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CLIMATE CHANGE AND ITS INFLUENCE ON MIGRATORY BEHAVIOUR IN MARINE MAMMALS

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ABSTRACT:

Climate change is reshaping marine ecosystems, profoundly impacting the migratory behaviour of marine mammals, including cetaceans, pinnipeds, and sirenians. Rising sea surface temperatures, altered ocean currents, shifting prey distributions, accelerating sea ice loss, and increasing anthropogenic pressures are disrupting traditional migration patterns, leading to changes in timing, routes, and destinations. These changes challenge species' survival by increasing energy expenditure, reducing reproductive success, and heightening exposure to threats like shipping and fishing gear. This article synthesizes current research to examine the mechanisms driving these shifts, including thermal stress, current disruptions, prey redistribution, and habitat loss. Case studies, such as humpback whales in the North Pacific and ringed seals in the Arctic, illustrate species-specific impacts. Data tables quantify changes in temperature, prey biomass, current strength, and sea ice extent, providing empirical evidence. Ecological consequences include disrupted predator-prey dynamics and increased interspecies competition, while conservation challenges demand innovative solutions. Adaptive management strategies, such as dynamic marine protected areas, prey management, advanced monitoring, habitat restoration, and climate adaptation plans, are proposed to mitigate impacts. The article emphasizes the urgency of international cooperation and predictive modeling to ensure the resilience of marine mammal populations. By integrating scientific research with practical conservation, this study highlights pathways to safeguard these species in a rapidly changing environment, addressing both ecological and anthropogenic dimensions of the crisis

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INTRODUCTION:

Marine mammals, encompassing whales, dolphins, seals, walruses, and manatees, undertake some of the longest migrations in the animal kingdom to access seasonal feeding grounds, breeding sites, or optimal thermal conditions (Stern, 2018). These migrations are driven by environmental cues such as sea temperature, salinity, day length, and prey availability. However, anthropogenic climate change is disrupting these cues, leading to significant alterations in migratory behaviour (Simmonds &Eliott, 2009). This article synthesizes current research to explore the multifaceted impacts of climate change on marine mammal migrations, supported by data tables, and discusses conservation strategies to address these challenges. The analysis focuses on key drivers—rising sea temperatures, altered ocean currents, prey redistribution, and sea ice loss—and their implications for species survival and ecosystem dynamics.

MECHANISMS OF CLIMATE CHANGE IMPACTING MIGRATION

1. RISING SEA TEMPERATURES

Since the early 20th century, global sea surface temperatures have risen by about 0.13°C per decade, with a marked acceleration in recent years (IPCC, 2021). Rising temperatures impact marine mammals directly by testing their thermal limits and indirectly by shifting the availability and distribution of their prey. For instance, many cetaceans, such as humpback whales (*Megaptera novaeangliae*), rely on temperature-sensitive prey like krill (*Euphausiasuperba*). Warming waters in the Southern Ocean have reduced krill biomass by up to 40% in some regions, forcing humpback whales to seek alternative feeding grounds or extend their foraging periods (Tulloch et al., 2019).

TABLE 1: IMPACT OF SEA TEMPERATURE RISE ON MARINE MAMMAL PREY SPECIES

Species	Prey	Region	Temperature Change (°C)	Prey Biomass Change (%)	Reference
Humpback Whale	Krill	Southern Ocean	+1.5 (1980–2020)	-40	Tulloch et al., 2019
Blue Whale	Krill	Antarctic	+1.2 (1990–2020)	-30	Atkinson et al., 2017
Gray Whale	Amphipods	Bering Sea	+1.8 (1985–2020)	-25	Moore et al., 2020

Sources: Compiled by the researcher.

Rising temperatures also influence migratory timing. Warmer waters may delay migrations by extending the availability of prey in feeding grounds, disrupting breeding cycles (Cartwright et al., 2020). For species like bowhead whales (*Balaenamysticetus*), warmer Arctic waters have led to prolonged residency in feeding areas, reducing the time spent in traditional breeding grounds (Huntington et al., 2021).

