Abundance and productivity of marbled murrelets (*Brachyramphus marmoratus*) off central California during the 2022 breeding season

Summary provisional data report to Luckenbach Trustee Council and California State Parks

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Introduction

In 2022, the U.S. Geological Survey Western Ecological Research Center (USGS-WERC), in cooperation with the U.S. Fish and Wildlife Service and California State Parks, performed at-sea surveys as part of a long-term monitoring program to estimate abundance and reproductive output of marbled murrelets (*Brachyramphus marmoratus*) in U.S. Fish and Wildlife Service Conservation Zone 6 (central California—San Francisco Bay to Point Sur; Figure 1). Marbled murrelets have been listed as "endangered" by the State of California and "threatened" by the U.S. Fish and Wildlife Service since 1992 in California, Oregon, and Washington (U.S. Fish and Wildlife Service, 2021). Surveys to estimate the abundance of marbled murrelets at sea off central California have been done since 1999 (excluding 2004–06; Henkel and Peery, 2008; Peery and others, 2008; Peery and Henry, 2010; Henry and others, 2012; Henry, 2017; Felis and others, 2018, 2019, 2020, 2022a) and are funded by the U.S. Fish and Wildlife Service Natural Resource Damage Assessment and Restoration Program under the guidance of the Luckenbach Oil Spill Trustee Council. Information regarding marbled murrelet abundance, distribution, population trends, and habitat associations is critical for risk assessment, effective management and evaluation of conservation efficacy, and ultimately to meet federal- and state-mandated recovery efforts for this species.

The USGS-WERC continued at-sea surveys in 2022 to assess abundance and productivity for two primary purposes: (1) to maintain efforts to quantify the status of marbled murrelets in central California (U.S. Fish and Wildlife Service Conservation Zone 6) and (2) to help evaluate marbled murrelet response to ongoing corvid control in coastal California State Parks. Additionally, the CZU Lightning Complex wildfire burned large areas of marbled murrelet nesting habitat in the Santa Cruz Mountains during late August and September 2020 (California Department of Forestry and Fire Protection, 2021); changes in local murrelet abundance and reproductive output in the wake of this habitat loss are of conservation and management concern.

Recently updated analytical methods used herein are fully evaluated and described by Felis et al. (2023). For future annual reporting, we intend to provide provisional summary reports annually and fully published evaluations of methods, results, and monitoring effectiveness every five years, similar to the 5-year reporting cycle of the USFS Northwest Forest Plan (McIver et al. 2022). Publication of new data to our data release for this program (Felis et al. 2022b) will follow the same 5-year cycle.

Methods

In 2022, we completed nine at-sea boat-based surveys for marbled murrelets between Half Moon Bay and Santa Cruz, California (Figure 1, Table 1), following field methods described in Felis et al. (2023). In short, we performed surveys along randomized, ~100-km-long zig-zag routes designed to sample nearshore (200–1,350 meters [m] from coast) and offshore (1,350–2,500 m from coast) strata, with approximately four times greater effort within the nearshore stratum owing to greater marbled murrelet densities nearshore (Becker et al. 1997). We used line-transect methods (Buckland et al. 2001) by estimating murrelet observation distances from the transect line to correct counts for imperfect detection as a function of distance from the transect line. Two observers (one for each side of the boat) recorded all murrelet observations and classified them by behavior ("on the water" or "flying") and age class (after-hatch-year [AHY] or hatch-year [HY]). We performed surveys during a previously established survey window (June 1–August 24; Felis et al. 2023; Peery et al. 2007) and allocated surveys to two periods within this window: three surveys during June 1–July 9 and six surveys during July 10–August 24. We used data from all surveys to estimate AHY marbled murrelet abundance, and we used the six surveys during the second survey period to estimate juvenile (HY:AHY) ratio (following Peery et al. 2007 and Felis et al. 2023) and HY abundance.

