Key points:

**Biological background – climate change and species distributions**

- *Species move and ecosystems change as the climate changes.* The spread of species that were not previously present in a given location (‘non-native’ species, or biological invasions *sensu lato*) into new biological communities, regions and countries is the means by which species survive climate change, and by which ecosystem functions are maintained. On the timescales of ice ages, nearly every species could be regarded as ‘non-native’ in its current distribution, and all ecosystems are ‘novel’. Present-day climate change is faster than in the past, and similar processes are operating.

- *UK species are on the move.* The distributions of species are changing globally, and generally spreading towards cooler environments, predominantly towards the poles and to higher elevations. This evidence is particularly strong for Great Britain. On average, species are moving northwards at approximately 5 metres per day.

- *Species vary in their responses.* There is also strong evidence that the rates and even directions that species are changing their distributions vary considerably, particularly because of differences in habitat availability.

- *‘No change’ is not an option that is on the table.* Climate change and other drivers are altering the composition of biological communities (i.e., which species are present in a given location, and how abundant each of them is) virtually everywhere, and change is set to continue throughout the remainder of the 21st century.

- *Many European species are endangered by climate change.* Those with small geographic distributions (e.g., mountain plants and butterflies in southern Europe, or species restricted to moist ravines in the Mediterranean) are endangered with extinction as a result of climate change because they are either unable to move northwards, or run out of higher elevations to which they could retreat.

**Biological background – biological invasions**

- *UK invasions are not exterminating native species.* Around 2,000 non-native species have been added to the British fauna and flora without, as far as we know, any single British species becoming extinct as a direct consequence. Some British species have died out for other reasons, especially habitat change, but the net result of invasions has been to increase the total number of species in the UK.

- *Some non-native species are ‘invasive’.* Invasive species are defined as being ‘harmful’, which is usually taken to mean that they reduce the abundances or distributions of other species (e.g., grey squirrel and pox virus reducing red squirrels), they change the structure or function of ecosystems (e.g., coypu altered waterways in East Anglia before their control), or interfere with human social or economic interests (e.g., Asian hornets which have potential to harm beekeeping interests, or Japanese knotweed which you could be fined up to £5,000 or be sent to prison for up to 2 years for improper disposal that allows the plant to spread into the wild).

- *UK species are not globally endangered by invasions.* No UK native species that has declined as a result of biological invasions is endangered at European or global level.
• **Arrival of non-native species is increasing the number of species on the Earth.** More new species have come into existence over the past 350 years in Britain and Europe as a result of biological invasions – hybrid speciation – than have become extinct through invasions. An example is a new species of monkeyflower in Scotland, which is the hybrid offspring of one North American and one South American species of monkeyflower. This is true with respect to Britain and Europe (the opposite is true globally).

• **Very few non-native species become harmful.** Evidence to date is that species which have been present in the UK for longer periods of time are not more problematic. Therefore, the suggestion that a serious risk will emerge in future from currently non-problematic non-native species is not supported by the evidence.

• **Disease is the main challenge.** Most serious declines of current UK species (but only rarely changes to ecosystems) are associated with the invasion of pathogens which have spread through human transport from distant parts of the world, and to which one or more native species are not resistant.

• **Most species eventually recover from disease.** Normally, there is sufficient genetic variation present that the victims of invasive diseases eventually recover (e.g., after decades for rabbits experiencing myxomatosis), but this is not inevitable.

• **UK Overseas Territories at greatest risk, not GB & NI.** Disease and predation problems that cause species-level extinctions are virtually confined to remote oceanic islands and to isolated ancient lakes, where the native (endemic) species are far less likely to be resistant to new pathogens or able to escape new types of predator. The British Isles do not fall into this category because nearly all UK species are colonists from continental Europe over the last 15,000 years. Endemic species on UK Overseas Territories are at much greater risk.

• **Both native and non-native species are responding to drivers of change.** The expansion and declines of native and non-native species are largely responses to other human activities, such as land management and climate change, rather than the cause of change.

• **Native species generate just as large impacts as non-native ones.** Biological communities are primarily being invaded by ‘native’ UK species because of anthropogenic climate change. Deliberate re-introduction of the beaver is set to make widespread and major changes to aquatic ecosystems, and bracken fern, brambles and nettles consume more land than do any non-native plants.

• **Non-native species are regular species that happen to come from elsewhere.** Some native and some non-native species are directly beneficial to human interests, some are harmful, but a majority are benign with limited impacts one way or the other.

