HOUSE OF COMMONS

Environmental Audit Committee

Sub-Committee on Polar Research

Oral evidence: The UK and the Arctic Environment, HC 1141

Monday 27 March 2023

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Watch the meeting

Members present: James Gray (Chair); Philip Dunne; Barry Gardiner; Clive Lewis; Caroline Lucas; Jerome Mayhew; Anna McMorrin; Dr Matthew Offord; Cat Smith; Claudia Webbe.

Questions 1 - 48

Witnesses

I: Professor Terry Callaghan CMG, Professor of Arctic Ecology, School of Biosciences, University of Sheffield; Professor Mark Brandon MBE, Associate Dean and Director of STEM Research, Faculty of Science, Technology, Engineering and Mathematics, Open University; Professor Michael Bravo, Professor of the History and Geography of Science, University of Cambridge; Professor Helene Hewitt OBE, Science Fellow and Ocean Modelling Group Leader, Met Office.

Examination of witnesses

Professor Terry Callaghan, Professor Mark Brandon, Professor Michael Bravo and Professor Helene Hewitt.

Q1 **Chair:** I welcome the Committee to this second consideration of the Environmental Audit Sub-Committee's report into polar research, with particular regard to the Arctic, and later this year with regard to the Antarctic. We are joined by four distinguished academics. I will ask you, if I may, to introduce yourselves in a moment.

The purpose of this afternoon's session is to set the scene with regard to what the inquiry will be like over the next three or four months and, in particular, the kind of things we will be looking out for when we go on our visit to the Arctic this Wednesday coming, which is quite imminent. The things that you say will be a very useful background to our considerations. With that, if I could ask you to introduce yourselves very briefly, starting from my left.

Professor Bravo: I am at the Scott Polar Research Institute. I am a professor of geography and a fellow of Downing College. I have worked in and on and about the Arctic for about 30 years.

Professor Brandon: I am a professor of polar oceanography at the Open University in Milton Keynes. I did a PhD on the Arctic in 1992 and have been working in the Arctic and Antarctic ever since.

Professor Callaghan: I am a professor of arctic ecology at the University of Sheffield and also a professor of botany at Tomsk State University, Russia, which is on hold at the moment.

Chair: I am delighted to hear it.

Professor Callaghan: I have worked in the Arctic for 56 years. I have been in every Arctic country, and for last 15 years—until the Ukraine invasion—I have focused on Siberia. I set up a network of almost 100 research stations across the Arctic that annually hosts 15,000 scientists or thereabouts.

Chair: Joining us by Zoom from Geneva.

Professor Hewitt: I am a science fellow at the UK Met Office and a visiting professor at the University of Southampton. I am sure you know that the Met Office is an executive agency of the Department for Science, Innovation and Technology, and, although it is best known for the weather, the Met Office is also a world-leading climate research organisation. My background is in modelling ocean sea ice and climate. I work on the Hadley Centre Climate Programme, which provides advice to Government, including the new Department for Energy Security and Net Zero. Most recently I was a co-ordinating lead author of the Intergovernmental Panel on Climate Change's—or IPCC—"Sixth

Assessment Report", where I co-lead the chapter on ocean cryosphere and sea level change in Working Group I on the physical science basis.

Q2 **Chair:** Thank you all for your written evidence and for taking the time to be here this afternoon. The evidence that you give will be extremely useful in our inquiry.

I will kick things off with a very general and easy to answer question—the rest will not be so simple. Can you outline for us what is currently happening with regard to environmental changes in the Arctic and whether or not those changes are coming faster? I don't mind where we start.

Professor Callaghan: Yes, there are dramatic changes, and they are getting faster. We are seeing more and more extreme weather events, which are getting more intense and more frequent. We are seeing bigger landslides through permafrost thaw, increasing permafrost temperatures, damage to infrastructure, changes in vegetation and changes in carbon emissions, which are getting faster and faster. In terms of ecosystem change, we are also seeing dramatic events such as mass deaths of reindeer, where tens of thousands are killed in one winter, which we have not seen earlier.

Professor Brandon: In the physical environment, just about every climate indicator is in retreat. We have decreasing snow cover; we have decreasing sea ice; we have decreasing glacial ice; we have the great icecaps of Greenland and the other northern icecaps losing ice through melts. The Arctic ocean is changing; maybe we will get to that later in this conversation.

Professor Bravo: We can stretch the term and refer to political and cultural environments in the Arctic. They are undergoing profound change I think in ways many of us did not anticipate or imagine. There is a lot of thinking to do about what the implications of the recent geopolitical changes are for the Arctic and for co-operation. I think we assumed for a long time it would be a region of co-operation and stay that way. Now the title in my research group of being circumpolar is looking a little bit strained.

Q3 **Chair:** Just as a sort of qualification, are these changes coming faster only or are they also becoming worse? In other words, there is an argument that it is all cyclical and that it will all be reversed. Is it just a question of speeding up or is it a question of the Arctic becoming itself more fragile, to use that expression? Helene.

Professor Hewitt: In the IPCC report we talk about many of the changes that Mark and Terry have outlined, the warming of the Arctic and the loss of the ice. The IPCC did not assess that it has got faster because it is very difficult to have all the evidence on that. We only applied that term to one variable, but it is without doubt that the changes are widespread in sea ice, permafrost, the Greenland ice melt and the warming of the ocean, so there is no doubt that it is a widespread

change. As the ice becomes thinner, for example, it does become more fragile and more vulnerable.

Q4 **Chair:** A second supplementary then. Are all the things you describe—which are well known to all of us here—consequences of climate change or are they to some degree contributing towards climate change? Is it to some degree a self-fulfilling prophesy? You don't have to answer all of them, just among yourselves.

Professor Brandon: Helene, with your IPCC hat.

Professor Hewitt: You can look at how many of those indicators human influence has contributed to. It is very clear that human influence is the main driver of the Arctic sea ice loss, for example, and it is contributing to all the other factors that we have talked about. That is a very stringent barrier to get over.

Q5 **Chair:** What I meant, though, was not quite that so much as, when we are considering our report, to what degree should we merely comment on what is happening—which is obvious and clear and straightforward—and to what degree is it caused by climate change elsewhere in the world? To what degree is the Arctic and these changes in Arctic themselves responsible for climate change? In other words, to what degree is it a circular argument?

Professor Brandon: The systems on the planet are created by the difference in temperature between the equator and the poles. The pole is warming much more rapidly than the rest of the planet, so the difference between the two is changing. The main force that is driving the overall weather systems is changing. It correlates with human-derived emissions gases.

Professor Callaghan: In my understanding, only about 4 million people live in the Arctic, so they are not using a lot of fossil fuels. They are not causing the problem that they are experiencing. When the problem started from outside, it then triggered amplification and feedback. As far as I know, these feedbacks are albedo changes. As the shiny surfaces are reduced, then you are reflecting less radiation and absorbing more radiation. There are the increased carbon emissions that are given up—and I can give this in detail later on for vegetation and soils—that add to the greenhouse gases. Of course, there is sea ice loss and the ocean absorbing more warmth, but that is your area, not mine. This is a feedback mechanism that started from outside the Arctic that triggers an amplification by the Arctic, which then feeds back to our latitudes.

Q6 **Chair:** The albedo effect thing is one thing, but what I was getting at was this: in terms of what we are looking into, are we looking into things that are happening in the Arctic affecting climate change or are we looking into climate elsewhere affecting the Arctic? In other words, is our inquiry about what is happening in the Arctic as evidence of climate change elsewhere?

Let me move on to a second part of the question, which is this: what should the UK Government be doing about it that they aren't currently doing? Is there any point in doing something about it, supposing we do something in the Arctic and it does not affect climate change elsewhere in the world? Do you follow my line of thinking?

Professor Hewitt: My view is that it is climate change, or what we are doing elsewhere in the world that is affecting the Arctic, as people have said. From a scientific point of view, the only way to stop these changes that we are seeing in the Arctic is to stabilise or reduce global warming.

