HOUSE OF COMMONS

Environmental Audit Committee

Oral evidence: The Changing Arctic, HC 842

Tuesday 3 July 2018

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Watch the meeting

Members present: Mary Creagh (Chair); Mr Philip Dunne; Mr Robert Goodwill; James Gray; Caroline Lucas; Kerry McCarthy; Anna McMorrin; Joan Ryan; Alex Sobel.

Questions 1-109

Witnesses

I: Professor Sheldon Bacon, Head of Marine Physics and Ocean Climate Change, National Oceanography Centre; Dr Richard Wood, Climate, Cryosphere and Oceans Group, Met Office Hadley Centre; Professor Mark Inall, Director of Scottish Alliance for Geoscience, Environment and Society, Scottish Association for Marine Science; and Professor Martin Siegert, Co-director, Grantham Institute for Climate Change & Environment, Imperial College London.

II: Professor James Ford, Research Chair and Professor at the Priestley International Centre for Climate, University of Leeds; Mr Rod Downie, Chief Advisor, Polar Regions, WWF; Professor Eric Wolff, Professor, Department of Earth Sciences at Cambridge University, The Royal Society; and Dr Alexandra Middleton, Assistant Professor, University of Oulu.

Written evidence from witnesses:

- National Oceanography Centre - written evidence | PDF version (172 KB)
- Met Office - written evidence | PDF version (155 KB)
- Scottish Association for Marine Science - written evidence |PDF version (127 KB)
- Grantham Institute, Imperial College London - written evidence | PDF version (96 KB)
- Professor James Ford - written evidence | PDF version (62 KB)
- Royal Society - written evidence | PDF version (110 KB)

Examination of witnesses

Witnesses: Professor Sheldon Bacon, Dr Richard Wood, Professor Mark Inall and Professor Martin Siegert.

Q1 **Chair:** I welcome our guests for the first panel in the first hearing on The Changing Arctic inquiry. The Committee is very excited to have such a distinguished and eminent group of people in front of us. For the purposes of Hansard, please could you introduce yourselves?

Professor Bacon: I am Sheldon Bacon. I am the Head of Marine Physics at the National Oceanography Centre based in Southampton.

Professor Siegert: I am Martin Siegert. I am Co-Director of the Grantham Institute at Imperial College London. I am a glaciologist.

Professor Inall: Good morning. I am Mark Inall. I am Director of the Scottish Alliance for Geoscience, Environment and Society and a Professor of Oceanography at SAMS, the Scottish Association for Marine Science.

Dr Wood: I am Richard Wood. I am Head of Oceans and Cryosphere at the Met Office Hadley Centre.

Q2 **Chair:** Thank you. You can tell us afterwards what the cryosphere is, but I am sure it will emerge.

Professor Siegert: Anything to do with ice.

Q3 **Chair:** It is to do with ice, okay. Let's start with ice. It is at its lowest level since satellite measurements began in 1979 and we have in our brief that the Greenland ice sheet has been losing 270 billion tonnes of ice per year on average since the early 2000s. Has it been decreasing at a constant rate or is the melt accelerating?

Dr Wood: Statistically speaking, you can say that the rate of sea-ice loss has been accelerating. We have measurements of sea-ice extent in the Arctic from satellites since about 1980. There are lots of year-to-year variations but if you look at the long-term decline you can split that time in two, before the early 2000s and after the early 2000s. It is certainly the case that the decline has been greater in the second half of that period.

Q4 **Chair:** Does that mean it is accelerating?

Dr Wood: It is faster in the more recent period. What we can't confidently do yet is interpret that as an increase in the long-term rate of change, because what you observe is a combination of long-term climate change plus natural year-to-year and decade-to-decade variability. Statistically, yes, the ice has been declining faster more recently but we

would not be confident yet to attribute that to an acceleration of the very long-term trend.

Q5 **Chair:** Is this rate of 13% per decade constant across all decades or is greater in the more recent ones?

Dr Wood: That is the more recent rate and it is a little bit slower than that. That is the average rate since 1980. It is faster in more recent decades and a little bit slower in the early part of the period.

Q6 **Chair:** What is the rate in the most recent decade?

Dr Wood: I don't have that number to hand. We can send it to you.

Q7 **Chair:** Does anyone know it?

Professor Siegert: I don't know the number. What we have to distinguish when we are talking about ice in the Arctic is there is sea ice, which is a very, very thin layer floating on the ocean and that has a very large waxing and waning every year. It gets colder in the winter and grows and it shrinks back in the summer. I think it is the summer minimum that we are talking about and how that is becoming reduced. We have to compare that against the land ice, which is much more significant by volume and rests predominantly in Greenland. There are some other glaciers dotted all around the Russian high Arctic, Norwegian high Arctic, but Greenland is by far the largest store of land ice and any ice in the Arctic.

Q8 **Chair:** I have mixed up two things. Let's keep it on sea ice. What are the processes that are causing sea ice to reduce?

Professor Bacon: It is melting and it is growing thinner and the minimum extent is reducing. That is because the Arctic is warming and there is a process called Arctic amplification. The Arctic is warming roughly twice as fast as the rest of the planet. The planet is warming at about 1 degree centigrade per century and the Arctic is warming at about double that. It is a very simple process to understand conceptually. It is called albedo: bright colours, whites and silvers reflect light and heat back to where it came from; dark colours absorb it. If you imagine a patch of land in Siberia that is exposed and is surrounded by snow, the dark patch will absorb heat, get warmer, melt the snow around it, which will absorb more heat, which will get warmer and melt more snow around it. The same process applies to sea ice. If you have a patch of ocean exposed it will absorb heat, get warmer, the block of warmth will expand and absorb more sea ice.

That writ large is what is happening to the Arctic. There is accelerated warming in the Arctic because of this albedo feedback process. It applies to more parts of the climate system than just sea ice. Clouds, for example, are relevant as well. Clouds can act like an insulating blanket that retain warmth near the surface. Low clouds in the late season, the autumn, will keep in summer warmth and extend the season longer than

has been happening in the past. We think we understand that the Arctic is warming, we think we understand it is warming faster than the rest of the planet and we think that is why the ice is declining, not just in extent but in thickness.

Professor Inall: I think the important point is to think of the Arctic—someone mentioned the minimum extent. The Arctic is always going to be dark and cold in the winter and there is always going to be ice warming, so we are talking about the summer minimum. There is a common misconception that the Arctic is going to become completely ice-free for ever and a completely accessible place. It is highly seasonal; it will always be dark. That is astronomical and that is not changing, so it will always be dark and frozen in the winter.

Q9 **Chair:** Can we move on to what the reduced sea ice and the fresh water influx from melting glaciers are doing to the ocean? Who would like to talk about that?

Professor Siegert: I could mention about sea level, if you wish. Sea level is going up. We have had measurements since 1850 on that. We have time gauges in ports all around the world measuring the level of the ocean going up. Initially there was quite an error to that but there was a signal within it that was quite unmistakeable. Then we got better at measuring the ocean in the 20th century and now we are very good at measuring it with satellites and things. In the latter part of the 19th century sea level was going up at about 0.8 millimetres per year, in the middle part of the 20th century it was about 2.4 millimetres per year and now it is about 3.2 millimetres per year. There has been an acceleration in the rate of sea level rise. About half of it is due to the thermal expansion of the ocean—so as the ocean gets a bit warmer it expands and the sea goes up as a consequence—but the other half is due to melting ice and most of that is coming from the Arctic and some glaciers all around the world. It is important to think about the proportion of ice that is involved.

Professor Bacon: Martin is talking now about land ice transferring.

Professor Siegert: Land ice, not sea ice. Sea ice has displaced its weight in water. If it melts there is no sea level result.

Q10 **Chair:** Okay, sea ice melting is not material for sea level rise?

Professor Siegert: Not for sea level, no.

Chair: Thank you for explaining that.

Professor Siegert: But for further warming, as Sheldon was saying, the colour of the surface it makes a big difference to climate change, of course. The Greenland ice sheet, and of course the Antarctic ice sheet, are the big concerns. If the Greenland ice sheet melts, the whole of it melts, sea level will go up by 7 metres globally and in the Antarctica it would be over 60 metres if that melts globally. This is the huge stores of

ice on our planet that are losing mass at the moment and Greenland in particular. The result is that we see that with the sea level. We can measure the ice sheets themselves but another way to look at it just the level of the ocean and it is going up.

Putting it into context, the ice age was 20,000 years ago. That is pretty much yesterday in geological time. There was enough ice on the planet; you take water from the ocean and you dump it on the land as ice and the ice sheets build up. There was ice sheet in Great Britain, Scandinavia, North America, expansion of other ice masses. The sea level was 120 metres lower then than it is now. It means that the sea level has gone up between 20,000 years ago and 10,000 years ago by 120 metres at an average of about 12 millimetres per year. Then we have the interglacial, where we should be, the nice stable period, and what we have done with climate change in the last 150 years is kick it into a new level, another level of warming that is way above what we should be having during this interglacial period and the cryosphere is responding again, another phase of deglaciation. We are now within an order of magnitude of the deglacial signal in sea level rate as we were during the first phase of deglaciation between 20,000 and 10,000 years ago.

Q11 **Chair:** Just say that again slowly. What do you mean? We are in order of magnitude of what?

Professor Siegert: The rate of sea level change between 20,000 years ago and 10,000 years ago was about 12 millimetres per year and we are 3.2 millimetres now and it is getting higher through time, so we are approaching that type of signal. All it really means is that the ice sheets, the glaciers, are responding to global warming in a way that they have done naturally in the past, but of course this is not natural anymore. We are outside the natural envelope. This is human induced.

Professor Inall: Probably a quarter of the current sea level rise signal is from Greenland alone at the current rate of change.

Q12 **Chair:** How much is responsible for Antarctic?

Professor Siegert: That is a good question. At the moment it is not too much. The reason is because we know that part of the Antarctic ice sheet is being lost, and there has been a lot of press about that, for good reasons, but it has been counterbalanced to a degree by the snowfall in other parts. You have more snowfall on one hand and you have melting on another. It balances itself out, but it is unlikely to be sustainable into the future because we will get more melting. That is the prediction. We know the melt from Antarctica is accelerating and the snowfall cannot keep pace with that, so we expect Antarctica in the future to be contributing more to sea level than it has done until now.

Q13 **Alex Sobel:** How high could the sea level rise? If we don't do anything about climate change, how quickly could that come?

Professor Siegert: The Intergovernmental Panel on Climate Change did a good assessment of this with best and worst case scenarios, taking action on climate change. It is always going up, there is nothing we can do about that. It takes quite a lot of energy to melt ice and once you warm the planet it does not melt instantaneously. It might melt in some years, so there is a lag—it is always catching up. That is the problem and the IPCC thought the minimum it could be is about 40 centimetres higher by the end of this century; the maximum it could be is 80 centimetres to 1 metre. When you speak to many glaciologists and you ask what is likely to happen, the census is more towards 1 metre than 40 centimetres. That is in this century.

Professor Inall: Another issue about the ice sheets is that they behave in a quite nonlinear fashion. They are not slowly melting or gradually increasing their melt rates. You get catastrophic shifts. It is a solid substance and you get large pieces breaking and entering the ocean or you get a sudden release of a glacier that may have been pinned at a rock point and when it melts behind that it may suddenly accelerate or if you have more melt water falling, percolating down through the ice sheet, it may move faster. You see in the historical records very catastrophic changes when ice sheets collapse where instead of seeing quite a slow change trend you see sudden changes. The ocean also has a very important role in the atmosphere. The ocean's heat content is enormous and particularly there is a strong flow of heat from the north Atlantic into the Arctic. We are seeing strong changes in the way that heat is affecting the ice sheets as well as the sea ice. Part of the sea ice decline, particularly in the Barents Sea, is thought to be from oceanic heat origin as well as atmospheric warming.

Q14 **Chair:** That is that Atlantification process?

Professor Inall: It is, yes.

Q15 **Kerry McCarthy:** Some people talk about the Himalayas and the Tibetan glaciers as being the third pole. You have been talking very much about Greenland and the Antarctic. Is what is happening there significant as well?

Professor Siegert: It is in terms of the ice melting and there is a kind of winnowing down. It is quite interesting but we don't have to go into that here. Lakes are being fed by glacier melt water, they are being dammed by moraines, bunches of sediment that have ice within them, and that gives them strength. The ice is melting away and so the dam of all that water is starting to become less effective and we are getting these outwashes of the lakes as well. The reason we focus on Greenland and Antarctica is that they are by far the largest source of ice. There is 66 metres or so of sea level equivalent in those ice sheets. There is something like 300,000 other glaciers around the world and if you melted all of those, sea level goes up by 0.5 metre. We are primarily focused on Greenland and Antarctica for the sea level implications. There are many implications about freshwater supply, just a barometer of change. Ice is

an interesting substance so we can map the changes of global warming all around the world where we have glaciers, but for sea level the major one is the polar ice sheets.

