BRITISH ECOLOGICAL SOCIETY

UK's role in Arctic sustainability

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 5,000 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.

2. The Arctic is home to diverse, globally important and largely pristine marine, freshwater and terrestrial ecosystems, harbouring over 21,000 species. Major threats to Arctic ecosystems include climate change, invasive alien species, industrial development and local disturbances. Climate change is the primary driver of environmental change in the Arctic, and exacerbates other pressures.

3. Current knowledge of many Arctic species, ecosystems and their stressors is fragmentary, with a lack of data and scientific understanding.

4. Major changes to terrestrial ecosystems include permafrost thaw, with significant implications for greenhouse gas emissions; northward shifts in the distribution of fauna and flora, including increased vegetation growth; and ice sheet and glacier melt.

5. Major changes to marine ecosystems include substantial sea ice loss, ocean acidification and increasing threats from invasive alien species.

6. 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.

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

What are the most significant environmental changes taking place in the Arctic, what is changing and what does it mean for the Arctic and the UK?

Overview

8. The Arctic[1] is 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[2] (see Appendix 1 for a map of Arctic habitats).

9. The Arctic provides a rare example of largely pristine wilderness, harbouring over 21,000 species of mammals, birds, fish, invertebrates, plants and fungi able to cope with the harsh environment of the Arctic, which benefit from large areas of intact, functioning ecosystems[2].

10. The environmental threats in the Arctic include climate change, invasive alien species, pollution, industrial development and local disturbances, and their impacts are likely to increase. The most visible changes in the Arctic are those to the physical environment, including warming temperatures, glacier and ice sheet melting, the loss of sea ice and an increasing collective footprint from industrial activities. The resulting ecological impacts are often much harder to see[2].

11. Climate change is the primary driver of environmental change in the Arctic, and often exacerbates other pressures. Climate change is fast and severe in the Arctic with temperatures rising twice as fast as in other parts of the world, leading to decreasing snow cover, permafrost extent and sea ice cover[3].

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 recent Arctic Biodiversity Assessment, carried out by Conservation of Arctic Flora and Fauna (CAFF)[4], 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"[5].

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[1] 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.

[2] Conservation of Arctic Flora and Fauna (CAFF). 2013. Arctic Biodiversity Assessment: Report for Policy Makers. CAFF, Akureyri, Iceland.

[3] AMAP, 2012. Arctic Climate Issues 2011: Changes in Arctic Snow, Water, Ice and Permafrost. SWIPA 2011 Overview Report

[4] 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. https://www.caff.is/about-caff

[5] Conservation of Arctic Flora and Fauna (CAFF) (2013) Arctic Biodiversity Assessment. Status and trends in Arctic biodiversity: synthesis. CAFF, Akureyri, Iceland.

13. The Arctic plays a key role in global climate. Its terrestrial ecosystems hold vast stores of carbon in their soils that is prone to release as greenhouse gases as the Arctic warms. The Arctic's expansive ice and snow cover is important for reflecting solar energy back into space. Warming-induced loss of this reflective cover exacerbates global warming.

The terrestrial environment

Permafrost thaw

14. The Arctic tundra ecosystem is characterised by permafrost – rock, soil or sediment that has been frozen for at least two consecutive years[2]. Climate change is causing the warming and thawing of permafrost due to increased temperatures, with the extent of near-surface permafrost expected to be reduced significantly under a range of climate scenarios[6].

15. While 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[7], it also has global implications for greenhouse gas emissions and climate change. Permafrost thaw has the potential to exacerbate climate change through the release into the atmosphere of some of the pool of organic carbon frozen in the soil, in the form of carbon dioxide and methane. It is estimated that the Arctic region contains approximately 1672 Pg of soil organic carbon, 50% of the global total[8,9]. While projections for the rates of thaw and levels of greenhouse gas release are highly uncertain, the loss of even a small proportion of this carbon store could have significant climate impacts[10].

16. Permafrost thaw forms thermokarsts: irregular surfaces of marshy hollows and small hummocks created by the movement of newly thawed soil, which can create a more varied ecosystem[7]. 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[11].

Changes in terrestrial ecology

17. Climate change is the most important driver of change in Arctic terrestrial ecosystems, with interacting pressures such as the increased footprint of human activity also important.

