House of Lords Select Committee on the Arctic call for evidence

This evidence is submitted on behalf of the National Oceanography Centre to the House of Lords Arctic Committee on 29th September 2014.

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In addition Dr Bacon gave oral evidence to the House of Lords Arctic Committee at the hearing on Tuesday 15th July 2014.

About us:

The National Oceanography Centre[1] was formed on 1 April 2010 by bringing together into a single institution the Natural Environment Research Council's activity at the National Oceanography Centre, Southampton (NOCS) and the Proudman Oceanographic Laboratory (POL) in Liverpool. The NOC works in close partnership with the wider marine science community to create an integrated research capability. NOC is the focus for UK oceanography.

Declaration of interests:

NOC welcomes the opportunity to respond to the House of Lords Select Committee on the Arctic call for evidence. The National Oceanography Centre (NOC) is a focal point for UK Marine Science, which is carried out globally including in the Arctic and adjacent oceans. Many of its programmes are funded through public money, accessed via NERC and EPSRC as well as other government departments such as DEFRA.

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Evidence Summary:

[1] The Arctic is experiencing significant environmental changes which include:

- Rising atmospheric and oceanic temperatures
- Alterations to the hydrological cycle, and oceanic and atmospheric circulation patterns
- Melting sea and land ice, including changes to the permafrost
- Changes in the extent and thickness and age of Arctic sea ice and planetary albedo
- Ocean acidification and alterations to nutrient regimes and primary productivity

[2] Such changes have potentially global impacts, with real environmental, social and economic implications for the UK. Environmental impacts include:

- 'Spinning-up' of the Arctic Ocean through increased ocean atmospheric interactions
- Increased coastal erosion
- Landslides, earthquakes (related to both isostacy and landslides) and tsunami events
- Distribution and occurrence of biological communities, including phytoplankton and fish
- Extreme weather and storm events, including storm surges
- Sea level rise and coastal flooding

[3] Economic and social impacts, in both the near and far field (from the Arctic) include:

- Increased operation of shipping routes across the Arctic in future ice free summers
- Improved access for cable laying, renewable energy resources and mineral wealth.
- Improved commercial fishing opportunities, including UK fishing grounds.
- Disruption to native peoples

[4] Balancing economic development against preservation and protection of the natural environment will be critical as the Arctic continues to change. However, current knowledge about the Arctic is not comprehensive enough to be able to adequately inform decisions on how to best manage this environment. Consequently there is a need for improvements in:

- Continued investment (e.g. through NERC's Arctic Research Programmes) in sustained scientific research projects (including modeling, observation and paleoclimate studies) in the Arctic and adjacent waters.
- Access to the region, including diplomatic negotiations and use of novel technologies such as marine robotics.
- Access to data and data sharing to maximise value from research projects.

[5] Mitigation and adaptation strategies that the UK could be involved with in the Arctic include:

- Managing invasive species and ship emissions, ensuring compliance of trading partners with international conventions.
- Undertake environmental monitoring in the Arctic region
- Improving understanding of the flux and inventory of methane and CO_2.

[6] The current legal governance of the Arctic is through UNCLOS, of which part 13, focusing on Marine Scientific Research is seen as fit for purpose. The FCO has observer status on the Arctic Council. NOC has a NOC has a memorandum of understanding with the FCO which will facilitate information flow to and from the council. The UK governments approach, as set out in the Arctic Policy Framework seems appropriate for the future management of, and interaction with the Arctic region.

Consultation Questions:

1. What are the main issues arising from recent and expected changes in the Arctic region? How will these changes impact upon the Arctic, and what is the impact for the UK?

[7] The Arctic is experiencing significant environmental changes, affecting both continental and oceanic areas. Such changes have potentially global impacts, as the Arctic plays a critical role in the functioning and regulation of Earths environmental and climatic systems.