Professor Bacon: In the shorter term, though, melting glaciers are more accessible than Greenland or Antarctica. They don't have a large volume of water to contribute but they do have a fast response time. Many of you will have seen photographs or news stories about alpine or Himalayan glaciers retreating and there being less snow in places where there used to be over the course of coming decades. This is the fast response part of the glacial melt processes that we are seeing due to global warming. It is worth about a third of the total sea level rise.

Dr Wood: Currently the glaciers are contributing more than the ice sheets in total but if you look long term, as Martin says there is a limit to what the glaciers can contribute.

Q16 **Chair:** How confident are we in predicting how the physical processes in the Arctic Ocean will change in the future?

Professor Bacon: Mixed.

Q17 **Chair:** Tell us the bits you are confident about and the bits that you are less confident about.

Professor Bacon: It is to do with bringing predictions down from a global planetary scale to regional scales. Models are excellent at doing global scale mean climate evolution pictures. It is trickier, just on account of the amount of resolution and the amount of physics you can stuff into even the biggest computers, to get down to regional scales and the longer timescale that is needed for climate. The picture that I mentioned earlier of the Arctic amplification, so the double rate of warming, is confident. That is simple physics and we know how that is going to play out. There are unknowns. There is the potential for the evolution of physical processes in the Arctic that we have not come to appreciate yet. I can give you an example if you like.

Chair: Yes, please.

Professor Bacon: The media and many scientists are hypnotised by Arctic sea ice, quite rightly so. Its decline is important, not just as a bellwether of changing global climate but dynamically you may be aware that there are huge ocean circulation patterns that link the waters of the world. Ocean movements are not just about surface waves. There are great currents like the Gulf Stream. Eventually the Gulf Stream ends up flowing past the UK. I could give you a whole lecture about that. 60 north is a fascinating latitude. It is the Shetlands and it is also the southern tip of Greenland and the middle of Siberia. We are incredibly privileged in the UK in climate terms. What is happening in the Arctic as you remove the ice seasonally is that you let the winds push the ocean more directly.

At the moment the Arctic Ocean is incredibly slow and sluggish, the currents are weak and the turbulent mixing processes that might seem a bit abstruse but mixing is a way you can bring heat up that is currently buried below the surface in the ocean—deep, warm layers of water. You can do that because the warm layers are salty and that keeps them down, like the old experiment where you make an egg float in the middle of a jug of water by having salty water at the bottom and fresh water at the top. As the Arctic Ocean accelerates, it will get more turbulent and that has the potential to stir up the subsurface layer of heat and if that comes to the ocean surface then I think all bets are off. We really have not been able to explore the potential of that for the future of the Arctic Ocean, its environment and the surface layer of sea ice even in the middle of winter.

Professor Inall: There are big unknowns about the role of the Arctic in the carbon cycle. There are huge stores of carbon in the permafrost and we don't know whether the Arctic is going to be creating more carbon in the atmosphere or less. The change we know is going to happen in warming is happening in front of our eyes but we don't know whether that will increase or decrease the mobility of this huge reservoir of carbon and ditto for methane. Methane is a 30 times more powerful greenhouse gas than CO_2. It is likely that there will be a small increase in methane coming out from the Arctic. The CO_2 is unknown but the reserve is enormous. They are the unknowns: the fate of the permafrost, the fate of vegetation moving northwards as permafrost freezes and greening. The greening is moving northwards of plants that take CO_2 out of the atmosphere, but there is also a browning effect whereby you unlock carbon that is stored in the permafrost and as there is more rain and non-frozen water it washes this carbon out into the ocean, which becomes available and possibly more efflux of carbon dioxide coming out of the atmosphere. We just don't know which will dominate.

Q18 **Chair:** Dr Wood, in 2014 the IPCC report stated with medium confidence, "The Arctic Ocean is likely to be nearly ice-free in September before 2050 under a high emission scenario". Do we have confidence in predictions like that? Do you think they are underestimating it?

Dr Wood: I think we should take what the IPCC says. The process of the IPCC is really to gather and synthesise a whole lot of strands of research evidence and they come up with these fairly specific statements of confidence. My personal feeling is that that statement is probably still a pretty good assessment of where they are. It is important to stress that that is for the high emission scenario specifically. There will be two future IPCC reports. At the moment the IPCC is working on a special report on the oceans, cryosphere and climate change and I think that is due for publication within the next year. That will update the evidence from there. My personal guess is that those statements about when the Arctic will be seasonally ice-free will be at a similar level of confidence. However, there is research going on at the moment in the modelling world to try to understand the still fairly wide range of model projections

for Arctic ice loss. Maybe in time for the IPCC's sixth assessment, which is due out in 2021, results from current research may be fed into a slightly higher level of confidence in those sort of projections.

Q19 **Chair:** How will meeting the ambitions of the Paris agreement, the intention to limit global temperature increase to 1.5 degrees, affect the Arctic? Do we know what processes it will slow?

Dr Wood: There has been a number of independent pieces of research on this, which all come up with a fairly similar answer. This is based on models because it is projecting into the future, but a number of studies recently have looked at the difference in the likelihood of a seasonally ice-free Arctic under 1.5 degrees and 2 degrees warming. Pretty consistently they come up with the same kind of answer, which is that at 2 degrees there may be a 40% chance of a seasonally ice-free Arctic whereas at 1.5 the prognosis is dramatically lower, more like a few percent.

Q20 **Chair:** Under 10?

Dr Wood: Under 10, yes, maybe 3%, 4%, 5%. I would not put too much emphasis on it if it was just one study but several studies, using slightly different methods and slightly different experimental designs, all seem to be getting that same kind of trajectory.

Q21 **James Gray:** You make a very good point about the probability of being an ice-free Arctic as a result of the Paris agreement, but to what degree will 1.5 degrees lessen the reduction in ice? Leaving aside the extreme of an ice-free Arctic in the summer, to what degree does the Paris agreement help to simply reduce the speed of reduction?

Dr Wood: It is perhaps interesting to think of the ice-free Arctic as an extreme projection in the sense that for many of the high emission scenarios we expect to see that as quite likely. I think you can extrapolate from those ice-free calculations the fact that there is a significant reduction of the rate of loss and potentially any kind of levelling off. There is a bit of subtlety around whether you think of 1.5 degrees as what is the climate like when we cross 1.5 or whether we stabilise the climate at 1.5.

Q22 **James Gray:** Leaving aside the hyperbole and the catastrophes, obviously we don't want that to happen and if that becomes less likely that is a good thing, but the outcome of the Paris agreement would be the hope that there is a limited effect on the reduction in sea ice now. What I am trying to get at is how subtle, how successful will that be?

Professor Inall: I was going to answer in a different way to say that this ice-free is a very emblematic thing but actually it is all a matter of degree and even reduced ice cover—the sea routes have already opened. There are already goods coming over the top through the northern sea route. How it affects the way global trade works, for instance, or the use and exploitation of resources in the Arctic, whether we get to completely ice-

free or a little bit, that size is a bit immaterial. It is very emblematic, I agree, and it is the barometer of change, but we will continue to see a reduction in sea ice even if we hit 1.5. It is not going to stop at where it is just now. The projections out will continue to decline and in such a way that the northern sea route—well, it is already open, you have to argue.

Q23 **Kerry McCarthy:** My questions are about the ecology in the Arctic and some of the issues about the permafrost thaw and methane release and increased vegetation that we have already slightly touched on. If I could start with Professor Inall, how will the NERC "Changing Arctic Ocean" project quantify the effects of climate change on the ecosystems, marine biology and the biogeochemistry of the Arctic Ocean? Why does this matter to the UK?

Professor Inall: How will it quantify? The process of quantification of change is one that, with the research funded by the programmes you refer to, is a combination of going and making observations and understanding how an ecosystem works. For instance, there is a project that looks at copepods, which are very fatty little animals, crustaceans, that live in the Arctic and they basically are the food chain. They supply food for everything above it. They are 90% of the biomass of the Arctic and they are absolutely vital. They are very fat rich with a high calorific content.

Chair: That is a new word. Thank you. They are tiny?

Professor Inall: Arctic krill. You may have heard of Antarctic krill.

Chair: They are marine life?

Professor Inall: They are marine life. They live in the ocean and basically they supply all the marine food. The marine food is eaten by polar bears, seals, seabirds and so on; copepods are the basis of the food chain in the Arctic Ocean. You go to the Arctic and you look at how these animals behave. You put in harmlessly radioactive traces to follow elements and nutrients and food through their lifecycle, through their living. You gain a better understanding of the process of that important species. You then take that gained understanding and put it into algorithmic models that you can run forward in time. It is a combination of understanding how the system works, codifying that understanding in a computer and then pushing that forward in time, in the same way as we make all future predictions. That is how it works.

Q24 **Kerry McCarthy:** This work is being done now. Do you have historical data to compare it against or is it all very much this is the baseline?

Professor Inall: There is from our collaboration with Norwegian, Canadian, Alaskan partners who have been operating and working in the Arctic for perhaps longer than the UK has in a serious fashion. They are limited but they are sometimes a series that we can compare or behavioural observations that we can compare with current data.

On what is the importance to the UK, there are the connections that we have already touched on, particularly the way in which the physical system of the atmosphere in the ocean affects our weather and climate and what happens in the Arctic does not stay in the Arctic. The Beast from the East was essentially a breakdown in the atmospheric pattern around the Arctic and we felt the consequences of that. Similarly, if there are huge outpourings of fresh water from glacial melt in Greenland, historically the relatively warm water that bathes our shores, which Sheldon referred to, in the past glacial epochs stopped completely and plunged northern Europe into ice age, much colder climates. The teleconnections between what happens in the Arctic and the UK are predominantly physical, but there are others—tourism, fisheries, particularly with opening the sea routes as I mentioned earlier—that may have big consequences.

Q25 **Kerry McCarthy:** Could you explain specifically how these creatures fit in? I get the ice melt and all that that we have been talking about, but if there is a decline in copepods, the things at the bottom of the food chain, how does that have a knock-on effect within the Arctic system? What does that mean for the wider picture that we are talking about?

Professor Inall: The predominant thing within the Arctic ecosystem is warming and species moving further north. For instance, mackerel are being found off 80 north, which has never happened before, and they live off these smaller animals at the bottom of the food chain. The fish and the bears and the cetaceans essentially live off these. The changes that are going on in the Arctic are to do with more light availability as the ice recedes and also the availability for the ocean to become more stirred up by the action of the wind on the ocean, which affects the basis of the food supply for these copepods. They eat nitrate, earth, chemicals in the water column, and the way those chemicals are generated, created and resupplied are very much dependent on whether the water is seasonally ice covered or not. There is going to be a huge shift in fisheries, particularly in the Barents Sea. In some ways one can think of the Barents Sea as is it the new North Sea? We are on the edge or we are approaching great change and the Barents Sea is a shallow shelf sea like the North Sea

Q26 **Kerry McCarthy:** There has been quite a lot of attention on krill in the Antarctic and what that means but we don't really talk about a similar pattern in the Arctic. Is that because the numbers are not declining in the same way?

Professor Inall: I can't answer that question. I am not aware of studies showing a decline in the copepod population in the Arctic, but I may have to be corrected on that. It certainly has not received as much attention as the Antarctic krill.

Q27 **Kerry McCarthy:** Ocean acidification is happening at least twice as fast in the Arctic Ocean as in the Atlantic and Pacific Oceans. Why is that and what does it mean for marine wildlife?

Professor Inall: Carbon dioxide is more soluble in cold water. The Arctic is generally colder. There is more CO_2 going into the Arctic Ocean because it is colder so it can have a greater effect or it has always held a greater amount of dissolved carbon dioxide. The effect of reducing pH is twofold. One is that for animals that create outside shells from calcium carbonate there is a point at which when the pH gets too low to acidic it becomes energetically very difficult to create their hard outer skeletons. That can be for anything from the microscopic to the crustaceans, crabs, lobsters and so on. They all have the same chemistry in creating their shells. There is also a metabolic effect. It is more metabolically challenging for these creatures that are not used to it to operate in a lower, more acidic environment.

Q28 **Kerry McCarthy:** That could have a knock-on effect throughout the food chain?

Professor Inall: Absolutely, yes.

Q29 **Kerry McCarthy:** The final question is about the permafrost. Methane is not talked about as often as other sources of greenhouse gas emissions do. Do you think that the concentrations of carbon dioxide methane from permafrost in the Arctic are adequately taken into account when we look at future predictions of greenhouse gas emissions?

Professor Inall: I will refer briefly to my previous answer. There is a current uncertainty as to whether we will see more carbon dioxide coming out of the permafrost or whether the greening will reduce CO_2.

