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ABUNDANCE OF EASTERN NORTH PACIFIC GRAY WHALES 2023/2024

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ABUNDANCE OF EASTERN NORTH PACIFIC GRAY WHALES 2023/2024

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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. 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). In general, these surveys have recorded an increasing trend in ENP gray whale abundance until the 2015/2016 season. Since then, however, estimated abundances indicated a decline from 26,960 whales (95% CI = 24,420-29,830) in 2015/2016 to 14,526 whales (95% CI = 13,194 - 16,040) in 2022/2023 (Eguchi et al. 2023). This decline, which overlapped with a multi-year unusual mortality event (UME)[1] that was declared in 2019 by NOAA's National Marine Fisheries Service, raised concern about the status of the population. This report presents a new estimate of abundance for ENP gray whales migrating southward off the central California coast between December 2023 and February 2024.

Methods

Data for this updated abundance estimate were collected during the 2023-2024 southward ENP gray whale migration between 28 December 2023 and 16 February 2024. Counts were made from a shore-based watch station at Granite Canyon, California, by teams of observer pairs rotating from a larger pool. Each survey day was split into six 90-minute shifts. As was the case for the previous analyses since 2006, only shifts with at least 85 minutes of survey effort were included in the analysis. Some shifts were less than 85 minutes due to inclement weather and less-than-ideal sighting conditions (e.g., Beaufort sea state greater than 4). Sampling and analytical methods are described in a previous publication (Durban et al. 2015).

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

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

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 whales passing the watch station on those two dates is assumed zero. The daily count data are assumed to be random deviates from binomial distributions 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 a function that fits better for each count. These functions are (a) a normal distribution with the peak in the daily number of whales passing occurs at the midpoint of the migration and (b) a spline fit that allows the overall migration curve 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 migration curves best matches the daily number of observed whales. The final abundance estimate is the sum of the total number of whales passing the survey area each day (i.e., both observed whales and the estimated number of unobserved whales), 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 2006/2007 to estimate parameters that are shared among yearly datasets, earlier annual abundance estimates change as more data are added to the analysis (Table 1). In the past, the latest annual estimate (Nhat) was reported and estimates for previous years were maintained as originally estimated and not revised based on the addition of new data (e.g., Eguchi et al. 2023). This report represents a change from the previous reporting approach in that it provides the revised earlier estimates (Nhat) based on the addition of new data. Table 1 provides both Nhat (revised) and Nhat.2023 (original) estimates for comparison purposes. In future reports, only updated estimates will be provided.

Similar to previous reports (Eguchi et al. 2022, 2023), 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.” Using the first definition, these dates are determined using sightings rather than estimated abundances. The latter definition, however, is only applicable for estimated numbers if the model has a unimodal distribution. In our approach, the model selected a better function between the normal and spline fits for each day. 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 date.

Linear models were fitted to the relationship between median dates and year. In order to estimate change points, if they exist, we fitted segmented linear models using the *segmented* package (v. 2.0.3, Muggeo 2017). All statistical analyses were conducted within the R statistical environment (v. 4.3.2, R Core Team 2023).

Results and Discussion

Abundance estimates

From 28 December 2023 to 16 February 2024, 16 trained observers completed 263.6 hours of survey effort over 36 survey days. A total of 1069 groups of 2208 gray whales were counted, with the highest daily count of 185 whales on 16 January 2024 (Figure 1). Due to inclement weather and other constraints (e.g., poor visibility due to fog and rain), some observation periods were < 85 min in duration and were excluded from analysis. Consequently, 220.4 hours of survey effort was retained for analyses. The estimated total abundance of gray whales during the 2023/2024 southbound migration was 19,260 (95% Credible Interval: 17,400 - 21,300.5, CV = 0.0512, 20-percentile = 18,430; Figure 2). This estimate includes the multiplicative correction factor for nighttime passage (mean = 1.0875, SD = 0.03625, Perryman et al. 1999). This estimate represents a 32.6% increase from the previous estimate for the 2022/2023 season (14,530; Table 1).

