THE ROYAL SOCIETY

1 November 2019

Dasgupta Review on the Economics of Biodiversity – Call for Evidence

Overview

- The Royal Society is the National Academy of Science for the UK and the Commonwealth. It is a self-governing Fellowship of many of the world's most distinguished scientists working across a broad range of disciplines in academia and industry. The Society draws on the expertise of its Fellows and Foreign Members to provide independent and authoritative scientific advice to UK, European and international decision makers. We welcome the opportunity to respond to the Dasgupta Review on the Economics of Biodiversity call for evidence.
- Our response highlights existing work relevant to this consultation drawn from a range of policy reports published by the Society. Most of these adopt a global perspective, though we have also included information from reports specifically focussed on the UK.
- In addition, the Society is currently developing a major programme of work called Living Landscapes on the future of UK land use, led by Charles Godfray FRS and Georgina Mace FRS. Much of this work touches on biodiversity and is very relevant to the concerns of this review. We would be happy to engage further with HM Treasury as this work develops.

Part 1: Biodiversity and Ecosystem Service Science and Evidence

Question 1 (Biodiversity and Ecosystem Service Science): IPBES assessments and GEO6 will form an important part of the Review's assessment of the state of biodiversity, the biosphere and its ability to deliver ecosystem services. What further evidence should the Review consider in this area? What does the scientific evidence on global biodiversity and ecosystem condition decline suggest about the Earth's ability to continue providing services essential to human prosperity over different time periods?

ANSWER:

- Climate change and biodiversity loss are inherently linked, affecting the Earth's long-term ability to continue providing services essential to human prosperity.
- Ecosystems mitigate climate change by removing the greenhouse gas carbon dioxide from the atmosphere. In recent years roughly a quarter of the carbon dioxide emitted by human activities (due largely to fossil fuel burning and land use change) has been taken up and stored in the plants and soils of terrestrial ecosystems. In this way, ecosystems act as carbon "sinks".
- Researchers are exploring ways to manage ecosystems to enhance these carbon sinks beyond the capacity they have exhibited in the past. Examples of practical interventions relevant to a UK context include forestation and the restoration of wildlife habitats such as wetlands and peatlands.
- In October 2018, the Intergovernmental Panel on Climate Change warned that allowing the planet to warm more than 1.5 °C could have long-lasting and in some cases irreversible consequences for ecosystems and that this threshold will be passed by 2030 if current rates of warming continue.

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- In addition to rising temperatures, researchers are observing changes in precipitation patterns, the occurrence and severity of extreme events, species' behaviours, and the chemistry of the ocean, among other effects. Concurrently, ecosystems are being modified by a multitude of human-induced stressors, including resource extraction, habitat degradation and conversion, invasive species, and pollution. This could affect their ability to continue providing these services in the future.
- More details can be found in the Royal Society's report on 'Greenhouse gas removal' (especially Sections 2.1-2.2 & 3.4).
- The interlinked nature of climate change and biodiversity was the subject of a joint Royal Society and US National Academy of Sciences report on 'Climate change and ecosystems.'

Question 2 (Limits): What is the best available evidence on the regenerative rates and carrying capacity of ecosystems e.g. fisheries? What is the best evidence on, and most compelling examples of, maximum sustainable yields, and where ecosystem thresholds and tipping points have been shown to affect sustainable economic growth?

ANSWER:

- A major challenge for the research community is determining where, when, and why tipping points in climate and biosphere function are most likely to occur.
- Tipping points are more likely as global average temperatures increase further, and the occurrence of one tipping point would make others more likely.
- Advanced warning of abrupt changes can be found in many complex systems. These warnings may manifest as a slower recovery from the same perturbation or disturbance as the ecosystem gets closer to a tipping point, such as in the case of corals that undergo repeated bleaching events.
- In other cases, impending tipping points may manifest as increasing fluctuations. For example, oceanic circulation models have been used to experimentally collapse the Atlantic Meridional Overturning Circulation (which includes the Gulf Stream), showing that fluctuations in the circulation slow down as collapse nears.
- Another major research challenge for understanding potential abrupt changes in ecosystems is to address the complexity introduced by multiple interacting drivers and disturbances, where spatial variation can dampen, amplify, or synchronize changes.
- Impacts may be of relatively small scale, with population level effects, or much more expansive, with climate system changes and ecosystem effects that are at least subcontinental in extent.

