Behavioral Response of Rough-toothed Dolphins to Exposures from Multiple Sources of Sonar

E. Elizabeth Henderson[1], Robin W. Baird[2], Cameron R. Martin[1], Michaela A. Kratofil[2], Annette E. Harnish[2], Sabre D. Mahaffy[2], Steve W. Martin[3]

From 2011 through 2025, 25 LIMPET satellite tags were deployed on rough-toothed dolphins (*Steno bredanensis*) off the island of Kaua'i, Hawai'i, part of a known island-associated resident community whose range overlaps with the Pacific Missile Range Facility (PMRF). Navy testing and training activity regularly occurs on PMRF and often includes the use of MFAS. Twelve of the tags recorded dive data; ten of the tags overlapped with periods of MFAS exposure from hull-mounted surface ships, active sonobuoys, and helicopter-dipping sonars; and five animals were present for all five phases of the training (Before, Phase A [training activity but no MFAS], Interphase, Phase B [training activity with MFAS], and After). Median received levels for these animals were estimated to be 141 to 159.8 dB re 1µPa for hull-mounted MFAS (n=10); 84 to 123.5 dB re 1µPa for helicopter-dipping MFAS (n=6), and 77.2 to 103.5 dB re 1µPa for active sonobuoys MFAS (n=10). Tracks resulting from Argos satellite and GPS positions were smoothed and interpolated every 5-min using *crawl*; the subsequent step lengths between positions (in meters), speeds (in m/s), turning angles between positions (in radians), and heading between positions (in bearing degrees) were compared for all animals and for the five animals with data in all five phases using Kruskal-Wallis Analyses and Multiple Comparison tests.