Using the time-series of estimated abundance of ENP gray whales (Table 1), a recent integrated population modeling analysis indicated that fluctuations in the gray whale abundance were likely associated with access to feeding areas and the availability of benthic prey in the Arctic region (Stewart et al. 2023). The time-series of data suggests that observed fluctuations are not rare and that observed declines in abundance might represent short-term events that have not resulted in any longer-term impacts on the population. That is, despite occasional declines in abundance, the population has shown a generally increasing trend since the time-series of data began in 1967 (Figure 2). The 2023/2024 abundance estimate is consistent with the previously observed pattern of fluctuating abundance, indicating that the ENP gray whale population is increasing after several years of observed decline. While this estimate indicates population level resilience, continued monitoring is essential to determine future fluctuations in abundance and calf production that may be increasingly driven by climate change, especially in the Arctic region where most ENP gray whales spend the summer feeding (Perryman et al. 2021, Joyce et al. 2023). NOAA/NMFS plan 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 regarding the status of the population.

Migration phenology

As previously reported (Eguchi et al. 2023), timing of migration, measured by the median migration date, changed significantly over the survey period (Figure 3). From the beginning of the survey (1967) through 1970s, they were generally earlier than 10 January (Day 40). They linearly increased over the 1980s, 1990s, and early 2000s. Since the mid 2000s, there was a linear decline. When the time-series of data was updated to include the 2023/24 season, estimated change points were 1976.5 (SE = 3.89) and 2008 (SE = 3.37). As expected, these estimated change points were not statistically different from those from the last year's report (1976 $\pm$ 3.63, 2008 $\pm$ 3.84). The estimated slopes for the three segments were -0.104 (SE = 0.355), 0.476 (SE = 0.0885), and -0.273 (SE = 0.162), respectively. Estimated slopes also were not different from those previously reported (-0.13 $\pm$ 0.361, 0.468 $\pm$ 0.077, -0.238 $\pm$ 0.221, Eguchi et al. 2023a). The median migration date for the 2023/2024 season was 47, which was 6 days earlier than the previous season. The biological and ecological significance of this difference is unknown. Studies on Arctic environmental fluctuations and the body condition and health of gray whales may provide information on possible causes of changes in the southward migratory 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 prior to the 2006/2007 season are from Laake et al. (2012), where confidence limits were computed using the lognormal distribution. For the 2006/2007 through 2023/2024 seasons, the method of Durban et al. (2016) was used. Nhat.2023 refers to the estimated abundance (Nhat) reported in Eguchi et al. 2023.

Season	Nhat	LCL	UCL	Method	Nhat.2023
1967/1968	13,426	11,171.4	16,135.6	Laake	13,426
1968/1969	14,548	12,439.8	17,013.4	Laake	14,548
1969/1970	14,553	12,371.5	17,119.2	Laake	14,553
1970/1971	12,771	10,899.1	14,964.5	Laake	12,771
1971/1972	11,079	9,236.5	13,289.0	Laake	11,079
1972/1973	17,365	14,848.6	20,307.8	Laake	17,365
1973/1974	17,375	14,799.3	20,399.0	Laake	17,375
1974/1975	15,290	12,972.7	18,021.2	Laake	15,290
1975/1976	17,564	14,844.1	20,782.3	Laake	17,564
1976/1977	18,377	15,714.0	21,491.3	Laake	18,377
1977/1978	19,538	16,448.2	23,208.3	Laake	19,538
1978/1979	15,384	13,154.7	17,991.1	Laake	15,384
1979/1980	19,763	16,800.5	23,247.8	Laake	19,763
1984/1985	23,499	19,744.2	27,967.8	Laake	23,499
1985/1986	22,921	19,523.2	26,910.2	Laake	22,921
1987/1988	26,916	24,026.0	30,153.6	Laake	26,916
1992/1993	15,762	13,797.3	18,006.4	Laake	15,762
1993/1994	20,103	18,050.1	22,389.4	Laake	20,103
1995/1996	20,944	18,585.9	23,601.3	Laake	20,944
1997/1998	21,135	18,500.6	24,144.5	Laake	21,135
2000/2001	16,369	14,526.0	18,445.8	Laake	16,369
2001/2002	16,033	14,007.2	18,351.8	Laake	16,033
2006/2007	19,126	16,644.2	21,977.8	Laake	19,126
2006/2007	20,640	18,569.0	23,985.8	Durban	20,750
2007/2008	18,450	16,414.8	21,490.0	Durban	17,820