[8] The issues and impacts seen in the Arctic are occurring because of a warming climate. Global atmospheric temperatures have increased by 0.8°C in the last 100 years[2], with larger increases in Arctic regions[3]. These increases have mainly been attributed to rising atmospheric greenhouse gas (GHG) concentrations, released from the anthropogenic combustion of fossil fuels and other processes such as changes in land usage patterns.

[9] GHGs prevent incoming solar radiation, once absorbed by the earth from being radiated back out of the planetary system through the atmosphere. Thus energy is stored in the ocean and atmosphere causing them both to warm.

[10] Rising oceanic and atmospheric temperatures cause further global environmental issues (e.g. sea-level rise, changes to atmospheric circulation patterns and the hydrological cycle). Many of these issues are particularly important in the Arctic and in some cases have climatic feedback effects. Feedback effects further enhance the warming trends observed.

[11] As the Arctic warms the temperature difference between the poles and the mid latitudes decreases. This impacts the jet stream (the high altitude winds which affects the weather patterns in the Northern Hemisphere), slowing its speed. As it slows it tends to meander, and can drift further southwards, significantly impacting the weather in the UK. Likely consequences include heat waves in the summer, increased storminess/heavy rain, or snow in winter. Such extreme events have social and economic impacts for the UK.

1. Ice melt and changes in ocean physics

[12] Warmer atmospheric temperatures are causing an ***observed reduction in the extent and thickness of Arctic summer sea ice***. Summer 2012 resulted in the minimum recorded summer sea ice extent of less than four million square kilometres, a reduction of 45% compared to the 1980's and 1990's[4] coverage. Scientists predict that over the coming decades the Arctic Ocean will be ice free in summer, however knowing when exactly this will occur is not straightforward[5].

[13] This will allow ***shipping to operate across the Arctic in summer***, leading to further economic and commercial opportunities in the UK (discussed further in question 2). However, the opening of

shipping routes could have adverse environmental effects such as pollution from ship engine exhausts, noise/disturbance/physical impacts on marine life, and difficult-to-clear oil spills (see question 6). There may also be security implications for increased shipping routes in an ice-free Arctic. Given the remoteness of the region, search and rescue coverage may be limited, and large areas of Arctic marine space that fall under national jurisdiction of neighbouring powers may not be freely accessible by naval units without prior permission.

[14] The reduction in ice cover also ***reduces planetary albedo*** (the reflection of solar radiation), resulting in a dark-coloured ocean that absorbs more heat than the ice, which used to be present. Furthermore, melting of ice and permafrost around the Arctic Ocean rim has resulted in the increase of freshwater inputs and modifications of nutrient inputs to the Arctic Ocean.

[15] ***Arctic sea ice is becoming thinner and younger***, as each winter's growth builds upon less ice from in previous winters. In 1988 26% of the Arctic was covered in multiyear ice that was over four years old. By 2013 only 7% of the Arctic was covered by multiyear ice[6]. Increasing extents of thinner ice will result in quicker melt of sea ice each year, thereby exacerbating the overall Arctic ice loss each summer and increasing wave heights through greater interactions between the atmosphere and surface ocean. This will also affect the wider ecosystem, such as under-ice primary production, species that seek refuge and feed on sea-ice algae and species that rely on the sea ice surface for habitat.

[16] Despite likely future ice-free summers it is predicted that thin annual ice will still be formed in winter for the foreseeable future. Consequently ***seabed mountings*** will have to be used to moor any equipment all year round in the Arctic – this could include marker buoys for shipping routes and oil and gas installations which will need to be seabed mounted to avoid winter ice damage. ***Arctic bathymetry and circulation will need to be thoroughly understood*** prior to such installations. In addition the biological communities associated with the reduced environment will need to be understood if effective environmental impact assessments of any future operations are to be undertaken.