## All Baseline/Before Tracks 2011-2025
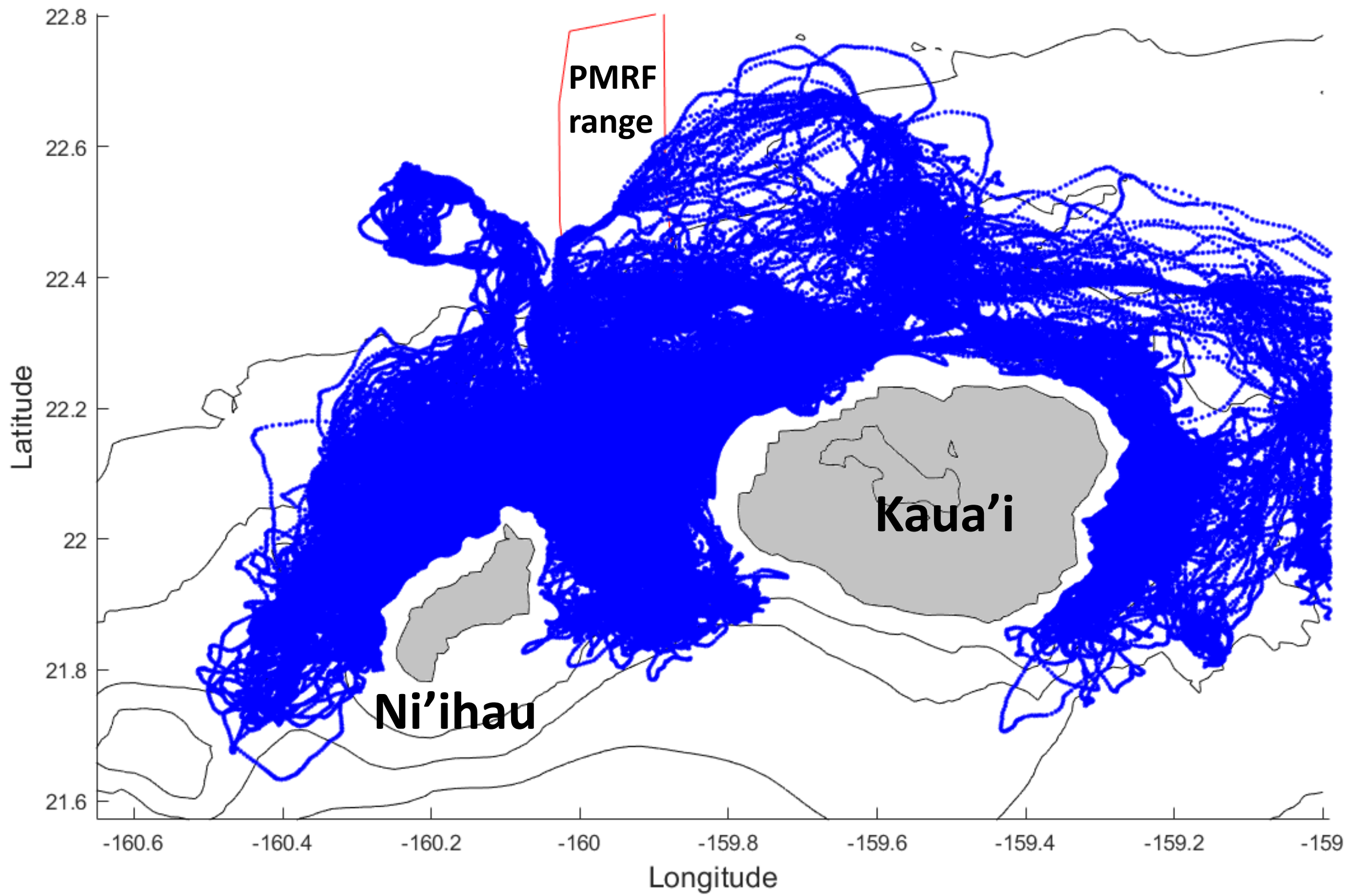
MOVEMENT ANALYSIS

Kruskal-Wallis Analysis of Movement Variables Across Training Phases

	All Animals	SbTag002	SbTag003	SbTag014	SbTag015	SbTag023
Bearing (deg)	X^2 = 2109.2 p<0.001	X^2 = 196.0 p<0.001	X^2 = 122.3 p<0.001	X^2 = 534.3 p<0.001	X^2 = 1051.8 p<0.001	X^2 = 28.3 p<0.001
Step Length (m)	X^2 = 1106.3 p<0.001	X^2 = 183.3 p<0.001	X^2 = 318.1 p<0.001	X^2 = 1903.7 p<0.001	X^2 = 1680.3 p<0.001	X^2 = 18.8 p<0.001
Turning Angle (rad)	X^2 = 23.8 P<0.001	X^2 = 7.52 p = 0.11	X^2 = 6.3 p=0.18	X^2 = 14.7 p<0.001	X^2 = 52.6 p<0.001	X^2 = 4.5 p=0.35
Speed (m/s)	X^2 = 1270.4 P<0.001	X^2 = 173.8 p<0.001	X^2 = 361.4 p<0.001	X^2 = 2320.1 p<0.001	X^2 = 2135.3 p<0.001	X^2 = 38.5 p<0.001

➢ Conducted K-W and multiple comparison analysis (**bold** = significant):
  ➢ Data from all animal tracks
  ➢ 5 animals with data Before, Phase A, Interphase, Phase B, After
  ➢ Arrows indicate significant change in behavior relative to **Before** ⬆⬇

All Animals

Bearing (Deg)

Step Length (m)

Turning Angle (Rad)

