



HOUSE OF LORDS

Environment and Climate Change Committee

Corrected oral evidence: Nitrogen

Wednesday 12 February 2025

10 am

Watch the meeting

Members present: Baroness Sheehan (The Chair); Lord Ashcombe; Lord Duncan of Springbank; Lord Jay of Ewelme; Lord Krebs; The Earl of Leicester; Lord Lennie; Lord Rooker, Lord Trees.

Evidence Session No. 2

Heard in Public

Questions 12 - 25

Witnesses

[I](#): Professor Jeremy Biggs, CEO, Freshwater Habitats Trust; Dr Alexander Lees, Manchester Metropolitan University; Dr Ed Rowe, Senior Biogeochemical Modeller, UK Centre for Ecology and Hydrology.

Examination of witnesses

Professor Jeremy Biggs, Dr Alexander Lees and Dr Ed Rowe.

Q12 The Chair: Good morning and welcome to the Lords Committee on the Environment and Climate Change. Today we will be taking evidence from an expert panel of witnesses for the second session of our inquiry into the efficient use and management of nitrogen in the environment, focusing today on ecological and climate change impacts.

Before we start, I remind everyone that the session will be webcast live on Parliament TV and that a transcript will be taken and made public. Witnesses will have the opportunity to review the transcript and make minor amendments.

I remind Members that they should declare any relevant interests the first time they speak. I will take the opportunity here to say that I am a director of Peers for the Planet, which is an unpaid role.

Before asking the first question, I say a really big thank you to our panel of expert witnesses for taking the time to be with us this morning. Before asking the first question, I will come to each of you in turn and ask you to say a few brief words of introduction. May I start with you, Professor Biggs?

Professor Jeremy Biggs: I am the CEO and co-founder of the Freshwater Habitats Trust. Perhaps for today, another relevant piece of information is that I was a peer reviewer for the clean and plentiful water chapter of the OEP's review of the environmental improvement plan, which came out recently.

Dr Alexander Lees: I am a reader in biodiversity at Manchester Metropolitan University and a lab associate at the Cornell Lab of Ornithology. I am a conservation biologist interested in global change impacts on biodiversity—the fragmentation, the degradation and the land use change that is altering biodiversity globally. I am also interested in both a teaching and a research capacity in wicked problems, of which the nitrogen issue is certainly one.

Dr Ed Rowe: I am from the UK Centre for Ecology and Hydrology, based in north Wales. I am a plant and soil ecologist working particularly on nutrient cycles. I have had a focus on nutrient nitrogen for some time and I head up the UK National Focal Centre for Modelling and Mapping of Critical Load and Critical Level Exceedances, which is a rather long title for a part of the UNECE air convention—the Convention on Long-Range Transboundary Air Pollution.

Q13 The Chair: What are the main impacts of nitrogen deposition from the air on plant species and how does that impact ecosystems more widely? May I start with you, Dr Lees?

Dr Alexander Lees: There are multifaceted impacts: we have eutrophication, acidification, direct foliar damage and then various

trophic, cascading, secondary, indirect impacts. Eutrophication is perhaps the most well-known impact on the terrestrial plant species. Biodiversity accrues at large spatial scales across topographic gradients. Some areas have more fertile soils and different climate gradients, different rainfalls, and so on. This diffuse and point-based nitrogen pollution ends up fertilising the soils, which is a major negative impact on species of plants that are naturally adapted to habitats with very poor, very low nutrient loads.

What happens with this exceedance of these nutrient thresholds is that we get a turnover in community composition towards more nitrophilic plant species. That leads to the loss of often these rare and specialist species associated with habitats such as sand dunes or heathlands and some woodland systems that are nitrate limited.

In addition to that, we have acidification—the process of changes in the pH, which some species are maladapted to—for many species such as lichens and particularly mosses, of which the UK has incredibly important international populations, lots of endemic species. We can get direct foliar damage on those species, which leads to local extinctions.

There is also—we can perhaps touch on this later on—evidence of impacts on fauna and other associated processes.

The Chair: Before moving on to our other panellists, could you give some examples of the nitrophilic species?

Dr Alexander Lees: The nitrophilic species might be lots of graminoids, so lots of grass species tend to do better with high nitrogen levels—I am thinking woodlands. That might also be things such as brambles and stinging nettles you often see alongside paths, where you get high exceedance with urination by dogs, for instance. You get these drifts in composition. That is to the detriment of some incredibly rare species.

The UK has endemic species in some of these systems—dune helleborine, for instance—which are found nowhere else and are extremely intolerant of these high nitrogen loads, which are in exceedance over the best part of most of the country—certainly, most of England, less so in parts of Scotland and Wales.

The Chair: And nettles?

Dr Alexander Lees: Nettles, certainly, yes, a very obvious indicator of very high nitrogen loads.

The Chair: Are there any other indicators—plants such as nettles? You have mentioned brambles.

Dr Alexander Lees: There is a whole suite of species. You often have a sister species, which is closely related, you will have a turnover from one species in the same genus to another species. A lot of these species have very broad geographic ranges, because they are the dominant competitors. It is almost ecology 101, where in a battle between

competitively dominant and subordinate species, the subordinates end up occupying these more ephemeral habitats, often early successional habitats or habitats with very poor nutrient loading.

The Chair: Would any of our other panellists like to comment further?

Dr Ed Rowe: Maybe just to highlight the role of light availability. Nutrient nitrogen is a fertiliser and a lot of our natural habitats are naturally very limited by nitrogen, so their productivity is limited. Of course, if you apply fertiliser to vegetation things tend to grow more. The things that respond, as Alex says, are these tall growing, light-demanding species such as nettles and brambles. They cast more shade, so they are growing tall, they have thin leaves, so they make a lot of leaf for a given amount of biomass of carbon, and they drop a lot of litter. What you end up with is less sunshine at ground level.

It is very clear that the most threatened plants in the UK are short species. They are short species that need a lot of sunshine at ground level. Things such as harebell used to be very widespread, and now it is rather restricted to very infertile grasslands because of all the fertilisation.

Most of the evidence that we have is around plants—lichens, mosses as well—but by implication we think that there are likely to be effects on animal species that need sunshine at ground level—so reptiles. We are getting evidence now for effects on butterflies, particularly butterflies that have only one food plant that likes those infertile conditions. It is trickier to pick up evidence for animals because they move around more.

The Chair: Just picking up something that Dr Lees mentioned—the impact on mosses, lichens and fungi. Why is that important?

Dr Ed Rowe: Atmospheric nitrogen affects them more because they do not have a cuticle. Vascular plants have a waxy cuticle that keeps out ammonia and oxidised nitrogen, so they tend to be more influenced. But why are they important?

The Chair: In terms of soil. We hear that they are important for the health of our soils.

Dr Ed Rowe: Some mosses are very involved in soil formation, such as sphagnum mosses on peatlands. Bryophytes and lichens do not seem to be all that important for people. They are not one of those charismatic, iconic species, but they have a critical role in our ecosystems because they provide refuges for things to hide in over the winter—invertebrates, the larvae or the eggs get laid among the lichens.

