TRENDS IN UK FUNDING FOR ECOLOGY

BRITISH ECOLOGICAL SOCIETY

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The views and recommendations presented in this report are not necessarily those of the organisations to which the reviewers belong and should therefore not be attributed to those organisations.

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EXECUTIVE SUMMARY

Ecology is a key discipline in the effort to tackle the twin crises of biodiversity loss and climate change by protecting and restoring nature. For this reason, and for the many other benefits it brings to society, sufficiently funding ecological research should be a priority. Despite this, there have been suggestions for years that ecology is receiving a decreasing proportion of overall research and development (R&D) funding at the expense of sciences that underpin high-value industries or other socio-economic objectives such as health and defence.

This report provides evidence for this debate by analysing the amount of funds available for ecological research in the UK, using a combination of publicly available data and data provided by governmental organisations and funding institutes.

QUESTIONS

1	Has unadjusted funding for ecology changed over time?
2	Has funding for ecology kept up with inflation or decreased in real terms over time?
3	Has funding for ecology increased at the same rate as overall R&D funding?
4	Has funding for ecology increased at the same rate as it has for other fields?

SCOPE

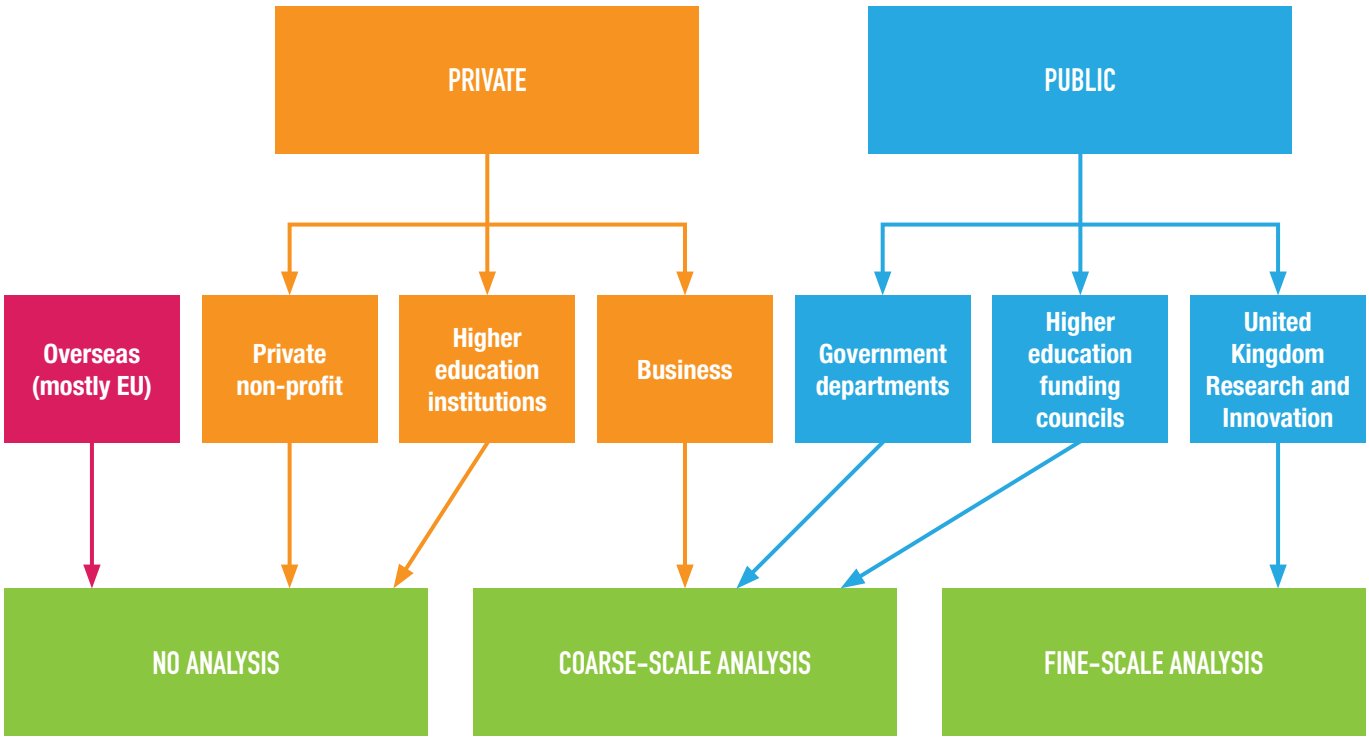
Research funding in the UK comes from sources that can be grouped into three broad categories: public, private and overseas (Figure 1). The data available for analysing what the funding goes towards varies between funding sources.

Lack of available data means that coarse-scale analysis is only possible for some categories of funders (higher education institutions, business, government departments and Higher Education Funding Councils (HEFCs)), and fine-scale analysis is only possible for projects funded by United Kingdom Research and Innovation (UKRI) (Figure 1). Fine-scale analysis here means that we can analyse the individual projects that money is spent on and whether they can be classed as ecology, and coarse-scale analysis means that the available funding data have been aggregated into broad subject or departmental groups, and we cannot tell exactly what projects have been funded.

UKRI is a non-departmental public body, which brings together funding from seven disciplinary research councils as well as Research England and Innovate UK. UKRI funds a significant amount of research every year, approximately 11% of all UK R&D funding. This is likely to include a large proportion of the ecological research in the UK as our coarse-scale analysis suggests that the field only receives a small proportion of the research funding of business and other government departments. The two research councils that are most relevant to ecology and fund almost all of the scientific ecology research within UKRI are the Natural Environment Research Council (NERC) and the Biotechnology and Biological Sciences Research Council (BBSRC).

In this executive summary, we only present the UKRI fine-scale analysis which focuses on funding from UKRI between 2006 and 2021. Coarse-scale analyses and an overview of the structure of UK research funding and how the overall amount of funding has changed over time are presented in the full report.

FIGURE 1 SOURCES OF R&D FUNDING IN THE UK AND THE TYPE OF ANALYSIS THAT WAS POSSIBLE FOR EACH OF THEM



Source: Own elaboration

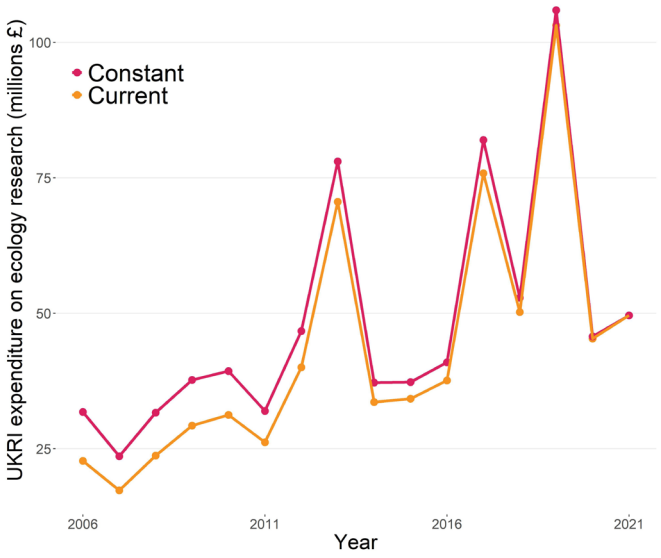
METHODOLOGY

UKRI has developed the **Gateway to Research** (GtR) website as part of the Innovation and Research Strategy of the Department for Business, Energy and Industrial Strategy (BEIS). GtR's objective is to provide information about publicly funded research[i] and it provides data on research funded since January 2006. We designed a methodology to classify which projects count as ecology, and thus show how funding for ecology has changed over time and what proportion of UKRI funding goes toward the field.

RESULTS

There was a real-terms increase in the amount of funding awarded to ecology projects by NERC and BBSRC between 2006 and 2021 (Figure 2). In 2021, £49.6 million was awarded to ecology research, compared to £31.7 million in 2006 in constant prices (when accounting for inflation). There was a 56.1% increase in funding in constant prices over this period.

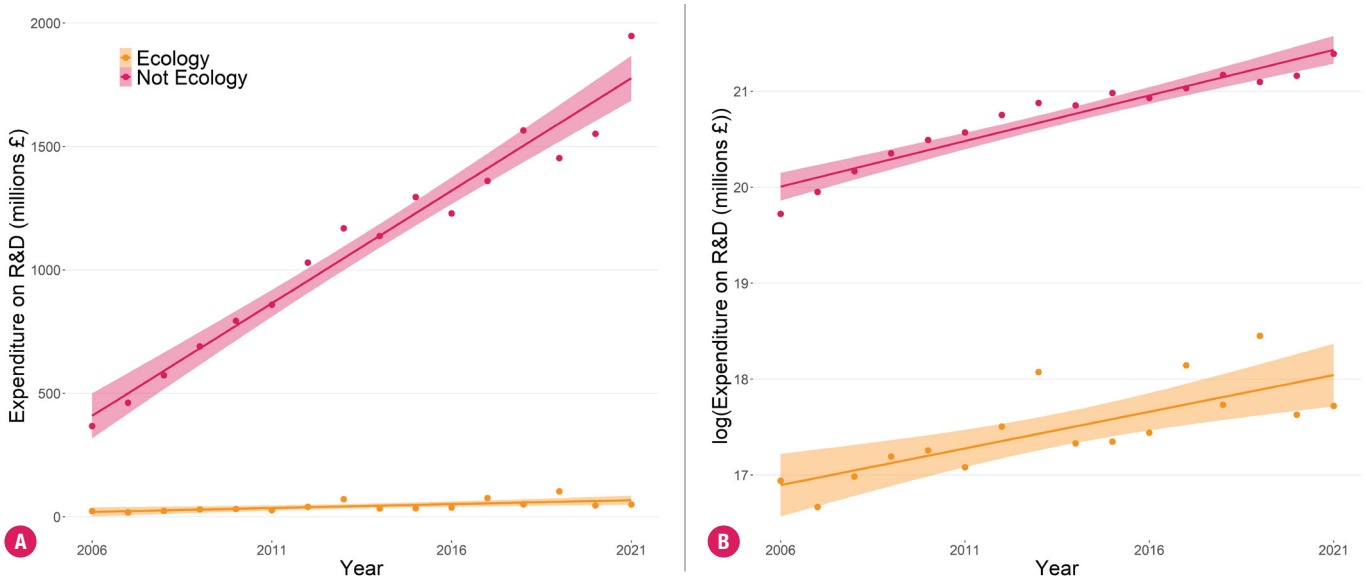
FIGURE 2 THE CHANGE IN THE AMOUNT OF FUNDING AWARDED TO ECOLOGY PROJECTS BY NERC AND BBSRC BETWEEN 2006–2021 IN CURRENT AND CONSTANT PRICES. INFLATION WAS CALCULATED USING THE CONSUMER PRICE INDEX



Source: Own elaboration using data from UKRI *Gateway to Research*[ii]

Crucially, the change in annual research funding over time was significantly different between ecology and non-ecology research, with non-ecology research increasing at a much greater rate (Figure 3). From 2006 to 2021, funding for ecology research increased by 118%, whereas funding for non-ecology research increased by 430%.

