Scientising the 'environment': The School of Environmental Sciences, University of East Anglia, 1967-1990.

Elliot Honeybun-Arnolda
100048427

Thesis submitted for the Degree of Doctor of Philosophy to the

School of Environmental Sciences,
University of East Anglia

July 2022

Abstract

There is a major gap in science studies concerning how the 'environment' came to be known and governed through practices of science in the post-war United Kingdom. Yet the 'sciences' of the environment are the predominant means by which we have come to know challenges of environmental change. This thesis engages with history and geography of science, environmental history, and STS literature to question how the 'environment' became an object of thought for a new university, how new knowledge emerged as both a product of co-production and as a tool of co-production. The 'environmental sciences' emerged in response to the changing post-war world, continuing to respond and change with the world around them. I demonstrate this through four linked case-studies concerning the emergence and development of ENV between the 1960s and 1990s. I make three key contributions: I shed light on how different sciences and practices of interdisciplinarity emerged as constitutive of the 'environmental sciences' and how these diversities led to different forms of knowledge about different kinds of environmental change. Numerous cultures of 'environmental' knowledge bloomed in the ENV space but not necessarily in a unified or interdisciplinary way. I proffer an 'ecology of co-production sensibility that demonstrates new conceptual links to offer a novel approach for research in science studies. I also illuminate how ENV as a historical space of 'co-production' responded to and shaped the world around it in politically and epistemically important ways. I conclude with a critical examination of the future direction in which ENV and the 'environmental sciences' might head in the 'Anthropocene'.

We are environments just as much as we are in environments; we both surround and are surrounded.

(Benson 2020, p. 1)

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Abbreviations

ACSP	Advisory Council for Scientific Policy
APB	Academic Planning Board
ARC	Agricultural Research Council
BES	British Ecological Society
BIO	The School of Biological Sciences
The Broads	The Norfolk and Suffolk Broads
CAP	Common Agricultural Policy
CLIMAP	Climate Long-Range Investigation Mapping and Prediction
CO2	Carbon Dioxide
COHQ	Combined Operations Headquarters
CRU	The Climatic Research Unit
CSA	Chief Scientific Advisor
CSERGE	The Centre for Social and Economic Research on the Global Environment
DSIR	The Department of Scientific and Industrial Research
EIA	Environmental Impact Assessments
ENV	The School of Environmental Sciences
ENV WP	The School of Environmental Sciences Working Party
ENVMAN	Environmental Research Management Ltd.
ERDA	Energy Research and Development Administration
ESA	Environmentally Sensitive Areas
ESRC	Economic and Social Research Council
FAO	Food and Agriculture Organisation
GARP	Global Atmospheric Research Program
GCM	Global Climate Models
GPCC	Geographical Patterns of Climatic Change
HE	Higher Education
HWMP	Historical Weather Mapping Project
IBP	International Biological Program 1964 - 1974
ICSU	International Council of Scientific Unions
IGY	International Geophysical Year 1957/1959
IMF	International Monetary Fund
IMO	International Meteorological Organisation
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
LLNL	Lawrence Livermore National Laboratory
LSE	The London School of Economics
MAFF	Ministry of Agriculture, Fisheries and Food

MHLG	Ministry of Housing and Local Government
MRC	Medical Research Council
NATO	The North Atlantic Treaty Organisation
NERC	Natural Environmental Research Council
NFU	National Farmers' Union of England and Wales
NMS	National Meteorological Stations
NOAA	The National Oceanic and Atmospheric Administration
NRIC	Nature Reserves Investigation Committee
NRTC	Natural Resources Technical Committee
OECD	Organisation for Economic Co-operation and Development
PNS	Post-normal science
RMS	Royal Meteorological Society
RSPB	Royal Society for Protection of Birds
SISTER	Special Institutions of Scientific and Technological Education and Research
SSSI	Sites of Special Scientific Interest
STS	Science and Technology Studies
UEA	The University of East Anglia
UGC	University Grants Committee
UK	United Kingdom
UKMO	The United Kingdom Meteorological Office
UN	United Nations
UNEP	United Nations Environmental Program
Unesco	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climatic Change
US DOE	United States Department of Energy
USA/US	United States of America
WCRP	World Climate Research Program
WMO	World Meteorological Organisation
WW1	The First World War
WW2	The Second World War
WWR	World Weather Records
WWW	World Weather Watch

Figures

Acknowledgements

The work throughout this thesis was made possible by a UEA Faculty of Science PhD studentship for which I am very grateful to have received. It has been a long and eventful journey for which there are many thanks of support needed.

First and foremost, this was all made possible and bearable by my supervisors Martin Mahony and Jason Chilvers to whom I am eternally grateful for the support, inspiration, and confidence they have given me over the last few years. From the early discussions around ideas and plans in the office (and the pub!) through to the endless drafts they have read and commented on, I am very thankful to have had them there alongside me throughout for both professional and personal challenges. Martin, you have been an endless source of inspiration and encouragement and no words can demonstrate how grateful I am for everything over the last four years. You have been the best mentor, colleague, and friend a first-generation university student (let alone PhD!) could ever have asked for – thank you for opening so many doors for me. Jason, your advice, and guidance have also been invaluable, you've helped to both broaden and sharpen my thinking in the thesis and beyond and have always helped to ease my concerns and see the bigger picture, thank you.

To my colleagues in 3S – thank you for always being so supportive and inspiring, for offering important feedback on various forms of the thesis at various stages of my journey and most of all thank you for being so fun – it really has made a difference. I would also like to say many thanks to Tim O'Riordan who has been a wonderful mentor – we've had so many thought-provoking, impassioned, and informative conversations over the years – that have shaped, not just the thesis but how I see my purpose in a world that is becoming increasingly difficult to live in (as I write this today temperatures have reached almost 40 degrees Celsius in Norwich).

I would also like to thank my friends at Historians for Future who have provided an outlet for my wider concerns and ideas. They have all inspired great confidence in my belief that needed change can happen.

I am indebted to those that made this research possible. Thank you to all the people who were interviewed by me, some of them multiple times, your insights and memories have been so central to the arguments of this thesis, and I have greatly enjoyed talking with and learning from you all. I would like to thank all the archivists for have aided my research over the years. Your help and assistance allowed me to traverse a previously unknown territory with ease! I am particularly indebted to both Bridget Gillies and Justine Mann of the UEA Archives who helped me work through the Zuckerman Collection, sending me PDF scans of files and essentially saved my thesis progress during the first COVID-19 lockdown in 2020. Thank you both so much. I am grateful to both the British Society for History of

Science who provided a small research grant for me to continue my research in times of uncertainty and delay and to the UEA Hardship Fund who supported me earlier this year in a time of great financial difficulty.

Thank you so much to my friends – my brothers! You have been there in so many ways. I know this would not have been possible without your ongoing support (and housing!) – you make the difficult things easy, the dark things light and I hope I can repay you all the favour. I would like to thank Noam Obermeister and Reuben Martens for their continued enthusiasm, source of critique and intellectual stimulation throughout this journey. I am very grateful to Annie Fortuny-Gomez for the support, fun times and many chats we had in the earlier stages of this thesis particularly when I was grappling with many new and challenging conceptual ideas.

To my parents, thank you for always supporting me in everything I choose to do. Your love, warmth and kindness allowed me to feel safe in the choices I made – even in times of uncertainty - knowing you were there to back me up, pick me up and encourage me once more. My dad – Robbie – you created the stable foundation on which to safely fall back on if anything got tough. Our early walks, birdwatching and chats about animals in my younger years shaped my love for nature and the 'environment' much more than you will ever realise. My mum – Laura – you provided the confidence, the inspiration and the belief that I could make a positive mark on the world, you provide the wings that enable me to fly. Your passion, commitment, empathy and drive has moulded me into who I am today.

And lastly, to my partner Lorna and our wonderful dogs, Dilly and (very recently) Herbie. This is all for you. Lorna, you have been the most supportive and loving partner I could ever ask for. You motivate me in endless ways, have been incredibly patient during the many times I have read you my thesis, kept me calm during the downs and been my greatest supporter. You have kept me going during this journey – I'm not sure I would have made it without you. You are the best friend, the best partner, the best critic, the best supporter, and the best audience – for the thesis and for life – I could ever ask for. Thank you.

1. Introduction: Post-war science and the 'environment'

There is a major gap in the history and geography of science concerning how the 'environment' came to be known and governed through the practices of science in the post-war United Kingdom. There is little work that explores what socio-political, institutional and material arrangements facilitated the emergence of a new, interdisciplinary field of the 'environmental sciences', enabled the embedding of this new kind of knowledge in new ways of governing society across multiple scales, how the realities of this 'new' arrangement of knowledge-making in science worked in practice. This thesis seeks to fill this gap by exploring an institutional history of the School of Environmental Sciences at the University of East Anglia (ENV).

Over the last 50 years, awareness of the challenges of environmental change have been dependent on the sciences that have made them knowable (Taylor and Buttel 1990). Yet, despite the prominence of environmental challenges, little work has investigated why and how these particular groups of disciplines were organised in this way nor why the 'environment' was problematised as a scientific issue. There has been work related to, what can be argued to be the 'constitutional disciplines' of the environmental sciences like climatology (Hulme 2009; Edwards 2010; Howe 2014), ecology (Worster 1994; Bocking 1997) or the earth sciences (Shortland 1993; Oreskes and Doel 2002; Doel 2003; Goossen 2020) that explores their role in the scientisation and politicisation of environmental challenges. However, there has been little attempt to understand the politics and power of scientisation and problematisation of the 'environment' through scientific interdisciplinarity. Understanding the 'scientisation' of the 'environment' and how interdisciplinarity figured through and between different disciplines is important to inform and historicise present debates about knowledge-making and world-making practices in the 'Anthropocene'.

The emergence of the 'Anthropocene' has spurred much debate among scientists, social scientists, humanists, artists and other scholars. The 'Anthropocene' is arguably the recognition that the anthropogenic impact on the planet is so sustained and severe that it will be identifiable in the geological record and a new epoch will come to exist (Bonneuil and Fressoz 2016). The 'Anthropocene' carries the alarming message that humans are now altering earth and environmental systems in many complex and massive ways (Crutzen

2002; Steffen et al. 2015) that are akin to geological forces - massive and irreversible - such as climate change, biodiversity collapse, and transforming biogeochemical cycles of water, nitrogen and phosphates. For critical social scientists, geographers and historians, this carries with it ontological, epistemological, political and ethical challenges regarding the current state of, and the possibility of re-thinking, how knowledge and political systems connect, relate and meet the challenges of this new epochal system (Castree et al. 2014; Beck 2019; Renn 2020). Environmental historians and historians of science have also laid out the importance of thinking about the intellectual and political history of the 'environment' to imagine our present and future response to living and knowing in the 'Anthropocene' (Warde et al. 2018; Güttler 2019). The challenges and realities of the 'Anthropocene' are I contend, a direct offshoot from the different knowledges produced by the 'environmental sciences' in the decades prior to the 'Anthropocene' emerging as a concept. Thus, learning and reflecting on how the 'environmental sciences' came about and made knowledge, through what means and contexts and for what purpose can help us imagine, engage with and critically interpret the future/s we may intentionally or unintentionally find ourselves inhabiting.

The massive, multiple and 'wicked' challenges of environmental change have rendered linear applications of knowledge for solutions ineffective (Hulme 2009). For many, the globalisation of environmental challenges and change has led to a reduction in the local specificities and nuance (Hulme 2010), an uneven understanding of power of the production, circulation and reception of knowledge (Mahony and Hulme 2018) and a disregard of the diverse ways in which knowledge and environmental worlds are produced (Jasanoff and Martello 2004). This stems from the perceived view of science as a placeless enterprise that geographers and historians of knowledge have sought to challenge (Livingstone 2003; Finnegan 2008; Renn 2020). There is a continued paradox between a perceived need for local perspectives to help counter a global and placeless view of science, and a view that science and knowledge-making always occur somewhere, for some reason and for specific (or to cross) scales (Jasanoff 2017). In other words, science is always co-produced: with social order, scale, place through a mutual construction of the normative and the epistemic (Jasanoff and Wynne 1998; Jasanoff 2004b). The co-productionist idiom, which holds that "the ways in which we know the world are inseparable from the ways in which we have chosen to live in it" (Jasanoff 2004a, p. 2), greatly informs the conceptual

position and approach of this thesis as I explore a history of the 'environmental sciences' that is co-produced through inter- and crossdisciplinary practices and co-produces new social and political orders.

Existing works in science studies (**Chapter 3**) often engage with one of two dominant versions of co-production: the co-productionist idiom as a means to study the relations between science, technology and society or knowledge co-production, as a means to produce knowledge with a variety of stakeholders that is either or both socially robust and politically relevant. The history of the 'environmental sciences' I opine throughout this thesis brings both of these versions together as it made new knowledge and (re)shaped new social and political orders. I illuminate this more precisely through a relational co-productionist conceptual approach – an 'ecology' of co-production - that informed and guided both my case selection and analysis throughout. Within this, I draw from and reflect on a range of tools and concepts like epistemic lifestyles, sociotechnical imaginaries, mangles of practice, trading zones and geographies of knowledge sensibilities to explore what and how different forms of knowledge operate, evolve and constitute the 'environmental sciences' vis-à-vis interdisciplinary thinking and practice and the contingent nature in which they emerge in the specific institution of ENV.

1.1. The School of Environmental Sciences, University of East Anglia

The University of East Anglia (UEA) was established in 1963 as one of the new universities (Beloff 1968). These included Essex, Kent, Lancaster, Sussex, Warwick and York. These new universities emerged out of a felt need to expand university enrolment to match the new, booming student numbers and changing demands of a new technoscientific Britain, whereby the state played a core and decisive role in influencing and guiding social, economic, education and technoscientific policy (Agar 2020) and UEA was part of the great post-war expansion of higher education in the UK. New universities were constructed to match the rise in applicant numbers and improve Britain's graduate numbers in science, technology, social studies, and town-planning to meet the new development demands of post-war society. The post-war expansion guided by the state also aimed to illustrate to the world that higher education was an opportunity for all and not just for the privileged. As a

move, it was symptomatic of the types of central planning that relied on scientific advice set out by the British government at the time (Edgerton 2005; Gascoigne 2019). UEA set out in the main an academic style that was "against excessive specialisation" (Beloff 1968: p. 105) and in favour of 'interdisciplinary' approaches, which is mirrored in ENV. Solly Zuckerman, the first UK Government Chief Scientific Adviser, proposed 'The School of Environmental Sciences', which reflected his interests and concerns regarding newly articulated 'environmental' issues, e.g., integration of the study of forestry, resource conservation, agriculture and the effects of both toxicology and population growth (Sanderson 2002). The interdisciplinary approach that emerged from Zuckerman's proposal of an eclectic mix of interrelated sciences, and his desire for science graduates to transcend traditionally narrow training, is still committed to by the administrators (and ethos) of ENV today.

ENV has been chosen as a key space of knowledge-making to demonstrate how and why an interdisciplinary form of the 'environmental sciences' was institutionalised in Britain. ENV has been heralded as a school with influential global impact for the research and work conducted in and around the institution, signified by the Queen's Anniversary Prize awarded in 2017. The Prize celebrates innovation, achievement and public benefit in UK higher education and was awarded for the work in building scientific understanding and public awareness of the 'environment' and its challenges. Yet, this thesis, through in-depth historical and qualitative research, addresses how 'success' or the products and practices of knowledge-making were not pre-determined but instead contingent on the social, political, cultural contexts and the material and institutional realities in which they (re)formed and the epistemic, normative visions and practices of the researchers doing the work.

Specifically, ENV emerged from a vision of Solly Zuckerman who was deeply embedded in the science arm of a government machine that was committed to a core programme of central planning, organisation and control for post-war recovery and growth (as shown in **Chapters 4** and **5**). However, as the political will and ability to plan or guide society waxed and waned, aligning with a more market-based approach to social ordering and progress (Agar 2019) so did the composition and socio-political impact of the 'environmental sciences' in ENV (as demonstrated in **Chapters 6** and **7**). This meant that ENV had to re-imagine and re-grapple with its epistemic and institutional importance in a political and educational landscape that had shifted the focus from state-guided planning to market and competition-based innovation and research. This thesis explores these changing

conditions and questions where both the institution of ENV and inter/discipline of the 'environmental sciences' may go in **Chapter 8.**

1.2. Research questions

The research questions arose from historical gaps this thesis seeks to fill (**Chapter 2)** and the conceptual themes from science studies that inform my approach (**Chapter 3**).

1.) How and why did a particular vision of the 'environmental sciences' emerge in post-war Britain, and how did it materialise at UEA?
2.) How did the vision for a new interdisciplinary field of 'environmental sciences' play out in practice, in the case of ENV? How were different practices of interdisciplinarity shaped by different conceptions of the 'environment'?
3.) How did ENV knowledge circulate and get put to work across different spaces and scales?
4.) What worlds were co-produced with the new 'environmental sciences' of ENV? Where might the world-making environmental sciences go next?

1.3. Structure of thesis

This thesis's structure follows a standard model in critical and interpretive social sciences. This dissertation begins with a review of the historical literature (**Chapter 2**) and conceptual work to build the conceptual framework and methodology (**Chapter 3**) – an 'ecology of co-production' – which guides and frames my empirical and theoretical exploration. The following four empirical chapters (**4-7**) investigate the historical emergence of ENV in post-war Britain (**Chapter 4**), how ENV worked in practice in its earliest years (**Chapter 5**) before explicitly focusing on two seemingly marginal cultures of research on opposing scales: the global activities of the Climatic Research Unit (**Chapter 6**) and the local environmental management of the Broads (**Chapter 7**). I then discuss the broader themes and contributions of the thesis in relation to the empirical and conceptual contributions emerging from the conceptual framework and research questions, highlighting key

opportunities for institutional reflection in ENV concerning the 'environmental sciences', the future of interdisciplinarity, and possible areas for future research for both practitioners of the 'environmental sciences' and scholars in science studies (**Chapter 8**).

2. Histories of the 'environmental sciences' and environmental histories

The 'environmental sciences' as an inter/discipline and a new means of organising particular sets of scientific knowledge is relatively new. It is thought that Solly Zuckerman coined the phrase in a memo in 1959 (Warde et al. 2018).[1] However, there has so far been minimal work that has engaged directly in historicising the 'environmental sciences', how the phrase came about, for what purpose and in what contexts. In other words, little work has explored the processes of problematisation that underpin the grouping together of sciences under the 'environmental' label and their existence as a predominant way of knowing and understanding the 'environment', in the West (Taylor and Buttel 1992; Barry and Born 2013).

In this review chapter, I demonstrate how historians and other researchers in recent years have, variably and separately, problematised the 'environment' as an object of inquiry in contrast to the perceived growth of interdisciplinary environmental research by scientists. In light of the growing prominence and pervasiveness of the 'environmental sciences' vis-à-vis trans-local and multi-scalar environmental challenges or the emergence and growing recognition of the 'Anthropocene', there is a particular yet poorly established need for researchers to engage, construct and share histories of the 'environmental sciences'. Notably, the 'environment' as a concept emerged in the post-war period as a means to articulate the interrelatedness and interconnectivity of planet Earth and its inhabitants' lives and actions, the implications of emerging technological and economic developments and the potentially detrimental effects of increasing populations and life expectancy (Bonneuil and Fressoz 2016). Key to these is the centrality of (interdisciplinary) science as a way of understanding the 'environment', its changes, and challenges, but histories of the 'environmental sciences' are marginal in the history of science, at best.

Nevertheless, there have been numerous strands of work in the humanist fields of history, history of science, historical geography and environmental history that have responded to the rise of the environmental challenge in the same ways numerous scientific disciplines have done. Yet, these bodies of work, as I go on to demonstrate in this review,

[1] I dispute this in **Chapter 4.**

have been often implicitly aligned to the environmental *problematique* rather than historicising it directly, and they have largely remained epistemically separate from one another.

Furthermore, in academic and non-academic life, the 'environmental sciences' are mentioned or dealt with as an obvious, preconfigured or inevitable way of humans making sense of the world and the 'environment' around them. In many cases beyond academia, the 'environmental sciences' are unheard of, but individuals may often successfully hazard a guess on what the main lines of inquiry are. The vagueness surrounding what the 'environmental sciences' are, both in academia and beyond, can, as Mike Hulme has often noted in the knowledge politics of climate change, lead to contestations, disagreements and differences in values and understandings of what scientific knowledge is and how it should be used in policymaking and society (Hulme 2009) or even in general readings of the challenge of environmental change. As Hulme (2021, p. 1) notes, "we are not all on the same page; we are not even all reading the same book."

However, the heterogeneous nature of science and knowledge is what science studies scholars seek to elucidate across many lines of inquiry (Pickering 1995; Shapin 1995; Knorr-Cetina 1999; Nowotny et al. 2001; Jasanoff 2004b; Stirling 2007; Barry and Born 2013; Bijker 2017). Yet, paradoxically few scholars have historicised or explored the vagaries of the 'environmental sciences' as a new form of knowledge-making, or the problematisation supporting their emergence and the politics in which they emerge and are sustained. These, I argue, are vital to critically discern the emergence, the evolution and practices of environmental knowledge. For instance, to ascertain what forms of knowledge count, the methods and practices in which knowledge is made and the role of shifting relations between different ideas, concepts, the social and the cultural that are crucial pre-cursory moves to help imagine where environmental knowledge may go in the future. This is particularly pertinent with the changing conceptual arguments of knowledge in the Anthropocene (Smith 2013; Renn 2020) and the changing knowledge economy of universities and research centres (Furedi 2010; Meusburger 2018).

To begin, this review explores histories of interdisciplinarity in relation to histories of knowledge. Interdisciplinarity is seen as a novel strategy in knowing and 'solving' new problems associated with the 'environment'. However, as I outline, interdisciplinarity has long been central to histories of knowledge and the organisation, formation and evolution

of disciplines – and their ontological commitments – prior to any 'environment'. I then move on to work in STS, environmental history and political theory that has sought to investigate the emergence and making of a global 'environment', the construction of new environmental expertise and the global co-production of science and social order in a post-war world. I then counter this by engaging with studies of more local and regional interactions with environmental change by environmental historians that have often been excluded from understandings of the global construction of the 'environment' to reassert that different problematisations of the 'environment' exist and (re)shape knowledge-making. There is major (and often hidden) conflict I argue between the two positions: the sciences oriented around the 'environment' and histories of 'environments'. Understanding the ontological view of the 'environment' is fundamental to understanding epistemological, normative and historical starting points in any historical narrative. I conclude by stating that we need more 'less-than-global' histories if we are to reconcile this conflict, write more representative and responsible histories of the 'environment' and its sciences and understand a fuller political history of 'environmental' ideas.

2.1. Histories of inter/disciplinarity

The rise of the sciences of the 'environment' in the 20th century can be seen as a response to a growing awareness of interconnectivity in disciplinary knowledge that was re-orientating to the many forms of environmental concern and challenge. Interdisciplinarity as a mode of 'doing things together' aims to combine different forms of knowledge to produce new insights and understanding for challenges that are not easily understood through existing disciplinary formations. In some respects, it can be argued that the 'environmental sciences' were a rejection of existing silos of knowledge in an attempt to legitimise, understand and unify new trans-local and multi-scalar environmental concerns. Notably, this was a response to a broad, unified 'environment' and its many challenges, and not multiple or specific 'environments' (Conway 2019; Benson 2020).

Peter Bowler's (1992) monograph on the 'history of the environmental sciences' is the first attempt to historicise and outline what the 'environmental sciences' are and how they came about. Beginning with Ancient Greek philosophy, Bowler takes the reader

through numerous historical periods to explore the 'origins' and development of environmental thought, finishing with 20th century ecology and environmentalism. The text is rich in detail as an introduction for students but, as a result, portrays the emergence of the 'environmental sciences' as a teleological inevitability through a linear progression of constitutional disciplines and ideologies through time and space, rather than assessing each stage in the context and under the conditions in which they emerged. A more careful attention to the histories of the 'environmental sciences' would unpick and uncover the foundations of interdisciplinarity that are (re)shaping and guiding their existence.

How knowledge(s) evolve(s), remould and transform to become applicable and relevant for 'new' problems reveals the fluidity of our knowledge systems, infrastructures and practices (Renn 2020), how paradigms shift to match and meet the demands of empirical observation (Kuhn 1962), or even how the fabric of epistemology is weaved to expand or transform the possibility of what it is to know and become knowable (Foucault 1970). As many of the main fields of knowledge today did not exist in any recognisable form in the mid 18th century (Rouse 1987), some of the 'new' problems in knowledge have been historical concerns in other forms. The act of 'disciplining' knowledge unfolded, in part, as a method to organise science and emphasise the production of knowledge in the 19th century, as universities began to institutionalise knowledge-making and learning (Kohler 1981; Golinksi 1998; Weingart and Stehr 2000; Schaffer 2013).

Moreover, disciplines and the definitions of what disciplines are, are contested even between scholars working in the same field, through a lack of conceptual clarity, varying institutional cultures and normative disciplinary aims (Sugimoto and Weingart 2015). Broadly, a discipline can be defined by its institutionalisation through academic departmentalisation (Becher and Trowler 2001; Lenoir 1997) or as an exercise of epistemic power through colonial and imperial regimes (Schaffer 2013). The act of 'disciplining' knowledge is also sociologically intriguing within the broader field of social studies of science (Wray 2005). New disciplines or new specialisations emerge not only in paradigm shifts or as acts of rebellion against disciplinary power but out of professional and institutional necessity – to carve out a niche in an expanding body of knowledge or network of institutions and to secure jobs (Price 1963; Ben-David and Collins 1966; Geison 1981).

Multiple scholars have recognised interdisciplinarity as the most appropriate research framework or practice to address the multi-dimensional and ever-increasing

complexity of the social and 'environmental sciences' (Bammer 2017; Hein et al. 2018), as it brings diverse experts together to solve complex challenges. Consequently, it has become a key issue for governments, funding agencies and researchers (Barry and Born 2013). Interdisciplinarity can be defined as "a variety of boundary transgressions, in which the disciplinary and disciplining rules, trainings and subjectivities given by existing knowledge corpuses are put aside" in attempts to produce new forms of knowledge (Barry and Born 2013: p. 1). But interdisciplinarity is not historically novel. For example, disciplines like astronomy have transformed over time through collaborative endeavours between experts (like instrument makers, experimental physicists, meteorologists), shared methods and materials – which in today's terms would be considered interdisciplinary practices (Schaffer 1996). Thus, it is not a new framework for modern challenges and historical perspectives can be gleaned to support present or future endeavours.

Moreover, changing environmental concerns throughout history have required input from a range of diverse actors like farmers, foresters, water body experts, health advocates, and so on (Thomas 1983; Sheail 2002) to overcome and manage areas of interest – even before formalised structures of expertise and knowledge were recognised. Crucially, it is suggested by political theorists Ernesto Laclau and Chantai Mouffe (1985) that disciplines should not be regarded as homogenous entities. Instead, they are multiplicitous processes, enacted and contingent on the evolving and heterogenous cluster of problems, ideas, methods and approaches to which they respond and cement through the extent to which their process and boundaries are contested or dissolved. Interdisciplinarity, in this vein, would be a characteristic process within the wider historical evolution of knowledge (Renn 2020).

Nonetheless, Barry and Born (2013) seek to interrogate how interdisciplinarity is 'problematised' and has attained an epistemological and normative authority to solve complex, interrelated problems between science and society. Taken from Foucault (2001), "problematisation doesn't mean the representation of a pre-existent object, nor the creation through discourse of an object that doesn't exist. It's the set of discursive or nondiscursive practices that makes something enter into the play of the true and false and constitutes it as an object for thought" (p. 1489). Barry and Born (2013) propose to understand the nature of interdisciplinarity, to historicise its conception, and how it became mobilised and embedded as an approach, rather than assume that interdisciplinarity is a

method or practice that has come into being as an obvious solution to the 'wicked', multidimensional problems of the 20th and 21st centuries. For the 'environment' and its sciences, this is a critical point of interest to help understand how the 'environment' has emerged in uneven and multiple spaces of origin as a singular object of interest and thought to be made knowable through interdisciplinarity (Jasanoff and Martello 2004).

Barry and Born (2013) have characterised three different models of interdisciplinarity to describe how different practices and visions come about between disciplines, within institutions and in interpretive frameworks. 'Integrative-synthesis' describes the types of interdisciplinarity that characterise research between disciplines with a shared vision or goal and with the same commitments to problems . 'Service-subordination' is used to demonstrate interdisciplinarity whereby one or more discipline/s is expected to fill the gaps left by the dominant or focal discipline/s – like science's interpretation of the role of social scientists or humanities in communicating environmental challenges (Hulme 2011). Lastly, an 'agonistic-antagonistic' model directly connects competing epistemologies and ontologies to supersede the limits of prior forms of knowledge systems and practice to create new forms – like art/science (Shapin 2018). However, this mode of interdisciplinarity, Barry and Born (2013) argue, can only be "understood diachronically in terms of a dynamic imperative to supersede prior epistemological and/or ontological commitments" and how "this dynamic cannot be grasped by attributing a spurious unity" (p. 13). In other words, disciplinary knowledge evolves over time, with changing authority and use that precede any 'modern' battles between the normative and the epistemic. Instead, these are mutually constitutive, constantly in flux and formation and speak more to a longer history of knowledge-production and organisation.

More broadly, interdisciplinarity is continually falsely looked on as a novel response to the production and application of knowledge beyond the academy for government, industry, and market needs by policymakers, university management, and funding bodies. As Nowotny et al. (2001) argued, scientific knowledge evolved in the late 20th century to become more geared toward policy input and social relevance. They characterise this as a shift between Mode-1 to Mode-2 knowledge production, in which inter-/transdisciplinarity

became an important part.[2] This shift in production also helped to dissolve the boundaries that were typical between scientific and non-scientific activity (Gieryn 1983) as scientists and non-scientists were needed to work together to produce policy-relevant, or 'post-normal' science (Funtowicz and Ravetz 1993). 'Post-normal' science expands on Kuhn's (1962) characterisation of normal science by arguing that challenges in the late 20th century required more diverse forms of expertise and decision-making through extended peer networks in times of high uncertainty and high stakes. These new types of scientific knowledge align most apparently where "the hybridity of environmental problems resists purification into distinct natural and social elements" (Barry and Born 2013: p. 26). Most notably, these approaches emphasise 'doing things together' – with other experts and actors to produce interdisciplinary knowledge that can deal with complex and hybrid problems.

As a result, an interdisciplinary approach to the plurality and multi-scalar nature of environmental challenges appears inevitable and straightforward – if not novel - yet how did the hybridity of environmental problems become so? The emergence of the 'environmental sciences' brought with it a recognition of the interrelatedness of what were previously thought to be objects of the world. However, how and to what extent and through what forms interdisciplinarity came about in practice as a form of institutionalised science and as a desired model of operation to know and understand the 'environment', is yet to be understood fully, as this chapter now seeks to explore.[3]

2.2. Histories of the 'environment'

The 'environment' as understood today in the West is not what it used to be. The idea of interdisciplinarity has been formative in rendering the 'environment' an object of thought, needing new forms of knowledge to be made about it. Yet historically, there have been many changing formulations of what 'an' or 'the' environment is and was for. There have

[2] Mode 1 is defined as the advancement of new knowledge within disciplinary silos, whereas Mode 2 is defined as research or academic activity related to a broader set of problems in society or politics, often involving multi/inter/transdisciplinary knowledge-making practices (see Nowotny et al. 2001)

[3] To what extent interdisciplinarity was successful is a running theme of this thesis' empirical material, as discussed further in the next chapter.

been multiple, historical problematisations concerning the constitution of an 'environment' as an object of thought and knowledge.

Herbert Spencer's idea was the first to use the 'environment' as both a description and causal factor in the interactions between the singular surroundings of biological organisms and the organisms themselves (Spencer 1855; Pearce 2010), but there had been many similar ideas throughout human history and thought. For instance, Keith Thomas (1983) has explored the dynamic relationship between humans and their 'natural world', exploring the changing cultural, economic and social relationship between communities in Britain and their surroundings. Auguste Comte, in 1838, reanimated an earlier idea of a 'milieu' to encompass and articulate the surroundings of entities in any form and their role in positivist philosophy.

Today, the 'environment' as we would understand it broadly originates from Rachel Carson's (1962) influential book *Silent Spring* which helped to unify a global 'environment' by illuminating the shared human concerns about the wider effects of rising chemical use, toxicology, and the death of wildlife in agriculture through the local and specific use of DDT in the USA (Benson 2020). Notably, the changing conceptual history of the 'environment' and its pre-cursory ideas demonstrates how different understandings of the 'environment' do not presuppose ontological or epistemological realities. Instead, they are very much bound up with the construction of those realities, how we want to live, how we may want to know about it and for what purpose. The 'environment' is not a fixed or robust term but is historically and geographically contingent, fluid and malleable. Understanding the 'environment' or 'environments' as multiple poses several epistemological and ontological challenges pertaining to what environmentalism is, what environmental concerns are and ultimately, how we might make new or explore existing forms of knowledge about them.

Philip Conway (2019) details this in a thesis titled *The Historical Ontology of Environment: From the Unity of Nature to the Birth of Geopolitics*. Conway explicates the historical-conceptual relations by which the variable concept of the environment (alongside climate and milieu) has "constituted elements of 'world-making' practices," e.g., the "national, planetary, and imperial" (p. 10). In doing so, Conway illuminates the evolving nature of the idea of 'the environment' in substantial depth – arguing that 'the environment has had differing definitions that are specific to the contexts that surround its use each time. The variability of the 'environment' fundamentally demonstrates problems about

ontology. For instance, that is to say, the 'environment' of 1899 (the immediate surroundings of an organism) is different to that of 1967 (a global object of ecological concern) and even that of 2021 (a connected set of earth systems responsive to human influence and imbalance), but each concept was developed for its own valid epistemic and normative use. Conway underscores the risk of anachronism in historicising ideas of the 'environment '. To counter, specific conceptions of the 'environment' need to be unpacked and understood in the contexts and realities in which they emerge and continue to emerge to understand specific forms of problematisation and response. This is crucial to discern how forms of knowledge-making, like interdisciplinary sciences, seem to become the hegemonic mode of knowing and researching an 'environment'.

Etienne Benson (2020) adopts a similar approach to understanding the history of the 'environment'. Benson historicises multiple changing ideas of the 'environment' across numerous time periods and regions. Benson demonstrates how the 'environment' or 'environments' have been put to work across several different contexts, cultures and disciplines in productive ways. This makes generating an overarching historical account of the 'environment' or 'environments' difficult. However, emphasising this complexity is Benson's aim. He explores various cases to demonstrate this: from the colonial legacies of environmental history and health through British physicians and illness in tropical environments, to the geographies of material accumulation and representation of natural order in the museum, to the ideas of a 'social environment' accounting for the lives and well-being of settlements in Chicago. Generating productive and overarching histories of the 'environment' and 'environmentalisms' is, for Benson, flawed. Instead, historians should strive to recognise the rich and diverse threads of environmental history that shape difference and diversity in our responses to environmental challenges and change today if we are to gain a firmer grip on the current environmental crisis.

For Conway and Benson, then, ideas of the 'environment' are multiple, relational, ontologically associated and differentiated in historical periods or 'epochs' (see Larsen and Harrington Jr. 2021). How then might the 'environment' look like today? Has it formed and been formed through the changing relations of disciplines in which it is embedded, the spaces in which they emerge or the scales in which it is applied? And how might this have shaped a scientisation of the 'environment'?

2.2.1. The modern 'environment'

Paul Warde et al.'s (2018) intellectual history of the 'environment' explores the rise of the 'modern environment' as we may imagine it today. In *The Environment,* Warde et al. (2018) seek to establish the origins and gain some scholarly grip on the modern 'environment'. In Conway's (2019) transitory conceptual history terms, Warde et al. (2018) delineate a key ontological moment in modern environmental history. They define the 'environment' now as an object of measurement and imagination, going from a backdrop to an active agent in human history, as an object of new-found expertise that waxes and wanes in response to different stimuli of environmental change and surrounds us all. The modern 'environment', they claim, begins with William Vogt's (1948) *Road to Survival*, in which Vogt assesses the environmental health of the world vis-à-vis documenting the environmental complications associated with rising population and resource consumption. It was one of the first widely-read texts associated with newly rising and understood 'environmental' concerns.

Thomas Robertson (2012) has also claimed that both Vogt and Fairfield Obsorn Jr (1948)'s best-selling books on environmental challenges and change were crucial moments in the emergence of a new global science and political order. The problematisation of the modern environment as a unified surrounding meant that local specificities and nuance could be erased as part of the post-war push for global thinking that could appeal on an international scale (albeit predominantly Western). Both texts were immensely critical of the resource and consumption-driven growth and population increases of the modern age that were associated with the growing cultural hegemony of the USA and foresaw the challenge of environmental change to beyond the USA. Vogt and Osborn, Robertson (2012) notes were concerned about the health of the 'environment' as resource planning and socio-economic development shifted from regional to international models through new infrastructure and institutions like the IMF, World Bank and varying channels of the UN. In the post-war society, the UN was seen to be the standard of international order and organisation, and there was a radical re-imagination of human-environment relationships, changing scales and growing awareness, as a result (Latour and Weibel 2020).

Rachel Carson's (1962) *Silent Spring* is commonly known as the primary catalyst for the modern environmental movement and unifying growing environmental consciousness.[4] Despite appearing some 15 years later to Vogt and Osborn Jr, Carson's argument about the overuse of chemicals in agriculture and the disinformation campaigns by industry and public officials helped articulate the interconnected and perhaps irreparable global scale of environmental destruction that was emerging from local events like DDT spraying. Carson warned of environmental collapse arising from the misuse of pesticides (or 'biocides' due to the non-targeted effects on all forms of life), bioaccumulation of toxins, and underscored humankind's shared vulnerability vis-à-vis the fragile relationship we hold with the natural world. Importantly, Carson's work injected the vision of environmental damage of chemicals to the public and illuminated the changing role of expertise, conflicts of interest of regulatory bodies, and the circulation of disinformation in society. Public officials were accepting uncritically the claims of industry, Carson argued, downplaying the damaging effects of chemicals as the weaponisation of expertise was thrown into the public view (Carson 1962; Lytle 2007; Agar 2008; Oreskes and Conway 2010).

The use of expertise and counter expertise in public arenas represents what historian of science Jon Agar (2008) argues as one of the key transformations of science in the post-war period. Agar argues that transformations of science in the 'long 1960s' came about in three waves.[5] The first wave witnessed a multiplication and entrenching of expertise in knowledge-systems, and the second wave enabled the performance of this throughout different public arenas.[6] Science and knowledge-makers often disagree behind closed doors in the university's halls, the laboratory's benches or through not widely read journals and books. Yet, during these waves, conflicts in expertise became more public as industry, organisations, governments, and activists used different forms of science and expertise to justify decision-making, operations or social movements. As this became more commonplace, the need for additional experts seemingly manifested, as competing claims

[4] There is a long history of more regional recognition of class, economic and social inequality and environmental challenges in the USA (see *Myth of Silent Spring: Rethinking the Origins of American Environmentalism,* Chad Montrie, 2018).

[5] The 'long 60's' spans from the late 1950s-early 1970s.

[6] The last wave is characterised by the self-reflection and internal observations of scientists and researchers concerning scientific work – kickstarting the fields of SSK and STS.

from competing industries, like divergence on the threat of pesticides and toxicity (Carson 1962), meant that knowledge conflicts were becoming more visible to the public eye.

In the UK, public awareness of new scientific advisors in government signalled a shift in government strategy and decision-making, one that publicly relied on and reinforced the authority of science and scientists (Zuckerman 1980). Additionally, the use of expertise to underscore authority and communicate knowledge was capitalised on by many organisers and scientists themselves in many social and cultural movements concerning the social and environmental implications of scientific and technological progress, like nuclear weapons and disarmament (Roszak 1968). During the 'long 60's', the 'environment' was gaining traction – in multiple ways - as an object of concern and inquiry.[7] As noted in the above, this was both a transformative period in human understanding of their surroundings and the ways in which they know the world and act in it, and the beginning of a reflexive concern for our unified actions as humanity and the impact on the world in which we live. However, the 'environmental sciences' specific purpose and practices during this period are little understood.

In sum, the 'modern' environment emerged in the 20th century as for the most part a new, unified and global object of concern proposed by concerned environmentalists and international scientists.[8] The emergence of a new 'environment' as an object of inquiry has led to many researchers investigating how and through what disciplines reactions to environmental problems and new 'environmental' expertise came about.

2.2.2. New 'environmental' expertise

Warde et al. (2018) characterise the modern 'environment' as both a concept that has been institutionalised through academia and new universities, and transnational organisations (UNEP, UNESCO, WMO and so on), the emergence of 'interdisciplinary' conferences, a proliferation in terminology and concepts (like ecosystems, biodiversity, sustainable development) and most critically, the cultivation of new experts to make use of these new

[7] I expand on this further in Chapter 4.

[8] What the 'modern' environment means is dealt with more substantially in **Chapter 4**. For now, it serves as context to demonstrate the knowledge politics surrounding the new 'environmental sciences' coming into being.

ideas and concepts. Notably, the 'environment' gained traction as a new object of concern in which different branches of science – geology, physics, biology, chemistry and later, ecology and economics could investigate and make sense of from their disciplinary viewpoint. New forms of expertise emerged as disciplinary experts collaborated, shared ideas and methods, and produced new knowledge and discourse concerning different aspects of the new 'environment' (Liss and Slater 1974; Oreskes and Doel 2002; Lave 2012; Howe 2014). The cooperation and collaboration of these scientists were observable through the sharing and disseminating of research or future-orientated discussion in international and 'interdisciplinary' conferences like the 1955 week-long event 'Man's Role in Changing the Face of the Earth' in the USA. Although deemed 'interdisciplinary', the first conference had very little participation from non-scientists and minimal attendance from non-natural scientists. Consequently, this had implications that, alongside a push for environmental policy and advice in Western governments (Zuckerman 1980; Agar 2019; Selcer 2019), led to natural science framings of environmental change coming to dominance.

Warde et al. (2018) also demonstrate the co-production of new experts with the rise in institutions, conferences and international programmes that sought to deal with environmental challenges on an international scale. The need for new environmental expertise and professionals generated new experts of environmental change that, in turn, reshaped both public and scientific understandings and ontologies of the 'environment' (Agar 2008). For instance, disciplinary experts had to reframe and evolve existing expertise with the creation of the USA National Environmental Policy Act in 1969, which required the first form of environmental impact assessments (Liroff 1976). This was a major move in constructing a new political discourse concerning 'environmental' impacts of action, which required the construction of new thresholds, limits and guidelines from policymakers, engineers and economists (Liroff 1976). The absence of scientists, like ecologists, in policymaking stimulated new forms of expertise to further develop in response (Caldwell 1977). Despite the recognition of the rise of new expertise, little work has deconstructed 'environmental expertise' beyond an amalgamation of multi-disciplines (Warde et al. 2018) to fully appreciate the generative effects of the co-production of the 'environment' and 'environmental expert' and science (Wynne 1991; Jasanoff 2005). As such, even within the sciences we see different responses to the *environmental problematique* akin to their

particular epistemologies and ontologies that construct the 'environment' (and so, also what would constitute a problem) in slightly different ways.

Notably, Warde et al.'s (2018) vision of the 'environment' came about in the post-war period due to changing resource use, growing populations, increased consumption and economic development that, in part, resulted from the internationalisation of political and social order and science. This new version of the 'environment' came about during a transformative time in the history of science, where scientific ideas were being used to support social and cultural movements, experts and new forms of expertise were being deployed to counter each other as the industry grew and scientists began to question their endeavours and reimagine their practices and methods (Agar 2008).

2.3. Science and internationalism

Alongside a proliferation of new expertise, the post-war period brought with it a period of the internationalisation of science and governance. Viewing these together, I argue, can illustrate more emphatically how visions of a 'global' environment as an object of concern emerged from the knitting together of numerous sciences aligned to support military strategy, national aims and advancing earthly knowledge.

Perrin Selcer (2019) illuminates this by revealing how an 'environment' was made that was a global object of concern through technocratic visions of global political order and international society. As Western nations came out of the world war and embarked on post-war recovery, the UN was founded by 51 countries as a symbol of the world community, peace and international security. At the time, it was thought to be the new standard model for a growing, global and interconnected world community and world order (Latour and Weibel 2020). Selcer (2019) explored how the UN and its agencies' normative aims constructed global knowledge infrastructures and, through entanglements of actors and socio-material collectives of international science projects, enabled a global 'environment' to emerge that was of global concern to be globally governed and so, became a global object of thought. For those involved, the UN's operations were to be the new standard of scientific objectivity aiming to transcend the nation-state and support a globalised, synoptic perspective of governance and management, and encourage transnational research

programmes – like the FAO-Unesco Soil Map of the World (Selcer 2019) or the WMO's World Weather Watch or Global Atmospheric Research Program (Zilman 2009).

Additionally, the emergence of the International Geophysical Year (1957-1958) (IGY) also stimulated significant changes in the ways the planet was viewed, the scientific practices that supported knowledge-making and circulation, and demonstrated an international politicisation of science. Two scientists, Lloyd Berkner (1905-1967) and Sydney Chapman (1888-1970), proposed the IGY in the early 1950s instead of the historically recurring Polar Years as a means of gathering global data to understand the Earth's atmosphere (Needell 2000) coinciding with a time of maximum solar activity (1957-1958) (Korsmo 2007). Taken on by IUCN, the IGY was by far the largest international scientific project of the 20th century, with over 60,000 scientists from 66 nations involved (Doel 2003). The IGY was a significant milestone in the development of the earth sciences and geophysics. It was jointly a significant political event that demonstrated a pause in the tensions between the West and the Soviet Union during the Cold War (Doel 2003). Those involved knew the mutual benefit of international cooperation in advancing the sciences of the earth and the aims of national security and intelligence (Needell 2000). There were thus deep entanglements between advancing disciplinary knowledge, policy and national strategy or ambition, e.g., the launching of satellites as a symbol of technological advancement and to secure data on enemy territory in once inaccessible areas (McDougall 1985). Scientists involved, particularly from the US, were free and confident to discuss scientific matters of interest with military and political officials (Doel 2003).

As the IGY progressed, it illuminated the power of international collaboration, sharing of data and tools, strategic competition, global thinking and the unsettledness of political jurisdiction and control. Notably, new disciplines (or ways of viewing disciplines) emerged like planetary-scale oceanography or meteorology, knitted together from numerous standpoints (Lehman 2020), the need to chart the uncharted to justify territorial claims (Collis and Dodds 2008) and rising interest in atmospheric gases (Howe 2014; Fleming 2016). New ways of viewing the earth globally also emerged: as a set of socio-material spaces and processes of military and scientific conquest and as a total, interrelated and fragile environment needing to be protected (Goossen 2020).

After the IGY ended, the earth sciences in the USA enjoyed continued funding and involvement with national security and strategy. In particular, seismology, geophysics,

oceanography, and geodesy boomed through the promise of advancing understanding of different terrains, risks and military programmes in a way that was unlike the weaponised physics of the Cold War (Rainger 2000; Warner 2002; Dennis 2003; Bruun 2020). The field sciences provided much-needed knowledge about stealth, mapping, different 'environments' and weather prediction to supplement the physical knowledge concerning destruction, bombing and weapons. The emergence of the funding for the earth sciences funnelled new understandings of the Earth's terrain and systems in material ways. The 'environments' were physical environments with physical geographical characteristics – like the Arctic. Consequently, a physical earth science bias led to disadvantages of the earth's more ecological and biological aspects, as these were thought to be of minimal use for defence and intelligence needs, despite the growing environmental movements and concerns (Doel 2003). Environmental historians claim that the internationalisation of earth science, interdisciplinary collaboration and the emphasis on advancing knowledge about different 'environments' of the IGY led to the emergence of the 'environmental sciences' as a new branch of science (Doel 2003; Masco 2010; Warde et al. 2018). It is unclear, however, where the point of detachment from 'earth' into 'environment' occurs, particularly as the more biological and ecological aspects of the planet and how they relate to physical 'environments' were present, if much less integrated than the earth sciences work during the IGY (Aronova et al. 2010; O'Riordan 1999).

Nonetheless, biologists and ecologists did attempt something similar through the IBP (1964-1974), in which the plan was to transcend ecological thinking internationally (Aronova et al. 2010). However, it was not deemed a success due to the difficulty in mirroring the IGY's approach, where the research methods, institutional structures and forms of data management conflicted with the aims, values and more local practices and interests of ecologists involved (Aronova et al. 2010). Yet, the internationalisation and publicising of biology and ecologists through the IBP did benefit biology and ecology's standing (and improved understanding) among publics (Robin 1993). This demonstrates how particular epistemologies and ontologies of researchers concerned with the 'environment' may not always be cohesive with a global framing of science and practice.

In a similar vein, the WMO formed under the auspices of the UN (Edwards 2006; Zilman 2009) also helped to integrate meteorologists into an international community, creating standards and research and training programmes in which global knowledge could

be made and shared about climate, weather and forecasting (Edwards 2010; Oldfield 2018). Similarly, the setup and aims of both the UNFCC and the role of the IPCC also reveal how the challenge of climate change and policy was becoming understood and framed as 'global' (Miller 2004).

The works associated with the internationalism of science can reveal how the 'global' and unified histories of the environment and responses to environmental problems are not inevitable, but instead, the result of specific political contexts, relationships of patronage, institutional, social and material arrangements, and are embedded in particular normative and epistemic aims – through models of international and interdisciplinary scientific collaboration that are linked with national security and political aims.

2.3.1. The co-production of global knowledge and global order

The internationalisation of science has led to an emergence of thinking on global scales for a global environment. Science was attempted to be made on a worldwide scale to understand global systems, like the atmosphere and oceans, chart new terrains, and be used for strategic and military aims. In order to do this, new networks, communities and infrastructures needed to be made, and new ways of operating, managing and governing came about.

Paul Edwards' (2010) seminal text *A Vast Machine* demonstrates how the construction of global climate has been contingent on the global knowledge infrastructures and normative aims of the WMO to internationalise and collaborate on global scales. Akin to making a global 'environment', a global climate homogenises and standardises data collection, reducing real lived experiences of local climate changes for ease of organisation, understanding, and governance on global scales. This endeavour demonstrates the move of post-war internationalists to standardise, organise and manage a usually heterogeneous and culturally specific production of knowledge (Rouse 1987).

In this vein, Sheila Jasanoff (2001) shows how the idea of planetary consciousness, stemming from a photograph of Earth from space by William Anders (1968), has also played a part in encouraging new forms of global knowledge and order. The image, named 'Earthrise', was mobilised through multiple material and discursive contexts to help

construct an air of shared community, thus becoming a transformative agent for Western environmentalism. Additionally, both the politics of exclusion and exclusions of knowledge involved in the production and circulation of global environmental images that prioritise particular images of particular places in particular times over others demonstrate that the 'view from everywhere' is not the 'view from everyone' (Hulme 2010; Grevsmuhl 2016).

More explicitly, Silke Beck et al. (2017) explore the co-production of global environmental science and global environmental politics. Understanding how and why a 'global' environment came about can help us make sense of the social and cultural values, practices and processes that shape and reshape the normative and epistemic aims behind practically and discursively engaging with the environment in this way. Beck et al. (2017) similarly note the presence of transnational knowledge infrastructures that help generate, circulate and uphold global forms of knowledge and collaboration within and for the 'global' environment. They also underscore the critical importance of the globalising trend for discursive political use and the framing of a 'global' environment and 'global' environmental problems. These framings and articulations help generate global environmental knowledge as a solution. This, in turn, underscores the need for new global infrastructures to grow in areas of global environmentalism and politics. Moreover, the emergence of a 'global' environment and global knowledge infrastructures has brought the concurrent production of new global experts and organisations that speak authoritatively through 'new' environmental expertise – like the UNEP, the WMO and later on, the IPCC.

2.3.2. Thinking 'ecologically'

As both a scientific discipline and a broader way of thinking, ecology has contributed to the construction of the 'global environmental sciences'. As a science, ecology emerged in the 19th century, as the study of the relations between organisms and their surroundings, as an inclusive and diverse way of describing the relations between living organisms (of any size) and their surroundings in (any 'environment') as an interacting whole (Bramwell 1989; Worster 1994). Indeed, describing the relations between living organisms and their surroundings has been foundational in the mainstream use and application of 'environment'

as a term, an object of inquiry, and in constructing ecology's own disciplinary identity (Bocking 1997).

The ideas that underpin descriptions of the relations between organisms and their surroundings have led to a greater understanding of environmental collapse, management and systems-based thinking in other social arenas (Worster 1994; Aberle 2012; Benson 2020). Events like the *Dust Bowl* (see Worster 2004) displayed critical failures in relations between organisms (farmers) and their surroundings (American prairies). Over-farming and the increase of mechanisation led to the destabilisation of soil structure that turned to dust during extended drought periods – with devastating social, economic and environmental consequences. Most notably, ecological understandings of environmental collapse contradicted existing views that human action would not catastrophically harm their surroundings and signalled the need for forms of intervention (scientific, government, economic). Additionally, during and after the World Wars, there was disruption to the flow of markets and goods (Taylor 1988; Benson 2020). This meant that food and resource security and economic activity were put at risk. Researchers needed to understand and track the flow of materials and identify possible substitutes to maintain and protect life and activity. After WW1, researchers from the US, Soviet Union, Norway and Italy then turned their attention to understanding the processes behind where and when the natural world produced and consumed these resources by following through their chemical or biological activity across different earth systems (Kragh 2001; Oldfield and Shaw 2013; Benson 2020). This new understanding led to a new international and interdisciplinary way of understanding the earth, environments and its sciences. Ecologists used these techniques to explore the flow and circulation of materials in ecological systems on both local and larger scales, as interest in the exchanges of matter and energy became essential to discern how living and non-living things interact in different environments and how the knock-on effects of interruption or alteration to the system play across the 'natural' world (Hagen 1992; Coleman 2010; Benson 2020).

This way of thinking – in relational and systemic terms – helped to contribute to the 'ecological metaphor' as a means of understanding the interactive and mutually sustaining relationships of different ways of knowing, living, being and finding a place in the world (Morton 2007, 2012; Coleman 2010). The ecological metaphor and systems approach gained further traction when scientists who had become more involved in the operations of

WW2 gained authority in wider social and political worlds. As a result, a technocratic way of imagining a post-war reconstruction included an understanding of the relationality of social systems and the movement of materials, people and ideas (Taylor 1988) that emphasised globality through interconnectivity.[9]

In sum, ecologists and ecological thinking helped problematise the 'environment' in several ways. Firstly, ecologists directly helped make environmental challenges legible through the broadly conceived scientific study of organisms and their surroundings. Other critical thinkers then adopted this type of study and theorizing to help illustrate the interrelatedness of all aspects of living and acting in the world, which helped construct a shared consciousness of the reliance on the environment of all organisms on Earth.[10]

2.3.3. The problem with the global view

However, Hulme (2010) has argued that the framing and authority of global environmental knowledge and modes of global environmental governance are fractious, brittle and erasing of the local differences of experience, ideals and values that contribute to how challenges of environmental change are understood or managed and how possible futures imagined. Additionally, constructing a 'global' environment challenges the scalar properties of experience (Camprubí and Lehmann 2018). There is epistemological and ontological detachment from localised experience, bodily affects and contextual challenges in rendering 'global' environments. Notably, the 'environmental sciences' have developed in such a way, through the internationalisation of science, construction of transnational organisations and global knowledge infrastructures, that it is easy to overlook the historical complexity of multiple global environments and knowledge (Beck et al. 2017; Camprubí and Lehmann 2018). Instead, attention to how global environments and knowledges become global – as political, epistemological, sociological and geographical processes and the scaling of scientific visions – is crucial to re-grounding and re-connecting with local experiences of environmental change in productive ways (Fleming et al. 2006) and discerning how

[9] I explore this in more detail in Chapter 4.
[10] I expand on the 'ecological' metaphor for my own conceptual thinking in the next chapter.

particular responses to the environmental *problematique* gain more traction in global discourse than others.

Nils Güttler (2019) offers some middle ground through a criticism of the lack of work on the histories of the 'environmental sciences'. The histories of the 'environmental sciences' are unique in the sense that they draw together the rise of ecological thought, concern and understanding of environmental change with the mutual construction of global infrastructure through international institutions. In engaging with histories of the 'environmental sciences' on a more interdisciplinary and regional scale, Güttler (2019) argues that the complex interactions between 'environments', knowledge, culture and politics can be understood more tangibly through regional (or local) histories of science, as scientific knowledge has been perceived to be at the heart of knowing and understanding the challenges of environmental change (Taylor and Buttel 1992; Warde et al. 2018). A more regional or local approach to constructing historical accounts can reveal the diverse make-up of the 'environment', its sciences and the processes behind scaling up and multi- or interdisciplinary working.

The new 'global' environment has emerged as an object of concern and inquiry through the co-production of global knowledge and global order. Nonetheless, the sciences that constitute 'global environmental science' are not inherently global but instead are epistemologically and ontologically specific and undergo varying processes of collaboration, circulation and standardisation of data, tools, and expertise to scale knowledge up (Jasanoff 2017; Coen 2018). Moreover, an emphasis on the global obscures the changing relations between disciplines, scales and spaces that underpin how the 'environment' is problematised in the first place. The contents of this review chapter, so far, has outlined how the modern 'environment' became a unified and global object of concern through international science and policy communities and organisations. Yet, historical understandings of the 'environment', social and disciplinary responses to the environmental problem and change span beyond the 20th century, as Conway (2019) and Benson (2020) noted. Thus, thinking through histories of science exclusively from a scientific and political lens obscures the rich and complex engagements of historians and humanities-based scholars, who have often tended to engage with more local and trans-local 'environments'. Historians of science and environmental historians have, for the most part, remained detached from each other in scholarly work. There is much promise in bringing them both

together. Environmental histories are also fundamentally interdisciplinary in their subjects of research and require diverse perspectives and knowledge - like the 'environmental sciences' (Hughes 2016) - to fully understand and outline the changing processes of place and space in relation to environmental change. A new way of bridging this disparity can and should yield further critical historical insight into the scientisation and interdisciplinarities of the environment beyond the post-war, Cold War political and military push of the USA and the West.

The novelty of the 'environmental sciences' may arguably be how it groups and orders existing forms of knowledge to create new perspectives, alter social order and political action vis-à-vis environmental change and concern. Much of the existing work has pointed out and underscored the co-production of global environmental knowledge and global environmental orders – through the internationalisation of science and politics. Ultimately, new knowledge is then produced through the amalgamation of expertise and new experts are made about a new object of concern (Warde et al. 2018). The 'environmental sciences' then, I argue, are an interdiscipline – a combination of various branches of disciplinary knowledge working together to create cohesive new forms of environmental science (O'Riordan 1999). How might historians of science seek to understand and represent the plurality of the 'environmental sciences' beyond the global and discern the many ways and spaces in which it became an object of thought?

2.4. Local and regional analyses: environmental history

While some historians have marked the 'environment' as a global phenomenon, concern for 'environments' has had a long history, in multiple forms, preceding any formal or institutionalised programme of science. The recent interest in the modern 'environment' brings about a risk of underestimating the so-called "moral economy of nature on the part of ordinary people" and the extent to which 'environments' of the past have brought with them concerns, anxieties, prosperities and optimism for the individuals or societies who have made use of them (Bonneuil and Fressoz 2016: p. 172). James Lovelock (1987) warned against studying the history of the 'environmental sciences' through a disciplinary lens and argued for attention toward the complex interaction of different environmental systems.

Building on this, Peter Bowler (1993) encouraged a more borderless and careful exploration into histories of the 'environment' that draws from history and science. In this vein, this section is concerned with local or regional histories of the 'environment' that are predominantly found in environmental history, not the history of science. As I go on to detail, there is much worth in entangling environmental history, history of science and STS.

The ontological diversity of 'environments' or the 'environment' is best captured through the breadth of topics in which environmental historians are interested. For instance, there have been recent and rich case studies in forestry (Catton 2017; Speece and Sutter 2019), landscape and land-use changes (Sayre 2017) and rivers, oceans and water bodies (Skelton 2017; Evenden 2018; Emanuel 2019) that explore and emphasise the complex changing interactions between cultural, technological, and social change that take place and (re)shape specific environmental features, uses and meaning. Or alternatively, there has been focus on animal interactions and the multiple ways in which they have changed over time, e.g., the role of predators and ecological control (Van Nuys 2015) or the size of populations (Cushing and Frawley 2018). These works demonstrate a historical interest in changing environments but often overlook the roles these play in the emerging and reactive 'environmental sciences' or indeed in the making of an 'environment' with which to be concerned.