[17] The observed water column in the Arctic to date is ***highly stratified*** with a cold fresh layer at the surface overlying a denser, saltier and cold layer (known as the halocline), which insulates the surface (including sea ice) from warmer waters underneath. The currents in the Arctic are slow[7]; the waters currently circulate at approximately 1-2 cm/s, almost an order of magnitude slower than the open ocean.

[18] Scientists predict that ***removing the sea-ice will result in a 'spinning up' of the Arctic Ocean***[8], as there will be a direct link between the ocean and atmosphere. Increased wind stress at the ocean surface will transfer more momentum into the ocean and increase current speeds, to those comparable with the Atlantic Ocean. Turbulence in the ocean will increase which generates ocean mixing and enables heat stored in the deeper waters to reach the surface ocean. This rising warmer water acts as a feedback promoting further ice loss.

[19] Reductions in the sea ice extent are also ***exposing more coastal areas,*** previously covered by ice all year round. This exposure, coupled with increased current speeds is likely to result in higher rates of coastal erosion, which will need consideration in a future ice free Arctic.

[20] Despite representing ***1% of the global ocean***, the Arctic Ocean receives ***10% of the global total freshwater input***, making it prone to changes in the hydrological cycle at high northern latitudes Freshwater sources come from melting sea and land ice melt, including the melting of permafrost[9].

[21] ***Thawing of the permafrost*** is predicted to release methane into the atmosphere[10], which was previously stored in the ice as methane clathrates. Methane is a particularly strong greenhouse gas. Such methane releases are likely to cause relatively short periods of further warming in the atmosphere as methane has a residence time of approximately 10 years in the atmosphere[11]. Historical evidence of such short warming periods has been observed in the paleoclimate record.

[22] The dissociation of methane clathrates in the continental shelf under the sea may cause sediments on the shelf slope to destabilise[12]. Such destabilisation may trigger ***tsunami events***. Evidence of such a tsunami event has been observed in the sediment core paleoclimate record off the coast of Norway[13]. ***Further research*** from a paleo, contemporary and future modelling perspective will enable better understanding of the impacts of dissociation.

[23] Land ice, such as the Greenland Ice Sheet, is also melting and further contributing to freshwater input to the Arctic Ocean. The weight of the ice on land deforms the Earth's crust and mantle. As the weight of the ice is removed the crust and mantle are able to rebound. This is known as ***isostatic rebound*** and has the potential to cause earthquakes and trigger tsunami events. Submarine landslides near to the UK that are large enough to generate tsunamis have been very rare and it is thought that only six have occurred beneath the Norwegian and Greenland Seas during the last 20,000 years. However, more research is needed to better understand the mechanisms triggering landslide occurrence and their likelihood for tsunami generation and propagation towards the UK.

[24] ***Increased riverine inputs and terrestrially derived organic matter*** are being observed across the Arctic from melting land ice. This is affecting the quality and quantity of nutrient inputs with impacts on primary production across the Arctic shelf. Increased organic matter in the water column impacts the optical properties of the water, causing light to be absorbed much more rapidly with depth[14]. This reduces the light available to fuel primary production, impacting the biological communities of the Arctic. Organic matter in the ocean also accelerates the heating of surface waters, exacerbating sea ice melt and reducing stratification[15].

[25] As the sea ice melts it is likely that a continued freshening of the Arctic Ocean will be observed, the impacts of which are uncertain. Scientific evidence suggests that such freshening will reduce the density of the water in the Arctic, slowing the rate of deep-water formation. Reduction in the amount of deep-water formation is likely to ***slow down the Thermohaline Circulation (THC)***[16] in the

global ocean and ultimately decelerate the distribution of heat around the planet. In the UK the THC is responsible for keeping the climate significantly warmer than countries at similar latitudes (e.g. Canada and the Southern tip of Greenland). A slowdown of the THC will therefore cause an overall cooling of the climate in the UK with social and economic impacts as winters become more severe[17].