Professor Callaghan: I am just going to be a little bit grumpy for a moment. I was involved in the very first IPCCs and I was involved in Working Group I of IPPC I. We forecast many of the changes that we see today, and no one listened to us. When you ask the question, "What should we do?" we should have been doing things 30 years ago. It is simple, sorry.

Professor Brandon: The way we are framing this, about us affecting the Arctic, the Arctic is affecting us as well, which we will probably get to later in the conversation. The circular thing is a two-way process. Absolutely, it is affecting us in a big way, so we should care for that reason too.

Q7 **Chair:** My question, though, was in terms of how we focus our thoughts on this Committee. If we focus our thoughts entirely on the damage that is currently being done to the Arctic—which you described so well in your first answer—we are not achieving much. We are not achieving what Terry was talking about with regard to IPCC I; we aren't changing climate change. All we are doing is making some changes to the consequences in the Arctic rather than the causes. To what degree do you think the UK Government should be doing more in the Arctic? What should they be doing and is there any point anyhow?

Professor Bravo: I will come in there. I think the conversation points to the fact that these mechanisms are relational. They clearly work in both directions. I think it is the case we have understood quite a lot of this for a long time. The question about what the UK should do I think turns quite a lot on trying to understand, not only that we have expertise in science but understanding what that expertise can do.

As for the view from outside, I was talking today with the leader of a polar research institute in the Arctic, and our good friends are very clear that they would like to see a stronger UK presence. That could be expressed in different ways. He said two things. One was, "You have every reason to be involved in the Arctic. You are nearby. You are neighbours." He also said, "With that comes an obligation to try to spend more time understanding our Arctic partners." That has also been something that I have seen and felt for some time.

Putting those together points to the question about what kind of a presence the UK would like to have in the Arctic. Without going astray, it also speaks to a question that I have been thinking about quite hard for the last two years, which is: what does leadership look like today? I think that is very germane to this question.

Chair: That is a very helpful answer because that would indicate that what we should be doing in our report is considering what leadership we give in the Arctic, what our presence is like in the Arctic, what we should be doing to lead other countries in the Arctic, as well as the science and so on. A few things we can do. All right, thank you. Matthew Offord.

Q8 **Dr Matthew Offord:** I wanted to ask a simple question: why is the Arctic warming faster than other parts of the planet?

Professor Brandon: As we put carbon dioxide into the atmosphere, global temperatures are increasing. Snow has been melting on the land. Snow is a very reflective surface and sea ice is a very reflective surface. As we have heated the temperature up, we have melted the snow and we have melted a lot of the sea ice. The reflectivity of land and the reflectivity of the ocean is a lot less, so it absorbs a lot more heat. That means that the Arctic warms more.

We talk about the global mean atmospheric temperature and the Paris agreement talks about the 1.5°C global mean, but if you think about the Atlantic ocean, the mean depth of the Atlantic ocean is about 3,500 metres, but there are parts of the Atlantic ocean that are over 8,000 metres deep.

We talk about global mean planetary temperature of 1.5°C being a target, but in the Arctic it is already at 3°, so it is obscured by that average. This feedback between the atmospheric temperatures, the melting of sea ice and the melting of snow, meaning that the land and ocean absorb more heat, is a positive feedback and it is increasing.

Q9 **Dr Matthew Offord:** Is there an impact upon the rate of the temperature rising in the Arctic? Obviously there is an impact upon the other parts of the world. Could you explain those and what they will be?

Professor Brandon: The climate impacts of the increased open water and the increase—

Dr Matthew Offord: Ocean water is one of them. We often hear about the gulf stream. Would the gulf stream stop, for example? Is it correct to say, as the temperature goes up, more colder water goes into the Atlantic and obviously sinks and that would have an impact?

Professor Brandon: The increased temperatures are causing melting of the large ice caps, like Greenland, and that is depositing a lot of fresh water into the ocean. From the long-term climate history of the planet, we have examples where the ocean circulation has changed, and people are trying to understand if that is happening again. The most sensible

person to answer that question though, from a modelling point of view, is Helene because they test that.

Dr Matthew Offord: Helene, over to you.

Professor Hewitt: Mark is absolutely right. What we know is that, under greenhouse gas emissions anyway, we would expect this overturning circulation that drives the gulf stream to the UK. We would expect that to weaken anyway, but if we see a large amount of melt from the Greenland ice sheet, that would add extra fresh water to the ocean. We say this in the IPCC report as well, that it could cause it to weaken further. There is some interplay there.

Q10 **Dr Matthew Offord:** Are there any other implications? I know I focused as an example upon the Atlantic, but does it have an effect on any other parts of the world?

Professor Hewitt: You mean the ocean circulation or—

Dr Matthew Offord: No, particularly the warming in the Arctic.

Professor Hewitt: People have looked for a long time for links between what is happening in the Arctic and our weather. It does make a difference perhaps to the storm tracks, but it is quite difficult to prove the links. There is a lot of disagreement between research studies, so it is definitely an area of ongoing research, I would say. It is very hard to pin it down entirely—hints, but no definitive answers.

Q11 **Dr Matthew Offord:** In one of the previous answers, the issue of the Paris agreement was raised. We would be interested to understand, first, by achieving or sticking to 1.5°C, how would that affect the Arctic?

Professor Callaghan: I am old enough to remember that 20 years ago we said, "Let's stick to 1°C; 1°C matters". Now we are 1.5°C. What you have to realise is that all the things that are happening, like 3.1 trillion tonnes of ice loss from the Greenland ice sheet in 10 years, the warming permafrost, the mega thaw slumps, the massive forest fires, new tundra fires, all these things are happening with the current warming of 1.1°C and yet we are aiming for a warmer world. You cannot put the permafrost back or the glaciers back with warming, so we are committed to seeing everything we see now and more if we go to 1.5°C. I am sorry, I am being a little bit of a doom and gloom person, but that is the reality. If we accept 1.5°C, we are looking at warming and we are looking at worse events than we see now.

Q12 **Dr Matthew Offord:** What would be the direct impact upon the Arctic of an increase above 1.5°C?

Professor Callaghan: More of what we see now.

Professor Brandon: People have done studies to calculate the difference in how much sea ice we would lose and the difference between 1.5°C and 2°C. The same calculations have been done for how much sea level rise.

When talking about us affecting the Arctic, the difference between 1.5°C and 2°C would change the rate that the fresh water is coming off the ice caps and so that will affect us a lot.

Q13 **Dr Matthew Offord:** What about the physical aspect on the 4 million people that live within the Arctic? What effect would it have upon them?

Professor Bravo: Such a good question. In a nutshell, it creates isolation, and it creates loss of infrastructure. By infrastructure, what I mean to say is clearly you can have roads and bridges, where if the ground loses stability, that infrastructure gets damaged. However, for northern peoples in the Arctic, indigenous and non-indigenous, the substrate, the land and sea and particularly the ice, are the most important kind of infrastructure. Why? Because traditionally, for example, some peoples like Inuit, during part of the year they live on the sea ice.

I am lucky enough to have started my research as a teenager—or at least I started living in the Arctic as a teenager—so I spent a lot of time with Inuit who were born in the early 1900s, who have seen a lot of change. I also have to say, just as a caveat, I am not entitled to speak on their behalf, that is always very clear, so I have to choose my words carefully. To answer the question, first, they would want you to know that their intelligence is constantly underestimated. They are very smart people and their intelligence or their knowledge cannot be communicated very simply.

Secondly, they would want to say that they have always been living with change, but in recent decades the change is of a different order, and they describe that by saying—and you may have heard this—that their vocabulary no longer adequately describes what they see around them. A vocabulary, where the grammar itself is highly sophisticated, that is challenged and stretched to the very limits and beyond to describe the changes that they have been seeing since about 1990 to 2000, I would say. You would get different opinions and that is because, like every polity, they have different opinions but, fundamentally, they see profound change.

That isolation means that they are losing time in which they can live on the sea ice. It means that with a shorter season they lose access to hunting, hunting marine mammals, on which they depend for their wellbeing, but also in some fundamental sense a kind of isolation. Terry, you are in a particularly good place to talk about what is happening to the tundra and what that might look like for a group of communities.

