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Received Levels of Odontocetes Tagged During Submarine Command Courses at the Pacific Missile Range Facility in 2023 and 2024

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ADMINISTRATIVE INFORMATION

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EXECUTIVE SUMMARY

In August 2023 and February 2024, Cascadia Research Collective (CRC) conducted small boat-based satellite tagging of odontocetes at the Pacific Missile Range Facility (PMRF), with acoustic support from Naval Information Warfare Center (NIWC) Pacific and Naval Undersea Warfare Center (NUWC) Newport, directing the tagging boat towards locations of acoustic detections on the range. Seventeen days of tagging effort were conducted over the two years during the biannual Submarine Command Course (SCC) training events. In total 19 odontocetes were tagged: 14 short-finned pilot whales (*Globicephala macrorhynchus*), 3 common bottlenose dolphins (*Tursiops truncatus*), 1 pantropical spotted dolphin (*Stenella attenuata*), and 1 melon-headed whale (*Peponocephala electra*). Additionally, 3 humpback whales (*Megaptera noveangliae*) were tagged in concert with this effort to test new tags, and that data was also analyzed herein.

The resulting tag tracks were smoothed and interpolated with positions every 5 mins using *crawl* in R, while dive profiles were modeled using a custom-built program in Matlab based on the output of the dive behavior log files. Received levels were estimated in 3D using a parabolic propagation modeling equation for every transmission from three sources producing mid-frequency active sonar (MFAS): hull-mounted MFAS from surface ships, active sonobuoys, and helicopter-dipping MFAS. The resulting received levels were binned by 5-mins, corresponding to the 5-min track positions, with the highest median received level (plus/minus 2 standard deviations) reported for each bin, along with an overall cumulative sound exposure level (cSEL) for each animal resulting from their total cumulated exposures.

Dive behavior was statistically analyzed across diel period (dawn, daytime, dusk, and nighttime) and SCC phase (Before, Phase A, Interphase, Phase B, After), when there was enough dive data across periods for analysis. Movement behavior in response to MFAS was assessed qualitatively. Resulting assessments indicated that there were some statistically significant differences in dive depth and dive duration for some individual pilot whales across different diel or SCC phases, but these differences varied by group or individual, with no consistent differences for any metric across any period. Dive rates and the percentage of time spent on the surface did not differ significantly for any individual across any period, and dive depths and durations did not differ significantly for any other species. No large scale or obvious horizontal movement was observed for any of the individuals, with several pilot whales and the melon-headed whale transiting back and forth across the range and relatively close to the areas of training activity throughout bouts of MFAS. However, the melon-headed whale did move off the range after their first, highest received level bout of exposures, which could have been a short distance, short duration avoidance behavior.

These results are discussed in the context of the residency status of individuals and species with all pilot whales being from resident, island-associated communities, and all three bottlenose dolphins also being from a resident, island-associated population. The melon-headed whale and spotted dolphin were not known individuals, but melon-headed whales have been increasingly observed in the Hawaiian Islands in the last eight years and therefore may be more frequently exposed to MFAS than they were a decade ago. These

data will be added to the growing dataset of tagged odontocetes exposed to MFAS at PMRF. These aggregated data can be analyzed using more sophisticated modeling techniques to quantitatively assess behavior in response to MFAS, and to examine potential changes in response over time to look for changes in behavioral response patterns.

ACRONYMS

ANOVA	Analysis of Variance
COMPACTFLT	Commander, U.S. Pacific Fleet
CPA	Closest point of approach
CRC	Cascadia Research Collective
GPS	Global Positioning System
LIMPET	Low Impact Minimally Percutaneous Electronic Transmitter
MFAS	Mid-Frequency Active Sonar
NIWC	Naval Information Warfare Center
NUWC	Naval Undersea Warfare Center
PMRF	Pacific Missile Range Facility
SCC	Submarine Command Course
SD	standard deviation

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1. INTRODUCTION

Cascadia Research Collective (CRC) undertook field work off the Pacific Missile Range Facility (PMRF) in 2023 and 2024, continuing long-term odontocete photo-identification and satellite tagging efforts conducted in the Hawaiian Islands for more than 20 years (Baird et al., 2011, 2024a). These field efforts align with a biannual Navy training event, the Submarine Command Course (SCC), creating an opportunity for an opportunistic, real-world behavioral response study of potential effects of mid-frequency active sonar (MFAS) on odontocetes. CRC is supported by personnel from the Naval Undersea Warfare Center (NUWC) Newport and the Naval Information Warfare Center (NIWC) Pacific, who direct CRC to locations of acoustically detected odontocetes on the range.

Species of interest include short-finned pilot whales (*Globicephala macrorhynchus*), false killer whales (*Pseudorca crassidens*), pygmy killer whales (*Feresa attenuata*), melon-headed whales (*Peponocephala electra*), common bottlenose dolphins (*Tursiops truncatus*), rough-toothed dolphins (*Steno bredanensis*), and, when possible, Blainville's beaked whales (*Mesoplodon densirostris*) and killer whales (*Orcinus orca*). The results of this effort add to CRC's long-term datasets exploring the home range and habitat use for these species, many of which are resident to the Hawaiian Islands in general and the islands of Kauaʻi and Niʻihau specifically (Baird 2016; Kratofil et al., 2023). In addition, these data build on general knowledge and understanding of how these individuals and populations may respond to MFAS. This report provides information on the estimated received levels and movement patterns of odontocetes, and humpback whales (*Megaptera novaeangliae*) exposed to MFAS at PMRF during these two tagging efforts.

2. METHODS

2.1 FIELD EFFORTS

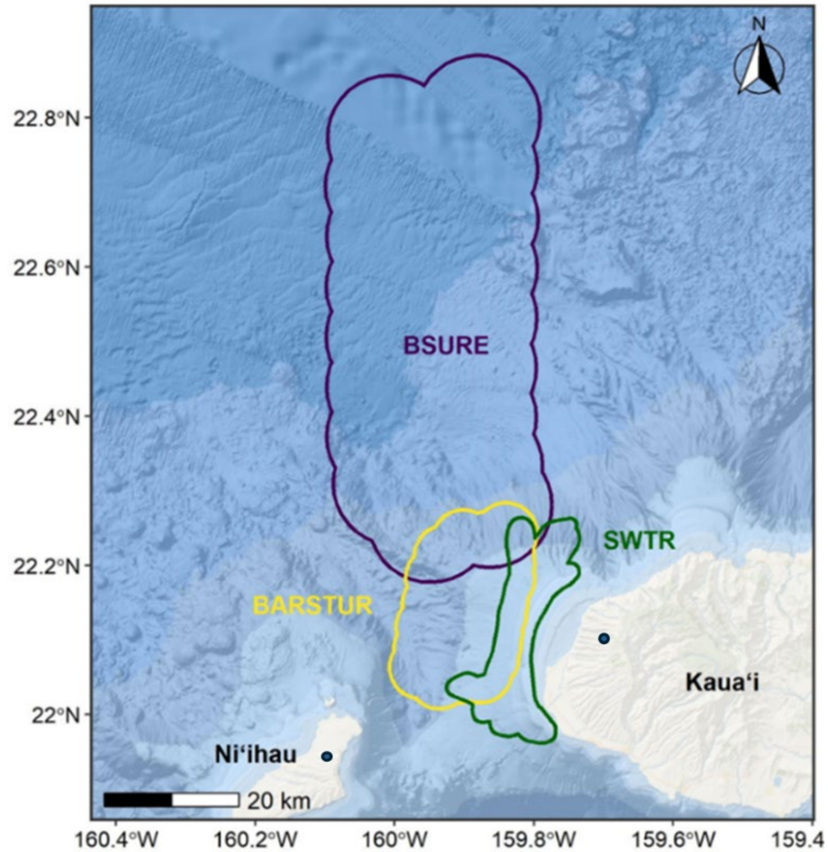
Small boat-based field work was conducted between Kauaʻi and Niʻihau in August 2023 and February 2024 using a 7.3-m rigid-hulled inflatable boat (RHIB). SCCs occur in five phases used for analysis (Table 1). These phases are: Before (involving any data prior to the start of Phase A), Phase A (a period of training activity that does not include hull-mounted MFAS from surface ships), an Interphase without training activity but during which sources may still be present on the range, Phase B (a period of training that includes surface ship hull-mounted MFAS along with other sources of MFAS), and After.

The small-boat surveys were primarily conducted during the Before phase, during Phase A, and through the Interphase. Although, one day of small-boat effort was undertaken that overlapped with Phase B of the SCC in February 2024. Odontocetes were encountered both on and off the instrumented hydrophone range with the survey vessel conducting their search efforts so as to maximize the number of encounters with high-priority species. When on the PMRF range (Figure 1) and vocalizing groups of odontocetes were detected and localized on the hydrophones, the small boat was directed by personnel from NIWC Pacific and NUWC Newport towards locations (either manually or automatically generated localizations when available or general areas of active hydrophones) of acoustic detections of priority species. Once encountered, data were recorded on species, behavior, group size, group spacing, age and sex class of individuals within the group when discernable, and encounter start and end times and locations. Photographs were taken of as many individuals as possible to add to long-term photo-identification catalogs of each species, and to facilitate the determination of age and sex classes when not made in the field, as well as to identify potentially resighted or retagged individuals. Tag deployments were attempted depending on the priority of the species encountered. In February 2024, a small number of tags were available for tagging humpback whales, which were targeted only when no higher priority species were known to be in the area.

Table 1: Start and end times in UTC and durations of August 2023 and February 2024 SCC periods. The Before phase represents the recording effort before the start of the SCC, and the After phase represents the recording effort after the end of the SCC, which is truncated to three days for analyses.

Period	Start Date	End Date	Duration (hours)
August 2023			
Before	7/28/2023 1:30	8/4/2023 18:00	184.5
TRACKEX	8/4/2023 18:00	8/5/2023 3:00	9.0
Between	8/5/2023 3:00	8/8/2023 16:00	85.0
Phase A1	8/8/2023 16:00	8/9/2023 18:30	26.5
Between	8/9/2023 18:30	8/11/2023 17:00	46.5
Phase A2	8/11/2023 17:00	8/12/2023 0:56	7.9
Between	8/12/2023 0:56	8/14/2023 16:00	63.1
Phase B	8/14/2023 16:00	8/17/2023 20:59	77.0
After	8/17/2023 20:59	8/24/2023 8:13	155.2
February 2024			
Before	2/5/2024 23:38	2/13/2024 16:30	184.9
Phase A	2/13/2024 16:30	2/17/2024 3:17	82.8
Interphase	2/17/2024 3:17	2/19/2024 17:15	62.0
Phase B	2/19/2024 17:15	2/22/2024 2:16	57.0
After	2/22/2024 2:16	2/29/2024 4:30	170.2

The primary tags deployed were SPLASH10-F tags (Wildlife Computers, Redmond, WA) in the Low Impact Minimally Percutaneous Electronic Transmitter (LIMPET) configuration. These tags also transmit Fastloc® GPS locations that are picked up not only by the Argos satellites but by a recording goniometer on board the tagging vessel, and by MOTE receivers (land-based, stationary listening stations that continuously log telemetry data from satellite tags) located on the islands of Niʻihau, Kauaʻi, and Oʻahu. Tags were deployed with a Dan-Inject pneumatic projector and were attached with two gas-sterilized surgical grade titanium darts (Schorr et al., 2009; Baird et al., 2011). For larger species (i.e., short-finned pilot whales, humpback whales) 6.7-cm darts with two rows of backward-facing petals were used, while for smaller species (i.e., bottlenose dolphins, rough-toothed dolphins, pantropical spotted dolphins, melon-headed whales, Blainville's beaked whales), 4.4-cm darts with one row of backward-facing petals were used.



- The three areas are the Shallow Water Training Range (SWTR), Barking Sands Underwater Range Expansion (BSURE), and Barking Sands Tactical Underwater Range (BARSTUR). The two blue circles indicate the locations of the MOTE antennas.

Figure 1: The Barking Sands Underwater Range at the Pacific Missile Range Facility (PMRF). Tag Programming.

Tags were programmed following the methods outlined in Henderson et al. (2021, 2024) and are only broadly summarized here. All SPLASH tags were programmed to record dives greater than or equal to 50 meters and lasting longer than 30 seconds to reduce gaps in the behavior logs (Quick et al., 2019). SPLASH tags were programmed to continuously collect Fastloc®-Global Positioning System (GPS) data for all 24 hours of the day in 2023. This was adjusted in 2024 so that tags collected Fastloc®-GPS data only during the 12 hours of the day when there were limited or no Argos satellite overpasses, to improve data throughput. All SPLASH tags recorded time series data, with a subset of tags also programmed to collect dive behavior data.

Behavior log data included the start and end times of surface periods and dives, the maximum dive depth, and the shape of the dive (U, V, or square). Time series data (e.g., depth at pre-determined time intervals) were collected either continuously, or in the case of tags that also recorded behavior, on a one-day-on-five-days-off-one-day-on schedule, with the interval of time series data collection determined by species (Table 2). Tags were programmed to record dive and Fastloc-GPS data from the time deployed until three and a half days after the end of the SCC and continue to transmit the dive and Fastloc®- GPS data for an additional six days. To preserve battery life and provide longer-term tracks, tags were programmed to change to a one day on/one day off transmission duty cycle after the end of the six-day data transmission period. To potentially get continuous tracks for cohesive social groups (e.g., for short-finned pilot whales) when more than one tag was deployed in the same group, the days for switching to a two-day duty cycle was alternated. In 2023, tags began the two-day duty cycle after either August 26 or 27, and for 2024 duty cycling began March 1 for tags deployed early in the field project, on March 8 (MnTag002) or March 9 (GmTag252 and MnTag001) for a subset of tags deployed later in the project, or on March 11 for the lone beaked whale tag (MdTag023).

Table 2: Summary of tag programming regimes by species, year, and tag type.

Species	Year	Tag type	Data	# Hours transmitting to Argos per day
Gm	2023	SPLASH10-F	Argos, Fastloc, Behavior, Time Series (5 min)	13
Gm	2023	SPLASH10-F	Argos, Fastloc, Time Series (5 min)	13
Pe	2023	SPLASH10-F	Argos, Fastloc, Time Series (5 min)	13
Tt	2023	SPLASH10-F	Argos, Fastloc, Behavior, Time Series (5 min)	13
Tt	2023	SPLASH10-F	Argos, Fastloc, Time Series (5 min)	13
Sa	2023	SPLASH10-F	Argos, Fastloc, Time Series (2.5 min)	13
Gm	2024	SPLASH10-F	Argos, Fastloc, Behavior, Time Series (5 min)	16
Tt	2024	SPLASH10-F	Argos, Fastloc, Behavior, Time Series (5 min)	13
Md	2024	SPLASH10-F	Argos, Fastloc, Time Series (2.5 min)	16
Mn	2024	SPLASH10-F	Argos, Fastloc, Behavior, Time Series (5 min)	16
Mn	2024	SPOT6	Argos	16

- When there are multiple programming regimes for a single tag type and species within the same year, each regime is given a separate line. Gm = Short-finned pilot whale (*Globicephala macrorhynchus*), Pe = Melon-headed whale (*Peponocephala electra*), Tt = Common bottlenose dolphin (*Tursiops truncatus*), Sa = Pantropical spotted dolphin (*Stenella attenuata*), Md = Blainville's beaked whale (*Mesoplodon densirostris*), Mn = Humpback whale (*Megaptera novaeangliae*).

2.2 DATA PROCESSING

Argos and GPS location data were processed following the methods detailed in Kratofil et al. (2023). To summarize, the Argos position data (estimated with the Kalman-filter algorithm) were processed through the Douglas-Argos Filter available on Movebank (Douglas et al., 2012; Kranstauber et al., 2011) to remove erroneous locations, while the Fastloc®-GPS was processed through a custom filter. The resulting locations were combined and then fit with a continuous time-correlated random walk (ctcrw) model using the *crawl* package in R (Johnson et al., 2008; Johnson & London, 2018). These modeled data were used to predict locations in 5-min intervals; these 5-min periods match the period over which received levels are binned (Henderson et al., 2021, 2024).

The dive behavior logs were also checked for possible tag failures, following the methods of Henderson et al. (2021, 2024). The Depth and ZeroDepthOffset values in the tag status files are checked for drift, an indication of a possible pressure transducer failure. Values exceeding +/- 10 meters and +/ 9 meters, respectively, are flagged as such possible failures. Extreme ascent or descent rates (taken from twice the dive depth divided by the dive duration) greater than 3 m/s are also flagged as a possible indicator of a tag malfunction, and corresponding dives were examined individually.

The dive behavior logs that pass the QA/QC steps are then used to build models of dive cycles based on known dive data for each respective species. The start and end times of dives and surface periods (i.e., times when the animal remained above 50 m), along with maximum dive depths and the dive shape, are combined with the smoothed *crawl* tracks following the methods described in Henderson et al. (2021, 2024). Briefly, estimated minimum and maximum bottom times, ascent and descent times, and ascent and descent rates are bound by published dive rates, and are used to estimate dive depths interpolated at 60 points per dive to create dive models. When dive behavior is missing, MOTE reception logs, goniometer data, and Argos or GPS update times are checked to determine when the animals were at the surface.

2.3 DETECTION AND LOCALIZATION OF MFAS

Raw acoustic data were recorded for approximately seven days before the start of the SCC, the duration of the tagging effort and the SCC activity, and approximately seven days afterward in both years (Table 1). These data were used to detect any MFAS transmissions in the 1-10 kHz band from hull-mounted surface ships, active sonobuoys, and helicopter-dipping sonar. The signal detection and localization methods followed Henderson et al. (2024) and resulted in “tracks” of MFAS that were then used to estimate received levels for each tagged animal from each exposure.

The Peregrine parabolic equation propagation model developed by Oasis Ltd (Heaney and Campbell, 2016; based on the range-dependent acoustic model [RAM; Collins, 1993]) was used to estimate the transmission loss from the closest transmission from each active ship (closest in time to the center time of each 5-min bin) to each animal’s location, out to the furthest extent and across multiple radials covering the error ellipse of that location. For the other two MFAS sources, only the ping closest in distance to the animal was modeled, since these transmit for relatively brief periods and don’t move during their period of transmission. The process for determining which pings are modeled from each source type are consistent with the methods described in more detail in Henderson et al. (2024). Propagation modeling was conducted for each radial across the full depth range from the surface to a maximum of 5400 m, resulting in up to 600 depth bins of 9 m spacing and 1000 distance bins; the radial spacing depended on the distance of the longest radial slice. Rather than model a single frequency, each transmission was modeled with 10-log spacing across 200 Hz of bandwidth around the transmission frequency; this helps to reduce constructive and destructive interference from modeling only a single frequency.

The resulting transmission loss data for each 5-min location were combined, along with the estimated depth of the animal at that location and time interval, to obtain 3-dimensional estimates of received level, reported as the median value plus/minus 2 standard deviations (+/- 2 SD) for each 5-min interval and for each active source at that time. These methods are reported in greater detail in Henderson et al. (2021, 2024) and Martin et al. (2024). What results from this analysis is a median +/- 2 SD received level estimate from all three sources for every tagged whale at each 5-min smoothed track position that received an estimated exposure louder than 60 dB (the estimated ambient noise floor for the region in the mid-frequency band [Dahl et al., 2007], although ambient noise levels are often higher [Madrigal et al., 2024; Richlen 2018]).

2.4 DIEL AND BEHAVIORAL RESPONSE ANALYSIS

Timing and general locations of tagged animals were first assessed in relation to the timing and general location of both Phase A and Phase B to determine whether additional assessments of potential behavioral responses were warranted. If tags ceased transmitting prior to the start of Phase A, if tagged individuals were in the acoustic shadow of Kauaʻi or Niʻihau during Phase A and B, or if tagged individuals had moved >100 km from the general area of the SCC they were not considered in the behavioral analyses. For each tag with dive behavior data that was considered, the coverage of dive and surfacing data during each phase was first evaluated to provide an indication on the robustness of comparisons among phases. To do this, the duration of all dives and surfacing periods within each phase were summed up then divided by the total durations of the respective phases. When calculating the duration of dive data, any dive or surface periods that spanned more than one phase had their durations split (e.g., such that a surfacing period beginning in Phase A and continuing into the Interphase would have its duration split between the two periods based on when the Interphase begins). As not all tags transmitted for the full duration of each Phase, coverage relative to the duration of each tag was also evaluated. To do this, the duration of all dives and surfacing periods within each phase were summed with those that occurred over multiple phases split as before and divided by the total duration of tag transmission during each phase.

To account for the impacts of diel patterns on diving behavior, the coverage of each tag based on time of day for each SCC Phase was also calculated. Dive and surface periods were each assigned a time of day based on when they started, defined as either dawn, day, dusk, or night. Dawn was defined as the period before and after sunset, with solar angles between 6° below and above the horizon. Day was defined as the period after sunrise and prior to sunset with solar angles > 6° above the horizon. Dusk was defined as the period prior to sunset with solar angles between 6° below and above the horizon. Night was defined as the period after sunset and prior to sunrise with solar angles >6° below the horizon. The durations of surface periods that spanned more than one time of day were split (e.g., such that a surface period beginning at dawn and continuing into day would have its duration split between the two times of day based on when day begins). As before, surface periods that crossed multiple SCC phases had their durations split between phases. Due to their short duration, no dives were split based on either phase or time of day, unlike they were when calculating the duration of dive data for each phase. Coverage by time of day for each tag was calculated as the total duration of dive and surfacing periods within the time of day and SCC phase of interest, divided by the total duration of the time of day within that particular phase (e.g., the dawn total duration for Phase A would represent the sum of the duration of all dawns within Phase A). For the Before and After phases, the total duration of the phase was calculated as 3 days (72 hours) prior to the start of Phase A, and 3 days (72 hours) following the end of Phase B, respectively.

Metrics calculated included the dive rate (number of dives per hour), percentage of time spent at the surface (i.e., during periods with no excursions >50 m), median dive depth, and median dive duration among SCC phases and times of day for each tag, to assess potential responses to MFAS exposure in their diving behavior while also accounting for known diel patterns (see Owen et al., 2019, Shaff & Baird 2021, West et al., 2018). For all metrics, only 3 days (72 hours) of data following the end of Phase B (i.e., After) were used where available.

We restricted analyses of dive depth and duration among phases for each of the diel periods to those that had certain minimum levels of coverage of data during a particular phase/period, to reduce the likelihood that a small sample of dive/surface data during any phase/period would bias the results. For example, during the night-time period within Phase B, dive/surface data would need to be available for at least 50% of the night-time periods to be included. Minimum levels (i.e., sufficient) of coverage for the shorter dawn and dusk periods varied by species to account for species-level variation in diving behavior, with those species that have the longest dive durations requiring a higher level of coverage during the shorter dawn and dusk periods (Table 3). Kruskal-Wallis one-way ANOVA tests were conducted to identify significant differences in dive depth and duration among phases, and by diel period, for each tagged individual with sufficient dive/surfacing coverage (SPLASH10 tags only), and post-hoc Dunn's tests with a Benjamini-Hochberg correction were conducted to identify phases where pairwise significant differences were detected (e.g., statistical difference between phase A and B; significance level for both tests = 0.05). These statistical procedures were not applied to test for differences between phases in dive rates (dives per hour) nor percentage of time at surface due to the nature of how these values were calculated (i.e., only single values for each SCC phase).

Table 3: Coverage requirements for each phase by time of day and species for inclusion in statistical comparisons between phases.

Species	Dawn % coverage required for inclusion	Day % coverage required for inclusion	Dusk % coverage required for inclusion	Night % coverage required for inclusion	Notes
Gm	80	50	80	50	Due to their longer dive durations, the dawn and dusk coverage requirements for this species are set at 80%.
Tt	70	50	70	50	
Mn	70	50	70	50	

- Gm = Short-finned pilot whale (*Globicephala macrorhynchus*), Tt = Common bottlenose dolphin (*Tursiops truncatus*), Mn = Humpback whale (*Megaptera novaeangliae*).

3. RESULTS

3.1 TAGGING AND PHOTO-IDENTIFICATION

Tagging was conducted August 6-13, 2023, and February 11-19, 2024, and a summary of the 22 individuals that were tagged, including their tag duration and overlap with SCC phases, is provided in Table 4. In 2023, six short-finned pilot whales, two common bottlenose dolphins, one pantropical spotted dolphin, and one melon-headed whale were tagged. In 2024, eight pilot whales, one bottlenose dolphin, and three humpback whales were tagged.

All six short-finned pilot whales tagged in 2023 had been previously identified, and two of the individuals had also been previously tagged. Three of the animals (GmTags241-243) were identified as members of Cluster W8, which is part of the western community of short-finned pilot whales (cf. Baird 2016; Van Cise et al., 2017). GmTag241 (HIGm2110) was previously seen twice off Kauaʻi in 2012 and 2023. GmTag242 (HIGm0046) was previously seen four times off Kauaʻi in 2003, 2005, 2012, and 2023. GmTag243 (HIGm1243) was previously seen three times off Oʻahu in 2003, 2005, and 2009, and three times off Kauaʻi in 2012, 2021, and 2023. This individual had also been previously tagged off Kauaʻi in 2012 (GmTag064 in Baird et al., 2012). The remaining three short-finned pilot whales (GmTags244-246) were identified as members of Cluster W18, which is also part of the western community. GmTag244 (HIGm0949) was previously seen three times off Oʻahu in 2006, 2009, and 2018, and four times off Kauaʻi in 2008, 2018, 2021, and 2023. This individual had also been previously tagged off Kauaʻi in 2018 (GmTag214 in Baird et al., 2019). GmTag245 (HIGm1159) was previously seen four times off Kauaʻi in 2008, 2018, 2021, and 2023, and GmTag246 (HIGm2767) was previously seen off Oʻahu in 2018, and four times off Kauaʻi in 2018, 2021, 2022, and 2023. Only one of the two bottlenose dolphins tagged in 2023 (TtTag042, HITt0376) had been previously identified. This individual had been previously seen seven times off Kauaʻi (the first time of which was in 2005) and is a member of the island-associated resident community of Kauaʻi bottlenose dolphins. While the other bottlenose dolphin tagged in 2023 had not been previously identified, it was tagged during the same encounter as TtTag042 and has therefore been linked by association to the same resident community. SaTag012 was compared to CRC's catalog of distinctive pantropical spotted dolphins (Gless et al., 2022), but no match was found to any previously identified animals, which is unsurprising given the lack of notches on the dorsal fin of this individual. Although CRC has a photo-identification catalog of melon-headed whales (Aschettino et al., 2012), this catalog has not been substantially updated since 2011, and the tagged individual from 2023 was not matched to the catalog.

All eight short-finned pilot whales tagged in 2024 had been previously identified, and one of the individuals had also been previously tagged. Two of the previously identified animals (GmTag251 and GmTag252, HIGm1157 and HIGm1151 respectively) were identified as members of Cluster W18 (see above). Both animals were previously seen twice off Oʻahu in 2008 and 2018, as well as off Kauaʻi in 2008, 2018, 2021, 2022, 2023, and 2024, and GmTag251 had also been previously tagged off Kauaʻi in 2018 (GmTag215, see Baird et al., 2019). GmTag253 (HIGm2460) was identified as a member of Cluster W16, which is suspected to be part of the western community. This individual had only been previously identified once, off Oʻahu in 2014. GmTag254 (HIGm1580) and GmTag255 (HIGm2102) were identified as members of Cluster W8 in the western community. GmTag254 and had been previously seen once off Oʻahu in 2009, and once off Kauaʻi in 2012, and GmTag255 had only been seen once off Kauaʻi in 2012. GmTag256 (HIGm2302) and GmTag257 (HIGm1551) were identified as members of Cluster W6, which is most likely part of the central community of short-finned pilot whales (i.e., those individuals that spend the majority of their time off Lānaʻi and eastern Oʻahu, see Van Cise et al., 2017; Kratofil et al., 2023). GmTag256 had only been seen twice previously, off Oʻahu in 2008 and 2013. GmTag257 had been seen four times off Oʻahu in 2008, 2009, 2015, and 2016, and only once off Kauaʻi in 2024. GmTag258 (HIGm1398) was identified as a member of Cluster W25 in the western community, and had been seen once off Oʻahu in 2013, and six times off Kauaʻi in 2011, 2013, 2014, 2016, 2020, and 2024. The lone tagged Blainville's beaked whale tagged in 2024 (MdTag023, HIMd314) had been previously sighted off Kauaʻi in 2019, 2021, and 2024, and had also been previously tagged in 2021 (MdTag021, see Baird et al., 2022). No data were obtained from this tag so this individual is not considered further. The lone tagged bottlenose dolphin in 2024 (TtTag044, HITt1057) had also been previously sighted six times off Kauaʻi (the first time in 2015) and is a member of the island-associated resident community of bottlenose dolphins off Kauaʻi. Fluke photos of the tagged humpback whales were submitted to HappyWhale for identification, and two of these individuals had been previously seen. MnTag001 was identified as HI20-0074, which was first seen in Hawaiʻi in 2020, and had been spotted an additional five times between 2020 and 2024 prior to being tagged. MnTag002 was identified as HIHWNMS-2023-1-20_G01AO05 in the HappyWhale catalog, and had been first seen in Hawaiʻi in 2021, and spotted an additional two times in 2021 and 2023 prior to being tagged.

Table 4: Tag deployment data for 2023 and 2024 satellite tags, including overlap with active SCC phases.

Tag ID	Tag type	Deployment Date/time (GMT)	End Date/time (GMT)	Duration (days)	Overlap with active SCC Phases
GmTag241	SPLASH10-F	2023-08-06 16:56	2023-10-04 15:23	58.94	A, B
GmTag242	SPLASH10-F	2023-08-06 17:34	2023-08-25 06:12	18.53	A, B
GmTag243	SPLASH10-F	2023-08-06 18:31	2023-09-08 09:44	32.63	A, B
GmTag244	SPLASH10-F	2023-08-10 19:01	2023-08-30 21:41	20.11	A, B
GmTag245	SPLASH10-F	2023-08-12 16:43	2023-08-19 21:31	7.20	B
GmTag246	SPLASH10-F	2023-08-12 17:01	2023-09-08 16:02	26.96	B
GmTag251	SPLASH10-F	2024-02-11 19:11	2024-03-01 17:52	18.94	A, B
GmTag252	SPLASH10-F	2024-02-11 20:20	2024-03-08 17:01	25.86	A, B
GmTag253	SPLASH10-F	2024-02-11 22:27	2024-02-28 08:09	16.40	A, B
GmTag254	SPLASH10-F	2024-02-15 18:25	2024-03-03 04:08	16.40	A, B
GmTag255	SPLASH10-F	2024-02-15 18:54	2024-04-09 03:56	53.38	A, B
GmTag256	SPLASH10-F	2024-02-18 19:29	2024-03-21 09:59	31.60	B
GmTag257	SPLASH10-F	2024-02-18 20:16	2024-04-01 15:53	42.82	B
GmTag258	SPLASH10-F	2024-02-19 19:33	2024-03-23 16:02	32.85	B
MdTag023*	SPLASH10-F	2024-02-13 23:58	2024-02-13 23:58	0	NA
PeTag037	SPLASH10-F	2023-08-12 21:25	2023-08-18 21:43	6.01	B
SaTag012	SPLASH10-F	2023-08-06 19:37	2023-08-18 21:42	12.09	A, B
TtTag042	SPLASH10-F	2023-08-13 18:55	2023-08-28 06:40	14.49	B
TtTag043	SPLASH10-F	2023-08-13 19:21	2023-08-23 17:47	9.93	B
TtTag044	SPLASH10-F	2024-02-19 18:23	2024-03-01 09:08	10.61	B
MnTag001	SPLASH10-F	2024-02-16 20:40	2024-02-19 17:32	2.87	A, B
MnTag002	SPLASH10-F	2024-02-19 21:19	2024-02-25 04:34	5.30	B
MnTag003	SPOT6	2024-02-19 21:44	2024-02-22 20:59	2.97	B

*Tag failed to transmit

3.2 BEHAVIORAL RESPONSE, DIEL ANALYSIS, AND RECEIVED LEVEL ESTIMATION

The following sections document data available for behavior analyses, as well as movements and estimated received levels for short-finned pilot whales, melon-headed whales, pantropical spotted dolphins, common bottlenose dolphins, and humpback whales across the two separate SCC training events. All but one of the 23 animals tagged at PMRF in 2023 and 2024 that successfully transmitted location data had a direct transmission path during at least part of Phase B of the SCCs (e.g., not blocked by land). A summary of tagged individuals, including exposure durations and maximum median received levels, are presented in Table 5. Sections below are organized by species, and within species in the following order: summary tables, followed by narratives for each individual or group including estimated received levels, track maps for those specific animals, dive behavior narratives for each individual or group with behavior log data, and applicable dive behavior figures.

Table 5: Summary of exposure data for each tagged odontocete, including the sources of exposure and the minimum, maximum, and mean period of exposure.

Tag ID	Exposure sources	Exposure period duration (min – max, mean) (minutes)	Highest Median SPL (dB re 1 µPa)
GmTag241	Ship, sonobuoy, helo	1 - 53, 18.4	80.1
GmTag242	Ship, sonobuoy, helo	3 - 38, 17	77.5
GmTag243	Ship, sonobuoy, helo	1 - 6, 3.7	68.2
GmTag244	Ship, sonobuoy, helo	3 - 91, 41.3	143.9
GmTag245	Ship, sonobuoy, helo	2 - 91, 35.9	143.9
GmTag246	Ship, sonobuoy, helo	2 - 148, 40.2	144.1
GmTag251	Ship, sonobuoy, helo	9 - 148, 63	156.1
GmTag252	Ship, sonobuoy, helo	9 - 148, 63	156.4
GmTag253	Ship, sonobuoy, helo	9 - 148, 59.3	150.4
GmTag254	Ship, sonobuoy, helo	9 - 148, 63.3	153.6
GmTag255	Ship, sonobuoy, helo	9 - 148, 63.3	154.8
GmTag256	Ship, sonobuoy	1 - 16, 8.7	123.9
GmTag257	Ship, sonobuoy	1 - 16, 8.7	123.9
GmTag258	Ship, sonobuoy, helo	9 - 148, 53.3	150.3
PeTag037	Ship, sonobuoy, helo	2 - 92, 35.8	TBD
SaTag012	Ship, sonobuoy, helo	2 - 73, 23.6	91.6
TtTag042	Ship, sonobuoy, helo	4 - 73, 27.2	125.5
TtTag043	Ship, helo	4 - 60, 34.5	115
TtTag044	Ship, sonobuoy, helo	4 - 148, 41.7	142.7
MnTag001	none	--	‘--
MnTag002	Ship, sonobuoy, helo	12 - 148, 62.3	143.9
MnTag003	Ship, sonobuoy, helo	4 - 104, 36.9	143.7

3.2.1 Short-finned Pilot Whales

Fourteen pilot whales were tagged at PMRF, six in 2023 (in three groups) and eight in 2024 (in five groups). Summary statistics are presented in Tables 6-10, including the percentage of available dive data for each individual across SCC phases (Table 6), and a comparison of dive parameters across phases, including statistical significance where applicable, for dives during dawn hours (Table 7), daytime hours (Table 8), dusk hours (Table 9), and nighttime hours (Table 10).

Table 6: Portion of dive/surfacing data by phase for short-finned pilot whales. The percentage of behavioral coverage is defined as the proportion of the duration of behavior log data relative to the duration of the tag within each phase.