FIGURE 3 THE CHANGE IN NERC AND BBSRC FUNDING FOR ECOLOGY AND NON-ECOLOGY RESEARCH



The change in the amount of funding awarded to ecology and non-ecology projects by NERC and BBSRC between 2006 and 2021 in current prices on **A (above left)** an arithmetic scale and **B (above right)** a logarithmic scale, with least squares lines of best fit and 95% confidence intervals. This is presented in current prices as we are interested in the differences between the two groups. The change in ecology prices in constant prices is presented in Figure 2.

Source: Own elaboration using data from UKRI *Gateway to Research*[iii]

[i, ii, iii] UKRI *Gateway to Research*. Available at: https://gtr.ukri.org [Accessed 29/03/2022]

DISCUSSION

UKRI funding for ecology has increased in real terms but not as fast as other subjects

This analysis shows that UKRI funding for ecology has increased in real terms since 2006, although there is big interannual variation. UKRI funding for ecology in constant prices also increased at a faster rate than the overall Gross Expenditure on Research and Development (GERD).

Despite this increase, UKRI funding for ecological research has not increased at the same rate as it has for non-ecology research over the same period so arguably the importance placed on ecological research by this vital research funding body research has been declining.

KEY RESULTS

1	**Unadjusted funding for ecology increased in current prices by 117.9% between 2006-2021.**
2	**Funding for ecology has not decreased in real terms over time. In fact, in constant prices there was a 56.1% increase between 2006-2021.**
3	**Funding for ecology has increased faster than overall R&D funding, measured as UK GERD.**
4	**Funding for ecology has not increased at the same rate as funding for other fields. UKRI funding for non-ecology research has increased at a significantly higher rate than funding for ecology.**

Little change in the importance placed on R&D funding in the UK

R&D funding has increased in real terms in the UK over the past three decades, although it has not done so as a proportion of GDP. The proportion of GDP given over to GERD is lower than the OECD and EU averages. This is worrying because R&D is a vital component of the response that is required to tackle the climate and biodiversity crises that we face.

There is a lack of data across all funding sources

Attempting to analyse how funding for ecology research has changed over time has revealed the lack of detailed data on what disciplines and subject areas R&D funding is spent on in the UK. This makes any detailed and robust analysis on the relative importance placed on disciplines and subject areas difficult. There are more data available in the public sector than the private sector, but it is still difficult for stakeholders or the public to hold public bodies to account for their R&D funding. This is a key problem for people or organisations who would like to investigate R&D funding in the UK, and advocate for specific disciplines.

FUTURE CHALLENGES AND OPPORTUNITIES

We urge UKRI, Defra and other public organisations to increase the amount of funding they provide for ecology research. Alongside public money, there are also opportunities to increase funding from private sources. Ecological consultancy work that helps businesses to mitigate risks from environmental degradation, and meet regulatory requirements, will generate a significant amount of valuable data. If the connections between ecology research and consultancy can be improved, these data could be used more often for research. Government requirements to fund research alongside consultancy work could also increase the funding available for ecology research.

The lack of data on R&D funding means that it remains very difficult to accurately assess the impact that any changes to the UK system would have on the funding received by different fields. Without better data, there may be a 'silent crisis' in ecology research, where a lack of funding undermines the ability of the field to provide benefits for society and help tackle the climate and biodiversity crises, but we are not able to recognise or quantify this.

1. INTRODUCTION

As an organisation that represents ecologists, assessing changes in the funding of ecology research is extremely important to the British Ecological Society (BES). This funding maintains the employment of our members and the value that they bring to society, including knowledge production and guidance of environmental, agricultural, economic and social policies. Our mission is 'Advancing ecology and creating solutions for a planet under threat'[1]. Funding is a vital part of this, and assessments of whether levels are adequate to achieve research goals, and whether this changes over time, are crucial.

1.1 THE VALUE OF ECOLOGY RESEARCH

The value that research provides is wide-ranging, but it is often difficult to measure. Research and development (R&D) funding is one of the indicators used to measure progress towards UN Sustainable Development Goal 9.5 'Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries'. Knowledge is of course valuable for its own sake, but it is impossible to exactly quantify the returns on investment in research, whether they be economic or otherwise, and whether they come from a single study or several funded by the same scheme. It is rare to be able to trace a definite path from funding to knowledge production and then to a particular policy, intervention or product[2]. Expertise and knowledge are often gained over time and across many different projects, and therefore it is difficult to assess the direct impact of a particular project.

Despite this, it is clear how important ecological knowledge production is. The classification of ecology research used here is based on BES's definition of ecology as 'the study of interactions among living things and their environment. It provides new understanding of these vital systems as they are now, and how they may change in the future'. It can be difficult to draw a line between ecology and closely related fields such as agricultural science, genetics and evolutionary biology. For the purposes of this report, ecology research must include a focus on:

- Non-domestic[iv] species;
- Interactions between species or between a species and its abiotic environment beyond negative impacts on crops or livestock and;
- Contemporary ecosystems.

Over the last two decades, which are the main focus of this report, the severity of the impacts of anthropogenic climate change, extinctions and ecological degradation have become increasingly apparent. In a policy context, improving understanding of environmental risk, including climate breakdown and the biodiversity crisis, and the options for managing it is the key benefit of ecology research[3]. Ecological expertise should be accurately communicated to the public so that it can inform the public debate surrounding these issues.

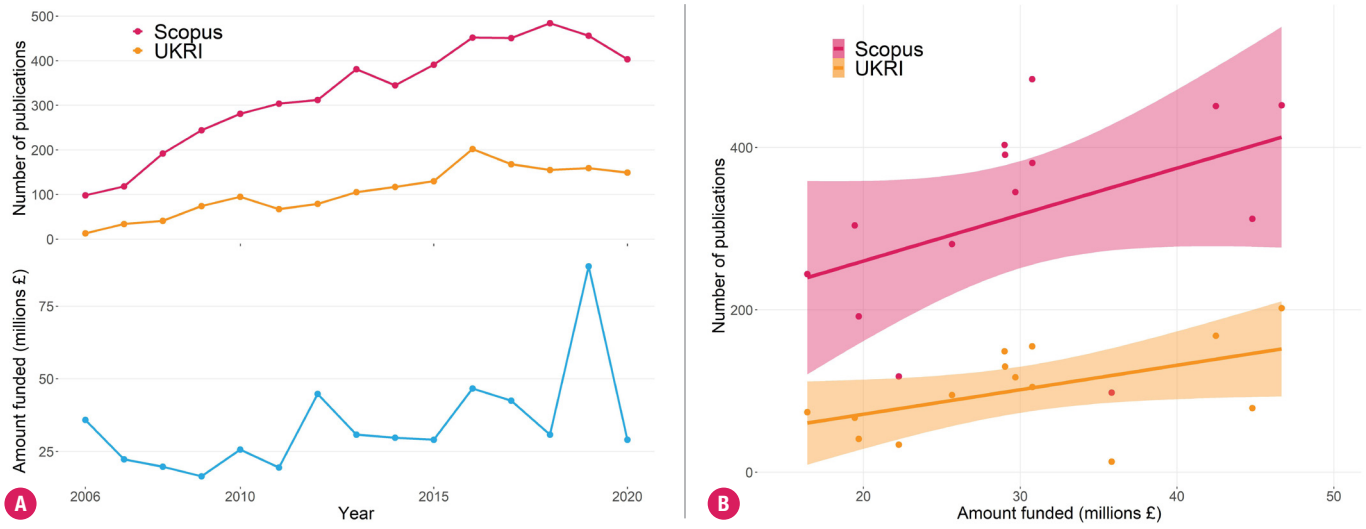
Ecology research underpins the design, management and assessment of successful conservation and land use programs[4], including agricultural practices that aim to promote biodiversity along with the provision of food and other societal benefits such as flood prevention[5]. There is substantial evidence that effectively protecting nature provides large economic benefits when ecosystem goods and services are accounted for[6]. Ecology research can also deliver public health benefits by contributing to the prevention of pandemics[7] and the creation or improvement of natural areas, which can improve physical[8] and mental health[9]. Ecology therefore has an important role in Sustainable Development Goals 2 (Zero Hunger), 3 (Good Health and Well-being), 6 (Clean Water and Sanitation), 11 (Sustainable Cities and Communities), 13 (Climate Action), 14 (Life Below Water) and 15 (Life on Land).

1.2 RETURN ON INVESTMENT

1.2.1 Publications

There are a few ways to measure the return on investment for ecological R&D. The most obvious, and potentially easiest to quantify, is the production of scientific papers. Quantifying the number of ecological papers published per unit of funding can be done by comparing online databases that list expenditure of a particular funding body, and publications by authors funded by the same organisation (Figure 1).

FIGURE 1 NERC FUNDING FOR, AND PUBLICATIONS RESULTING FROM, PROJECTS RETURNED BY A SEARCH FOR ECOLOG*



A (above left) The funding represented by the blue line includes all NERC-funded projects that began in that year and that contain a word beginning with 'ecolog*' in the abstract, reference or title on the UK Research and Innovation Gateway to Research database. The high expenditure in 2019 is due to expenditure on the founding of the Global Challenges Research Fund (GCRF) One Ocean Hub and Living Deltas Hub. The orange line includes all publications returned from the same search. The red line includes all publications returned when searching for papers on Scopus that have: authors with a UK affiliation, funding accredited to the NERC, and any word starting with 'ecolog*' in the abstract. **B (above right)** Amount funded against number of publications with least squares lines of best fit and 95% confidence intervals.

Source: Own elaboration using data from UKRI *Gateway to Research*[10] and Scopus[11]

[iv] Domestic species are animals and plants that have been selectively bred to live alongside humans. They are raised and cared for by humans for food, clothing, medicine, companionship or other uses. This includes cows, dogs, cotton and wheat.

Both Natural Environment Research Council (NERC) funding for ecology research, and papers published by NERC-affiliated authors, have increased since 2006 (Figure 1). However, Poisson regression that excluded 2019, where expenditure was significantly higher than usual due to two big projects being founded (Global Challenges Research Fund (GCRF) One Ocean Hub and Living Deltas Hub), showed significant effects of funding on number of publications but also a significant interaction between year and funding (Table 1). Funding seems to have a variable impact on publications over time. This suggests that while funding is obviously a central element in determining how much ecology research occurs in the UK, there are other factors that affect how many publications are produced in any given year. These include funding cycles, as fewer papers may be published in years where many academics are applying for large grants, and disruptions to scientific publishers such as the COVID-19 pandemic. This analysis is not fully comprehensive, and only intended to be indicative of any trends.

