdTag022 increased during MFAS periods
- Whales left range during ship MFAS
- Moved 49-68 km from center of training activity
- May continue foraging (missing dive records)
- Returned to range after training
- Male from 2021 (MdTag2021) resighted in 2024
  - Possibly resident population