Season	Nhat	LCL	UCL	Method	Nhat.2023
2009/2010	20,960	19,200.0	23,060.0	Durban	21,210
2010/2011	20,820	19,040.0	22,710.0	Durban	20,990
2014/2015	23,440	21,264.8	26,055.8	Durban	28,790
2015/2016	27,450	24,884.8	30,180.0	Durban	26,960
2019/2020	20,630	18,840.0	22,710.5	Durban	20,580
2021/2022	17,430	15,800.0	19,220.0	Durban	16,650
2022/2023	14,530	13,234.8	15,960.0	Durban	14,526
2023/2024	19,260	17,400.0	21,300.5	Durban	

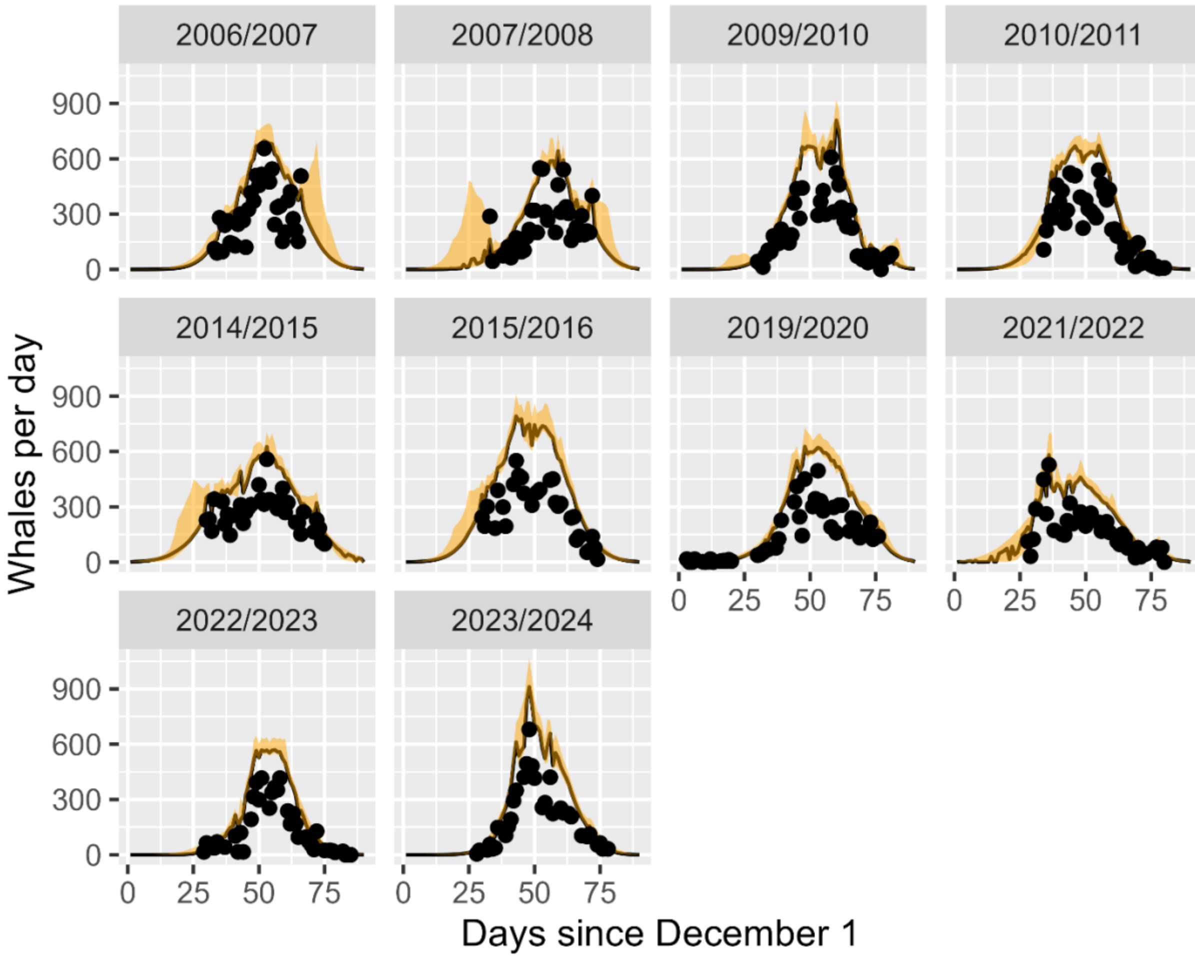

Figure 1: Daily estimated numbers of gray whales migrating through the sampling area off Granite Canyon. Black lines are medians and orange bands indicate 95% credible