TABLE 1 RESULTS OF THE POISSON REGRESSIONS THAT TESTED WHETHER THE NUMBER OF PUBLICATIONS WITH NERC-AFFILIATED AUTHORS AS LISTED ON A) SCOPUS AND B) UKRI GTR VARIED OVER TIME AND DEPENDED ON THE AMOUNT NERC FUNDING GIVEN TO ECOLOGY RESEARCH

A Null deviance 681.67 on 13 degrees of freedom, Residual deviance 144.02 on 10 degrees of freedom

Variable	Estimate	Standard Error	z-score	p-value
Year	0.028	0.017	1.69	NS
Funding	-3.6×10^{-6}	1.1×10^{-6}	-3.18	0.0015
Year:Funding	1.8×10^{-9}	5.6×10^{-10}	3.19	0.0014

B Null deviance 424.93 on 13 degrees of freedom, Residual deviance 69.82 on 10 degrees of freedom

Variable	Estimate	Standard Error	z-score	p-value
Year	-0.036	0.030	-1.21	NS
Funding	-1.0×10^{-5}	2.1×10^{-6}	-4.84	<0.0001
Year:Funding	5.0×10^{-9}	1.0×10^{-9}	4.85	<0.0001

1.2.2 Other impacts of research

Besides publications, other impacts of research such as changes to policy or land management are harder to measure[12]. Funding ecology is vital not only for the continuation of basic ecology research, but also for the success of environmental policy-making [13,14]. Despite this, it can be almost impossible to say that the resources used on a particular study directly led to specific policy impact, such as the targets set in the Environment Act 2021 for the recovery of nature. It is even harder to say that particular research had an ultimate impact such as preventing the extinction of a certain number of species. For one, there can be a time lag between the publication of research and its use in policy or management. However, the fact that that we cannot predict the future, especially in systems as complex as ecosystems, means that constantly furthering our ecological understanding is a sensible strategy to inform future policies that may protect against future threats and crises.

There is also a difference between impact and influence, where influence can be even harder to quantify. In the environmental field, activities and policies will be informed by many sources of research which all have influence on the direction of travel; whilst a study may not have an immediate impact, it can be part of the development of a body of knowledge that influences the direction of policy in the long term. For example, many studies have contributed to showing how important peatlands are as a carbon sink in the UK. The protection and restoration of peatlands are now key parts of land use and climate change policies in all four nations of the UK. Indirectly, ecology research has the potential to inform activities that produce very large environmental, socio-economic and health benefits.

1.3 IS ECOLOGY FUNDING CHANGING?

There have been suggestions for years that the proportion of R&D funding given to ecology is declining in favour of sciences that underpin high-value industries or other socio-economic objectives such as health and defence[15]. However, the extent to which ecology funding has been changing remains unclear. Investigating this requires an in-depth review of the projects that are funded in the UK, and whether the proportion of resources spent on ecology has changed over time.

1.4 SCOPE AND OBJECTIVES

This report outlines the trends in the amount of funds available for ecology research in the UK using publicly available data. The time span depends on the funding sources, but the main analysis focuses on research council funding between 2006-2021. The research councils were brought together in UKRI in 2018 and UKRI maintains these data. The aim is to investigate whether funding for ecology has been declining over this period, reducing the resources available for research in the field.

First, we cover overall trends in UK R&D funding and demonstrate how they have changed since 1990, both in monetary terms and as a proportion of Gross Domestic Product (GDP), in order to provide context for changes in ecology funding. We go on to outline the complex landscape of UK R&D funding, and the movement of money between different categories of organisations who provide and spend the money. We then go through each class of funders in turn and use the data available to analyse changes in the amount of funding given to ecology research. Finally, we discuss the evidence for changes in the proportion of R&D funding spent on ecology research, and what that means for the field.

QUESTIONS

1	Has unadjusted funding for ecology changed over time?
2	Has funding for ecology kept up with inflation or decreased in real terms over time?
3	Has funding for ecology increased at the same rate as overall R&D funding?
4	Has funding for ecology increased at the same rate as it has for other fields?

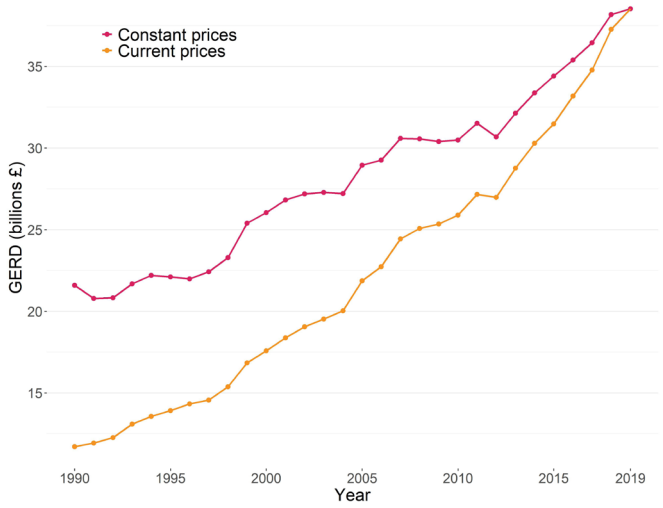
2. OVERALL TRENDS IN UK RESEARCH AND DEVELOPMENT FUNDING

The Office for National Statistics (ONS) releases annual estimates of the R&D performed and funded in the UK. These data provide a broad overview of funding, but not a detailed breakdown of the financed topics. Despite this broad-brush approach, the ONS data give vital context for this report.

Ecology is not funded in isolation, but rather as part of a broad and complex landscape of various topics and subject areas. If funding for ecology increases at a lower rate than the total increase in R&D funding, this means that the proportion of resources given to ecology is decreasing overall.

In general, UK spending on R&D has continuously increased for the last few decades. There has been an average annual growth rate of 2.1% in constant price[v] gross expenditure on R&D (GERD) since the 1990 level of £21.6 billion, demonstrating a long-term upward trend (Figure 2). In 2019, the UK spent £577 per head of population, which represents an increase of 56.8% from the 1990 total of £368 in constant prices. There is a disparity in R&D expenditure between the nations of the UK, even when controlling for population differences. England received £606 per capita in 2019, compared to £507 for Scotland, £423 for Northern Ireland and £248 for Wales.[16,17].

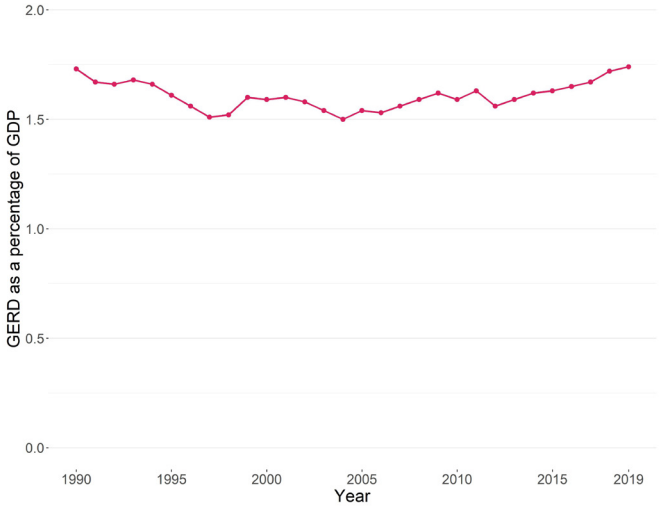
FIGURE 2 GROSS UK DOMESTIC EXPENDITURE ON R&D, 1990 TO 2018



Source: Own elaboration with using data from ONS (2021) *Gross domestic expenditure on research and development, UK: 2019*[18]

UK GERD spending must be understood in the context of economic growth as well as inflation. UK spending on R&D is often measured by calculating GERD as a proportion of GDP. GERD as a percentage of GDP declined steadily between 1990-2004, from 1.73% to 1.50%, which indicates a relative decrease on the emphasis placed on R&D in the UK's public and private sector budgets (Figure 3). Since then, the percentage has fluctuated between 1.52% and 1.71%, showing a gradual upward trend. The 2019 estimate of 1.74% of GDP was slightly up from 1.72% in 2018 and above the mean of 1.61% for the period 1990-2018. This fell below the OECD average of 2.4% and the EU-28 average of 2.0% in 2018[19].

FIGURE 3 UK'S GROSS DOMESTIC EXPENDITURE ON RESEARCH AND DEVELOPMENT (GERD) AS A PERCENTAGE OF GDP



Source: Own elaboration using data from ONS (2021) *Gross domestic expenditure on research and development, UK: 2019*[20]

The UK government aims to increase R&D funding to 2.4% of GDP by 2027[21], a target which has been stated in several policies over the past five years[22,23,24,25,26] and has the central objective of improving living standards and economic growth across the country. Whilst some support will come from a public funding injection of £7 billion into R&D over the next 5 years as part of the National Productivity Investment Fund, achieving this target will require a significant increase in funding from other areas of the public sector and the private sector.

[v] Constant prices are altered to control for inflation, whereas current prices are not.

3. UK R&D FUNDING STRUCTURE

In order to determine if funding for ecology research has changed over time, we must first understand where UK R&D funding comes from. This sets out which sources of data need to be interrogated in order to discover how funding for ecology has changed over time.

The complexity of the R&D ecosystem in the UK is well documented[27] and makes gaining a full understanding of ecology funding challenging. The UK R&D funding environment can be broadly categorised into funding from the following sources:

- Government funding, including:
  - Government departments
  - Higher Education Funding Councils (HEFCs);
  - UK Research Innovation (UKRI)
- Private non-profit funding
- Overseas funding
- Business funding
- Higher education institutions

The complex structure[28] and details of the flows of funding from organisations that fund research to those that conduct research in the UK from 2019 are outlined in table 2.

TABLE 2 FLOWS OF RESEARCH AND DEVELOPMENT FUNDING IN THE UK IN 2019

	Government & UKRI[2]	Higher Education	Business Enterprise	Private Non-Profit	Total £million
Sector providing the funds:					
Government	1,503	421	1,202	102	3,228
UKRI[1]	819	2,707	634	198	4,358
HEFCs[2]	-	2,859	-	-	2,859
Higher Education	21	-	28	17	65
Business Enterprise	81	362	20,192	25	20,660
Private Non-Profit	81	1,247	75	364	1,766
Overseas	157	1,472	3,818	137	5,583

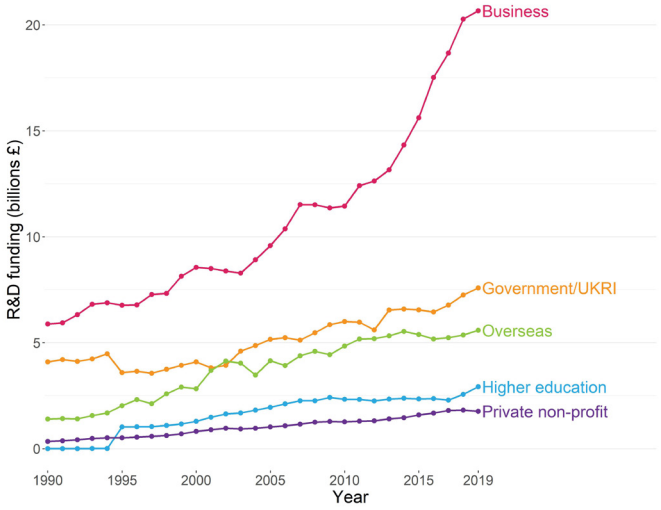
[1] UKRI - UK Research and Innovation.

