Landscape Ecology
The science-practice interface of connectivity in England
--Manuscript Draft--

Manuscript Number:	LAND-D-18-00296R3
Full Title:	The science-practice interface of connectivity in England
Article Type:	Original research
Keywords:	connectivity; landscape scale; implementation gap; green infrastructure; Governance; financial crisis
Corresponding Author:	Dimitrios Bormpoudakis, Ph.D School of Anthropology and Conservation, University of Kent Canterbury, Kent UNITED KINGDOM
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	School of Anthropology and Conservation, University of Kent
Corresponding Author's Secondary Institution:	
First Author:	Dimitrios Bormpoudakis, Ph.D
First Author Secondary Information:	
Order of Authors:	Dimitrios Bormpoudakis, Ph.D
	Joseph Tzanopoulos
Order of Authors Secondary Information:	
Funding Information:	FP7 EC Grant (grant 226 852 (SCALES project))	Not applicable

Abstract:	Context A disconnect has been identified at the interface between landscape science and practice. More commonly, it is assumed that better or more targeted science would lead to better practice. Others argue that such a view is partial, and propose an understanding that foregrounds how social and political factors shape the science-practice interface. Objectives In this study we explore how (the combination of) different conceptualisations, novel governance architectures, and political-economic conditions shape the science-practice interface between landscape ecology and practice, using connectivity conservation and enhancement initiatives in England as a case study. Methods We conducted interviews (n=36) with practitioners involved in connectivity-related projects (predominantly Nature Improvement Areas and Green Infrastructure initiatives). We transcribed and analysed the interviews using standard methods of qualitative analysis. We also conducted a desk study of green infrastructure strategies (n=58 documents). Results Enhancing or maintaining connectivity is perceived positively by conservation and planning practitioners in England. Quantitative assessments are rare on the ground. Conceptual ambiguity, lack of resources (time, personnel, software and hardware), novel governance architectures, and changing economic and political conditions are implicated. Conclusions We find that the co-articulation of conceptual ambiguity and resource issues with novel forms of governance in changing economies is diminishing opportunities and creating challenges for (ecological) connectivity conservation. This is particularly true in relation to large scale operationalisation that requires multi-scale and multi-partner coordination.

Response to Reviewers:	We have added the requested paragraph, see lines 653-664.

1 **The science-practice interface of connectivity in England**
2
3 Dimitrios BORMPOUDAKIS[1,*], Joseph TZANOPOULOS[1, 2]
4
5
6 [1] School of Anthropology and Conservation, University of Kent
7 [2] Kent Interdisciplinary Centre for Spatial Studies
8 * Corresponding author
9
10 *Corresponding author contact details*
11 e-mail: **bormpd@gmail.com**
12 Mobile telephone number: +447821544386

Abstract

Context

A disconnect has been identified at the interface between landscape science and practice. More commonly, it is assumed that better or more targeted science would lead to better practice. Others argue that such a view is partial, and propose an understanding that foregrounds how social and political factors shape the science-practice interface.

Objectives

In this study we explore how (the combination of) different conceptualisations, novel governance architectures, and political-economic conditions shape the science-practice interface between landscape ecology and practice, using connectivity conservation and enhancement initiatives in England as a case study.

Methods

We conducted interviews (n=36) with practitioners involved in connectivity-related projects (predominantly Nature Improvement Areas and Green Infrastructure initiatives). We transcribed and analysed the interviews using standard methods of qualitative analysis. We also conducted a desk study of green infrastructure strategies (n=58 documents).

Results

Enhancing or maintaining connectivity is perceived positively by conservation and planning practitioners in England. Considering both planning and ecological contexts, quantitative assessments are rare on the ground. Conceptual ambiguity, lack of resources (time, personnel, software and hardware), novel governance architectures, and changing economic and political conditions are implicated.

Conclusions

We find that the co-articulation of conceptual ambiguity and resource issues with novel forms of governance in changing economies is diminishing opportunities and creating challenges for (ecological) connectivity conservation. This is particularly true in relation to large scale operationalisation that requires multi-scale and multi-partner coordination.

1. Introduction

1.1. The science practice interface in ecology and conservation

It is widely recognised that there is a disconnect between the science and practice of ecology and conservation (Pullin and Knight 2005; Beunen and Opdam 2011; Salomaa et al. 2016; Opdam 2018). More commonly, it is considered that there is a "gap" between science and implementation because the former "*has a poor record of translating research into action*" and the latter is not utilising lessons derived from research (Knight et al. 2008:602). Particularly in conservation (Bertuol-Garcia et al. 2018), the onus for forging better connections between science and practice falls on enhancing knowledge production, exchange and use through evidence-based science, ensuring the practical and societal relevance of science and engaging with other forms knowledge, e.g. qualitative and local (Knight et al. 2008; Opdam et al. 2013; Castella et al. 2014). This linear model of expertise of the science-practice interface (henceforth "the linear model") is built on the (explicit or implicit) assumption that if "*people just knew, they would of course do something – and since they are not, there is a need for policies that influence attitudes, behaviours and choices*" (O'Brien 2013:588). According to this model, the responsibility for this disconnect is placed primarily on knowledge-transfer bottlenecks (Bertuol-Garcia et al. 2018).

Studies critical of the linear model of the science-practice interface have emerged from a variety of theoretical and empirical angles. The field is large enough to preclude detailed description here, but some of the main points of criticism (based on Cash et al. 2003; Nowotny et al. 2003; Harding 2006; Görg 2007; Wyborn 2015b; Toomey et al. 2017; Bertuol-Garcia et al. 2018) revolve around: a) the repositioning of practitioners from mere recipients of "facts" to

62 "judges" of scientific claims; b) the basis of their "judgments" (which is not necessarily scientific

63 but can be influenced by cultural, political and economic factors); c) the inseparability of

64 sciences and society; d) the challenge of the universality of Western positivist science and; f) a

65 move towards transdisciplinary research involving a diverse set of institutions (not only

66 universities and research centres).

1.2. The science practice interface in landscape ecology

68 Within landscape ecology, several authors have highlighted the need for a transformed

69 understanding of the science-practice interface. Opdam et al. (2013) and Pinto-Correia and

70 Kristensen (2013) for example, argue that the landscape as a material and immaterial entity can

71 be the "medium and the method" for a new transdisciplinary union of research and practice in

72 urban and rural planning and design, and sustainability science. Nassauer and Opdam (2008) and

73 Nassauer (2012) argue that in landscape ecology the concept of landscape "design" can work as

74 the missing link or boundary concept that could bring science and practice closer. Others stress

75 the merits of collaborative research or the adaptive co-production of knowledge (Wyborn 2015a,

76 2015b) as ways to overcome disconnects in the science-practice interface.

