The Changing Arctic inquiry

A response from the British Ecological Society to the House of Commons Environmental Audit Committee

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Founded in 1913, we are the world's oldest ecological society, with over 6,400 members worldwide. As the voice of the UK's ecological community, we communicate the value of ecological knowledge to policymakers and promote evidence-informed solutions.

Summary and introduction

1. In line with the expertise of our membership, this response will focus on the questions posed by the Committee that relate to scientific research and the environmental changes in the Arctic. This is an update version of our response to the EAC inquiry in 2017.

2. The Arctic is home to diverse, globally important and largely pristine marine, marine, freshwater and terrestrial ecosystems, harbouring over 21,000 species of mammals, birds, fish, invertebrates, plants and fungi, which benefit from large areas of intact, functioning ecosystems. The Arctic also plays a role in supporting indigenous communities, and providing globally important ecosystem services, notably climate regulation.[1,2] The Arctic[a] is also home to a diversity of marine, freshwater and terrestrial habitats, including vast expanses of lowland tundra, wetlands, mountains, extensive shallow ocean shelves, millennia-old ice shelves, pack ice and huge seabird coastal cliffs[3] (see Appendix 1 for a map of Arctic habitats).

3. Climate change is shifting the Arctic to a 'new normal', characterised by a warmer, wetter and more variable environment and reduced volume of sea and land-based ice.[4,5] Climate change also interacts with other major threats to Arctic ecosystems, including pollution, invasive alien species, industrial development and local disturbances.[6,7]

4. These environmental pressures are driving major physical and ecological change. Key changes in terrestrial ecosystems include permafrost thaw, northward shifts in the

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[a] There is no universally agreed definition of the Arctic, but it is most often defined as the region north of the Arctic Circle, 66° 34' N.

distribution of fauna and flora, increased vegetation growth, and ice sheet and glacier melt. Key changes to marine ecosystems include substantial sea ice loss, ocean acidification and spread of invasive alien species.[8,9]

5. The rapid change taking place in the Arctic has significant implications for future greenhouse gas emissions (and therefore the pace of continuing climate change), sea level rise, and weather patterns at lower latitudes, and is therefore globally relevant. The contribution of Arctic change to these global-scale trends is substantial, and in the case of sea level rise, dominant. This is reflected in estimates of the global economic consequences of Arctic warming, which under the current warming trajectory range from USD 77 billion to USD 1 trillion/year.[10]

6. Nonetheless, current knowledge of many Arctic species, ecosystems and their stressors is fragmentary, with many data and knowledge gaps remaining.

7. The creation of an office to promote UK Arctic expertise beyond NERC programmes could better recognise the wealth of research across different institutions, strengthen the UK's presence in the region and help foster international collaborations.

8. Funding a diverse range of research areas beyond the most high-profile topics was strength of the NERC research programme and should be maintained, with interdisciplinary collaboration and use of novel technologies key.

How is the arctic changing?

What are the most significant environmental changes taking place in the Arctic? What might they mean for the UK, for example in terms of sea level rise or changes to climate? How well prepared is the UK Government for these impacts?

Overview

9. The environmental threats driving change in the Arctic include climate change, invasive alien species, pollution, industrial development and local disturbances. The impacts of these threats are likely to increase over time, and to interact with each other. The most visible resulting changes in the Arctic are those to the physical environment, including temperature rise, glacier and ice sheet melt, sea ice loss and an increasing collective footprint from industrial activities. Ecological impacts are often much harder to see.

10. Climate change is the primary driver of environmental change in the Arctic. The Arctic is warming twice as fast as the global average, leading to warming and loss of permafrost, loss of sea ice and land-based ice, decreased duration and extent of snow cover, an increased frequency of some types of extreme event, and complex changes in vegetation communities.[11]

11. These impacts have global implications. The Arctic's expansive ice and snow cover reflects solar energy back into space, meaning warming-induced loss of this reflective cover accelerates warming. The loss of land-based ice also contributes substantially to global sea level rise; the Arctic has been the dominant source of global sea level rise since at least the mid-1970s, and melting rates are accelerating. Further, the terrestrial Arctic holds approximately 1672 Pg of soil organic carbon - 50% of the global total[12], prone to release in the form of greenhouse gases as the Arctic warms. The greenhouse gases could be in the form of methane or carbon dioxide, depending on the anaerobic conditions. The Global Atmospheric Lifetime[13] of methane in the atmosphere is short, meaning it can be reduced quicker than many other gases. Reducing emissions of short-lived gases such as methane will therefore result in quicker atmospheric reductions.[14]

