https://doi.org/10.25923/2y0r-e352

NOAA Technical Memorandum NMFS

MARCH 2025

UPDATED CONDITIONING RESULTS FOR THE IWC GRAY WHALE RANGEWIDE OPERATING MODEL

André E. Punt[1], John R. Brandon[2], Greg P. Donovan[3], Geof H. Givens[4], Aimée R. Lang[5], Peter Mahoney[6], Jonathan Scordino[7], and David W. Weller[5]

1 University of Washington, School of Aquatic and Fishery Sciences
Seattle, Washington

2 ICF International Inc., San Francisco, California

3 Beannacht, Haddenham, United Kingdom

4 Givens Statistical Solutions, Santa Cruz, California

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

6 NOAA Alaska Fisheries Science Center
Marine Mammal Laboratory, Seattle, Washington

7 Makah Fisheries Management, Marine Mammal Program
Neah Bay, Washington

NOAA-TM-NMFS-SWFSC-720

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

Punt, André E., John R. Brandon, Greg P. Donovan, Geof H. Givens, Aimée R. Lang, Peter Mahoney, Jonathan Scordino, and David W. Weller. 2025. Updated conditioning results for the IWC Gray Whale Rangewide Operating Model. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-720.
https://doi.org/10.25923/2y0r-e352

Updated Conditioning Results for the IWC Gray Whale Rangewide Operating Model

André E. Punt, John R. Brandon, Greg P. Donovan, Geof H. Givens, Aimée R. Lang, Peter Mahoney, Jonathan Scordino, David W. Weller

BACKGROUND

The Scientific Committee of the International Whaling Commission conducted the Gray Whale Rangewide Review (GWRR) over five workshops during 2014 to 2018 (IWC, 2015, 2016, 2017, 2018, 2019a). The objectives of these workshops included: (1) Reviewing available information on stock structure and movements of gray whales in the North Pacific, and; (2) Developing a modelling framework to evaluate the performance of quota control rules for aboriginal subsistence whaling, relative to IWC management objectives for such, given the set of plausible stock structure hypotheses developed during the workshops with associated uncertainties around spatiotemporal mixing between feeding groups. Outcomes from the GWRR included a set of plausible stock structure hypotheses. The stock structure hypotheses considered whether or not there was an extant Western Breeding Stock (WBS) as well as the extent of mixing between three putative feeding groups within the Eastern Breeding Stock (Western Feeding Group [WFG], Northern Feeding Group [NFG], and Pacific Coast Feeding Group, PCFG[1]). Two of the stock structure hypotheses (3a and 5a; Table 1) formed the base case for many of the analyses. The population dynamics models were based on 11 sub-areas within the North Pacific (Figure 1; see Annex D of IWC, 2019a) and were used to evaluate the conservation and utilization performance of aboriginal subsistence whaling take limits with a focus on the Makah Management Plan (IWC, 2019b).

The population dynamics models developed during the GWRR were fitted to: (1) three sources of abundance data (the NOAA time series of population counts off California, the estimates of abundance for the PCFG, and the estimates for the WFG / WBS); (2) the proportions of stocks / feeding groups in some of the sub-areas based on photo-identification data, and; (3) data on survival rates for the PCFG and data on bycatch by sub-area. The models also involved assumptions about the annual immigration rate from the NFG to the PCFG and the proportion of animals killed due to bycatch in fisheries from each feeding group (Annex D of IWC, 2019a). Assumptions about the annual immigration rate from NFG to the PCFG were informed by modeling simulations of PCFG population genetics under a variety of scenarios of immigration rates of NFG to the PCFG (Lang and Martien, 2012).

Subsequent to the GWRR, new information pertaining to stock structure was reviewed by the Scientific Committee of the IWC, which determined that hypotheses 4a and 7a should be elevated to high priority for inclusion in the modeling, while hypotheses 3a and 5a should be considered medium priority (IWC 2021, 2022). Hypotheses 4a and 7a consider the WFG to be a breeding stock of gray whales rather than a feeding group of the Eastern Breeding Stock. Of note, however, is that hypotheses 3a and 4a and hypotheses 5a and 7a are functionally equivalent for modelling purposes (see Table 1) and hereafter are referred to as 3a and 5a to maintain consistency with previous reporting in IWC (2019a). In addition, new data are available on removals (aboriginal takes and bycatch) and abundance (ENP gray whales from NOAA California counts and estimates of abundance for the PCFG). In 2019, the number of gray whales stranded along the coast of North

[1] WFG: animals that feed regularly off Sakhalin Island according to photo-identification data; PCFG: animals that have been observed in two or more years during the feeding season in the PCFG area (41° N to 52° N along the coast of North America, excluding Puget Sound) according to photo-identification data; NFG: animals found in other areas (and for which there is relatively little information including photo-ID) (IWC, 2019a).