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- Further information and a map of potential 21st-century climate and ecosystem tipping points can be found on p.7 of the conference report of the joint Royal Society and US Academy of Sciences report on 'Climate change and ecosystems.'

Part 2: Biodiversity and Economic Prosperity

Question 3 (Biodiversity and Economic Prosperity – Conceptual Framework): Biodiversity supports the provision of many ecosystem services, which are important for economic prosperity and growth. Economic growth also affects the demand for, and supply of, the Earth's resources. What conceptual frameworks and typologies clearly describe the relationship between biodiversity, ecosystem productivity and resilience, ecosystem services, economic prosperity and economic growth? Where have these frameworks been applied to reveal critical relationships? What are the most critical aspects of these relationships for the Dasgupta Review?

ANSWER:

- There is no simple relationship between population growth and growth in consumption: people do not consume equally, due to social, political, cultural and technological effects.
- A number of ways of conceptualising or representing the relationship between population growth, economic development and environmental degradation have been developed; none of these is unproblematic. Some suggest that degradation is a 'phase' of development, others that degradation might intensify as development continues.
- These conceptualisations include the Kuznets Curve, the IPAT equation, and STIRPAT.
- The Kuznets Curve assumes that environmental degradation follows an inverted U-shaped curve as development proceeds. It suggests that societies introduce greater environmental protections as basic material needs are met. It is important to understand the Kuznets curve because some people use it to argue, probably incorrectly, that no policy interventions are required to prevent environmental degradation in the course of economic development.
- The Kuznets Curve has been demonstrated to be appropriate only for a very limited set of cases, such as sulphur or particulates in the atmosphere, but not for the accumulation of waste or for long-term and more dispersed costs, such as carbon dioxide, which typically have been found to increase continuously with income.
- The IPAT equation (I=P*A*T) is one of the most well-known frameworks for describing the relationship between population, consumption and the environment is. It relates environmental impact (I) to population size (P), affluence per capita (A) (a measure of consumption and production) and the level of environmentally damaging technology (T).
- When applied carefully it can also be a useful accounting identity for relating historical population trends, economic growth and changes in technological efficiency to the level of resource use and emissions. It enables questions to be asked about the potential for technological change, the relationship between economic growth and population change, and the potential feedback mechanisms between environmental impact and population growth.

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- However, it does not account for other drivers of environmental changes such as policy, institutions and complexity of social factors that have been shown to be significant in regional and local scale assessments. It has been criticised for being too simplistic, for treating the variables as being independent of each other, and for not allowing for non-linearities, thresholds and feedbacks in environmental systems or cumulative environmental effects. IPAT does not look at the effects of population characteristics (such as age structure, sex structure, distribution and density) that may influence both consumption and the technology used.

- STIRPAT—Stochastic Impacts by Regression on Population, Affluence and Technology—is an attempt to capture more complexity and interactions between the IPAT variables. STIRPAT allows for the consideration of context when analysing population-environment relationships by adding control variables to the model. For example, the model can include demographic characteristics other than population size, such as age structure and urbanisation. While most STIRPAT analyses have been applied at the macro-level of countries, the model can be used on any spatial scales from cities to nations.

- More details can be found in Chapter 3 of the Royal Society's report on 'People and the planet', noting that the Society has not revisited this work since its publication in 2012 and new conceptual frameworks may have emerged since.

Question 4 (Biodiversity and the SDGs): What are the links between biodiversity and economic prosperity that are most critical to synergies and trade-offs across the SDGs? How should sustainable economic growth be defined and measured given the evidence of how the SDGs and economic prosperity are affected by biodiversity loss? The review is interested in relevant links with biodiversity and economic growth across all the SDGs, particularly climate mitigation and adaptation, poverty reduction, food production, human health and wellbeing, consumption and production, and gender and broader inequalities.

ANSWER:

- There have been efforts underway in the Amazon to provide viable value chains for products derived from ecosystems such as food, nutraceuticals, cosmetics, fragrances, pharmaceuticals, and industrial oils. These efforts have a goal of creating a new sustainable development paradigm for tropical forests where the value of the ecosystems and attention to management may help to reduce ecosystem changes linked to climate change and human activities such as deforestation, mining, and dam construction.