Individual	Percentage of dive/surfacing data				
	Before	Phase A	Interphase	Phase B	After
GmTag241					
Duration overall (days)	1.96	3.37	2.63	3.21	47.77
Days behavior log data	NA	NA	NA	NA	NA
Percentage behavioral coverage	NA	NA	NA	NA	NA
GmTag242					
Duration overall (days)	1.93	3.37	2.63	3.21	7.38
Days behavior log data	1.18	0.71	0.52	0.78	0.64
Percentage behavioral coverage	61.14	21.07	19.77	24.30	8.67
GmTag243					
Duration overall (days)	1.90	3.37	2.63	3.21	21.53
Days behavior log data	1.89	3.32	2.62	3.20	2.24
Percentage behavioral coverage	99.47	98.52	99.62	99.69	10.40
GmTag244					
Duration overall (days)	0.00	1.25	2.63	3.21	13.03
Days behavior log data	NA	NA	NA	NA	NA
Percentage behavioral coverage	NA	NA	NA	NA	NA
GmTag245					
Duration overall (days)	0.00	0.00	1.97	3.21	2.02
Days behavior log data	NA	NA	NA	NA	NA
Percentage behavioral coverage	NA	NA	NA	NA	NA
GmTag246					
Duration overall (days)	0.00	0.00	1.96	3.21	21.79
Days behavior log data	0.00	0.00	1.95	3.20	2.18
Percentage behavioral coverage	NA	NA	99.49	99.69	10.00
GmTag251					
Duration overall (days)	1.89	3.45	2.58	2.38	8.65
Days behavior log data	1.88	3.44	2.58	2.37	2.91
Percentage behavioral coverage	99.47	99.71	100.00	99.58	33.64
GmTag252					
Duration overall (days)	1.84	3.45	2.58	2.38	15.61
Days behavior log data	1.82	3.44	2.57	2.37	3.13
Percentage behavioral coverage	98.91	99.71	99.61	99.58	20.05
GmTag253					
Duration overall (days)	1.75	3.45	2.58	2.38	6.25
Days behavior log data	1.74	3.38	2.44	2.23	5.66
Percentage behavioral coverage	99.43	97.97	94.57	93.70	90.56
GmTag254					
Duration overall (days)	0.00	1.37	2.58	2.38	10.08
Days behavior log data	0.00	1.35	2.58	2.37	2.74
Percentage behavioral coverage	NA	98.54	100.00	99.58	27.18
GmTag255					
Duration overall (days)	0.00	1.35	2.58	2.38	47.07
Days behavior log data	0.00	1.34	2.57	2.37	3.11
Percentage behavioral coverage	NA	99.26	99.61	99.58	6.61
GmTag256					
Duration overall (days)	0.00	0.00	0.91	2.38	28.32

Individual	Percentage of dive/surfacing data				
	Before	Phase A	Interphase	Phase B	After
Days behavior log data	0.00	0.00	0.89	2.37	2.91
Percentage behavioral coverage	NA	NA	97.80	99.58	10.28
GmTag257					
Duration overall (days)	0.00	0.00	0.87	2.38	39.57
Days behavior log data	0.00	0.00	0.86	2.37	2.93
Percentage behavioral coverage	NA	NA	98.85	99.58	7.40
GmTag258					
Duration overall (days)	0.00	0.00	0.00	2.28	30.57
Days behavior log data	0.00	0.00	0.00	2.27	6.11
Percentage behavioral coverage	NA	NA	NA	99.56	19.99

Table 7: A comparison of dawn diving parameters from short-finned pilot whales with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Dawn dive rate (dives/hr)							
GmTag243	NA	1.67	2.93	1.76	NA	-	
GmTag246	NA	NA	NA	2.61	NA	-	
GmTag251	NA	0.88	1.31	0.47	1.48	-	
GmTag252	NA	1.11	0.89	0.46	1.46	-	
GmTag253	NA	1.26	NA	NA	0.41	-	
GmTag254	NA	NA	2.03	2.86	3.05	-	
GmTag255	NA	NA	0.00	2.11	0.80	-	
GmTag256	NA	NA	NA	2.54	3.11	-	
GmTag257	NA	NA	NA	2.49	2.94	-	
GmTag258	NA	NA	NA	NA	1.13	-	
% time in surface periods during dawn							
GmTag243	NA	57.18	27.91	55.21	NA	-	
GmTag246	NA	NA	NA	52.27	NA	-	
GmTag251	NA	82.03	75.49	88.66	69.52	-	
GmTag252	NA	85.43	83.83	87.48	60.79	-	
GmTag253	NA	72.60	NA	NA	97.02	-	
GmTag254	NA	NA	66.54	27.77	24.72	-	
GmTag255	NA	NA	100.00	57.97	79.10	-	
GmTag256	NA	NA	NA	33.56	26.06	-	
GmTag257	NA	NA	NA	40.53	28.98	-	
GmTag258	NA	NA	NA	NA	71.30		
Median dive depth dawn (m)							
GmTag243	NA	767.50	527.50	751.50	NA	0.74	
GmTag246	NA	NA	NA	655.50	NA	NA	
GmTag251	NA	639.50	559.50	623.50	671.50	0.63	
GmTag252	**NA**	**86.50**	**415.50**	**767.50**	**647.50**	**0.03**	**No sig. adj. p-values**

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
GmTag253	NA	743.50	NA	NA	49.50	0.16	
GmTag254	**NA**	**NA**	**81.50**	**679.50**	**735.50**	**0.01**	**Inter-B; Inter-Aft**
GmTag255	**NA**	**NA**	**NA**	**655.50**	**743.50**	**0.04447**	**B-Aft**
GmTag256	NA	NA	NA	703.50	703.50	0.69	
GmTag257	NA	NA	NA	671.50	623.50	0.63	
GmTag258	NA	NA	NA	NA	767.50	NA	
Median dive duration dawn (min)							
GmTag243	NA	17.38	13.98	15.63	NA	0.45	
GmTag246	NA	NA	NA	12.37	NA	NA	
GmTag251	NA	12.17	13.17	14.63	13.85	0.88	
GmTag252	**NA**	**7.93**	**10.93**	**16.17**	**16.43**	**0.04**	**A-Aft**
GmTag253	NA	14.73	NA	NA	4.40	0.16	
GmTag254	**NA**	**NA**	**8.53**	**15.25**	**14.87**	**0.03**	**Inter-B; Inter-Aft**
GmTag255	NA	NA	NA	13.77	15.70	0.1714	
GmTag256	NA	NA	NA	15.07	15.77	0.95	
GmTag257	NA	NA	NA	15.40	15.33	0.94	
GmTag258	NA	NA	NA	NA	15.43	NA	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

Table 8: A comparison of daytime diving parameters from short-finned pilot whales with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Day dive rate (dives/hr)							
GmTag243	1.50	0.78	0.88	1.03	0.95	-	
GmTag246	NA	NA	0.74	0.88	0.34	-	
GmTag251	1.15	1.36	1.63	1.68	1.02	-	
GmTag252	1.09	0.71	0.55	0.57	0.69	-	
GmTag253	1.26	0.90	1.47	0.75	0.87	-	
GmTag254	NA	NA	2.03	1.58	1.11	-	
GmTag255	NA	NA	0.97	0.85	0.77	-	
GmTag256	NA	NA	NA	1.14	0.75	-	
GmTag257	NA	NA	NA	1.01	0.83	-	
GmTag258	NA	NA	NA	2.14	1.04	-	
% time in surface periods during day							
GmTag243	59.15	76.42	73.84	69.18	72.78	-	
GmTag246	NA	NA	84.22	84.48	91.81	-	
GmTag251	74.94	72.55	63.51	62.60	78.19	-	
GmTag252	88.11	85.41	93.52	85.47	81.57	-	

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
GmTag253	71.06	79.32	72.03	81.09	81.12	-	
GmTag254	NA	NA	57.30	66.54	72.25	-	
GmTag255	NA	NA	84.87	84.57	84.15	-	
GmTag256	NA	NA	NA	78.16	84.30	-	
GmTag257	NA	NA	NA	80.01	87.35	-	
GmTag258	NA	NA	NA	51.25	77.94	-	
Median dive depth day (m)							
GmTag243	**815.50**	**863.50**	**935.50**	**879.50**	**815.50**	**<0.01**	**Bef-A; Bef-Inter; Bef-B; A-Aft; B-Aft**
GmTag246	NA	NA	719.50	151.50	695.50	0.09	
GmTag251	**719.50**	**647.50**	**751.50**	**711.50**	**687.50**	**<0.01**	**Bef-A; A-Inter; A-B; Inter-Aft**
GmTag252	**63.50**	**623.50**	**64.50**	**687.50**	**703.50**	**<0.01**	**Bef-A; Bef-B, Bef-Aft; A-Inter; Inter-B; Inter-Aft**
GmTag253	671.50	655.50	655.50	711.50	687.50	0.24	
GmTag254	**NA**	**NA**	**679.50**	**695.50**	**735.50**	**<0.01**	**Inter-Aft; B-Aft**
GmTag255	NA	NA	127.50	639.50	687.50	0.05	
GmTag256	NA	NA	NA	97.50	639.50	0.18	
GmTag257	**NA**	**NA**	**NA**	**607.50**	**71.50**	**0.03**	**B-Aft**
GmTag258	NA	NA	NA	703.50	671.50	0.11	
Median dive duration day (m)							
GmTag243	17.23	18.03	18.28	18.23	17.17	0.06	
GmTag246	**NA**	**NA**	**16.17**	**11.50**	**14.72**	**0.02**	**Inter-B**
GmTag251	13.53	13.83	13.93	14.48	14.35	0.54	
GmTag252	**5.97**	**14.03**	**6.78**	**15.47**	**16.77**	**<0.01**	**Bef-A; Bef-B; Bef-Aft; A-Inter; A-Aft; Inter-B; Inter-Aft**
GmTag253	**14.83**	**14.27**	**13.58**	**16.05**	**14.30**	**<0.01**	**Inter-B**
GmTag254	NA	NA	15.57	14.70	15.33	0.16	
GmTag255	NA	NA	8.23	12.63	14.23	0.13	
GmTag256	NA	NA	NA	9.47	13.85	0.54	
GmTag257	NA	NA	NA	13.38	7.60	0.07	
GmTag258	NA	NA	NA	15.00	14.67	0.30	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

Table 9: A comparison of dusk diving parameters from short-finned pilot whales with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Dusk dive rate (dives/hr)							
GmTag243	NA	2.88	2.97	2.76	NA	-	
GmTag246	NA	NA	NA	2.87	NA	-	
GmTag251	NA	2.16	2.76	3.29	2.47	-	
GmTag252	NA	2.50	1.83	2.71	2.58	-	
GmTag253	NA	2.94	2.70	2.42	2.81	-	
GmTag254	NA	NA	2.60	2.60	2.06	-	
GmTag255	NA	NA	1.05	1.67	2.13	-	
GmTag256	NA	NA	NA	2.42	2.02	-	
GmTag257	NA	NA	NA	2.27	1.72	-	
GmTag258	NA	NA	NA	1.14	1.94	-	
% time in surface periods during dusk							
GmTag243	NA	39.57	32.93	30.67	NA	-	
GmTag246	NA	NA	NA	37.18	NA	-	
GmTag251	NA	53.37	43.21	27.43	44.99	-	
GmTag252	NA	45.63	56.42	33.27	37.22	-	
GmTag253	NA	32.08	41.17	42.03	37.01	-	
GmTag254	NA	NA	43.38	31.66	54.61	-	
GmTag255	NA	NA	79.52	57.94	52.36	-	
GmTag256	NA	NA	NA	35.88	50.19	-	
GmTag257	NA	NA	NA	29.74	75.45	-	
GmTag258	NA	NA	NA	74.77	72.06	-	
Median dive depth dusk (m)							
GmTag243	NA	535.50	511.50	607.50	NA	0.23	
GmTag246	NA	NA	NA	639.50	NA	NA	
GmTag251	NA	655.50	559.50	567.50	607.50	0.52	
GmTag252	NA	623.50	575.50	575.50	559.50	0.95	
GmTag253	NA	531.50	719.50	639.50	543.50	0.33	
GmTag254	NA	NA	567.50	559.50	559.50	0.60	
GmTag255	NA	NA	671.50	687.50	507.50	0.16	
GmTag256	NA	NA	NA	671.50	567.50	0.24	
GmTag257	NA	NA	NA	727.50	79.50	0.05	
GmTag258	NA	NA	NA	519.50	65.50	0.12	
Median dive duration dusk (min)							
GmTag243	NA	12.72	13.57	15.10	NA	0.50	
GmTag246	NA	NA	NA	13.40	NA	NA	
GmTag251	NA	13.10	11.28	13.65	13.37	0.50	
GmTag252	NA	14.03	13.93	14.90	14.57	0.80	
GmTag253	NA	13.48	13.50	14.87	13.80	0.50	
GmTag254	NA	NA	13.52	15.53	12.80	0.07	
GmTag255	NA	NA	11.60	14.80	13.58	0.15	
GmTag256	NA	NA	NA	15.90	14.93	0.09	
GmTag257	**NA**	**NA**	**NA**	**19.00**	**7.13**	**0.03**	**B-Aft**
GmTag258	NA	NA	NA	13.32	6.50	0.25	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

Table 10: A comparison of nighttime diving parameters from short-finned pilot whales with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Night dive rate (dives/hr)							
GmTag243	3.48	4.02	2.86	3.48	3.91	-	
GmTag246	NA	NA	3.20	4.32	4.15	-	
GmTag251	3.66	3.43	3.21	1.99	2.28	-	
GmTag252	3.75	3.38	2.73	2.29	2.50	-	
GmTag253	3.80	3.55	3.41	2.64	2.22	-	
GmTag254	NA	NA	3.11	3.07	2.08	-	
GmTag255	NA	NA	2.74	3.00	1.93	-	
GmTag256	NA	NA	NA	3.27	2.19	-	
GmTag257	NA	NA	NA	3.49	1.95	-	
GmTag258	NA	NA	NA	2.48	2.06	-	
% time in surface periods during night							
GmTag243	39.21	35.17	44.71	32.71	29.37	-	
GmTag246	NA	NA	43.99	33.98	28.60	-	
GmTag251	36.07	33.54	45.28	66.28	51.39	-	
GmTag252	33.07	33.77	49.23	58.96	47.59	-	
GmTag253	32.32	37.51	44.64	54.50	54.46	-	
GmTag254	NA	NA	32.56	37.76	56.03	-	
GmTag255	NA	NA	51.17	40.28	61.26	-	
GmTag256	NA	NA	NA	44.59	57.65	-	
GmTag257	NA	NA	NA	33.38	62.94	-	
GmTag258	NA	NA	NA	53.76	55.37	-	
Median dive depth night (m)							
GmTag243	**238.00**	**115.50**	**303.50**	**248.00**	**151.50**	**<0.01**	**Bef-A; A-B**
GmTag246	**NA**	**NA**	**351.50**	**157.50**	**375.50**	**<0.01**	**Inter-B; Inter-Aft; B-Aft**
GmTag251	**391.50**	**407.50**	**311.50**	**149.50**	**559.50**	**<0.01**	**Bef-Aft; A-Aft; Inter-Aft; B-Aft**
GmTag252	**327.50**	**311.50**	**179.50**	**147.50**	**559.50**	**<0.01**	**Bef-Aft, A-Aft; Inter-Aft; B-Aft**
GmTag253	**391.50**	**275.50**	**143.50**	**171.50**	**543.50**	**<0.01**	**Bef-Inter; Bef-Aft; A-Aft; Inter-Aft; B-Aft**
GmTag254	NA	NA	504.50	487.50	527.50	0.87	
GmTag255	**NA**	**NA**	**161.50**	**471.50**	**367.50**	**0.02**	**Inter-B**
GmTag256	NA	NA	NA	155.50	171.50	0.10	

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
GmTag257	NA	NA	NA	177.50	215.50	0.36	
GmTag258	**NA**	**NA**	**NA**	**183.50**	**492.50**	**<0.01**	**B-Aft**
Median dive duration night (min)							
GmTag243	**9.83**	**8.90**	**11.78**	**11.33**	**10.30**	**<0.01**	**A-Inter; A-B; A-Aft**
GmTag246	**NA**	**NA**	**10.93**	**8.95**	**10.83**	**<0.01**	**Inter-B; B-Aft**
GmTag251	**10.70**	**12.23**	**11.03**	**9.68**	**12.80**	**<0.01**	**Bef-A; Bef-Aft; A-Inter; A-B; A-Aft; Inter-Aft; B-Aft**
GmTag252	**11.03**	**12.50**	**11.33**	**10.37**	**13.67**	**<0.01**	**Bef-A; Bef-Aft; Inter-Aft; B-Aft**
GmTag253	**11.37**	**10.65**	**8.93**	**10.10**	**13.67**	**<0.01**	**Bef-Aft; A-Aft; Inter-Aft; B-Aft**
GmTag254	NA	NA	13.23	12.55	12.53	0.20	
GmTag255	NA	NA	12.08	11.95	12.63	0.10	
GmTag256	NA	NA	NA	9.87	9.65	0.28	
GmTag257	NA	NA	NA	10.90	11.62	0.93	
GmTag258	**NA**	**NA**	**NA**	**11.07**	**13.58**	**<0.01**	**B-Aft**

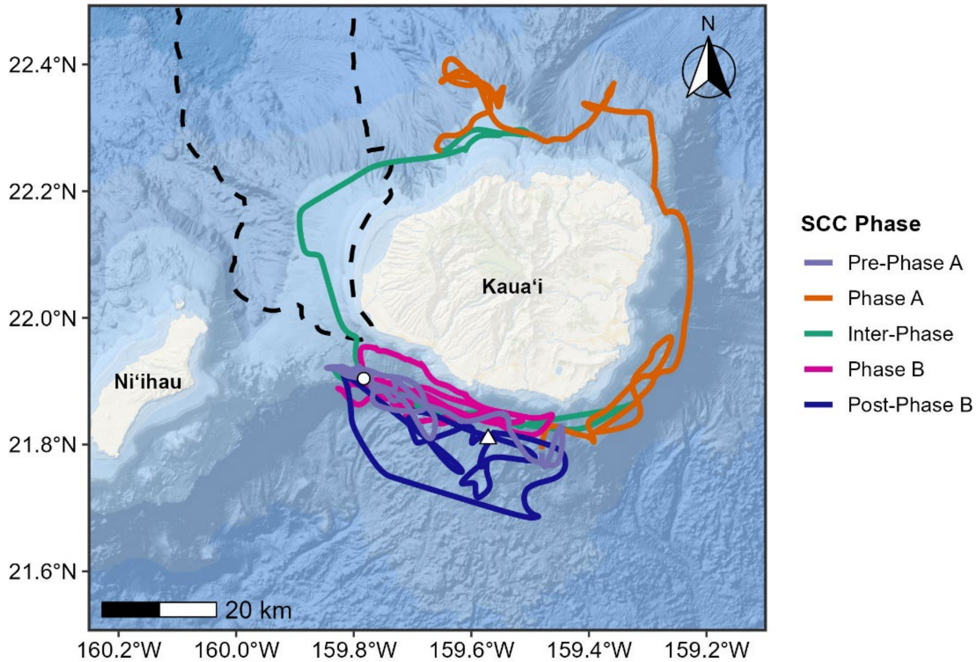
- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

3.2.1.1 GmTag241, GmTag242, GmTag243

These three individuals were tagged within the same group in 2023 south of the range, and GmTag241 and GmTag242 generally remained associated throughout their deployments. GmTag243, however, split off from the other two animals prior to the start of Phase A, though they did reassociate later. Information was available on movement patterns for Before (1.90-1.96 days), Phase A (3.37 days), the Interphase (2.63 days), Phase B (3.21 days), and After (7.38-47.77 days; Table 6).

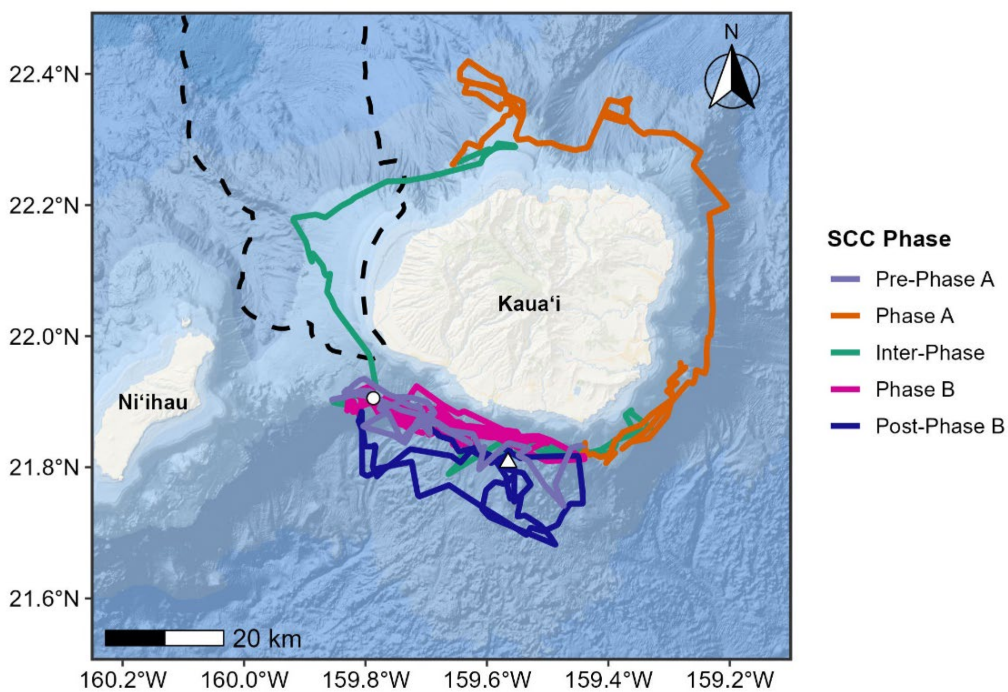
This group spent several days in an area-restricted movement (ARM) behavioral mode south/southwest of Kauaʻi during the Before, Phase B, and After phases (Figures 2-4). GmTag241 and GmTag242 circumnavigated counterclockwise around the eastern side of Kauaʻi over the course of Phase A and the Interphase, passing through the range during the Interphase, and spent the remainder of the SCC off the range to the southwest of Kauaʻi (Figure 2 and Figure 3). GmTag243 remained to the south of the range throughout the SCC, only entering the range briefly during the After phase (Figure 4). Low level exposures occurred for all three animals when they were back together southeast of the range during Phase B, but the median received levels were relatively low, <90 dB re 1 μPa (Figure 5 through Figure 7, Table 11 through Table 13); most of the transmissions were blocked by the island. There was no apparent change in movement behavior during Phase B.

Exposures occurred prior to and then at the start of a series of deep dives for all three individuals, and again there was no apparent change in dive behavior (see the Dive Behavior analysis).



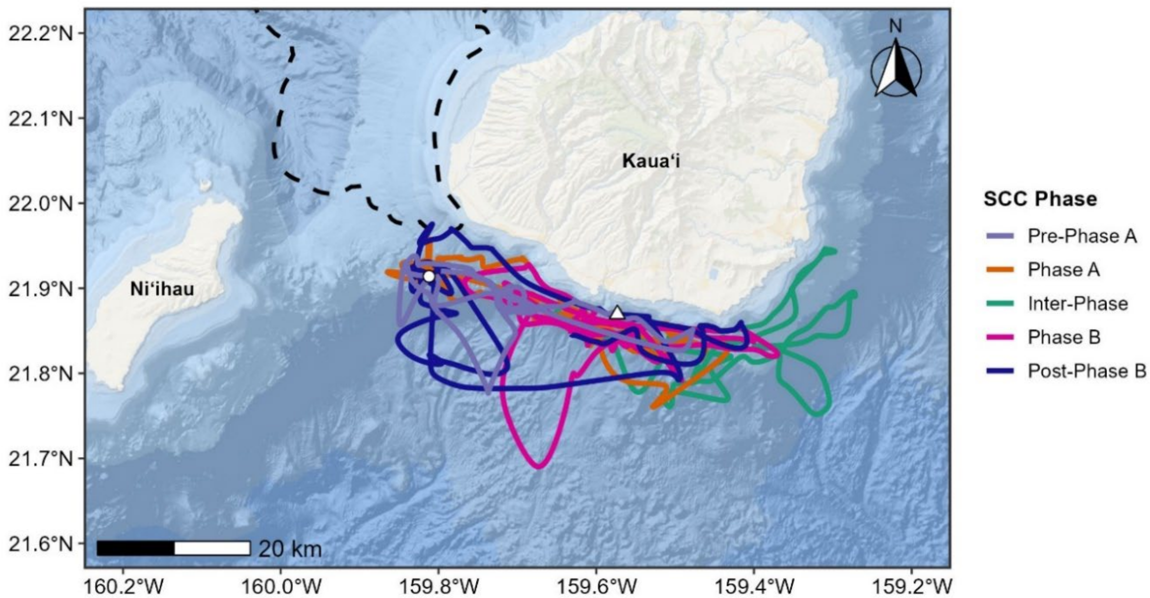
- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Figure 2: Movements of GmTag241 during the August 2023 SCC event (see text for description of phases).



- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Figure 3: Movements of GmTag242 during the August 2023 SCC event (see text for description of phases).

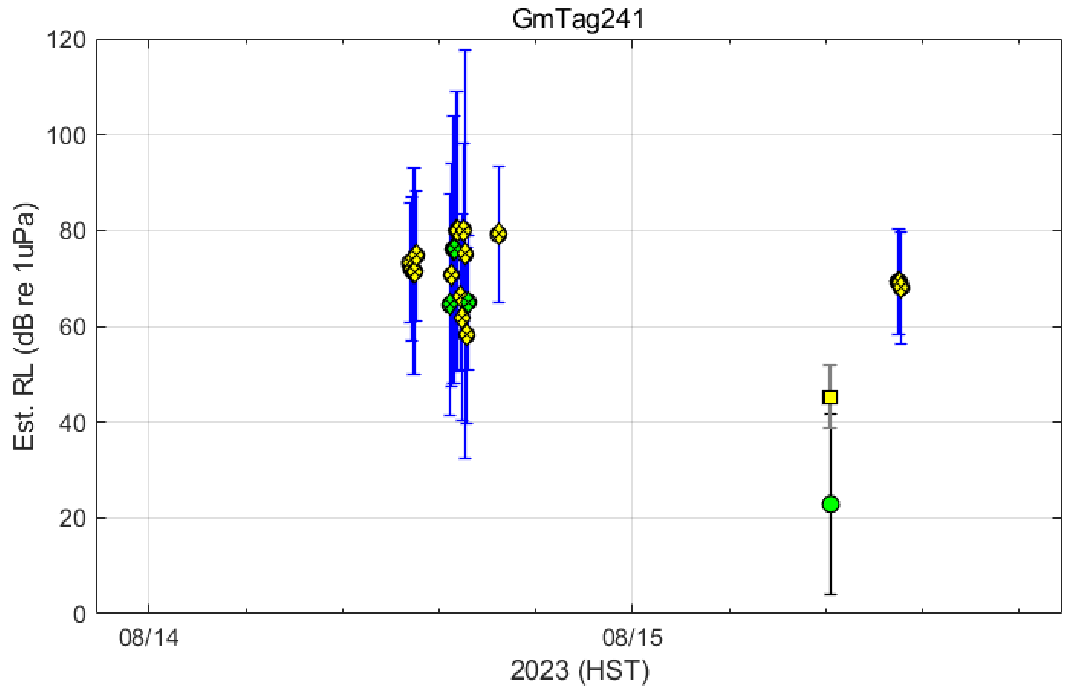


- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Figure 4: Movements of GmTag243 during the August 2023 SCC event (see text for description of phases).

Table 11: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag241.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	80.1 (61.9, 98.2)	92.6	65.2
Dipping Sonar	Below ambient	66	75.3
Sonobuoy	Below ambient	below ambient	67.1

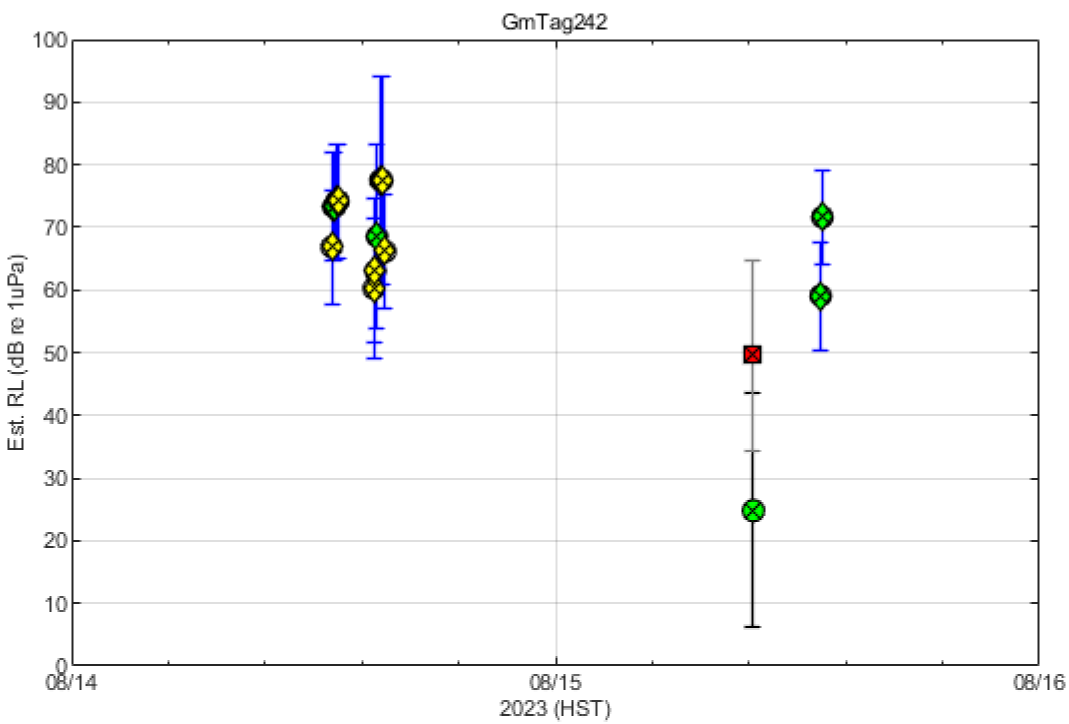


- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 5: Stoplight plot for the received levels for GmTag241 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

Table 12: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag242.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	77.5 (60.9, 94.1)	88.8	65.7
Dipping Sonar	49.6 (34.3, 64.8)	83.8	74.6
Sonobuoy	Below ambient	Below ambient	66.5

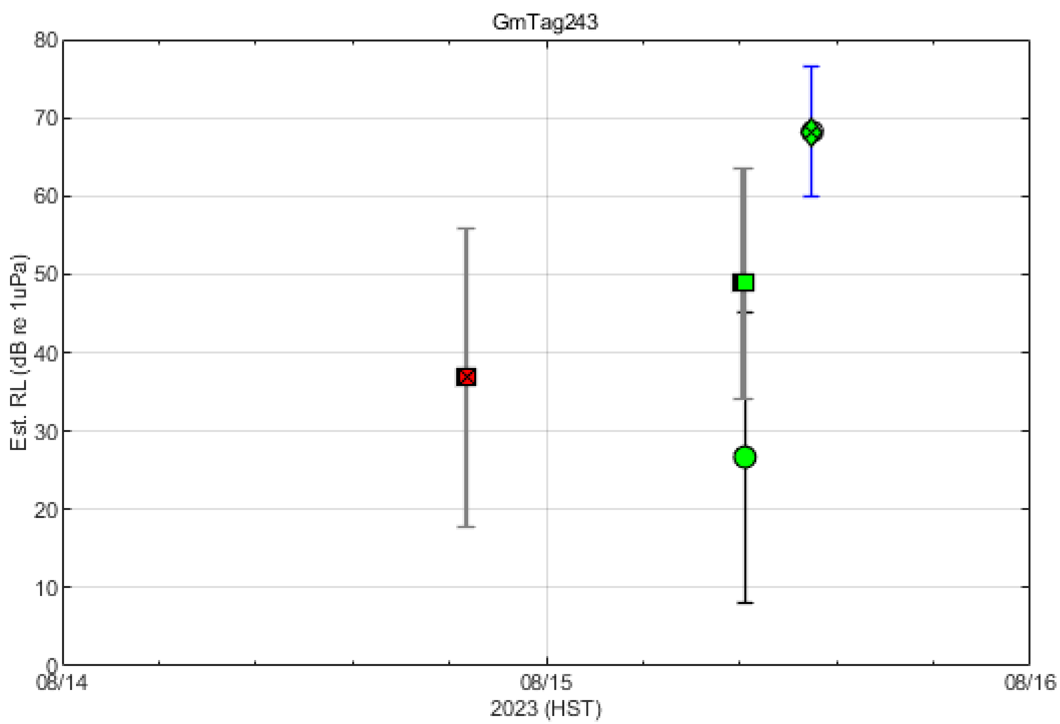


- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 6: Stoplight plot for the received levels for GmTag242 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

Table 13: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag243.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	68.2 (60.0, 76.5)	71.2	70.5
Dipping Sonar	48.9 (34.2, 63.6)	78.1	74.7
Sonobuoy	Below ambient	Below ambient	66.7



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The "x" within colored symbols indicates the probability of exposure was < 100%.

Figure 7: Stoplight plot for the received levels for GmTag243 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.1.1.1 Dive Behavior

GmTag242 and GmTag243 transmitted behavior log data for each phase (Table 6). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis, and only GmTag243 had sufficient data to be analyzed.

Dawn dive metrics could only be calculated for Phase A, the Interphase, and Phase B due to limited behavioral coverage during other phases. Dawn dive depths and durations did not have statistically significant variation between phases, but dawn dives were longest and deepest during

Phase A, and shortest and shallowest during the Interphase (Table 7, Figure 8A). Dawn dive rates for GmTag243 were lowest in Phase A (1.7 dives/hr), then rose to a high during the Interphase (2.9 dives/hr), and fell off during Phase B (Table 7, Figure 8B).

Daytime dive depths had statistically significant variation between phases, but daytime dive durations did not (Table 8). The median daytime dive depth began at 815.5 m during the Before phase, then rose to a high of 935.5 m during the Interphase, before beginning to decline again and eventually returning to 815.5 m during the After phase (Table 8, Figure 8A). Daytime dives were significantly shallower during the Before phase compared to all other phases except the After phase, and daytime dives were significantly shallower during After compared to during Phase A and Phase B (Table 8). Conversely, median daytime dive durations for each phase ranged from 17.2 mins (After) to 18.3 mins (Interphase, Table 8). Daytime dive rates began at their overall highest value of 1.5 dives/hr during the Before phase, then sharply fell to 0.8 dives/hr during Phase A (Table 8, Figure 8B). Afterward, daytime dive rates increased slightly, reaching 1.0 dives/hr during Phase B before falling slightly to 0.95 dives/hr during the After phase (Table 8, Figure 8B).

Dusk dive metrics could only be calculated for Phase A, the Interphase, and Phase B due to limited behavioral coverage during other phases. Dusk dive depths and durations did not have statistically significant variation between these phases, but dusk dives were longest and deepest during Phase B, shortest during Phase A, and shallowest during the Interphase (Table 9, Figure 8A). Dusk dive rates began at 2.9 dives/hr during Phase A, rose to a high of 3.0 dives/hr during the Interphase, and fell to a low of 2.8 dives/hr during Phase B (Table 9, Figure 8B).

Nighttime dive depths and durations had statistically significant differences between phases (Table 10). The median night dive depth began at 238 m during the Before phase, then dropped sharply during Phase A to its lowest value of 115.5 m, before rising to its highest value of 303.5 m during the Interphase, then gradually declining again (Table 10, Figure 8A). Nighttime dive durations followed a similar trend, with the shortest median dive durations matching the shallowest dive depths during Phase A, and the longest nighttime dive durations matching the deepest dives during the Interphase (Table 10). Nighttime dives were significantly shallower during Phase A compared to the Before phase and Phase B, and nighttime dive durations were significantly shorter during Phase A compared to the Before phase, the Interphase, and the After phase (Table 10). Nighttime dive rates began at 3.5 dives/hr during the Before phase, then rose to their highest value at 4.0 dives/hr during Phase A, before falling sharply to their lowest value of 2.9 dives/hr during the Interphase, then gradually rising (Table 10, Figure 8B).

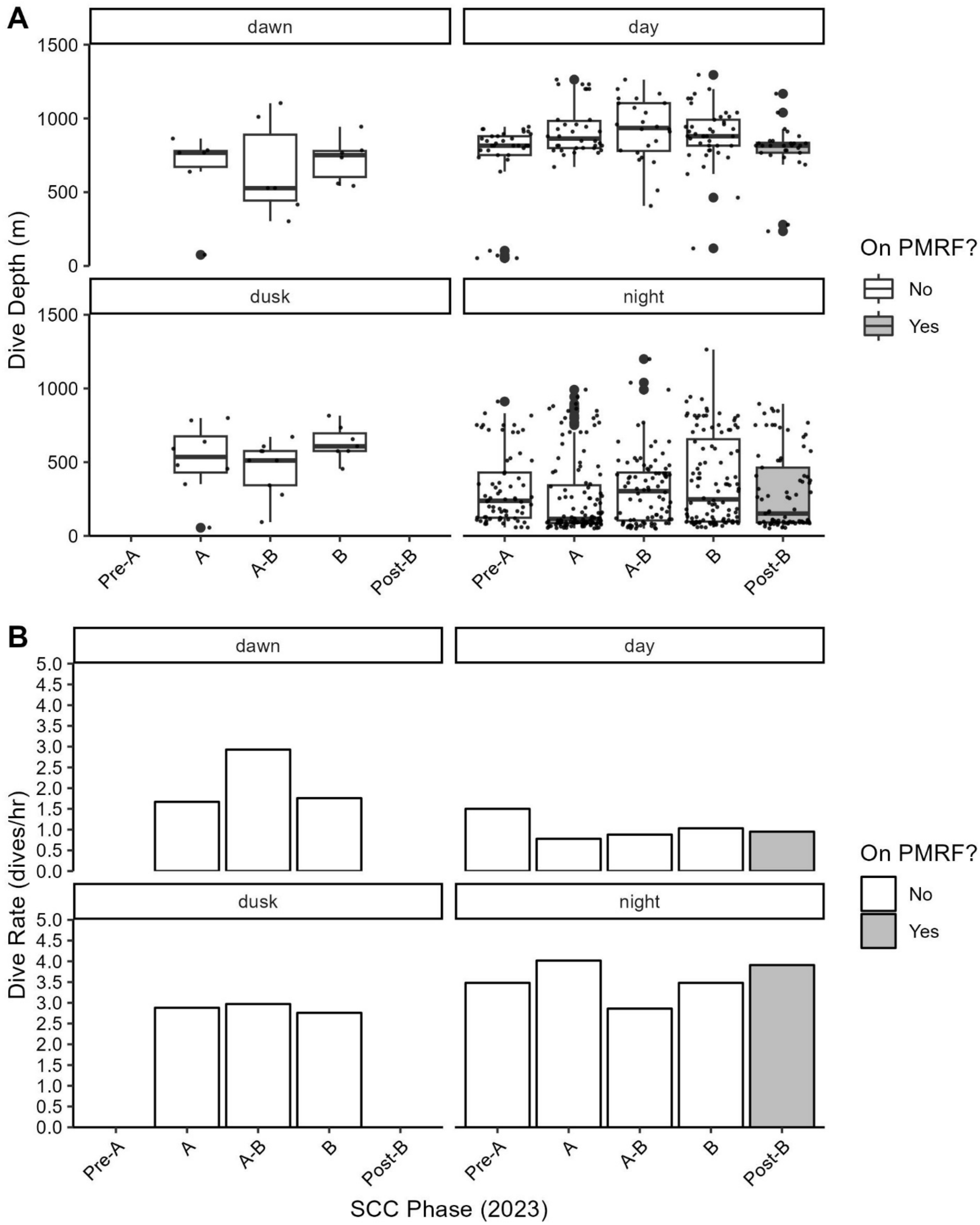
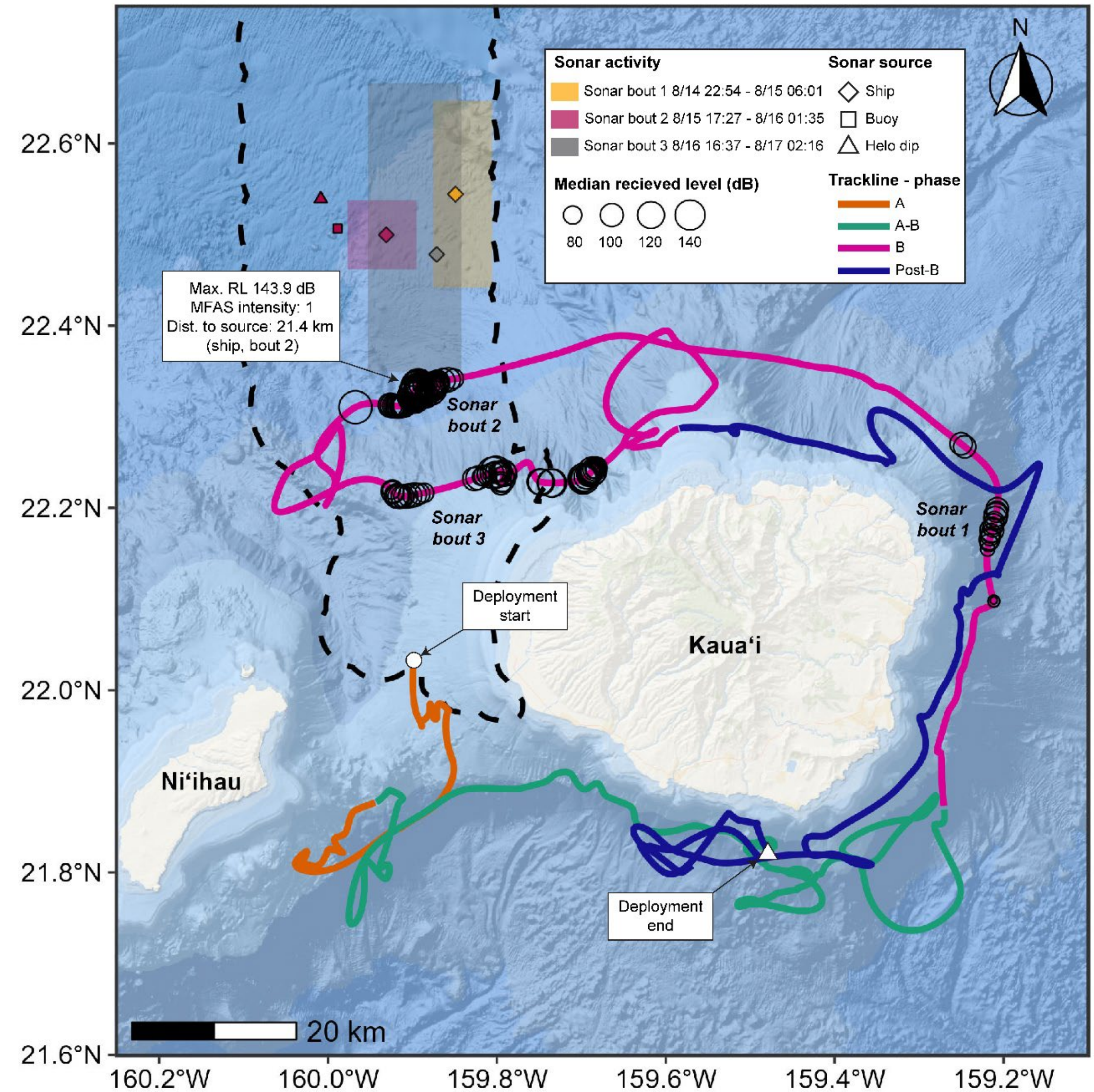


Figure 8: (Top) Boxplot showing dive depths of GmTag243 by SCC phase and time of day. (Bottom) Barplot showing dive rates of GmTag243 by SCC phase and time of day.