### Policy issues

• **Manage change rather than attempt to defend the status quo.** Policy must recognise that every biological community and ecosystem has changed over the last century, and this will continue into the future. We must manage change in ways that humans find desirable. Stopping change or attempting to re-create the past are not viable long-term options.

• **Defining species as non-native on the basis of whether humans introduced them is both undesirable and inoperable.** This is undesirable because humans are now the main vector of the long-distance movement of species and it is agreed that long-distance movement will help species survive climate change, and it will fail for most groups (e.g. insects) because the exact means by which they arrive is usually unknown.

• **The movement of species can be seen as beneficial or harmful.** Biodiversity policies to adapt to climate change are at odds with those aiming to prevent invasions. Climate change adaptation is about facilitating the movement of species (enabling ecosystems to adjust) and saving species by
assisted colonisation (e.g., can European species saved from global extinction by establishing them in the UK?). Invasive and non-native species policy is primarily about manning the barricades, and then taking actions to control species if they get past. Invasive species policy could therefore indirectly cause the extinction of species by making it hard to relocate species that are endangered by climate change.

- **Policies are required to move species.** Guidelines and formal policies are needed to accommodate the transfer of responsibilities for protection between states and regions (as species shift their own distributions) and to facilitate assisted colonisation – the deliberate movement of climatically-endangered species from one state to another.

- **Bring the horticultural community on board.** Gardeners and horticultural societies can contribute as citizens to the conservation and propagation of climate-endangered species. Most plants from southern Europe are already growing in British gardens, and these will increasingly establish wild populations as the climate warms. Treating these as invasive (because they were originally moved by people) is highly undesirable.

- **Avoid new diseases arriving from far afield.** A default position could be that any species of European and North African origin is deemed acceptable or desirable until proven otherwise (facilitating adjustments of distributions and ecosystems under climate change), whereas species from further afield (e.g., East Asia, North America, southern Hemisphere) are scrutinised until proven innocuous or disease free. Nonetheless, hardly any of the species from further afield will actually go on to become problematic.

- **Focus actions on overseas territories for which there are endemic species.** This primarily applies to relatively remote oceanic islands, rather than to near-continent locations.

- **Clarify use of language.** Much of the language surrounding non-native species and biological invasions is pejorative. Adopt neutral language to avoid this because the majority of the world’s species are on the move; they must be protected where they move to, not repelled because of negative linguistic connotations.

- **Don’t synonymise change with harm.** Species and ecosystems are under constant flux, so it is important not to define any change from a baseline state as harmful. Our biodiversity and ecosystem indicators need to be ‘change-proofed’ to avoid bias. For example, a native species indicator might highlight losses (negative) and an invasive species indicator that ‘foreign’ species are establishing (also regarded as negative). Add the two together and re-orientate perceptions and the trend is positive – an increased total number of species.

- **Tackle the drivers of change not the consequences.** This includes controlling emissions and climate change, sanitary standards of imported biological products and land management.

- **Beware estimates of economic damage.** Distinguish between costs from non-native species where there is clear consensus that action is required (e.g., humans and livestock diseases), where policy is generating costs (e.g., Japanese knotweed) and where costs represent preferences rather than an objective need (e.g., conservationists removing Himalayan balsam, despite ‘uneducated’ members of the public and beekeepers liking them). High costs associated with stated preferences are optional. Management costs of native species can be just as high.

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**Brief vita**

- **Chris D Thomas, BA (Cantab), MSc (Bangor), PhD (Texas), Hon PhD (Helsinki), FRS, FRES**
- Anniversary Professor, Department of Biology, University of York
- Director of the Leverhulme Centre for Anthropocene Biodiversity
- President of the Royal Entomological Society

• Author of over 300 scientific articles on ecology, evolution, environmental change and conservation (Clarivate Analytics Highly Cited Researcher 2018, and in previous years)

• Marsh Award for Climate Change Research 2011; Marsh Award for Conservation Biology 2004; President’s Medal of the British Ecological Society 2001; Scientific Medal of the Zoological Society of London 1998

• Presented some 300 invited seminars (e.g., 19 in academic year 2017-18, in Bulgaria, Canada, France, Germany, Holland, Ireland, the UK and USA).

• Contributing world-leading (4* at REF 2014) impacts in policy development and knowledge exchange in climate change (via Intergovernmental Panel on Climate Change) and conservation (stimulating landscape conservation policies).

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