- Nature-based solutions in cities can have biodiversity benefits, while also contributing to other sustainable development goals. Measures include increased tree canopy cover, protection or restoration of streams, development of urban stormwater management structures, construction of green roofs and walls, increased area devoted to parks and open spaces, and restored coastal ecosystems to serve as protection. In addition to the

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biodiversity benefits, these efforts can contribute to climate action, improved human mental and physical health, and other social benefits such as reduced crime and increased social cohesion.

- These examples are drawn from the joint Royal Society and US National Academy of Sciences report on 'Climate change and ecosystems.'

Question 6 (Benefits of Tackling Biodiversity Loss and Costs of Inaction): What is the best evidence on the economic benefits of biodiversity? What evidence exists on who benefits from biodiversity? What positive business cases (win-wins) exist for tackling biodiversity loss e.g. impacts on jobs, productivity, income, human health outcomes? Conversely, what is the best evidence on the costs of current trajectories of biodiversity loss? What evidence is there of the distribution of these costs within and between countries?

ANSWER:

- In terms of win-wins, making land use decisions for better biodiversity outcomes can also have a number of other benefits.
- Replacing cropland or degraded land with forests could enhance biodiversity and have other positive global sustainability impacts, such as improved carbon sequestration, improved soil quality and reduced flooding, erosion and eutrophication.
- Wetland restoration also has the potential to contribute to multiple global sustainability goals, such as climate action, improved water quality, flood protection, ecosystem restoration, biodiversity preservation, and job creation.
- Restoring habitats can provide additional environmental benefits by providing protection from natural disasters; for example, salt marshes acting as flood defences or mangroves providing protection from tropical storms. However, depending on the previous land use of restored land, wetland restoration could either improve or diminish the heat-reflecting capabilities of those areas, possibly providing an additional benefit or detriment for climate change mitigation.
- More information on these topics can be found in Sections 2.1 and 2.2 of the Royal Society's report on 'Greenhouse gas removal'.
- Ecosystem-based approaches that support biodiversity can also be effective in reducing the impact of extreme weather events, including drought, heatwaves and flooding. There is evidence that they are cost effective, either on their own or in combination with other approaches. In addition these approaches can also have co-benefits such as improving access to food, water, livelihoods, biodiversity, climate change mitigation and protection against other hazards, making them low-regret or no-regret options.

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- An assessment of the cost-effectiveness of such interventions can be found in Chapter 3 of the Royal Society's report on 'Resilience to extreme weather'.
- This report includes a case study of such measures in use to decrease river flooding in Pickering, North Yorkshire (pp.103-105). Following a flood in 2007 that caused over £7 million damaged, the 'Slowing the Flow' initiative was developed to increase the level of flood protection for Pickering from a 25% chance to a less than 4% chance of flooding in any one year. Measures included constructing large woody debris dams and creating woodland among others. While further flood peaks need to be captured and tested before definite conclusions can be drawn, modelling studies predict that these measures should be successful in achieving at least the target level of flood protection for the town.
- There are a variety of methods that can be used to place an economic value on biodiversity loss. The Society compared five such methods in assessing the cost of biodiversity loss attributable to agricultural ammonia emissions in the UK. These produced an estimated cost of £0.2–£4 per kilo of ammonia, with further costs associated with human health impacts.
- More detail can be found in the Royal Society and RAND Europe report on 'The impact of ammonia emissions from agriculture on biodiversity' (Section 2.6).

Question 8 (Opportunities from Tackling Biodiversity Loss): How can new technology assist with restoring biodiversity, while simultaneously delivering economic prosperity? e.g. artificial intelligence, biotechnology. What economic opportunities exist from protecting, restoring and enhancing biodiversity? e.g. learning from nature (biomimicry), biopharma, among others.

ANSWER:

- Gene drives—systems that bias the inheritance of a particular DNA sequence—are being researched as a means of controlling or removing invasive species, one of the largest threats to biodiversity.
- Gene drives have also been proposed as a means of increasing the resistance of endangered species to disease and other threats, for example by targeting the mosquitoes that spread avian malaria to birds.
- Much of the work on invasive species has focused on removing rodents from islands where they threaten ground nesting birds. This approach is being supported by not-for-profit organisations like Island Conservation.
- In this context, gene drives are being investigated as a potentially more effective and more humane way of eradicating rodents than existing trapping, hunting or poisoning programmes.
- Gene drives are also being considered as a way of controlling other invasive species, including wasps in New Zealand. and cane toads in Australia.