Environmental histories also illuminate the trans-local and multi-scalar aspects of environmental change. Work has explored changing environments from continental regions (Death 2016; Liu and Beattie 2016) to nation-states (Thomas 1982; Sheail 2002; Keeling and Sandlos 2015; Bello 2016; Zhang 2016; Dagenais 2017; Itoh 2017) to more specific regional histories (Miller 2016; Okie 2016; Osborn 2016; Haidvogl et al. 2018). However, while the nation and regional variability outlined above is wide, most works are typically located and oriented around North America. This is likely to be because environmental history enjoyed much institutional success in North America, commonly being found within History departments, in contrast to Europe (Hersey and Vetter 2019) and having stemmed from a growing interest of the environmental impacts of settler colonialism of 19th and 20th century American life (Worster 1990b; Suttler 2013). Moreover, a particular interest in land-use changes and ecological consequences - or more materialistic environmental histories - in the US (Worster 1990b, 2004) help to delineate differences in US environmental concerns from that in Britain. For instance, the view of environmental change in the US that stemmed from

the lack of environmental management or policy which did not prevent poor farming practices or encourage sustainable forestry (Carson 1962; Worster 1990a; Barton 2000) are distinct compared to Britain, for example, where environmental changes have arguably occurred more through rigourous urban planning or human disaster (Sheail 2002, 2007).[11]

Critically, whilst not explicit in environmental history, the resource management and policy concerns directly fed into the emergence of 'environmental science' in the USA, with early departments like The Yale School of the Environment formally being The Yale Forestry School, or The State University of New York College of Environmental Science and Forestry originally being founded in the early 20th century as a state college of forestry. As the field of environmental history developed in the USA, however, environmentally deterministic accounts were beginning to be backgrounded as environmental historians became more interested in the cultural responses and changing relations to the natural world in space and time (White 1985), yet this did not extend to the study of environmental knowledge-making practices that made these changes knowable through scientific interdisciplinarity. Moreover, there was little introspection into what made an 'environment' so, what made it different to other 'environments' and how this may shape historical understandings of environmental change. Toward the early 21st century, environmental historians in the US also began to be more aware of the international aspects, and the synergies with other places of environmental change (McNeill 2003) as environmental knowledge and awareness started to boom on a global scale (Benson 2020).

On the other hand, British environmental history has often focused on changing relationships between humans and the natural world (Thomas 1982; Sheail 2002), with little explicit investigation into what constituted 'environments'; rather the idea that they were changing 'environments' was a given. Keith Thomas (1982) explored the changing cultural attitudes between humans and their natural surroundings from 1500-to 1800. Thomas demonstrates the evolution from a predominantly anthropocentric world view of control and dominance over nature (including animals) in the early modern period to a more romantic and less secular way of viewing the natural world. Importantly for this review chapter, developments in different forms of science or 'natural history' (including geology, botany, ecology and astronomy) also brought about new ways of viewing the world with

[11] Where ENV was founded and is located.

new cultural ways of living and being. In this vein, cultural views of animals moved from exclusive human utility to being understood as important objects of information, ordering and classification to reveal the secrets of the natural world, or as companions to improve human lives. Both romantic and scientific views of the natural world changed British attitudes in ways that still largely remain in conflict today – preservation for amenity and scenic beauty or conservation for scientific and educational purposes.[12] The text serves as an essential foundation for understanding the historical contexts that have underpinned different cultures of 'environment' and environmental awareness that have emerged between multiple publics in Britain (O'Riordan 1985).

In a more refined view, John Sheail (2002) explores the changing environmental history of Britain throughout the 20th century. Sheail demonstrates that this was a significant time in Britain's development with many implications for society-environment interactions. The 'environment' figured in many aspects of Britain's social and economic improvements, from direct impacts vis-à-vis urban planning, sanitation improvements, water resource use and behaviours, and forestry management to more gradual shifts resulting from policy changes in recreation, conservation or pollution control. Unlike other countries, Sheail noted that the UK, historically, has been less susceptible to more 'natural' environmental disasters, like major droughts and flooding, and more susceptible to problems emerging from human activity or error – like the Torrey Cannon oil spill off the coast of Devon in the 1960s – and this has shaped what he sees as the lower levels of concern and unresponsible environmental attitudes in both British society and politics. Yet, Sheail does not engage critically with what forms of 'environment' these are – namely the damaged surroundings from government planning and policy – but rather moves from case to case tracing the development of policies for managing both land and water resources. The responses to 'environmental problems' are very different to US environmental history and the effects these different views play on the scientisation of the 'environment' in each country are unexplored. Sheail's work, on the other hand, demonstrates how work in environmental history often directly supports the calls against the globalised view of environmental and climate challenges; in particular, the argument that no one experiences or lives in a global environment or climate (Edwards 2010; Camprubí and Lehmann 2018),

[12] Discussed further in **Chapter 7**

but people do live in environments and experience local changes. However, environmental histories are often disjointed from one another, like the US and UK examples here, and often detached from the deconstruction of globalism in science studies. Yet, there is much promise in bringing environmental history into conversation with the history of science to help prompt reflections about different views and versions of 'environments', the role in constructing the 'environmental sciences', discerning interdisciplinarity as an appropriate mode of knowledge-making and can be a means of bridging the gap between epistemology and experience that a global environmental science and politics has eroded (Camprubí and Lehmann 2018).

It is apparent that the growing rise of environmental concerns, awareness and understanding of environmental change or, more widely, the problematisation of the 'environment' has in part brought with it a growing historical interest to make sense of historical changes in their terms and contexts to discern the pertinence, power and relevance of the environmental challenges we have framed in the modern age. Humans have mutually constructed how they make sense of, relate to and utilise the natural world and problematised the 'environment/s' for particular normative and epistemic aims. Nonetheless, there has been little direct unification between environmental history and the history of science or STS.

However, Dolly Jørgensen et al. (2013) edited a collection of essays demonstrating the intersections between environmental history and STS. Core tenets of research, in STS, like knowledge production, social and political processes or the establishment and legitimisation of expertise, for Jørgensen et al., are more than applicable in the making, analysing and writing of environmental history. How different actors perceive the 'environment' in moments in time and space have material and intellectual consequences for historicising environmental change and imagining environmental futures. A more conscious and intentional investigation into the mutually constitutive relations of environmental history and STS can radically alter our historical understandings of environmental change, processes of human-environment relationships and knowledge-making practices. Mark Hersey and Jeremy Vetter (2019) have more explicitly outlined the 'shared ground' between the history of science and environmental history. They argue that histories of science and environmental histories are almost impossible to divide, sharing great overlaps in methods, guiding epistemic and normative aims or principles and objects

of concern – both presently and historically (White 1967). As the discipline of environmental history developed, crossovers between the history of science and environmental history became more apparent and obvious (White 2001; Anker 2002). Historians of science began to investigate spaces and practices of science as objects of concern amidst a broader turn toward the social construction of science (Golinksi 1998), whilst environmental historians had already begun to investigate the social construction of environmental problems (Bird 1987). This led to a broader appreciation of the changing role of the 'field' (Kohler 2002, 2006), the regional or cultural differences in the reception and production of knowledge (Livingstone 2003) and a growing consciousness of the interacting role 'environments' play in social and cultural change (McNeill 2003).

The intersections of environmental history and history of science emerged more organically with what could be argued as histories of the 'environmental sciences'. Scholars like Donald Worster (1994, 2004) pursued accounts of environmental history that foregrounded power and politics in the ecological understanding, awareness, and destruction of certain landscapes like *The Dust Bowl* – that came from poor management and ignorance of ecological knowledge. Additionally, Peder Anker's (2001) comprehensive work on the mutually constitutive role ecology played in perpetuating imperial agendas and the rise of ecology as a discipline is another important example of the overlap between the history of science and environmental history. Ecological science, Anker notes, was being exported and circulated as a tool to guide management and strategy overseas to make sense of and to order different 'environments, populations and ultimately guide different traditions of conservation and preservation policy, rather than determine the (im)possibility of action and livelihoods, like that of *The Dust Bowl* (Worster 2004).

Beyond ecology, there are other aspects of the histories of the 'environmental sciences' that draw from environmental history. For example, Zeke Baker (2021) recently explored how climatic theory among meteorologists, physicians, natural philosophers and their publics, in the 18th to mid 19th century, was viewed through a lens of inherent change, a constant, relational state that was never stable. The transition to climate as 'stable' idea was a product of 'co-production' between the ideologies of positive climatology and agricultural capitalism, which moulded the framing of climate into a stable, static and geographic concept and something that could be predicted or forecasted. In doing so, climatologists drew from historical records of temperature to facilitate and manage

productivity and trade within national and imperial economic orders. This is mirrored by some indigenous knowledge that views 'climate' as constantly changing, always in flux or interaction (Green et al. 2010) and is representative of cultural variances in environmental history and history of science.

2.5. Conclusions: Writing less-than-global histories of the 'environment'

In sum, whilst there is a lack of local and regional histories of the modern 'environment', there is an abundance of work in environmental history that illuminates a piecemeal narrative against the globalist views of an environment and its challenges. Appropriately, the overlapping links between human/nonhuman relationships and perceptions of what the environment is, how it may change, how it has changed and why have begun to be understood as inseparable from questions about knowledge and power with wider implications for knowledge-making practices stemming from varying responses to the problem of the 'environment'. For instance, how environmental change is defined depends on positionality, cultural understanding, and different knowledge systems – like the authority of expertise, circulation and application of knowledge or political saliency. Still, existing work in environmental history tends to avoid the deconstruction or deep analysis of scientific knowledge's role in evolving understandings and the problematisation of environmental change or historicise the environmental problem itself. This has major implications for how we understand the processes, contexts and conditions concerning which environments became known as problematic, how they became known as problematic and how solutions (if any) are perceived and why.

In much of the West, the rise of science in the 20th century has brought with it political and epistemic authority and the emergence of new forms of science – like the 'environmental sciences' (Agar 2012). Yet, the intersections between environmental history and the 'environmental sciences' are still to be fully explored. Nonetheless, the multiple arrangements, ideas and visions of the 'environment' or 'environments' emerging from this review in historical and scientific work have illustrated the role of multi- or interdisciplinary responses to environmental problems and how this may have shaped the emergence of the interdisciplinary 'environmental sciences'. For instance, the role of multiple disciplines

meeting at conferences to discuss and produce new environmental expertise (Warde et al. 2018), the planetary wide interest in geophysics and environmental systems from the IGY (Doel 2003; Goossen 2020) or the plethora of historical environments and environmental change found in environmental history.

In later chapters, I argue that the new 'environmental sciences' emerged as a product of western internationalisation, expanding infrastructure, the scientisation of government and interdisciplinary working (Edwards 2010; Warde et al. 2018; Güttler 2019). However, the internationalisation of science and order neglects the spatial variability and uneven effects of environmental change and socioeconomic struggles that this broad and encompassing vision of the 'environment' brought about (Rouse 1987; Moellendorf 2015; Oldfield 2017, 2018; Rodenbiker 2020). The literature predominantly focuses on the US, Cold War and global (Western) formations of the 'environment' and its sciences. How do other Western nations, like the UK, figure in these accounts and with what effects? There is a strong need to write less-than-global historical accounts of the 'environment' and the changing relations between the disciplines that make the 'environment' and its changes known.

Moreover, there are big gaps in histories of critical institutions like universities (Meusburger et al. 2018) that traverse the scales of knowledge-making from local to global. There are multiple stories to be told about the 'environmental sciences' that can help uncover the historical relations between scientific interdisciplinarity, knowledge-making and environmental change and to illuminate how that knowledge was made (or co-produced). Next, I explore and review conceptual work concerning two versions of co-productionist analyses bridging them together through a relational 'ecologies' of co-production sensibility to explore the multiple, ongoing and dynamic realities and constitutions of the 'environmental sciences'.

3. Ecologies of co-production

In this chapter, I seek to carve out a theoretical and conceptual approach that responds to the challenges outlined in the previous chapter. Firstly, to better understand the diverse realities and geographies of what the 'environmental sciences' are, beyond dominant 'global' or US-based framings, and the role these play in the construction of historiographies of the 'environment'. Secondly, to understand the wider, ongoing, relational and mutual construction of science, society and politics that shape and were shaped by the emergence and evolution of the 'environmental sciences'. Lastly, to discern how the 'environmental sciences' in their many forms are *actually* made and operate as a practice. In **Chapter 2**, I explored the historical rise of the ecological sciences and how this introduced a new relational framework for thinking, engaging and understanding the connections of different environments and systems in a post-war world. In this chapter, I expand on this 'ecological thinking' to explore the relationality between different concepts in science studies and demonstrate how together they can support a more expansive and inclusive study of what the 'environmental sciences' in ENV are, how they operate and what worlds they co-produce.

There have been two dominant forms of co-production in STS, geography and cognate disciplines; a deliberate and prescriptive form of knowledge co-production that involves diversifying the actors involved in socially and politically relevant knowledge production, and a broader mutual construction between knowledge and society. Silke Beck (2019) has usefully labelled these two versions as normative-procedural and philosophical-analytical modes of co-production. The 'environmental sciences' in ENV specifically seem to have both emerged as a novel way of producing new interdisciplinary science – different disciplines 'doing things together' and also a result of changing wider relationships between knowledge, politics and society as a result of new environmental challenges. I ask, then, what difference does it make to view co-production ecologically, to take the two dominant forms (and others) as mutually constructed, and how does this help to understand the mutual constitution of the 'environmental sciences', society and politics? I use the ecologies metaphor to understand the relational co-productions in the multiple spaces and scales of the 'environmental sciences' found within and on the periphery of a key institution, ENV. This is novel as existing approaches in science studies, namely co-productionist analyses, fail

to capture the complexity of the multi-scalar and multi-spatial aspects of the co-production of knowledge and social order. I thus outline how a range of concepts form a co-productionist toolbox. By unifying these, I demonstrate a more ecological approach to analysing the co-production of knowledge and social order that goes beyond a fixation on the nation-state and co-production as a discrete phenomenon.

An ecological approach to understanding co-production draws from the relationality embedded in the philosophies of relational and systems-based ecological thinking in the previous chapter (Morton 2007; Coleman 2010; Benson 2020) and builds on emergent work concerning the opening-up and democratisation of multiple forms of participation in the critical and interpretive social sciences (Chilvers and Kearnes 2016a, 2016b). I propose that it is a valuable and practical approach in which to explore the diversities and exclusions, spaces and interrelations, histories and constitutions, and responsibilities and affects of relational co-productionist thinking. Utilising an ecologies of co-production approach, as I will go onto detail, can help (more intentionally) construct less-than-global histories of the 'environment', emphasise how co-production is ongoing and emergent, capture the ontological multiplicity of 'environments' and to illuminate the diversity of practices, epistemologies and participants involved in the knowledge-making involved in the construction and problematisation of the interdisciplinary 'environmental sciences'. As a result, I can attend to the multiple overlapping and co-existing co-productions embedded in the 'environmental sciences', society and politics in different spaces, across different scales and through different time periods.

I begin this chapter by exploring the origins of efforts to study the mutual construction of knowledge, power and social order before a refinement through the co-productionist idiom. I then explore various tools aligned to co-productionist ideas and interventions, both explicitly and implicitly, to demonstrate the diversity of ongoing co-productions that are always ongoing in studies of knowledge, society and politics. Lastly, I illustrate what an 'ecology of co-production' approach or sensibility might look like as a guide to researching, case-study selection and analysis, how to put the approach in action, to help clarify what the multiple and ongoing forms of co-production are in the history of ENV, and how the methods used and positionality of myself reflect an ongoing commitment to an 'ecology of co-production' sensibility.

3.1. Knowledge, social order and power

In the mid 1980s, Steven Shapin and Simon Schaffer (1985) explored the conflicting ideas between Thomas Hobbes (1588-1679) and Robert Boyle (1627-1691) in Restoration England during the 17th century that concerned the value and authority of experimental science and methods as a new form of knowledge production. The dispute between Hobbes and Boyle stemmed from a disagreement about Boyle's experimental method with an air-pump. Both Hobbes and Boyle embarked on "quests for certainty" as they "proffered radically different solutions to the problem of knowledge" (Shapin and Schaffer 1985: p. 147) in a time of fractured politics and civil unrest. Rather than attempt to ascertain knowledge through higher entities, e.g., God and religion – as it previously had been, Boyle developed an experimental programme to "secure assent by way of experimentally generated matter of fact" (Shapin and Schaffer 1985: p. 23). Notably, 'facts' about the world were there to be known, externally located in human surroundings, and human intuition and skill were needed to find ways to extract and make 'facts' legible through scientific knowledge. For Boyle, the air-pump and the vacuum it created was a novel means of revealing properties of nature for verification from other individuals. Boyle argued that experiments conducted in private spaces (the protected space of the laboratory) with 'reliable' witnesses, meant that facts could be attested to and described as natural phenomena (Shapin 1988). This new way of creating facts – or knowledge – was to be unmodified by religion, politics or other interpretative stances and gained credibility through accounts and legitimisation of trustworthy witnesses (Latour 1990, 1991). As a result, the emergence of 'scientific facts' helped produce a new ordering of society, one of consensus where the potential for interpretive differences (and consequently, conflicts) was replaced with 'indisputable' matters of fact verified by witness testimony.

On the other hand, for Hobbes, knowledge is 'power' and thus, there should be no interpretations or a higher entity that people could appeal to beyond the head of the state. Boyle's new construction of verified 'facts' was therefore a problem. Hobbes was trying to propose a philosophy that unified society through a sovereign lead. The lead was a designated actor that emerged from the multiple wishes and wills of the broader social body, rather than imposed by fear or terror (Latour 1990). Hobbes' concern centred around

Boyle's new experimental science (through the air-pump and its vacuum) that created new and unnecessary opportunities for dissent, as scholars and others in society could 'believe' in immaterial entities – like spirits - due to the unique properties of a vacuum. Hobbes thought that the newly created Royal Society might then be in dispute with the King (Shapin and Schaffer 1985).

Additionally, the new creation of experimental spaces with 'reliable' witnesses was an exclusive event, and this for Hobbes meant that the construction of facts would create more division than a unified society under a sovereign. By visiting this dispute, Shapin and Schaffer (1985) illustrate the power dynamics concerning the production and normative aims of knowledge, highlighting that "solutions to the problem of knowledge are solutions to the problem of social order" (p. 335). Boyle was advocating a new experimental method. The construction of facts through reliable witness verification could offer consensus for society within the turbulent and divided times of restoration England. Hobbes, alternatively, was advocating for the rejection of Boyle's experimental method as the exclusivity of the experimental space and witness testimony to the 'fact' may be unreliable and thus exacerbate the division of the polity which was a threat to the harmony of the state. Thus, questions of knowledge production were intertwined with questions of social order and were enmeshed with power to shape how the post-Restoration period unravelled.

Bruno Latour (1990, 1991) further – and conversely – argued that knowledge could only be viewed as 'power' in an asymmetrical analysis of science and society. In appealing to the social context of Restoration England to explain the dispute and its outcomes, Latour argues that Shapin and Shaffer took 'society' for granted, ontologically. The social context of knowledge-making cannot be appropriately used to justify and explain the use of knowledge for ordering society as the existence of the social does not presuppose the relations between the actor-networks that (re)construct it. Latour is critical of the over-deconstruction of Boyle's science (e.g., what an experiment is and who counted as a witness) and the lack of deconstruction of power and politics in the make-up and constitution of society. For Latour (1991), this is a serious omission as Boyle and Hobbes, he argues, are "inventing our modern world",

> A world in which the representation of things in the intermediary of the laboratory is forever dissociated from the representation of citizens through the intermediary of the social contract (p. 27).

Thus, Boyle creates a political discourse in which politics is excluded, whilst Hobbes creates a politics of knowledge in which Boyle's experimental science is excluded. The problem for Latour (1990) is that there is no more a macro nature than there is a macro society. Both are products of the ongoing (re)construction of the relations between actors in a network. To fully discern this Latour proposes a symmetrical analysis to map out how the key domains that are figured in our knowable and material worlds are products of continual, fluid and extended networks of humans and nonhuman interactions. In this vein, both science and society are mutually sustaining arenas that are (re)shaped by the many ways in which we can articulate, know, and understand how the human and nonhuman figure in relation to our existence (Latour 1991).

However, the conventional view of the 'modern' world and 'being modern' involves demarcating divisions between different worldy arenas- like the 'Other' (Said 1978), dualities between 'nature' and 'culture' (Latour 1987), the human and nonhuman (Bennett 2009), the mind and body, and so on. Even the earliest social studies of science work by Robert Merton (1910-2003) focused on social norms and values of scientists - as external to them - rather than an embodied scientific knowledge that is entangled with the material practices and realities of science (Pickering 1995).

Yet, for Latour, separate arenas may be more fruitfully replaced by hybrid networks between human and nonhuman (including 'Nature'). These emphasise the entanglements between social constructions, space and agency within an 'actor network' revealing how things figure, happen and (re)act in the world beyond cause-and-effect analyses (Latour 1996, 2005). Latour approaches the study of knowledge as "a collective process" (Latour 1987, p. 29) or 'doing things together', made up of an assortment of facts, machines, humans and nonhumans, occurring in an assortment of varying spaces in multiply productive ways. Scientists do not pluck 'facts' out of thin air, as Boyle contends, nor are they awaiting to be 'discovered' or made legible from an external backdrop to human affairs, nor is the production of knowledge exclusively shaped by social factors. Instead, it is a lively ongoing process of accumulation, inscription, debate, circulation, strengthening of

rhetoric, controversy settling and embedded within material and technological realities being 'co-produced' between the different actors involved, emerging from 'centres of calculation' and spaces of knowledge-making.[13]

Other researchers have utilised these ideas in geographical work to explain the spatial extension of academic mobility and the making of universities as centres of knowledge-making, accumulation and circulation (Jöns 2008) and socio-spatial elements of military intelligence (Barnes 2006). However, these types of works are concerned with more the stability and emergence of knowledge rather than the power and politics of different places, materialities and social contexts that mould and contour how we know and what is possible to know. Nor do they deal with intentionally intervening in co-productionist work; rather Latour's emphasis on the collective action of humans and nonhumans in the production and circulation of knowledge represents a flat ontology in which the thickness and the importance of power dynamics are obscured and hidden within a network framed analysis. In this view, 'co-production' is a necessary but important practice in making and sharing knowledge. The 'co-production' of Latour's network 'doing things together' in knowledge making is an outcome of social and material context and participation that shapes the production and circulation of particular forms of knowledge, that are contingent on the place in which they emerge. Whilst it is an important analytical tool to help open up analysis to include multiple relations and actors, the approach does not account for the powers dynamics that (re)shape the possibility and materialities of decision-making or participation, like the inclusion or exclusions concerning involvement in the network. As a result, the wider implications of these exclusions/inclusions and power distributions and patterning are left unattended to. As a result, Sheila Jasanoff (2004a, 2004b) has attempted to advance a more explicit framework to understand the relation between science, technology and society through more focused exploration of patterns and distributions of power in science and technology and their relation to the construction of order through the development of a 'co-productionist idiom' and various related conceptual tools.

[13] Latour (1987) explains that 'centres of calculation' are spaces in which the processes of accumulating objects of knowledge like fossils, maps, data occur – which are immutable and mobile – and are inscribed, made intelligible through representations. This makes knowledge-making a cyclical process where knowledge builds up, not simply extracted. As cycles repeat the centre can know and act from a distance, as new materials are inscribed, made knowable and circulated back out externally as products of knowledge.

3.1.1. The co-productionist idiom

The co-productionist idiom is a philosophical-analytical framework to help understand the mutually constitutive relationship between science, politics and society and guide the ways in which we act and live (Jasanoff 2004a, 2004b). Co-production can be understood as a mutual construction of the epistemic and the normative, describing how "the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live it" (Jasanoff 2004a, p. 2). Knowledge is simultaneously a "[product] of social work and constitutive of forms of social life" and explicitly acknowledges that scientific knowledge "both embeds and is embedded in social practices, identities, norms, conventions, discourse, instruments and institutions ... in all building blocks of what we term the social" (Jasanoff 2004a, p 2/3). Co-production also emphasises that knowledge does not appear externally or come into being independently; it is attached to thought and action, forms of intervention and engagement situated in diverse cultural, social and political settings that itself helps to (re)make. As a result, knowledge does not emerge distinctly from political thought, nor do institutions automatically rearrange themselves to meet the demands of science or technology.

Crucially, the co-productionist idiom seeks to carve a middle ground between the social constructionist approaches of sociology of science and the complexity of hybrid networks and materialist accounts of science and technology. It does so by proposing that the material, technological and institutional realities are shaped and are shaped by the social and political contexts in which knowledge emerges and the power dynamics that enable such contexts to materialise. In this vein, how and what knowledge emerges (Shostak 2003), how knowledge becomes standardised through social and scientific practices and why this matters (Bowker and Star 2000), techniques behind making science legible (Hilgartner 2000; Jasanoff 2001), how stability in knowledge is achieved (Galison 1996; Renn 2020), how particular visions of scientific and technological futures come to be, over others (Storey 2015), how science traverses scales to construct new global orders (Miller 2004) are all important topics of enquiry that go beyond existing studies of science, and foreground the intersections between knowledge, power and social order. The co-productionist idiom was developed as a framework to study the relations between science,

technology and society, in part a culmination of work in the previous decade (Latour 1987; Shackley and Wynne 1995; Jasanoff 1996; Jasanoff and Wynne 1998).

As such, Shackley and Wynne (1995) addressed developments in global climate change from a sociology of science perspective. Global climate change is fraught with regulation through the construction of policy, and within this, there are particular kinds of criteria desired of scientific knowledge as an input to decision-making that are not decided solely by the scientific community (Gibbons et al. 1994). Yet, the policy and scientific world may appear miles apart to an outsider. However, Shackley and Wynne (1995) introduced the view that global climate change modelling is mutually constructed with policy goals and institutional arrangements. For example, the growing need for political action and forecasting illustrated by the UK's Department of Environment in 1988 was grounded in the future developments of GCMs, which shaped the material and institutional development of GCMs through the construction of the Hadley Centre (Shackley and Wynne 1995). This, in turn, reshaped how the effects of climate change were made legible to policymakers and thus, channelled government funding further into modelling. How policy challenges are framed is contingent on the scientific knowledge that makes them legible and the representations they enable (Shackley and Wynne 1996), which then reshape the expectations of science, scientists and the production of knowledge. The idea of mutual construction underscores the interactive and reciprocal nature between science and policy domains which has become ever more prominent given the perceived scope and threat of environmental challenges (Turnhout et al., 2016).

Jasanoff (1996) introduced the idea of 'co-production' to recapture questions concerning authority making, interpretations and the normative aims of scientific knowledge that had been side-lined by the epistemological preoccupations of other forms of social studies of science. It also serves to unite the academic and the political vis-à-vis knowledge and social change and helps to bridge the macro and micro politics of science concerning interactional processes, values of expertise, authority, and power absent in Latour's earlier work. The idea of 'co-production' acknowledges the mutual construction of knowledge and forms of life – beyond the narrow view of climate science and policy – for Shackley and Wynne (1995). For Jasanoff, this is applicable to all facets of life in which knowledge infiltrates and is more appropriate to capture the full extent of the relations between science, technology, and society. These ideas are more fruitfully combined when

Jasanoff and Wynne (1998) explore a kaleidoscopic and entangled terrain of science and decision-making. Exploring environmental and climate knowledge through an interpretive lens of co-production, they reveal that science (and decision-making) is indeed not value-free or impartial but instead contingent on the infrastructure available, values of scientists and policy makers, framings of the problems and processes of making science and natural orders legible through a mutually constitutive matrix of expression, practice, objects and interpretations.

However, not until *States of Knowledge* does Jasanoff (2004a, 2004b, 2004c) fully flesh out the 'co-productionist idiom' as a guiding framework. Jasanoff draws on several historical and contemporary examples to construct not only a framework of enquiry but also a transformational worldview of knowledge and social order that explicitly positions the nation-state as central to analyses of power and social order. Importantly, Jasanoff (2004b) delineates two varieties of co-production: constitutional and interactional. Constitutional forms of co-production are predominantly concerned with the emergence and stabilisation of knowledge: why states of knowledge emerge, how they are arrived at and the processes behind being held in place, evolving or being abandoned. Or, more simply, how life is perceived and organised around particular orders of experience, observation or representations. Latour's actor-network theory (1991) can be understood as an early iteration of a constitutional form of co-production concerned with how knowledge is produced, the emergence of socio-scientific practices and how knowledge becomes durable through extension, processes and performance, like the mobility of facts, 'black boxing', or the coming together of gestures, skills, machines in emergent scientific practice. Interactionist forms of co-production are less concerned with what we know and more with how we know what we know (including sense and world-making activities) and the variations of this throughout history. Shapin and Schaffer's (1985) investigation of the conflict between Boyle and Hobbes is an important example of interactionist co-production that centres analysis on conflicts, interactions and re-ordering of ideas, world-making and reality building. At their core, these approaches seek to analyse the ways in which knowledge and order shape the many (and difficult to quantify) ways in which we live, act, understand and imagine in the world.

Since the philosophical-analytical form of co-production originated, there have been numerous concepts or 'tools' that have sought to demonstrate and explore different models

of co-production. However, existing works have often kept them separate or used the tools to analyse and explain discrete events or scale. This ignores the multiple and relational forms of co-production that are ongoing and that have occurred. Instead, I argue that grouping these tools in a co-productionist toolbox can more appropriately demonstrate the relationality of these tools to be used in a relational co-productionist ontology.

3.1.2. A co-productionist toolbox

Several concepts have emerged to explicitly help interpret and assess the co-production of knowledge and social order. I consider several concepts and approaches to be aligned with co-productionist normativities and that I argue could and should be included as part of a co-productionist toolbox.

Firstly, Jasanoff (2005) builds on the idea of civic epistemology. Civic epistemologies are the way in which publics assess claims by science, expectations of how knowledge should be made, and how credibility, rationality, robustness, and expertise is assessed in public. As a conceptual tool, it emphasises the array of diverse cultural views between nation-states view of science and its role in society, exploring the processes and practices behind how knowledge becomes salient and how this varies nationally. Scientific claims and knowledge are not ubiquitous but are instead moulded by the contexts in which they both emerge and are received. As a result, across the globe patterns of scientific authority, cultures of understanding, productions of knowledge and methods that judge the legitimacy of knowledge claims widely differ. Jasanoff (2005) explores this through three comparative case studies of biotechnology: the UK, Germany and the USA. Whilst they differ in the cultural ways of understanding knowledge-making and use, the processes behind each are often systematic, institutionalised and articulated through practices rather than a set of binding or formal rules.

	United States Contentious	Britain Communitarian	Germany Consensus-seeking
Styles of public knowledge-making.	Pluralist, interest-based	Embodied, service-based	Corporatist, institution-based
Public accountability (basis for trust)	Assumptions of distrust; Legal	Assumptions of trust; Relational	Assumption of trust; Role-based
Demonstration (practices)	Sociotechnical experiments	Empirical science	Expert rationality
Objectivity (registers)	Formal, numerical, reasoned	Consultative, negotiated	Negotiated, reasoned
Expertise (foundations)	Professional skills	Experience	Training, skills, experience
Visibility of expert bodies	Transparent	Variable	Nontransparent

Figure 1: Comparative view of USA, British and German civic epistemologies, taken from Jasanoff (2005, p. 259).

As we can see in Figure 1, there are distinct differences across many facets of the way publics know or make sense of knowledge and the ways in which public knowledge is created. For the UK specifically, public accountability and trust appear to be built by experienced experts which bring with them a relational assumption of trust through service-based knowledge-making. Indeed, if we look at the role of the Chief Scientific Advisor in Britain and the individuals who have held the position, we can note that they are experienced, possess scientific authority and are widely known for solid communication skills (House of Lords Select Committee on Science and Technology 2012). Importantly, analysis of civic epistemologies can provide richer insight into the fabric and power of modern social order and knowledge systems through the joint stitching of public knowledge, trust and reason with policy and decision-making. The merit of civic epistemologies is arguably its ability to show how the processes and materialities of public understanding of science are ongoing negotiation between the empowerment of normative attitudes that frame ideas of responsibility and uses of knowledge, and the social and

political realities entrenched in knowledge production, use and decision-making (Ezrahi 2008).

Notably, there have been several papers that use civic epistemology to help understand how forms of knowledge emerge, what kinds of knowledge they are, the values and morals binding and shaping understanding, production, use and synthesis and to what extent these are coherent or compatible with, and how they (re)shape the social body or political order (Iles 2007; Miller 2008; Mahony and Hulme 2016; Donovan and Oppenheimer 2016; Forsyth 2019). Returning to the UK Hadley Centre, Mahony and Hulme identified that not only was the institutional formation part of a co-production of knowledge and policy (Shackley and Wynne 1995), but the ways in which the Centre was to operate exemplified a British civic epistemology of "pragmatic empiricism" through the means of constructing "sound science" with "independent judgment" of climate prediction amidst well-connected alliances and diverse actors (Mahony and Hulme 2016, p. 466). Clark Miller (2008) also employed the notion of civic epistemology in examining the increasingly important role they play in the shaping and organisation of international communities of governance. Policy (particularly environmental) challenges have been increasingly framed in international terms, yet often the epistemic dimensions of these are often ignored (Miller 2004) due to the construction of social processes like trade, markets, pandemics, and natural systems – like the climate or ozone layer - as ontologically global. Accepting these processes as global phenomenon – rather than seeking to uncover the processes that aid the construction and framing of them as global – continues to reify internal/external divisions of human/social, nature/culture and exacerbates the idea that these processes are inherently or obviously 'global'. Instead, Miller (2008) argues that it is often a small yet loud community or network that shape and reshape knowledge claims and determine the importance of international issues. This is demonstrated through the perceived importance of the IPCC (by climate scientists, politicians and policymakers) in providing authoritative climate knowledge for policy (Beck and Goerg 2009; Hulme and Mahony 2010) or through the overwhelming westernisation of the UN in biodiversity conservation (Miller 2003). As a result, analysis of civic epistemologies can reveal how inter/transnational communities of experts emerge in certain socio-political conditions, how cosmopolitan knowledges meet, order and undergo restructuring in relation to each other (Beck 2016), how or why they gain traction and the processes behind how authority and credibility are built or lost in the new construction of

global civic order and knowledge (Jasanoff 2011). Yet, the presence of 'global civic epistemology' increases the homogenisation of diverse and nuanced ways in which cultures and nations assess, understand, and make knowledge claims. The 'global' will be perceived as planetary wide, but rather it often builds from Western forms of knowledge or perspectives from transnational institutions, particularly in the mid-20th century. In sum, homogenising forms and understandings of knowledge to make the 'global' obscures the complexity and entanglements of the terrains of knowledge and ideas of reality that are already being overly refined in civic epistemologies on the national scale.

The historical works explored in the previous chapter have detailed how particular forms of science and visions of international order have dominated histories of the environment, how the hegemony of global framings shape understandings of environmental challenge, concern and policy, and the prescriptive push for more interdisciplinary methods and approaches to embrace the cross-disciplinary and cross-scalar environmental challenge(s). However, very little attention is paid to the role of civic epistemologies in hindering or enabling environmental concerns, the conditions surrounding the politics of knowledge that cultivate concern, or the production and understanding of environmental knowledge and the construction or reception of policy or government departments.[14] Nor do civic epistemologies, or wider co-productionist work attend to the finer-grained analysis below the nation-state, e.g., the regional, institutional or local. This signals a lack of priority for STS researchers focusing on the structures and institutions of knowledge-making and politics beyond the nation-state. Although in the previous chapter I demonstrated the more local engagements from some historians of science and environmental historians, the lack of less-than-nation-state inquiry needs to be embraced by more scholars in science studies. As mentioned above, existing work in co-productionist analysis focuses on discrete spaces and scales, rather than the multiple, relational and ongoing moments of co-production.

Nonetheless, Maud Borie et al. (2021) have sought to characterise knowledge-making practices in international expert organisations – IPCC and IPBES - through 'institutional epistemology' which can support a shift from national to institutional scale. Both IPCC and IPBES attempt to provide knowledge and expertise from 'nowhere' and 'everywhere', respectively. The IPCC attempts to provide science for policy through

[14] Except for Mahony and Hulme (2016).

consensual framings of a predominantly numerical model-based global climate. On the other hand, IPBES attempts to democratise knowledge and decision-making through epistemic pluralism in which a global environment is emergent through an aggregation of expertise and place-based knowledge (Borie et al., 2021; Warde et al., 2018). Borie et al. (2021) note that both organisations make knowledge and expertise from 'somewhere', and identifying institutional epistemologies can shed light on the spatial contexts, values, norms, and aims that contribute to the processes of knowledge-making, circulation and uses. Notably, the concept of institutional epistemologies resituates organisational and expert knowledges that try to transcend scalar boundaries by illuminating spatial differences between normative and epistemic aims of international institutions, and the differences in how authority is constructed and legitimised in institutional settings. Rather than focusing on the nation-state level, it takes heed of how organisational and research cultures, varying epistemic and normative aims, and varying modes of institutionalisation and legitimisation can all shape how knowledge is made, understood, framed, valued, debated and re-circulated – despite whether or not the institution seeks to transcend space and scale. Different modes of co-production occur in different institutions as they produce, circulate and stabilise varying epistemic and normative aims – whether state-led, commercially or publicly funded -individual institutions or organisations will (re)shape and be constitutive components of a civic epistemology.

Relatedly, Simon Shackley (2001), some 20 years earlier, proposed a similar idea of 'epistemic lifestyles' to explore how the differences in institutional organisation and composition shaped what and how knowledge was produced. Epistemic lifestyles can be understood as the particular sets of intellectual questions and problems, the research practices (both individual and collective), the social connections and networks, the broader, more mundane activities that make up the daily work routine and the guiding sense of purpose, achievement and value that enable knowledge to be made within institutions (Shackley 2001). Specifically, Shackley uses this idea to understand differences in research or institutional cultures while exploring the social networks of climate change modellers. However, Shackley does not emphasise that the diversity in research cultures or agendas shapes nation- or world-making practices. Nor is the concept of 'epistemic lifestyles' conventionally a co-productionist tool. Yet, the focus on social processes and normative aims in the practice and production of knowledge is fundamentally co-productionist.

Additionally, exploring the differences in research cultures between groups can foreground why some methods of science, ideas, values and visions work out and others do not. Histories of science are as much about the failures as they are successes (Kuhn 1962; Parkes 2019), and epistemic lifestyles can provide insight into the social and geographical processes of scientific progress beyond epistemic success. Combining epistemic lifestyles and institutional epistemologies can reassert the institutional and local scales of co-production that are ongoing and multiple in the history of the environmental sciences.

Furthermore, to understand how and why particular visions of sociotechnical and scientific futures (or even methods of knowledge-making) like the 'environmental sciences' as a new inter/discipline arise, become durable or falter, Jasanoff also helped establish the concept of sociotechnical imaginaries (Taylor 2004; Jasanoff and Kim 2009, 2015). There are multiple ideas and visions that are proposed to create and shape futures but not all come to fruition for several reasons. Unlike the historical aspects of civic epistemologies, sociotechnical imaginaries focus on the future-making powers of particular forms and imaginations of the role scientific knowledge plays in realising that future. Specifically, sociotechnical imaginaries are "collectively held, institutionally stabilised, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff 2015a, p. 4). Its merit is found in helping to explore differences between the relations between science, technology, and society of why some visions or imaginaries gain traction over others. For instance, the use of sociotechnical imaginaries can explain why some forms of technology or science evolve differently over time and space, or it can reveal why some visions of socio-scientific/technical futures emerge, fail, stabilise, or develop over time, like waste to energy markets in the UK (Levidow and Raman 2020) or the performativity of knowledge circulating from the IPCC (Beck and Mahony 2018).

More broadly, sociotechnical imaginaries can enable us to identify the roles science and technology play in individual, collective, political or material understandings about the world in which we live, the world in which we want to live (Lawless 2020) and how these visions themselves are co-produced (Longhurst and Chilvers 2019). Sociotechnical imaginaries, I argue, can also be used on smaller geographical or social scales, rather than focus exclusively on major dominant re-orderings of futures and constitutions, the concept can be used to explore how and why particular ideas and values about research

programmes and cultures form, embed, dissolve or strengthen (Shackley 2001; Borie et al. 2021). Doing so supports an ecology of co-production approach that intentionally foregrounds the relational, multiple and ongoing co-productions which include the often less analysed regional, institutional, local and even marginal, excluded or forgotten histories and visions of science or knowledge.

Going beyond the social and geographical processes behind knowledge-making and circulation, Andrew Pickering's (1995) 'mangle of practice' foreground the messy reality and materialities of an ongoing production of scientific knowledge (and society). As a performative idiom, focusing on the 'mangle' emphasises the more interactional aspects of co-production that Jasanoff (2004b) claims. Pickering explores a messy ontology where humans and nonhumans operate and perform through sometimes intentional, sometimes serendipitous flows, becomings, emergence and 'happenings' – like scientific knowledge - then manifest from these ongoing practices. In this view, knowledge is a product of interaction, construction, negotiation and reconciliation between human and nonhumans – like scientific tools and ideas. The 'mangle' approach to scientific knowledge-making, as I go on to explore further in **Chapter 5,** can help materialise a critical understanding of how and why interdisciplinary science works in some instances, and not in others and how the reconfiguration and extension of scientific cultures produces new forms of 'environmental' knowledge.

The co-productionist toolbox I have outlined is not an exhaustive set of concepts but provides a useful starting point with which to view the many, simultaneous and relational co-productions operating in the philosophical-analytical vein. The ecologies of co-production approach is an attempt to overcome the dichotomy that has formed between the two dominant versions of co-production.

3.2. 'Doing things together: normative-procedural co-productions

'Co-production' as a term first emerged in the literature in the 1970s, after the emergence of ENV, most notably through the work of Elinor Ostrom (Ostrom et al. 1973; Ostrom and Whitaker 1973). Ostrom explored the role and constitution of public services as a supporting arm of government and how they are co-produced by the users who

participate in both the explicit aims of the service or the implicit binding social contracts they signify, like policing. Put simply, when society operates with collective participation – things happen when people do things together. More recently, co-production has been talked about in relation to practices of knowledge production (Lemos et al. 2018; Miller and Wyborn 2018).

These forms of co-production – normative-procedural - are often explicit attempts to intervene in and produce knowledge with and between a variety of new actors or stakeholders in deliberative or participatory circumstances; doing things together to make new knowledge for societal or political challenges. Yet, this is not novel and much of these recent calls in environmental fields like sustainability science, climate services and conservation biology (Djenontin and Meadow 2018; Norstrom et al. 2020) rehearse earlier arguments of the 1990s for socially responsible and politically relevant knowledge (Funtowicz and Ravetz 1993; Gibbons et al. 1994).

Importantly, 'new' knowledge practices and methods, like PNS (Funtowicz and Ravetz 1993; Ravetz 1999) or Mode-2 (Gibbons et al. 1994; Nowotny et al. 2001) emerged from 'new' social contracts built between society and science (Lubchenco 1998; Gibbons 1999) and rather than being discrete normative interventions, they can be possible moments for co-productionist analyses when adopting an ecological approach. Thus, I explore how the framings from philosophical-analytical co-production, like an exploration into politics and power, boundaries and exclusions can inform better understandings of the politics and power of normative-procedural interventions and to understand how these modes are themselves co-produced. For instance, the perceived need for politically relevant and socially robust knowledge (re)shapes knowledge production through the need to settle uncertainty, disputed facts, and crises in expertise. This, in turn, then reshapes how knowledge systems may operate, produce knowledge, and be understood and legitimised in the long run – like the scientisation of climate change politics and politicisation of climate science from the 1980s (Howe 2014) with the emergence of the IPCC and global temperature indexes becoming the dominant metric to discern complex climatic changes.[15]

The ecologies of co-productionist approach promotes introspection and a focused attention toward a 'co-production of co-production'. This helps to unify the two dominant

[15] More on this in **Chapter 6**.

approaches, in ways that existing work does not, in a relational framing that crosscuts time and space. The entanglement of both analytical and instrumental forms of co-production is critically important to illuminate new insights into the history of the 'environmental sciences'. Whilst the recognition and introduction of new practices of knowledge-making like PNS and Mode-2 and the general idea of normative forms of 'co-production' follow on from the institutionalisation of the 'environmental sciences' in the 1960s, I have demonstrated in the previous chapter how the 'environmental sciences' emerged from an eclectic group of disciplines 'doing things together' and in other ways beyond the formal institutions of knowledge-making. Interdisciplinarity, I argue, is a form of co-production that has been a constitutional aspect of the emergence and development of the 'environmental sciences'. Therefore, an ecology of co-production perspective can more acutely illuminate the co-productionist practices of environmental scientific knowledge production and the wider co-production of environmental science and social order. I will now lastly detail how geographies of knowledge can help to highlight the spatial variability and complexity in the ecology of co-production approach, before noting how I have used it as a guiding sensibility to map, research and analyse my empirical material

3.3. Geographies of knowledge

Science and knowledge are intrinsically spatial phenomena. Science and the production of knowledge happens in places, circulates between spaces and is (re)moulded by the various material, social, technological, infrastructural and political realities of space and place. For most of the 20th century, the organised study of science ignored the spatial aspects of knowledge. Yet, now there is bountiful work that can be organised under the guise of the geography of science or geographies of knowledge. This section explores the underexplored yet prominent shared lines of enquiry between co-productionist analyses and geographies of knowledge.

Geographies of science and knowledge scholarship have striven to uncover science and the production of knowledge as a pursuit that is contingent on the social, spatial, temporal, political, religious and economic contexts in which it was formed (Livingstone 2003; Finnegan 2008; Naylor 2005, 2010; Schaffer 1998; Shapin 1988; Mahony 2021). By

going against a dominant view of science or knowledge being 'placeless', and that truth or 'facts' are external to be discovered 'out there', geographers of knowledge recognise that the material and cultural realities of space and place (re)shape the production, circulation and reception of scientific knowledge. Moreover, the realities of space and place influence scientific practice, circulation and progress in numerous ways, calling attention to the uneven distribution and production of knowledge.

In David Livingstone's seminal book (2003) *Putting Science in its Place*, he demonstrates the various points of interest geographers of science can explore, in tandem or individually. He begins by detailing the epistemological ideas and justifications for new engagements of the spatialities of science. Livingstone notes that closer analysis can come in two related forms. Firstly, the study of various venues of science, e.g., the laboratory, museum, field, tent, botanical gardens and the different contexts that impact the construction or emergence of knowledge. Next, the role of wider and varying regional contexts of science in influencing the construction and mobility of scientific knowledge. For instance, using the case of Darwinism, Livingstone illustrates how different places reacted differently to the new evolutionary theory. In New Zealand, where "religious ardor rarely rose above the lukewarm", Darwinism was warmly welcomed by New Zealand imperialists to legitimise the colonisation of Maori land (Livingstone 2003: p. 122). In this vein, Maori people were portrayed as barbaric and less civilised than the Imperialists which legitimised their colonisation regime. On the other hand, Livingstone explains how Darwinism was fiercely resisted in the American South as it threatened traditional beliefs of Christianity and the idea of a 'Creator'. This point by Livingstone is co-productionist as it highlights how two geographically distant areas responded differently to scientific claims and how scientific knowledge is put to work for different aims vis-a-vis supporting or restricting different ideologies in different places.

Livingstone also uncovers the varying geographies of scientific endeavour between cities and towns in Victorian Britain. Using the example of Manchester, Livingstone notes how 'Manchester science' was bound-up in municipal politics. As the population rapidly increased in the early 19th century, the merchant and manufacturing classes were the powerhouses of economic growth. The merchant and manufacturing classes were then marginalised in the social order as Manchester grew with metropolitanism and were keen to advance political reform seeing the possibility of scientific engagement to promote "the

democracy of the intellect". As "science could be used to support social progress and sustain an ethic of hard work", it then "became a major vehicle of cultural expression among those who wanted to counter Manchester's social isolation from metropolitan trends" (p. 106). Along these lines, Simon Naylor (2010) and Ian Inkster and Jack Morrell (1983) have also highlighted this uneven geography of scientific culture in the UK.

Consequently, science is not understood or received evenly at a nation-state level, as ideas of civic epistemology, states of knowledge and other co-productionist ideas might suggest. Instead, it is bound up in numerous spatial interactions entrenched in the production, progression and circulatory behaviours of scientific activity and knowledge and shape the construction of scale itself (Camprubí and Lehman 2018). To achieve national homogeneity or even national reach – numerous spatial barriers, like variable cultural and social engagement, appropriate infrastructure, or economic support, must be first overcome.

Advancing this further, Livingstone (2003) also notes the normative role of scientific knowledge and practice in shaping national identities. For instance, Livingstone knots together examples of national laboratories, national academies of science, national surveys, the development of new expertise in mapping and surveying with the reformulations of ideas of nationhood and national identity through the demarcation of territory, managing cultural, financial and demographic resources and pursuing national scientific goals. Notably, concerning co-production, these geographers of knowledge are aligned to the constitutive form of the co-productionist idiom (Jasanoff 2004b), like Latour (1991), which focuses on processes of emergence, stabilisation, intelligibility and portability of knowledge. However, some geographies of knowledge scholarship can also be viewed as aligned to the interactional models of co-productionist enquiry, dealing with the spatial aspects of how we know what we know, how we organise and reorganise ideas of reality and expression, expertise and questions of authority or power.

For example, the role of place can have a strong 'pull' on (re)shaping scientific practice. As Raf De Bont (2009) states, place "plays a role in orientating the scientist toward a particular type of research and to a particular use of the spaces at his [sic] disposal" (p. 221) in his study of marine stations in Naples and Wimereux, he states how the social composition of labs can and do influence the type of research conducted within them through the "ecologies in which they work" (p. 221). Notably, this overlaps with the notion

of epistemic lifestyles (Shackley 2001). Whilst Shackley doesn't emphasise the 'pull' of the site of climate modellers, the site is entangled with the social composition, and the social composition is made up of guiding values, social norms, particular research, value and legitimisation of expertise or authority. Notwithstanding, the work cultures and dynamics that in turn construct the space as a place of shaping scientific practice – like the laboratory or the field (Gieryn 1983, 1995, 2006) or emphasising the institutional and organisational variability of knowledge production (Gibson 2019; Borie et al. 2021).

Other works have dealt with the social geography of exclusion in historical geographies of science (Schaffer 1998; Shapin 1988). Simon Schaffer (1998) uncovered that in an attempt to reduce external disturbances on measurements in physics laboratories in the late 19th century, a model of the country house was used as part of a solution to improve insulation from wider influences. This exposed a "privileged and carefully demarcated milieu" (p. 153) that counter-intuitively turned the 'view from nowhere' into a highly localised, exclusive and isolated space of authority and expertise-making. Almost a decade earlier, Steven Shapin (1988) analysed the network of sites associated with the experimental work of the early Royal Society, in which he determined connections between knowledge production and the spatial distribution of participants. As a result, this led to "irresolvable problems of trust" where some people in society have access to witness phenomena and others do not. Those that did have access were granted such privilege "through the tacit system of recognition, rights, and expectations that operated in the wider society of gentlemen" (p. 389). Thus, access to early experimental works and spaces was highly exclusive and created a reality of science and progress through the eyes of witnesses, their knowledge claims and verification. These works critically reveal important historical understandings about the social constitution of knowledge-making practices, verification, authority, and science's normative claims against non-science and non-scientists (Gieryn 1983). Similarly, Warde et al.'s (2018) emphasis on the coming together of natural and earth sciences at conferences to explore the human impacts on the natural world in the 20th-century post-war period, in part, demonstrates the exclusivity and channelling of newly emergent concerns through physical science epistemologies by participation and exclusion of social scientists and humanities researchers. On the other hand, it also reveals how spaces – like the conference – (re)gain power as spaces of authority and expertise building and sharing (Craggs and Mahony 2014). Geographies of knowledge scholarship attend to

the (often neglected in science studies) role space and place have in producing and circulating knowledge, yet the links to co-production are for the most part unexplored.

3.3.1. Geography and co-production

While geographers of knowledge have often been more closely aligned with constitutive forms of co-production, Martin Mahony and Mike Hulme (2018) have sought to demonstrate a new approach to investigate the intersections of space, power and knowledge-making in an attempt to reconcile the unevenness between co-productionist analysis and geography of knowledge scholarship. They propose the idea of 'epistemic geographies of climate change' to attend to the spaces in which climate change figures through imaginations, discourses and framings, beyond the existing interest in circulation, emergence and stabilisation of knowledge. In doing so, geographers and science studies scholars (including historians) can more fruitfully recognise and attend to a more symmetrical analytical treatment of co-production – both constitutive and interactional forms – when investigating spatialities of knowledge in the (re)construction of society. Notably, this kind of work speaks to the aims of conceptualising an 'ecology of co-production' sensibility; as a way of reconciling and uniting disparate works and ideas to understand how representations and understandings of the natural world, the relationality of ideas, tools and methods attain stability and power through the mutual construction of the 'environmental sciences' and society. This also aligns researchers to the spaces of normative co-production in relation to the broader philosophical-analytical modes as interrelated and mutually constitutive in the production of knowledge and order.

3.4. Toward an ecology of co-production

I have outlined so far, the complexity and entangled nature of mutual construction of the normative and the epistemic, acknowledging the diversity of tools with which to uncover this whilst emphasising the spatialities of these interactions. I have also outlined the importance of 'doing things together' as means of knowledge-making for the

'environmental sciences' and the need to emphasise the relationality and spaces of these approaches if we are to address both the historiographical and conceptual gaps of **Chapter 2**.

Notably, researchers have made several moves in attempts to more fully engage with relational co-productionist approaches (Beck 2019; Chilvers et al. 2018). The co-productionist toolbox supports an investigation of the variable intersections of science, technology, and society through often passive, implicit, and usually difficult to discern collectives of social ordering and action (Chilvers and Evans 2009). Importantly, the toolbox reveals the pervasive embeddedness and entanglements of science, technology and society and can be unified through an ecology of co-production sensibility. However, the concepts in the co-productionist toolbox are often associated with the nation-state (e.g., civic epistemology compared between nations, and the sociotechnical imaginaries of how particular visions engulf and shape national social and political order). There are some attempts to discern co-production on a global scale (Miller 2004; Jasanoff 2011), yet to call these 'global' is to obscure knowledge and social orders on the periphery, e.g., the epistemological systems and ontologies of the non-West. Shackley (2001) and Borie et al. (2021), between two decades, have made important moves in illuminating the importance of institutional cultures and epistemologies in the co-production of knowledge and the social order in which it moulds and is moulded. Yet there are notable gaps concerning these works' material, practical and theoretical application and how to acknowledge multiple, ongoing co-productionist practices across multiple spaces, scales and through different 'mangles'.

So, how might we piece together the co-productionist toolbox to provide new perspectives in historical and social studies of science? How do we combine co-productionist sensibilities and historiographic case studies in ways that make sense, and are meaningful and generative?

Firstly, the works in the previous chapter have demonstrated the fluidity of the 'environment' as an idea and object of concern. Pinning it down to make sense of it depends on the tools used for the pinning and the position from which one approaches it. For instance, a meteorologist would bind the environment and investigate it differently from an ecologist. As might same-discipline researchers in Brazil, the UK, Bangladesh or Vietnam. It is apparent, then, that the production of science, specifically, in this case, the

'environmental sciences', is not homogenous and is contingent on the normative and epistemic aims of the researcher, the institutional epistemology in which they are situated, the civic epistemologies in which they are embedded and the guiding visions of desirable sociotechnical futures under which they labour.

There are shared interests between both histories of science and STS researchers (Jasanoff and Dear 2011) in studying the 'environmental sciences'. Whilst historians of science may resist a foray into or from STS researchers (Daston 2010), STS has been inter- and cross-disciplinary since its inception (Jasanoff 2013) – taking methods, concepts and ideas, and moulding them into their own to investigate the relations between science, technology and society. Histories of the 'environment' and knowledge are trans-local, multi-scalar and of multi-disciplinary origin. As products of doing things together that both are shaped by and shape knowledge and order, the 'environmental sciences' are ideal objects of study in which to deploy an ecology of co-production sensibility to carefully attend to the multiple and relational co-productions at play.

An ecology of co-production presents a new way to guide research, positionality and analysis. Co-productions are emergent, relational and ongoing – everything, I contend, is co-produced and making sense of this effectively has been largely missing in existing work. Therefore, I intentionally and deliberately set out to explore four key themes: spaces and interrelations, diversities and exclusions, histories and constitutions, and responsibilities and affects.

Spaces and interrelations: To move beyond studying discrete bounded moments or spaces of co-production, an ecology of co-production emphasises attention to the intersecting spatialities and relational aspects on multiple and ongoing co-productions. Similar to the work in geography of science, a relational-ecologies approach can emphasise how specific spaces of co-production are deeply interrelated and entangled e.g., shared actors, knowledges, aims and organisation that then dictate how forms of knowledge are validated, legitimised, used, presented and scaled up or down. This has deep implications for how and what knowledge is institutionalised, what forms of resistance are met (like existing civic epistemologies), how ideas or imaginaries become collectively held and how new orderings of society emerge (or not). Opening up and tracing the relations between spaces of co-production will help us transcend silo framings and existing understanding to enable greater

awareness and attention to the diversity of actors, knowledges, values and aims in new and productive ways (Maas et al. 2021).

Diversities and exclusion: Intentionally seeking out diverse or excluded forms of co-production can be transformative in shaping the ways in which we know and operate in the world and widening the landscape of co-productionist analyses. Both forms of co-production are bound by assumptions, normativities and geographies that by their nature are exclusionary. History of science and science studies have usually focused on important and hagiographical stories or central accounts of co-production and relevant actors from the outset. Yet, there is a vast understanding to be had when attempting to demonstrate how the 'mundane' often figures in knowledge and world-making practices (Michael 2016), making the strange familiar (Schaffer 2021) or unpacking co-productions on the periphery (Medina 2013). There are numerous productive and meaningful co-productions that continue to (re)make knowledge and social order but are never highlighted. An ecologies approach can offer promising ways of attending to these diversities, spaces and the interrelations with wider co-productions.

Histories and constitutions: The two preceding sections point us to varying spaces and scales of co-production but as mentioned above, deliberate and interventionist forms of knowledge co-production are not novel or contemporary. Rather in some sense, knowledge is always co-produced between different actors, knowledges, materials, institutions. Historicising co-production can alert us to differing temporal scales and make sense of how moments of co-production become durable formations in society and space, like how states of environmental knowledge came to emerge as inter/trans/multidisciplinary endeavours. An attention to the diverse histories of co-production can demonstrate the different realities through which new ways of ordering and knowledge-making come about (Trischler 2016) and how they do not come about in isolation, but rather come amidst multiple and conflicting forms that compete to (re)shape ordering of society and structures of knowledge (Renn 2020).

Responsbilities and affects: An ecologies of co-production sensibility prompts more attentive and careful approaches to the practice and analysis of co-production. Drawing

from the interpretive and critical sensibilities of philosophical-analytical forms in understanding the transformative and unintended consequences of power, inclusion, politics, future making and ordering and applying these ideas more fully into the practice and processes of normative-procedural modes. Rather than knowledge co-production being a discrete event with intended aims, or gatekept by particular scholars, it goes beyond any prescribed conditions e.g., there are longer lasting effects, consequences on the wider co-production of knowledge and order that cannot be described as 'good' or 'bad' co-production – co-production is an emergent process, ongoing and transformative. Utilising an ecologies approach can direct to both present and past co-productions in this vein to explore what questions of responsibility and reflexivity were present in previous engagements – like the nation-centredness of power and order (Jasanoff 2005) or the dominance of North America and Europe in histories of the 'environmental sciences'- in which this project resides. This final theme is more of a reflexive consideration of the implications of co-productionist work both my own, the works I have explored and the work that is ongoing, rather than a prescriptive suggestion.

ENV is a stellar case in which to enact and think through this approach as part of a university institution with its own relational geographies of knowledge making and circulation (Meusburger et al. 2018). As outlined in the introduction, ENV has been one of the top institutions in producing and sharing the 'interdisciplinary environmental sciences' from local to global scales, both at home and abroad and through many changing research cultures and aims of the 'environmental sciences'. Paradoxically though, there has been little attention given to the role of universities in the making, stabilising and circulation of this new form of knowledge despite the role universities played in the disciplining and institutionalisation of knowledge (Kohler 1981; Weingart and Stehr 2000).

In everyday and indeed in academic life, we often see the visual and material representation of things we are trying to know, see or view; akin to witnessing a cluster of mushrooms on the forest floor. If not privy or participating, most aspects of intellectual world-making happen behind closed doors and an outsider would only see a cluster of mushrooms that is so to speak some form of *knowledge*. However, for the mycologist, underground is a tangled web of mycelium that feeds, connects and shapes the flourishing of the mushroom, and connects it to all life on earth. In this vein, studies of science have

sought to show how knowledge is not the end-product but instead a collective, in-flux, piecemeal process. No longer are studies of scientific achievement, revolution or individuals useful as we have grown to re-understand and revalue the importance of situating historical details or stories in the contexts in which they emerged, recognising the imprint of the places they are embedded in and inclusive of all the actors involved. Rather what is interesting is studying the mycelium-like webs that help to produce or hinder the production and circulation of knowledge. The advent of the co-productionist idiom (Jasanoff 2004b) and the co-productionist toolbox has helped scholars uncover, I would argue, clusters of mushrooms and their underlying mycelium. I now propose that an ecology of co-production can emphasise the wider, entangled and relational co-productions of co-production – like a wider mycelium structure that weaves and wanes throughout the undergrowth and deeper underground. Knowledge, society, technology, politics, culture are not separate arenas in which daily life operates. Instead, the ways in which we know and operate in the world are bound up with the ways in which we have already chosen to know and structure it. Thus, life and reality are locked in a rich entanglement of the epistemic and the normative – co-producing categories of ordering, knowing and understanding.