America increased markedly and led to the declaration of an Unusual Mortality Event in the U.S.[2] (Fauquier et al., 2024) that extended through 2023. The NOAA population counts off California during the winter of 2019/2020, 2021/2022, and 2022/2023 indicated that the abundance had declined by ~50% since 2015 and 2016 (Stewart and Weller, 2021; Eguchi et al., 2022, 2023). The most recent estimate of abundance (Eguchi et al., 2024) suggests an increase in abundance relative to 2022/2023.

Given the recent ENP mortality event and its implications for U.S. abundance thresholds under the management plan for Makah whaling, the U.S. government requested that results from the IWC Gray Whale Rangewide Operating Model be presented in terms of ENP abundance (here referred to as NFG abundance[3]) relative to carrying capacity. This report presents such results to inform operational management questions in the U.S., in terms of assessing whether the ENP stock remains at or above its maximum net productivity level following the recent mortality event.

METHODS

The specifications for the analyses from the GWRR were modified by two changes to the model specifications (apart from extending the modelled period from 1930–2016, to 1930–2024) to (a) estimate the annual survival rate for the NFG in 1998 and 1999 for the first UME, and (b) estimate a survival rate for the NFG for 2018–2022 for the most recent UME. The analyses are conducted for an MNPL of 0.6, the value most commonly assumed when conducting assessments of baleen whales by the Scientific Committee of the IWC (see also Punt and Wade (2010, 2012)). Uncertainty is quantified using a bootstrap procedure that involves sampling abundance estimates, mixing rates, etc. from their sampling distributions (see Annex E of IWC (2019a) for specifications).

RESULTS

Model fits

Excluding additional mortality during 2019-2022 led to poor fits to the NOAA population counts from California (results not shown). Figure 2 shows the fits to the abundance estimates and Figure 3 the fits to the other data sources. The models mimic the NOAA population counts from California well (Figure 2). There is some evidence that since ca. 2018 the model predicts higher PCFG abundance than the abundance estimates themselves, although the modeled trajectories of abundance are within the confidence intervals of the estimates (Figure 2). This is because the model does not include a mechanism that would allow it to mimic the estimated negative trend in PCFG abundance over recent years (Figure 2). The fits to the estimates for the western part of the range are poorer but this is consistent with the analyses conducted for the GWRR. The fits to the mixing proportions, the immigration rate and the bycatch data are adequate, with the fit to the survival rates for the PCFG poorer (as was the case for the GWRR).

---

[2] Updated reporting on this event is available at https://www.fisheries.noaa.gov/national/marine-life-distress/2019-2023-gray-whale-unusual-mortality-event-along-west-coast-and

[3] Two stocks of gray whales are recognized in the U.S. Stock Assessment Reports: the eastern North Pacific stock, which includes the NFG and PCFG, and the western North Pacific stock, which includes the WBS and WFG (Carretta et al., 2024). The abundance of the PCFG is small (estimated at 202 individuals (SE = 19.1) in Harris et al. 2024), and thus the abundance of the NFG is representative of the US eastern North Pacific stock.

Parameter estimates of stock status relative to MNPL

Figure 4 shows the distribution of the estimates of the mortality parameters of the population dynamics model. The model fits infer that the mortality events of ENP gray whales during 1998-1999 and 2019-2022 were substantial (13% and 10% annual reductions in abundance on average but note that the 2^{nd} mortality event was longer so its effect was larger). Figure 5 shows the time-trajectories of abundance for the NFG expressed relative to current (time-invariant) carrying capacity, with the assumed value for MNPL indicated by a horizontal line. Figure 6 shows (current) carrying capacity, current (2024) 1+ abundance, and current (2024) 1+ abundance[4] relative to current carrying capacity in the form of histograms for the NFG. Table 2 lists some key management-related statistics.