12. Current knowledge of many Arctic species, ecosystems and their stressors is fragmentary, making detection and assessment of trends and their implications difficult for many aspects of Arctic biodiversity[2]. The 2013 Arctic Biodiversity Assessment, carried out by Conservation of Arctic Flora and Fauna (CAFF),[b] concluded that "there is a critical lack of essential data and scientific understanding to improve the planning and implementation of biodiversity conservation or monitoring strategies in the Arctic".[15]

The terrestrial environment

Permafrost thaw

13. The Arctic tundra ecosystem is characterised by permafrost – rock, soil or sediment that has been frozen for at least two consecutive years. Climate change is causing the warming and thawing of permafrost due to increased temperatures. The extent of near-surface permafrost is expected decrease significantly under a range of climate scenarios, dropping by as much as two thirds by 2080 under a high emissions scenario.[16]

14. Permafrost thaw has local and regional impacts on hydrology (distribution and movement of water), vegetation and topography (arrangement of surface land features), with the potential to create a more varied, "wetland-like" Arctic biome.[17] It also has global implications for greenhouse gas emissions and climate change; the Arctic region contains approximately 1672 Pg of soil organic carbon - 50% of the global total – much of which is stored in permafrost.[18, 19] While projections of thaw rates are highly uncertain, and the level of greenhouse gases released from permafrost has so far been small, the loss of even a small proportion of this carbon store could have significant climate impacts and permafrost thaw is expected to contribute substantially to future global greenhouse gas emissions.[20, 21]

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[b] Conservation of Arctic Flora and Fauna is the biodiversity working group of the Arctic Council and consists of National Representatives assigned by each of the eight Arctic Council Member States, representatives of Indigenous Peoples' organizations, and Arctic Council observer countries and organizations. CAFF's mandate is to address the conservation of Arctic biodiversity, and to communicate its findings to the governments and residents of the Arctic, helping to promote practices which ensure the sustainability of the Arctic's living resources.

15. Permafrost thaw forms thermokarst landforms: irregular surfaces of marshy hollows and small hummocks created by the movement of newly thawed soil, which can create a more varied ecosystem. However, permafrost thaw presents a societal and economic challenge. Infrastructure such as buildings and roads are vulnerable to structural damage, slump and collapse, with the potential cumulative cost from climate-related damage to Arctic infrastructure estimated to reach up to $5.5 billion over the course of the century.[22]

Snow and land-based ice

16. Predicted changes in snow cover vary widely over the Arctic. On average, snow cover duration and extent are decreasing, and are expected to continue to do so. This reduces habitat availability for a range of species and has implications for vegetation communities, which would typically be protected from harsh winter conditions by insulating snow cover, as well as for permafrost temperature and soil processes (and therefore rates of carbon gain and loss).

17. Glacier and ice sheet freshwater discharge (meltwater and solid ice), is rising at an accelerating rate[23] and will continue to increase in the 21st century.[24] Melting of this land-based ice in the Arctic at present is the greatest single driver of global sea-level rise, accounting for 35% of current levels. Recent work on melt processes and an acceleration of melting rates in the Arctic now suggest that IPCC predictions of global sea level rise are underestimated.[25] Increased fluxes of freshwater discharge to the oceans will also have consequences for ocean salinity, nutrient and suspended sediment concentrations[26] in marine waters. This is likely to have impacts upon marine microbial communities in Arctic regions.

18. Retreat of Arctic glaciers and expansion of proglacial forefields (land in front of a glacier previously covered by ice) will drive shifts in ecosystem species composition and biogeochemical cycling on land, with implications for the nutrient and dissolved organic matter composition of rivers sourced from these regions.[27]

19. Expansion of melt zones on glaciers and ice sheets due to climate warming will be accompanied by widening of biologically active zones on ice surfaces. In zones of net photosynthesis on glacier surfaces, organic matter accumulation and subsequent surface darkening are likely to result (the "Bioalbedo effect").[28] This surface darkening may further accentuate melt rates via a positive feedback effect.

The marine environment

Sea ice

20. Sea ice is the defining feature of the Arctic Ocean. Due to global warming, the monthly March (usually the annual maximum) ice extent for 1979 to 2017 has declined on average 2.74% per decade[29], while ice thickness in the central Arctic Ocean has declined by at least 65% overall since 1975. Arctic summer sea ice cover – and particularly the amount of multi-

year ice – is decreasing at the fastest rate, with the 2017 maximum of 14.42 million km^2 the lowest in the 38-year satellite record.[30] The ocean is predicted to become largely ice free in summer as early as the late 2030s.[31]

21. Decreased sea ice cover has a direct impact on ice-associated species and food webs, from iconic species such as polar bears to unique microbial communities; this habitat is fragmenting and there is a real risk that it may be "irrevocably lost" under predicted future climate.[32] Polar bears have become the most visible popular symbol of environmental change in the Arctic. While there is considerable uncertainty over the current and anticipated impacts of sea-ice loss on polar bear populations, expert assessment[33] and statistical models[34] have suggested that a decrease in the region of 30% is possible by the mid-21st century.