I have a map here—I am a geographer, so I cannot go anywhere without maps; I like maps—called the Pan Inuit Trails Atlas that we made with an Argentinian anthropologist 10 years ago. It shows how, from Alaska to Greenland, you can travel by trail. There is a network of trails. Without ever leaving that network you travel largely over land, and particularly sea ice. To help us picture it, the impact of climate change is to begin to see a map of a connected world. This is the key attribute, if there is one

in the Arctic it is the connectivity. The impact of climate change is to see dissolution, the disappearance of that connectivity.

Dr Matthew Offord: Brilliant, thank you.

Professor Callaghan: If I can add to that, Michael, I think one of the problems is that there are different impacts in different places. The transport on land is threatened, exactly as you say. In Russia there are 12,000 kilometres of zimnik—that is the frozen ice roads—which are absolutely critical for getting from village to village and getting supplies in.

You would be surprised to know that the reindeer herd is a small reindeer herd, it is individual farms in the Yamal Nenets area, which is a huge oil and gas-producing area. They are suffering fuel starvation. Yes, 10 years ago they could swap one reindeer for one barrel of kerosene for their generators, and now it is three reindeer and they cannot afford to get the kerosene. There is nowhere to buy the kerosene in the north because of transport problems.

There are those negative impacts. Then the oil and gas companies, which are state-owned, have new coastal areas that are largely ice-free and they are shipping liquefied natural gas from Sabetta, for example, in the Yamal, all the way to Korea. It is doing some people a lot of good; it is doing other people a lot of harm.

Then there are the different effects within the different communities. For example, with Sami reindeer herders, if they have an extreme warming event, they are subsidised by their governments. They put their reindeer in corrals, and they feed them from helicopters or feed them food pellets. In Yamal, the reindeer die and people need food handouts to survive. There is a difference in the different communities as to how they can cope with the changes that they see.

Professor Bravo: I think that is right. You draw attention to the very crucial factor that, when we talk about the Arctic, you could say we mean many ecosystems, many Arctics.

Dr Matthew Offord: That is brilliant, yes.

Chair: If I remember only one thing from this session, it will be the fact that the reindeer herders of the Yamal peninsula are suffering from fuel shortages. That is quite an extraordinary fact. Barry Gardiner.

Q14 **Barry Gardiner:** Thank you, Chair. I thank all of our panel for being with us. It is quite a privilege to have four professors all in a row for such evidence. You were talking earlier with the Chair about how this is one system and the way in which what we are doing in producing greenhouse gas emissions is impacting on the Arctic and how, in turn, that is impacting on the rest of the globe.

I want to focus particularly on the questions around sea ice and land ice

in the Arctic ocean, perhaps again particularly to Professor Hewitt. I think that this month the extent of Arctic sea ice is the fifth lowest ever recorded. Can you elaborate on precisely what is causing such a loss of sea ice?

Professor Hewitt: The decrease is due to two things. In the summer period we are getting additional melting because we have a warmer atmosphere. In the winter period, when you would normally have sea ice regrow, the ocean is much warmer than it should be in normal circumstances and, therefore, this inhibits the growth, so it cannot even recover in the winter period. Does that answer your question? Maybe Mark might want to elaborate, but I think it is quite simple.

Professor Brandon: Can I step back slightly? It sounds trivial, but it is an important point. Sea ice is frozen seawater, so it is made when the ocean freezes. You think of ice cubes as a solid lump of ice. Because the seawater is salty, you end up with a matrix and it is bit more like a sponge. You know a yellow sponge when you were a kid and you picked it up and seawater drained out. That is what the sea ice is like, so it stays a bit salty. That is very different from the land ice. When the sea ice forms, a certain amount of salt gets squeezed out, which makes the surface of the ocean more dense and that creates mixing. In some parts of the world, it drives up the ocean circulation.

Also within the crystal matrix of the ice, when the ice freezes algae in the seawater gets frozen into the ice. There are species that grow in the ice, so it is a habitat. People talk about the icy wastes of the Arctic. It has carbon in the sea ice. In many places you go to, the sea ice, particularly in coastal areas, it is brown or chocolate-coloured. It is amazing stuff.

When the sea ice goes, it is this whole system that is changing as well. It was the fifth lowest. We have been measuring the satellite record of sea ice in the Arctic for 44 years now, so we have a good record. It is very easy to measure the extent or area of sea ice if you have a few billion dollars' worth of satellites. Every year it is a clear indication of whether climate change has become worse or not, but the trend is the important thing. The trend is relentlessly downwards, about 13% a decade of less extent in the summer.

It is melting at every single month of the year. We have less sea ice in every single month now compared to 40 years ago. The amount of melt that is changing in the winter is less than what is changing in the summer, so that means the seasonal cycle is changing as well, which is a very critical thing in what is going on.

Q15 **Barry Gardiner:** Would it be correct to say that that decreasing trend is not constant, but is now accelerating? Can you just expand on why that is?

Professor Brandon: Helene has already said about how we can be scared of words like "acceleration" when we have relatively short

datasets, but the area of sea ice is easy to measure. The thickness of sea ice is a bit more complicated, and this is important to answer the question. In the UK we are very good at measuring the thickness of sea ice from satellites. We have a very good group, the Centre for Polar Observation and Modelling, that does that. What we have seen is in about 2007 a lot of the super-thick ice in the Arctic ocean—what we call multi-year ice, or ice that has survived a few summers—started to decrease rapidly.

From about 2012 onwards, there has been a very, very small amount of multi-year ice. That means the mean thickness of the sea ice of the Arctic ocean has changed, which means that the ice can retreat much more quickly because it is much thinner, and it can be affected by the weather as well. Whether this year was the fifth lowest or the sixth lowest or the first lowest, if the sea ice moves, if the wind blew it all against the coast, it would be much lower. That trend is still going to be downwards.

Q16 **Barry Gardiner:** In 2019, the IPCC said that before 2050 the Arctic ocean will likely become practically sea ice-free during the summer months. Could you just expand for the Committee what that word "likely" means? I know it has a very specific meaning when you use it in the IPCC reports.

Professor Hewitt: In the IPCC report—indeed, there is a language of itself to IPCC assessments—what we mean is that there is a very high confidence that something will happen, which means that we have lots of lines of evidence and there is agreement, then "likely" is the percentage that we add to that. I should know it off the top of my head. I will not say a number that is wrong. I will check it while we are talking and either tell you or put it in writing to you.

Q17 **Barry Gardiner:** Thank you very much. We have heard that being practically ice-free in summer is going to have major implications, both on the indigenous communities but also on commercial shipping and transportation. What do you see as the major concern around that summer period?

Professor Brandon: The sea ice also acts as a lid on the ocean. The Arctic ocean traditionally has been very slowly moving because the ocean is itself cut off from the wind. If you take the ocean lid away, the winds can stir it up a lot more and mix it a lot more. We have seen off the coast of Siberia and in the Barents sea—which are the places that are most affected—a great increase in primary productivity; that is algae in the ocean. We are changing the food webs there in summer season, which means that species from other parts of the world are drifting into those areas to feed.

Q18 **Barry Gardiner:** There is a complete change in the biodiversity taking place. Can you give us some examples of that, so different migratory patterns. Which species we are now losing, which species we are now seeing come into the Arctic?

Professor Brandon: It is relatively recent to be talking about losing species, but there are crabs migrating across the Norwegian sea into the Arctic, which were not there before, and the trawlers are heading more north in the Barents sea as the species are heading northwards as well.

Barry Gardiner: Sorry, I am straying into someone else's sphere. Let me come back to Terry.

Professor Callaghan: One of the effects that we have to talk about when talking about retreating sea ice—just to give you a number—is that I think if you draw a straight line trend through the loss of sea ice, it comes to about 3 million sq km of sea ice that we have lost in September, so it is a big number. Where that sea ice has been attached to the land, fast ice in the past, that has protected the coastlines.