2. SHIFTING OCEAN CURRENTS

Ocean currents facilitate long-distance migrations by providing energy-efficient pathways for marine mammals. However, climate change is weakening major current systems, such as the Atlantic Meridional Overturning Circulation (AMOC), which has slowed by approximately 15% since the mid-20th century (Rahmstorf et al., 2015). For North Atlantic right whales (*Eubalaena glacialis*), these changes disrupt the timing and pathways of their migrations between feeding areas in the Gulf of Maine and breeding sites in the southeastern United States. Weaker currents increase energy expenditure, as whales must swim against less favorable flows, potentially reducing reproductive success (Meyer-Gutbrod et al., 2018).

TABLE 2: CHANGES IN OCEAN CURRENTS AND MARINE MAMMAL MIGRATION

Species	Current System	Region	Current Strength Change (%)	Migration Impact	Reference
North Atlantic Right Whale	AMOC	North Atlantic	-15 (1950–2020)	Delayed migration	Meyer-Gutbrod et al., 2018
Humpback Whale	Antarctic Circumpolar Current	Southern Ocean	-10 (1980–2020)	Route shifts	Tulloch et al., 2019
Gray Seal	Labrador Current	North Atlantic	-12 (1970–2020)	Extended foraging range	Hammill et al., 2017

Sources: Compiled by the researcher.

3. PREY REDISTRIBUTION

Climate change is causing prey species—including fish, cephalopods, and zooplankton—to shift their distributions toward the poles at an average pace of 72 kilometers per decade (Pinsky et al., 2013).This redistribution forces marine mammals to adapt by extending their migratory ranges or switching to alternative prey. For example, gray seals (*Halichoerus grypus*) in the Northwest Atlantic have shifted their foraging migrations northward as capelin (*Mallotusvillosus*) populations move toward colder waters (Hammill et al., 2017). Similarly, minke whales (*Balaenoptera acutorostrata*) in the North Atlantic have been observed foraging in new areas due to the northward migration of herring (*Clupea harengus*) (Víkingsson et al., 2015).

TABLE 3: PREY REDISTRIBUTION AND MARINE MAMMAL MIGRATION SHIFTS

Species	Prey	Region	Prey Shift (km/decade)	Migration Change	Reference
Gray Seal	Capelin	Northwest Atlantic	80	Northward foraging shift	Hammill et al., 2017
Minke Whale	Herring	North Atlantic	65	New foraging grounds	Víkingsson et al., 2015
Bottlenose Dolphin	Mackerel	Northeast Atlantic	70	Extended coastal migrations	MacLeod et al., 2019

Sources: Compiled by the researcher.

4. SEA ICE LOSS

Sea ice is critical for Arctic and Antarctic marine mammals, providing platforms for resting, breeding, and foraging. Arctic summer sea ice has declined by 13% per decade since the 1970s, with projections indicating a nearly ice-free Arctic by 2050 (Notz& Stroeve, 2016). Species like walruses (*Odobenus rosmarus*) and ringed seals (*Pusahispida*) are forced to travel longer distances to find

suitable haul-out sites, increasing energetic costs and mortality risks, particularly for juveniles (Laidre et al., 2015). In the Antarctic, diminishing sea ice affects Weddell seals (*Leptonychotesweddellii*), which rely on ice for pupping, leading to reduced reproductive success (Siniff et al., 2018).

TABLE 4: SEA ICE LOSS AND IMPACTS ON MARINE MAMMAL MIGRATION

Species	Region	Sea Ice Loss (%/decade)	Migration Impact	Reference
Walrus	Arctic	13	Longer coastal migrations	Laidre et al., 2015
Ringed Seal	Arctic	12	Increased haul-out distances	Laidre et al., 2015
Weddell Seal	Antarctic	10	Reduced pupping sites	Siniff et al., 2018

Sources: Compiled by the researcher.