22. Arctic marine ecosystems are highly productive, and especially important for marine mammals including seal and whale species. Specialised marine algae and phytoplankton (microscopic marine plants) form the base of the food web, with timings of spring "blooms" governed by light availability and sea ice break-up. There is evidence to suggest that the timing, duration and extent of these blooms have altered as a result of decreased sea ice cover and earlier melt, with consequent disruption of the food chain, especially where mismatches develop between the timing of the bloom and zooplankton (microscopic marine animals) lifecycles. This has effects further up the food chain, affecting fish stocks and populations of some marine mammals.[35,36]

Ocean Acidification

23. Increased carbon dioxide concentrations in the atmosphere are also leading to acidification of ocean waters worldwide.[c] The Arctic Ocean is particularly vulnerable to ocean acidification as it has the ability to absorb carbon dioxide more readily than warmer waters. Recent studies suggest that acidification in the Arctic is happening at least twice as quickly as in the Atlantic or Pacific oceans.[37]

24. Ocean acidification decreases the concentration of carbonate ions (CO_3^{2-}) in the water, damaging organisms such as molluscs and shellfish that rely on these ions to form their shells and skeletons. It is anticipated that populations of such organisms will be negatively affected as ocean acidification increases. These groups contribute substantially to commercial fisheries in regions of the Arctic, and their potential decline could have significant economic as well as ecological impacts.[38]

Marine invasive species

25. As Arctic sea routes become increasingly ice free and navigable due to climate change, levels of commercial shipping traffic is anticipated to increase in the coming decades, alongside

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[c] Ocean acidification is the process by which pH levels of seawater decrease because of greater amounts of carbon dioxide (CO_2), an important greenhouse gas, being absorbed by the oceans from the atmosphere.

other industrial activity in the region such as oil and gas extraction.[39] Increased Arctic shipping alongside climate change has the potential to increase the risk of introductions of non-native species, mainly through ballast water discharge, that may displace or outcompete resident species. High densities of zooplankton, including many non-native species, are already discharged through ballast water in the Arctic, including several well-known marine invaders including barnacles and crab species.[40]

26. Marine biological invasion threats to the Arctic are poorly understood. While the number of documented established marine non-native species, including invasive species, is low in the Arctic, the detection effort is also substantially lower compared to other regions. A recent study[41] identified 23 non-native marine species in samples of ballast water, including the European green crab, considered among the 100 worst invasive species worldwide by the International Union for the Conservation of Nature (IUCN). While such species cannot currently survive Arctic conditions, predicted increases in surface temperatures and changes in salinity level for Arctic waters are likely to reduce the environmental barriers preventing colonisation.[42]

27. Current ballast water management practices do not prevent non-native species from being transferred to the Arctic. Developing appropriate management practices requires further research into the impact of translocated marine species under climate change scenarios to adequately assess risk and derive appropriate policies. The Arctic Biodiversity Assessment identified the growing need for measures to prevent the establishment of invasive non-native species in the Arctic, prioritising early detection and preventative actions in areas of human activity and disturbance. It recommended the development of an Arctic Invasive Species Strategy, which is being pursued by working groups of CAFF and Protection of the Marine Environment (PAME).[d,43]

Changes in plant ecology

28. Vegetation dynamics play a key part in determining the role of the Arctic in the global climate system, by having a central influence over the rates of important physical, chemical, and biological processes and feedbacks within the carbon and hydrological cycles.[44] However the net impact of vegetation change on Arctic carbon cycling is still uncertain. While some studies have suggested that increased vegetation growth may help offset atmospheric CO_2 increases, others have found that it may exacerbate soil carbon loss (and hence CO_2 release) due to accelerated decomposition rates.[45]

29. The distributions of many flora and fauna are shifting as the Arctic continues to warm. Boreal[e] species and ecosystems are already moving into the south of the Arctic region, and the treeline is expected to move north. In some cases, movement of species causes novel or

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[d] Protection of Arctic Marine Environment is one of six Arctic Council working groups. It is the focal point of the Arctic Council's activities related to the protection and sustainable use of the Arctic marine environment and provides a unique forum for collaboration on a wide range of activities in this regard.