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[6] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

[7] Becker, M.S., Davies, T.J., Pollard, W.H. (2016) Ground ice melt in the high Arctic leads to greater ecological heterogeneity. Journal of Ecology. 104, 114-124

[8] Webb, E.E *et al* (2016) Increased wintertime CO2 loss as a result of sustained tundra warming. Journal of geophysical research: Biogeosciences. 121, 2 249–265

[9] Tarnocai, C. et al (2009) Soil organic carbon pools in the northern circumpolar permafrost region, *Global Biogeochemical Cycles,* 23 (2), DOI 10.1029/2008GB003327

[10] Schuur, E.A.G. *et al.* (2015) Climate change and the permafrost carbon feedback, *Nature,* 520, pp171-179

[11] Melvin, A.M., *et al*. (2016) Climate change damages to Alaska public infrastructure and the economics of proactive adaptation. Proceedings of the National Academy of Sciences of the United States of America. 114. 2 E122–E131

18. The distribution of flora and fauna is shifting northwards as the Arctic continues to warm. Shrubs are growing taller and spreading, boreal[12] species and ecosystems are already moving into the south of the Arctic region, and the treeline is expected to move north. Tundra species are expected to move into increasingly higher latitudes, and some Arctic species and ecosystems could disappear, or remain only as isolated fragments in high mountain areas or islands[2]. According to the recent 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"[5]. However these predictions carry large uncertainties and it is possible that new and different habitats and ecosystems could form in response to a rapidly changing climate.

19. The phenomenon of earlier seasonal vegetation growth and increased biomass (the total weight of vegetation in a given area) is known as *Arctic greening*. For much of the past 30 years (duration of satellite records) Arctic tundra has been greening. These structural changes in Arctic ecosystems alter their functioning, leading to feedbacks to climate that remain uncertain.

20. Vegetation dynamics play a key role in the changing climate system through important physical, chemical, and biological processes and feedbacks within the global carbon and hydrological cycles[13]. Carbon cycling is still uncertain. While some studies have suggested that increased vegetation growth may offset atmospheric CO_2 increases, others have found that it may exacerbate soil carbon loss due to more productive vegetation increasing decomposition rates (and hence CO_2 release) of soil organic carbon[14].

21. While the long-term greening trend is clear, recent research has observed a decline in greenness between 2011 and 2014, with an overall *Arctic browning* trend towards reduced biomass[15,16]. Possible drivers of this trend include increased snow cover in certain regions, and extreme events such as extreme winter warming and increasing tundra fires[16,17,18]. Further research is required to establish the causes and extent of this trend, which add 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.[19]

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[12] 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.

[13] Bi, J., Xu, L., Samanta, A., Zhu, Z., Myneni, R. (2013) Divergent Arctic-Boreal Vegetation Changes between North America and Eurasia over the Past 30 Years. *Remote Sensing*. 5, 2093-2112

[14] Hartley, I.P. *et al* (2012) A potential loss of carbon associated with greater plant growth in the European Arctic. Nature Climate Change. 2 DOI: 10.1038/NCLIMATE1575

[15] 'Arctic browning' is the loss of biomass and canopy in Arctic ecosystems.

[16] Phoenix, G.K., and Bjerke, J.W. (2016) Arctic browning: extreme events and trends reversing arctic greening, *Global Change Biology*, 22 (9), pp2960-2962.

[17] Epstein, H.E., *et al.* (2016) Tundra Greenness. Arctic Essays. Available: http://arctic.noaa.gov/Report-Card/Report-Card-2016/ArtMID/5022/ArticleID/283/Tundra-Greenness

[18]Rocha,A.V. *et al* (2012) The footprint of Alaskan tundra fires during the past half-century: implications for surface properties and radiative forcing, Environmental Research Letters, 7, 4

[19] Treharne, R. *et al*. (2016) Arctic Browning: vegetation damage and implications for carbon balance. Geophysical Research Abstracts Vol. 18, EGU2016-8838, 2 http://adsabs.harvard.edu/abs/2016EGUGA..18.8838T

22. 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[17].

Migratory species

23. 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[20].

24. Overharvest and habitat loss and degradation threaten some Arctic migratory species, including birds throughout their global ranges[2]. Broad-scale, multi-species trends for Arctic migratory birds are currently unavailable[21]. The Arctic Biodiversity Assessment recommended 'improved monitoring and research to survey, map, monitor and understand Arctic biodiversity' [22] , including migratory species.

Glacial ice

25. Glacier and ice sheet freshwater discharge (meltwater and solid ice), are rising[23] and will continue to increase in the 21st century[24]. This will result in increased fluxes of freshwater to the oceans, with consequences for ocean salinity, nutrient and suspended sediment concentrations[25] in marine waters. This is likely to have impacts upon marine microbial communities in Arctic regions.

26. 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[26].