Estimates of carrying capacity and status relative to OSP (Optimal Sustainable Population)

The estimates of carrying capacity for the NFG were 25,433 age 1+ gray whales (90% CI 23,975-27,795) and 25,143 age 1+ gray whales (90% CI 23,956-27,521) under hypotheses 3a and 5a, respectively (Table 2). Estimates of OSP (at maximum net productivity level of 60%) were 15,260 age 1+ gray whales and 15,086 age 1+ gray whales under hypotheses 3a and 5a, respectively. The modeled abundance of the NFG in 2024 was 17,003 (lower 20^{th} percentile 16,248) age 1+ gray whales and 17,051 (lower 5^{th} percentile 16,253) age 1+ gray whales under hypotheses 3a and 5a, respectively, which were above the respective estimates of OSP under each stock structure hypothesis.

REFERENCES

Carretta, James V., Erin M. Oleson, Karin A. Forney, Amanda L. Bradford, Kym Yano, David W. Weller, Aimée R. Lang, Jason Baker, Anthony J. Orr, Brad Hanson, Jeffrey E. Moore, Megan Wallen, and Robert L. Brownell Jr. 2024. U.S. Pacific marine mammal stock assessments: 2023. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-704. https://doi.org/10.25923/aqdn-f357

Eguchi, T., Lang, A.R. and Weller, D.W. 2022. Abundance and migratory phenology of eastern North Pacific gray whales 2021/2022. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-668.

Eguchi, T., A. R. Lang and D. W. Weller. 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.

Eguchi, T., Lang, A. and Weller, D. 2024. Abundance of eastern North Pacific gray whales 2023/2024. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-695.

Fauquier, D., Raverty, S., Cottrell, P., MacConnachie, S., Urban R., J., Viloria-Gómora, 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., Lang, A., Stewart, J.D., Lefebvre, K., Gulland, F., Goldstein, T., Calambokidis, J., Moore, S., Goley, D., Lui, A., Anthony, S., Baker, J., Wilkinson, K., Viezbicke, J., Greenman, J., Keogh, M., Greig, D., Brill, K., Wilkin, S. and Rowles, T. Eastern North Pacific Gray Whales (*Eschrichtius robustus*): an update on the 2019-2023 Unusual Mortality Event. Paper SC/69B/E01 presented to the International Whaling Commission Scientific Committee. 9pp.

Harris, J., Calambokidis, J., Perez, A. And Mahoney, P.J. 2024. Recent trends in the abundance of seasonal gray (*Eschrichtius robustus*) whales in the Pacific Northwest, 1996 - 2022. AFSC Processed Report. 2024. 18pp

IWC. 2015. Report of the Workshop on the Rangewide Review of the Population Structure and Status of North Pacific Gray Whales. *J. Cetacean Res. Manage* 16 (Suppl.) 489-528.

IWC. 2016. Report of the Second Workshop on the Rangewide Review of the Population Structure and Status of North Pacific Gray Whales**.** *J. Cetacean Res. Manage* 17 (Suppl.) 567-81.

IWC. 2017. Report of the Third Workshop on the Rangewide Review of the Population Structure and Status of North Pacific Gray Whales. *J. Cetacean Res. Manage* 18 (Suppl.) 643-71.

[4] "1+ abundance" is the total number of individuals that are aged one year or older.

IWC. 2018. Report of the Fourth Rangewide Workshop on the Status of North Pacific Gray Whales. *J. Cetacean Res. Manage* 19 (Suppl.) 521-36.

IWC. 2019a. Report of the Fifth Rangewide Workshop on the Status of North Pacific Gray Whales. *J. Cetacean Res. Manage* 20 (Suppl.) 569-99.

IWC. 2019b. Report of the Standing Working Group on Aboriginal Subsistence Whaling Management Procedures. Annex E to report of the Scientific Committee. *J. Cetacean Res. Manage* 20 (Suppl.) 120-82.

IWC. 2021. Summary of gray whale stock structure hypotheses. Annex F to the Report of the Scientific Committee. *J. Cetacean Res. Manage* 22 (Suppl.) 166-174.

IWC. 2022. Summary of gray whale stock structure hypotheses. Annex G to the Report of the Scientific Committee. *J. Cetacean Res. Manage* 23 (Suppl.) 00-00.

Lang AR, Martien. 2012. Using a simulation-based approach to evaluate plausible levels of recruitment into the Pacific Coast Feeding Group of gray whales: Progress report and preliminary results. Paper SC/M12/AWMP4 presented to the Scientific Committee of International Whaling Commission.

Punt, A.E. and P.R. Wade. 2010. Population status of the eastern North Pacific stock of gray whales in 2009. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-207, 43 p.

Punt, A.E. and P.R. Wade. 2012. Population status of the eastern North Pacific stock of gray whales in 2009. Journal of Cetacean Research and Management, 12(1):15-28.