They also have a role in slowing down water. Forests with a lot of lichens store more water, so they buffer the hydrological flows. Some people would say that they are important for a sense of place. If you go to Cornwall or the Llŷn Peninsula or these unpolluted places, the trees are festooned with lichens, and we do not see that in a lot of England.

The Chair: Before I move away—before I move to Lord Ashcombe for his question—from excess nitrogen pollutants that end up in the air and cause problems, would any of you like to say a few words about nitrous oxide and its impact as a greenhouse gas, possibly—is that increasing or decreasing?

Dr Ed Rowe: I am not sure what the trend is, to be honest. Certainly, nitrous oxide is a very persistent and effective greenhouse gas. It is 300 or 400 times as effective as CO₂. There are circumstances where you can have a lot of nitrous oxide release from soil. If you have nitrate entering a region of the soil that is anaerobic or organic matter that is decomposing in anaerobic soil, then you can have these N₂O emissions.

Lord Krebs: Very briefly, perhaps for Ed Rowe. Does it make a difference whether the nitrogen is in gaseous form or in liquid form?

Dr Ed Rowe: As soon as it enters the plant or the moss it becomes liquid or it becomes dissolved. One of the key issues with gaseous ammonia is it forms a very alkaline solution. You have this alkalinising effect on mosses and lichens. That is part of its toxic effect. But as a nutrient it is less important. It is all available nitrogen that can be used to make proteins.

Q14 **Lord Ashcombe:** We have many different habitats through this country from top to bottom. I am wondering how nitrogen pollution affects different habitats. I am sure it is in different ways, which I think you have just begun to touch on so it is quite convenient. Then a second one: how do they bounce back from nitrogen pollution? That is one of the goals, of course.

Dr Alexander Lees: The most important habitats being impacted are grassland systems, heathlands, peatlands, montane systems, and sand dunes, which are all habitats that have naturally very low nutrient concentrations.

In some of these systems, such as sand dunes, the process of acidification can happen much more quickly than in the other systems. There is some evidence that also, in the long run, they might be a little bit more resilient, because they might be able to bounce back from that change. But there is precious little evidence at the moment of recovery across the UK, for instance. There is some experimental evidence, some work by the Rothamsted institute, on some permanent plots where they had reduced nitrogen loads, where they had some return of floral diversity or plant diversity in those sites.

But there were also management regimes in place there, so they were removing cuttings on an annual basis. That is obviously removing the nitrogen load. It might be a case where you have to have active intervention. Although nitrogen at the atmospheric deposition level is falling, we still have incredible cumulative loads across most of these ecosystems. I think the expectation is that it is probably quite a long time until we see some of these changes—although, again, that might be quite habitat dependent.

There is also a big unknown, which is: at what point might we get alternative stable ecological states, where you have that very different vegetation structure and whether that might act as a negative feedback and prevent a change back to a prior ecosystem community.

Lord Duncan of Springbank: It is a question about variation within the United Kingdom. Do you notice a variation between the different devolved component parts: Scotland, Wales and Northern Ireland?

The Chair: Lord Duncan, we do have a question on that precise issue later.

Lord Duncan of Springbank: I beg your pardon, sorry. Ignore that then.

The Chair: Professor Biggs, you wanted to come in.

Professor Jeremy Biggs: I was going to add an extra remark or two about fresh water, where, of course, nitrogen is a major pollutant. It is quite hard to separate the effects of atmospheric deposition from what is running off from the surface in one way or another. Generally, people will think of the surface run-off sources as more important, which I think we will come to later on.

I was going to add that when we talk about fresh water, we are talking about a whole range of ecosystems of ponds, lakes, rivers, streams, as well as the wetland habitats that we have been touching on a bit. You can see some evidence in fresh water of declines in nitrogen concentrations; obviously, this is dissolved nitrogen rather than specifically associated with particular sources, whether that is from the air or from the land.

You can see some recovery in smaller catchments where nitrogen levels are going down quite quickly on a 20-year timescale when you stop applying nitrogen. One might expect—although we do not have very good evidence yet—recovery following that.

There is just a slightly different perspective on the environment if you start looking into the water, because we are thinking then both about nitrogen stimulating the growth of marginal plants that grow at the edge of the water and encouraging the growth of highly competitive species in the water, which will then outcompete more sensitive plants growing under the water. I expect you will be very familiar with the ideas of growth of algae smothering underwater plants and those associated phenomena.

Perhaps it is also worth saying early on that that does not happen in the absence of other pollutants. We are talking about the co-effects of nitrogen and phosphorus in water. Managing one without managing the other is not going to be very effective in the long term. In our organisation, we spend a lot of time trying to recreate clean water. We are not so worried about cleaning up because that is so difficult. A much more direct outcome is derived by making new water bodies that are fed

by clean water, so you do not have the pollution problem to start with. But perhaps we can come back to that later as well.

The Chair: Do you have anything to add, Dr Rowe?

Dr Ed Rowe: Maybe a bit about recovery. There is a lot of interest in this topic at the moment. Part of the problem is that we have not seen a lot of recovery in the environmental conditions so nitrogen deposition has come down a little but there has been a lot of accumulation of nitrogen in ecosystems.

The Chair: Can you name some of those systems?

Dr Ed Rowe: Particularly systems that have organic matter in the soil, so bogs and heaths tend to have organic matter with a high carbon to nitrogen ratio. The nitrogen that is going in ends up immobilised in the organic matter. It stores this nitrogen for quite a long time; we think probably millennia. A lot of that nitrogen is going into rather inert pools, but some of it is turning over and becoming available over time. There is this legacy effect of the cumulative nitrogen in soils.

If you contrast that with epiphytic systems—systems on tree bark—they do not have a lot of soil, so there is not much capacity to buffer and store nitrogen. Those can recover quite fast, so over a two- to five-year timescale we see recovery of species.

Q15 **Lord Krebs:** About this business of recovery and bouncing back: bouncing back to what? Is there some primordial state that we can identify or is it looking to what it would have been 20 years ago or something like that? What is the benchmark for bouncing back or recovery?

Dr Ed Rowe: That is an extremely good question. We also have to look at this in the context of climate change. We have little hope of returning to the way our ecosystems were composed before that. We are ending up with a different climate, and so it is not reasonable to expect that we are going to end up with the same ecosystem that we had before.

My view is that in the new climate nitrogen will still be a problem. It will still be causing species loss with the same mechanisms that it does now, and we could have, shall we say, more interesting ecosystems without the nitrogen—more diverse, more orchids.

The Chair: Before we move away, perhaps I can just quote you something that the Soil Association has said: "Nitrogen deposition is one of the greatest threats to ancient woodland in the UK". Can you comment on that, so we have that for our records?

Dr Ed Rowe: Nitrogen is one of the greatest threats to biodiversity globally. It is thought to be the second after land use change. We see the signal of air pollution on species distributions far more strongly than we do climate change—so far. We know that nitrogen has wiped out species across a lot of central England, say. I am sorry, can you return me to the

question?

The Chair: It was about the impact on ancient woodlands, in particular.

Dr Ed Rowe: Ancient woodlands should have a lot of lichen and bryophyte interest, so that is being damaged directly. We expect to see impacts of nutrient nitrogen on the woodland ground flora, but the evidence for those changes is not as strong as it is for open habitats, so there is an interaction with what the trees are doing with nitrogen.