[26] ***Global sea levels are predicted to rise*** due to ice melt in the Arctic. Increased freshwater inputs to the Arctic from melting land ice (including permafrost) will contribute to rising sea levels. Current research suggests that the Greenland Ice Sheet is melting at a rate of 0.2± 0.1 mm/yr [18] and if entirely melted will contribute approximately 7m to global sea level[19]. The transfer of a global sea level rise to regional seas and coastal sea level rise is complicated and is dependent on varying factors. Sea level rise will threaten low-lying areas around the globe, increasing the occurrence and rate of beach erosion, coastal flooding, and contamination of freshwater supplies[20]. Much of the global population lives in coastal areas and may become threatened by rising sea levels in the future. As an island rising sea levels are something that the UK will particularly have to be prepared for and devise mitigation strategies against in the future.

2. Changes in ocean chemistry and the problem of Ocean Acidification.

[27] Due to a lack of observations currently (because of a hostile and logistically challenging environment) the Arctic biogeochemical system and its function is not well understood. This makes it difficult to predict what future changes will occur and what impact they will have on CO_2 uptake, Ocean Acidification and food webs etc. The problem is exacerbated due to a lack of a long 'baseline' (i.e. observations over many years/decades), to differentiate what is normal response of the system to natural variability and what is due to climate change.

[28] The cold waters of the Polar Regions are able to absorb more atmospheric CO_2 than warmer regions. This is important for storage of anthropogenic CO_2 in the ocean. The Arctic is a region of deep-water formation, thus any CO_2 absorbed in high latitude waters is transported down to depth and removed from contact with the atmosphere for potentially thousands of years. A warming climate is likely decrease the deep-water formation and CO_2 absorption in the Arctic, with negative implications for anthropogenic carbon storage in the ocean.

[29] Uptake of CO_2 also alters the ocean chemistry, making waters more acidic. Arctic waters are currently experiencing widespread and ***rapid ocean acidification (OA)***. Ocean acidification will affect many biological processes including calcification of coral and marine plankton species.

[30] The ***biological impacts*** of OA in the Arctic are likely to be significant, however current research is insufficient to precisely assess the nature and extent of Arctic ecosystem vulnerability. However OA will likely alter fish species composition in the Arctic and affect Arctic fisheries[21].

[31] Despite the importance of the Arctic for CO2 uptake, ***little is known about the sinking of carbon, particularly in its organic form in the Arctic***. To date only a handful of measurements have examined carbon export in the Arctic region. NOC/NERC scientists have been involved with international research programmes such as EURO-BASIN[22], working with partners in Canada, North America and Europe to improve observations of carbon export in the Arctic.

[32] NERC's Ocean Acidification Research Programme is a five-year collaborative programme with a budget of £12m funded by NERC, the Department for Environment, Food & Rural Affairs (Defra) and the Department of Energy & Climate Change (DECC). The overall aim of the programme is to provide a greater understanding of the implications of OA and its risks to ocean biogeochemistry, biodiversity and the whole Earth system.

3. Changes to the Biological Community from High to Low Trophic Levels

[33] The ***distribution and occurrence of biological communities will be altered*** by rising water temperatures, sea ice melt, and changing nutrient inputs from riverine runoff, as well as increased human activities. Highly specialised species dependent on the Arctic sea ice for their survival will likely become endangered or extinct[23]. However, other species will thrive. This change is already evident with declines in populations of polar bears in some Arctic regions[24]. Furthermore, new species are now being caught in trawling nets in the Arctic, including North Atlantic mackerel and cod[25]. Changes in fish stocks in the Arctic will have economic and commercial impacts (discussed in question 2).

[34] The UK has a strong research community examining the driving factors and impacts of a changing Arctic climate. However, such research needs continued investment to ensure that data continues to be collected at high enough spatial and temporal resolution to be able to document the rapid changes that are occurring. Some elements of the Arctic system are currently under observed especially biological systems (discussed further in question 5).

