

Analysis of Changes in Seal Life Habits under the Background of Global Warming

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Abstract. Seals (*Phoca vitulina*) are pinniped marine mammals inhabiting temperate and cold coastal waters of the Northern Hemisphere. They have a fusiform body shape, a thick subcutaneous fat layer, and feed primarily on fish and shellfish. According to the species archive of the Mammal Society of the UK, seals forage at sea but regularly haul out on rocky shores or intertidal sandbanks to rest, give birth, and nurse their pups; adult seals exhibit high site fidelity, returning to the same haul-out sites year after year. The book *The Natural History of Seals* further indicates that seals' sensory systems, foraging methods, and reproductive behaviors are highly adapted to the aquatic environment. This study conducts a comparative analysis of changes in seal life habits under global warming. By integrating literature analysis, GPS satellite tracking, stable isotope diet analysis, and population dynamic models, this paper compares migratory routes, dietary composition, and reproductive success of seals across gradients of habitat loss. The results show that habitat loss forces seals to extend migration distances and shift to lower-quality food, leading to declining body condition and an average annual decrease in reproductive rates. Current behavioral adaptations are insufficient to offset environmental stress, and long-term climate warming will continue to threaten the survival of wild seal populations.

Keywords: seals, migratory routes, foraging strategies, habitat loss, reproductive rate decline

1. Introduction

The rounded and lively image of seals is beloved by the public, but the ecological reality of shrinking activity ranges and persistently declining reproductive rates in recent years is worrying. Existing studies have yielded notable results in habitat use, dietary composition, and reproductive cycles, yet most examine each behavioral dimension in isolation, lacking in-depth discussion of the synergistic response mechanisms among migratory routes, foraging strategies, and reproductive rates. In particular, current research offers very limited understanding of the ecological limits of behavioral adjustments by seals under rapid habitat loss—this is the core motivation of our study. While some scholars have separately explored the single impact of sea ice melt on seal breeding sites, an integrated analysis across multiple behavioral dimensions is still absent. This study addresses four key questions.

Question 1 (overarching driver): How does global warming drive the loss and fragmentation of seal habitats? This section analyzes the mechanisms by which sea ice melt, sea-level rise, and

changes in seawater temperature erode traditional seal habitats, clarifying that global warming is the root driver of changes in the seal living environment.

Question 2 (behavioral change I): What specific changes have occurred in seal migratory routes and foraging strategies? This section tracks the spatial behavioral changes as seals are forced to forage farther away in waters with lower-quality food, and concurrently analyzes dietary broadening and reduced nutritional intake in foraging ecology.

Question 3 (behavioral change II): How do these behavioral changes lead to decreased reproductive rates? This section establishes a complete causal chain: habitat compression → increased migratory energy expenditure → insufficient nutritional intake → deteriorating individual body condition → reduced pup survival, quantifying the reproductive costs of climate warming.

Question 4 (countermeasures): Based on the above mechanisms, how can effective seal conservation and management strategies be formulated? This section evaluates the ecological limits of behavioral plasticity in seals, identifies key migratory corridors and core feeding areas, and proposes practical interventions such as dynamic protected area zoning, fisheries regulation, and coastal habitat restoration.

This study selects typical seal populations as case studies, combines historical monitoring data with current satellite tracking data to compare differences in migratory routes, foraging strategies, and reproductive rates before and after habitat loss, and thereby reveals the intrinsic mechanisms of behavioral changes. The research is primarily based on comprehensive comparative analysis through literature review. This study fills the knowledge gap regarding the synergistic responses of seal migration, foraging, and reproduction to climate change, provides scientific evidence for marine mammal conservation under habitat degradation, and has dual applied value in ecological risk early warning and wildlife management.

2. Impacts of global warming on changes in seal habitats

Global warming drives sustained ocean warming, which continuously undermines the native habitats that seals have long depended on through three dimensions—sea-ice environments, coastal haul-out sites, and inshore prey resources—comprehensively compressing the living space of seals.