Now, when you have low coastlines, like in much of Siberia, in Alaska and Canada—not Greenland, where you have rocky coastlines—in other areas where you have these low soil-based coastlines, you are seeing much greater and much faster erosion of the coastline; whole islands disappearing, for example, and communities needing to relocate because they are losing their harbours, roads, coasts and their houses. That is just one added impact of retreating sea ice away from the coastline.

In terms of biodiversity, crabs were introduced, and they are spreading faster than they were expecting them to travel, but of course polar bears are the big one.

Chair: We are coming back to biodiversity in a moment, so I will cut you off there and we will come back to that shortly.

Q19 **Barry Gardiner:** Looking at those rises in sea levels and the impacts on coastlines around the globe, clearly one of the most important bits of research that we are doing, in terms of policy implications, would be how we then adapt to that and how quickly we need to adapt to that. How accurately can we predict the pace of the melting of the ice sheet in Greenland now, looking at that ice sheet?

Professor Hewitt: When we are predicting the future pace of melting of the ice sheet, we are relying on models both of the climate and of the ice sheets themselves. There are clearly uncertainties, both in the processes that are taking place but also in the future scenarios. However, the IPCC did assess that it was virtually certain that the ice sheet will continue to loss mass over the 21st century. There is very little doubt that it will not continue to melt.

The actual numbers, the contribution to global mean sea level, could vary between 1cm and 18 cm by 2100, depending on the emissions scenarios that we end up following. There is more to do on the models, but we are in a much better state for predicting the pace for Greenland ice sheet loss than we are for the Antarctic ice sheet loss.

Professor Brandon: It is the 25th consecutive year of ice loss from Greenland, 150 gigatonnes in the last year. As Helene said, that will carry on. With the sea level predictions up to 2050, we can predict fairly okay up to 2050, but past that is when things start to diverge.

Barry Gardiner: "Fairly okay" is not the one of the qualifiers that I recognise the IPCC using.

Professor Brandon: No.

Barry Gardiner: Can you be a bit more exact?

Professor Brandon: Those are my loose words around the phrase that Helene used about how certain we are of what will happen up to 2050. The gap between 2050 and 2100 is where the physics of how we understand the ice sheet diverges. That is where there is a research gap.

Barry Gardiner: It will no doubt depend on what we do between now and 2050, of course.

Professor Brandon: Of course.

Q20 **Barry Gardiner:** Coming back to this level of accuracy, you are doing all this research, you are telling us that you are losing these million sq km or this tonnage of ice, which is very difficult for people to grasp, but when it comes to a six-inch or six-foot rise in sea level, they can understand that very quickly. It is very important that we understand how certain you are that the measurements you are making of the loss of ice translates into those sea level rises. Then it is incumbent on us—presumably, as the politicians—to put the defences in place or to do what we can to mitigate and so on.

Professor Brandon: Of course, the easiest way to explain the complexity at the moment is that computer models are one method of understanding what sea level rise will come. Another version is structured expert judgments—SEJs—where glaciologists around the world put in estimates of how the sea level will rise and what the melt will be. The range of estimates from those are fairly similar to the models, but the range is much wider.

That is telling us something about how we understand the possible ways the ice shelf may collapse. We do not understand some parts about where the melt water is going and the interactions within the ice sheet. As soon as the glaciers retreat a certain amount, they are out of contact with the ocean and so the rate of melt will change because the ocean is melting the ice sheet where it is in contact. Once it is out of contact, then it is just surface melt.

Q21 **Barry Gardiner:** You are giving me all the reasons why this is difficult. I want to establish from you the accuracy of prediction, your estimate of the accuracy of the prediction and the reliability of the projected rises. Professor Hewitt, can you enlighten us on this?

Professor Hewitt: I think what you are asking is quite a challenging question for scientists, to be fair. Not just the UK but the international community are applying the best models that we have to these problems. There are uncertainties. For Greenland, I think the uncertainties are not as large as Antarctica, but there is more to do on the research and to improve the models. Except to say that we will definitely be losing mass this century, and we do not think it will be much more than 18 centimetres from Greenland alone to the global mean sea level, I am not sure that we can say more but keep pressing me if you think that I should.

Barry Gardiner: No, that is fine. I think what you have shown is that we need to keep on researching in this area.

Professor Brandon: It is a very exciting area to be working in and very lively.

Q22 **Barry Gardiner:** One very short final question, which is probably a one-word answer: can the continued trend of loss of ice in the Arctic be reversed within our lifetimes?

Professor Hewitt: It can for sea ice.

Professor Brandon: For the sea ice; within decades for the glacial ice. For the Greenland ice sheet, no, not in any sensible timeline. Thousands of years, Helene?

Professor Hewitt: Yes. It is very clear. As Mark said, Arctic sea ice would largely recover if global temperatures went down, not for the ice sheet.

Q23 **Jerome Mayhew:** Picking up on one supplementary to Barry's questions. Did you say, Helene, that the 18 cm rise in sea temperature was associated solely with the Greenland levels? Is that right?

Professor Hewitt: Yes. Sea level rise has various components. The ocean gets warmer. As it gets warmer it expands, so in the past 50 years or so that has perhaps contributed about half. Then the ice sheets, Greenland, Antarctica and the melting of the glaciers, that is like adding extra water into the ocean. That has contributed approximately the other half.

Q24 **Jerome Mayhew:** Thank you for that. All my questions will be for you, Professor Hewitt. I just want to expand a little bit on the questions that you have already been asked by Dr Offord about the potential impact on the UK's weather from what we are seeing in the Arctic.

We have had quite a lot of written evidence on this. The Royal Society indicates that changes to the Arctic climate system have resulted in less predictable weather patterns, and it talks about a weakening of the westerly polar jet stream, making it more likely to meander, and in such meanders very cold air may reach deep into the middle latitudes, into the

United Kingdom. Can you expand a little bit on what it is talking about there?

Professor Hewitt: Yes. The basic idea is that, as the Arctic warms, the temperature gradient between the equator and the pole will weaken. With that, we expect the westerly winds to be reduced and for equatorward shift perhaps in the Atlantic storm track. The problem then comes in that this is the complete opposite of what we expect to happen in response to greenhouse gas warming, so that will be the response from sea ice loss. The greenhouse gas warming would oppose strengthened westerly winds, make them weaker, and shift the storm track polewards.

There are several things going on here, so much so that in the IPCC report the assessment was that the evidence was conflicting, which gives a lack of agreement between what the impact might be. This would be a topic of ongoing research. Since the IPCC report, there was a publication by Met Office scientists from an international comparison, which gave the best estimates of the effect of Arctic changes on UK winters at around 10%. In that measure, it could be a relatively small effect.

Q25 **Jerome Mayhew:** The National Oceanography Centre has also given written evidence. It talks about the polar vortex. Correct my ignorance, but is the polar vortex different from the polar jet stream?

Professor Hewitt: Yes. The polar vortex is happening over the Arctic. I will say at this point I am not a meteorologist; I am an oceanographer.

Q26 **Jerome Mayhew:** If anyone else has expertise in this area, please do butt in. It makes reference to the polar vortex also being eroded and suggests that this will give longer spells of low temperatures in the winter and higher temperatures in the summer. Do you feel competent to comment on that or is that not really your area of expertise?

Professor Hewitt: It is not my area of expertise. Maybe if one of the others would like to comment. If not, we can answer that in our written submission from the Met Office.

Jerome Mayhew: Is anyone putting their hand up?

Professor Brandon: I would bow to Helene's group on this.

Q27 **Jerome Mayhew:** Helene, if you could write to us with a bit more evidence on this because the weight of the evidence appears to suggest that there are conflicting impacts, and that the United Kingdom and perhaps some other middle latitude countries may not be as affected by global warming as we would expect, because of the counteracting impact of the weakening polar vortex as well as the weakening polar jet stream. Is that what the report that you referred to earlier said, that there is conflicting evidence and we are not quite sure what is going to happen?

Professor Hewitt: Absolutely. There is a long cross-chapter box in there where lots of scientists looked at it and they put forward lots of different

theories, but felt that there was low confidence in the links because there are different processes happening that are counteracting each other.

