Density and Abundance of Cuvier's and Blainville's beaked whales in the Mariana Archipelago using drifting acoustic recorders: Progress Report February 2023

Project team:

Erin Oleson, Pacific Islands Fisheries Science Center
Jennifer McCullough, Pacific Islands Fisheries Science Center
Janelle Badger, Pacific Islands Fisheries Science Center
Jay Barlow, BarlowAGAD
Robin Baird, Cascadia Research Collective
Taiki Sakai, Contractor for Southwest Fisheries Science Center

Abstract

NOAA Fisheries Science Centers have increasingly relied on passive acoustic datasets to augment traditional visual-based assessments with recent efforts including drifting recorders (DASBRs) resulting in beaked whale habitat preferences in the Mariana Archipelago and first-ever acoustic-based density and abundance estimates for Cuvier's beaked whales along the entire US west coast. In 2021 the Navy supported line-transect survey for cetaceans throughout the Mariana Archipelago and throughout the large-scale survey effort DASBRs were deployed with the goal of collecting data on the occurrence of beaked whales and other cryptic deep-divers. Additional funds were available after the survey from the Navy to pursue density and abundance estimates for Cuvier's and Blainville's beaked whales by fitting the acoustic-based estimator to the Mariana Archipelago DASBR dataset. From the 21 deployments duty cycled recording 2 of 10 minutes, both Cuvier's and Blainville's beaked whales were detected throughout the archipelago on these 2-min files (335 and 395 files with detections, respectively). As there are no available tag data collected on these beaked whales in the Mariana Archipelago, required ancillary data for the DASBR density estimation framework, such as dive cycle durations and echolocation depths to determine probability of detection, are obtained by synthesizing information from other regions. Intermediate results are not provided at this time, as analyses are still underway and rely in part on datasets provided by partners who have not yet provided their consent for publication of the results arising from the use of their datasets. We anticipate completion of the density estimates for both species by mid-summer, with final report delivered by September 2023.

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Erin Oleson
Jennifer McCullough
Janelle Badger
Jay Barlow
Robin Baird
Taiki Sakai

5d. PROJECT NUMBER

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5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Pacific Islands Fisheries Science Center, NOAA Fisheries, Honolulu, Hawaii
BarlowAGAD
Cascadia Research Collective
Southwest Fisheries Science Center

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14. ABSTRACT

NOAA Fisheries Science Centers have increasingly relied on passive acoustic datasets to augment traditional visual-based assessments with recent efforts including drifting recorders (DASBRs) resulting in beaked whale habitat preferences in the Mariana Archipelago and first-ever acoustic-based density and abundance estimates for Cuvier's beaked whales along the entire US west coast. In 2021 the Navy supported line-transect survey for cetaceans throughout the Mariana Archipelago and throughout the large-scale survey effort DASBRs were deployed with the goal of collecting data on the occurrence of beaked whales and other cryptic deep-divers. Additional funds were available after the survey from the Navy to pursue density and abundance estimates for Cuvier's and Blainville's beaked whales by fitting the acoustic-based estimator to the Mariana Archipelago DASBR dataset. From the 21 deployments duty cycled recording 2 of 10 minutes, both Cuvier's and Blainville's beaked whales were detected throughout the archipelago on these 2-min files (335 and 395 files with detections, respectively). As there are no available tag data collected on these beaked whales in the Mariana Archipelago, required ancillary data for the DASBR density estimation framework, such as dive cycle durations and echolocation depths to determine probability of detection, are obtained by synthesizing information from other regions. Intermediate results are not provided at this time, as analyses are still underway and rely in part on datasets provided by partners who have not yet provided their consent for publication of the results arising from the use of their datasets. We anticipate completion of the density estimates for both species by mid-summer, with final report delivered by September 2023.