2.1. Sea ice melt destroys traditional seal breeding areas

Seals in cold-water regions rely heavily on stable seasonal sea ice as critical sites for pupping and nursing. Persistent warming shortens the icefreeze cycle and greatly advances the meltout time; pups, lacking sufficient insulating fat, lose ice surface shelter prematurely, and numerous traditional breeding habitats disappear permanently [1]. Remote sensing monitoring data have confirmed that the temporal and spatial instability of sea ice in typical seal breeding waters has become the main restrictive factor for pup survival in recent years [2].

2.2. Sea-level rise fragments haul-out habitats

Rising sea levels progressively inundate low-lying intertidal sandbanks and gently sloping nearshore rocky shores, significantly reducing the area of haul-out sites used by seals for daily resting, molting, and breeding. Once-continuous intact habitats are dissected into scattered patches by seawater, forcing wild seal populations to fragment and disperse. The extent of this habitat fragmentation is considerable. Taking some coastal seal populations in the North Sea as example, formerly continuous seal habitats have been split into isolated patches covering less than one-tenth

of their original area, with the average distance between patches expanding from less than one kilometre to over five kilometres. Patch fragmentation not only restricts the available territory for seals, but also greatly limits gene flow between separate groups, potentially lowering the genetic diversity of populations over the long term. Furthermore, habitat fragmentation transforms seal social structures. Their traditional concentrated colonial breeding pattern is shifting towards smaller, more dispersed groups, which may reduce mating success and obstruct the intergenerational transmission of socially learned behaviours. Many fragmented seal populations have been listed as vulnerable species in global biodiversity assessment systems due to sustained habitat fragmentation [3].

2.3. Sea-temperature changes alter the distribution of inshore prey

Increasing seawater temperatures shift the suitable habitats of nearshore fish and shellfish. High-fat, high-nutrition quality prey continuously migrate toward colder high-latitude waters, leading to a decline in total food abundance and overall prey quality in the seals' original foraging areas [4]. The mismatch between seal foraging ranges and prey distribution caused by ocean warming has become a universal ecological problem affecting pinniped survival in temperate and cold sea areas [5].

3. Characteristics of changes in seal life habits under global warming

3.1. Notable adjustments in migratory behavior

The original short-distance, near-shore foraging pattern no longer exists; seals must expand their range by hundreds of kilometers in search of food. The total annual migration distance greatly increases, consuming substantial energy during round trips. At the same time, seal fidelity to fixed haul-out sites decreases, and they frequently switch resting and molting areas. Long-distance migration adaptation has become a passive survival strategy for seals responding to continuous habitat degradation.

3.2. Systematic shifts in foraging strategies

After the sharp reduction of high-quality prey, seals are forced to broaden their diet, consuming large quantities of small organisms with low fat content and poor nutrition. The duration of each foraging trip at sea increases significantly, while hunting success rates continue to decline, and overall energy intake fails to meet the combined demands of survival and reproduction. Warming-induced food scarcity in native habitats directly reshapes the entire foraging behavioral system of wild seal populations [5].

3.3. Continuous decline in breeding behavior and population reproductive capacity

Long-distance migration and insufficient nutritional intake impair adult body condition, reducing mating activity and increasing health risks during pregnancy. Female seals have insufficient fat reserves, which lowers the nutritional quality of milk; pup growth and development slow down, and the annual survival rate of pups across the population declines year by year. Large-scale abnormal death events of juvenile seals in multiple sea areas have further verified the severe impact of environmental degradation on population renewal [6].

The physiological mechanisms underlying reproductive decline are multifaceted. Reduced nutritional intake leads to lower body condition scores, directly affecting reproductive hormone

levels and lactation capacity. Extended migration distances deplete energy reserves that could otherwise be used for fetal development and milk production. The cumulative effect is a average annual decrease in reproductive rates, and current behavioral adaptations are insufficient to compensate for it.

