https://doi.org/10.25923/e9at-x936

NOAA Technical Memorandum NMFS

AUGUST 2023

EASTERN NORTH PACIFIC GRAY WHALE CALF PRODUCTION 1994-2023

Tomoharu Eguchi, Aimée R. Lang, and David W. Weller

NOAA Fisheries
Southwest Fisheries Science Center
Marine Mammal and Turtle Division
La Jolla, California, USA

NOAA-TM-NMFS-SWFSC-685

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

About the NOAA Technical Memorandum series

The National Oceanic and Atmospheric Administration (NOAA), organized in 1970, has evolved into an agency which establishes national policies and manages and conserves our oceanic, coastal, and atmospheric resources. An organizational element within NOAA, the Office of Fisheries is responsible for fisheries policy and the direction of the National Marine Fisheries Service (NMFS).

In addition to its formal publications, the NMFS uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series, however, reflect sound professional work and may be referenced in the formal scientific and technical literature.

SWFSC Technical Memorandums are available online at the following websites:

SWFSC: https://swfsc-publications.fisheries.noaa.gov/

NOAA Repository: https://repository.library.noaa.gov/

Accessibility information

NOAA Fisheries Southwest Fisheries Science Center (SWFSC) is committed to making our publications and supporting electronic documents accessible to individuals of all abilities. The complexity of some of SWFSC's publications, information, data, and products may make access difficult for some. If you encounter material in this document that you cannot access or use, please contact us so that we may assist you.
Phone: 858-546-7000

Recommended citation

Eguchi, Tomoharu, Aimée R. Lang, and David W. Weller. 2023. Eastern North Pacific gray whale calf production 1994-2023. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-685.
https://doi.org/10.25923/e9at-x936

Eastern North Pacific gray whale calf production 1994-2023

Tomoharu Eguchi, Aimée R. Lang, David W. Weller

INTRODUCTION

Eastern North Pacific (ENP) gray whales (*Eschrichtius robustus*) migrate annually between foraging grounds in the Arctic and wintering grounds in Baja California (Rice and Wolman 1971). Females nurture their newborn calves in protected lagoons in Baja California Sur, Mexico, and migrate north with them in the spring of each year. Shore-based counts of female gray whales accompanying their calves (i.e., mother-calf pairs) have been conducted annually from the Piedras Blancas Lighthouse Station in central California since 1994 with the exception of 2020 due to COVID-19. Survey methods were evaluated in detail at the outset of the study (Perryman et al. 2002) and both survey methods and the analytical approach used to estimate total annual calf production have remained consistent through the 2019 survey (Perryman et al. 2021).

In 2021, Stewart and Weller (2021) presented a new Bayesian modeling approach to estimate annual calf production of ENP gray whales. This approach accounted for uncertainty during unsampled periods (i.e., evenings, weekends, and during periods of unworkable weather). Here we provide estimates of calf production for the 1994-2023 period using the Bayesian approach. A comparison of estimates between the methods of Perryman et al. (2021) to those used by Stewart and Weller (2021) was provided in Eguchi et al. (2022a).

METHODS

Data for this analysis were collected between 1994-2023 using standardized methods and processed to be consistent with previous analyses (Perryman et al. 2002, Weller and Perryman 2019, Perryman et al. 2021, Stewart and Weller 2021, Eguchi et al. 2022a). Briefly, a rotating pair of observers conducted counts of mother-calf pairs from a shore station during a watch period of, typically, a maximum of 12 hours per day. Watches were terminated due to poor weather (inclement weather, such as rain, fog, etc.), visibility or sea conditions, resulting in total daily effort frequently being below the maximum of 12 hours.

The annual survey was not conducted in 2020 due to COVID-19. In 2021, the survey was completed under COVID-related staffing restrictions, which included a three-person rather than four-person observer rotation during some weeks. Staffing limitations also resulted in one week of the 2022 survey and one week of the 2023 survey being restricted to a three-person team. During periods when the three-person rotation was in place, the maximum survey effort in a given day was limited to 9 hours rather than the typical 12 hours for a four-person rotation. This nine hour limit was instituted to prevent observer fatigue.

The previous analysis using the method of Perryman et al. (2002) was based on the following observations and assumptions. Perryman et al. (2002) determined that: (a) the number of calves passing offshore and outside of the range of shore-based observers was negligible (data from aerial surveys) and (b) the passage rates of mother-calf pairs were consistent between daytime and nighttime periods (based on recording from infrared sensors). Based on independent replicate counts from two different shore-based observation stations conducted over seven consecutive years (1994-2000), detection probability was estimated to be 0.889 (SE = 0.06375, Perryman et al. 2002). All of these assumptions were maintained for the method of Stewart and Weller (2021) and the analysis presented here.