[e] Boreal species have adapted to the climatic zone south of the Arctic, especially the cold temperate region dominated by forests of birch, poplar, and conifers.

altered interactions, for example outbreaks of typically boreal herbivorous insects are now occurring in some southern Arctic regions.[46] Similarly, tundra species are expected to move to higher latitudes, and some Arctic species and ecosystems could disappear, or remain only as isolated fragments in high mountain areas or islands. According to the 2013 Arctic Biodiversity Assessment, it is "possible that half the present tundra may be replaced by the end of the 21st century by shrubs and trees from the south".[47] However these predictions carry large uncertainties

30. Within the Arctic, one well-established consequence of gradual summer temperature increase is the tendency for vegetation to respond by increasing in quantity and productivity, a phenomenon known as *Arctic greening*. For much of the past 30 years (duration of satellite records) Arctic tundra has been greening on average, largely reflecting an increase in cover and height of shrubs.

31. However, while a long-term greening trend remains clear, substantial reductions in greenness have been identified at local-regional scales in recent years, with an overall *Arctic browning*[f] trend towards reduced biomass observed between 2011 and 2014.[48] Among the possible drivers of this trend are increased snow cover in certain regions, and an increasing frequency of extreme events such as extreme winter warming (which causes snow thaw and premature loss of plant dormancy) tundra fires, and outbreaks of herbivorous insects.[49,50,51] Further research is required to establish the drivers and extent of Arctic browning, which adds uncertainty as to future anticipated vegetation change, nutrient and water cycling, and permafrost degradation in the Arctic, with further implications for the Arctic carbon balance.[52]

32. Overall, vegetation in the Arctic tundra has been responding dynamically over the course of the last several decades to environmental change. These vegetation changes are not spatially or temporally consistent, suggesting that there are complex interactions between atmosphere, ground (soils and permafrost), vegetation, and herbivore components of the Arctic system.

Migratory species

33. The Arctic is home to migratory species of importance to ecosystems across the world, including Arctic breeding birds that migrate to the UK and as far south as Africa, and ocean mammals and seabirds that travel through the Bering Strait to the Pacific. The health of these ecosystems is therefore intimately connected to those in the Arctic.[53]

34. Overharvest and habitat loss and degradation threaten some Arctic migratory species, including birds throughout their global ranges. Broad-scale, multi-species trends for Arctic migratory birds are currently unavailable.[54] The Arctic Biodiversity Assessment

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[f] 'Arctic browning' is the decline of vegetation greenness in Arctic ecosystems, reflecting a loss of biomass or reduction in productivity.

recommended 'improved monitoring and research to survey, map, monitor and understand Arctic biodiversity'[55], including migratory species.

UK-led Scientific Research

How active has Government been in supporting UK research in the Arctic? What impact has the Natural Environmental Research Council's (NERC's) recent 5-year research programme had so far? Are there any gaps in the current research programme that the NERC should address in future programmes?

35. The UK is good at promoting its Arctic research and being involved in Arctic forums. However, the UK has a wealth of Arctic expertise across a number of universities and research institutes; this needs greater recognition and integration.

36. In addition to the NERC Arctic office, whose remit is primarily focused on supporting NERC funded Arctic research programmes, an office representing the broader wealth and diversity of UK Arctic expertise is necessary. This could help to better promote the UK's research and impact within international forums. Many countries have an interest in and an office for the Arctic, we need to ensure the UK does not get left behind. This is increasingly important given the recent claims of American Arctic scientists' research and data being deleted.