77 A research lacuna remains regarding the interplay between science, practice and governance

78 in landscapes that have shifted to "governance-beyond-the-state" and "adaptive governance"

79 models (Swyngedouw 2005; Wyborn 2015a), especially when large-scale strategic land-use

80 coordination is required (Adams et al. 2016). Considering that what we call landscape "practice"

81 nowadays has evolved to include a constellation of actors beyond landowners and the various

82 arms of the local/national state, and now includes consultants, community groups, NGOs,

83 activists, businesses, quasi-public institutions, universities, usually in some form of organised

84 partnership. This research gap is particularly acute in the context of unstable economic (e.g. post-

85 financial crisis) or rapidly changing political (e.g. Brexit in the United Kingdom) conditions that

86 suddenly alter financial, governance or legal architectures. Our study is an attempt to explore the

87 science-practice under such conditions using the lens connectivity conservation and

88 enhancement.

89 Connectivity conservation could be a fertile ground for empirically informing this knowledge

90 gap. Most pertinently, connectivity is interesting from a science-practice interface perspective

91 because it can have multiple meanings due to the different scale-, site-, species- or landscape-

92 dependent definitions and concepts that abound. For landscape ecologists, connectivity is

93 predominantly a referent for two related concepts: structural connectivity, which could be

94 defined as the extent to which different "habitat types" are linked; and functional connectivity,

95 which is related to movement and responses of individuals and/or species across the landscape an

96 (including habitat patches and a permeable matrix) (see Crooks and Sanjayan 2006). For

97 planners, connectivity has additional meanings, such as footpath connectivity (Ellis et al. 2016),

98 or cultural heritage connectivity (Antonson et al. 2010). As Hodgetts (2018) argues, connectivity

99 has also been implicated in facilitating and furthering particular types of spatial planning that

100 favour powerful interests, as well as to signify the connection people and nature.

101 Secondly, particularly in its large-scale implementation, e.g. at landscape, regional or even

102 national scales, connectivity conservation requires coordinated operationalisation across

103 jurisdictions and organisations. New governing architectures, such as "governance-beyond-the-

104 state" (Swyngedouw 2005), provide opportunities and barriers for coordination which remain

105 worthy of further investigation if their potential for partnership, knowledge-production and

106　　adaptation is to be realised (Beunen and Opdam 2011; Wyborn 2015a). Additional reasons that

107　　make connectivity an interesting case study of the science practice interface include: a)

108　　conceptually and empirically, its efficacy is still a focus of scientific debate, generating "friction"

109　　(*sensu* Tsing 2005) between different scientific schools (Hodgson et al. 2011; Moilanen 2011;

110　　Fahrig 2013), including the well-known habitat loss versus fragmentation debate (Villard and

111　　Metzger 2014) ; b) connectivity has become one of the cornerstones of conservation and

112　　landscape planning (Crooks and Sanjayan 2006; Wu, 2013), especially as an adaptation strategy

113　　for climate change (Vos et al. 2008); c) connectivity assessments often require expertise in

114　　mathematical or computational methods (Termorshuizen et al. 2007), especially as scientific

115　　legitimacy increases; d) connectivity can sometimes have negative consequences, such as

116　　promoting fire, spread of invasive species or disease.

117　　　　As a result of this complexity, concepts that are related to connectivity conservation have

118　　provided several case studies for exploring the science-practice interface in landscape ecology.

119　　Beunen and Hagens (2009) found that while ecological networks were popular in the

120　　Netherlands, they were still rarely implemented in spatial planning practice as a result of the

121　　ambiguity of the concept. Nassauer and Opdam (2008) explored the design method for robust

122　　ecological corridors in the Netherlands to suggest new ways of linking science and practice in

123　　landscape ecology. Von Haaren and Reich (2006) in their study of connectivity conservation in

124　　Germany found that scientific findings play a minor role in establishing ecological networks.

125　　However, more recent studies about the German-wide Ecological Network show that more

126　　robust quantitative methodologies are indeed employed, although "stronger link[s] between the

127　　scientific and conceptual basis of habitat networks is needed" (Schweiger 2015: 298).

128　　Termorshuizen et al. (2007) in their study of planning documents in the Netherlands found that

129 while the spatial conditions for maintaining sustainability were recognised, the use of

130 quantitative assessments and strategies was limited, as they can be data hungry, time consuming

131 and require expert knowledge. While Termorshuizen et al. (2007) recognised the shifting

132 governance architectures of landscape management, considering them empirically was outside

133 the scope of their study. Finally, in a major recent study drawing on a literature review,

134 interviews and focus groups, Keeley et al. (2018) list the challenges and opportunities for

135 implementing corridors, albeit without taking into account how governance and political

136 economic complexities can affect the science-practice interface.

137   Nevertheless, so far, limited attention has been paid to the science-practice in connectivity

138 *per se*. Wyborn in a series of papers (2015a, 2015b, 2015c) has delved in depth in two case

139 studies (in Australia and USA), showing how a complex function of material (including

140 resources), cognitive and social capacities shape the interactions between connectivity science

141 and practice. Bergsten and Zetterberg (2013) discovered that lack of data and the choice of focal

142 species were the main barriers for planners adopting a particular method for connectivity

143 assessments in Swedish planning departments. Hodgetts (2018:83), in a conceptual study

144 identifies five "types" of connectivity, and argues that the differences are indeed problematic

145 because these different types of connectivity are considered separate: "sharing a coincidental

146 terminology, but pertaining to different things."

147   In this context, we can argue that there is a need for further studies of both the on-the-ground

148 utilisation of scientific knowledge and methods in general, and of connectivity analyses in

149 particular. The main aim of this study is to fill a gap in how the combination of different

150 conceptualisations, novel governance architectures, and political-economic conditions shape the

151 science-practice interface between landscape ecology and practice, using connectivity

152 conservation and enhancement initiatives in England as a case study. To achieve this we answer

153 the following research questions:

154   a) Which are the various connectivity-related concepts and methods employed in

155   conservation and landscape planning practice?

156   b) What are the criteria for method choice to assess connectivity?

157   c) How has connectivity and the science-practice interface of landscape ecology more

158   broadly been affected by recent changes in conservation and landscape governance?