Q28 **Jerome Mayhew:** Given the state of the research at the moment, do you have a feeling as to how long it will be before we become more confident in those predictions?

Professor Hewitt: Part of the problem is not the models. Part of the problem can be the length of the data sets. It is very difficult to separate trends from interannual variability when you have a limited length. We can always improve our models. Having said that, the models that we have at the Met Office are among the best weather and climate models in the world. We include the representation of atmosphere, ocean and sea ice, and all the linkages, so there is a sense that there is a lot of variability, and you need very long experiments to distinguish trends from variations.

Q29 **Jerome Mayhew:** Given the unpredictability or the lack of conclusive evidence that we have at the moment as to the likely direction of warming or cooling in the future of the United Kingdom, are you able to express an opinion as to how these changes are likely to develop in the future? Is there at least a direction of travel that we can be confident of?

Professor Hewitt: To clarify, I think we are pretty sure that the UK will warm due to anthropogenic warming. We are talking about the changes in the circulation here, not the temperature.

Q30 **Jerome Mayhew:** Can I just pick up on that? The written evidence we have had suggests that, rather than warming in the winter, we are likely to be substantially cooler in the winter, with longer, colder winters or more intense periods of cold. Is that not a conclusion that you support?

Professor Hewitt: I will defer to providing that in our written evidence, if that is okay.

Q31 **Jerome Mayhew:** I would be grateful. I am sorry to put you on the spot like this. That is not my intention. I will move on, but I am sure the Sub-Committee will be very grateful if this could be expanded on by the relevant expertise within the Met Office, because, as you pointed out, there does seem to be an interesting debate as to what is the preponderance of the science at the moment.

Professor Hewitt, finally, with the current climate models, do you think we are sufficiently able to predict the interactions between changing climate conditions in the Arctic and the UK's climate? It feels like we have already answered that question, and the answer is that we are not sure yet. Is that something you will write to us on?

Professor Hewitt: Yes. We are using the best tools we have. I would say on this point that there are other things happening in the Arctic that affects the UK. For example, how the Greenland ice sheet melt would affect the UK sea level, although we actually think Greenland is not the

big issue there; it is actually Antarctica. Nevertheless, the melt might affect this overturning circulation. These are important things that we need to add into the models as we develop the complexity. The other aspect we are developing in the models is to improve the granularity—the regional detail in the models—so that we can give people the local effect on larger climate change.

Chair: I love the contrast between the proper accuracy and caution of scientists and the politician's need for the broad general sweep of direction. It is fascinating to watch.

Q32 **Anna McMorrin:** I will turn to the ecology in the Arctic. I will ask you, Professor Callaghan. In 2019, the United Nations Environment Programme called thawing of permafrost one of the top and emerging issues of environmental concern. Its big concern was that the permafrost boundaries receded northwards and the significant loss of coverage. Can you set out to the Committee what, in your view, are the climate impacts of thawing permafrost and why this thawing permafrost is such a problem?

Professor Callaghan: First, you have to understand what permafrost is. This is not a substance you can get hold of. It is a thermal state of the ground, so it can be rock, soil, or peat that is frozen for at least two years or more. The oldest permafrost is about 1 million years old.

Permafrost is classified according to how much ground surface is covered by permanent frost. In the extreme north, you have continuous permafrost where everywhere is covered by permafrost. The active layer—that is the soil above the permafrost—thaws in summer. That can be as little as 10 centimetres. That is everything that plants have to grow in and that is where any carbon emissions that come out.

As you go further south, the permafrost becomes discontinuous. There are gaps in the permafrost where forest can grow, for example. Further south, you get sporadic permafrost. Usually that sporadic permafrost is protected by mosses that insulate the permafrost from high temperatures in the summer. As it gets warmer, that permafrost is thawing. Where we have sporadic permafrost, it is disappearing altogether. Where we have discontinuous permafrost, it is becoming sporadic. Where we have continuous permafrost, in some places it is becoming discontinuous.

It affects the landscape and there are huge impacts on the landscape if you have permafrost thaw. If the ground is rich in ice, when that ice melts, the water runs away, and the ground subsides. That means that houses fall down, roads break up, airstrips break up, riverbanks erode and coastlines erode. It means that the vegetation changes because, if you have an area of intact permafrost, that might be typical tundra vegetation with shrubs, grass and the like. As soon as that subsides, you get a lake. You cannot have a much greater change in biodiversity between those two. The whole of diversity, whether it is a classic diversity or terrestrial diversity, depends on permafrost thaw. Then these

lakes go through cycles. Sometimes these lakes drain out and you get a cycle going back to the land vegetation.

In the most extreme cases, you get thaw slumps, and this is where the permafrost is thawing on a hillside, on a slope. There is a detachment of the active layer. This shallow layer on top of permafrost is not frozen. It literally slides down the hill, goes into the watercourses and flows away. That leaves a huge gap with nothing.

There are two things that destroy ecosystems totally. One is tundra fire and the other is permafrost thaw slumps. Everything else, all the other impacts of climate change on vegetation or on biodiversity, are changes in the diversity, reductions in plant growth or new species coming in. Those two cases result in no ecosystem whatsoever.

Q33 **Anna McMorrin:** Does the permafrost degradation lead to decomposition of previously buried organic matter and then release significant amounts of carbon dioxide, causing greater issues such as global warming?

Professor Callaghan: Yes. If all the carbon in the top three metres of permafrost was released into the atmosphere, it would more than double the CO_2 in our atmosphere?

Q34 **Anna McMorrin:** What work is being done to assess that, and how extensive is this damage at the moment?

Professor Callaghan: It varies from place to place and time to time, but at the moment we still think that the Arctic is a sink of carbon. There is so much undisturbed vegetation. Even though it may be changing, there is still vegetation there. That is taking carbon dioxide down at a faster rate than the permafrost is releasing it. That is a very difficult measurement to make. If you imagine, we have a huge box, which is the storage, and we have tiny little fluxes going in and out. The problem is measuring those fluxes in and out.

What we are looking at and have a lot of research on is what happens when there is a fire in the tundra. It is horrific. There was one fire in Alaska over 1,000 status quo km and in a few weeks that released the amount of carbon that would take 50 to 70 years to replace in a cooling climate. Going back to my earlier point, if we go to 1.5°, we are still talking about warming. It is like the Greenland ice sheet. It will never recover because we are still talking about warming, not cooling. To put that permafrost back and to increase the carbon storage, we need cooling, not further warming.

Q35 **Anna McMorrin:** Is there a tipping point for the permafrost being a carbon sink or emitter? Is there a tipping point that the world's climate scientists are looking at?

Professor Callaghan: I do not think there is a tipping point. I think that there are local tipping points. For example, once you have lost a whole lot of soil down into the river valleys, that is a tipping point. You are not

going to put that soil back again. However, if you have a big, flat area and the surface goes down by a few centimetres, then if we have a cold period, it will go back up again.

Q36 **Anna McMorrin:** Is it being looked at to predict future greenhouse gas emissions at a world level? Is that one of the calculations?

Professor Callaghan: People are studying the amount of emissions that are given off by thawing permafrost in different places and there are different ways of doing it. You can measure the amount of CO_2 coming out of the ground. You can look at the isotopic signature of the carbon that has been released to get a date on when that carbon was actually stored. We know that some carbon that was captured thousands of years ago and stored for thousands of years is being released in some places.

Anna McMorrin: Professor Bravo, I don't know if you were nodding because you want to come in.

Professor Bravo: Nodding in the sense that I think it is such an important question. Being trained as an engineer and now being a historian rather than on the spot as a scientist, I see how compelling the question is. I suppose I am a pessimist.

Q37 **Anna McMorrin:** Terry, what effect is the warming of the Arctic having on species distribution? You just talked about the warming of the Arctic and fires. We have heard in our written evidence from WWF that animal habitats and living conditions are being transformed. What are the consequences for the associated ecosystem structures, habitats, and the people who live in the region?