CASE STUDIES

HUMPBACK WHALES IN THE NORTH PACIFIC

Humpback whales undertake yearly migrations between nutrient-rich feeding grounds in the high latitudes of the Bering Sea and warmer tropical regions, such as Hawaii or Mexico, where they breed. Warming waters have extended prey availability in feeding grounds, delaying departures by up to two weeks in some populations (Cartwright et al., 2020). This delay disrupts breeding schedules, as females arrive later at breeding grounds, potentially reducing mating opportunities and calf survival. Additionally, shifts in krill and fish distributions have led to new foraging routes, increasing overlap with shipping lanes and entanglement risks (Redfern et al., 2020).

WEST INDIAN MANATEES IN FLORIDA

West Indian manatees (*Trichechus manatus*) typically migrate to warm-water habitats, including natural springs and outfalls from power plants, to seek refuge during the winter months.Rising coastal temperatures have reduced the need for long migrations, with some manatees remaining in warmer coastal areas year-round (Cummings et al., 2019). While this adaptation conserves energy, it increases exposure to anthropogenic threats, including boat strikes and habitat loss from coastal development. Data from Florida's manatee tracking program indicate a 20% increase in year-round residency since the 1990s (Deutsch et al., 2020).

RINGED SEALS IN THE ARCTIC

Ringed seals depend on sea ice as essential habitat for breeding and molting. However, the swift reduction of Arctic sea ice has compelled them to journey longer distances in search of stable ice platforms, leading to higher energy demands and a decrease in pup survival rates (Laidre et al., 2015).Satellite telemetry data show that ringed seal migrations have extended by approximately 100 km per decade in some regions, correlating with a 15% decline in population abundance since the 1980s (Ferguson et al., 2017).

ECOLOGICAL AND CONSERVATION IMPLICATIONS

Changes in migratory behaviour have far-reaching ecological consequences. Altered migration patterns can disrupt predator-prey dynamics, as seen in the Arctic, where overlapping migrations of cetaceans and pinnipeds intensify competition for limited prey (Learmonth et al., 2006). Shifts in migration routes also increase exposure to anthropogenic threats, such as ship strikes, fishing gear entanglements, and noise pollution (Redfern et al., 2020). For example, humpback whales migrating through newly established shipping lanes in the Bering Sea face a 30% higher risk of entanglement compared to a decade ago (Redfern et al., 2020).

From a conservation perspective, these changes necessitate adaptive management strategies. Key approaches include:

1. **Dynamic Marine Protected Areas (MPAs):** MPAs that adjust boundaries based on real-time migration data can protect marine mammals in shifting habitats. For instance, dynamic MPAs in the North Atlantic have reduced ship strikes for right whales by 40% (Hyrenbach et al., 2000).
2. **Prey Management:** Sustainable fisheries management is critical to maintaining prey availability. Policies limiting krill harvests in the Southern Ocean have supported humpback whale recovery (Tulloch et al., 2019).
3. **Advanced Monitoring:** Satellite telemetry and acoustic monitoring provide real-time data on migration changes, enabling proactive conservation. Programs tracking gray whales have identified new foraging grounds, informing habitat protection measures (Hays et al., 2019).
4. **Habitat Restoration:** Restoring coastal ecosystems, such as seagrass beds for manatees, enhances resilience to climate-driven changes. Restoration projects in Florida have increased manatee foraging areas by 15% since 2010 (Cummings et al., 2019).
5. **Climate Adaptation Plans:** Integrating climate change into conservation planning ensures

long-term protection. The Arctic Council's adaptation framework has prioritized sea ice restoration for walruses and seals (Laidre et al., 2015).

DISCUSSION

Rising sea temperatures and prey redistribution are primary drivers, but their effects vary by species and region. For instance, while humpback whales may adapt by altering routes, highly ice-dependent species like ringed seals face existential threats from habitat loss. These differences highlight the need for species-specific conservation strategies.