3.2.1.2 GmTag244

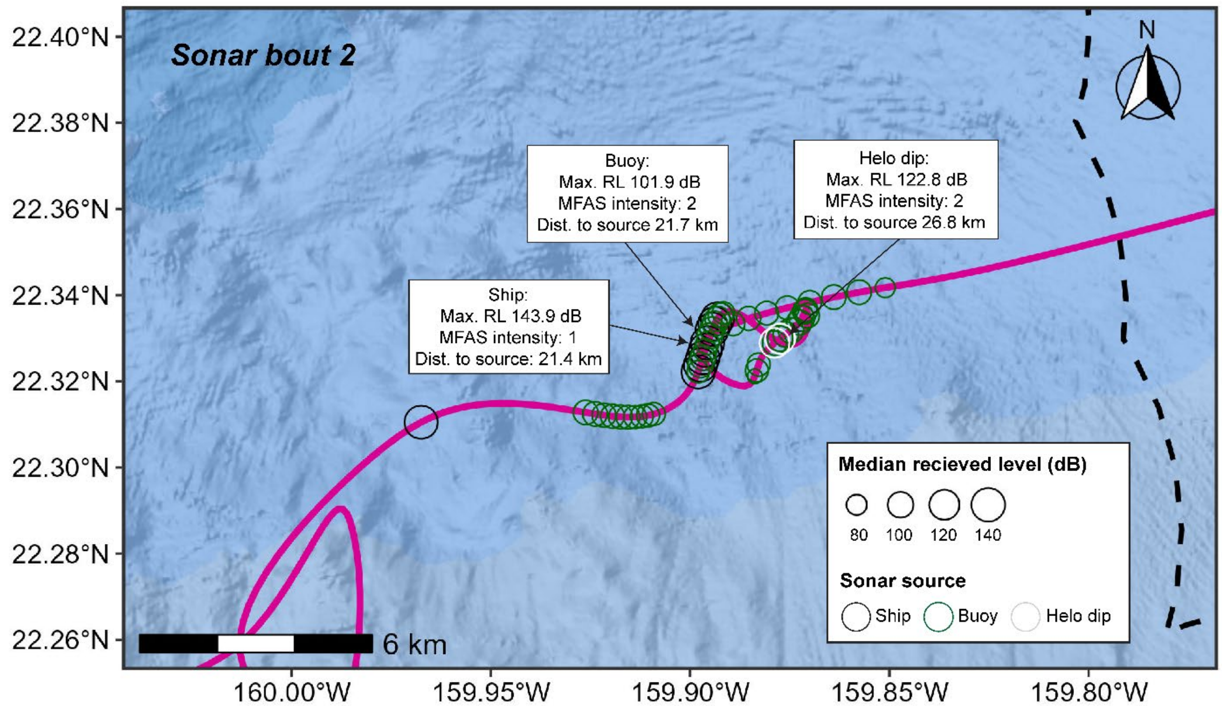
GmTag244 was tagged during Phase A on the range, and information was available on movement patterns for Phase A (1.25 days), the Interphase (2.63 days), Phase B (3.21 days), and the After phase (13.03 days; Table 6). GmTag244 was briefly on the range during Phase A and spent the first four days south/southwest of the island in an ARM behavioral pattern, with similar locations and movements to the previous group of pilot whales. GmTag244 then circumnavigated Kaua'i over the course of the Interphase and Phase B, crossing the range twice during Phase B (Figure 9). During the first day of Phase B, GmTag244 was east of the range coming around the northwest corner of the island and was exposed to a fairly low-level exposure bout (median received levels largely < 100 dB re 1 μPa, Table 14) then headed directly west onto the range where there was a series of exposures from all three sources (Figure 10). The whale turned around west of the range and crossed the range again for another series of exposures from all 3 sources, this time slightly further north and closer to the area of activity (median received levels 60 – 144 dB re 1 μPa, Figure 11). GmTag244 continued past the north side of the island and back around to the south during the After phase.

The first exposure bout occurred during the first deep dive of a series. This dive and the next dive extended to 700-800 m, but the dives over the next 10 hours only extended to 400-500 m. After this GmTag244 began diving to 700 m again, at which time the second bout of exposures began. The whale completed two more deep dives then started a series of shallow dives lasting for 7 hours. This period occurred while the whale was transiting the range heading west. They then began a series of deep dives again on the west side of the range and while they started moving east again; this dive series lasted 16 hours. The third bout of MFAS exposures began during the end of this long deep dives series while the animals were transiting east across the range. They moved back into a surface mode after this period for the remainder of the exposure bout. However, all the transitions between series of deep dives and long intervals near the surface appeared to be consistent with their behavior in the Before and After phases, although there was not enough data across all periods to analyze their behavior statistically.



- The maximum, median estimated received levels (RLs) that occurred during each 5-min exposure bin are plotted as open circles, with the size of the circle scaled to RL level, and time is given in GMT. Additionally, the RL circles are colored by "intensity" which is characterized by the frequency of MFAS exposures that occurred during that given 5- min exposure bin. The shaded rectangular polygon represents the area of ship activity during each of the three MFAS bouts that GmTag244 was exposed to and the corresponding diamond point represents the mean ship location during the bouts. Note: After is restricted to three days after the end of the SCC. The dashed black line represents the PMRF boundary.

Figure 9: Movements of GmTag244 during the August 2023 SCC event (see text for description of phases).

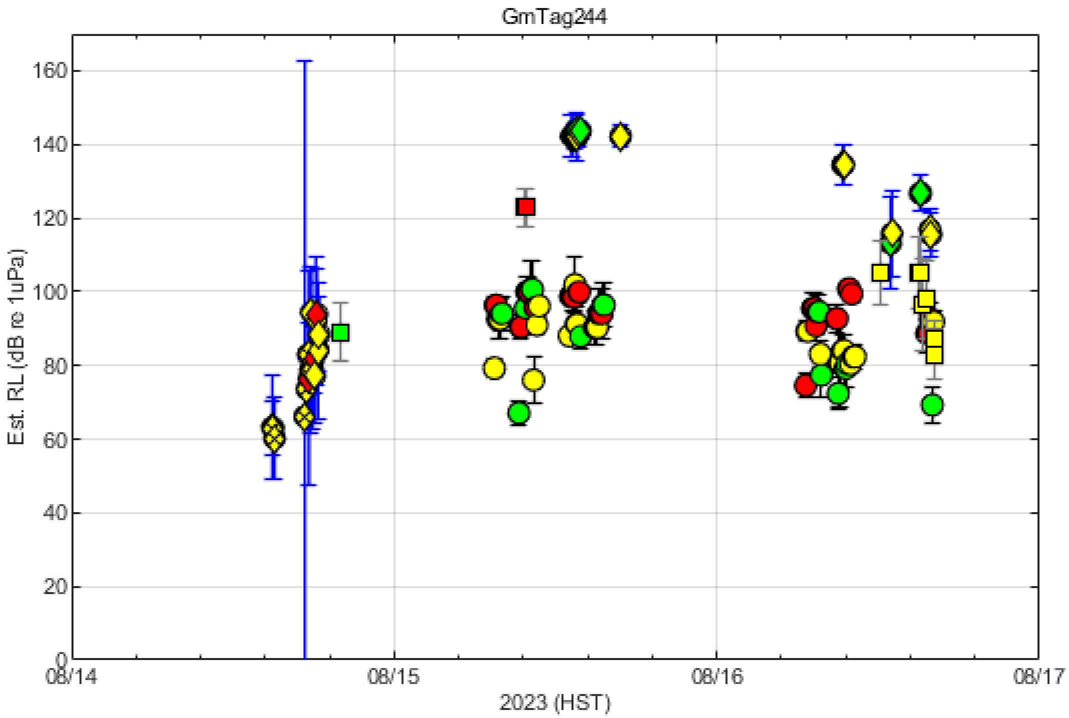


- Locations of the maximum median received levels and associated distances from hull-mounted surface ship MFAS, helicopter-dipping MFAS, and active sonobuoy MFAS are indicated. The RL circles are colored by source type during that given 5-min exposure bin.

Figure 10: A close-up version of Figure 9 showing the track of GmTag244 only during Sonar bout 2 of Phase B.

Table 14: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag244.

	Highest median RL (± 2 SD) dB re 1 µPa	**Overall cSEL dB re 1 µPa²**	**CPA (km)**
Ship	143.9 (139.1, 148.8)	157.6	16.3
Dipping Sonar	122.8 (117.9, 127.7)	143.9	26.8
Sonobuoy	101.9 (94.2, 109.6)	128.4	18.2



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The "x" within colored symbols indicates the probability of exposure was < 100%.

Figure 11: Stoplight plot for the received levels for GmTag244 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.1.3 GmTag245 and GmTag246

GmTag245 and GmTag246 were tagged during the same encounter in 2023 southeast of the range during the Interphase and remained together throughout the remainder of their deployment periods (Figure 12 and Figure 13). Information on movement patterns was available for these animals for the Interphase (1.97 and 1.96 days for GmTag245 and GmTag246, respectively), Phase B (3.21 days), and the After phase (2.02 and 21.79 days for GmTag245 and GmTag246, respectively, see Table 6). They initially conducted a few days of ARM-type behavior south of the island, then came around the east side and received their first bout of low-level exposures during Phase B, with median received levels <100 dB re 1 µPa (Figure 14 and Figure 15, Table 15 and Table 16). Very similar to GmTag244, these whales headed west directly onto the range, where they received their second, highest level bout of exposures with median received levels from hull-mounted MFAS reaching 142 - 144 dB re 1 µPa, then turned and headed east, where they received their third and final bout from all three sources (median received levels 68 – 136 dB re 1 µPa) before moving back around the east side of the island.

The first bout of exposures started at the start of a series of deep dives, and GmTag245 and GmTag246 continued to conduct these deep dives for another 12 hours. The second series of exposures occurred while the animals were at the surface and doing shallower dives to about 100 m.

There was one dive during MFAS to 200 m, which was the deepest dive during this period but not uncommon during periods of shallow dives. The third exposure bout also started during a series of deep dives that continued for 3 hours, followed by almost 8 hours at the surface as the animals transited east from the range. See the Dive Behavior section for a detailed statistical analysis.

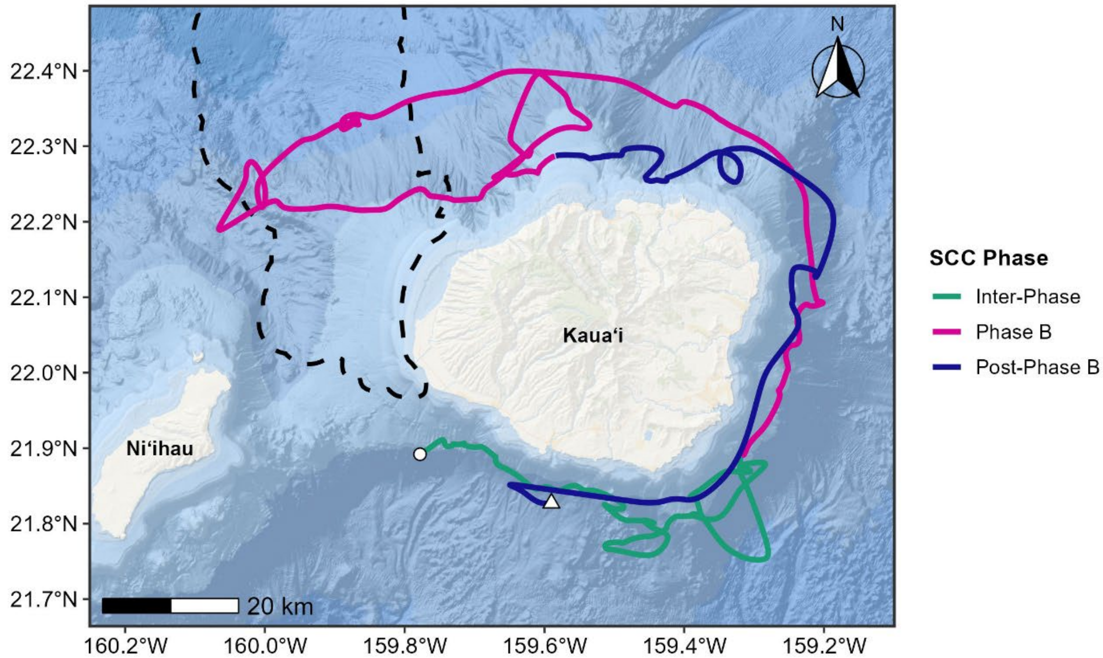


Figure 12: Movements of GmTag245 during the August 2023 SCC event (see text for description of phases). The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

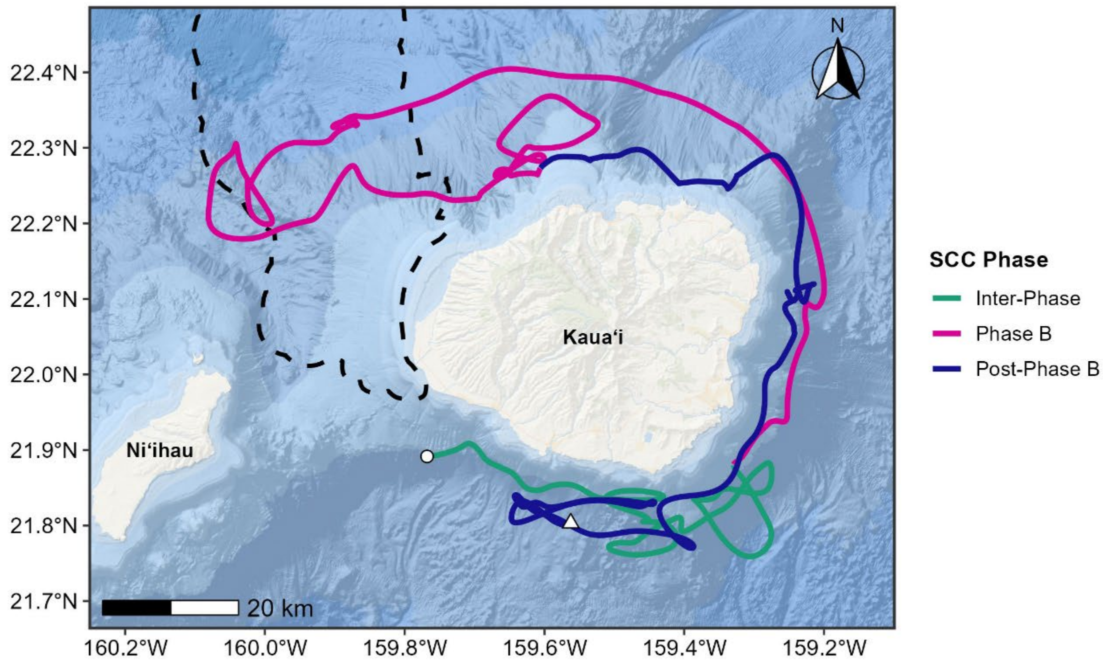
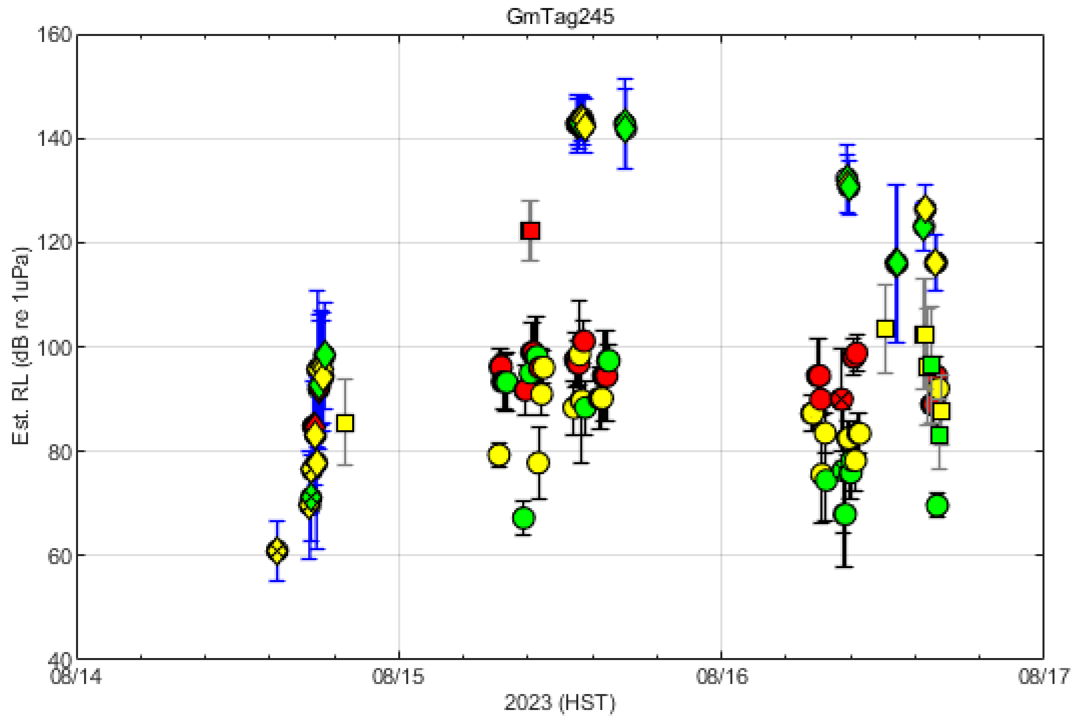


Figure 13: Movements of GmTag246 during the August 2023 SCC event (see text for description of phases). The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Table 15: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag245

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	143.9 (139.4, 148.4)	158.3	16.8
Dipping Sonar	122.2 (116.3, 128.0)	144.7	27.1
Sonobuoy	101.1 (97.1, 105.1)	130.1	18.4

The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

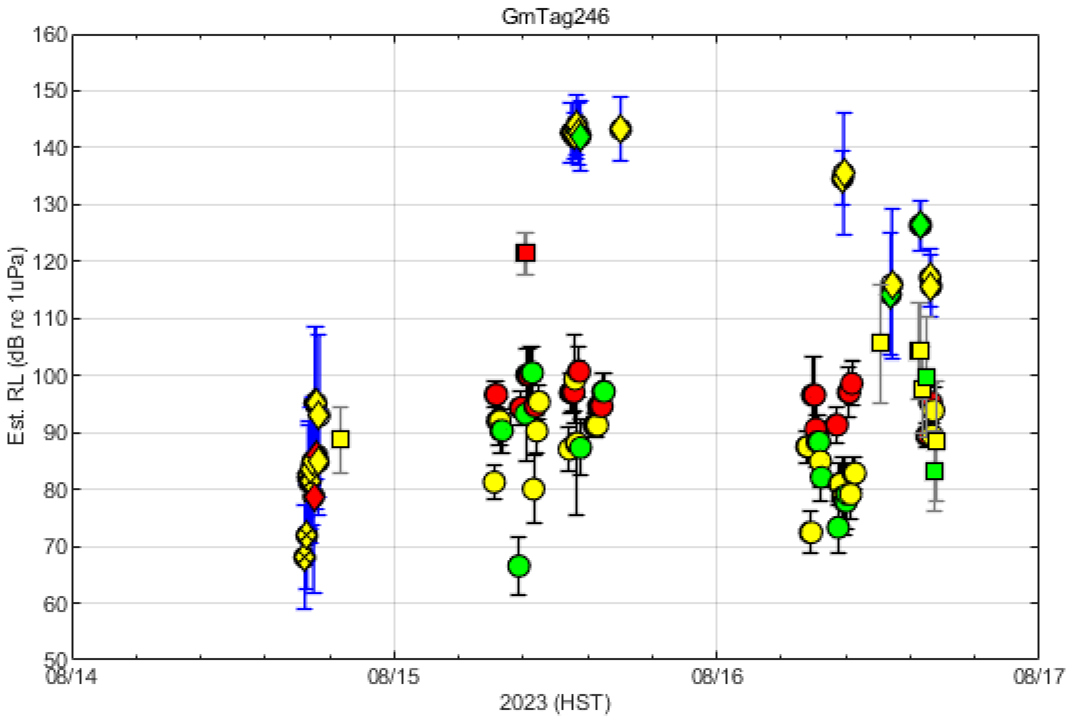


- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 14: Stoplight plot for the received levels for GmTag245 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

Table 16: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag246.

	Highest median RL (± 2 SD) dB re 1 μPa	Overall cSEL dB re 1 μPa²	CPA (km)
Ship	144.1 (138.7, 149.4)	157.9	17.4
Dipping Sonar	121.5 (117.8, 125.2)	140.4	25.8
Sonobuoy	100.7 (96.4, 105.1)	127.8	17.3



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The "x" within colored symbols indicates the probability of exposure was < 100%.

Figure 15: Stoplight plot for the received levels for GmTag246 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.1.3.1 Dive Behavior

GmTag246 transmitted behavior log data during the Interphase, Phase B, and the After phase (Table 6). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis. Data from dawn and dusk were restricted to only Phase B, and data from across multiple phases were only available for day and night periods.

There were statistically significant differences in daytime dive durations, but not daytime dive depths, between phases (Table 8). Dives during the day were deepest and longest during the Interphase, then fell sharply in both median depth and duration during Phase B, and rose once more during the After phase (Table 8, Figure 16A). Daytime dives were significantly deeper during the Interphase than during Phase B (Table 8). Daytime dive rates began at 0.74 dives/hr during the Interphase, then rose to a high of 0.88 dives/hr during Phase B, then fell to a low of 0.34 dives/hr during the After phase (Table 8, Figure 16B).

There were also statistically significant differences in nighttime dive depths and durations between phases (Table 10). Nighttime dives were shallowest and shortest during Phase B, deepest during the After phase, and longest during the Interphase (Table 10, Figure 16A). Nighttime dives were significantly deeper during the After phase compared to the Interphase and Phase B and were significantly shallower during Phase B compared to the Interphase (Table 10). Nighttime dives were also significantly shortest during Phase B compared to the Interphase and the After phase (Table 10).

Nighttime dive rates began at 3.20 dives/hr during the Interphase, then rose to a high of 4.32 dives/hr during Phase B before dropping to 4.15 dives/hr during the After phase (Table 10, Figure 16B).

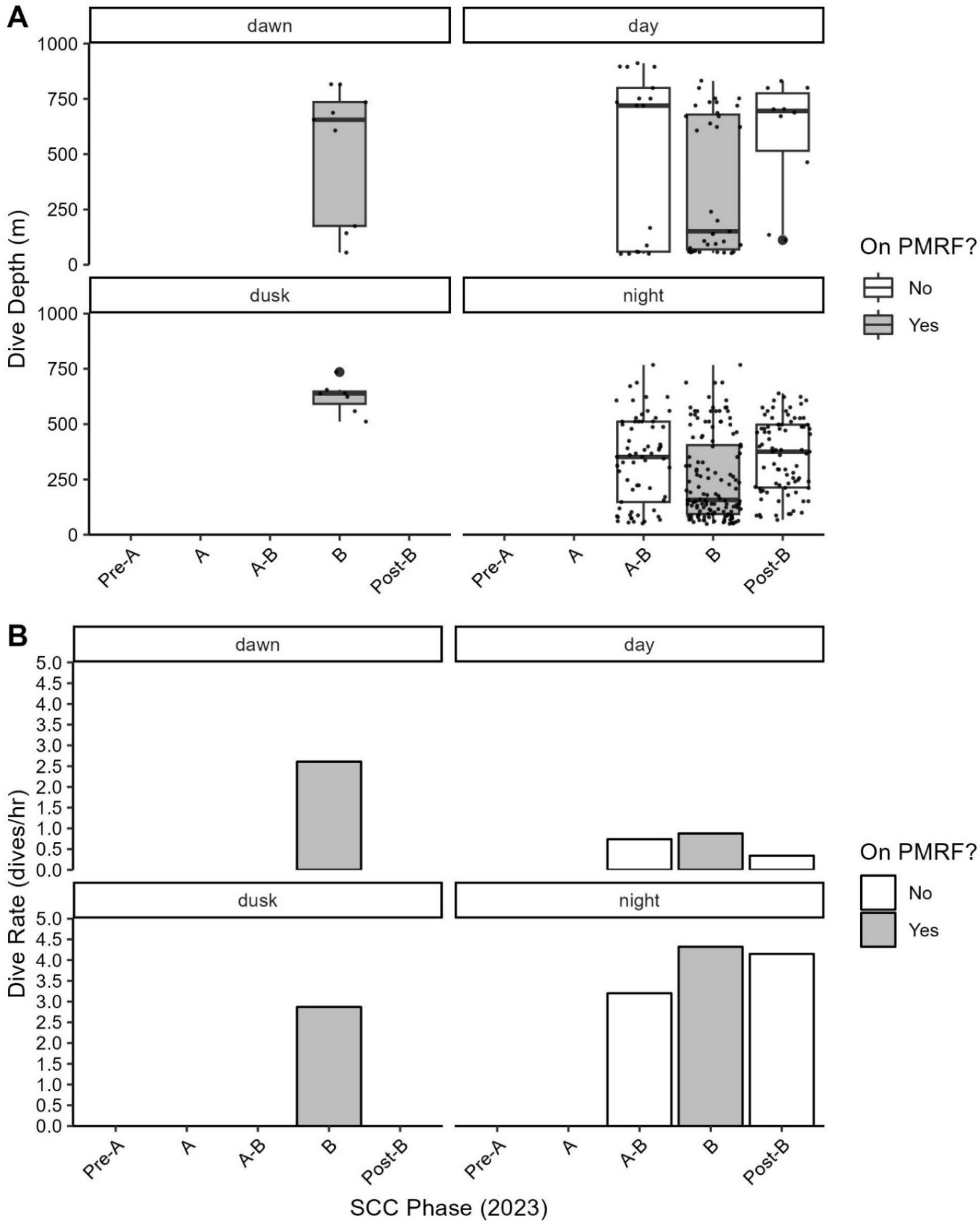
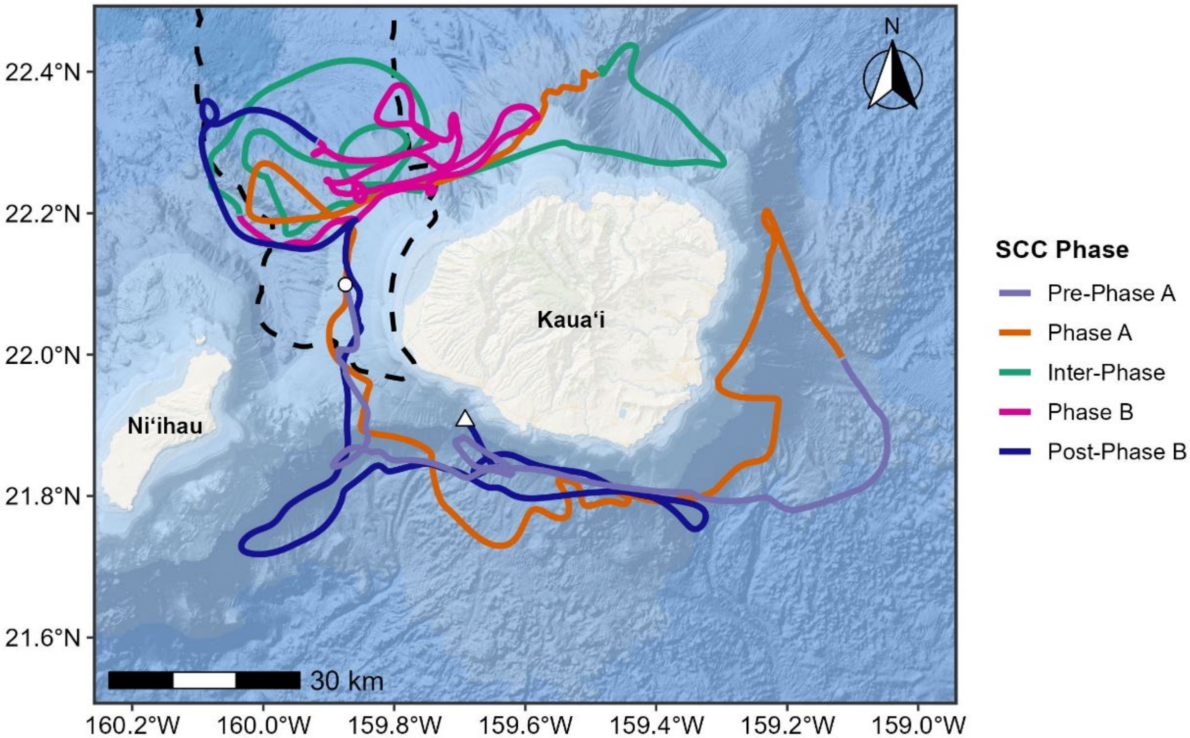


Figure 16: (Top) Boxplot showing dive depths of GmTag246 by SCC phase and time of day. (Bottom) Barplot showing dive rates of GmTag246 by SCC phase and time of day.

3.2.1.4 GmTag251 and GmTag252

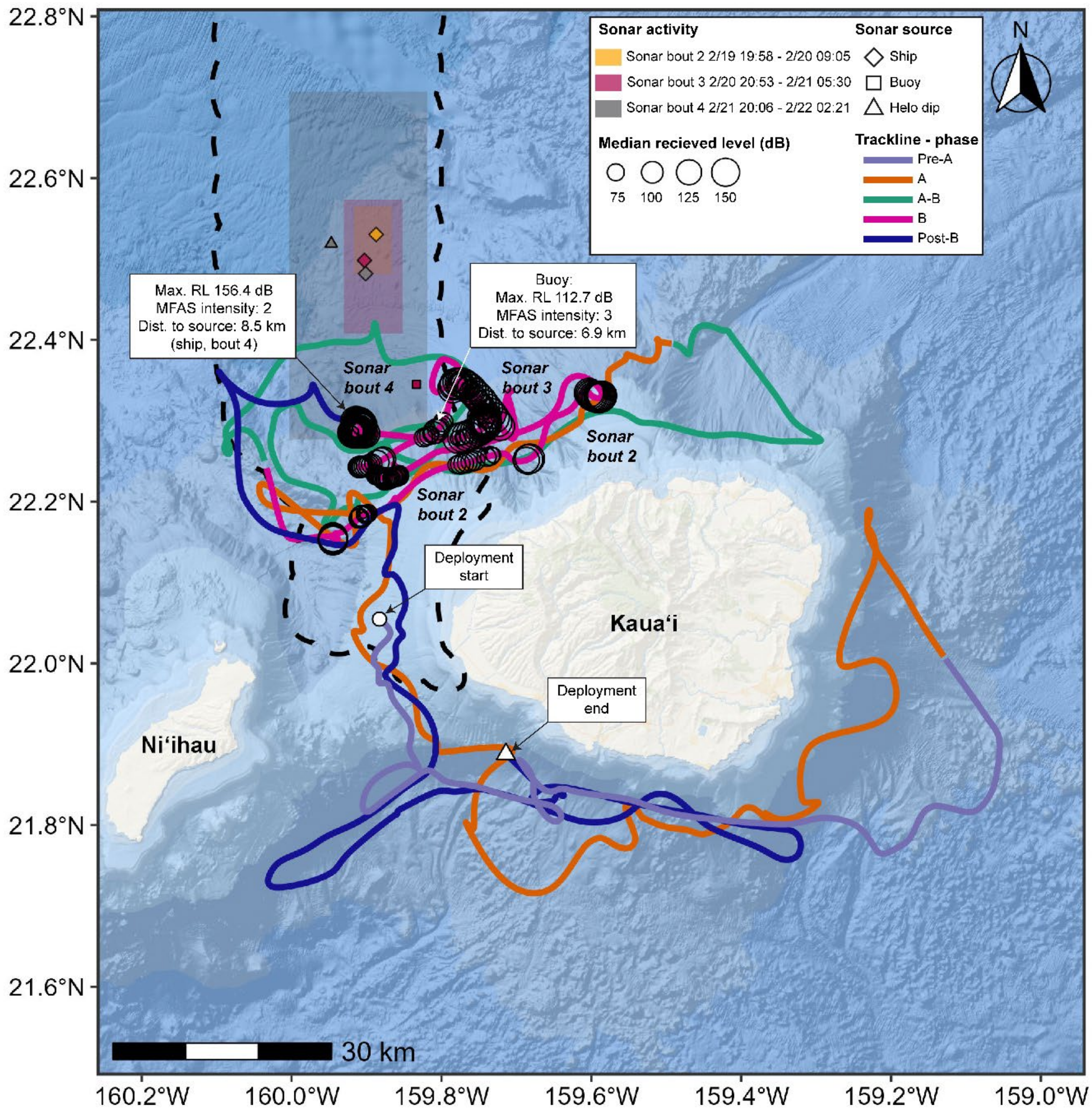
GmTag251 and GmTag252 were tagged during the same encounter on the range in February 2024 and remained associated throughout the overlapping period of tag attachment. Information was available on movement patterns for these two tags for the Before phase (1.89 and 1.84 days for GmTag251 and GmTag252, respectively), Phase A (3.45 days), the Interphase (2.58 days), Phase B (2.38 days), and the After phase (8.65 and 15.61 days for GmTag251 and GmTag252, respectively, Table 6). Though both animals departed the range shortly after being tagged, they moved south/southwest of the island, to a similar area as the other pilot whales. They returned to the range during Phase A and remained on or in close proximity to the range during the Interphase and Phase B, eventually departing the range after Phase B concluded (Figure 17 and Figure 18). They received some of the highest exposure levels of all the pilot whales, with median received levels reaching 156 dB re 1 μPa from hull-mounted MFAS during their final bout of exposures (Table 17 and Table 18). They did not appear to change their movement behavior during any of the MFAS bouts, but instead moved in a large ARM pattern across the range, with repeated movements off the range to the east and then back on the range again, both between and during bouts of MFAS (e.g., Figure 19), and remained on the range for the start of the After phase before moving south.

Similar to the other pilot whales, GmTag251 and GmTag252 had exposure bouts that occurred both during periods of deep diving and during surface periods. However, during the bout of active sonobuoy transmissions on February 20 (Figure 20 and Figure 21), GmTag251 started conducting a series of deeper dives while GmTag252 remained at the surface. GmTag252 joined the deep diving behavior towards the end of the series, during exposures from sonobuoys and hull-mounted MFAS. The last bout of MFAS exposures began while both whales were at the surface. Once again, GmTag251 started conducted deep dives sooner and for a longer period than GmTag252, but both did conduct deep dives during the hull-mounted MFAS, with the end of the exposures coming when both animals were back at the surface. See the Dive Behavior section for a more detailed statistical analysis.



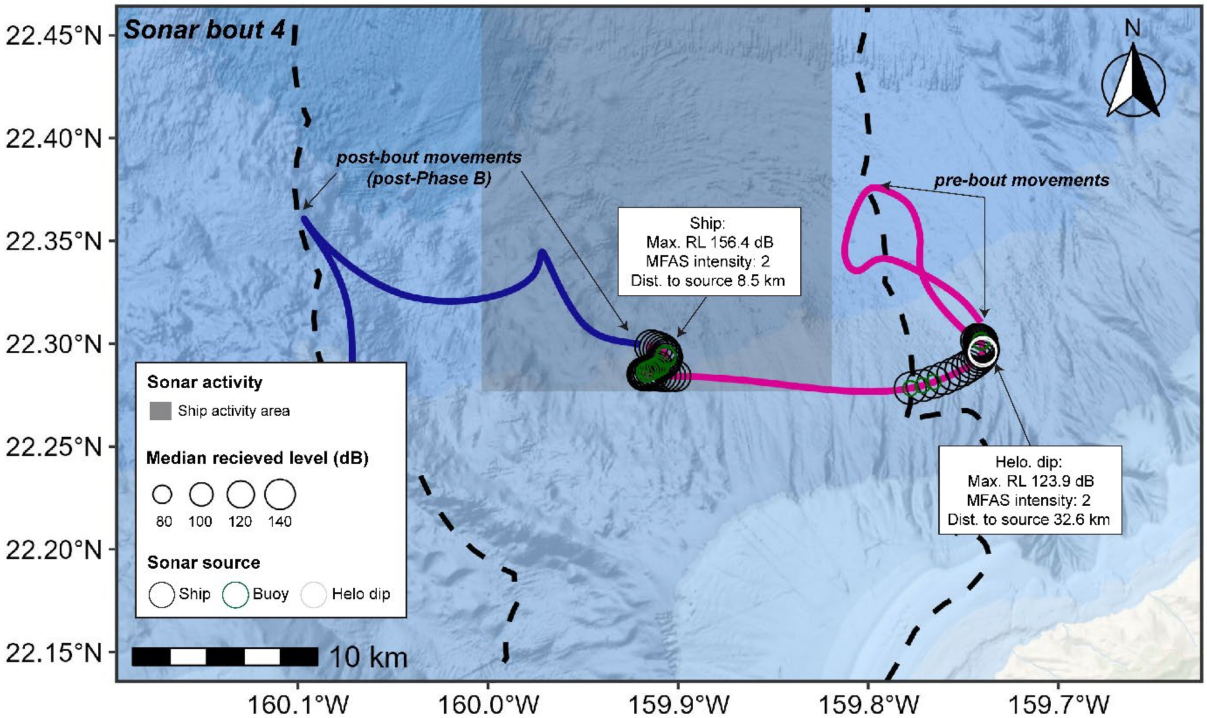
- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Figure 17: Movements of GmTag251 during the February 2024 SCC event (see text for description of phases).