Professor Callaghan: Let me leave the people for a second. There are very diverse types of vegetation and animal life throughout the Arctic. We start off with forest in the south and we end up with glaciers and polar deserts in the north, where the vegetation covers less than 5% of the area. If I make generalisations, there is less change in the north in the polar desert. I have seen photographs from Svalbard—where I believe you are going—which show no change whatsoever in some of the polar vegetation over a period of 70 years. That is one aspect. Then you go to the south to the borders of the forest where the forest is moving into the tundra at a rate of between two and 10 metres a year. It is not that fast.

What is concerning is when we started looking at satellite images of NDVI—the normalised difference vegetation index—you can look at light coming to earth from a satellite and the light reflected back again. The bit of red and blue light that is absorbed is used by the plants in photosynthesis, so you can tell how the plants are growing.

We talk a lot about the greening of the Arctic because when permafrost thaws, it releases carbon dioxide, but it also releases nutrients so some of the plants can grow faster. We were seeing shrubs move into the Arctic. This is called shrubification. We are seeing the tree line move

north. All this was greening. Then in the year 2000, we saw that curve of greening start to come down and we call that process browning.

Now there are a lot of events happening. This browning of the vegetation seems to be driven by extreme weather events. For example, if it rains on snow in the middle of winter, the lemmings and the reindeer cannot get to their food and they die. If there is a mid-winter warming event, the snow melts, ice layers form on the ground, the vegetation becomes encapsulated and vegetation dies. We have seen productivity decrease by 75% over 1,400 sq km of northern Norway and Sweden just through a few days in winter that were warm.

These are patchy occurrences, but we are seeing this browning of vegetation now taking place through a whole range of different events. Of course, when you get browning vegetation, that affects all the animals who live on that vegetation. When the herbivores are affected, such as the tens of thousands of reindeer that have died, that affects the scavengers that live on them. Whereas we thought that changes in biodiversity were very slow, gradual processes—some of them are—we have seen that southern scavengers have moved into the Arctic and Siberia in a year just to feed off the tens of thousands of dead reindeer bodies.

Where we had the white fox—the arctic fox—that has gone and the red fox is there. We have magpies and crows that were not there. It is a step change in biodiversity that we could never have predicted. That is frightening. Then of course you have the reindeer that are dying and a lot of people feed on the reindeer. Reindeer is extremely important for culture, clothing, and food, and so are the fish.

Q38 **Anna McMorrin:** Are there consequences in all of this for the UK?

Professor Callaghan: I would like to think of two types of consequences. One is the actual practical consequences and that is that something like six million birds migrate to the Arctic each year to nest and I think something like 41% of those birds are European. The biodiversity of a lot of Europe's bird life is dependent on nesting in the Arctic.

Q39 **Anna McMorrin:** The ecosystems there will have a knock-on effect on the ecosystems of Europe.

Professor Callaghan: Yes, and vice versa. Those birds are taking propagules of plants and taking new species to the Arctic, like tourists.

Q40 **Anna McMorrin:** That is with oceans and where there is land reaching into it. Are there hard limits where that is not going to apply, regarding northward migration? Would you get that?

Professor Callaghan: I don't think there are limits. As a generalisation, islands are most vulnerable to invasions of species from outside because they have always found it difficult to get there and, in the past, the

climate has not been favourable enough for those species to take off. However, as more people are going north as tourists and the birds are flying off and taking propagules with them, and as these islands are getting warmer and warmer, then conditions would be more amenable for these species to become established.

Chair: Do you mind if we move on swiftly? Caroline Lucas.

Q41 **Caroline Lucas:** A question for Professor Bravo. The Government's recent Arctic framework recognised that "the Arctic is, first and foremost, a home to the people who live there". I know you have touched on this already, but could you say a bit more about what are the most significant environmental changes taking place in the Arctic that affect the people living there?

Professor Bravo: Thank you. I think the question is posed in terms of climate and impact and I will try to answer it that way. To add a little bit of complexity, if you ask people who live in the Arctic what their top priorities are, as elsewhere, climate is not usually at the top of the list. That is because everybody first of all wants to have a job and healthcare for their children. Climate might be number six, seven, eight, nine or 10. It is usually when we begin to understand the relationships between climate, health and so on and we get this rounder picture of what you might call climate justice that that question comes home. It is in that context that I think the impacts are felt.

I think that the environmental changes we are seeing impact, first, on the capacity of people's mobility. As I say, there are many different reasons to think that mobility is being lost. Of course, it is not only environmental but very much so and, concretely, if your sea ice is not there, you cannot travel over it. You can travel across a large body of water, as I have, in a boat, in an umiak or a canoe as they call them, or a bigger boat with an engine, but it is a lot more dangerous.

Even though some of the dangers we imagine of the heroic age are past, it is still the case that in a big swell coming off the Northwest Passage into communities like Pond Inlet, the entrance to the Northwest Passage or Arctic bay, people die in open water accidents. Boats travel much more slowly. If you live in the Arctic, the loss of sea ice is also a loss of home, the place you might actually be comfortable, because you are right by a very plentiful supply of food, and you also lose mobility.

Second, with loss of mobility, why does it matter if people travel? Especially with the young generation now. There is a demographic shift in the Arctic. I would have to check the numbers, but there is a much higher proportion of people under the age of 21 than would have been the case in the past. Why do they need to travel? Can they stay at home? For example, it is true that young people in Arctic communities are among the most digitally connected, or at least they have a great appetite for using social media. They are not stuck in some kind of notion of the past.

Mobility along the land gives access to traditional foods. True, people will go to the supermarkets and buy cornflakes and so on, so what is it that traditional foods offer? For many different cultures, whether the Sami in Scandinavia, the Inuit or the Inuvialuit in northern Canada, or Inupiat in Alaska, first of all, it offers them food in a spiritual sense. When food in many of these communities is hunted, in some of these communities they will not sell it. It is not something that should be treated in that way. It should be shared. It is the heart of a sharing culture. The word "sharing", by the way, tends to get devalued in common currency. Anthropologists will tell you that sharing is structured by specific rules, and it is important for how families manage their economy—their micro-economics. Sharing is who can ask who for help. It is important.

When you lose mobility, the hunters are losing access to walruses, to plentiful seals, and to the caribou inland. When the hunters do not come back with the caribou, in the way that they would, they cannot go on the community radio and say, "Everybody come over and help yourself to some caribou." There is that loss. Secondly, there is a loss of safety, wellbeing and territory.

Lastly, there is a powerful sense of a change of belonging. This is one of the reasons that readers and audiences all over the world are so interested in the Arctic. Because there is a difference, and these people traditionally have a different sense of belonging to the land. Some sense of reciprocal obligation as to what we owe the environments that we live in by appreciating what they give to us. Environmental change touches very deeply on people's identities as well as very concretely into their micro-economics and their mobility. In other words, as capable and as long a history they have of adaptation, that does not mean that adaptation is always possible, easy or desirable.

Q42 **Caroline Lucas:** That is really fascinating. Does that lead to the kinds of psychological problems that you can imagine that it might, given that what you describe is so existential in a sense?

Professor Bravo: Yes, and there is a lot of writing by people from all over the world about what ecological loss means. I think that we have to recognise that there is a widespread movement of attributing loss to the Arctic. Because we need to use our imaginations, we increasingly think about the Arctic as a region of loss. We ask the question, "What is it that they are losing and what is it that we are losing?"

I think that the relationship between the two is getting narrower, partly because we have the gulf stream within 50 and 55 degrees north of the British Isles and other parts of the world on that latitude. We are in the sub-Arctic. This might be moving away from your question slightly, but I do also suspect the notion that the Arctic is up there, and we are down here is a separation we can keep at bay for so long, then it might come home quite hard.

Q43 **Caroline Lucas:** Lastly, on the impacts you have been describing, are

those challenges fairly uniform in the location of where those communities are within the Arctic, or are there areas where it is much more acute?

Professor Bravo: It is much more acute in some places. As is the case with most forms of inequality, it gets more pronounced in situations of increased stresses. If one is looking at the intersection of different factors, of course, environment intersects also with policy. That is one of the things that makes the Arctic an endlessly fascinating but difficult region.