Dr Wood: With the models that are used to make climate projections, the current generation or the old generation of climate models does not explicitly model those effects. You can estimate the size of those effects and the permafrost is probably a less important source of methane than wetlands globally. There is a new generation of climate models that are starting to model the wetland source of methane explicitly and we are working towards modelling permafrost within the climate models but we are still a little way off being able to model it explicitly within the climate models. Having said that, the estimates that you can make of the size of the effect are that the wetlands is the more important thing to go for first because it is a bigger potential source of methane.

Kerry McCarthy: Is that changes to the wetlands that are having—

Dr Wood: Yes, changes to the wetlands. The wetland methane basically comes from life in the wetlands dying and then decomposing at the bottom. There are a number of effects like fertilisation by just having more CO^2 in the atmosphere, which means that the life grows faster so you produce more and that turns into methane. The increased warmth tends to increase the rate of the biology, so there is a number of effects that will tend to increase the source of methane from wetlands around the world, not just in the Arctic.

Q30 **Kerry McCarthy:** On the question of whether the greening of the Arctic,

the vegetation, could offset the impact of the permafrost thaw, do you say that it is a bit too soon to judge?

Dr Wood: It is, but I am aware of one set of studies in Greenland where they have found a balance between the greening and the browning, so a balance between the release of CO_2 through thawing of the permafrost and the uptake through the greening, vegetation growing. It is a little limited but that evidence suggests a balance in an Arctic setting, which was in Greenland, but that is the only study I am aware of.

Professor Siegert: There is a lot of research still to be done in this area. We have not really quantified the store of methane in permafrost in a reliable way. There has been a lot of ecological studies but these are quite difficult-to-access places. The Arctic is quite an unpleasant place to be in the summertime with lots of insects and things. It is difficult to do fieldwork in some of those places and so a lot of research is still needed.

Q31 **Anna McMorrin:** Can I ask Professor Martin Siegert on plastic pollution, what evidence do you feel that plastic waste from the UK, in particular, ends up in the Arctic? What are the consequences on the natural environment and wildlife there?

Professor Siegert: The work that we have done at Imperial College, not my work but colleagues of mine at Imperial, is studying how surface ocean currents cause things that are floating to move around the ocean and plastic is an obvious thing. It is not the only thing, we can do it with ice as well, but plastic is a good thing to do. The first thing to say is that we know that there is plastic in the ocean in the Arctic that has been picked up in the sea ice. We know it is there. When you do the calculations running a model on plastic that is emitted in rivers from the UK and north-western Europe, it gets into the North Sea and hangs around the North Sea but then the ocean currents take it out. Ocean currents are not necessarily these big rivers of water that go from one place to another in a direct way. It is like a complex interconnected series of eddies and they all move in a certain direction. A good example is a colleague of mine put 30 buoys in the ocean within about half an hour of each other and you could see them all in one place and they were all pinging away and you can still track them now. A year or two later they are everywhere. Some of them are following each other, quite strangely, one-to-one relationships, but a lot of them are distributed.

It is very difficult to do that, but what we can say is that a high proportion of the plastics that get into the North Sea will end up going further north and end up in the Arctic. By and large, plastics that we emit from rivers in the United Kingdom going into the North Sea, and possibly even to the west as well, will be tracking north and heading to the Arctic. It is difficult to ascribe, to attribute how much of that is our fault, but it is also quite difficult to see how that plastic can come from many places other than north-western Europe.

Q32 **Anna McMorrin:** What impact does that have?

Professor Siegert: It is the same as we have heard about. I am not a marine biologist but it is fair to say that it is quite well broadcast and known that it does impact the ecology and living organisms that unfortunately start to eat this stuff and it gets into the food chain. It is an obvious answer really to your question.

Q33 **Anna McMorrin:** Following on from that, in your view what further research needs to be done to look at the flow of that plastic waste?

Professor Bacon: I think the research has barely started.

Professor Siegert: That is exactly right and I was going to say that, Sheldon. There is budget imbalance. We know approximately how much gets into the ocean but we can see only about 10% of that, so where is the other 90% of the plastic that is in the ocean? Is it on the seafloor; where is it? It is early days of this research where we are really picking this up as a major problem. It is something that has been known about for a little while but we really have not done thorough research to quantify. The questions you are putting to us are very good questions but I don't think we have proper answers to them at the moment.

Professor Inall: There is something very specific about the Arctic in two respects. One is that all the waters surrounding the UK head that way and the other point is it is a bit of a dead end and plastic floats and it also accumulates on the surface where there is ice. There are peculiarities about the Arctic. When I say it is a dead end, in terms of ocean circulation, waters enter on the surface and they leave at depth. There is some water that leaves on the surface from the Arctic but most of it enters on the surface, sinks and leaves at depth. There is a feeling there will be another garbage patch developing in the Barents Sea. There are peculiar issues for the Arctic and plastics.

Professor Bacon: I am not a biologist or an ecosystem scientist, so I consulted with a colleague, Professor Richard Lampitt at the National Oceanography Centre, yesterday. The first thing to remember about plastics in the ocean is that they might start out as footballs or fishing nets or polythene bags but they degrade and they take decades to degrade, possibly even longer, and they degrade into ever smaller particles. The terrifying endpoint of this—I really found this startling—is that when they get down to a few micrometres they are small enough to cross the biological cell membrane uninhibited. The second point is that plastics adsorb. That means they accumulate pollutants on their surfaces. You can imagine little plastic poison pills entering cells of living organisms at some point. We know nothing about the biology, the ecosystem impacts, the distribution, the degradation timescales.

It is a very early stage of research and yet the UK does pretty well and I think north-west Europe does pretty well. The plastic that we see in the Arctic basically gets there through ocean currents, the warm waters that bathe our shores and give us our mild climate. 85% of the plastic that enters the world oceans comes from China and Southeast Asia and it

contributes to the so-called great Pacific garbage patch. The real problem with plastics is right out in the Pacific, nevertheless we are seeing plastics entering the Arctic. To illustrate the kinds of things we don't know, when you get down to these micro, tiny scales, fibres are a real problem, fibres that you get on your fleece. We cannot yet distinguish between natural fibres that come from plants, bits of trees that break down and become cellulose fibres, and these tiny plastic fibres that are found floating around in the ocean. We are barely at the stage where we can differentiate between human-made plastic and plant-originating material. I think there are many causes for concern and we have not even scratched the surface yet.

Q34 **Anna McMorrin:** Do you believe it is possible to trace that plastic pollution back to its original source, either through looking at the currents or the actual makeup of it?

Professor Siegert: You would need some tracer to be able to do that. There would need to be something special about our plastic to identify it and we have not got that.

Q35 **Anna McMorrin:** Has any research been done on local communities across the Arctic on how they might be affected by plastic pollution?

Professor Bacon: I don't know.

Q36 **Anna McMorrin:** Is there a real need for more research in this area of plastic pollution on an international level?

Professor Inall: We don't know the answer to that question. There is a host of EU-funded programmes on the Arctic cluster. A lot of those are involving indigenous communities and looking at the general effects of climate change and sea ice and permafrost on local communities. I don't know for sure but I imagine the plastics issue is filtering into that network of research projects at the European level. I am not aware of any at the UK level.

Q37 **Anna McMorrin:** Do you believe the UK should be taking a large amount of responsibility for those plastics?

Professor Siegert: Personally, yes, of course. We know it is happening, we know we are emitting plastics and we know where a lot of it is ending up.

Q38 **Anna McMorrin:** And how?

Professor Siegert: Well, that is a very good question and it is not really a glaciological one.

Q39 **Chair:** We as a Committee have done our own input into that and we have also done quite a lot on microplastics in the past and we are about to do an inquiry into fashion. All of these topics—

Q40 **Anna McMorrin:** And producer responsibility.

Professor Siegert: But we do have an ocean plastics network at Imperial College and I know about it because we run it through the Grantham Institute and it involves design engineers, material science, production engineers. You can't stop it; once it is in the ocean, it is in the ocean. We need to stop it at source and that is to reduce the types of plastics that we have, make them more biodegradable, use less, all of those things you will know about. It is a problem on land not in the ocean.

Q41 **Chair:** Professor Inall, you said that there may be a sixth so-called garbage patch forming in the Barents Sea. Can you just—

Professor Inall: I can't amplify much on that, I am afraid.

Chair: That is helpful. We will move on. We are going to come on to the weather now, our favourite topic.

Q42 **Mr Philip Dunne:** Professor Inall touched on the Beast from the East as having come directly from the Arctic. Dr Wood, could you give us the Met Office's view of the impact of Arctic weather on the UK weather?

Dr Wood: There are a number of ways in which the Arctic is connected to UK weather in increasing levels of uncertainty. Probably the most established link is from the changes in atmospheric circulation in the Arctic to changes in atmospheric circulation over the UK. The Beast from the East was a really great example of that. In winter in the stratosphere, because there is no sun in winter, the Arctic stratosphere gets very cold and that generates the low pressure that generates quite a strong, steady circulation called the polar vortex up in the stratosphere. That system relates to the winter but occasionally you find waves propagating up from lower down in the atmosphere and they interact with this vortex and weaken it.

That effect gets paid back down to the lower atmosphere through—it would be a postgraduate lecture to go into the detailed process—basically interaction of waves in the atmosphere with the mean winds in the atmosphere. When we get one of these sudden stratospheric warmings where the vortex breaks down, that effect gradually propagates back down through the atmosphere to the surface where it takes typically 10 days or so to see the effects from the stratosphere propagated back down to the surface.

What we typically get in the winter when we see one of those sudden stratospheric warmings is the jet streams in the atmosphere move north and that allows cold continental winds in from the east, which we saw at the beginning of March when we had that exceptional cold event. That was a good example of something that was connected to the stratosphere.

Q43 **Mr Philip Dunne:** You can see a causal relationship between the impact of changes to the polar vortex affecting UK weather. Is that within 10 days or is there a greater delay before it hits here?

Dr Wood: That is the sort of time delay between seeing the changes up in the polar stratosphere and the changes in our weather.

Q44 **Mr Philip Dunne:** Does the current heat that we are experiencing, which seems unusually unseasonal for June, bear any relationship to what is going on in the Arctic?

Dr Wood: Not as far as we know, no. The polar vortex itself breaks down in the summer when the sun gets up and starts heating the stratosphere. The connections in summer are much less clear.

Q45 **Mr Philip Dunne:** Are our models capable of predicting what is going to happen to UK weather in relation to what is happening in the Arctic?

Dr Wood: Are you thinking of climate change type scales or—

Mr Philip Dunne: No, the climate models that you use.

Dr Wood: The climate models that we use to look decades ahead are much improved now to where they were at the time of the last IPCC report. Most climate models now do have a properly resolved stratosphere, so we are resolving those processes. The current state of knowledge around this polar vortex is that we probably expect it to weaken somewhat under climate change. It would be very tempting to extrapolate from that and say that these effects would come down to the surface and give us more easterly winds in winter but because the mechanisms of that propagation are quite subtle, I don't think we can really be confident in making that link yet. The answer to your question is that the models are improving and the next generation of climate models will be resolving these processes better, so we might expect to have a slightly more confident assessment of that at the time of the next IPCC report.

Professor Bacon: I want to chip in here, if I may. Richard has an admirably nuanced view of the position as befits his position in the Met Office. I want to give you a much blunter amateur physicist's view, and it is the same explanation I gave to the Lyndhurst Women's Institute last year actually.

I mentioned earlier that the Arctic is warming at twice the speed of the rest of the planet. That affects our weather by a simple physical mechanism. I am going to ask you to watch my hands here. This is the rest of the planet, which is warm and it is warming; this is the Arctic, which is cold but warming. What happens as the planet warms but the Arctic warms faster is the temperature difference decreases between the Arctic and the rest of the world. Here is the analogy. The strength of the normal westerly winds that flow over the British Isles in any old day most of time is governed by the north-south temperature difference between the Arctic and points south, including us. As that temperature difference decreases, it is like the tension in a bowstring. Imagine a bow oriented north-south with the string stretched according to the temperature difference. As you decrease the temperature difference the string

slackens and what this bow is firing is not arrows but depressions, weather systems. As the tension decreases, you get more chance that weather systems are going to stall, just pass more slowly or even stop.

Some winters ago—2010, 2009 I think—the country was blanketed with snow and Heathrow was shut for days. Attribution of events is an impossible task but you can make an argument that those events were symptomatic of this process happening, that we are starting to see changes in what is called persistence—the durations of weather spells. Associated with changes in persistence are changes in extremes: snowfall, flooding, even maybe this type of event where you get blocking highs. If you get a blocking high in the Continent, it can be because the bowstring has slackened so much that depressions can't knock the highs out of the way anymore.

There is a strong argument, physically based, that says that as the temperature gradient decreases it must affect our weather. How it manifests is a very tricky thing to diagnose, either from measurements or from models. That is where the complexity genuinely intervenes and it becomes hard to predict. I hope you don't mind my slightly simplistic—

Dr Wood: I think that was a nice explanation of one of the fundamental drivers but, as Sheldon says, you need complex models because there is a lot of factors.

