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EDITED AND REVIEWED BY
Mark Meekan,
University of Western Australia, Australia

*CORRESPONDENCE
Jan-Olaf Meynecke
o.meynecke@griffith.edu.au

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Editorial: Whales and climate

Jan-Olaf Meynecke[1*], Solène Derville[2] and Russell Richards[3]

[1]Whales and Climate Program, Griffith University, Gold Coast, QLD, Australia, [2]Marine Mammal Institute, Oregon State University, Newport, OR, United States, [3]School of Business, University of Queensland, Brisbane, QLD, Australia

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Editorial on the Research Topic
Whales and climate

Background

Baleen whales have exhibited alterations from their traditional migration, breeding, and feeding patterns in recent years (Ramp et al., 2015; Moore et al., 2019). Climate change is recognised as a key factor driving these shifts, leading to concerns about the recovery of whale populations. Whales face heightened vulnerability due to their extensive seasonal migrations, exposure to extreme climatic conditions from polar feeding grounds to tropical breeding grounds within a few months each year, low reproduction rates and long lifespans (Tyack, 1986; Corkeron and Connor, 1999). The future population recovery of all baleen whales is intricately tied to climate change and its impact on their feeding and breeding habitats (Thomas et al., 2016; Tulloch et al., 2019) (Figure 1).

The objective of the Whales and Climate topic was to contribute research that enhances the understanding of the intricate relationship between baleen whales and climate change. Climate impacts on the marine environment are inherently complex, marked by uncertainty, time lags, non-linearities, and a multitude of pathways, obscuring cause-and-effect relationships. The topic provided a platform to help quantify the interactions between climate change and mysticeti. It illuminated how past, present, and future climate conditions influence various aspects of the whales' life cycle, including breeding, feeding, and migration, as well as their overall recovery from whaling. Additionally, the Whales and Climate topic aimed to assess the relative vulnerability of different whale populations and species to the effects of climate change. By defining impacts and potential relationships with climate conditions, we aspired to advance modeling approaches and promote the integration of future climate projections into research on whales and climate.

The research of the 13 papers included in this Research Topic investigated body conditions, changes in migration timing, species distribution and abundance, relationships with environmental factors and the potential role of whales in carbon sequestration.

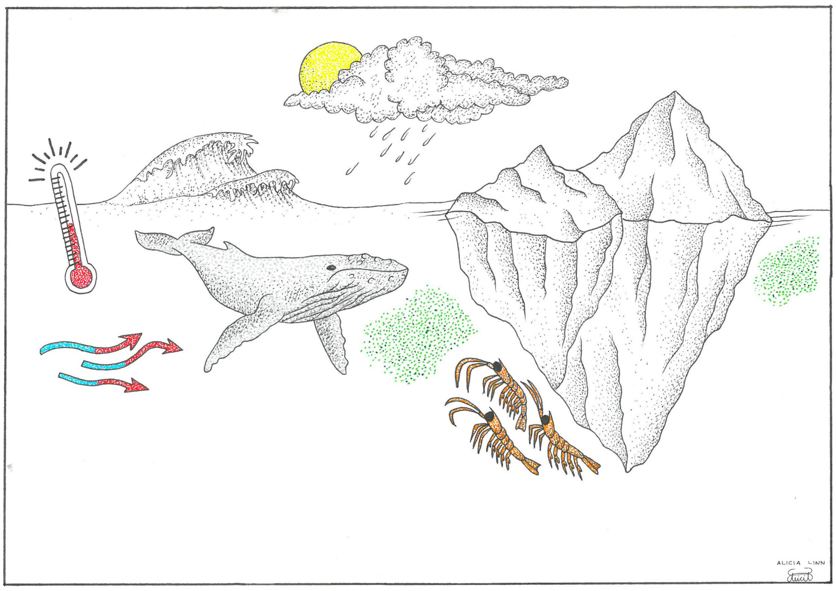

FIGURE 1
An artist impression of whales and climate change illustrating some of the factors influencing the whale´s life cycle such as volume of sea ice, phytoplankton blooms, krill abundance, wind directions and speed and ocean temperature.

Research output and findings

A review identified a number of key environmental drivers of the feeding, calving and migration areas of humpback whales (*Megaptera novaeangliae*) (Meynecke et al.). Feeding studies revealed a preference for upwelling areas with high chlorophyll-a and dynamic fronts, rich in prey (e.g., Fleming et al., 2016). Calving grounds were characterized by shallow, warm waters with gentle currents for better calf survival (e.g., Smith et al., 2012). Migration routes favoured shallow, near-shore waters with moderate temperature and chlorophyll-a levels (e.g., Zerbini et al., 2006). A review on contemporary distribution and abundance of humpback whales in the Southern Hemisphere provided a comprehensive overview of the species' current status, focusing on post-whaling trends in population growth, changes in distribution and migration patterns, and instances of supplementary feeding. These results were linked to environmental change (Seyboth et al.).

Habitat and migration shifts

The response of whales to changing climatic conditions have been documented in many regions worldwide (Simmonds and Eliott, 2009; Tulloch et al., 2019; Derville et al., 2023) and are likely reflecting adaption of baleen whales to their environment. Habitat and migration shifts were analysed in five studies. Findings from Costa Rican humpback whale breeding grounds from 2000 to 2020 suggested that intensified warming events may reduce migration to Costa Rica, possibly leading to the whales seeking more thermally suitable areas along the Mexican-Guatemalan coasts (Pelayo-González et al.). Changes in migration patterns were also reported for humpback whales in Western Australia. The study was based on 16 years of acoustic data from Western Australia's Perth Canyon and defined trends of earlier arrival by 1.4 days/year during the northward migration, and the possibility of earlier departure during the southward migration (Gosby et al.). Sea surface temperature (SST) was identified as the most significant predictor for whale presence, with an increase of 1°C in SST corresponding to a 4.4-hour decrease in daily acoustic presence.