Speed (m/s)
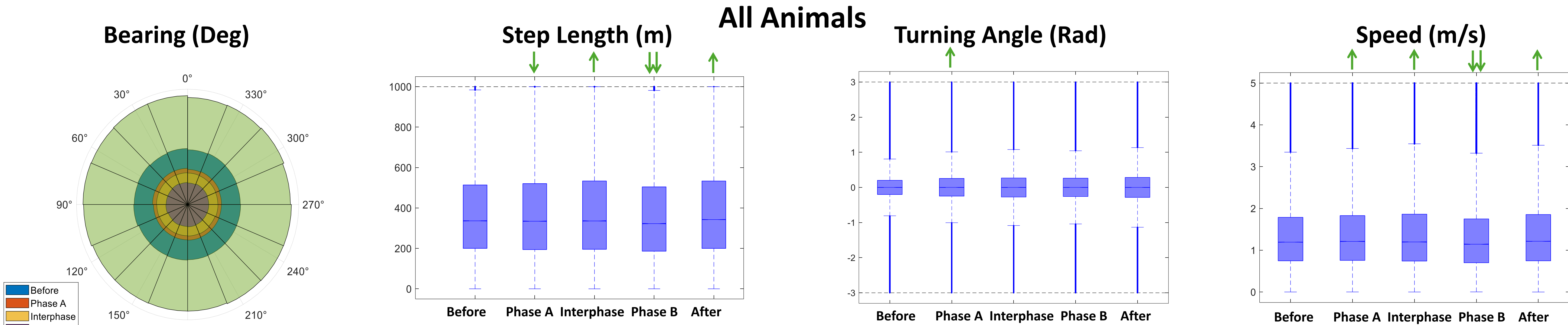
Comparison of SbTag002, SbTag003, SbTag014, SbTag015, and SbTag023
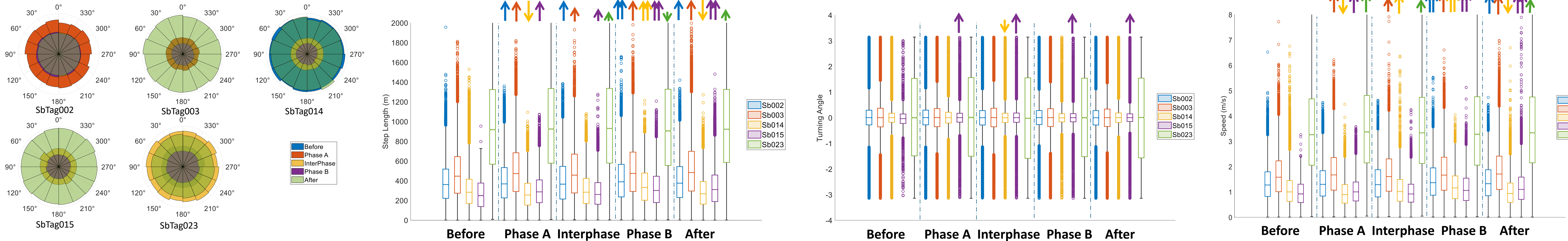
Results

➢ Changes in movement behavior variables
  ➢ Most increased from Before through SCC
  ➢ Not consistent across individuals
  ➢ Some highest swim speeds/step lengths in Phase B (Sb002, Sb014, Sb015)
➢ Tracks remained in same areas during Phase B as general species' habitat use
➢ Received levels remained consistent throughout Phase B
  ➢ Most < 160 dB re 1 µPa
  ➢ No indication of avoidance by decreasing levels
➢ Resident population
  ➢ May be habituated to MFAS
  ➢ May not have alternate foraging habitat

SbTag002

SbTag002	Ship	Dipping Sonar	Sonobuoy
Highest median RL (± 2 SD) dB re 1 µPa	143.1 (133.8, 152.4)	N/A	98.0 (92.9, 103.0)
CPA (km)	25.8	N/A	20.6

SbTag014

SbTag014	Ship	Dipping Sonar	Sonobuoy
Highest median RL (± 2 SD) dB re 1 µPa	159.8 (149.0, 170.7)	112.7 (97.5, 127.8)	96.8 (89.7, 103.8)
CPA (km)	14.0	34.7	30.8

SbTag023

SbTag023	Ship	Dipping Sonar	Sonobuoy
Highest median RL (± 2 SD) dB re 1 µPa	141.9 (127.2, 156.6)	123.5 (101.1, 145.9)	96.6 (88.7, 104.6)
CPA (km)	27.1	25.2	22.2

Hull-mounted ship MFAS ◆ Active sonobuoy MFAS ● Helicopter-dipping MFAS ■ Few pings per 5-min bin Mod num pings per 5-min bin Several pings per 5-min bin