159 **2. Methods**

160 **2.1. Case study**

161 England can act as solid ground for empirically investigating the science-practice nexus and

162 connectivity conservation in particular. England and the United Kingdom are home to top-level

163 research and scientific organisations (e.g. British Ecological Society) and national environmental

164 NGOs are among the most productive research-wise and popular in terms of membership and

165 volunteers (e.g. the Royal Society for the Protection of Birds is the oldest and among the largest

166 conservation NGOs in Europe). Also, England is unique in the sense that connectivity

167 conservation has rocketed to the mainstream of conservation and planning, and the urge for

168 "more, bigger, better and joined" (Lawton et al. 2010) protected areas forms one the backbones

169 of English conservation (Isaac et al. 2018). A case in point are the 12 Nature Improvement Areas

170 (NIAs), launched by the Department for Environment, Food and Rural Affairs (Defra) in 2011

171 and operating since 2012, aiming at creating more and better-connected habitats at the landscape

172   scale. NIAs were funded as a competitive funding scheme operating in rural and urban areas all

173   over England. They were presented as a "bottom-up" policy that allows diverse partnerships to

174   "lead" conservation on the ground, "based on the recommendations of local people" (Defra

175   2011). 76 partnerships applied for the £7.5 million available and after a process similar to a

176   research or art grant proposal including evaluation in stages, business plans and interviews, 12

177   areas were selected in 2012. Moreover, landscape ecology-influenced concepts such as wildlife

178   corridors, landscape permeability or stepping stones have also interpenetrated land-use planning.

179   Green Infrastructure (GI), a concept and policy mainly coming from a planning perspective, has

180   incorporated connectivity at its core not only in the United Kingdom, but in Europe and across

181   the world (Garmendia et al. 2016), and according to recent reports, it seems to be a "good

182   example" of "successful transfer of connectivity research to practice" (Žlender and Thompson

183   2017).

184   **2.2. Data collection and analysis**

185   In order to explore the science-practice interface of landscape ecology through the lenses of

186   connectivity, we focused on gaining information from initiatives that have connectivity as a

187   central element of their remit. The main country-wide connectivity-related initiatives in England

188   are the aforementioned NIAs and GI initiatives and partnerships; thus we chose respondents that

189   are active within them.

190   To answer questions related to connectivity conceptualisation and methodological

191   application, we interviewed 14 representatives from nine (out of 12 in total) NIA partnerships

192   and 13 from eight GI partnerships and organisations. Preparatory desk studies revealed that there

193   are additional organisations related to connectivity, such as NGOs, public sector organisations,

194 consultants, even academics. Thus, to have a wider sample and information from other projects

195 or organisations that are involved with connectivity conservation, we also talked with three

196 representatives from organisations or projects that deal with connectivity of specific genera (or

197 focal species) and six respondents involved in connectivity assessments in a professional

198 capacity (consultants, university staff, and NGO and public sector employees). In total 36 open-

199 ended interviews were conducted in 2012-2015 with a range of practitioners including

200 consultants, state officials and scientists, local government officials and NGO staff. The

201 geographical spread of the NIA and GI partnerships and projects we interviewed cover the

202 breadth of England, with a slight bias towards the South East. The themes around which the

203 interviews were based upon were: how do they understand connectivity; whether they measure

204 connectivity or not; which method or metric they use; which criteria do they use for choosing a

205 method; how is connectivity conservation operationalised. It is important to note that in our

206 discussions with respondents we never initiated discussions around resources. Furthermore, since

207 we identified the theme early on in our interview schedule we explicitly choose not to introduce

208 resources-related themes ourselves to avoid biasing data collection.

209   We recorded and transcribed the interviews for qualitative analysis, which has been shown to

210 be a suitable way to explore individual's perceptions of knowledge-practice processes (Denzin

211 and Lincoln 2011; Moon et al 2016). We first induced codes, i.e. quotation categories that are

212 identical or similar in some way. Then, after the coding phase, we created themes which

213 according to our research questions and desk study better represented the relations between

214 codes and reflected the opinions of our interviewees (Table 1). As is common practice, we use

215 interviewee quotes to illustrate key themes in the results section. Analysis was conducted using a

216 combination of qualitative analysis software (NVivo 10) and hand drawn graphs and notes. All

217 interviewee quotes are anonymised. Ethical approval was obtained from the School of

218 Anthropology and Conservation, University of Kent.

219   The empirical data from the interviews were complemented by a desk study of all strategies

220 and plans for GI we could find online using Google searches, supplemented by searching

221 through the recovered documents for extra links to older documents (see Termorshuizen et al.

222 2007 for a similar methodology). In total, 58 documents were recovered as of December 2015

223 (see supporting material Table 1 for details and links, and a Google Earth file for the

224 geographical cover). They ranged from local scale to city scale or even regional level plans and

225 strategies. The GI-related documents were closely studied and the following information was

226 recorded: who developed the plan or strategy (e.g. a local council's planning division, or a

227 consulting firm); whether connectivity was assessed or not (yes/no); methodology for

228 connectivity assessment (specific methodology); connectivity concepts.

229   To investigate how connectivity has been affected by changes in conservation governance

230 and landscape-scale planning in England, we relied on public data on government spending and

231 human resources, the aforementioned interviews and desk study, as well literature on the subject

232 (including own work, see Apostolopoulou et al. 2014).

3. Results

234 The 36 respondents (16 female and 20 male) had a variety of backgrounds (ecology, biology,

235 planning, physical and human geography). 66.6% have postgraduate degrees (11 have MSc

236 degrees, 11 PhD degrees, and two are professors), while 12 have BSc or BA degrees.

237   Connectivity assessments in England are made by a variety of institutions and

238   partnerships, and involve a plethora of actors from the public, private and voluntary sectors.

239   There are several tools and methods devised, used and promoted mainly by Non-Departmental

240   Public Bodies such as Natural England and Forest Science, large NGOs, universities and private

241   consultants. Commonly this is done within specific projects by conservation partnerships (e.g.

242   NIAs, European Union LIFE projects, National Parks).

243   **(Insert Table 1 here) Themes used in the analysis and examples of codes.**

244   **3.1. Connectivity: concepts and methods**

245   Several connectivity concepts were articulated by the interviewees. The most significant division

246   was between connectivity as a landscape/ecological concept and connectivity from a planning

247   perspective. The former, mainly articulated by respondents who are involved in projects or

248   organisations dealing with nature conservation (14, 35% of the sample), involved a continuum of

249   connectivity concepts. These concepts ranged from the structural to the specifically species-

250   based and functional.