[35] Enhanced riverine inputs (as discussed previously) are causing ***increases in nutrient concentrations in the Arctic***. However, little is known about their fate. NOC scientists have undertaken pioneering baseline research[26], which suggests that, for unknown reasons, nitrate inputs to and outputs from the Arctic balance. However, the Arctic acts as a large source of phosphate and silicate. This implies that the ***Arctic plays a key and poorly understood role in shaping North Atlantic planktonic ecosystems.***

2. Will changes in the Arctic lead to new economic and commercial opportunities? What are these opportunities, and how might they be delivered? What should be the role of the UK Government, of British businesses and of other sections of civil society?

[36] Changes in the Arctic are likely to lead to new economic and commercial opportunities. As ice melts and summers become ice free in the Arctic Ocean greater commercialisation opportunities will arise through the instatement of regular ***shipping routes, service cable laying*** and access to natural resources including ***energy*** (e.g. oil and gas) and ***mineral wealth***.

[37] Similarly with the expansion of fishing grounds north into Arctic waters there is potential for ***increased commercial fishing opportunities***. The Arctic waters are already highly lucrative with respect to fisheries. In 2002 fisheries of the circumpolar north accounted for more than 10% of the worlds wild fish catch and more than 5% of the crustacean catch[27].

[38] ***Environmental changes in the Arctic can have far field effects away from the true Arctic environment***. The circulation in the ocean is three dimensional, and as such, Arctic derived waters can be found at depth outside the geographical limits of the Arctic. A prime example of this is the cold Arctic water flowing five miles west of Shetland at 500 m depth[28]. This cold Arctic current is an important feature, sustaining highly productive fishing grounds for the UK. Thus any changes in the Arctic could also have economic and commercial implications for UK fisheries.

3. How should economic development be balanced with environmental protection in the Arctic? Are appropriate systems in place to ensure the correct balance is found and maintained? How should the UK be involved in establishing this balance?

[39] ***Economic development must be balanced against preservation and protection of the natural environment***. In order to be able to protect an environment the ***baseline against which change is being measured*** must be known. In the Arctic the baseline is already changing so it will be difficult to assess the impact of any environmental protection measures implemented. In addition, the hostile and logistically challenging environment presents significant challenge in observing the Arctic marine system.

[40] Furthermore the ***scientific evidence is currently not sufficient*** to be able to say whether the change in the Arctic region will be “good” or “bad” overall. Clearly some species will lose out to Arctic climate change, whilst others will gain.

[41] The UK marine science community has access to the ***Natural Environmental Research Council (NERC)’s significant capabilities*** in polar ocean observations. Current observational infrastructure includes ***ice strengthened research vessels,*** such as the James Clark Ross[29] capable of working in ice-covered waters (up to 1 m thick) and the ability to deploy ***Autonomous Underwater Vehicles (AUVs) under ice*** to collect data and operate beneath the ice shelf. Further capital investment in the development of novel autonomous technologies would further enhance our capabilities to access and measure the changing Arctic environment[30].

[42] Furthermore NERC has invested resources into ***sustained observation programmes.*** These include the ***Extended Ellet Line***[31], which measures ocean properties in the NE Atlantic where waters flow into and out from the Arctic region and which therefore establishes a baseline against which changes in the Arctic and adjacent waters can be measured and ***MASOX (Monitoring Arctic Seafloor – Ocean Exchange)*** where NOC/NERC have previously provided instrumentation for a sustained seafloor observatory to monitor methane outputs in the Svalbard archipelago[32].

[43] Given that rapid change can be expected, ***there is a long-term need for a broad spectrum of scientific observations by the international science community***, using both traditional research ships and novel technologies such as marine robotics. Improvements in such observations across the Arctic will help scientists to better understand the processes currently occurring and validate Arctic models for more accurate future predictions of changes.