Raw data were processed to reflect the total number of calves passing within four 3-hour periods per day and the survey effort per 3-hour period following Weller and Perryman (2019). The method of Perryman et al. (2002) used direct corrections for detection probability and effort to generate total calf production estimates. For example, if two calves were observed passing during a 3-hour period, that would be corrected for detection probability by dividing the total observed calves by 0.889, for a total estimate of 2.247 calves for that 3-hour period. The detection probability-corrected calf counts were summed for each 1-week period. Then, to account for both the portions of 3-hour watches that were terminated by poor conditions, and the unobserved night and weekend periods, the weekly total counts were multiplied by the number of hours in a week (168) divided by the total weekly effort. In 2016, for example, 22 calves were counted during the third week of survey effort (April 12-16). This was corrected to 24.747 calves to account for detection probability. There were 39.6 total hours of survey effort during that week, so the final estimate was 24.747 * (168/39.6) = 104.99. The same calculation was made for each week of the survey, and summed across weeks for a total calf estimate. Variance was incorporated via Taylor series expansion from the variance in estimated detection probability, the number of survey days, and the variance in the corrected total number of animals passing per 3-hour period (Weller and Perryman 2019).

In Stewart and Weller (2021), a Bayesian model was developed to account for uncertainty associated with detection probability, effort and unsampled periods. In addition, an estimate of a passage rate that varies by week was used to help inform the undetected calf estimates from unsampled periods. Detection probability is therefore scaled by the proportion of time within a 3-hour survey period that observers were on watch. We made the assumption that, for example, if observers were only on watch for 1.5 out of 3 hours, then the probability of detecting a whale that passes during the 3-hour period is approximately 0.889 * 1.5/3 = 0.4445. Similarly, nights and weekends were broken into 3-hour periods, each of which had 0 sightings and 0 effort. Any missing watch periods, either due to inclement weather conditions or observer limitations (i.e., the use of three-person watch teams), were also recorded as having 0 sightings and 0 effort. The detection probability during unobserved periods was therefore 0. In some years, an annual survey was concluded mid-week after three consecutive days of 0 sightings of calves. In these cases, we populated the remainder of the final week with 0 sighting and 0 effort survey periods to maintain consistency across weeks. For these years, the number of weeks surveyed was not consistent across years because of the differences in migration end dates but were instead designed to capture the full northbound migration from start to finish.

As reported by Stewart and Weller (2021), the Bayesian approach used here resulted in generally greater estimates than the earlier method by Perryman et al. (2002). The estimator in Perryman et al. (2002) was negatively biased because it did not account for whales that were not sighted when no whales were observed. Because the observed number of whales was divided by the sighting probability (0.889) to calculate "corrected" number of whales, when no whales (zero whales) were observed, the correction resulted in zero, even though it was possible that the observers missed one or more whales. The Bayesian approach somewhat alleviated the problem by assuming the binomial likelihood of observation. Details of the analytical model can be found in Stewart and Weller (2021) and Eguchi et al. (2022a).

RESULTS and DISCUSSION

Calf production

From 27 March 2023 to 26 May 2023, 409 hours of survey were completed. Daily survey effort ranged from zero to 12 hours. A total of 80 mother-calf pairs were counted, with the highest daily count of 12 pairs on 21 April 2023 or 1 calf per hour of survey effort on that day (Figure 1). The estimated number of mother-calf pairs during the 2023 migration season was 412.4 (95%CI = 321 - 524).

Total calf production of ENP gray whales has been notably low since 2019 (Figure 2). In 2022, calf production was estimated at 216.7 (SE = 33.4, 95% CI = 159-290), representing the lowest estimate on record (Eguchi et al. 2022a). While the 2023 estimate is nearly twice that number, it is markedly lower than the estimates in many other years of the time series, including those from 2011 through 2018.

This period of low calf production occurred during an Unusual Mortality Event (UME) of eastern North Pacific (ENP) gray whales that has spanned more than four years (2019-2023). In brief, from 17 December 2018 through 05 April 2023, a total of 638 gray whales stranded along the Pacific coast of North America across three countries (Canada, Mexico and United States). Two hundred and sixteen whales were reported in 2019 (including two whales from December 2018), 172 in 2020, 115 in 2021, 105 in 2022 and 30 as of 05 April 2023 (Fauquier et al. 2023).