The 'ecology of co-production' approach is intended to further this specifically by revealing the complexity and variability of co-production/s across multi-spatial and multi-scalar aspects throughout past moments in the making of the sciences of, and concerned with, the 'environment' in ENV. There is plenty to be known, uncovered and demonstrated through writings, film and other forms of representation – yet the histories and knowledges that we share are bound up with our pre-configurations, imaginations, values, ideals and histories that shape what is knowable to us, and what is possible to be known by us as researchers or writers. Histories that make the familiar strange and the strange familiar are arguably more useful in unsettling our narrow visions of past worlds, organisations, disciplines and practices and contribute to fuller understandings of the messiness, complexity and random orientations of the world. Notwithstanding, they can also point out the structural persistence and uneven orientations of the world that may often be obscured from view and lock particular legacies in place – like one that focuses on scientific interpretations of the newly 'conceived' environment.

3.4.1. Method and approach

To support my conceptual framework, aligned with historical and STS methods, I employed archival work, interviews, documentary analyses and some minor scientometrics to map my topic of enquiry (ENV) and structure my empirical work around the themes outlined above. It is worth briefly reflecting on how historical methods and approaches, in recent years, have been subject to more conceptual and epistemological critical reflection before exploring how and why I used these methods.

An archive is an important source of information for historians. Nonetheless, there are ongoing debates about the power of archives in creating new stories and for what purpose; historical data can come from archives, but a purposeful creation of an archive can equally create new histories (Brothman 2001; Hodder 2017; Lewenstein 2006; Manoff 2004). Documents in archives can emphasise particular stories and remove others (Manoff 2004; Lorimer and Philo 2009) as different kinds of 'remembering' like data deposition or trail following can promote the different kinds of stories told. Consequently, the absence of material is as revealing as an abundance of material (Hodder 2017) and can generate important reflections on the intentionality of absence and the power of the creator (Derrida 1995), the serendipity and contingency of historical knowledge – utterly dependent on saved material, retold stories, or preserved objects. With this in mind, the archive is more than a repository of data but a central figure in the production of historical knowledge – both as a reservoir for extraction and a mould in which preconfigured forms and stories are channelled. To counter this, aligned with the ecologies sensibility, I embarked explicitly on including unofficial documents – both institutionally held in ENV and personal files from my research participants – that may be seen on the margins or periphery of historical research.[16] I circulated a call through the department and through a network of interviewees for any historical material that participants were willing to share. Historical material, I stressed for my research, meant anything beyond the past 10 years. The intention behind this was to include a more ethical and just representation, in pursuit of a more responsible intervention regarding input from my respondents and institution of interest, to share the stories that they felt might be relevant, or necessary, rather than

[16] Alongside official archival sources such as The Zuckerman Archive and The National Archives, UK.

myself imposing historical order onto a blank canvas with the potential power involved in constructing an institutional history. Although of course, the interpretations, final judgement and write-up was entirely my own work.

Whilst the archive can hold and supply many data in multiple forms, it does not provide everything (McGeachen et al. 2012). To supplement this co-creation-esque method, I conducted semi-structured (and sometimes multiple) interviews and oral histories with over 20 retired ENV researchers, technicians, alumni and ex-research partners, all involved with ENV sometime between the 1960s and the 1990s. Interviews are important sources of historical knowledge – particularly when they relate to those involved with the event or moment of interest. As a method, they can fill the gaps associated with absences in archival material, in any form (Hodder 2017). By being able to speak with participants about recent history of science phenomena, events, stories (and co-productions) has the merits of direct recollection without the need for interpretation of sources or filling the gaps. Although, there is a risk of anachronistic or hazy recollection without cross-source verification (Lewenstein 2006).

Nonetheless, interviews or oral histories with scientists can also be important research material in their own right. Researchers can learn more about what scientists 'do' and the social worlds in which they operate and which they produce (Weiner 1988). Steven Shapin (2008) notes how interviews with scientists can also reveal more internal understandings of (inter)disciplinary structures and organisations that may not be found in a documentary analysis or aired in public. Paul Merchant (2019) has recently drawn from his extensive work contributing to the British Library Oral History of Science collection and has outlined the promise oral histories and their content hold for understanding the social processes of individual scientists. Merchant (2019) notes that there is much worth for historians of science to explore through oral histories how scientists view their work, how they view the success of their work, their accounts of becoming scientists and more generally about personal narrative in science to promote a more historical sociological understanding of scientific biographies beyond hagiographic reports of achievement and success. In this vein, researchers can explore the ideas, values, or beliefs that guide work and shape epistemic lifestyles (Shackley 2001) directly to discern scientists' normative and epistemic aims.

Moreover, Brian Williams and Mark Riley (2020) have explored the promise of individual and subjective accounts that oral histories can provide for environmental history. There are numerous ways that oral history can support environmental history that are currently, they argue, underused. Oral histories can dislodge the reliance on archives and expand the co-construction and participatory engagement in histories of the environment, focusing on the voices or stories and expertise that can be often excluded. Further, oral histories can foreground the entanglements of social and geographical relations within environmental histories by engaging with the stories of people involved in their own terms.

Overall, using interviews or oral histories in combination with archival and documentary analyses will, I argue, support the ecological sensibility and attention outlined above if operationalised appropriately. My own questions (see **Appendix**) were a guide in which to stimulate and begin deep and reflective conversations with those who had been previously involved with ENV and for each participant, each conversation embarked on its own direction in different ways mostly exploring the practices, evolution and imaginaries of their work and careers. The questions needed be broad enough to give each participant a sense of where our conversation was heading whilst minimising the risk of interviewer bias. Critically, qualitative coding of the interview transcripts enabled the themes above to be flagged to support interpretative analysis or further conversations at a later date.

Additionally, a combination of methods enables cross-verification of accounts and, in some cases, can help guide conversation and recollection (for instance, discussing methods in a paper or ideas behind research projects). The method of discussion-based, loosely structured interviews (and sometimes repeated interactions) with respondents attends to the responsibility, and ethical considerations researchers have toward their respondents in providing accurate historical accounts (Cantor 2006). Moreover, it also demonstrates careful attention to the wider implications and transformative properties of knowledge it promotes, the spaces it helps define and circulate between and within. This kind of closeness with respondents and material is only possible if participants are alive and thus, would necessarily be aligned with more recent histories of science.

However, this type of recent history has been dealt with substantially in a collection edited by Ron Doel and Thomas Söderqvist (2006). The collection explored numerous pertinent issues concerning the writing and telling of recent histories of science or technology. Within, questions concerning positionality (Lewenstein 2006), voice (Cantor

2006; De Grieff a and Olatre 2006), methods (Doel and Henson 2006) surface and new directions are laid out with topics to consider or reflect on in one's own work. For this study, a critical chapter is the ethics and responsibility of 'commissioned' histories (Cantor 2006), given my affiliation and funding with my topic of interest, as I will now go on to explain.

3.4.2. Ethics and positionality

This project is in a unique position. It is funded by the Faculty of Science at the University of East Anglia. It deals with The School of Environmental Sciences (a department within the Faculty of Science) as its primary case study. It is conducted by an ENV graduate who is still a member of the School. Written like this, it starts to sound a lot like a conflict of interest. The issues of 'commissioned' histories and unease from the history community, as outlined by David Cantor (2006), are valid and relevant here.

Cantor explains that histories that are written about funders can be susceptible to manipulation and are at odds with the critical distance that academic histories strive for. Yet, Cantor notes the hostile funding conditions (even back in 2006!) and recognises that rejecting commissioned histories can be detrimental to pursuing academic careers, even if some historians have now distanced themselves from them. The distrust comes, principally, when funders commission histories for ulterior motives – to demonstrate unwavering success, or more insidiously, to promote false stories, like that of the tobacco industry (Oreskes and Conway 2010). Commissioned histories are more suspicious, Cantor argues, in areas with vested commercial interests like the medicine and tobacco industries. On the other hand, being involved in an institutional history from within, I would argue, has enabled access to (or ease of access) to participants and personal documents an 'outsider' may not be privy to. Nonetheless, I attempted to introduce my own critical distance, taking stock of this. The empirical chapters that follow all deal with moments before my birth and before my supervisory team became involved with ENV. Moreover, my interviewees were with the staff that I had not had substantial (or any) contact with before starting the doctoral programme, nor did it relate to any of the subjects I had studied during my undergraduate time in ENV. During discussions with ENV's administrative team, I also was given the freedom to pursue, explore and write as I saw appropriate and with no external influence or comment from them. Further, my funding was not guaranteed. I was

enrolled in competition-based financing from the Faculty of Science and was up against four other SCI-based PhD projects. I was, thankfully, successful. Consequently, I would assert that this has given me enough critical distance to remain an outsider within.

Practically, as this was not a conventional commissioned history – celebrating ENV's successes in a teleological manner - but rather an exploration guided by an ecologies of co-production sensibility, I had to be selective and partial in my cases. I began by doing an open call for archival material (which returned an unofficial bundle of material from the School's administrators tabled in the **Appendix**) preliminary interviews and document scans to construct a timeline of interest for ENV. I then chose four 'co-productions' to zoom in on that I felt represented the ecologies sensibility; the origin of ENV and its historical emergence, the early working years and the spaces and interrelations of 'doing things together', the formation of CRU as a diverse space of knowledge-making across multiple scales not originally involved in ENV's founding, and the often excluded history of ENV researchers' local involvement with the environmental management of the Broads. The justifications for each will be outlined at the beginning of each chapter and each chapter demonstrates multiple co-productions in multiple spaces across varying scales. As I have been selective in my cases, aligned with the relational ecologies approach, I have missed out numerous important research areas like most of the earth sciences, meteorology and oceanography, and some of the more recent advances in the social sciences. The chapters are also not methodologically equal – due to participant access, document access and COVID-19 some rely more heavily on interviews whereas some are more archive centric. Importantly, the thematic and interpretive analysis, aligned with the framework, remained the same for whatever data I obtained.

The rest of this thesis now is laid out as follows. In the next chapter, I explore the origins of the 'environmental sciences' in ENV at UEA in the post-war period and the co-production of science-policy and higher-education (HE). I follow this with an enquiry into the early founding years and how ENV worked in practice as both a new institution and new inter/discipline as numerous scientific disciplines worked together. I then scale up looking at how a particular research group in ENV, CRU, helped co-construct and co-produce global knowledge and framings of climate change and science. I then finish my empirical work on a more local note, exploring how different ENV disciplines helped discern the Broads as an 'environment' of concern and through interactions with non-scientists and stakeholders,

changing conservation policy and producing innovative forms of environmental management. I conclude by discussing the future of knowledge making for the environment in the Anthropocene, considering what worlds have been made as a result of ENV, and assessing where ENV might go.

4. Imagining the 'environmental sciences': Solly Zuckerman and the emergence of ENV

This first empirical chapter begins my exploration into the history of ENV by exploring the social processes and historical contexts that cultivated the very idea of a university department focused on the 'environmental sciences'. In doing so, I demonstrate multiple co-productions, predominantly on the nation-state scale vis-à-vis the mutual construction and development of UK science-policy, HE and a new environmentally orientated technocratic vision of society (Wilson 1963) imagined between scientists, civil servants, politicians and academics.

To understand the social, historical or geographical factors and the material and institutional arrangements re/shaping how, why and what vision of ENV came about in 1960s Britain at UEA is to understand the historical processes and moments concerning what the 'environmental sciences' were in ENV's conception and what they were intended to be for.[17] If how we know the world is intimately bound up with the ways in which we have already chosen to live it (Jasanoff 2004b), then any form of institutional history is shaped by the ways and visions in which that institution is imagined, made possible and by the pathways that led them to it becoming a material reality.

In this vein, I draw from the co-productionist toolbox to explore how the vision of ENV was co-produced through the future-making powers and imaginations of a small group of science advisors, and the material realities of science and technology in post-war Britain. I employ Jasanoff and Kim's (2009, 2015) concept of 'sociotechnical imaginaries' to elucidate how an idea of ENV and the 'environmental sciences' came about as a vision of a desirable future and of transformative normative and epistemic change, before becoming embedded and extended through the institution of ENV. I go on to explore how the sciences of the 'environment' or in Zuckerman's vision, the 'environmental sciences' emerged, as a new and interdisciplinary science, in response to changing socio-scientific and political concerns embedded in and constitutive of an emerging technoscientific government, and also

[17] Although, origin histories reveal the speciousness of delineating and framing origins as discrete or bounded events of historical interest. Instead, historical works on origins emphasise complexity, long-historical moments and contexts and the blurring of what may be considered key events, developments, interactions and so, on both pre- and post- the moment of historical interest, in flux and often evolving, see Shapin 1996; Fleming 2016; Benson 2020.

materialised collectively - co-produced - between discussions from various types of actors involved in and around the government machine. Importantly, this chapter provides foundational ground for ascertaining how and why a particular vision of the 'environmental sciences' came to be in post-war Britain, during a time of strong central planning, and how it emerged in ENV and what for, acting as a lynchpin to explore the other research questions throughout the rest of the dissertation.

Visions of desirable sociotechnical futures are thought to often begin from a vanguard vision (Hilgartner 2015; Storey 2015). Consequently, this chapter is focused on exploring Solly Zuckerman and his multifaceted role in the UK government to explore conditions and contexts that contributed to the vision of a university department associated with the 'environmental sciences'. Zuckerman is thought to have coined the term the 'environmental sciences' (Warde et al. 2018), was an influential scientific advisor to the British government and proposed a new School of the Environmental Sciences for the new UEA. This chapter begins by delving deeper into the background of Solly Zuckerman - both his social and intellectual background - before then moving on to three key aspects of his career (operational research during WW2, scientific advice in government, and higher-education policy) to discern how and where nascent ideas or preconceptions of ENV and the 'environmental sciences' may have emerged, shaped by the challenges he was aware of and making known, and the infrastructural and institutional contexts in which they came about and helped to create. To conclude, I illustrate how Zuckerman's eclectic career, fledgling authority and research practices within a conducive technocratic government context posit the vision of ENV as a long-term and durable sociotechnical or socioscientific vision of desirable futures rather than a reactionary response to challenges in government and politics. Moreover, rather than elevate the role of the individual or vanguard (Hilgartner 2015), I use the ecologies framework to foreground the collective processes of co-production that shaped and were shaped by Zuckerman's career, his work and discussion with others which had ultimately informed the constitution of the sociotechnical imaginary of the 'environmental sciences'.

Finding an entry point in historical writing is a somewhat arbitrary task but doing so can help to orient and align the historical narrative in a way that is easy to understand for the reader. Therefore, establishing a rough starting point for this thesis through an

exploration into the emergence of ENV and the idea of the 'environmental sciences' is where I begin.

4.1. Solly Zuckerman: a vanguard vision?

Solly Zuckerman (1904-1993) was a zoologist and anatomist before becoming involved with operational research during WW2 before then eventually becoming a scientific advisor to the British government. Zuckerman was born in South Africa and had initially begun training in medical school to help him leave South Africa by first studying in Cape Town before moving to University College Hospital in London (Rosenhead 1993; Burt 2006). However, before leaving South Africa, Zuckerman began to become interested in the anatomy and social behaviours of apes (Zuckerman 1926). Eventually, this interest guided him away from a medical career. Zuckerman took up a position in the London Zoological Society in the mid-1920s and then a fellowship at Yale to study primate physiology before returning to England for demonstration work in Human Anatomy at the University of Oxford. During this time, in the pre-WW2 period, Zuckerman's interests spanned from primate anatomy and the influence this had on behaviours of reproductive processes and formation of eggs, to relationships between the pituitary and hypothalamus glands and primate evolution, where he then became Professor of Anatomy at Birmingham University from 1939.

Zuckerman was a bright student and even brighter researcher and became well-known amongst his peers, early on, as a cross-disciplinary thinker (Burney 2012). Zuckerman was also highly sociable, enjoying parties and intellectual conversation that went onto (re)shape his thinking and way of life (Zuckerman 1988; Burt 2006). In 1932, he published *The Social Life of Monkeys and Apes* which sought to demonstrate what he believed were the deterministic characteristics of primate behaviour and, thus, social order in apes. The scientific method and knowledge could give empirical legitimacy to speculative claims that had preceded him (Burney 2012). For Zuckerman, the primate mind and behaviour were determined by the "physiological events" that shape their behaviours and actions, e.g., the monkey society is based on dominance, physical strength and sexual power (Zuckerman 1932: p. xi-xii; see also Bernard and Bernard 1934 and Burt 2006). In a similar vein, humans experience, understand and act differently to a range of stimuli and participate in society through language and collective memory – Zuckerman posits that "cultural phenomena may

not.... prove to be absolutely different from physiological events" (Zuckerman 1932: p. 19). Zuckerman's ideas can be understood as foregrounding human society and behaviour as deterministic variables shaped by a range of physiological, social and cultural factors. Interestingly, despite this Zuckerman remained cautious about projecting his research claims for comparison with humans (Burney 2012), as the only comparative similarities between humans and other primates, for him, were menstruation cycles (Haraway 1978). Yet, as I will go on to argue, Zuckerman's deterministic ontology was paramount in shaping his earlier views on the role of science in shaping human society. Importantly, *Social Life* was widely well-received in many areas of research: sociology (Bernard and Bernard 1934), psychology (Tinklepaugh 1932; Munn 1934), anthropology, as well as from anatomists and zoologists (Hartman 1932), although it was scantly received by primatologists themselves and widely criticised for its theory (Burt 2006). Nonetheless, *Social Life* demonstrates the nascent interdisciplinarity of Zuckerman's thinking and ideas by drawing from intellectual traditions like animal physiology, human palaeontology, physical anthropology and mammalian sociology (Haraway 1978), despite his rather deterministic conclusions on primate behaviour and society.

Notably though, Zuckerman is often found in literature as an actor of historical interest due to an intermediary and advisory role he played between science and the state and was a key actor, with much influence during a time of critical central planning by the British state. Typically existing work focuses on his operational research and advisory role in bombing strategy during WW2 (Edgerton 2006; Burney 2012; Bonneuil and Fressoz 2016), his narrow view of 'technologists' in enabling nuclear warfare and arms (Spinardi 1997) or his many advisory roles to the government (Agar 2003; Gummett 1980).[18] Philip Gummett described him as one of the 'giants' in government science due to the authority and command he held in government circles and the far-flung reach he had with political contacts throughout West during the advisory role he played in UK government between the 1940s-1970s.[19] The UK government enabled intellectuals like Zuckerman and others to circulate between circles of strategic and scientific interest as advisors (Sheail 1995a) as scientific advice became a highly sought-after tool for government strategy and planning in

[18] Not forgetting Burt (2006), who studied Zuckerman's early career in primatology.
[19] Formally until 1971.

the post-war period. The phrase, 'Send for Solly!' was often quipped in the British press to answer any difficult scientific or strategic decision the UK Government required.[20] The status of Zuckerman as the key scientific advisor in Britain was emboldened by his appointment as Britain's first Chief Scientific Advisor to Labour Prime Minister Harold Wilson in 1964. Consequently, Zuckerman became a symbol of the technocentric intentions of the Labour government as the publicly visible lead in the government-science-policy machine. Zuckerman's tasks included discussing, researching, creating committees, and advising on a myriad of government concerns that he and others thought should be of interest for future development and planning in society.

As I go on to explore, Zuckerman's presence in government helped to co-create the 'scientific advisor role'. The new scientific advisor role was crucial in discerning and delineating what was to be understood as new 'environmental' concerns, how they were framed and how these concerns might be productively dealt with in national (and international) arenas. As a scientist-cum-military and government advisor, Zuckerman's way of working can be viewed as the early inceptions of what was to become a distinct British civic epistemology – surrounding the authority and trust of the British population in the 'general expert' role - within technocratic government (Jasanoff 2005). As a result, knowing that Zuckerman supposedly coined the term the 'environmental sciences' (Warde et al. 2018) and proposed ENV as a new School of research and teaching whilst acting as a scientific adviser to the UK government (Sanderson 2002) positions Zuckerman as a key figure in at least starting to understand how particular visions of the environment are co-produced with particular visions of desirable futures. To do so, I follow Zuckerman's journey between collectives of science, war and government. I explore how each (changing) collective may have altered, imprinted and ordered Zuckerman's ideas to problematise a new 'environment' and vision of society that was to embrace new 'environmental concerns' through scientific interpretation.

[20] The Last of the Moguls, The New Scientist, 29/10/1964.

4.1.1. Zuckerman in War

Before the Second World War, scientific aspirations and practices were concerned mainly with 'pure' or 'basic science' (Science in War 1940). These were essentially scientific efforts that attempted to understand, research and try to advance the 'basic' scientific principles of disciplines (like biology, chemistry and physics) and their 'pure' curiosities of a seemingly natural world and its phenomena, distinctly separate from social, political and military worlds (Schauz 2014). Applied uses of scientific knowledge came in the form of justifications for imperial agendas; through economic policies for landscape, population (un)settlements, health and hygiene, observation and territorialism, and broader social control (Anker 2001; Mahony and Endfield 2018; Benson 2020). The full social uses of science in government at home were yet to be realised or imagined by the majority of both scientists or those in government.

Nonetheless, WW1 laid the groundwork for a closer relationship between science, technology and the state through the development of poison gases, industrial production of materials and medicines, and the emergence of an 'environment' as an encased surrounding, that could be used for all kinds of terror and damage on its inhabitants (Sloterdijk 2009). Yet the 'soldier' and the 'scientist' were not yet symbiotically involved, with the benefits of scientific knowledge not fully discerned or harnessed (Roland 1985), nor was the full grasp of 'environmental' strategy in warfare recognised. Nonetheless, some scientists began to recognise their worth to the state even if the government had not. As a result, a resurgence emerged after the post-WW1 depression and with a looming WW2 – scientists began to reckon with doing politics (Leggett and Sleigh 2016). Zuckerman was amongst this group believing that science could support military and social endeavours and wanted to add empirical detail to these claims.

Zuckerman and colleagues anonymously published *Science in War* in 1940, which has been interpreted as paving the way for operational research to become a major effort in WW2 (Rosenhead 1993). *Science in War* (1940) lambasted the disregard and poor organisational capacity for science and technical knowledge in existing government operations of the time, taking particular dissatisfaction in the possible absence of the scientist and technical expertise for the looming war effort. Science, for the authors, can not only provide ad hoc and immediate responses to challenges but can also survey the present

situation, prophesise future challenges and try to prepare against the unknown unknowns. Notably, the authors draw on various examples of success from applying scientific knowledge for social and military operations (e.g., Haber's synthetic ammonia for nitrate substitution in agriculture and bombs or the biological and psychological insights into camouflage efficiency). The authors then claim that scientists and scientific knowledge may support livelihoods, health, and well-being during wartime through improved land management, industry, and the economy. For instance, land use and food security were vital to ensure the general population's health and, science, they argued, could shed light on improving soils, improving seeds (quality of crop/resistance to pests) and maximising agricultural output through fertilisers and herbicides. They also argued that reducing war to a 'logical' scientific operation, e.g., strategic bombings for maximum socio-economic damage, would improve success in war efforts. The authors strongly believed that the scientist's rational, logical and inquisitive mind could generate empirical understandings, practical solutions and foresee challenges that escaped the less technically trained civil servants, ministers, and military personnel. After the book was published, several scientists, including Zuckerman, were recruited for the war effort.

Science in War emerged from Zuckerman's 'Tots and Quots Society' of scientists that met to discuss the role of science in society, featuring a group of young and to-be-world eminent scientists.[21] The group would meet regularly to discuss, challenge and propose ideas, solutions or research agendas that positioned science as a way of alleviating UK society's challenges. Science could, for the society's members, become a key input for societal development and possible futures insofar as improved knowledge and scientific thinking could create new realms of the imaginable and the possible (Taylor 2004). The promise of science had made itself apparent through the advancements laid out in *Science in War* and could radically improve other aspects of social order if utilised by government or ministers in positions of authority and power.

Despite the later success of the group's individuals, Zuckerman never intended it to be so impactful – despite continuously proclaiming the exceptional foresight science and

[21] But not only scientists, Hugh Gaitskell, an economist and then Labour leader in 1955 and Richard Crossman, a lecturer in Classics, then later on Labour MP, were also involved.

scientists could possess – as seen in a diary entry in 1964 about a BBC programme on the society,

> I was made to appear a very far-seeing person who knew that science could contribute to government... when in fact the only reason why the Club was started was to arrange an additional focus for gay and bright conversation. The serious purpose of the Club only emerged *accidentally* as it were.[22]

Nonetheless, the group mirrors Zuckerman's two interests – socialising and intellectual conversation and, importantly brought together a range of individuals who would mostly go on to alter Zuckerman's career positively. One of the group's key members was John Desmond (JD) Bernal, a Marxist crystallographer from Cambridge University. Bernal used to lecture regularly to the group on the social aspects of science and developed a close personal and intellectual relationship with Zuckerman. Bernal also strongly believed science to be a solution to many – if not all – problems in the world and was an enthusiastic advocate of the Soviet science programme. Bernal authored a book titled *The Social Function of Science* (Bernal 1939) which was widely well-received. The book positioned science atop a 'citadel', trickling down into society as a solver of all 'modern' problems, but could only work, for Bernal, in a Marxist or centrally planned society. Interestingly, many of his ideas (such as the usefulness of research, applied research, public engagement, and compiling estimates of government funding (Pielke Jr. 2014)) have become integral to science-policy debates today in many non-Marxist settings. Zuckerman notes that Bernal's view on science and their relationship greatly influenced his work, understanding and visions of how science should operate in and for society or government (Zuckerman 1988). However, the duo went their separate ways in later life due to Bernal's increasingly extreme views on communism (Zuckerman 1988). The emergence and presence of scientists involved in Zuckerman's group does, however, demonstrate the exclusivity and privilege of being involved in such a powerful group – a handful of scientists with distinct leadership and confidence in their ability and trust in science (Sheail 1984) would go on to (re)shape,

[22] Solly Zuckerman's Narrative diary 1964, 10/11/1964, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/PERS/1. Emphasis added.

organise and advise on many post-war challenges arising from the co-production of science and society.[23]

This view of science, and more specifically, a scientific programme for the government as a functional tool that can determine and shape human behaviour and actions can be traced back to Zuckerman's (1932) work in *Social Life*. Despite noting that his results on the physiological impact on the social hierarchies of apes did not apply to humans, Zuckerman's deterministic views on sociology and science can be seen running through his view of science's role in society. For Zuckerman, humans are subjected to many complex and variable factors that shape behaviours and actions. Cultural effects can be just as equal as physiology in determining human behaviour. Notably, the key point here is that certain influencing factors act upon and shape humans and, consequently, society. Science (in its many forms) can and should be understood empirically, as a cultural phenomenon, and then can be put to work for the normative aims of government. The complexities and entanglements between different forms of science, social order and government were yet to be understood but the cultural value and authority of science and the 'expert' were beginning to surface, if only between the scientists themselves at this point. This view gained traction, as I will show, in government due to the perceived effectiveness of science and operational research in WW2.

After being accustomed to Zuckerman's way of working, Bernal - who had been endorsed by the Ministry of Home Security's Research Department to analyse the physical effects of bombings on buildings - suggested that Zuckerman and his expert knowledge in primate anatomy deal with the impact of bombings on humans (Burney 2012). With Bernal investigating weapon sizes from the damage caused to buildings, it seemed appropriate to suggest Zuckerman survey the possible effects on humans.[24] By the Summer of 1941, Zuckerman and Bernal were invited, by The Earl Mountbatten (Captain of the HMS Illustrious, to be Chief of COHQ later that year), to serve as scientific advisers to Combined Operations Headquarters (COHQ), the department of Britain's War Office based in Whitehall

[23] In the present, a proliferation of scientific expertise has led to a politicisation of science where choices and advice can be selectively put to work, at the detriment to others. This is particularly illuminating during the earliest years of the ongoing COVID-19 pandemic, in the UK. COVID-19 has demonstrated how some scientists might have had the close ear of government ministers but 'science' was one of many beacons of advice – a stark contrast to the post-war Britain and the fewer numbers of experts involved with government.

[24] Newspaper cuttings 1943, John Desmond Bernal: Scientific and Personal papers, Cambridge University Library, Cambridge, UK. GBR/0012/MS/Add.8287 D.5.

and tasked to develop ideas and equipment to make life and war operations difficult for the enemy.

Zuckerman also similarly acted as a scientific advisor for strategic bombing as part of the Bombing Analysis Unit in 1944.[25] The operation set out to determine the possible effects of bombing key points of infrastructure and enemy communications – e.g., high traffic rail and roadways, airfields, and submarine pens – with the hope of catalysing wider socio-economic collapse and extinguishing the German threat.[26] The overlapping tasks of different departments and units during Britain's wartime efforts and Zuckerman's traversing the boundaries replicates the idea of the scientist circulating between disciplinary silos via interdisciplinary practices. Expertise in one silo might well be re-applied in beneficial ways elsewhere with other experts. Doing things together – in this case – normative-procedural co-production applies beyond the production of science to warfare strategy between scientific experts, military leaders and technologists.

For instance, in early, exploratory work, Zuckerman noted a flaw in bombing research that he found in animal sociology: that evidence claims were based on anecdotal observation and conjecture (Burney 2012). Work about guidance and preventative measure for bomb blasts had emerged anecdotally from the Spanish Civil War, and Zuckerman viewed 'science' to be the beacon of 'truth' in a newly perceived civic agnotology. Public and political speculation was fuelled by the absence of science and anecdotes filled the knowledge gap (Burney 2012). As a result, wielding science as the bearer of truth and logic, Zuckerman grounded strategy plans in empirical data and inductive reasoning, alongside those with military experience and authority. The benefit of applying scientific logic, method and rationality reduced warfare to a scientific investigation. Zuckerman writes about targeting only steel bridges which take an estimated 3-weeks to repair, rather than stone or concrete bridges, or surveying the traffic of in-use rail cars, daily frequency and cargo held before the targeted bombing.[27]

Additionally, when asked for advice on establishing another bombing research programme, Zuckerman stressed the need for qualified and competent individuals that can

[25] Solly Zuckerman to Headquarters Allied Expeditionary Air Force, RAF. Formation of the Bombing Analysis Unit, 24/9/1944, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/BAU/1.
[26] SZ to RAF; Solly Zuckerman, Analysis of the effects of attacks on railway communications, 8/10/1944, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/BAU/1.
[27] SZ, Analysis of the effects of attacks on railway communications, SZ/BAU/1.

ask and generate questions beyond the immediate task and expertise of military personnel, that support the overarching goal, and that can account for a whole suite of factors that would lead a "dissolution of a state and a society" in Germany and "not just a series of bomb explosions here and there".[28] These sorts of questions and suggestions that aimed to align the programme around both the technical capacity of the weapons involved and around the factors that would lead to a declining morale and eventual social collapse indicate Zuckerman's interdisciplinary approach to method and process that was also found in *Social Life* (Zuckerman 1932). If the physiology of populations were affected by the diverse range of external phenomena– in this case, the economy and public sentiment amidst technologies of physical and social infrastructure – then the destruction of this would lead to societal and population collapse, much more than the direct murder of populations. Zuckerman's way of surveying the challenges around him from many different perspectives was a core reason behind the growth of his reputation as a thorough, comprehensive, rational thinker grounded in empiricism and was why his ideas and advice were highly sought after by decision-makers (Peyton 2001).

Zuckerman's involvement in the war not only created the possibility to become more embedded in the UK government machine, but the bombing research also created a nascent awareness and concern for an 'environment' and its destruction. The 'environment' at this stage was rarely spoke about in public discourse but was thought to be a neo-Spencerian definition e.g., the surroundings of human and nonhuman life, in which life is acted or performed from the organism level through to social groups and populations (Spencer 1857; Benson 2020). The concern and destruction of an 'environment' for Zuckerman came through as the aim of complete desolation of surroundings in Germany and enemy territory, as a way of limiting socioeconomic activity and shattering morale during his bombing work. Again, whilst often not discussed in terms of 'environments', scientists were beginning to understand the world as a set of systems – interrelated and interconnected between the human and nonhuman resources and societies. Damage to the system, in this case physical infrastructures that upheld the organisation and activity of social and economic life - would lead to cataclysmic damage for everything participating or contingent on the regulation and

[28] Solly Zuckerman letter to HQ of Allied Expeditionary Air Force, 25/9/1944. The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/BBRM/1.

continued production of that system. This systems-based thinking became key for ecological studies (as mentioned in **Chapter 2**) and set the path for an 'environmental understanding' centred around surroundings, relations and interconnectivity (Benson 2020). Consequently, after seeing the destruction and ruins of Cologne in 1945, Zuckerman developed an idea to explore the natural, or 'environmental', destruction of war (Bonneuil and Fressoz 2016). However, the idea never came to fruition.[29]

Yet, arguably the idea stuck in his mind as he moved from war-time operational research to science advisor in government as Zuckerman became more cognisant of the dynamic relationship between humans and their surroundings of 'environments'. Human actions can alter the 'environment' or their surroundings, which then in turn reshape the possibility of further or future action available in that 'environment'. From bombing key points of infrastructure that would limit communications or transport for the enemy to Zuckerman's later recognition of the impacts of chemical overspills into water bodies or the rapid growth of population and consumption of resources – surroundings or 'environments' became a central part of his thinking about the social life and development of populations. Zuckerman and his unit's bombing work during WW2 can be argued as an important form of early 'environmental' knowledge-making in discerning how surroundings reacted to particular styles and velocities of bombing and the socioeconomic and emotional consequence of this on the 'environments'' inhabitants.

Zuckerman's involvement in WW2, then, was foundational in the later development of the idea and vision of the 'environmental sciences' in several ways. Practically, Zuckerman built and retained many important military or political connections in the UK and beyond during his time in operations research. The perceived success of his operational research decisions propelled him into governmental circles for the rest of his career. In these circles, Zuckerman brought a particular vision of the advisory role science should play in society, and a thorough approach to researching and understanding social challenges, to be exhibited through new forms of scientific expertise in government. This was crucial as it enabled Zuckerman to be involved with, and become aware of, a range of challenges to government and society that arguably formed the later justifications for his idea of the

[29] Zuckerman's title, On *the Natural History of Destruction*, was eventually taken up by writer and UEA academic W.G. Sebald, for a treatise on the absent-presence of the destruction of German cities and societies in postwar German literature.

interdisciplinary 'environmental sciences'. More conceptually, Zuckerman's work on bombing can be seen as an important form of environmental knowledge-making that later shaped his understanding of surrounding environments and the impactful role of the activities of both social groups embedded within them and the related systems (of destruction) between land, urban structures and atmosphere. For Zuckerman, the 'environment' was another factor that determined the social life and actions of humans, like science. Thus, controlling the environment – in this instance, through maximum atmospheric and biological terror – meant extensive damage to the social and economic systems of the enemy. Ideas that have the power to alter how society is imagined or thought through differently do not materialise out of thin air; they are entangled and mutually constitutive of the cultural, social and epistemic contexts and circumstances in which they emerge. They are both products and agents of co-production. Lastly, Zuckerman's ability to traverse and circulate between different boundaries of siloed expertise both helped him to see the promises of cross-expertise thinking and the practicalities of doing things together beyond science.

This section has demonstrated how Zuckerman's wartime involvement in operational research was vital in creating a sense of authority in government for his expertise, ideas and vision. It has also revealed how his empirical work and witnessing of bomb destruction cultivated early environmental concern, challenges, and understanding. How this was (re)shaped, deepened, and began to flourish as a more transformative (and collective) vision of social and epistemic change – both in science and society - through a position of epistemic and cultural authority as a scientific advisor is discussed in the following sections. The ecologies sensibility emphasises the interest in spaces and relations, affects and responsibilities and this next section illuminates the role Zuckerman played in co-producing and impressing on his colleagues as he circulated, strategized and organised for operational research – grounded in a wider understanding of how societies, environments and populations *work* together – and how this might be applied for more normative and less violent governmental endeavours.

4.1.2. Zuckerman in Government

When WW2 ended, many of the scientists involved, including Zuckerman, were kept on as technical advisors to varying levels of government officials as the British government sought to re-focus efforts for post-war reconstruction and recovery (Zuckerman 1975). This suited Zuckerman having been a long-standing advocate of the use of science to support social progress. Scientific knowledge, Zuckerman claimed, was always 'social' due to the role it plays in social progress and the transformative effects on "the environment within which it was distilled" (Zuckerman 1959b, p. 136). Akin to the operational research work in WW2, society had challenges, Zuckerman and others argued, that could be solved by science's theoretical and practical power. Knowledge could and should be used to shape order. Science could be applied to discern the state's problems – both at present and in the foreseeable future – to survey and understand empirically possible causes, courses of action, and map the many plethora of intended and unintended consequences. This unidirectional view of science feeding into society and governance is symptomatic of Zuckerman's (and other intellectuals) belief in empiricism, inductive thinking and the performance, power and authority of the scientific programme (Ezrahi 1990). Yet, this view obscures insight into the mutually affective and constitutive relationship between science and society, including the very construction and understanding of what domains science and society are, how they are or are not distinctly divided domains, and the new social organisation of scientists it was creating. As scientists, like Zuckerman, became more involved in advising ministers and government officials and became privy to the known and forecasted strategic or social challenges, and began to imagine and ascertain possible future challenges, the social agency of scientists began to change. Rather than being in distinct arenas from the government, scientists became vital cogs in the government machine. As science and technology proliferated understandings and possible pathways of development in the Western world, successful governance of the nation-state became a much more difficult task. The heterogeneous nature of the world made knowable and advanced on by science and technology challenged the order and power of existing governments who now looked to scientists for advice and expertise. This section explores the co-production of Zuckerman's evolving view of science and the newly conceived 'environmental' challenges, that emerged in response to a growing awareness of new challenges in the UK and beyond.

Following the successful advancement of operational research during WW2, Zuckerman was recruited for many newly-created advisory committees. As formal bodies of knowledge-making, discussion and mediums of advice to government officials, the committees mushroomed out into others as they took place, discussed and predicted future challenges. During these sessions, Zuckerman and colleagues became more aware of the details and the multiplication of challenges (present and future), the entanglements between them, and the perceived need for more expertise and empirics to make conclusions. From this, 'environmental' challenges came into existence, and the new vision of a scientific society began to surface – one that favoured knowledge to be used as evidence or to hypothesise scenarios for decision-making and new orderings of society.

4.1.3. Many committees, many concerns

In post-war Britain, there was an emphasis on reconstruction. But it is a misnomer that Britain only became interested in the reconstruction of society in the post-war period. Rather, there were plans for reconstruction before, during, and after the war. The rise of the Labour Party and the welfare state has often been overemphasised as key to the transformation of British society (Pollard 1983). David Egerton (2011) instead notes two other key factors in the reconstruction of post-war Britain: improved military-industrial practices and technologies for both war and peace, and a new rise of economic nationalism. There were other areas of transformative change occurring in Britain that surfaced new visions and understandings of 'environments': changing land use and town-planning, inclusive of management practices aligned to growing populations, urbanisation, increased agricultural need and water uses (Sheail 2002). The very idea of 'reconstruction' in the post-war period brings into view a whole range of opinions and discussions, power relations and material constraints concerning what reconstruction might look like, for what purpose, who gets to decide this, how it might be achieved and when. This also brought about the possibility and introduction of many new and evolving challenges and the need for knowledge in some form to help decide this as part of a centrally planned programme.

In Britain, there was a range of advisory committees to survey existing knowledge, identify present and future challenges, and to advise ministers on possible courses of action.

Zuckerman was involved in a number of these between the 1940s and 1970s. These included the Committee on Industrial Productivity (where Zuckerman chaired a technological sub-group) that discussed the need for new "specialised expertise" concerning resource and supply issues, and the emergent public interest in industrial productivity.[30] Or the NRTC that formed in 1950 to assess and advise on the use, conservation, and development of 'British' natural resources.

Most notably, Zuckerman was involved with the creation and was deputy chair of the Advisory Council for Scientifc Policy (ACSP). The ACSP was created to guide the government's scientific policy from 1950 to the mid 1960s. Zuckerman's role initially was to act as a member who could "speak authoritatively on behalf of the biological sciences".[31] The Barlow Committee proposed setting up the ACSP to support the Lord President of the Council, the minister responsible for the ARC, MRC, and the DSIR to help modernise their operations for future challenges in science, government and policy. Precisely, Britain needed a group that was able to survey the current strength of science in Britain and recommend action for future scientific policy, collect and maintain up-to-date statistics, and, where necessary advise on an ad-hoc basis on scientific challenges and orchestrate scientific advice for the relevant government departments.[32] Consequently, the ACSP was intended to be a key body of knowledge-making, problem-solving and advice for the government machine. The ACSP, from its inception, embarked on a range of exploratory work to build a picture of Britain's scientific, technological, and industrial capacity. Over the course of its existence, it created numerous sub-committees (Research and Productivity, Poisonous Substances, Scientific Manpower, Toxic Substances in Consumer Goods, Foreign Seaweed etc.). These topics surfaced with a major concern in Zuckerman's mind: a future of increasing population growth and the challenge of preserving natural resources and managing the livelihoods and health of larger populations.[33]

[30] Committee on Industrial Productivity, 1947-1952. The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/CIP.
[31] Privy Council Office to Zuckerman, 23/1/1946, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/FSP/2; The Barlow Committee also had a membership of top scientists, including Bernal.
[32] Need for a science secretariat, 16/9/1945, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/FSP/2.
[33] Future Growth of World Population, Papers by Professor Solly Zuckerman, 1960, The National Archives, London, UK. CAB 124/2844.

This was not unique to Britain or either Zuckerman, but rather, at the time, a major concern for the USA and other Western states. There were, as discussed in **Chapter 2**, several 'environmental' concerns then emerging (Warde et al. 2018). Moreover, new ideas of global order and community were emerging through the construction of the United Nations and its various agencies and other transnational agreements (Miller 2015; Selcer 2019). The interconnectivity of a globalised world was surfacing many new forms of interrelated challenges, including the uneven resource consumption, population growth and toxicology of an industrialised world. Notwithstanding, the 'environment' and its challenges were in limited discursive use (Conway 2019) but the recognition of the human impact on surroundings and the planet were gaining traction in scientific and government circles. Zuckerman was connected to key individuals and became aware of these emergent concerns whilst involved with the ACSP. Zuckerman regularly corresponded with The Conservation Foundation and its director, Fairfield Osborn Jr, about the puzzles of conservation – resources, animals, landscapes - sharing papers of interest and with TCF often updating Zuckerman with yearly operations reports.[34]

Zuckerman also presented a talk concerning population and non-biological resources at the World Population Conference organised by the UN in 1954.[35] During his committee work, Zuckerman became aware of many challenges in science, Britain's capacity for scientific endeavours and the challenges of this encased by concerns regarding Britain's power in the post-war political topography. As a result, he published widely on these concerns. Zuckerman wrote for magazines, academic journals and newspapers, on the need for the recruitment of new scientists, engineers, and technologists (Zuckerman 1956b, 1956c, 1956d, 1958a, 1959a), new specialist teachers to match (Zuckerman 1957, 1958b), and the geopolitical importance of not falling behind the USA, Soviet Union, or even continental Europe itself in the perceived science and technology race (Zuckerman 1955). Zuckerman also participated in the emerging global order through joining in with discussions in organisations like NATO and the UN pertaining to those challenges that, in his view, post-war global society was going to face. For Zuckerman, the diversity of the sciences was the

[34] Correspondence with Fairfield Osborne, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/CF/1.
[35] Solly Zuckerman, Population in relation to non-creatable biological resources, 1954, World Population Conference, Rome, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/WPC/1.

key to generating solutions, based on previously successful endeavours concerning resource substitution, improved agricultural production, land-use, and town planning. As a result, inter- and multidisciplinary means of working and sharing knowledge were meandering through and shaping the social organisation of science in response to post-war challenges and change. Doing things together, and sharing expertise and perspectives to generate new knowledge, was thought to provide solutions needed for the emergent challenges.

Crucially, the post-war period also demonstrated major changes in international and nation-state planning and governance. An emergent global order was gaining traction through directed efforts of the West in an attempt to ensure long-term peace and cooperation (Miller 2015). This also enabled much more interconnection vis-à-vis knowledge, economies, and migration. Concurrently, Zuckerman and others were enabling and shaping technocratic governance in the UK through the introduction of expertise and scientific advice (Wilson 1963; Gummett 1980). The proliferation of experts not only manifested in government but also across the knowledge economy in Britain (Agar 2008). Expertise, publicly visible conflict in expertise and an amalgamation of expertise for new areas of concern were powerful factors in co-producing a fertile context of a technocratic society, through which the environment and its sciences could emerge (Agar 2008; Warde et al. 2018) in the UK.

Broadly, Zuckerman's increasing involvement with governmental affairs, strategy and policy through his committee and advisory work, reveals a wider, changing role of the authority of science in society. Scientists enjoyed participation in a wide range of committees and activities on the back of success from the war efforts. Scientists like Zuckerman were visibly involved in public affairs – something which was recognised in the media and reinforced the framing of science as a tool to guide policy and decision-making. This supports Agar's (2008) view on the multiplication of expertise in the 'long 1960s'. As expertise and conflicts in expertise became more public, the need for additional experts came with it. In the UK, the new and public presence of scientific advisors signalled a shift in government strategy and decision-making, one that publicly relied on and reinforced the authority of the rigour of scientific expertise, as growing visibility of expert conflict demonstrated a non-unified science. Rather, particular forms of scientific expertise, that were grounded in different methods and normative aims meant that the presence of

scientists and expertise were key components of order-making vis-à-vis policy and decision-making.

The embedding and power of scientific advice, expert dis/agreement into the government machine, extended through a nascent civic epistemology (re)shaped how challenges were framed, what solutions were deemed viable or possible and why some visions of the future – like sociotechnical or socioscientific ones were persistent and perceived as attainable over others. This in turn contributed to the scientifically oriented futures or worlds that were made, and deemed possible to be made in the future. In other words, sociotechnical imaginaries in the UK were co-produced with the embedded presence of scientific advisors in government. Zuckerman's journey from operational research in war to CSA demonstrates the UK government's shifting epistemic and normative aims. It is well documented that science influenced government, but government influenced science during this time in countless ways. The presence of scientists in, or supporting, the government enabled certain forms of applied research to be funded for particular aims and later on became a key component of governmental research and science policy (Agar 2019a) and shifted the ways in which science and scientists organised their work in relation to policy (Sarewitz and Pielke Jr 2007). Knowledge was being produced and funded for government research that would change the landscape of knowledge-making in the UK. Institutions were created to support these aims – as seen in committees and ministries – that reshaped further epistemic and normative aims of knowledge-making in the UK.

To sum up, Zuckerman was involved, to varying degrees, in a wide range of committees reviewing, understanding, and advising ministers on a range of loosely related topics of government interest in post-war Britain. These types of interventions were specific and discrete. Yet, the more fluid and relational aspects of co-production can be found in the broader shifts of the epistemic and normative aims and place of science in British society; the former inseparable from the latter and vice-versa.

The challenges intersected various government interests: population, health and livelihoods, economic and social development, national self-sufficiency, and geopolitical tensions and were co-products of science and policy interest. Necessarily, to manage these challenges, scientists, civil servants, and ministers tried to discern ways of grouping and ordering them together in an effective way, to go beyond existing institutional and disciplinary arrangements. One of these ways was the construction of new universities.

Zuckerman's role as chair of the sub-committee on Scientific Manpower illuminates this desire more emphatically. Zuckerman's vision of a science-led, centrally planned society depended on the scientific workforce's key and yet lacking resources. The sub-committee comprehensively explored a whole suite of issues pertaining to the country's future scientific endeavours and workforce. This included the analysis and prediction of university graduate numbers and comparing them to other nations (like the USA), distributing surveys to employers to ascertain their concerns and needs for scientists, the discussion of science teaching in schools and prospective places in universities for scientific disciplines, analysing census predictions, and so on.[36] As chair, Zuckerman often decided the topics for discussion or avenues to pursue and was met with no resistance. The future was to be scientific, and a workforce needed to be cultivated to support this. For this to happen, student numbers needed to increase in scientific disciplines, and universities needed expansion to match.

4.2. Post-war Higher Education Reform

Concurrently, several higher education reforms that Zuckerman was directly involved in led to the emergence of UEA and, subsequently, ENV. After WW1, student numbers were boosted from the return of those in service who were provided studentships that covered the cost of tuition and accommodation (Brewis et al. 2020). This was not intended as recompense but more to aid in national rebuilding and to support individuals' reintegration into post-war life (Brewis et al. 2020). In this era, many institutional bodies concerned with increasing higher education opportunities came into existence, like the University Grants Committee (UGC), as governments began to realise the importance of research, science, and higher education in the war effort (Irish 2015; Bonneuil and Fressoz 2016).

After the Second World War, Britain found itself in a similar position. There were scores of soldiers returning to the UK with no jobs and little (from the government's perspective) to do, and there were scores of potential students enlisted in military service before pursuing degrees (The Percy Report 1947). Meanwhile, as outlined above, the prominent political thinkers and intellectuals were speculating on and discussing

[36] Multiple minutes and agendas between 1950-1960, Advisory Council on Scientific Policy, Committee on Scientific Manpower, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/ACSP/8/1.

technocratic visions of futures (Wilson 1963). Several challenges were emerging that outlined many threats to the livelihood of populations. As science and technological development was thought to be the solution, and expertise was multiplying, it became clear that the current size of the workforce, i.e., trained scientists and technicians, was lacklustre for both immediate and future scientific needs. To understand what was needed, a committee was established in 1944 by the Minister of Education, Rab Butler (1902 – 1982), to assess the needs for higher technical education and the capacity of existing institutions and disciplinary programmes to meet the challenges of a scientific and technological Britain. The results were published in The Percy Report (1947) and included concerns about the poor application of science in industry linked to an inadequate capacity in training, the ineffectiveness of existing educational programmes, and the uneven standings between the university and technical college courses. Specifically, concern arose about a predicted increase in industrial demand for workers and the need for scientists "who can administer and organise and apply the results of research to development" (The Percy Report 1945, p. 5). Britain was in a difficult position. There were large numbers of soldiers returning to Britain, and new training was needed if a significant proportion of them were to be trained and prepared for the new science, technology and industrial era, and there was little room at existing institutions to do so. The Percy Report (1945) painted a clear picture that,

> ...industry must look mainly to universities for the training of scientists, both for research and development and of teachers of science; it must look mainly to Technical Colleges for technical assistants and craftsmen. (p.6).

Moreover, the Report explicitly criticises existing university degrees' narrowness, with undergraduate courses being "too short and too specialised" (p. 15). It was thought that existing universities were growing stagnant in their disciplines and curricula, and this was reflected by the growing issues of graduate suitability for new technological, scientific developments and growth in the industry, and the post-War boom was

> [taking] place against the background of a vigorous and continuing debate on the appropriateness of the courses on offer to a swiftly changing industrial society (Lowe 1988: p. 159).

Not only was society rapidly changing, and scientific knowledge becoming a core avenue to achieve societal, and development goals, the very nature of disciplinary knowledge was coming under question. Historians of knowledge have underscored how transformations in knowledge systems emerge when the social apparatus holding them together as legitimate and useful forms of knowledge begins to wane (Renn 2020). 'Borderline problems', as Jurgen Renn (2020) notes, occur when existing organisations or groupings of knowledge – like particular disciplines - fail to effectively make knowledge for the purpose required of its user and so often lead to generating new ways of thinking and new modes of organising disciplines e.g., interdisciplinarity. A new social relevance to scientists and their work was emerging in new normativities and interventions in post-war Britain, to solve both current challenges and assure the possibility of new expertise for emergent challenges.

Additionally, there were more practical concerns surrounding the capacity for student numbers for the existing universities. A post-War boom in university enrolment saw a 50% proportional increase in those choosing to study science (7,600 in 1939, 19,400 in 1956), a 30% increase in those studying technology (5,300 in 1939, 12,300 in 1956), and a doubling of science graduates over the pre-war figures had been achieved just a few years later.[37] The capacity of existing UK higher education to support a growing scientific workforce was also assessed by the Committee on Future Scientific Policy, which included Zuckerman, publishing The Barlow Report on Scientific Manpower in 1946. The Barlow Report signalled a still growing concern over existing universities' ability to match society's need for scientists, engineers, and technologists. Existing universities were thought to struggle to construct new 'science' buildings to match the growing increase and fell short in providing appropriate residential facilities for new students and staff. This paved the way for a more practical conversation that indicated that expanding and constructing new universities may be the best course of action to solve the workforce gap.[38]

Later, Zuckerman (1956b,1956c, 1956d) continued thinking about these challenges, underscoring the need for more scientists and technologists to support the changing scientific society he was actively involved in making. For Zuckerman, universities were the

[37] Draft note on the university expansion programme, European Productivity – Project No. 412 Agency, The National Archives, London, UK. CAB 124/2040.
[38] Committee on Higher Education papers 1-5, 1961, The National Archives, London, UK. ED 117/1.

answer in providing new graduates, or to some extent, scientific citizens, to match the future demands. In sum, the embedding of scientific advisers in government helped to enable what was going on elsewhere in the world; a proliferation of science and technology to support social and economic development. However, alongside these concerns for a capable scientific workforce to implement and guide a technocratic future, new concerns for the 'environmental' effects of intensifying agriculture, resource depletion, urbanisation, and population growth were surfacing, both in the UK and abroad. It was deemed by those involved that existing knowledge systems and institutions were ineffective to deal with modern society and its challenges – whether accelerating industrial development and economic growth, or their 'environmental' consequences. Thus, the idea for new universities and new courses was born, and new socioscientific worlds that desired interdisciplinary working and science for policy and advice were being created through the co-production of science and higher education policy. A relational ecologies approach emphasises how the mutual construction of science-policy and higher-education policy was contingent on the earlier changing contexts and emerging challenges associated with post-war reconstruction and governance that necessitated the need for innovative forms of scientific expertise – beyond disciplinary silos in traditional universities and the institution of science more broadly. Science as a cultural phenomenon, in Zuckerman's *Social Life* view, can deterministically shape behaviour, action and visions of desirable futures – but what if 'science' is not fit for purpose? If science is not fit for purpose that the structures and institutions that support or produce knowledge must be evolved, practitioners of that knowledge must be cultivated and systems to use that knowledge must be constructed, as explained above.

4.2.1. Norwich as a chosen site

The UGC in 1957 pushed for a decision on the expansion of universities, deciding that it was more beneficial to construct new ones (as opposed to extensions on existing ones) in a 'cost per place' comparison with 'cost of providing them elsewhere',

> The planning and inauguration of a new College requires the full-time attention of a highly qualified staff for some years before the new College fructifies in an output of new students. Even then, if the new College is not to outgrow its strength, a further period must inevitably elapse before it is large enough to be economic. Yet a new College at Brighton has special attractions for the Committee. London University cannot, owing to shortages of lodgings and the congested sites of its Colleges, expand sufficiently to meet the prospective demands upon it. At Brighton it is hoped lodgings will be easier to obtain than elsewhere, as students will be on vacation at the peak of the holiday demand. Brighton may therefore do something to relieve the pressure on London.[39]

Norwich, like Brighton, was identified as a city that could house a new university, with no competing universities nearby and the potential to relieve the pressures of congested, industrial towns (Muthesius 2000). Agar (2020) also argues that this was a rejection of 'Big Science'; by actively situating new universities away from spaces of rapid innovation and growth. The new universities were permitted to cultivate their own forms of education and research, which was arguably a crucial factor in developing ENV. With Norwich being decided as a site for a new university, the next task was to formulate what the university would offer. Existing conversations from the previous Percy (1945) and Barlow (1946) reports noted the ineffectiveness of existing degree programmes for real-world application, technological innovation and use in post-war Britain.

The conversations continued throughout the 1950s, culminating in The Robbins Report (1963). The Robbins Report (1963) was an extensive review of Britain's HE landscape, the role the university should play in social, scientific, and technological endeavours and the planning or coordination of new institutions. The recommendations of the Robbins Report were accepted by the government and dealt with the perceived ineffectiveness of existing institutions and disciplinary programmes. As a result, the new universities did not have to be rigidly scientifically orientated nor confined to particular modes of teaching or research (Pellew and Taylor 2020). This was a key focus for the new universities as discussed by the Robbins Committee in 1960,

[39] University Grants Committee, 5/1957, The National Archives, London, UK. CAB 124/2040.

> Is there room at the "middle" level, for a "liberal arts and sciences" course that is less specialised than the typical university course, less vocationally biased than the majority of technical college course, and less firmly tied to a single profession than the training college course?[40]

The new universities that formed[41] were relatively free to pursue new and experimental ways to reconnect cognate disciplines, again as outlined in The Robbins Report:

> There are long-established and natural groupings of subjects: chemistry, physics and mathematics, and, in the humanities, English with history and French, are obvious examples. We are arguing that there should also be experiments in new combinations of subjects which have recognisably organic connections: technology, for instance, with some social studies showing the more general implications of the technologist's profession; philosophy and mathematics with the history of science; and, for many students, some study of the past as well as the present state of the disciplines they study (The Robbins Report 1963, p. 94).

The new universities were to be 'institutional experiments' according to Agar (2020), following the "variety of imaginative institutional arrangements for Higher Education [that] were pitched in the 1950s and 60s ... concerning the provision of science and engineering teaching and research" (p. 122), in new spaces of higher education – between the bustling metropolis and rural country. In doing so, they enabled the possibility for creative and imaginative ways of learning, teaching, and new research to emerge in British HE.

So far, this chapter has explored the co-production of science policy, scientific advice and UK higher education. The increasing prominence and normative aims of science policy and the need for new institutions created an additional demand for the further embedding of science in government and as a tool for imagining and materialising futures between the mutual construction of knowledge-making and ordering of society (Jasanoff 2004b). The

[40] Committee on Higher Education papers 6-10, 1961, The National Archives, London, UK. ED 117/2.
[41] The new universities of this period were Sussex, East Anglia, York, Lancaster, Kent, Essex and Warwick.

post-war period saw visions of desirable technocratic futures for government and science advisors, like Zuckerman, manifest through new policies surrounding science and HE. UEA and Norwich surfaced as a new university to be founded, but how did the 'environment' and its sciences become a desired, institutionalised, and legitimate form of knowledge through a degree programme at UEA?

4.3. 'A lot of things to be tidied and pepped up': A new environmental research council

In the post-war period, concerns for the 'environment' were beginning to be recognised in the Western world, and Zuckerman was acutely aware of this both worldwide and in the UK. In this vein, the new challenges of natural resource conservation, population growth management, toxicology of chemicals and land-use organisation were thought to be a challenge to the UK government and its populations, and Zuckerman was tasked with defining and constructing a new 'research council' (Warde and Sörlin 2015). This was a formative moment in the history of the emergence of the 'environmental sciences', as the term, I argue, first emerged in discussions about the new research council. I then posit that this new label amidst the fertile and receptive transformation in HE was vital in generating a new sociotechnical imaginary of the 'environmental sciences' for Zuckerman.

To begin, Zuckerman was given the opportunity to review the suitability of existing research councils for 'biological' research by the ACSP to determine whether existing institutional arrangements were suitable for the new group of challenges, at this point, loosely defined as 'natural resource' issues.[42] Biological research, in this case, was thought to include,

> ... research in the general field of natural resources, including fisheries ...research on the water balance ... on land capability and land use, nitrogen fixation and the mitigation of ... run-off, overseas research on ecology ... taxonomy, pedology, many

[42] E. M. Nicholson, Review of Organisation in Biological Research, 22/12/1959, The National Archives, London, UK. FT 22/16.

> aspects of biometrics and various aspects of fundamental biology of no particular interest to the Agricultural or Medical Research Councils.[43]

However, the challenges didn't quite fit into the existing organisation of what 'biology' was thought to be concerned with, nor was 'biology' deemed an appropriate discipline for these challenges to be researched in. [44] The Nature Conservancy, the government research body interested in ecological science that had recently formed to develop and protect national nature reserves and designate SSSIs, was already ruled out of taking on the task of becoming a new research council.[45] Due to its small size compared to the existing research councils and its lack of wider expertise, it was thought to be unable to subsume responsibility for researching the new areas of concern without appropriate and rapid expansion of research capacity.[46] There were additional concerns of needing a "consumer body" that could receive funding, formulate appropriate research plans, draw reasonable conclusions, and disseminate the results, which was only the case for fisheries, nature conservation, and pest control. Without consumers, the new funding streams were thought to be at risk of being poorly or ineffectively used. Thus, in a similar vein to the military funding of the earth and 'environmental sciences' during the Cold War explored in **Chapter 2**, the creation of new research institutions and patronage was gearing up to shape new consumers that were to align themselves to the new streams of funding, that in turn would then reshape the goals and orientations of the research council.