- The maximum, median estimated received levels (RLs) that occurred during each 5-min exposure bin are plotted as open circles, with the size of the circle scaled to RL level, and time is given in GMT. Additionally, the RL circles are colored by "intensity" which is characterized by the frequency of MFAS exposures that occurred during that given 5-min exposure bin. The shaded rectangular polygon represents the area of ship activity during each of the three MFAS bouts that GmTag252 was exposed to, and the corresponding diamond point represents the mean ship location during the bouts. Note: After is restricted to three days after the end of the SCC. The dashed black line represents the PMRF boundary.

Figure 18: Movements of GmTag252 during the February 2024 SCC event (see text for description of phases).

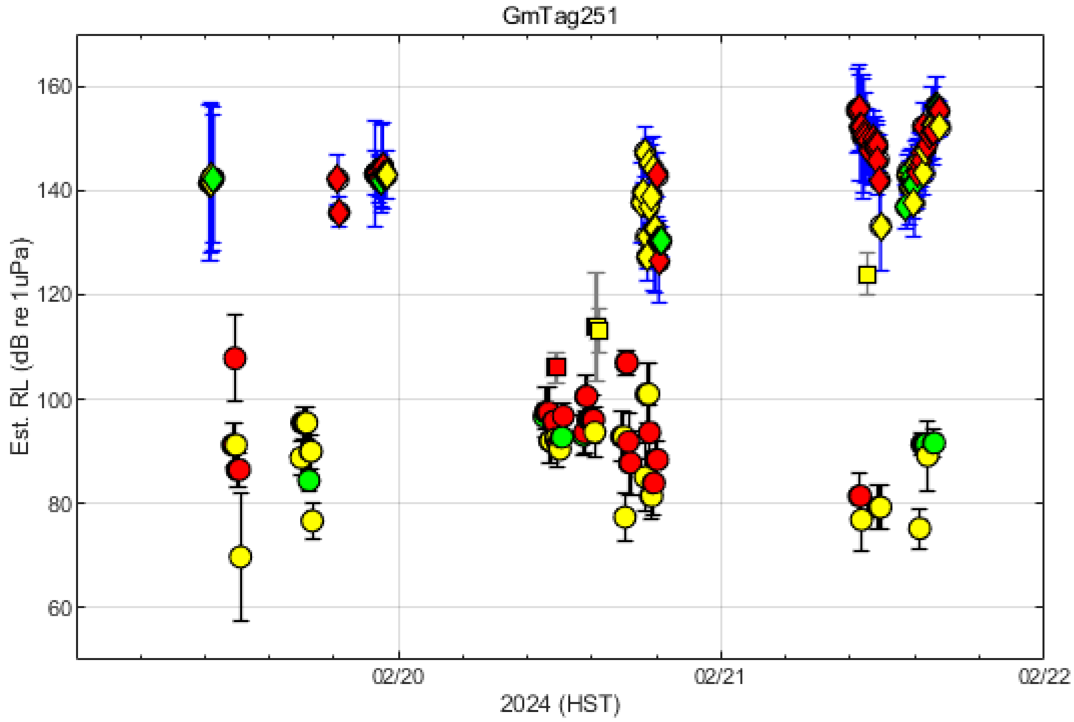


- Locations of the maximum median received levels and associated distances from hull-mounted surface ship MFAS, helicopter-dipping MFAS, and active sonobuoy MFAS are indicated. The RL circles are colored by source type during that given 5-min exposure bin.

Figure 19: A close-up version of Figure 18 showing the track of GmTag252 only during Sonar bout 4 of Phase B.

Table 17: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag251.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	156.1 (150.3, 161.8)	176.3	8.5
Dipping Sonar	123.9 (119.8, 128.0)	141.8	24.1
Sonobuoy	107.8 (99.7, 116.0)	130.3	8.6

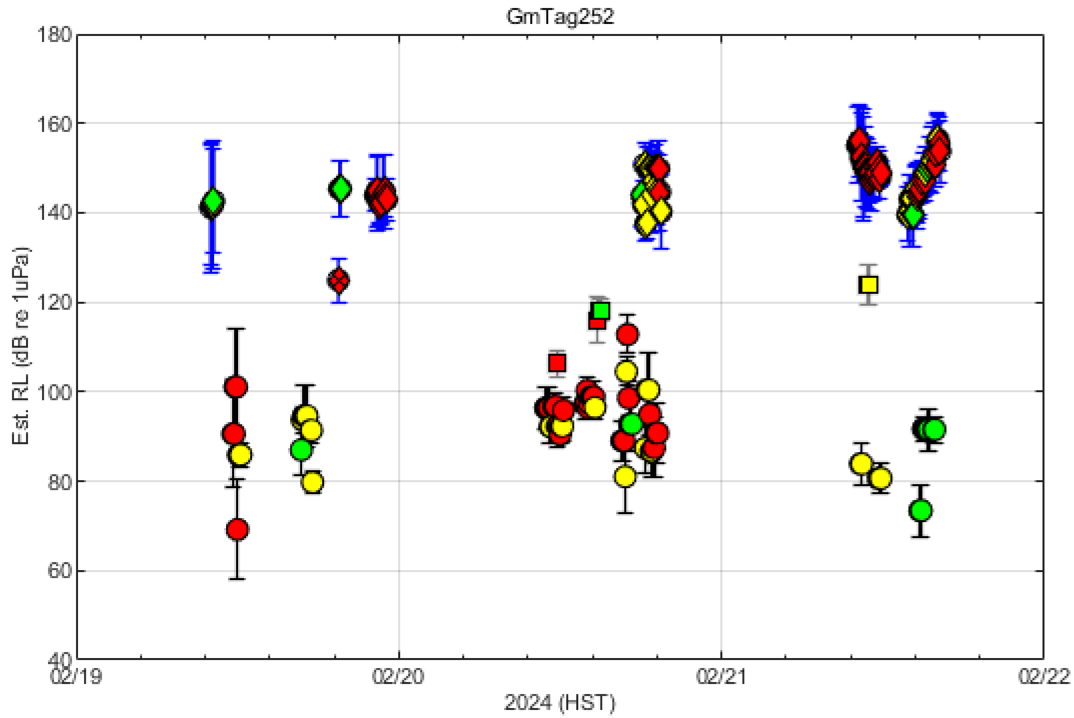


- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high.

Figure 20: Stoplight plot for the received levels for GmTag251 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

Table 18: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag252.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	156.4 (150.6, 162.2)	176.8	8.5
Dipping Sonar	123.9 (119.5, 128.2)	142.3	24.1
Sonobuoy	112.7 (108.4, 117.0)	131.1	6.9



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high.

Figure 21: Stoplight plot for the received levels for GmTag252 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.1.4.1 Dive Behavior

GmTag251 and GmTag252 transmitted behavior log data for each phase (Table 6). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis.

Dawn dive metrics were available for both tags for Phase A, the Interphase, Phase B, and the After phase, and could not be calculated for the Before phase due to limited coverage relative to the phase duration. There was statistically significant variation in both the dawn dive depths and dive durations between phases for GmTag252, but not for GmTag251. The median dawn dive depth for GmTag251 began at 639.5 m during Phase A, then declined sharply during the Interphase before gradually rising to a high of 671.5 m during the After phase (Table 7, Figure 22A). Conversely, GmTag252, started with its shallowest median dawn dive depth during Phase A, at 86.5 m, after which it sharply rose during the Interphase, and peaked at 767.5 m during Phase B before declining during the After phase (Table 7, Figure 23A). While there were statistically significant differences in dawn dive depths between phases for GmTag252, there were no pairs of phases with statistically significant differences between phases based on post-hoc Dunn's test adjusted p-values, likely due to the comparatively small number of dawn dives that were recorded for the tag (Table 7). Median dawn dive durations for GmTag251 started at a low of 12.17 mins during Phase A, then rose gradually to a high of 14.63 min during Phase B before falling again during the After phase (Table 7). GmTag252 showed a somewhat similar trend, starting at its lowest median dawn dive duration during Phase A, though the median dive duration rose continuously to reach a high of 16.43 mins during the After phase (Table 7). Trends in dawn dive rates were also somewhat similar between the two tags. Both had their lowest dawn dive rates during Phase B (0.47 and 0.46 dives/hr for GmTag251 and GmTag252, respectively), immediately followed by their highest dawn dive rates during the After phase (1.48 and 1.46 dives/hr for GmTag251 and GmTag252, respectively; Table 7, Figure 22B and Figure 23B).

Daytime dive metrics were available for all phases of the SCC for both GmTag251 and GmTag252, and there was statistically significant variation in daytime dive depths between phases for both tags, as well as in daytime dive durations between phases for GmTag252. GmTag251's median daytime dive depths began at 719.5 m during the Before phase, then dropped to their lowest value during Phase A, before peaking at 751.5 m during the Interphase, and declining for the remainder of the SCC (Table 8, Figure 22A). Dives were significantly shallower during Phase A compared to the Before phase, the Interphase, and Phase B for this tag, and significantly deeper during the Interphase compared to the After phase (Table 8). Conversely, GmTag252, began with its lowest daytime median dive depth at 63.5 m, which rose sharply to 623.5 m during Phase A before immediately plummeting again back to 64.5 m, then rising across Phase B to a high of 703.5 m during the After phase (Table 8, Figure 23A). Dive depths during the Before phase and the Interphase were significantly shallower than during any other phase for GmTag252 (Table 8). Daytime median dive durations for GmTag251 began at 13.53 mins and rose gradually to a high of 14.48 mins during Phase B before declining again during the After phase (Table 8). Daytime median dive durations for GmTag252 closely mirrored trends in daytime median dive depths for this tag; dive depths were lowest during the Before phase and the Interphase, and highest during the After phase (Table 8). There were also statistically significant differences in dive durations between phases for GmTag252, with the Before phase and the Interphase having significantly shorter dives than during any other period, and the After phase also having significantly longer dives than during Phase A (Table 8). Daytime dive rates were generally much lower for GmTag252 than for GmTag251, and the two animals showed differing trends between phases. GmTag251's daytime dive rates increased gradually from the Before phase to a high of 1.68 dives/hr during Phase B, before declining again in the After phase (Table 8, Figure 22B). Conversely, GmTag252's dive rates dropped from the Before phase to a low of 0.55 dives/hr during the Interphase, before gradually rising again across the remaining phases (Table 8, Figure 23B).

Dusk dive metrics were available for both tags for Phase A, the Interphase, Phase B, and the After phase, and could not be calculated for the Before phase due to limited coverage relative to the phase duration. There were no statistically significant differences in either dusk dive depths or durations between phases for either tag. GmTag251's median dusk dive depths were greatest at 655.5 m during Phase A, then dropped to a low of 559.5 m during the Interphase before gradually rising again across the remaining phases (Table 9, Figure 22A). Conversely, GmTag252's median dusk dive depths, started at a high of 623.5 m and gradually declined across all remaining phases (Table 9, Figure 23A).

Trends in median dusk dive durations were identical for both tags, with GmTag251 and GmTag252 both having their shortest median dusk dive durations during the Interphase, immediately followed by their longest median dusk dive durations during Phase B (Table 9). The two tags also shared the same timing for their peak dusk dive rates in Phase B, though there was some variation in trends prior to Phase B. Dusk dive rates for GmTag251 rose from Phase A to their peak at 3.29 dives/hr during Phase B before falling again during the After phase, while dive rates for GmTag252's dive rates declined during the Interphase before rising to their peak at 2.71 dives/hr during Phase B before falling again during the After phase (Table 9, Figure 22B and Figure 23B).

Nighttime dive metrics were available for all phases of the SCC for both GmTag251 and GmTag252, and there was statistically significant variation in nighttime dive depths and durations between phases for both tags. Nighttime median dive depths were shallowest for both tags during Phase B (149.5 m for GmTag251, and 147.5 m for GmTag252), and deepest for both tags during the After phase (559.5 m for both tags; Table 10, Figure 22A and Figure 23A). For both tags, dives during the After phase were significantly deeper than during any other phase of the SCC (Table 10). Trends in nighttime median dive durations between phases were identical for both tags, with durations rising from the Before phase into Phase A, then falling across the Interphase to their lowest values in Phase B (9.68 mins for GmTag251, 10.37 mins for GmTag252) before rising sharply to their highest values in the After phase (12.80 mins for GmTag251, 13.67 mins for GmTag252; Table 10).

For GmTag251 and GmTag252, dives during the Before phase were significantly shorter than during Phase A and the After phase, and dives during the After phase were also significantly longer than during the Interphase and Phase B (Table 10). Additionally, for GmTag251, dives during Phase A were also significantly longer than during the Interphase and Phase B, and significantly shorter during Phase A compared to the After phase (Table 10). Trends in nighttime dive rates between phases were also identical for both tags. Both tags began with their highest nighttime dive rates during the Before phase (3.66 dives/hr for GmTag251, 3.75 dives/hr for GmTag252), after which dive rates fell consistently to a low during Phase B (1.99 dives/hr for GmTag251, 2.29 dives/hr for GmTag252), then rose slightly during the After phase (Table 10, Figure 22B and Figure 23B).

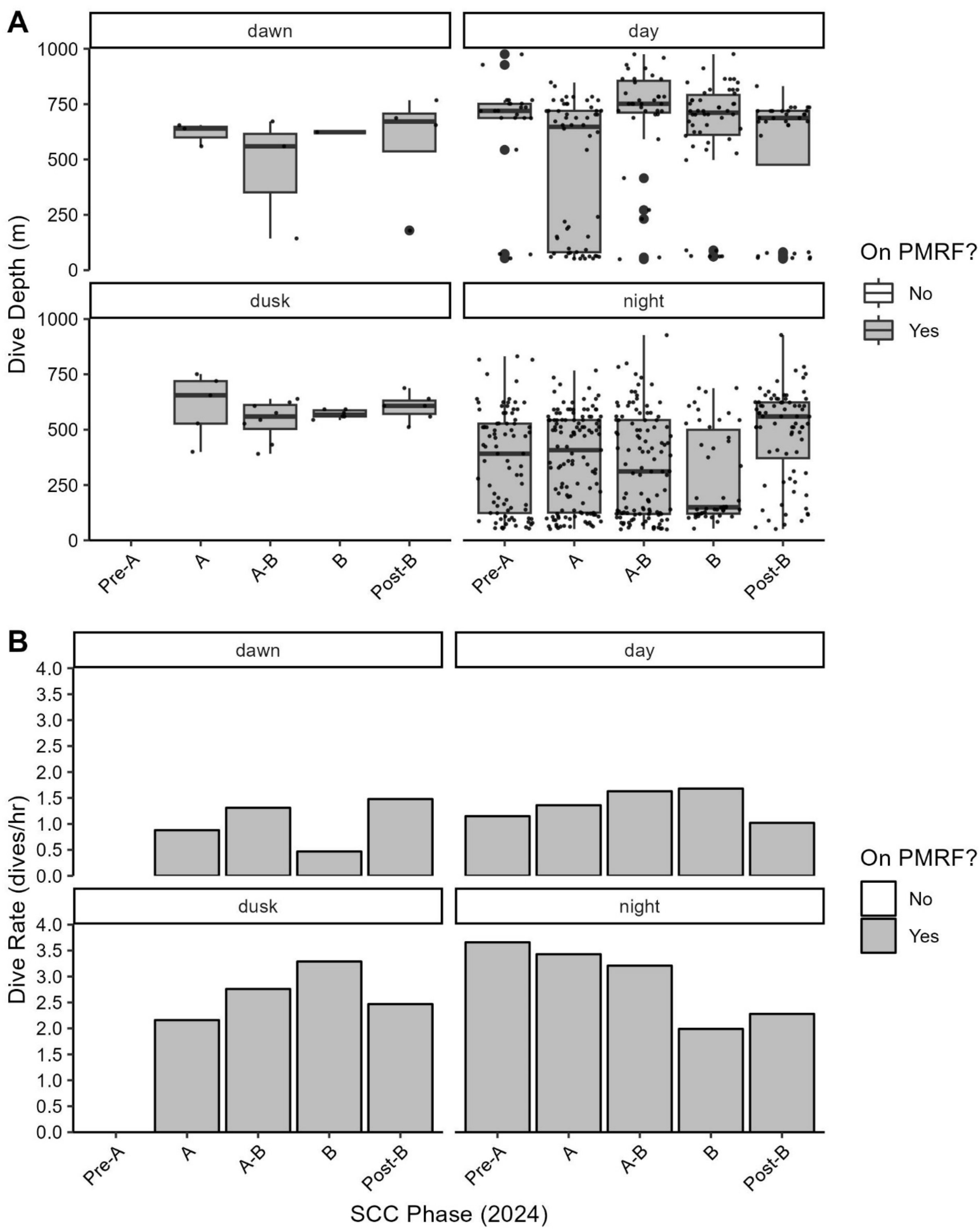


Figure 22: (Top) Boxplot showing dive depths of GmTag251 by SCC phase and time of day. (Bottom) Barplot showing dive rates of GmTag251 by SCC phase and time of day.

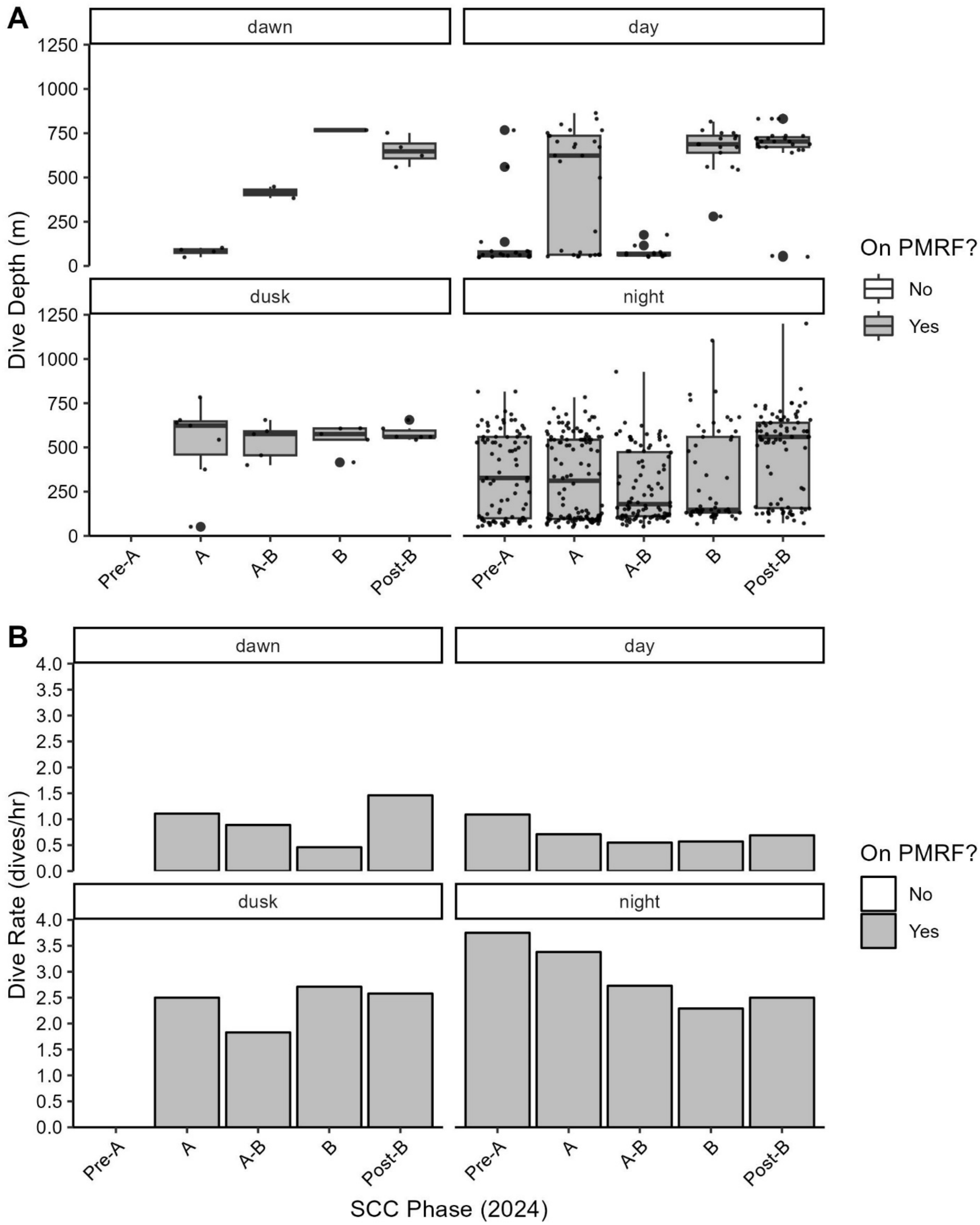


Figure 23: (Top) Boxplot showing dive depths of GmTag252 by SCC phase and time of day. (Bottom) Barplot showing dive rates of GmTag252 by SCC phase and time of day.

3.2.1.5 GmTag253

GmTag253 was tagged in 2024 prior to Phase A on the range, and information was available on movement patterns for Before (1.75 days), Phase A (3.45 days), the Interphase (2.58 days), Phase B (2.38 days), and After (6.25 days; Table 6). GmTag253 conducted one long loop around Niʻihau after being tagged and during the first half of Phase A, heading almost 50 km west of the island, before returning to the range (Figure 24). This whale continued moving on and off the range throughout the tag deployment, including during periods of exposure, with no changes in their movement behavior relative to MFAS, even though the median received levels from hull-mounted MFAS were between 127 and 150 dB re 1 μPa (Table 19, Figure 25).

Similarly, they continued alternating long periods of deep dives with short periods at the surface throughout their tag deployment, including during Phase B and bouts of active MFAS. Two of their three deepest dives, which approached 1000 m, did occur during MFAS, but their deepest dive was to >1100 m and occurred during the Interphase. See the Dive Behavior section for a detailed statistical analysis.

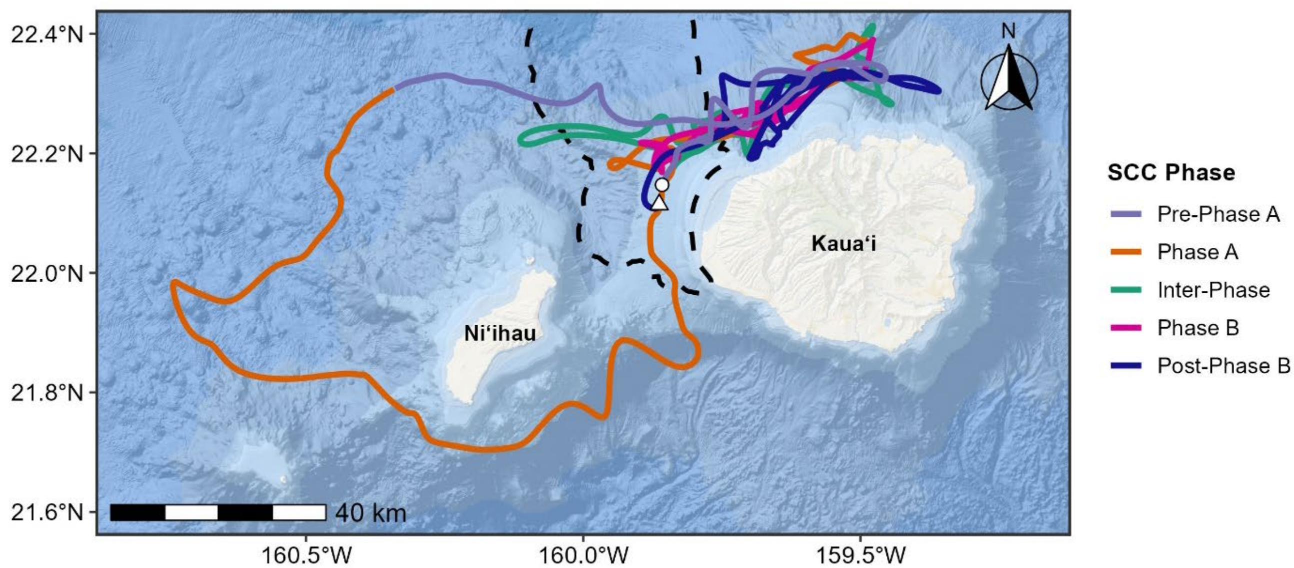
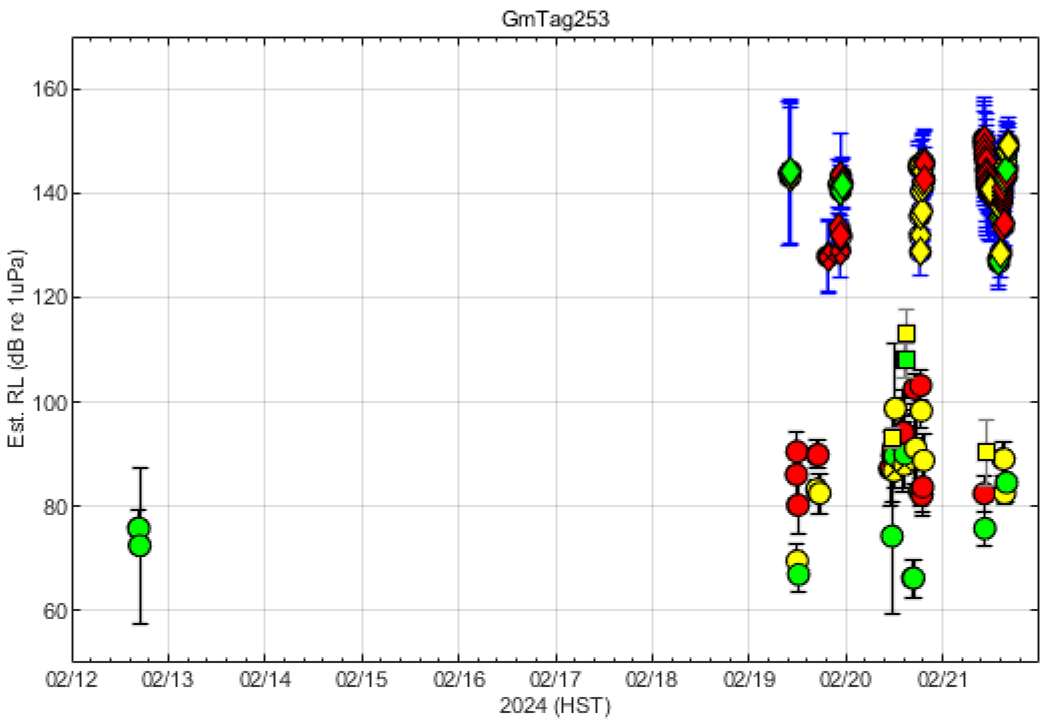


Figure 24: Movements of GmTag253 during the February 2024 SCC event (see text for description of phases). The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Table 19: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag253.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	150.4 (142.5, 158.3)	170.5	14.1
Dipping Sonar	113.2 (108.6, 117.8)	127.4	28.6
Sonobuoy	103.2 (100.4, 106.0)	127.6	13.5



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The "x" within colored symbols indicates the probability of exposure was < 100%.

Figure 25: Stoplight plot for the received levels for GmTag253 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.1.5.1 Dive Behavior

GmTag253 transmitted behavior log data for each phase (Table 6). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis.

Dawn dive metrics were only available for GmTag253 for Phase A and the After phase, due to limited behavioral coverage during other phases. Median dive depths and durations were greater during Phase A than during the After phase, but there were no statistically significant differences between the two phases for either value (Table 7, Figure 26A). Dawn dive rates also varied between the two phases, with 1.26 dives/hr for Phase A, and 0.41 dives/hr for the After phase (Table 7, Figure 26B).

Daytime dive metrics were available for all phases, and there were statistically significant differences in daytime dive durations between phases. Daytime median dive depths began at 671.5 m during the Before phase, then declined during Phase A and the Interphase before peaking at 711.5 m during Phase B, then falling again during the After phase (Table 8, Figure 26A). Daytime median dive durations followed a similar trend, beginning at 14.83 mins, then declining through the Interphase before peaking at 16.05 mins during Phase B before falling again (Table 8). Daytime dives were significantly longer during Phase B compared to the Interphase (Table 8). Daytime dive rates began at 1.26 dives/hr during the Before phase, then sharply dropped during Phase A before peaking during the Interphase at 1.47 dives/hr, then dropped sharply again (Table 8, Figure 26B).

Dusk dive metrics were available for GmTag253 for phases A through the After phase but were unavailable for the Before phase due to limited behavioral coverage. Median dusk dive depths began at 531.5 m during Phase A, then rose to a high of 719.5 m during the Interphase before falling over the course of the remaining phases (Table 9, Figure 26A). Conversely, median dusk dive durations rose continuously from Phase A to a high of 14.87 mins during Phase B, before falling again during the After phase (Table 9). Dive rates were mostly comparable between phases, ranging from a high of 2.94 dives/hr during Phase A to a low of 2.42 dives/hr during Phase B (Table 9, Figure 26B).

Nighttime dive metrics were available for all phases, and there were statistically significant differences in nighttime dive depths and durations between phases. Nighttime median dive depths began at 391.5 m, then fell to a low of 143.5 m during the Interphase before rising again to a high of 543.5 m during the After phase (Table 10, Figure 26A). Nighttime dives were significantly deeper during the Before phase compared to the Interphase, and significantly deeper during the After phase compared to all other phases (Table 10). Similarly, median nighttime dive durations began at 11.37 mins, then fell to a low of 8.93 mins during the Interphase before gradually rising to a high of 13.67 mins during the After phase (Table 10). Nighttime dives during the After phase were significantly longer than dives during any other phase (Table 10). Nighttime dive rates began at a high of 3.80 dives/hr, then continuously fell across the remaining SCC phases to a low of 2.22 dives/hr during the After phase (Table 10, Figure 26B).

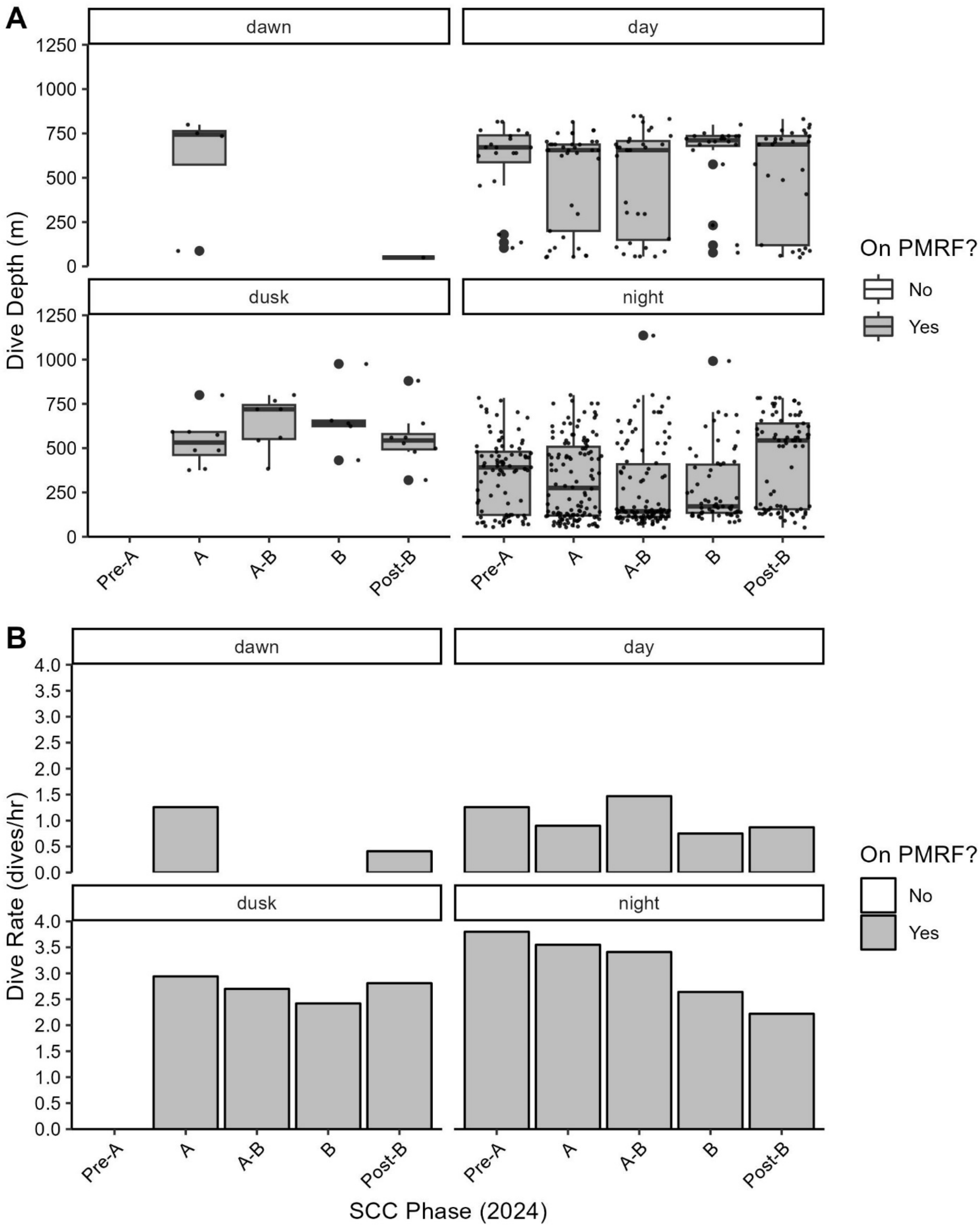


Figure 26: Top. Boxplot showing dive depths of GmTag253 by SCC phase and time of day. Bottom. Barplot showing dive rates of GmTag253 by SCC phase and time of day.

3.2.1.6 GmTag254 and GmTag255

GmTag254 and GmTag255 were tagged during Phase A within the same group in 2024 southeast of the range and generally remained associated for the duration of the tag deployments. Information was available on movement patterns for the two tags for Phase A (1.37 and 1.35 days for GmTag254 and GmTag255, respectively), the Interphase (2.58 days), Phase B (2.38 days), and the After phase (10.08 and 47.07 days for GmTag254 and GmTag255, respectively; Table 6). Though both animals were off the range during Phase A, they entered the range during the Interphase (Figure 27 and Figure 28). Much like the other pilot whales in 2024, GmTag254 and GmTag255 were on the range or to the east throughout Phase B, with multiple bouts of MFAS exposures occurring as they moved back and forth, and no apparent change in their movement behavior (e.g., Figure 29). Received levels remained consistent and relatively high through each exposure bout, up to a median received level of 155 dB re 1 µPa (Figure 30 and Figure 31, Table 20 and Table 21), which fits with them remaining in the same general area on the range throughout Phase B. These whales moved much further to the east than the other whales in the After phase, then moved back onto the range. Exposures occurred during both deep dives and surface periods, again with no apparent change in their dive behavior.