Shore-based counts of southbound migrating gray whales off the coast of California, which began in 1967, have shown declines in the abundance of ENP gray whales during the UME. In 2016 abundance was estimated at 26,960 (95% Credible Interval: 24,420-29,830) whales, indicating that the population had roughly doubled since 1967. Since 2016, however, the population declined to 20,580 (95% Credible Interval:18,700-22,870) in 2020, to 16,650 (95% Credible Interval:15,170-18,335) in 2022, and then to 14,256 (95% Credible Interval: 13,195-16,040) in 2023 (Eguchi et al. 2023).

The results of gray whale research in the wintering areas off Mexico were recently (May of 2023) presented to the Scientific Committee of the International Whaling Commission

(IWC 2023). In summary, the data collected off Mexico in 2023 showed: (a) that body condition of whales appeared to be improving (Valerio-Conchas et al. 2023), (b) the number of strandings is decreasing (Martínez-Aguilar et al. 2023) and (c) the abundance of whales, including mother-calf pairs, is increasing over what was observed in the past several years overlapping the UME (Urbán et al. 2023). These observations from the ENP gray whale wintering areas of Mexico, in combination with the slightly higher number of calves recorded in 2023 by our survey off California, provide some early indications that the pace of the UME is slowing and may soon be approaching an end. NOAA/NMFS/SWFSC continues to closely monitor ENP gray whales with regular surveys to estimate abundance, calf production and body condition (e.g., Perryman and Lynn 2002; Perryman et al. 2002, 2021; Eguchi et al. 2022a, 2023) in order to provide the best scientific information available regarding the status of the population.

ACKNOWLEDGEMENTS

Our shore-based surveys of gray whales conducted from the Piedras Blancas Light Station would not be possible without the support and hospitality provided by U.S. Department of Interior's Bureau of Land Management. We are particularly indebted to the support, over decades, provided by John Bogacki, Jim Boucher, Ryan Cooper, and Jodie Nelson. A long list of talented field biologists contributed to this data set but the contributions by Richard Rowlett, Susan Chivers, Morgan Lynn, and Jim Gilpatrick stand out because of their talents and dedication during their 20+ years participating on the survey. Wayne Perryman pioneered this study in 1994 and lead the field effort for more than 20 years. His contributions to the science and fun of the project have everything to do with its enduring quality and success.

LITERATURE CITED

Eguchi, T., Lang, A. R. and Weller, D.W. (2022a) Eastern North Pacific gray whale calf production 1994-2022. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-667. https://doi.org/10.25923/4g6h-9129

Eguchi, T, Lang A. R., and Weller, D.W. (2022b) Abundance and migratory phenology of eastern North Pacific gray whales 2021/2022. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-668. https://doi.org/10.25923/x88y-8p07

Eguchi, T., Lang A.R., and Weller, D.W. (2023) Abundance of eastern North Pacific gray whales 2022/2023. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-680. https://doi.org/10.25923/n10e-bm23

Fauquier, D., Raverty, S., Cottrell, P., Macconnachie, S., Urbán, J. R., Viloria-Gómera, L., Martínez-Aguilar, S., Swartz, S., Huggins, J. L., Rice, J., Halaska, B., Flannery, M., Danil, K., Savage, K., Garner, M., Duignan, P., Burek Huntington, K., Weller, D. W., Stewart, J., Lefebvre, K., Gulland, F., Goldstein, T., Calambokidis, J., Moore, S., Goley, P. D., Lui, A., Anthony, S., Baker, J., Wilkinson, K., Viezbicke, J., Greenman, J., Keogh, M., Greig, D., Brill, K., Wilkin, S., and Rowles, T. (2023). Update on the eastern North Pacific gray whale (*Eschrichtius robustus*) 2019-2023 Unusual Mortality Event. Paper SC/69A/E08 presented to the International Whaling Commission's Scientific Committee. 10 pp.

IWC (2023). Report of the Scientific Committee, Bled, Slovenia, 24 April – 6 May 2023. 127 pp.

Martínez-Aguilar, S., González-Cisneros, A., Valerio-Conchas, M., Rodríguez-González, F. M., Lobo-Barrera, R., Zamora-Zavala, L. A., Olguín-Hernández, J. A., Castillo-Romero, F., Zaragoza-Aguilar, G. A., Rivera-Rodríguez, J., and López-Paz, N. (2023). Gray whale stranding records in Mexico, during UME 2019-2022: 2023 update. Paper SC/69A/CMP17 presented to the International Whaling Commission's Scientific Committee. 11 pp.