To estimate the density and abundance of murrelets, we corrected murrelet observations for imperfect detection as a function of distance from the survey transect line ("distance-correction") using detection function modeling with the "Distance" package in R (Buckland et al. 2001, Miller et al. 2019). Detailed methods are described in Felis et al. 2023. In brief, for AHY murrelets we used a global (all years pooled) hazard-rate model with ~Year as a factor covariate (Figure 2) to account for differences in survey crews and vessels among years, and because our goal was to produce the most accurate annual abundance estimates (Felis et al. 2023). For HY murrelets, there were insufficient annual observations to include ~Year as a covariate; therefore, we used a global hazard-rate model with ~Vessel as a two-level covariate (Figure 2) to account for a smaller/slower vessel in 1999–2003 and a larger/faster vessel in 2007–present (Felis et al. 2023). We included all murrelet observations within 100-m perpendicular distance ("truncation distance") of the transect line and modeled them using continuous distance values. We did not include flying murrelets (1–21% of AHY observations annually, 0% of HY observations) because of annual inconsistencies in how they were recorded (Felis et al. 2023). Overall study area and stratum-specific abundance estimates were generated by applying global detection models to each year's observation data with the Distance dht2 function in R, which estimated survey-specific densities that were then averaged and applied to the study area (104.65 km^2 for each stratum, 209.3 km^2 total) for annual abundance estimates.

We also calculated the ratio of HY to AHY murrelets (HY:AHY ratio) following methods described in Felis et al. (2023) and Peery et al. (2007). The HY:AHY ratio was "date-corrected" to account for still-incubating AHY murrelets and unfledged HY murrelets missing from the water based on date-based phenology regressions developed by Peery et al. (2007). Note that the HY:AHY ratio was not "distance-corrected", nor were any observations excluded based on distance (no "truncation distance") or behavior, although no HY murrelets were observed flying.

Variances for all estimates are reported as standard errors, coefficients of variation, and log-normal 95% confidence intervals. We evaluated long-term trends in AHY abundance, HY abundance, and the HY:AHY ratio using generalized linear models (GLMs) with a negative binomial distribution, following Felis et al. (2023).

Results

We detected 145 groups (range 5–28 per survey) of 255 AHY marbled murrelets (range 11–52 per survey) on our nine surveys in 2022 (Figure, Table 1). After detection function modeling, we estimated an AHY abundance for 2022 of 397 murrelets (95% confidence interval [CI] 277–568; coefficient of variation [CV] 0.17; Table 2; Figure 3). The abundance estimate for 2022 was similar to the long term (1999–present) average of 379 murrelets (range 163–585 annually; Table 2). The GLM for AHY abundance was not statistically significant at the $p=0.05$ level, indicating no trend in abundance from 1999–2022 (slope=-0.0105, SE=0.009, t=-1.167, p=0.26).

Most murrelets were in the nearshore stratum (360 birds, 247–524 95%CI) and relatively few were in the offshore stratum (37 birds, 11–119 95%CI). Most murrelets were found in the central portion of the study area near Point Año Nuevo, Franklin Point, and Pescadero Point, and also near Soquel Point off Santa Cruz (Figure 1). Moderate, but more dispersed numbers of murrelets were seen in the northern study area between San Gregorio Creek and Half Moon Bay, as well as south of Point Año Nuevo to Davenport (Figure 1). Observers noted a lack of murrelets in Año Nuevo Bay (typically a hot-spot) on several early-season surveys, but this pattern did not persist into July and August.

We did not detect any HY marbled murrelets in 2022 (Table 1, Table 2, Figure 4). The long term (1999–present) average distance-corrected HY abundance estimate is 13 birds (range 0–31 annually) and the long-term average date-corrected HY:AHY ratio is 0.05 (range 0.00–0.12 annually; Table 2, Figure 4). The GLMs for HY abundance (slope=-0.0411, SE=0.0237, t=-1.736, p=0.10) and HY:AHY ratio (slope=-0.0116, SE=0.0207, t=-0.561, p=0.58) were not statistically significant at the p=0.05 level, indicating no trend in either metric from 1999–2022.

Tables and Figures

*Table 1. Marbled murrelet (*Brachyramphus marmoratus*) survey dates, route direction (direction from which route was drawn), transect length, and number of murrelet observations (groups, individuals, and hatch year birds) for all surveys, U.S. Fish and Wildlife Service Conservation Zone 6, central California, 2022.*

Date	Route direction	Transect length (km)	Number of groups	Mean group size	Number of individuals	Number of hatch year
2022-06-04	South	104.9	28	1.86	52	0
2022-06-23	North	103.7	22	1.50	33	0
2022-06-25	South	104.9	23	1.74	40	0
2022-07-11	North	105.8	15	1.67	25	0
2022-07-25	South	101.2	6	2.17	13	0
2022-07-27	North	99.6	13	1.69	22	0
2022-08-04	South	104.6	20	1.75	35	0
2022-08-06	North	103.6	13	1.85	24	0
2022-08-17	South	101.0	5	2.20	11	0

