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Food for Thought

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What gray whales are telling us about ecosystem change in the Pacific Arctic

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Abstract

Gray whales in the eastern North Pacific have been in steep decline for the past six years, and recent estimates of abundance, reproductive output, and strandings suggest this decline is continuing and could be accelerating. These developments have been particularly alarming as gray whales are considered a species of low conservation concern given their strong recovery from post-whaling levels. However, their recovery has coincided with rapid ocean warming, leading to reduced sea ice and increased northward transport of Pacific water through the Bering Strait that is impacting prey quality and availability in gray whales' sub-Arctic and Arctic feeding areas. The recent population downturn may in fact be a predictable result of the convergence of a strong recovery with compounding climate impacts.

Gray whales in the eastern North Pacific have been in steep decline for the past 6 years, and recent estimates of abundance, reproductive output, and strandings suggest this decline is continuing and could be accelerating (Eguchi et al. 2025, Lang et al. 2025). These developments have been particularly alarming as gray whales are considered a species of low conservation concern given their strong recovery from post-whaling levels. However, their recovery has coincided with rapid ocean warming, leading to reduced sea ice and increased northward transport of Pacific water through the Bering Strait that is impacting prey quality and availability in gray whales' sub-Arctic and Arctic feeding areas (Moore et al. 2022). The recent population downturn may in fact be a predictable result of the convergence of a strong recovery with compounding climate impacts.

Commercial whaling decimated many baleen whale populations in the 19th and 20th centuries (Rocha et al. 2014), and modern conservation and management actions have been largely focused on the recovery of these depleted populations. Following the international moratorium on commercial whaling, many populations have made stunning recoveries, returning to abundance levels nearing or exceeding their pre-whaling estimates in just a few generations (Thomas et al. 2016). These recoveries have been widely lauded as success stories of the modern conservation movement. Populations of humpback and gray whales in particular have made some of the strongest recoveries (Zerbini et al. 2019). Eastern North Pacific gray whales, which migrate seasonally from overwintering lagoons in Baja California Mexico to summer feeding areas in the Pacific Arctic, were one of the first species to be delisted from the US Endangered Species Act in 1994 due to their successful recovery.

The dynamics of the gray whale population following its delisting have been turbulent. Hundreds of dead gray whales washed ashore in 1999 and 2000, leading to concern among scientists and managers. Subsequent studies indicated that the population had likely reached carrying capacity (Moore et al. 2001), with conditions in their sub-Arctic and Arctic feeding areas driving a short-term die off (Moore et al. 2003). A recent analysis of half a century of data on abundance, reproductive output, strandings, and nutritive condition of gray whales found that the gray whale population has experienced multiple declines—and subsequent rapid recoveries—in the 1980s, 1990s, and 2000s in response to variable Arctic conditions (Stewart et al. 2023).

Starting in 2019, hundreds of dead gray whales began washing up on west coast beaches yet again. Reproductive output and nutritive condition declined in synchrony with elevated mortality rates, and the population dropped from its 2018 peak of almost 23 000 whales to around 17 000 by 2023 based on estimates from an integrated population model (Stewart et al. 2023). The same analysis found that acute hu-