In light of this, Zuckerman's task was becoming more complex. Not only did he need to spearhead the plans for a new research council, but he also needed to consider who may receive future funding. It was recognised that universities and other institutions were unlikely to make a move on their own to study the new emergent 'natural resource' challenges without "backing and financial support of a body with governmental authority," e.g., a new research council and so, the consumer body issue would optimistically resolve

[43] E. M. Nicholson, Review of Organisation in Biological Research, 22/12/1959, The National Archives, London, UK. FT 22/16.
[44] E. M. Nicholson, Review of Organisation in Biological Research, 22/12/1959, The National Archives, London, UK. FT 22/16.
[45] The role of the Nature Conservancy in the history of the 'environmental sciences' is discussed in more detail in Chapter 7. It would also later on become subsumed by NERC in the mid-1960s.
[46] E. M. Nicholson, The Nature Conservancy as a Research Council, 3/3/1959, The National Archives, London, UK. FT 22/16.

itself with the creation of one.[47] Another equally important task was to cement a name that signalled the intent and direction of future research and possible 'consumers'. This included mapping the extent to which 'natural resources' as an umbrella term either includes or excludes possible current knowledge gaps, for example, water supplies and conservation, town and country planning, nitrogen-fixing, soil quality or biostatistics. Notably, the diversity and extent of the perceived gaps in knowledge further confirmed the lack of existing institutional arrangements and the ineffectiveness of existing knowledge-making along disciplinary lines. Zuckerman, along with E. Max Nicholson (1904 – 2003) (Director of the Nature Conservancy), consulted with numerous civil servants (Edward Playfair, Otto Clarke and Roger Quirk) who had been involved in various science-policy matters with Zuckerman during the 1950s, and a Zoologist named James Gray (1891 – 1975) from Cambridge on the draft proposals for a 'Natural Resources Research Council'.[48] The purpose of this was to produce a "synthesis that would be acceptable to" distribute to Zuckerman's "various correspondents".[49] During the discussions, a memo arrived for Zuckerman in 1960 from Roger Quirk (1909 – 1964) that suggested a new 'Environmental Sciences Research Council' as a more inclusive term, based on the interdependent, physical and earth sciences work of the IGY (1957/1958) that dealt with the 'natural environment'. Quirk wrote:

> The sciences dealing with the natural environment of water, air and the earth have come into prominence recently, through such activities as the International Geophysical Year, the basic theme of which was the interdependence of a wide range of sciences in this sphere - geophysics, geology, meteorology, oceanography, glaciology, marine biology, astronomy. Interest in space research and radioastronomy has drawn attention even beyond the atmosphere. But, concurrently with this increase in interest, there have, in recent years, come to the notice of the ACSP, and the Office of the Minister for Science, a number of

[47] E. M. Nicholson, Proposed Natural Resources Research Council, 17/2/1960, The National Archives, London, UK. FT 22/16.
[48] Solly Zuckerman, Proposed Natural Resources Research Council, 2/3/1960, The National Archives, London, UK. FT 22/16.
[49] Letter from R.N Quirk to Solly Zuckerman, 6/7/1960, The National Archives, London, UK. FT 22/16.

> deficiencies in the equipment, organisation and financing of many of the relevant fields of science.[50]

Quirk, here, notes the numerous advances in sciences of the 'natural environment' that had not been of immediate government concern but may benefit British science and research through the pursuit of a new 'environmental' research council. Firstly, the IGY had demonstrated a new way of doing science on an international scale, framing interrelated natural sciences in new ways to make knowledge about, within and "beyond the atmosphere" to construct 'global' knowledge for a 'global' earth. This way of understanding the planet as a series of interconnected 'environments' that enveloped planet earth was epistemologically and discursively (thanks to Quirk) novel.

The IGY came to fruition from post-war recognition of the interconnected and, thus, international aspects of studying the atmosphere and oceans (Doel 2003; Lehman 2020), with existing and narrow ways of practicing interdisciplinary earth sciences coming together under a shared intellectual pursuit and interest, aligned to the *integrative-synthesis* mode of interdisciplinarity (Barry and Born 2013; Renn 2020) amidst cold-war tensions between the US and Soviet Union (Doel 2003). As demonstrated in **Chapter 2**, the earth sciences were not alone in the internationalisation of science. The WMO also made a concerted effort to improve international collaboration and sharing of data, tools, and techniques concerning atmospheric and meteorological science (Miller 2001; Edwards 2010). Yet, to Quirk, the UK lacked institutional and scientific support to participate in the newly emerging, global 'environmental sciences'.

Moreover, Quirk notes that the lack of administrative, financial, and infrastructural support that can guide and establish the new grouping of the 'environmental sciences' has been recognised and may be fixed by creating a new research council. If the 'environmental sciences' were to materialise as a response to the newly emergent challenges to society and future-making, the infrastructure and institutions to support this needed to be in place (Güttler 2019). Quirk recognised that a new research council would be one step towards this. Quirk then makes the case as to why the 'environmental sciences' rather than 'natural

[50] Quirk to Zuckerman, Proposed environmental sciences research council, 6/7/1960, The National Archives, London, UK. FT 22/16.

resources' may be more inclusive of Britain's challenges. Quirk agreed with an earlier comment from Playfair, who noted that a natural resource framing weakened the whole premise of the new comprehensive Research Council, as it did not truly capture the UK's natural resource issues, nor did it capture some of the more important gaps that had been proposed:

> The general idea seems to be a very worthwhile one, but I confess that I am rather disappointed by its presentation. I cannot help feeling that by building it round the concept of "natural resources" you greatly weaken it and make it appear rather artificial. For one thing, you do not really cover an important proportion of the country's natural resources in the true sense [coal, iron ore, agricultural products].[51]

The suggestion by Quirk concerning the IGY and the 'environmental sciences' was originally someway off the more geographically orientated, biologically challenging, or surroundings-based challenges of toxicology, land use, and resource consumption that were troubling Zuckerman and ministers. However, Quirk used this to his advantage.

Edward Playfair (1909 – 1999) was still pressing for a 'Biological Research Council'. Playfair argued that a biological approach to the entire project would only strengthen the proposal, helping it appear more rational and inclusive of the problem areas in the UK, such as microbiology, while leaning on 'biology' already being a well-understood way of organising knowledge. Gray was not averse to 'Natural Resources' but noted that fisheries were not a natural resource in the conventional sense and should be dealt with via a relevant committee.[52] As a result, Quirk continued to push for a broader term, the 'environmental sciences', that would include biology and the troublesome aspects of fisheries as interdisciplinary, constitutional components:

> ...there is a coherent scientific whole (and also, as it happens, a number of "problem" fields) in the field of what, ponderously, are, I suppose, called "Environmental Sciences", covering the land, the sea, and the atmosphere of the

[51] Letter from Edward W. Playfair to Solly Zuckerman, 7/6/1960, The National Archives, London, UK. FT 22/16.
[52] Letter from James Gray to Solly Zuckerman, 9/6/1960, The National Archives, London, UK. FT 22/16.

> planet, and the biological assemblages in, and on, the air, the water and the land. This seems to me both a scientifically viable concept and, taking it as a whole, an area where it is rather important for a lot of things to be tidied up and pepped up.[53]

Quirk illustrates the capacity of the 'environmental sciences' to be used as a conceptual or epistemic umbrella under which to organise the newly proposed Research Council to deal with the wide-spanning research and strategic challenges of both the UK and, later, the globe. The concerns around current and potential gaps in knowledge vis-a-vis pollution, conservation (of resources and the natural world), toxicology and chemical use and effects all crosscut many scientific disciplines (e.g., in these cases atmospheric physics, ecology, chemistry) and many spaces (e.g., the atmosphere, the agricultural field and urban areas). These are not exhaustive but are what Quirk mentions as 'problem fields'. Importantly, the idea of the 'environmental sciences' would encapsulate all of these together – the plethora of spaces in which challenges emerge and the multiple disciplines that would make knowledge about these challenges – in a novel way of ordering existing knowledge and producing new knowledge about them beyond disciplinary silos. Thus, the idea of a 'new' way of doing science was born.

I argue that the memo and its discussions reveal how multiple understandings of the 'environment' emerged and how Zuckerman was privy and receptive to them, that then shaped his later thinking about grouping together the sciences of the 'environment' - in his view – in an 'environmental sciences' department. It also illustrates the collective nature of vision and how Zuckerman was not entirely responsible for the emergence of the 'environmental sciences' idea. Instead, the idea came about through governmental responses to growing socioscientific challenges in the UK, the internationalisation of science and its community, the need for new institutional and scientific training for graduates and many conversations between civil servants and academics.

The memo by Quirk precedes a proposal of ENV by Zuckerman to Christopher Ingold (1893 – 1970) during their time on UEA's Academic Planning Board (APB)[54]. It is one of the first recorded uses of the term 'environmental sciences' in the UK. Zuckerman's response to

[53] Letter from Roger. N Quirk to Solly Zuckerman, 6/7/1960, The National Archives, London, UK. FT 22/16.
[54] The group of eminent scientists and scholars recommended by the UGC to deal with the processes of course design, staff hire and planning of academic endeavours in the new university.

this is absent from the archives, but amidst the suggested names, in a later draft document, Nicholson titles it the 'Nameless Research Council', which would suggest a rejection. Nonetheless, the ideas about different facets of science being interconnected are retained in a core summary by Zuckerman.[55] This Research Council ended up being the NERC, coming into existence in 1965, and Graham Sutton (1903 – 1977), from the UK Meteorological Office, who took the position of the Chair, is credited with suggesting the substitution of 'resources' with 'environment' (Sheail 1992), thus representing a compromise between the proposals for a 'Natural Resources' and 'Environmental Sciences' Research Council.

To sum up, Quirk's memo reveals one of the earliest, if not the earliest, documented use of the term 'environmental sciences' in an official capacity. I contend that this helped provide Zuckerman with conceptual terms and the language to interrelate the previously diverse set of challenges in science and for the state, aiding his vision of the 'environmental sciences' that he proposed for UEA later that year. Zuckerman was also well aware of the need to train graduates in science to study, understand and solve the challenges of the future. However, there was no 'environmental science' for scientists to be trained in yet. As Zuckerman moved through and interacted with various aspects and actors in science and HE policy, the ways in which he began to discern and imagine how science might be used in the future moved from more reactionary and immediate goals to more long-term visions of transformative change. Zuckerman identified the space and possibility of creating a new school of science that stemmed from the new funding arrangements coming from the new NERC, and that would make a new generation of environmental scientists that produced environmental knowledge, a new way of organising scientists and thus creating an entirely new sector in post-war technoscientific industrial Britain. This can be discerned as the origin of the 'environmental sciences' sociotechnical imaginary that was realised and embedded through the founding of ENV. Zuckerman's and others' vision of the 'environmental sciences' (that was altered slightly from that of NERC as I will discuss below) as a mode of knowledge-making, and tool to imagine futures, was subject to numerous administrative and institutional processes that (re)shaped how it was embedded within the UEA APB and

[55] E. M. Nicholson, The Nameless research council, 18/8/1960, and Solly Zuckerman, Unnamed document, 23/8/1960, The National Archives, London, UK. FT 22/16.

ENV WP as the School was founded during a period of important post-war science-policy and HE reform.

4.3.1. Embarking on a Division of Environmental Sciences: a sociotechnical imaginary

Having now been established as a new university endeavour by the UGC, UEA needed discussions about what kinds of studies it would offer. The APB, including Zuckerman, for UEA, was tasked with bringing the university vision to life. Attending to the normative aims of the UGC and education committees, interdisciplinarity as a way of teaching and creating new knowledge together between disciplinary experts was to be experimented with. In early discussions, the APB proposed a broad range of scientific studies that may be pursued. Amongst these was Zuckerman's idea of the 'environmental sciences' that went beyond the natural science focus of NERC encompassing areas of the social sciences and even perhaps the humanities. Zuckerman, writing to Ingold in 1960, proposed,

> ...If one had it in mind to do something absolutely new and fresh in science, I am wondering whether Norwich could not embark in its faculty of Science, on a Division of Environmental Sciences – meteorology, oceanography, geology, conservation etc. etc. If it were, I am quite certain that nobody would ever be able to say that scientists were trained in a narrow way ... Conservation would lead to the social sciences, population studies etc. and so over into the preoccupations of at any rate one sector of those who teach the humanities.[56]

The novelty of the 'environmental sciences', as a new way of organising science and encouraging interdisciplinarity, coupled with the main aims of broadening schools of study in UEA as part of the HE reform led to the proposal being accepted with no disagreement from others in the APB. The acceptance of the proposal marks the approval of the idea that there should be an institutionalised group of sciences dedicated to the new object of

[56] Letter from Solly Zuckerman to Christopher Ingold, 24/9/1960, The Zuckerman Archives, UEA, Norwich, UK. SZ/UEA/4/6.

concern, the 'environment'. Importantly, this also signals that Zuckerman's vision of inter/multidisciplinary scientific thinking for the future was also gaining traction.

Notably, the presence of many disciplines – including the humanities – that orient around the 'environment' mimic Zuckerman's thorough and multidisciplinary perspective-based science approach found in his previous work and the multiple forms of 'environmental' challenge that had been surfacing. Zuckerman's authority in generating and projecting ideas – even if from collective discussion with others like Quirk - that are then accepted, articulated, and made reality – through the embedding of ENV in UEA – reveals how ideas and the imaginary can be understood as powerful tools of social change (Jasanoff 2015b).

The 'environmental sciences' in ENV, at this moment, was an idea of a tool that could possibly make new knowledge about and respond to the growing awareness of environmental concerns – both in the UK and beyond at the time. The 'environmental sciences' were a considered response by Zuckerman and colleagues to the social and technological change emerging in UK and for its workforce, rather than solely being a reactionary idea to knowledge gaps, or 'borderline problems' in science (Renn 2020). The 'environmental sciences' combined existing disciplinary expertise to deal with the new 'environmental' challenges in an interdisciplinary way – they were a direct normative-procedural intervention to bridging and filling gaps in knowledge. As a sociotechnical imaginary, Zuckerman's proposal for ENV emerged amidst the mutual construction of UK science and HE policy, the mobilisation of scientific advice and expertise in government and growing ideas that interdisciplinary working was the way forward.

UK government operations and planning began to be channelled through scientific advice and experts. As this occurred more frequently, and as new challenges emerged, or existing ones became more complex, further expertise and scientific advice were sought after by ministers and advisors themselves. The world of scientific advice and policy that had been created undoubtedly prioritised and favoured the institution of science for knowledge-making and planning in government, which was a product and success on behalf of the normative aims of Zuckerman and colleagues aim in the pre-war period. The newly embedded position of the scientific adviser in Whitehall, cemented by Zuckerman's CSA appointment, favoured scientific ways of seeing and acting in the world on a national level.

4.4. Conclusions: ENV as a response to and tool of socioscientific change

Throughout this chapter, I have explored how the 'environmental sciences' came about as new way of making knowledge about new object(s) of inquiry at a new university, UEA. My 'ecologies of co-production' sensibility and commitment to the spaces, relations and constitutions has illuminated this historical moment as a collective of co-production linked both through the idea of sociotechnical imaginaries and visions of desirable futures (Jasanoff and Kim 2015) and the normativities of interdisciplinarity as the desired method of scientific practice.

Specifically, I have revealed how this vision of environmental scientific futures emerged from discussions between Zuckerman, government officials and civil servants about new challenges in science and society. Rather than arising from a vanguard (Hilgartner 2015), the sociotechnical imaginary of the 'environmental sciences' emerged from collective processes of co-production. The chapter adds important historical detail to histories of the 'environment' in which the UK context has been overlooked, despite being pivotal in creating the 'environmental sciences' as an umbrella term and mode of socioscientific organisation.

The collective vision came about for several reasons: orientating around and between discussions from Zuckerman with others. Firstly, Zuckerman's social and political authority and ideas came from a distinguished career as a scientific advisor to the UK government. This was made possible through the changing and dynamic relationship between science and government that emerged in the post-war period. This position meant that Zuckerman became aware of the many complex challenges post-war Britain faced and being involved in steering the direction of post-war planning Zuckerman had a strong influence. Many of those beginning to surface were broadly related to 'the environment': resource depletion, toxicology, population growth. The 'ENV' idea was born from this, alongside a new research council and the development of new and innovative universities that were to train a new generation of scientists and technologists through generative and meaningful discussions between colleagues about the futures Britain and the world were heading toward. The ENV vision brought together multiple forms and understandings of the 'environment' beyond the hegemony of earth and natural scientific interpretations surfacing in the aftermath of the IGY. The environment for ENV was as much about the

concern for damaged surroundings from resource depletion, toxic waste and so on, as much as it was about a set of interconnected global systems. ENV was a unique space in which the 'environment' was being problematised and constituted as an object for thought (Barry and Born 2013).

This chapter has explored how a sociotechnical imaginary of the environmental sciences was cultivated through the co-production of scientific advice and science policy in the UK government amidst a vision of an 'environmental sciences' that responded to and was responsive of wider socio-political, scientific and economic changes. This vision of the 'environmental sciences' came about as a tool to produce new experts for a 'new' environment for a new environmental society and as a new means of organising scientific practice through interdisciplinary means that deeply considered the future Britain was embarking on and may find itself in after the post-war reconstruction.

However, the vision originated from government advice circles and aligned with nation-state scales, a new UK scientific society that was, for the most part, centrally planned. How the idea became a reality is shown through the founding of UEA-ENV but how the imaginary faired in a new institution, gained traction, legitimacy and became collectively held is core to understanding the saliency of the sociotechnical imaginary of the 'environmental sciences', the power of the scientific expert in government and the problematisation of interdisciplinarity to solve environmental challenges. Through Jasanoff's (2015b) stages of sociotechnical imaginary work, the next chapter explores the embedding, resistance, and extension of Zuckerman's vision of the interdisciplinary 'environmental sciences', through 'mangles of practices' in the ENV 'trading zone'.

5. Science in the Trading Zone: crossing the borders of knowledge?

This chapter explores interdisciplinarity as an explicit form of normative-procedural co-production. In the previous chapter, I noted how the idea of the 'environmental sciences' as knowledge co-production through scientific disciplinarity emerged from collective discussions spearheaded by Solly Zuckerman, new forms of technocratic governance and planning and wider changes to social order. I now go onto to explore how scientific interdisciplinarity as a mode of doing things together played out in practice in ENV's founding years and what this revealed about the durability and extension (and even multiplicity) of the vision of the 'environmental sciences'. The relationality between both discrete, normative forms of co-production like interdisciplinarity and more analytical, diffuse forms of the co-production of knowledge and order is highlighted further in this chapter. The vision of ENV was grounded in interdisciplinary knowledge-making to support the broad conceptualisation of different ideas and visions of (future) environmental change, concerning different constitutions of 'environments' that would impact current and future social and political orders. Yet, as I illuminate, the practices and realities of scientific organisation in ENV were not quite materially or practically aligned with the vision, despite being discursively orientated around interdisciplinarity. However, this did not necessarily hinder the interdisciplinary evolution of the 'environmental sciences'. Yet not until Zuckerman formally joined ENV was the wider vision of the 'environmental sciences' cemented and made a durable and scientific reality.

Jasanoff (2015b) has demonstrated that there are continual and ongoing processes of embedding, resistance, and extension that emergent sociotechnical imaginaries and visions go through if they are to become embedded in cultures, institutions and materialities, and thus become collectively held and institutionally stabilised visions of desirable social change. For Jasanoff (2015b), embedding implies the moment (or moments) of converting the hypothetical and the imaginary into 'solid' identities, discernible through long-term durable routines or practices pertaining to the imaginary. Forms of resistance are core moments in defining and shaping the longevity and arrangements of a sociotechnical imaginary, where old orders and new visions come into conflict. These moments can reveal the social apparatus, infrastructures, interactions and contexts that enable successful

imaginaries to take hold and gain potency, becoming stable and collectively held visions (Jasanoff 2015b). As a result, I explore how the processes of becoming collectively held and stable formations – within a particular institution and through different disciplinary perspectives - can reveal minor moments of resistance – not as potent as 'old orders' against new futures, but instead through practical and material concerns in making the imaginary possible in more situated sites of knowledge-making vis-à-vis the university and ENV.

With regard to Zuckerman's colouring of interdisciplinarity for the new 'environmental sciences', this chapter conceptualises ENV as a 'trading zone' vis-à-vis a space of co-production. In doing so, I ascertain how diverse groups of epistemologically and ontologically different sciences operated and collaborated in practice, and to what extent interdisciplinary collaboration and new knowledge produced collaboratively were achieved in the first decade (Galison 1997). Additionally, through the coupling of 'trading zones' and sociotechnical imaginaries, I offer insight into the diversity of cultures and varied interactions in a newly emergent inter/discipline, how the disunity of science is counterintuitively a crucial factor in its strength and stability concerning innovations in knowledge and the materiality of co-production through Pickering's (1995) 'mangle of practice'. Moreover, I show what and how varying processes of extension helped the idea of 'environmental sciences' gain traction, traverse scales and gain strength as an authoritative form of knowledge and new expertise. In doing so, I show how the 'environmental sciences' also co-produce new worlds of how things ought to be, including both social futures and the organisation of knowledge-making (Callon 1984; Latour 1990, 1993; Jasanoff 2015b).

This chapter is structured as follows: after briefly describing ENV as a trading zone in which the sociotechnical imaginary of the interdisciplinary 'environmental sciences' operates and becomes tractable and to what extent knowledge is or is not co-produced. I then explore the social and geographical processes that underpin how the imaginary became collectively held, institutionally stabilised and extended beyond the university. Firstly, I detail how the ENV Working Party (ENV WP) search and commitment for a particular type of dean reveal how Zuckerman's vision of the 'environmental sciences' was deeply embedded in the ENV administration. I then explore how different visions of interdisciplinarity were constructed and made possible in the earliest years, how different epistemologies and ontologies collaborated or conflicted in moments of resistance as ENV

was finding its feet and how new modes of co-production came about through 'science for hire' and a series of transdisciplinary seminars.

5.1. ENV as a trading zone

Analysable moments of co-production can be found in processes of emergence of new cultures of knowledge-making (Jasanoff 2004a, 2004b). **Chapter 4** demonstrated the contexts and conditions that led to the formation of ENV at UEA and the emergence of the interdisciplinary 'environmental sciences' as a forms of knowledge co-production, a wider epistemic endeavour within the social organisation of science and normative tool of social change. Interdisciplinarity was framed by Zuckerman, the UEA APB and the University Grants Committee (UGC) as the means to revitalise and transform the landscape of knowledge-making amid a broader post-war technocratic vision. Interdisciplinarity was also how the new degree programme at ENV was to operate through research and teaching. Consequently, establishing how Zuckerman's imaginary of interdisciplinarity materialised in practice is vital in ascertaining how and why it became an embedded, collectively held, and institutionally stabilised vision of desirable change and as a legitimate form of knowledge-making and demonstrates the performative nature and construction of scientific knowledge and interpretation.

Interdisciplinarity has a long intellectual history (Klein 1996; Barry and Born 2013; Sugimoto and Weingart 2015), and much discussion has ensued over how different forms of expertise collaborate, through what aims, with what reasons, and to what extent. Peter Galison (1997) identified how the scientific disciplines are heterogeneous, disunified, and must learn or implement methods and techniques to collaborate and reconcile ontological and epistemological differences in practice and procedure. Trading zones are the spaces of reconciliation in which occurs the material, epistemic and social collaboration of disunified disciplinary or epistemic silos. This happens through varying methods of concept sharing, instrument building, experimenting, knowledge exchange and theorising as disparate or cognate traditions rub up against each other and collaborate to co-produce new ideas, vision and knowledge. Additionally, this supports a relational co-productionist view that disciplines are not homogenous entities but rather heterogeneous and relational

components characterised by their multiplicity and organised around a shared and evolving cluster of problems, methods, ideas that are fluid and dynamic (Laclau and Mouffe 1985).

To think of ENV as a trading zone is an important conceptual move in unpacking the interacting role of the different cultures of knowledge-making which emerged in and shaped the early ENV. Zuckerman's imaginary of the interdisciplinary 'environmental sciences' helps understand the visions, normative aims, and beliefs in the scientific endeavour to solve and manage social and epistemic challenges emerging in a post-war and globalising democracy. Conceptualising ENV as a trading zone provides the analytical tools to describe and demonstrate how and in what forms this played out, the processes that ensued and how the imaginary became embedded, what forms of resistance it met, overcame or evolved with, and the mechanisms by which it extended and circulated beyond ENV. In following these processes, moments of co-production become clearer.

5.2. The search for a dean

Stephen Hilgartner notes that sociotechnical imaginaries often begin with a singular, vanguard vision that disperses out into the wider community or worlds through various processes of extension and circulation, gaining traction collectively as desirable futures are recognised and made possible through varying material, institutional and infrastructural arrangements (Hilgartner 2015; see also Storey 2015). In this instance, the idea of institutionalising the sciences concerned with many forms of the 'environment' and the label of the 'environmental sciences' emerged from collective discussions between Zuckerman, Quirk, Gray and Nicholson concerning the composition, epistemic aims and purpose of a new Research Council and more broadly, government planning. Although thought to be unsuitable for the new Research Council, Zuckerman reframed and packaged the idea for the university setting. Zuckerman envisaged both the broad environmental training of scientific graduates who, in his vision, were to fill the gap in the workforce for a future scientific Britain, and a mixture of scientific experts who were to deliver and teach this interdisciplinary environmental programme. This section explores how the sociotechnical imaginary of the 'environmental sciences' became embedded and institutionalised within the walls of UEA, gaining traction through the academic community

who saw the merit in developing an 'environmental sciences' curriculum and research programme.

The first step in bringing Zuckerman's proposal to life was identifying a dean; one that was willing and able to implement Zuckerman's vision of ENV. Zuckerman himself was too preoccupied with other professional commitments, namely being the UK CSA.[57] Nonetheless, his vision remained the lodestar that guided the work of the ENV WP, which began the search for a dean by first drafting an advert to be published in January 1966, stating:

> The University proposes to establish a School of Environmental Sciences with interest in the subjects of Geography, Geology, Geophysics, Land Use, Atmospheric Science and Oceanography. The Dean will be the holder of the first chair in one of the subjects and in addition will be responsible for the organisation and administration of the School and for the general development of the group of subjects within the School.[58]

The advert was published in national newspapers and academic magazines and illuminated ENV's commitment to scientific interdisciplinarity in working and teaching. Aside from geography and land-use, the disciplines mentioned were natural sciences, demonstrating a view of the 'environment' as one that envelopes or connects different systems of the planet. Zuckerman's suggestion of the social aspects of the environment (or the more 'damaged surroundings' notion of the environment) vis-a-vis conservation, population studies and the humanities had been seemingly disregarded in an attempt to unify different natural sciences despite the pressures from UGC to implement innovative interdisciplinary degree programs. It was nonetheless recognised in the planning of both BIO and ENV that the organisations of knowledge through disciplinary forms were "arbitrary", noting that two centuries ago, knowledge-making was broadly construed under the term "natural philosophy" (Bennet-Clark 1963; in Agar 2020 p. 129). Different forms of expertise have

[57] Frank Thistlethwaite to Solly Zuckerman, 6/11/1964, The School of Environmental Sciences unpublished archives, UEA. Norwich, UK.
[58] Draft advertisement for Dean position, 1/1966, The School of Environmental Sciences unpublished archives, UEA. Norwich, UK.

always come together to produce 'new' knowledge in the past (Schaffer 2013). The new universities, in some sense, were attempting a return to this, to unify disparate and arbitrarily organised branches of knowledge for the new challenges emerging to order and planning. Nonetheless, the disunity between sciences remained rife, let alone the disunity between science and humanities-based forms of knowledge (Galison 1996; Shapin 2018). Some forms of science were more conducive to organic overlaps and interdisciplinary working than others, as suggested in **Chapter 2**, despite multi-disciplinary reactions to the modern environmental problem. Based on this, it may be discerned that ENV WP had decided to excise population and conservation-based studies from the early years to make the practical management and implementation of the School an easier task, despite no explicit mention of this featuring in the archives. This signals how spectacular and transformative ideas may never usually be translated fully and can be diluted down through practical, administrative or management, or human and financial capital issues when brought to fruition (Rogers 1962).

Nonetheless, the addition of geography to the proposal proved central to the hiring of a dean and, indeed, securing the longevity of ENV. Geography can be viewed as a 'bridging' discipline connecting and moulding disparate forms of scientific knowledge within ENV (Youngblood 2007). The ad also revealed ENV's ambitions to become the key place of 'environmental' study through the growth it intended, stating that "it is intended that the number of undergraduates in the School should increase year by year from 30 in 1967/8 to 240 in 1972/3". Students needed to be attracted to the new degree programme to achieve this. Not only was ENV recruiting for a brand new interdiscipline, ENV was also in competition with existing universities and degree programmes and wanted to ensure institutional longevity. It was proposed by the administrators that ENV's staff, once hired, was to focus efforts to recruit students who would usually apply to geography, geology and geophysics degrees, with a potential pool of candidates being estimated at 1403 students.[59] As this was a new subject, there no were A-level students explicitly studying environmental science or studies. The new dean was to develop a course and staff body that could attract geographers (both human/arts and physical/science) in pursuing the broad 'environmental

[59] Environmental Sciences, Assistant Registrar to Registrar, 19/1/66 and 3/3/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK; The numbers were provided by Universities Central Council on Admissions.

sciences'. ENV was gearing up to be a critical space of knowledge-making that was being shaped by (and would go onto shape) the many worlds – government, scientific and social- that led to its construction.

This was unlike Lancaster, which had recently set up an 'Environmental Studies' programme, headed by British climatologist Gordon Manley (1902- 1980) as an oddly repackaged version of physical geography. Lancaster's 'environmental studies' paid, according to the ENV WP, "little or no attention to the 'environment' as a whole", despite the best intentions from Manley on the teaching of science to humanities students and humanities to science students, concerning the broad scope of environmental change (Agar 2020).[60] On the contrary, ENV was to be developed in the broadest sense to attract "main-stream geographers", paying attention to the "human and economic aspects of geography" via the addition of "land-use" and foregrounding the diversity of perspectives - rather than strive for a unified discipline – by retaining 'sciences' rather than 'science' in the name 'environmental sciences'.[61]

From the outset, ENV was positioning itself to reframe how the 'environment' could be known, understood and researched – utilising the fluidity and breadth of geography as a sort of epistemic launchpad, something that Lancaster had not done. ENV was slowly embedding itself as an academic endeavour with the chance to produce an innovative and genuinely new course for students via the entanglements of both physical and human geography, reframed discursively and epistemically for the new 'environmental' challenges with multiple disciplinary experts to lead the teaching and research. This was a challenging task and the commitment to Zuckerman's proposal meant that the search for a dean was arduous and meticulous. An enquiry into this reveals the processes of embedding the sociotechnical imaginary of ENV.

Once the advert was posted publicly in the media and circulated through the ENV WP's academic networks, there was considerable interest from applicants. Many were interested in what they viewed as the freedom to pursue their ideas under the umbrella of ENV. Geoffrey Eglinton, a chemist at Glasgow, wanted to pursue an interdisciplinary field of

[60] G.A. Chadwick, Notes of Meeting Held 30th July, Environmental Sciences Working Party, 1/8/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.
[61] Visit to Cambridge to speak to Professor J.A. Steers and B. Farmer about our plans for Environmental Sciences, N. Sheppard, 11/3/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.

organic geochemistry that would have benefited from being in close quarters with "geologists, soil scientists, limnologists, oceanographers and palaeobotanists".[62] Conversely, the human geographer Andrew T.A. Learmonth wanted to pursue a greater mix between social sciences and the earth sciences.[63] There was also an interesting suggestion from the Cambridge geologist Walter Brian Harland to "discard most of the words like 'oceanography', 'geology', 'geophysics' and so on..." in favour of studying the environment as more loosely, 'solids', 'fluids' and 'biological systems'.[64] Even Hubert Lamb of the UK Meteorological Office offered himself for the position before later arriving at ENV as Director of the Climatic Research Unit (see **Chapter 6**).[65] These and many other applications sparked interest and debate among the members of the ENV WP but were disregarded broadly on the basis that the ideas had moved too far away from the original idea proposed by Zuckerman, or because they did not have enough of a strong background within the constitutive disciplines of the advert to guide ENV in the crucial early years. The key to the success and longevity of ENV and the 'environmental sciences', in the first instance, was thought to be student numbers and, subsequently, the future careers of ENV graduates. If student numbers were to come from both arts (human) and science (physical) based geographers, then it was thought that ENV needed a dean who could traverse both arts and science.

5.2.1. A Geographer at the helm

With this in mind, the ENV WP decided that a geographer was most likely the best suited for the position, and they cast their nets back out, looking to old candidates and utilising networks to tap up those who had not applied already. Benny Farmer, a geographer at Cambridge who joined the ENV WP late on, proposed that the School pursue "environmental *studies* in the widest sense". As a result, Farmer suggested three candidates; Keith Clayton (1928 – 2013) (who had previously applied and interviewed but

[62] G. Eglinton to A. Katritzky, 10/1/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.
[63] A. T.A. Learmonth to Frank Thistlethwaite, 25/1/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.
[64] W.B. Harland to Frank Thistlethwaite, 3/2/1966, and D. Osborne to ENV WP, 8/2/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.
[65] Hubert Lamb to D. Osborne, 29 December 1966. J.R. Jones Archives, University of East Anglia, Norwich, UK. UEA/Jones/40.

was deemed not ready, professionally, to take on a dean position), Donald Walker (a biogeographer at the Australian National University who had been in Cambridge recently on a visiting fellowship) and Christopher 'Kit' Kidson, who'd previously unsuccessfully enquired in the early '60s to Frank Thistlethwaite (1915 – 2003) the Vice-Chancellor of UEA about positions in geography but who was now thought to be settled in Aberystwyth.[66] Farmer himself had been also been offered the job after this but had rejected it due to being too settled both family- and research-wise in Cambridge.[67] Meanwhile, Farmer secured a glowing reference from Clayton's former boss at the LSE, Ogilvie Buchanan. Buchanan wrote that he was confident Clayton was up to the task of being the new dean.[68] Despite this, Clayton was still not considered, and the ENV WP moved to also secure references for Walker (who had not applied for the position) and Kidson. Walker received excellent references, but Kidson did not. It was suggested that Kidson would not be someone who followed authoritative guidance and was "hard on his younger colleagues".[69] This was not the personal characteristics of a dean that the ENV WP had in mind to entrust with the task of developing the new ENV school and to help guide junior colleagues in shaping the direction of ENV, their careers and the broader field. As a result, unbeknownst to him, Walker received an invitation for the dean position with contingencies in place to reapproach Clayton if Walker was to decline.[70]

Meanwhile, the decision for a geographer to be dean had created some anxiety for some in the ENV WP about how comprehensively fulfilled the earth sciences aspects of the 'environmental sciences' would be with a geographer at the helm. Brian Funnell (1933-2000), a geologist (also from Cambridge) who had interviewed for the dean position had resurfaced as a suitable candidate for the first lectureship after a dean was found.[71] Walker

[66] Notes of Meeting Held 30th July, Environmental Sciences Working Party, G.A. Chadwick, 1/8/1966, The School of Environmental Sciences unpublished archives, University of East Anglia, Norwich, UK. Emphasis added.
[67] Benny Farmer to Frank Thistlethwaite, 1/9/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.
[68] Ogilvie Buchanan to Benny Farmer, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.
[69] Alfred Steers to Frank Thistlethwaite, 18/11/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK; Benny Farmer to Frank Thistlethwaite, 7/11/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.
[70] Letter to Donald Walker, 30/11/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.
[71] Notes of Meeting Held 27th September, Environmental Sciences Working Party, G.A. Chadwick, 27/91/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.

rejected the offer on 9th December 1966. Despite being flattered at the approach, there were several critical aspects that Walker noted influenced his decision.[72]

Principally, Walker had spent the last five years building up a postgraduate unit in Australia and was eager to "reap the fruits" and "hungry for the intellectual satisfaction they will bring", rather than begin completely anew in the UK and in ENV. Nonetheless, Walker mentioned that if he had accepted, he would have liked to change the aims of ENV and the syllabus noting that his view on the environment had been swayed by the "Australian countryside", a stark contrast to Norfolk. Walker was more attuned to the warmer, drier climates, poor soils, indigenous communities and displacement, and different vegetation and organisms leading to a vastly different suite of 'environmental challenges' than those in Norfolk and the UK (Robin and Griffiths 2004). Walker's view of spatially diverse 'environments' and environmental knowledge is relevant, however, for the types of 'environments' that needed science. The 'environment' is not a global phenomenon but rather constituted by many diverse environments in many diverse spaces. Walker felt his local knowledge and accustom were not applicable for the perceived 'environmental challenges' needing to be dealt with in Norfolk and UEA, and so did not feel well equipped (if in the position) to accept the job.

Consequently, in the early months of 1967 Clayton and Funnell were invited back in for a roundtable discussion to discuss ideas for ENV, including interdisciplinary pursuits, structure of the degree programmes and career avenues for graduates. Both performed very well and were seemingly well aligned with one another, and it was then decided that both should be hired as Chairs in Geography and Geology respectively, to take ENV in the desired direction of the ENV WP, close to Zuckerman's original conception, with Clayton being the dean for the first four years. Thus, now ENV had the beginning of a faculty who could take the idea of the proposed 'environmental sciences' vision forward.

This section has illuminated how commitments to desirable sociotechnical futures vis-à-vis Zuckerman became embedded at UEA through the administrative tasks and desires of the ENV WP. The vision for environmental scientific futures proposed by Zuckerman was moulded by the collective administration of the ENV WP to maximise the chances of it

[72] Donald Walker to ENV, 9/12/1966, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.

becoming a possibility. They did so by harnessing the pulling power and fluidity of geography and geographers. Importantly, the adaptation from geography contradicts the view that geography failed to capture the attention of the new universities (Johnston 2004); rather, geography was a central feature for new scientific endeavours in the new universities. Geography acted as a bridging discipline (Youngblood 2007). It helped move the 'environmental sciences' from the periphery of academic knowledge to the centre by being a vital component of the early environmental sciences recruitment, both in Lancaster and UEA. Consequently, the loyalty shown by the ENV WP illuminates the authority of Zuckerman's ideas about how the sciences of the 'environment' were to be imagined and organised, the forms they were to take, and how knowledge should be made and taught to a new generation of students.

5.3. Toward a new interdiscipline?

Clayton was hired in 1967, a year before students were welcomed to set foot in the lecture halls of ENV, to prepare the acquisition of books, technical equipment, and the hiring of staff. Funnell was to start at the same time as the students. Clayton had the important task of recruiting the founding staff despite being continually doubted during his own recruitment process. With geography and geology being decided by the ENV WP as central to the successful recruitment and enrolment of students, Clayton had hired staff who were all geographers or geologists in first- or advanced-degree training.[73] Neatly outlined in Anthony Young's (2016) autobiography, the founding staff were as follows.[74] The geographers included: Richard Hey from Cambridge, who was interested in river hydrology; John Harvey (1939 – 2019), a lecturer from the Marine Sciences Laboratory in Wales and interested in marine hydrology and physical oceanography; Athol Binns, a PhD graduate from Queen Mary College in London hired as a lecturer in climatology; Anthony Young, a lecturer in geography from the University of Sussex who specialised in all things soil and tropics related; John Tarrant (regional geography); David Hauser (economic geography); and

[73] A Report on The School of the Environmental Science, 1968 -1981, Anthony Young, The School of Environmental Sciences unpublished archives, University of East Anglia, Norwich, UK; Correspondence with Environmental Scientist (g).
[74] The careers of Tarrant, Hauser and Chroston before ENV have been difficult to reconstruct.

Clayton himself, a geomorphologist from LSE. The geologists were the geophysicist Neil Chroston; Joe Cann a postdoctoral research fellow at Cambridge who specialised in hard rock geology; Geoffrey Boulton a research fellow in Geology at Birmingham turned hydrogeologist for Kenya Department of Water Supply interested in soft rock geology; Nick McCave a British geologist who had recently received a PhD from Brown University; and Funnell a marine geologist from Cambridge. Crucially, this eclectic mix of predominantly earth and physical science expertise was the staff roster tasked with developing the original undergraduate programme and was oversubscribed by the time it was up and running in the first year.[75]

Notably, the early staff were to work together to teach basic (and overlapping) introductory courses of earth sciences, geography and ecology before students then went on to choose module options. The following year, after a second round of hiring the staff became more diverse, including Fred Vine (a geophysicist and geologist – to join in 1970), Peter Liss an ocean chemist post-doctoral researcher from Southampton and David Dent, a soil scientist. Consequently, ENV and Clayton had begun to construct a space that included multiple strands of science working toward producing a new and interdisciplinary 'environmental sciences' curriculum and field.

Yet, it is important to note, in the earliest years both through the ENV WP's plans, the composition of staff and the modules available favoured the natural sciences and physical geographers in their approaches to understanding the 'environment' as a series of planetary-wide physical systems. The social aspects of environmental change vis-à-vis conservation of resources, population growth and the overlaps with humanities work were, for the most part, side-lined or repackaged to deal with ecological, agricultural and planning studies. The integration of the sociotechnical imaginary in ENV can then be discerned as enduring minor forms of resistance during emergence.

Critically, there were particular ways of conceptualising the 'environment' for different disciplines. The ontological differences (re)shaped different practices, the guiding values, lines of enquiry and methods of knowledge-making. For the natural and earth scientists – the physical, chemical and biological aspects of the environment were key

[75] 52 enrolled students, 20 more than estimated. Student numbers, The School of Environmental Sciences unpublished archives, UEA, Norwich, UK.

(Oreskes and Doel 2003). The interaction between physical earth systems – like oceans, atmospheres, soils, climate were beginning to be understood in the post-war period (Doel 2003) and this led to more *integrative-synthesis* models of interdisciplinary collaboration (or knowledge co-production). This emerged as new instruments and techniques led to the creation of new physical and numerical knowledge the earth began to be recognised as interconnected and susceptible to alteration from human processes (Oreskes and Doel 2002; Warde et al. 2018). A shared ontology was critical for an interdisciplinary epistemology. The challenge of understanding why, how and with what effects environmental change emerged began to surface as an imperative task for the management of resources, activities and protection of human life and matched the growing desire for a unified global community, global networks, and infrastructural globalism (Edwards 2010; Selcer 2019).

On the other hand, for human-oriented (or arts) geographers, the human and public perception of new and local environmental challenges, or the role of land management (Kates 1963; O'Riordan 1969; Tarrant 1974) and the effects on surroundings were of interest. Notwithstanding, there was little critical social science understanding of this kind of earthly 'environment' in the 1960s, rather social and human environmental work focused on planning and politics. More regional and microscale literature on environments flourished in the mid 20th century onwards, predominantly focusing on historical changes and interactions between humans and their environment through the discipline of environmental history (Thomas 1983; White 1985).

But, in ENV there were multiple problematisations of the 'environment' emerging as objects for thought – hence the diverse range of perspectives being employed. ENV is one of the earliest examples of the institutionalisation of multiple research cultures sharing and collaborating long-term, in a host space or 'trading zone', the university (Galison 1997; Knorr-Cetina 1999). ENV was from the outset, a space of co-production – even if interdisciplinarity was thought to be more aligned to the disciplines that shared a common ontology.

Zuckerman's original vision can be viewed as both a means of producing interdisciplinary graduates and co-produced knowledge through interdisciplinary practices. The aim was to support both the epistemic challenges concerning the newly emergent conceptualisations of the 'environment' and the normative challenges of post-war and

future Britain – that required understanding of the interconnected planetary systems and more immediate understandings of the 'environment' as surroundings for various streams of planning and conservation. Now that ENV had a group of scholars sharing these aims, researching and teaching, how did it play out in practice? Examining the publication history of ENV reveals the patterning and authorship of published research. By reviewing both Web of Science and Scopus databases from the years 1967-1974, scraping work from all those in ENV at the time, combined with a broad search on *Google Scholar,* I gained insight into the research and publishing activities of ENV in the earliest years to discern how visions of the interdisciplinary 'environmental sciences' played out in practice in the ENV trading zone.

Initially, roughly over half of publications found in the databases between 1968-1974 were sole-authored, with the majority of work published in specialist disciplinary fields related to the earth or atmospheric sciences or oceanography. There were several papers published in the multi-disciplinary science journal *Nature*.[76] From the more human-orientated geographers, work was published in geography or area studies journals like *Regional Studies* or *Agricultural Geography*. There were co-authored papers – often with graduate students or others in similar departments; for instance, the geologists in ENV would collaborate with other geology departments. So, whilst ENV was a space of knowledge co-production, interdisciplinarity through formal publications was minimal. However, although there was little formal collaboration within ENV itself represented in publications, this may be misleading. As soil scientist David Dent recalls, he enjoyed working with a geologist on field expeditions:

> ...we crawled on our bellies, deep under glaciers. Washed by ice cold water. To find out how they work in winter, as opposed to just in summer, so we did that in midwinter as well. And that was... we went several times. So, [we] made several trips to [Iceland]. It was always great fun. ...[77]

These collaborations culminated in a few publications (Boulton and Dent 1974; Boulton, Dent and Morris 1974), but also shaped how each other thought about science,

[76] 36 out of 70 publications were sole-authored. 10 of 70 papers were published in Nature.
[77] Interview with David Dent.

'environments', and their work within. For instance, Boulton, a geologist, interested in glacial environments and glacial processes, was collaborating with Dent, a soil scientist, to ascertain variable origins of glacial till – what were once thought to be soils formed from glacial retreat can also be subglacial in formation, thus changing the ways stratigraphy and sedimentology in glacial regions may ultimately be understood (Boulton and Dent 1974). The core methods of observation and description in the field meant that both disciplines could easily share, collaborate and build on one another's expertise to generate new ways of understanding earthly processes – like soil formation in glacial environments and how to measure environmental change.

There were also recollections, from Dent, concerning informal collaboration through conversations concerning teaching and research projects with a range of individuals in ENV beyond their expertise, noting specifically conversations with an ecologist, a river hydrologist and an environmental chemist concerning possible course collaborations and fieldwork. This demonstrates the seeming significance of scientists or researchers with diverse specialisations being in close contact with one another to share ideas, and views, collaborate on papers or courses, and ultimately shape new interdisciplinary thinking and cultures of knowledge-making. For example, numerous staff and research students mentioned the importance of the coffee room as a space of informal knowledge exchange and interaction (cf. Livingstone 2003):

> ... we all regularly met in the coffee room and had lunch together and exchanged ideas, and people would share what they were working on. [78]

> ... when I saw for example [another member of staff] with a cup of coffee, I knew alright, I've can interrupt [them] now. And dearly did and coffee [breaks] often lasted for hours while we talked through ... science. Marvellous.[79]

[78] Interview with former Research Student (a).
[79] Interview with Environmental Scientist (e).

Further, several researchers (geologists, chemists, geographers, geophysicists) were mentioned in the acknowledgements sections of early research publications as crucial components in engaging discussions and idea development.

If researchers are physically separated, as we will see in **Chapter 6,** the culture of research being separate from others in the wider constructs a boundary, behind which the researchers tend to remain in the periphery, hindering cross-department interdisciplinary work, particularly in formative early periods. Nonetheless, for most in the ENV trading zone, disparate experts were able to come together in informal spaces of interaction and rest, like the coffee room or between offices, to 'talk science', discuss research plans, and opportunities and bounce ideas off one another for the teaching curriculum. Different visions of what the 'environment' was from different scientific disciplines meant that there was much worth discussing with a chemist about how best to understand the environmental chemistry of soil or asking a climatologist to demonstrate on a meteorology course. Importantly, this meant that the degree programme was interdisciplinary and promoted interdisciplinary knowledge and approaches in ENV graduates, even if the earliest actual research produced and published was not.

Nonetheless, the research work of environmental chemist Peter Liss was almost explicitly interdisciplinary from the outset. Liss embarked on an interdisciplinary research and teaching programme studying chemistry entangled with oceans and atmospheres and made meaningful collaborations inside and out of ENV. Liss recounts that ENV's multi-disciplinary arrangements were crucial for this,

> I've got to say that my research was quite interdisciplinary. I mean, I was studying the ocean, the atmosphere and how they interact. That's... that's quite interdisciplinary in the sense that in many universities, not UEA, fortunately, but in many universities, there are separate departments of meteorology and oceanography.[80]

Liss also recounts being able to attend an interdisciplinary and international conference in Israel on Marine Geochemistry early on in his ENV career, funded by ENV, that enabled him

[80] Interview with Peter Liss.

to make lifelong connections through international collaboration and a fledgling interest in air-sea gas exchanges.[81] Moreover, Liss notes that the freedom from ENV administrators emphasised that this was a new inter/discipline carving out its own space and was empowered to explore the emerging links between cognate disciplines,

> I think we were given, well, effectively carte blanche to develop whatever field we wanted. I mean, within resources, either [that] the University and School had or resources we could win, you know, from some research council or whoever. So, I think we had an - I mean, we were encouraged to think broadly and on a broad canvas... [and] there was a lot of freedom ... and a lot of emphasis on doing whatever you think needs to be done in this, this totally new subject area.[82]

It is worth reflecting on why oceans-atmosphere work was more conducive to interdisciplinary working and knowledge-production than an ecologist and sedimentologist working together, for instance. Oceans and atmospheres are both understood to be fluid chemical systems and reservoirs (Liss and Slater 1974; Liss 1975). Ontologically, it can be seen that oceanographers and meteorologists viewed their objects of enquiry (atmospheres and oceans) similarly and shared methodological techniques and practices. A shift from description and observation to applying physical principles, standardised methods and numerical techniques came from physicist Wilhelm Bjerknes (1862-1951), becoming the dominant practice in meteorology as future weather-system behaviour could now be predicted through mathematics-based calculations (Oreskes and Doel 2002; Ellingsen et al. 2018). This overspilled into oceanography as a previously inaccessible object of concern, now investigable through physical methods, instruments and analysis, and the field almost mirrored meteorology in the post-war period (Hendershott 1980). For scientists like Liss, it seemed apparent to investigate the possibility of interaction due to the shared physical and numerical approaches, instruments and the ease at data sets. Liss and colleagues in ENV sought after existing data by writing to other scientists. They collected a range of data on air-sea-gas interactions, which was essentially "a data assimilation exercise" in discerning

[81] Interview with Peter Liss
[82] Interview with Peter Liss.

the interactions of air-sea-gases and the interactive role of oceans and atmosphere in global chemical cycles (Liss and Slater 1974).[83] So, whilst scientometrically speaking, there was little formal record of interdisciplinary work *within* ENV, it is worth noting that the social aspects and research culture, which are usually invisible, had some significant effects, as recollections from researchers suggest.

5.3.1. A dichotomy between the natural and social sciences

Despite some of the more successful interdisciplinary collaborations in ENV, the uneven composition of natural and social science in the earliest years of ENV is notable, given Zuckerman's proposal in 1960 that highlighted the need for natural scientists, social scientists and humanities to work together in a broad study of the 'environment'. Yet social science and humanities-based scholarly works were few and far between. During the 1970s, the environmental movement in the West proliferated, as conservationist ideas from Carson, Vogt, and Osborne Jr gained traction and researchers from social and political sciences, like Bob Kates, Bill Clark, and Tim O'Riordan began to become more involved.

Notably, O'Riordan joined ENV in the mid 1970s having published on the role geographers can play in the social aspects of the environment (O'Riordan 1970) and then whilst in ENV publishing on the inadequacy of existing social approaches to the 'environmental sciences' (O'Riordan 1973). Notwithstanding, there were several human-based geographers – John Tarrant, David Hauser, John Barkham and Malcolm Mosely in the early years of ENV. However, there was epistemic tension or friction between the natural or realist approaches to science through different problematisations of 'environment'. As Fred Vine stated,

> ... there is this social geography side [of the 'environmental sciences'] which obviously separates off and you couldn't really include that – although they call it

[83] Interview with Peter Liss.

> social science and they would like to think it is a science and, in some sense, it is a science, but it's not a hard science [laughs] in the way that other sciences are...[84]

And another mentions that,

> ...for the majority of ENV, interdisciplinarity meant bringing physical disciplinary sciences together, chemical sciences together. So, Met and Oceans was seen as interdisciplinary rather than Met, Oceans and political sciences and sociologists.[85]

There were, then, seemingly some boundary issues between natural and social sciences in ENV (Gieryn 1983). However, this leads to an interesting sociological and philosophical question regarding the constitution and characteristics of science about the 'environment' and as a tool for ruling institutions, both conceived by Zuckerman and others more broadly. Science in government in the post-war period drew from many fields, as demonstrated by various members with different forms of expertise involved in the various committees for particular challenges (as shown in **Chapter 4**). The 'scientist' was not only a specific expert in some instances for some problems but was, more broadly, when involved in government, 'the generalist'. In this instance, the shared values, norms and beliefs of what 'science' is and how it works produced narratives, strategies and helped guide decision-making in a scientisation of politics. Things like rationality, logic and the types of questions 'scientists' ask are what Zuckerman and others (Science in War 1940) saw as the significant advantage of recruiting and embedding science in government – rather than the nuances of disciplinary practice and expertise. As a result, this signalled an emergence of a distinct civic epistemology in Britain (Jasanoff 2005) and how 'the generalist' through broad scientific and military expertise and scientific advice gained authority and established the trust for an outsider – e.g., the public and press, in science-policy matters in the post-war period. Whilst the internationalisation of science in the post-war and Cold War period made interdisciplinary and collaborative work in the earth and 'environmental sciences' the norm in government and international circles (as seen in **Chapter 2**), Zuckerman emphasised

[84] Interview with Fred Vine by Paul Merchant, National Life Stories: An Oral History of British Science, transcript (p. 53), British Library, London, UK. C1379/25.
[85] Interview with Environmental Scientist (b).

different conceptions of the 'environment' as constitutional to the 'environmental sciences' normative and epistemic importance. Yet the growing dominance of scientific authority, expert organisations and the transmutability of natural science methods, theories, instruments and data meant that circulation and scaling was seemingly easier in a world that was becoming more global, standardised and increasingly focused on mapping and predicting forms of environmental change.[86] Qualitative or interpretive frameworks are not as easily scaled or circulated as shown in **Chapter 2**, and this may be why social scientists and human geographers were not the bulk of the nascent 'environmental sciences' in ENV.

Additionally, when ENV as an interdisciplinary research and teaching programme came to manifest, there was a struggle to reconcile the different epistemologies and ontologies of the founding staff's expertise beyond the overlap of shared ways of viewing and understanding the earth (meteorology and oceans, soils and sedimentology). It is apparent, then, that the sociotechnical imaginary of the interdisciplinary 'environmental sciences' struggled in the earliest years to be 'interdisciplinary' in publications, beyond the sciences or 'integrative-synthesis' models of interdisciplinarity (Barry and Born 2013). Nonetheless, as an idea and normative tool for knowledge-making, it helped to generate new views of the earth and environmental systems and served as an important tool to globalise and internationalise systems knowledge, like ocean chemistry or atmospheric currents. This served a purpose in helping to transform existing disciplinary knowledge systems and social views of knowledge to match the need and use of science at the time (Schaffer 2013; Renn 2020), namely the internationalisation of science and global co-production of knowledge and order.

Moreover, through poor institutional and infrastructural support, the ENV trading zone restricted the formation of different types of interdisciplinary cultures or models of research. This was made apparent by the boundary work and competing visions of what the 'environment' is and how it should be known, by the natural and earth scientists. Moreover, this was exacerbated by the lack of financial support or rewarding professional incentives from ENV and outside organisations, like NERC, to prioritise these kinds of work.[87] For instance,

[86] Not forgetting the intense debates, conflicts and disagreements concerning quantitative or numerical data in positivist sciences, and geography (see Barnes 2004).
[87] Multiple interviewees noted this.

> It’s a lot easier to publish if you publish in a ... chopped up little thing where you've got a journal already waiting for you. It's ... much more difficult to get to work in something you know damn all about. And also to get published In the kind of journals that have always had some kudos, which are the chopped-up specialist things. And you can see it happen. So those who went that way ... all became Professor somewhere else.[88]

And another noted the dissuading factors for multi-/interdisciplinary research projects,

> I've suddenly remembered that you only got promotion if you had gotten the grant, and all the papers that are published just have your name on, certainly you [as] first name and probably one of your research staff as second name. But you didn't get any credit if there were five people on a topic that only could have been written up with the five people's involvement. There was no credit for that.[89]

Consequently, these institutional factors meant there was little appetite or incentive in ENV for these interactive connections to be made. Yet, in the sociology of inter/disciplines and specialisations, rewarding incentives like professional development are key in cementing and embedding new specialisations within or beyond disciplinary formations. Early work in the sociology of specialisms argued that new specialisms emerged from a demand for effective research and as new scholars looked to create their own epistemic space to advance their professional careers (Price 1963; Ben-David and Collins 1966). For ENV, this is partly relevant as a number of the early staff noted the allure of epistemic freedom given by ENV:

> ...we were encouraged to think broadly and on a broad canvas... there was a lot of freedom ... and a lot of emphasis on doing whatever you think needs to be done in this totally new subject area.[90]

[88] Interview with Environmental Scientist (e).
[89] Interview with Environmental Scientist (d).
[90] Interview with Environmental Scientist (a).

> ...pretty much everything was started from scratch with generally the Zuckerman idea - as interpreted by Keith [Clayton], to produce this broad, but deep environmental sciences syllabus, which we invented from the top of our heads ... and that itself is very exciting. Especially if you're young.[91]

As a new university, UEA was encouraged to create new interdisciplinary research programmes that drew on existing and new connections between existing disciplines. Therefore, the emergence of the new HE policy is an important factor in enabling the freedom to think and generate new ideas, in this case through Zuckerman's interdisciplinary vision. Further, as the academic literature increases, new generations of scholars seek new ways to review, organise and understand large bodies of work and the personal ways of understanding are thought to shape and generate the emergence of new specialities (Price 1963). As time goes on, these new specialities may lead to new disciplines or knowledge-systems (Ben-David and Collin 1966). Like how Liss and colleagues amassed large amounts of data and explored them in new ways to produce knowledge about the ocean-atmosphere interactions (Liss and Slater 1974) that generated broader understandings of environmental change.

Other work has explored the social contexts of increased communication and collaboration in science that led to the new ways of organising and producing knowledge, positing that the wider transformations in science in society led to new emerging specialisms or disciplines – e.g., the Cold War and radio astronomy (Geison 1981). More recently, work has sought to re-emphasise the importance of the epistemic in generating new specialisms or disciplines as science progresses through discoveries and conceptual breakthroughs (Wray 2005). Similar to that of marine geophysics as emphasised by Fred Vine in the case of verifying plate tectonic theory then feeding into the teaching in ENV,[92]

Nonetheless, despite the original aims of the cohesive and interdisciplinary 'environmental sciences', disciplinary silos were still prominent for some years after ENV's founding – even with *integrative-synthesis* models of interdisciplinarity. This was due to the

[91] Interview with Environmental Scientist (e).

[92] Interview with Fred Vine by Paul Merchant, National Life Stories: An Oral History of British Science, transcript (p. 53), British Library, London, UK. C1379/25; Interview with Research Student (a).

persistence of academic structures that preferred and rewarded disciplinary work. Even more, the interviewees here have mostly been given pseudonyms under 'environmental scientist' but most would not define themselves as such and may rather identify themselves according to their specific constitutive discipline e.g. soil science, oceanography, sociology, economic geography, conservation biologist and so on.[93] With the wider academic milieu unaccommodating, it was believed that ENV could have done more in the early years, it was noted, to break down these existing divisions, as originally intended,

> ENV has always been primarily a multidisciplinary rather than an interdisciplinary institution. I never really felt that interdisciplinary work was actively encouraged; there wasn't a strong culture of interdisciplinary collaboration across the department as a whole. Interdisciplinarity may have been the ENV ethos, but it could have been promoted more assiduously.[94]

It was not until much later in the history of ENV when interdisciplinary work between natural and social sciences was institutionalised and embedded in the School with the creation of the Centre for Social and Economic Research on the Global Environment (CSERGE) in the early 1990s and Tyndall Centre for Climate Change Research in the early 2000s[95], when perhaps the School was more institutionally stable with more journals and outlets to publish in. [96] From the outset, these were intended to be interdisciplinary centres of environmental research. Still, even these underscored particular ways of understanding the 'environment', how knowledge should be made, and for what purpose. Specifically, CSERGE emerged and secured funding from the ESRC when evidence-based decision-making had been increasingly used in Thatcher's government and embedded into science policy (Agar 2019b). Whereas the Tyndall Centre was borne amidst a more conducive interdisciplinary and policy-relevant science culture in the UK (Weszkalnys and Barry 2013).

[93] Except for the Climatologists.
[94] Correspondence with Climatologist (c).
[95] Both CSERGE and Tyndall were formed as a result of external funding both with explicit remits for interdisciplinary research. CSERGE focused on examining 'all' aspects of decision-making with environmental resources, including collaboration between economists, political scientists, geographers, social scientists. Tyndall was formed to bridge the gap between climate scientists, social scientists and policy makers and to further promote interdisciplinary working around climate change.
[96] With exception of The Climatic Research Unit as I argue in the next chapter.

Fundamentally, different forms of knowledge co-production emerge for different purposes, from different ways in which we have chosen to live and subsequently know the world.

Nonetheless, to reiterate in late 1960s and early 1970s, ENV was a group of diverse experts working in conjunction with one another with the broad aim of advancing scientific knowledge about different strands of the 'environment' for students and researchers further afield. Where interdisciplinary work did occur, in the combination of two or more disciplines to produce new insights and knowledge, disciplines already had pre-existing connections through shared methods, instruments, practices, or views of the 'environment' (Barry and Born 2013). Cultures or models of interdisciplinary work emerged in spaces with much overlap, being more easily commensurable or intelligible. As environmental concerns became more widely expressed in the UK and globally, e.g., specific political concerns and movements (Porritt 1984) or social, justice and ethical issues of pollution governance (Bugler 1972), ENV's knowledge-making evolved in tandem with the wider politics of the environment and embraced more fully social, political and economic ways of understanding the 'environment'. ENV was co-producing and being co-produced by the wider developments in knowledge and social order.