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- For further information see the Royal Society's report on 'Gene drive research' (especially p.12), and the President of the Royal Society's speech on 'Potential and risks of recent developments in biotechnology' (especially section 2.c.)
- In 2018, the Royal Society published a report titled 'Science: tackling the illegal wildlife trade'. This looks at the role of a range of new technologies for tackling the trade including smart shipping technologies, new optical recognition approaches, biological and chemical identification and isotope analysis. Note that this does not consider the impact of these technologies on local or global economic prosperity.

Question 9 (Economic and Finance Decision Makers): Which sectors of the economy rely most on biodiversity and ecosystem services? How are they affected by biodiversity decline? Please provide strong case and/or sectoral examples and evidence on how changes in biodiversity (loss or gain) has affected, or been affected by, economic and finance decision-making.

ANSWER:

- An emerging economic sector in which changes in biodiversity will have severe future economic impacts is the use of marine genetic resources (MGRs).
- The oceans are home to a diverse range of biological materials. MGRs incorporate units of heredity (e.g. the genes of marine organisms), their products (e.g. proteins) and substances synthesised by biological processes, (e.g. antibiotics and biomaterials.)
- The maintenance of biodiversity in ocean environments underpins opportunities to discover novel MGRs for use in antibiotics, anticancer drugs, nutritional supplements, and enzymes used in biotechnology.
- The discovery-based nature of MGRs makes it inherently difficult to assess the market value of this sector. However, publicly available information suggests that global sales of marine biotechnology products are presently >$1 billion per annum. This value is dominated by pharmaceutical and cosmetic industries.
- Natural products dependent on MGRs have found a range of uses including Estée Lauder's skincare brand Resilience which utilises an anti-inflammatory extract from a Caribbean coral, and Prialt, a painkiller based on the synthetic derivative of a cone snail.
- The genes that underpin the creation of substances such as these can gain a high commercial value and are often protected by patents.
- While such patents for marine-derived genes and natural products have been in a minority compared to those of terrestrial origin, their number is rapidly increasing. This is particularly true in the case of new and sustainable sources of antibacterial, antiviral, antiparasitic and antifungal compounds.
- High biodiversity areas are associated with discovery of more valuable MGRs. Marine protected areas play an important role in protecting biodiversity. Provided that designated marine protected areas are respected, there is enough data to conclude that prospecting for MGRs is not, in general, an intrinsically damaging maritime activity.

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- Further information can be found in the Royal Society's report on 'Future ocean resources'.

Part 3: Causes of Biodiversity Loss

Question 11 (Economic Sectors): Which economic sectors have the biggest impact on biodiversity loss? Which economic sectors are most affected by biodiversity loss? Please reference evidence and analysis (including case examples) that underpin and illustrate your answers.

ANSWER:

- An emerging economic sector that has the potential to adversely affect valuable ecosystems is deep-sea mining.
- Terrestrial mining activity has had significant local and regional environmental impacts. These impacts are now mostly strongly regulated and mitigated against during all stages of exploration and exploitation. The deep-sea ecosystem is however, unusual, fragile, and under-studied, but provides many valuable ecosystem services.
- Both mining and shipboard processing could have a significant, and potentially permanent, impact on local and regional deep-sea ecosystems.
- An example of such a negative impact is the harvesting of resource-rich 'polymetallic nodules' using bottom trawling. Bottom trawling is known to be particularly damaging when performed below 600m water depth, and most nodule-rich regions are significantly deeper than this.
- A number of experiments have simulated the long-term impacts of deep sea mining of metallic resources. These have identified a number of negative outcomes at a local scale, including:
    - The removal of unique sea-floor habitats over a wide area
    - Particle plumes, occurring over 1 – 2km from the site of extraction.
    - sediment compression limiting recolonization by organisms
    - toxicity from substrate break-down
    - potential acute toxicity of the mining by-products
    - removal of unusual geological features of potential scientific interest.
- Regional impacts include:
    - sub-lethal effects on the ecosystem and individuals
    - dispersion of sediment plumes
    - possible bioaccumulation of metals in the ecosystem.
- Further information can be found in the Royal Society's report on 'Future ocean resources'.