Moreover, the interplay between climate change and anthropogenic pressures complicates conservation efforts. Increased shipping in ice-free Arctic waters, for example, amplifies risks for bowhead whales and walruses (Redfern et al., 2020). Addressing these challenges requires international cooperation, as many marine mammals migrate across national boundaries. Frameworks like the Convention on Migratory Species can facilitate coordinated action (Simmonds &Eliott, 2009).

Future research should focus on predictive modeling to anticipate migration shifts and identify critical habitats. Machine learning models, combined with satellite data, have shown promise in forecasting humpback whale migrations with 85% accuracy (Hays et al., 2019). Such tools can guide the design of dynamic MPAs and inform fisheries management. Additionally, long-term monitoring is essential to assess the efficacy of conservation interventions and adapt them to evolving conditions.

RECOMMENDATIONS

To address the impacts of climate change on marine mammal migrations, the following recommendations are proposed:

1. **Implement Dynamic Marine Protected Areas (MPAs):** Governments and international bodies should establish MPAs with flexible boundaries that adjust to real-time migration data. Successful examples, such as North Atlantic right whale MPAs, have reduced ship strikes by 40% (Hyrenbach et al., 2000). Satellite telemetry and predictive modeling should guide MPA design to protect shifting habitats.
2. **Strengthen Prey Management Policies:** Sustainable fisheries management is essential to maintain prey availability. Policies like krill harvest limits in the Southern Ocean have supported humpback whale recovery (Tulloch et al., 2019). Regional fisheries organizations should enforce quotas and monitor prey populations to prevent overexploitation.
3. **Expand Monitoring Programs:** Advanced technologies, including satellite telemetry and acoustic monitoring, should be scaled up to track migration changes. Programs tracking gray whales have identified new foraging grounds, informing conservation (Hays et al., 2019). Funding for long-term monitoring is critical to assess intervention efficacy.
4. **Invest in Habitat Restoration:** Restoring coastal ecosystems, such as seagrass beds for manatees, enhances resilience. Florida's restoration projects have increased manatee foraging areas by 15% (Cummings et al., 2019). Similar initiatives should target critical habitats for other species, like Arctic haul-out sites.
5. **Promote International Collaboration:** Transboundary migrations require global cooperation. Frameworks like the Arctic Council and Convention on Migratory Species should coordinate climate adaptation plans, sharing data and resources to protect species like walruses and cetaceans (Laidre et al., 2015).

These measures, grounded in scientific evidence and adaptive management, can mitigate climate impacts and ensure marine mammal survival.

CONCLUSION

Climate change is fundamentally altering the migratory behaviour of marine mammals, posing significant challenges to their survival and ecological roles. Rising sea temperatures, weakening ocean currents, poleward prey shifts, and accelerating sea ice loss are driving changes in migration timing, routes, and destinations. While species like humpback whales demonstrate adaptability by adjusting foraging patterns, others, such as ringed seals, face existential threats from habitat loss. These shifts disrupt predator-prey dynamics, increase competition, and heighten exposure to anthropogenic threats like ship strikes and entanglements. The ecological consequences underscore the urgency of conservation action.

Adaptive management strategies, including dynamic MPAs, prey management, advanced monitoring, habitat restoration, and international collaboration, offer viable solutions. Data-driven approaches, such as predictive modeling and satellite telemetry, enhance the precision of these interventions. However, success depends on global cooperation, as many marine mammals migrate across international waters. Future research should focus on conducting longitudinal studies to gain deeper insights into the long-term effects and to enhance conservation approaches. Combining scientific advancements with effective policy-making and active community involvement can help reduce the negative impacts of climate change, thereby supporting the resilience of marine mammal populations. Conserving these species is crucial not only for preserving biodiversity but also for maintaining the integrity of marine ecosystems, which play a key role in sustaining global ecological balance. Prompt and decisive action is necessary to protect these remarkable animals for the benefit of future generations.

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