intervals from the method of Durban et al (2015). Solid circles indicate observed counts adjusted for the daily survey effort.

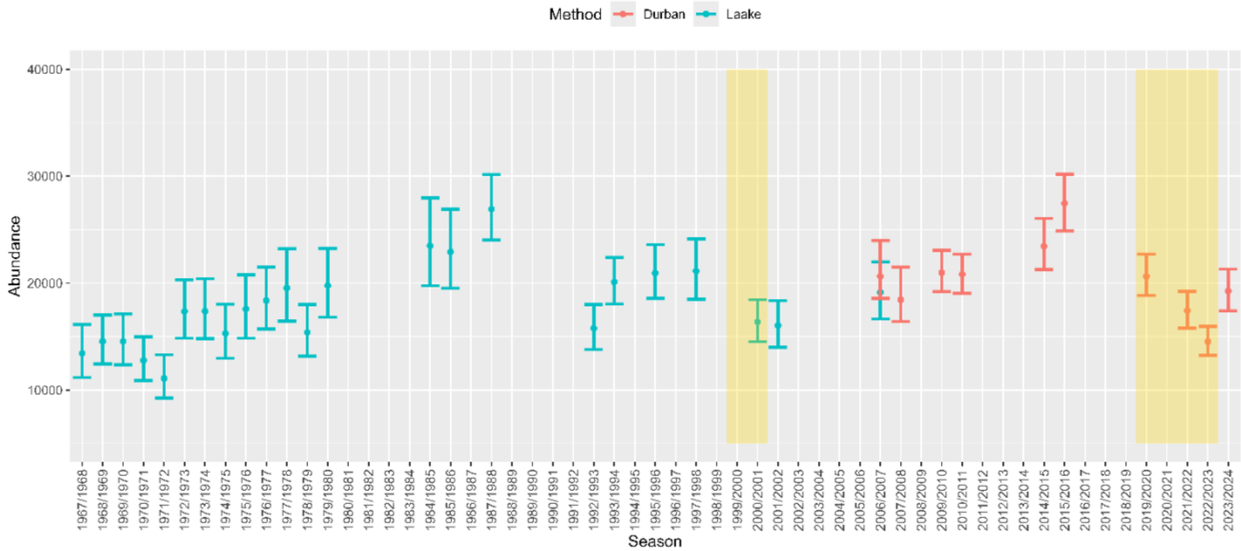

Figure 2: Estimated abundance and 95% CIs (confidence intervals for the method of Laake et al. and credible intervals for the method of Durban et al.) of gray whales from the visual surveys off Granite Canyon, CA, between the 1967/1968 and 2023/2024 seasons. Estimates in green indicate those from Laake et al. (2012) whereas those in red (from the 2006/2007 season) indicate using the method in Durban et al. (2016). Yellow boxes represent unusual mortality events.