251   *I normally say that there is structural connectivity going to functional connectivity, so*

252   *these are the ends of this continuum. Some of that can be quite abstract and quite pattern*

253   *based e.g. structural measures for some of our work we may assess whether this one*

254   *particular* [withheld] *grant scheme changes the structural connectivity of landscape … The*

255   *other end of the continuum is more about functional connectivity, which is very* [species]

256   *specific… So some of our work will be very much species-based, how they move and*

257   *interact with the matrix and quite a sort of complex understanding, while others will be*

258   *very abstract and very simple* (R32, public sector scientist).

12

259   *The movement of individuals across landscapes, or genetic material. It's basically the flow*

260   *of individuals or genes between different areas and I leave it fairly open* (R11, NIA

261   representative).

262   Planning conceptualisations, articulated by the majority (60%, 8 out of 13) of GI

263   practitioners, stress its multifunctional character, for example "*connecting green space through a*

264   *footpath network*" (R18, GI partnership representative), i.e. combining urban habitat connectivity

265   with transport connectivity and peoples connections to nature. Note that this type of

266   conceptualisation did not only prevail among planners in our sample. For example, a NIA

267   representative noted that connectivity in their case also means more community connections such

268   as "*community gatherings*", arguing that if "*we just make our* [connectivity concept] *only*

269   *ecological, we don't make ourselves relevant to the people making a living in the area.*"

270   The desk study of GI initiatives revealed that in this context, which is more related to

271   urban and urban fringe planning, connectivity is also conceptualised in a variegated way. In

272   contrast though to most ecologically-minded respondents and organisations, the analysis of GI

273   strategies revealed that almost 80% (46) of the documents articulated diverse articulations of

274   connectivity – *even in the same document.* Thus, for example, in a single document (Swindon

275   Borough Council 2011) one can find the following: "*inter-connected 'park belt'*" (p. 19); "*River*

276   *Ray and River Cole corridors with connections to Coate Water*" (p. 19); "*connectivity between*

277   *existing neighbourhood, borough-wide and strategic scale recreational open spaces*" (p. 33);

278   "*enhancing and improving connectivity within existing wildlife 'hot-spots'*" (p. 35);

279   "[c]*onnecting people and place*" (p. 55).

280

281   Similarly to concepts, connectivity assessment methods used lie on a continuum from

282   structural pattern-based to functional and species-based. Pattern-based methods include patch-

283   based assessments e.g. nearest neighbour distance, patch size and shape. The middle ground is

284   occupied by models that use a particular species and habitat, often using a focal-species approach

285   (e.g. Watts et al. 2010). This approach is one of the most common, as it utilizes expert opinion

286   and is not data hungry, often feasible using already available data. It is actually an approach used

287   by several organisations in England, e.g. Forest Research, Natural England and several

288   consultants working on connectivity.

289   Interviewees with an ecological background or within ecologically-minded organisations

290   stressed the importance of actually assessing connectivity from a landscape ecology perspective

291   (70% of the NIA representatives). A minority (two) also criticised the influence of planning

292   concepts in habitat network design. For example, a consultant (R03), with experience in the

293   NGO and public sectors argued:

294   *"There's very few landscape ecologists and spatial ecologists in conservation and that*

295   *really does worry me especially with what I have seen in ecological network definition and*

296   *green infrastructure modelling – well I wouldn't actually even call it modelling, it's so*

297   *simplistic and a lot of local authorities are confusing ecological networks with GI and they*

298   *think that GI will provide an ecological network, it's a completely different thing. They do*

299   *it mostly through overlay analysis, and accessible greens and maybe putting a few arrows*

300   *on the map. I have seen some really shocking ecological networks as well which have been*

301   *just arrows on a map."*

302   Nevertheless, the most scientifically robust methods, like individual based models, graph-

303   based models or metapopulation approaches are the rarest on-the-ground and are usually

304   related to discreet projects. Exceptions include: the BEETLE least-cost path based

305   connectivity model developed by Forest Research (Watts et al. 2010) which is used by several

306   organisations across the UK (e.g. Somerset Wildlife Trust 2016); the Condatis software

307   Hodgson et al. (2012) which implements a conductivity-based connectivity model (used by

308   e.g. Buglife projects in Kent and Sussex and the Northern Forest tree planting initiative in

309   Liverpool); Natural England's National Biodiversity Climate Change Vulnerability Model

310   (NBCCVM) which includes a module on habitat fragmentation and is used by many

311   organisations and partnerships (Adaptation Sub-Committee 2013). Furthermore, when these

312   types of sophisticated approaches are employed, model development and application is

313   usually – but not always, see Northern Forest Condatis application at https://iale.uk/northern-

314   forest-thinking-about-landscape – outsourced either to the particular model developer (e.g.

315   Forest Research, Natural England) or experienced private consultants. Further evidence of

316   such approaches was found in European Union and Defra funded projects, such as the

317   Cheshire Econet project (http://maps.cheshire.gov.uk/econet/about.asp) or the Dorset AONB

318   habitat connectivity mapping under the EU Interreg Cordiale project

319   (http://www.southdevonaonb.org.uk/our-work/active-projects/completed-projects/cordiale),

320   and some species-specific graph-theoretic applications (e.g. Bormpoudakis et al. 2016, on

321   great crested newts and its application in compensation schemes). Notably, the deployment of

322   quantitative methods for modelling connectivity is almost exclusively related to

323   ecological/conservation rather than planning contexts.

324 In fact, few of the interviewees mentioned the use of such an approach. NIA

325 representatives were the most aware and during the interviews mentioned several of these

326 methods. Furthermore, NIAs took part in workshops and collaborative interactions where

327 concepts and methods of connectivity assessment and measurement were presented and

328 debated. Each NIA used a simple scoring system to calculate a "*comparative indicator of*

329 *habitat connectivity*" (*ibid*) which is "*a proxy measure of connectivity based on the*

330 *contribution of actions to improve connectivity*" (Collingwood Environmental Planning 2014:

331 60), and different local indices of habitat connectivity ranging from technically complex to

332 simple (e.g. the ratio of the area (ha) of a particular protected habitat patch to the distance to

333 its nearest neighbour (m) or the number of weirs removed or lowered along a river as an

334 indicator of connectivity for anadromous fish) (Collingwood Environmental Planning 2015).

335 Confirming our interview results regarding the approach to connectivity from a planning

336 perspective, the desk study of GI strategies revealed that only 6.7 % (four) of the GI

337 documents analysed incorporated a systematic method for assigning corridors. 94% (56)

338 simply overlaid maps within a GIS to allocate GI areas (Snäll et al. (2016) highlight the limits

339 of such an approach), while a limited number (9.7%, six) incorporated some form of previous

340 connectivity-related work (usually as maps in an overlay GIS exercise).

