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ABUNDANCE OF EASTERN NORTH PACIFIC GRAY WHALES 2024/2025

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Introduction

The Southwest Fisheries Science Center (SWFSC) regularly conducts shore-based surveys of eastern North Pacific (ENP) gray whales (*Eschrichtius robustus*) to estimate abundance along the west coast of the US. These estimates are obtained from visual survey data collected off central California between December and February during the gray whale southward migration, and provide regular updates to a time series of abundance estimates that began in 1967 (Laake et al. 2012). Surveys have recorded increasing trends in the first two decades (1967/1968 to 1987/1988) and following the 1999/2000 unusual mortality event (UME[1]) through the 2015/2016 season. Since then, however, estimated abundances indicated a decline from 27,430 whales (95% CI = 24,930-30,180) in 2015/2016 to 14,770 whales (95% CI = 13,410-16,250) in 2022/2023 (Table 1). This observed decline overlapped with a multi-year UME that extended from 2019 to 2023. This decline, along with the low estimate for the 2022/2023 season, raised concerns about the status of the population. Results from the 2023/2024 season indicated an increase in abundance to approximately 19,260 (95% CI = 17,400 – 21,300; Eguchi et al. 2024). The estimated rate of increase over the two seasons (2022/2023 to 2023/2024) was notable and may suggest that assumptions about migratory behavior were violated during the 2023/2024 survey. This report presents a new estimate of abundance for ENP gray whales migrating southward off the central California coast between December 2024 and February 2025.

Methods

Data for this updated abundance estimate were collected during the 2024-2025 southward ENP gray whale migration between 31 December 2024 and 14 February 2025. Counts were made from a shore-based watch station at Granite Canyon, California, by observer pairs rotating from a larger pool. Each survey day was split into six 90-minute shifts from 0730 to 1630. While previous analyses since 2006 have included shifts with at least 85 minutes of observation effort, shifts with at least 60 minutes of observation effort were included in the analysis reported here to maximize sample size.

The estimated abundance reported here was computed using the N-mixture modeling approach previously used by SWFSC for surveys conducted between the 2006/2007 and 2023/2024 seasons (Durban et al. 2015, 2017, Stewart and Weller 2021, Eguchi et al. 2022, 2023, 2024). In this approach, the sighting probability of shore-based observers was estimated by using data from replicate surveys (i.e., data collected simultaneously by two independent observer teams) that were completed in the 2009/2010 and 2010/2011

[1] https://www.fisheries.noaa.gov/national/marine-life-distress/2019-2023-gray-whale-unusual-mortality-event-along-west-coast-and

seasons and covariates that affect sighting probabilities (i.e., visibility, sea state, and observers). These sighting probability estimates allowed the total number of whales passing through the survey area during a watch period to be estimated from the observed number of whales, even in years when replicate surveys were not conducted.

In the analysis, the start date of the southward migration for the Granite Canyon study site is fixed at 1 December and the end date at 28 February, where the number of southbound whales passing the watch station on those two dates is assumed to be zero. The observed number of whales per survey period (minimum of 60 minutes) is assumed to be a random deviate from the binomial distribution with the estimated sighting probability and the true but unknown number of whales in the sampling area, which is assumed to change as a function of the number of days since 1 December. The model fits two possible functions to the daily counts of whales and selects the function that best fits each count. These functions are (i) a normal distribution with the peak in the daily number of whales passing occurring at the midpoint of the migration (15 January) and (ii) a spline fit that allows the change in the daily number of whales to flexibly match the observed daily counts without expectations about the shape of the curve. The model then internally selects which of these two candidate functions best matches the daily number of observed whales. The final abundance estimate is the sum of the estimated daily number of whales passing through the survey area, with a correction factor applied to account for those that migrate through the study area at night (Perryman et al. 1999). The modeling approach is described in detail in Durban et al. (2015; 2017).

Because the N-mixture modeling approach uses all data since the 2006/2007 season to estimate parameters shared among all datasets, abundances are re-estimated for all seasons as more data are included in the analysis, providing slightly different estimates as new data are added. Before the 2024 report (Eguchi et al. 2024), only the new estimate was provided, while the estimates for previous years were maintained as reported. In the 2024 report, we provided both old and new estimates. This report only provides updated estimates for all years since the 2006/2007 season. For previous estimates, see Eguchi et al. (2024).