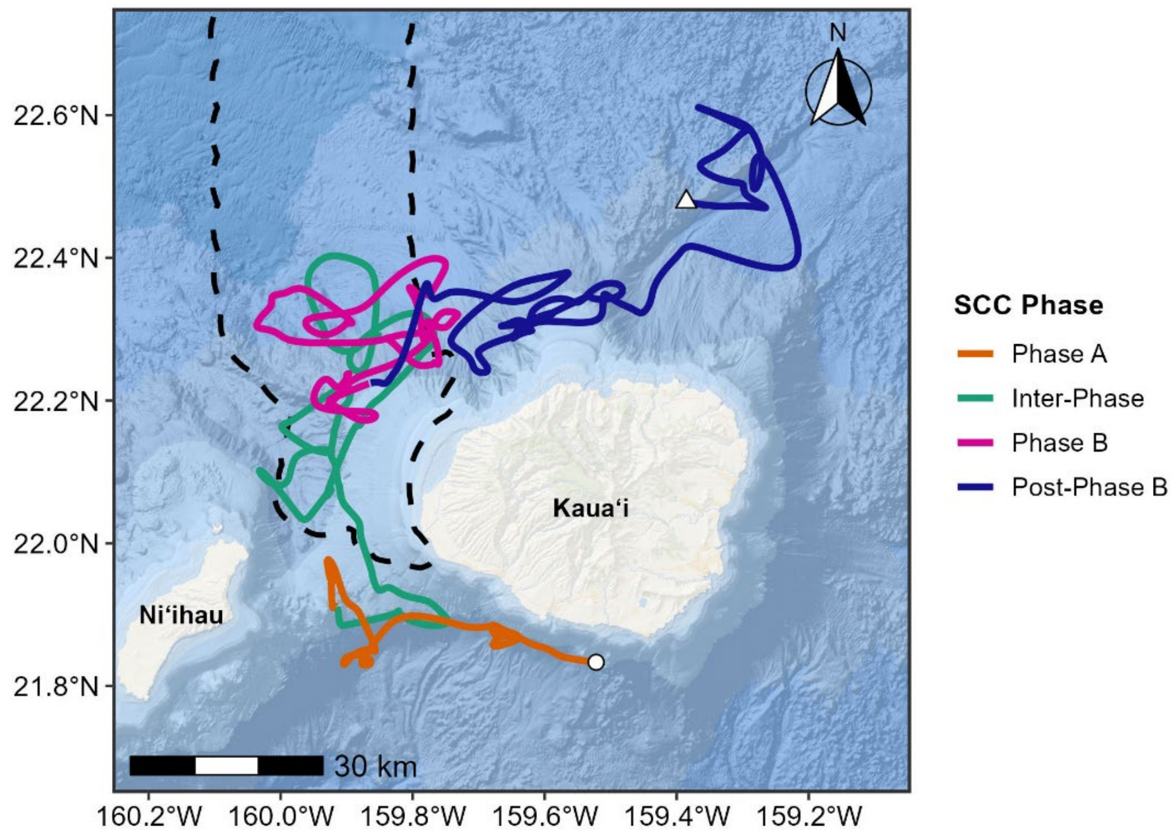
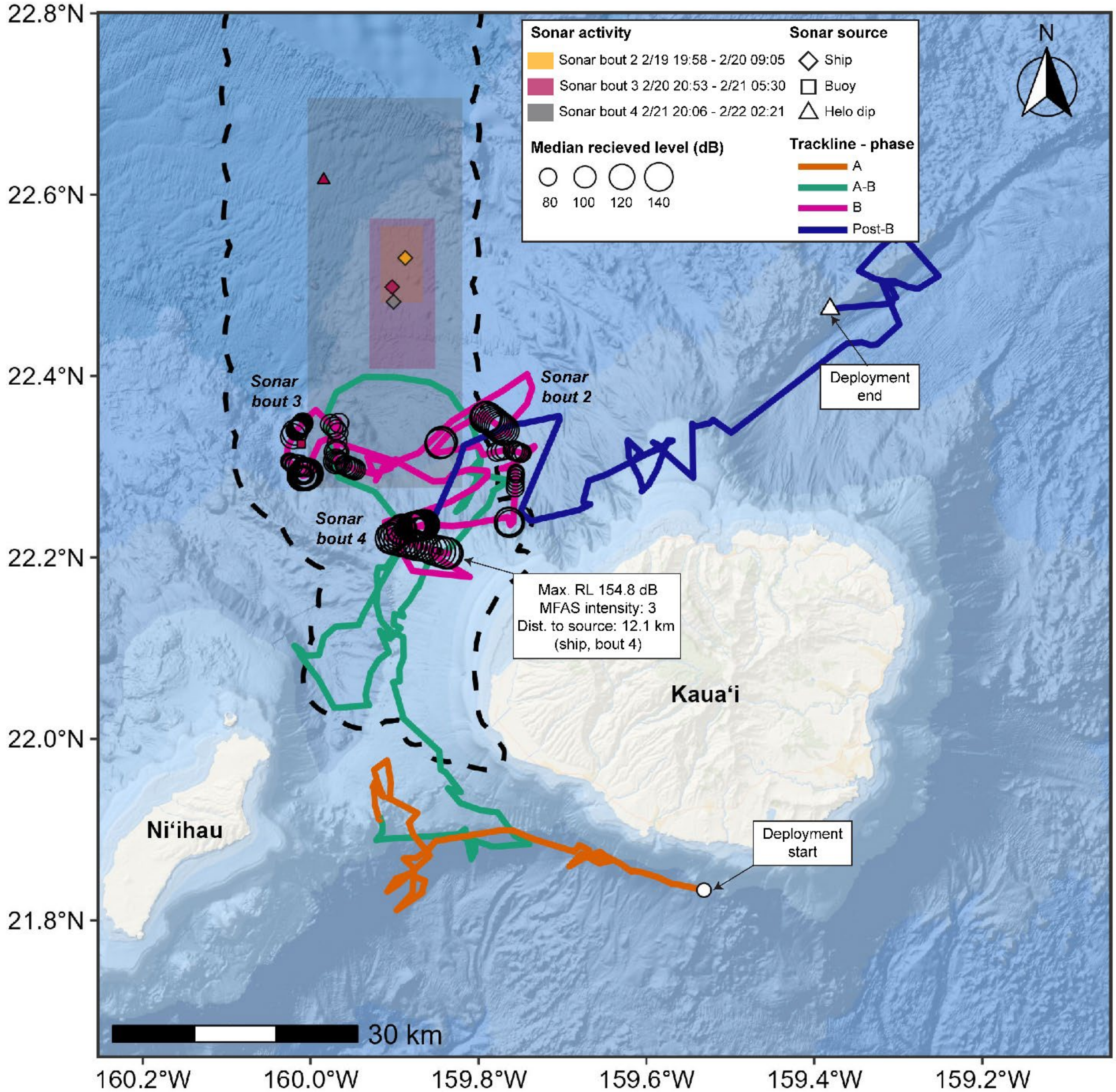


Figure 27: Movements of GmTag254 during the February 2024 SCC event (see text for description of phases). The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.



- The maximum, median estimated received levels (RLs) that occurred during each 5-min exposure bin are plotted as open circles, with the size of the circle scaled to RL level, and time is given in GMT. Additionally, the RL circles are colored by "intensity" which is characterized by the frequency of MFAS exposures that occurred during that given 5-min exposure bin. The shaded rectangular polygon represents the area of ship activity during each of the 3 MFAS bouts that GmTag255 was exposed to and the corresponding diamond point represents the mean ship location during the bouts. Note: After is restricted to 3 days after the end of the SCC. The dashed black line represents the PMRF boundary.

Figure 28: Movements of GmTag255 during the February 2024 SCC event (see text for description of phases).

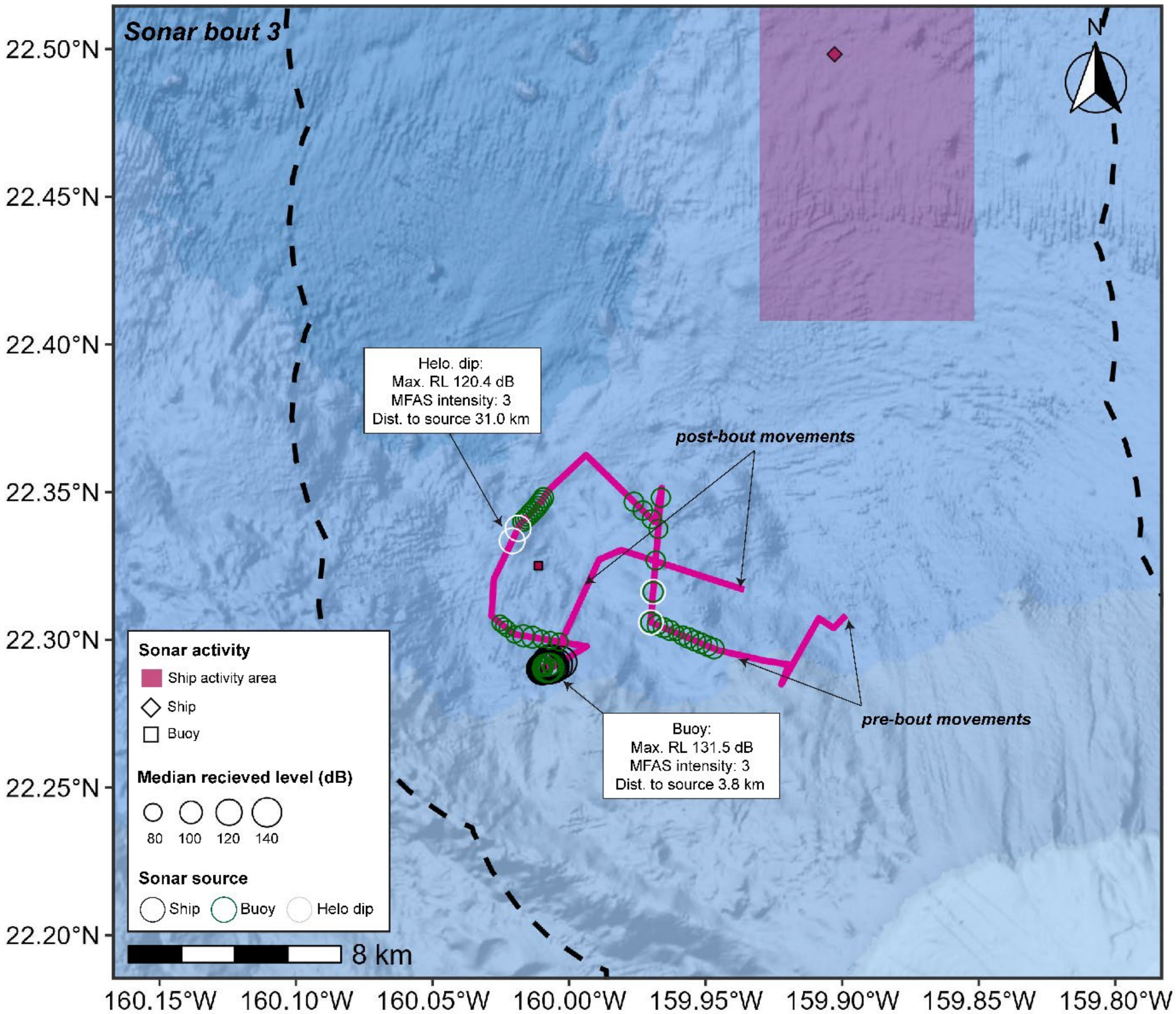
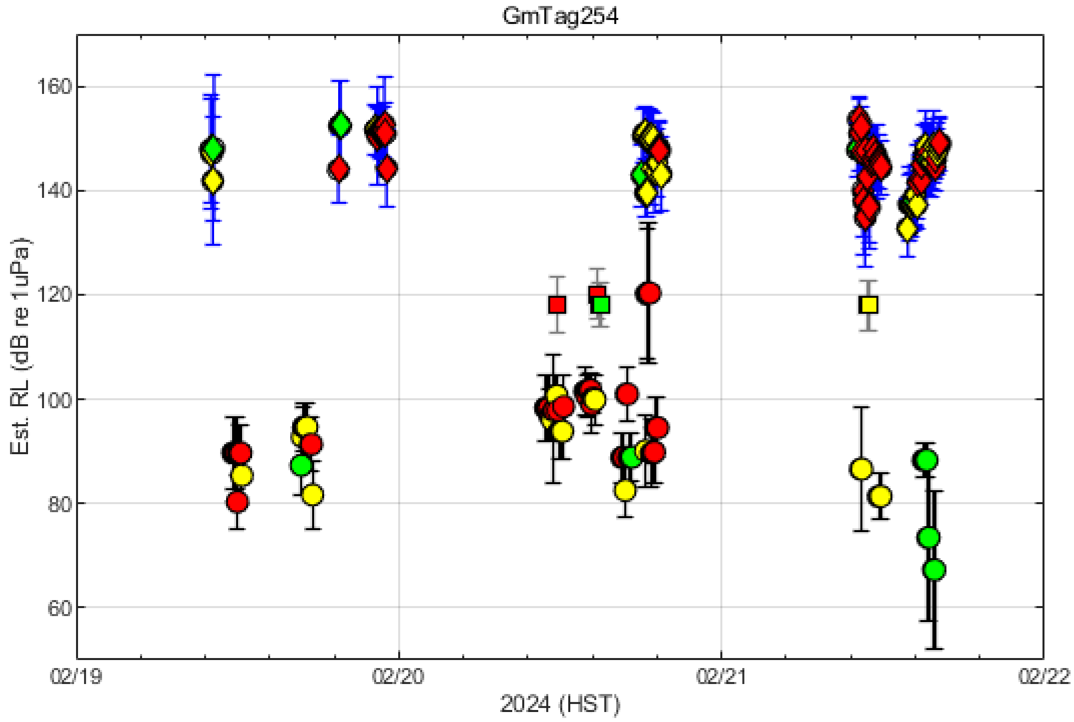


Figure 29: A close-up version of Figure 28 showing the track of GmTag254 only during Sonar bout 3 of Phase B. Locations of the maximum median received levels and associated distances from hull-mounted surface ship MFAS, helicopter-dipping MFAS, and active sonobuoy MFAS are indicated. The RL circles are colored by source type during that given 5-min exposure bin.

Table 20: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag254.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	153.6 (149.5, 157.7)	175.7	7.7
Dipping Sonar	120.1 (115.3, 124.9)	142.9	11.6
Sonobuoy	120.3 (106.9, 133.7)	147.2	5.5

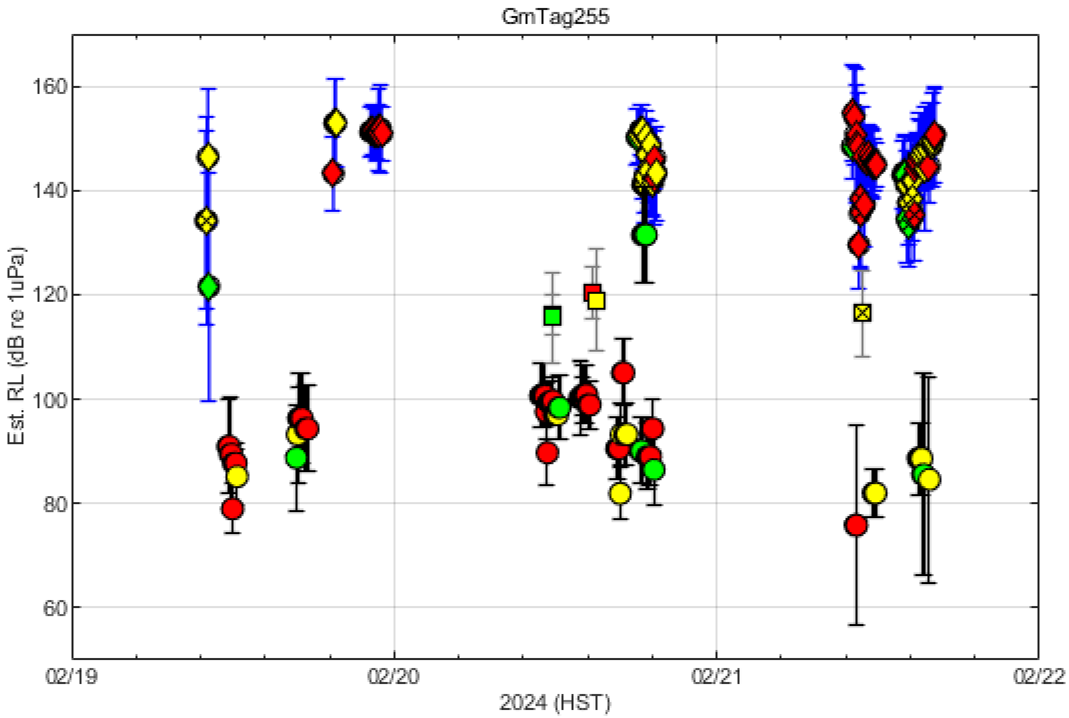


- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high.

Figure 30: Stoplight plot for the received levels for GmTag254 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

Table 21: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag255.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	154.8 (145.5, 164.1)	175.9	11.5
Dipping Sonar	120.4 (115.4, 125.4)	141.4	15.8
Sonobuoy	131.5 (122.1, 140.8)	153.5	3.8



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 31: Stoplight plot for the received levels for GmTag255 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.1.6.1 Dive Behavior

GmTag254 and GmTag255 transmitted behavior log data for each phase from Phase A through the After phase (Table 6). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis. Metrics were available for both tags for the Interphase, Phase B, and the After phase.

GmTag255 did not perform dawn dives during the Interphase, and hence did not have median dawn dive depth or duration metrics for this phase. However, there were statistically significant differences in dawn dive depths between phases for both tags, as well as statistically significant differences in dawn dive durations between phases for GmTag254. Median dawn dive depths were lowest for GmTag254 during the Interphase (81.5 m), then rose sharply in Phase B to 679.5 m before peaking at 735.5 m during the After phase (Table 7, Figure 32A). Similarly, GmTag255 also had its peak dive depth during the After phase, with values during Phase B and the After phase being comparable to those of GmTag254 (Table 7, Figure 33A). Dawn dive rates were lowest for both tags during the Interphase and rose continuously for GmTag254 to a high of 3.05 dives/hr during the After phase. For GmTag255, dive rates rose to a high of 2.11 dives/hr during Phase B, but fell afterward (Table 7, Figure 32B and Figure 33B).

There were statistically significant differences in daytime dive depths between phases for GmTag254, but not for GmTag255. Median daytime dive depths began at a low of 679.5 m for GmTag254 during the Interphase, and rose to a high of 735.5 m during the After phase, while

GmTag255 began at a much lower median daytime dive depth of 127.5 m during the Interphase, though it also rose to a comparable 687.5 m during the After phase (Table 8, Figure 32A and Figure 33A). Daytime dives during the After phase were significantly deeper for GmTag254 compared to daytime dives during other phases (Table 8). Median daytime dive durations began at a high of 15.57 mins for GmTag254, then fell to a low of 14.70 mins during Phase B before rising again during the After phase, while in contrast durations rose consistently from Interphase to the After phase for GmTag255 (Table 8). Daytime dive rates fell between the Interphase to the After phase for both tags (Table 8, Figure 32B and Figure 33B).

Median dusk dive depths across phases were comparable for GmTag254, ranging from 559.5 m (Phase B and the After phase) to 567.5 m (Interphase; Table 9, Figure 32A). For GmTag255, however, median dusk dive depths rose from the Interphase to a high of 687.5 m during Phase B before falling sharply to 507.5 m during the After phase (Table 9, Figure 33A). Median dusk dive durations rose for both tags between the Interphase and Phase B and also fell afterward (Table 9). Dusk dive rates, however, had differing trends. GmTag254 had a dive rate of 2.60 dives/hr for both the Interphase and Phase B, but had a lower dive rate during the After phase, while GmTag255's dive rate rose consistently from the Interphase through the After phase (Table 9, Figure 32B and Figure 33B).

There were statistically significant differences in nighttime dive depths between phases for GmTag255, but not for GmTag254. GmTag254's median nighttime dive depths ranged from a low of 487.5 m during Phase B to a high of 527.5 m during the After phase, while GmTag255's median nighttime dive depths began at a low of 161.5 m during the Interphase and immediately rose to a high of 471.5 m during Phase B (Table 10, Figure 32A and Figure 33A). Dives during Phase B were significantly deeper than during the Interphase for GmTag255 (Table 10). Trends in median nighttime dive durations also differed between tags; GmTag254's median nighttime dive duration declined consistently after the Interphase, while GmTag255's median nighttime dive duration only declined in Phase B before rising to a peak of 12.63 mins in the After phase (Table 10). Nighttime dive rates declined across phases for GmTag254, ranging from a high of 3.11 dives/hr in the Interphase to a low of 2.08 dives/hr in the After phase (Table 10, Figure 32B). Conversely, GmTag255 showed an increase in dive rate between the Interphase and Phase B, though it did also decline to a low in the After phase (Table 10, Figure 33B).

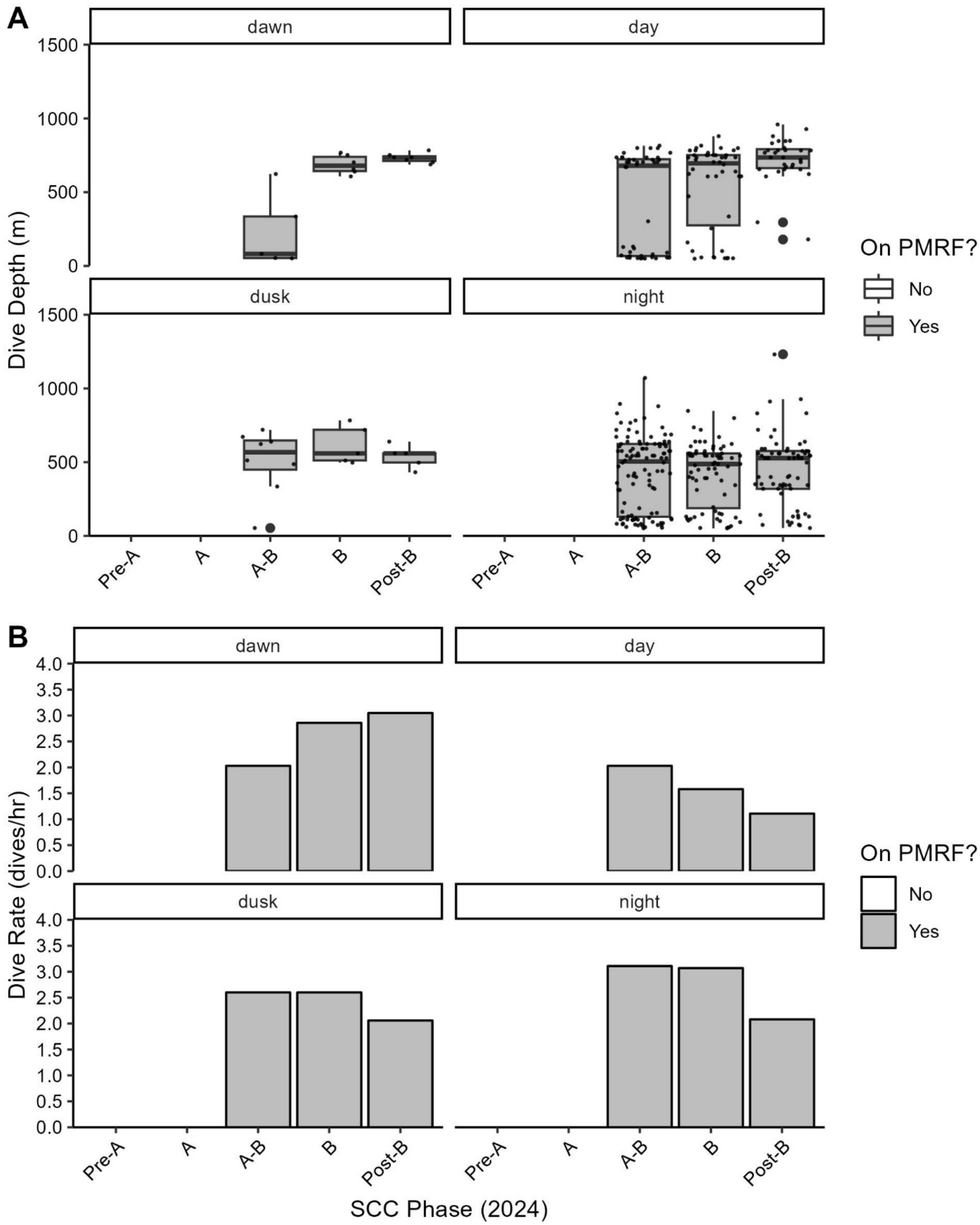


Figure 32: (Top) Boxplot showing dive depths of GmTag254 by SCC phase and time of day. (Bottom) Barplot showing dive rates of GmTag254 by SCC phase and time of day.

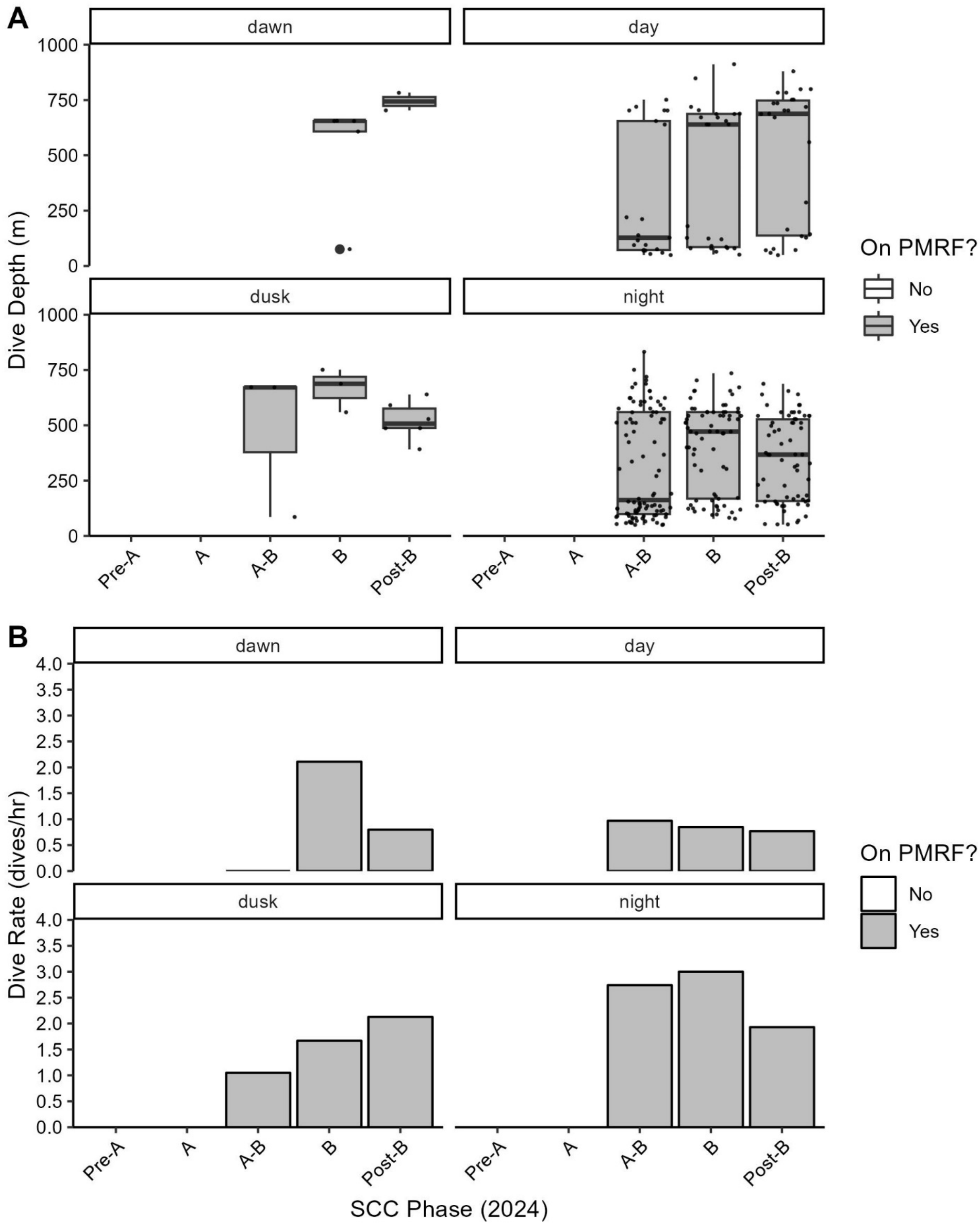


Figure 33: (Top) Boxplot showing dive depths of GmTag255 by SCC phase and time of day. (Bottom) Barplot showing dive rates of GmTag255 by SCC phase and time of day.

3.2.1.7 GmTag256 and GmTag257

GmTag256 and GmTag257 were tagged in 2024 during the Interphase in the same group, south of the range, and information was available on the movement patterns of these two tags for the Interphase (0.91 and 0.87 days for GmTag256 and GmTag257, respectively), Phase B (2.38 days), and the After phase (28.32 and 39.57 days for GmTag256 and GmTag257, respectively; Table 6). Both animals moved away from the range during the Interphase and were still well south of the range during their single brief period of exposure at the start of Phase B. They remained south of the island for the rest of Phase B and neither animal was on the range at any point during the SCC (Figure 34 and Figure 35), and there was not an acoustic path to any more MFAS exposures after the initial bout (Figure 36 and Figure 37, Table 22 and Table 23). They did move around Kaua'i to the east and north after the exercise was over.

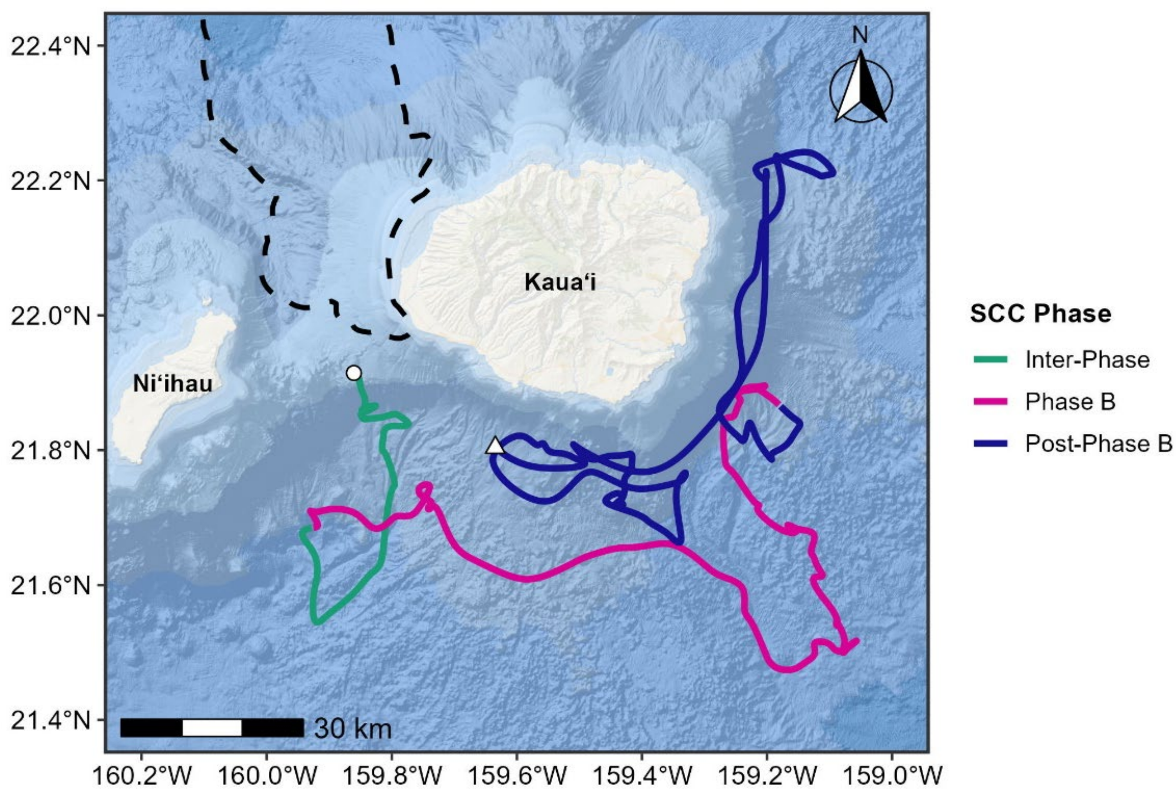
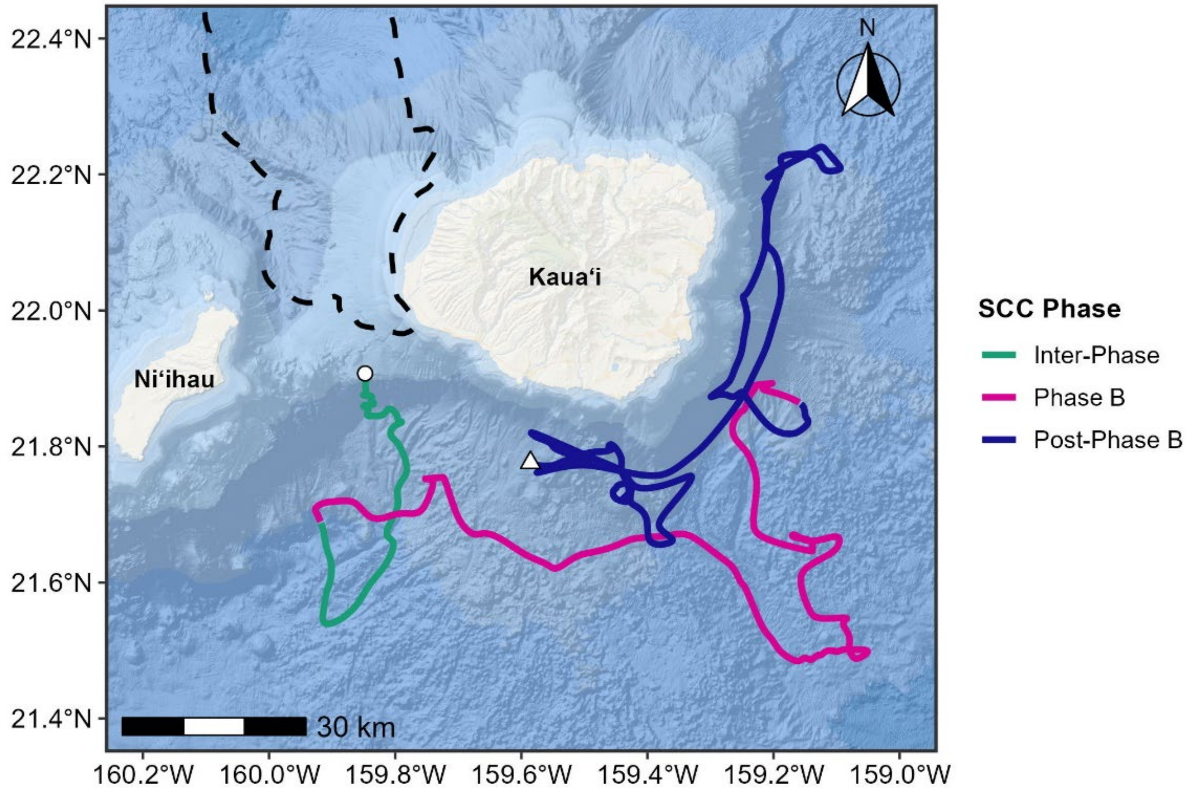


Figure 34: Movements of GmTag256 during the February 2024 SCC event (see text for description of phases). The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

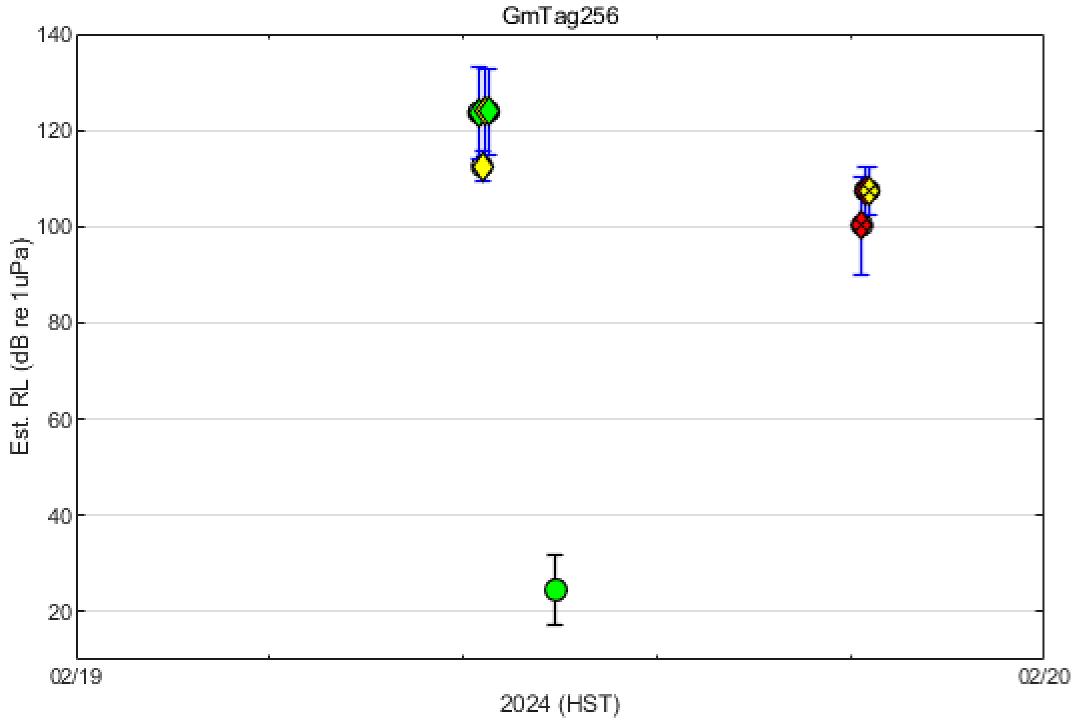


- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Figure 35: Movements of GmTag257 during the February 2024 SCC event (see text for description of phases).

Table 22: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag256.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	123.9 (114.9, 132.9)	132.8	88.2
Dipping Sonar	N/A	N/A	N/A
Sonobuoy	Below ambient	Below ambient	76.0

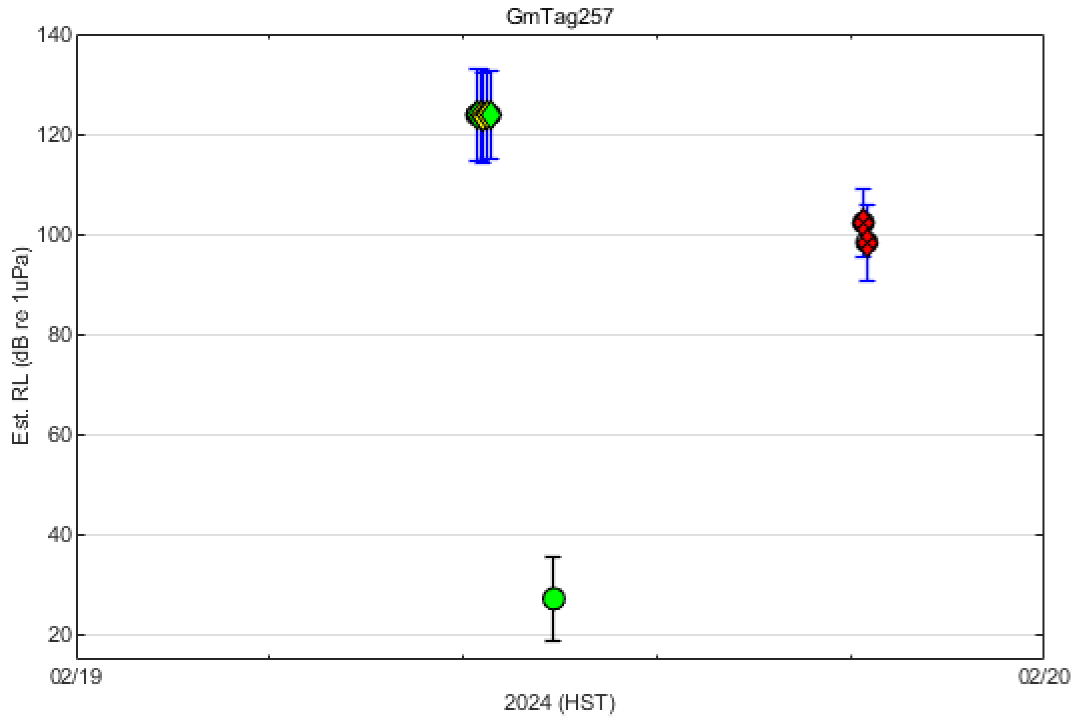


- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 36: Stoplight plot for the received levels for GmTag256 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

Table 23: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag257.