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NOAA Fisheries Science Centers have increasingly relied on passive acoustic datasets to augment traditional visual-based assessment efforts. Both Southwest and Pacific Islands Fisheries Science Centers (PIFSC) have recently incorporated drifting acoustic spar buoy recorders (DASBRs) into their standard large-scale survey designs. Drifting autonomous instruments have many advantages, especially for species that are difficult to see at the surface, vocal at depth, and whose sounds have been well characterized such that they can be readily identifiable from autonomous recordings. In the Pacific Islands, drifting recorder data formed the basis of a recent study on habitat preferences of deep-diving beaked whales and *Kogia* species (e.g. McCullough et al. 2021). Substantial investment in the statistical treatment of these datasets for beaked whales led to the first-ever acoustic-based density and abundance estimates for Cuvier's beaked whales along the entire US west coast (Barlow et al. 2021a). The analytical framework is designed specifically for deep diving beaked whales that occur in discrete groups, such that additional statistical exploration and development is needed use the DASBR dataset for other species.

The Pacific Marine Assessment Program for Protected Species (PacMAPPS) is a multi-agency (NMFS, Navy, BOEM) initiative that supports cetacean surveys in regions of joint interest. In 2021 the Navy supported line-transect surveys for cetaceans throughout the Guam and Commonwealth of the Northern Mariana Islands (CNMI) Exclusive Economic Zones (EEZs), a project known as the Mariana Archipelago Cetacean Surveys (MACS). As with other recent large-scale survey efforts, PIFSC deployed DASBRs throughout the survey region with the goal of collecting data on the occurrence of beaked whales and other cryptic deep-divers. Traditional line-transect assessments for those species are often challenged by very low encounter rates, resulting in density and abundance estimates with high uncertainty, or in some cases, no estimates if groups were not seen during the 'on-effort' portions of the survey. Previous experience in the Marianas suggested that encounter rates for beaked whales on the DASBRs would be orders of magnitude higher within the DASBR data than in the visual survey or towed array datasets, likely enabling examination of density for some beaked whale species using the newly developed methods of Barlow et al. (2021a).

At the completion of the MACS 2021 survey, additional funds were available from the Navy to pursue density and abundance estimates for Cuvier's and Blainville's beaked whales using the DASBR dataset. This progress report on that effort will provide an update on work to date, with project completion expected in September 2023.

Methods and Results to Date

Data collection

DASBRs consist of a vertical hydrophone array with 2 hydrophones spaced 10m apart and centered at 150m depth. The recorders are deployed from the ship during standard visual survey operations and left to drift for 2-25 days before their recovery, aided by an Iridium tracker within the buoy's surface float. PIFSC has deployed DASBRs during four large-scale

surveys since 2017, two near Hawaii and two in the Mariana Archipelago. The details of the DASBR configuration and deployment location and duration during Mariana Archipelago surveys are found in Hill et al. (2020) and Yano et al. (2022). Acoustic data were recorded in 2018 at 288 kHz sampling rate and duty cycle of 2 minutes on, 3 minutes off, and in 2021 with a 384 kHz sampling rate and duty cycle of 2 minutes on, 8 minutes off.

The MACS 2021 effort provided data from 21 DASBRs deployed throughout the Guam and Commonwealth of the Northern Marianas (CNMI) EEZ (Figure 1a, Appendix 1). The 2018 DASBR dataset (n=8, Figure 1b, Appendix 1) from deployments between the island chain and the west Mariana Ridge is also being used to provide additional data from the study area which are needed to derive parameter estimates or examine sensitivity in those estimates.