*Table 2. Annual after-hatch-year (AHY) and hatch-year (HY) marbled murrelet (*Brachyramphus marmoratus*) abundance estimates and HY:AHY ratios, including log-normal 95% confidence intervals (CI), standard errors (SE), coefficients of variation (CV), and sample sizes (k; number of surveys), for all surveys conducted June 1–August 24 (AHY abundance) and July 10–August 24 (HY abundance and HY:AHY ratio [R]).*

	AHY Abundance (June 1 – August 24)				Reproductive output (July 10 – August 24)							
						HY Abundance			HY:AHY Ratio		
Year	k	N (95%CI)	SE	CV	k	N (95%CI)	SE	CV	R (95%CI)	SE	CV
1999	5	391 (290–527)	55.1	0.14	4	18 (4–97)	11.2	0.60	0.057 (0.024–0.137)	0.027	0.47
2000	8	340 (227–509)	62.7	0.18	4	7 (1–38)	4.3	0.61	0.024 (0.010–0.061)	0.012	0.50
2001	15	540 (442–660)	53.5	0.10	8	23 (12–43)	6.9	0.30	0.070 (0.039–0.126)	0.021	0.31
2002	15	569 (466–696)	56.3	0.10	11	20 (12–34)	5.1	0.25	0.051 (0.036–0.073)	0.009	0.18
2003	12	585 (480–714)	57.5	0.10	8	19 (11–35)	5.6	0.29	0.049 (0.032–0.075)	0.011	0.22
2007	4	330 (191–572)	82.0	0.25	3	8 (0–247)	7.9	0.97	0.049 (0.009–0.268)	0.052	1.06
2008	4	163 (88–305)	48.0	0.29	4	0	NA	NA	0	NA	NA
2009	8	444 (334–591)	59.6	0.13	4	9 (1–54)	5.7	0.64	0.028 (0.009–0.087)	0.018	0.62
2010	7	256 (173–377)	44.8	0.18	3	16 (2–116)	8.5	0.53	0.081 (0.034–0.197)	0.039	0.47
2011	6	303 (240–384)	36.2	0.12	3	19 (4–83)	7.9	0.41	0.080 (0.052–0.124)	0.018	0.22
2012	6	381 (291–498)	49.5	0.13	3	5 (0–136)	4.6	0.94	0.029 (0.007–0.111)	0.022	0.78
2013	6	388 (236–640)	84.3	0.22	3	31 (6–175)	14.7	0.47	0.122 (0.048–0.312)	0.062	0.51
2014	9	330 (226–483)	58.5	0.18	6	24 (7–84)	12.7	0.54	0.081 (0.036–0.182)	0.035	0.43
2015	9	211 (148–302)	35.8	0.17	6	8 (3–17)	2.6	0.34	0.059 (0.030–0.114)	0.020	0.35
2016	7	531 (335–842)	108.5	0.20	5	26 (8–81)	11.7	0.45	0.108 (0.045–0.260)	0.051	0.47
2017	9	462 (342–623)	67.8	0.15	6	6 (1–28)	4.0	0.69	0.022 (0.007–0.074)	0.015	0.68
2018	9	266 (181–391)	48.5	0.18	6	8 (2–35)	5.1	0.65	0.047 (0.014–0.158)	0.032	0.68
2019	8	321 (213–482)	63.9	0.20	6	6 (1–29)	4.1	0.69	0.025 (0.007–0.097)	0.020	0.77
2020	9	408 (279–596)	72.6	0.18	6	4 (0–32)	3.9	1.00	0.019 (0.006–0.056)	0.011	0.61
2021	9	350 (184–664)	104.1	0.30	6	8 (2–25)	3.9	0.50	0.041 (0.014–0.120)	0.024	0.60
2022	9	397 (277–568)	68.7	0.17	6	0	NA	NA	0	NA	NA

*Figure 1. Study area in U.S. Fish and Wildlife Service Conservation Zone 6 showing nearshore (200–1350m from coast) and offshore (1350–2500m from coast) strata, survey routes (grey lines), and marbled murrelet (*Brachyramphus marmoratus*) detections (red circles) from Half Moon Bay to Santa Cruz, central California, in 2022. All observations are after-hatch-year birds, no hatch-year birds seen in 2022.*