Punt, A.E., Scordino, J., Brandon, J., Donovan, G., Eguchi, T., Givens, G.H., Lang, A.R., Mahoney, P., and Weller, D.W. 2024. Preliminary Updated Gray Whale Assessment Models and Implications for the Performance of Gray Whale Strike Limit Algorithms. SC/69A/IST/01.

Stewart, J.D. and Weller, D.W. 2021. Abundance of eastern North Pacific gray whales 2019/2020. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-639.

Table 1. Summary of the stock structure hypotheses (IWC, 2021).

Stock structure hypothesis	Key features
3a	Whales exhibit matrilineal fidelity to feeding grounds. A single breeding stock (the Eastern Breeding Stock, EBS) exists that includes the Northern Feeding Group (NFG), the Pacific Coast Feeding Group (PCFG), and the Western Feeding Group (WFG). Whales from all three feeding groups migrate to Mexico. Although a second breeding stock (the WBS) may once have existed, the WBS is assumed to have been extirpated. Southern Kamchatka and Northern Kuril Islands (SKNK) is used by both the WFG whales and the NFG whales.
4a*	Identical to hypothesis 3a, except that the WFG represents a second breeding stock of whales that mate largely with each other while migrating to Mexico (M).
4b	Identical to hypothesis 4a, except that NFG whales do not feed off SKNK. In addition, a Western Breeding Stock (WBS) exists that overwinters in Vietnam-South China Sea (VSC) and feeds in the Okhotsk Sea (OS) (but not Sakhalin Island (SI)) and SKNK. Thus, SKNK is used by both the WFG whales and the whales of the WBS.
4c	Identical to hypothesis 4a, except that on occasion whales migrating between the Sakhalin feeding region and Mexico travel through the Northern Bering and Chukchi Sea (BSCS) sub-area.
4e	Identical to hypothesis 4a, except that the western breeding stock is extant and feeds off both coasts of Japan and Korea and in the northern Okhotsk Sea west of the Kamchatka Peninsula but not off Sakhalin Island (i.e., all of the whales feeding off Sakhalin overwinter in the eastern North Pacific).
5a	Whales exhibit matrilineal fidelity to feeding grounds. Two breeding stocks exist: the EBS and the WBS. The EBS includes three feeding groups: the PCFG, NFG, and WFG that feeds off SI. The WBS whales feed in SI, OS, and SKNK and migrate to VSC to overwinter. SKNK is used by the WFG, the NFG, and the feeding whales that are part of the WBS.
7a*	Identical to hypothesis 5a, except that the WFG represents a third breeding stock of whales that mate largely with each other while migrating to M.
6b	This hypothesis assumes that the WFG does not exist, but that whales feeding in the SI sub-area represent an extant WBS that utilizes two wintering grounds (VSC and M). This hypothesis differs from hypothesis 7a, in that 1) all removals off China and Japan are assumed to be western breeding stock animals, and 2) the abundance estimates for Sakhalin are assumed to relate only to the western breeding stock.

* Base-case model

Table 2. Key population size metrics for the Northern Feeding Group for the two models. The point estimates for (current) carrying capacity and 2024 1+ abundance (with 90% bootstrap confidence intervals in parenthesis) are based on fitting the models to the actual data and the lower 20th percentiles are based on the bootstrap samples for the model outputs.

Quantity	Model 3a0	Model 5a0
(Current) carrying capacity	25433 (23,975; 27,795)	25143 (23,956: 27,251)
2024 1+ abundance		
Estimate	17003 (15,435; 18,670)	17051 (15,462; 18.694)
Lower 20th percentile	16248	16253