Similarly to the recent reports (Eguchi et al. 2022, 2023, 2024), we examined the annual median migration date, which was defined previously (Rugh et al. 2001) as "the date when 50% of the whale sightings had been recorded at a research site or (if data were not available for calculating the median) the date corresponding with the apex of a unimodal sighting curve." Following the first definition, median migration dates are determined using sightings rather than estimated abundances. The latter definition, however, is applicable for estimated numbers if the model has a unimodal distribution. In our approach, the model selected whichever was the better function for each day between the normal and spline fits. Consequently, the results are not unimodal for some years (Figure 1). We, therefore, use the date when 50% of the whale sightings had been recorded as the median migration date.

To examine possible changes in the median migration dates over time, segmented linear models were fitted to the relationship between median migration dates and year using the *segmented* package (v. 2.1.1, Muggeo 2017). All statistical analyses were conducted within the R statistical environment (v. 4.4.1, R Core Team 2024). Abundance estimation was accomplished using the same WinBUGS code as in Durban et al. (2015), Stewart and Weller (2021), and Eguchi et al. (2022, 2023, 2024) via the R2WinBUGS package (Sturtz et al. 2005) in R.

Results and Discussion

Abundance estimates

From 31 December 2024 to 14 February 2025, 16 trained observers completed 271.6 hours of survey effort over 46 days. A total of 934 groups, comprised of 1,693 whales, were counted. The highest daily count was 121 whales on 21 January 2025 (Figure 1). Due to inclement weather and other constraints (e.g., poor visibility due to fog and rain), some observation periods were less than 60 min and were excluded from analysis. Furthermore, groups that were migrating north were excluded from the analysis. These exclusions resulted in a total of 264 hours of survey effort, with 1,655 whales in 914 groups for further analyses. Finally, the abundance estimate reported here includes the multiplicative correction factor for nighttime passage (mean = 1.0875, SD = 0.03625; Perryman et al. 1999).

The estimated abundance of ENP gray whales during the 2024/2025 southbound migration season was 12,950 (95% Credible Interval: 11,690 - 14,450, CV = 0.0534, 20th-percentile = 12,400). This estimate is the third lowest since these surveys began in 1967 and represents a decrease from the most recent low estimate in the 2023/2024 season. This estimate generally aligns with the observed decline between 2015/2016 and 2022/2023 (Table 1; Figure 2). Throughout the time series, estimated abundances fluctuated abruptly at various points in time (Figure 2). Significant increases in abundance from one season to the next cannot be explained by demographic reasons alone (e.g., 1971/1972 to 1972/1973, 1992/1993 to 1993/1994, 2021/2022 to 2022/2023; Figure 2). Efforts are underway by SWFSC to determine the reasons for these sudden increases, which may be caused by biases associated with mismatches between analytical assumptions, including sampling and modeling, and the migratory behavior of whales in particular years.

Using the time series of estimated abundance of ENP gray whales reported here and separate time series of reproduction, mortality, and body condition, a recent integrated population modeling analysis indicated that fluctuations in gray whale abundance were likely associated with access to feeding areas as mediated by sea ice extent and the availability of benthic prey in the Arctic region (Stewart et al. 2023). Fluctuations in estimated abundance for this population are not rare (Figure 2). The observed declines in abundance might represent short-term events without any longer-term negative impacts on the population. That is, the occasional declines in estimated abundance that have occurred since the time series began in 1967 have generally been followed by periods of increasing numbers (Figure 2). However, the duration and magnitude of the current decline, coupled with the low calf production that has occurred since 2019, raise concerns that recent and continued environmental changes in the Arctic and sub-Arctic feeding grounds could be impacting population resilience.