In sum, the realities of ENV's founding from (largely) physical geography and the earth sciences, with positivist epistemologies, meant other forms of knowing and disciplinary practices were not prioritised or seen as important as the positivist approaches and so, interdisciplinary work beyond these sciences was not easily recognised or formed. Yet, the framing and intent of the vision set out by Zuckerman embodied and practiced by ENV, Clayton, and the WP administrators cultivated a shift in values and encouraged a collective and enduring belief that the 'environment' was worth knowing and teaching scientifically. The materiality of ENV's early institutional culture reveals the division of practices between disparate 'environmental' ontologies. Interdisciplinarity is not a given in a trading zone, the practices and performances of researchers need to be aligned both ontologically and epistemologically and as time progressed, this culture transformed as more nuanced and shared understandings of the 'environment' came to be in ENV, from the knowledge ENV produced. The mangle of interdisciplinarity is ongoing, unstable and contingent on the discursive imaginaries guiding practices and the material realities of spaces in which they are performed (Pickering 1995). Moreover, the imaginary and vision of ENV continued to mould and be moulded by to the changing epistemic and political

contexts that (re)shaped how researchers became concerned with the 'environment'. Some researchers were becoming aware of the multiplicity of values (including financial) that ENV knowledge, through different forms of 'doing things together, began to cultivate and attract and altered their scientific practices accordingly.

5.3.2. ENVMAN Ltd – Science for hire?

In the late 1970s, two scientists in ENV, Richard Hey and David Dent pursued an independent environmental consultancy for environmental management (Environmental Resources Management Ltd, or 'ENVMAN') that offered pay-for-service research, scientific reports and reviews grounded in ENV's scientific interdisciplinarity. As an extension of the sociotechnical imaginary of the 'environmental sciences', ENVMAN operated as a translation agent (Callon 1984; Latour 1994) through which research could be conducted and applied practically for organisations, businesses, and individual environmental needs and be financially valuable. ENVMAN was set up to practice applied science to produce tangible results on a local scale for different 'environmental' challenges. As one founding member recollects,

> [ENVMAN] came from the fact that some of us thought that what we were finding out scientifically was also of practical value and people would want to know. And since we're not paid very much why not earn a bit more? Why not go to interesting places that other people have to pay to go? So ENVMAN came out of have practical applications of the things which you can do in a transdisciplinary way that other people aren't doing. And therefore, there's a market for you. [97]

ENVMAN was commissioned for wide-ranging work, including work for organisations and private businesses, becoming a successful consultancy in the process, and even offered to help ENV out of financial difficulty during the university funding cuts in 1980.[98] The sociotechnical imaginary of the 'environmental sciences' composed a vision of the future in

[97] Interview with ENVMAN
[98] Interview with ENVMAN.

which ‘environmental challenges’ in Britain were to be solved through scientific knowledge, interdisciplinary practices and new scientific training for graduates. ENVMAN were more closely aligned and demonstrative of this as both a soil scientists and hydrologist worked together (and with others) to ‘hire’ out their knowledge for applied use. Zuckerman foresaw a Britain riddled with challenges across many scales, in many spaces and of varying severity as the social, industrial, and technological landscape changed. ENVMAN saw a gap where their new knowledge could be used to support local authorities manage rivers from pollution or erosion, help farmers predict the effects of soil drainage, or assess the environmental impacts of urban development (ERM 1980). Despite appearing to be an embodiment of the future Zuckerman envisioned, this payment-for-knowledge or management consultancy model was “a thorn in the side of ENV” and seriously condemned by some members of staff at the time.[99] The issue here was seemingly the,

> more straight-laced colleagues who thought we should be doing science, not this practical stuff. They probably would’ve approved more if we weren’t asking money for it. But because we were asking for money for it and [we] had the best cars in the university as a result of this.

It is important to stress that not all in ENV felt this, and there were “probably two camps split down the middle”. [100] The reasons for this were unclear to those in ENVMAN,

> I’ve never understood why anyone should think that ... if you do something and get paid for it, that you shouldn’t do it and it’s the wrong thing to do. ‘Academics should be writing papers, in *Nature*!’ ..., you know? But certainly not writing reports for other people! Including the Broads Authority, and then getting money for it and then a better car! But there we are.

At one stage, ENVMAN had been commissioned for river restoration work but could not get any ecologists from ENV or BIO involved and had to outsource half the work to Queen Mary

[99] Interview with ENVMAN.
[100] Interview with ENVMAN.

College in London, as "the academics we had within the department were either too busy or not interested".[101] The lack of interest or disapproval from ENV academics echoes the frictions mentioned above about what the 'environmental sciences' are, what problems the knowledge produced should address, what it should be used for, how it should be made and more broadly, the objectivity of science and, more implicitly, the worlds that are and could be created as a result.

By taking money for direct application, it can be argued that the opposing scientists felt this would dislodge them from their perceived position as a 'citadel' (Irwin and Michael 2003) or as a disinterested arbiter of truth (Shapin 1996). The endeavour by ENVMAN as a translation agent reveals how the multiplicity of the normative aims of 'environmental sciences' could materialise, as Zuckerman also intended. ENVMAN utilised and shared new co-produced knowledge (from the relevant experts in the School if they were available) to be applied to solve new and local 'environmental' challenges but was not confined by the rigour of academic science. ENVMAN enrolled the idea of the 'environment' and its sciences and mobilised knowledge to straddle the boundaries of public and private interest, solve local problems and forecast environmental futures through EIAs and decision-making. This also marks an early example of the neoliberalisation of science and knowledge that goes beyond biotechnology, biomedicine or patenting (Lave et al. 2010) but instead is demonstrative of an early monetisation of nature and knowledge for management or strategy plans (Castree 2008a, 2008b). At the time, the resistance by some academics in ENV reveals the difficulty in dissolving and relinquishing pre-existing normative and epistemic aims of science – despite being orientated institutionally to epistemic freedom, knowledge innovation and knowledge co-production. Interdisciplinarity was encouraged but seemingly not for profit. Thus, the freedom to construct and pursue the innovative 'environmental sciences' was challenged by the social and professional values, ideas and beliefs of the purpose of science in the university. Meanwhile, Zuckerman transformed the knowledge-making landscape of ENV and cemented his vision of interdisciplinarity and the normative aims of the 'environmental sciences' through the creation of five weekend long seminars.

[101] Interview with ENVMAN.

5.4. The Zuckerman Seminars

The founding and setting-up of ENV happened mostly without Zuckerman. Zuckerman proposed the idea of the 'environmental sciences' and stepped back. As I have outlined, the administrators of ENV attempted to remain close to Zuckerman's original vision, with the practical (and somewhat crucial) addition of geography as a bridging discipline to recruit students and provide a foundation for founding staff to build from. The processes and practicalities of setting up ENV and its operations in the early years represent how Zuckerman's idea of a new way of making knowledge, albeit slightly altered, was becoming collectively held by the staff and university and on its way to gaining stability as a new way of organising research and teaching. However, Zuckerman had envisioned something more transformational than the production of new knowledge, having discerned the present and future 'environmental' challenges to Britain and elsewhere in the world. Indeed, the teaching of students an inter/multi-disciplinary curriculum satisfied to some extent the production of new graduates and subsequently 'scientific citizens' that were able to problem-solve the modern 'environmental' challenge beyond the halls of academia. Yet, what makes Zuckerman's vision a sociotechnical imaginary is its vision for a wider, transformative co-production of a new scientific and social order, a vision of scientific knowledge being used to solve new 'environmental' problems and guide decision-making and strategy. The early years and commitment from staff to pursue research and develop teaching curriculums signal that the vision of the 'environmental sciences' was being collectively held and institutionally stabilised in UEA, yet wider social, institutional and epistemic changes needed to be forged to achieve Zuckerman's wider interdisciplinary aims. Thus, in 1969 when Zuckerman retired to Norfolk after stepping down from formal governmental duties, he was made a Professor-at-Large in the Environmental Sciences. This new position for Zuckerman meant that he could more freely aid the making of desirable environmental and socioscientific futures and help circulate, embed, and extend the imaginary in spaces beyond the university (Jasanoff 2015b).

With more time for ENV, Zuckerman organised a series of seminars, funded mainly by the Ford Foundation of the USA, to discuss and foreground environmental challenges for Britain. From the outset, Zuckerman was keen to bring together many actors and experts to

understand and be best equipped to manage the wide-spanning and complex challenges both in the present and future. However, instead of students, Zuckerman brought together scientists, academics and representatives from business, government, and industry to discuss and propose proactively specific strategies of research that constructed research programmes, forecasted problems and cultivated desirable visions of environmental futures. The themes of the seminars throughout the 1970s were varied and included discussions on the challenge of environmental change, control of environmental change and pollution, environmental standards, social and political consequences of cars, management of water resources, regional policy and planning and environmental impact assessments. The 'seminars' (more like conferences today) explicitly co-produced visibility and knowledge of 'environmental' challenges, the authority of ENV experts and cross-arena collaboration. They were also labelled as Zuckerman's "brainchild" in ENV due to the explicit objective of bringing together scientists, researchers, civil servants, politicians, and representatives of government and business to consider key environmental issues.[102]

By 1970, Zuckerman had witnessed ENV materialise. The vision that was proposed almost a decade prior had begun to bear its fruit as the School now had around 150 students across the three years of the undergraduate programme, numerous research and postgraduates students, supported by around 20 staff.[103] However, the production of knowledge from the new 'environmental sciences' and ENV, Zuckerman felt, may have different priorities concerning environmental challenges than those of industry, government and the public.[104] What good was this knowledge if it wasn't known or used effectively in the arenas which could catalyse change?

Zuckerman had wide-reaching and important network connections and thus, decided to propose, and secured funding from UEA for, a weekend long-seminar called 'The Challenge of Environmental Change'.[105] This was one of the first-ever seminars (or conferences) in the UK that saw academics from ENV and elsewhere, business

[102] Ford Foundation seminar description. The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/UEA/9/3.
[103] A Report on The School of the Environmental Science, 1968 -1981, Anthony Young, The School of Environmental Sciences unpublished archives, University of East Anglia, Norwich, UK.
[104] Application for a grant to finance a series of seminars on Man and the Environment to be organised by Sir Solly Zuckerman at the University of East Anglia, 1970, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. Ford Foundation Microfilm 71-50.
[105] The challenge of environmental change, 1970, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/9/3/2/1.

representatives, research students and government ministers discussing privately the core environment challenges of the future ahead.[106] The weekend-long seminar hosted a diverse range of participants and topics. For example, representatives from the OECD and HM Treasury spoke on economic growth, representatives from the MAFF and the Water Resource Board spoke alongside scientists about the future of food and water, and concerns about technological changes (urban design, transport, recreation), changing land-use and conservation were also considered. The weekend concluded with a talk on the possible policy implications and challenges for government concerning all that was discussed, amidst a background context of rapid environmental change, delivered by Lord Kennet (1923 – 2009), Parliamentary Secretary, Ministry of Housing and Local Government.[107] Lord Kennet had been sent by Prime Minister Harold Wilson who had received a direct letter from Zuckerman discussing the plans for the seminar.[108]

The participants, through Zuckerman's pre-decided topics, were able to present and discuss various and intersecting aspects of environmental change. Notably, as environmental change was suspected to impact and alter multiple aspects of the public, industrial, scientific, and governmental worlds, there was a perceived need by Zuckerman and organisers to bring the 'key' individuals from the affected domains into conversation and space with each other. The seminar and its participants were co-producing and co-constructing what was to be understood or delineated as areas of environmental concern. The inter-/transdisciplinary organisation of the seminar and its proceedings had a marked effect on participants, as R. M. Shaw, the Deputy Chief Medical Officer at the time, wrote to Vice-Chancellor Frank Thistlethwaite, stating, "I have found the weekend most stimulating and enjoyable, and I have come away with a new and much better-balanced outlook to the whole problem" as a result of hearing a range of experts perform and present their knowledge.[109] A representative from the research organisation, the Nature Conservancy, noted the uniqueness of gathering a host of different and diverse experts, "...[it was] the

[106] The challenge of environmental change, 1970, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/9/3/2/1.
[107] Application for a grant to finance a series of seminars on Man and the Environment to be organised by Sir Solly Zuckerman at the University of East Anglia, 1970, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. Ford Foundation Microfilm 71-50.
[108] Cabinet Office to Solly Zuckerman, 11/2/1970, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/9/2/2.
[109] R.M. Shaw to F. Thistlethwaite, 16/3/1970, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/9/2/2.

first occasion when I have ever heard a really fertile dialogue between the scientific conservationists, sociologists, demographers and economists".[110] Meanwhile, a junior academic from BIO also heralded this opportunity to learn from other disciplines, government and industry as,

> ...the chance for a young academic engaged in active research to contribute something (and we did!) and to learn a considerable amount concerning other philosophies and other professions and their views on the subject of environmental change was most welcome. I hope we do it again.[111]

Moreover, there were to be perceived effects on industrial activity, as a representative from the Home Office and the director of the Water Resources Boards acknowledged the challenges pertinent to their jobs,

> ...I found the background provided by the conference of great interest; at times perhaps a little remote from, but at other times very relevant to, my day-to-day job of trying to assess the extent and nature of deprivation and devise remedies for it.[112]

> ...There will also be short-term repercussions [for the water industry] as far as I'm concerned...[113]

As a result, the seminar was deemed a great success by participants, Zuckerman and UEA, achieving new awareness of and action on environmental challenges. Yet, conceptualising the 'seminar' as a space of co-production of knowledge, authority, and future-making (Craggs and Mahony 2014) and as part of a wider epistemic geography of environmental change (Mahony and Hulme 2018) encourages us to question the uneven topographies of

[110] M.E.D. Poore to F. Thistlethwaite, 18/3/1970, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/9/2/2.
[111] Godfrey Hewitt to F. Thistlethwaite, 18/3/1970, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/9/2/2.
[112] D.A.C Morrison to F. Thistlethwaite, 23/3/1970, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/9/2/2.
[113] A. F. Rowntree to Solly Zuckerman, 18/3/1970, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/9/2/2.

space and power, and the implications for world- and sense-making, including the futures imagined within the seminar room.

Zuckerman, having planted the seed of a vision of desirable social change concerning the interdisciplinary 'environmental sciences', now drew from his network and institutional affiliation to support the extension of this way of viewing and co-producing the world in arenas beyond the university and disciplinary knowledge. As 'The Challenge of Environmental Change' was invite-only with Zuckerman's esteemed colleagues and networks, in what he discerned as authoritative positions, able to attend and present, it was by definition exclusionary and aligned to the technocratic view of scientific advice in government – where the position of expert should be listened and adhered to. Research students were granted attendance with permission by association with UEA and ENV.

The effect of the presence of elite and authoritative figures in the first (and subsequent) seminars was twofold. The gathering of expert individuals to speak 'freely' and discuss, carve out and agree on the possible course of action between government, research, and business gave legitimacy to the futures and agendas they circulated beyond the seminar rooms. On the other hand, it also narrowed and closed the possible worlds that were envisioned and possible to be envisioned through the few actors that were involved, that in turn continued to cement and legitimise their positions of authority and expertise. Moreover, the act of the conference or seminar as a space to perform, protest, circulate knowledge, and carve futures in deliberative and discursive spaces is underscored as the main means to illuminate new knowledge and possible modes of ordering the world. From the outside, the seminar/s positioned ENV as an emerging space, a key player and producer in the nascent field of the interdisciplinary 'environmental sciences'.

Nonetheless, being deemed a success, Zuckerman then set his sights on securing more substantial funding to create a series of similar seminars to stimulate the production of robust programmes of research that would support policy formulation and business strategy with all relevant actors involved as three entangled and supporting cogs.

Zuckerman applied to the Ford Foundation, based in the US, for financial support to create five or six similar seminars that discussed topics that emerged in the 'Challenges of Environmental Change' seminar in more detail, with a greater emphasis on international

reach.[114] The idea was "to make a major contribution to environmental planning in the 1970s" and reconcile disparate aims and priorities between industry, research and government. [115] Zuckerman noted the "unusually great" complexity concerning environmental problems that require interdisciplinary knowledge and how solutions in one field, e.g., academia, may not be appropriate for another like industry, government or the electorate.[116] The Ford Foundation was approached specifically due to the potential international scope and international impact that would not have been possible with a UK funder, and was aided by Zuckerman's relationship with McGeorge 'Mac' Bundy (1919 - 1996), the president of the Foundation at the time.[117]

Bundy and Zuckerman had been associated some years prior, with Bundy operating in a similar position to Zuckerman in the US as a national security adviser in the 1960s, continuing as a 'Special Consultant' to President Johnson even after he departed from politics. The Ford Foundation, by this point, played no role in the automobile company Ford,[118] but was initially set up to receive and donate funds for science, education and philanthropic endeavours that would advance human welfare (Bak 2003) as a means of avoiding loss of family control through the new taxation of the estate from the Revenue Act of 1935 (Greenleaf 1964). When Bundy took over the Foundation, there was a marked shift in philanthropic endeavours to more political, social and public interest initiatives – with the 'environment' being an important topic of international, managerial and epistemic concern (Bundy 1970; Bird 1998). Bundy was even touted as the president of a staff that 'rejected capitalism' which made the Ford's family wealth, with the last living link to the Fords renouncing trusteeship and no longer paying interest (Richman 1979). Nonetheless, ENV

[114] Application for a grant to finance a series of seminars on Man and the Environment to be organised by Sir Solly Zuckerman at the University of East Anglia, 1970, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. Ford Foundation Microfilm 71-50.
[115] Application for a grant to finance a series of seminars on Man and the Environment to be organised by Sir Solly Zuckerman at the University of East Anglia, 1970, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. Ford Foundation Microfilm 71-50.
[116] Application for a grant to finance a series of seminars on Man and the Environment to be organised by Sir Solly Zuckerman at the University of East Anglia, 1970, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. Ford Foundation Microfilm 71-50.
[117] Application for a grant to finance a series of seminars on Man and the Environment to be organised by Sir Solly Zuckerman at the University of East Anglia, 1970, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. Ford Foundation Microfilm 71-50; Solly Zuckerman to Frank Thistlethwaite, 30/3/1970, The School of Environmental Sciences unpublished archives, UEA. Norwich, UK.
[118] Having sold its non-voting shares in the 1950s, it became institutionally detached.

and its constitutive groups enjoyed much funding from the Ford Foundation over the next decade.

The funding was approved, and UEA and Zuckerman were granted $24,000 for three years.[119] Zuckerman requested an extension near the end of the three years, and five seminars were organised, with the proceedings published over five years. This was a crucial moment in ENV's history as it legitimised Zuckerman's vision of preparing numerous discussions and presentations of contemporary environmental challenges, giving visibility to a way of knowledge-sharing and future-making that drew from government, academia, and business, made possible by the patronage of a transnational institution. As an emerging inter/discipline and object of concern, the 'environment' and its sciences were being articulated and made as 'global' through the perceived relational impacts of more localised or regional challenges, e.g., the Ford Foundation funding seminars on environmental challenges in the UK.

The topics, decided by Zuckerman, were intentionally orientated to generate cross-sector discussion,

> It cannot be too strongly stressed that the critical significance of these seminars is the way in which they serve to bring together the academic, the civil servant (and his [sic] political masters) and the industrialist. It is the promotion of communication between these groups that is the particular concern of the Seminars.[120]

In this vein, Zuckerman was also keen to strengthen the political and social understanding and reflexivity of scientists and their work. The ever-growing and ever-changing challenges of the environment, for Zuckerman, were not confined to the boundaries of science (like all problems Zuckerman concerned himself with), and so, Zuckerman thought that the researchers in ENV needed reminding of this. Practically, the seminars operated more like a workshop; there were speakers presenting ideas or papers with discussion to follow, intermittently interspersed with lunch and tea. Papers were always pre-circulated, and

[119] Budget, 1/12/1970, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. Ford Foundation Microfilm 71-50.
[120] Application for a grant to finance a series of seminars on Man and the Environment to be organised by Sir Solly Zuckerman at the University of East Anglia, 1970, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. Ford Foundation Microfilm 71-50.

often, Zuckerman also shared questions for discussion – like what are environmental standards? Should standards themselves be standardised or vary nationally? What are the competing or converging priorities of business, government and universities? This was done intentionally to ensure the flow and continuation of conversations in a more informal manner.[121]

The papers across the five seminars boasted a line-up that drew together key researchers and those in powerful positions, including Gordon Cameron, an economist who went on to be a consultant for the Secretary of State for Scotland, presenting on 'Regional Economic Policy in the UK' for a seminar on regional policy and planning for Europe. Or David Pearce, an eminent environmental economist at Leicester and Dietrich Hammer of the Commission of the European Communities. Or lastly, Martin Holdgate of the Department of the Environment who presented multiple topics on pollution abatement. The presentations and discussions contributed to making environmental challenges visible from the performances of knowledge from newly emerging 'environmental' experts.

Presenters aside, the attendees saw directors of industry associations, water boards, ministers, and scientific advisors alongside an array of UEA and other researchers. It appeared that most of the key individuals in the emergent environmental landscape with interest in environmental challenges and concerns attended or presented at one or more of the seminars. As a 'trading zone', the seminar space enabled new articulations of environmental change and challenges were being shared and made knowable through discussion and presentation between government, university, and industry's seemingly disparate arenas between seemingly disparate forms of expertise. But how did ENV manage to secure the attention and presence of so many key individuals? The seminars were an embodiment of Zuckerman's command and network. The main bulk of invites came from Zuckerman or was approved by Zuckerman. Zuckerman also often chaired the discussions and wrote the forewords or epilogues of the published proceedings. The materiality of the seminars is a direct illustration of the command of Zuckerman. Moreover, the seminar series can be viewed as a direct intervention by Zuckerman to extend his vision of the interdisciplinary 'environmental sciences' beyond the university to stimulate more durable

[118] Zuckerman to others, 1971, The School of Environmental Sciences unpublished archives, University of East Anglia, Norwich, UK

and legitimate visions of environmental scientific futures in response to the narrow institutional focus of ENV in the founding years.

The Zuckerman seminars, like ENV, contributed to a wider circulation of the 'environmental sciences' sociotechnical imaginary proposed by Zuckerman (through collaboration and graduates), cementing particular epistemologies and ontologies over what the 'environmental sciences' are and how they should operate as an inter-discipline, on a national and political level. The participation of government ministers who attended and stayed for weekend-long seminars further underscores Zuckerman's social and political authority, legitimising ENV as a site of environmental knowledge-making through their commitment to attending such events concerning environmental challenges. It is unlikely that this would occur in the present day due to an institutional shift in the architecture of UK science policy that has multiplied the number of experts and advisors in government; now, 'science' goes to the government rather than the other way round (Keenan, Flanagan and Cunningham 1998).

Moreover, the lack of interest and institutional structure to support and incentivise more disparate scientific disciplines vis-a-vis between the social and natural sciences or applied science as a consultancy and environmental management demonstrates why the Zuckerman Seminars were crucial in re-guiding the direction ENV was heading. Without Zuckerman's involvement, ENV may not have been able or as easily able to truly cultivate more inter/transdisciplinary discussion that was thought to be needed for the modern environmental challenge. More empirically, in the broader intellectual history of the environment and the 'environmental sciences', conferences have been a foundational part of making new environmental expertise, new research agendas, consensus and, consequently, institutionalising the 'environment' as a science (Warde et al. 2018; Güttler 2019). The Zuckerman Seminars extended this and helped contribute to ENV's growing reputation as a site of environmental scientific knowledge-making and emphasising inter/transdisciplinary components of the institution that were lacking in the research programme and helped to underscore the authority and relevance of interdisciplinary approaches.

5.5. Conclusions: An embedding of ENV

This chapter has explored how interdisciplinarity as a form of knowledge co-production embedded in the sociotechnical imaginary of the 'environmental sciences' played out in practice, becoming collectively held and institutionally stabilised. The idea of interdisciplinarity was at the forefront of HE and science reforms (**Chapter 4**) and key to Zuckerman's proposal, yet the institutionalisation of interdisciplinarity practices, as shown in this chapter, was multiple and uneven at best in the founding years of ENV. This created tension and resistance between the world Zuckerman imagined of a transformational and interdisciplinary 'environmental sciences' and society, and the world deemed practically achievable by the administrators of ENV. Not until Zuckerman returned and used his connections to secure a series of seminars did ENV substantially and collectively branch out beyond the university and existing disciplinary silos. Zuckerman's presence helped to materially and discursively encourage challenging ideas between different forms of knowledge – science, industry and political. More importantly, this chapter underscores those emergent ideas, imaginaries, forms, and knowledge-making processes as not discrete moments of co-production, but as waxing and waning performances between different actors over time, reflective and contingent on the material, social, institutional, and epistemic contexts in which they emerge. For instance, interdisciplinarity in ENV was received well by the disciplines and individuals for whom methods, instruments, and ontologies of the 'environment' were shared – like atmospheric and ocean scientists or geologists and hydrologists – and who could embrace 'integrative-synthesis' models of work and work in reciprocal ways (Pickering 1995; Barry and Born 2013).

On the other hand, collaboration through more 'agnostic-antagonistic' models of interdisciplinarity (Barry and Born 2013) between disparate disciplines, like economists and climatologists or alternative forms of knowledge like applied environmental management, or discussions between university, industry and government, were low-priority until Zuckerman returned. With the power, authority, and wealth of connections, Zuckerman was able to fund and organise intentional coming-togethers of who he thought were the key and relevant experts for the challenges of environmental change in one space over several years. This helped to support both the extension and legitimisation of the imaginary of an

interdisciplinary environmental socioscientific future and ENV as a space of knowledge co-production

The following two empirical chapters seek to explore this further. I intentionally uncover diverse spaces of co-production operating at different scales, ascertaining how they become constitutional aspects of the 'environmental sciences' at ENV and the role they play in (re)shaping visions of environmental change. I use an ecology of co-production sensibility to uncover the visions and cultures of knowledge-making that appear on the margins and peripheries of ENV. To support this, I have chosen two aspects of the 'environmental sciences' which did not appear in Zuckerman's original proposal but became core features of ENV and in understanding translocal and multi-scalar environmental change, the Climatic Research Unit and ENV's work in the Broads.

6. Making knowledge global, making global knowledge: The Climatic Research Unit

This chapter explores the origins of climate research in ENV through the Climatic Research Unit (CRU). Zuckerman's original proposal did not include the climate and thus it was not thought to be a core aspect of the early years in ENV. By using an ecology of co-production approach I intentionally seek to uncover the co-productions both within and through CRU as it remained on the periphery on ENV for a few decades to demonstrate how points of resistance in sociotechnical imaginaries are equally important in the broader co-production of knowledge and order. This chapter explores the multiple co-productions that emerged as CRU moved from historical forms of climate reconstruction and internal interdisciplinary working to the construction of a global temperature index to discern anthropogenic impact on climatic changes for forecasting and planning new climate futures with external partners. I argue that the changing epistemic lifestyles that resulted from changing directors, and CRU's institutional autonomy, were key factors in enabling these changes to occur.

To do so, through the 'ecology' sensibility or approach I outlined in **Chapter 3**, I utilise the concept of 'epistemic lifestyles' (Shackley 2001) to describe how the changing cultures of research in CRU – embodied in the contrasting directorships of Hubert Lamb (1913 – 1997) and Tom Wigley – contributed to the realisation and normative aims of the 'environmental sciences' imaginary in ENV and shaping the material realities of climate knowledge-making, unique to the institution of CRU. Exploring the epistemic lifestyles of CRU provides an entry point into the changing social interactions, normative aims and daily processes that constitute and are constitutive of cultures of research and shape the performances of knowledge-making by the actors enrolled. Notably, conceptualising 'epistemic lifestyles' as a tool of co-production and necessarily related to 'sociotechnical imaginaries' (Jasanoff 2004b; Jasanoff and Kim 2015) in the ecologies framework illustrates the relational and contingent nature of ways of knowing, the varied performances and materialities of co-production, sense-making and living in the world. In particular, I emphasise how knowledge-making, future-making and institutional normativity are fundamentally defined (and are defined by) and embedded in social and geographical

processes – like the researchers who cultivated and put visions in place or the communities that shared them.

It is worth briefly reaffirming what epistemic lifestyles are before this chapter begins. Epistemic lifestyles are the particular sets of intellectual questions and problems, the research practices, the social connections and networks and the plethora of mundane activities that make up the practice of daily scientific work; coupled with a guiding sense of purpose, achievement and value that enables work and knowledge to be produced within specific institutions or cultures of research (Shackley 2001). Specifically, Shackley used this idea to understand differences in research, institutional cultures, and social networks of climate change modellers. Yet, I argue that the concept can be widened to encompass and understand differences between wider knowledge-making practices within particular institutions. Rather than focus on the important but fine-grained analysis of different modellers at different research centres to comparatively explain why particular institutions produce and circulate different types of models in discrete moments, exploring changing epistemic lifestyles within one research culture in an institution like ENV can reveal the more uncertain, blurred and ongoing social processes that (re)shape the evolution and circulation of knowledge in particular places, like CRU. Akin to the visions of desirable futures made possible through advances in science and technology, epistemic lifestyles can be viewed as a productive tool that enables particular groups or cultures of science to achieve, work and articulate scientific futures. In the case of ENV, CRU was a bonus to the School and was established in 1971. For the most part, it functioned more or less as an independent institution until ENV administratively and financially absorbed it in 1994. CRU was initially proposed by Lamb to be a centre to focus on the historical reconstruction of climate completely unrelated to the original aims of Zuckerman and ENV.

This chapter is laid out as follows. Firstly, I explore Lamb's academic and professional background to discern the origins of his epistemic ideals that contribute to the epistemic lifestyle he cultivated in CRU. I then outline the contexts and background behind the founding of CRU; Lamb's involvement with the WMO and CRU's place in the wider climatological research community – this laid the foundations for the ways in which CRU (via Lamb) saw its value in the world and the ways in which it was to make knowledge. Next, I explore two key projects in CRU's early history that demonstrate the shifting and changing epistemic lifestyles between Lamb and Wigley – the Historical Weather Mapping Project

and Geographical Patterns of Climatic Change. During the lives of these projects, Wigley arrived and takes the helm of CRU and knowledge-making in CRU expands via international collaboration – predominantly associated with funding from the US DOE. Lastly, I reveal how Wigley's presence and guidance transformed the historical work of CRU to become more aligned with the growing and hegemonic numerical ways of knowing and understanding climate through international collaboration, patronage and networking and how CRU became a formative space of climate knowledge-making and circulation.

6.1. A meteorologist's history: Hubert Lamb

Lamb is recognised today for his important foundational work in historical climatology. Yet, from the 1950s until the inception of CRU, Lamb was carving out and establishing the historical study of past climate and weather fluctuations against the grain and interests of the meteorological community in which he emerged. It was, however, far from predetermined that the UKMO (and indeed, other institutions) were to embark on numerical and statistical-based forecasting and modelling. Rather, it was an outcome of ongoing and diverging epistemic and philosophical approaches coming together to determine the best ways to discern and grapple with researching a new 'dynamic' climate (Heymann 2010; Martin-Nielsen 2017). During the mid-20th century, climate was increasingly being seen as a dynamic and changeable system, to be understood through numerical simulations of weather patterning, rather than as a 'stable' object of regional, geographical concern (Heymann 2010). At the UKMO, this posed many challenges to the legitimacy of their predictions, the future of their research, epistemic authority, and institutional culture (Martin-Nielsen 2017). To keep up with broader developments and emerging technologies and to legitimise their efforts against public and political criticism, the UKMO embarked headfirst into "objective mathematical predictions" made by "powerful electronic computers" (Mason 1978, p. 297).

Whereas Lamb, moving away from the main UKMO activity, was granted permission in the mid 1950s, by Graham Sutton, director at the time, who was sympathetic to his ideas and methods in historical climatology, to peruse the archives in the UKMO basement for an RMS essay competition. Lamb enjoyed much freedom in the archives, as he recollects how

he was “wonderfully free from interruptions, two floors below the ground” (1997 p. 181). The archives possessed historical observations, weather logs and miscellaneous documents and were rich in description that had not formally been analysed before. It was in this vein that Lamb began to identify that climate varied over long time periods, as opposed to climate change being a recent phenomenon, enabling Lamb to propose a research programme that dealt with this (Lamb and Johnson 1959; Lamb 1964).

Fundamentally, Lamb’s approach to climatic variability and fluctuations centred around the idea that climate went through a 200-year cycle of cooling and warming trends; an idea that he had developed through his archival work in the UKMO basement. For Lamb, there was more to be known about past climates beyond the relatively recent instrumental records to verify or calm growing concerns about modern climatic changes. Lamb argued that attributions of recent trends might have been skewed toward the agency and impact of human action and ignorant of the cyclical nature of the historical climate. Specifically, one example Lamb underscored is the similarity between cooling in the 1960s and the 1760s, which supported the cyclical premise of his hypothesis.[122]

Lamb trained in geography and his meteorological training insisted he was to provide clear and precise articulations, to generate forecasting based on observational reports and weather maps. Lamb thought that to fully understand the processes that shape climatic stability or fluctuations, climatologists needed to have a thorough historical understanding of processes and phenomena in order to ascertain what was ‘natural’ and what was not (Lamb 1997). Lamb (1969) thought existing statistical tables were now defunct in the view of climatic variations and what was needed was more historical data about past climatic variations, why and where they happened, and to provide a base from which scientific and numerical predictions could work from and discern the extent of human impact. Importantly, Lamb (1997) believed that the historical work he was developing,

> ... had the unusual feature that it is made of the physical laws that are the scientific basis of modern meteorology to recapture the patterns of wind flow over the Earth and the prevailing weather patterns in each epoch... This made it possible to

[122] JS meeting with Hubert Lamb, 25/4/1974, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. 1.3 155 Box 109, Folder 1109.

> construct the *probably* global patterns of wind and weather from whatever fragmentary reports and scattered evidence were available. This effort promised to serve the cause of climatic science, as well as history. (p. 196, emphasis added).

Notably, Lamb was actively seeking – without stating it – to pursue an interdisciplinary research programme drawing on the promise of history to inform and legitimise present and future understanding of climatic variability in climate science. This way of viewing climate and its changes led to Lamb leaving the UKMO and seeking epistemological refuge elsewhere (Martin-Nielsen 2015) due to clashes over epistemic standards, cultures of research and ultimately differences in knowledge-making and imagined futures for climatology.

Two cultures of prediction emerged – one grounded in numerical methods and another grounded in historical approaches (Martin-Nielsen 2017). When Sutton left to become director of NERC, Basil John Mason (1923- 2015), a cloud physicist, took the helm at UKMO and invested heavily in the technological aspects of forecasting, and then modelling, to push numerical methods into full operation and Lamb's historical approach was now beyond the margins of the UKMO operation (Martin-Nielsen 2017). Lamb was cautious about reducing the future of climate to a purely physical phenomenon made knowable and predictable through numerical and statistical methods without the historical knowledge of past climatic fluctuations (Martin-Nielsen 2015). Although now, much of the knowledge we hold about climate is generated through machines, models and transnational infrastructure (Edwards 2010) and 'climate' is tightly coupled with 'the environment' (Howe 2014; Warde et al. 2018), Lamb was committed to legitimising and promoting his epistemic ideals in the form of historical climatology, not necessarily linked to modern environmental change, and he needed an institutional space and funding to build this programme.

Eventually, Lamb established the Climatic Research Unit in ENV in 1971 as a place to embark on his particular vision developing climatology via historical reconstructions. in doing so, Lamb imparted his epistemic ideals onto junior colleagues generating a particular epistemic lifestyle of historical description and reconstruction using a range of sources. CRU became an alternative space of climate knowledge-making and a key site of historical climatology to help settle the alarmist claims emerging elsewhere in the community.

6.1.1. Lamb's epistemic ideals

The coming together of two cultures of prediction, research and more broadly competing visions of scientific futures was not inevitable but came about through differences in epistemic standards, normative aims, and the worlds desired to be lived in. It is worth exploring Lamb's biographical details to understand how and why his particular epistemological and ontological approaches to climate research and his caution toward numerical approaches came about.

I argue that Lamb's epistemic unease of numerical approaches predominantly stemmed from a social and academic life that tried to channel him down the mathematical route. Firstly, Lamb grew to resent mathematics and numerical approaches (Lamb 1997). This resulted from his stern and authoritarian father (Ernest Horace Lamb, 1878 - 1946), who was a renowned Professor of Engineering at Queen Mary's College of the University of London. Ernest Lamb had torn young Hubert away from the studies he enjoyed – History, Greek and Latin – to study on the "science" side of the school curriculum (Lamb 1997: p, 19). Moreover, when Lamb enrolled at the University of Cambridge and, partway through, chose to pursue geography instead of chemistry and physics, he recalls his father commenting on the mediocrity of the degree, proclaiming it would be one he would regret all his life.

Later on, as mentioned above, Lamb was trained to understand future weather as the outcome of historical weather patterning early in his meteorology career. This stayed with him throughout his career as Lamb developed a view that the future could be predicted with inferences from the past and equally that present conditions could reveal past conditions. As a result, it can be argued that Lamb embodied a certain set of epistemic ideals that shaped the way he thought, understood and made sense of the world, one that can be seen as a grounding in the past to determine the present and future. These were a commitment to historical analyses to make sense of the current world and future - rather than relying on statistical, numerical and computer modelling that reduces real-world observations into a set of statistical points and ran the risk of applying modern-day conditions that were not present in past climates. Lamb (1997) felt there was much worth in historical research ways of knowing the world. This showed most clearly in his desire to provide historical descriptions and to reanalyse existing weather and wind pattern work to

establish long-term trends in climate. Climates did change but Lamb believed this was through natural cycles and not something to be immediately concerned with. The desire to focus on historical research led Lamb to embark on archival work to explore the realms and realities of past climatic changes.

Before embarking on the founding of CRU and whilst distancing himself from the numerical work gaining traction in the UKMO, Lamb made lasting connections with the Quaternary Research Group from the University of Cambridge. Lamb's participation through meetings, presentations and chats enabled him to become more aware and interested in the growing knowledge of past climates and the range of different indicators to ascertain different climates (like flora and fauna) and embarked on reclassifying weather indexes from historical documents and observations (Lamb 1997). This solidified his desire for a centre of historical climate research. However, unlike Zuckerman's vision for ENV, Lamb's vision of historical climate garnered much more fragmented support.

6.2. The origins of the Climatic Research Unit

With Lamb arguing that the rise of a changing concept of climate needed a historically-grounded investigation into past climates to aid the understanding of present climatic trends and to enable forecasting into the future in epistemically legitimate ways, he set out to find a space for this to happen. In the mid 1960s, Lamb's friend and colleague, Gordon Manley, climatologist and geographer, suggested that Lamb took over his position as head of Environmental Studies at Lancaster. Still, Lamb declined, not wanting the burden of administrative duties or teaching taking up his research time in such a febrile and important time for climate change research (Lamb 1997). Contradictorily, Lamb had become aware of the new ENV at UEA through his daughter and wrote to the Secretary of UEA about the possibility of setting up a new climate centre,[123] and, contrasting the discussions with Lancaster, proposed himself for the vacant dean position.[124] Lamb's dean proposal was not seriously discussed, like the other candidates mentioned in **Chapter 5,** due to deviation from Zuckerman's original vision for ENV, in which climatology did not appear. Nonetheless, the

[123] Hubert Lamb to Secretary of the University of East Anglia, 5th October 1966. Unpublished archives at The School of Environmental Sciences, University of East Anglia, Norwich, UK.
[124] Hubert Lamb to Derek Osborne, 29/12/1966, J.R. Jones Archives, University of East Anglia, Norwich, UK. UEA/Jones/40.

proposal for a separate centre, later on, was met warmly by the then newly appointed dean Keith Clayton who, alongside Zuckerman, helped Lamb secure separate and short-term funding from the Nuffield Foundation and Shell Petroleum to help establish the new centre, CRU. [125] Notably, Zuckerman used his networks to scan for potential funding as a sign of agreement with Clayton that attaching CRU onto ENV was a worthwhile endeavour – despite the 'environmental sciences' and climate research remaining epistemically separate in the wider research community. The promise of new knowledge of climatic variability was stressed to industry and was desired, particularly, by Shell who faced some long-term planning issues around oil storage facilities and demands for oil amidst changing winters and energy use.[126]

Lamb aimed to build a unique centre (in the UK) of research that could calm the frenzy of the alarmist forecasting from others in the climate community of "impending doom".[127] The central premise was that the rise of numerical modelling and projections that were forecasting increased global warming needed grounding and validation from historical material to ensure the forecasts were legitimate and plausible. In doing so, CRU set out the following aims,

> i) To establish the facts of the long record of climate in the past and to make them accessible to knowledge by presentation in reliable maps, diagrams, and tables,
> ii) to subject the mapped data to meteorological and other forms of analysis so as to Identify the processes involved in climatic fluctuations, particularly any repeating cyclic processes, recognition and monitoring of which may provide a forecasting tool,
> iii) to take special interest in the processes and history of variation in the North Sea (and other northern seas in this sector of the hemisphere).[128]

Lamb's vision of CRU's position in the wider climatological community is clearly outlined in the aims – the historical records of the climate of the past are to be collected and analysed scientifically to help support emerging future climate concerns. CRU's spatial proximity to

[125] First Annual Report of the Climatic Research Unit, October 1971 – September 1972. Hubert Lamb.
[126] Chalkley to Hubert Lamb, 8 September 1966, J.R. Jones Archives, University of East Anglia, Norwich, UK. UEA/Jones/40.
[127] Seventh Annual Report of the Climatic Research Unit, October 1977 – September 1978, Hubert Lamb.
[128] Second Annual Report of the Climatic Research Unit, October 1972 – September 1973, Hubert Lamb.

the North Sea meant that it could become the core site for studying the North Sea and northern sea climatic processes, supported by the local interest in the area. However, Lamb could not quickly achieve these aims by himself; establishing a research centre or institution would require the collaboration and commitment of a team. The early team consisted of ex-UKMO staff and meteorologists who were also aligned and keen to participate in (or, in some cases, continue with their own) historical research.[129]

Despite the initial support from Nuffield and Shell, the first few years of CRU's existence were beset with financial uncertainty, as Lamb noted in many of CRU's early annual reports, almost leading to collapse (Lamb 1973). Relying on 'soft' money resulted from ENV's willingness to host CRU without financially committing to any staff other than the director until 1994.[130] This proved paramount to CRU's future in research, as this arrangement meant that CRU had to become very good at bending or bending to the funding streams in the earlier years to establish themselves. If researchers could attract funding for different research topics, they could pursue them. As Ron Doel (2003: p. 640) notes, establishing relationships of patronage is key to survival and shapes research agendas in significant ways:

> Any investigation of the growth of scientific fields must take into account the influence of patronage on scientific institutions. New funding not only creates new facilities, it also emphasises certain kinds of inquiries over others. In particular, patronage can shape research schools, and hence influence the production of researchers, guide the questions that researchers ask, place newly trained recruits in other leading research institutions, and affect the boundaries and core areas of larger research communities.

Importantly, CRU was embarking on research projects through flexible funding, with little interference from its funders. For example, after a few years of financial hardship, another grant from Wolfson was to be received over five years totalling $100,000, for no specific purpose except to help support Lamb and CRU's research aims. Lamb's vision was slowly

[129]Second Annual Report of the Climatic Research Unit, October 1972 – September 1973, Hubert Lamb.
[130] 'Soft' money is essentially non-permanent funding from outside organisations, like grants or donations.

becoming a reality as the piecemeal funding came in and enabled the recruitment of research students, old UKMO staff and administrative staff.

The ad-hoc style of research and funding, despite not being conducive to institutional longevity, coupled with the institutional and financial separation from ENV, importantly meant that CRU could retain 100% of overheads. This acted as a safety net and enabled blue-sky types of academic research aligned to Lamb's aims for the unit and vision of a historical climatology.[131] This was particularly important, as climate changes vis-à-vis warming or cooling were thought to have variable and multi-scalar impacts on local agriculture through international planning and conflict.[132] Thus, if Lamb could provide evidence that the climate changes were cyclical, then human impacts and changes, like the energy crises emerging throughout the 1970s, may not be a significant contributing factor as suspected and oil companies like Shell could plan and prepare accordingly.

Moreover, the early ad-hoc research permitted personnel from CRU to pursue different forms of historical climatology research, not limited to particular aims or geographies (e.g., the UK or Europe) but instead allowed members of CRU to cultivate a diverse set of expertise through, for example, reconstruction of daily weather maps, historical analyses of seasonal rainfall, reconstruction of monthly weather and circulation maps and understanding the variability of winds and currents in the North Sea. Members of CRU were variably building up historical understandings of the plethora of factors that can influence weather and climatic variation. Consequently, as researchers from CRU traversed different university departments, institutions, and organisations presenting their results to a transdisciplinary audience and consulting on a range of inquiries, they became known as the go-to historical research centre.[133] Akin to Zuckerman's networks of the previous two chapters, Lamb also used his connections and authority to share the knowledge CRU (and himself) was producing, to create a library from donated data, gifted maps and books, and later on, to host an international WMO conference on long-term climatic fluctuations in 1975.[134]

[131] Correspondence with Climatologist (c).
[132] JS meeting with Hubert Lamb, 25/4/1974, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. 1.3 155 Box 109, Folder 1109.
[133] Seventh Annual Report of the Climatic Research Unit, October 1977 – September 1978, Hubert Lamb.
[134] Lamb was Chair of the WMO working group on climatic fluctuations and decided CRU was most appropriate space for this meeting

The presence of the WMO conference enabled Lamb to publicly display both the Unit and staff to international colleagues and underscore the international importance of historical (and interdisciplinary) understandings of climatic fluctuation. Whilst CRU relied on 'soft' money, they did not necessarily struggle for funding and the financial and institutional freedom allowed Lamb to cultivate a particular epistemic lifestyle in CRU that helped grow the field of historical climatology by sharing analysis of historical data with other institutions. One of the earliest and most important collaborations Lamb initiated was a working partnership with colleagues at the Lamont-Doherty Geophysical Observatory in New Jersey and Brown University on a project named CLIMAP. CLIMAP aimed to build and exchange the earliest data for paleoclimatic reconstructions derived from tree-ring data. From the outset, Lamb was casting the net wide to establish a full and thorough understanding of past climate and variation indicators and was promoting the use and applicability of CRU's knowledge far and wide.

Although often working alone – like historians and those in the wider humanities customarily did – Lamb recognised the need for collaboration due to the geographical and temporal scope of the available data. If CRU was to become a globally recognised site of historical climate research, as Lamb intended, international collaboration and networking were needed and came, for Lamb, in the forms of research partnerships and international conference hosting.

6.2.1. The World Meteorological Organisation: a global science network

A key moment of legitimisation of CRU's and Lamb's early efforts was the WMO Conference on long-term climatic fluctuations in August 1975. The WMO was founded under the auspices of the United Nations (UN) (Edwards 2006; Zillman 2009) and can be argued to be part of the internationalisation of the scientific community that bore the origins of the 'environmental sciences' (see **Chapter 4**). The WMO was formed in 1950 as a specialised intergovernmental agency of the UN that sought to achieve international cooperation between meteorologists through the rapid exchange of data and standardisation of meteorological observations. It differed from its predecessor, the IMO, by transcending "the restriction and sovereignty of national weather services" that the IMO was hindered by,

enabling meteorologists to draw on government power via the unification and authority of the UN for implementation (Edwards 2010, p. 194). The WMO also emerged in a time of rapid technological change and development. The materialities of this change brought with it new methods of spatial expansion through the construction of new meteorological infrastructure, such as producing new forms of satellite data that could transcend the local contexts in which they were embedded (Edwards 2006).

Importantly, meteorological observations were truly global in scope and scale, and the WMO was intentionally embarking on standardising data within networks globally to produce global data. By the 1960s, then, the WMO had direct efforts to make this reality through the creation of systems, standards and institutional mechanisms through the World Weather Watch (WWW) (Edwards 2006, 2010).[135] Broadly, the WMO wanted to cultivate an internationally cooperative community of scientists to share and collaborate standardised data through the various streams of networks it produced. The WMO supported lower-income nations via training (either through events or bursaries for events) and purchasing equipment to assist in participation in this new international community. In turn, this contributed to what Paul Edwards (2010) terms 'infrastructural globalism' – the building of technical systems to amass global data that help to support and legitimise the creation of international institutions and, ultimately, channelling global ways of thinking, management and governance. The WMO helped to further construct climate as a global system and object of knowledge-making through the connection and reassembling of loosely coordinated existing networks of climate and weather observations, practices, instruments, and people in making large-scale data initiatives (Oldfield 2018).

Yet meanwhile, Lamb had a strong relationship with the WMO - as being regarded as one of the world's leading climatologists - primarily during his time at the UKMO, but this continued throughout his time in CRU.[136] The WMO hosted events like conferences and symposia but also held 'expert' meeting workshops to discuss challenges and solutions, new research pathways, or to seek advice on establishing international networks. Due to Lamb's connection, CRU was involved in a number of these, but most notably in the mid 1970s, when the WMO-sponsored conference on Long-term Climatic Fluctuations took place in

[135] Numerous Annual Reports of the World Meteorological Organization. Available at: library.wmo.int. Last Accessed: 20/1/21.
[136] Correspondence with Tom Wigley.

1975, with the conference topic decided due to Lamb being chair of the relevant working group. Akin to the Zuckerman seminars (see **Chapter 5**), Norwich and CRU hosting an international symposium helped to illustrate CRU as an authoritative site of historical understandings of climatic fluctuations.[137] Yet, this also signals that the emerging view of CRU being an important site was contingent on the authority and reputation of a central leader – Hubert Lamb in WMO and climatology networks – and his guiding ideas, values and aims for what sort of institute CRU should be. Arguably though, the WMO's interest in climatic fluctuations was not neatly aligned with the newly pursued globalist arm of meteorological endeavours, collaboration and observation. This is demonstrative of the multiplicitous aims and achievements of climatology (and meteorology) that Lamb was striving to retain during the growing hegemony of numerical methods and technological innovation. Climatology, for Lamb, was interdisciplinary and requires insights from history, geography, geophysics, archaeology, chemistry, statistics, atmospheric physics and so on, rather than being reduced to standardised, observational and homogenous global data sets (Lamb 1972). CRU's performance and hospitality at the WMO conference underscored this in the wider community, as several CRU staff presented their historical research, guided by Lamb, to a keen and interested audience.

The meeting itself hosted over 250 multi-disciplinary scientists from over 30 countries and a lot of eyes were turned toward the work CRU was embarking on. One participant that became aware and impressed by the work of Lamb and CRU was Mike MacCracken from the Lawrence Livermore National Laboratory (LLNL). The LLNL was associated with developing nuclear weapons and energy through science and technology and was interested in US energy independence. MacCracken, working at LLNL at the time, was later influential in supporting CRU to become a core member of the US Department of Energy's CO2 Programme. Importantly, there was a resounding agreement on the future study of climatic fluctuations noted at the end of the conference and for Lamb, the cementing of the Unit's aims and purpose, that "vigorous efforts to solve the problem of climatic fluctuations ... at both national and international levels ... [are] one of the central tasks that society must face".[138] This was predominantly orientated around the increasing

[137] Hubert Lamb to Elmore Jackson, 13/2/1974, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. 1.3 155 Box 109, Folder 1109.
[138] Fourth Annual Report of the Climatic Research Unit, October 1974- September 1975, Hubert Lamb.

awareness and possibility of human-made climate changes that had been growing in traction in the post-war period.

6.2.2. Rising levels of CO_2 research

Whilst CRU was carving out its own space and trying to ensure financial stability, CO2 research and numerical modelling were progressing elsewhere in the wider scientific and climatological community. Major anxieties about climate change due to human impact surfaced and became a cause for concern.

During the mid 1950s, as Lamb was embarking on archival work in the UKMO, few scientists were concerned with the possible effects of increasing atmospheric CO2. There was little to no recognition of it being considered an 'environmental' issue. Instead, as shown in preceding chapters, many scientists were concerned with both the range of newly conceived environmental issues such as population, resource strain, pollution and with the ideals of environmental management techniques that would alleviate these issues in a new post-War order. Within this new post-War order came a nascent collaborative community that welcomed internationalism in science. The IGY was also on the horizon (1957/58), signalling new forms of global collaboration and advancement in geophysics, earth sciences and oceanography (Doel 2003; Goossen 2020; Lehman 2020) and the WMO had just been founded (Edwards 2006; Zillman 2009). Domestically, the UK government was propagating a science and technology university boom by forming new courses and entirely new universities to keep up with continental Europe, the USA, and the Soviet Union.[139] In a fertile time for global environmental science, why was the issue of rising levels of atmospheric CO2 not more central to concerns with environmental change?

Initially, the role of atmospheric CO2 in the earth's temperature was unclear or underestimated from Arrhenius to Callendar, due to the uncertainty behind the role of oceans (Anderson et al. 2016). It is not fruitful to obscure the details of this rich history for the sake of brevity in this chapter, but a growing collective in the science community began to break new ground on the links between atmospheric CO2 and ocean reservoirs (Bolin and

[139] University of East Anglia, The Background Story, 1962, The Zuckerman Archives, University of East Anglia, Norwich, UK. SZ/UEA/10.

Eriksson 1959; Weart 1997, 2008) and the spectre of rising atmospheric CO2 in human lifetimes became a real possibility. At this time, the onset of the IGY (1957-58) - which has been heralded as playing a foundational role in the emergence of a research agenda that would become known as 'atmospheric science' (Howe 2014; Fleming 2016) - had furnished Roger Revelle and his team with funding for research into atmospheric CO2 under the Atmospheric Carbon Dioxide Program. Charles David Keeling, a postdoc at the time, was hired to head the program. Keeling struggled at first to receive the funds needed for recording infrared spectrophotometers, with it being argued that it was too specialised for the measurements of a highly fluctuating atmospheric gas like CO2 to make accurate, continuous records on a strip-chart (Weart 2008). After being set up in Hawaii and Antarctica, Keeling extracted an accurate baseline for atmospheric CO2. The IGY eventually ended, and a few years and funding issues/solutions later, Keeling revealed a detectable rise in atmospheric CO2 from the accumulated records, now known as 'The Keeling Curve' (Howe 2010).

After this, it started to become very clear that atmospheric levels of CO2 were rising through visual representation of a steepening graph curve, but questions now began to circulate concerned with the plausibility of attributing this to anthropogenic causes or whether this was part of natural climate variability, and either way, what possible effects this might have (e.g., temperature rises). This research continued through the 60s and the 70s in many different geographies and, as I discussed in **Chapter 2,** was shaped by the formal embedding of US Cold War research rationalities (Edwards 2010). Developments in CO2 research at this time then began to overlap with the growing awareness and interest from the broader science communities in environmental issues that emerged in part from recognition of the impact of economic, scientific, and technological development over the past century (Howe 2010). Some researchers still disputed the idea of CO2 warming, but the consensus was slowly growing.[140] As research moved forward into the 1970s, there was a growing cognisance in the international (Western) community of the possible links between climate changes, increasing atmospheric CO2 and human activity, yet Lamb remained sceptical that human impact would be a genuine cause for concern.

[140] Interview with Mike MacCracken, former US Department of Energy.

6.2.3. Historical Weather Mapping Project (HWMP)

Nonetheless, as CRU grew in staff and finances in its earliest years, Lamb managed to secure more funding of $120,000 from The Rockefeller Foundation after much correspondence between Lamb and foundation administrators. The funding was to financially support and grow the *HWMP* project that Lamb had started independently, with unsurprisingly slow results. *HWMP*, in Lamb's eyes, was "likely to be one of the Unit's main, and most distinctive, contributions to the knowledge of the past climate record".[141]

The project's main aims were threefold and were the embodiment of Lamb's view on the promise of historical climatology in supporting climate change research and subduing alarmist concerns. Firstly, there was substantial work on the construction of daily weather maps for parts of Europe from 1781 onwards. Secondly, there were to be monthly mean temperature maps (January and July only) created from instrument observations from 1680. Lastly, and in Lamb's view, the most ground-breaking for the Unit, season by season maps were to be made through an organised assembly of historical data that had been neglected.[142] For the most part, before 1700, climatological data was qualitative and to be found in Annals and Chronicles, old diaries, ships logs and so on, and had been previously untapped.[143] Lamb believed that with the help of historians, linguists and meteorologists, historical material could be used to extract and compile data for reconstruction and analysis of past climates. This was also to be supported by the new forms of indicators like isotope work, tree-ring measurements, and other archaeological interpretations. The aim was to reconstruct historical climate data and revise climatological time series to investigate rapid or severe periods of climatic change.

The funding from the Rockefeller Foundation supported the employment of graduate linguists, trained historians and a scientist, Tom Wigley. Wigley had trained as a meteorologist and had vast expertise in atmospheric chemistry, fluid mechanics and pollution,[144] and was hired to support Lamb on the 'scientific' aspects of the *HWMP* project.

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[141] Fourth Annual Report of the Climatic Research Unit, October 1974- September 1975, Hubert Lamb.
[142]Fourth Annual Report of the Climatic Research Unit, October 1974- September 1975, Hubert Lamb; Frank Thistlethwaite to L. D. Stifel, 18/10/74. The Rockefeller Foundation, The Rockefeller Archives, New York, USA. 1.3 155 Box 109, Folder 1109.
[143] Fourth Annual Report of the Climatic Research Unit, October 1974- September 1975, Hubert Lamb.
[144] Transcript from Interview with Tom Wigley, 10/7/2007, by Tony Rogers as part of the Centenary Project of the Bureau of Meteorology, State Library of South Australia. OH 834/35.

Wigley was much more numerically oriented. Wigley had an almost opposite background to Lamb, having had rigorous training in mathematics, pursuing a PhD in plasma kinetic theory and previously teaching statistics before arriving at CRU. Wigley moved to England to work on the *HWMP* project and became heavily involved in numerous other projects. Wigley was, from the outset, very keen on collaborative work both within and outside of CRU. This led to very fruitful new relationships developing both internally and externally, and he became director of the Unit once Lamb had retired.[145]

Elsewhere, Lamb (1972) had already published the first volume of *Climate: Present, Past and Future,* which was a foundational text outlining Lamb's views on climate and history. Yet, *HWMP* was arguably the institutional realisation of Lamb's vision of climatology. CRU was intended to be a 'calm' centre amidst the alarmist views elsewhere in the scientific community and the HWMP supported that. The use of Wigley's scientific expertise was intended to help analyse the constructed maps, indicate barometric pressures and wind flow, and to statistically compare them with more recent instrumentally-observed and representative 'types' of atmospheric circulation behaviour. If the results were aligned, then the legitimacy of historical analyses of climate would be confirmed, with possible applications for prediction (Kelly 1979). Lamb also believed this would support the efforts of CRU's collaborators elsewhere who were developing theoretical models, claiming that they "greatly need our proposed maps of the last 1000 years to test their models".[146]

As the project progressed formally until 1980, it became clear that Lamb, not a trained historian, had embarked on "deeply flawed" extraction work when engaging with the documentary sources both at the beginning of *HWMP* and elsewhere.[147] Wigley noted that Lamb "used secondary or tertiary sources and never went back to the primary sources," and by not being thorough in the investigation, one can miss that "the same event [was] being documented five times in different years, so it looks as though it was a lot more floody [sic] or stormy than it ever was".[148] This was uncovered by historians Wendy Bell and Astrid Ogilvie (1978) during their time in CRU, and through their work under various guises

[145] Multiple interviewees mentioned this.
[146] Hubert Lamb to Elmore Jackson, 3/5/1974, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. 1.3 155 Box 109, Folder 1109.
[147] Transcript from Interview with Tom Wigley, 10/7/2007, by Tony Rogers as part of the Centenary Project of the Bureau of Meteorology, State Library of South Australia. OH 834/35.
[148] Transcript from Interview with Tom Wigley, 10/7/2007, by Tony Rogers as part of the Centenary Project of the Bureau of Meteorology, State Library of South Australia. OH 834/35; Also, repeated by other interviewees.

of the *HWMP,* but Wigley noted "we almost never openly criticised Hubert" despite all of this. However, Lamb was aware of the flaws, having met and told Ralph W. Richardson. Jr, Director of Natural and Environmental Sciences at The Rockefeller Foundation, during a visit to CRU, that "it has been found that 50% or more of the Units climate data contained in the compilations of secondary sources have had to be rejected as unreliable", but it was unclear whether Lamb had accepted that his earlier work itself "was founded on shaky grounds and included a fair fraction of suspect data".[149]

However, Wigley, rather than critique Lamb's achievements, saw this flaw in the early work as "inevitable" as during this time resources in this area of work were "very limited" and having only recently received funding from The Rockefeller Foundation and is a necessary part of the progression of climatological knowledge. [150] Rather than confirm what Lamb had long argued – that natural climatic variations were far more significant than any human-induced change – instead, the *HWMP* partially revealed the lack of credibility in sources and that the foundation built from previous reconstruction and proxy use was essentially flawed. The discrediting helped boost the epistemic authority of numerical approaches, such as modelling, for climate change understanding occurring elsewhere at the time, which CRU eventually adopted under Wigley's directorship (Heymann 2012). Yet, Wigley allowed and guided the *HWMP* project to continue during his directorship, commencing with revising the historical record and Lamb's initial weather decadal indices.[151] Wigley hired professional historians and organised new trips to the UKMO to extract previously untapped records. Notably, this work revealed the complexity (through high spatial variability) in ascertaining global trends. But after 1980, the project disbanded, and the employed historians were let go due to a lack of funds for historical research. Nonetheless, the historical climatology vision Lamb had established was crucial for CRU securing a key partnership with the US DOE and the evolution of historical methods through Wigley's directorship helped this relationship to flourish and widen CRU's involvement with the wider community.