	Highest median RL (± 2 SD) dB re 1 µPa	**Overall cSEL dB re 1 µPa²**	**CPA (km)**
Ship	123.9 (114.7, 133.0)	134	88.2
Dipping Sonar	N/A	N/A	N/A
Sonobuoy	Below ambient	Below ambient	74.8



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 37: Stoplight plot for the received levels for GmTag257 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.1.7.1 Dive Behavior

GmTag256 and GmTag257 transmitted behavior log data for the Interphase, Phase B, and the After phase (Table 6). However, when broken down by time of day and phase only metrics were available for both tags for Phase B and the After phase for all times of day, as not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis.

Median dawn dive depths did not change between phases for GmTag256, remaining at 703.5 m, and declined slightly for GmTag257 from 671.5 m during Phase B to 623.5 m during the After phase (Table 7, Figure 38A and Figure 39A). Median dawn dive durations also had minimal variation between the phases for both tags, ranging from a low of 15.07 mins (Phase B, GmTag256) to a high of 15.77 mins (After, GmTag256; Table 7). Dawn dive rates increased from Phase B to the After phase for both tags, reaching 3.11 dives/hr for GmTag256, and 2.94 dives/hr for GmTag257 (Table 7, Figure 38B and Figure 39B).

While the median daytime dive depth for GmTag256 rose dramatically from Phase B (97.5 m) to the After phase (639.5 m), the overall distribution of dive depths between the two phases were similar, and there were no statistically significant differences between the phases (Table 8, Figure 38A). However, for GmTag257, the median daytime dive depth dropped sharply from 607.5 m to 71.5 m between Phase B and the After phase, and the difference between the two phases was statistically significant (Table 8, Figure 39A). Similar to median daytime dive depths, the median daytime dive duration increased between Phase B and the After phase for GmTag256, and declined for GmTag257, though there were no statistically significant differences between phases for either tag. Daytime dive rates dropped between Phase B and the After phase for both tags (Table 8, Figure 38B and Figure 39B).

Median dusk dive depths declined slightly from Phase B to the After phase for GmTag256, but declined much more sharply for GmTag257, plummeting from 727.5 m to only 79.5 m, though the difference was not statistically significant (Table 9, Figure 38A and Figure 39A). Median dusk dive durations also decreased slightly between Phase B and the After phase for GmTag256, and much more sharply for GmTag257, dropping from 19 mins to 7.13 mins (Table 9). The difference in dusk dive durations between Phase B and the After phase for GmTag257 was statistically significant (Table 9). Dusk dive rates dropped between Phase B and the After phase for both tags (Table 9, Figure 38B and Figure 39B).

Median nighttime dive depths had limited variation between phases for both tags, though both did increase slightly (Table 10, Figure 38A and Figure 39A). Median nighttime dive durations also had minimal variation, and trends differed slightly between individuals; GmTag256's median nighttime dive duration decreased slightly between Phase B and the After phase, while GmTag257's median nighttime dive duration increased slightly (Table 10). Conversely, nighttime dive rates, decreased sharply for both tags, falling from 3.27 dives/hr to 2.19 dives/hr for GmTag256, and from 3.49 dives/hr to 1.95 dives/hr for GmTag257 (Table 10, Figure 38B and Figure 39B).

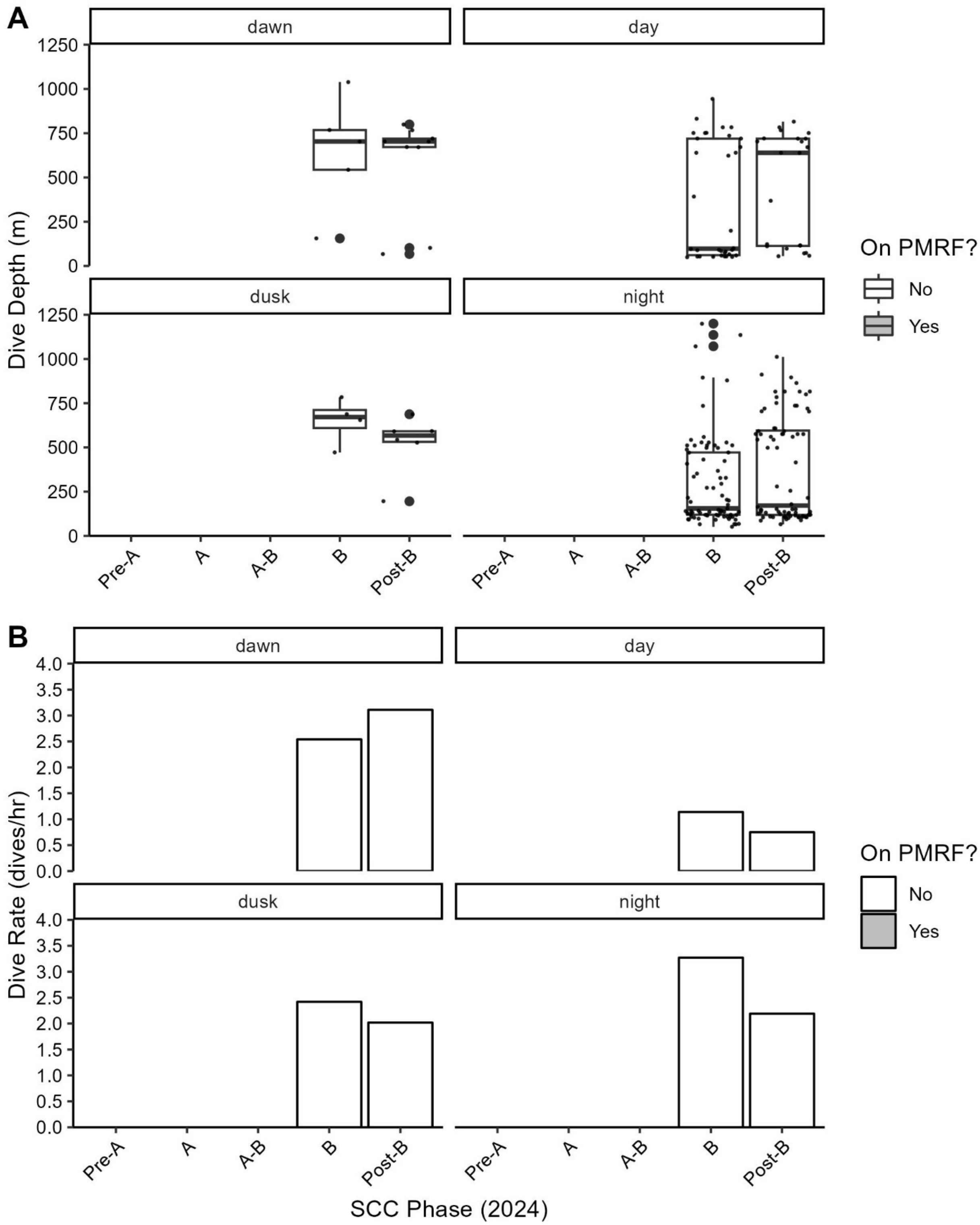


Figure 38: (Top) Boxplot showing dive depths of GmTag256 by SCC phase and time of day. (Bottom) Barplot showing dive rates of GmTag256 by SCC phase and time of day.

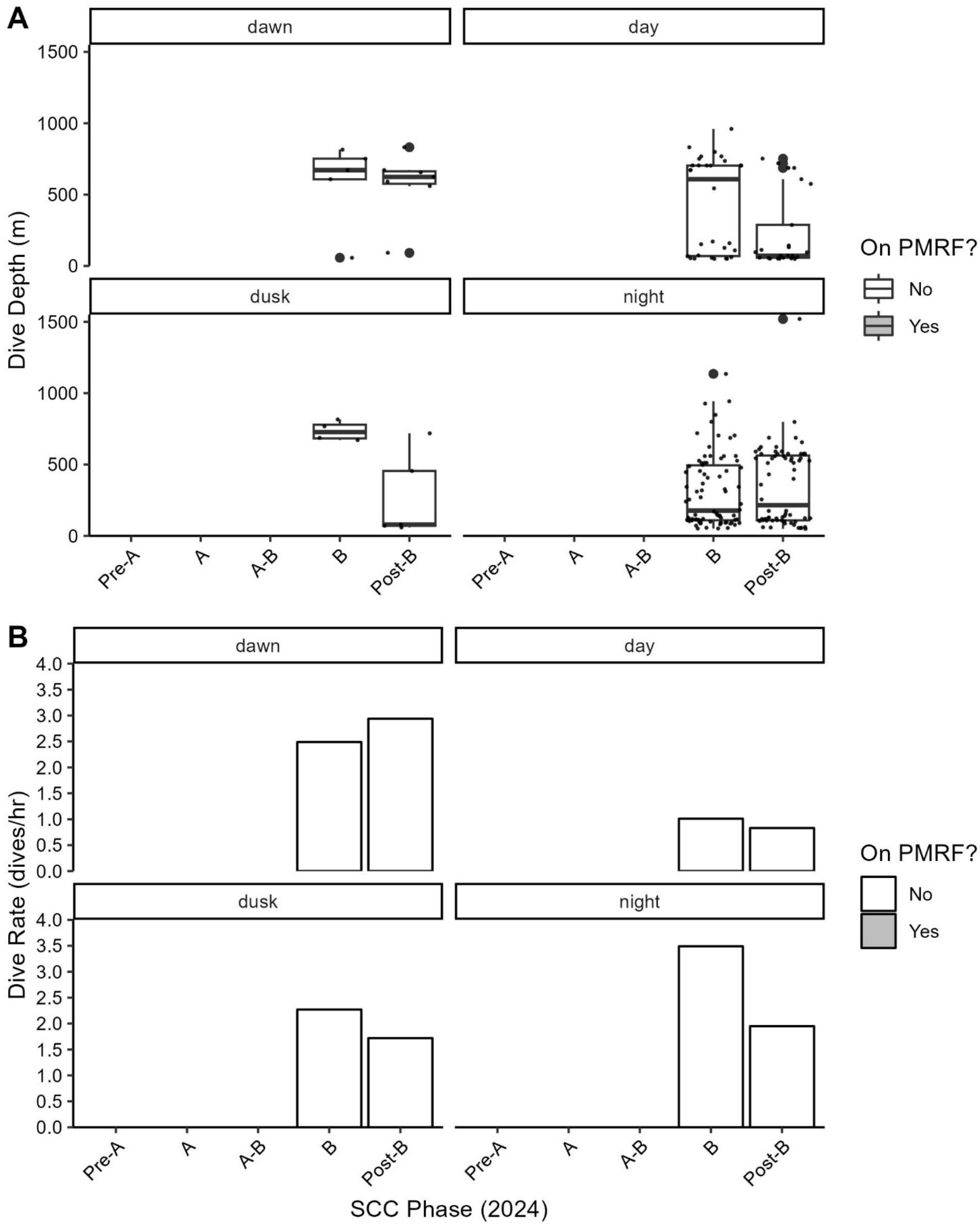
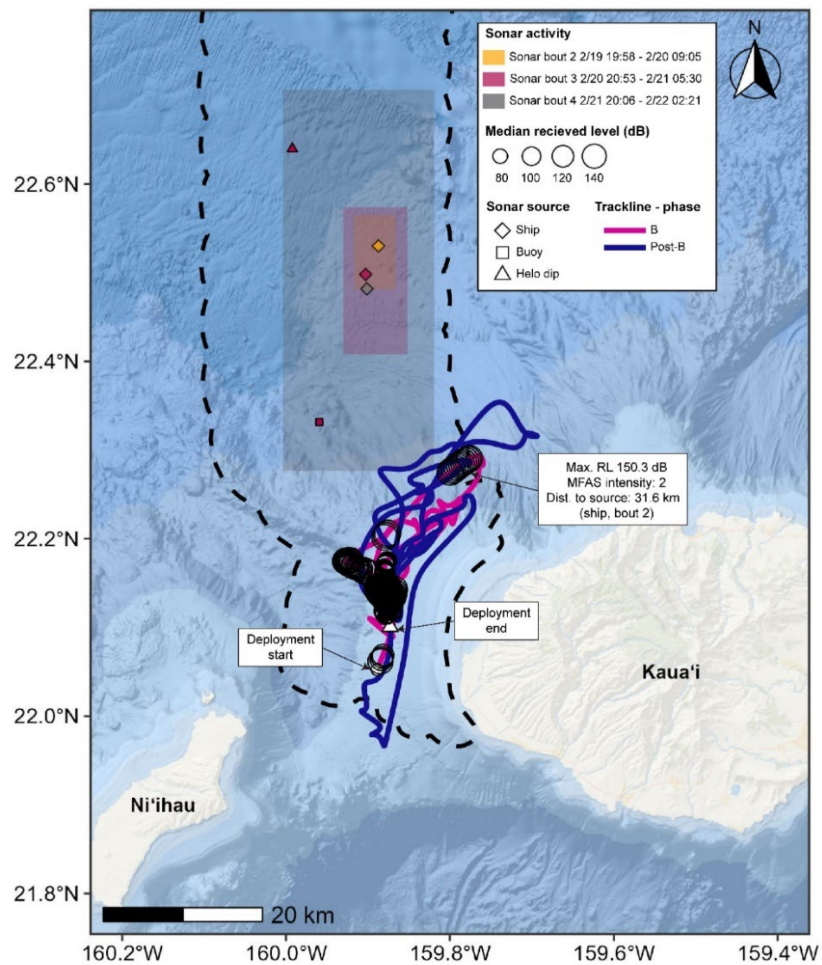


Figure 39: (Top) Boxplot showing dive depths of GmTag257 by SCC phase and time of day. (Bottom) Barplot showing dive rates of GmTag257 by SCC phase and time of day.

3.2.1.8 GmTag258

GmTag258 was tagged on the range in 2024 during Phase B and remained on the range for almost the entire duration of Phase B and the three days following the SCC (Figure 40). Information was available on the movement patterns of this tag for Phase B (2.28 days) and the After phase (30.57 days; Table 6). The tagged animal received multiple bouts of MFAS exposures while remaining on the southeast corner of the range throughout Phase B while moving in an ARM behavior pattern, with no apparent changes in movement behavior (Figure 41). Since they remained in the same general area of the range, their received levels remained consistent throughout Phase B (Figure 42, Table 24), with median received levels from hull-mounted MFAS reaching 150 dB re 1 μPa, median levels from helicopter-dipping MFAS reaching 105 dB re 1 μPa, and median received levels from active sonobuoys reaching 110 dB re 1 μPa from the closest sonobuoy during sonar bout 3 (Figure 41).



- The maximum, median estimated received levels (RLs) that occurred during each 5-min exposure bin are plotted as open circles, with the size of the circle scaled to RL level, and time is given in GMT. Additionally, the RL circles are colored by “intensity” which is characterized by the frequency of MFAS exposures that occurred during that given 5- min exposure bin. The shaded rectangular polygon represents the area of ship activity during each of the three MFAS bouts that GmTag258 was exposed to and the corresponding diamond point represents the mean ship location during the bouts. Note: After is restricted to three days after the end of the SCC. The dashed black line represents the PMRF boundary.

Figure 40: Movements of GmTag258 during the February 2024 SCC event (see text for description of phases).

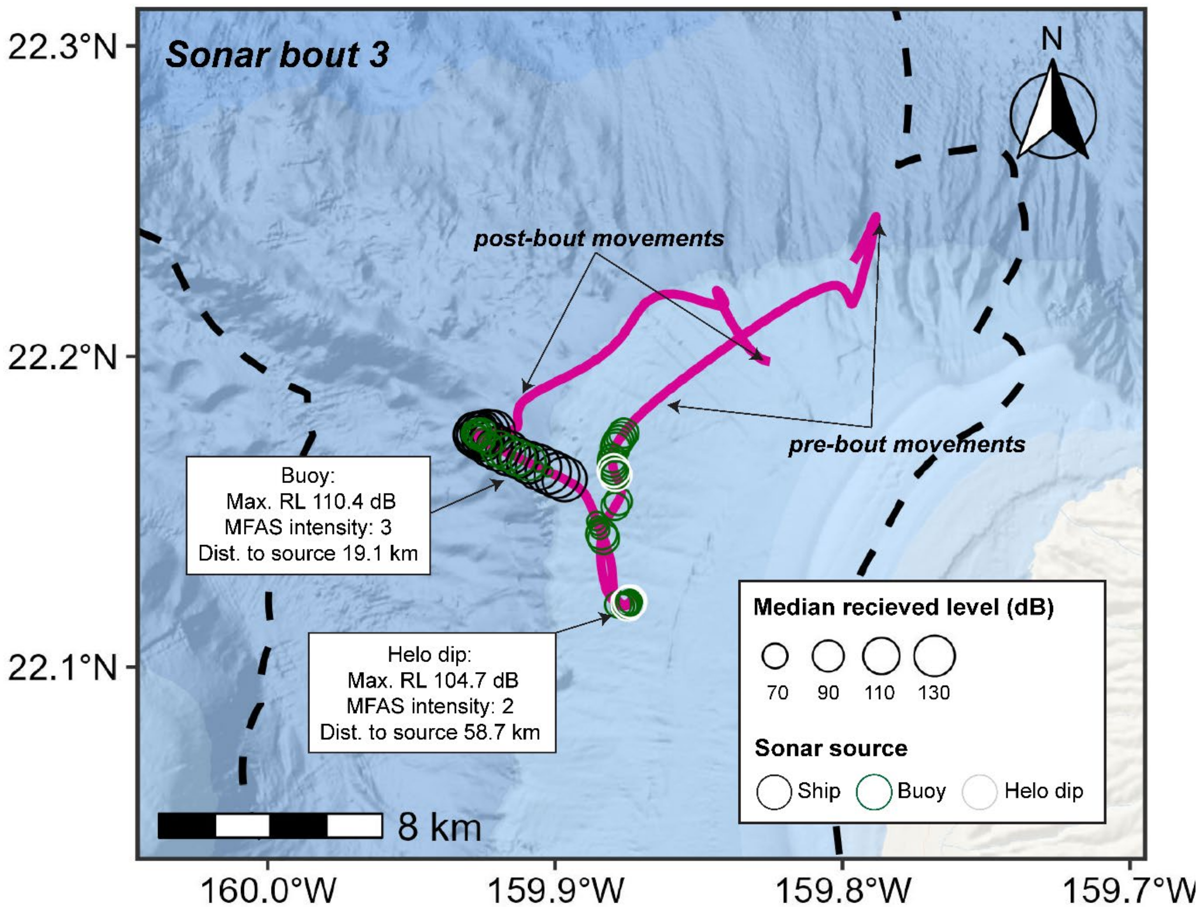
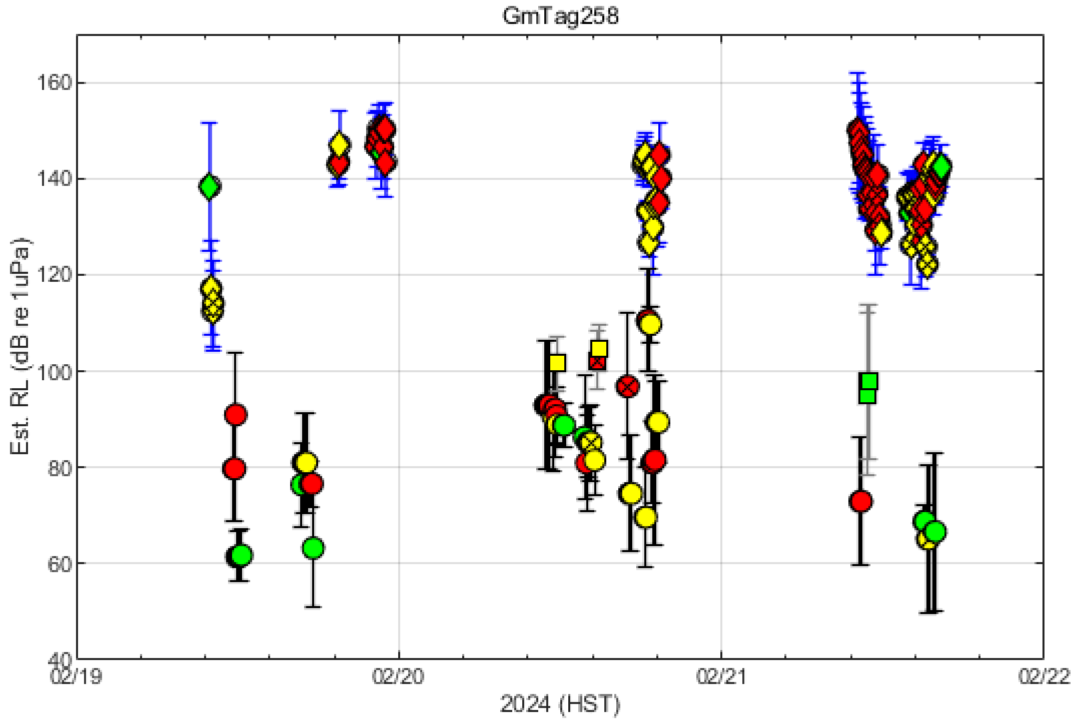


Figure 41: A close-up version of Figure 40 showing the track of GmTag258 only during Sonar bout 3 of Phase B. Locations of the maximum median received levels and associated distances from helicopter-dipping MFAS and active sonobuoy MFAS are indicated. The RL circles are colored by source type during that given 5-min exposure bin.

Table 24: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for GmTag258.

	Highest median RL (± 2 SD) dB re 1 μPa	Overall cSEL dB re 1 μPa²	CPA (km)
Ship	150.3 (145.4, 155.2)	171.5	18.9
Dipping Sonar	104.7 (99.9, 109.5)	129	31.2
Sonobuoy	110.4 (99.8, 121.1)	132.3	18.8



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The "x" within colored symbols indicates the probability of exposure was < 100%.

Figure 42: Stoplight plot for the received levels for GmTag258 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.1.8.1 Dive Behavior

GmTag258 transmitted behavior log data for both Phase B and the After phase (Table 6). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis. Dawn dive metrics were only available for the After phase, and are not discussed for this tag, though values are reported in Table 7. However, day, dusk, and night dive metrics, were available for both Phase B and the After phase.

Median daytime dive depths decreased slightly between Phase B and the After phase for GmTag258, falling from 703.5 m to 671.5 m (Table 8, Figure 43A). Similarly, median daytime dive durations also decreased between phases, as did the daytime dive rates (Table 8, Figure 43B). Median dusk dive depths dropped sharply between Phase B and the After phase, falling from 519.5 m to 65.5 m, and median dusk dive durations also fell from 13.32 mins to only 6.5 mins (Table 9, Figure 43A), though the differences were not statistically significant. In contrast, dusk dive rates increased between Phase B and the After phase (Table 9, Figure 43B). There were statistically significant differences in both nighttime dive depths and durations for GmTag258, with nighttime dives in Phase B being significantly shallower and shorter compared to nighttime dives in the After phase (Table 10, Figure 43A). Nighttime dive rates dropped between the two phases, falling from 2.48 dives/hr in Phase B to 2.06 dives/hr in the After phase (Table 10, Figure 43B).

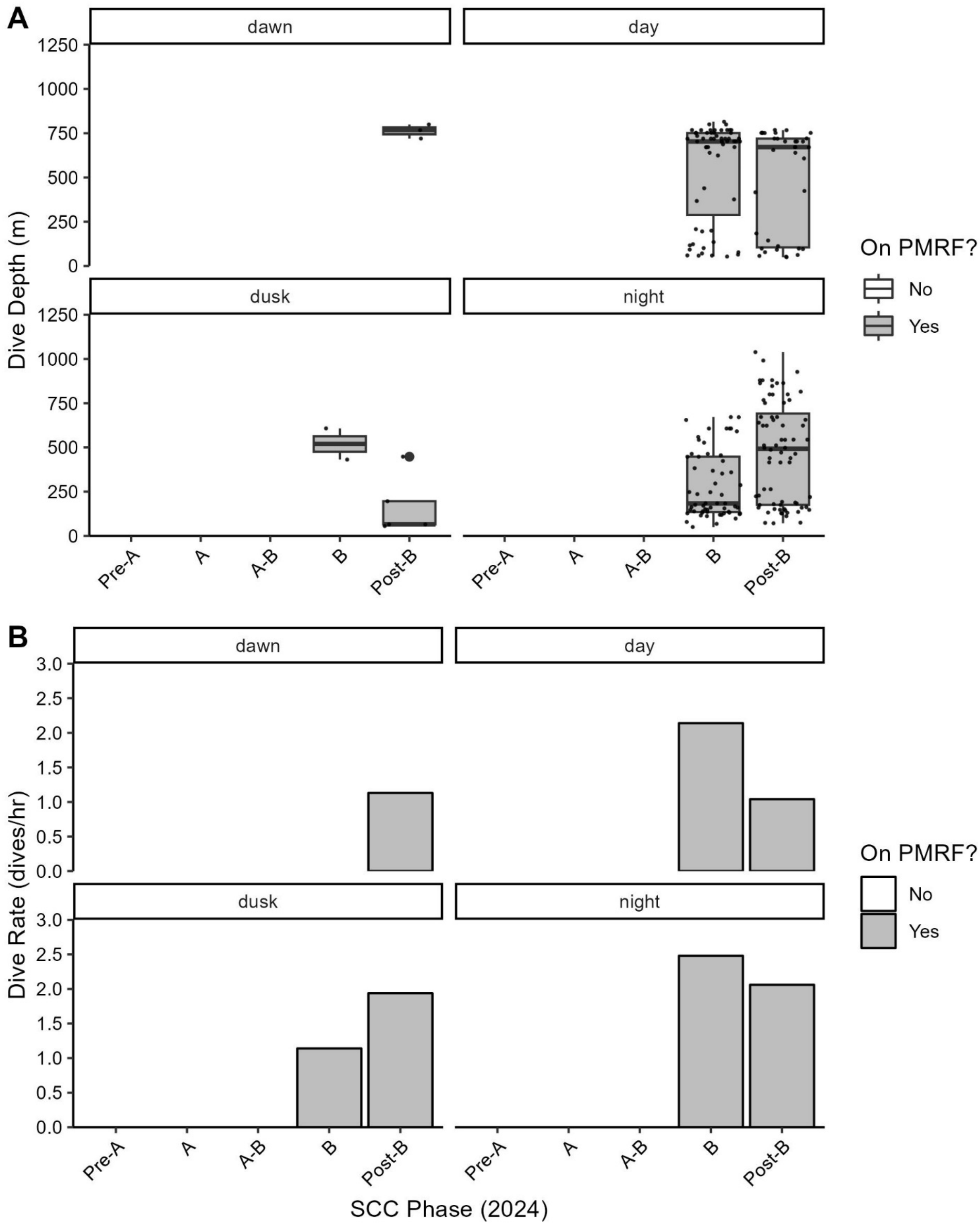


Figure 43: (Top) Boxplot showing dive depths of GmTag258 by SCC phase and time of day. (Bottom) Barplot showing dive rates of GmTag258 by SCC phase and time of day.

3.2.2 Melon-headed Whale

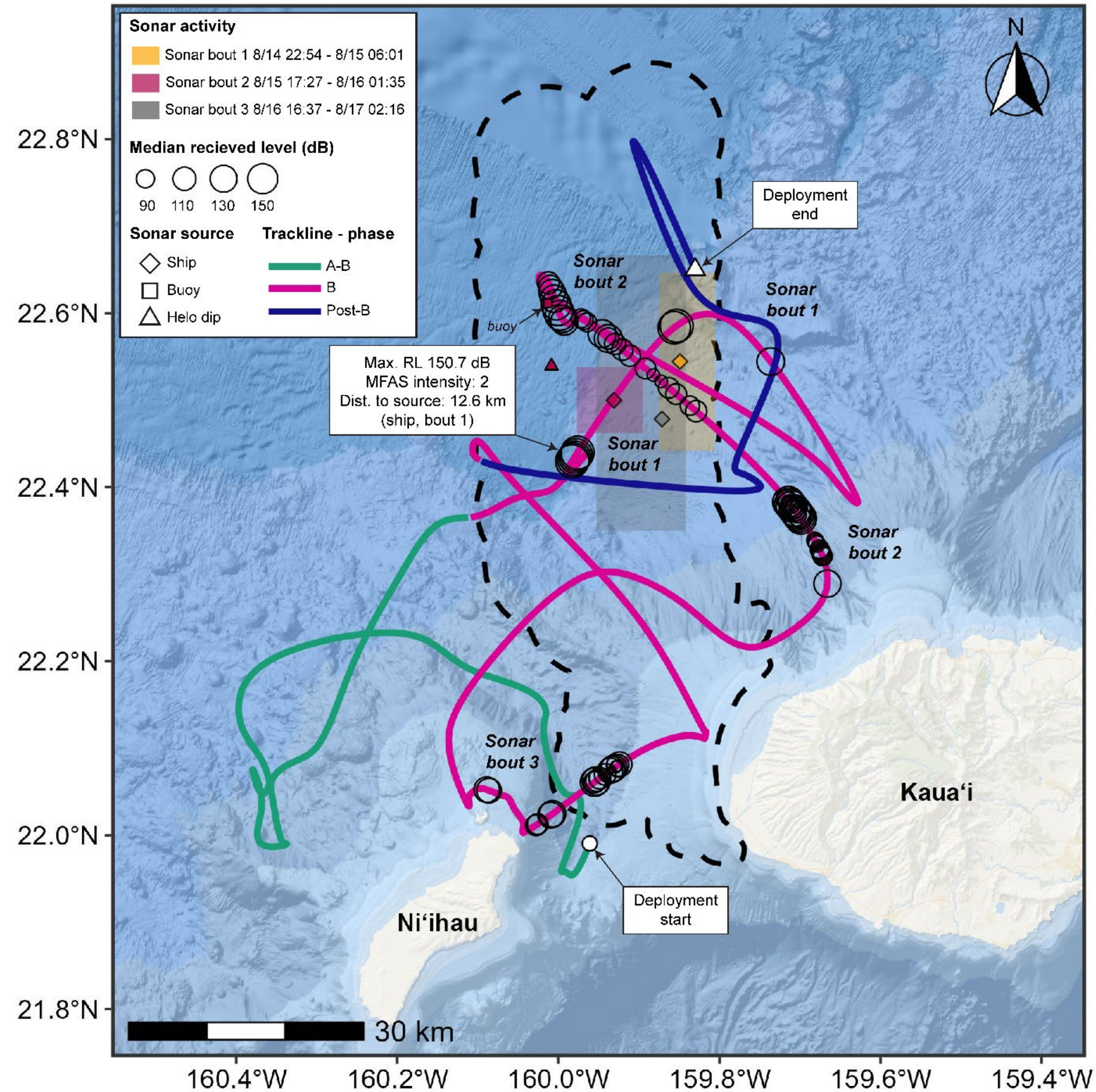
3.2.2.1 PeTag037

Only one melon-headed whale was tagged in 2023. Summary statistics are presented below in Table 25.

Table 25: Percentage of dive/surfacing data by phase for the melon-headed whale. The percentage of behavioral coverage is defined as the proportion of the duration of behavior log data relative to the duration of the tag within each phase.

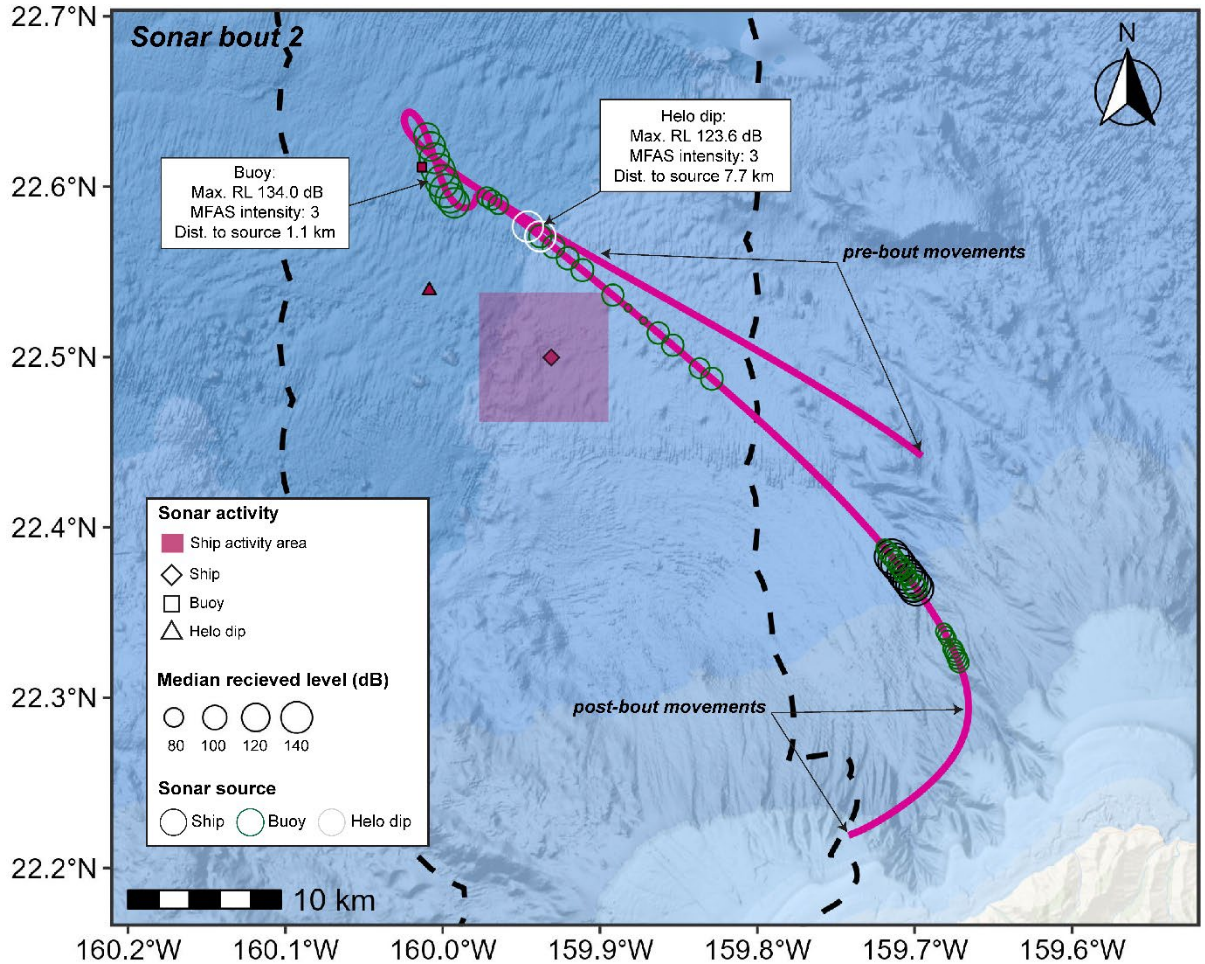
Individual	Percentage of dive/surfacing data				
	Before	Phase A	Interphase	Phase B	After
PeTag037					
Duration overall (days)	0.00	0.00	1.77	3.21	1.03
Days behavior log data	NA	NA	NA	NA	NA
Percentage behavioral coverage	NA	NA	NA	NA	NA

PeTag037 was tagged south of the range during the Interphase, and information was available on movement patterns for the Interphase (1.77 days), Phase B (3.21 days) and the After phase (1.03 days; Table 25). During this time, PeTag037 crossed the range multiple times, generally remaining on the range during Phase B and the After phase (Figure 44). Note that the location data for this tag were sparse, leading to a broad zig-zag movement pattern (the broad scale movement patterns are real/backed up empirically, but some of the extreme linear movements are a result of interpolation). This animal had the closest and highest received level exposures of any tagged animal in 2023 or 2024. At the start of Phase B, they moved onto the range for the first time, where they were close to the area of training activity (with the active ship within their error ellipse) and were exposed to their first and loudest exposure bout, with median received levels up to 159 dB re 1 µPa (Figure 46). After this bout they traveled east of the range, then turned and returned to the range, to an area close to the area of MFAS activity during sonar bout 2 (Figure 45), where they received exposures from all three sources as they transited east back across the range. They moved off the range to the east, and received another bout of MFAS exposures, and finally returned to the southern portion of the range for the final bouts of MFAS. Due to their repeated, close encounters with the training activity and MFAS, they ended up with an overall cumulative SEL of 175 dB re 1 μPa^2 (Table 26). They continued to move back and forth across the range a few more times after Phase B before their tag stopped transmitting. There was only a very brief period of dive behavior recorded on this tag after deployment; there was no dive behavior log recorded during Phase B.



- The maximum, median estimated received levels (RLs) that occurred during each 5-min exposure bin are plotted as open circles, with the size of the circle scaled to RL level, and time is given in GMT. Additionally, the RL circles are colored by "intensity" which is characterized by the frequency of MFAS exposures that occurred during that given 5-min exposure bin. The shaded rectangular polygon represents the area of ship activity during each of the three MFAS bouts that PeTag037 was exposed to and the corresponding diamond point represents the mean ship location during the bouts. Note: After is restricted to three days after the end of the SCC. The dashed black line represents the PMRF boundary.

Figure 44: Movements of PeTag037 during the August 2023 SCC event (see text for description of phases).