The International Whaling Commission's Scientific Committee has reviewed and endorsed previously generated ENP gray whale abundance estimates (IWC 2024). In their review, it was noted that some of the correction factors and assumptions incorporated into the analysis are dated and should be re-evaluated. These include estimates of detection probability, the proportion of whales passing during nighttime hours, and availability bias. One component of addressing the availability bias in the visual survey data is calibrating group size estimates. Previous crewed aerial surveys and dual-observer tracking experiments have demonstrated that visual observers tend to underestimate the number of whales in a group, which can negatively bias abundance estimates and influence trends (Rugh et al. 2008, Laake et al. 2012). To address this potential bias, flights by uncrewed aerial systems (UAS) were conducted over two-week periods during the two most recent surveys. Comparisons of group size estimates made by visual observers with those from UAS aerial videos are ongoing.

The long-term time series of abundance estimates presented here has been a key component of understanding the population dynamics of ENP gray whales (Stewart et al. 2023). Continued monitoring is essential to track future fluctuations in abundance and calf production, which may be increasingly driven by ecosystem changes, especially in the Arctic region where most ENP gray whales spend the summer feeding (Perryman et al. 2021, Joyce et al. 2023). In the wake of the recent apparent decline in abundance, SWFSC plans to closely monitor the population with regular surveys to estimate abundance, calf production, and body condition of gray whales. The results of these research efforts will continue to provide the best scientific information available to assess the status of the population.

Migration phenology

As previously reported (Eguchi et al. 2022, 2023, 2024), the timing of migration, as measured by the median migration date, changed significantly over the survey period (Figure 3). From the beginning of the survey (1967) through the 1970s, these median dates were generally earlier than 10 January (Day 40). They linearly increased over the 1980s, 1990s, and early 2000s to 21 January (Day 51). Since the mid-2000s, there has been a linear decline to 18 January (Day 48; Figure 3). An analysis using a linear segmented regression indicated that change points in slopes occurred at years 1977.5 (SE = 4.30) and 2005.3 (SE = 4.43). The estimated slopes for the three segments were -0.0667 (SE = 0.323), 0.511 (SE = 0.134), and -0.189 (SE = 0.138), respectively. The median migration date for the 2024/2025 season was 51, which was 4 days earlier than the 2023/2024 season. The biological and ecological significance of these changes is unknown. Studies on body condition, environmental fluctuations, migration paths, shifts in diet, and health status may provide insight into the possible mechanisms underlying changes in the migration timing of gray whales.

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Tables and figures

Table 1: Estimated abundance (Nhat) and 95% lower (LCL) and upper (UCL) confidence limits of gray whales from the visual surveys off Granite Canyon, CA. Estimates before the 2006/2007 season are from Laake et al. (2012), where confidence limits were computed using the lognormal distribution. For the 2006/2007 through 2024/2025 seasons, the method of Durban et al. (2016) was used. Estimates since the 2006/2007 season change as more data are added. See text for details.

Season	Nhat	LCL	UCL	Method
1967/1968	13,426	11,171.4	16,135.6	Laake
1968/1969	14,548	12,439.8	17,013.4	Laake
1969/1970	14,553	12,371.5	17,119.2	Laake
1970/1971	12,771	10,899.1	14,964.5	Laake
1971/1972	11,079	9,236.5	13,289.0	Laake
1972/1973	17,365	14,848.6	20,307.8	Laake
1973/1974	17,375	14,799.3	20,399.0	Laake
1974/1975	15,290	12,972.7	18,021.2	Laake
1975/1976	17,564	14,844.1	20,782.3	Laake
1976/1977	18,377	15,714.0	21,491.3	Laake
1977/1978	19,538	16,448.2	23,208.3	Laake
1978/1979	15,384	13,154.7	17,991.1	Laake
1979/1980	19,763	16,800.5	23,247.8	Laake
1984/1985	23,499	19,744.2	27,967.8	Laake
1985/1986	22,921	19,523.2	26,910.2	Laake
1987/1988	26,916	24,026.0	30,153.6	Laake
1992/1993	15,762	13,797.3	18,006.4	Laake
1993/1994	20,103	18,050.1	22,389.4	Laake
1995/1996	20,944	18,585.9	23,601.3	Laake
1997/1998	21,135	18,500.6	24,144.5	Laake
2000/2001	16,369	14,526.0	18,445.8	Laake
2001/2002	16,033	14,007.2	18,351.8	Laake
2006/2007	19,126	16,644.2	21,977.8	Laake
2006/2007	20,840	18,699.8	25,290.8	Durban