The Chair: I think Professor Biggs wanted to come in, and then Dr Lees.

Professor Jeremy Biggs: I wanted to come back to Lord Krebs's point about what we are aiming for. In fresh water, a very widely used approach is to think about the reference condition. Reference condition means more or less the best examples, the least damaged examples that we can find of a particular freshwater environment, and we use those as the target for our monitoring and management. That, for example, is the principle underpinning of the Water Framework Directive, and we would have the same principle apply when we evaluate and monitor ponds as well.

Dr Alexander Lees: I would like to speak to Lord Krebs's question on terrestrial ecosystems as well. Plant data we have a lot of from this country; we have been systematically recording that for a very long time. When people are doing these longitudinal studies and/or space for time swap studies where you are comparing across these gradients, we can look at historical plant atlas data from the end of the 19th century, beginning of the 20th century, that predate the Haber-Bosch process. We can look at those as reference conditions.

But as Dr Rowe said—this may be a moot point moving forward—even on the scale of the UK, given that many of the species have quite wide distributions, I think we would expect to retain quite a few of these communities, if perhaps not exactly at the same latitudes.

On ancient woodlands, obviously the data on community turnover is less strong for plants, but we also have some inkling now, especially based on studies in the continent, that declines in some bird species may have been a result of this historical ongoing nitrogen pollution.

The loss of species such as wood warbler, which formerly was quite a common species throughout lowland England, we have seen similar declines in that species in places such as Switzerland. They have pointed the finger potentially at eutrophication as a driver of changes in woodland understorey and density, which disfavour that species over other species of *Phylloscopus* warblers, for instance.

Q16 **Lord Trees:** Some of what you are talking about leads nicely into my question, which is about the interaction of nitrogen with the carbon cycle in soils and so on. Could you say a bit about that? We recently did an inquiry on methane. We have a lot of grassland in the UK, particularly in upland areas and so on, so how does nitrogen affect the carbon cycle, the

emissions of carbon, CO₂ and methane, or the sequestration of those?

Dr Ed Rowe: Nitrogen is a fertiliser, so it stimulates productivity, and the effects on global forest systems in particular are to increase carbon fixation and carbon storage. There is a trade-off there, or there is a benefit of nitrogen pollution. But you have to set that against increased N₂O emissions. With more nitrate, we get more N₂O, which is a very powerful greenhouse gas.

I am not quite sure what the balance between the two major processes are. I am not quite sure what the balance is. I think methane is less affected by the nitrogen cycle in general.

Professor Jeremy Biggs: Perhaps I can add a remark or two about fresh water here. We have been doing some recent research on pond-related work. There we found that ponds in a range of continental European situations and the UK as well, were acting as net sinks for nitrogen dioxide, surprisingly. We know that ponds can be powerful emitters of greenhouse gases. In that context, nitrogen is probably unhelpful because, generally speaking, the more fertilised waters are, the more polluted they are by nutrients, though we would not necessarily distinguish phosphorus and nitrogen as the source of that pollution. But the more nutrient enriched they are, the more likely they are to be producing greenhouse gases, with perhaps this exception of N₂O, where they can be sinks.

Again, there is a different nuance often for freshwater systems. As one does, I was browsing through the literature this morning. I noticed there is a very recent paper from, I think, Danish¹ researchers looking at forest nitrogen. This is not my area of expertise so this is perhaps something for the write-up to look out for. But as nitrogen pollution has been dropping, that has led to less storage of carbon in soils as a corollary of that effect of cleaning up the atmosphere.

But I am not an expert in those areas. So I just mention that for interest, really, as a very current piece of information that has literally just come out, I believe.

Dr Alexander Lees: As a specific example from the UK in upland areas, there are interesting interactions between climate change and nitrogen pollution on effects of how much carbon is sequestered in blanket bogs. There is some evidence that in some of the wettest areas it might help a little bit the sphagnum mosses, which are the engine behind that carbon sequestration. But in slightly drier areas you end up getting competition with other species, grasses or heather, and that will inhibit the amount of carbon being sequestered by the sphagnum mosses. It is currently an area of inquiry academically, people looking at different systems, but I think there is lots of evidence that it will probably hamper at a global scale deposition.

¹ The witness intended to say US researchers instead of Danish researchers.

Lord Trees: How would nitrogen affect the soil microbiome and the general soil health? That is quite important, we understand.

Dr Ed Rowe: Can we unpack the idea of soil health a little? For a human being, it is clear when you are healthy and when you are not healthy. For a soil, I would say it depends on what you want from the soil. If you are a farmer, then a healthy soil is one that is aerated and has a high nutrient availability and grows good crops. If you are interested in soil from the point of view of carbon sequestration, you might want to keep it waterlogged and anaerobic. So "health" is not quite the right term to be using in this context.

The effects of nitrogen on soil processes are multiple. It is involved in a great many transformations in soil. It is involved in the competition between plants and microbes, between saprophytic microbes, ones that decompose for energy and ones that are symbiotic; so mycorrhizae, for instance, these fungi that associate with tree roots. All of that is affected by increasing the load of this limiting element. So it is complex.

As Alex says, in some circumstances you can have increased decomposition of organic matter because of the extra nitrogen availability, so a loss of carbon in that sense. In other circumstances, you can have more build-up of organic matter because of the extra inputs. In general, nutrient-poor systems are more complicated than nutrient-rich systems. In a nutrient-rich system there are certain strategies that will do very well and certain species will prevail. In nutrient-poor systems there is a much greater diversity of strategies that plants have for acquiring nitrogen, phosphorus, potassium and the other nutrients, and it is that diversity that gives rise to the diversity of plants.

Q17 **Lord Jay of Ewelme:** I want to turn back to the question of water, which Professor Biggs already talked about a bit. You have already touched in a way on part of the question I wanted to ask, which is: what are the main impacts of excess nitrogen in aquatic ecosystems, and have those impacts changed over time? Do you want to add anything more on that?

Professor Jeremy Biggs: There is not much more to add. I was going to say that the main effects are twofold. There is a stimulation of growth of some plants and a suppression of growth of others. Say, with the plants under the water, that is partly to do with competition and partly because they do not like the conditions of more enriched water.

There is this divide as well, it is worth understanding, in Britain between broadly acid soils and broadly neutral, more calcium-rich soils. Very crudely, that is upland versus lowland, but there are naturally acid rich soils in the lowlands as well. That does affect the way that they respond to nitrogen. I think you asked about the change in time?

Lord Jay of Ewelme: I did.

Professor Jeremy Biggs: In fresh water we have one or two examples of very long time runs going back into the 19th century of nitrogen levels,

specifically in the River Thames, which we use as a surrogate for the rest of the environment, because that is the only data we have, and we can see the levels back in the 1880s roughly when we imagine—we assume, with some evidence—that that is back near where natural levels would have been before serious industrialisation, major industrialisation, shall we say. We see levels rising from then onwards and there is another spike in the Second World War, around then, as grassland was ploughed up and that set a new higher baseline level. Since then, policies have tried to drive down nitrogen concentrations in fresh water and we have seen broadly a slow decline since then—but it is very slow. It will take many years or will probably never get back to the levels that we saw in the 1800s, except in particular locations, but in general it will not get back down to those levels unless we have very major land use changes.