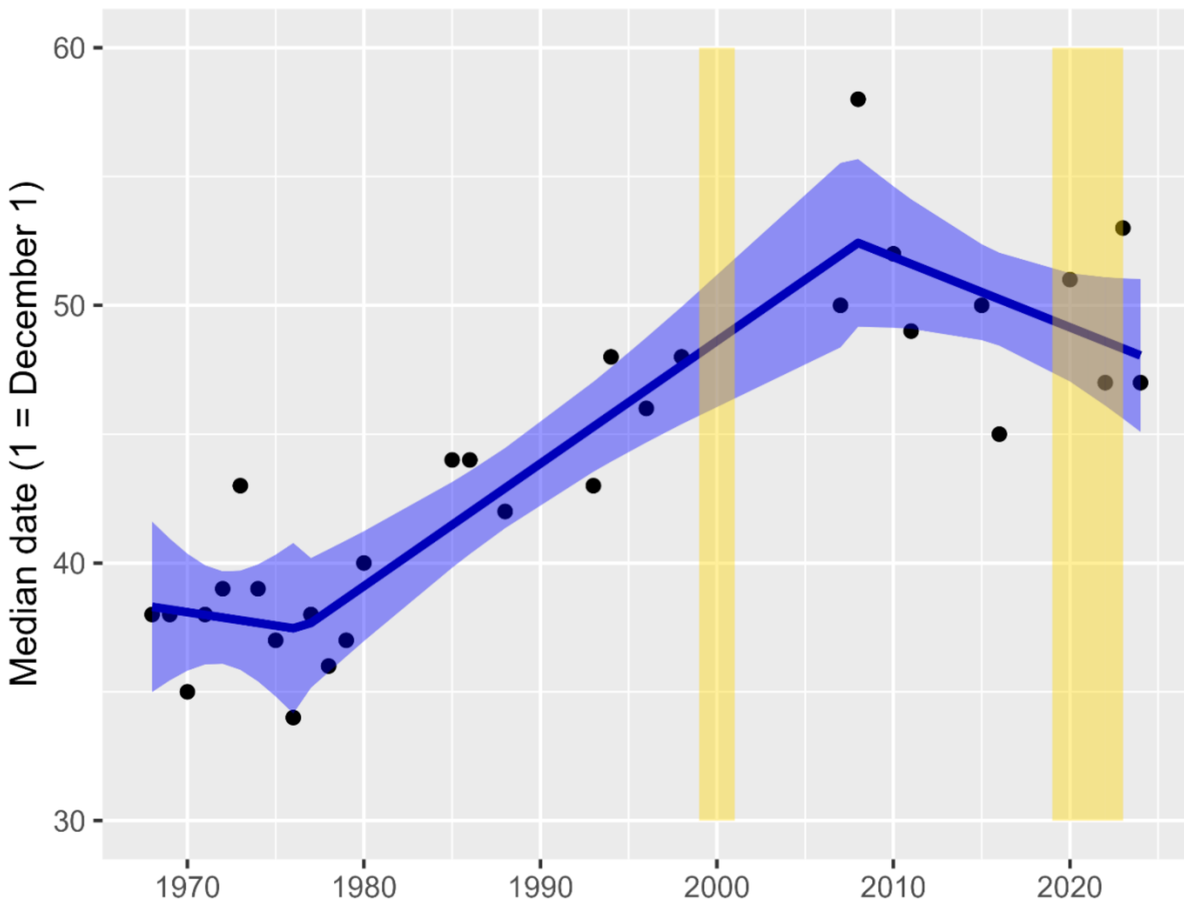

Figure 3: Changes in median date of gray whale migration at the sampling area off Granite Canyon, CA (the date when 50% of the whale sightings had been recorded). December 1 of each year is 0 and January 10 is 40. Data before the 2006/2007 sampling season are from Rugh et al. (2001, Table 1). Regression lines are linear models with change points. Yellow vertical bars indicate the designated UME.