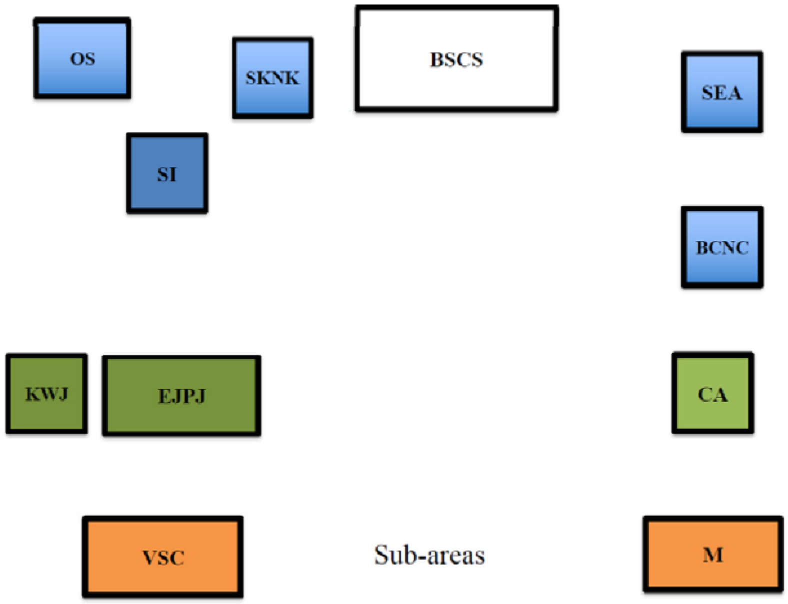

Figure 1. The sub-areas in the population dynamics model (IWC, 2019a) arranged geographically. OS = Okhotsk Sea, SI = Sakhalin Island, SKNK = Southern Kamchatka and Northern Kuril Islands, BSCS = Northern Bering and Chukchi Sea, SEA = Southeast Alaska; BCNC = British Columbia to Northern California, KWJ = Korea and the west coast of Japan, EJPJ = east coast of Japan, CA = California, VSC = Vietnam-South China Sea, M = Mexico. Colors indicate: breeding (orange), migration (green), and feeding (blue) grounds.