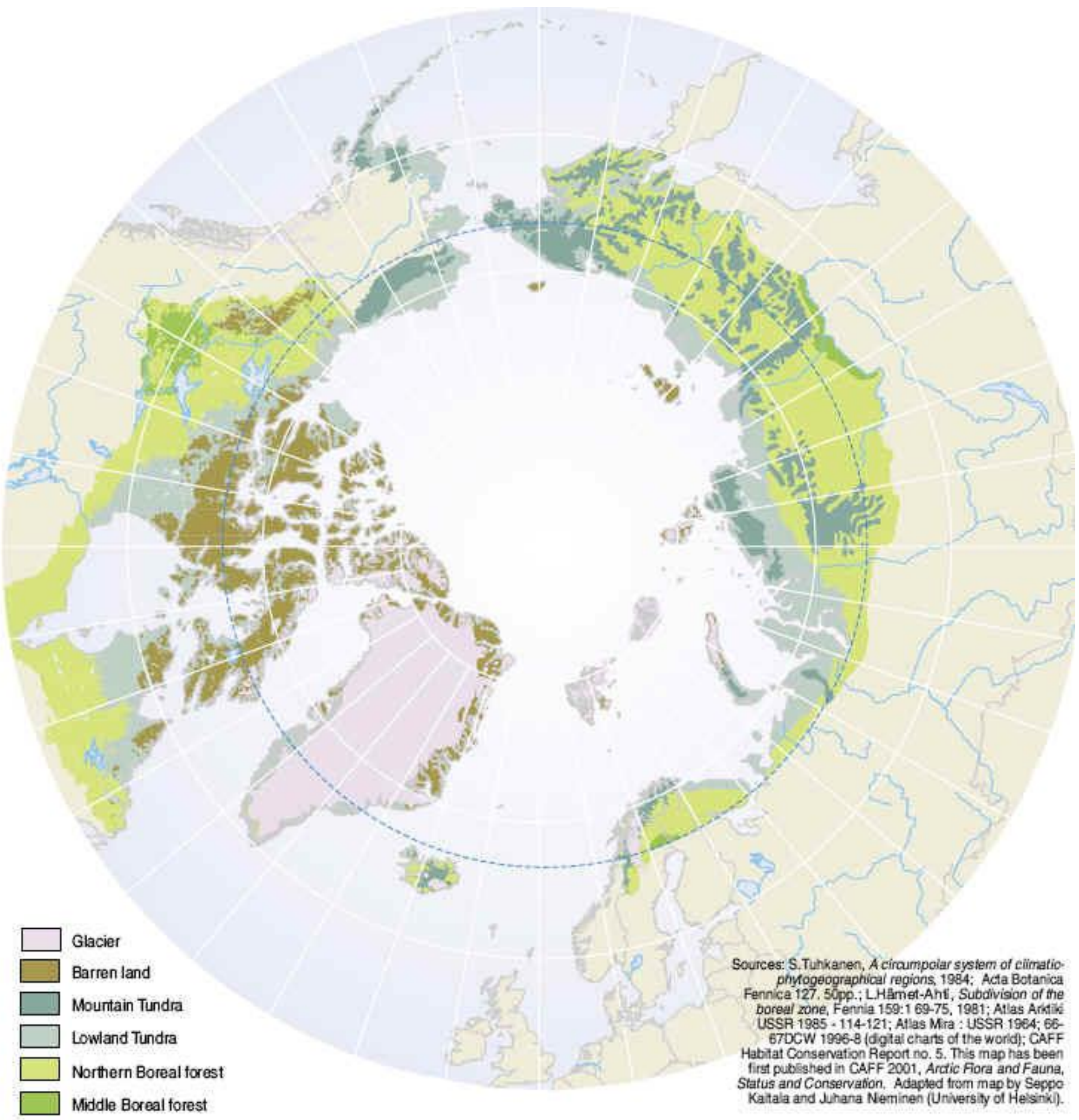
37. An office representing the wider community of Arctic experts should aim to strengthen and develop the UK's expertise and presence in the Arctic terrestrial and oceanic research and associated initiatives. It should help foster and fund international collaborations in order to strengthen the sense of a shared responsibility for understanding the Arctic and operating within it in an appropriate manner.

38. The NERC programme helped to raise the UK's standing within international Arctic research circles. The diversity of the research funded by the NERC programme was seen as very positive. It will be important to continue funding a diversity of research areas, including examining the relationship between permafrost thaw, glacier loss, vegetation change and the carbon balance and not just the flagship issues such as sea ice loss. These less publically known issues are just as alarming as the more visible issues and therefore require an equal research attention.

39. Continuing to fund a diverse range of research needs, particularly with interdisciplinary collaboration involving other research councils such as the Economic and Social Research Council (ESRC) is vital to tackle the complexities of the issues facing the Arctic; in addition to the complex set of economic benefits and environmental challenges Arctic human communities are likely to face.

40. Key to the success of future research in the Arctic (both marine and on land) will be the development of novel technologies which enable better access and higher resolution, long term temporal monitoring in challenging locations (for example, autonomous underwater vehicles, in situ sensors, improved satellite coverage).

Appendix 1: map of Arctic habitats



Sources: S.Tuhkanen, *A circumpolar system of climatic-phytogeographical regions*, 1984; Acta Botanica Fennica 127. 50pp.; L.Hämet-Ahti, *Subdivision of the boreal zone*, Fennia 159:1 69-75, 1981; Atlas Arktiki USSR 1985 - 114-121; Atlas Mira : USSR 1964; 66-67DCW 1996-8 (digital charts of the world); CAFF Habitat Conservation Report no. 5. This map has been first published in CAFF 2001, *Arctic Flora and Fauna, Status and Conservation*. Adapted from map by Seppo Kaitala and Juhana Nieminen (University of Helsinki).

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