341 Despite the different approaches to connectivity, interviewees were definitely positive

342 about the role connectivity could play in the landscape, place or species their organisations are

343 working on. Although it was to be expected based on our sample, circa 90% of the

344 respondents agree that the issue of connectivity "*is fundamental*" for managing rural and

345 urban landscapes.

3.2. Criteria for method choice and implementation

The main outcome regarding the method choice when assessing connectivity is that there is neither a single specific method nor a particular scale that are suitable for connectivity analyses. 80% of the respondents note though that *"having a unique approach to connectivity is wrong"* (R28, NIA representative) and the way it is measured should be case-dependent (or site- and problem-specific). Our result is confirmed by the findings of the NIA final evaluation report, released 1.5 years after the completion of our NIA interviews, which notes that "[h]*abitat connectivity may be best considered and measured at the local level ... targeted at particular species/habitats*" (Collingwood Environmental Planning 2015:69) and that it "*is questionable whether habitat connectivity in an abstract sense means very much because it is place and species specific*" (*ibid*: 83).

Moreover, as indicated above, there is clear evidence of disconnect when it comes to methods that are endorsed by the ecological scientific community and what is actually used on-the-ground. On the one hand, there is some worry that methods developed in academia are not suited to the actual needs of practitioners (30% of interviewees). As two interviewees told us (R01 and R05, a consultant and NIA representative respectively):

"I think the methods that are used in academia are largely unsuitable for use outside research projects because it simply takes too long, they are too complicated to use and they cost too much."

On the other, in our case, most practitioners were not looking down on science, but were looking to inform and better their practice through the use of science. That was also true for organisations and projects that were not explicitly related to connectivity conservation.

368   *"The result* [of previous connectivity analyses] *were tens and tens of GIS layers, but it*

369   *needs to be more digestible and simple for the people, e.g. for local plan consultations …*

370   *Now I am more informed about the direction but for someone who is not an academic it is*

371   *difficult to keep up … Connectivity is a useful method for targeting our effort in an era of*

372   *limited resources and personnel."* (R27, National park employee)

373   Finally, we also came across a few cases (4, 10% of the interviewees) where practitioners on

374   the ground felt that connectivity conservation or enhancement is fairly straightforward even

375   without the use of purely scientific methods, i.e. "*it is not rocket science*" (R30, NIA

376   representative). As a local planning officer told us (R17):

377   *To a degree it's going to be based on the ranger's gut feeling. Considering the ranger's*

378   *experience and knowledge of the area, it's not that difficult.*

379   Moreover, the influence of resources (Table 2) on the choice of methods to assess and

380   implement connectivity was strongly argued by several interviewees (23 out of 36, 64.8%),

381   including NIA representatives (9 out of 14, 64.2%). Many NIA representatives (7 out of 14,

382   50%) were familiar with a host of connectivity metrics and methodologies, while all of them had

383   clear ideas about the available methodologies. Despite that, some NIA partnerships were having

384   difficulties in calculating structural connectivity indices themselves or were unable to give us a

385   clear-cut answer on the method they would be using. After the completion of the NIA-related

386   interviews the 2nd year monitoring report for the NIAs was published and only 2 of the 12 NIAs

387   managed to quantitatively assess connectivity (Collingwood Environmental Planning 2013). As

388   our interviewees told and as was later revealed by the publication of the monitoring and

389   evaluation of the NIAs project, measuring connectivity "*remained a challenge*" for NIAs

390   (Collingwood Environmental Planning 2015: 83).

391   Overall, the themes around which organisations' resource-related issues were grouped were

392   mainly centred on software, personnel, time and budget restrictions (See Table 2). We recorded

393   organisations: (a) with no access to GIS when most connectivity analyses require it (or

394   computers powerful/new enough to run GIS analyses); (b) personnel without GIS capabilities;

395   (c) limited funds for hiring skilled personnel; (d) experts that could not fund the application of

396   their knowledge; (e) no time for sophisticated analyses; (f) project-based exercises that were

397   rarely taken further or incorporated in organisational or institutional workflows. This element of

398   our findings is confirmed by the results of a survey published in van Dijk et al. (2013: 23), which

399   found that 8 out of 17 (47%) NIA representatives found "*local GIS expertise / resource*" would

400   be a barrier to the use of Natural England's NBCCVM model.

401   **(Insert Table 2 here)**

402   This is particularly revealing in the case of a large NGO, which is quite sophisticated in their

403   understanding of connectivity concepts and methods. According to their own words (R21, NGO

404   representative):

405   *We translate [scientific] theory into practice ... We pride ourselves as we try to look at*

406   *what we do from a scientific perspective. We do make an effort to explain in a quasi-*

407   *scientific way population ecology to our volunteers...* [However] *the only way we*

408   *measured connectivity is mean distance between occupied patches ... We don't have the*

409   *resources to do more than that ... I describe it as a crude measure of connectivity, but we*

410   *have the distance between sites and that says quite a lot.*

411   A desk study revealed similar cases, such as the Kent Wildlife Trust's Living Landscape

412   project (a landscape-scale conservation initiative) which was not "*at present in a position to*

413   *carry ... least-cost analysis*" (Moyse and Rowsell, 2007:121); the Conservation Target Areas

414   mapping project in Oxfordshire "*explored the possibility of using a detailed scoring system to*

415   *decide which areas should be included in the target area mapping. This was not feasible in the*

416   *limited time available."* (Hawker and Burrell 2006:3).

417   **3.3. Governing conservation and landscape-scale planning in England**

418   Significant changes have occurred in English spatial governance in the last 20 years. For our

419   study, the most significant would be the move away from the "strong state" paradigm to a form

420   of governance that empowers a new and growing host of actors independent from the local or

421   national state. This trend, tied to neoliberal conservation and environmental governance (Castree

422   2008; Apostolopoulou et al 2014), is especially evident in landscape-scale conservation and

423   planning (Adams et al. 2014), but also clear in the type of organisation that was involved in

424   producing GI strategies and plans as revealed by our analysis (Table 3; see also Table 2 in

425   supplementary material for a list of actors involved in each NIA). NGOs, consultants, local

426   community groups and private companies have all seen their governance roles and powers

427   enhanced during the last two decades, resembling what Erik Swyngedouw (2005) termed

428   "*governance-beyond-the-state*".