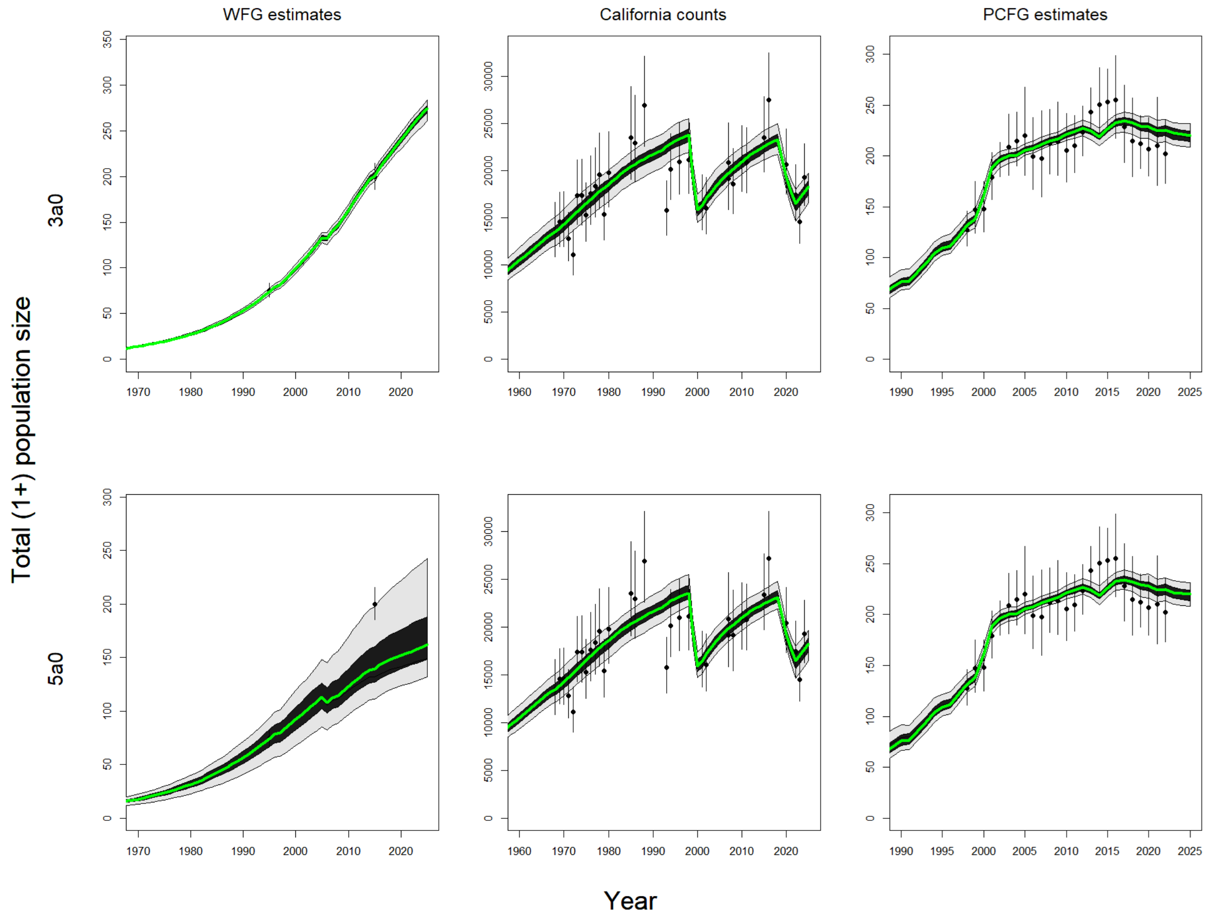

Figure 2. Fits to the abundance estimates for models 3a0 and 5a0. WFG denotes the Western Feeding Group. The green lines denote the medians of the bootstraps, black shading covers 50% of the distributions and the grey shading covers 90% of the distributions.

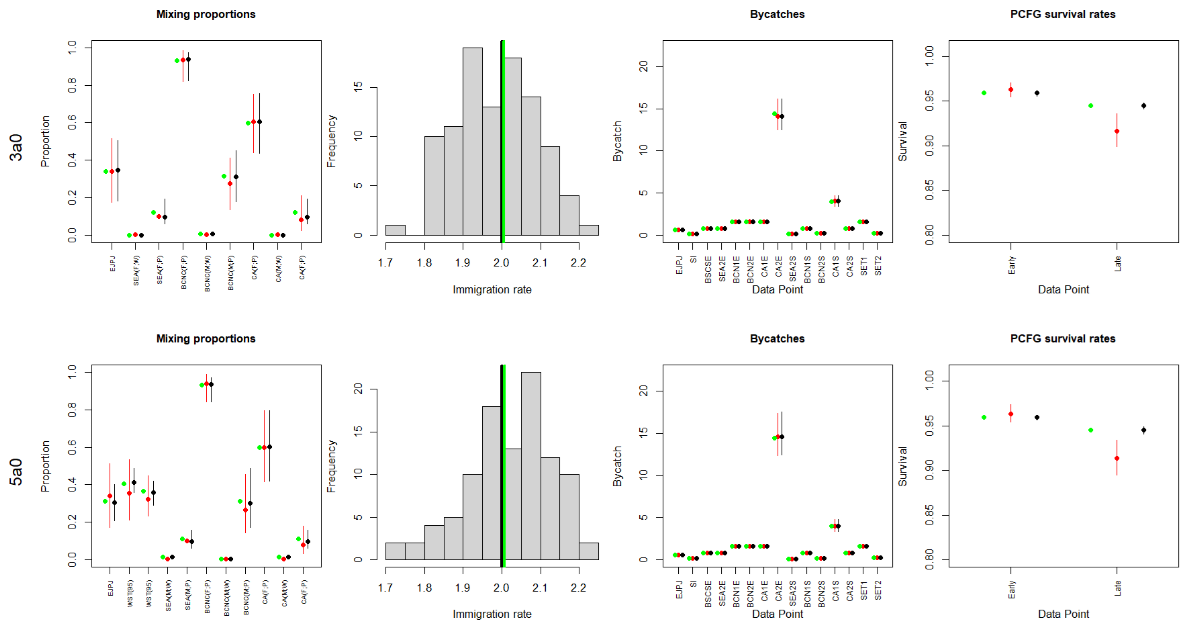

Figure 3. Fits to the mixing proportions (first column), the assumed immigration rate of 2[5] (second column; black is the value used for conditioning and green is the model prediction based on fitting to the actual data), the average bycatches (third column), and the PCFG survival rates (fourth column) for models 3a0 and 5a0. The red points are the data (with their 90% sampling confidence intervals), the green points are the model predictions based on the fit to the actual data, and the black points are the medians of the predictions based on the bootstrap replicates (with the 90% confidence intervals). The survival rate for PCFG whales includes two groups: the ‘early’ group are whales that were first observed in 1998 or prior and whales that were first observed as a calf in any year observed, and the ‘late’ group are whales first observed in 1999 or later that were not known to be a calf following the definition used in abundance estimates (Harris et al., 2024).

[5] This rate refers to the average number of NFG whales immigrating into the PCFG each year between 2001 and 2008.