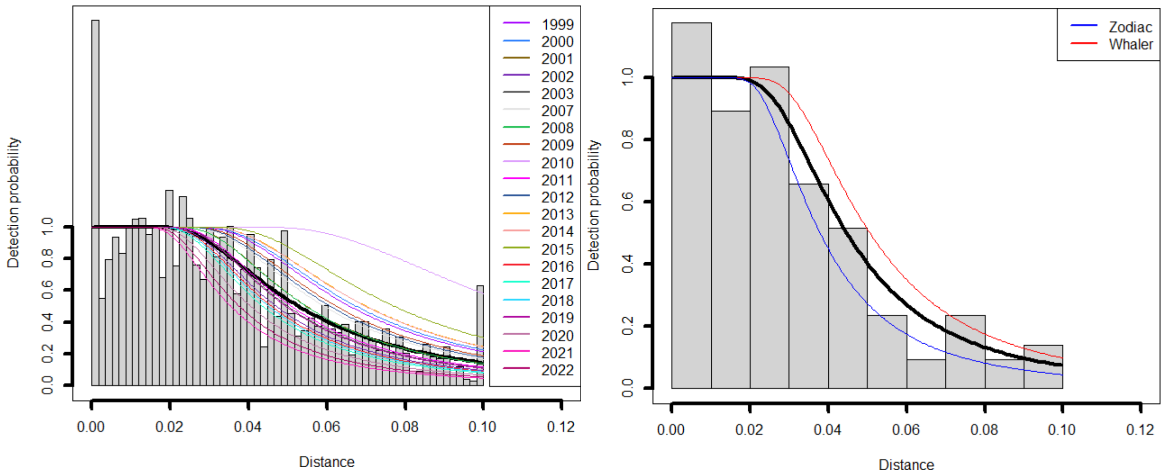

*Figure 2. Modeled probability of detection for after-hatch-year (AHY; left) and hatch-year (HY; right) marbled murrelets (*Brachyramphus marmoratus*) as a function of perpendicular distance (km) from vessel in U.S. Fish and Wildlife Service Conservation Zone 6, central California, 1999–present). Hazard rate key function models were developed with ~Year as a covariate for AHY and ~Vessel as a covariate for HY (smaller Zodiac 1999–2003, larger Whaler or similar 2007–present). Histograms show the distribution of observation distances, black line shows the overall modeled detection function, and individually colored lines show the modeled detection function for each level of covariate. Observations were truncated at 100-m (0.1-km) perpendicular distance from the vessel. Note that observation distances were binned for background histogram plotting but detection-function-modeling was conducted with continuous observation distances.*