[2] HEFCs - Higher Education Funding Councils, including Research England are funded by government and primarily provide funds for higher education institutes to perform R&D. For the purposes of reporting R&D funding they are classified separately from the rest of government.

Source: Data from ONS (2021) *Gross domestic expenditure on research and development, UK: 2019*[29]

In 2019, the largest R&D funder in the UK was the business enterprise sector, which funded £20.7 billion (53.6%) of total UK-performed R&D (Table 2 & Figure 4). This was an increase of 1.9% from £20.3 billion in 2018. At £7.6 billion (19.7%), the UK government, which includes UK Research and Innovation (UKRI) was the second largest source of UK R&D funding in 2019, increasing by 4.6% compared with 2018. The amount of R&D funded by business has increased over time, and sharply since 2012. Other sectors have not seen a concomitant increase in the amount of funding they provide, so business now provides over half the amount of total R&D funding in the UK.

FIGURE 4 COMPOSITION OF UK GROSS DOMESTIC EXPENDITURE ON RESEARCH AND DEVELOPMENT BY FUNDING SECTOR IN CONSTANT PRICES, 2013–2019. HIGHER EDUCATION INCLUDES FUNDING FROM HEFCS



Source: Own elaboration using data from ONS (2021) *Gross domestic expenditure on research and development, UK: 2019*[30]

Access restrictions and inconsistent record keeping make a full overview of funding for ecology almost impossible. However, there are a range of data sources that record the projects that R&D funding has been spent on. In general, there tends to be more data available for public funding sources than private sources:

- Government funding:
  - Government departments
  - HEFCs
- UK Research Innovation (UKRI)
- Overseas Funding (EU only)

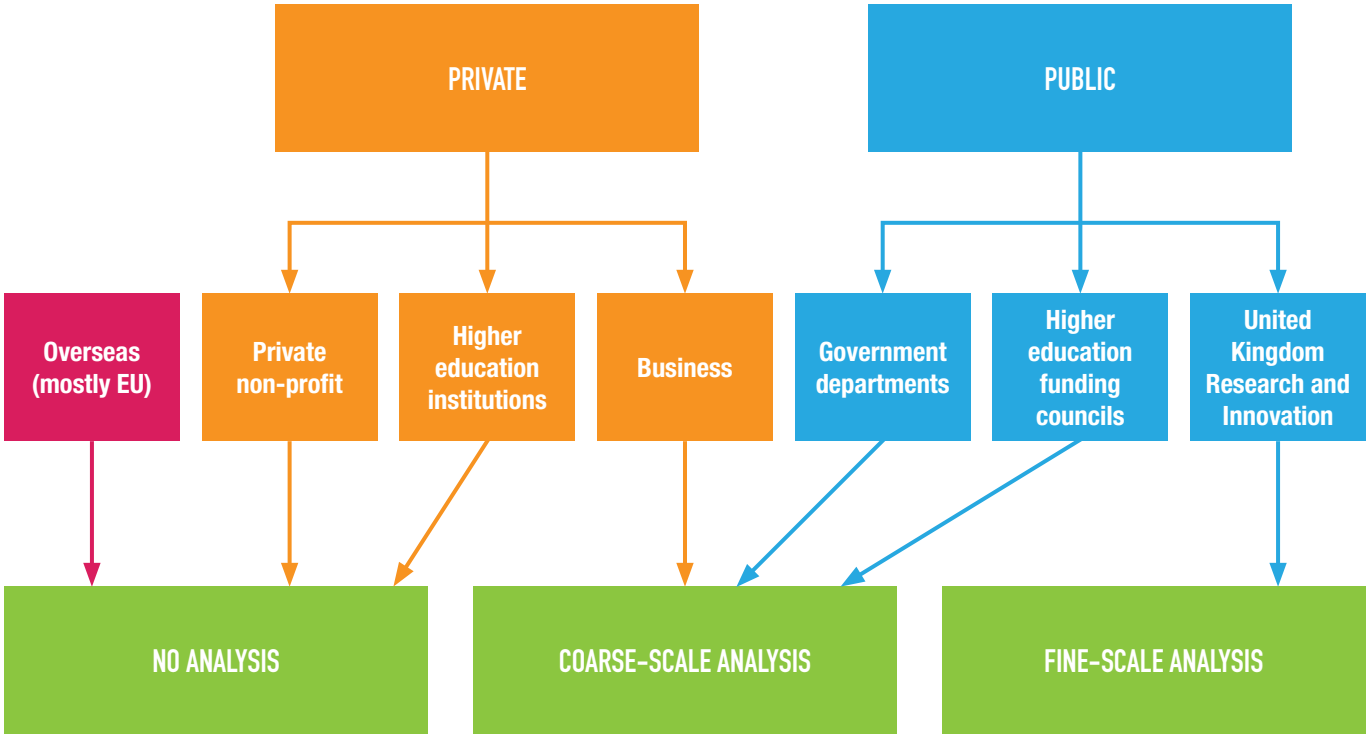
There are no collated data available to carry out analyses for private non-profit or higher education institutions. There are some data available for business, and in Section 4.1 we present an analysis for this, but it is not at a scale that allows for precise identification of ecological funding.

There are data available for EU funding. However, we do not include an analysis of that here because this study focuses on UK priorities for R&D funding. EU funding will mostly come from the Horizon Europe programme if the UK is able to join as an associate nation[vi]. Due to Brexit, the UK did not contribute to decisions regarding the structure of the current programme, which runs from 2021-2027. Even if the UK does associate to Horizon Europe, it will not be able to participate in decisions regarding which fields are prioritised for funding in future programmes. Whilst associate countries have the same access to funding as EU countries, they do not have any say in the structure of the programme[31].

The exclusion of EU funding from this analysis means that the data we analyse here represent around 27% of all UK R&D funding. In addition, the fine-scale analysis presented in Section 5 is only possible for UKRI projects, which represent approximately 11% of all UK R&D funding[vii].

In the following two sections we will examine each sector in turn, and show, in the greatest detail possible, the extent to which funding is provided for ecology, and how it has changed over time (Figure 5).

FIGURE 5 SOURCES OF R&D FUNDING IN THE UK AND WHETHER FINE-SCALE, COARSE-SCALE OR NO ANALYSIS WAS POSSIBLE IN THIS REPORT



Source: Own elaboration

[vi] Horizon Europe is the EU's current €95.5 billion research and innovation programme that will run until 2027. In December 2020, an agreement was made for the UK to associate to Horizon Europe as part of the Brexit deal, giving UK researchers access to funding under the programme. However, confirmation is subject to ratification of the Trade and Cooperation Agreement between the UK and EU. At the time of writing, there has been over two years of uncertainty over the UK's participation in Horizon due to disagreements over the Northern Ireland Protocol. Despite this, it now looks much more likely that the UK will be able to rejoin Horizon due to the new proposed post-Brexit legal agreement between the EU and the UK, called the Windsor Framework. Ursula von der Leyen, the European Commission president, stated in a press conference for the announcement of the agreement on 27th February 2023 that work on an association agreement could begin immediately.

[vii] These proportions are estimates because the figures that show the proportion of funding spent on R&D by sector group HEFCs and Higher education institution funding together, and do not separate non-EU and EU overseas funding.

4. COARSE-SCALE ANALYSIS – BUSINESS, GOVERNMENT DEPARTMENTS AND HIGHER EDUCATION FUNDING COUNCILS

4.1 BUSINESS

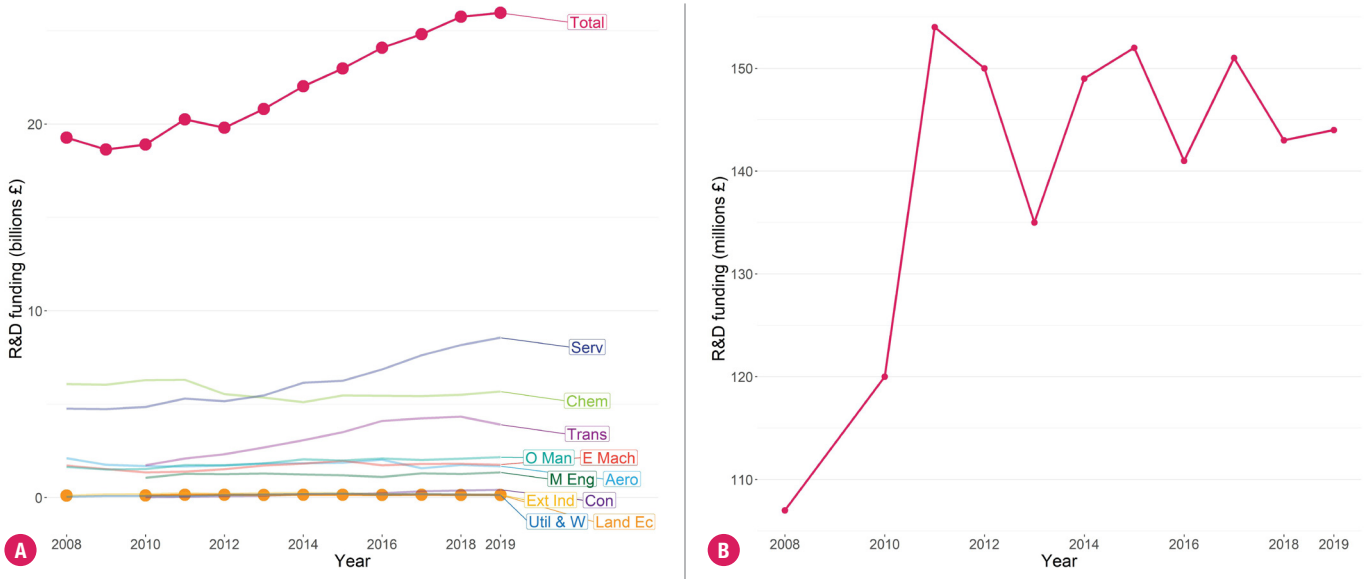
Considering the priorities of business is vital for understanding UK R&D funding. However, there are limited sources of collated data available that allow us to test how much of these resources go towards ecology, and whether this has changed over time. The data that are available suggest that ecology is not a significant priority for business. The expenditure on R&D performed by UK businesses is categorised into broad product groups by ONS. This represents almost all the funding that UK businesses allocate to R&D, as only a small proportion of business R&D funding goes towards R&D actually performed by other organisations (Table 2). This suggests that businesses may not be a significant funding source for ecology. Here, funding for ecology is likely to fall under the 'Agriculture, hunting & forestry; fishing' category, termed 'Land economy' on Figure 6a. It is uncertain how much of this funding goes towards ecology as defined in this report, as much of it is likely to fund research on domestic species, including the productivity of farmland and forestry plantations. Funding for this reached a maximum of £154 million in 2011, out of a total of £20.3 billion. Funding for this product group increased from 2008-2011, and has stayed largely steady since then, with some variation (Figure 6b).