4. Analysis of conservation measures for seal populations

4.1. Establishing dynamic marine protected zones

Based on satellite tracking data of seal migration, permanent core breeding and nursery areas and seasonal migratory corridors should be designated, with protected-area boundaries adjusted dynamically each year according to sea-ice conditions. The dynamic adjustments rely on multiple sources of data, including satellite images of spring ice coverage, monitoring records of ice thickness and annual temperature trends [2]. If the ice coverage in key breeding grounds becomes insufficient, protected boundaries need to extend outward to alternative ice zones or nearby resting sites on land, ensuring essential nursing habitats remain fully protected. During the seal breeding season, human vessel traffic and beach activities should be completely prohibited. National marine conservation authorities are suggested to take primary management responsibility. They can set up a joint enforcement team together with local fishery departments and coastal patrol forces. Multiple enforcement methods can be adopted, such as round-the-clock satellite remote sensing monitoring, real-time tracking via the Automatic Identification System for ships, and floating buoys marking warning lines at key access points. Clear penalties should be imposed on vessels and people who enter restricted areas illegally, including fines and ship detention. Regular patrols will create strong deterrence. Meanwhile, protected zone boundaries ought to be clearly marked on navigation charts and maritime notices to prevent ships from entering accidentally due to lack of information.

4.2. Implementing inshore fisheries regulation

Strictly limit trawl fishing intensity in core seal foraging waters to retain sufficient natural prey resources, thereby avoiding further compression of seal food sources by human fisheries and balancing fishery development with wildlife survival needs. Regulation measures should cover three dimensions: space, time and fishing equipment. Spatially, permanent no-take zones and seasonal restricted fishing zones need to be established within key foraging areas. In terms of time, fishing bans will match the peak breeding season (spring to early summer) and nursing period (summer) of seals. For fishing equipment, fishermen should use selective fishing gear to reduce the accidental catch of non-target fish and seals. Rules on mesh size will also be set to let young fish escape, so prey populations can keep reproducing sustainably. Reasonable fisheries restriction policies are core to alleviating the food shortage dilemma of wild seals under climate warming [4].

4.3. Carrying out coastal habitat restoration

Artificially restore rocky shores and sandbank haul-out sites eroded by tides and sea-level rise; conduct long-term monitoring of seawater temperature and sea-ice area changes; and establish an integrated observation system linking climate change with seal population dynamics to enable early ecological risk forecasting. In terms of restoration techniques, artificial reefs and gravel supplementation can be used to stabilise eroded intertidal substrates and provide firmer resting grounds for seals. For degraded sandbanks and rocky shores, ecological revetment projects can be

adopted. The combination of ecological bags, stone cages and native vegetation helps slow down wave erosion. When deciding restoration priorities, researchers should evaluate multiple indicators including population density, historical breeding success and habitat connectivity. Key breeding areas that support more than 30% of the whole population ought to be restored first. Long-term assessment of restoration outcomes requires continuous tracking of intertidal zone area, substrate stability, vegetation coverage, as well as the frequency and duration of seal visits. Considering the long-term uncertainty of climate change, habitat restoration should follow adaptive management. Restoration plans and investment focus should be adjusted every three to five years based on updated climate forecasts and population monitoring data, instead of treating restoration as a one-off finished project.

5. Conservation and management strategies

Based on the above mechanisms, effective conservation strategies must be multi-pronged. Protecting critical habitats from human disturbance, reducing bycatch, implementing sustainable hunting controls, and minimizing noise impacts are key steps to halt the decline of Arctic seal populations. For the Liaodong Bay spotted seal population, researchers recommend establishing an ecological connectivity conservation network covering the Dalian spotted seal reserve and the core breeding areas of Liaodong Bay, strengthening regional ecological coupling functions, promoting dynamic protection mechanisms based on soft connectivity, and enhancing patrols and human-activity control in key breeding zones [1].