Perryman, W. L., and Lynn, M. S. (2002). Evaluation of nutritive condition and reproductive status of migrating gray whales (*Eschrichtius robustus*) based on analysis of photogrammetric data. Journal of Cetacean Research and Management 4:155-164.

Perryman, W.L., Donahue, M. A., Perkins, P.C., and Reilly, S.B. (2002) Gray whale calf production 1994-2000: Are observed fluctuations related to changes in seasonal ice cover? Mar Mammal Sci 18:121–144. doi: 10.1111/j.1748-7692.2002.tb01023.x

Perryman, W. L., Joyce, T., Weller, D. W., and Durban, J. W. (2021) Environmental factors influencing eastern North Pacific gray whale calf production 1994-2016. Mar Mammal Sci 37: 448-462. https://doi.org/10.1111/mms.12755

Rice, D.W. and Wolman, A.A. (1971) Life history and ecology of the gray whale (*Eschrichtius robustus*). Am Soc Mammal (special issue) 3:1–142.

Stewart, J.D. and Weller, D.W. (2021). Estimates of eastern North Pacific gray whale calf production 1994-2021. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-653. https://doi.org/10.25923/jebs-9k39

Weller, D.W. and Perryman, W.L. (2019) Eastern North Pacific gray whale calf production estimates 1994-2018. Present to Sci Comm Int Whal Comm 4.

Urbán, J. R., Viloria-Gómora, L., Martínez-Aguilar, S., and Swartz, S. L. (2023). Gray whale abundance in Laguna San Ignacio and the Bahía Magdalena Lagoon complex, B.C.S., Mexico in 2023. Paper SC/69A/CMP21 presented to the International Whaling Commission's Scientific Committee. 15 pp.

Valerio-Conchas, M., Martínez-Aguilar, S., Swartz, S. L., and Urbán-R., J. (2023). Gray whale's body condition in Laguna San Ignacio, B. C. S., Mexico during Unusual Mortality Event of 2019-2022: 2023 update. Paper SC/69A/CMP16 presented to the International Whaling Commission's Scientific Committee. 8 pp.

Table 1: Eastern North Pacific gray whale calf production 1994-2022 with Mean, Median, SE, 95% lower (LCL) and upper (UCL) confidence limits. Years with unusual mortality events are highlighted in gray.

Year	Mean	Median	SE	LCL	UCL
1994	1,038.9	1,027.0	99.0	873.5	1,254.5
1995	656.3	652.0	69.4	538.5	809.0
1996	1,195.1	1,184.0	108.0	1,016.0	1,420.5
1997	1,632.8	1,619.0	142.6	1,394.0	1,938.0
1998	1,435.6	1,419.0	117.3	1,253.5	1,697.0
1999	484.0	481.0	52.8	395.0	595.0
2000	318.0	315.0	36.9	254.0	403.0
2001	300.8	299.0	36.3	235.5	375.0
2002	922.3	918.0	84.3	771.5	1,105.0
2003	845.2	839.0	77.6	710.5	1,013.6
2004	1,643.4	1,636.0	145.5	1,388.5	1,958.6
2005	1,014.4	1,008.0	93.5	859.5	1,215.0
2006	1,137.6	1,132.0	106.8	958.5	1,373.5
2007	453.9	451.0	50.7	364.0	568.0
2008	612.1	608.0	62.2	501.5	750.5
2009	360.1	356.0	43.4	286.0	455.5
2010	295.3	293.0	37.4	228.5	375.0
2011	931.7	924.0	88.5	784.5	1,123.5
2012	1,266.9	1,259.0	113.4	1,067.0	1,505.5
2013	1,229.3	1,220.5	114.6	1,036.5	1,481.0
2014	1,606.7	1,589.0	142.8	1,367.0	1,912.0
2015	1,558.0	1,542.5	141.6	1,318.9	1,889.6
2016	1,458.3	1,446.5	132.4	1,236.5	1,753.5
2017	1,143.3	1,133.0	105.2	965.5	1,371.0
2018	950.2	944.0	89.6	800.5	1,152.5
2019	356.5	353.0	43.2	282.0	452.0
2021	382.3	380.0	48.1	295.0	488.0
2022	216.7	214.0	33.4	159.0	290.0
2023	412.4	411.0	51.6	321.0	524.0