4.2 GOVERNMENT FUNDING

Government funding for R&D should, at least in theory, be more transparent than the private sector because public bodies should be accountable for the public resources that they spend. Whilst all of this funding is ultimately a public resource, and will therefore be subject to government priorities, the exact projects it is spent on will also depend on other social, economic and institutional factors.

Government R&D spend is split into three categories according to the funding body: UK Research and Innovation (UKRI), government departments and higher education funding councils (HEFCs). Data are available in different places, and processed and stored in different ways, so we carried out separate analyses for each of the three categories. We expected to be able to conduct fine-scale analyses for each type of government funding but only coarse-scale analysis was possible for government departments and HEFCs, as presented in Sections 4.2.2 and 4.2.3 respectively. A fine-scale analysis of UKRI funding is presented in Section 5.

FIGURE 6 BUSINESS R&D FUNDING CATEGORISED INTO BROAD PRODUCT GROUPS WITH LAND ECONOMY HIGHLIGHTED



A (above left) Expenditure on R&D performed in UK businesses: broad product groups, 2008-2019. **B (above right)** Expenditure on 'agriculture, hunting & forestry; fishing' broad product group, named Land economy on graph A. Both in constant prices

Source: Own elaboration using data from ONS (2020) *Business enterprise research and development, UK: 2019*[32]

4.2.1 UK government R&D funding by socio-economic objective

Aggregated government R&D funding data are reported centrally by the ONS, and are presented showing the proportion of government expenditure that funds different socio-economic objectives (Figure 7). One of these objectives is 'Environment', which is likely to contain most of the funding for ecology research.

The proportion of UK government R&D expenditure within the socio-economic objective of Environment changed very little between 2008-2019, 3% in 2008 and 2% in 2019[33]. It is striking that such a small amount of UK government R&D spending goes towards environmental subjects when the UK faces such important and challenging environmental crises.

4.2.2 Government departments

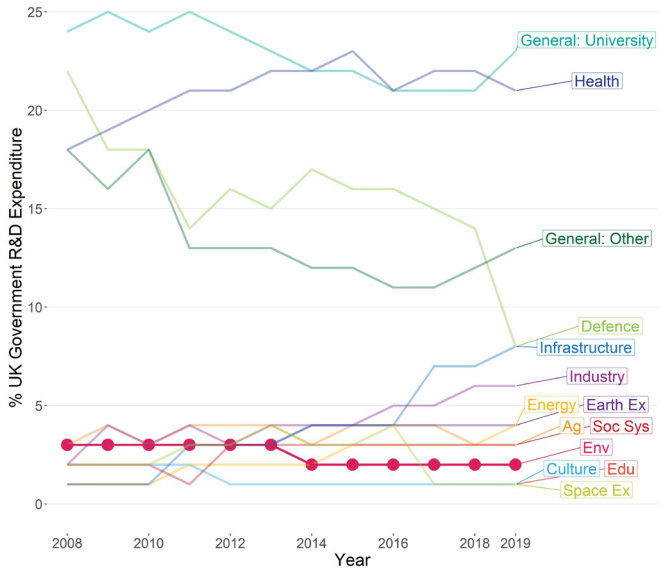
The UK government owns many research institutes and laboratories which are managed by various government departments. Government departments fund their own R&D, receive funds from other sectors and provide substantial funds to other sectors (Table 2). Whilst government departments are only responsible for ~30% of public spend on R&D[34], they still represent an important portion of total investment. Also, as this is the most direct form of R&D spending by the government, it will arguably give the clearest indication of governmental priorities.

Individual departments are free to invest in areas of individual importance[36], so there are a few departments that are of most interest for this report because their remits include things that are relevant to ecology as defined in this report. At the UK level, these are the Department for Business, Energy and Industrial Strategy (BEIS), the Department for Environment, Food and Rural Affairs (Defra) and the Department for International Development (DFID), which became part of the Foreign, Commonwealth & Development Office (FCDO) in 2020. BEIS has responsibility for climate change, and 'supporting sustainable development' is part of DFID/FCDO's first 'Priority Outcome'. Defra is the department most involved in environmental and ecology research in the UK, and states that 'Our mission is to restore and enhance the environment for the next generation, leaving it in a better state than we found it'.

A paucity of available data prevented fine-scale analysis and prevented any analysis of R&D by departments or directorates in the devolved administrations (Appendix 1). However, while it is not possible to analyse the amount spent specifically on ecology within each UK government department, another way of getting a coarse-scale idea of governmental R&D priorities is to look at the relative amount spent by different departments, and how it has changed over time. This may give an indication of the relative priority given to ecology and environmental R&D. R&D expenditure at the UK departmental level is well captured in the ONS Science, Engineering and Technology dataset (Figure 8)[37].

FIGURE 7 UK GOVERNMENT EXPENDITURE ON R&D BY SOCIO-ECONOMIC OBJECTIVE, PERCENTAGE SHARE: 2008–2019, WITH ENVIRONMENT HIGHLIGHTED

This includes the research councils (UKRI from 2018), HEFCs, UK government departments, devolved nation governments and UK contributions to EU R&D expenditure.

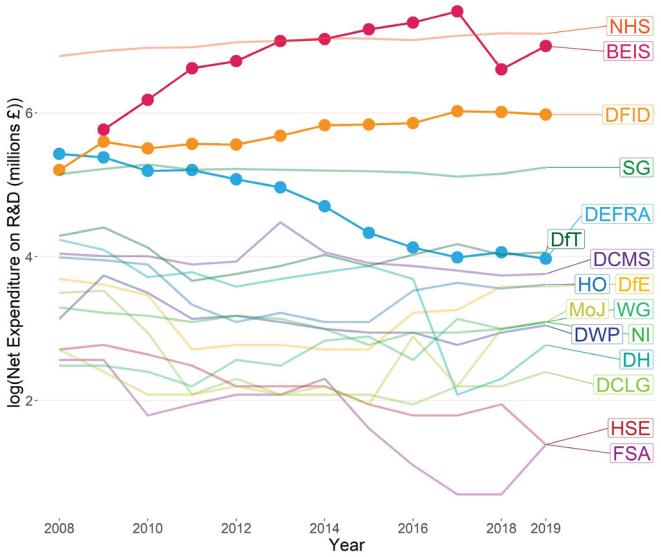


Ag - Agriculture
Culture - Culture, recreation, religion and mass media
Defence - Defence
Earth Ex - Exploration and exploitation of the earth
Edu - Education
Energy - Energy
Env - Environment
General: Other - General advancement of knowledge: R&D financed from other sources
General: University - General advancement of knowledge: R&D financed from General University Funds
Health - Health
Industry - Industrial production and technology
Infrastructure - Transport, telecommunication, other infrastructure
Soc Sys - Political and social systems, structures and processes
Space Ex - Exploration and exploitation of space

Source: Own elaboration using data from ONS (2021). *Research and development expenditure by the UK government*[35]

FIGURE 8 UK GOVERNMENT NET EXPENDITURE ON R&D BY DEPARTMENT IN CONSTANT PRICES: 2008–2019 ON A LOGARITHMIC SCALE, WITH DEFRA, BEIS AND DFID HIGHLIGHTED

Departments that only had R&D expenditure for a few years, including the Foreign and Commonwealth Office, and departments that no longer exist, such as the Department for Energy and Climate Change, have been removed.



BEIS - Business, Energy and Industrial Strategy
DCLG - Communities and Local Government
DCMS - Culture, Media and Sport
DEFRA - Environment, Food and Rural Affairs
DfE - Education
DFID - International Development
DfT - Transport
DH - Health (excluding NHS)
DWP - Work and Pensions
FSA - Food Standards Agency
HO - Home Office
HSE - Health and Safety Executive
MoJ - Ministry of Justice
NHS - National Health Service
NI - Northern Ireland Departments
SG - Scottish Government
WG - Welsh Government

Source: Own elaboration using data from ONS (2021). *Research and development expenditure by the UK government*[38]

Defra's expenditure on R&D in constant prices decreased from £241 million per year in 2008 to £53 million per year in 2019 (Figure 8). R&D funding does change as competencies change over time. For example, the Innovate UK programme reported its expenditure as part of BEIS figures up until 2017, and then as part of UKRI from 2018. DFID funding increased from £182 million in 2008 to £394 million in 2019, and BEIS funding increased from £319 million in 2009 to £1022 million in 2019, but it is hard to know how much of this funded ecology research as these departments' remits include aspects that are far from ecology.

In general, the large decrease in Defra R&D expenditure could suggest a reduction in focus on environmental and ecological subjects within the government, but further analysis is needed to confirm this.

4.2.3 Higher Education Funding Councils (including Research England)

Under the UK's dual support R&D funding scheme, funding for specific projects is provided by the research councils of UKRI, businesses and charities, the EU and government departments. This pillar is covered in the other sections of this report.

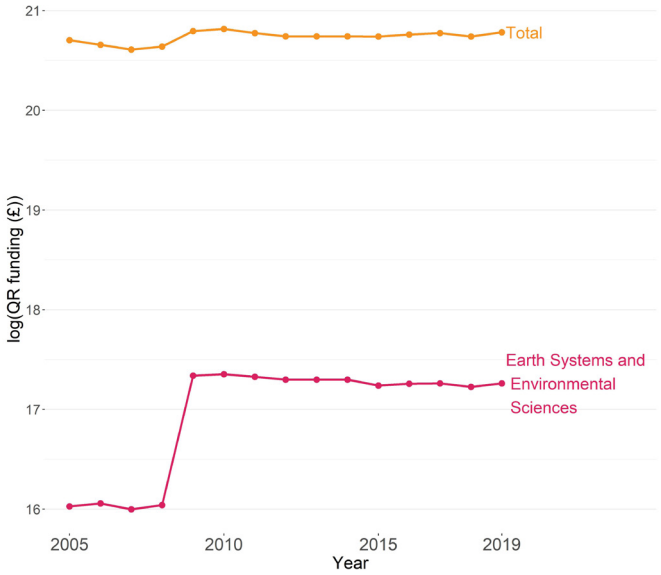
The other pillar is funding that is provided directly to higher education institutions via HEFCs[viii]. The funding is provided by the HEFCs to universities and colleges, which in turn allocate it to researchers and projects. HEFCs and Research England are funded by the government. However, being non-departmental public bodies, they are deemed not part of any government department.