27. 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, increased organic matter and surface darkening are likely

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[20] Speer, L., Nelson, R., Casier, R., Gavrilo, M., von Quillfeldt, C., Cleary, J., Halpin, P. and Hooper, P. (2017). Natural Marine World Heritage in the Arctic Ocean, Report of an expert workshop and review process. Gland, Switzerland: IUCN. 112p.
[21] Deinet, S., Zöckler, C., Jacoby, D., Tresize, E., Marconi, V., McRae, L., Svobods, M., & Barry, T. (2015). The Arctic Species Trend Index: Migratory Birds Index. Conservation of Arctic Flora and Fauna, Akureyri, Iceland. ISBN: 978-9935-431-44-8
[22] Conservation of Arctic Flora and Fauna (CAFF). 2013. Arctic Biodiversity Assessment: suggested research and conservation priorities. CAFF, Akureyri, Iceland.
[23] Bamber J *et al* (2012). Recent large increases in freshwater fluxes from Greenland into the North Atlantic. *Geophys Res Lett* **39**.
[24] IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D *et al.* (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324.
[25] Hawkings JR*, et al.* (2015) The effect of warming climate on nutrient and solute export from the Greenland Ice Sheet. *Geochemical Perspectives Letters* **1**, 94-104.
[26] Hood E *et al* (2015) Storage and release of organic carbon from glaciers and ice sheets. Nature Geosci 8, 91-96.

to result (the "Bioalbedo effect")[27]. This surface darkening may further accentuate melt rates via a positive feedback effect.

The marine environment

Sea ice

28. 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[28]. 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[29]. The ocean is predicted to become ice free in summer within a few decades[2].

29. 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[30]. 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[31] and statistical models[32] have suggested that a decrease in the region of 30% is possible by the mid-21st century.

30. 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[33,34].

Ocean Acidification

[27] Benning LG *et al* (2014) Biological impact on Greenland's albedo. *Nature Geosci* **7**, 691-691.
[28] National Snow and Ice Data Centre (2017) Arctic Sea Ice News and Analysis http://nsidc.org/arcticseaicenews/ Accessed 21.04. 2017
[29] National snow and ice data centre (2017) Arctic sea ice maximum at record low for third straight year http://nsidc.org/arcticseaicenews/ Accessed 10.4.2017
[30] Michel, C., et al (2013), Chapter 14: Marine Ecosystems, in CAFF 2013. Arctic Biodiversity Assessment. Status and trends in Arctic biodiversity. Conservation of Arctic Flora and Fauna, Akureyri
[31] O'Neill, S.J. *et al* (2009) Using expert knowledge to assess uncertainties in future polar bear populations under climate change, *Journal of Applied Ecology,* 45 (6), pp1649 – 1659.
[32] Regehr, E.V. *et al* (2016) Conservation status of polar bears (*Ursus maritimus)* in relation to projected sea-ice declines, *Biology Letters*, 12, http://dx.doi.org/10.1098/rsbl.2016.0556
[33] Leu, E *et al.* (2011) Consequences of changing sea-ice cover for primary and secondary producers in the European Arctic shelf seas: Timing, quantity, and quality. *Progress in Oceanography* **90** 18–32
[34] Larsen, J.N *et al* Polar regions. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R *et al* (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1567-1612.

31. Increased carbon dioxide concentrations in the atmosphere are also leading to acidification of ocean waters worldwide[2,35]. 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[36].

32. 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[37].

Marine invasive species

33. 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 other industrial activity in the region such as oil and gas extraction[38].

34. 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[2]. 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.

35. 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[39] 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[39].

36. Current ballast water management practices do not prevent non-native species from being transferred to the Arctic[39]. 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-

[35] 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.
[36] Di Qi et al (2017) Increase in acidifying water in the western Arctic Ocean, *Nature Climate Change*, 7, pp 195-199.
[37] Mathis, J.T. *et al* (2015) Ocean acidification risk assessment for Alaska's fishery sector. *Progress in Oceanography*. **136**, 71–91.
[38] Polar Regions Department (2013) Adapting To Change: UK policy towards the Arctic. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/251216/Adapting_To_Change_UK_policy_towards_the_Arctic.pdf
[39] Ware, C. *et al* (2016) Biological introduction risks from shipping in a warming Arctic. *Journal of Applied Ecology*. **53**, 340–349

native species in the Arctic, prioritising early detection and preventative actions in areas of human activity and disturbance[22]. 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) [40,41].

How does the Government's focus on promoting and funding UK scientific research in the Arctic increase its influence with the Arctic States and other international fora relevant to the Arctic? How does the UK's involvement in international scientific fora (such as the International Arctic Science Committee) and bilateral research projects between countries help?

37. 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.

38. 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.

39. 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.

What impact has the Natural Environmental Research Council's (NERC) recent 5 year research programme had so far? What is being done to assess its impact in the future? What is the process for deciding what follows?

40. 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.

41. Continuing to fund a diverse range of research needs, particularly with interdisciplinary collaboration involving other research councils such as the Economic and Social Research

[40] 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.

[41] Conservation of Arctic Flora and Fauna. Arctic Invasive Species. Accessed April 2017 https://www.caff.is/invasive-species

Council (ESRC) is vital to tackle the complexities of the issues facing the Arctic, as highlighted above.

42. 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