[149] Dr R.W. Richardson trip to England 17/11/1977-29/11/1977, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. 1.3 155 Box 109, Folder 1116.
[150] Tom Wigley and Martin Ingram, Historical Weather Mapping Project – assessment of progress – for The Rockefeller Foundation. 11/1977, The Rockefeller Foundation, The Rockefeller Archives, New York, USA. 1.3 155 Box 109, Folder 1116.
[151] Ninth Annual Report of the Climatic Research Unit, October 1979 – September 1980, Tom Wigley.

6.3. The United States Department of Energy and a global temperature index.

The US DOE was formed officially in 1977, succeeding the Energy Research and Development Administration (ERDA), a short-lived US government organisation created in response to the 1973 oil crisis to aid the pursuit of American energy independence (Buck 1982). Geopolitical tensions in the Middle East and rising domestic energy demand meant that a once distant threat impacted many parts of the US economy and energy shortages became more frequent. ERDA was to organise and formulating new lines of scientific inquiry that could explore possible energy stability and independence futures by reorganising existing governmental agencies for new aims, including the dissolution of the Atomic Energy Commission. ERDA proposed that "coal reserves be rapidly developed to serve as the backbone of the United States' energy resources" as a domestic solution that could drive energy production and ensure stability.[152]

So, ERDA, in the spring of 1975, organised a meeting to address what kinds of problems they should address. At this time, acid rain was surfacing as a key pollution issue and as a result, this was the topic of choice (Munton 2007). Several representatives were invited from the myriad of laboratories associated with the now-dissolved Atomic Energy Commission to discuss and produce an acid precipitation programme. One participant, Mike MacCracken, attended from the LLNL in California, despite neither he nor anyone from the LLNL being involved in acid raid rain research. Whilst attending, MacCracken realised a glaring omission in ERDA's research aims: the investigation of the release of CO2 into the atmosphere from the long-term burning of US coal.

MacCracken's background was in understanding paleoclimates through modelling and proxy reconstruction. He was hired for the LLNL by Edward Teller (1908 – 2003), 'the father of the Hydrogen bomb', to look at the possibility of increasing sulphur dioxide in the atmosphere from a fleet of supersonic aircraft and to model the possible effects on climate and ozone. As a result, MacCracken was aware of the early research into atmospheric CO2 and proposed in a letter that ERDA consider that "carbon dioxide effects be considered in evaluating energy strategy for the next generation" due to the evidence of increasing levels

[152] Mike MacCracken to Rudolf J. Englemann, 27/3/1975, Division of Biomedical Environmental Research, US Energy Research Development Administration,. Mike MacCracken's Personal Files.

of CO2 from anthropogenic causes.[153] The letter was circulated to "maybe a dozen leading scientists, generally, ones they weren't working with", requesting comments on whether or not the CO2 issue was one worth pursuing.[154] The recipients included J. Murray Mitchell Jr, Wallace 'Wally' Broecker and Bert Bolin[155]. The responses were overwhelmingly favourable to the pursuit of research into the effects of increasing atmospheric levels of CO2.

Eventually, as a result of a "very cold winter in '76 and '77", a national climate programme was formed.[156] Tasks were divided up in a cooperative effort, and participating groups took on specific roles for the broader investigation into climate variability; the NOAA took up the carbon cycle and various forms of atmospheric projection, whilst MacCracken headed a team that focused on climatic studies and CO2.

While establishing a research programme to assess the relationships between CO2 and climate, MacCracken decided it was best to accrue a broad knowledge synthesis. Having known CRU's work through Lamb and the WMO conference in 1975, CRU was deemed the obvious choice. MacCracken recalls that,

> ... a lot of the things you want to do at the time is understand what has happened and what is happening to the climate and the group that was doing by far the best assembly of information, and this was before Jim Hansen started doing it, before other groups really started doing it, were [CRU].[157]

Indeed, CRU was unique in working on historical understandings of climatic fluctuations, variations in geography and reconstructive analysis with proxy indicators. This meant that CRU, as an institution, possessed the crucial understanding of historical trends that may be important to test current and future trends again as Lamb had intended.

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[153] Mike MacCracken to Rudolf J. Englemann, 27/3/1975, Division of Biomedical Environmental Research, US Energy Research Development Administration, Mike MacCracken's Personal Files

[154] Interview with Mike MacCracken.

[155] Murray Mitchell was a close friend of Lamb and helped to secure a grant from the EPA for a key project named 'Geographical Patterns of Climatic Change' and an early detector of warming, Broecker played a vital role in understanding ocean circulation impact on climate change and Bolin as we've seen, contributed to understanding the role of oceans as carbon sinks and later played key roles in the institutionalisation of climate science and policy.

[156] Interview with Mike MacCracken.

[157] Interview with Mike MacCracken.

From CRU's end, the funding also came about "from a desire in the dendroclimatological community for better data", which in turn came about from CRU's involvement (or academic mobility) in interdisciplinary conferences in the US where the need for an instrumental climate database arose. [158] CRU was aware of the US DOE's interest in a "large-scale temperature index" and aimed to secure the funding to help produce this, as a means of understanding the implications for climate of increasing carbon emissions. [159] This also was the emergence of a new version of what Chris Russill (2016: p. 37) calls 'the test' e.g., whether or not scientists are able to spot human influence in the global warming records. The test, Russill notes, has had a longer history dating back to the nineteenth century but the modern fascination with scientific understandings of carbon emissions, their accumulation in the atmosphere and how this affects temperature helped to establish thresholds for what dangerous levels may be and how to organise international policy as a result to keep within safer temperature limits (Boykfoff et al. 2010).

Subsequently, the US DOE funded CRU through open and loose contractual obligations that permitted the "best people" to get contract funding, regardless of where they were in the world – unlike some other Washington agencies. The majority of funding in agencies that was dedicated to CO2 research was locked in carbon cycle work with the US Congress laying "out rules that you can't support other agencies", even if they were better suited for the work required.[160] A solution to this was to reach out to the university community. CRU had been doing the research US DOE required vis-à-vis compiling masses of historical data from reconstruction work, proxy work and beginning to discern geographical patterning of climate change. As CRU were financially and administratively free, they were not bound by restrictions, like some agencies in the US, and CRU were then ideal candidates for US DOE funding. Importantly, this demonstrates the importance of the epistemic lifestyles and freedoms Lamb had endowed on to the Unit whilst at the helm, whether intentionally or not.

Yet by this time, Wigley succeeded Lamb as director and the relationship with the US DOE, and indeed the research practices, behaviours and forms academic mobility changed. Researchers in CRU collaborated, participated in workshops, published and shared data with

[158] Correspondence with Climatologist (c).
[159] Interview with Climatologist (b).
[160] Interview with Mike MacCracken.

other institutions linked to the US DOE, like the University of Massachusetts. Unlike Lamb, Wigley was very hands-on in project supervision, encouraging his colleagues and peers to write and publish during this formative time of climate change knowledge-making. The differences between both directors are readily discernible – each had differing ideas about and favoured processes of knowledge-making, along with different objects of concern, uses of knowledge and preferred scales of research – as I will demonstrate through another project Wigley helped to transform, named Geographical Patterns of Climatic Change.

6.3.1. Geographical Patterns of Climatic Change (GPCC)

GPCC was a project that intended to investigate the spatial patterning of climate change over the past 3/4000 years through historical, yet geographically restricted, existing and new datasets examining temperature and precipitation changes.[161] It was funded firstly by NOAA befoe being taken over by the US DOE to help derive scenarios for warm worlds.

Through the work and results of the *GPCC,* it began to emerge that the spatial patterning of climate change over the past 4000 years was more complex and contingent than previously imagined.[162] Wigley helped develop the project further by drawing on proxy climate data to discern past climates. The proxy climate data used in *GPCC*, e.g., glacial, palynological, dendroclimatological, was supplemented with more recent data from instrumental records to better understand the mechanisms behind changing climates and how future climate change may appear, based on historical evidence.[163] Over its lifespan, the *GPCC* project moved from Northern to Southern hemisphere coverage as access and techniques to make data usable became more widely available. CRU maintained a constant connection with the US DOE and collaborators through workshops, updates and planning meetings.[164]

During these events, new research projects were discussed, prepared and embarked on. These included a focused programme on scenarios for a high CO2 world and a move

[161] Sixth Annual Report of the Climatic Research Unit, October 1976 – September 1977, Hubert Lamb.
[162] Ninth Annual Report of the Climatic Research Unit, October 1979 – September 1980, Tom Wigley.
[163] As the temperature records across the globe began to be combined and analysed.
[164]Ninth Annual Report of the Climatic Research Unit, October 1979 – September 1980, Tom Wigley; Tenth Annual Report of the Climatic Research Unit, October 1980 – September 1981, Tom Wigley.

toward understanding global temperature variability. By the 1980s, CRU was embedded into the US DOE machine in researching and collaborating to detect and project the role of CO2 in changing climates. To try and get a concrete grasp beyond the existing 'noise' of climatic variability, understanding the reasons behind the possible rise in temperature was key. Initial understandings of temperature variability were taken from WWR, a consolidation of station records published by the Smithsonian Institution and the US Weather Bureau (Jones et al. 1985). However, these had many omissions. Estimates of global temperature variation had often mainly been dependent on land-based Northern Hemisphere data, but through obtaining and then digitising a new assembly of ship observations, it was possible to construct and unite both land and marine data (Jones et al. 1985; Jones et al. 1986). Moreover, CRU and collaborators added considerable data to the Northern Hemisphere coverage in the WWR through a reinvestigation of the material available from manuscripts in the UKMO archive (Bradley et al. 1985).

The archive and historical work thus returned as a source of knowledge extraction, to be repurposed into discerning temperature variability exclusively rather than other indices like storms, rainfall or windflow and with the view into constructing mass coverage. Importantly, due to the variances in observation and data collection, statistical methods were implemented to homogenise the data and remove anomalies to grid and map the data globally, reducing error risk (Bradley et al. 1985; Bradley and Jones 1985; Jones et al. 1985). Then, global temperature variations were still thought to be uncertain but nonetheless of great importance in revealing the sensitivity of the climate system, through temperature changes due to external forcing, e.g., volcanic eruptions or changing CO2 concentrations (Jones, Wigley and Wright 1986; Jones et al. 1986).

Knowing the state of 'global' temperature, albeit not something that could be felt or experienced (Hulme 2009), enabled policymakers like the US DOE and scientists to discern, understand, and communicate the risk of CO2-driven climate change (Russill 2016). Notably, this all emerged from CRU's involvement with the US DOE – emerging from Lamb's historical foundations and advanced through Wigley's numerical interests, culminating in two state-of-the-art reports published by the US DOE in 1987 on detection (MacCracken and Luther 1987a) and projection (MacCracken and Luther 1987b) of CO2 emissions. The reports laid bare the current landscape of climate change and CO2 research and identified the future

challenges for the scientific and political communities and wider society. Notably, CRU was the only major contributor not based in the USA.[165]

CRU's ongoing involvement illuminates the mutual construction of CRU's knowledge and the US DOE's research agenda in shaping and reshaping further developments in CO2 and climate change research. The early funding from the US DOE supported "ongoing research ... to derive a warm world scenario" from yearly data sets to assist the aims of the US DOE in forecasting the effects of CO2 from coal.[166] It expanded to then produce "some evaluation of computer models of the climate system ... how good are they? How faithfully do they capture the aspects of the real-world climate system that we care about?".[167] From this work, CRU made and maintained many key networks through collaborative work, particularly with the University of Massachusetts and with NOAA in Asheville, which was "doing a lot of the recovery of old data" by digitising it through scans and then sharing it with CRU who "got access to that [data] early".[168]

Moreover, through NOAA and this work, CRU also became involved with many others across the international community as data was shared, work became increasingly collaborative, and a global climate change science was being built as institutions and centres of climate knowledge were sharing data and knowledge across the West; a new ecology in which CRU saw its niche.[169] This collaborative work between CRU and other Western institutions resonated with the internationalism of science and policy that emerged in the post-War period (Miller 2001). CRU was becoming a key component of the 'vast machine' of global climate knowledge-making and infrastructure that dominated much of how we know about climatic changes (Edwards 2010). The US DOE was a core facilitator in the epistemic and technological advances in understanding the links between CO2, rising temperatures, and variable climate change. Being involved with the US DOE CO2 research program meant that CRU had financial and epistemic freedom to pursue new lines of enquiry contingent on Wigley's ability to bend and bend to the available funding. In doing so, CRU began to cement itself as an important site in global temperature understanding. Yet, more global

[165] CRU played a lesser role in MacCracken and Luther (1987b) which also included John Mitchell of UKMO.
[166] Interview with Mike MacCracken.
[167] Interview with Climatologist (b).
[168] Interview with Climatologist (b).
[169] Correspondence with Climatologist (a).

cooperation and unification of data observations were emerging through the infrastructural globalism of the WMO, in which CRU became embedded and active.

6.4. Infrastructural globalism and academic mobility

Additionally, as Lamb retired in 1978 and Wigley took the helm, CRU became further involved with multiple aspects of WMO's research programme due to the work they were doing that was aligned with many of WMO's normative and epistemic goals.[170] Firstly, CRU participated in the Global Atmospheric Research Programme (GARP) and then the World Climate Research Programme (WCRP), which the ICSU jointly sponsored. [171] GARP aimed to advance meteorological and numerical weather prediction. In contrast, the WCRP set out to understand whether climate could be predicted and to discern the effect of human activity on climate.[172] Through these associations, members of CRU were invited to numerous meetings and workshops as 'experts'. These involved scientists (often meteorologists, like Lamb) from differing institutions across the globe and acted as spaces of consensus building. These workshops combined differing geographies of meteorological and climatological knowledge embodied through the 'expert'. Quite often, differences in understanding and technique in observation needed to be reconciled – either through knowledge sharing, training or discussion, and the events offered chances for those invited to discuss challenges or issues within the operations of the broader WMO projects and how best to continue with these programmes,

> ...these [WMO meetings] were more discussing the operations as to how the networks were going. 'Is this particular network of weather balloons working?', 'Are they putting up enough balloons?', 'Are there still gaps around the world in service stations?', 'What can we do to improve things?'.[173]

[170] Correspondence with Tom Wigley.
[171] The Climatic Research Unit, 21/10/1977. The Rockefeller Foundation, The Rockefeller Archives, New York. USA. 1.3 155 Box 109, Folder 1109.
[172] World Meteorological Organization, Programmes: World Climate Research Program. Available at: https://public.wmo.int/en/programmes/world-climate-research-programme. Last accessed 19/1/21.
[173] Interview with Climatologist (b).

Within this, one member of CRU recollects that "the person who was running this used to ask me to give a bit of science. I'd give an hour's talk on what the current issues in some aspects of the climate were".[174] Notably, not only were participants establishing research programmes, they were also sharing up-to-date knowledge, much like general conferences, which shaped the future actions and decisions of the WMO in deciding avenues of research to pursue. As such, the imprint of the WMO organisation circulated beyond the meeting and shaped the future of knowledge-making in the field. As this was predominantly a Western led initiative and English-language based, when the WMO gained a reputation as the fulcrum for state scientists under the guise of a global community, it obscured the view that this was a reification of the imposition of Western knowledge that was co-producing particular social orders.

The pursuit of making global knowledge shapes the world in numerous ways (Hulme 2010), as outlined in **Chapter 2**. Namely, the idea that the international science-policy community came together to explore the challenges of 'global' meteorology or climate and to decide on solutions, what is possible and what is not, what constitutes appropriate knowledge-making through the standardisation of techniques, practice and data leading into the decision of who counts as an expert and what expertise even is. Yet, the conferences and workshops are important sites of authority building, future-making, knowledge-making and performance and are fraught with unequal power structures (Craggs and Mahony 2014). Thus, exploring what was emerging from these meetings and how and who was involved can contribute to clarifying that the international or global stance of the WMO was not always as 'global' as intended.

Only national meteorological scientists (NMS), researchers and affiliates often could attend, although CRU always got permission from UKMO to go as a substitute.[175] However, this was not comparable for researchers in poorer countries, and so many were unable to attend if the NMS did not approve or decided to abstain from attendance altogether. This had real implications for how nations in the global South embarked on collecting and analysing data – in the early years, the idea of a global climate, global meteorology, and weather was not, then, as entrenched as the present. Therefore, in the 1970s/80s,

[174] Interview with Climatologist (b).
[175] Interview with Climatologist (b).

participation in the WMO and subsequent knowledge-making, standardisation and circulation were administratively exclusionary by being state attended only – particularly in non-Western countries – limiting collaboration between research and university institutions in the West and the rest.

The WMO also played a key role in anthropogenic climate change discussions as they co-sponsored several conferences in the Austrian city of Villach in the 1980s. The most prominent was 1985, which is often touted as the moment when climate change was reframed as a political issue requiring international consensus and collaboration in knowledge-making, helping to plant the early seeds for the IPCC (Agrawala 1998). Members of CRU attended the meeting through the connections built through relationships with both US DOE and the WMO. Being involved with Villach-1985 underscored the legitimacy of the direction Wigley adopted after Lamb's retirement as CRU were able to become a part of the discursive and institutional arrangements of constructing and circulating climate as a global object of concern.

It is also fruitful to explore the changing academic mobility to highlight the difference between the epistemic lifestyles and modes of operation within CRU and the geographies that followed. As Heike Jöns (2008, 2015) has previously argued, investigating academic mobility can detail how centres of knowledge production are co-produced with knowledge circulation and spatial embeddedness. In doing so, we can reveal the differing intentions between knowledge sharing and receiving between Wigley and Lamb and explore CRU's changing relationship with and participation in the global geographies of climate change research.[176] Figures 2 and 3 represent the outgoing circulation of CRU staff during both the Lamb and Wigley eras, respectively. It is discernible that there is a major emphasis on travel and knowledge circulation to North America during both Lamb and Wigley's time as directors. This supports the view that climate change research predominantly was

[176] I do this by revealing the differences between academic mobility of CRUs staff with Lamb and Wigley as a director using data extracted from the Climatic Research Unit's Annual Reports that detailed academic visits both to and from CRU.[176] Within this, I have divided academic mobility into 'networking' and 'knowledge transfer' where possible and when details permit. Networking is defined as a visit only with no sign of seminar or lecture given. Knowledge transfer is defined as an active sharing of work through seminars, courses, workshops or lectures. The data was extracted, and coordinates were manually added to a CSV file. Next, this was uploaded into Stanford University's Palladio tool (https://hdlab.stanford.edu/palladio/) to visualise historical data. It works by placing latitude and longitudinal coordinates from the CSV file on open-source global maps, and one can visualise points or flows of data, e.g., the travel between two points. However, as useful as it would be, the tool does not allow static labels to be generated on the map.

European and North American based in the post-war. Cold War period. Interestingly, there was a distinct lack of networking and knowledge transfers between the Soviet Union and CRU from 1971-to 1986, despite the prevalence of Soviet scientists in climatological research (Oldfield 2018).[177]

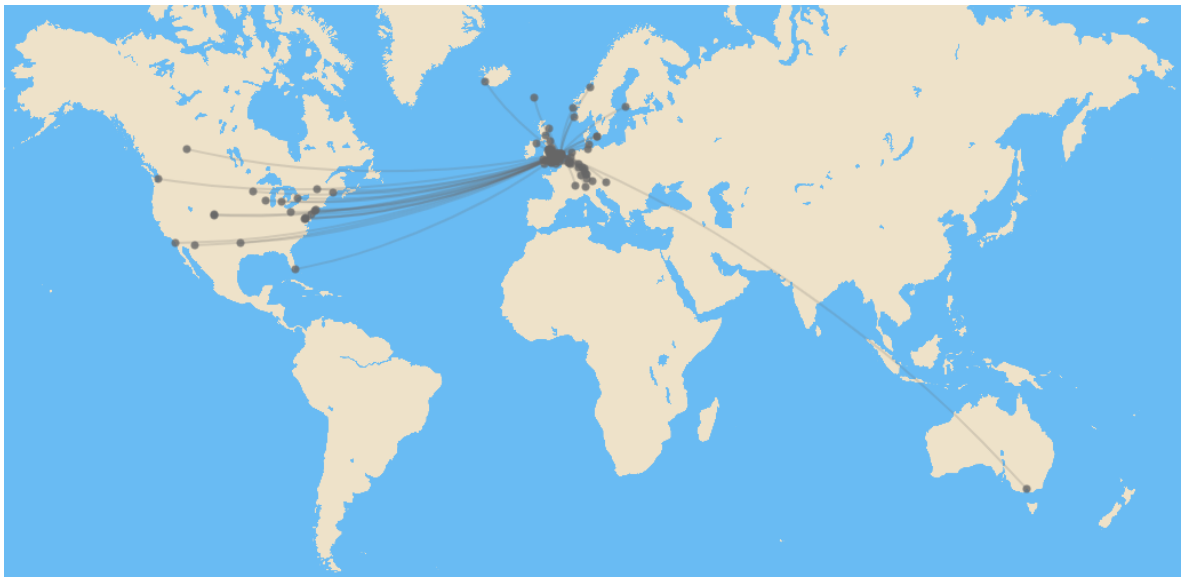

Figure 2. CRU outgoing knowledge transfers and academic networking during Hubert Lamb's directorship, 1971 – 1978.

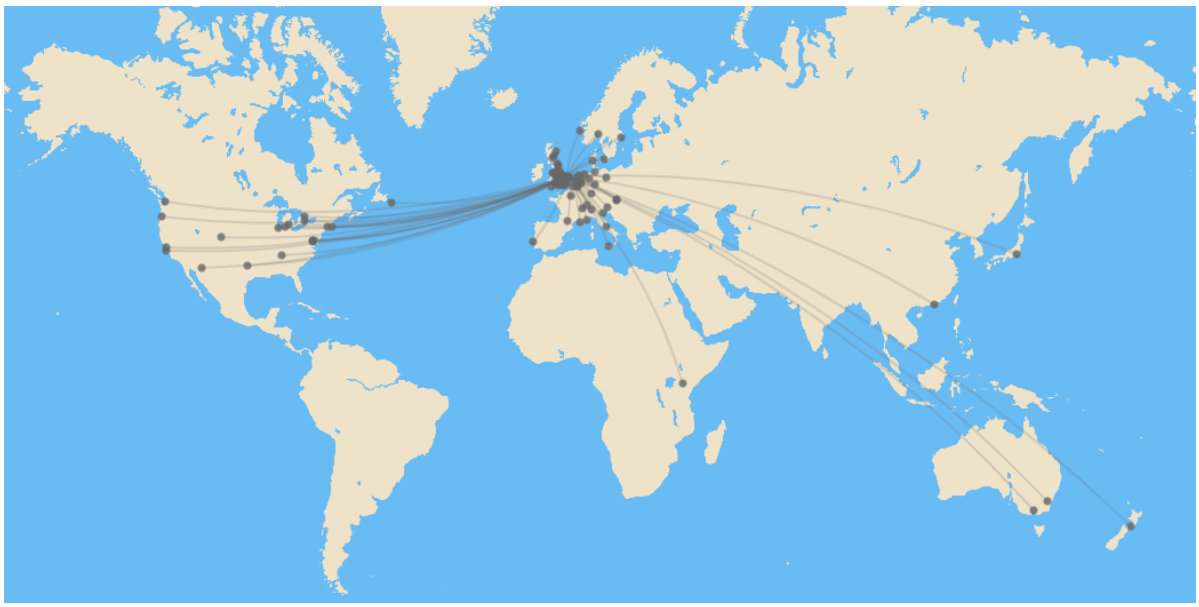

Figure 3. CRU outgoing knowledge transfers and academic networking during Tom Wigley's directorship, 1978 – 1986.

[177] There were, however, gifts of documents and books by soviet climate scientists for Lamb's early CRU library.

Moreover, whilst Wigley was director, international circulation increased, particularly in Europe and beyond. In Figure 3, there are multiple flows from CRU to Europe, additional points in Africa, Asia, Australia, and New Zealand. This demonstrates Wigley's focus on collaborative research and knowledge sharing. As CRU moved toward research that focused on rising carbon dioxide emissions, global temperature work and human impact, CRU became more involved in international communities and built more international relationships as the problem of climate change was being increasingly framed as a global one. Additionally, there was an increasing number of groups embarking on climatic change research as knowledge was being made about the possible implications, and thus, CRU had more institutions to interact with and circulate knowledge to. Broadly, the increasing volume of network flows from CRU also represents their success financially and epistemically, as they gained more research staff and projects to work on, from Wigley's shift to CO2 and global temperature work. Lamb worked alone most of the time and was keen on reconstructing historical climate, predominantly focused on Britain and Europe, so there was less emphasis on wider academic travel and knowledge circulation beyond the geographies vital to his research (e.g., Iceland and Scandinavia).

Overall, we can see in Figures 2 and 3 that CRU expanded its participation in multiple international geographies of climate change research. The relationship between CRU, the WMO and other institutions is indicative of the global geography emerging in climate-related knowledge-making and circulation as knowledge infrastructures proliferated (Edwards 2010). CRU's involvement with discussions and research underscored its importance as a centre of knowledge-making and a constitutive part of the wider community. However, this global knowledge is partial and situated. As I have explained, the exclusionary attendance arrangements and linear mode of data collection and training for state meteorologists in the global South led the West and WMO to act as a 'citadel' with knowledge trickling down and outwards – rather than being deliberative or normatively co-produced (Irwin and Michael 2003). As a result, this top-down model opens doors to certain kinds of futures whilst closing others about ways in which meteorology and climate research is made, how knowledge is shared, for what use, and how solutions are imagined.

6.5. Conclusions: Changing directors, changing aims

In 1978, when Lamb retired as the director of CRU, concerns about a changing climate due to human activity were gaining traction in the international communities of science and policymaking. And so, when Wigley succeeded Lamb as the new director, there was a growing, collectively felt need, in the Western climatology community, for further research. This would be research that explored a.) how climates were changing across the earth, b.) the extent to which carbon dioxide and other greenhouse gas emissions may be causing the changes, and c.) how might different climates (and environments) alter in future scenarios of warming or cooling. Lamb's departure meant that CRU's aims could now be more focused on this line of research: the present and future of climatic change.[178] I argue that more concentrated attention on anthropogenic climate change vis-à-vis CO2 research can be viewed as a transition between epistemic lifestyles (Shackley 2001) associated with each director. The shift meant that CRU's aims and outputs moved from primarily individual, humanities-based, yet interdisciplinary historical reconstruction work on climate to a broader scoped, numerical and globally-orientated climate work. This eventually would lead to CRU becoming a globally significant site of climate knowledge-making in the early 1990s. The shift in research aims solidified CRU as a core collective within ENV and helped render climate change a central challenge for the 'environmental sciences'.

Lamb founded CRU in response to the growing emphasis on numerical modelling in weather forecasting and climate projections at the UKMO, an institution in which Lamb, with interests in historical reconstruction, no longer felt he fit (Martin-Nielsen 2015). CRU, for Lamb, was a place of epistemological freedom in which he could pursue a self-described second career (Lamb 1997: Martin-Nielsen 2017). Conversely, Wigley arrived at CRU convinced that CO2 would be "the most important factor in determining multi-decadal climate changes". Shortly after becoming director, Wigley changed the epistemic and financial pursuits of CRU to sustain and grow the Unit for this new era of climate research.[179] The Unit's new aims were "to understand the many separate interacting elements of the climate system, how they operate and what variations of their ranges are",

[178] Fifth Annual Report of the Climatic Research Unit, October 1975 – September 1976, Hubert Lamb; Sixth Annual Report of the Climatic Research Unit, October 1976 – September 1977, Hubert Lamb.
[179] Correspondence with Tom Wigley.

building from the historical reconstructions developed by Lamb but with a renewed focus on the geological, biological and social implications of these changes and the role of carbon emissions in temperature increases.[180] Financially, Wigley pursued (and secured) continual funding by applying for competitive research grants beyond the UK – rather than solely focusing on large grants from Foundations or minor consultancy work. Intellectually, this also involved building on the connections with the US DOE– which Lamb had begun – and engaging in more collaboration with the international climate change community (focusing on the 'alarmist' forecasting of climate changes that Lamb was so averse to). As a result, the following years witnessed tremendous growth in research projects, funding streams, numbers of research students, an increase in collaboration with international partners, and the development of a broad interdisciplinary research programme between similar, subordinate or antagonistic epistemologies.

For instance, by the early 1980s, CRU had a comprehensive research programme that looked at various climate challenges (e.g. the Arctic and Antarctic, dendroclimatology, climate impact assessments, climate change and 'general' climatology) and collaborated with numerous institutions in Europe and the US.[181] This shift in aims, practices, connections and networks, I argue, is paramount to the subsequent success of CRU but was impossible without the foundational work done by Lamb and without his original vision of the interactive and fruitful relationship between climate and historical research. Lamb's epistemic and normative vision of historical climatology helped lay the foundations and guide the early social and epistemic history of CRU's research. Building on this, Wigley expanded from an initial interest in and concern about the role of CO2 in climate change using CRU's professional, epistemological, and financial foundations to participate in more global climatological research. From his scientific orientation, Wigley also encouraged more international academic mobility within CRU itself. This enabled CRU researchers and knowledge to circulate between and through different spaces, which Lamb had also encouraged on more local scales (through inter-university seminars and lectures). Different problematisations of the 'environment' or in this case, climate, led to different epistemic lifestyles emerging in CRU that (re)shaped the production, circulation and use of knowledge.

[180]Ninth Annual Report of the Climatic Research Unit, October 1979 – September 1980, Tom Wigley; Tenth Annual Report of the Climatic Research Unit, October 1980 – September 1981, Tom Wigley.
[181] Biennial Report of the Climatic Research Unit, October 1982 – September 1984, Tom Wigley.

Nonetheless, the two epistemic lifestyles detectable during this period were not discrete or separate. Instead, the shift was more diffuse as projects grew and more funding became available, and as Wigley reorientated and refocused Lamb's historical exploration to support the construction of global climate analysis vis-à-vis mapping, patterning, and temperature analysis.

To conclude, whilst the story of CRU's rise to global success *could* be penned down to shifting scientific endeavours or paradigms (Kuhn 1962), the ecology of co-production approach demonstrates how CRU as a unique space of knowledge-making and circulation in the global geographical network of climate knowledge, was contingent often fraught with uncertainty and crucially knowledge was made through social interactions, networks, relations and organised through different interdisciplinary projects. Lamb's direct aim to combine historians, climatologists, linguists, and other researchers is a crucial example of 'agonistic-antagonistic' modes of interdisciplinarity or knowledge-co-production, wherein disparate ontologies and epistemologies meet to produce novel and innovative ways of making knowledge and viewing challenges (Barry and Born 2013). Yet, when CRU grew in impact, size and success, these more extreme forms of antagonistic interdisciplinarity subsided and were challenging to maintain productively and coherence on international scales. This is also a good example of when interdisciplinarity does not work as intended – the uncovering of shaky data – but the recruitment of Wigley changed the course of CRU's institutional and epistemic development. Additionally, as CRU's reputation grew, ENV sought to cement institutional links – both administratively and financially. A once marginal space of knowledge-making was now attractive for researchers and incoming students.

I now move onto the final empirical chapter of the thesis as I explore another branch of the 'environmental sciences' as they manifest on more local scales, for more applied uses and through a more contested and challenged 'subordination-service' mode of interdisciplinary research (Barry and Born 2013) and response to an eclectic environmental problem.

7. Environmental sciences in action? ENV in and around the Broads

In contrast to the nationally embedded science-policy origins of ENV , and the evolving globally orientated collaboration and knowledge-making of CRU, ENV's involvement in producing the 'environmental sciences' for environmental management in the Norfolk Broads was much more locally-focused and applied. This chapter focuses on exploring historical forms of normative-procedural co-production both between researchers in ENV, and with stakeholders, policymakers and organisations. These specific interventions laid the framework for broader changes in epistemic and normative order through the emergence of environmental management for both planning and conservation amidst responses to environmental, cultural, political and economic changes, and the need for knowledge to support and map decision-making. I use the ecologies of co-production sensibility to intentionally seek out the different contexts and the different interactions between actors that (re)shape the production and need of Broads knowledge and discern how they relate, constitute new and diverse purposes of ENV knowledge and 'environmental problems' in different 'environments' as constructed by different uses, aims and interactions between different actors within the newly emerging Broads 'environment' (O'Riordan 1969; Barry 2021). Like the previous chapter, different problematisations of the 'environment' between different disciplinary strands meant that different cultures of research and knowledge production were (re)shaped by epistemic lifestyles, political context and willingness to collaborate of the researchers involved.

The Broads is a wide area of low-lying wetlands in Norfolk and Suffolk that became so from the infilling of manmade, medieval peat excavations. The Broads had 'environmental challenges' that became formal matters of concern through institutional and scientific interest, in the post-war period toward the end of the 1940s (George 1976; Latour 2004). The 'challenges' were an eclectic mix; the water was murky, plastic islands of litter floated around the water bodies, the banks were caving in, and aquatic plants were either dying or over-flourishing. There were many stakeholders and interested practitioners, yet none could discern causes or origins with tangible and evidence-based knowledge. There were suspicions and anecdotal accounts of visual degradation noting that the water quality became more turbid in the 1950s (Ellis 1965), but there was no formal strategy or

management plan in place. Crucially, it was thought that without evidence-based knowledge, the problems would not be solved in the Broads due to the multiple and conflicting uses – for scenic beauty, boating, angling, and so on. In part, this chapter focuses on ENV's involvement in the knowledge-making and environmental understanding of a local landscape and its challenges, and in part, the co-production of institutional and infrastructural arrangements that make use of and need local scientific knowledge. As a multifaceted 'environmental' problem, in the sense that the Broads exhibited encounters between many disparate materials and processes, either in proximity or not of one another, that challenged the innate constitution of the landscape (Barry 2021), the Broads embodied the interdisciplinary vision(s) that ENV was created for in a time of changing state involvement. The emphasis transitioned from central planning and top-down scientific advice to market-based approaches fostering innovation, environmental governance and management with a growing collective of actors. Yet how this was put into practice was contingent on the particular imaginaries and epistemic lifestyles of the researchers and collaborators inside and out of ENV.

The normative and spatial conditions in which knowledge-making in the Broads emerged, unlike that of CRU, meant that it was oriented around the local landscape and concerned decision-making and planning in the area. ENV's work in the Broads is a critical case study to help understand how the 'environmental sciences' can be made on a local scale, be applied, and be socio-politically relevant on more regional and national scales. It can also contribute to understanding how facts become 'matters of concern' (Latour 2004) – where facts become gatherings of concern, worry and persistent structures of normative and epistemic agency. What follows concentrates on illuminating the interdisciplinary processes and co-productions behind the drive for ENV to produce local environmental knowledge. The local, in this instance, denotes close spatial proximity between the university and many of the Broads, and the impact and application of the knowledge produced (for local authorities and stakeholders). This historical involvement from ENV in the establishment of the environmental management of the Broads is not often celebrated in the corridors of ENV. Yet as a case, externally it helped to demonstrate ENV's authority and newfound expertise as an interdisciplinary environmental research institute; it shows how multiple epistemic lifestyles and visions of the 'environment' come about in interdisciplinary ways, become enmeshed and seemingly work together on more local and

applied scales, and is an important historical moment of the co-production of knowledge and order, through science and environmental management.

This chapter is outlined as follows: firstly, I explore the historical origins of the Broads challenge in the context of overuse, conflicting social and economic activity, degradation and scientific uncertainty. I then situate the problematisation of the Broads amidst the scientisation of nature in Britain, management of landscape and the creation of a Broads Authority. I delineate how ENV's involvement in Broads research is an important historical example of a 'subordination-service' form of interdisciplinarity outlined by Barry and Born (2013) as it demonstrates the centrality of scientific epistemologies and the gap-filling of political and economic ontologies in environmental management, governance and strategy despite efforts from researchers to equalise socio-political, cultural and economic 'environmental' concerns through varying means. The realities of interdisciplinary research, in this case, reveal how it is not always intentional, collaborative practices that are key. Rather, an organisation can situate and use disparate knowledge to create interdisciplinary understanding, policy and action for environmental management.

7.1. History of the Broads challenge

The Broads challenge is, in part, a result of the character that makes the landscape so unique and in part, a result of a lack of knowledge and sufficient planning. The Broads (see Figure 4) are a unique area of low-lying wetland formed by multiple rivers and lakes in the east of England, formed from manmade medieval peat excavations (Lambert 1960).

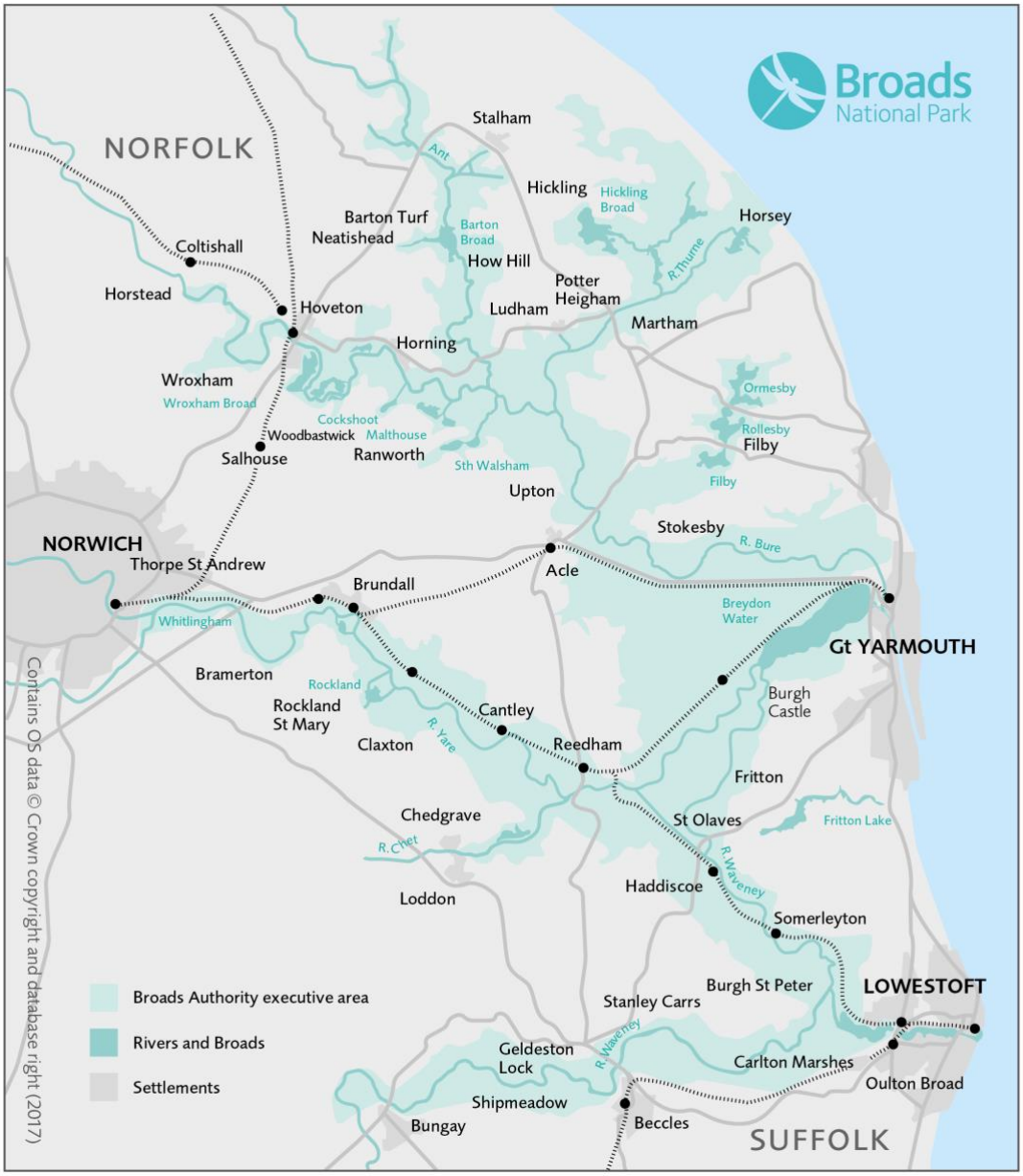

Figure 4: The Broads, taken from https://www.visitthebroads.co.uk/maps

Historically the landscape has been used for multiple forms of recreation, enjoyment of the tranquil landscape and scenic views, birdwatching, angling, and boating (George 1992; Matless 2014). By the 20th Century, the Broads were the only remaining low-lying wetland area in the UK. Degradation was first noticed as visibly turbid waters in the mid-1940s and noted in an official capacity through anecdotal observations in the 1950s (Ellis 1965; George 1976; Moss 1977). The residents and users of the Broadland area were unsure of what needed to be done to restore clarity to the water due to uncertainty concerning the causes, extent and impact of the damage. Eventually, it was deemed by the newly founded Nature Conservancy (1965) as an area of concern that would benefit from scientific research

to ascertain what was going on and how best the site may be restored (Matless 2014). From the outset, the problems in the Broads were conceived as scientific ones, and scientific knowledge was to be used directly for problem-solving.

Possible courses for action were limited. Interested parties and those with remit and power over the Broads were spread far and wide. There were the local authorities of Norwich, Great Yarmouth, Lowestoft and a range of rural district councils that had a broad interest in the wider environment of the area regarding public health and populations, planning and development. The Great Yarmouth Port and Haven Commissioners were interested in navigation. They exercised power over the waterways, whilst the River Authority and Internal Drainage Boards held remit over land drainage, management, pollution control, water conservation and administration of fisheries. Indirectly, government arms like MAFF were interested in land use that promoted agricultural interests. MHLG was concerned with aspects of the Broads related to local water supply, sewage disposal, and land use. The Nature Conservancy had also introduced a scientific interest in the area. There was also significant interest from tourist and travel organisations, Norfolk naturalist societies, the National Farmers Union (NFU), East Anglian Waterways Association and unaffiliated recreational users. Most notably, the diverse bodies had no interest in the new scientific components of the area emerging with post-war Britain's technocracy and science policy. Instead, they were mostly concerned with successful and harmonious management that would allow the continuation of activities with minimal challenge. Nonetheless, the foundations were being laid for scientific management as a new form of nature conservation and knowledge-making in Britain, and the Broads became a central feature of this.

7.2. A new nature conservation in Britain

Shortly before UEA-ENV was founded, the Nature Conservancy, the government agency interested in ecological research, had signalled in a report (1965) that the new incoming Schools of ENV and BIO might take to task the much-needed scientific enquiry of the Broads landscape. This statement reflected the growing commitments to the scientisation of landscape, reframing preservation to conservation and scientific forms of management and

planning emerging in a post-war, technoscientific Britain. The ways in which the challenges in the Broads were being framed as a knowledge issue that could be solved by the ingenious mind of the ecological scientist (or scientists) reflected the governmental aims at the time, and that had been cultivated since the post-war period (as seen in **Chapter 4**).

The 'environmental sciences' origins as a sociotechnical imaginary from Zuckerman, as a new transformative mode of living, knowing and acting in an environmentally-conscious and scientific world, emerged from multiple problematisations of the 'environment' as an object for thought and as a tool with which encourage normative change. The more damaged surroundings vision of the 'environment' – expressed through toxicology, pollution, land-use conflicts – resonates with the local and regional disputes of the Broads. Local countryside and other areas, regardless of their condition, did fit into the 'environmental science' concerns for Zuckerman but were presumably thought to be problems for aquatic as a study between humans and their water-based surroundings, rather than the externalised disorder of an atmosphere or land-based 'environment' (Barry 2021) for the physical and earth science-dominated ENV in the late 1960s/early 1970s. The multiplicity of environmental problems, sciences and histories has contributed to the messy and complex ways environmental concerns and problems come to the surface (as discussed extensively in **Chapter 2**). Nonetheless, how conservation aims came about in Britain had important implications for how the Broads were conceptualised and problematised as an area of environmental concern and challenge, which in turn had epistemic and normative implications for future 'environmental' management.

Previously, public interest in the countryside, landscape and natural areas aligned with preserving landscape for recreation, heritage, natural beauty and aesthetic enjoyment. Natural beauty and aesthetics were made popular through British romantic writers like William Wordsworth, whilst land ownership and management were associated with those of the Upper Aristocratic classes (O'Riordan 1985; Sheail 2002). In the late 19th Century, there were also more concerted and organised efforts to protect specific lands, buildings, and monuments to preserve their beauty and historical interest, culminating in the creation of the National Trust in 1895 (Jan Oosthoek 2015; O'Riordan 1985). Yet, there had been a shift in the discourse of wartime and post-war Britain: from preservation to conservation. With this shift came a divergence between landscape management, land use, and wildlife conservation, creating a separation between the British countryside's historical, social and

cultural, and scientific uses (Reynolds 2016). This had significant implications for the remit and scope of the emerging 'environmental sciences' – at UEA and beyond.

7.2.1. The scientisation of nature

While Zuckerman and others from **Chapter 4** had embarked on operational wartime research, a group of scientists and civil servants had remained in the UK aiming to preserve the British landscape and nature whilst investigating land use for post-war reconstruction.

A committee, NRIC, had been set up by the relevant Nature-preservation organisations (like the Society for the Promotion of Nature Reserves) to examine the feasibility and suitability of proposals for nature reserves and other land-use planning matters. This included talking to relevant landowners and organisations involved with possible sites (Nature Reserves Investigation Committee 1942). Around the same time, scientists and professional societies began to explore the possibility of nature reserve creation. Arthur Tansley (1871 - 1955), a pioneer in British ecology, had been left out of the NRIC and instead became chair of an additional nature reserves committee organised by the British Ecological Society (Sheail 1995b), an academic society dedicated to fostering and promoting ecological knowledge in Britain, in which Tansley was the first president. Notably, the BES-organised committee thought they were the "best qualified to advise on the right areas to be reserved" due to their scientific expertise (Sheail 1995b: p. 272). Moreover, to foreground the conservation of nature in Britain's post-war planning as a scientific endeavour, not a management one, they sought a more direct role in advising the government drawing from the groups vast reservoir of ecological expertise (Sheail 1984, 1995a, 2002).

If Britain were embarking on serious and widespread land-use transformations, then there would be massive implications and alterations to the 'natural' world. For ecologists and naturalists alike, this was a cause for concern. For the ecologists, this was an opportunity to designate safe areas of conservation based on future scientific investigation and education. Indeed, Tansley drew from his substantial survey work on British vegetation (Tansley 1939) to support the NRIC in proposing possible conservation areas. In doing so, Tansley attempted to systematically designate 50 sites that were representative of the

diverse vegetation of the British countryside. It was agreed that protecting areas of scientific interest – delineated from Tansley's work – would ensure that there would be 'enough' sites to advance the fledgling field of ecology, improving education and professional training. Crucially, it was important not to lose any potential sites of scientific interest during the land-use planning in post-war Britain.

Geoffrey Dent, a naturalist who was key in proposing the idea of a conference on 'Nature Preservation in Post-War Reconstruction' in 1941, jointly run by the RSPB and Society for Protection of Nature Reserves, raised some objections to the scientific approach to 'conservation', opting for preservation as a broader inclusive term. Dent noted that a reliance on science as a justification for land management and planning ignored existing public interest in wildlife, landscape and countryside enjoyment and that there may not be widespread public support (Sheail 1995a, 2002). There needed to be ways of illuminating the worth of designated areas of land and why preservation of a particular area of vegetation was more worthy than agricultural land to feed and support a post-war public. Questions surfaced over who would manage areas, how powers and authority would be designated, how decisions would be made and how the land would be acquired – through central government or local authorities - in an already struggling post-war economy (Sheail 2002). These uncertainties underscored the need for public support to be secured to avoid wasting time, resources, and efforts. Eventually, through trial areas in Suffolk in the late 1940s, lessons were learned about how best to manage conservation areas, the aquistion of land, the sense of public support and insights into the statutory powers needed (Sheail 2002).

John Sheail (1995b) explicitly explored how, on the contrary, popular appeal gained traction through the discursive switch from 'preservation' to 'conservation'. This discursive shift was a "positive and vigorous approach to meeting the challenges of post-war reconstruction" (p. 276) in a forward-looking Britain. This shift was found in the influential report *Nature Conservation in Great Britain* (1943), published by the Society for the Promotion of Nature Reserves. As the many challenges of post-war reconstruction came to the fore, science, scientific advice, and expertise became more apparent and involved in all forms of discussions: formally, through advisory groups and committees; and informally, through professional societies or voluntary groups publications. Akin to the Society for the Promotion of Nature Reserves, the voluntary groups were formative in bringing nature

reserves into the political and public eye and were now campaigning for a scientific approach. The report defined conservation as "the pursuit of scientific and economic studies, the enjoyment of nature by the public, and promotion of education in natural history" (quoted in Sheail 1995b: p. 276). This was an important moment in the scientisation of nature. Protection of land through conservation was now being argued as a multi-beneficial pursuit that included both the British public's historical enjoyment of the natural world and a representation of the new scientific Britain. Tansley also supported this throughout his work and involvement with the BES-committee, arguing that a scientific approach to conservation would go hand in hand with post-war development, much like Zuckerman was advocating for broader social and economic development. With the idea of conservation now being discussed on scientific grounds, the BES, harbouring a new sense of scientific authority, began discussions for a new governmental body that would direct ecological research to support the advancement of British science, economy, and development success of the country, and so the idea for what would become the Nature Conservancy was born (Sheail 1984, 1995a, 1995b; Bocking 2012). The institutional landscape was changing to match the technoscientific ideas and visions of a post-war Britain.

All the while, the idea of creating National Parks was circulating in the government body as areas distinct to scientific interest. Fundamentally, National Parks were intended to create places of outdoor recreation, scenic beauty, and areas of wildlife preservation (Sheail 1984, 2002) in line with Britain's national planning aims. National Parks had been discussed for several years on the grounds of recreation and to represent the government's interest in wildlife preservation (Anderson 1990). The idea of National Parks came originally from the US – as important exercises of governmental control and management of the natural world, moulding the (supposedly) feral landscape into bounded areas of human enjoyment through recreation and scenic beauty (Sheail 2010). By the 1940s, after many discussions, government interest had ramped up.

Firstly, John Dower (1900 – 1947), a civil servant with a strong interest in the National Park idea, wrote a report on *National Parks in England and Wales* that the UK Government published in 1945. In the report, Dower stated that the creation of national parks would preserve the beauty of the landscape, enable the public to have access to and enjoy open-air spaces, and protect wildlife, buildings and "places of architectural and

historical significance" whilst maintaining existing farming use (p. 6). Dower proposed many sites for consideration – in which the Broads were designated as a reserve site. For Dower, the Broads were an area with too many complications from conflicting uses – navigation, drainage, agriculture – and had incurred much misuse already (Dower 1945). As a result, the area was thought to be unsuitable for immediate National Park status but rather an area with complex management issues needing to be dealt with by local authorities. Key here is that for Dower, creating a National Park – what it was to be and where it was to be designated – depended on the powers and process of how they were to be administered and governed (either by a commission body or a single ministry). The Broads was a difficult challenge and other, simpler areas that were not at risk of environmental and landscape collapse would take precedence.

Nonetheless, Dower's report led to the formation of the National Parks Committee, chaired by the politician Arthur Hobhouse (1886 - 1965) and the construction of another subcommittee, the Wildlife Conversation Special Committee. The Wildlife Conservation Special Committee looked at the implementation of nature reserves and was chaired by Julian Huxley (1887 – 1975), despite Dower promoting the overlap of landscape and wildlife conservation (Sheail 1984).[182] Like many others in government science policy at the time, both committees contained several scientists (biologists, geologists, physiographers, ornithologists) to help capture the breadth of expertise needed to discuss and plan the potential endeavours. The Huxley group, in particular, was viewed as a significant opportunity for scientists to exert and publicise their expertise to generate authority in the public eye and stress the scientific grounds for conservation in Britain (Sheail 1984), alongside the previous suggestions by non-governmental groups.

The National Parks Committee sought to consider Dower's recommendations and embark on the necessary procedures to make them a reality. Two years later, they published a report in 1947 (Hobhouse Report 1947) that proposed 12 areas, including the Broads (which was included due to its unique qualities and recreational popularity), despite its challenges (Sheail 1975). Concurrently, The Huxley Report (1947) delineated nature conservation areas and conceived of SSSIs as an addendum to nature reserves. Notably, there were supposed discursive and practical differences concerning sites that were to be

[182] Huxley moved on to Unesco and was replaced by Tansley shortly after.

chosen for enjoyment or conservation and the wider responsibility of science to shape this or not. Nonetheless, nature reserves were becoming a predominantly scientific endeavour, as nature conservation was becoming increasingly discussed in relation to post-war biological research, much like the 'environmental' issues under Zuckerman's purview.[183] The eventual separation of both scenic, recreation, amenity and scientific aims meant that both programmes could receive public support and government patronage (Sheail 1995b). However, this separation would prove a thorn in the side of environmental management (and the 'environmental sciences'), particularly in areas with multiple stakeholders, high uncertainty and high stakes.

The separation of conservation for scientific or amenity purposes was a political tactic that commanded scientists like Huxley and Tansley to shape the course of post-war Britain's ecological reconstruction. Yet ironically, the emergence of the 'environmental sciences' in ENV came to knit the disparate challenges and divisions back together by creating new expertise, a new interdisciplinary organisation of science, and a scientifically oriented society, citizens and government. The political and institutional culture that emerged hardened the divisions between science and amenity understandings of the British countryside through management, funding, and organisations, like The Nature Conservancy. The ineffectiveness of the administration and relevant powers to make a difference became starkly apparent through spaces like the Broads – which continued to degrade with minimal respite and remained, so to speak, on the periphery of emerging 'environmental challenges' in Britain.

7.2.2. The Nature Conservancy

Nonetheless, The Dower and Hobhouse reports were key factors in establishing the first National Parks under the implementation of the National Parks and Access to the Countryside Act 1949. In contrast, the Huxley Report (1947) and the work of Tansley were influential in the creation of the Nature Conservancy. The arrival of the Nature Conservancy signalled a more concrete shift towards the scientisation of nature from the UK

[183] There is a complex history to this containing many actors and streams of thought in the political history of Britain's institutions and nature conservation; see John Sheail (1984) for a stellar overview.

government. E. M. Nicholson, who was also involved in the discussion around the 'Environmental Sciences Research Council' and NERC from **Chapter 4,** played a core role in its founding. Nicholson, like others, was concerned that the UK government was embarking on a national planning programme with little regard for the possible effects on "the fauna, flora, and even geography" of Britain (quoted in Sheail 1995b: p. 279/80) and scientific research could furnish the government with this needed knowledge. Nicholson, like Zuckerman, noted the gap science could fill in planning and decision-making. It was thought that Britain might head down an irreversible path without an appropriate understanding of the implications and suggested a new scientific organisation to pursue this research. Often, the Nature Conservancy is seen as an extension of the National Parks Act (1949), but by the 1960s it had arguably become an established scientific endeavour, gaining traction during a time when science and scientists had gained momentum in the governing, planning and management of Britain, its countryside, and its publics.

The Nature Conservancy was a culmination of the shift to a new and particular view of the natural world in Britain that evolved beyond an appreciation of the natural world for amenity, recreation, and scenic beauty and an extension beyond central planning of the state. Rather this shift reconceptualised different landscapes and habitats as new areas of scientific study (Sheail 1993). This, importantly, allowed 'natural' areas to be organised, known, and governed through scientific means. Further, they acted as "buffers between the policy-making and decision-taking machinery" (O'Riordan 1985: p. 117) as the mediator between government and science, as scientific advice proliferated in the early 1980s. This had further implications for the ways in which the new 'environmental sciences' could emerge and 'should' emerge, the types of environmental problems that came to be known and were possible to be known, and solutions that could be suggested. Importantly, how the British countryside was divided – to be either protected or conserved for either amenity, scenic beauty and public enjoyment, or scientific interest to garner public support and government patronage – also meant that other ways of knowing and using areas of the natural world were precluded from view, e.g., public health, spiritualism, morality and ecocentrism (Thomas 1983).

Ultimately, I have explored how the arrival of national parks, nature reserves and the very idea of these, was not inevitable. According to Sheail (1984), one of the core reasons for this was the particular network of personalities involved, similar to **Chapter 4**, with an

overlap of the group of scientists interested in forms of technoscientific control, authority and management in post-war Britain. This also often means that the politics and processes (re)shaping the construction of conservation or preservation areas and what this means and is intended to entail, also shape future avenues of science policy, management and possible visions of action. Rather than embracing the entanglements of human and nonhuman, or the co-production of the natural and the social, the false dichotomy reinforces human agency and power over the 'natural' world (Latour 1987). This closes off possible routes of practice or action whilst simultaneously underscoring the favourability of others that fit existing preconceptions and approaches, in this instance, a science-led system.

The ideas above stem from the period of scientific control and power that I have outlined earlier, dissipating through the government vis-à-vis scientific advisers and committees in **Chapter 4**. In sum, historicising and outlining the apparent division of science-led vs other forms of conservation approaches reveals the plethora of transformative effects and consequences from the normative intentions of actors and institutions with particular visions of desirable socioscientific futures and new means of organising and producing knowledge.

7.3. Management of the Broads

If the Broads were included in the Hobhouse Report's (1947) recommendations to be a National Park, why was it not designated as one? The conditions of the Broads had not improved since Dower (1945) had noted the difficulties of managing a Broads National Park. Yet, the National Parks Committee still favoured it as a 'scientifically' unique and recreationally important corner of the British countryside that should be preserved under the National Parks Act 1949. This would ensure that the intrinsic character of the Broads would be retained through conservation and remediation of the water bodies. The Broads was an extensive, navigable river system that possessed a large amount of commercial boat traffic at this time (George 1994) and, as a result, would be challenging to designate as a predominantly natural area for recreation and preservation. The Great Yarmouth Port and Haven Commission was responsible for the jurisdiction of navigation (Woolley 2019) and, because of this, had significant political and economic authority in the area at this time, and

strongly opposed any form of National Park status that may interrupt the regular boating activity.[184] Therefore, without National Park status, nor any form of management programme or strategy being planned and ongoing visual degradation of the wider Broads landscape and waters, there was a real risk of ecological, economic and social collapse (Matless 2014). There were, nonetheless, nature reserves and SSSIs designated but this protected certain parts of the Broads as scientific objects of interest. Thus, the emerging rule of scientific institutions clouded the total protection of the landscape, e.g., aspects like beauty and enjoyment that were not bracketed into scientific interest were deemed not important factors for consideration, despite the long cultural history of Broads use and aesthetic enjoyment (George 1976; Matless 2014).

7.3.1. The making of the Broads Authority

Almost two decades of indecision, continued debate, failed management and deterioration passed before the Countryside Commission (a statutory body expanded from the National Parks Commission to cover the entire remit of countryside protection) re-demonstrated their interest in the area with an emergence of new scientific evidence of degradation from UEA (Mason and Bryan 1975; Phillips 1976; Moss 1977).[185] The scientific work from UEA gave legitimacy to the previous anecdotal evidence concerning the increase in turbidity – made visible by the murky waters – and cemented the links that it was negatively impacting the aquatic ecology of numerous Broads. However, causes were still yet to be discerned.

The Countryside Commission organised a consultation with many Broads stakeholders in 1976 that drew predominantly from the new science from ENV and BIO and stakeholders of the Broads (Countryside Commission 1977). Unlike the Nature Conservancy, the Countryside Commission were not a governmental research organisation. Instead, they were the government body that regulated and managed the countryside drawing from both stakeholder and scientific knowledge to inform decision-making. The responses of the consultation were published as a pamphlet and arrived "from the many organisations and individuals who are concerned about the future of the Broads", with the majority being

[184] Interview with Environmental Scientist (b).
[185] Mason and Bryan were based in the School of Biological Sciences, whilst Phillips and Moss were in ENV.

deeply concerned about the ongoing deterioration and future of the Broads 'environment'.[186] As a result, four possible solutions were laid out, a) an early designation of the Broads as national park, b) the designation of the Broads as a national park contingent upon amendments to the legislation, as existing powers given under the National Parks and Access to the Countryside Act 1949 that, at present, were perceived not to be sufficient or inclusive enough to retain the diverse recreational and commercial uses of the Broads, c) the establishment of an authority specially equipped to deal with the Broads or, d) changes that were dependent upon a reorganisation of the water industry. Whatever the option was to entail, the Countryside Commission identified that short-term measures (like a 'Broads Consortium' that had previously been trialled in response to The Nature Conservancy's (1965) report) would need to be in place to ensure swift management of the area. The old 'Broads Consortium' was a mix of the local authorities, river and navigation established to govern and manage the area. Yet the lack of statutory power meant that co-operation between competing interests was difficult and ineffective (Matless 2014).