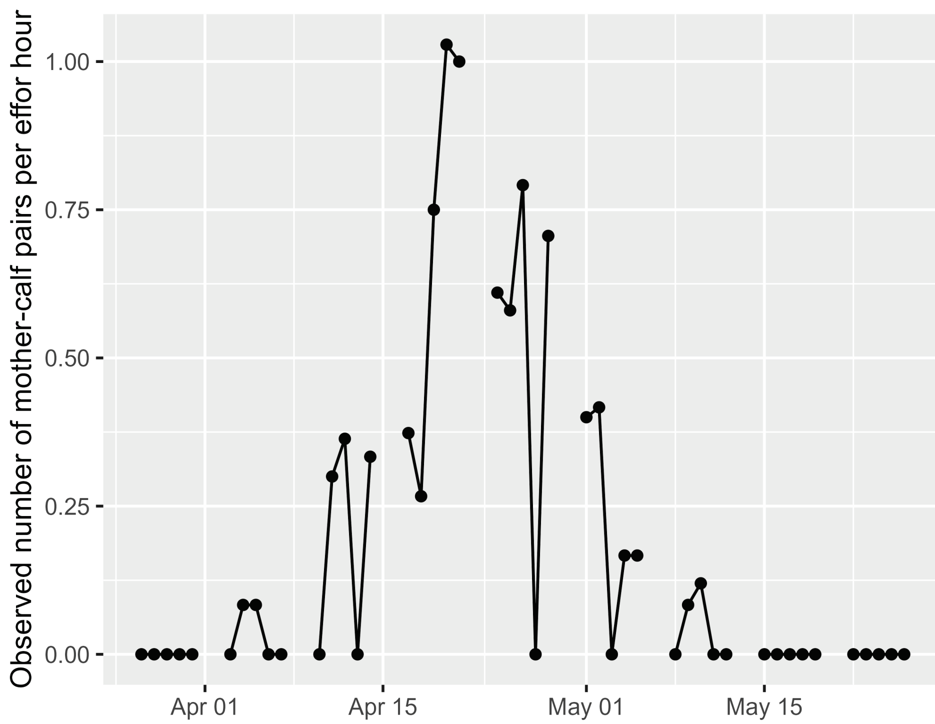

Figure 1: Observation rate (numbers per hour of survey effort) of mother-calf pairs of gray whales migrating through the sampling area off Piedras Blancas during the 2023 survey period.

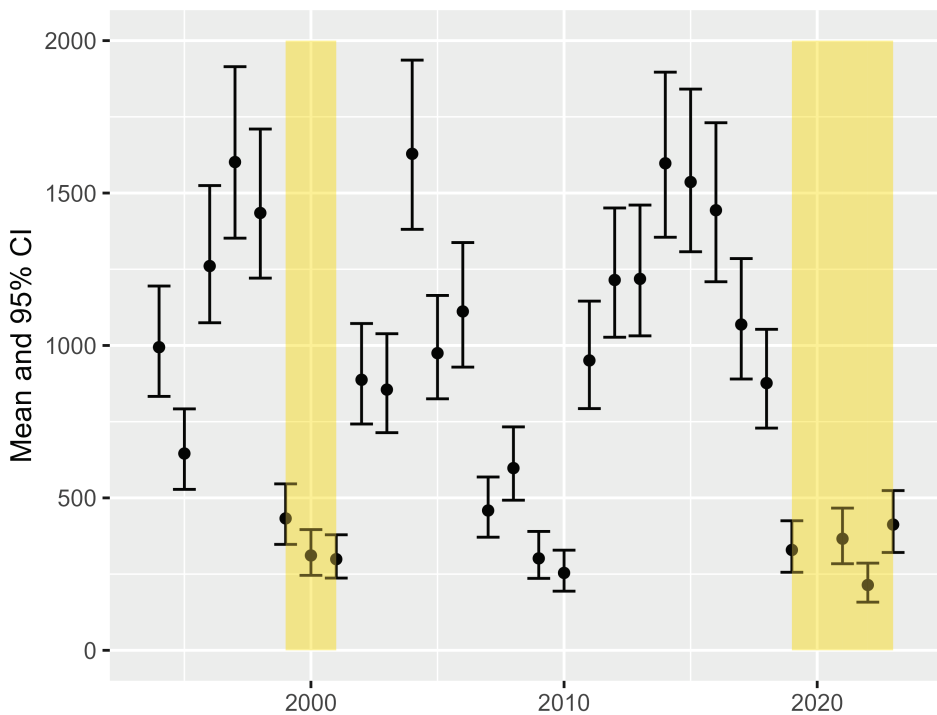

Figure 2: Estimated means and 95% CIs of the number of mother-calf pairs of north-bound gray whales off Piedras Blancas since 1994.