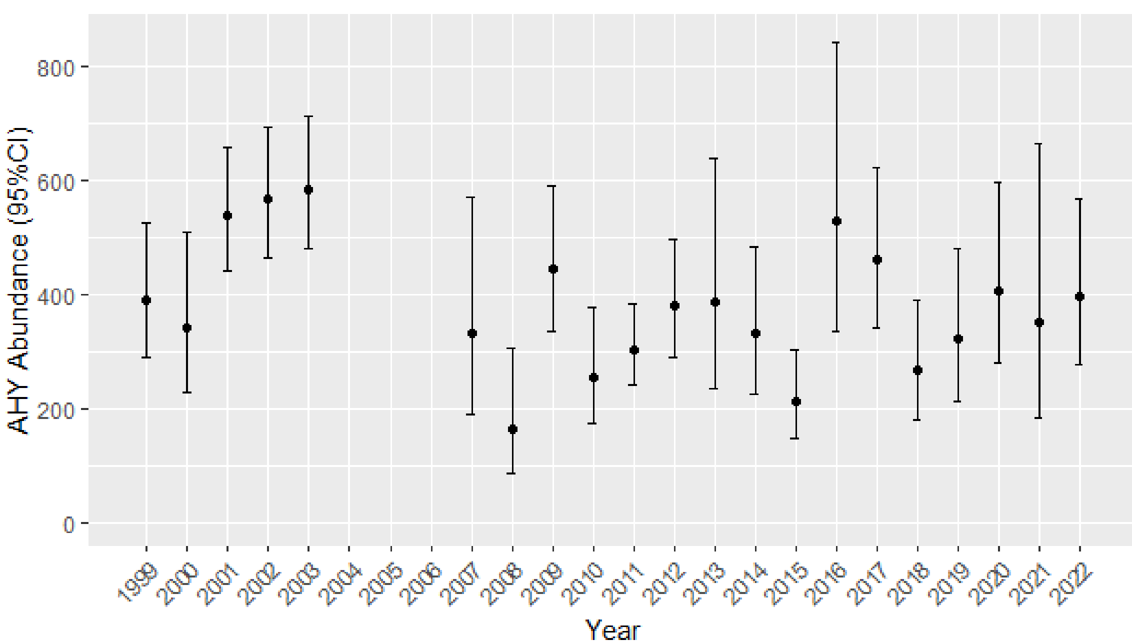

*Figure 3. Annual after-hatch-year (AHY) marbled murrelet (*Brachyramphus marmoratus*) distance-corrected abundance estimates and log-normal 95% confidence intervals (error bars) for the entire study area (combined nearshore and offshore strata) for all surveys June 1 – August 24, 1999–present.*

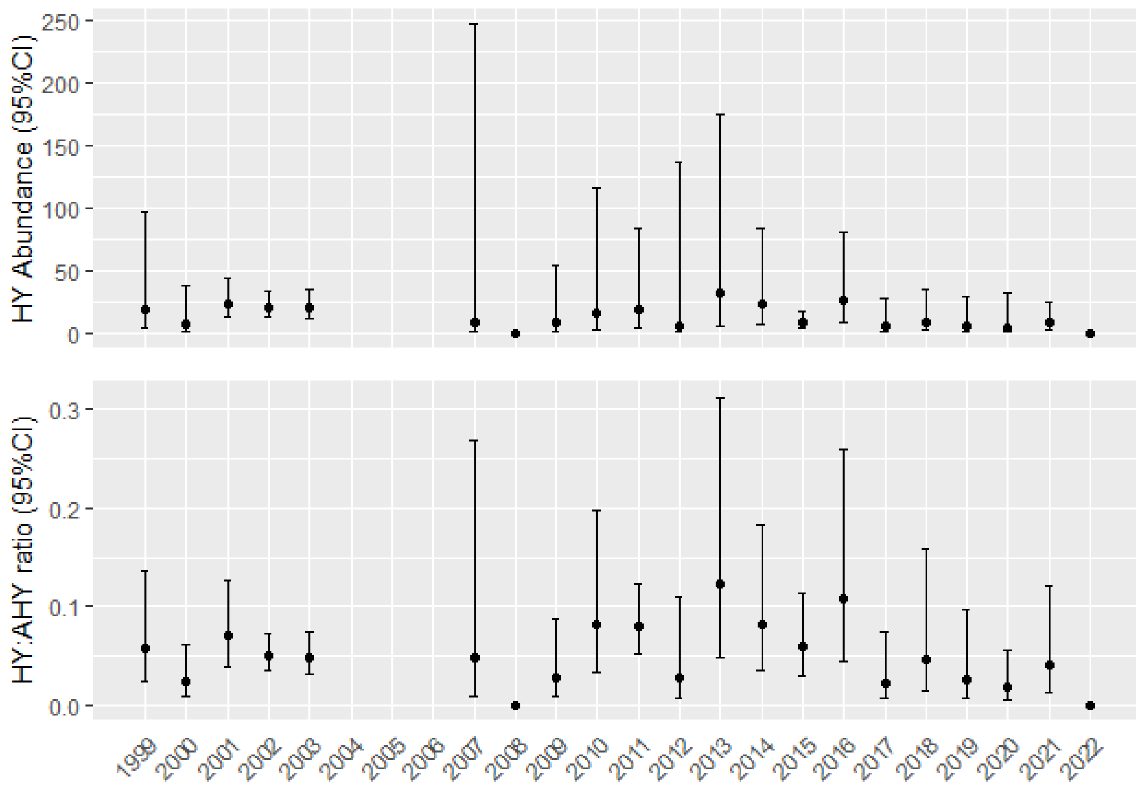

*Figure 4. Top: Annual hatch year (HY) marbled murrelet (*Brachyramphus marmoratus*) distance-corrected abundance estimates with log-normal 95% confidence intervals (CI). Bottom: Annual marbled murrelet date-corrected HY:AHY ratios with log-normal 95% confidence intervals (CI).*

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