Where we do have land use changes that can affect enough of a water body's catchment—the place where the water comes from—that is not necessarily a huge area, around a rich wildlife pond the catchment can be quite tiny, a hectare or two but it is still the catchment, and in those smaller catchments it is much more likely that we could see levels back down to near natural baselines if they are not already at that level now.

Lord Jay of Ewelme: Thank you for that. As a follow-up question—again, you have touched on this, in a way—are coastal waters affected in the same way as inland rivers and lakes and are there particular vulnerabilities in marine environments? I used to chair a Lords Committee on Northern Ireland and we talked quite a bit about Lough Neagh. There is pretty awful pollution in Lough Neagh. Going back to the discussion we had about recovery, can you see any chance of that recovery?

Professor Jeremy Biggs: Lough Neagh, because it has a very big catchment—we have not worked on Lough Neagh directly so I know it only from literature and general understanding—I am guessing that Lough Neagh's catchment is probably about half of Northern Ireland. I think I have heard something like that, so a very big area, so it will need very major changes in land use, farming and the way sewage is processed in Northern Ireland to have any chance of repairing Lough Neagh. Again, I do not know the details of the lough very well specifically. I would expect it to be a very long time to see restoration there, a 100 year-plus timescale would be a plausible guess, I think.

Going back to your other questions about the difference between coastal and inland, again I will emphasise I am not a marine specialist or a coastal specialist, I am a freshwater biologist, but broadly speaking the enrichment of both coastal and inland waters is caused by the same two main problems: nitrogen and phosphorus, it is both of those together, and there is perhaps a recent development over the last 10 or 15 years. People used to think that phosphorus was the dominant nutrient in inland fresh waters, in lakes, ponds, rivers and so on, and that the dominant pollutant in the sea was nitrogen. I think now we have all moved to a position, or most people have moved to a position, where we think both

are important in both places. That is quite a major change in the traditions of freshwater biology, recognising that both are a problem in both places.

Lord Jay of Ewelme: Thank you. Do Dr Lees and Dr Rowe want to add anything to any of that?

Dr Alexander Lees: On the marine environment there is evidence for similar sorts of turnover in species composition, so in coastal areas and rocky shores, for instance, we see a turnover from perennial macroalgae to more bloom-forming species. There is evidence of benthic changes as well associated with these high nitrogen loads. In the North Sea it is not to the same detrimental impact as we have in the Baltic, which is more shut out from external influence without the same levels of mixing, but there is some emerging evidence of some regions in the North Sea, such as the Dogger Bank, having relatively low oxygen concentrations, which would be indicative of an ecosystem that is unhealthy.

To add then to the freshwater example, it is a good example of issues affecting vertebrates. We have several endemic fish in the UK associated with these very deep oligotrophic lochs. One of those is a species called the vendace, which occurs in the north of the UK, and that was known only from four sites and it is now extinct in three of those, and the causal factor was eutrophication of those lochs. There are now ark populations of that species that have been introduced to other sites, but for many of these freshwater vertebrates and invertebrates as well it is a huge issue.

The Chair: Can I ask a quick supplementary on the ecological impact on areas of SSSIs? Dr Lees, would you like to say something on that?

Dr Alexander Lees: This is certainly something we should be talking about later on. In the context of England, we see exceedance of these thresholds in pollution above which we see deleterious impacts on plant communities, so one can assume that most of our SSSIs that are designated for their biodiversity interest suffer from exceedance. There are some emerging policy options that perhaps Ed might want to speak to to try to identify the most at-risk areas and think about how we might mitigate those impacts.

Q18 **The Chair:** Excellent, thank you. The other thing I want to quickly run past the panel is: do you want to talk about what impacts things such as physical modifications and changes to natural flows and water levels have on the amount of nutrients in waterways? Do these modifications impact on the run-off from agriculture? Professor Biggs.

Professor Jeremy Biggs: I would say that, on the whole, physical modifications do not really have any substantial impact on the nutrient levels in fresh waters. It is what is running into those water bodies that affects nutrient levels, pollutant levels generally and of course there will be some minor impacts here and there but really the two issues are not connected. If one imagines a policy scenario where people might suggest that physically modifying rivers, making them bendy again—we have

done quite a lot of work on this ourselves and I will come back to my analysis of that in a second—none of that has any substantial impact on nutrient levels.

In fact, one of the major findings of the last few years about what people have begun to call “rewiggling” of rivers—not a term I am very fond of personally, but anyway they call it that now—mostly that does not work very well. In fact, there was a global paper published just a couple of weeks ago repeating that fact, that all that physical restoration work has a pretty small impact. One of the larger reasons for that is because it does not usually make any difference to nutrient levels that are affecting the restored parts of the rivers. I would say that is not a line that policy should be going down, hoping to benefit from modifications to physical structure as a way of controlling the impacts of nutrients. Unfortunately, it is the other way around, really.

The Chair: Would anyone like to add anything to that?

Dr Ed Rowe: Not on that, but I would like to respond about the protected sites a bit more.

The Chair: Very briefly.

Dr Ed Rowe: Yes, so as Alex said, a lot of our sites are in exceedance of that critical load and there are strategies that could be used to try to improve the protection of the site. You can put measures in to reduce emissions from farming in the zone around the site and that is quite effective for reducing the emissions of ammonia and therefore the transfer of ammonia and the deposition of dry reduced nitrogen on to the site, but there are aspects that are not controlled by that, so the longer-range transport of particularly oxidised nitrogen coming from further afield is not much affected by those buffer strips.

Q19 **Lord Krebs:** I should have declared relevant interests when I spoke earlier so I will declare them now. I am scientific adviser to Marks & Spencer and to Drax plc, the energy company.

I wanted to come back to something that Jeremy Biggs talked about a few moments ago: eutrophication. I will focus the question to Jeremy initially. You said that maybe 30 years ago we associated eutrophication with phosphorus, particularly in freshwater habitats and perhaps more with nitrogen in marine habitats, but now the view is that both elements are important in both environments, freshwater and marine. Can you unpack that a bit? Why has that view changed and what is thought to be the balance of contribution of phosphate and nitrate in eutrophication in the two kinds of habitat? Also, as a final point, what are the sources of nitrogen that are coming into particularly freshwater habitats?

Professor Jeremy Biggs: The reason, I suspect, that phosphorus was always seen as the primary driver in freshwater was because of big, whole-lake experiments, particularly in North America, where they manipulated phosphorus and they had some very strong and clear results. But then gradually over the years people just got more

information about what the effects of nitrogen were in running waters, but to a degree in lakes as well, and it just gradually built a weight of evidence that both were having some effects. It was just growth of knowledge, really, and I suppose some people also had a suspicion that if elevated levels of one nutrient has effects on plant growth, why does another common plant-stimulating nutrient, nitrogen, not also have a similar effect? It was a gradual transition.