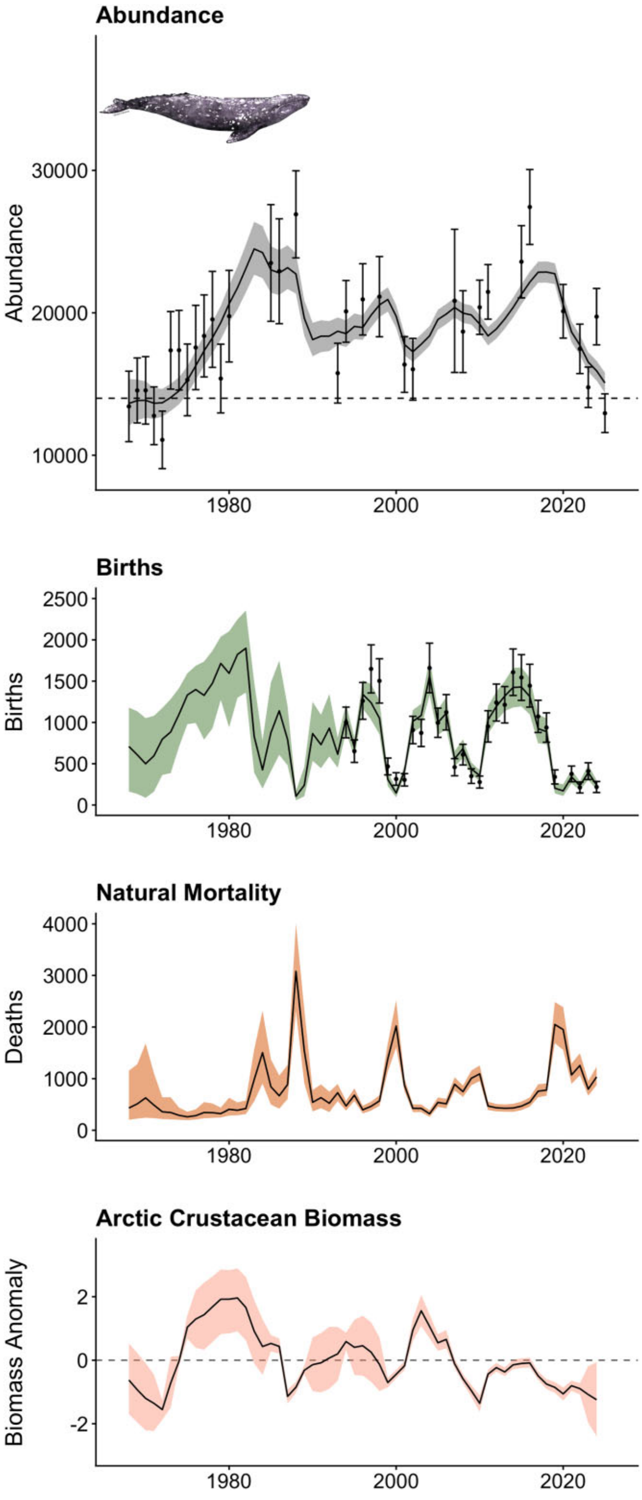

Figure 1. Gray whale population response to benthic prey biomass in the Arctic. The ongoing mortality event and reproductive failure has resulted in a > 30% abundance decline in the past 6 years, coinciding with declining benthic prey caused by Arctic warming. Survey estimates of abundance and total births are represented by points (median) and whiskers (credible intervals), and colored ribbons in all panels represent model-estimated values from the integrated population model presented in Stewart et al. (2023) and updated with data through 2025. Dashed horizontal lines are reference lines to better visualise directional trends through time.

man stressors, such as vessel strikes and entanglements, were not a major driver of mortality in the gray whale population, and post-mortem findings of stranded gray whales identified emaciation as the most common cause of death (Raverty et al. 2024). Stranding rates declined to typical levels by 2023, leading the National Marine Fisheries Service to close the Unusual Mortality Event that it had declared in 2019. However, the population has continued to decline (Eguchi et al. 2025), due in part to an ongoing reproductive failure. Calving rates have fallen to historic lows for the longest sustained period in the past thirty years of monitoring (Lang et al. 2025), and strandings are back on the rise in 2025.