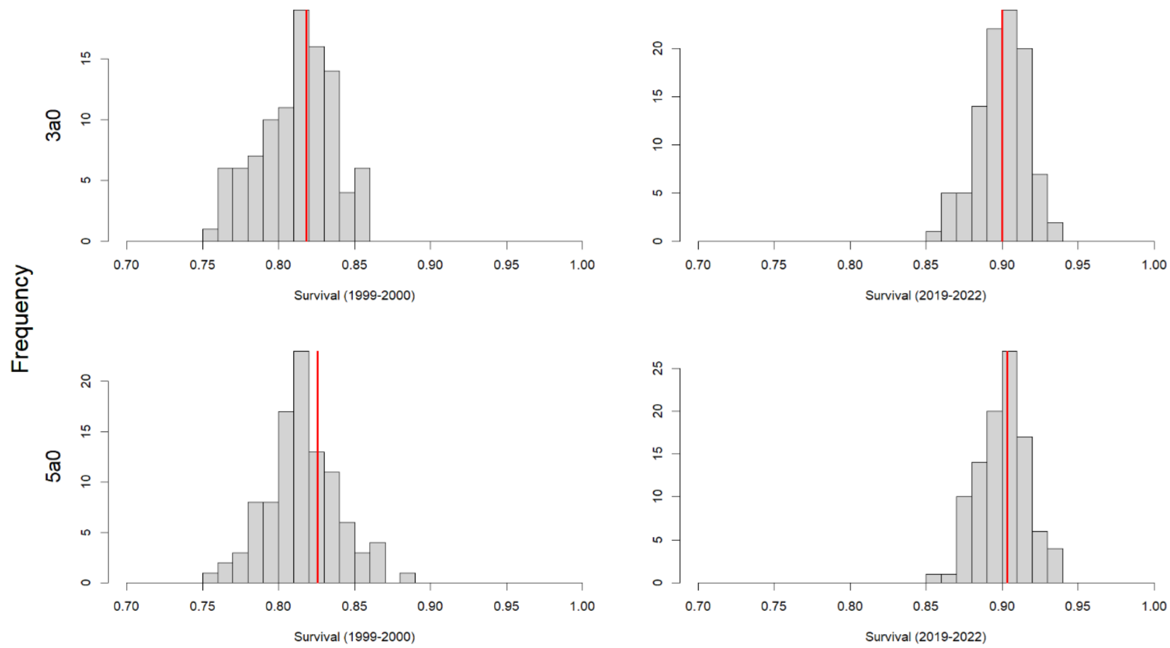

Figure 4. Bootstrap distributions for the annual survival multiplier for the two mortality events captured in the model. The vertical red lines denote the estimates from the original data for models 3a0 (upper panels) and 5a0 (lower panels).

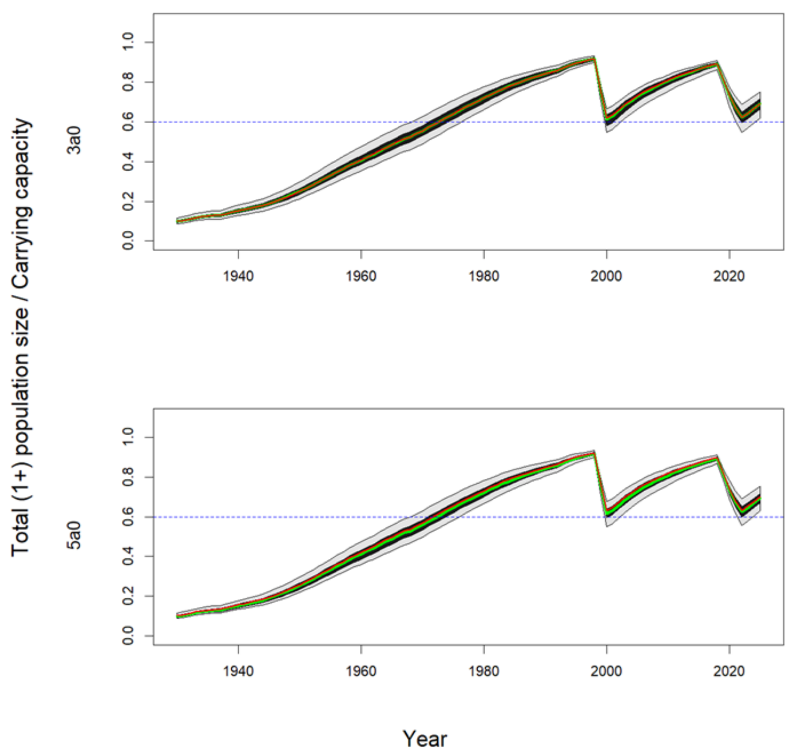

Figure 5. Bootstrap distributions for total population size relative to carrying capacity for the Northern Feeding Group based on models 3a0 and 5a0. The red lines denote the estimates from the actual data, the green lines denote the medians of the bootstraps, the black shading covers 50% of the distributions and the grey shading covers 90% of the distributions. The blue dotted line denotes the assumed MNPL of 0.6*K*.