You can see this still baked into policy, though, because the Water Framework Directive sets out targets only for phosphorus. It does not have any targets that are ecologically relevant—it does have drinking water targets for nitrogen—and there is a legacy effect there that is leading us to not think hard enough about the nitrogen in fresh water, I would say. Ironically, there is a set of standards that could be applied, rather like the phosphorus ones, to fresh water for nitrogen. Currently they are sitting in a scientific paper by a perfectly credible bunch of people, the same people who invented the phosphorus targets for the Water Framework Directive, but they just have not been applied, possibly because policymakers might be a little worried about the implications of it because it would instantly show that a lot of rivers were failing on yet another major pollutant.

I did not answer the final part of your question, I think.

Lord Krebs: The sources of nitrogen going in.

Professor Jeremy Biggs: Okay. I am sure you will be very familiar with the sources. It is all the usual suspects, essentially. On the whole, in the lowlands, we all feel that the surface-borne sources are numerically larger than the atmospheric ones. There is atmospheric deposition as well but that is always more prominent in the nutrient-poor uplands. The sources are sewage effluent, the run-off from urban areas, the run-off from farmland, various kinds of agricultural sources—it is the familiar usual suspects. Nothing really has substantially changed there in our understanding of sources.

Lord Krebs: Can I ask a couple of very short follow-up points before turning to the other two witnesses as to whether they have any points to add? First, is the contribution of phosphorus and nitrogen to eutrophication additive or multiplicative or not known?

Professor Jeremy Biggs: I do not I have a good answer to that. I think it would be additive but I do not think I could point you to a set of graphs that show the proportion that is due to the phosphorus and some impact that is due to the nitrogen.

You need to manage them both down to near natural levels to be sure of having the maximum effect, but I do not think I could point you to data that answers your question precisely. I do not think anyone has done that kind of experiment, really. It is a very hard observation to make because it is very hard to take one down and not the other, which you would need to be able to do to really bottom out that observation.

Lord Krebs: A final point about sources of nitrogen. I was once told that the amount of nitrogen falling in rainwater today is roughly comparable with the amount of nitrogen that was added to agricultural land in the middle of the 19th century, before Haber-Bosch. Is that true or is there any evidence to support that assertion?

Professor Jeremy Biggs: I do not know the data well enough to absolutely answer that with authority, but it does sound plausible to me. It sounds plausible because input levels would have been much lower. As you can see in the past, as with the long run in the Thames data going back to that sort of time, that does seem an entirely plausible remark to have made from somebody who had that data available. The other two might know more about that. They have a better understanding of deposition than me.

Dr Ed Rowe: A typical nitrogen deposition rate across much of the UK would be around 20 or 30 kilograms of nitrogen per hectare per year on to open habitats. Woodlands get nearly twice as much, and that is the amount you might apply as a top-dressing, these days, to your spring grass. In the 19th century, before the Haber-Bosch industrial process for fixing nitrogen, a lot of the nitrogen in agriculture would have come from fixation—so, legumes in the system, beans in your rotation and, yes, I guess that over the rotation, the inputs of nitrogen would be comparable, maybe 20 or 30 kilos per hectare per year.

It is interesting to compare that with the amount of offtake that you have. If you are producing a crop of, say, 10 tonnes of wheat per hectare per year—that is a good yield to have—and that grain is around 2% nitrogen, then you are exporting 200 kilos of nitrogen per hectare per year. That has to be replaced somehow.

Dr Alexander Lees: On the mobility of those two elements, there is also emerging evidence that you get biological processes by which both nitrogen and potassium can be moved around the landscape after deposition. For instance, we have burgeoning populations of feral Canada geese that might spend time feeding in farmer's fields. They will go to roost afterwards on a water body that might be an oligotrophic body—a nutrient-poor one—so the geese are transferring nitrogen or potassium into these systems and nutrifying them. We are probably getting similar impacts from deer feeding in farmers' fields and then going to woodlands. That is particularly the case for phosphorus, which is less mobile than nitrogen. So, some of these biological processes may also be important transfers between habitats, especially for potassium.²

There was an interesting paper recently that indicated that a combination of both garden bird feeding and feeding-introduced gamebirds ends up with a huge impact on deposition of phosphorus through the transfer of the bird food into some of these phosphorus-poor habitats.

The Chair: Before we move on, and we are tight for time, may I ask

² The witness intended to say phosphorus instead of potassium.

Professor Biggs very quickly if he can tell us a little bit about what is meant by limiting nutrients, and the role of nitrogen and phosphorus within that?

Professor Jeremy Biggs: It means limiting nutrients that can be used up by some biological process and reach the point at which they prevent further growth or reproduction of whatever organism you are interested in, by having been exhausted—in the case of freshwater, essentially, having all been taken out of the water. If you supersaturate the system with either, say, phosphorus or nitrogen so you could never reach that limit, that means there is no longer a limit on the growth process that is stimulated by that nutrient. That is a quick summary of that process and what that might mean.

I was going to add one other remark, just for general understanding. You can go to parts of lowland England in particular, but the uplands as well, where there are waterbodies, usually small ones—ponds, ditches, small lakes—which are surrounded by old-fashioned intensity farmland. There we can see freshwater systems which are not fundamentally different from what would have existed even before agriculture. They have the same kinds of plants and animals in them. Those can survive in that modern-day environment with a low-intensity agricultural system around them, and that is often what we are doing in nature reserves: trying to emulate that old-fashioned farming system with those very low inputs. There are inputs to make some things grow, usually livestock, but they are much lower inputs, and those that seem compatible with very good quality freshwater ecosystems. I wanted to add that as a bit of context.

Q20 Lord Lennie: Under the Water Framework Directive 2017, there is a requirement for river basin management plans. In your opinion, how sufficient are those plans in reducing pollution and protecting catchment areas, given that by 2027, they are required to assess all rivers as being of good ecological status?

Professor Jeremy Biggs: I am with the OEP on this. The OEP, as you probably know, did an analysis of the Water Framework Directive, including river basin management plans. A one-line summary of that is that they are not working, they will not work and they are not good enough. You will probably know that court cases have also been brought by some of the NGOs about the validity and effectiveness of river basin management plans, which are being contested now. Really, they are not working. There is a useful quote on this, and it is worth reading the summary paragraph that OEP wrote in their Water Framework Directive analysis. It is pretty much saying that if we go on as we are with river basin management plans unchanged, there is no chance of meeting those 2027 targets. There is no chance that we are going to do that anyway, but there is no chance that they will be met any time in the future, either. It is not a very good policy mechanism. It is mainly not detailed enough, but there might be a resource issue after that. It is not prescriptive enough in the right places. The measures in it are too generic, and they are just not applied with enough attention to detail, essentially.

Dr Ed Rowe: I am not so familiar with the river basin management plans and how that connects with catchment-sensitive farming. I have had quite a focus on air pollution—air-pollutant nitrogen—but the Environment Agency is certainly getting more interested in air pollution by nitrogen now and starting to take that into account in its assessments of catchment-sensitive farming.

Lord Lennie: Professor Biggs, you said that they are not prescriptive enough. Are there specifics that should be in them that are not?

Professor Jeremy Biggs: This is something that the OEP also echoed recently. The strongest recommendations that might make a difference would be to begin including in river basin management plans small waters, as they make up roughly half the water environment. We are talking about ponds, small lakes, small headwater streams, which are largely written out of the Water Framework Directive at the moment for various reasons—sometimes accidentally, sometimes deliberately. If we were to work on those, we have good evidence from our own organisation and others now that these are biologically the richest part of the water environment, yet we effectively exclude them completely from water policy.