It seems there is something fundamentally different happening with this current population decline. Previous population busts have been followed by rapid recoveries in birth rates and subsequent boom years within 2–3 years post-decline. We are now in the seventh year of the current downturn, and the population has declined by more than a third. What has changed? The obvious answer is the climate. Gray whale population dynamics, including previous booms and busts, are correlated with the biomass of the benthic crustaceans they target in shallow Arctic basins (Stewart et al. 2023). The productivity of these benthic systems is tightly coupled to sea ice dynamics (Joyce et al. 2023, Niemi et al. 2024) and water column circulation patterns (Moore et al. 2022). Algae grow on the underside of Arctic sea ice, and subsequently die and sink to the seafloor, where they provide a carbon source for benthic infauna. The Arctic is the most rapidly warming region on the planet, which is causing dramatic declines in sea ice in the Pacific sector feeding areas of gray whales. With sea ice melting earlier in the year, carbon export to the seafloor is reduced, leading instead to an increase in zooplankton productivity in the water column and a weakening of the pelagic-benthic coupling that has sustained benthic productivity in shallow Arctic basins (Grebmeier et al. 2006, Niemi et al. 2024). Impacts to benthic systems have been compounded by increasing water temperatures and stronger currents, altering the benthic sediment composition and habitats that the highest quality gray whale prey (benthic amphipods) rely on. Collectively, these rapid changes have caused a regime shift in gray whales' Arctic and sub-Arctic feeding areas (Grebmeier et al. 2006), reducing the quality and quantity of their benthic prey (Grebmeier et al. 2018, Stewart et al. 2023). It should come as no surprise that we are seeing significant and persistent responses to this new reality in gray whale population dynamics.

Indeed, the fluctuating trends in abundance of gray whales over the past half-century match theoretical expectations for a recovered population experiencing environmental variability and a subsequent climate-driven decline in prey availability (Stewart et al. 2025). As baleen whale populations recover from overexploitation, intraspecific competition increases, likely making recovered populations more sensitive to environmental conditions than depleted populations. Given the rapid and accelerating impacts to their high-latitude feeding areas, the ongoing decline of the gray whale population is therefore not surprising, though it is alarming. What remains to be seen is how gray whales will adapt to these new conditions. Gray whales have survived through ice ages and previous periods of global warming (Pyenson & Lindberg 2011), although the current pace of warming is much faster than changes over the past 24 000 years (Osman et al. 2021). While gray whales have evolved to feed in benthic habitats, they are flexible consumers, and have been documented feeding on pelagic prey such as zooplankton and fish (Moore et al. 2022, Webber et al. 2024). A small subpopulation of gray whales feeds on a combination of benthic and pelagic prey on the west coast of the USA and Canada (Darling et al. 1998,Hildebrand et al. 2021), which may represent the behavioral plasticity and resiliency that allowed the species to persist through previous periods of major environmental change (Pyenson & Lindberg 2011). As Arctic sea ice cover decreases, transport of warm, nutrient rich water from the North Pacific has increased (Woodgate & Peralta-Ferriz 2021), advecting krill and other pelagic prey into the Chukchi Sea and attracting previously rare baleen whales such as humpback and fin whales (Moore et al. 2022). These enhanced pelagic feeding opportunities could serve as a source of resilience for gray whales in the face of climate change.

Whales have long been recognised as valuable sentinels of ecosystem health (Moore 2008, Hazen et al. 2019). The dramatic decline we are currently seeing in the gray whale population is an indicator of fundamental disruptions to Arctic and sub-Arctic ecosystems that are most likely cascading through the food web and impacting species that are more difficult to monitor. This should not come as a surprise, given the rapid pace of warming in the Arctic. But we should be concerned by the clear message that gray whales are sending us about the health of Arctic ecosystems.

Author contributions

Joshua Stewart (Conceptualization [equal], Visualization [equal], Writing – original draft [equal]), M. Tim Tinker (Conceptualization [equal], Writing – review & editing [equal]), Jacqueline Grebmeier (Conceptualization [equal], Writing – review & editing [equal]), John Calambokidis (Conceptualization [equal], Writing – review & editing [equal]), Sue Moore (Conceptualization [equal], Writing – review & editing [equal]).

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Data availability

The data and code used to produce Fig. 1 is available at https://zenodo.org/records/8201214.

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