These resources are used to fund teaching and engagement as well as research. The portion that is earmarked for research is called Quality-related Research (QR) funding in England and Wales and Research Excellence Grant (REG) in Scotland. HEFCs judge the quality of research in each subject area within each institution using the Research Excellence Framework (REF)[ix] and use this, along with measures of the volume of research and subject cost weights, to target funding where research quality is highest. As the QR funding is un-hypothecated, universities are free to direct it as they wish, rather than specifically to the research area for which their 'excellence' is awarded, thus allowing cross-subsidisation into other research areas.

Research England publishes the amount of QR funding it allocates divided into 36 categories. One of these is Earth Systems and Environmental Sciences, which we analyse here (Figure 9).

FIGURE 9 THE AMOUNT OF THE QUALITY-RELATED RESEARCH FUNDING ALLOCATED BY RESEARCH ENGLAND THAT IS SPENT ON THE SUBJECT AREA OF 'EARTH SYSTEMS AND ENVIRONMENTAL SCIENCES'

From 2005-2008, funding was reported for 'Environmental Sciences' and 'Earth Systems' separately, and only the Environmental Sciences funding is presented. The increase from 2008-2009 is therefore due to these two subject areas being reported together, and not due to a large increase in funding to environmental research.



Source: Own elaboration using data from UKRI. *Our funds for research and knowledge exchange.*[39]

From 2009-2014, the proportion of funding allocated to Earth Systems and Environmental Sciences stayed largely steady between 3.15% and 3.19%, and then decreased very slightly to 2.95% in 2019 (Figure 9). Between 2005-2008, when Environmental Sciences funding was reported separately, the proportion given to that subject stayed around 1%. Assuming that funding for ecology research will generally fall into the Environmental Sciences category, this is likely to have stayed around this level for the entire period.

[viii] The HEFCs are the Scottish Funding Council (SFC) and Higher Education Funding Council for Wales (HEFCW) although the HEFCW will be dissolved in 2023 and its responsibilities will be taken on by the newly established Commission for Tertiary Education and Research in Wales. The Department for the Economy holds the competency for this in Northern Ireland. These are responsible for the distribution of funding for higher education to universities and further education colleges throughout the UK. The Higher Education Funding Council for England (HEFCE) ceased to exist in 2018, when its research funding competencies were largely moved to Research England, which sits within UKRI.

[ix] The REF website describes the process as 'a process of expert review, carried out by expert panels for each of the 34 subject-based units of assessment (UOAs), under the guidance of four main panels. Expert panels are made up of senior academics, international members, and research users. For each submission, three distinct elements are assessed: the quality of **outputs** (e.g. publications, performances, and exhibitions), their **impact** beyond academia, and the **environment** that supports research.' https://www.ref.ac.uk/about-the-ref/what-is-the-ref/

5. FINE-SCALE ANALYSIS – UKRI

5.1 UKRI STRUCTURE AND FUNDING

A new non-departmental public body, United Kingdom Research and Innovation (UKRI), came into operation in 2018. UKRI brought together the seven research councils with Innovate UK and Research England.

The research councils are:

- Arts and Humanities Research Council (AHRC)
- Biotechnology and Biological Sciences Research Council (BBSRC)
- Economic and Social Research Council (ESRC)
- Engineering and Physical Sciences Research Council (EPSRC)
- Medical Research Council (MRC)
- Natural Environment Research Council (NERC)
- Science and Technology Facilities Council (STFC)

The research councils are responsible for funding and co-ordinating academic research within their field, as well as funding postgraduate studies. Council funding is project-orientated, representing one pillar of the "dual support" funding system[40]. Through this combined approach, research councils offer competitive project-based funding, whilst Quality-related Research (QR) funding is given to higher education institutions. QR block funding is based on quality assessment through the Research Excellence Framework (REF) and gives greater flexibility for use and seven-year periods of assured funding. The dual support system is widely regarded to be a key feature of UK research funding.

Innovate UK is the UK's innovation agency which provides money and support for product and service development and commercialisation. Innovate UK is also responsible for the Catapult Network of R&D centres which connect businesses with research and academic communities.

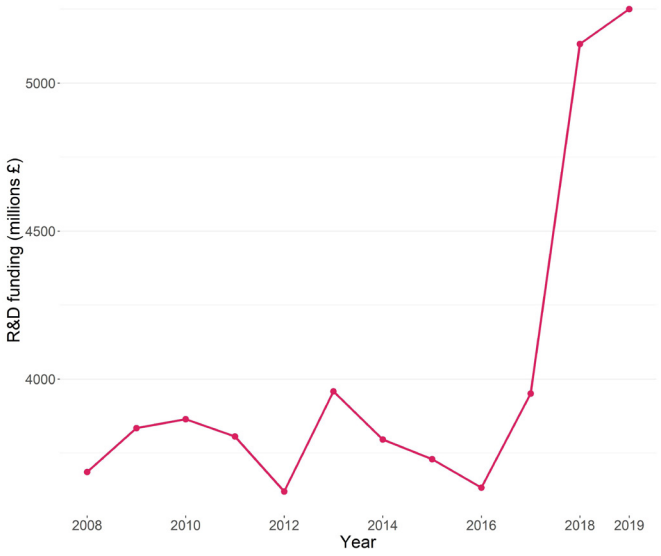
Research England is responsible for the former research functions of the Higher Education Funding Council for England (HEFCE)[41]. Research England is therefore responsible for the block grant funding element of the dual support system in England. Analysis of the R&D funding for for higher education funding councils (HEFCs) and Research England are reported in Section 4.2.3.

UKRI funds a significant amount of research every year (Figure 10). It is also likely that it funds a significant amount of the ecology research in the UK, as the field seems to only receive a small proportion of business and government department funding (Figures 6-9). The two research councils that are most relevant to ecology are NERC and BBSRC.

NERC funds research across the environmental sciences, as well as research infrastructure, services, facilities and data centres, and provides advice to government when there is a national or international environmental emergency such as a flood or earthquake[42]. BBSRC funds bioscience, people and research infrastructure that contribute to tackling global challenges, such as sustainable food production, climate change, and healthy ageing[43].

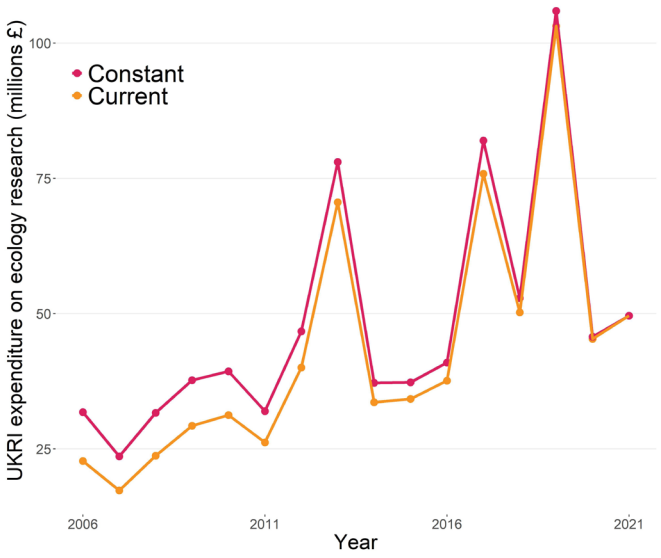
FIGURE 10 TOTAL RESEARCH COUNCIL SPENDING ON FUNDING R&D (EXCLUDING RESEARCH ENGLAND) IN CONSTANT PRICES

The total for UKRI in 2018 is not directly comparable with the total for research councils in earlier years. This is due to the inclusion of Innovate UK (which was previously reported as part of BEIS).



Source: Own elaboration using data from ONS (2021). *Research and development expenditure by the UK government*[44]

FIGURE 11 THE CHANGE IN THE AMOUNT OF FUNDING AWARDED TO ECOLOGY PROJECTS BY NERC AND BBSRC BETWEEN 2006–2021 IN CURRENT AND CONSTANT PRICES. INFLATION WAS CALCULATED USING THE CONSUMER PRICE INDEX



Source: Own elaboration using data from UKRI *Gateway to Research*[45]

UKRI has developed the **Gateway to Research** (GtR) website as part of the Innovation and Research Strategy of BEIS. GtR's objective is to provide information about publicly funded research[46]. This provides open access data from the UKRI research councils and Innovate UK, along with the National Centre for the Replacement, Refinement and Reduction of Animals in Research (NC3Rs). GtR therefore provides a resource which allows users to assess the amount of funding that has been spent on ecology research by UKRI, and whether this has changed as a proportion of total funding from 2006. The challenge lies in distinguishing which of the projects listed on GtR are classed as ecology. In order to do this, we consulted with the BES Special Interest Groups to discuss how ecology research is funded by UKRI. This allowed us to refine a methodology for a keyword search for NERC and BBSRC projects that was likely to return ecology projects (Appendix 2).

There was a real-terms increase in the amount of funding awarded to ecology projects by NERC and BBSRC between 2006-2021 (Figure 11). In 2021, £49.6 million was awarded to ecology research, compared to £22.7 million in 2006, which is equivalent to £31.7 million in constant prices when accounting for inflation. There was a 56.1% increase in funding in constant prices over this period.