If there were a single thing we could do to river basin management plans, it would be to encourage those small waters to be properly included in the plans. It is a kind of win-win because, being smaller, they have smaller catchments, which are more likely to be able to be managed in an effective way to improve their quality. We have evidence of the ability to improve these small waters, making quite substantial improvements at a whole landscape level. Sorry, that is a piece of jargon that is meaningless without the data, but perhaps there will be a chance to write some of this into notes that you can read more usefully for the inquiry later.

The Chair: Thank you very much. We will hold you to that.

Professor Jeremy Biggs: Yes, we would be very happy to do that because there is so much to say, which you cannot really get across in a few quick sentences.

That would be one of my recommendations, but the prescriptions at the moment are very generic. There will be broad prescriptions for a whole catchment about establishing less nutrient-intensive farming, but when it comes down to it, all of that happens farm by farm, and it is very hard to organise that properly. But that level of detail is what is needed to make those river basin management plans have some effect.

If there were a single thing, it would be the small waters: making a start at the top, thinking about the smallest ones that we can most easily do something about, and working from there, almost. At the moment, it is very heavily focused on fixing sewage works. River basin management plans do deal with that—never mind how well it is going in terms of being organised by the water companies—but the agency does a lot of work on those and it does make a difference. For the rest of the landscape, I am

not really exaggerating in saying that it is pretty hopeless. That is a populist word that is interpreting what OEP has written and said already, and I really would recommend that you look at the OEP's report about water, because it is quite an important moment in what it has said that the Government should pay attention to.

Lord Duncan of Springbank: Changes to these management plans could be made without change to legislation, then. They would be implementation elements that could be brought about without there being the cumbersome element of having to change the law. Is that right?

Professor Jeremy Biggs: Yes.

The Chair: Just a quick supplementary from me. You mentioned the importance of the small waters. Who has oversight over them? Is it local authorities?

Professor Jeremy Biggs: In a strict policy sense, it is different in Scotland, Wales and Northern Ireland, because it is a devolved matter and it does vary from country to country. Let us do England first because it is easiest and quickest, and we do not have much time.

The Chair: Just do England for now.

Professor Jeremy Biggs: Ultimately, this is the responsibility of Defra, but that is devolved mainly to Natural England and the Environment Agency. The problem is that they are mostly driven by policies in the Water Framework Directive and, to a degree, by the previous legislation on freshwater that came from various UK native laws and from the Habitats Directive, which identified the most important sites, and we still carry that over into current legislation. Those two organisations are the drivers.

With respect to small waters, the biggest obstacle is the Water Framework Directive specifically excluding—there is a limit at 50 hectares for standing water, so any lake or pond of less than 50 hectares, which is quite big, is automatically written out of the rules and any headwater stream with a catchment of less than 10 square kilometres is also parked and forgotten about. They are technically covered, but they are just put aside and not shown properly on maps, so no one thinks about them. That is an important barrier. That would be the one thing that could be changed, but it does not need a change in legislation to do it; it is purely the way the law is implemented.

Lord Duncan of Springbank: The Water Framework Directive being a European directive, what are the results from other European countries? Is it a pan-European failure in this area, or is it just that we are not very good at implementing it?

Professor Jeremy Biggs: It is a problem wherever the Water Framework Directive is implemented. Very few of the member states ever did something different to the 50 hectare limit, for one thing, and we are all struggling. We all have the same problems with nutrient pollution from

farming and from different sources all over the whole of the lowland continent. Rivers and lakes are generally cleaner in places where the land use is less intensive. In this country, the best water quality is in Scotland, where we have large areas with the least intensive land use, and some of our best freshwaters because of that. Wales is half way between the two. Northern Ireland gets caught by the fact that there is a very intensive farming and livestock industry there. But that is pretty much universal.

Q21 Lord Ashcombe: That leads very well into my question and has probably half-answered it already. We have heard quite a lot about the issues. What do we think the geographical spread of these issues is across the United Kingdom? Picking up on that, where do we think we are particularly vulnerable—in some areas, I am sure, more than others?

Dr Ed Rowe: There are sensitive habitats across the United Kingdom, but the amount of pressure varies a lot. In areas where there is a lot of industry and road use, you have a lot of nitrogen oxide emissions. In areas with a lot of livestock farming, there are a lot of ammonia emissions, and you can see that in the pattern of concentration of deposition across the country. If you are downwind of a dairying area such as Shropshire or Devon, you are likely to have a lot of nitrogen deposition. You can see the amount of pressure related to the distribution of livestock production, in particular. There is a lot of livestock production in Northern Ireland, and Northern Ireland is downwind of the Republic of Ireland, where there is an awful lot of dairying and livestock production. That is in contrast to Scotland, a lot of which is downwind of the Atlantic. So Scotland has been less affected by atmospheric nitrogen pollution.

There is also transboundary pollution—pollution coming over from the Netherlands, Belgium and France, if you are in the south-east. I guess this has a bearing on policy responses. The four countries of the UK have different targets. This is a devolved matter, so they are tackling this in different ways and the thinking is often that we want to have policies around what we can control. So Wales, say, is not in control of emissions in Ireland and it is not in control of long-range transport from the continent, but there are emissions that can be controlled from within Wales, so that has been the policy focus.

Lord Ashcombe: Are the devolved areas talking to each other about these issues? Taking your example, Wales could be downwind of England, should it come from the east, which it is doing a lot at the moment.

Dr Ed Rowe: There is good co-operation and communication among the statutory nature conservation bodies. Natural England, NatureScot—the organisations that are set up to protect nature in the different countries—meet the experts and specialists regularly. Those are meetings that I attend, and the communication is great. The Governments, I would say, are not communicating quite as well, and there is a kind of jurisdiction issue, with Defra being responsible partly for the UK and partly for England. That needs work.

The Chair: May I ask a quick supplementary to that? Looking at the

maps of the levels of exceedance of critical loads for nitrogen in the UK, there are a couple of black spots, the largest one of which is just on the northern Welsh border, perhaps around the Wye Valley, along with a black spot in Norfolk. Can you talk a bit about the causes of those?

Dr Ed Rowe: I suppose the implication of looking at the Wye Valley is that, we know there is a lot of intensive livestock production, through poultry units in particular, in that part of the world, and in Norfolk we have a lot of pig production. Those are not quite as problematic as they used to be. If you have a large factory unit producing poultry, it is fairly easy to put scrubbers on it to take out the ammonia, and there are regulations around that. The smaller poultry units are more of a problem. Open-field livestock farming and intensive grassland-producing beef and dairy are comparatively unregulated. The black spots that you see around the Welsh border are more to do with the dairy industry in Cheshire and Shropshire.

Q22 **Lord Rooker:** Good morning. I would like to ask you about the wider benefits, such as net zero, biodiversity goals, nature restoration, that can come from tackling nitrogen production. In a way, I will ask a supplementary to that. I was astonished that we went through the whole of the discussion on question 6 and the word “farmers” was not mentioned by anybody. Are there current incentives for the agriculture sector sufficient to deliver benefits on nitrogen, biodiversity, greenhouse gases and soil health? For catchment-sensitive farming there is an advisory system, which is used. My experience of visiting such operations when I was a Minister was that the farmers know what they are doing—they are the heroes, in a way—but the external advice about the shape of the land, the diversity, is incredibly useful. We have help and advice, but are there other incentives that could be beefed up or introduced that would help?