Professor Bacon: Yes, it is complex but for me that is the number one reason why Arctic change impacts the UK, its direct effect on weather and extremes.

Q46 **Mr Philip Dunne:** Can you point to whether changes in sea level from melt will directly impact on our coastline?

Professor Siegert: That is a really good question and it is a complicated answer, I am afraid. Assuming most of it comes from Greenland, the thermal expansion can be everywhere, so if the Arctic warms the ocean will warm and we have an impact of that directly here. But the Greenland ice sheet is so large that it has a gravitational pull and it is a big mass, so the sea level close to Greenland is higher than it would be if there was no Greenland ice sheet there because it gets pulled towards the ice. Bizarrely, if the Greenland ice sheet starts to melt, right next to Greenland the sea level actually goes down because that gravitational pull gets reduced. It is strange, isn't it? You also get an isostatic response. That means that because there is less weight on the crust, the crust starts to go up as well by Greenland.

The strange thing right next to Greenland is that the relative sea level at Greenland goes down while in the rest of the world the sea level goes up. The further away from Greenland you go the less significant that process becomes and by the time you get to the UK it really won't change too much from Greenland but it is the southern latitudes and the mid latitudes that really will see it. Conversely, if Antarctica changes we will

see the brunt of that here because we are so far away from Antarctica that we don't have any of that effect to protect us. We talk about global sea level and 120 metres or whatever it is everywhere. Actually if there is a change it is to do with the distribution of the gravity and the land and the mass of the planet as it changes from having blobs of huge stores of water in two locations to having it more distributed around the world. It is the mid latitudes that will really get it. The low-lying Pacific nations, for example, will get it from both directions.

Q47 **Mr Philip Dunne:** That is not what I was expecting you to say, so it is very interesting. DEFRA has responsibility for the National Adaptation Plan and it has identified, I think it says in the brief, 270 residential properties at risk of collapse into the seas surrounding the UK. That seems quite a precise number. How does that sit alongside what you have just told us?

Professor Siegert: I don't know I have the answer to that. It is what you would expect. Sea levels go up and coastal erosion takes place. We have a lot of people living by the coast and there are bound to be some people affected by flooding, by erosion of cliffs. I don't have anything to say about those numbers and whether they are to be expected, high or low or whatever, but you can understand the logic behind it that it would be expected.

Dr Wood: The sea level projections for the UK will be updated. We are currently using the 2009 UK climate projections and these are going to be updated in November with the new UK climate projections. I think those projections take account of more recent estimates of some of these gravitational effects, for example, that Martin mentioned. There will be a little bit more detail and some more update and some spatial details as well available later this year.

Professor Inall: Coastal erosion is part sea level, part storminess, waves, other processes that erode coastal environments. As we have been hearing, the atmosphere is likely to be more energetic, which whips up the surface of the ocean to be more energetic. There is the combined effect of stormier seas and higher sea level.

Q48 **Mr Philip Dunne:** Is it your sense that DEFRA has a good understanding of what the risks are and has any plan at all to try to improve sea defences, structures that are already there but may be overwhelmed?

Professor Siegert: I think this is about timescales. We can look at the IPCC predictions of sea level rise, somewhere between 0.5 metre and 1 metre, but that is this century. If it is on the timescales we are predicting, that is what we have to deal with for our coastlines in this century, but sea level is unlikely to stop at that point. It is going to continue to go up. The destination is all about decisions we make now about reducing carbon dioxide and keeping global warming to within 1.5 or 2 degrees of what it was in 1850. That is our big challenges but if we don't do that sea levels will just keep going up. You have heard about

this huge store of water potential that there is to melt and sea levels to go up. I would imagine DEFRA's position is on dealing with the situation at hand, which is an expected sea level of 0.5 metre and 1 metre to come within sea defences and protecting cities, London being a key example of that but other coastlines as well.

Mr Philip Dunne: We will ask the Ministers when they come to see us. Thank you.

Professor Siegert: But for a longer-term plan it is really essential as well. We can't imagine that it will stop in 2100. It is an arbitrary piece of timeline. There is no reason it will suddenly stop at that point. Things will keep going on.

Dr Wood: The new UK projections do look to 2300 for the sea levels, so there is a longer-term view. There will be some information on that.

Q49 **Chair:** We have been told that London is safe until the end of the century, so everything crossed for that. Professor Inall, in your evidence you talked about a tipping point in the climate. Do you want to say anything more on that? What would that be and what would it look like?

Professor Inall: I think what I was trying to draw out was a distinction in the way that ice behaves and that you may get sudden changes in land-fast ice. It does not change in a gradual linear, same amount each year fashion. You tend to get rapid changes and then some stability for a while and then rapid changes and some stability for a while.

Q50 **Chair:** The consequences of that tipping point might include cooling of our climate and changes to rain patterns that would affect agriculture, fisheries, energy and transport?

Professor Inall: Historically there was an enormous ice sheet that covered the whole of North America and it collapsed in a sudden event; it flooded the North Atlantic with fresh water on the surface and plunged northern Europe into an ice age. I do not think the feeling is that that is the direction we are heading but we see this as a possibility in the climate record. That is what you would call a tipping point, where there is some event that puts the system into a different state. No longer does the warm water circulate in the pattern it does, it changes to some other state because of either an accumulation of events or a catastrophic event that occurs.

Q51 **Chair:** Are we in agreement that we do not think that is how it is going?

Professor Siegert: Tipping points are very interesting concepts and it was quite fashionable to study these a few years ago. We are talking about thresholds in the system; that is maybe a better way to look at it. An example of a tipping point could be the Greenland ice sheet. It is massive and it is really high, 3,000 metres above sea level, or a bit less than that. The point is that when you go higher you get colder. The further up you go, the higher the elevation, the temperature goes down.

If you start to melt the Greenland ice sheet and you lower its surface, you also raise the temperature of its surface as well. There is no extra warming there but as a consequence of it being lower.

As it gets lower, the surface gets warmer and you can melt it more, so you can regard that as a tipping point. Once it gets below a certain elevation, there is a runaway effect, because as it gets lower it simply gets warmer and more melting takes place and that causes it to lower even further. It is like a feedback-type process. Those are the sorts of thing and you reach a threshold in a natural system and it takes off. There is a feedback that takes off and you cannot stop it. A runaway effect happens.

Dr Wood: You could categorise these threshold events as low probability but high impact if they were to happen. They are low probability and it is quite hard to predict or project forward in time what that probability is. There is quite a lot of research going on, including research that we are involved in, in trying to characterise whether you could, by observation, give yourself some sort of early warning that these events were likely to happen. That will give you time for adaptation, for example, if you knew that some big impacts were coming. There is quite active research in this area of thresholds in the climate system but it is very much focused on this early warning idea now.

Q52 **James Gray:** Mentioning the Greenland ice sheet, could you explain to me something I never quite understood? Putting aside the thinning of it, why is it moving and how fast is it moving and in which direction?

Professor Siegert: Greenland has ice flows that are solid but if you apply large stresses over long periods of time, it flows. It is a very slow-viscous fluid, somewhere between a Newtonian viscous fluid and a plastic, it does not matter, it flows. You can see it in glaciers. If you go to the Alps, you can see this beautiful flow structure of the glaciers forming out. We have known that for a long time. That is a deformation of the ice itself.

If you have a situation where underneath the ice you get water forming, either from the surface, which comes down underneath it, or by melting underneath the glacier as well, then you lubricate the bed. If you lubricate the underside, you can slip it. The ice can slide across the bed. If you have weak sediments on mud underneath that, that has virtually no strength at all and the glacier can simply slide over that. You get very slow flow in the middle, but as you go towards the end of the ice it gets quicker and quicker and these other processes start to kick in. You get the sliding taking place and you get the deformation of that really weak sediment. Velocities can be upwards of a kilometre a year or even more than that by the time you get to the edge of the ice.

Professor Inall: It is not that slow. Ten metres a day for a Greenland ice sheet is not unusual. You could see it. If you sat there for a day, you would see it.

Professor Siegert: You get these rivers of ice, these ice streams, coming out and taking ice from the centre of the ice sheet and putting it into the ocean. It will end up in the ocean.

Chair: Thank you, that is fascinating. We are going to move on.

Q53 **Mr Robert Goodwill:** We have already talked a little bit about the way that research should develop. How can we improve future Arctic research to ensure the United Kingdom continues to be a world leader in Arctic science? I am yet to meet a scientist who does not say we should spend more money on research to get a more accurate picture of what is going on, but how can we focus within a realistic prediction of what might be available?

Professor Inall: I would start with a positive story about Sir David Attenborough, the new polar research vessel. That has brought us into a European programme of sharing facilities in the Arctic, icebreakers, ice-strengthened ships in the Arctic. For me that is a good news story; others on the panel may have a different view.

Q54 **James Gray:** I should mention that we had Sir David here last night. A hundred and twenty people came and we had a fantastic description of what the ship will do. It was absolutely brilliant, a £200 million UK contribution to Arctic science.

Professor Inall: It is superb and we hope he will join the ship when it sails up into the Arctic in 2020. We are running a rehearsal cruise to demonstrate the capability of the ship. That is good news.

The UK also has an Arctic station in Ny-Ålesund in Svalbard, at 80 degrees north. That is a good infrastructure that is available. It is quite small, quite modest, and very modest in terms of our Antarctic science capabilities and infrastructure. We put a lot more money into Antarctic science than Arctic science, I would say. There are the geopolitical reasons for that but, as you hear the evidence here about how important the Arctic is to the UK, my personal view is that we do not do enough in the Arctic, because of its potential effect on the UK.

A final point would be that we seek to gain a lot with the changes in the Arctic, particularly with increased trade through that region, and I think we will be looking more northwards than we have been. You have heard a lot about Greenland. One area that the UK has not funded strategic directed research towards is the Greenland ice sheet. Martin may correct me on that, but that is an area that I think is underplayed in the UK.

Professor Siegert: There was a Norwegian review of their polar science last year, a very important nation for polar science. They did an assessment of the scientific papers that had been written by all nations in the Arctic and the Antarctic. According to them, it turns out that by volume of research that is conducted we are the fourth largest Arctic nation, so that is pretty good. I think it was the United States, Canada and maybe Russia and we were fourth.

We are the second largest polar nation, including Antarctic as well. We are the second largest to the United States on that. The split between the Arctic and the Antarctic on the volume of research that we do is roughly 50:50. There is a lot of research that the UK does in the Arctic and we should be really proud of that and it is a great success story.

The question we should all be asking ourselves is: is that the end point or can we do much better with the resources that we have available? You heard we have a new icebreaker facility, which is a wonderful opportunity to do concentrated science in certain places where that can go that we were not able to do before.

There are opportunities for us to do better. Infrastructure is really critical in the polar regions, the Arctic or the Antarctic. You need kit to get there. It is a difficult place to work and it does need money to do those sorts of things. It also needs a level of co-ordination as well. Most of the research that gets done in the Arctic from the UK, about 50% of all our polar work, is by and large done in individual institutions, universities and research centres and things. I feel sometimes that we could do with being a bit more communicative within the United Kingdom and co-ordinating it a little bit more.

Q55 **Mr Robert Goodwill:** Something like a British Arctic science organisation?

Professor Siegert: Yes, but we have to be careful that we do not create a silo when we do that and that what we are creating is something that is truly facilitating. It is not a bad news story, it is very good because we do loads of great work in the Arctic and in the Antarctic. The question I think we should be asking is: with the resources that we put in and maybe even some extra resources, how can we take that to a new level, as the Arctic and the Antarctic are so important to us? That was an open question.

Professor Bacon: I completely agree with everything Martin said. By way of background, I think it is worth understanding the difference in the nature of the two research communities, the Antarctic versus the Arctic, in Britain. For historical reasons there has always been a focus for Antarctic research in what is now the British Antarctic Survey, and much of the other research that happens in the Antarctic tends to have to pass through that. It is the logistics gateway for the Antarctic.

In complete contrast, Arctic research in the UK is scattered over many dozens of institutions and it grew up in that way as a function almost of personal curiosity within many universities and institutions. The issue that faces us today—and I think the four of us in different ways have been trying to confront it for dozens of years—is how to build this scattered research effort into a cohesive community effort.

We have all been approaching that in different individual and institutional ways but there is a lot still left to do. Martin alluded to the possibility that

it does not necessarily need extra resource, it needs better targeting of existing resource. The Natural Environment Research Council, which I think is a fine part of the UK, has been funding Arctic research to the tune of about £3 million a year through a sequence of targeted, directed research programmes. I think the current one is a missed opportunity, frankly.

Q56 **Mr Robert Goodwill:** Do you think the benefits of co-ordination would outweigh the possible silo risk that Professor Siegert raised?