429   **(Insert Table 3 here)**

430   A second and related key change in English conservation, and one that directly links with

431   both our case study initiatives (NIA and GI), has been the steady increase in large-scale

432   conservation projects. As Adams et al. (2014:585) note, the fundamental feature of these projects

433 is that "*they are an attempt to coordinate land use and conservation management over a larger*

434 *extent than can typically be maintained by a single conservation landholder*", requiring hybrid

435 forms of governance, partnerships, and coordination between state and non-state actors.

436   The rise and implementation of large-scale or landscape scale conservation coincided with

437 the financial crisis of 2008-2009 which resulted in significant cuts that have affected both public

438 spending on biodiversity and Natural England staff (Fig. 1). Furthermore, while the interviews

439 were conducted before the Brexit referendum (June 2015), several of our interviewees were

440 worried that post-crisis funding and staff cuts along with cuts in Common Agricultural Policy

441 funding are sure to affect not only connectivity conservation, but nature conservation in general.

442   *"There is one issue I wanted to flag up today, the issue of the new Common Agricultural*

443 *Policy … There is no doubt, I would say at least 90% of the work that we can achieve*

444 *ecologically depends on grants for farmers that are available through the* [Common

445 Agricultural Policy]*".* (R28, NIA representative)

446   Staff number reduction in Natural England, the public body responsible for nature

447 conservation in England, was also highlighted by the interviewees. An experienced private

448 consultant confirmed that he is facing difficulties as "*more and more* [Natural England] *senior*

449 *staff with a lot of experience and scientific knowledge are leaving and are not replaced*" (R01).

450

451   **(Insert Figure 1 here)**

452 The effects of resources on the interface between science and practice have been highlighted

453 above. Some interviewees, however, also noted that the way these limited resources are allocated

21

454   in competitive funding, limited-time projects like the NIAs is having an additional effect on the

455   strategic and cooperative character of connectivity and landscape scale conservation. It is

456   particularly interesting to note that while interviewees highlighted the powerful potentials of

457   partnership-based and bottom-up projects, they noted how the current governance architecture of

458   NIAs and other initiatives is hindering this potential.

459   *"[T]hese NIAs that haven't got GIS, why not find another that has got GIS, and work*

460   *together; if you can do this for us, we will help you do something else ... I think a lot of this*

461   *is because the funds are competitive, they are often working against each other rather that*

462   *with each other."* (R32, public sector scientist)

463   *Ideally you need some kind of national plan, to know that you are looking at a coherent*

464   *network along the lines of the Lawton report... So a lot of action at the local level helps,*

465   *you know, doing better conservation is going to help, but we need to be a bit more targeted*

466   *and strategic about that kind of thing."* (R15, public sector employee)

467   Note that competitive funding for conservation is relatively recent phenomenon in English

468   conservation, which according to our data is to some extent responsible for the turn of several

469   organisations towards connectivity conservation.

470   *"Funding is limited so you have to focus your efforts in particular areas* [and] *funders are*

471   *interested in projects which take a landscape scale approach ... When Landfill tax started*

472   *you could only apply for funding on one site, not for taking a landscape approach. In the*

473   *last five years this has changed and they are interested more in a landscape scale*

474   *approach ... In the last ten years everyone is gradually moving toward thinking about*

475   *larger scales"* (R21, NGO representative).

476   The concerns of the respondents highlight the interplay between novel forms of governance in

477   large-scale scale conservation with the market logics of funding instruments such as competitive

478   bidding.

479   **4. Discussion**

480   Opdam (2018:7) argues that a central challenge for landscape ecology is "bridging the gap

481   between science and practice", and that understanding the way "scientific information interacts

482   with social processes" is fundamental to that goal. Our paper is a contribution towards resolving

483   that challenge, looking at the science-practice interface through the lens of connectivity

484   conservation.

485   **4.1. Connectivity as a scientific object**

486   The conceptualisations of connectivity underpin the way it is assessed in England. First, whether

487   it is quantified or not depends on the understanding of what connectivity actually is: when the

488   idea is that it is "*not rocket science*", professional or experiential ranger knowledge may be used;

489   or when the concept comes from a planning background, it is usually equated with corridors,

490   footpaths or "*nodes in a network of green spaces*". Second, when connectivity is considered a

491   central component of conservation, it is usually seen as a continuum of approaches, from the

492   structural and pattern-based to the functional and biological.

493   However, as the diversification of actors involved in contemporary environmental

494   governance continues (Apostolopoulou et al. 2014; see Table 2 in the Supplementary Materials

495   for a list of the actors involved in the NIAs scheme), so are the conceptualisations of

496   connectivity diverging according to different positionalities within the science-practice space. In

497   our case, actors from a planning perspective usually understood connectivity entirely differently

498   from actors coming from an ecological perspective (e.g. connectivity as better footpath links

499   between green areas versus connectivity as species dispersal least-cost paths). As a result, and

500   particularly for GI-related initiatives that usually arise from planning frameworks, landscape

501   connectivity assessments are rare on the ground and often do not meet the needs of nature

502   conservation (see Termorshuizen et al. 2007 for a similar assessment for the Netherlands).

503   The diverse conceptualisations of connectivity we uncovered also partly reflect Hodgetts'

504   (2018) reading of connectivity as "plural". We discovered elements of the diversity he

505   documents in the workings of landscape and conservation planning, in both rural and urban areas

506   (see map of GI strategies in Supplementary Material). Hodgett's argues that we should view

507   connectivity as "multiple", meaning that we should holistically embrace the diversity of its

508   "plural types" without reducing the concept to just one type (e.g. ecological connectivity). His

509   understanding resonates with Tsing (2005) who posits that "friction" between knowledge claims

510   is actually *creative* – provided it is recognised that it exists. Read in this context, our data

511   indicates that while a scientific concept (like connectivity) can be universally lauded, if most

512   practitioners are faithful to their "own connectivity", ignoring, dismissing or even suppressing

513   different approaches, then the productive "friction" that Tsing (2005) argues can reshape the

514   divides between science and practice cannot do its work. On the other hand, considering that

515   most GI strategies we read did indeed employ multiple types of connectivity and that very few

516   actually used quantitative assessments limits Tsing's (2005) and Hodgett's (2018) "creative

517   friction" interpretation and adds further complexity to the understanding of the science-practice

518   interface of connectivity conservation.

519   Although further work would be required, perhaps a starting point would be to accept that

520   connectivity, like other ambiguous concepts like resilience, is Janus-faced (Brand and Jax 2007)

521   in terms of science implementation. On the one hand they may have positive aspects, for

522   example in promoting connectivity operationalisation in diverse landscapes. On the other hand

523   they may also have negative aspects, for example in diluting certain aspects of connectivity

524   conservation, as our findings regarding GI initiatives and the lack of ecological/quantitative

525   assessments indicate.