A change in migration patterns and timing can lead to an overall habitat shift as detected in a study on cetaceans from the Northwest Atlantic. Habitat suitability was assessed for 16 species using generalized additive models based on data sets of SST, bottom temperature, distance to 1000m depth and other variables collected between 2010 and 2017 by NOAA. The outcomes suggested an average northward shift of habitats by 178 km (Chavez-Rosales et al.). In the Indian Ocean 18 years of acoustic recordings likely from pygmy blue whales (*Balaenoptera musculus brevicauda*) in relation to SST, chlorophyll-a concentration, El-Niño Southern Oscillation (ENSO), and Indian Ocean Dipole (IOD) showed that whale songs increased annually. The early arrival and greater duration of presence in Chagos Archipelago was correlated with higher chlorophyll-a concentration and positive IOD phases (Huang et al.). Similar shifts in call detections were presented in a study from the eastern Indian Ocean on pygmy blue whales (Truong and Rogers). Analysing 16 years of acoustic data from Cape Leeuwin, the authors correlated migration of pygmy blue whales in the eastern Indian Ocean with environmental drivers. They found increased whale calls during La Niña years, particularly linked to enhanced productivity in the Great Australian Bight and Indian Ocean feeding areas.

The warming of whale feeding grounds has profound effects on whales ranging from the establishment of new feeding areas, reduction of time spend in traditional feeding grounds and shifts in migration routes (Cabrera et al., 2022; Pendleton et al., 2022).

However, the warming of breeding areas also poses an additional challenge for whales. High-resolution SST projections, showed that by the end of the century, 35% of humpback whale breeding areas in Hawaii may surpass or approach current temperature thresholds under a moderate emission scenario, rising to 67% under intensive emissions (Hammerstein et al.).

Body conditions and feeding

Body condition of whales can serve as an environmental indicator that reflects changes in the marine ecosystem due to their position in food webs and sensitivity to alterations (e.g., George et al., 2015; Christiansen et al., 2020). Body conditions of blue whales (*Balaenoptera musculus*) were assessed on the west coast of the US from photographs collected from 2005-2018 (Wachtendonk et al.). This analysis revealed that better body conditions were associated with negative Pacific Decadal Oscillation (PDO). Poor body conditions were detected during a marine heat wave. More detailed assessment of body conditions can be undertaken using aerial photogrammetry (Christiansen et al., 2020). A study found declining body conditions from gray whales (*Eschrichtius robustus*) documented in the Arctic and sub-Arctic region and the Oregon coast vary greatly amongst sub-groups depending on the impact climate change has on their distinct feeding grounds.

Due to low population sizes, northern right whales (*Eubalaena glacialis*) are particularly vulnerable to environmental variability driven by climate change (Meyer-Gutbrod et al., 2021). Collection of long-term data sets such as photo identification of individual whales can serve as valuable tools to assess reproduction rates in relation to climate change. Right whales utilising the Gulf of St. Lawrence since 2015 exhibited increased birthing rates, with maternal behavior guiding offspring habitat use (Bishop et al.). This shift was attributed to increased water temperature and productivity in the region.

Shifts in feeding location can also be detected through stable isotopes (Best and Schell, 1996). Linking stable isotopes extracted from baleen from humpback whales and southern right whales (*Eubalaena australis*) (1963-2019) with large scale climate indices such as Southern Annular Mode (SAM) revealed Western Pacific humpback whales exhibited elevated isotopes during La Niña and positive SAM phases, possibly due to reduced feeding opportunities (Dedden and Rogers). In the Indian Ocean, the opposite occurred, suggesting improved feeding during positive SAM phases.

Whales play vital roles in marine ecosystems through the distribution of nutrients (Roman et al., 2014). Baleen whales may help remove carbon from the atmosphere but are unlikely to have the potential for sequestration sufficient to mitigate climate change, contrary to popular perception.

However, prioritising large-scale marine protection and addressing ecological gaps can enhance resilience and promote natural carbon capture in particular through phytoplankton (Flynn et al., 2023).

Perspectives

This Research Topic provided multidisciplinary investigations on whales and climate relations by applying state of the art methods. The findings shed light on the complex interplay of environmental and behavioral factors impacting on whale populations, emphasising the necessity of updating conservation measures amid climate-induced habitat shifts. For vulnerable species, the potential contraction or displacement of their habitats could exacerbate population declines (Stewart et al., 2023).

The following points are suggested for future research to assess impacts of climate change on whales.

1) Bridging multi-scale analysis to better understand the mechanisms behind ocean changes and whales.

2) Building large data sets based on standardised data collection and collaborations to create data-driven models for local and regional case studies with high-resolution climate data.

3) Seeking adaptive ecosystem management and urgent greenhouse gas reductions to preserve the whales' ecological integrity.

Author contributions

JM: Conceptualization, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. SD: Conceptualization, Validation, Writing – review & editing. RR: Conceptualization, Validation, Writing – review & editing.

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Conflict of interest

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