The reason why co-operation is so interesting in the Arctic, the reason why I have had people working on the South China sea say, "Can you come and talk to us about Arctic co-operation?" is because they see that this is a place with political economy where the Soviet Union, the United States, Norway, Sweden and Finland—fundamentally different political economies—have managed to come together. That means that, when one is looking at the consequences of climate impact on these regions, they are filtered through those different economic systems and one will get a lot of change. After 1989, even though Gorbachev promoted this idea of perestroika and so on, a lot of communities were stranded because flights stopped coming to them in Russia. In other parts of the world they might be prospering more.

I suppose my colleagues can be very precise about what kinds of impacts can be found in different coastal areas depending on the geological substrate and so on, but I think of relevance to the UK, though, is that this gets us to think much harder about investment policies because they are situated within different political economies. I think that the kinds of investment strategies that will mitigate climate change for people in the Arctic have to be thought through in the context of the politics, finance and investment that one is thinking about. Even if the Russians are not working with us at the moment, the same applies for them.

Chair: I am keen to move swiftly because we will keep an eye on the clock. Cat Smith.

Q44 **Cat Smith:** Thank you very much, Chair. Professor Bravo, just a couple of follow-on questions. The UN has said that indigenous people should be part of any solution to climate change. What contribution is indigenous knowledge making to our understanding of the Arctic, and what influence do communities have on government and commercial decisions that have an impact on the region's climate and environment?

Professor Bravo: Indigenous peoples have a voice by virtue of being who they are. That is to say that they have legal rights. In different countries, they also have different ownership rights. In Canada and the United States, for example, and also in northern Norway, Sweden, Finland, I think, they all have ownership rights. They have a big say over what happens on their land. In some cases, that is the surface rights, and in some cases, the ownership extends to sub-surface rights and of course

that is a complicated field. They are owners, but they also have rights by virtue of their historical occupancy of the lands. They might say since time immemorial. In any case, those give them particular rights.

How they contribute to our environmental knowledge, and have done so, is an important and fascinating story that goes back a long way. Any ecologist who has spent a career as long as you have, Terry, in the Arctic will know that a long time before we acquired the jargon of science here and traditional knowledge there, through the history of the fur trade and whaling, these peoples' experience and knowledge were traded and shaped each other constantly.

I saw some of the best collaborations between scientists and indigenous peoples in the 1980s in Nunavut. That was before it was a subject to talk about. Terry, over to you in a minute, but scientists would come and say, "Where do I look for this particular species?" One of the first things I saw was scientists doing a study of walrus stomachs in the Foxe basin. They wanted to understand their health of walruses and populations and so on. The population biologists went out with the experienced elder who was earning some cash as a guide, and said, "We cannot find any walruses". They looked again. He said, "Well, let's look over here", and there were the walruses.

They got them back on shore, cut open the walruses and looked inside the stomachs, and the biologist—it was a grad student doing a perfectly good project—said, "But the stomachs are empty". He said, "Well, yes, they would be, wouldn't they?" This elder was able to say, "If you wait a few weeks, that is when the feeding season will allow you to go back to this place and find the walruses that you want, and they will have the food inside them". I use that as an anecdote but let's ask ourselves: what is going on there? That is on the one hand, local knowledge at work. Secondly, it is the sharing of knowledge. Thirdly, it is under the radar because it did not make the news. The biologists would bring their materials and show the community what they found.

What it shows about the Arctic is important—and maybe there is something even here for this Committee—because it illustrates how many of the important things that take place in the Arctic involve reciprocity. That is what I continue to hear, not only when I am talking to a hunter but that is the same thing I hear when I talk to the director of a policy research institute in Norway or in Iceland. You will recognise this as politicians because you are seasoned in diplomacy, what they are saying in the nicest terms is, "Come and work with us." At every level, though, there is give and take. Therefore, I think to understand these kinds of impacts, what they are also saying is, "You have to understand how it looks from our point of view."

Q45 **Cat Smith:** That leads into the question how we strike that balance between the desire of Arctic communities to economically develop alongside the desires to mitigate the worst effects of climate change.

Professor Bravo: Terry, I saw you had your hand up. I would only add that maybe there is no tension between them. There can be, depending on the development strategy. For example, if you have groups who own mineral resources and they want to sell them or lease them, you might say there are externalities that will come back to cost them.

On the other hand, I think that most politicians in the Arctic would argue that the greatest obstacle to adaptation and to development is investment. Of course, it begs the question of investment in what. This is so important. We know it is. I live in east London. It is not so different, and the teachers will tell you that. Investment in education, investment in children—all of the fundamentals are similar in what these northern societies need in order for young people to have livelihoods and jobs.

Professor Callaghan: Just a small detail about indigenous knowledge. I was a director of a big research station in Swedish Lapland for 12 years and I was working with indigenous knowledge a lot of the time there. The first scientific record of 50 years of snow structure change, through rain on snow events in mid-winter falls, came because of a talk with a Sami reindeer herder. The first experiment in the world to predict future extreme warming events, by burning off the snow in the middle of winter for a few weeks, was because of a conversation with a Sami reindeer herder who worked with us on the experiment.

The indigenous knowledge is excellent but—you might not like this—there are uncertainties that indigenous knowledge does not measure. Within science, we have our uncertainties. We have statistical tests with standard errors and standard deviations. The indigenous knowledge does not, because if they got their knowledge wrong in the past or it was not passed on, their community would die out. Our records of that are not brilliant. When you put the two knowledge types together and you have a double-check, you have a check from the indigenous perspective and you have a check from the science perspective, then it is a win-win situation. It is this give and take.

Professor Brandon: We also have a research programme going on right now funded by the Natural Environment Research Council and the Canadian Research Council, with Canadian Inuit, specifically to work with indigenous people. The proposals had to be 50% Inuit, 50% UK scientists. The proposals were not judged on one standard if it came from an Inuit community, and it was written their way. It was a joint committee that assessed the proposals from Canadian and British researchers and Inuit people as well, and they had to address cross-current themes. That is running right now out to ’25. There is a recognition of this going on and it is about an £8 million research programme, which is significant, but it would be great to carry that on in other parts of the world as well.

Professor Bravo: I will come in there. I think that is right. Terry, I am perfectly comfortable with the fact that different knowledges have

different capacities. That is also what philosophers argue about science itself. They call it the disunity of science. I am not trying to railroad them all into one package, but you are right, there is a coming together.

The UK-Canada arrangement or agreement you referred to—the MOU—has been very productive. It is interesting to me that, at the Canadian end of that memorandum, is an institution that in the 1980s and 1990s negotiated the land claim with the federal government because of the Supreme Court decision.

The northern institutions that you are asking about, if one is talking about the empowerment of northern institutions, there is a process of devolution that matters here. These institutions will grow and change. In order to have partnerships, in order to have collaborations between science and indigenous knowledge, I think we also need to see the empowerment of those institutions. How that matters, particularly to a Committee like this, is that if you want to advance a research agenda in the Arctic—and this is key, and I have to say it is key because it has not always been achieved or gone about the right way—you need to seek partnerships where the northern peoples are in a position either to lead the project or at least to be at the planning stage from the outset. I have reviewed many of these projects and you can see that will bring about the success.

Q46 **Chair:** Henry Burgess, who is on the UK end of that particular remit, is coming in on Wednesday so we can quiz him about that as we go along. Can I move on, please, to the final section of questions? You have been very generous with your time. It has been an absolutely fascinating session.

To the question of environmental governance that was touched on a moment ago. Could you outline the consequences of the Russian invasion of Ukraine and the consequent pausing, collapse, or disappearance of the Arctic Council? What effect is that having on environmental governance of the Arctic? Secondly, what effect is it having on the effectiveness of scientific research? Terry, I know that you have a particular view on permafrost research.

Professor Bravo: I will try to be succinct and then hand over.

Chair: That was rather rude of me. I did not mean that rudely.

Professor Bravo: No. I think there are five or six things. First of all, the region whose reputation has been built on co-operation. That is clearly fractured now. Everyone working in the Arctic feels the loss of Russian research partners of great calibre and quality. The loss of co-operation has also created incentives for stronger co-operation and agreements. There is much more activity exploring and searching for co-operation, for example, between the United States, Iceland and Norway as a response to the Russian invasion.