526   Nevertheless, it seems that if landscape ecology is to become a scientific field which can

527   influence practical application of its concepts, it has to accept and embrace this multiplicity.

528   Considering that landscape planning is inherently a large-scale, regional, national or even

529   international endeavour, this could pose new challenges. Particularly as novel governance

530   architectures characterised by decentralisation and rescaling are solidified, landscape approaches

531   such as ecological networks which require coordination between different groups or some form

532   of standardisation (e.g. methodological) could face barriers to implementation. As we showed in

533   the case of NIA's, the different approaches to connectivity create a geographically and

534   organisationally anarchic (not in the political sense) science-practice interface, with different

535   approaches, conceptualisations, methodologies, data, etc. employed to operationalise

536   (supposedly) the same concept. This ostensibly bottom-up implementation of landscape science

537   can result in uncoordinated land use allocations that do not do justice to any of the different types

538   of connectivity (or corridors, or ecological networks, etc.). Thus, letting a thousand types of

539   connectivity to bloom may be a productive – and in fact necessary step for landscape ecology,

540   but could come with a price to pay: the "*price of anarchy*" for the lack of coordination among the

541   different partnerships, NGOs, land owners, public institutions, and all the actors involved in

25

542   spatial planning (Youn et al. 2008). Finding a way to balance between connectivity-as-multiple

543   and connectivity-as-single (e.g. ecological) is perhaps the way forward (Hodgetts 2018).

544   That is not to say that some types of connectivity, e.g. ecological connectivity, are better or

545   preferable than others, but to underline that sometimes policy tools that are designed to enhance

546   and maintain a particular type of connectivity (e.g. NIAs for landscape/ecological connectivity)

547   can fail to do so as a result of the multiplicity of the concept.

548   **4.2. Recourses as a complex governance and political-economic issue**

549   As our data reveals, the connectivity assessment method used by NIA and GI partnerships

550   depends on the problem at hand and a combination of institutional experience and background,

551   data available and resources at hand. The latter proved to be a very significant determinant of the

552   method used for measuring connectivity in England. Tools, funding, personnel and time

553   available for each organisation or partnership attempting to undertake connectivity

554   measurements were limiting factors in the choice of methods and metrics used.

555   Therefore, while the matter of relevant research and informed practitioners is crucial, the

556   research-to-practice punctuated continuum is not *just* a matter of knowledge exchange, but based

557   on our findings, it is *also* a matter of resources. Considering the diverse set of resource-related

558   constrains put upon organisations (hardware and software; experienced or skilled personnel;

559   time; project-based funding; staffing problems), it is understandable that the work is often either

560   "*crude*" (R32) or outsourced (e.g. to consultancies or state organisations such as Natural

561   England), reducing the capacity for experimental learning that forms part of adaptive

562   management that comes with in-house production (Plummer et al. 2013). Indicative of the

563   situation in England, especially for local governance, only 1/3 of local authorities employ in-

564   house ecologists (Defra 2012), and post-financial crisis some UK cities have been forced to let

565   go of 90% of parks and countryside staff (Douglas 2014).

566   While the issue of insufficient resources is often included as one of the constituents of

567   particular science-practice architectures, often it is not discussed further (Pullin and Knight

568   2005), or even dismissed as beyond the competence of "*practitioners and scientists*" (Arlettaz et

569   al. 2010:836). As our results and other reports indicate (see Figure 1; Eggermont et al. 2013), in

570   the post-financial crisis climate of tight state budgets (almost globally) this is no longer the case

571   (see also Adams et al. 2016) and it is a fact that should be considered when proposing evidence-

572   based science and the systematic review as the main remedy.

573   The dwindling public resources for conservation, and the way these are dispersed to

574   conservation and other actors are tied to the novel forms of land-use governance that emerged in

575   England in the last two decades and to the way science and scientific concepts are used in

576   practice. As mentioned above, financial and other resources have been repeatedly implicated in

577   the implementation gap in landscape ecology and conservation (e.g. Termorshuizen et al. 2007;

578   Keeley et al. 2018). The novelty of our findings is that they indicate that resources are not a

579   static, constant, and identical concern for conservation practitioners. Resources are influenced by

580   and co-implicated with governance, funding architectures and national (economic and political)

581   policies in determining how science is used in practice. Furthermore, because this articulation is

582   determined by multiple factors that often vary in space it creates *geographies of the science-*

583   *practice interface,* which so far have been neglected in the literature (Eden 2016) with most

584   studies assuming a geographically homogeneous science-practice interface.

585   Our results also resonate with Adams et al. (2014) who identify a paradox between the

586   doctrine of governance-beyond-the-state and scientific paradigms such as large-scale

587   conservation or systematic spatial planning that require the state "*in full command of both its*

588   *territory and its extractive sectors*" (Sandberg 2007, cited by Adams et al. 2014:583). In the

589   English case, our results echo the findings of Lockhart (2015:341), who in the context of

590   biodiversity offsetting identified a contradiction between rolling out a "*mandatory offsetting*

591   *system with the sufficient resources to deliver meaningful outcomes*" and the de-regulation and

592   austerity agendas of the 2010-2015 UK government.

593   Our results regarding competitive funding in a period of diminishing public expenditures for

594   the environment are also salient. First, in an era of severe cuts to the environment sector,

595   organisations that supply public benefits and goods increasingly have to conform to specific

596   criteria to acquire funding. Second, the findings also highlight the Janus face of partnership

597   working and the need for more nuanced approaches to the study of partnerships, especially in

598   cases that require extra-local multi-partner coordination like connectivity conservation. As the

599   NIAs case shows (see also Collingwood Environmental Planning 2015), partnership can be a

600   very efficient way of achieving agreements and providing space for deliberation, a way to tackle

601   larger projects and maybe even are required for achieving ambitious targets. Nevertheless, when

602   these partnerships are competitively funded, there are at least two inherent dangers: conservation

603   on-the-ground being dictated by the funders; and driving up competition among partners and

604   reducing the inherent benefits to be gained from fruitful collaboration. Furthermore, considering

605   that agri-environmental schemes embedded in the Common Agricultural Policy were the main

606   source of funding for a significant amount of actions (see also Adams et al. 2016 who make a

607   similar case), the post-Brexit situation in England becomes crucial. How agri-environmental

608 funding gets directed will play a role in the ability of organisations and partnerships not only to

609 measure and enhance connectivity, but also make good use of the science that they are familiar

610 with and underpins their actions.