The re-emergence of a 'Broads Consortium' as a stopgap between permanent planning and management illustrates the challenge of modern environmental politics. Modern environmental challenges, across all scales, exhibit conflicting interests, unequal power relations, competing claims and the dominant view that science and politics are separate domains. The Broads and its stakeholders exhibited similar characteristics some 30 years prior to the consultation in 1977. There was a cycling through ineffective management techniques, continual disagreement, and a desire for the linear application of scientific knowledge for landscape management (George 1994). A consortium then was nothing more than a hollow stopgap, with no real statutory authority, but externally, it represented action to the interested publics. This mode of publicly visible yet materially hollow management resonates with the perceived ineffectiveness of British political culture and institutions to deal with environmental challenges and the multiple origins of environmental concern publicly (O'Riordan 1976, 1985).

With an interest in designating national parks, the Countryside Commission opted for option 'b' as the best approach but requested responses from stakeholders once more.

[186] Countryside Commission. (1977). The Broads: Possible Course of Action; By this point, with the rise of environmentalism and the environmental sciences – the area was being discursively called an 'environment'.

The complexity of the Broads vis-à-vis the multiple and often conflicting uses of the many Broads and surrounding areas coupled with, at the time, diffuse power spread between many authorities and organisations meant that decision-making was a complicated, lengthy, public process and required engaging all the stakeholders. This was unusual at the time because often central powers would delineate or create particular legislation, Acts or management plans without extensive consultation with stakeholders but the new environmental challenge was shifting this (Sewell and O'Riordan 1976). At the present, democratic decision-making and consensus-building through broader participation are proposed for complex issues in environmental management, governance and policy (Turnhout et al. 2010; Chilvers and Kearnes 2016b; Turnhout et al. 2020). But, in the 1970s, this was new ground and seen as critical to finally unlocking the Broads challenge in ways that would suit and include all interested stakeholders in decision-making and deliberation.

In 1979, the submissions to the Countryside Commission were published and were broadly favouring a reconstituted Broads consortium that was a political and institutional experiment stemming from the national park authority. Notwithstanding, many respondents thought this type of endeavour was an ideal solution but believed it would be too unrealistic to imagine that the central government would create and finance the creation of a new special body. This was overcome, however, through various concessions. It was decided that a newly constituted authority may be possible if funding was not to depend on the central government. The Broads Authority, then, was proposed to be created with finance coming from local authorities, the Countryside Commission, the Anglian Water Authority and Great Yarmouth Port and Haven Commissioners. The Broads Authority was to act as a coordinator between the various authorities and interested organisations, with the help of existing staff members from the relevant authorities with power. This meant that it would possess the appropriate statutory powers to have more influence over the water and navigation by containing relevant parties from host institutions without having 'statutorily imposed control' that would come from a formal national park that could take control of the waters and navigation authorities.[187] To avoid the continual cycling of inaction, if the Broads Authority had not been formed and in place by 1978, then the Countryside

[187] Countryside Commission. (1979). The Broads: Comments and Decision.

Commission was to proceed with national park designation. In any case, reconsideration of park status was to occur by the end of 1983.

It was also paramount that a Broads Officer be appointed as the vanguard to take strategy and management forward, to be the leading adviser of the Broads Authority and bring in substantial 'local' knowledge.[188] There were over 1400 applications, signalling significant interest in the management of the Broads environment, with Professor Aitken Clark (1936 – 2010), from Clemson University, South Carolina, taking up the post (George 1992). Surprisingly, Clark was an architect and did not possess substantial local knowledge of the Broadland area but was thought to be a strategic thinker, thus able to organise and manage the entangled strands of Broads degradation effectively with minimal conflict (George 1992). From here on, the Broads would now have a special authority with a designated Broads Officer and a team built through an amalgamation of seconded staff from the relevant authorities and could finally implement and work on management or strategy plans. This was ultimately made possible with the early scientisation of the Broads from UEA that could assess and detail the possible extent and causes of the damage to cultivate a base in which solutions or strategies could be practically imagined.

In sum, interest and concern about the management of the Broads environment had emerged on the local agenda through stakeholders and organisations with vested interests in the area, as diverse as these may be, during the post-war period in the mid 20th century. The consensus concerning a need for environmental management was ever-growing but the framework to put this in place – both scientifically and politically – was absent at first. Further, little could be achieved with minimal financial help, commitment to reconciling organisational differences, or power of authority to implement changes. However, the emergence of governmental organisations like the Nature Conservancy and the founding of BIO and ENV signalled a shift toward the scientisation of the British landscape and countryside and the role scientific knowledge may be able to play in Broads management. The Broads challenge was one of many interrelated collectives of environmental degradation that were beginning to gain traction and that cross-cut economic, social and cultural arenas. Importantly, it was an 'environment' with many areas of concern, with high risk, high stakes and numerous stakeholders. Unknown causes were impacting the existing

[188] Countryside Commission. (1979). The Broads: Comments and Decision.

order of the Broads landscape and environmental knowledge emerged as a solution to improve understanding, implement environmental management and develop strategy to ensure the economic and social longevity of the Broads environment. The arrival of more concrete 'evidence' through peer-reviewed articles that confirmed local observations through the lens of ecological expertise (Mason and Bryant 1975; Phillips 1976; Moss 1977) underscored the perceived importance of scientising the Broads for decision makers; a process in which ENV and its researchers were key actors.

7.4. Scientisation of the Broads

Initially, new scientific knowledge centred around what degradation was happening and where, theorising what might be causing it, how it might be uncovered and ultimately, how it might be mitigated. I have addressed earlier on in this dissertation how ENV came into existence as a result of changing scientific and higher education policy, focusing on a range of different intellectual and society-building pursuits concerning different aspects and challenges of the environment. When ENV was founded, it predominantly focused on physical and earth science conceptualisations of the environment that had emerged out of the IGY. However, as the School grew it branched out into other understandings and avenues of 'environmental' research, hiring additional lecturers beyond Zuckerman's original vision. The ways in which the local countryside and other areas of the British landscape had become framed as areas of scientific interest, education or conservation led to a widening of what was becoming known as the environment and, subsequently, the 'environmental sciences' and environmental problems. Along these lines Brian Moss (1943 - 2016), an aquatic ecologist, was hired as a new lecturer in ENV. Moss arrived at UEA in 1972 having worked on lake ecology in the USA.

Moss has been described as the "wizard of lake ecology" (Maberely et al. 2020) due to his work on the interaction between water quality, macrophytes and phytoplankton (aquatic plants and microalgae), making arguably the most notable contribution in his career in the Broads (Jeppesne and Johnes 2016). Moss believed that the complexity of the 'natural' world should not be distinct from the complexity of the 'social world', striving to uncover the relations and materialities of how they are mutually productive (Maberely et al. 2020; also noted by multiple interviewees). This view embodied the 'epistemic lifestyle' of

his research programme and team in ENV. Moss adopted the view of an ecosystems-based and 'global' environment in which his work on water (from the 'source to the sea') fitted amongst a plethora of other aspects of the environment, challenges, and so, found a home in ENV amongst geographers, soil scientists, geochemists and oceanographers, alike.[189]

In his work, Moss advocated for solutions-based environmental management, believing that policy should be underpinned by 'sound science'. In this vein – Moss thought that the interdisciplinary ethos of ENV was essential but social and political aspects were to be subordinate to the service of scientific knowledge (Barry and Born 2013). Despite all the best intentions to proffer and develop interdisciplinary science, Moss' training and early insights into the Broads were very much top-down, citadel-esque 'science' as a preconfigured institution that trickled down into other social arenas (Irwin and Michael 2003). Moss, throughout his career, sought to publish and produce knowledge that could be used in a linear application for policy and environmental management.

In terms of research management, Moss acted as the head of his research students and staff – who offered advice, comments, and suggestions to guide the research as he saw fit. This kind of work meant that there were numerous friendships created and a tight group formed, but there was little cross-disciplinary work with the rest of ENV.[190] Yet, students and colleagues alike recall a more humanistic and interdisciplinary approach to Moss' teaching, as he would sometimes recite and print poetry for them on the outskirts, amongst the reedbeds of a quiet Broad before conducting in-situ experiments, analysing water quality or taking sediment samples (Jeppesne and Johnes 2016). This demonstrates how Moss believed in and equipped students with other ways of understanding and sense-making in and for the 'environment', but not necessarily as an equal means of knowledge-making; rather as ways that improved understanding, awareness and sympathies for environmental complexity and non-scientific responses that was thought to reflect the types of interdisciplinary working between scientists and non-scientists in the Broads.

Upon arrival, Moss was immediately both interested and concerned by the murky waters of the various Broads. Interested in the Broads 'ecological puzzles' (Jeppesen and

[189] Yet most of Moss' international organisation, like EU, projects work would come later in his career after ENV. Although Moss later noted that he missed the 'interdisciplinary culture of ENV', Brian Moss to Trevor Davies, 3/3/2002 1/1966, The School of Environmental Sciences unpublished archives, UEA. Norwich, UK.
[190] Interview with former Research Associate (a).

Johnes 2016; Moss 2001), Moss became set on understanding what was causing the turbid waters and almost immediately recruited Geoffrey Phillips as a PhD student to assist in early exploratory work. Supported by the Nature Conservancy, Moss' early work was foundational in co-producing environmental science and environmental challenges, that being the mutual construction of creating knowledge about and discerning the challenges of the Broads.

Moss (1977) had advanced the earlier work from BIO's Christopher F. Mason and R. J Bryant (1975) that looked at ecological changes in the Broads using the notes from Martin George of the Nature Conservancy's previous anecdotal observations. According to Moss' exploratory sampling of 82 areas across the Broads in 1973, the water's turbidity resulted from increased phytoplankton numbers that resulted from nutrient loading from human activities like agricultural run-off and/or effluence from sewage treatment works (Moss 1977). This, Moss argued, created an oversaturation of nutrients and, thus, a flourishing of phytoplankton, leading to a decrease in lower-level aquatic life. Moss' preliminary survey and Phillips' PhD (1976) guided a future research programme as much was still to be understood about nutrient loading, tidal/seasonal variation, and differences between the Broads. Notably, this work provided the Broads Authority and other stakeholders with empirical scientific evidence that could be used for decisions and justifications regarding management and action plans. Now that there was published scientific evidence and not just local anecdotal observations it would be challenging to ignore publicly. However, the continued uncertainty furnished Moss with a substantial body of work over the coming decade and continual support from the Broads Authority, the Nature Conservancy and other relevant authorities who held an interest in the natural and ecological sciences of the Broads.

7.4.1. ENV in the Broads Authority

From its inception, the Broads Authority played an instrumental role in the making, financing and organising of environmental knowledge about the Broads and it still does so

today.[191] The numerous bodies of water and interconnected waterways, the wide-range of neighbouring land-uses, the varying levels of recreational enjoyment or visits and the plethora of different fauna and flora renders planning and management a difficult task. What works for one Broad may not work for another; the challenges found within one Broad may be non-existent in another, and so on. To organise and remain aware of research in the Broads, the Broads Authority constructed official research registers that provide a comprehensive survey of the work involved from 1970 to the present day.[192] Crucially, the research registers reveal what work was done and by whom, why and the funding streams present. Various strands within ENV dominated the earliest years of the Broads Authority research. In close proximity, ENV scientific knowledge was circulating from UEA to and from multiple spaces and actors related to the Broads. Moss and the team could travel to and from various Broads in a day or two to collect data, analyse it by night and have the preliminary analysis of results by the following morning, ready to guide the next experiment.[193] This 'localness' is a key aspect of what constitutes the 'environmental sciences' as multi-scalar – rather than focus on international collaboration, international workshops, and conferences - the 'scientisation of the Broads' by Moss was experimental, applied and focused on applied models of environmental management and restoration.

The construction of a research and management plan was a main priority for the new Authority in the 1970s. Aitken Clark created working groups and various committees to tackle what he thought were the main issues and implicitly outline the visions of desirable and achievable futures for the Broads environment. The working groups involved a range of individuals with varying expertise, epistemic ideals, and visions of the environmental future with researchers from ENV at the heart. In the early years, the Broads Authority depended on the academic input of ENV researchers and science to help problem-solve the new Broads environmental challenge. In the main, ENV's newly emerging inter- or multidisciplinary space, with the recent recruitments in the 1970s, enabled a diverse range of perspectives of what the 'environment' was, what its challenges may be and how best to make knowledge about them beyond a predominantly natural or earth science-based

[191]Multiple interviewees mentioned this point.
[192] Multiple Broads Authority Research Register available at The Broads Authority office in Norwich, UK; Interview Broads Authority representative (a)
[193] Interview with former Research Associate (a).

approach. The multiplication of different, and sometimes competing, sometimes collaborating visions of the 'environmental sciences', like ecological, social and economic perspectives, enabled ENV knowledge to reach additional spaces and scales of application. However, it also demonstrated numerous forms and extents to which interdisciplinarity came to fruition, why and how.

In the early 1980s, the Broads Authority created three working groups, Ecology, Landscape and Recreation. These working groups contained a range of individuals working together with either relevant expertise or interest in the area. For example, there was Brian Moss and John Barkham from an expanding ENV, J. Sullivan from the RSPB and an environmental scientist named A. Scowen from the planning department of Norfolk County Council in the Ecology group.[194] The purpose of the groups was to establish the needs of each concerning the possible management strategy and to co-design recommendations of policy or plans, drawing from the different knowledges and perspectives available. The distilling of the working groups into three categories signifies the normative intentionalities of the Broads Authority's institutional view of the importance and possible organisation of the Broads environment for management and research of the area. The construction of these groups set about the trifurcation of the Broads challenge for administrative, epistemic and normative ease and seemed to neglect the social and political aspects of the Broads challenge – vis-à-vis interactions with its many stakeholders. Yet once plans and policy had been decided, they were to be discussed and deliberated by an overarching Strategy committee chaired by another researcher, a social and political scientist in ENV, Tim O'Riordan. The act of delegating the core strategical approach to the social scientists is a typical representation of how those external to the social sciences perceive the role of the social scientists as practitioners of resolution or communication (Barry and Born 2013), rather than instrumental producers of knowledge (Kattirtzi 2016). The discussions culminated in a key report titled *What Future for Broadland?* published by the Broads Authority in 1982 (Broads Authority 1982).

The report outlined and proposed a comprehensive set of policies – alongside the needed staff, costs and timings – that would, in their view, finally set up a sufficient and

[194] Broads Authority (1982a). Towards a nature conservation strategy for Broadland. Report of the Ecology Working Group.

long-awaited management plan for the Broads, drawing from the diverse range of expertise in the working groups. There was a consistent view that environmental management needed to include "safeguarding of existing habitats and features recognised as being of wildlife, landscape or historic importance" and "the improvement of water quality" (Broads Authority 1982: p. 92). This, the report argued, would sustain and conserve the overall enjoyment of the Broads for the foreseeable future and unite the intrinsic qualities of the Broads that had previously been in conflict during the bifurcation of wildlife conservation and landscape protection in UK policy. Importantly, this type of management plan, one that considered multidisciplinary expertise, the interests of different stakeholders alongside trying to remediate degradation, was new and unique to environmental management and conservation in Britain.

Notwithstanding, the increasing rise of science and technology in the West in the post-war period also increased the levels of uncertainty and possible negative impacts and risks of scientific endeavours associated with conservation and management. As discussed in **Chapter 3**, the rise of uncertainty, risk and high stakes has led to the need to open up expertise through an extension of participation (or 'peer community') beyond the scientific community, like farmers and residents or all those with stakes in the issue (Funtowicz and Ravetz 1993) or the bringing together of multi/trans/interdisciplinary experts to work on knowledge for social and political application (Gibbons et al. 1994). The Broads Authority recognised the importance of a scientific grounding and, through the involvement of non-scientists, acknowledged the diversity of relevant expert knowledges to go beyond the power of science to help curb uncertainty with the establishment of a Broads Research Advisory Committee in the 1980s. This committee "was a very strong force in the sending the science into the heart of the Broads Authority system" and signalled the intent and authority of science in decision-making and environmental management (Broads Authority 1982; George 1992).[195]

[195] Interview with Environmental Scientist (b).

7.4.2. Creating a research programme: 'do-able' environmental problems

Once the 'ecological' research plans had been established and supported by the Broads Research Advisory Committee, Moss and a varied team of research assistants and graduate students spent the next 12 years embarking on a comprehensive programme of research in an attempt to quell the uncertainty of the Broads degradation. The causes of eutrophication were continuing to appear complex, multiple and variable across the Broads, with diverse forms of biomanipulation proposed as restoration techniques (Moss et al. 1979; Moss 1983; Moss et al. 1986; Moss et al. 1988; Stansfield et al. 1989). By being unable to proffer a broad-brush explanation and solution, restoration and management were hindered with further research needed. Moreover, many of the experiments were expensive, practically difficult and created tension with the other stakeholders due to the heterogeneity of the Broads 'environment' and use.[196]

The perceived applicability and the visibility of the progress of Moss and his research team's work for the Broads Authority exemplify Moss' vision of a linear application of science and helped Moss secure a range of funding from numerous sources – like that of CRU – there was much value in ENV's knowledge for real world application and planning which created a new set of market actors – the scientists (Agar 2019). The free flow of money enabled the hiring of graduate students to support work on the Broads puzzle - both for the scientific world and the funders' interests - the growth of Moss' team in ENV and a new knowledge economy that suited consultants, innovation and advisory expertise, whether from universities or elsewhere, on more local levels. For instance, one of Moss' research team notes a diverse portfolio of funders, including Anglian Water and the Soap and Detergent Industry Association, with different interests and uses for scientific evidence. Anglian Water had the task of protecting the area's water quality and so funded expensive experiments for Moss to interrogate the source of water degradation.[197] The Soap and Detergents Industry Association were, meanwhile, under scrutiny for their role in decreasing the water quality and so also funded research. This work explored the possible role of phosphates in increasing the turbidity of Broadland water to show there were other mechanisms at play beyond their cause in order to alleviate some of the public pressure on

[196] Interview with former Research Associate (a).
[197] Interview with Environmental Scientist (b).

their activities.[198] Akin to the 'earth sciences' in the US – funding from vested interests, whether military or industry – shapes the ways and extent to which water degradation sources were known (or at least, exonerate industrial causes) (Doel 2003). This also intersects with the activities of CRU, highlighting a more applied side of the sciences of the 'environment' that had stemmed from the sociotechnical imaginary of an interdisciplinary 'environmental sciences' and the future socioscientific challenge, beyond advancing academic knowledge.

Moss' involvement with knowledge-making in the Broads is illustrative of how the 'environmental sciences' are directly involved in making 'environmental' problems known and defining what counts as 'environmental' (Taylor and Buttel 1992). In this instance, Moss drew from ecological science to guide his vision of why the Broadland waterscape was deteriorating, what may be done about it and with what wider purpose this would serve vis-à-vis, the new entanglements of post-war society, recreation and consumption impacting the Broads. With its overarching aims of extending the scientific study of the natural world, the Nature Conservancy placed renewed emphasis on the field, or particular aspects of the British landscape and natural world, as sites of scientific inquiry. Similar to the ideas behind ENV's creation – the field represented a fruitful opportunity to create new forms of science in the modern, post-war reconstruction period that could be used to guide land-planning, to help educate new scientists and advance various forms of 'field' knowledge. In the case of the Broads, through ENV and Moss, the new 'environmental sciences' helped produce scientific knowledge about the Broads environment and reconceptualise the localised degradation as 'environmental' challenges. This had significant implications for the future of knowledge production in the Broads' environmental management. Moss had confirmed the original anecdotal concerns and helped the growing idea that the Broads environment was a complex set of interrelated systems to be interpreted through scientific means.

Additionally, for Moss to embark on scientific enquiry – he had to ascertain 'do-able' problems in the Broads arena (Fujimura 1987) that culminated from his 'epistemic lifestyle' and vision of the 'environmental sciences'. Typically, 'do-able' problems guide the work of scientists and are conceptualised as an "alignment of several levels of work organisation" (Fujimura 1987: p. 258). This involves production (carrying out a well-defined task) and

[198] Interview with former Research Associate (a). Also noted by former Research Associate (b).

articulation (pulling everything together: including the mundane jobs that are integral to the overall task) within three layers of organisation – the experiment, the laboratory and the social world (e.g., the School or discipline). Moss' exploratory work was foundational in constructing a 'do-able' research programme. He created hypotheses to be tested in experiments, but rather than in the laboratory; these were to take place in the field – in various areas of the Broads. So, unlike the amassing of existing data or creating computer models of other strands of ENV, Moss (and Phillips) quite literally produced novel knowledge and understanding about the Norfolk wetland environment, using ecological science and techniques to ascertain and articulate new environmental problems, under the remit of ENV and the environmental sciences for the multiple reasons of scientific interest, use and problem-solving.

This also mirrors what Rebecca Lave (2012) has described as the political economy of the environmental sciences,

> [The] environmental sciences ... are driven by the normative environmental commitments and perceptions of crisis of the public and of scientists themselves rather than scientific breakthroughs. They thus are characterised by their relatively undeveloped content, often drawn from pieces of existing fields and not yet fully integrated ... [they] study highly complicated systems and are based on new scientific paradigms that emphasize complexity. This gives their findings a high level of uncertainty that is not commensurate with the expected role of science as arbiter of truth... [they] deal with issues in which the general population has power interests ... thus they may intervene in scientific debates to support solutions they believe address their needs. In many cases the new environmental sciences deal with issues that are similarly central to developing or established markets, which adds to the demand for certainty (p. 125).

The 'environmental sciences' are not products of blue-sky research but rather are (and have always been) moulded and entangled with the aims of problem-solving, social relevance and responding to the gaps in existing knowledge system (Renn 2020) and the markets in which they had formed. Growing uncertainty, growing risks, and growing demand for expertise in a newly emerging field or 'market' have altered how knowledge is produced, applied, and

circulated. No longer is knowledge made for the sake of advancing knowledge or produced by one group. Rather, the desired applications of knowledge shape and reshape the conditions for it to emerge, and diverse forms of expertise are needed – whether that is interdisciplinary, multiple institutions or from extended peers, like stakeholders (Funtowicz and Ravetz 1993) – the 'environmental sciences', as I have outlined throughout this thesis, have always been multiple and have always been co-produced.

However, the Broads case also further signals the authority of scientific approaches and scientific knowledge in enabling particular pathways. Thus, whilst the diversification of expertise and knowledge was needed, akin to the arguments in **Chapter 5**, scientific knowledge was atop the hierarchy.

Uncertainty and risk characterised the Broads degradation and fuelled a research programme for Moss for many years. Science was seen as the answer to problems in the emerging market and government concern for land-use planning and management (Sheail 1992). Yet planning, management and non-scientific analyses, in turn, shaped the 'science' that was done, like the introduction of new perspectives, new policy, funding opportunities and the creation of organisations like the Broads Authority.

7.5. The politics of the environment

Tim O'Riordan arrived in ENV in the early 1970s as one of the first emerging social and political environmental scientists in the UK. O'Riordan had a geography background, coming from the geography department at the University of British Columbia already possessing extensive knowledge of the Broads management challenges, having completed a PhD on the 'environmental capacity of the Broads' in (1967). O'Riordan was to be a key component of the social and political understandings of the Broads environmental challenge.

As mentioned above, O'Riordan was asked to be Chair of the Strategy Committee due to his relevant expertise in countryside and environmental politics, knowledge of the Broads, and relationship with key actors. O'Riordan's 'epistemic ideals' and ontological differences concerning what the 'environment' was, how knowledge was to be made, and research practice(s) diverged from the scientists he shared the hallways of ENV with. In this vein, scientists in ENV predominantly viewed O'Riordan's work as supplementary and

providing a service to the central views of science, filling in the gaps that natural and earth sciences failed to acknowledge or capture and, in doing so, helped to construct an aura of interdisciplinarity beyond the sciences within the School.[199]

Beyond the ecological challenges of the Broads, there were many other social, political and cultural aspects to be considered. O'Riordan was deeply involved in the Broads Authority arrangements as an external participant and was pursuing other forms of knowledge and understanding in ENV. For instance, the challenge of determining acceptable pollution levels is a deeply political and subjective task (Cotgrove 1980). Science seemingly defines levels of acceptable pollution in a water body, but these are not 'matters of facts' or clear-cut limits that are obviously drawn from the 'natural world' (Latour 2004). Instead, they are deeply embedded collectives of action, decision, politics, and practice entwined with various other factors. For instance, the levels or thresholds in ecotoxicology may be determined on short-time scales and localised areas and define what may be 'safe' for humans or other wildlife but still toxic or damaging after long-term accumulation and real-world exposure (Cairns Jr 1992). Or further, pollution levels may be a 'safe' level but still are not aesthetically pleasing, disrupting other ways of enjoying the area beyond tangible damage to life or landscape. Crucially, environmental challenges are, as O'Riordan argues, entangled between political, technological, social and cultural worlds over time and space, and any form of successful environmental management or planning must be conscientious, aware and aligned to this (O'Riordan 1976b). The Broads challenge, problem-solving and management began focused on ecological sciences due to how the British countryside had been siphoned into protection on the grounds of conservation and scientific education. However, what also made the Broads an area of interest was its scenic beauty, Its unique landscape and wildlife and its multiple uses. As a result, the natural or ecological sciences dominating decision-making or planning excluded, at first, many other matters of concern in the Broads environment.

O'Riordan attempted to fill this gap and published extensively on the political, social and cultural aspects of the environment (and specifically, the politics of Broads management) – that was largely being ignored by the scientists, politicians and the public. In some respects, this contributes to the view that social and political science in

[199] Multiple interviewees mentioned this point.

interdisciplinarity operates as a subordinate to science. However, O'Riordan was uniquely going against the grain of an emerging natural and earth science-focused ENV.

Moreover, in 1976, O'Riordan and a colleague, W. Derrick R. Sewell, assessed the idea of public participation in environmental decision-making across the US, Canada and UK (Sewell and O'Riordan 1976). As a result of eroding trust in government and a changing post-war society, there was much reason to increase the role of public decision-making. However, they noted the difficulty of achieving this in Canada and the UK due to the ineffective and inadequate existing institutions and political processes that exclude key forms of knowledge (e.g., potential pollution levels, knowledge of who is granted permission for certain degrading activity and to what extent) that would shape public input. Expanding involvement in any decision-making to stakeholders can, if not approached appropriately, widen divisions between particular groups in society. For instance, those who are politically literate and with political power can dominate conversations where it is vital that marginal voices are heard. Importantly, they concluded that while increasing public participation in environmental decision-making may be beneficial in unlocking often contested battlegrounds, long-term transformation can be found in education to improve political, social and environmental consciousness. Notably, environmental decision-making was not a one-time thing but the beginning of wider, reflexive understandings of social change – both in the present and future.

Also, in the same year, O'Riordan published the seminal *Environmentalism,* foregrounding the two major approaches to future-making, environmental management and governance – ecocentrism and technocentrism. In Britain particularly, environmentalism can be traced to two origins: concern for the 'natural' world and one as a way of organising, managing and governing people, resources, and land (O'Riordan 1976a). As new institutions, organisations, and populations emerge, new patterns of political and economic power (like in post-war reconstruction Britain) bring conflicts as visions of order compete. Akin to splitting land-use protection into either enjoyment or science and conservation - the entangled, messy core of how things actually are, the nuance of historical cultural and social uses and enjoyment are lost.

These ideas are pertinent to O'Riordan's involvement with the Broads Authority and ENV for several reasons – demonstrating his epistemic ideals and commitments to a particular view of what environmental knowledge should be used for. First of all, the Broads

Authority was a new institutional arrangement consisting of an amalgamation of existing powers from local authorities. By being bespoke for the Broads, they set out to manage the diversity of challenges of the Broads environment that would involve the plethora of interested stakeholders – increasing public participation in environmental management, decision-making and planning (O'Riordan 1976b). An interest in knowing the totality of the Broads environment – beyond the natural sciences – meant that the social sciences and economic understandings of the Broads environmental challenges and viable solutions were able to be considered and used as evidence for decision-making. Next, by being a major commentator and critic of the UK's capacity to deal with environmental challenges, O'Riordan could actively shape and propose ideas for environmental management of the Broads (and wider environment policy) that were grounded in the specific context of Broadland use and reflexive of the role of science in decision making (O'Riordan 1979). O'Riordan's broad involvement in the Broads authority – in strategy, stakeholder engagement, decision-making and the mundane activities or practices that the role entailed – directly informed his teaching in ENV on a module called 'Countryside Politics'.[200]

Whilst Moss believed in a linear application of 'sound science' to guide policy or decision-making in the Broads, O'Riordan warned of the implications of ecologists remaining distinct from environmental politics. O'Riordan (1979) used Moss and his team as objects of study to commentate and explain how ecologists and the way in which they worked had implications for how challenges were framed and how solutions were made imaginable. O'Riordan ultimately argued that ecologists need to be more reflexive of the social and institutional contexts in which they operate and to play a wider role in informing stakeholders of the implications of particular forms of action. Additionally, O'Riordan (1980a, 1980b) also commented on and critically assessed the social and political landscape of Broads research. He explored the vast range of options, impacts, and benefits of land drainage in the Broads during intense conflict between agriculturalists and conservationists. In this vein, O'Riordan co-supervised an MPhil student with Moss, Clive Doarkes. Doarkes was to learn the ecological expertise and research skills whilst also possessing the reflexivity, awareness and understanding of the diverse socio-cultural interest of Broadland actors that made the Broads unique and, like other students in ENV, was trained in a

[200] Interview with Tim O'Riordan.

multi/interdisciplinary way. Doarkes produced a "gazetteer ... of the main marsh dykes (Halvergate Marshes) and species mix over a period of two-years", which proved crucial in developing a solution to what was known as the Halvergate Marsh saga.[201]

Doarkes' MPhil (1980) built on previous work from the Nature Conservancy concerning marsh dyke vegetation in the Yare basin valley area, revealing the factors conducive to rich and diverse flora of ecological importance and that were unique to the area. This work would benefit both conservation aims whilst surveying the landowner's view of drainage in a future scenario. Doarkes found that agricultural practices, nutrient levels, water levels, and the presence of ditches shaped the levels of biodiversity in the Halvergate Marshes and that not all factors were flourishing, mainly due to poor land practices and ineffective management.[202] Importantly, from a conservation perspective, these factors needed to be restored and maintained if the area was to be designated as an SSSI. This work was sent right to the heart of an ongoing political issue concerning the Halvergate Marshes that became nationally recognised concerning the conservation of the marshes and drainage for agriculture. ENV knowledge was being more explicitly used, at this point, in relation to direct problem-solving in politics, being used to help inform environmental management and planning.

7.5.1. The Halvergate Marshes: conservation or drainage?

The Halvergate Marsh saga tested the organisation and political strength of the Broads Authority as they strived to find a middle ground between farming interests and direct-action groups associated with Friends of the Earth. The work from Doarkes provided the evidence needed for an SSSI. From a Broads Authority perspective, these were important designations that supported their policy of safeguarding the landscape and would make the management issue a lot easier by law. Intriguingly, the work was also favoured by the NFU, as it in part "demonstrate[d] the way agriculture was actually supporting the ecology" and reveals how agricultural, development and conservation interests could work in tandem, rather than one way or the other.[203]

[201] Multiple interviewees mentioned this point.
[202] Interview with former Research Student (b).
[203] Interview with former Research Student (b).

However, the issue at hand predominantly came from a loophole in existing legislation. The Common Agricultural Policy (CAP), which meant common and consistent prices for farmers, alongside a possible SSSI designation created a dichotomy between agricultural and conservation interests. Put simply,

> If a farmer wanted to drain the marsh, the argument was that the farmer could then threaten to plough and deep drain the marsh, in which case, you [would] destroy the plant life and the Broads Authority and all the agricultural interests would be forced to pay the farmer the loss of revenue from the upgraded subsidised crop. If you were growing wheat or barley as a result of this transfer from a high-water table grazing to much lower and deeper water table with much bigger dykes arable, then you will be stopped from doing it. But the [Wildlife and Countryside Act 1981] Act said if they're going to be stopped from doing it, you're going to pay the farmer what they would otherwise have earned in the high production thing. Even if [the farmer] didn't actually convert, [they] just had to threaten...[204]

There were many shortcomings and weaknesses in the policy; favouring the farmers who only needed to threaten and prove that they had the capacity to drain – without draining, over those with the task of safeguarding the environment, amenity and access, e.g., the Broads Authority and the Countryside Commission. This set-in place the major grounds for conflict that would persist for a number of years,

> So, that had two really very anger-inducing effects. One was that the cost of that payment was far too high for anyone like the Broads Authority to cough up ... they were really way out of sight and what the Broads Authority would do for the whole of the Halvergate marsh. And secondly, they were a completely false analysis, what you were seeing was that anyone had a right under the European subsidy laws to go for intensive agriculture, because they were supported by the European subsidies. And they automatically would get paid if that right was taken away from them so

[204] Interview with Environmental Scientist (b).

> then if you like the base case, was that the highest intensity agriculture was the greatest degree of environmental mischief.[205]

After several years of negotiations, inaction and disagreements in early 1984, a decision was made. This was to be known as the Broads Grazing Marsh Conservation Scheme and lasted three years as an experimental solution. The Scheme signalled an end to the contestations between conservationists and those in favour of drainage and the ineffectiveness of previous intervention. The scheme involved annual payments of £125 per hectare for landowners or tenants as an incentive to keep grazing compatible with conservation aims – allowing for the mutual development of both conservation and agricultural interests of the Broads environment (Turner 1985). It differed from previous payment programmes as it removed the large costs associated with payment for otherwise lost profit if landowners or farmers were required to maintain and conserve, rather than drain. It was also set to be tremendously cheaper than the suggested offers of £250 – £ 400 per hectare in compensation, under the previous policy, a cost that neither the Broads Authority, nor constituent local authorities, were willing to pay nor could afford to pay. The Scheme came about from trialling the idea of paying farmers to be stewards of the land, rather than compensating for lost production. Instead, everyone was given a payment, not just those who threatened to drain, and would at first be financed via the Countryside Commission on agreement that the government ministry MAFF (who had a remit and interest in agriculture) would carry this on after the 3-year trial period, if deemed suitable to carry on.

This position was favourable with the majority of landowners, as discovered by Martin George and colleagues when they travelled around to speak to both the landowners and farmers about the proposed scheme.[206] The historical land ownership of Halvergate meant that most landowners were scattered around and rented out the land to local farmers who were set to gain "more money per acre than they would have gotten otherwise" as "they were never planning to change anything". Consequently, it was a "small number of highly aggressive farmers" who were influential in Norfolk and heavily involved in intensive farming that were making all the noise and pushing agendas.[207] Moreover, MAFF

[205] Interview with Environmental Scientist (b).
[206] Interview with Environmental Scientist (b).
[207] Interview with Environmental Scientist (b).

themselves were also set to save up to £250 per hectare in annual subsidies for protection from conversion under this new scheme (Lowe et al. 1987). On the back of this resolution ESA legislation came into existence through the Agricultural Act in 1986.[208] Two years later, 14 ESAs were created, one of which was Halvergate.[209] Again, this case demonstrates the new market that (re)shaped the ways in which environmental management was deemed practical and viable. Central planning subsided as a new set of interactions and actors embedded in economic systems and capital flows began to dominate the ways in which the environment was to be known, managed and governed (Lowe et al. 1987; Bonneuil and Fressoz 2016).

7.5.2. Widening knowledge for management

Beyond the natural sciences, ENV researchers produced and circulated knowledge, enabled wider participation and gave voices to stakeholders: the policymakers, the farmers, other scientists or boaters and others. In doing so, ENV was also considerate of the many matters of concern between agriculture and conservation interests. In the case of Halvergate, this was through the policy sphere but elsewhere it was through work and involvement with the Broads Authority, discussions in committees and publications of reports. Different forms of ENV knowledge, from the different visions of 'environment' and expertise, were circulating to and from UEA to produce an inter/transdisciplinary and deliberative or normatively co-produced management plan for the Broads environment. This laid the foundations for future environmental management of the Broads (and other comparable wetlands) that was interdisciplinary, and expert-led. Through decentralised authorities, local forms of environmental management can solve the newly emergent and localised environmental challenges and can do so effectively to stimulate more national or international political and social change.

It is important to note that not only was O'Riordan attempting to shape the environmental management of the Broads, but the decade of his involvement with the

[208] The Agricultural Act 1986 gave political importance and authority for the conservation and protection of agricultural and countryside goods and services.
[209] For a comprehensive account of the Halvergate Marsh Saga see Chapter 12 in Lowe et al. 1987.

Broads also (re)shaped his views on environmental management. In 1985, O'Riordan proclaimed that the existing culture of the environment had not evolved to match the social and economic development aims of Britain, drawing on the earlier Broads impasse. For instance, environmentalism was now split among many avenues – the conservationists and ecologists, those keen on landscape heritage and scenic beauty, and those concerned about the toxicology of pollution, notwithstanding any possible overlaps. For O'Riordan, this was symptomatic of the fragmentation of environmental concern throughout environmental history in Britain (also see Sheail 1995b, 2002) and introduced bigger questions about power and world-making beyond scientific knowledge: whose and what expertise were we to listen to? How would futures be imagined and put in place that were democratic and just?

The fragmentation and bifurcation of concern often divided the commitment to action between conservation and recreation or development and urbanisation. Sustainable development and environmental management that promotes remediation and longevity of environmental spaces must recognise the interrelated constitutional aspects of conserving the environment for various users and interested actors (O'Riordan 1985). This required an expansion of what the 'environment' was – beyond the natural world but rather all entangled aspects of heterogenous collectives possessing many matters of concern. Chiefly, O'Riordan noted that this was being overlooked by the Broads Authority - as crucial historical, cultural and social elements (e.g. social practices of anglers and boat users) of the Broads concern were not receiving the same attention or focus as ecological challenges, and science led-management was the central focus.[210] Instead, environmental management should focus on the mutual construction of conservation, development and recreation of the area improving the quality of life of stakeholders, residents and users alongside the quality of the Broads environment and the diversity of expertise that underpins the use and knowledge beyond scientific framings. Thus, O'Riordan, committed to this vision, remained involved with the Broads Authority, advising and guiding well into the 1990s and teaching students directly about the politics of the Broads.

By the 1990s, the Broads Authority gained institutional and political authority, and the environmental sciences had multiplied across many national laboratories, organisations and university departments. New techniques of understanding environmental challenges

[210] Interview with Tim O'Riordan.

had emerged (e.g., valuing nature in environmental economics), a more globally orientated environmental order was emerging through a further internationalisation of science and politics (e.g. the Rio Conference in 1992, the formation of the IPCC in 1988, various environmental programmes through the World Bank etc.), the construction of global knowledge infrastructures (Beck et al. 2017) and environmental knowledges were mushrooming across the UK and the rest of the world. This meant that the Broads Authority no longer had to rely on ENV as a key source of knowledge-making – having co-produced environmental science and environmental challenges in the 1970s and early 1980s. However, despite the foundational involvement of Moss and his team and the centrality of science, Moss never received formal institutional recognition of his work and left ENV for a Chair at the University of Liverpool. ENV's involvement continued in a more supplementary and advisory role for the ecological and environmental pursuits of the Broads Authority.

7.6. Valuing and assessing nature: environmental economics and impact assessments

ENVMAN from **Chapter 5** became involved with the Broads Authority on a consultancy and not academic level, producing a range of reports, including novel EIAs. Kerry Turner, an environmental economist, arrived in ENV in the late 1970s from the Public Sector Economics Research Centre at the University of Leicester, and helped pioneer the development of environmental and other forms of environmental assessment, spearheaded by the eminent economist David Pearce. Turner's work in ENV stemmed from trying to "promote the spread of environmental economics research" predominantly through interdisciplinary means vis-à-vis environmental management, project appraisal work and promoting forms of environmental assessment to manage environmental challenges.[211]

EIAs and, subsequently, varying forms of economic assessment like cost-benefit analyses were new ways of viewing and understanding the 'environment' and organising environmental knowledge to practically aid in management and decision-making processes (Lamb 2014; Sandmo 2015). EIAs emerged in part to help decision and policymakers to gain a grasp and make legible the new and increasing environmental challenges in ways

[211] Correspondence with Kerry Turner.

understood to policy, decision-makers and aligned with an emerging market that was growing in prominence in social order and public political discourse. Yet, EIAs also acted as tools to help traverse the scales of understanding environmental challenges. EIAs mobilise environmental and ecological analysis for the context and scale in which it is required, sometimes requiring homogenisation, sometimes requiring complexity (Lamb 2014). Further, despite appearing to appear politically objective, EIAs are situated, partial and embedded with institutional and disciplinary biases aligned to particular epistemic and normative aims of their contexts or those that implement them (Richardson 2005; Bond and Pope 2012). With this in mind, how did an environmental economics view of the Broads shape management and knowledge production from ENV? This section is brief due to COVID-19 impacts on documentary and participant access. Yet, it remains in the thesis to provide a brief but further insight into the Broads' multiple and simultaneous visions of environmental management.

There is great difficulty in assessing the economic cost and benefit of environmental changes (Ashby 1980; Pearce 1976, 1979). Namely, the difficulty is in translating an economic indicator to the natural world and environment, something which was in its infancy back then, and making it intelligible and meaningful, e.g., how are environmental qualities of the Broads valued in relation to social or human enjoyment, or ecology, or both? How do we calculate the permanent loss of these services through financial means? However, through Turner and ENVMAN, the idea "of contingent valuation" emerged to help gain some purchase on the concept of usefully "valuing conservation areas" to aid in environmental assessment work[212]. Contingent valuation emerged from, essentially, the need to understand the value of environmental characteristics. Through the creation of hypothetical markets and stakeholders' willingness-to-pay (WTP), this can be ascertained, for instance, by determining the public's WTP for the preservation of the ecological, aesthetic and recreational benefit of Broadland wetland (Turner 1983; Turner et al. 1983). Turner and colleagues also noted that this overestimates the existence of demand for preservation, and in a material world, it is often not clear cut (Turner 1983; Turner et al. 1983). Regardless, the concept of valuing nature emerged in part for the need of ENVMAN's assessments through interdisciplinary work between an economist, a soil scientist and a

[212] Interview with Environmental Scientist (d).

river hydrologist – creating new tools in the ENV trading zone. Together, they could re-articulate economic terms to value core environmental properties that would be lost or saved depending on particular courses of action. The need for new specialised knowledge (economic valuation of the environment) paved the way for new ontologies of 'ecosystem services' and natural capital that emerged later on.

An economic view of the environment remained a crucial part of the Broads management and decision-making once the foundational ecological knowledge of Moss had emerged. Moreover, this form of analysis served as a point of inquiry for Turner's later career in ENV – circulating from the Broads (Turner and Brooke 1988) to other wetlands (Turner et al. 2003; Turner et al. 2008), and to other environmental realms like climate risk within the Broads (Turner and Palmieri 2016) and more broadly, ecosystem services (Turner and Daily 2008). Within each, Turner collaborated in a very interdisciplinary way with each of the relevant disciplines in an attempt to forge appropriate valuations and subsequent environmental appraisals in strategy, policy and decision-making.[213] This vision of the interdisciplinary environmental sciences, as understood by Turner, was supported through work in the Broads and helped to cement and make legible environmental challenges, scenarios and decisions in ways that were more discernible for businesses, government and transnational organisations - beyond the interpretive framework of the sciences.

The work in valuing nature and knowing the environment in economic terms was solidified at the national scale in 1989 when David Pearce, who spearheaded the Leicester group, led the publication 'Blueprint for Green Economy' (Pearce et al. 1989) for the Department of Environment, whilst being a special advisor to Chris Patten. In doing so, Pearce et al. (1989) operationalised valuing environmental goods and harms to create the space for market interventions as a form of decision-making and environmental management (Agar 2019b). This was conducive to the views of Thatcher's private secretary, Bernard Ingham, and the general ideas of market interventions and that pricing "must be a better mechanism than armies of regulators to secure a sound environment" (quoted in Agar 2019b, p. 246). This had profound implications for how the government presented environmental challenges as market failures that would eventually be corrected (Agar 2019b). The consequences of viewing nature in this light were mentioned by Turner (1983)

[213] Correspondence with Kerry Turner; Interview with Environmental Scientist (d).

in a report for the Broads Authority that recognised the ontological and epistemological differences between the ecocentrist and the economist in environmental management. The two realms, environment and economy, can be reconciled through renewed attention that "all human societies and their internal economic systems depend on the maintenance of the external life-support system provided by the biosphere" (Turner 1983, p. 20). Turner recognises the interrelational aspects of the 'environmental sciences' and the mutual construction with economic ways of understanding environmental change (Jasanoff 2004). In particular, as environmental goals shape and limit "economic methods used," the economy determines how particular environmental components are preserved (Turner 1983; p. 19). Turner maintained his links with the Broads Authority – even serving as Chair in the 2000s. Turner's way of viewing the environment was cemented as more than a 'subordination-service' intervention (Barry and Born 2013) through the emergence and funding of CSERGE in the 1990s as he continued to embark on interdisciplinary environmental management with colleagues in ENV and beyond.

7.7. Conclusions: Environmental science for environmental management

The scientisation of government and decision-making – that aided the formation of ENV – in post-War Britain channelled framings of conservation of the natural world and how it was to be understood (and managed to restrict degradation) through the natural sciences. However, for the Broads, as a landscape with many interested parties and stakeholders, successful management and planning of the area required an assembly of knowledges from an assembly of producers constrained within the boundaries of an emerging market-based economy. ENV helped to make the plethora of challenges and Broads voices knowable. As a result, ENV scientists were foundational in constructing and connecting the early assembly of knowledges that cemented 'matters of concern' into legitimate environmental challenges and shaped environmental policy, even if not directly in collaboration. ENV researchers supported this on many fronts. Firstly, they aided the institutional and infrastructural development of the Broads Authority and environmental management between the 1970s and 1990s. Secondly, they produced knowledge and provided scientific evidence as means of legitimising concerns and possible management solutions and opened-up scientific

concern beyond natural science approaches. In the process, the diverse views of the 'environment' and what the sciences of the environment should be for and how they should be made, helped to make legible how the social and cultural aspects of environmental management and science are constitutive of modern environmental challenge and politics. However, this also meant that the Broads was a space of intense conflict, negotiation and epistemic battle and ENV knowledge was being used to justify particular lines of action across different spaces and scales. On the one hand, scientific legitimacy was lent to specific forms of management and planning scenarios. On the other, numerous parties with rich cultural and social histories of use and enjoyment of the Broads with views and expertise that a science-led approach had neglected.

The Broads challenge represents many matters of concern competing and jostling for dominance in the landscape of environmental knowledge. This is typical of all environments across the planet, in one way or other. Failure to acknowledge and manage these effectively leads to degradation of the area. As ENV researchers embarked on many forms of research, as shown in the above, they began to discern and discuss these problems and how the environment may be managed to restore and mitigate environmental problems. Andrew Barry (2021) recently theorised the constitution and character of environmental problems. What makes an environmental problem an environmental problem? For Barry, it is "a relation or encounter between unlike or disparate materials or processes that are often, although not necessarily, in proximity with one another" (p. 4). In the case of the Broads, this is seen through the diverse materials and processes that were actively degrading the Broadland environment, e.g., the phosphates from sewage effluents and nitrate runoff from nearby agricultural land. The possibility of land-use change through drainage and the posed risk of transformational landscape, ecological, social and economic change is also seen through the possibility of broad environmental problems materialising.

As I have shown, the Broads management began with a science-led approach but became orientated and entangled with many matters of concern by the arrival of new and collaborative visions of the 'environment' – social, cultural, historical and economic – worked together to co-produce knowledge, if not directly in collaboration. As a result, it laid the foundations for an interdisciplinary and multi-perspective-based programme for environmental management that carried on, beyond ENV, in the Broads Authority organisation. In the earliest and formative years of the Broads Authority, ENV knowledge

was shared through meetings, committees, and discussions with stakeholders of the Broads to generate and promote strategy and research plans. This cemented an evolving model of interdisciplinary working as multiple experts were called upon through wider deliberative engagements in the Broads Authority's schema and funded for their advice or expertise. Yet, the growth and institutionalisation of the 'environmental sciences' in the 1990s and beyond, in part originating from the worlds ENV, its knowledge and alumni were creating, meant that there was a wider range of actors, institutions and experts for the Broads Authority to draw from. Nonetheless, ENV and its researchers were key in producing novel knowledge, management and research programmes and stakeholder engagements in the local and bounded area of the Broads. The close geographical proximity aided ENV and researchers' regular interaction and involvement with the Broads Authority, at first, when the demand for knowledge and expertise was there, like CRU's relationship with the US DOE (see **Chapter 6**). Lastly, I now move on to reflect on the empirics of this thesis, assess the historical and conceptual contributions and seek to answer the research questions outlined in **Chapter 1**.

8. ENV as an 'ecology of co-production'

The construction of any form of historical work is always contingent on the positionality, epistemological, ontological and, as this thesis has demonstrated, the normative aims of the researcher. This thesis has been constructed through an 'ecology of co-production' framing, concerned with how the multiplicity of the 'environmental sciences' emerged through a range of socio-political, institutional, material, epistemic and normative arrangements. I asked in **Chapter 3** – what difference does it make to view co-production ecologically?
I have demonstrated how the 'environmental sciences' are both multiple in scale, space, epistemic normative alignment and multiple in the actors that work to produce environmental scientific knowledge through numerous models of inter/transdisciplinary practice and relational cultures of research. The institutional history of ENV, in this thesis, is not one about straightforward epistemic or educational success; rather, it is a story about the contingent nature of knowledge-making, institutional freedom concerning the production of knowledge, the imagination of futures and the opening-up of scientific practice through multi/inter/transdisciplinary needs and the knowledge co-production between different forms of expertise. The co-production of knowledge and order is deeply embedded in world-making and being, from the construction of perceived margins or spaces to the more affective considerations of responsibility, intentionality and ethics in knowing and scientific practice, and opening up the relationality of modes and methods of knowledge-making to include wider communities of participation. The 'environmental sciences' have always been co-produced and have always co-produced. The landscape of knowledge-making is messy, fluid, dynamic and contingent.

This chapter aims to revisit the research questions outlined in **Chapter 1** to underscore the three main contributions of this thesis: 1.) The empirical contributions that shed light on how and why different sciences and practices of interdisciplinarity emerged as the constitutive components of the 'environmental sciences' and how different versions of the 'environmental sciences' operated, interacted and made knowledge about different 'environments' and environmental change in response to changing epistemic, social and political contexts simultaneously in the same space. 2.) The conceptual contributions of

joining concepts like epistemic lifestyles, trading zones and different models of interdisciplinarity with explicitly co-productionist tools like civic epistemologies and sociotechnical imaginaries to create a toolbox that enables relational, dynamic and multi-scalar analyses of studies of scientific knowledge and society. 3.) The normative contributions associated with the use of an 'ecology of co-production' sensibility. The 'ecology of co-production' sensibility foregrounds the relationality between the normative and analytical forms of co-production and allows more diverse (and thus fuller) histories to be explored, in tandem with one another and with critical relations between them highlighted and expanded on. The implications of doing so reveal that the 'environmental sciences' are both co-produced and co-producing. I then assess and explore the future implications of this work vis-à-vis the future of the 'environmental sciences' in the Anthropocene.

8.1. Empirical contributions

This thesis has produced new knowledge and understanding about the history of the 'environmental sciences' in numerous ways. The first research question – **How and why did a particular vision of the 'environmental sciences' emerge in post-war Britain, and how did it materialise at UEA?** – was answered predominantly in **Chapters 4** and **5**. The 'environmental sciences' became a formal, institutionalised branch of knowledge in Britain through the creation of a new department in a new university. It emerged as both a product of collectively imagined visions of socioscientific futures orientated around many constitutions that position new 'environments' emerging as an object of thought and political concern, and as a new social practice and process of scientific research that encouraged interdisciplinary thinking and knowledge-production. This critically led to the construction of new environmental 'expertise' and new 'environmental' science graduates and citizens that went on to cement the logics of the 'environmental sciences' as an institutionalised yet diverse branch of knowledge-making.

Notably, existing histories of the 'environment' tend to focus on the construction of global thinking and understanding of 'environmental' systems and challenges (Warde et al. 2018; Selcer 2019; Benson 2020; Goossen 2020), the transformation of earth sciences amidst US Cold War tension, strategy and policy and the internationalisation of science and

order (Doel 2003; Beck et al. 2017); or they focus on much more localised and specific aspects of environmental change over time in discrete places or regions (White 1984; Sayre 2017). As a result, **Chapter 4** opens up new critical historical insights into the UK's role in turning the sciences of the environment into the 'environmental sciences' and the making of the diversity of environmental challenges known through the agency, network and vision of Solly Zuckerman. The post-war period was a formative time for Western states. The UK was no exception, and on the back of scientists' involvement in operational research and strategy during WW2, scientific knowledge had cemented its epistemic authority within government circles and was beginning to be mobilised as a normative tool for governance and strategy through scientific advice. Mass unemployment, an economic downturn and the need for post-war reconstruction meant that scientists and advisory committees looked to assess the future needs of the country and the role scientists and technologists could play in both post-war reconstruction and protecting the UK against a whole suite of social and economic challenges. This endeavour illuminated both the emergence of new 'environmental challenges', how they were formed, the weakness of existing research councils and university institutions in producing scientists and the research needed, and the interdisciplinary ways in which this was to be addressed. As a result, the conditions for collective discussions between scientists, civil servants and ministers, often led or dominated by Zuckerman, concerning the formation of the new university meant that UEA, and ENV were created. Furthermore, unlike the origins found in military and governmental strategy (van Keuren 2003; Doel 2003), the 'environmental sciences' in the UK and UEA did not have direct government influence (although they were aligned to broader normative and epistemic aims of a socioscientific society) and so enjoyed much institutional autonomy to pursue and develop knowledge as the practitioners deemed fit. Although the model of interdisciplinarity set out followed closely the proposal laid out by Zuckerman. This had important implications for how the 'environmental sciences' materialised and developed over time in ENV, predominantly centred around 'natural' or physical science laying the foundations for ENV to become a key site of 'environmental' knowledge-making without the wider military-geopolitical interest found in the USA or Soviet Union. Yet, the efficacy of 'interdisciplinarity' varied between competing or shared epistemologies and ontologies: disciplines that shared existing views and methods were more likely to engage in coherent performances of knowledge production and to synthesise different perspectives (Pickering

1995). Interdisciplinarity more broadly matured over time as the 'environmental sciences' tried to forge their own identity, values, methods and tools within the Zuckerman framework. These insights support the growing co-productionist literature of the 'sociotechnical imaginary' as a core and critical form of interpretive social analysis, moral or value discernment and as a normative tool, guiding decision and policymaking (Jasanoff and Kim 2015) but emphasises the importance of scientific knowledge, collective discussion and individual agency, rather than technology, in imagining futures, democracy, and development on nation-state scales (Ezrahi 1990). It also extends the ideas beyond the policy worlds to demonstrate how programmes of higher education and organisations can help align knowledge and actors toward and help (re)shape nation-state goals and aims.

Critically, the role of Solly Zuckerman is not to be understated. I have attended to the collective practices and origins of the 'environmental sciences' yet the agency and power of Zuckerman strongly influence and continued to influence the practices and direction of ENV. However, as Zuckerman grew older and the key role of individuals waned in government as central planning transitioned into a more complex machine with numerous governing bodies shaped and reshaped by emerging neoliberal markets so did the uniqueness and potency of ENV (Agar 2019) more institutions emerged with more experts and greater competition for funding and impact of work meant greater dilution of the ENV institution.

Answering the second research question - **how did the vision for a new interdisciplinary field of environmental sciences play out in practice in the case of ENV? How were different practices of interdisciplinarity shaped by different conceptions of 'the environment?** – required a more direct comparative analysis between the different strands or cultures of research as the School developed exploring the materialities and interactional aspects of knowledge-making to ascertain if (and how) ontological differences between researchers (re)shaped the ways in which the 'environment' was problematised, came to be known and the methods or practices behind knowledge co-production.

The variable extent to which interdisciplinarity was put to work in the early years of ENV (**Chapter 5**) demonstrates the institutional, disciplinary and structural politics of new ways of thinking or 'doing things together' in knowledge systems (Renn 2020). For the early years, ENV administrators, including Keith Clayton, gave the new lecturers free reign to develop courses and research as they saw fit. Principally, ENV researchers collaborated in

ways that were more 'natural' to them, e.g., visions of the 'environment', methods and instruments of research that were innate or aligned to their earlier disciplinary training. This is demonstrative of what Barry and Born (2013) label as an 'integrative-synthesis' mode of interdisciplinary working, wherein at the heart of the disciplines working together, they have the same commitments, values and shared ideas. In ENV's earliest years, what enabled this was the collaboration and perceived ease between disciplines and researchers with similar ontologies – like earth and soil sciences or oceans and atmospheres. The materiality of interdisciplinarity was contingent on the willingness of the researcher to engage, interact and negotiate interdisciplinary knowledge in the 'trading zone' (Galison 1997). However, through a more direct intervention by Solly Zuckerman brough together competing and disparate epistemologies and ontologies for short periods of time in a seminar series and idea of transdisciplinary environmental sciences emerged more emphatically. It became less about the 'mangle of practice' and more about the seminar space as a site of intentional knowledge co-production. This was exemplified through the work of researchers like Brian Moss, Kerry Turner, Tim O'Riordan, Tom Wigley and ENVMAN who saw direct social, economic and political relevance and value to their work and the work ENV could be doing.

In Chapters **6** and **7,** I intentionally explored the margins of the ENV vision by focusing on two areas of research which were not in the original proposal for the School, climate and environmental management, but which arguably carved out and cemented their own space in the 'environmental sciences'. Both CRU and the Broads work were inter/transdisciplinary in different ways. For CRU, the types of work taken on were contingent on the funding that could be secured, particularly whilst Lamb was director, and as CRU grew, more research staff were hired with different backgrounds to help work on other projects, like *HWMP* and *GPCC*. The practice of interdisciplinarity in CRU's case was direct, intentional and later on housed in one, cylindrical space, now known as The Hubert Lamb Building. The shared offices and coffee rooms enabled a conducive atmosphere for formal and informal interactions that allowed different disciplinary experts to learn from and engage with one another. This came about, in part, due to the financial constraints CRU experienced in the earliest years, and the need to secure funding and projects. On the other hand, interdisciplinary approaches formed the epistemic ideals and lifestyles of Hubert Lamb – who directly sought to bring climatologists and historians together and Tom Wigley

– who was interested in the scientific complexity and extent of climatic changes both in the past and the magnitude of human influence at the time and in the future.

Conversely, for the Broads, interdisciplinary research came from the need to understand multiple 'environmental problems' occurring in multiple disciplinary spaces – like hydrology, soils, various strands of ecology, social uses and cultural heritage – and the need to manage restorative and sustainable actions in the area. This could not be done from a single disciplinary standpoint, despite the early dominance of ecology in discerning the degradation of the water. In this instance, interdisciplinarity beyond the sciences was not adopted completely per se (in the earliest exploratory work); rather, the Broads Authority brought together different experts and knowledge to discuss, strategize and plan management and research programmes. In the 1970s and 80s, as I show in the latter stages of the chapter, more applied, consultancy and interdisciplinary research was directly funded and organised by ENV scientists and the Broads Authority.

Interdisciplinary efforts are not novel, but rather as **Chapters 5, 6** and **7** have illustrated, they are in constant processes of formation, negotiation and performing in a multiplicity of disciplinary perspectives, contingent on the conductivity of the spaces in which knowledge could be co-produced (Galison 1997; Barry and Born 2013) and the agency and intentions of the individuals involved. While the vision of UEA and ENV imagined new ways of doing and teaching science concerning the new object of concern, the 'environment', the methods and practices that were to underpin the interdisciplinary science were absent. It was an aim but with no guidelines or framework. As a result, many forms of interdisciplinarity took place with variable impact and success contingent on the researchers' particular ontologies, epistemologies and scientific personality, the normative aims, epistemic ideals of knowledge produced, and the institutional and financial autonomy in which it took place. This contributes to our understanding of interdisciplinarity as both a normative and epistemic aim: as a distinct mode of knowledge co-production, the 'environmental sciences' operated as a range of discrete collectives of knowledge-making rather than an institutionalised 'interdiscipline'.

The third research question – **how did ENV knowledge circulate and get put to work across different spaces and scales?** – is more aligned to the histories and constitution of ENV knowledge production and its mobility within and beyond the university institution. The multiplicity of different research cultures of the 'environmental sciences' within ENV

that – to some extent – emerged from varying levels of interdisciplinary and collaborative research also was circulated and put to work in various ways. This is most apparent in the global and local cases of CRU and the Broads, despite demonstrating how scales are traversed and co-constructed through epistemic and normative aims. The multiplicity of knowledge produced was put to work and circulated in multiple ways that became constitutive aspects of the spaces they were formed.