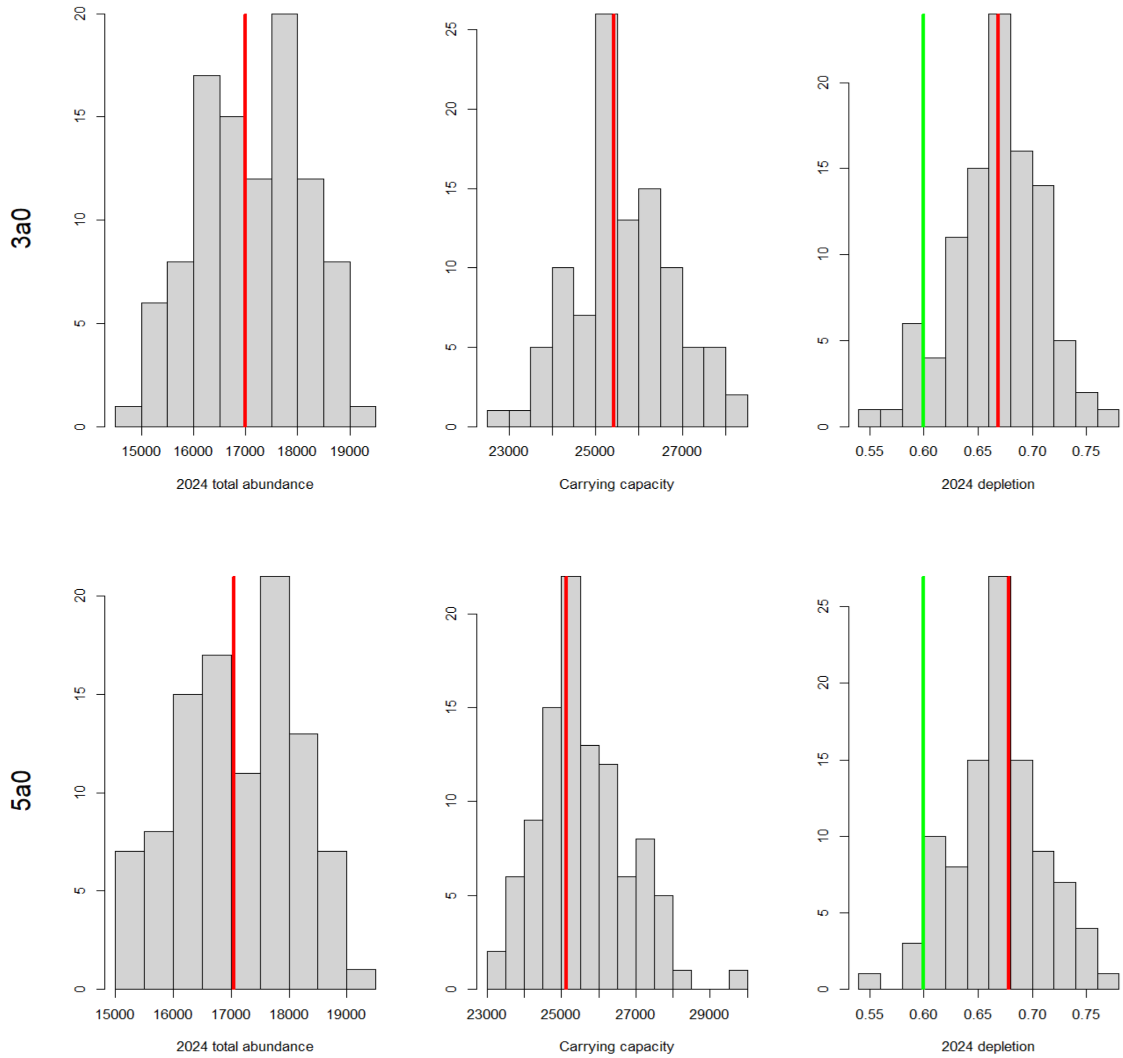

Figure 6. Bootstrap distributions for current (2024) 1+ abundance, (current) carrying capacity, and 2024 1+ abundance relative to (current) carrying capacity for the Northern Feeding Group for models 3a0 and 5a0. The red vertical lines are the estimates based on the actual data and the green vertical lines are the assumed MNPL of 0.6*K*. The red vertical lines denote the best estimates of the variables.