Professor Bacon: Yes. The preceding two rounds of targeted funding from the NERC on the Arctic were directed at aspects of the physical climate system and I think that community starts to gain impact and cohesion as a result. The latest one is targeted at biology and ecosystems, and that cohesion starts to dissipate and the impact starts to dissipate as a result.

Professor Inall: We do have the UK Arctic Office and I think you will hear from Henry Burgess next week or at some point. That has provided a level of co-ordination that was absent before. As Sheldon alluded to, the organic growth of the Arctic research community in the UK could be harnessed a bit more by some more cleverly directed research within existing budgets.

Q57 **Mr Robert Goodwill:** Is it correct to say that in terms of the measurements of sea ice, sea temperature, currents and so on, we are at a point where we get diminishing returns on what we do? Are there other areas we should maybe diversify into, such as, for example, the point that Professor Siegert mentioned about looking at the effective greening and methane emissions measured against CO_2 fixing?

Professor Siegert: There are always things to do, so we have to think about the way to approach it. What I would like to see in the future is support for long-term collaboration. We cannot do things on our own. We have an interest in working in the Arctic but most of our research is collaborative internationally and we are better off for that, to increase the level of multidisciplinarity in this. As we have talked about today, you change the physical system but you impact the biological system and potentially impact social systems as well. A full appreciation of how those things are working together is very important. Of course, an exchange of people and scientists, not just across the UK but internationally as well. That would really improve our standing, improve our science and help long-term planning as well.

Dr Wood: It is probably worth mentioning that Arctic research is not solely funded by NERC within the UK. The Met Office research programmes, both climate and weather research, are funded separately through Government. We do have some good examples of this integrated way of working. We have an example from the previous NERC Arctic research programme, where research that was done in that programme on measuring the drag of air as it flows over sea ice has resulted in

improvements that we have already managed to get into weather and climate models. That is a remarkably quick transition, from the person doing the observations to something that is improving weather and climate predictions operationally.

The reason that happens is because within the science communities you have different funding streams but people work very closely together to try to line up different programmes to get that pull-through. The other thing absolutely to stress here is that we are operating in an international context. Certainly in terms of fieldwork, it is a major challenge to make sure that co-ordination exists.

Q58 **Mr Robert Goodwill:** One area where international collaboration and data sharing is not working is the US sea-ice model, which, for whatever reason it may be, is a closed-source database. It may be that they want to keep secret where their nuclear submarines can surface or it may be because of the impact of big fossil-fuel influences in Washington, I do not know. Would it help if that was shared more widely so we could do that, and do you know why that is?

Dr Wood: I am not sure if I am answering your questions, so stop me if I am not. You may be aware that within the UK our climate models have historically used a US sea-ice model. That has been a very successful relationship, a very positive collaboration over many years. A few years ago our colleagues in the US made a technical, scientific decision, a long-term decision, about the direction that they want to take the formulation of that model. I will not go into the details but it is about how you split the world up into a grid of points to predict the sea ice. It is essentially a technical decision. They made that for very good reasons. It was not compatible with the way we see our modelling capability develop.

The way we have managed that in the UK is we have developed a new consortium of international partners based on another well established sea-ice model that we are gradually transitioning to. The development timescales are quite long and we have been able to integrate that into our long-term development plan. For the next IPCC report in 2021 we will still be using the US model, and that causes us no problems. Then we have a transition in progress at the moment to this new international consortium that will be used for our climate model projections if there is a seventh IPCC assessment report some time in the 2020s.

It is not a matter of closed source for us; it is more a matter of a technical decision about the way that model is going. As I say, because of the long lead times, and we have had very good relationships with our American collaborators through this process, we have been able to manage that within our long-term development schedule.

Q59 **Mr Robert Goodwill:** I am still confused why the US made that decision, because normally scrutinising each other's models and learning from each other's mistakes and progress would seem a good thing.

Dr Wood: The model will still be open and the results will still be published through the scientific literature. To my knowledge, it is not a case of making anything secret or closed source. It is purely a technical decision that has gone in a slightly different direction to the way we see our models developing.

Mr Robert Goodwill: Thanks for clarifying that. I am not sure if I am altogether clear but I understand it is not a conspiracy, it is a scientific decision.

Q60 **Chair:** Thank you. We are going to finish with a very quick question to Professor Inall about the impact on Scotland. We have talked about the changes to the biology, the fact that Scotland is on some of the Arctic latitudes and there are opportunities for blue growth, but also that the North Sea is thought to be sensitive to increased freshwater export from the Arctic, with some models predicting stagnation. How can the UK ensure that opportunities arising from the changes to the Arctic contribute to the sustainability of near-Arctic communities such as northern Scotland?

Professor Inall: Scotland has taken a very keen interest in what they call the new north, or the high north, rather than the Arctic, since we are not an Arctic nation. The First Minister has been very proactive in this, attending the Arctic Circle Assembly in Reykjavik on two occasions and hosting an Arctic Circle forum summit in Scotland last November, which is available. The Scottish Government are looking to develop an Arctic strategy of policy statement, and that is ongoing.

The key areas for Scotland are in expertise sharing with Arctic states in terms of sustainable fisheries management, perhaps as learned in the hostile northern North Sea and the seas to the north of the UK. Integrated coastal management—there has been a lot of effort from Marine Scotland and the Scottish Government on marine protected areas and designated different levels of protection to different marine areas and holistically exporting that scientific knowledge to Arctic communities.

In planning for port infrastructure, they have been looking at Scapa Flow, Stornoway, Shetland and Moray Firth as possible places where port infrastructure for shipping that is coming over the top through the northern sea route could be processed or exchanged or whatever. They are seen as strong opportunities there.

There is great interest in the supply chain for oil and gas but not the exploration itself. The Scottish Government have a strong carbon emissions target and they are interested in the expertise in Aberdeen in the supply chain but not so much in the production. There is an enormous debate about oil production in the Arctic.

The final two areas are social and tourism. In the tourism area there is a memorandum of understanding between what they call now Visit Scotland and the Iceland Tourist Board, learning about small communities

that are suddenly inundated by a cruise ship with 2,000 people on board. These are issues that affect many parts of the world but the small communities in northern Scotland are seen very much as part of the tourist route up into the Arctic, and that is already the case. It is already the case that the cruise ships stop in Scotland on the way, so again sharing best practice, sharing knowledge, memorandums.

Also on the impact on local communities, Scotland has a long history of rural communities having various trials and tribulations over the decades and centuries. Much of the history and the stories of those communities speaks a lot to some of the issues that are going on in the Arctic communities now who are finding their environment changing and being displaced. There is a strong link between rural, remote communities on how they develop in those changing environments and historically how communities have developed and how those lessons may be shared and learned. Those are the areas, in my understanding, of greatest interest to the Scottish Government at the moment.

Chair: Excellent. Thank you all very much. We are going to hear a lot more about that with our second panel. We are going to have the changeover now.

Examination of witnesses

Witnesses: Professor James Ford, Mr Rod Downie, Professor Eric Wolff and Dr Alexandra Middleton.

Q61 **Chair:** We are going to start our second panel. Thank you all very much for those of you who sat through the first session, which was fascinating. For Hansard, can I ask you to introduce yourselves my left to right, starting with Professor Wolff, please?

Professor Wolff: I am Eric Wolff. I am the Royal Society Professor in Earth Sciences in Cambridge. My own work is on studying how climate changed in the past, through drilling ice cores in Antarctica and Greenland, but here I am representing the Royal Society.

Dr Middleton: My name is Alexandra Middleton and I come from Oulu Business School, University of Oulu, in Finland.

Professor Ford: My name is James Ford. I am a Professor and Research Chair in Climate Change Adaptation at the University of Leeds.

Dr Downie: Good morning, my name is Rod Downie. I am the Chief Advisor on Polar Regions at WWF-UK.

Q62 **Alex Sobel:** We heard from the last panel significant evidence of issues of climate change in the Arctic on the environment. How do you think these changes are affecting or could affect the circumpolar people who live in these Arctic regions? Most people have heard of the Inuit but there are a number of other ethnic groupings: the Chukchi, the Evenks, and so on. How is this affecting their livelihoods and their prospects?

Dr Middleton: There is not so much evidence and some of this evidence is quite patchy. I would refer to the Arctic Resilience Report that was published in 2016. It identifies 19 regime changes and gives 25 different case studies of how local communities adapt to climate change. The way they can adapt is through increased resilience or through the loss of resilience when they lose their livelihood and when the communities diminish. One example of strong resilience could be the town of Kiruna in Sweden, where the city had to be changed because of the mine underneath. The people accepted it because it brings them jobs and it supports their living.

As someone who lives in the Arctic, I can give you a couple of examples as well. We have a downhill skiing championship in Levi. It is every November. You would think that you would have guaranteed snow by then but it had to be cancelled several times because there was no snow. In my hometown, Oulu, we have a ski race that starts on the river in March, but it does not start there anymore because you cannot guarantee that the ice is strong enough. These are a couple of examples I can come up with.

Professor Ford: I mostly work with the Inuits. We hear a lot information from the newspapers about the impact that climate change is having on the Inuit way of life. I think climate change does bring both risks and opportunities. On the risk side we are seeing increasing danger. If the sea ice changes, we see the ice dynamics changing. The ice is thinner in areas where it is normally thick. We see the ice freezing up later in the year, thawing earlier in the year. We are seeing it taking longer for the ice to reach a thickness at which it can be safely used.

All these factures affect transportation on the ice. For Inuit communities in northern Canada and Greenland, which is where I do most of my work, that is the main means of transportation. There are no permanent roads between communities. People rely on semi-permanent trails on the sea ice and on the land. With climate change, it is increasing danger. We do see increasing instances of people falling through the ice.

Research in my team has shown a doubling of search and rescue in the Canadian territory of Nunavut, for example, in the last decade with sea-ice change partly responsible for that. We are seeing compromised hunting and fishing. For Inuits, hunting is not just a hobby, it is a way of life. It underpins food, culture and wellbeing. Changes in wildlife species and changes in the sea ice are having a very direct impact on food systems. In many cases food security is being compromised, and the work in my team and others has demonstrated that, with substantial impacts on people's health.

We also see new opportunities as well with climate change. With more open water in the summertime with our ice, we are seeing increasing potential for fisheries and commercial fisheries. There is a lot of interest

in both Greenland and northern Canada about developing fisheries with more open water in the summertime.

We are also seeing an increasing opportunity for resource development. Again with enhanced shipping, it makes it more economic for resource development in the Arctic. Obviously that bring brings both benefits for jobs and employment, which for many Arctic communities is a big challenge, but it brings challenges as well around the environmental impacts of those developments at the same time that you have the climate changing.

One thing to keep in mind is that when looking at the impacts of climate change, it is not just about climate change, it is about how these changes interact with society. We have all heard stories of Inuits falling through the ice and dying because of this, and, for sure, climate change has a role there; the ice is changing. When we zoom in we find a bit more of a complicated story. What we are seeing is changes in land skills among people using the ice. Traditional knowledge is being weakened in many contexts, so those important skills of how you read ice thickness, safety skills, are not being transmitted through the generations like they once were. The environment is changing and it is becoming more dangerous, at the same time that people's knowledge and ability to use those trails safely is diminishing. If we look at many impacts of climate change in the Arctic and globally, on the one hand we have climate change but what is important is how the change interacts with society in specific contexts.

Dr Downie: The Arctic was described by Ban-Ki Moon as the ground zero for climate change. Arctic people and Arctic wildlife are living on the frontline. The profound effects both on people and wildlife were very clearly articulated at a recent event hosted by James Gray MP, called the Arctic Voices. This was a historic first, in which we had women from Inuit, Gwich'in and Sami communities come over and, for the first time ever in the Houses of Parliament, spoke with absolute passion and conviction about the effects of climate change on their societies, on their subsistence livelihoods. I think it would be worth the note from that meeting feeding into the evidence for this meeting. That would be a great contribution.

We heard from those women how, for example, changes in caribou migration and distribution is changing across Alaska. We heard from the Inuit how sea-ice loss is affecting their ability to travel and to hunt and to fish sustainably in the Arctic. We heard from the Sami about how their culture is so inherently linked to reindeer herding and how unpredictable weather patterns now mean that rain is routinely replacing snow. That is causing a crust of ice on the terrain, which means that their reindeer herds cannot smell the vegetation underneath the ground and they cannot dig through it to get to the lichen that sustains them through the winter. Entire herds of reindeer are dying off as a result of this.

There are also other very good examples across the Arctic, where, as a result of climate change, we are seeing increased human-wildlife conflict, in particular conflict with polar bears. For example, because the sea ice is thawing earlier and freezing later during the year, the polar bears are spending longer on shore. As a result of that, they are coming increasingly into contact with many of the communities along the northern coast of the Arctic. Imagine walking your children to school or your grandchildren to school and you are faced with the danger of a polar bear that weighs seven or eight times your body weight. That is a very, very real threat to Arctic people who are living on the frontline of climate change.