Dr Alexander Lees: I can speak first to the wins from reducing pollution, and with consideration of our international and national commitments to biodiversity. Given that many of these habitats are nitrogen-sensitive, the UK has an important European, and in some cases important international, proportion of some of them. We have around 13% of the world’s blanket bogs, a habitat to which the biggest threat is arguably nitrogen pollution. We have 20% of Europe’s lowland heathlands and a large proportion of Europe’s sand dune ecosystems; and then we have all these assemblages of incredibly nitrogen-intolerant species, some of which have incredibly important European populations, and some of which are found only in the UK. Then we contrast that with all these targets for nature restoration, and if we are unable to reverse loss of these species, we cannot possibly diminish the extinction risk that has been a promise, or reduce the levels of degradation of these habitats. Addressing this question is fundamental to bending the curve of biodiversity loss, if you like.

Dr Ed Rowe: Farming is at the heart of all this. A statistic is that the global carrying population without industrial nitrogen fixation would be around 3 billion, so we now have over twice as many people as would be

supported by that. There are billions of people in the world who are dependent entirely on industrial nitrogen fixation, and we cannot deny the importance of food security. It is fundamental to our existence, so we need to have farming and to have food with protein being produced for all the people of the world. I would question whether we are producing that food in the most efficient places and in the ways that would reduce the impacts on biodiversity. I think we could do better.

Farmers are on the same side, in the sense of not wanting to waste their nitrogen fertiliser. These leaks to the environment that we worry about are economic losses for them. Maybe the point is that those economic losses have not been weighed that highly in a farm budget, so the amount of budget that goes on nitrogen fertiliser is not that large compared to the cost of the land, the machinery, the labour and all the other inputs. It makes sense for farmers to reduce their risk by making sure that they are not limited by nitrogen. If you do not apply enough nitrogen and you have a poor yield, you will feel a bit stupid because it would have been quite cheap to apply that nitrogen.

For the same reason, the use of legumes in agriculture has declined because it is complicated. It breaks up your rotation, and maybe you are not making as much profit in that year, so again, it is cheaper to apply nitrogen fertiliser. Until we change the economics of that, either by controls and legislation to stop emissions, for example, or a simple thing like having a nitrogen tax to change the economics, farmers are still not going to weigh that nitrogen loss very highly.

Another issue is just lack of awareness. People are not so aware of the sheer scale of atmospheric nitrogen impacts on the environment.

Lord Rooker: When you say “people”, do you mean the farmers?

Dr Ed Rowe: I am often surprised at my fellow scientists. Biodiversity people are often not all that aware of atmospheric nitrogen pollution, despite its extreme importance.

Lord Rooker: Before Professor Biggs comes in, is it more controls or better incentives that are required? There are thousands of farmers out there, looking after land of various sizes. I am not sure whether there is a conflict—whether it is controls or better, more targeted incentives. Is that a legitimate supplementary?

Professor Jeremy Biggs: I will come in on catchment-sensitive farming if I may. As you say, there are lots of farmers taking up catchment-sensitive farming. The problem is—again, I refer you to the recent OEP report in which this was written about—that it is not concentrated enough. It is scattered all over the place, because it is quite hard to implement the kind of land management that might have an impact on a whole catchment. Catchments are often very big areas, but they can also be small, so we return here to a point about small waters and the ability to make those less intensive, because that, in the end, is really what makes an impact here.

Catchment-sensitive farming has been quite carefully reviewed and so far, it has had almost no impact on the ecology of rivers, and I suspect nothing much on lakes, but that might be to do with not being able to look at enough places. It is a great idea and it is applying lots of ideas that are well-evidenced. There are a lot of small-scale studies that show you can control run-off pollution from farmland, but then we cannot implement it well enough. If there was one single recommendation, it would be to target those measures on to much smaller catchments, starting with headwaters, because then, you might get enough of the catchment modified into a form that was not generating pollution to make a difference to the freshwaters.

Down on the Thames near Oxford, none of the catchment-sensitive farming going on around there is having any impact at all on the Thames, because it is just not affecting a big enough part of the landscape. That is a fundamental problem with our agricultural systems. They do leak quite a lot of pollutants, even when they are well managed, and that is why we started the conversation with this slightly jargoned term of a “wicked problem”. What that really means is a very difficult problem to solve in policy terms.

The only practical short-term solution to making some impact here is to start with smaller catchments, which, again, is why OEP has suggested that as one of the options for this kind of approach to land management for controlling pollution. It is a very difficult problem to solve, unfortunately.

The Chair: We are going to move on fairly rapidly, but I would like to come to the Earl of Leicester first for a supplementary.

The Earl of Leicester: Dr Rowe made a very important point about the fact that currently, we have a world population of 6 billion and if we did not farm without artificial nitrogen, that would drop to 3 billion, so it is clearly quite an issue. Is it not true to say that with regenerative movement in farming—I should register my interest as a farmer in Norfolk—and coming to Lord Rooker’s point about incentives or regulation, we need education and communication to pass on the benefits of using less nitrogen and more regenerative systems, which would reduce the need for artificial nitrogen, although there is always going to be some need for it? Perhaps Dr Rowe has an opinion on that, or is regenerative agriculture just too small at the moment?

Dr Ed Rowe: It is a catch-all term. Regenerative agriculture covers a lot of ideas, and some of them are great. Some of them can affect your nutrient losses or your productivity. Some of them are maybe a little unrealistic—expecting organic inputs to give you the kind of yields that you can get with artificial inputs does not really work on a large scale, I would contend.

Things that farmers can do to improve their nitrogen use efficiency are generally good, but we would have to go into specifics about your particular practices.

The Earl of Leicester: Particularly the fixing of nitrogen through the use of legumes.

The Chair: We do need to move on.

Q23 **Lord Duncan of Springbank:** Following on from some of the comments of Professor Biggs, I am aware that these are nuanced issues but the Office for Environmental Protection is a relatively new body. Has it been successful in encouraging government to refocus or re-examine, or not?

Professor Jeremy Biggs: I am not very closely involved in the management of the OEP. I have literally just peer-reviewed the one main report, and I follow what it does with interest because it is the regulator. The OEP would claim that it has had some successes. It is relatively new to tackling the water pollution issues, so we will see how the water management plays out. Particularly at the moment—and this, I am afraid, is an England-focused answer—the extent to which the Water Commission takes on board things that the OEP says, and the extent to which the Government do so in the revised Environmental Improvement Plan, will be a substantial test of its influence. That will be the proof of the pudding: whether the things we are seeing said in those comments on the previous Environmental Improvement Plan are taken up by the Government in the new one they are working on right now. The jury is probably still out on that.

Lord Duncan of Springbank: That is helpful. Thank you.

Q24 **The Earl of Leicester:** Are there ways in which climate change will increase or exacerbate the risks posed by nitrogen pollution?