Season	Nhat	LCL	UCL	Method
2007/2008	18,680	16,510.0	22,300.0	Durban
2009/2010	20,390	18,609.8	22,410.0	Durban
2010/2011	21,470	19,640.0	23,500.2	Durban
2014/2015	23,585	21,290.0	26,410.0	Durban
2015/2016	27,430	24,930.0	30,180.0	Durban
2019/2020	20,110	18,300.0	22,060.0	Durban
2021/2022	17,470	15,840.0	19,330.0	Durban
2022/2023	14,770	13,410.0	16,250.0	Durban
2023/2024	19,730	17,850.0	21,850.2	Durban
2024/2025	12,950	11,690.0	14,450.2	Durban

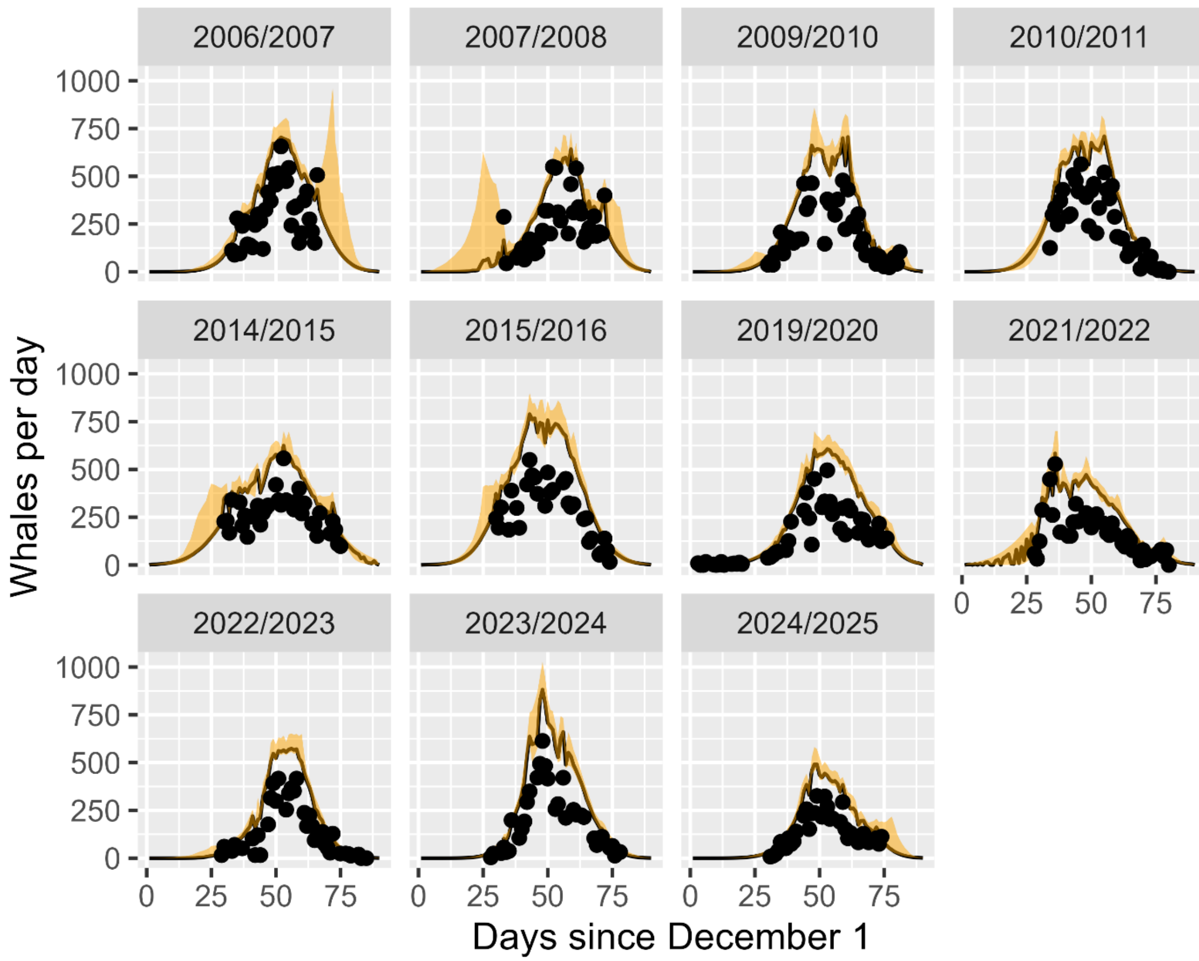

Figure 1: Daily estimated numbers of gray whales migrating through the sampling area off Granite Canyon, CA. Black lines are medians, and orange