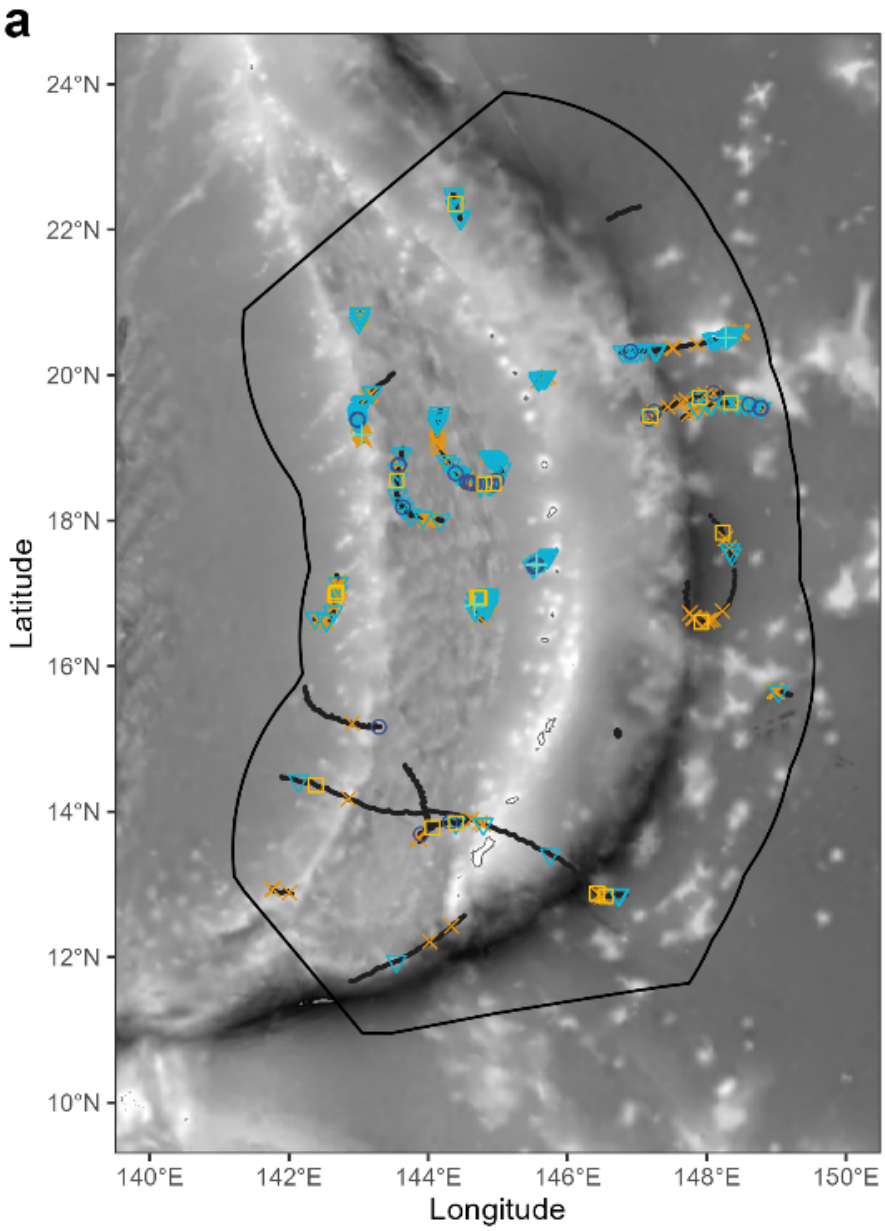

Figure 1a. DASBR tracks and beaked whale detections in 2021. Blainville's = blue downward triangle; Cuvier's = orange "x"; Longman's = purple circle; BWC = yellow square; *Kogia* spp. = pink upward triangle; unknown BW = teal cross.