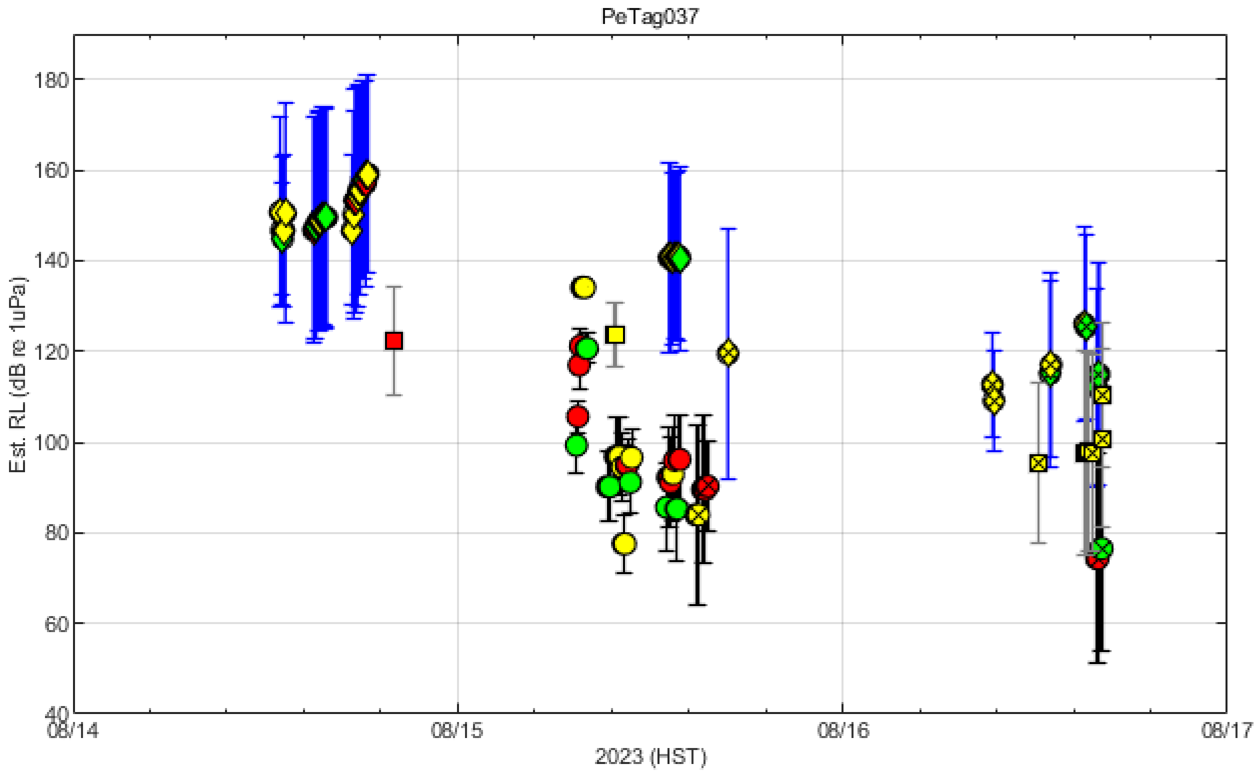


- Locations of the maximum median received levels and associated distances from helicopter-dipping MFAS and active sonobuoy MFAS are indicated. The RL circles are colored by source type during that given 5-min exposure bin.

Figure 45: A close-up version of Figure 44 showing the track of PeTag037 only during Sonar bout 2 of Phase B.

Table 26: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for PeTag037.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	159.1 (137.3, 180.9)	175.3	2.7
Dipping Sonar	123.6 (116.6, 130.5)	148.3	7.7
Sonobuoy	134.0 (132.1, 136.0)	149.9	1.1



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 46: Stoplight plot for the received levels for PeTag037 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.3 Pantropical Spotted Dolphin

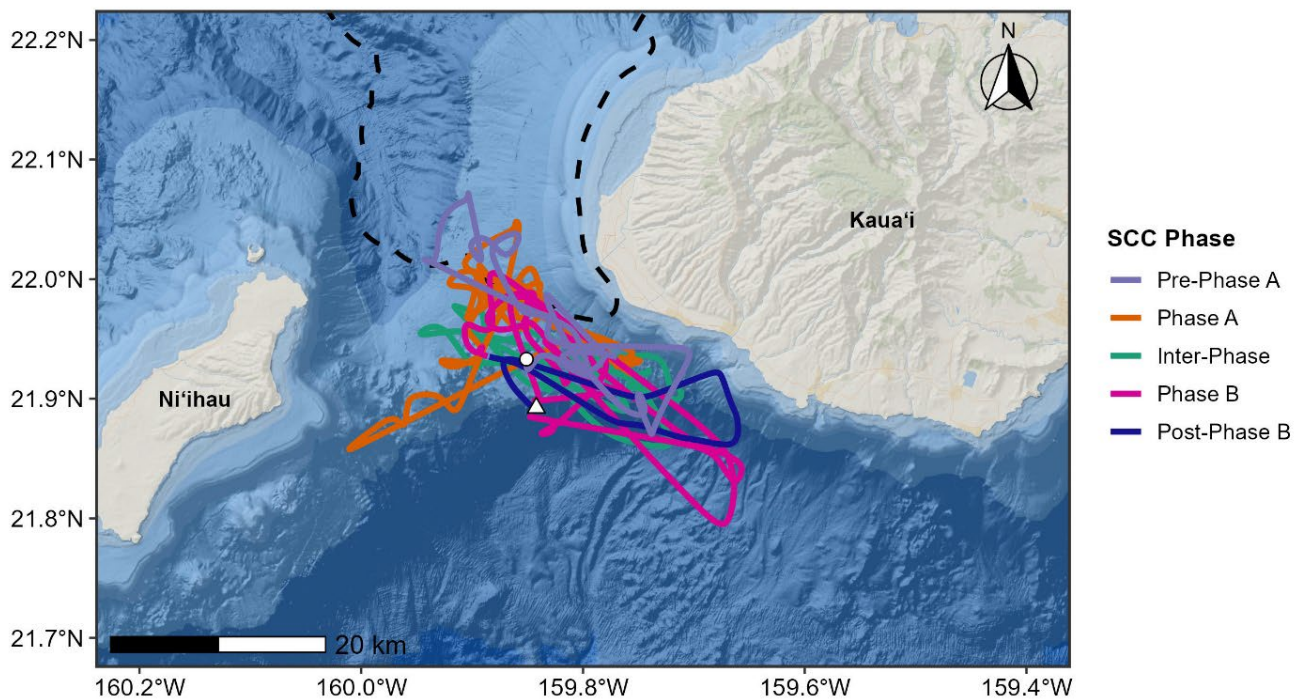
3.2.3.1 SaTag012

Only one pantropical spotted dolphin was tagged, in 2023. Summary statistics are presented below in Table 27.

Table 27: Percentage of dive/surfacing data by phase for the pantropical spotted dolphin. The percentage of behavioral coverage is defined as the proportion of the duration of behavior log data relative to the duration of the tag within each phase.

Individual	Percentage of dive/surfacing data				
	Before	Phase A	Interphase	Phase B	After
SaTag012					
Duration overall (days)	1.85	3.37	2.63	3.21	1.03
Days behavior log data	NA	NA	NA	NA	NA
Percentage behavioral coverage	NA	NA	NA	NA	NA

SaTag012 was tagged south of the range in 2023 prior to Phase A, and information was available on movement patterns for Before (1.85 days), Phase A (3.37 days), the Interphase (2.63 days), Phase B (3.21 days), and After (1.03 days; Table 27). SaTag012 generally remained to the south of the range or at the southern end of the range and remained in this area in an ARM pattern for the duration of their tag deployment, including during Phase B and multiple MFAS exposures (Figure 47). Received levels for all sources were largely below 100 dB re 1 μPa (Figure 48, Table 28), and there were no apparent changes in movement behavior as they zig-zagged in ARM behavior through a relatively small area for several days. The tag dive behavior was somewhat limited, but they did not appear to dive deeper than 20 m during any MFAS exposures.

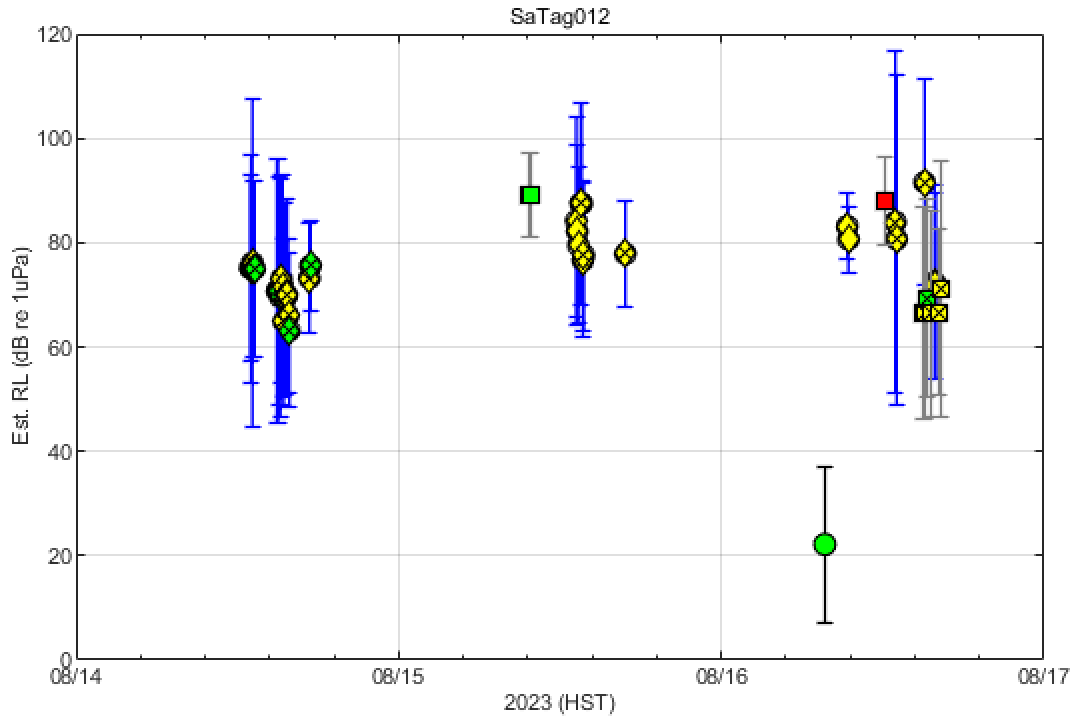


- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Figure 47: Movements of SaTag012 during the August 2023 SCC event (see text for description of phases).

Table 28: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for SaTag012.

	Highest median RL (± 2 SD) dB re 1 μPa	Overall cSEL dB re 1 μPa²	CPA (km)
Ship	91.6 (71.9, 111.2)	102.7	52.0
Dipping Sonar	89.2 (81.2, 97.2)	116.7	68.7
Sonobuoy	Below ambient	Below Ambient	61.9



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 48: Stoplight plot for the received levels for SaTag012 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.4 Common Bottlenose Dolphins

Three bottlenose dolphins were tagged, two in 2023 in one group and one in 2024. Summary statistics on the percentage of dive behavior for each individual across each phase of the SCC are presented below in Table 29. The diel and phase analysis of dive behavior was conducted for bottlenose dolphins, but none of the results were statistically significant, therefore, the results of those analyses can be found in the Appendix.

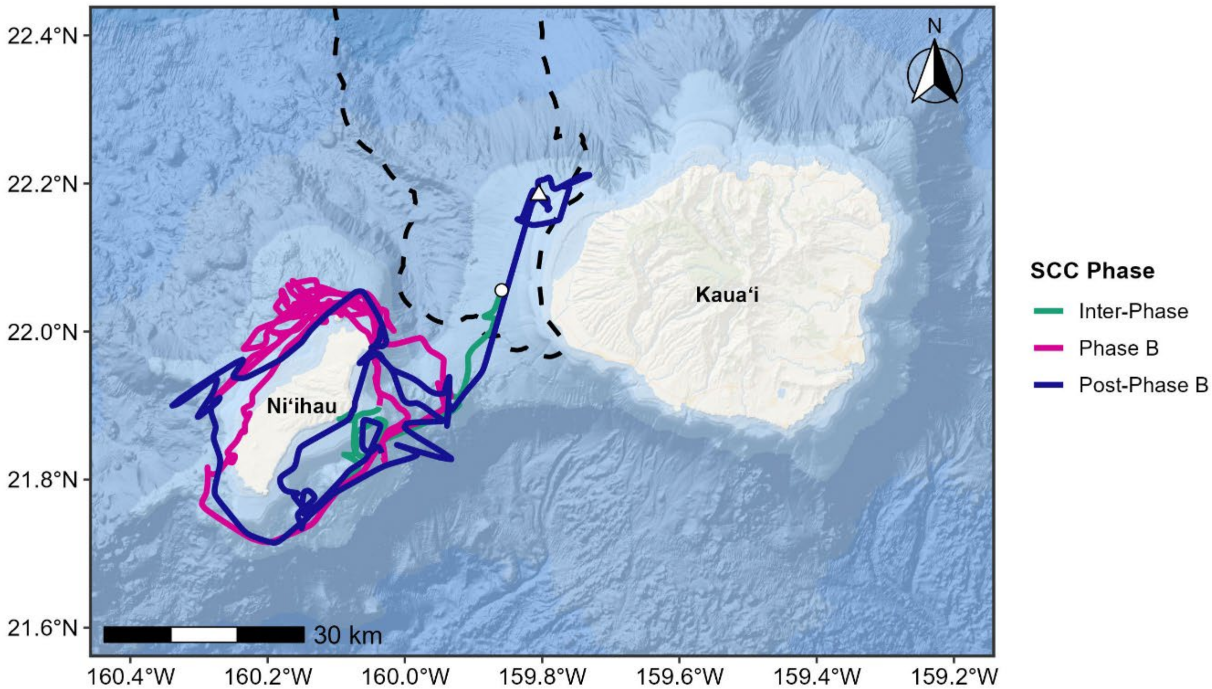
Table 29: Percentage of dive/surfacing data by phase for common bottlenose dolphins. The percentage of behavioral coverage is defined as the proportion of the duration of behavior log data relative to the duration of the tag within each phase.

Individual	Percentage of dive/surfacing data				
	Before	**Phase A**	**Interphase**	**Phase B**	**After**
TtTag042					
Duration overall (days)	0.00	0.00	0.88	3.21	10.40
Days behavior log data	0.00	0.00	0.87	3.20	1.79
Percentage behavioral coverage	NA	NA	98.86	99.69	17.21
TtTag043					
Duration overall (days)	0.00	0.00	0.86	3.21	5.87
Days behavior log data	NA	NA	NA	NA	NA
Percentage behavioral coverage	NA	NA	NA	NA	NA
TtTag044					
Duration overall (days)	0.00	0.00	0.00	2.33	8.29
Days behavior log data	0.00	0.00	0.00	1.17	0.58
Percentage behavioral coverage	NA	NA	NA	50.21	7.00

3.2.4.1 TtTag042 and TtTag043

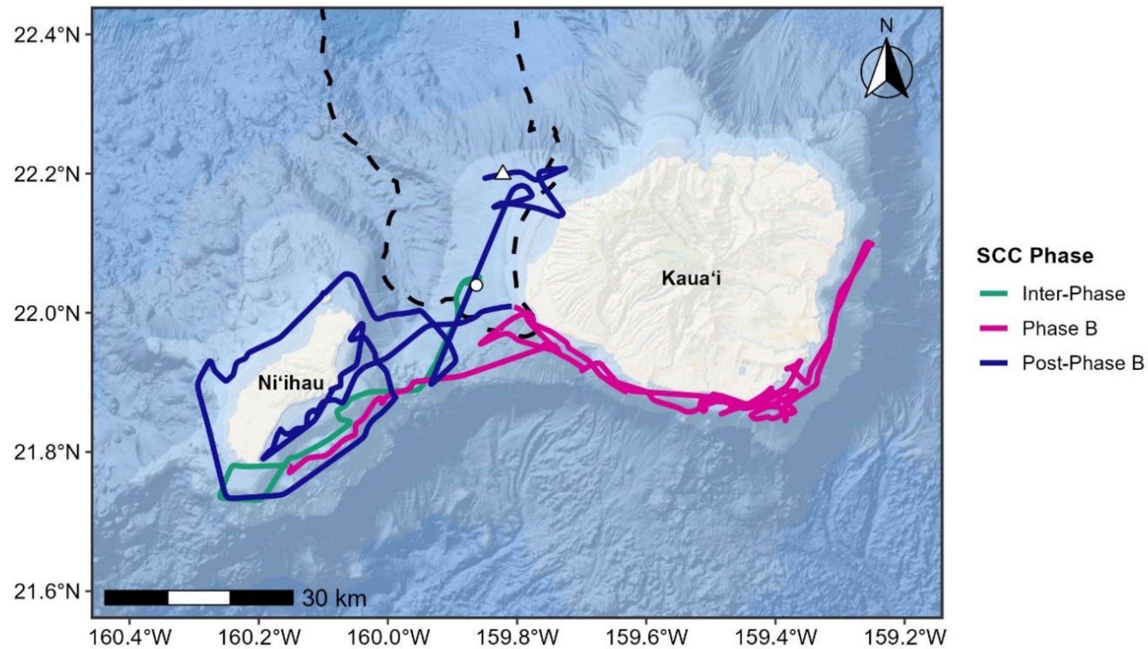
TtTag042 and TtTag043 were tagged in the same group in 2023 during the Interphase, and information was available on their movement patterns for the Interphase (0.88 and 0.86 days for TtTag042 and TtTag043, respectively), Phase B (3.21 days), and the After phase (10.40 and 5.87 days for TtTag042 and TtTag043, respectively; Table 29). Though the two animals were initially associated, they quickly separated and only reassociated after Phase B. While both tagged animals were briefly on the range during the Interphase and the After phase, TtTag042 spent the majority of the deployment circumnavigating Niʻihau, while TtTag043 split its time between circumnavigating Niʻihau and travelling along the south coast of Kauaʻi (Figure 49 and Figure 50).

Both dolphins only received exposures when they were on the northern (TtTag042 only) or eastern (both dolphins) side of Niʻihau, with received levels remaining low to moderate for both dolphins. TtTag042 had received levels from hull-mounted MFAS up to 126 dB re 1 μPa (Figure 51, Table 30), but median levels for the other two sources remained below 100 dB re 1 μPa. Median hull-mounted MFAS received levels reached 115 dB re 1 μPa for TtTag043 (Figure 52, Table 31), but levels for the other two sources were close to or below ambient noise levels. TtTag042 continued to circle Niʻihau during Phase B, moving in an ARM-type pattern, with continued zig-zagging during the exposure bouts; therefore, it is difficult to determine if any of the movements may have been in response to MFAS. The exposures occurred during both deeper and shallow dives, as well as when the animals were at the surface, and there was no apparent change in dive behavior. See the Dive Behavior section below for a detailed statistical analysis.



- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Figure 49: Movements of TtTag042 during the August 2023 SCC event (see text for description of phases).

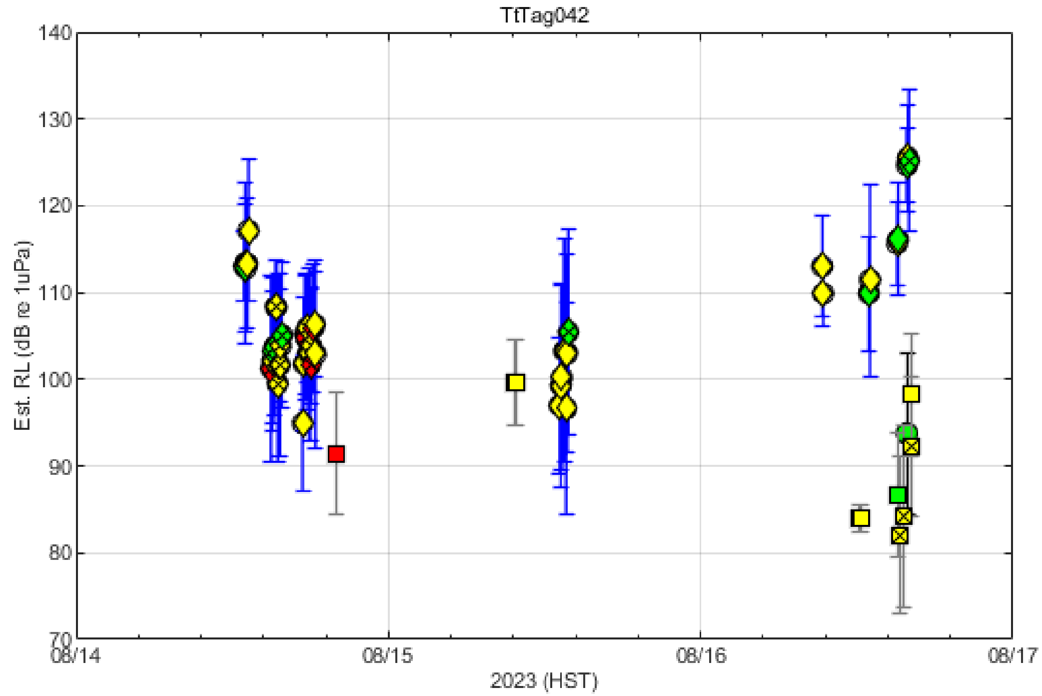


- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location within 3 days (72 hours) after the end of Phase B is shown as a white triangle.

Figure 50. Movements of TtTag043 during the August 2023 SCC event (see text for description of phases).

Table 30: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for TtTag042.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	125.5 (119.4, 131.7)	136.3	39.1
Dipping Sonar	99.6 (94.6, 104.7)	121.4	58.8
Sonobuoy	93.8 (84.4, 103.1)	102.7	48.5

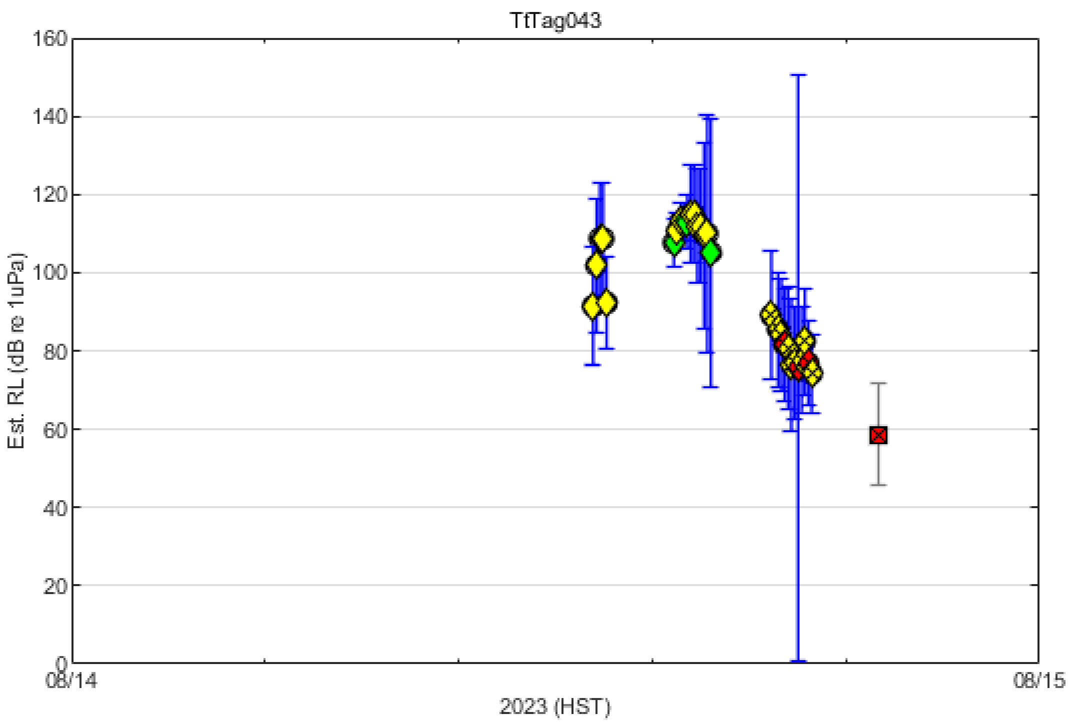


- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 51: Stoplight plot for the received levels for TtTag042 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

Table 31: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for TtTag043.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	115.0 (102.7, 127.3)	128.2	56.3
Dipping Sonar	58.8 (45.6, 72.0)	84	69.2
Sonobuoy	N/A	N/A	N/A

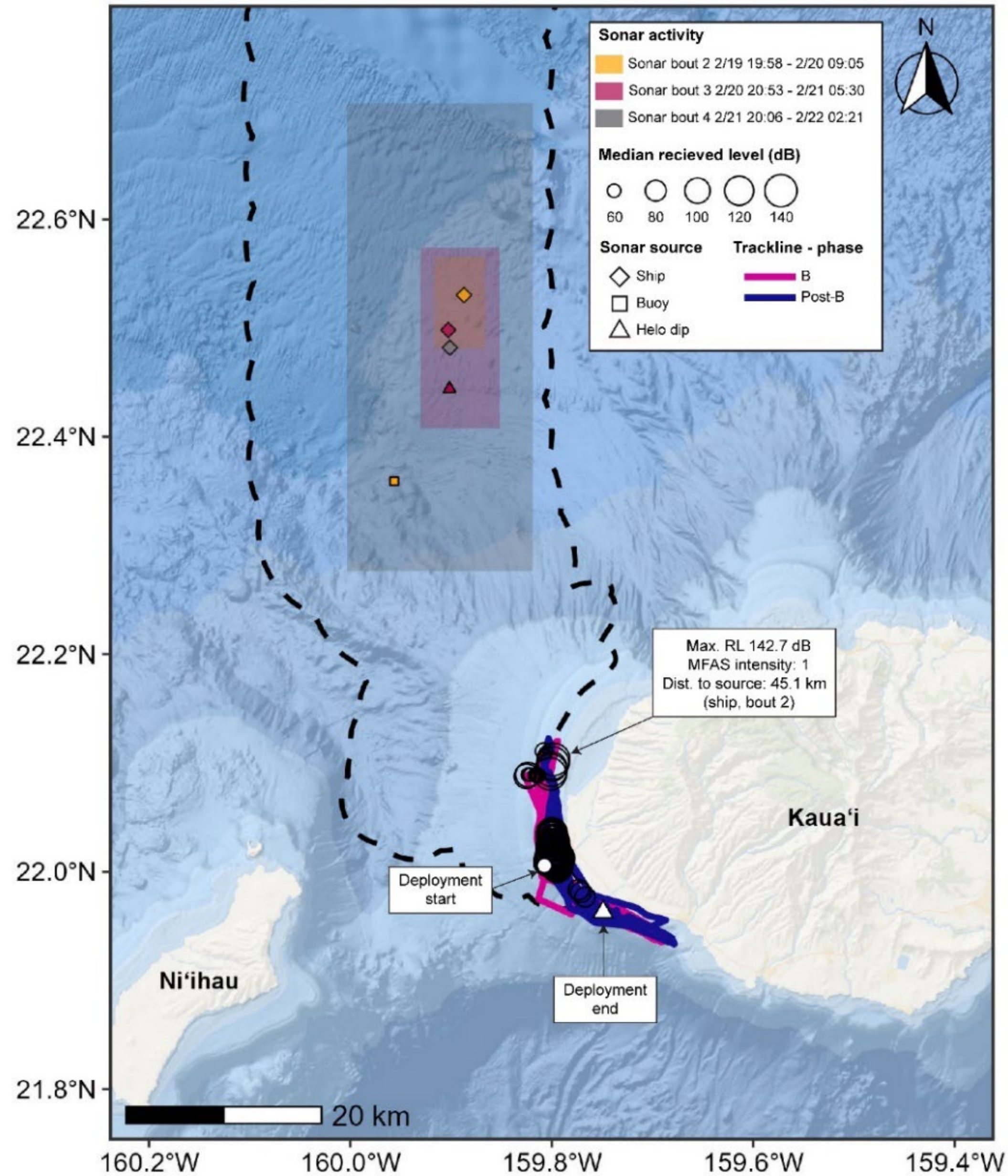


- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The "x" within colored symbols indicates the probability of exposure was < 100%.

Figure 52: Stoplight plot for the received levels for TtTag043 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars). TtTag044

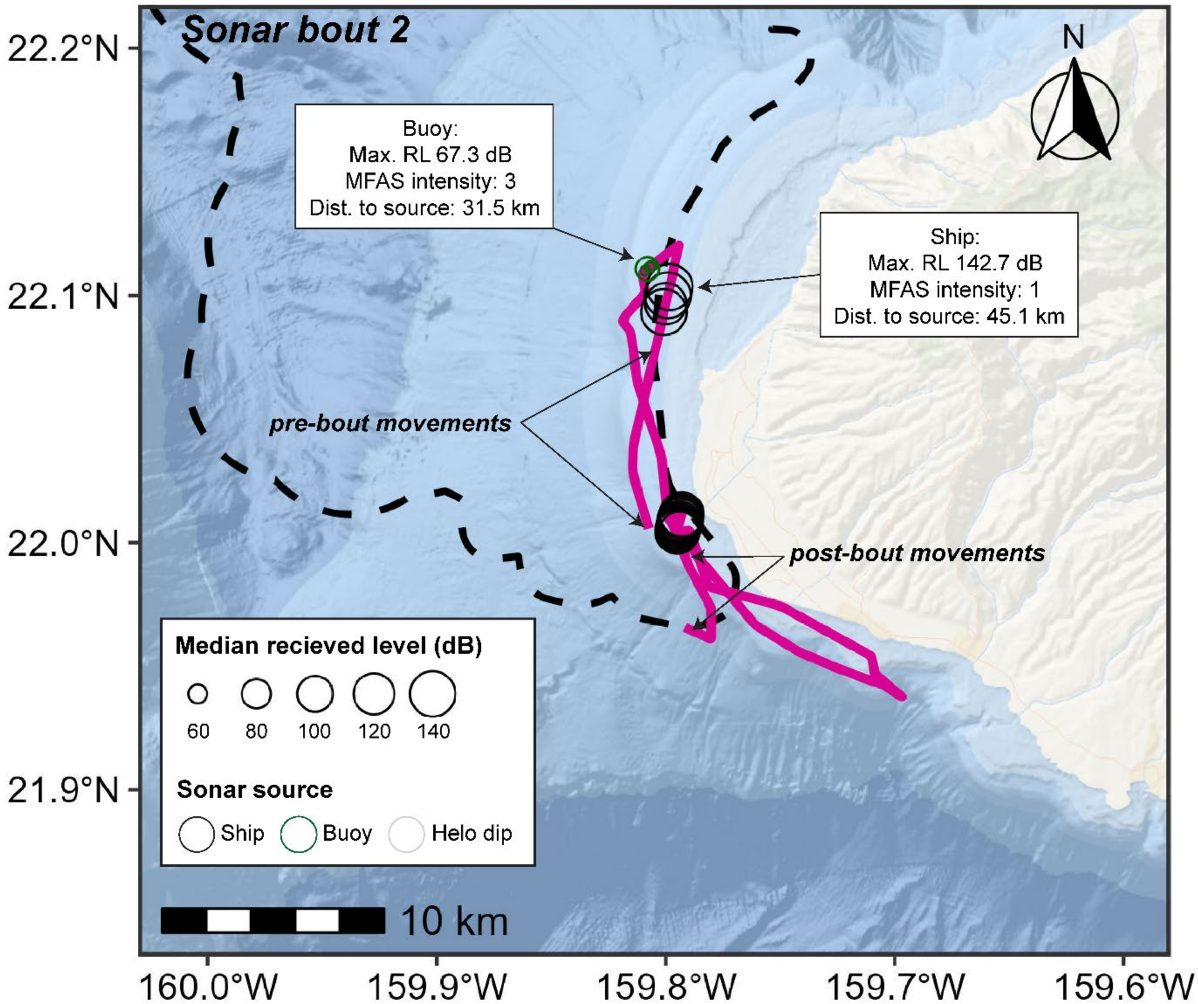
TtTag044 was deployed in 2024 during Phase B on the range, and information was available on movement patterns for both Phase B (2.33 days) and the After phase (8.29 days; Table 29). TtTag044 spent most of this time near the southeastern edge of the range and was on the range for most of Phase B, moving a few times to the southwest side of Kaua'i (Figure 53).

This dolphin also moved in a zig-zag, ARM pattern throughout the tag deployment, so while they did have several sharp directional turns in their track during MFAS, they had numerous other sharp turns throughout their track in the absence of MFAS (Figure 54). Received levels were largely consistent between the exposure bouts for each source type (Figure 55, Table 32). The MFAS started during some initial shallow diving in the top 100 m. The second bout of hull-mounted MFAS occurred during a deeper dive to 200 m; unfortunately, there are several periods of missing dive data after this so the final bout of hull-mounted MFAS has no concurrent dive record.



- The maximum, median estimated received levels (RLs) that occurred during each 5-min exposure bin are plotted as open circles, with the size of the circle scaled to RL level, and time is given in GMT. Additionally, the RL circles are colored by "intensity" which is characterized by the frequency of MFAS exposures that occurred during that given 5-min exposure bin. The shaded rectangular polygon represents the area of ship activity during each of the three MFAS bouts that TtTag044 was exposed to and the corresponding diamond point represents the mean ship location during the bouts. Note: After is restricted to three days after the end of the SCC. The dashed black line represents the PMRF boundary.

Figure 53: Movements of TtTag044 during the February 2024 SCC event (see text for description of phases).

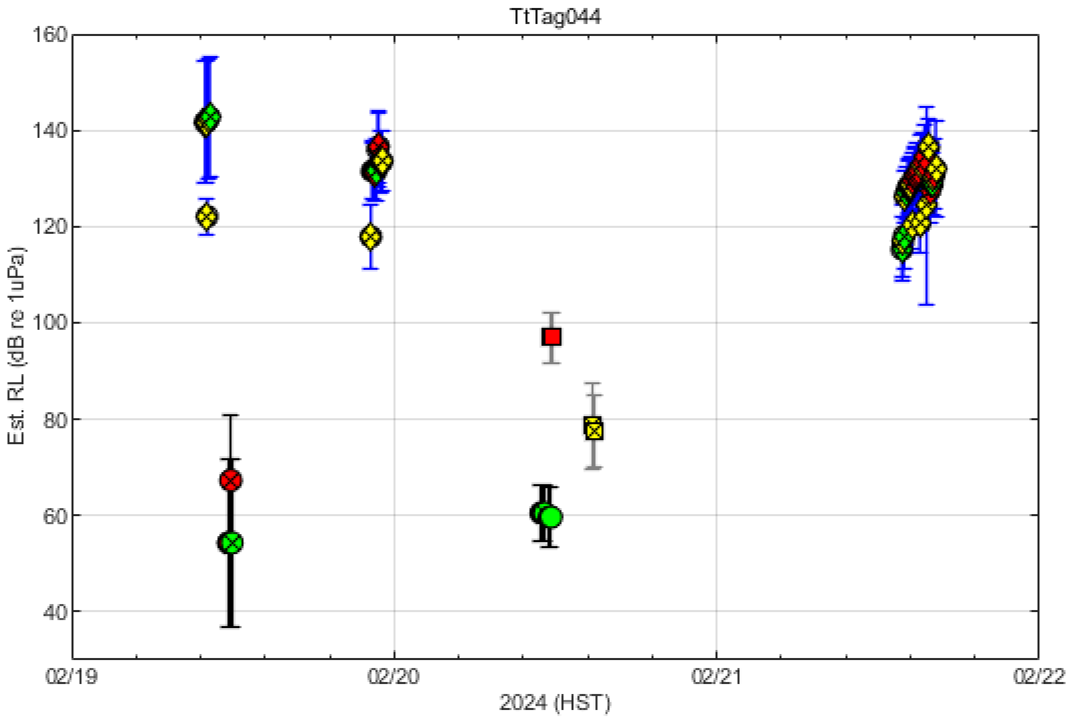


- Locations of the maximum median received levels and associated distances from hull-mounted surface ship MFAS and active sonobuoy MFAS are indicated. The RL circles are colored by source type during that given 5-min exposure bin.

Figure 54: A close-up version of Figure 9 showing the track of TtTag044 only during Sonar bout 2 of Phase B.

Table 32: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for TtTag044.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	142.7 (130.3, 155.2)	157.3	37.0
Dipping Sonar	96.9 (91.7, 102.2)	109.7	40.1
Sonobuoy	67.3 (53.6, 81.1)	102.4	31.5



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The "x" within colored symbols indicates the probability of exposure was < 100%.

Figure 55: Stoplight plot for the received levels for TtTag044 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

3.2.5 Humpback Whales

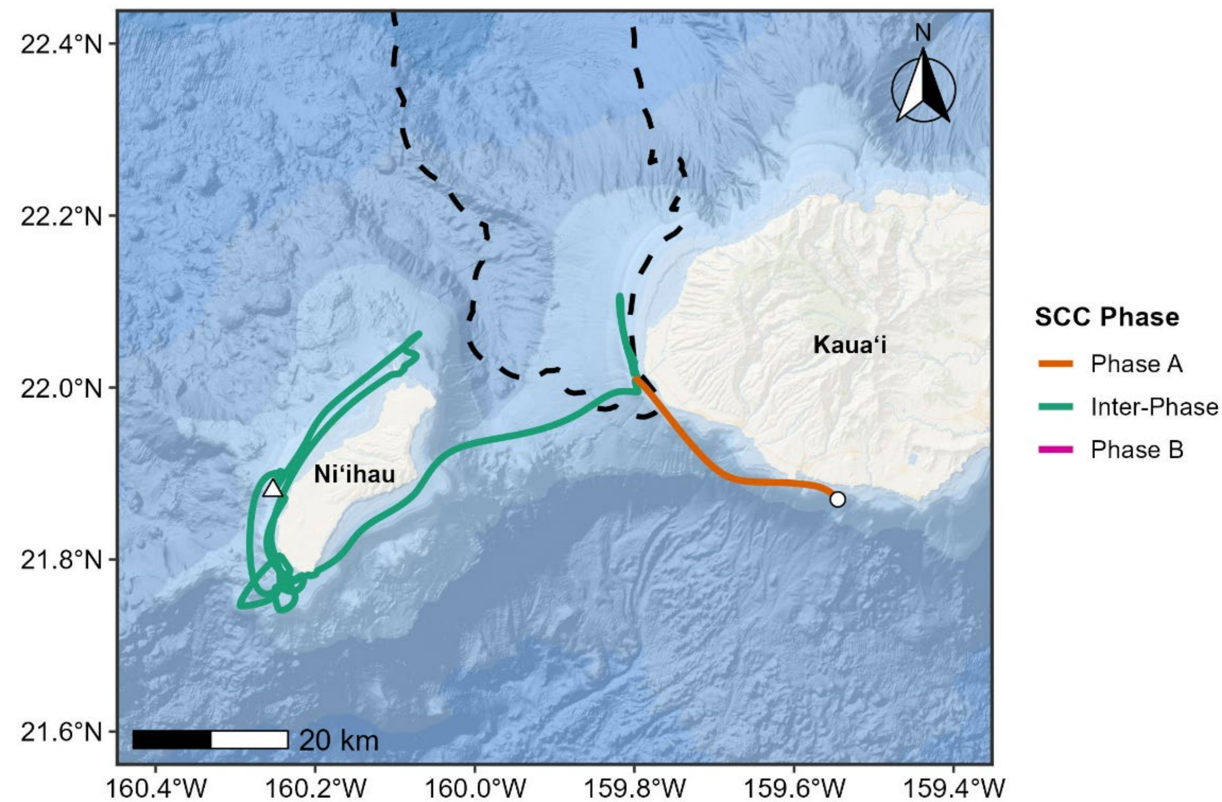
Three humpback whales were tagged in 2024, one individual in one group (MnTag001), and two individuals in another group (MnTag002 and MnTag003). While this was not a target species for tagging under Commander, U.S. Pacific Fleet (COMPACTFLT), these tags were provided by Wildlife Computers for testing, and the results have been analyzed and included along with the rest of the tagged animals. Summary statistics are presented in Table 33 on the percentage of dive behavior for each individual across each phase of the SCC.