[44] We can anticipate an acceleration of hydrocarbon extraction in the Arctic. However society and ***the oil and gas sector will face formidable challenges*** in locating, containing and removing under-ice oil spills should they occur. The monitoring and detection of oil spills under ice is difficult due to the inability of satellite remote sensing to track spills and biological remediation processes are slower due to the lower sea temperature. If heavy specialist equipment is not pre-positioned in the region there may be considerable delays in accessing the location of a spill, particularly in winter months, and personnel will need to be trained in oil spill removal techniques that are effective at low temperatures, and in the winter months would need to be undertaken in darkness. New research to understand oil spill dispersion and degradation in polar waters may be required.

4. What are the human aspects of the expected climatic and economic changes in terms of local populations, current and future?

[45] The expected changes will affect local populations in several ways including altering fisheries and climate and opening shipping routes and commercial activity.

5. Are there sufficient data on the Arctic to make informed policy decisions? If not, where are the gaps and how should they be remedied?

[46] ***To date there is insufficient data on the Arctic to make informed policy decisions.*** However there is a growing body of scientific evidence which may be of use when making short term policy decisions relating to the Arctic. Nevertheless, ***scientific understanding of on-going environmental change is needed*** to realise sound long-term policies. The UK is in a good position to help deliver this knowledge, with research expertise in a wide range of areas including, modelling, observation, and paleoclimate studies.

[47] ***NERC has an Arctic research programme***[33] which aims to consolidate and enhance research capabilities and address scientific uncertainties. £15 million is being invested into the five-year

programme, over the period 2010-2015. To date the NERC Arctic programme has funded the following marine related projects, which include NOC expertise:

- ***TEA-COSI*** (The Environment of the Arctic: Climate, Ocean and Sea Ice) – aiming to deliver a substantial enhancement in the understanding of key Arctic ocean and sea ice processes and their impact on the Arctic and wider climate system, in both the present and future[34].

- ***SEATS*** (Submarine Estimates of Arctic Turbulence Spectra) – aiming to provide insight into how the close links between fluid dynamic scales and biogeochemical cycles will change under conditions of an increasingly ice-free Arctic[35]

- ***Will climate change in the Arctic increase the landslide-tsunami risk to the UK?*** – This project aims to clarify the frequency and timing of major Arctic submarine slides during the last 20,000 years, and determine which generated far-field tsunamis[36].

[48] Despite such funding current scientific knowledge is not comprehensive enough to be able to adequately inform policy decisions. As such, continued investment into marine scientific research in the Arctic is essential. Some of the key gaps and problem areas include:

- State of the art models, predicting the occurrence and position of Arctic currents, have been developed which are validated through ocean observations[37]. Given likely future changes in circulation there is a need for ***investment in both observations and modelling*** to enable robust predictions of future conditions to be made.

- ***Access to the region*** – Novel technologies such as unmanned autonomous vehicles (e.g. Autosub[38]) will help scientists to gain better access to the Arctic in the future. Access into the Arctic can be further enabled through the use of shared Infrastructures such as the international research base at Ny-Ålesund on the Svalbard archipelago[39] and via bartering for ship time[40]. Some regional powers exercise much higher levels of control over access to the Exclusive Economic Zones (EEZ) and may extend their continental shelf claims. The region is subject to a high likelihood of geopolitical change, which may increase the risk of reduced access to Arctic waters for marine scientific research.