bands indicate 95% credible intervals from the method of Durban et al (2015). Solid circles indicate observed counts adjusted for the daily survey effort.

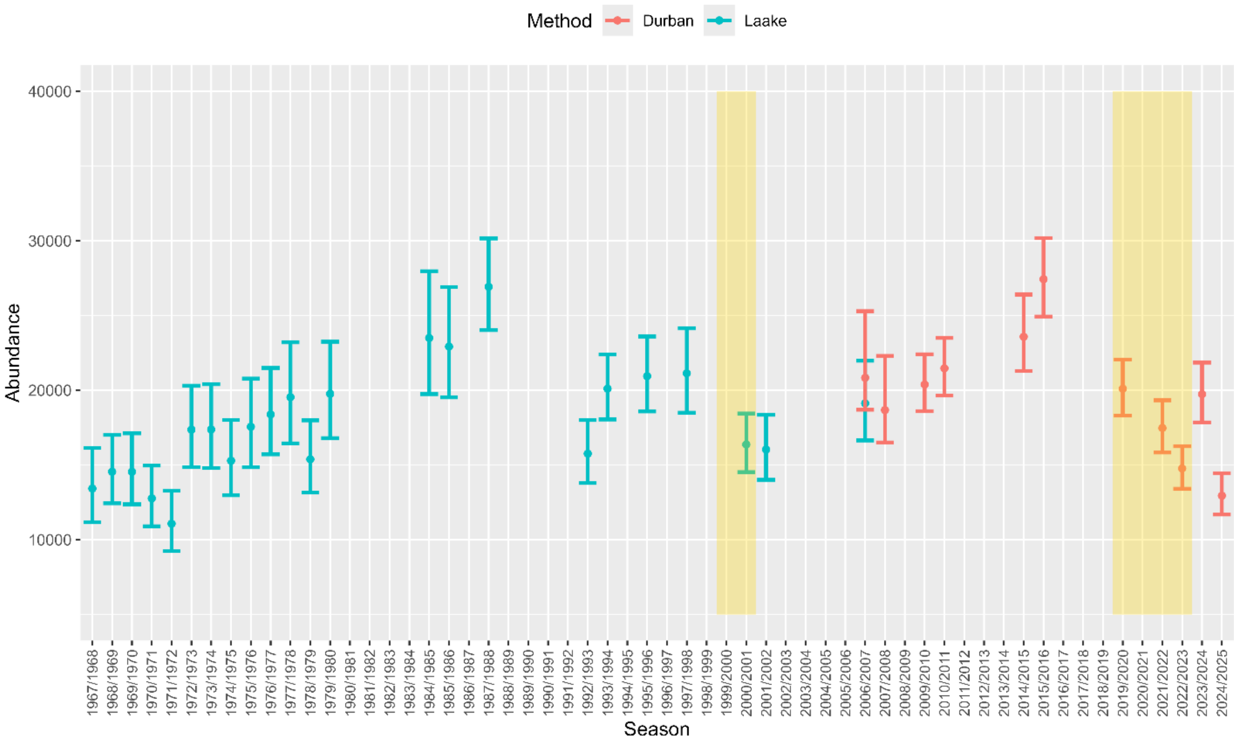

Figure 2: Estimated abundance and 95% CIs (confidence intervals for the method of Laake et al. and credible intervals for the method of Durban et al.) of gray whales from the visual surveys off Granite Canyon, CA, between the 1967/1968 and 2024/2025 seasons. Estimates in green indicate those from Laake et al. (2012), whereas those in red indicate using the method in Durban et al. (2016). Yellow boxes represent unusual mortality events.