Table 33: Percentage of dive/surfacing data by phase for humpback whales. The percentage of behavioral coverage is defined as the proportion of the duration of behavior log data relative to the duration of the tag within each phase.

Individual	Percentage of dive/surfacing data				
	Before	Phase A	Interphase	Phase B	After
MnTag001					
Duration overall (days)	0.00	0.28	2.58	0.01	0.00
Days behavior log data	0.00	0.27	1.66	0.00	0.00
Percentage behavioral coverage	NA	96.43	64.34	0.00	NA
MnTag002					
Duration overall (days)	0.00	0.00	0.00	2.21	3.10
Days behavior log data	0.00	0.00	0.00	2.20	0.64
Percentage behavioral coverage	NA	NA	NA	99.55	20.65
MnTag003					
Duration overall (days)	0.00	0.00	0.00	2.19	0.78
Days behavior log data	NA	NA	NA	NA	NA
Percentage behavioral coverage	NA	NA	NA	NA	NA

3.2.5.1 MnTag001

MnTag001 was deployed during Phase A to the southeast of the range in 2024, and information was available on movement patterns for Phase A (0.28 days), the Interphase (2.58 days), and Phase B (0.01 days; Table 33). MnTag001 had no exposures to MFAS during this time, though it did cross onto the range during both Phase A and the Interphase (Figure 56).

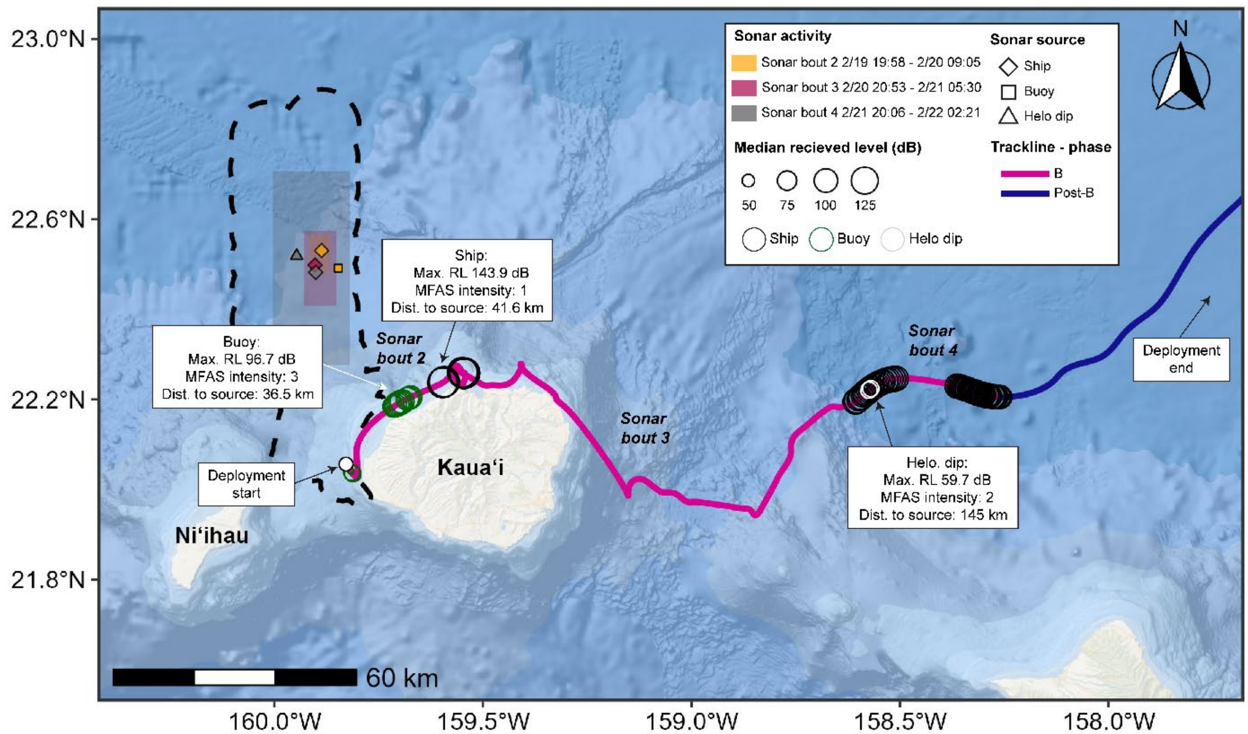


- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location is shown as a white triangle.

Figure 56: Movements of MnTag001 during the February 2024 SCC event (see text for description of phases). MnTag002 and MnTag003

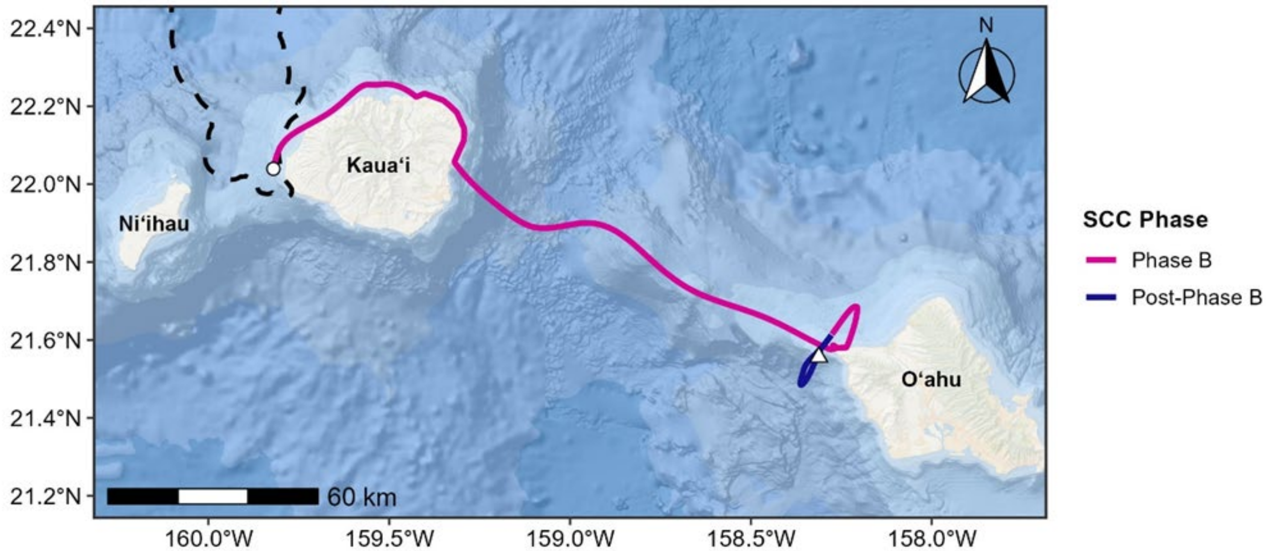
MnTag002 and MnTag003 were deployed onto two animals in the same group on the range during Phase B in 2024, and while the two appeared to initially remain associated, their tracks split in different directions during Phase B (Figure 57 and Figure 59). Information was available on movement patterns for these two animals for Phase B (2.21 and 2.19 days for MnTag002 and MnTag003, respectively), and the After phase (3.10 and 0.78 days for MnTag002 and MnTag003, respectively; Table 33). MnTag002 continued to move east along the northern side of Kaua'i after tagging, following the northern edge of Kaua'i, where it received its first few bouts of MFAS from all three sources (Figure 57). It did turn in one loop while at the surface during the first hull-mounted MFAS exposures, then dove to 60 m, but continued along the same path afterward. This first bout of MFAS had the highest received level, with median received levels up to 144 dB re 1 µPa from hull-mounted MFAS, and lower levels from the other two sources (Figure 60, Table 34). It continued traveling west and started to conduct deeper dives to 200-250 m during the final bout of hull-mounted MFAS at much lower received levels; it continued conducting these deeper dives throughout the bout. MnTag002 then turned and began traveling northwest and appears to have started its migration at that point. MnTag003 was also tagged southeast of the range at the start of Phase B, immediately receiving a very low-level bout of sonobuoy MFAS (Figure 61, Table 35). They continued traveling east along the northern side of Kaua'i, again with multiple bouts of MFAS from all three sources, but rather than turning northwest like MnTag002, this whale followed the Kuli'ou'ou Ridge southeast to O'ahu, where it received a few final lower received level bouts of

MFAS. There were no apparent changes in movement behavior throughout the deployment as the animal remained in a directed travel state until it reached O‘ahu. We did not receive any dive behavior from this tag.



- The maximum, median estimated received levels (RLs) that occurred during each 5-min exposure bin are plotted as open circles, with the size of the circle scaled to RL level, and time is given in GMT. Additionally, the RL circles are colored by “intensity” which is characterized by the frequency of MFAS exposures that occurred during that given 5-min exposure bin. The shaded rectangular polygon represents the area of ship activity during each of the three MFAS bouts that MnTag002 was exposed to and the corresponding diamond point represents the mean ship location during the bouts. Note: After is restricted to three days after the end of the SCC. The dashed black line represents the PMRF boundary.

Figure 57: Movements of MnTag002 during the February 2024 SCC event (see text for description of phases).



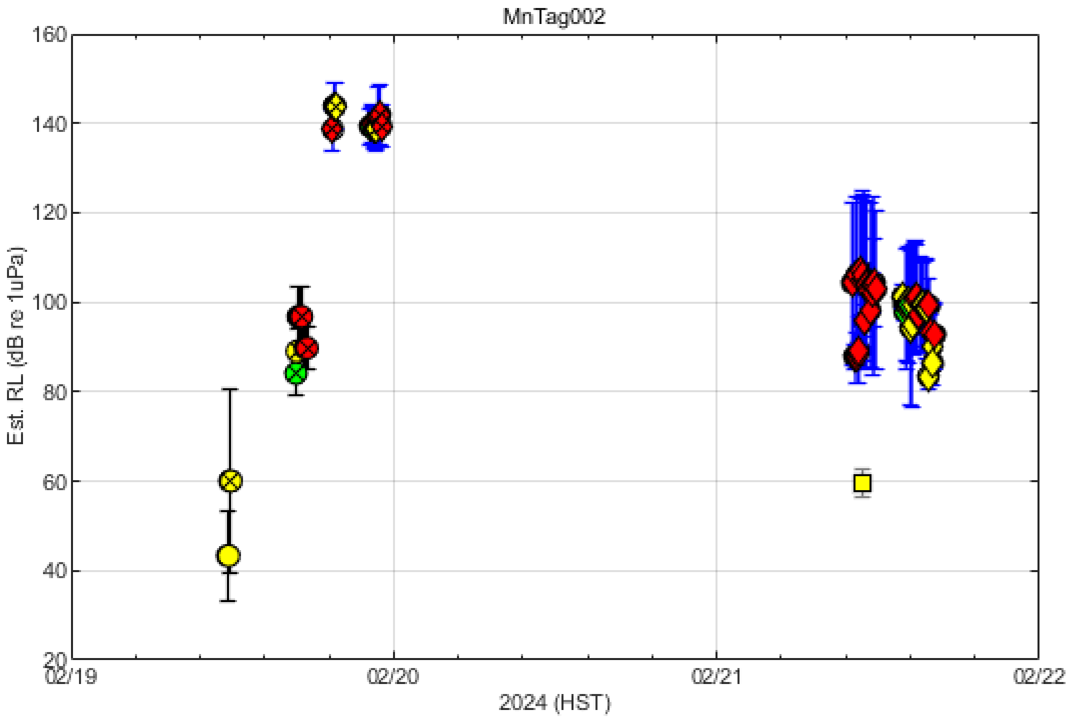
- The dashed black line represents the PMRF boundary, the deployment location is shown as a white circle, and the final location is shown as a white triangle.

Figure 58: Movements of MnTag003 during the February 2024 SCC event (see text for description of phases).

Table 34: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for MnTag002.

	Highest median RL (± 2 SD) dB re 1 µPa	Overall cSEL dB re 1 µPa²	CPA (km)
Ship	143.9 (138.6, 149.1)	161.2	41.3
Dipping Sonar	59.7 (56.6, 62.9)	75.6	145.1
Sonobuoy	96.7 (90.2, 103.3)	118.6	36.4

The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.



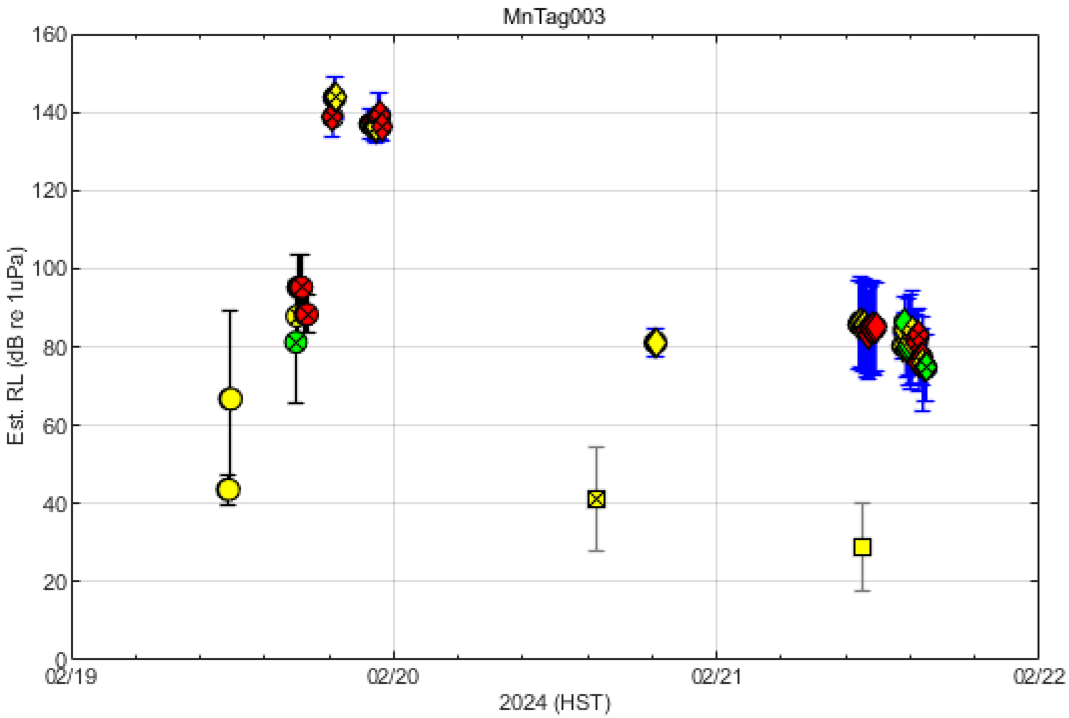
- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 59: Stoplight plot for the received levels for MnTag002 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

Table 35: Received level details including highest median received level (± 2 SD), overall cumulative SEL, and closest point of approach (CPA) for each source for MnTag003.

	Highest median RL (± 2 SD) dB re 1 μPa	Overall cSEL dB re 1 μPa²	CPA (km)
Ship	143.7 (138.5, 148.9)	159.1	41.3
Dipping Sonar	Below ambient	60.6	143.9
Sonobuoy	95.2 (86.9, 103.5)	115.5	37.6

The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.



- The symbol indicates the median RL for each 5-min bin, while the error bars indicate ± 2 standard deviations around the median. The color indicates the relative number of pings that occurred in that 5-min bin, with green being few, yellow being moderate, and red being high. The “x” within colored symbols indicates the probability of exposure was < 100%.

Figure 60: Stoplight plot for the received levels for MnTag003 from surface ships (diamond shape, blue error bars), helicopter-dipping sonar (squares, grey error bars), and active sonobuoys (circles, black error bars).

4. DISCUSSION

This report details the movement and dive behavior of 23 tagged cetaceans during two SCCs at PMRF in 2023 and 2024, along with the associated received levels from three sources of MFAS. This is the first time all three sources of MFAS that occur during Phase B of an SCC have been comprehensively analyzed for these species and the opportunity allowed for the investigation of behavioral responses to difference source types and received levels. However, there were few apparent changes in movement behavior identified for any of the sources at any received level, even for individuals receiving moderate to higher-level exposures. There were some differences in dive behavior across the exposure periods and diel periods for some individuals, but no overt changes in dive behavior in apparent response to any exposures. This is likely due to the majority of the tagged animals being from resident, island-associated populations that are routinely exposed to MFAS.

All six pilot whales tagged in 2023, and seven of the eight pilot whales tagged in 2024 were from known western island communities, and one pilot whale from 2024 was from a known central island community. All but two pilot whales received exposures from all three sources of MFAS (active sonobuoy, helicopter-dipping, and hull-mounted surface ship). GmTag252, GmTag254, and GmTag255 had statistically significant differences in their dawn median dive depths or dawn median dive durations across different phases of the SCC, although the differences occurred across different phases for each individual (i.e., there were no consistent differences between the same phases for all animals).

For daytime dives, GmTag243, GmTag246, GmTag251, GmTag252, GmTag253, GmTag254, and GmTag257 had statistically significant differences in their median dive depths and/or median dive durations between different phases of the SCC, while for nighttime dives there were significant differences between phases for the same two variables for GmTag243, GmTag246, GmTag251, GmTag252, GmTag253, GmTag255, and GmTag258. In both diel periods, the differences varied by individual as to which phases were different. GmTag257 also had significant differences in median dive durations during the dusk period between Phase B and the After phase. These results highlight the strong inter-individual variability in dive behavior, even among individuals within the same groups.

It is possible that these differences across phases and diel periods are likely more related to individual-level or within-group variation in behaviors (e.g., Visser et al. 2014), behavioral changes across habitat/prey gradients, or possibly individual sensitivities rather than a species-level response to MFAS. Several individuals and groups in both years spent considerable time in an ARM behavioral state south/southwest of Kaua'i at different points during the SCCs, which may indicate a preferred foraging habitat for this species. Several individuals in both years also spent time during Phase B moving back and forth across the range, receiving moderate to moderately-high (120 to 160 dB re 1 μPa) median received levels of MFAS from surface ships, and moderate median received levels (110 – 125 dB re 1 μPa) from helicopter-dipping MFAS.

Median received levels from sonobuoys rarely surpassed 100 – 110 dB re 1 μPa, although for GmTag254 and GmTag255, median received levels reached 120 and 132 dB re 1 μPa, respectively. These animals were on the range for almost the entirety of Phase B, and fairly close (within 4 – 16 km) to the sources throughout the bouts of exposures. These whales did conduct fewer deeper dives throughout the diel period during Phase B and then even deeper dives the After phase as compared to the Interphase but given their consistent presence on the range those differences may have been in response to prey availability rather than in response to MFAS. Similarly, GmTag258 remained on the range and conducted the same movement patterns throughout Phase B and the After phase, receiving similar levels from all three sources during all exposure bouts, but without any changes in behavior.

Their dive depths and dive rates changed from Phase B to the After phase, with fewer, deeper dives after, but this again may have been in response to prey rather than to MFAS.

The single tagged melon-headed whale received exposures from all three sources and received the highest received level from all three sources of any animals tagged because they transited through the area of training activity on the range during two bouts of MFAS. Their CPAs to all three sources were between 1 and 8 km, and in fact the sources fell within the error ellipse of their crawl-smoothed track in several instances. This animal was moving northeast across the range through the area of activity and then off the range during that first, loudest exposure bout, and then they turned and headed back across the range, turning south at the start of the second bout of MFAS and moved directly towards and through the area of activity during the second bout of MFAS. This proximity led to the highest maximum median received levels of 159 dB re 1 μPa for hull-mounted MFAS, 124 dB re 1 μPa for helicopter-dipping MFAS, and 134 dB re 1 μPa for active sonobuoy MFAS. They crossed the range again between bouts of MFAS, moving further south, then came back across the range during the third bout of MFAS, before turning north again at the end of Phase B. These animals received high levels of MFAS from all three sources and passed very close to the sources multiple times. While they did move off the range after the first two high level bouts of MFAS, there were no apparent large-scale avoidance movements, and they returned to the range for subsequent exposure bouts, and in fact approached sources repeatedly.

Unfortunately, no dive behavior from Phase B was received so it is unknown if this animal was foraging during these movements, but it seems highly likely as a driver of their behavior. It is interesting to note that melon-headed whale sightings on and around PMRF have increased dramatically in recent years. Melon-headed whales are thought to be sensitive to high-intensity underwater sounds, based on a 2004 near-mass stranding event associated with RIMPAC off Kauaʻi (Southall et al. 2006), and a 2008 mass stranding in Madagascar associated with a high-power 12 kHz multi-beam echosounder used by a nearby survey vessel (Southall et al. 2013). From 2011 through 2016 CRC spent 113 days on the water off Kauaʻi, covering 12,912 km of survey trackline, yet had no melon-headed whale sightings.

In contrast, from 2017 through 2023, CRC spent 78 days on the water covering 7,899 km of trackline, and there were 17 sightings of melon-headed whales. This dramatic change in melon-headed whale use of the area around Kauaʻi remains unexplained and is not reflected in the encounter rates for any other species. This change could be a result of variation in oceanographic conditions at different spatiotemporal scales (e.g., from daily fluctuations to interannual climatic cycles), as such conditions influence availability and abundance of their prey. Understanding demographic patterns of melon-headed whale presence off Kauaʻi/Niʻihau (e.g., whether the same groups use the study area versus a constant flux of new groups) could provide insight into factors potentially causing this observed increase in their presence and thus their exposure to MFAS. This is therefore an area worthy of focused effort in future years, particularly if behavioral responses to MFAS are observed during future SCCs.

The single tagged spotted dolphin received exposures from all three sources. This animal remained at the southern end or south of the range and Kaua'i for all five phases of the SCC, with constant ARM movement behavior and no changes in this behavior, even during the low-level exposure bouts. There was limited dive behavior for this animal, but they appeared to remain near the surface throughout their MFAS exposure periods.

Two of the three tagged bottlenose dolphins were from a resident, island-associated population, and the third dolphin is assumed to be as well due to their multi-day association with a known animal. Two of three bottlenose dolphins received exposures from all three sources. None of the dolphins appeared to have varied their movement behavior relative to any MFAS exposure; two of the dolphins were off the range during all of Phase B so any exposures were received at a distance, while the third dolphin remained at the southwestern edge of the range throughout Phase B and the After phase, hugging the coast of Kaua'i the entire time. Median received levels for active sonobouys and helicopter-dipping MFAS remained below 100 dB re 1 µPa for all three dolphins, and even for TtTag044 at the southern edge of the range the hull-mounted MFAS did not exceed 143 re 1 µPa dB. None of the bottlenose dolphins had statistically significant differences in their dive behavior across phases of the SCC.

Two of the three tagged humpback whales had been previously photographed and identified via HappyWhale. While these are not target species of interest for COMPACTFLT, they were tagged during the 2024 effort in order to test a new tag prototype for Wildlife Computers. Since humpback whales had previously been tagged at PMRF under a COMPACTFLT-associated effort (Henderson et al. 2019, 2022), these tags were analyzed here for comparison with those data. One humpback whale did not receive any MFAS exposures, while two received exposures from all three sources. These two animals were tagged together in a group, and both transited east away from the range around the northern edge of Kaua'i during Phase B. They received their highest median received levels at this time, around 144 dB re 1 µPa from hull-mounted MFAS and below 100 dB re 1 µPa for the other two sources. One animal moved in a small loop during this bout of exposures but continued traveling east, while the other animal didn't appear to change their behavior at all. While both animals received MFAS as they continued to move east, the levels were low and there were no other changes in their movement behavior. Neither animal had any significant changes in their dive behavior across phases of the SCC.

The high number of pilot whales from this effort has brought the total number of tagged pilot whales at PMRF to 43 over a decade of tagging effort from 2014-2014. These data, in conjunction with pilot whales tagged in the Atlantic Ocean during a separate behavioral response study effort, are going to be analyzed using a newly developed movement model in order to assess potential behavioral responses in a quantified manner. This is the first test of this model in a species other than beaked whale, but this method may be available for use in the future with other odontocetes at PMRF where there is enough tag data available (e.g., bottlenose dolphins, rough-toothed dolphins [*Steno bredanensis*]). Therefore, the horizontal movement analysis in this report was done at a qualitative level; perhaps less obvious changes in movement behavior will be detected with this new method and can be utilized in the development of future U.S. Navy behavioral risk functions. Similarly, the aggregated data from the now 25 tagged rough-toothed dolphin are also being analyzed in a separate effort to look for potential behavioral responses. This long-term collaborative effort has yielded high numbers of tags, coupled with long-term social and spatial data on these populations that lend themselves to larger meta-analyses of response at the group- and population-level that cannot be achieved by smaller, shorter-term studies.

Furthermore, these aggregated data seem to indicate that while there were individual- and group-level differences in movement and dive behavior both within and between all tagged species, none of the individuals or species seemed to demonstrate specific, overt responses to any MFAS at any received level or from any source. In fact, several pilot whales, one melon-headed whale, one spotted dolphin, and one bottlenose dolphin remained on or near the range throughout Phase B of the SCC and received relatively consistent and moderate to high levels of MFAS across multiple bouts of exposures due to their consistent movement behavior. While dive behavior did vary across diel and SCC phase for several individual pilot whales, these differences varied by group and individual and may have been due to prey differences and foraging behavior rather than MFAS received levels.

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APPENDIX A
NON-SIGNIFICANT STATISTICAL RESULTS

A.1 BOTTLENOSE DOLPHINS

The following tables include comparisons of dive parameters, including any statistically significant differences, across each phase for dawn dives (Table A-1), daytime dives (Table A-2), dusk dives (Table A-3), and nighttime dives (Table A-4).

Table A-1: A comparison of dawn diving parameters from common bottlenose dolphins with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Dawn dive rate (dives/hr)							
TtTag042	NA	NA	NA	2.93	NA	-	
% time in surface periods during dawn							
TtTag042	NA	NA	NA	59.72	NA	-	
Median dive depth dawn (m)							
TtTag042	NA	NA	NA	455.50	NA	NA	
Median dive duration dawn (m)							
TtTag042	NA	NA	NA	8.53	NA	NA	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

Table A-2: A comparison of daytime diving parameters from common bottlenose dolphins with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Day dive rate (dives/hr)							
TtTag042	NA	NA	NA	1.65	1.46	-	
TtTag044	NA	NA	NA	1.78	NA	-	
% time in surface periods during day							
TtTag042	NA	NA	NA	77.61	81.83	-	
TtTag044	NA	NA	NA	83.48	NA	-	
Median dive depth day (m)							
TtTag042	NA	NA	NA	543.50	543.50	0.60	
TtTag044	NA	NA	NA	109.50	NA	NA	
Median dive duration day (m)							
TtTag042	NA	NA	NA	9.03	8.82	0.35	
TtTag044	NA	NA	NA	5.43	NA	NA	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

Table A-3: A comparison of dusk diving parameters from common bottlenose dolphins with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Dusk dive rate (dives/hr)							
TtTag042	NA	NA	NA	2.50	NA	-	
% time in surface periods during dusk							
TtTag042	NA	NA	NA	61.19	NA	-	
Median dive depth dusk (m)							
TtTag042	NA	NA	NA	543.50	NA	NA	
Median dive duration dusk (m)							
TtTag042	NA	NA	NA	8.53	NA	NA	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

Table A-4: A comparison of nighttime diving parameters from common bottlenose dolphins with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Dusk dive rate (dives/hr)							
TtTag042	NA	NA	NA	2.50	NA	-	
% time in surface periods during dusk							
TtTag042	NA	NA	NA	61.19	NA	-	
Median dive depth dusk (m)							
TtTag042	NA	NA	NA	543.50	NA	NA	
Median dive duration dusk (m)							
TtTag042	NA	NA	NA	8.53	NA	NA	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

A.1.1. Dive Behavior

TtTag042 transmitted behavior log data for the Interphase, Phase B and the After phase (Table 3-26). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis. Dawn and dusk dive metrics were only available for Phase B, and are not discussed for this tag, though values are reported in Tables 30 and 32. Day and night dive metrics, however, were available for both Phase B and the After phase.

There was minimal variation in daytime dive depths and durations between Phase B and the After phase, with no statistically significant differences between phases (Table A-2, Figure A-1A). Daytime dive rates fell only slightly between Phase B and the After phase, going from 1.65 dives/hr to 1.46 dives/hr (Table A-2, Figure A-1B). Nighttime dives were both shallower and shorter during the After phase compared to Phase B, but these differences were also not statistically significant (Table A-4, Figure A-1A). Nighttime dive rates also decreased between Phase B and the After phase, going from 2.56 dives/hr to 1.92 dives/hr (Table A-4, Figure A-1B).

TtTag044 transmitted behavior log data for both Phase B and the After phase (Table 3-26). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis. Only Phase B daytime met the cutoff for inclusion in the analysis, and hence the dive behavior results for this tag are not discussed further, though values are reported in Table A-2.

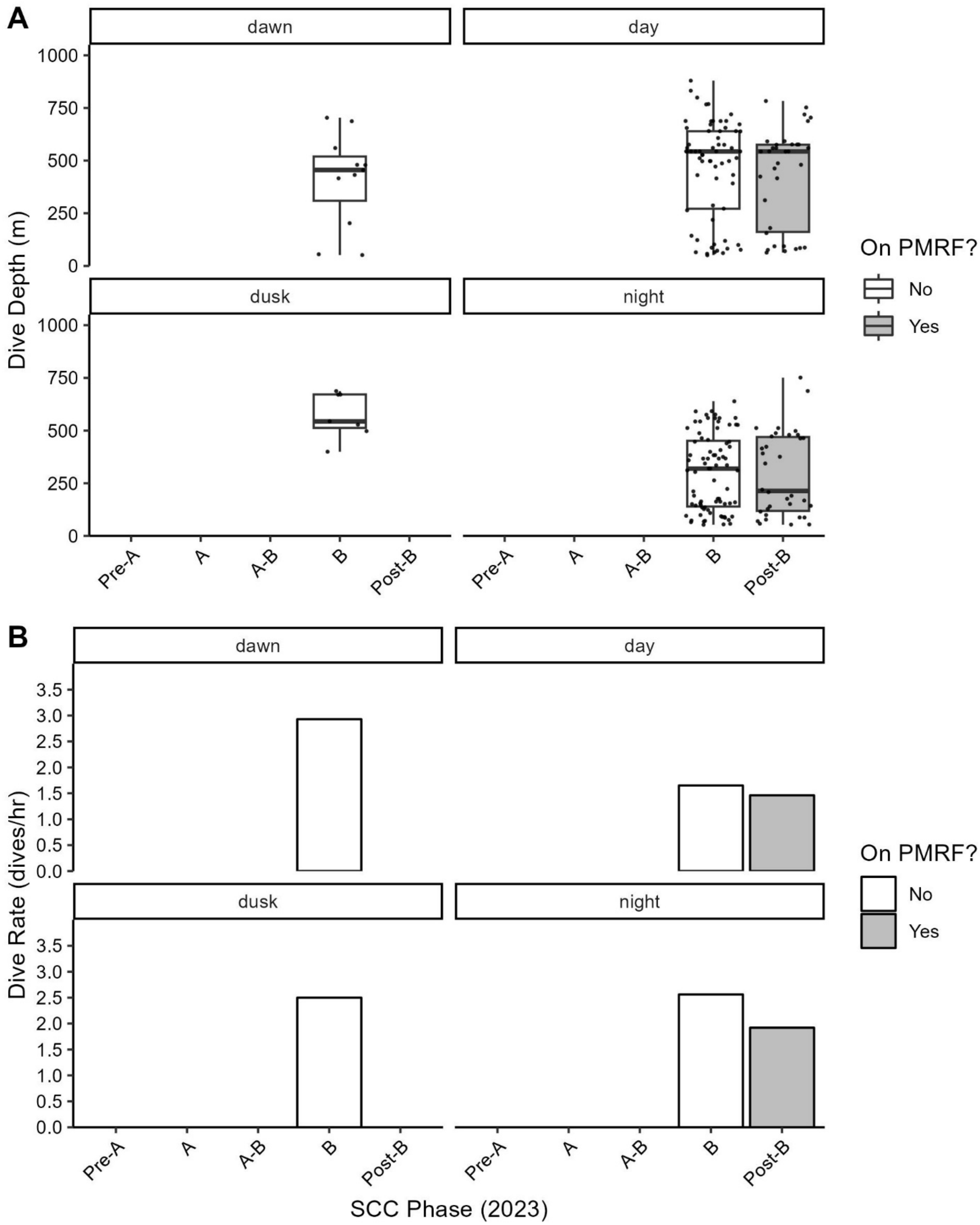

Figure A-1: (Top) Boxplot showing dive depths of TtTag042 by SCC phase and time of day. (Bottom) Barplot showing dive rates of TtTag042 by SCC phase and time of day.

A.2. HUMPBACK WHALES

Summary statistics on the comparison of humpback whale dive behavior across phases for dawn dives (Table A-5), daytime dives (Table A-6), dusk dives (Table A-7), and nighttime dives (Table A-8).

Table A-5: A comparison of dawn diving parameters from humpback whales with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Dawn dive rate (dives/hr)							
MnTag001	NA	NA	1.14	NA	NA	-	
Mntag002	NA	NA	NA	2.86	NA	-	
% time in surface periods during dawn							
MnTag001	NA	NA	86.44	NA	NA	-	
MnTag002	NA	NA	NA	81.20	NA	-	
Median dive depth dawn (m)							
MnTag001	NA	NA	110.50	NA	NA	NA	
MnTag002	NA	NA	NA	53.50	NA	NA	
Median dive duration dawn (m)							
MnTag001	NA	NA	7.17	NA	NA	NA	
MnTag002	NA	NA	NA	4.03	NA	NA	

- -Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

Table A-6: A comparison of daytime diving parameters from humpback whales with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Day dive rate (dives/hr)							
MnTag001	NA	NA	1.56	NA	NA	-	
Mntag002	NA	NA	NA	3.56	NA	-	
% time in surface periods during day							
MnTag001	NA	NA	87.41	NA	NA	-	
MnTag002	NA	NA	NA	57.55	NA	-	
Median dive depth day (m)							
MnTag001	NA	NA	58.50	NA	NA	NA	
MnTag002	NA	NA	NA	77.50	NA	NA	
Median dive duration day (m)							
MnTag001	NA	NA	3.77	NA	NA	NA	
MnTag002	NA	NA	NA	7.00	NA	NA	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

Table A-7: A comparison of dusk diving parameters from humpback whales with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Dusk dive rate (dives/hr)							
Mntag002	NA	NA	NA	3.56	NA	-	
% time in surface periods during dusk							
MnTag002	NA	NA	NA	57.55	NA	-	
Median dive depth dusk (m)							
MnTag002	NA	NA	NA	77.50	NA	NA	
Median dive duration dusk (m)							
MnTag002	NA	NA	NA	7.00	NA	NA	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

Table A-8: A comparison of nighttime diving parameters from humpback whales with behavior log data exposed to MFAS for phases that meet the required coverage cutoff.

Dive parameter per individual	Before	Phase A	Interphase	Phase B	After	Kruskal-Wallis Test p-value	Post-hoc Dunn's test significant pairs
Night dive rate (dives/hr)							
MnTag001	NA	NA	0.81	NA	NA	-	
Mntag002	NA	NA	NA	0.47	NA	-	
% time in surface periods during night							
MnTag001	NA	NA	91.37	NA	NA	-	
MnTag002	NA	NA	NA	95.47	NA	-	
Median dive depth night (m)							
MnTag001	NA	NA	71.50	NA	NA	NA	
MnTag002	NA	NA	NA	53.50	NA	NA	
Median dive duration night (m)							
MnTag001	NA	NA	6.50	NA	NA	NA	
MnTag002	NA	NA	NA	6.70	NA	NA	

- Kruskal-Wallis one-way ANOVA significant results (i.e., significant differences among phases were detected) are shown in bold. Pairs of phases where significant differences were detected are listed in the associated post-hoc Dunn's test column (level of significant 0.05). Values for dive rates and percentage time in surface periods represent single values for each individual for each period, thus no statistical testing was undertaken for these values.

A.2.1. Dive Behavior

MnTag001 transmitted behavior log data for both Phase A and the Interphase (Table 3-30). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis. Only the dawn, daytime, and nighttime Interphase periods met the cutoff for inclusion in the analysis, and hence the dive behavior results for this tag are not discussed further, though values are reported in Tables A6-A8.

MnTag002 transmitted behavior log data for both Phase B and the After phase (Table 3-30). However, when broken down by time of day and phase, not every time of day and phase met the required coverage (relative to the phase duration) for inclusion in the analysis. Only Phase B dawn, day, dusk, and night met the cutoff for inclusion in the analysis, and hence the dive behavior results for this tag are not discussed further, though values are reported in Table A-5 through Table A-8.

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14. ABSTRACT			

In August 2023 and February 2024, Cascadia Research Collective (CRC) conducted small boat-based satellite tagging of odontocetes at the Pacific Missile Range Facility (PMRF), with acoustic support from Naval Information Warfare Center (NIWC) Pacific and Naval Undersea Warfare Center (NUWC) Newport, who directed the tagging boat towards locations of acoustic detections on the range. A total of 19 odontocetes were tagged, including 14 short-finned pilot whales, 3 common bottlenose dolphins, 1 pantropical spotted dolphin, and 1 melon-headed whale, along with 3 humpback whales. The resulting satellite tag tracks were smoothed and interpolated with positions every 5 minutes, and during the phase of Navy training with mid-frequency active sonar, received levels were estimated in 3D using a parabolic propagation modeling equation for transmissions from hull-mounted ship sonar, active sonobuoys, and helicopter-dipped sonar. Dive behavior were statistically analyzed across diel period (dawn, daytime, dusk, and nighttime) and SCC phase (Before, Phase A, Interphase, Phase B, After), when there was enough dive data across periods for analysis. Movement behavior in response to MFAS was assessed qualitatively. Resulting assessments indicated that there were some statistically significant differences in dive depth and dive duration for some individual pilot whales across different diel or SCC phases, but these differences varied by group or individual, with no consistent differences for any metric across any period. Dive rates and the percentage of time spent on the surface did not differ significantly for any individual across any period, and dive depths and durations did not differ significantly for any other species. These aggregated data can be analyzed using more sophisticated modeling techniques to quantitatively assess behavior in response to MFAS, and to examine potential changes in response over time to look for changes in behavioral response patterns.

15. SUBJECT TERMS						
mid-frequency active sonar, received level, behavioral response, odontocete, satellite tag						
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