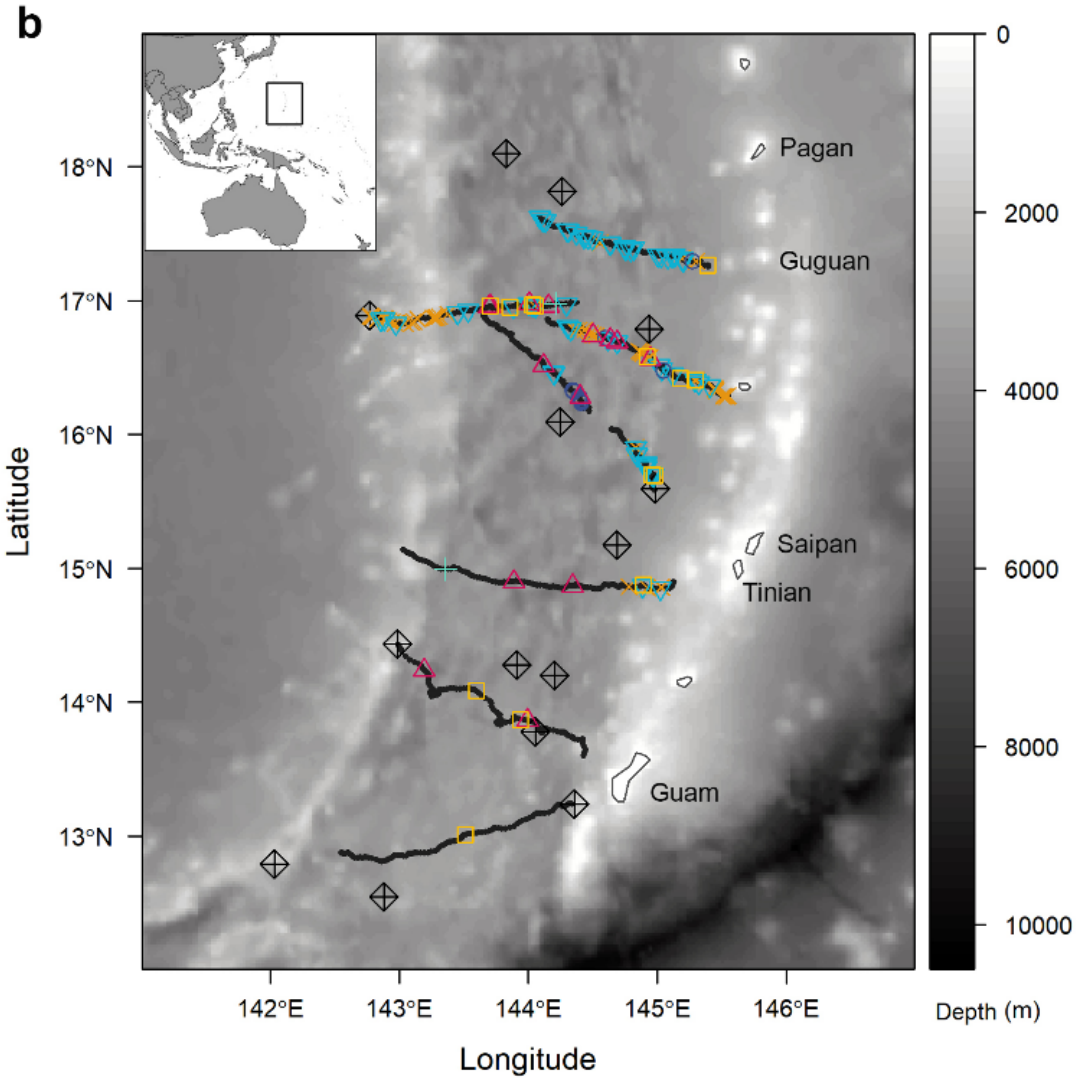

Figure 1b. DASBR tracks and beaked whale detections for 2018, extracted from McCullough et al. (2021). Blainville's = blue downward triangle; Cuvier's = orange "x"; Longman's = purple circle; BWC = yellow square; *Kogia* spp. = pink upward triangle; unknown BW = teal cross.

DASBR data processing

The detailed acoustic data processing approach is provided in Barlow et al. (2021a), and is only summarized here. A semi-automated approach was used to detect beaked whales within the 2018 and 2021 DASBR datasets. Acoustic data files were processed using PAMGuard software (version 2.01.05; Gillespie et al., 2009) to detect echolocation pulses using the Click Detector module (IIR Butterworth 4 kHz high pass filter) and to classify those pulses based on peak frequencies and the presence of a frequency change (upsweeps). Vertical bearing angles were estimated from the time-difference-of-arrival of the same echolocation click on the upper and lower hydrophones using the cross-correlation algorithm in PAMGuard. To identify beaked whale echolocation pulses, analysts reviewed the pulse detections in the time-bearing display

within PAMGuard Viewer software. All potential beaked whale encounters were identified to species based on four criteria: having a downward bearing angle that remains relatively constant, peak frequency, duration, and the frequency contour, which is generally upsweeping for beaked whales (e.g. Baumann-Pickering et al. 2014). Surface reflections are occasionally present for beaked whale signals and can aid in discriminating beaked whales from dolphins.