Dr Ed Rowe: We have the direct effects of temperature on ammonia emissions—we get more emissions in a warm year—but the big effect is via global food security. We must think about a world at the end of this century where a lot of the food-producing areas are not going to be so productive, to say the least. The Punjab, Ukraine—there are a lot of areas that are likely to become too hot or too desertified to produce food. Where we are going to feed the planet from is the elephant in the room, and northern latitudes or higher latitudes such as the UK are going to have to take more responsibility for producing global food, I think.

Dr Alexander Lees: In a biodiversity context, the degree of synergy between nitrogen and a change in climate is something of an unknown. For instance, with heathland systems, we might get over-fertilisation and an increase in some species—heather, for instance—and then if we get recurrent droughts and wet periods, you could easily get build-up of vegetation, and wildfires, potentially, as a result. A recent paper described these as climate shocks in the context of California, where they had extreme rains, lots of build-up of vegetation and then drought. There are interactions between the two. In the context of the UK, increased rainfall may well lead to changing interrelations with the soil chemistry, downstream impacts on plant species, and trophic cascade up the food web.

The Earl of Leicester: Wildfires would produce potash and phosphates, not nitrogen, but would that add to pollution, or would it be some sort of benefit?

Dr Alexander Lees: There was a recent study in Germany, where there are huge problems with heathland ecosystems, so they have done some controlled burns to try to reduce nitrogen loads in some of those areas. It might work in that context, although in the UK, where we have very high return frequency with controlled burns, we end up with less biodiversity. Balancing that use of fire and trying to replicate natural fire frequencies might help, but we must be very careful not to end up with very large wildfires. It must be carefully managed.

Professor Jeremy Biggs: Broadly speaking, most freshwater biologists would expect that increased global heating will worsen the problems of nutrient enrichment, as a broad simplification. We are going to have to run to keep still, because we need to keep reducing nutrient levels that impact the quality of freshwaters, just to have any chance of mitigating the increasing risk of enrichment because of climate change. It will have that broad effect.

Q25 **Lord Krebs:** In a way, I think you have touched on this question in some of the previous answers, but it would be very helpful to get a summary from each of our witnesses. In your view, what more could be done by the Government, the public or specific actors to reduce the negative impact of nitrogen on biodiversity ecosystems and soils? We have heard from Jeremy Biggs about the neglect of small waters as part of the current deficit. I will turn to Alex first to give us an answer.

Dr Alexander Lees: The low-hanging fruit is certainly thinking about site-based action plans, given that we know that the downwind movement of ammonia can really reduce biodiversity at the site level. It is easier to treat that issue than the wet deposition through rainfall going over a much broader spatial scale, so having some site-level action plans seems incredibly important. Perhaps developing nitrogen budgets as well, on a more macro scale, would be useful. Just thinking about independent economic assessments of nitrogen budgets and treating the whole thing more holistically, mention was made in the first session of the “many octopuses” of nitrogen. That makes it sound like a cabal of Bond villains, perhaps, but the issue seeps into climate change and land use change, our diets, agriculture productivity and so on. Having a cross-sectoral approach to this challenge seems important.

I did a bit of unscientific googling last night to see how many hits I could get on “climate” versus “nitrogen”, for instance, on the government website. There was an order of magnitude of more hits for “climate”, despite the fact that it should be a cross-cutting theme. Perhaps in the order of likelihood of things that happen but maybe that will be something that will emerge from these sessions, I hope.

Dr Ed Rowe: I wonder whether there is something around “disclosivity” that could be fixed. At the moment we produce statistics on emissions

from farmland, but we must produce them at a scale where individual farms cannot be identified. That means that farmers have very little incentive to make their holding better than the next one. We have all these ideas of covering slurry tanks or injecting slurry. If a farmer takes up those measures, it makes no difference to the statistics that are reported. If we want to incentivise farmers to have better practice, maybe we should open up that box at a local scale a little better. In the end, though, I think you have to change the economics for farmers to make them worry about their nitrogen losses more.

Lord Krebs: On the first point, you are saying the data exists at an individual farm level but it is not revealed. Who collects the data?

Dr Ed Rowe: I believe it is a consultancy called Ricardo that do the national emissions inventory. It is not quite my area.

Professor Jeremy Biggs: One thing I had on my list to suggest to you was that we need a measure of the nitrogen status. We are just talking freshwater again now, of course. We need a measure of the nitrogen status for the water bodies in the Water Framework Directive, just like we know the phosphorus target that we want for each water body, which is driving literally billions of pounds of investment now. We have no equivalent measure for nitrogen in water. That could be applied easily. The science is done and the levels are set; it would just need to be applied. That would then mean we would know what we were aiming for in each of the water bodies, which would enable us to target our measures much better. We do need to target more. We will not achieve nitrogen reductions everywhere in freshwater because it is too difficult—it requires too much land use change—but that would help us to at least know where we would have most effect. That would be the most important thing, apart from the other things I said earlier.

We should go on forcing down as far as we can the atmospheric emissions—it is just that that is quite a blunt lever—away from small individual sites, as Alex said. The site-based approach is good because, again, that is focusing on the smaller areas where we are most likely to have most effect quickly, whether that is protected sites or the rest of the whole freshwater network that is not specifically protected by SSSI designations or SAC designations.

The Chair: Can we go back to Professor Biggs and Dr Rowe? You mentioned that the farm-level data is not disseminated widely. Do you have any idea why? To me, in terms of incentivising action in reducing nitrogen, it seems it would be very helpful.

Professor Jeremy Biggs: I am not going to say anything useful, because I do not know the answer to that question. I do not really know those datasets, so I do not have anything helpful or interesting to add.

The Chair: Okay. Before I bring in the Earl of Leicester, to follow up on that point, Professor Biggs, would the government schemes under ELMS and the SFIs not benefit from having that data at a farm level?

Professor Jeremy Biggs: I suppose they might do. I do not know, is the honest answer. I do not know those datasets very well at all. A lot of farmers are doing a great job in trying to reduce pollutant inputs, but they have so much to do. They would need advisers to help them to do it, because it is pretty difficult stuff; they are really busy and are all up against it these days.

Dr Ed Rowe: Your question was why data was not released. Currently, I think it is a privacy issue—an individual farmer does not want to be blamed for polluting their local environment, understandably. If we see it the other way around, people could be rewarded for good practice.

The Chair: Indeed. It could be used to incentivise action. Earl of Leicester, the final question goes to you.

The Earl of Leicester: It is just an observation to Dr Rowe. I am fairly certain that our farming operation is not measured for pollution. That may be the case if you had, for instance, intensive dairy, but as individual farmers I am not sure that we are measured. You make a very good point that if the good farmers were incentivised and rewarded for what they were doing, that would work very well.

The Chair: Thank you. I do have a final question and I understand it is a bit late in the day, so if you are not able to answer it today, if you could write into us with the information, we would be very grateful. Do each of the experts have a view on the current revision of the national emissions ceilings under the Gothenburg Protocol of the UNECE Air Convention? It is a technical question, but one that we would like an answer to. Will you write into us with your thoughts on that? That would be much appreciated.

Thank you very much for appearing today and taking the time out to do so. We look forward to receiving the supplementary written evidence that you have undertaken to provide to the committee. With that, thank you very much again, and I close the public session of this meeting.