To put some figures behind that, in 2007 there were nine reports of human-polar bear conflict across the whole of Greenland. Ten years later, by 2017, we saw 21 incidents in one single community, Ittoqqortoormiit, between August and December, 21 incidents. This is predicted to increase. These events are going to increase as bears spend more time on land, so it is a real priority for us to ensure community safety and also to try to reduce the sorts of defence kills that happen when polar bears come into contact with communities.

Q63 **Alex Sobel:** Following on from that, do you have any views of the consequences, particularly on subsistence-based harvesting, of the impact on local communities?

Professor Ford: The main focus of my work is working with communities, focusing on the subsistence way of life, which is extremely important to not only Inuits but indigenous groups across the Arctic. These are people who have had very strong relationships with the environment going back generations, so there is a very well developed indigenous knowledge among communities about the environment and how it is changing.

Increasingly, scientists are turning to this knowledge to document and better understand the changes that we are seeing, but also to start to understand what are some of the impacts and vulnerabilities being faced. We have already heard about things like how sea-ice change is affecting transportation. That is one of the main challenges. The sea ice is a means of getting from A to Z. The ice itself is a hunting platform; it is where people fish. It is also a means of going between communities, and we are seeing those networks being significantly constrained. All the work in northern Canada and Greenland is pointing towards negative impacts of food security from the changes that we are seeing, with some opportunities, especially in the summertime with more open water. We are seeing increasing potential for fishing, for boats, for example.

One of the big challenges, though, for many Inuit communities is they are living very close to the poverty line. If northern Canada was its own nation, it would rank the same as Guatemala on a human development index. It is very much a middle-income country. Inuits are very resilient and they are very adaptable to change and people are adapting to

change, but it comes with costs. In response to changing sea ice, people are using more land-based trails, which take longer and use more gas. Many people cannot afford that gas. In the summertime people are taking advantage of more open water, but many people cannot afford boats to take advantage of those changes.

In some ways, we look at Inuit societies and we are seeing growing divisions in communities. Those people with money and with access to resources can adapt some more. They can buy boats and afford the extra costs of having to go on to land. They can afford the latest equipment, but those who cannot are unable to adapt. It is often those people who cannot afford it who also cannot afford to buy food in the store. If you go into an Arctic supermarket, you will see how expensive things are. I have seen a litre of milk for about £8, a loaf of bread for £6 or £7. Replacing food that people hunt and fish with food from the store is not always possible. Yes, a lot of challenges.

In northern Canada and Greenland, in some of these smaller, more traditional communities, the impact of climate change on the subsistence hunting is the main impact that climate change is having and will have in the future.

Q64 **Alex Sobel:** I was on the Ivory Bill Committee and we have the Ivory Bill coming back on to the floor of the House on Wednesday. I am going to speak, and I particularly took up the case of the narwhal but there are other Arctic species that are hunted for their tusk and horn. We have evidence that those are arriving in particular into the UK for trade. Maybe for Rod, because I know the WWF has an interest in this, what is being done to monitor the trade of Arctic species, the products from Arctic species in the UK and in the EU?

Dr Downie: This is in relation to the Ivory Bill. The view from WWF is that the UK Government should remain focused on the key issue, which is elephant ivory, because we do not want to see any delay in action in passing this Bill. With that in mind, we consider that the clause within the current Bill is appropriate. That states that the Secretary of State could extend the Bill to include other ivory-bearing species such as walrus and narwhal, as you mentioned, that are listed on CITES at a later stage. That would allow for better analysis and evidence and an appropriate consultation on that issue.

What we understand from the IUCN is that trade in walrus or narwhal ivory is not currently considered to be a conservation threat—that is the IUCN's view on this—but rather climate change is the threat to those species in the loss of their sea-ice habitat, so we think that is where the focus should be.

Q65 **Alex Sobel:** That was my follow-up question. Has any work been done to quantify how changes in transportation systems affect local communities and their growth? You mentioned the £6 bread and the £8 milk.

Professor Ford: There is some work going on in my team at the moment to try to do that, but generally no. Most work on Arctic transportation systems focuses on the Arctic Ocean. It is looking at how changes in sea-ice conditions affect the potential for shipping, be it boat shipping or cruise tourism. That is where most of the research is being done.

That is also some work looking at changes in winter roads. Across the Arctic, winter roads are very important. These are roads built up on the snow, frozen lakes and frozen rivers and they are very important for access to communities and also to resource development sites. We have seen some work in Russia, mainly across the Arctic, trying to quantify some trends there.

When it comes to the unmaintained trails—semi-permanent trails on the sea ice and on the land, which are very important for the small, remote communities—we know some trends that we have documented from communities. We have observed these trends. We know that access is decreasing but there have been no attempts yet to quantify those trends.

Q66 **Chair:** Can I ask about the seal regulations? Currently seal imports are banned—baby harp seal and hooded sealskins under EU regulations—with an Inuit exception that allows for the placing of seal products from hunts traditionally conducted by Inuit and other indigenous communities. Does anyone have any thoughts on what we will need to do as a result of us leaving the EU? If not, we will move on.

Q67 **James Gray:** First of all, narwhal trade is banned under CITES anyway. You cannot bring narwhal tusk into the UK under CITES can you? Surely you cannot move them internationally.

Dr Downie: Under CITES you can. Canada is the only exporting country of narwhal. The UK is definitely not a significant importer of narwhal products. Between 2011 and 2016, through CITES, just one single narwhal ivory item was imported into the UK and that was for personal purposes.

Q68 **James Gray:** That leads me on to the second question. I was very interested in Professor Ford's comments about the economic differences between the people who are disadvantaged by climate change in the high north and those who gain advantage from it. I was very struck by a recent visit to Grise Fiord, where the poverty is unbelievable among the ordinary Inuits. Of course there are people who are doing tourism and deep sea fishing and all those things. They are different groups of people. The Inuit really are suffering up there.

I met one young man who sold three narwhal tusks for US$3,000 each, as a result of which he was paying for his university tuition in Ottawa. Well done him. That is great stuff. They were saying, for example, in Grise Fiord, out of the 44 polar bears they were allowed to kill last year, they only killed 20 because of a lack of ice. They could not get to them. That is having a real effect on their lifestyles, having a terrible effect on

family life and on alcoholism, drug dependency, crime and incest, whereas there are rich people coming in with tourism and yachts but they are a different group. Is that what you are saying?

Professor Ford: Yes. This is linked into talk about walrus ivory, narwhal ivory and sealskins, because for Inuits they see selling these items as byproducts of hunting. When people catch a narwhal, they are using every single piece of that narwhal. Nothing goes to waste. Anything that is not consumed by people goes to the dogs, and likewise with seal and walrus. They see the ivory as a byproduct and it is an important source of income. In place I worked in, a guy got a double-tusk narwhal and he sold it for $8,000 and that enabled him to buy a new snow machine to maintain his hunting activities.

Coming into communities, there needs to be capitalised subsistence-based harvesting, which in turn maintains access to traditional foods and it enables people to adapt to climate change. Inuits would point out that wildlife is extremely well regulated in Arctic Canada, through a combination of both science and traditional harvesting.

Q69 **James Gray:** The point I was making was not really about ivory. It is because in Grise Fiord they said the ice used to come in September and now it comes in February. That means there are four or five months where they used to kill seals and now they cannot. The poverty is appalling. I was picking up on the point you made earlier on about there being benefits from the ice withdrawing, and disbenefits, but the disbenefits fall disproportionately on those who are least able to deal with it, whereas the deep-sea trawlers and the yacht owners and the tourists are all A1. The problems for the Inuit population in Greenland and northern Canada are appalling.

Professor Ford: Exactly. Your observation is in Grise Fiord. All the communities in which I work in have very similar observations in terms of the opportunities to take advantage of that are very difficult because you need access to resources and finance, you need education, all of which are in such short supply in many of these small, remote communities.

One focus of the Canadian Government has been to assist communities to identify these sorts of needs. In Canada at the moment the federal Government have spent a lot of money on developing adaptation plans, working with communities to identify risk areas and to prioritise what needs to be done to reduce those vulnerabilities and to take advantage of the opportunities.

Q70 **Joan Ryan:** You moved on to the area we are going to ask about. It sounds like clearly some traditional communities and traditional employment is suffering. What I want to ask about is how the Arctic is developing economically and how does this vary region to region, which comes back to some of the points just being made. Are the businesses in the Arctic able to capitalise on the opportunities to increase employment for local people and encourage others to want to live and to work there?

Dr Middleton: Maybe I can start.

Joan Ryan: I have a second question for you that you might want to address as well, about digital connectivity for the Arctic and whether it is progressing quickly enough to sustain immediate and future business development. That is a little add-on.

Dr Middleton: The economic aspect of Arctic development is very much driven by hydrocarbons. We know that 25% of them are located over there. There is a lot of exploration of it in the Barents Sea because it is one of the most accessible ones and it does not freeze, and also in the Kara Sea in Russia. There are a lot of mineral deposits and mineral ores and gold and copper, the demand for which will grow in the future.

What is difficult right at the moment is the lack of both physical and digital infrastructures, because if you are going to explore these minerals or oil or gas you will need to have a certain risk. You would have to have digital satellite coverage over there. Also you would need to build roads and you would need to have mobile broadband in those places. There is a big project now in Russia, in Sabetta, but it does not have the rail connection. They are thinking about connecting it to the main railroads.

All this economic development is very much dependent on the people who live there, on their communities. I am not talking now about indigenous people but people who live in the cities also, in a much broader way. If we are talking about the European Arctic and Murmansk and Arkhangelsk regions, if we look in the population structure we see that the proportion of young people from zero to 19 years old is decreasing dramatically. It is a 7.5% decline, whereas everywhere else there is a slight growth. In the active people from 20 to 39 years old, we see a decrease of 6.8% for the last 10 years. It is the people who get education, who establish families. The next group, which is from 40 to 65 is also decreasing, 3.1%. The only one group that we see increasing is old people, 65-plus. If we are talking about economic development, we should think about how to attract people there and how to attract families and young people.

You were asking about the solution to this problem as well. First of all, I think it is providing an attractive education, because we also see disparity in tertiary education attainment in these territories, and universities should be multifaceted. They should be providing very modern and comprehensive education. Then we would think about supporting vibrant communities, the cultural life, to attract women and families. Of course, urban planning and healthcare are the main solutions and digital connectivity is very important as well.

Q71 **Joan Ryan:** In the "Business Index North 2018" report, Finland's chairmanship of it, connectivity was identified as one of the priorities for the area. Would you agree?

Dr Middleton: I would absolutely agree because connectivity is essential for education in sparsely populated areas, for medicine, for shipping, for monitoring of weather conditions that would contribute more to our knowledge on climate change, also to cloud computing, tourism. There is a growing cluster of data centre industries in the north that all use green power, which is fuelled by hydropower stations. All of them would need some sustainable solutions in the future, with, for instance, sea cables connecting this area of the Arctic to the rest of the world.

Q72 **Joan Ryan:** Is it affordable? What are the broadband expenses?

Dr Middleton: Today they are quite affordable. We documented basic broadband accessibility and availability and 95% of all the population would have basic broadband. There are some disparities in fast broadband. Usually it would take about 3% of disposable income of people for broadband expenses.

Q73 **Joan Ryan:** Does anybody else want to come in on the economy and sustainability of it?

Dr Downie: If I may, yes, on the wider issue of sustainability in the Arctic. As you say, it is a very diverse group of people who call the Arctic home and they all have aspirations, or many of them have aspirations, for prosperity and to be part of the wage economy, and that is totally understandable.

For WWF it is really important that we use the sustainable development goals as building blocks for sustainable development in the Arctic. It is an absolute priority, I think, within the Arctic Council under the Finnish chairmanship, to use the sustainable development goals. I wanted to flag the recent edition, the current edition, of WWF's Arctic journal *The Circle*, which focuses on sustainable development goals shaping the future of the Arctic. I will provide a copy for the Committee, of course.

We think it is really important that there is an integrated approach to social, economic and environmental issues, an approach in which both people and nature can thrive. That needs governance mechanisms, in this case through the Arctic Council, which thinks and acts in a systems way, which understands the sorts of interactions and connections between ecological systems and also institutions.

Q74 **Joan Ryan:** What should the UK be doing to support sustainable Arctic development?

Dr Downie: I am happy to come in on that as well. Clearly, as we have seen this morning, the UK has incredible scientific excellence in the Arctic, and also policy expertise. I think using both of those to help implement the sustainable development goals is absolutely crucial for the UK. Also to take the sorts of Arctic messages that we are hearing into international and global forums, in particular explaining that the actions of nations that sit outside of the Arctic have quite dire and important consequences for sustainable development in the Arctic.

In the UK finance sector, we need to be fully accounting for environmental risks and also for the value of ecosystem services in any development that comes through UK funding. We also need to be able to support low-carbon economies across the Arctic. That means investing in renewable energy, both financially but also with UK expertise in renewable energy, including wind, geothermal, hydropower, but also building innovative partnerships within Arctic communities. The UK has incredible expertise in renewable energy and in particular in remote, off-grid renewable energy. That is definitely one example that we could contribute to.