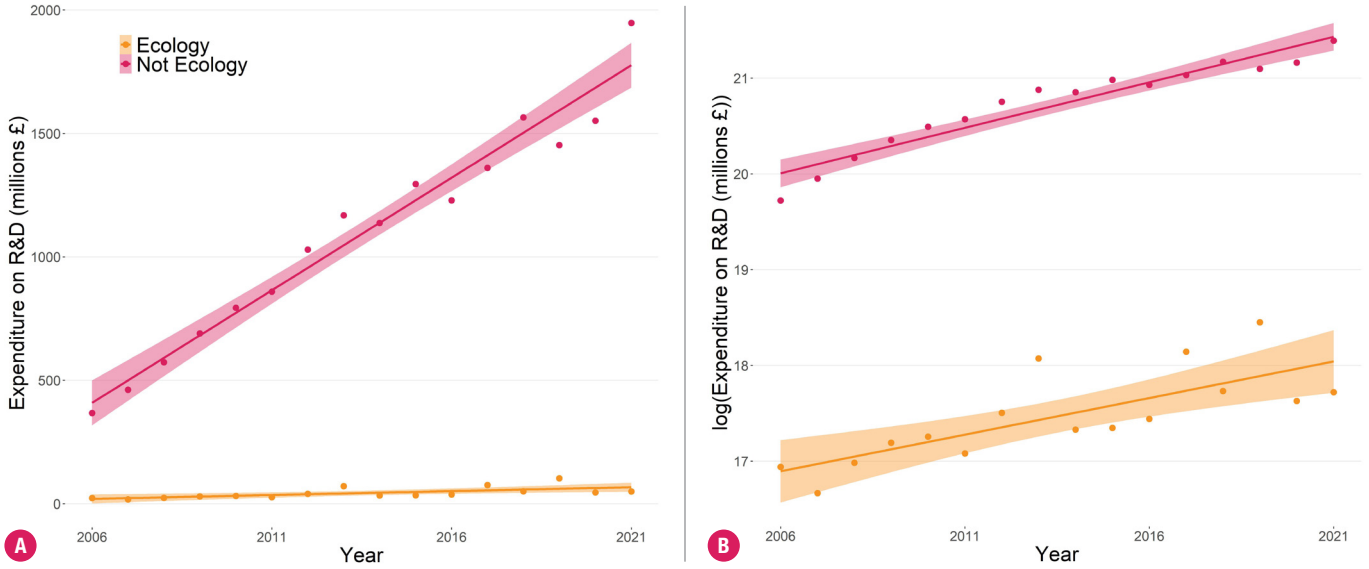
Crucially, the change in annual UKRI research funding was significantly different between ecology and non-ecology research (Table 3). Funding for non-ecology research increased at a much greater rate than funding for ecology research (Figure 12).

While UKRI funding for ecology research has increased over the study period, it has not increased at the same rate as it has for non-ecology research. Therefore between 2006-2021 the proportion of UKRI funding given to ecology decreased.

TABLE 3 RESULTS OF THE LINEAR REGRESSION THAT TESTED WHETHER ANNUAL RESEARCH FUNDING VARIED OVER TIME, AND WHETHER THE RATE OF CHANGE DIFFERED BETWEEN ECOLOGY AND NON-ECOLOGY RESEARCH – ADJUSTED $R^2 = 0.99$, $F = 946.8$ ON 3 AND 28 DEGREES OF FREEDOM, P-VALUE=<0.001

Variable	Estimate	Standard Error	t value	p-value
Year	3.2×10^6	3.5×10^6	0.91	NS
Research Subject	-1.8×10^{11}	9.9×10^9	-17.83	<0.0001
Year: Research Subject	8.8×10^7	4.9×10^6	17.93	<0.0001

FIGURE 12 THE CHANGE IN NERC AND BBSRC FUNDING FOR ECOLOGY AND NON-ECOLOGY RESEARCH



The change in the amount of funding awarded to ecology projects by NERC and BBSRC and to non-ecology projects by all research councils in UKRI between 2006 and 2021 in current prices on **A (above left)** an arithmetic scale and **B (above right)** a logarithmic scale, with least squares lines of best fit and 95% confidence intervals. This is presented in current prices as we are interested in the differences between the two groups. The change in ecology prices in constant prices is presented in Figure 11.

Source: Own elaboration using data from UKRI *Gateway to Research*[47]

6. DISCUSSION

In this report, we have attempted to test claims that funding for ecology research has declined over the past two decades. This is by no means a comprehensive analysis and should be treated as exploratory work. We did not contact individual businesses, universities and other research organisations to source data on what projects and subject areas research funding is spent on. This was beyond the scope of our work, but if done it would have allowed for much more detailed analysis. Despite the coarse scale of much of the analysis presented here, the work does highlight some important points of discussion.

6.1 UKRI FUNDING FOR ECOLOGY HAS INCREASED IN REAL TERMS BUT NOT AS FAST AS OTHER SUBJECTS

Fine-scale analysis is only possible for UKRI projects, which represent approximately 11% of all UK R&D funding. Whilst this is a small proportion of the overall UK R&D funding landscape, this may represent a large portion of UK ecology funding, as environmental topics make up a very small proportion of the funding allocated by other sources, including business and government departments.

This analysis shows that UKRI funding for ecology has increased in real terms since 2006, although there is large interannual variation. UKRI funding for ecology in constant prices also increased at a faster rate than the overall UK GERD, which increased by 31.6% between 2006-2019. UKRI funding for ecology increased by 56.1% between 2006-2021 (the figure for 2006-2019 would be misleadingly high due to the spike in 2019) (Figure 11).

Despite this increase, UKRI funding for ecology research has not increased at the same rate as it has for non-ecology research over the same period, so arguably the importance placed on ecology research by these vital funding bodies research has been declining.

ANSWERS

As a summary, we can use the analysis presented here to answer the four questions regarding UKRI funding for ecology research presented in Section 2.

1	Has unadjusted funding for ecology changed over time? **Yes, in current prices there was a 117.9% increase between 2006-2021.**
2	Has funding for ecology kept up with inflation or decreased in real terms over time? **Yes, in constant prices there was a 56.1% increase between 2006-2021.**
3	Has funding for ecology increased at the same rate as overall R&D funding? **Yes, it has increased faster than UK GERD which increased by 31.6% between 2006-2019.**
4	Has funding for ecology increased at the same rate as it has for other fields? **No, UKRI funding for non-ecology research has increased at a significantly higher rate than ecology funding.**

6.2 THERE HAS BEEN LITTLE CHANGE IN THE IMPORTANCE PLACED ON R&D FUNDING IN THE UK

R&D funding has increased in real terms in the UK over the past three decades, although it has not done so as a proportion of GDP. Arguably, R&D has not received a greater emphasis in the UK, instead it has just kept pace with other demands for funding. The proportion of GDP given over to GERD is lower than the OECD and EU averages. R&D is a vital component of the UK response to the climate and biodiversity crises and the UK is lagging behind other comparable countries in the proportion of resources it is providing for R&D.

6.3 THERE IS A LACK OF DATA ACROSS ALL FUNDING SOURCES

Attempting to analyse how funding for ecology research has changed over time has revealed the lack of detailed available data on what disciplines and subject areas R&D funding is spent on in the UK. This makes any detailed and robust analysis on the relative importance placed on disciplines and subject areas difficult. Difficulties including access, and inconsistent record keeping and formatting, make a full overview of the allocation of research funding to ecology almost impossible. This is not just important for ecology, but all fields and disciplines.

There are no centralised and easily accessible data available to carry out robust analyses for the majority of R&D funding in the UK including Private Non-Profit, Business and Higher Education Institutions. Business made up over half of all GERD in 2019 and the only analysis possible was the 'Broad Product Groups' in Figure 6. It may be possible to gain access to some of this information by contacting individual organisations, but this would likely be difficult and time consuming.

In the public sector, there are more data available, but it is difficult to find the subject areas, titles or funding spent on projects that have been funded. When looking at government departments, it is possible to see the amount that each UK department has spent, but not exactly what it has been spent on. Data on R&D spend at the directorate level are not available for Scotland, Wales or Northern Ireland. Higher Education Funding Councils (HEFCs) only publish funding broken down into very broad categories. Organisations should be accountable for the public resources that they spend and it is difficult for stakeholders or the public to hold public bodies to account if they are not able to find out what that money is spent on. This is a key problem for people or organisations who would like to investigate R&D funding in the UK and advocate for certain disciplines.

7. FUTURE CHALLENGES AND OPPORTUNITIES

Whilst we urge UKRI, Defra and other public organisations to increase the amount of funding they provide for ecology research, there are also opportunities to increase funding from private sources.

Business funds the majority of R&D in the UK, and ecology is currently a low priority for the sector (Figure 6), but it will increasingly need the input of ecological consultants. It is now well-understood that biodiversity loss and environmental degradation present risks to business operations, especially when a business directly depends on ecosystem services such as clean water supply[48]. Businesses will also increasingly require the support of ecological consultancies to comply with regulatory requirements such as Biodiversity Net Gain and to implement nature recovery projects such as those financed by the Landscape Recovery programme (one of the three programmes under the Environmental Land Management Schemes in England at the time of publication). This consultancy work will generate a significant amount of valuable data. If the connections between ecology research and consultancy can be improved, these data could be used more often for research. Government requirements to fund research alongside consultancy work could also increase the funding available for ecology research.

The lack of data on R&D funding means that it remains very difficult to assess the impact of changes to the UK R&D funding system, such as the delayed association to Horizon Europe, on specific fields. Horizon Europe is a huge research fund, and years of uncertainty regarding the UK's association to the scheme have had a significant impact on the UK R&D sector, with the participation of UK researchers in Horizon Europe projects falling by about 50% compared with before Brexit[49]. Even if the UK´s participation in Horizon Europe is secured, the number of UK researchers in European-funded projects may take some time to get back to pre-Brexit levels because research networks have been disrupted. Without better data, changes such as this could lead to a 'silent crisis' in ecology research, where a lack of funding undermines the ability of the field to provide benefits for society and help tackle the climate and biodiversity crises, but we are not able to recognise or quantify this.

ACRONYMS

AHRC	Arts and Humanities Research Council
BBSRC	Biotechnology and Biological Sciences Research Council
BEIS	Department for Business, Energy and Industrial Strategy
BES	British Ecological Society
DAERA	Department of Agriculture, Environment and Rural Affairs (Northern Ireland)
Defra	Department for Environment, Food and Rural Affairs
DFID	Department for International Development
EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
GDP	Gross Domestic Product
GCRF	Global Challenges Research Fund
GERD	Gross Expenditure of Research and Development
GtR	Gateway to Research
HEFC	Higher Education Funding Council
HEFCE	Higher Education Funding Council for England
HEFCW	Higher Education Funding Council for Wales
MRC	Medical Research Council
NC3Rs	National Centre for the Replacement, Refinement and Reduction of Animals in Research
NERC	Natural Environment Research Council
NRW	Natural Resources Wales
ONS	Office of National Statistics
QR	Quality-related Research
R&D	Research and Development
REF	Research Excellence Framework
REG	Research Excellence Grant
SFC	Scottish Funding Council
STFC	Science and Technology Facilities Council
SPICe	Scottish Parliament Information Centre
UKRI	United Kingdom Research and Innovation

APPENDIX 1

COARSE-SCALE ANALYSIS METHODS

GOVERNMENT DEPARTMENTS

We tried to source data directly from government departments in order to analyse the subjects that R&D funding was used for, but it was not possible.

UK

BEIS

In response to an email asking for data on the projects that their R&D budget funds, BEIS representatives said that it was not available and directed us to the UKRI Gateway to Research (GtR) database (Section 5).

DFID/FCDO

DFID maintains a list of projects that they funded as a separate department before being incorporated into the Foreign, Commonwealth and Development Office (FCDO)[50] in September 2020, but this does not contain spend data and we therefore could not analyse the amount that was spent on different subject areas. There is no similar list for research outputs published after 2 September 2020.