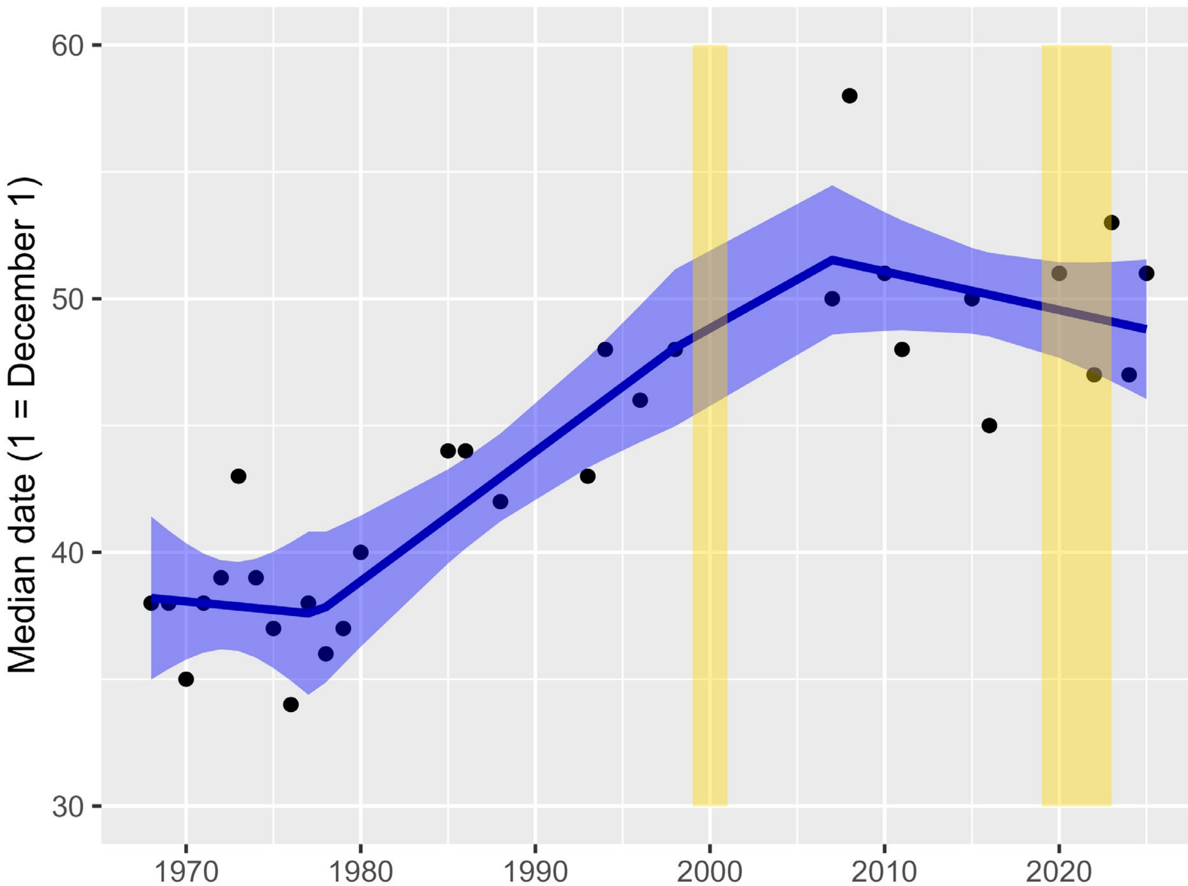

Figure 3: Changes in median date of gray whale southbound migration at the sampling area off Granite Canyon, CA (the date when 50% of the whale sightings had been recorded). December 1 of each year is day 1 and January 10 is 40. Data before the 2006/2007 sampling season are from Rugh et al. (2001, Table 1). Regression lines are linear models with change points (see text for estimates of change points). Yellow vertical bars indicate the designated unusual mortality events.