Acoustic detections classified as Cuvier's or Blainville's beaked whales were included in the density analysis if at least three pulses at the same bearing angle met the established criteria. The number of detections of each species in each DASBR survey year are reported based on the number of 2-minute data files with each species present (Table 1). The detection locations are shown in Figure 1.

Table 1. Number of DASBR drifts during MACS 2018 and MACS 2021 surveys, and the number of 2-minute recording files with detections and Cuvier's and Blainville's beaked whales.

Year	DASBR drifts analyzed	# Cuvier's beaked whale detections	# Blainville's beaked whale detections
2018	8	175	203
2021	21	335	395

Density estimation

The population density of Cuvier's and Blainville's beaked whales will be estimated using a group-based, point-transect survey method. Sampling intervals are equal to the file recording length (2 min). Barlow et al. (2021b) found that estimates of Cuvier's beaked whale density were not sensitive to snapshot lengths between 20 s and 20 min. The derivation of the density estimator is provided in Barlow et al. (2021a), and is not presented in detail in this progress report, though relies upon understanding of the fraction of snapshots with detections of each species (Table 1), the probability that a group is available to be detected with a snapshot, the effective survey area, and the mean group size.

Ancillary data are required to estimate some of these parameters. In particular, estimating the probability of detection relies on assessment of dive cycle duration and echolocation depth derived from time-depth tags deployed on each focal species. As there are no tag data available from the Mariana Archipelago, datasets from other regions, including Hawaii, the Bahamas, southern California, the US east coast, and other published values are used to examine the sensitivity in these measurements to geographic location, and develop appropriate values for use in the Marianas. Dive cycle duration estimates from previous DASBR deployments (Barlow & McCullough 2022) are also used to inform this parameter. Mean group size will use data from visual sightings of each species within the study area, as well as from other areas given the very low number of beaked whale sightings in the Marianas.

The table below (Table 2) provides an overview of the process to estimate density for Cuvier's and Blainville's beaked whales in the Mariana Archipelago, with individual tasks grouped based

upon the parameter estimate required to compute density for each species. Intermediate results are not provided at this time, as analyses are still underway and rely in part on datasets provided by partners who have not yet provided their consent for publication of the results arising from the use of their datasets.

Table 2. Density estimation approach and status for Mariana Archipelago beaked whales.

Task type	Task description	Status
Snapshots with detections	Run PAMGuard detectors for beaked whales across MACS 2018 and 2021 datasets. Classify beaked whales to species	Complete
	Tally total number of sound-files recorded during Mariana survey and fraction with beaked whale detections	Complete- Table 1.
Probability of detection with a snapshot	Collate available dive data from telemetry tags on Cuvier's and Blainville's beaked whales	Complete
	Analyze available dive datasets to estimate dive cycle duration and deep dive duration for the sampled region	Complete
	Compare dive cycle duration for MACS 2021 data to estimates from previous DASBR surveys (Barlow & McCullough 2022)	Complete
	Estimate Mariana Archipelago dive cycle duration for both species using data from other regions	Complete
	Measure declination angles from the vertical array for beaked whale detections within the 2018 and 2021 datasets	Complete
	Estimate distribution of echolocation depths via extrapolation from other studies in other regions	Complete
	Estimate acoustic encounter duration from DASBR data using mark-recapture approach described in Barlow et al. (2021a)	In progress
Effective area surveyed	Estimate effective area surveyed using maximum simulated likelihood approach	In progress
	Determine boundaries and size of the study area	In progress
Group size	Compile and compare mean group size information for each species from other regions and sightings in the Marianas.	Not yet started
Estimate density	Combine all parameters	Not yet started

We anticipate completion of the density estimates for both species by mid-summer, with final report delivered by September 2023. Navy will use these PAM-based density estimates to augment the visual/habitat-based density estimates that will ultimately feed into the Navy's acoustic effects analysis for the next Marianas EIS and consultations.