A group of government departments and research funders have come together to form the UK Collaborative on Development Research (UKCDR). UKCDR promotes communication between funders and keeps track of UK-funded development research around the world. They maintain a list of active projects funded by UK government departments as part of the FCDO's Official Development Assistance (ODA). However, this list is only current projects and a large proportion of them are delivered in partnerships with research councils and are therefore listed on the UKRI's GtR.

Defra

Defra has an online database of research projects called Science Search[51]. Science Search captures about 95% of Defra's funded projects and has been used before to track Defra's R&D spend, for example for a JNCC biodiversity indicator[52], which also looked at the whole Defra Group spend.

It is only available as an online database and cannot be downloaded in a format that can be analysed. We emailed Defra to ask whether they could provide the data in a CSV format or similar and are yet to receive a response. We will update this report if we gain access to these data.

DEVOLVED NATIONS

In Scotland, Wales and Northern Ireland, government R&D spending data is only published in aggregate and is not split up by department or directorate. This was confirmed by Natural Resources Wales (NRW) in Wales, by the Scottish Parliamentary Information Centre (SPICe) in Scotland, and by the Department of Agriculture, Environment and Rural Affairs (DAERA) in Northern Ireland. Analysis of the spend by each department or directorate is therefore not possible, and there is no information on projects that are funded.

HIGHER EDUCATION FUNDING COUNCILS

Despite the fact that Research England sits within UKRI, projects that it funds do not appear on the UKRI GtR online database. Instead, Research England and each of the devolved nation higher education funding councils (HEFCs) publish the amount of QR funding separately. Research England publishes the amount of QR funding it allocates divided into 36 categories. We are aware that not all funding for ecology research will fall into the category of Earth and Environmental Sciences but the funding allocated to the category can give a good indication of the available funding for ecology. It is not possible to see any finer categorisation of funding, or what projects were funded. Higher Education Funding Council for Wales (HEFCW) only publishes the funding given to very broad categories, with ecology likely falling into 'Science'. Scottish Funding Council (SFE) and the Northern Irish Department of Economy do not split it up by subject area at all. We therefore do not present any analysis of nations other than England.

UKRI

Gateway to Research (GtR) provides data on research funded since January 2006, but some early projects are missing due to the lack of comprehensive information. Also, MRC, Innovate UK and STFC do not publish all their data. GtR lists information on each project including title, abstract, duration of the project, the amount awarded, the researchers involved and a list of publications produced.

APPENDIX 2

FINE-SCALE ANALYSIS METHODS

When developing this project, our members informed us that two research councils fund almost all of the scientific ecology research within UKRI: NERC and BBSRC. There may be some interdisciplinary projects that could be classed as ecology under the definition we use here and receive funding from other research councils, but if this is the case then it is likely to be a very small proportion of ecology research funding. We restricted our results to these two funding councils because of this and also because including the others may have affected the results. Other research councils have projects that use words related to ecology in different ways. For example, one project funded by AHRC was 'The production ecology of pre-school television in Britain', and one funded by EPSRC was titled 'Modelling an artificial adaptive market ecology with evolutionary algorithms'. Including projects from other research councils in a keyword analysis therefore inflates the risk of classifying non-ecology projects as ecology. If projects returned by the search term 'Ecolog*' in an analysis using all research councils were classed as ecology, these example projects would be included and would increase the estimated funding for ecology research.

We asked the the BES Special Interest Groups (SIGs) about search terms which they thought would return ecology projects. Whilst UKRI Gateway to Research (GtR) allows users to extract projects according to classifications, including one for research topics, 'Ecology' is not listed as one of these. Instead, the classification used by GtR is more fine grained. 'Behavioural Ecology', 'Community Ecology', 'Conservation Ecology' and 'Population Ecology' are listed on GtR, but many projects that could be classed as ecology do not fall into any of these. It is not possible to manually go through and classify every project on GtR as ecology or not, so instead we identified possible search words that we thought would capture all ecology projects.

Search terms tested

Search term
Ecolog*
Biodivers*
"Conservation"
"Ecosystem"
"Food web"OR "Food chain"
Community AND Diversity
Species AND Diversity
Species AND Interaction
Species AND Richness
Mutualis* OR Parasit* OR Predat* OR Symbio*
"Vegetation" OR "Tree" OR "Plant species"
"Forest" OR "Woodland" OR "Grassland" OR "Heathland" OR "Peatland" OR "Bog" OR "Tundra" OR "Reef" OR "Saltmarsh" OR "Mangrove" OR "Seagrass" OR "Wetland"
Fung* AND Decompos*
Microb* AND Decompos*
"Invasive species" OR "Species management"
Pollinat*
"Soil" AND "Carbon"
"Nature-based solution" OR "Green infrastructure"
Search term
Agroecol*
Agriculture AND Ecol*
"Ecosystem services"
"Ecological Intensification"
Agriculture AND arable plan*
Agriculture AND weed
Agriculture AND bird
Agriculture AND avian
Agriculture AND diet
Agriculture AND invertebrat*

Agriculture AND Lepidoptera
Agriculture AND coleoptera
pollinat*
Agriculture AND mammal
Agriculture AND wildlife
Connect* AND ecol*
Connect* AND migrat*
Connect* AND movement
Restoration
“Carbon sequestration”
Mosses
Testate Amoebae
Biogeochemistry
Tropic* AND Ecol*
pantropic* AND Ecol*
“Natural Capital”
Pollution AND Ecosystem
Pollution AND Ecolog*
Pesticide* AND Ecol*
Environment* AND Law
Mutualis*
Parasit*
Predat*
Symbio*
Symbio* AND Plant*
Symbio* AND Agri*
Vegetation
Tree
“Plant Species”
Soil
Predat* AND behaviour*
Agri* AND Plant*
“Livestock virus” OR “Livestock disease”
“Climate Change” AND “Agriculture”
“Livestock” AND “Diet”
Connect* AND Migrat* -cell -brain
Breeding AND Avian
Climate AND Habitat*
Climate AND Species
Marine or Ocean*
Marine AND Habitat
Marine AND Species
Conservation AND Environment*
Species AND Diversity AND Trait
Species AND Richness AND *Diversity*

We extracted the projects returned by these search terms on 05/01/2022. In order to validate whether the projects returned by these search terms are ecology, we randomised the order of the results, then analysed the first 25 abstracts and classified them as ecology or not ecology. This classification was based on the BES’s definition of ecology as ‘the study of interactions among living things and their environment. It provides new understanding of these vital systems as they are now, and how they may change in the future’. It is worth noting certain research areas that were not considered to be ecology, and therefore not included in our research. This included researched projects that focused only on:

- Agriculture where the only focus was improving yields or benefits to humans. Projects thats included interactions with wild organisms were also excluded if they were classed as pests or biopesticides and the focus was on managing their impacts on crops or livestock
- Domestic species such as honeybees or cattle
- Genomics of wild species, and/or if individuals were brought into the lab and there was no research on their interactions with other species
- Physical geography and only non-biological processes. The movement of sediments and similar phenomena are important for ecology but research into them cannot be classed as ecology by itself
- Evolutionary biology. It is difficult to separate ecology and evolutionary biology as the two are inextricably linked, but projects such as the origin of particular mutualisms, or how ecosystems changed through certain ancient geological periods, were classed as evolutionary biology and not ecology. For example, a project called ‘Origin and co-evolution of land plant-fungal symbioses during the “greening of the Earth’ studied liverwort species with fungal associations in order to investigate the role of symbioses between plants and fungi in the evolution of terrestrial plants

At least 85% of the projects in the first 25 results of searches for each term (or the number that were returned by the search term if it was fewer than 25) had to be classed as ecology in order to assume that the term was relevant for ecology and was therefore included among our results. A high threshold was chosen because there was a lot of repetition in the projects returned by different search terms. For example, the project ‘Ecological consequences of genetic variation: does genetic variation in a keystone parasitic plant species drive community response to infection?’ was returned just on the title by the following search terms:

Ecolog*
Mutualis* OR Parasit* OR Predat* OR Symbio*
Parasit*
“Plant Species”

Because many ecology projects were returned by several search terms, we could set a high threshold and still have a relatively low risk of excluding ecology projects. For example, this project was classed as ecology because it was returned by the search term Ecolog*, even though projects returned by the other terms were not classed as ecology. A lot of ecology projects that were rejected by unsuccessful search terms were included in the results of successful ones.

Successful search terms

Ecolog*
Biodivers*
“Ecosystem”
“Forest” OR “Woodland” OR “Grassland” OR “Heathland” OR “Peatland” OR “Bog” OR “Tundra” OR “Reef” OR “Saltmarsh” OR “Mangrove” OR “Seagrass” OR “Wetland”
Fung* AND Decompos*
Microb* AND Decompos*
“Invasive species” OR “Species management”
“Nature-based solution” OR “Green infrastructure”
Connect* AND ecol*
Biogeochemistry
“Natural Capital”
Marine AND Habitat
Marine AND Species

The results of all successful terms were added together and duplicates were removed.

We also downloaded the entire GtR dataset (all projects funded by UKRI that were listed on the database) on 05/01/2022. The two datasets were merged, duplicates were removed, and all projects that were not returned by the chosen search terms were classed as non-ecology projects.

Next, the funding for each project was divided into calendar years across the duration of the project. We divided the total funding for the project by the number of months the project lasted for, assuming that funding was distributed equally across the lifetime of a project. We understand spending is not distributed across the lifetime of projects in this way, but this method gives an idea of financial commitments on behalf of the research councils over multi-year projects. We also ran the analysis with all expenditure assigned to the year that each project began, and it did not significantly change the results. The amount of funding per calendar year for a certain project was calculated by multiplying monthly funding by the number of months in which the project was financed for that year, as projects rarely start on 1 January or ended on 31 December. For example, if a project spanned September 2019-March 2021 (19 months in total) and had a budget of £19,000, then it was assumed to have £4,000 of expenditure in 2019, £12,000 in 2020 and £3,000 in 2021.

We calculated the total amount of funding allocated to all projects, both those focussing on ecology and the others, in each calendar year. We only used data between 2006-2021. GtR lists all research funded since January 2006, and whilst funded projects do stretch into the future, we only included full years of funding as the amount of funding awarded in 2022 was not completed until the the end of the year, after the analysis was conducted. We then analysed whether the annual amount of funding changed over time and plotted graphs of the amount spent per calendar year. The annual amounts of funding were positive integers, but as the numbers were very large the value of lambda was very large for the relevant Poisson distribution. In these cases, the Poisson distribution can be well approximated by a normal distribution. Therefore, we we used linear regression to test whether annual funding changed significantly over time, varied between ecology and non-ecology projects, and whether the change over time was different between the two groups.

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