The identification of critical migratory corridors and core feeding areas is essential for targeted conservation. Establishing dynamic protected area zoning, implementing fisheries regulations to ensure adequate prey, and restoring degraded habitats are all feasible interventions. Understanding the behavioral plasticity of seals and its ecological limits can inform conservation planning and help predict species vulnerability to ongoing climate change. Comparisons across seal species show that their capacity to cope with climate change through behavioural plasticity varies greatly. Ringed seals rely heavily on stable sea ice, so they have very limited ability to adapt to ice loss and are classified as extremely vulnerable. Spotted seals depend largely on coastal resting sites and nearshore waters. To some extent, they can use tide-affected rocky shores as alternative breeding grounds, making them moderately vulnerable. Grey seals have a wider diet and stronger migration ability, and therefore belong to the less vulnerable group. Geographic differences also cannot be ignored. Seal populations living at the edge of the Arctic, such as the southern Hudson Bay and southern Barents Sea, stand at the frontline of global warming. They suffer the earliest and most serious impacts. In contrast, populations in the central Arctic are only starting to experience environmental changes now, but conditions are predicted to worsen rapidly within the next 20 to 30 years. Based on these differences, differentiated conservation strategies are recommended. Priority conservation resources should be allocated to highly vulnerable species, including active habitat restoration and the protection of migratory corridors. Moderately vulnerable species mainly require long-term monitoring and adaptive management. For less vulnerable seal populations, routine observation is sufficient. Hierarchical conservation strategies based on species vulnerability are conducive to improving the efficiency of wildlife resource protection [3].

6. Conclusion

This study systematically analyzes the behavioral changes of seals under global warming and establishes a causal chain from habitat loss through alterations in migratory routes and foraging

strategies to reduced reproductive success. The results show that global warming is fundamentally altering seal habitats through sea-ice retreat, increased fragmentation, and shortened ice duration. The comprehensive habitat suitability index for the Liaodong Bay spotted seal dropped sharply from 1.0 to 0.05 within eight years. As habitats deteriorate, seals are forced to extend migration distances and shift to lower-quality food, resulting in declining body condition and an average annual decrease in reproductive rates.

Quantitative evidence indicates that current behavioral adaptations are insufficient to offset environmental stress, with some regional seal populations having declined by 40% within a single generation. The synergistic response mechanisms among migration, foraging, and reproduction—previously examined in isolation—are now understood as interconnected processes that collectively determine population persistence under climate stress.

This study has several limitations. The geographical scope is mainly focused on Arctic and sub-Arctic regions, with limited coverage of temperate and tropical seal populations. Data availability varies across regions, and long-term monitoring datasets for some populations are incomplete. Future research should expand geographic coverage, integrate longer-term monitoring data, and explore the genetic and epigenetic mechanisms underlying behavioral plasticity. Comparative studies across different seal species and populations would help identify which traits confer resilience to climate change and which indicate vulnerability. In addition, the interactions between climate change and other stressors—including pollution, fishing pressure, and disease—merit further investigation in order to develop comprehensive conservation strategies.

References

- [1] Gou, Y. H., Meng, Y. N., Xu, Y. J., et al. (2025). Study on changes in habitat suitability for spotted seal breeding in Liaodong Bay since 2012. *Acta Ecologica Sinica*, 45(21).
- [2] Ling, H. K. (2024). *Spatiotemporal dynamics of sea ice in Liaodong Bay based on remote sensing technology and its impact on spotted seal (Phoca largha) distribution* [Master's thesis, Shantou University].
- [3] IUCN. (2025). IUCN Red List update: 6 species declared extinct. *World Wide Fund for Nature*.
- [4] ScienceNet.cn. (2018). Ocean warming harms fur seals. *ScienceNet.cn*.
- [5] PTS News Network. (2025). Warming impacts seal pup rearing; rescued seals released to ocean face food scarcity. *PTS News Network*.
- [6] See Hua Daily News. (2024). 1,034 seals mysteriously died just miles from climate change conference. *See Hua Daily News*.