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Appendix 1

Deployment/retrieval locations and dates of drifting acoustic recorders, DASBRs, during the MACS 2018 & 2021.

	DEPLOYMENT			**RETRIEVAL**			
ID	LAT	LON	Time (UTC)	LAT	LON	Time (UTC)	Duration (h:mm:ss)
DS1	13.60	144.43	7/09/2018 08:13:06	14.43	142.99	7/20/2018 08:43:10	264:41:59
DS2	14.90	145.13	7/09/2018 18:10:54	15.14	143.03	7/20/2018 20:49:14	266:49:30
DS3	16.29	145.54	7/11/2018 12:14:40	16.86	144.15	7/24/2018 00:26:27	275:25:38
DS4	17.26	145.40	7/12/2018 14:34:54	17.63	144.09	7/24/2018 05:58:33	279:50:49
DS5	16.98	144.38	7/14/2018 16:12:47	16.88	142.77	7/22/2018 20:50:37	208:14:27
DS6	16.17	144.47	7/15/2018 06:47:55	16.89	143.65	7/23/2018 20:48:10	206:11:07
DS7	13.24	144.36	7/18/2018 09:12:23	12.88	142.55	7/27/2018 02:33:13	209:32:21
DS8	15.58	144.98	7/21/2018 09:04:31	16.04	144.65	7/25/2018 19:37:05	107:06:16
DS1	13.85	144.56	5/03/2021 08:47:28	14.67	143.67	5/28/2021 12:00:43	285:19:09
DS3	17.31	145.47	5/06/2021 08:43:05	17.52	145.79	5/11/2021 06:41:27	118:40:15
DS4	19.53	144.18	5/08/2021 19:56:40	18.87	144.86	5/25/2021 12:47:02	389:03:37
DS5	16.64	144.78	5/11/2021 20:04:47	16.78	144.82	5/25/2021 06:52:10	335:14:40
DS6	15.17	143.31	5/12/2021 10:20:31	15.71	142.24	5/26/2021 21:32:12	347:22:16
DS7	16.66	142.38	5/16/2021 10:24:46	17.24	142.68	5/26/2021 10:31:17	240:41:07
DS8	18.99	143.64	5/17/2021 09:45:45	18.01	144.20	5/25/2021 10:46:17	193:14:18
DS9	20.03	143.50	5/18/2021 10:53:11	19.11	143.08	5/24/2021 11:41:55	145:02:08
DS10	22.14	144.47	5/19/2021 10:09:51	22.49	144.36	5/23/2021 10:34:47	96:57:31
DS11	20.71	143.01	5/20/2021 19:47:17	20.88	142.99	5/23/2021 23:08:58	75:45:53
DS12	12.88	142.04	5/27/2021 19:39:07	12.94	141.76	5/29/2021 08:21:22	36:53:12
DS13	12.57	144.52	6/15/2021 11:26:47	11.67	142.89	6/24/2021 11:35:57	216:28:06
DS14	12.85	146.84	6/17/2021 11:04:46	14.48	141.88	7/11/2021 20:11:07	585:24:22
DS15	15.67	148.97	6/19/2021 12:30:20	15.61	149.21	6/21/2021 11:11:33	47:01:31
DS16	15.07	146.74	6/20/2021 09:59:11	15.05	146.74	6/26/2021 8:46:34	142:57:04
DS17	17.15	147.73	6/27/2021 09:53:15	18.07	148.05	7/08/2021 08:33:12	262:58:42
DS18	19.39	147.65	6/29/2021 05:03:29	19.55	148.78	7/07/2021 06:54:30	196:27:36
DS19	19.39	147.15	6/29/2021 12:01:39	19.76	148.22	7/07/2021 02:56:37	183:13:38
DS20	20.31	146.77	6/29/2021 19:46:49	20.59	148.52	7/06/2021 18:51:00	167:13:43
DS21	22.31	147.04	6/30/2021 15:16:53	22.15	146.59	7/03/2021 03:23:02	60:17:49
DS22	19.92	145.57	7/04/2021 02:32:48	19.98	145.73	7/05/2021 11:06:00	32:42:43