- ***Earth Observations –*** Satellites are key for providing data on changes in ice extent and variations in sea level, sea surface temperature and primary productivity. Through the UK's contributions to the European Space Agency (ESA) we are able to help inform data product development and get access to data from specific Earth Observation (EO) missions. The next series of ESA EO satellites (the Sentinel series) will help fill in some gaps in our knowledge in the Arctic region through the launch of the Sentinel Series of satellites. However, these will still be restricted in their polar coverage. The current CryoSat mission only covers up to 88° North. Improvements in satellite coverage would enable more comprehensive data collection. The

Cryosat satellite can deliver precise information on changes in ice thickness. Further, the Jason-2 and -3 satellites allow measurements of global sea-surface height, to an accuracy of a few centimetres every 10 days, which allows ocean circulation and mean sea level to be determined. This data is used in support of weather forecasting, climate monitoring and operational oceanography[41]. The proposed Jason-CS satellite missions will enhance these capacities. Ongoing support of these EO science programmes, through encouragement of Arctic observing capacity, is necessary to better understand the future impacts of change in the Arctic.

- ***Tide Gauge network and sea level measurements*** – The UK has an effective tide Gauge network[42] that helps to track variations in the tidal cycle and also support research on sea levels changes. The NOC also hosts the Permanent Service for Mean Sea Level[43], which collects, publishes, analyses and interprets global sea level data from tide gauges. Improvements need to be made in the tide gauge network globally by ground truthing their positions with in-situ GPS data. However the existing tide gauge network in the Arctic is not adequate to provide the full range of data required to give detailed information about the rate of sea level rise, storm surges, or tsunami incidence. Canada have cut their tide gauge network, and Russia is understood to have not invested in the region.

- ***Biogeochemical data –*** Much biological and chemical data is derived from scientists physically sampling and analysing water and organisms post collection. In situ data collection could be facilitated by novel technologies such as ***lab on a chip technologies***[44] (which measure chemical properties of the ocean) and ***biological sensors***[45] (which miniaturise technologies currently reliant on large instrumentation), which could be used in conjunction with autonomous underwater vehicles.

- ***Access to data*** – Given that data is difficult to collect and is not fully comprehensive, it is vital that collected data is made freely available though data centres such as the British Oceanographic Data Centre[46] and European Marine Observation and Data Network[47]. International connections made through science coordination programmes (e.g. IOC[48], EuroGOOS[49] and WCRP programmes[50]) also facilitate access to international datasets.

[49] The European Marine Board has made strategic recommendations regarding future investments in Arctic Science in its position paper, 'Navigating the Future IV'[51]. Implementing these recommendations through appropriately allocated funding will ensure long term benefits from Arctic research, and that polar resources are sustainably used in the future.

6. Are there climate change mitigation and adaptation strategies local to the Arctic that should be deployed or tested? What contribution can the UK make?

[50] Some potential areas where local mitigation strategies could be implemented but require further research or compliance with international regulations, include:

- ***Management of invasive species*** – Ballast water in ships is known to transport non-native species from one ocean region to another, causing native species to become endangered or extinct through competition for resources. The impacts of invasive species can be managed through ***ensuring compliance with international conventions*** such as the Ballast Water Convention[52] from both UK trade and its international partners.

- ***Undertaking environmental monitoring*** – as coastal (port and harbour) and offshore (oil/gas) infrastructures are built there will be a need to ensure environmental compliance and monitoring is undertaken to protect the environment. The UK could help with this by utilising its scientific expertise in both industry and academia.

- ***Minimising emissions from ships*** – emissions from ships transiting through the Arctic can be a source of pollution (e.g. soot particles from low grade fuel oil coating sea ice and changing its reflectivity resulting in a warming feedback effect). It will be important to mitigate against such pollution by ensuring compliance with new ship fuel regulations[53].

- ***Oil spill modelling*** – if oil and gas exploration was to be undertaken in the Arctic there would need to be contingency and mitigation measures implemented for the occurrence of an oil spill. Scientific research (through improved understanding of circulation, degredation and natural remediation rates and biogeochemical impacts in polar waters) and modelling capacity could help to better understand and predict the path of contamination in the region.

- **Improving understanding of the flux and inventory of methane and CO_2** in and out of Arctic Shelf storage (methane clathrates) and interactions/feedback with Arctic Climate change. This is an area where the UK science community already has a lead.