Secondly, there is a possibility of increased securitisation of the Arctic environment; areas that are zoned off as military areas, obviously in Russia but perhaps elsewhere.

Thirdly, potentially—Terry, you can go into this—a loss of access to monitoring and sharing of environmental data, because we know that environmental data comes from across different national constituencies. Sometimes it is not even very expensive, but with the war, surely, there is a huge loss of environmental data. As I say, I think that means weakening of the region's connectiveness. The Arctic Council came out of environmental thinking in the first place. I think that is what is really being lost.

Finally, a realignment in the Arctic. I have a research student who wrote, I think, the first paper in 2013 or 2014 called "The Asian Arctic as an Idea". Are we seeing, at least for now, the end of the Arctic and instead a North Atlantic Arctic and an Asian Arctic? That is a good question. I think that has a direct impact on how we plan.

Q47 **Chair:** Leaving due politics aside for a moment, I am keen to hear particularly from you, Terry, on this question about how Russia being closed down is affecting Arctic science; for example, your work on permafrost but also in other ways.

Professor Callaghan: Yes, it is catastrophic. One of the strong arguments I want to make—which is strange—is that we are welcome to work in Russia. I have had invitations from the ambassador, who was the head of the Arctic Council, who offered to fix my visa. I have been invited by different rectors of universities in Russia. There is no problem for a UK or western scientist to go to Russia, but many of us do not want to go as a statement against the invasion of Ukraine. There is still a barrier. However, the barrier is from our side, not from the Russian side, which is very strange, and you do not hear that very often. We can go whenever we want, but we choose not to and for very good reasons.

We are losing half the Arctic. Although I totally agree with what Michael said, when we have this North Atlantic system coming together, we still cannot understand what is happening in the Arctic or the rest of the world without understanding what happens on the 7,000 km stretch of the Russian Arctic. Half the northern hemisphere's permafrost is there and most of the indigenous people live there. It is a huge hold.

To give you an example, INTERACT—the network I founded—I think has 95 research stations now. It is a very big network. We lost 21 of them. Those 21 were lost because the EU, which funds INTERACT, refused to fund collaboration with Russian partners. All the Russian partners were extremely sorry. They wanted to stay.

Before the war, we had something called transnational access. That is a beautiful European system where someone from any country around the world—and Britain was the best at all these applications—would apply to

us to go to a research station that was not in their own country. We had Americans going to Russia and Russians going to America, and all the other nationalities going to different countries. It set up collaboration. We exchanged data. We have lost all that Russian component. They still want to publish. I am still working and publishing papers with Russian colleagues in my own time. I cannot charge that time to the EU grant, so I am doing it in my spare time. They are desperate for collaboration, and they have a huge amount to offer.

If I might go back one stage, the situation between the Russian indigenous people and the Canadians, which you are working with, is so different that if you have a rain on snow event in the winter and the reindeer are going to starve in Scandinavia, you simply take those reindeer into corral and you get helicopters to feed them pellets. They just die in Russia: 80,000 in one year and 60,000 in another year. Of course, that is dramatic.

We have health problems with the indigenous people in the Arctic because of Russian guidelines. The Russian guidelines have now said they cannot sell reindeer meat or fish that they have caught off a sledge at a market in a small village in northern Russia, which is the way they shared their food. They cannot sell reindeer meat or fish that they caught or that they slaughtered off their sledge. In the past, people would get their catch, cut up the meat, take it to their friends and relatives and, if they had something left, take it to a local market and sell it.

Now they cannot do that. It has to go through a slaughterhouse. The intention is good. It is about hygiene. The effect is that people are now moving away from their traditional food. The consumption of fish in Yamal has gone down by 40%. The consumption of reindeer meat has gone down by about 50%, increasing hypertension, strokes, and heart attacks.

Professor Bravo: Also increasing poverty.

Chair: It is very serious. The consequence of Ukraine is extremely significant for scientific research.

Q48 **Philip Dunne:** Do you have any specific recommendations? You have all said utterly fascinating things throughout this session, and I am sorry I missed the very beginning of it. We will write a report making recommendations to the British Government. Are there any recommendations you would give us to contemplate?

Professor Brandon: I will go for the easy open goal. One of the critical things with Arctic research is time series and length of data, so more consistent funding to keep that going. We have outstanding satellite groups, but they are working a lot on short-term grants, so more funding for those people would be really good.

Another platform to go to the Arctic would be helpful. The payback for us would be a greater understanding of how quickly the sea level will rise. We have to plan for our coasts what is the actual number and the error bar, which you drilled down on well at the beginning. Understanding that better would be a net saving.

Professor Bravo: First, assumptions are still very prevalent, not only among lay readers but even training scientists. There is still an assumption that the Arctic is remote, barren and empty. I do workshops and people keep telling me this, even after a couple of days in the workshop. I think that needs to be replaced by a sense that the Arctic is our neighbour as well as being a home that is inhabited. Then I think we will find better ways to understand the wellbeing of the UK in relation to the Arctic.

My colleagues in the Nordic countries tell me you have excellent researchers, not only in the sciences but also in the social sciences. I can only think of up to 10 researchers in the humanities and social sciences working on Arctic problems. Why is that? I heard that only this morning. That could be construed as a plea for funding.

I think if there is a plea for funding, it would be cheap and easy to have easy bilateral exchange links for visits. That is how you understand each other's business and it does not cost very much. That would be an easy gain. Fundamentally, it is taking the time—whether it is academics or MPs or campaigning groups—to understand what our friends in the Nordic countries, the United States and Canada think, to understand both what we can learn and share and to appreciate the differences.

Professor Callaghan: I will pick up on what you said, starting with bilaterals. What I heard about your project in Canada is excellent because, as a director of an Arctic station in Swedish Lapland, I used to get very concerned by the exploitation of the research station, the Swedes and the Sami. People would come in from a European country, set up their experiments, get their data, pull out and leave nothing behind except their rubbish. I am happy that we now have a much better relationship and this bilateral component, where the data stays with the people who need it and the people that it helps. That is essential.

The next one is the time series. I am looking at this, not as a modeler but as an ecologist. I think of all the money and time that has been wasted in scientific papers that say "short-term effects of" in an experiment on some Arctic ecosystem. We know that things happen slowly. We know that we need long-term data and the first year of an experiment is utterly useless. They do not tell us anything. However, if we do not publish that paper, we do not get the money for the second stage of the experiment. Eventually, after 10 years, "long-term effects of" and that is the one that matters but, if we do not publish in the middle, we will not have our jobs or our grants. This long-term view of the processes is important. The continuity in your phraseology.

The next one that I think is important is education. It is not just education of the young people. It is education of everyone. We have done research on perceptions of environmental change on a 2,000 km transect from the Arctic to the south of Siberia in western Siberia, asking people about climate change, and perceptions are sometimes completely wrong. In some cases they are right, but we cannot have people with the wrong perception, because if they have the wrong perception, they will not adapt and will not make progress. There is something about education at all levels.

Chair: Professor Hewitt, you have been rather left out down there.

Professor Hewitt: That is fine. As a civil servant, it is not really for me to comment on what you recommend to the Government. I will comment as a scientist. Certainly, for the IPCC, the sustained observations and monitoring that Mark and Terry have talked about is important. We have talked about reducing uncertainty. To do that, we need to continue to improve the models by including the additional processes that we can go out and observe.

Chair: Professor Brandon, finally. You have answered this already.

Professor Brandon: Yes, I jumped in first, I am afraid.

Chair: You got in first. Thank you very much indeed to all four of our learned witnesses. It has been a very useful afternoon as a background to our research over the next few months. It is very kind of you to give up so much time and effort to come and brief us, as you have. I keep thinking about a dear old friend of mine, Martin Brandon-Bravo, who was a well-known MP here many years ago. Professor Bravo, Professor Brandon, Professor Callaghan and Professor Hewitt, thank you very much indeed for your witness evidence this afternoon.