For **Chapter 5**, knowledge was made in the earliest founding years and published in existing disciplinary journals through the construction of new textbooks and taught to students in a new curriculum. As Zuckerman had aimed with his original proposal, students from ENV then left UEA, taking the new 'environmental sciences' vision into further research, industry, teaching, and other roles. The new 'environmental sciences' society stemmed from the diaspora of ENV graduates and research. Later on and more innovatively, the Zuckerman seminars were a chance for ENV knowledge, ideas and programmes of research to be demonstrated beyond the university to more national and politically aligned ministers and industry – who then reinserted this back into the academy network, as a matter of urgency, through the publication of the seminar proceedings. Zuckerman also shared reports of the seminars with the US-based Ford Foundation, which funded the events, to get more international coverage and reach across the Atlantic. The focus of **Chapter 5** showed how knowledge on the institutional scale was co-produced with national concerns and interests, and is thus typical of co-productionist analyses (Jasanoff 2004a). Still, it illuminates through an intentional organisation of key figures that ENV knowledge could reach the places the authoritative figure of Zuckerman had envisioned.

On the other hand, CRU's knowledge emerged from historical origins and viewpoints and, through involvement with the US DOE, became increasingly collaborative, international and sought to construct 'global' temperature sets due to ways in which CRU during this participation helped to frame and understand anthropogenic impacts on climate change. CRU's work assisted the data collection processes, assimilation and standardisation of data points that could be scaled up and compared to make global temperature changes legible. Notwithstanding, CRU's involvement with the US DOE and other institutions, like the WMO and the University of Massachusetts, supported sharing of data through workshops, collaboration, and standardised training programmes for NMS for future data sets and use. As a result, knowledge circulated through the conventional publication methods of papers,

books, and government reports, sharable data banks or models that other scientists could use and interpret. This helped to (re)design the infrastructure, knowledge and networks for 'infrastructural globalism' (Edwards 2010) that became entrenched in Western climate research and politics.

The environmental management of the Broads illuminates the more local aspects of knowledge-making. Researchers in ENV experimented, discussed, assessed and published on specific challenges of the Broads wetland environment. Specificity was key due to the complex and intrinsic ecological, social and economic environment and use of the area. General theories and methods could be used to begin an ecological analysis, but it was quickly recognised that more experimental ideas and techniques were needed. Further, more interpretive social and economic analyses were generated to produce inventive and useful ways of dealing with perceived challenges – like EIA and contingent valuation in politically literate terms. As a result, knowledge was shared more widely through workshops with stakeholders, consultancy reports and pamphlets alongside more traditional academic publications.

The production of ENV knowledge was, for the most part, novel and went beyond existing disciplinary knowledge production and circulation of teaching, journal publishing and book writing. Instead, as environmental challenges were continually being uncovered as socially and politically relevant and the internationalisation of science and order gained traction (Latour and Weibel 2020) and science gained cultural and epistemic authority for government and society (Agar 2012), knowledge needed to be repackaged for new spaces and new scales. The 'environmental sciences' in many forms, as I have demonstrated, were at the forefront and constitutive components of new ways of knowing and living as key moments of world-making in the 20th century (Jasanoff and Martello 2004); a world where humans are increasingly being made aware of their impact on both the surrounding environments and the systems that regulate our planetary environments. This would not be possible without the work and understanding that the 'environmental sciences' reveals.

The fourth research question deals with this directly and is the most important empirical contribution of the thesis in relation to the sociological and historiographic interest in scientising the 'environment': **what worlds were co-produced with the new 'environmental sciences' of ENV?** Processes of world-making do not occur in clean or discrete states; instead, they are performed against and evolve from "the backdrop of an

extant order" in which people or publics already know what counts as science, society, culture and politics (Jasanoff 2004b, p. 19). Co-productionist work enquires as to how and why ideas, values and methods of boundary work take place, under what circumstance and through what means, and how we know what we know (Gieryn 1999; Jasanoff 2004b) to help us to ascertain the interactive relationship between the normative and epistemic that is constitutive of world-making, world-knowing, problem generation and imaginations of the future. How then has the emergence of the 'environmental sciences' of ENV contributed and defined these practices?

Broadly, the emergence of a unified, global 'environment' and the sciences associated with it are argued to be a defining characteristic of 20th-century knowledge-making (Agar 2012; Warde et al. 2018). An external and shared object of concern – either immediately surrounding or as abstract, planetary wide systems, in which human agency has an impact – emerged and helped to cultivate a new planetary consciousness and moral environmentalism. This sparked numerous environmental movements and scientific endeavours and was politically orientated toward action and some form of change. Environmental consciousness and awareness, at its core, is not novel (as discussed in **Chapter 2)** but the scaling-up processes – both politically and scientifically – involved with modern environmentalism (O'Riordan 1976; Benson 2020) have enabled Western society to grasp and understand their shared stakes in a sustainable, long-term 'environment' and ultimately, the planet. The 'environment' became scientised and institutionalised amidst a cultural and governance shift toward science and scientific advice in the West.

In the UK specifically, a core group of multi-disciplinary scientists gained political authority during their time and success in operational research during WW2 and were able to help kick start a techno-scientifically oriented post-war reconstruction in which new 'environmental' challenges became known both domestically and internationally. The presence and practices of unwavering scientific and technological development for the scientific, domestic and international policy had 'environmental' consequences, which injected a renewed sense of caution in scientific endeavours. Nonetheless, different forms of science were thought to be able to solve the new challenges it had made known – like toxicology, population growth, food scarcity, resource management and so on. Although always being social and political (Zuckerman 1959b), science was being recognised more widely as being of social and political use and application in the post-war period. The

'environmental sciences' from their origins signify a changing world focused on the linear application of science to inform policy, science as a tool of governance, management and future-making that was relevant and needed in the late 20th century.

The specific vision of interdisciplinary scientific practices vis-à-vis knowledge co-production (**Chapter 5**) as a response to the environmental problem for Zuckerman and ENV helped to create new social organisations, scientific practices, interactional cultures, diverse institutional epistemologies and epistemic lifestyles of some scientists. The institutional and epistemic freedom given to mostly young researchers in the founding years of ENV permitted new and innovative research and teaching to occur. ENV as a 'trading zone' supported different forms and extents of interdisciplinary work – research, conversation, teaching – to come to fruition (Galison 1997). Arguably, this is what separates ENV from geography and earth sciences departments, regardless of whether actual interdisciplinarity was reached or embarked on. Rather, it is the space of possibility and the vision of an interdisciplinary future that supports a diverse range of experts to come together to create the interdisciplinary School, teaching programme and to produce interdisciplinary graduates. This, in turn, mushroomed out as the diaspora of graduates and publications circulated and cemented the interdisciplinary response to environmental challenges and sciences as seemingly 'inevitable' and innate in areas beyond the academy. ENV, as I have demonstrated, helped construct a world in which scientific interdisciplinarity was the perceived solution to the increasing challenges of environmental change and was well placed in the first 25 years of existence to lead the university response in trans-local and multi-scalar environmental knowledge-making, as seen in the final two empirical chapters.

The evolving work from historical climatology to the construction of global temperature data sets of CRU (**Chapter 6**) and its collaborators co-produced ideals of global knowledge, infrastructure and global framings of climate change (Edwards 2010). As the epistemic lifestyle of CRU changed, so did its institutional epistemology and culture of research. Yet, the financial and administrative realities of CRU's separation from ENV in its first two decades of operation meant that CRU had the unique position to embark on 'blue-sky' research, build relationships with partners and publish and present in a wide range of formats and spaces. In CRU, the production and circulation of knowledge was contingent on the social and epistemic contexts in which it was embedded. The group in CRU working on the construction of global temperature datasets worked closely in CRU and with external

collaborators because they shared the value of the importance of assembling global temperature data sets to act as key indicators of human-induced climate change and agreed on the modes of practice in which to make this possible. CRU, as a branch of ENV and the 'environmental sciences', illuminates how a centre of research that was brought in opportunistically and with little organisational commitment from the host, ENV, can and did flourish through numerous (and some overlapping) interdisciplinary projects into a key centre involved in the global co-production of the dominant, scientific, interpretive framework in which the transformative effects of climate change were made known and imagined.

The work from various members of ENV in the Broads (**Chapter 7**) illuminated how the 'environmental sciences' and knowledge were co-produced with visions of the environmental management of 'nature' (Eden 2001). Researchers in ENV predominantly engaged with the Broads through three different but related framings: ecological, political and economic. Each of these approaches produced different (and sometimes competing) views on how environmental management can occur, for what reasons and for different benefits. Ecologically, certain aspects of Broads restoration made sense but were politically difficult or economically unviable for the decision-makers The knowledge from ENV and other environmental research institutions embedded within the scientisation of government and a new economy of knowledge helped to conceptualise the Broads 'environment' as a constant space of negotiation and justification between different disciplines in ENV and beyond. Early anecdotal observations in the 1940s illuminated some form of degradation, playing a key instigating role as early epistemic evidence (Moore and Stilgoe 2009) but without the authority and confirmation of scientific knowledge. As the new 'environmental sciences' gained traction, in an emerging technoscientific Britain, and the Broads ecological problems became more public scientific interest emerged from ENV and Brian Moss. Yet, the presence of other researchers in ENV with different visions and epistemic commitments concerning what the 'environmental sciences' were, what knowledge could be made and how this could be used supported a more complex, inclusive and participatory approach to environmental management and with non-academic partners. The emergence of the Broads Authority directly led to policy creation and conservation of the Broads' use, ecology and character and ENV were, in the earliest years of the Broads Authority history, central to this. This laid the foundations for: more deliberative discussions with stakeholders and ministers,

an application of scientific knowledge for environmental conservation and protection both in the UK and Europe (Lowe et al. 1987; Chilvers 2008; Chilvers and Kearnes 2016a) and demonstrated the need for applied and local environmental knowledge made viable through a new market-based economy (Lave 2012).

In sum, beyond the empirical chapters, this thesis has demonstrated how the 'environmental sciences' are multi-scalar – from shaping individual action, morality, and cognition – to the construction of planetary wide governance and management plans. The 'environmental sciences' are multi-spatial, producing knowledge and creating forms of understanding and sense-making of particular challenges or processes: from the Cornish coastline to the mangroves of the Ayeyarwady delta to the melting Jakobshavn glacier to variable vegetable harvests for farmers in Kenya, for example. The 'environmental sciences' through ENV have produced and circulated a whole array of knowledge and contributed to the co-production of many new worlds that have altered the ways in which we know and live in the world. This was particularly pertinent for the first 25 years of its existence where ENV was a novel space where distinct epistemic communities could reconcile aims and perspectives to advance knowledge, shape action and agendas concerning the 'environment' and its challenges and to make those challenges knowable to the wider public and political community, as demonstrated by the Queens Anniversary Prize award. However, as I will go on to discuss in the final sections of this chapter, ENV's position changed amidst a changing world of science and politics as more institutions emerged, expertise further multiplied and ENV's authority as an expert organisation, I argue, weakened.

8.2. Conceptual contributions

I have used the 'ecology of co-production' sensibility and framing to guide my research, organise and analyse my findings and provide a history that is not a teleological or celebratory narrative. Rather, I have explored the co-production of co-production. The 'environmental sciences' have been co-produced through a range of actors, knowledges, contexts, and infrastructures but they have always, from the outset, co-produced – shaped order, knowledge and produced multiple new worlds – as I have shown. Science studies

typically focus on co-production as an analytical tool to explain how science and technology figure in world-making practices at nation-state levels. Or work focuses on co-production as a normative tool for knowledge-making in environmental and sustainability work based on the premise that expanding knowledge inputs between disciplines and beyond the academy will produce 'better', more robust and useful environmental knowledge. I have combined both views to demonstrate: 1.) how co-production as a tool for knowledge-making is not a recent phenomenon but rather been a constitutional component of what makes the sciences of the environment, the 'environmental sciences', 2.) how the 'environmental sciences' (re)make worlds across many spaces and scales, discernible through the many tools of the co-productionist toolbox. This becomes particularly relevant for contemporary debates associated with the links between environmental history and knowledge-making in the Anthropocene (Güttler 2019) and a new emphasis on critical zones, as spaces of localised interdisciplinarity, to make socially and politically relevant knowledge about environments (Latour 2014), as discussed in **section 8.5**.

The 'environmental sciences' in ENV emerged from collective discussions to become collectively held, and institutionally stabilised visions of desirable socioscientific futures (**Chapter 4)** masked behind the vanguard vision of Zuckerman (Hilgartner 2015; Jasanoff and Kim 2015). The ideas and imaginaries of the future involving ENV and the 'environmental sciences' were in interactive states of (re)emergence, negotiation and deliberation between the actors, materials and institutions involved in their conception, and as they extended and stabilised as new means and new modes of scientific idea and practice. This core vision shaped and continues to shape the interdisciplinary institutional epistemology of ENV (O'Riordan 1999). As a result, and demonstrated through **Chapters 6** and **7**, the broader socioscientific imaginary in ENV moulded and guided particular cultures of research that were exhibited through changing and diverse epistemic lifestyles.

The 'epistemic lifestyles' in ENV illuminate how and why particular cultures of research differ on an institutional level despite being housed in a university department with broader unifying aims and visions. Researchers in ENV responded to and viewed 'environmental' challenges in numerous ways that shaped the ideals, values, guiding aims and principles that shaped daily scientific life and practice (**Chapter 5**). Notwithstanding, these, in turn, led to a diverse array of cultures and strands of research that underscored the inter/multidisciplinary vision and epistemology of ENV. This demonstrates conceptually

the relationality and mutual constitution of the normative and the epistemic in histories and futures of knowledge-making. The 'environmental sciences' are co-produced by different contexts and actors which construct their multiplicity, and they are novel in that they are always co-produced and co-producing. The multiplicity of the 'environmental sciences' is a co-product of the competing normative and epistemic visions that emerge from the differences resulting from the disparate cultures, visions, imaginaries and knowledge-making involved in problematising the 'environment'. ENV was a particular response to the challenges of post-war reconstruction in Britain amidst a growing internationalisation of science and order. ENV then gained traction as it supported and influenced a growing political and scientific authority concerning the challenge of environmental change and the institution grew in staff numbers, student and research funding.

Yet, the materialities of co-production as illuminated through Pickering's (1995) 'mangle of practice' also underscore the contingent and serendipitous nature of individual staff hires and subsequent research practices, interactions and collaborations. The environmental sciences are made up through endless flows of scientists, researchers, knowledge-makers within and outside of the ENV institution, sharing similar or conflicting epistemic lifestyles and imaginaries to negotiate, overcome and produce usable environmental knowledge and expertise. This line of thinking can be applied to other social and historical studies of knowledge and how we might better understand the contingent and contextual nature and structures of our epistemological structures and ontological framings that have led (now a large) group of scholars to problematise the 'environment' as an object of thought and change.

The 'ecology of co-production' framing has demonstrated the complexity of the co-production of knowledge and order. Co-production is more of a spectrum – with varying levels of impact and intention, both implicitly and explicitly. Additionally, rather than focus on state-level power and organisation, co-production(s) occur at many scales, in many spaces, in many forms with many effects and the fabrics of existence – being, knowing, sense-making in the world – are bound up with numerous geographical, technological, social, material, infrastructural factors that enable or impede particular epistemic and normative avenues. As a result, disciplining knowledge has been a useful tool to organise knowledge production in times where a linear application of knowledge was needed and useful in cultivating forms of scientific identity and circulating knowledge, but the 'ecology

of co-production' sensibility orients toward the constructionist view of discipline making; knowledge is always made together to some extent and dividing it up into silos is an ordering intervention that can be challenged and historicised.

The 'ecology of co-production' sensibility also encourages an intentional exploration into (re)construction of the peripheries, the moments often excluded or forgotten, and the multiple practices and models of knowledge-making in histories and geographies of science in both Chapters **6** and **7**. **Chapter 6** revealed how CRU moved from the perceived periphery of climate research to become a key member of the research community involved in making climate change known through global temperature. The establishment of viewing climate change through the lens of global temperature was, for CRU, a fundamentally social and geographical process emerging from the renegotiation of epistemic norms and ideals and the creation of new, global relationships of funding, collaboration, and knowledge exchange, that made new understandings of environmental and climate change possible. Whilst **Chapter 7** as a case study of environmental management is an important testament to the diversity and importance of ENV knowledge, authority, and the benefit of different visions for the sciences of the environment in a time when the market began to figure in planning and the number of relevant actors multiplied - ENV at the time didn't acknowledge this, unlike the case of CRU which became formally and administratively tied to ENV in the 1990s. Beyond the researchers involved, there was arguably little wider recognition or respect for the work that was being done; Moss leaving for a Chair in Liverpool, O'Riordan being one of the only political and social scientists until the arrival of CSERGE, others doing local and applied work who also did not receive Chairs or received them far overdue.[214] This, I argue, is due to the global framing and internationalisation of science that emerged from the environmental movements and international expansion of the environmental sciences in the 1980s – when ENV was a forerunner and preference was on the global and international modes of science, collaboration and policymaking, and localised cases like the Broads were left to new organisations and economies of knowledge. However, ironically, emphasis has recently been on returning to local action, local governance, local management (Honeybun-Arnolda and O'Riordan 2020; Turner and Wills 2022) and understanding the local nuances of 'critical zones' as means of transforming our values,

[214] Multiple interviewees noted this point.

ideas, ways of living and knowing in an environmentally challenged planet (Latour 2014; Latour and Weibel 2020) but in ways that do not propagate pre-existing inequalities or power structures (Jackson 2021).

Yet challenging dominant forms of knowledge production and unshackling from pre-existing power structures can be difficult to advance and imagine. There are often practical tensions, as we have seen throughout this thesis, between novel forms or practices of knowledge-making and what can be seen as hegemonic ways of knowing, especially from those who are producing the knowledge in question.[215] Our existing knowledge and power structures have become so deeply embedded in the social and cultural imaginaries of thought in the West that what we think are novel modes of knowledge-making, management and governance are often not novel and have been attempted, ignored or forgotten in the past (Bonneuil and Fressoz 2016). Notwithstanding, the conceptual ideas put to work throughout this thesis enables scholars in science studies to be more reflexive and aware of the relationality of practices and performances of science, in different spaces of knowledge-making and the wider implications for both historic understandings and imagining the future and politics associated with knowledge-making for the Anthropocene.

8.3. Normative contributions

Did ENV change the world of the 'environmental sciences'? From my empirical and historical observations, I would argue that yes, the 'environmental sciences' at ENV were foundational in the first 25 years and whilst the idea of the 'environmental sciences' was cultivated through collective discussion in government circles, without Solly Zuckerman's involvement, ENV would not have emerged when nor how it did.

ENV did advance new knowledge and embed scientific interdisciplinarity as a desired goal and as an institutional form of knowledge-making, discover new environmental problems and shape new social orders – and by the 1990s, it was a major institution in 'environmental science' research. This is what made ENV so unique and important at the time. However, as the new millennium drew closer the 'environmental sciences' knowledge base was diffusing, with many actors or institutions now becoming involved in a much wider

[215] See both Jackson (2021) and Pickering et al. (2022) response for a very recent example of this challenge concerning Earth Systems Governance for the Anthropocene.

field – a number of which emerged from ENV as graduates - and science becoming much more politically orientated through new governmental departments, transnational organisations and institutional agreements (Jordan and O'Riordan 2003). The 'environmental sciences' from ENV shaped and reshaped ideas and imaginations of the future and scientific practices around policymaking and management of environmental challenges in the UK and beyond. The ability to draw from diverse ranges of expertise for multiple areas of concern is one of its key functions as a tool of knowledge-making. However, ENV during this period never managed to shake the view that 'science' only meant, for the most part, 'natural science' or positivist epistemologies and realist worldviews. As a result, as seen through the diverse cultures of research that worked for the most part as separate collectives under the ENV roof, comprehensive and institution-wide models of interdisciplinarity never surfaced (Barry and Born 2013). Nonetheless, the ideals and imaginary of Zuckerman remained and still remain central today - in part the legacy from a formative time in science policy and new knowledge innovation and in part a reality of the wider institution's inability to keep up with the continued changing world of a co-producing science and politics. ENV emerged as a School focused on interdisciplinary science to deal with the challenges of a newly emerging global 'environment' surrounding a 'global'. The emphasis was on creating new knowledge not repurposing pre-existing disciplinary knowledge. However, the material realities of interdisciplinary working proved difficult and continued to remain challenging within ENV between different ontological and epistemological positions and epistemic lifestyles of researchers in ENV.

Nonetheless, there was a profound effect on the ways in which environmental challenges were framed, discussed and the solutions that were possible: namely through the interpretive framework of science. This was pertinent and novel in the late 20th century, but recent years and urgency of the environmental challenge has called for new radical knowledge, politics and deep transformations of social change. The debate about the 'Anthropocene' has galvanised discussions concerning the use of the history of the 'environmental sciences' (Trischler 2016; Warde et al. 2018; Güttler 2019) by historicising approaches to how we have altered the ways in which know and live in the world, through new values, norms, morals, ethics and the blurring of epistemological boundaries within a scientific framework. Importantly, the 'Anthropocene' is leading to new and engaged conversations between scientists and humanists (Latour and Weibel 2020). Yet this is not

happening explicitly, at present, in ENV despite the presence and promise of diverse epistemologies and ontologies. I now go onto explore further how this might be taken up for future research.

8.4. From ecology to mycology – new approaches to representing histories of the 'environmental sciences'

I propose that building on the explorations through an 'ecology of co-production' that the 'environmental sciences' and indeed other formations of knowledge may be better understood through a mycelium-like-ecological web, as introduced in **Chapter 3**. Various co-products – institutions, constitutional moments, imaginaries, civic epistemologies, and so on – can be viewed as fruiting mushrooms or troops of mushrooms. Science studies researchers see what is at the surface or slightly below the surface and continue to tread the same ground. If we are well-trained and experienced, we may be able to discover the clusters predominantly below the surface at all times and acknowledge the future orientations of deep innovation that mimic the processes of spore dispersion. Yet, what is outlined is often a reification of the mushroom body or troop or the collective of knowledge – new knowledge in different ways. However, the mushroom body or troop is the final stage of life. It is the product of the mycelium that branches through webs and threads underground, entangled in nutrient absorption, facilitation, and diffusion before growing into a mushroom to circulate a diaspora of spores. The troops of mushrooms in this instance are the many facets of the 'environmental sciences'. The cultural-political context in which they are embedded is the mycelium underground – shaping and reshaping what is possible to form on the surface. A dispersion of spores is the potential for future knowledge-making and imaginaries of deep socioscientific change. The different power formations, social institutions, and cultural norms are akin to the biochemistry and nutrients that shape what particular mushrooms would develop – that is, they shape what co-product emerges. The spores from the mushroom body reshape the possibility of additional troops and the lines in which they orient.

In the 'environmental sciences', this can be understood as the circulation, reshaping and other co-production effects in an 'ecology' – except that the body or troop is never the

same nor too predictable. Unlike the rhizomatic structure of Deleuze and Guattari's (1980) assemblage that re/de/territorialises through attachment with other assemblages in a constant state of becoming, the mycelium approach to the 'environmental sciences' emphasises the alleged isolation of mushroom or troop – as a fruiting body or co-production enabled by the hidden interrelated spaces and constitutions of the cultural-political context in which it emerges extended through ontological nets and epistemological skeins. An 'ecology of co-production' approach isn't intended to reveal the continuous motion of co-production but instead seeks to reveal moments or cultures of research as co-products of the contexts in which they emerge entrenched in power structures operating at multiple scales and in multiple sites. The multiplicity of the 'environmental sciences' makes this way of observing them most fruitful and this may allow more organic connections between scientists and humanists for knowledge-making in the Anthropocene.

This view of the 'environmental sciences' can be translated to other forms of science and knowledge-making and can radically innovate historical, geographical and social studies of knowledge and order. In breaking down distinct categories and disciplinary formations in histories of knowledge, a more ecological and mycelium-like structural approach to unpacking co-production can reveal the complexity, multiplicity, power dynamics, portability and visibility of particular cultures of research within epistemic and normative aims and future orientations. This is particularly useful when thinking through the 'Anthropocene' regarding new ways to produce, respond and use knowledge and political systems (Castree et al. 2014).

Science studies scholars may also find fruit in adopting an ecological perspective to the analysis of their objects of study. Understanding singular aspects, moments or happenings on particular scales like the global or nation-state level can reveal important factors into why things are the ways in which they are, how they might've been otherwise and how they might be different in the future. However, as I have made the case for, the world may be viewed otherwise from an ecology of co-production perspective. Emphasising relations between scales, spaces and objects of study and intentionally seeking out diversity promotes a more responsible approach to discerning the composition and constitutions of knowledge-making and directly illuminating the contingency of some aspects while underscoring the agency, materiality, and political aspects of others. Like the randomness of the early researchers who applied for jobs in ENV during the 1960s and consequently

shaped the ENV curriculum in its most important foundational years but also the politically charged and intentional agency of Zuckerman and his vision for an environmental scientific society in a post-war Britain and how that might be achieved. Taking these together as important happenings to be explained and explored means that we at once both appreciate the serendipity and power of small moments in our history and the agency and materialities of existing power structures and figures in defining our presents and shaping our futures. Only looking back can we uncover fuller and more responsible histories concerning the co-productions of knowledge and social order and science studies scholars should strive to re-assess our histories, cautiously approach the present moment and analysis of this with humility and responsibility, and deeply reflect on the futures in which we are imagining and can possibly imagine regardless of whether this relies on practices of interdisciplinarity or other perhaps other organisations of knowledge-making.

8.5. The future of the 'environmental sciences' and ENV

The last research question - **Where might the world-making 'environmental sciences' go next**? - requires a more future-orientated lens and critical reflection on the broad contributions of this thesis.

The fluidity of the label the 'environmental sciences' is its strength, open to interpretation by the researcher to pursue their own epistemic and normative goals. In this vein, it is also its weakness as the uneven and varied nature of 'environmental science' across the planet makes reconciliation and agreement concerning controversy, challenge, policy and solutions difficult (Jasanoff and Martello 2004). Yet, ENV has been, as this thesis has demonstrated, very good at responding to the challenges of the wider world. There have been numerous strands of the 'environmental sciences' that emerge in ENV and make productive and important differences in the world – even without formal institutional support, like the early years of CRU and the involvement with the Broads Authority.

The 'Anthropocene' has brought an urgency, uncertainty and unevenness to the numerous transformations and has led several scholars to try and rethink how knowledge systems, and their connections to political systems, might be redesigned to meet the challenges of this new epoch (Castree et al. 2014; Lövbrand et al. 2015; Beck 2019; Latour

and Weibel 2020; Guldi 2021). The 'environmental sciences' have been paramount in the steps leading to the calls of, and providing a conceptual base for, an 'Anthropocene' yet, now it can be argued that the 'environmental sciences' have been superseded by new groupings of knowledge like 'sustainability sciences' and 'earth-system sciences'. These newer forms of knowledge posit that the 'Anthropocene' has collapsed the distinction between the two ideas of 'environment' emerging from the post-war period: one of surroundings and one of planetary systems arguing that local surroundings are intrinsically entangled with wider planetary systems (Biermann 2014). Both the 'sustainability sciences' and 'earth-system sciences' are thought to be more suited to meet the calls for epistemic and normative transformation in the current 'super-wicked' problem we now find ourselves with (Levin et al. 2012).[216]

Notably, the emergence of Anthropocene debates or 'super-wicked' problems – regardless of one's intellectual and philosophical position concerning them – demonstrate the radical changes between knowledge and problematisation in the present day. In the post-war period, knowledge was thought to be a satisfactory and useful tool that could be applied and funnelled into policy and decision-making. No longer is this the case. The last 24 months have demonstrated more publicly the politicisation of knowledge, particularly in the UK, during the ongoing COVID-19 pandemic. The rhetoric of 'following the science' employed by the British government demonstrates how the complexity of science is squeezed into particular normative aims of government through a choice pick of expertise (Bacevic 2020). Yet, COVID-19 has demonstrated how fast change can happen in extreme circumstances (Honeybun-Arnolda and O'Riordan 2020; Pagel 2022). The capacity for radical change is there, it just needs to be unlocked. The required forms of knowledge-making and transformative agent creation can happen in universities – much like the legacy of ENV in the post-war period.

The 'environmental sciences' in ENV can and should transform to help be a catalyst and transformative agent of change and world-making in the present day; it has a history of

[216] To put it briefly, 'super-wicked' problems are classed as containing multiple, entangled pressing issues needing to be simultaneously addressed and radically engaged with to gain any grip on or possibly solve. For instance, these being that time before irreparable damage occurs is running out, those who cause the problem need to solve it, weak or non-existent central authority to deal with the challenge and irrational deliberation and discounting that shirks decision-making to the future (Levin et al. 2012). These types of challenges are thought to be associated with global environmental problems (Levin et al. 2012), antimicrobial resistance (Littmann et al. 2020) and more recently, COVID-19 (Auld et al. 2021).

being well placed to respond to the challenges that surround it. But as 'environmental sciences' emerge from the co-production of institutions, cultures, spaces and researchers' normative and epistemic commitments that ebb and flow with the changing nature of 'environmental' or earthly concerns, then institutions need to be flexible and fluid in their responses to a changing world. This is not a criticism but rather one of the core and underappreciated features of what makes the 'environmental sciences' and the power of their world-making functions, effects and responsibility. Whilst the institution of ENV emerged in a culture shaped by the fecundity of science, it is now down to researchers and institutions to be reflexive about the future, ethics and responsibility of knowledge-making - how it might be organised or re-invented to suit present challenges. There are numerous world-leading and internationally recognised researchers across the board in ENV; if any institution would be able to adapt or construct new interdisciplinary perspectives for the Anthropocene challenge, then I would wager it would be ENV. Interdisciplinarity and knowledge co-production is not a given and needs to be worked on and committed to by open, reflexive and hopeful researchers. Having a diverse range of experts in one corridor will not suffice.

In a period of economic downturn, a rampant marketisation of higher education and a challenging job market in the UK and elsewhere, is there an appetite for new and radical visions of understanding knowledge and social order to become mainstream in teaching, research and wider education, whereby we do away with disciplines and focus on collectives or challenges of interest? Probably not. However, the COVID-19 pandemic has shunted the politicisation of science into more public viewing. This is a unique time in which the scientisation of politics and politicisation of science now circulates discourse beyond the academy. Inter/cross or even anti-disciplinarity is now needed more than ever to match the changing demands, applications and uses of knowledge to decipher, gain a handle on and manage 'super wicked' problems. Yet as this thesis has demonstrated, ideas and practices of interdisciplinarity vary depending on the social, material, economic and political contexts in which they emerge. Scholars, funding bodies and other organisers that propagate interdisciplinarity or knowledge co-production need to be explicit and aware of what they are calling for, how it might work in practice and how best to cultivate the conditions for inter/transdisciplinary work and my case studies are demonstrative of the challenges involved.

In this vein, there have been important moves towards 'critical zone' research groups and departments in the US and France – that explore the heterogeneous, complex interactions between human, nonhuman elements and the regulation of habitat, resources, and systems (National Research Council 2001; Latour and Weibel 2020; Mahony 2022) as a means to encourage more site-specific and inter/transdisciplinary 'environmental science'. There are also Anthropocene studies (like an MPhil at the University of Cambridge) and specific courses that seek directly to enable students to gain the critical skills and understanding needed to understand the politics of knowledge and geopolitics of the 'Anthropocene' and its histories and its processes and deal with the complex issues beyond science and arts framings. Nonetheless, in a period of economic recession, there may also be scope for a return to the historical bridging or 'traditional' disciplines that straddled the arts and sciences, such as geography. Notably, William Graf (2004) noted the similarity of 'critical zone' research aims, which was essentially the same purview as geography. Geography as a bridging discipline can traverse different epistemologies and ontologies whilst emphasising the importance of historical and spatial attention to the ways in which we know, act and imagine the world and its futures (Livingstone 1992). Geography was a central discipline from which the earliest ENV staff emerged, and many of the undergraduates who walk the halls of ENV are now enrolled onto geography degrees; perhaps the return of geography as an attraction for students has come full circle and these need to be embraced – to remake the much-needed links between humanities and science. Existing formations of the 'environmental sciences' clinging to ideas, visions and practices and the authority of 'science' of half a century ago are no longer fit for purpose and need radical reformulation or devolution to meet present-day challenges of knowledge and order in the world. ENV can be and should be the place of new innovative and collaborative thinking – expanding outwards and across scales through new 'ecologies of co-production' - as we find ourselves struggling still, across the globe, to find the socioecological, harmonious balance with the Earth's environment/s and to find normative and epistemic reconciliation amidst the ontological and epistemological politics of the 'Anthropocene'.

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Appendix 1: Participation Forms

University of East Anglia
Norwich Research Park
Norwich
NR4 7TJ
e.honeybun-arnold@uea.ac.uk

University of East Anglia

3S Science, Society & Sustainability

INTERVIEW PARTICIPATION INFORMATION AND AGREEMENT

You have been invited to take part in the **interview stage** of the research project which documents important moments in the ongoing development of environmental sciences. The collection of interviews will represent a range of individuals involved in environmental sciences and scientific work ranging from the 1960s to the present. The project is managed by Elliot Honeybun-Arnolda of the Science, Society and Sustainability (3S) research group at the University of East Anglia as part of his doctoral research. The project is guided by a PhD supervisory team which comprises of Dr Martin Mahony and Professor Jason Chilvers.
The purpose of this form is to explain how the recorded interview which you agree to undertake with the Elliot Honeybun-Arnolda will be collected, processed and analyse for use in of my PhD project. When you sign this form, you are agreeing to take part in the interview and allowing Elliot Honeybun-Arnolda to use the data generated for completion of a doctoral research project and wider dissemination of findings.

The project to which you are contributing

The environmental sciences have become a central feature of modern science and of societal efforts to confront grand challenges like climate change and sustainability. However, little is known about the history of efforts to convene and institutionalise this interdisciplinary field, particularly in the UK, and how new knowledge was produced and circulated around the world. This project will seek to reveal answers to these questions. This projected is situated in the Science, Society and Sustainability (3S) research group at the University of East Anglia, funded by a UEA Faculty of Science studentship. I aim to collect at least 15 interviews from individuals who have been involved with environmental science between January and December 2020.

As a participant, you will be interviewed by myself, the doctoral researcher in this project who has received specialist oral history and interview training. In the interviews the key aim is to allow you to speak about your experiences in the environmental sciences, for as long as you wish. The interviewer will have a set of topic areas aimed to gently guide the direction of the interview and to ensure we cover relevant historical moments and themes. The pace will be entirely led by you. We envisage that the interviews will average an hour in duration, but they can be longer or shorter, depending on your wishes. The recordings will take place at a time and in a place that is convenient for you, perhaps in a quiet room at your home or possibly at a venue booked by a member of the project team.

The interviews will be recorded on a digital recorder with professional standard microphones, usually these will be small lapel (or tie-clip) microphones worn by both you and I. You do not have to discuss anything you wish not to. Many people find telling their story interesting and are pleased to have had the opportunity to place their memories and experiences on record. However, some people may find remembering in this way difficult. I understand this and will be happy to take a break during the session if required. After the interview is complete, the audio

recording may be summarised and/or transcribed. In the event of transcription, a copy will be sent to you.

Any material used for research purposes will be anonymized with a pseudonym (e.g. job title) agreed between us to ensure anonymity and data protection for PhD and publications (during or subsequently).

Your personal data

Data protection legislation (the General Data Protection Regulation [GDPR] which came into effect on 25 May 2018, and its implementing legislation, the Data Protection Act 2018) has changed the way in which we inform you about how your personal data is stored and processed, and how you can get access to it.

For information about how the University of East Anglia will collect, process and use your personal data see the University of East Anglia's Data Protection Policy.

What we will do with your personal data

The data contained within this form will be held securely and not shared with anyone, unless the University of East Anglia is obliged to do so for legal purposes, such as evidencing ownership or demonstrating a valid Agreement.

For the duration project, I will store, process and retain your personal data in order to pursue the aims of the research. All data (audio files, transcripts) generated will be kept securely on an offline storage medium and will not be kept longer than necessary, once the project is complete. You can request a copy of the personal data the University of East Anglia hold about you at any time by contacting me at e.honeybun-arnold@uea.ac.uk.

All data stored at the University of East Anglia will be subject to the University of East Anglia's data protection policy and access will not be given to anyone outside of the project team.

Your agreement to take part

This Agreement is made between Elliot Honeybun-Arnolda and you ("the Interviewee"):

Signed: .....

Name in block capitals: .....Date: ……
Email:

University of East Anglia
Norwich Research Park
Norwich
NR4 7TJ
e.honeybun-arnold@uea.ac.uk

Project Information

You have been invited to deposit material which will inform a PhD project on the history of the environmental sciences. The environmental sciences have become a central feature of modern science and of societal efforts to confront grand challenges like climate change and sustainability. However, little is known about the history of efforts to convene and institutionalise this interdisciplinary field, particularly in the UK, and how new knowledge was produced and circulated around the world. The material that you deposit will be used to help answer these questions.

The project is being managed by Elliot Honeybun-Arnolda of the Science, Society and Sustainability (3S) research group at the University of East Anglia as part of his doctoral research, funded by a Faculty of Science studentship from the University of East Anglia. The project is guided by a PhD supervisory team comprised of Dr Martin Mahony and Professor Jason Chilvers.

The deposit agreement below outlines the terms and conditions pertaining to the temporary transfer of material between yourself and Elliot Honeybun-Arnolda.

Your personal data

Data protection legislation (the General Data Protection Regulation [GDPR] which came into effect on 25 May 2018, and its implementing legislation, the Data Protection Act 2018) has changed the way in which we inform you about how your personal data is stored and processed, and how you can get access to it.

For information about how the University of East Anglia will collect, process and use your personal data see the University of East Anglia's Data Protection Policy

What we will do with your personal data

The data contained within this form will be held securely and not shared with anyone, unless the University of East Anglia or the British Library is obliged to do so for legal purposes, such as evidencing ownership or demonstrating a valid Agreement.

For the duration of the project, the project team will store, process and retain your personal data in order to pursue the project's aims, objectives and activities. All data generated (copies of material) will be kept securely on an offline storage medium on a password protected device. You can request a copy of the personal data the University of East Anglia hold about you at any time by contacting the lead researcher at e.honeybun-arnold@uea.ac.uk.

All data stored at the University of East Anglia will be subject to the University of East Anglia's data protection policy and access will not be given to anyone outside of the project team. You retain the right to withdraw your material and any copies made at any point and can do so by emailing the lead researcher.

The material deposited will be stored safely in a locked cupboard(s) in an access-only building. Access will only be with project team.

Deposit Agreement

The terms and conditions of deposit on loan for the project are as follows:

1.) The Depositor is the legal owner of the documents and retains full ownership.
2.) The Depositor is transferring the material to the Researcher for the duration of the project (official end date September 2022) for use in doctoral research and related work only.
3.) The Researcher will use the material to provide contextual information, to identify themes relevant to the research and for use as evidence to support arguments.
4.) The Depositor grants licence to the Researcher to use the material for the duration of his doctoral research and for use in any subsequent publications. Use of the material is strictly for research and educational purposes such as: transcribed extracts in doctoral thesis and external publications (e.g. journal articles, books), scientific, historical and environment-focused lectures, workshops and research, other general academic conferences.
5.) The Depositor grants permission for copies to be made of the material (e.g. digitally) for research purposes.
6.) The Researcher will promptly return all material to the Depositor at the end of the project.
7.) The Researcher will return to the Depositor to discuss an appropriate courses of action if any material, that may be of use for research purposes, is found to be liable to cause damage or distress to the Depositor,
8.) The Researcher will return to the Depositor to discuss an appropriate course of action if any material, that may be of use for research purposes, is found to be liable to cause damage or distress to third parties mentioned in the material

This Agreement is made between Elliot Honeybun-Arnolda ("the Researcher") and you ("the Depositor", "I"):

Your name

Your address:

in regard to the deposited material:

Date/s:

Declaration: I, the Depositor confirm that I agreed to deposit this material hereby grant permission for the Researcher to use in all and any material for research purposes (as outlined in the above) only. I understand that this will not affect my ownership of the material and related copyright

This Agreement will be governed by and construed in accordance with English law and the jurisdiction of the English courts.

Both parties shall, by signing below, indicate acceptance of the Agreement**.**

By or on behalf of the Depositor:

Signed: .....

Name in block capitals:
.....
Date: .....

By the Researcher:

Signed: .....

Name in block capitals:
.....
Date: .....

Contact details:

PhD (lead) researcher: Elliot Honeybun-Arnolda, Science, Society and Sustainability (3S), University of East Anglia, Norwich Research Park, Norwich, NR4 7TJ. Email: e.honeybun-arnold@uea.ac.uk.

PhD Supervisor: Dr Martin Mahony, Science, Society and Sustainability (3S), University of East Anglia, Norwich Research Park, Norwich, NR4 7TJ. Email: m.mahony@uea.ac.uk.

Appendix 2: Topic Guide

SAMPLE INTERVIEW QUESTIONS (to generate discussion)

UEA-ENV

- Please, tell me about your time at UEA-ENV (start date, research careers, teaching, interactions beyond the university)
- What brought you to UEA and more specifically, The School of Environmental Sciences?
- What did you think you were getting into? What was your background? (interview/recruitment process)
- What did you think about the broader developments in the environmental science/challenges landscape? (including science-policy)
- How did UEA-ENV respond to these challenges? (successfully or not? Why?)
- Part of how the School and (UEA itself) distinguishes itself from others is its historic commitment to interdisciplinary knowledge-making. How has this played out in practice? (either you or others)

Research

- How do you decide research projects or avenues, are/were they in responses to goings on in the wider intellectual climate or emergent from conversations with colleagues (both here and elsewhere)? Or anything else?
- Is there anything you've tried to pursue but haven't been able to, in the environmental sciences or environmental realm? (i.e. no funding, time)
- How do you see your work fitting in the broader umbrella term of environmental sciences?
- Have you done any transdisciplinary work with stakeholders or the public more broadly? If, so what? Why did you do this? Why have you not done this?
- What do you think of as the environment? How has this changed? Has your view on environmental science or [*insert specific area here*] changed? How has practice (or knowledge-making) changed?
- Could you explain or characterise the relationship between UEA-ENV scientists or academics and the wider admin or technician teams? Has this changed since you began? How have they contributed to your practice and research?
- How has your research informed your teaching? i.e. curricula, how has this changed over time?

General

- What is/are environmental sciences?
- What do you think the future of environmental sciences is? (challenges, promises)

Appendix 3: Sample of Transcripts

1.) Interview with environmental scientist (b)

(EH: Elliot Honeybun-Arnolda, Interviewer)

Deterioration was a huge issue from the point of view of the international standing of the Broads as an ecological paradise. The commercial standing of the Broads as a place where people came to enjoy wildlife and beautiful rivers and streams, and because they didn't want to have sedimentation getting in the way-, and you mustn't underestimate the rate at which this micropore of the algae was filling up the rivers and Broads, especially the shallow Broads. And the third thing was that there was no easy way of dealing with that under the normal national park legislation so that you had to come up with a special body. And the special body then allowed the kind of, natural science input, the Brian Moss, Ros Boar input, to get much more of a say, because it was tailor-made to the particular conditions of the Broads. And that's an important thing for you to pick up in terms of your thesis, that actually environmental sciences was too important to ignore, and the Broads Authority was insufficiently flexible to accommodate. That combination gave the Broads Authority a distinctive scientific hue, that wouldn't have been the case in a national park, or any other, what you might call management organisation, compared with what you've got here. It's different today, but I'm talking about the late '70s.

EH: Yes. Two questions. One slightly unrelated. What was Moss doing before his work on the Broads?

Well, he was always an ecologist. He was always a water ecologist. And he was very interested in macrophytes and the conditions which gave rise to plant diversity in the Waterford area. So, basically, he was doing research on the Broads as soon as he came to UEA. What I can't give you an answer to is when he turned up in UEA. It was after my time. It was probably about '75. But we can find that out, or you can find that out. And you need to look at his bio, his biography, and Ros will give you all of that. But I'm pretty sure that he was working on all these things in the '70s. So he came into UEA precisely because he had a track record, because he ... work of this quality.

EH: Okay. Second point. So, whose idea was it to set up the Broads Authority? Obviously, it's a combination of things. But whose-,

Ah. Yes. This is in Martin's [George] book. So, I'll summarise it for you, but, basically, Martin and his team did a report in 1965 called, 'Report on Broadland'.

EH: Yes, I've got it right here. Yes.

That's it. Well, that was the first time that a systematic review-, you see who put the time into that, because there was environmental science input into that. But basically, Martin and his team showed that the Broads were fundamentally deteriorating from roughly the late '50s on. And, although they didn't attribute blame at that time, they attributed the fact that the ecological interests of the Broads were threatened. Therefore, it needed some form of management that could deal with this. I'll kill this phone [..]

Anyway, so going back, that report was instrumental. But it wasn't listened to. It wasn't listened to. [...] because nothing had been done up until then. And so, the issue was that the Great Yarmouth Port and Haven Commission, it's all in Martin's book, led by a guy called Des Truman, Desmond Truman, were absolutely opposed to any kind of national park status in the Broads. And they were really powerful at the time. And the water industry was uneasy because there wasn't enough evidence. So, they were not prepared to spend a lot of money on nitrate removal. And the farming people could see trouble if the Broads authority came in, mostly from a planning point of view. So, basically, the key players in the local authority just did not want to play ball. And so 'Report on Broadland' and [.....], and nothing happened until 1975. And in 1975, because of Brian's book, and because it became very clear that this was a threat to the well-being and economics of the area, something had to be done about the phosphorous releases from the sewage works in the Broads, of which the number one danger sewage work was in Stalham because that was putting nitrate-rich water-, or, in fact, I'm sorry it's phosphate-rich water. Nitrogen comes from the fields, that's a farming issue. We'll leave that to one side because it wasn't resolved until we dealt with Halvergate and the aftermath.

But in the '70s, the big issue was phosphates in secondary sewage treatment works which were getting through the membranes and coming into the Broads. And that's what Brian pinned down. When these phosphates were lying in the sediment which was the detritus of the algae as well as in the Broads column, you're going to get a complete loss of macrophytes. And that's what happened. So, Barton Broad was seen as a test case in 1976. And because of that, the Anglian Water funded Brian to do a whole series of very expensive experiments, including suction dredging of chunks of the Broad and isolating parts of the Broad away from fish to try to change the relationship between algae, zooplankton and small shrimp and the plant life. And they also had a series of test cases in Hickling Broad, where they put a column of heavy-duty rubber into circles, and they kept the water in the Broads free of the phosphates and allowed the macrophytes to grow. And inside those enclosures, there came a large amount of physical restoration of the water plants that we're after. So, we could tell that if we could get the macroplants to be left alone by boat movement and if we could get the macroplants to be left alone by nitrate enrichment, there was a fair chance they would come back. And as an aside, some of that butane of the heavy-duty rubber, I nicked thanks to my friend Martin, and put it into my pond which is right in front of my window as I'm talking to you. And that pond has stayed high with no leakage, and it's got the same butane that was on Hickling Broad in the 1970s. So there you are.

But what I'm really driving it is that Brian's work, which is classic environmental empirical science, showed three things. And again I'll do it in threes, (1) the phosphate-rich water coming from all the sewage treatment works in the Broads was the major culprit, (2) this would give rise to heavy sedimentation which, in itself, would recycle phosphorous, even if you took the stuff out from the sewage works, which meant that some form of suction dredging was vital, (3) the plants could come back in the natural ecology of the Broads, which, by the way, was part of the national commitment to conservation that would recur, all things being equal. That's what they were talking about. And, in fact, to prove that you needed a mechanism of removal of the phosphates from the sewage works, and then suction dredging from the Broads themselves. And during the decade between 1980 and 1990, that took place. They took a lot of nitrogen out of the system, Martin will give you all of that in the book, from the sewage works. But certainly, they started with Stalham, which

was a very expensive operation. £2.5 million to get the phosphates out of Stalham. And they suction-dredged chunks of Barton, the whole of Cockshoots, and quite a few other Broads as test cases in trying to get rid of this phosphate-releasing sediment. Which was the old algae and the old macrophytes dying but were phosphate rich. They had to be removed. You couldn't just let them be covered up by less phosphate-rich sediment. You had to remove it. All that work was done by the Environmental Science Research Team, mostly by PhD students.

As a result of that, it became imperative that the Countryside Commission, which was formed in the late '60s, 1968, and responsible for national parks, began to take a serious interest in creating a Broads National Park. And they knew that I'd written all this stuff up in my thesis, and Martin had sent all this to them. And eventually I got a visit from the Countryside Commission, a chap called Robin Herbert, as it turns out, in 1977, to my house here. And he asked me would I be prepared to be a Secretary of State nominee to this new body called the Broads Authority. I said, yes, I'd be delighted to. And in 1979, I was appointed to the first Broads Authority, which was a special statutory body but not under legislation. Well, it was under legislation, but it was, broadly speaking, under the Countryside Act 1968. It didn't have any special status in 1979, but it was deliberately seen as an experimental body trying to get this to work. And that was the history of the Broads Authority. And then it ran for ten years as an experimental body to 1989, and then it became a special statutory authority. It took three years to get that through parliament. And then in 1989 it became the Broads Authority, which was under special statute, what we have now.

EH: Yes. So, what did you get up to over that twenty years?

What did I get up to?

EH: Yes, from the beginning when they first asked you. What did that, kind of, involve?

Well, it evolved in the sense that they asked me because I was in environmental sciences and because I was close to [x] and to Martin, they asked me to chair what at the time was called the Strategy Committee. To chair it. And the Strategy Committee was looking at the relationship between boating and conservation, basically. And during that period, I got progressive information from Brian and from others that the sedimentation of the Broads was really damaging the boating interest, and that there was always a chance of macrophytes coming back. Big plants, water plants, coming back. And if they did come back, especially in the shallow of navigable Broads, there would be problems with boat navigation, boat access. And that would be a big issue from the point of view of the boating people. So, my job was to bridge all of that. And in that case, I had a very, what you might call, strong relationship with the Navigation Committee, but nevertheless, we were often at loggerheads, because the navigation people were by-and-large favouring the opening of the Broads and the commercialisation of the Broads, whereas I was favouring the environmental sciences of the Broads and the conservation of the Broads. And they saw me as trouble.

Appendix 4: List of interviewees

Name	Date	Medium
Environmental Scientist (a)	5/5/20, 26/5/20	Online
Environmental Scientist (b)	11/5/20, 18/5/2020, 2/10/20	Online
Environmental Scientist (c)	5/2/20	Online
Environmental Scientist (d)	28/10/20	Online
Environmental Scientist (e)	15/10/20	Online
Environmental Scientist (f)	30/7/20	Online
Environmental Scientist (g)	23/11/20	Email
Environmental Scientist (h)	20/11/20	Email
Environmental Scientist (i)	25/3/21	Online
Climatologist (a)	27/6/20	Email
Climatologist (b)	3/7/20, 18/11/20	Online
Climatologist (c)	11/8/20	Email
Climatologist (d)	4/8/20	Online
Climatologist (e)	2/12/20	Email
Climatologist (f)	10/11/20	Online
Climatologist (g)	15/1/21	Online
Former Research Student (a)	17/7/20	Online
Former Research Student (b)	29/10/20	Online
Broads Authority Representative (a)	27/10/20	Online
Former National Rivers Authority representative and ENV student (a)	20/11/20	Online
Former Research Associate (a)	15/10/20	Online
Former Research Associate (b)	3/12/20	Online
Former ENV technician (a)	4/2/20	In person
Kerry Turner (ENV)	5/11/20	Email
Mike MacCracken (former US Department of Energy)	16/7/20	Online

Appendix 5: List of Archives and Unofficial Documents

Name	Date
The Zuckerman Archive, Norwich, UEA, UK	04/06/19, 07/10/19, 07/01/20, 08/01/20, 09/01/20, 31/01/20, 11/02/20, 12/02/20, 27/02/20, 10/06/21, 21/06/21
H.H. Lamb Archive, Norwich, UEA, UK	10/06/21
The UEA Collection, Norwich, UEA, UK (UEA/JONES)	10/06/21, 21/06/21
The National Archives, London, UK CAB/UGC/ED	07/06/2019, 14/01/20, 15/01/20, 16/01/20, 18/02/20
Broads Authority, Norwich, UK	19/12/19
Rockefeller Archive Center, New York, USA	04/11/19 (proxy visit)
The Modern Records Centre, Coventry, University of Warwick, UK	14/01/20 (scans sent)

Unofficial documents consulted:

School of Environmental Sciences Unofficial Archive				
Volume number	**Title**	**Number of boxes**	**Contents**	**Covering dates**
001	School of Environmental Sciences - general	1	2 folders of general papers (correspondence, draft syllabus, media/newspaper)	1963-69, 1992-2000.
002	School of Environmental Sciences - environmental seminars	1	1 folder on general policy and organisation, 2 folders on seminar “The Challenge of Environmental Change”	1970-78, 1/1970-3/1970, 13-15/3/1970
003	--	1	2 folders of environmental sciences ‘selection’ committee for deanship, 1 folder of environmental sciences ‘working	1965-66, 1966, 1964-65,

			party' (draft syllabuses, correspondences, entry requirements 1 folder of various paper (prospectus for entry 1970/71), comparison between 1970-2009/10 extracts (one sheet), working party reports, admission reports, ENV alumni newsletter 6th June 2001, Environmental sciences: all grants starting between 01/8/09-31/7/2010, graduate destinations 1977-78;2005-6, summary of UEA-ENV 1968-1981, Climatic Research Unit OCT 2000 leaflet, Programme for "The opening of the WEYBOURNE ATMOSPHERIC OBSERVATORY" 12th April 1994, LGMAC report (no date, est. 1999/2000), 1995 Royal Society biographical memoirs of Solly Zuckerman, ENV Alumni newsletter,	Various

			campus map, brief history of UEA-ENV in 1989- written by Clayton (inc. staff list and current grants)	
004	School of Environmental Sciences - general	1	1 folder of general papers (various important correspondences, progress/advice reports) 1 folder of joint OU/UEA oceanography course papers, Loose papers; (letter (Brian moss), floorplans, 25th anniversary reunion attendees (students/staff) list, 25th anniversary synopsis/invite, ENV Alumni newsletter draft + tribute to Brian Funnell, Keith Clayton "where is he now?" + photo	1970-92, 1973-74, 2002, 1993, 2001, 2000 2000 n.d.
005		1	1 folder 'The Jackson Environmental Institute'; 1 folder Consultancy agreement with Hydro Environmental; 1 folder containing various and	1998-2003, 1994-95, 1969-98.

			incomplete financial documents +Review of ENV activities (1981).	
006	School of Environmental Sciences - seminars	1	4 folders of seminar files The City > Urban Management (postponed) -1974 The Social and Political Consequences of the Motor Car- 1972 The Formulation and Implementation of Environmental Standards – 10/1971 International Control of Environmental Change and Pollution – 7/1971	1971-1974.
007	School of Environmental Sciences - seminars	1	4 folders of seminar files Environmental Impact Assessment – 11/1975 Publication of Environmental Seminars (the public acceptance on innovation – 1990 is a new one, the rest in here are already known)	1973-76.

008	School of Environmental Sciences – international links	1	1 folder on Kenyatta collaboration agreement; 1 folder on Assiut University collaboration agreement; 1 folder on 'Ice Core' (from Kenya) documents 1 folder on 'Envirocat' (not international)	1993-95, 1994, 1975-78, 1973-1983.
	School of Environmental Sciences – board minutes	0	1 folder	1968-1971

Also consulted personal files from Mike MacCracken and all Climatic Research Unit annual reports from 1971 to 1988.

Appendix 6: COVID contingency plans

COVID-19 Scenario Building 2020

Scenario planner for possible effects on research based on continued lockdown* (at 3, 6, 9 months): case studies remain fixed for contigency plan BUT may swap/overlap/run concurrently
*lockdown doesn't necessarily mean home isolation but may include reduced services, closures to instituions, reduced access, sustained social distancing etc.

2020	Jan - March	April - June	July - September	October - December
Current Plan	Origin on the environmental sciences, UK and ENV	Zuckerman Seminars	History of CRU	ENV and Broads Authority
	-Predominantly archives and official documents	-Predominantly archives and official documents	-Archives - if around and offical documents, literature	-Archives - in BA office and official documents, literature
	-Supplemented with interviews or oral histories	-Supplemented with interviews or oral histories	-Interviews or oral histories (with or without unofficial archival material)	Interviews or oral histories (with or without unofficial archival material)
3-Month lockdown	Origin on the environmental sciences, UK and ENV	Zuckerman Seminars	History of CRU	ENV and Broads Authority
	-Predominantly archives and official documents	-Predominantly archives and official documents	-Archives - if around and offical documents, literature	-Archives - in BA office and official documents, literature
	-Supplemented with interviews or oral histories	-Supplemented with interviews or oral histories	-Interviews or oral histories (with or without unofficial archival material)	Interviews or oral histories (with or without unofficial archival material)
Possible solution(s)		-Work on cases that are not archival dependent	-Move interviews to online or phone **(if required - to save time for other cases)**	-Move interviews to online or phone **(if required - to save time for other cases)**
		-Analyse official documents e.g. the conference proceedings, any other coverage	-Search for online archival material (case-dependent)	-Search for online archival material (case-dependent)
		-Search for online archival material (case-dependent)	-Surrogate archive visit/scans if possible/ not open fully	-Surrogate archive visit/scans if possible/not open fully
		-Surrogate archive visit/scans if possible/ not open fully	-Respondents to share unofficial archival material through photos/ scans/dropbox if technically able (respondent dependent)	Respondents to share unofficial archival material through photos/ scans/dropbox if technically able (respondent dependent)
		-Conduct online/phone interviews for other cases - and do archival work at a later date		
		Work on literature reviews/intro/methods		
6-Month lockdown	Origin on the environmental sciences, UK and ENV	Zuckerman Seminars	History of CRU	ENV and Broads Authority
	-Predominantly archives and official documents	-Predominantly archives and official documents	-Archives - if around and offical documents, literature	-Archives - in BA office and official documents, literature
	-Supplemented with interviews or oral histories	-Supplemented with interviews or oral histories	-Interviews or oral histories (with or without unofficial archival material)	Interviews or oral histories (with or without unofficial archival material)
Possible solution(s)		-Work on cases that are not archival dependent	-Move interviews to online or phone	-Move interviews to online or phone (if needed to free up time)
		-Analyse official documents e.g. the conference proceedings, any other coverage	-Search for online archival material (case-dependent)	-Search for online archival material (case-dependent)
		-Search for online archival material (case-dependent)	-Surrogate archive visit/scans if possible/ not open fully	-Surrogate archive visit/scans if possible/not open fully
		-Surrogate archive visit/scans if possible/not open fully	-Respondents to share unofficial archival material through photos/ scans/dropbox if technically able (respondent dependent)	Respondents to share unofficial archival material through photos/ scans/dropbox if technically able (respondent dependent)
		Conduct online/phone interviews for other cases - and do archival work at a later date	-Reduce dependence on archives through interviews (freeing time for struggling cases that are archive dependent)	-Reduce dependence on archives through interviews (freeing time for struggling cases that are archive dependent)
		Work on literature reviews/intro/methods	-Analyse offical documents	-Analyse official documents
9-Month lockdown	Origin on the environmental sciences, UK and ENV	Zuckerman Seminars	History of CRU	ENV and Broads Authority
	-Predominantly archives and official documents	-Predominantly archives and official documents	-Archives - if around and offical documents, literature	-Archives - in BA office and official documents, literature
	-Supplemented with interviews or oral histories	-Supplemented with interviews or oral histories	-Interviews or oral histories (with or without unofficial archival material)	Interviews or oral histories (with or without unofficial archival material)
Possible solution(s)		-Work on cases that are not archival dependent	-Move interviews to online or phone	-Move interviews to online or phone
	This is the one i'm currently working in	-Analyse official documents e.g. the conference proceedings, any other coverage	-Search for online archival material (case-dependent)	-Search for online archival material (case-dependent)
		-Search for online archival material (case-dependent)	-Surrogate archive visit/scans if possible/not open fully	-Surrogate archive visit/scans if possible/not open fully
		-Surrogate archive visit/scans if possible/not open fully	-Respondents to share unofficial archival material through photos/ scans/dropbox if technically able (respondent dependent)	Respondents to share unofficial archival material through photos/ scans/dropbox if technically able (respondent dependent)
		Conduct online/phone interviews for other cases - and do archival work at a later date	-Heavily reduce dependence on archives through interviews (freeing time for struggling cases that are archive dependent)	-Heavily reduce dependence on archives through interviews (freeing time for struggling cases that are archive dependent)
		Work on literature reviews/intro/methods	-Analyse offical documents	-Analyse official documents

Key	Proceed as normal	Can be done with minor alterations	Cannot be done, find another option

2021	Jan - March	April - June	July - September	October - December
	RCC Visit	Write up/edit thesis: Submission 9/21		
	RCC Visit	Write up/edit thesis: Submission 9/21		
	-Zuckerman Seminar archive collection overlap			
	-Delay or reduce visit by one month if needed			
	RCC Visit	Write up/edit thesis: Submission 9/21		
	Zuckerman Seminars and CRU archival work (focused/ not just an overspill)	RCC Visit	Write up/edit thesis (less time): Submission 9/21	
	-Try to delay to regain time lost on previous cases			
	RCC Visit	Write up/edit thesis: Submission 9/21		Submission may be delayed
	Zuckerman Seminars main priority	RCC Visit	Write up/edit thesis (less time): Submission 9/21	
	-Maybe move seminars into other chapters			
	-Try to delay to regain time lost on previous cases/possibly cancel			