Professor Wolff: If I could make a very general comment, I think, especially as you heard in the first session, the way that we in the UK tend to look at Arctic change is that it is something happening in the Arctic that might affect us but we do not tend to think so often about this other aspect that Rod was talking about, that Arctic change is something that the rest of us are doing that is affecting people in the Arctic. They have not contributed to it, even per capita, anything like as much as us, so they are innocent victims in this. The fact that we have such strength in Arctic research in the UK means that it is something that we can offer to them. Obviously we are not an Arctic nation so there is a limit to some of the issues we can get involved in. In Canada in particular it is highly political the way indigenous people are treated by the rest of the nation. Nonetheless, we can contribute a lot of important research to try to help them through these issues.

Q75 **Caroline Lucas:** I want to come back to the increased commercial activity in the Arctic. Can you try to evaluate the economic opportunities it presents but also the risks that come with increased shipping to the environment and wildlife and where you would come down on that balance and how we can mitigate the downsides? Professor Wolff?

Professor Wolff: I am not sure that is a great one for me. Can I bat it along to someone else who works on wildlife?

Dr Downie: I am happy to come in on that.

Q76 **Chair:** Could you give us something on the commercial activity and set out what the commercial activity is going to look like, because your evidence was fairly comprehensive on that?

Professor Wolff: It is not the expertise of the Royal Society, it is something we were more quoting from particularly the G7 Academy statement. Maybe I should explain what that is about. The academies of the G7 nations, of which the UK is one, put out a statement on the Arctic earlier this year, which was presented to the G7 at its summit in Canada. That was led and driven by Canada. It particularly commented on the aspect that there are commercial opportunities in the Arctic that could help the livelihoods of people living in the Arctic but that assessing how to make those work for people in the Arctic rather than just for everybody else, rather than just being an imposition on everyone else,

does require a lot of thought and a lot of work. I am not sure whether you are asking me to quantify that.

Chair: That is fine. I just wanted you to set the scene, thank you.

Dr Downie: Caroline, you were asking specifically about shipping in particular. Shipping of course is a very necessary and very important part of life in the Arctic, particularly in remote communities. I believe about 90% of all goods are brought into those communities through travel by boat. Safe and environmentally responsible shipping is crucial. Of course, as Arctic shipping is set to increase, as we are seeing more ships and more vessels in the Arctic, that brings increased risks to Arctic wildlife through spills, through the introduction of invasive species, through underwater noise affecting cetaceans, ship strikes and also through just breaking up sea ice, which is an absolutely critical habitat for seals and polar bears and other species. An icebreaker ploughing through sea ice is destroying habitat.

We saw phase 1 of the polar code for shipping. It came into force back in January 2017. That was a good step forward in that we now have a legal instrument for shipping in the Arctic.

Q77 **Caroline Lucas:** What does it cover? Would it cover things like oil spills and how good the oil-spill plans are? I remember we did an EAC report into the Arctic some years back, and then it was shocking to see how poor the spill plans were.

Dr Downie: Yes, absolutely. It is probably more telling to highlight what it does not cover. It was certainly weaker than its original intentions. It does not cover the use and carriage for use of heavy fuel oils. We have a campaign with coalition members on that at the moment. Heavy fuel oils are much—

Mr Robert Goodwill: Like sulphur?

Dr Downie: Exactly, yes. It does not cover marine noise; it does not have any polar-specific areas of invasive species. It includes provisions such as the requirement for a polar operations manual that sets out explicit operational capabilities of ships.

Q78 **Caroline Lucas:** Which countries came together to come up with the polar code? Was that the Arctic Council?

Dr Downie: No, that was negotiated through the International Maritime Organisation, much wider than the Arctic Council, and it covers both polar regions.

Q79 **Caroline Lucas:** If we were to try to look at what levers there are for increasing the ambition of regulation in the area, would it be through revision of the polar code or through another tool?

Dr Downie: There are a number of tools. That was phase 1 of the polar code but it does not cover many of the smaller ships, like fishing vessels.

It does not cover vessels under 500 tonnes, for example. We need a phase 2 of the polar code to cover those areas.

Q80 **Caroline Lucas:** How long will that take? Was phase 1 a five-year process or was it five months?

Dr Downie: it was nearly a decade, I believe.

Caroline Lucas: Oh, my god. What can we do to make it faster?

Q81 **Mr Robert Goodwill:** We could use MARPOL annex 6, which is used for areas like the Channel and some of the sensitive areas. We could include more areas within that. That would be an easier quick fix than an overall changing altogether of the regulations, possibly?

Dr Downie: That is correct, yes. MARPOL has the provisions for special areas, for example. There are other measures that we could use like agreement within the International Maritime Organisation on things like reducing emissions of black carbon. We are pushing for that, to reduce black carbon by over 90% from ships globally, or at least in the northern hemisphere, which has an effect on Arctic environment, and introducing measures to immediately reduce carbon dioxide emissions from shipping.

Q82 **Caroline Lucas:** Are these all directed at the IMO?

Dr Downie: Principally the International Maritime Organisation.

Q83 **Caroline Lucas:** It does not have to wait for polar code 2, it can just bring—

Dr Downie: That is correct, yes. They are also reinforced through one of the Arctic Council's working group, which is PAME, Protection of the Arctic Marine Environment.

Q84 **Caroline Lucas:** I don't know how often these things meet, but in terms of where our Committee can be putting pressure, is there a particular moment when pressure would be helpful or is it just a general—

Dr Downie: It is a process within the International Marine Organisation. There are certain working groups that meet to focus on certain issues but the International Marine Organisation is the key in London, based here in London. There are other non-mandatory areas that I think would be very important. For example, the IMO has biofouling guidelines. Biofouling is about species coming in on the hulls of ships, attached to ships. They are non-mandatory, which makes it easier to negotiate, but they are not polar specific. Introducing polar-specific guidelines, for example, will address things like the abrasion of antifouling paints on the hulls of ships.

Q85 **Mr Robert Goodwill:** Ballast water also?

Dr Downie: Ballast water convention as well, exactly, yes.

Q86 **Caroline Lucas:** You mentioned invasive species. Do you think the influx of those species is inevitable considering the environmental and economic changes that are happening in the Arctic?

Dr Downie: Currently very few invasive species have become established in the Arctic, certainly compared to warmer waters and warmer areas. Obviously that is a good thing. CAFF, which is another of the Arctic Council's working groups, suggests that there are about 20 plants and animal species that have been brought in and have established. Of those about 10 are marine bioinvasions. That is absolutely set to change because we are seeing increased shipping but also because the thermal barriers are breaking down for these non-native species. Yes, I think it is becoming an increasing risk. The main vectors, as I said, are primarily ballast water and also hull fouling, but there are also other areas of ships like sea chests and anchor chains where organisms can get a grip and be transported into polar waters.

Professor Ford: I want to follow up on a few points on shipping. We are seeing increasing shipping across the Arctic and likely will do in the future. That is just a fact of life in the Arctic. Engaging communities I think is key because when ships come in to, say, a mine site and they are breaking through the ice, not only are they affecting habitat but they are also affecting the transportation routes that people use across that ice. We have a numbers of examples in Canada—the Voisey's Bay Mine and Baffinland Mine—that have worked with communities to identify the best times of the year for ships to come into the mines to take out the ore, to minimise effects on animals by avoiding breeding sites at key times of the year and also by avoiding doing transportation during times of the year where people are using certain transportation routes.

In the past there have been examples where people have been stuck on ice that has drifted out to sea, because people have crossed the lead created by an icebreaking ship or the icebreaking ship by creating that lead means that people cannot get across the ice, basically. There are a number of examples in a Canadian context where mining companies, the Government and communities are working together, joining both science and traditional knowledge, to manage some of those potential negative consequences. That is key.

Search and rescue is a big issue in the Arctic. We are seeing increasing cruise tours in many regions of the polar north. In a lot of regions there is very limited search and rescue capability if a ship goes down. If you go through the Northwest Passage, for example, the Canadian capability is very limited. Canada is providing air support where it takes a good four to five hours for a plane to reach the Northwest Passage. It would be a major incident if a ship was to go down or to get into difficulties. There is very little capability to deal with that in rescue and also in treating for any injuries that might result from such an incident.

Q87 **Caroline Lucas:** Is that what you mean in your evidence when you talk about a potential for a marine emergency? Is that the kind of thing you are talking about?

Professor Ford: Exactly. It could be anything from a ship going down to the outbreak of a disease on board a boat, everybody gets really sick and has to be evacuated. Those kind of things are very difficult in the Arctic.

Q88 **Caroline Lucas:** Is tourism overall a positive thing for the Arctic?

Professor Ford: There is a lot of interest, for certain, in the Arctic in tourism, especially in Canada where I work. There are concerns. If you are in a community like Grise Fiord with 330 people, if a cruise ship of 1,000 people comes into town, that is a lot of people coming in. It is a lot of opportunity but what we see in a number of communities is they expect the cruise ship to come in and then because of weather or the timing it does not come in and that community might spend six months preparing that event. If it does not happen, it is not good. Alternatively, a cruise ship can turn up without announcing itself. The community has no idea a cruise ship is coming in and then all of a sudden you have twice the population coming in, walking around, peering in people's windows, asking questions. There are opportunities, for sure, but it is a challenge of finding ways to manage those opportunities.

Q89 **Caroline Lucas:** I am interested in the different fora. What forum is the right one to try to have some guidelines as to what is the best practice when it comes to—

Professor Ford: For tourism, I don't know. It is not my area of expertise. I will pass that on to other members.

Dr Downie: There is an industry body call AECO, which is the Arctic—I forget what it stands for, but effectively it is an industry body that sets best practice guidelines for tourism.

Q90 **Caroline Lucas:** Is it about enforcing it in that case? Presumably best practice is not to turn up unannounced?

Chair: They are coming in to talk to us so we will ask them those questions.

Q91 **Caroline Lucas:** How extensive is mining, oil and gas exploration and how will it intensify in the future? We heard earlier in the morning about the impacts on climate change and yet we have even more mining going on. It almost feels like an albedo effect in its own right, that the more you have got the ice melting the more potential there is for folks to go up there and do more explorations that will then lead to more ice melting. I don't know if anyone wants to answer that.

Professor Wolff: That is really correct. Potentially there will be a lot easier access because of shipping and lot more ice-free land that could be used. It is a question of whether that is going to be managed properly. If it is completely unmanaged then it will be quite horrendous.

Q92 **Caroline Lucas:** How is it managed at the minute?

Professor Wolff: I am afraid that is not my area so I couldn't comment. It will be completely different in each country.

Dr Middleton: Yes, there is no one Arctic. I could say that the UK as a member of the Extractive Industry Transparency Initiative (EITI) could also contribute because you have some established rules on tax transparency and how to make each country accountable for how they use this tax money. Also there is an Initiative for Responsible Mining Assurance (IRMA) that has been under development for 10 years. It has some good points because it includes social and environmental performance, multistakeholder dialogue and a human rights perspective when we talk about extracting minerals. The Arctic Economic Council is working on that and is developing further the Arctic Investment Protocol that was released in 2015. I hope that the new protocol that will be developed by the Arctic Economic Council will take all these concerns into consideration and all companies that operate in the Arctic will adhere to the best social and environmental standards possible.

Dr Downie: It is worth highlighting that since the last EAC Arctic inquiry there has been something of a groundswell of commitments not to drill for oil and gas in the Arctic. There are some very positive examples on this that are worth drawing out. For example, in December 2016 Prime Minister Trudeau put all Canadian Arctic waters indefinitely off limits to future offshore oil and gas licensing with a five-year review process. We have a current moratorium in Russia on any new offshore oil and gas development, although the details of that are quite scant. Also, I think, within individual companies we are seeing a reluctance to move into Arctic drilling.

To give a few examples, the French oil giant Total in May 2016 wrote off any drilling for oil anywhere within the Arctic ice pack and, very interestingly, they cited not only the high risks of operating in the Arctic but also that they felt it was incompatible with the Paris climate change agreement. The point they were making was that in order to meet those targets some fuel reserves need to remain in the ground. We have also seen the Scottish Oil and Gas company Cairn Energy close down its offices in Nuuk in 2016 and it has indefinitely halted all of its activity in Greenland. They drilled, I think it was, eight wells off the coast of Greenland at a cost of over $1 billion and it proved not to be commercial at all. We saw the Anglo-Dutch company Shell's dramatic retreat from Alaskan waters after a number of failed attempts.

I think this is one area where the new policy that is coming from the UK on the Arctic needs some further consideration. I am thinking in particular of page 27 of that Arctic policy, which really should reflect this groundswell of commitment not to drill. It needs to recognise that it is not safe and that going after very high risk hydrocarbons in the Arctic Ocean is not compatible with meeting the Paris climate agreement.