7. Are current international governance and security arrangements appropriate for dealing with anticipated challenges in the Arctic? How should the UK support the Arctic states in their stewardship of the region?

[51] There are many international governance arrangements already in place for dealing with the Arctic, including the Arctic Council (as discussed in question 3) as well as international science coordination platforms (as discussed in question 5).

[52] The legal governance for ***undertaking international marine scientific research (MSR) in the Arctic is through UNCLOS*** (United Nations Convention on the Law of the Sea). Part 13 sets out the general provisions for MSR including ensuring provision for marine data acquisition, data dissemination and the collaborative workings of large-scale international programmes[54]. Although there is discussion

internationally focusing on whether UNCLOS part 13 is fit for purpose, it is our view that UNCLOS part 13 should be maintained and is suitable to regulate access into the Arctic.

[53] In order to undertake MSR in international waters ***diplomatic clearances*** need to be gained to enable legal access into exclusive economic zones (EEZ) according to UNCLOS. EEZ extend 200nm offshore and grant the sovereign state special rights over allowing exploration and use of marine resources, including energy production from water and wind[55]. Furthermore nations have access to the continental shelf up to 350 nm offshore[56], for which diplomatic clearance is also needed for research activities accessing the seabed. Through NERC's national capability funding of the National Marine Facility Sea Systems (NMFSS), staff at NOC have the expertise and knowledge to advise FCO to facilitate the UK processing of diplomatic clearances for MSR[57] by other member states and to inform the case for UK applications. Our experience is that states are being more rigorous in their assessment of MSR applications and we expect this will become increasingly an issue in the Arctic.

[54] The ***UK could also play a key role in scientific knowledge exchange and capacity development***. Such work could be developed between the scientific community and:

- Local communities dependant upon the region for their survival who may require education about the observed and predicted changes and impacts.

- Companies and corporations wishing to exploit the economic opportunities in the Arctic. This could include helping energy companies understand seabed habitats for cable laying and energy acquisition activities, and ensuring environmental damage from shipping routes and harbour infrastructures are minimised.

8. How effectively does the UK interact with Arctic governance structures? Is the UK Government's approach, as set out in the Arctic Policy Framework, proportionate and appropriate?

[55] The ***Arctic Council*** is the major coordinating body for Arctic rim countries and allows Arctic Circle countries and intergovernmental organisations observer status. The UK has permanent observer status granted which is coordinated through the Foreign and Commonwealth Office (FCO). The science community, in particular NOC, has a memorandum of understanding with the FCO, thus scientific input can be provided to the FCO and hence presented in the Arctic Council fora.

[56] The ***International Maritime Organisation*** (IMO) is an international regulating authority for the maritime industry. The IMO membership is constructed around 170 member states (of which the UK has membership), and various intergovernmental organisations and NGOs. Any future maritime activities taking place within the Arctic will therefore have to be compliant with IMO standards.

[57] ***UNCLOS*** is the regulatory framework through which the seas are governed. From a Marine Scientific Research perspective, UNCLOS is currently fit for purpose in guiding Activities. This is in agreement with the current UK governments approach as set out in the Arctic Policy Framework.

[58] Generally the Arctic Policy Framework seems proportionate and appropriate for future management of, and interaction with, the Arctic region. Working within the Convention on Biological Diversity Regulations, and with coordinating bodies such as OSPAR, will enhance environmental protection along with the facilitation and coordination of scientific research.

[59] From a MSR perspective, it is critical to remember that the Arctic comprises a large ocean surrounded by landmasses. It is therefore important that both terrestrial and marine Arctic research is supported to allow a full picture of system functioning and change to be obtained

[60] The responses provided in this inquiry are based on our best available scientific knowledge. We hope that the responses provided to this inquiry are of use. If any further information is needed please do not hesitate to contact us, via the response coordinator.

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[1] www.noc.ac.uk
[2] www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-direct-observations.html
[3] http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4135
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