Q93 **Caroline Lucas:** What does page 27 say?

Dr Downie: It is very open and encouraging to the oil and gas industry and to oil and gas. It is not compatible with the Paris climate agreement,

it is not compatible with sustainable developments in the Arctic and that is really our challenge to the UK Government on its policy.

Q94 **Chair:** We are running out of time so we will have to speed up with the answers. Professor Ford?

Professor Ford: I think the reason that the moratoriums have been put in place is because the price of oil is quite low. Drilling in the Arctic is extremely expensive, so when the price of oil increases the test will be will those moratoriums be respected in the light of that increase.

We have been increasing access to the Arctic with changing sea ice. We always have to bear in mind that the Arctic is still going to be cold, it is still going to have ice, it is still going to be a dangerous place to work, even with the most dramatic of climate change. Whether those opportunities are taken advantage of will depend as much on things such as insurance, of insurers willing to insure boats, supply ships, vessels working in the Arctic, as much as is it possible to work in these kind of locations. It is also dependent on the markets, the price of oil, the price of minerals. In northern Canada, for example, we see a scaling back of some large mining projects because the price of iron ore has collapsed and those projects are no longer as viable when prices decline. Working in the Arctic will always be extremely expensive.

Q95 **Kerry McCarthy:** I want to ask about the Arctic Council and I am going to start with WWF. The UK has observer status and you are there as an observer NGO. How does the role of an observer differ from being an actual member and what influence do you feel that you, as an NGO, can have over policymaking?

Dr Downie: The roles of state observers and non-state observers are a little bit different. WWF is a non-state observer and our role in the Arctic Council is to try to strengthen governance and stewardship and to really embed biodiversity, climate change resilience and sustainable development across the working groups of the Arctic Council.

Q96 **Kerry McCarthy:** You mentioned a couple of working groups. You said there is one on protecting the Arctic marine environment.

Dr Downie: That is right, PAME.

Kerry McCarthy: How many groups are there and is that the way that you get things done mostly, through the working groups?

Dr Downie: Yes, absolutely, it is through the working groups. For us observer is a misnomer because we are very active right across the working groups.

Q97 **Kerry McCarthy:** You are a full participant in those groups?

Dr Downie: Yes, in those groups, absolutely.

Q98 **Kerry McCarthy:** Do they produce reports that go to the Arctic Council itself? Is that how it works? You make recommendations and then it is

the council that makes the decisions?

Dr Downie: That is right, yes. There has been a number of landmark assessments in recent years. The Arctic Biodiversity Assessment, the Arctic Climate Impact Assessment recently, the SWIPA report—Snow, Water, Ice and Permafrost in the Arctic—which was a major climate report that came out last year.

As part of our role we are also calling for a much more progressive role for observers, including state observers, at the Arctic Council. The Achilles heel of the Arctic Council is in implementation. It comes up with all these fantastic reports with lots of recommendations but seeing those recommendations implemented at a national level is not always evident. In 2017 we released our first Arctic Council scorecard. We see ourselves as a critical friend to the Arctic Council. We like to challenge them on what they are doing. This was really focusing on implementation of recommendations that related to conservation and biodiversity.

Q99 **Kerry McCarthy:** You say the recommendations are not really implemented. Is there any enforcement mechanism or is it just up to the states involved whether or not they do anything?

Dr Middleton: Throughout the work of the Arctic Council three international agreements have been reached: the Maritime Search and Rescue in 2011, Oil Pollution Preparedness and Response in 2013 and the latest one in 2017 is Enhancing International Arctic Scientific Co-operation. Perhaps the next international agreement should cover sustainable business development in the Arctic or sustainable resource extraction, or whatever issues the observers agree in their groups.

Q100 **Kerry McCarthy:** Could observers trigger that workstream—if that is the right word for it—or does it need the Arctic Council to decide that is going to be the next thing that they focus on?

Dr Middleton: I am not sure of the internal mechanism of this.

Dr Downie: It largely falls to the chairmanship of the council. Currently Finland have a two-year chairmanship of the council and they set the priorities. It is great to see Finland setting sustainable development goals as a key priority there.

Q101 **Kerry McCarthy:** I know we don't have that much time—I could talk about that for quite a long time—so we will move on. For the sake of time, I will tie this in with the inevitable Brexit question. Two-thirds of UK Arctic papers have international co-authors; how important is it that the UK does take part in this world-leading research? The second part to that question is: will Brexit make a difference?

Professor Wolff: I am sure you have never had a researcher who has come in front of you and said that international co-operation is not important, but it is particularly important in polar research and in Arctic research for two particular reasons. The first is that it is incredibly

expensive and complicated, especially when it comes to Arctic Ocean research. Don't forget the Arctic is an ocean surrounded by land so ocean research is key to this. It is impossible to do it by yourself and if you try to do it by yourself you will not have all the experts on board. As an example, there is a programme coming up soon called MOSAiC. The German research ship the Polarstern is going to be frozen into the sea ice and then drift across the Arctic throughout a year and emerge the other side. That is a completely unique experiment. It has never been done before and it will tell us a lot about processes we have never been able to observe before during the polar night and it would be madness not to have all the international experts on board at the time. That is what they are doing. They have invited all the different countries to take part in that cruise, even though they are providing the ship and putting their ship potentially at risk—not really at risk but into the ice.

It is incredibly important from that point of view just to use the resources properly to study what is an incredibly big system in which we have only dipped our toe into very small parts of this huge area. A second reason, which is specific to the UK, is what I mentioned before. We are not an Arctic nation so unlike the Antarctic where I have done most of my research, we do not have the right to just go in somewhere. If we don't have international collaborators we don't have any airstrips, we don't have any ports, we don't actually have the right to be there. It is extremely important.

To try to conflate the two answers, because you also asked about—you were the first one to use the word—Brexit.

Kerry McCarthy: It was inevitable.

Professor Wolff: I would say again that in the Arctic case there is a particularity of being in the EU that it makes us a quasi Arctic nation because the EU has three Arctic nations: Finland, Sweden and Denmark through its Greenland connection. Inevitably the EU is particularly interested in the Arctic and will always raise it as an important point in a way that in the UK I am sure it is much harder to make out the case that the Arctic is important to us.

It makes us more involved. It gives us what I just talked about, the impetus to get involved with countries who are in the EU, and it has provided a lot of funding and glue for people to work together. In my own case, I can say—although it is not strictly speaking about this topic—the two biggest projects that I have taken part in were drilling to the bed in Greenland back in the 1990s and drilling to the bed of the ice sheet in Antarctica in the 2000s. Neither of those projects could have been done without European funding because we would never have managed to glue together the money properly without having the European Union as the centre of it.

Professor Ford: From a climate change angle, some of the biggest questions facing the Arctic include questions such as how will climate

change impact communities, affect economic sectors? What factors make communities vulnerable or relate to those changes? How can we adapt to climate change? What other adaptation options are available? How can policy involve climate change impacts? These are some of the big crosscutting issues facing the Arctic. They require international collaboration between researchers in different countries who bring different perspectives and expertise. Importantly, they also need interdisciplinary collaboration as well. It is not just a case of more physical science research documenting how the climate is changing, we need to have that research that brings together the natural sciences with the social sciences and the humanities to provide a complete understanding of Arctic change.

If you look at UK research to date, all these great numbers, I can count on one hand or list on one hand the number of people in the social sciences working in the Arctic on climate change issues. Of all those papers, 500-plus papers per year by Arctic researchers in the UK, probably fewer than 10 are from the social sciences. If you look at science in general, the big research programmes are now moving towards interdisciplinary, bringing together researchers from across disciplines. The Arctic research community—this is across the board—especially in the UK, remains pretty siloised and it is pretty dominated by the natural sciences. If the UK is to establish leadership in this area post-Brexit moving towards a model that seeks to focus on some of these big questions and says, "How can natural sciences, social sciences, humanities come together to answer some of these big questions?" that is were we can have leadership. Looking at partners, as partners encounter for example, the UK in 2017 signed a memorandum of understanding between Canada and the UK in science and technology.

Unfortunately, all the conversations we have been having to date are between the natural sciences. The social sciences have not been engaged in those yet and they need to be. Likewise, with Norway as well. Moving forward we really need to focus on these big questions and how can the science community as a whole come together.

Q102 **Kerry McCarthy:** I am aware that we are very pushed for time. Generally, concern has also been expressed about 17% of staff working on these sort of issues in the UK are from other EU countries. Is that a concern that you would share, that maybe academic staff would not want to be based in the UK working on these programmes post-Brexit?

Professor Wolff: Yes, but it is not a problem specific to Arctic science, it is science in general. We all have colleagues who are from the European Union who, whatever has been said, are still nervous about their future. I don't think there is anything more that can be said about that. That is still true.

Q103 **Kerry McCarthy:** I almost assumed that was a given. Are there any particular EU funding programmes that are particularly relevant to the Arctic and the research that is being done there? There is a lot of

uncertainty about whether we remain participants in things like Galileo and so on, but are there particular programmes that you feel that the UK Government ought to be arguing to very much be part of?

Dr Middleton: There is the Northern Periphery and Arctic Programme and its supporting cohesion policy. It is between the regions of Finland, Sweden and nine nations altogether, but Scotland is a very vital player there. It will be very much affected.

Q104 **Chair:** Is that a research programme?

Dr Middleton: It is both. It is a multi-stakeholder programme.

Q105 **Chair:** A research programme?

Dr Middleton: Not so much research.

Q106 **Chair:** What is it then? Is it a social—

Dr Middleton: Social and policy based.

Professor Wolff: There are numerous European programmes that are already funded by the EU. They fall under a net of something called the EU Polar Net, which co-ordinates them, but there are nine or 10 of these programmes that are run either under Framework 7 or Horizon 2020, which are all multi-million pound programmes that we have been in. Obviously we are concerned as to whether we would be in them in the future. From the Royal Society's point of view, we enjoyed the fact that the Prime Minister said in her speech recently that the plan was that we should be fully engaged with all these programmes and so we are hoping that comes to fruition.

Q107 **Chair:** Finally, do you think that the UK's Arctic policy, set out in "Adapting to Change and Beyond the Ice", adequately reflect the scale of changes taking place in the Arctic?

Professor Ford: I read the 2013 document on the train here called "Adapting to Change" but in the text nowhere was there anything on adapting to change. What changes do we need to adapt to? What are the adaptation policies available?

James Gray: It has been updated.

Professor Ford: I have read the 2018 one too and I also found very little information there about the adaptation policy landscape. What is taking place on the brief of adaptation? What policies at present are going to be affected by climate change both now and in the future? What are some of the policy needs? The policy science side of that thing is completely absent. That is one area that I think it is deficient and needs to be addressed moving forward.

Dr Downie: I wanted to highlight what I saw as the most significant change between the 2013 and 2018 versions of the UK's Arctic policy, which is this shift in framing from responsible development to sustainable

development. That was very important to us. We talked a lot to the Foreign Office about that change because of the need to recognise the sustainable development goals. We should not be too harsh, there are some good points in the UK's Arctic policy. Its focus on climate change and research is really important but we clearly need to meet those words with actions. For the UK Government to have a very clear plan to achieve net zero carbon emissions, as soon as possible but certainly within this half of this century, is one of the most critical things that the UK can do for Arctic protection and conservation.

Q108 **James Gray:** Do you detect as a perceived weakness in the report, which I think was agreed to by the House of Lords report a couple of years back, a nervousness in the Foreign Office or the British Government to not be an Arctic nation and we feel a bit embarrassed by the fact that we do not want to be poking our nose in the Arctic? Maybe we ought to be saying to the Government, "Be bolder, Britain does have big interests in the Arctic. Let's be slightly more ready to get stuck into doing a few Arctic things in a way that perhaps we have been nervous about doing in recent years". Is that a reasonable assessment?

Chair: Dr Middleton, what would Finland think?

Dr Middleton: I would think that we should stop looking at the Arctic as just a land of resources and minerals. There are people and thriving communities there and there is a lot of innovation potential that is happening there. It has not been mentioned very much in your other reports. We have Arctic expertise and something that works in the Arctic would work anywhere. In our report we also identified clusters of growth, which is aquaculture and—

Q109 **James Gray:** As a Finn, what do you think? What do you think the Finnish presidency of the Arctic Council would feel if Britain suddenly started making high profile pronouncements on Arctic matters? Do you think that the Finnish presidency would go, "What are you guys doing?" or would you in fact welcome greater involvement by the British Government?

Dr Middleton: Scotland is much closer to the Arctic Circle than China and China claims itself a near-Arctic nation. You could have a stronger statement as well.

Chair: We are going to have to leave it there. We will ask the politicians some of these more tricky questions. Thank you very much. That has been the longest Environmental Audit Committee meeting that I have chaired but it has been one of the most interesting. Thank you.