5. Conclusion

612 The disconnect between science and practice in ecology and conservation is related to

613 knowledge bottlenecks, but such an explanation on its own is partial and there are other

614 significant factors that have to be included in any model of the science-practice space. Firstly,

615 the plasticity and ambiguity of connectivity concepts creates potential barriers to

616 implementation. The issue is confounded by the proliferation of actors that are involved with

617 conservation on-the-ground that is in turn causing an explosion of different concepts and

618 approaches on an already debated (Fahrig 2013) subject such as connectivity. If our findings

619 hold, the positive aspects of more diverse actors and publics (Eden 2016) being involved with

620 practical conservation may result in ambiguities in the use of scientific concepts, leading to

621 coordination issues and dilution in the application of certain scientific concepts or advances. The

622 challenge is how not to erase this emerging plurality, but to find scientific and practical ways to

623 work around the inherent strategic coordination risks such a condition entails.

624   Secondly, the availability of resources seems to be a very important and material issue,

625 especially if we consider that funding issues are complex and interrelated and influence available

626 personnel, infrastructure (software and hardware) and time. While the issue of resources comes

627 up repeatedly in the literature, it is mostly confounded with funding, and there is little research

628 on what it means on the ground, nor any substantial interrogation of how political-economic

629 changes affect conservation on-the-ground. While this article did not aim to identify solutions,

630   there are some practical and relatively fast – but definitely *not* problem-resolving – measures that

631   could be taken. For example, more well-paid internships for young scientists could provide both

632   well-educated staff for conservation organisations and allow conservation to learn a lot from on-

633   the-ground conservation in a collaborative framework. Furthermore, more investment in open-

634   source software would make running quantitative connectivity analyses less costly; for example,

635   Natural England is writing some connectivity software using open source software libraries that

636   can be extended or added to any GIS. More broadly, moving away from project-based

637   conservation into longer term engagements that can be adaptive and continuous would allow for

638   better resource planning.

639   Third, the governance, political and economic drivers of knowledge utilisation are always

640   present, co-producing the science-practice nexus, in co-articulation resource issues. Hence, there

641   is no easy solution to the resource-related problems of the science-policy interface – certainly as

642   Wyborn (2015b:11) notes, more "*funding is not a panacea*". To paraphrase Lockhart (2015:342),

643   there is an irreducible and understudied relationship between the successful roll-out of large-

644   scale strategic planning and restoration initiatives, and their articulation with broader political

645   and economic paradigms, such as the UK variants of post-2008 neoliberalism.

646   To sum up, firstly, we have uncovered the divergent conceptualisation of connectivity and

647   how these conceptualisations influence if and how connectivity is assessed in conservation and

648   planning. Secondly, we documented the central role diverse resources play in the utilisation of

649   scientific methods by practitioners. Thirdly, we saw how governance-beyond-the-state is

650   implicated in shaping the science-practice interface of conservation in particular ways that are

651   essentially ambivalent. Fourthly, we showed how novel forms of governance, and particularly

652   competitive funding/bidding, can diminish the potential for fruitful partnership working.

653   In closing, we would like to flag up the generalisability of our results and discussion,

654   acknowledging that they are drawn from a UK context and certain limitations do apply.

655   Regarding conceptual "plurality", our findings should be applicable widely, considering

656   connectivity is a global concept, and its diversity of conceptualisation does not reflect a UK

657   peculiarity but has been well documented across countries (Crooks and Sanjayan 2006; Hodgetts

658   2018). Regarding the role of diverse resources in driving the practical implementation of

659   scientific concepts, we argue again that our findings are applicable in non-UK contexts, since

660   they are more often than not country or culture independent. Finally, while the particular

661   interplay between novel forms of governance, changing economies and large scale conservation

662   and planning may be unique to the UK or Europe (Apostolopoulou et al. 2014), we argue that

663   our findings allow for limited and careful interpolation since such changes have been, in

664   variegated form and to a certain extent, global (Brenner et al. 2010).

References

1. Adams WM, Hodge ID, Macgregor NA, Sandbrook LC (2016) Creating restoration landscapes: partnerships in large-scale conservation in the UK. Ecol Soc 21: 1. dx.doi.org/10.5751/ES-08498-210301
2. Adams WM, Hodge ID, Sandbrook L (2014) New Spaces for Nature: The re-territorialisation of biodiversity conservation under neoliberalism in the UK. T I Brit Geogr 39: 574–588. doi.org/10.1111/tran.12050
3. Adaptation Sub-Committee (2013)Managing the land in a changing climate. Adaptation Sub-Committee Progress Report 2013. Committee on Climate Change, London.
4. Antonson H, Gustafsson M, Angelstam P (2010) Cultural heritage connectivity. A tool for EIA in transportation infrastructure planning. Transp. Res. D 15: 463-472. doi.org/10.1016/j.trd.2010.05.003
5. Apostolopoulou E, Bormpoudakis D, Paloniemi R, Cent J, Grodzińska-Jurczak M, Pietrzyk-Kaszyńska A, Pantis JD (2014) Governance rescaling and the neoliberalization of nature: the case of biodiversity conservation in four EU countries. Int J Sust Dev World 21: 481-494. doi.org/10.1080/13504509.2014.979904
6. Arlettaz R, Schaub M, Fournier J, Reichlin TS, Sierro A, Watson JEM, Braunisch V (2010) From publications to public actions: When conservation biologists bridge the gap between research and implementation. Bioscience 60: 835–842. doi.org/10.1525/bio.2010.60.10.10
7. Bergsten A, Zetterberg A (2013) To model the landscape as a network: A practitioner's perspective. Landscape Urban Plan 119: 35-43. doi.org/10.1016/j.landurbplan.2013.06.009
8. Bertuol-Garcia D, Morsello C, N El-Hani C, Pardini R (2018) A conceptual framework for understanding the perspectives on the causes of the science–practice gap in ecology and conservation. Biol Rev 93: 1032-1055. doi.org/10.1111/brv.12385
9. Beunen R, Hagens JE (2009) The Use of the Concept of Ecological Networks in Nature Conservation Policies and Planning Practices. Landscape Res 5: 563-580. doi.org/10.1080/01426390903184280
10. Beunen R, Opdam P (2011) When landscape planning becomes landscape governance, what happens to the science? Landscape Urban Plan 100: 324-326. doi.org/10.1016/j.landurbplan.2011.01.018
11. Bormpoudakis D, Foster J, Gent T, Griffiths RA, Russell L, Starnes T, Tzanopoulos J, Wilkinson J (2015) Developing models to estimate the occurrence in the English countryside of Great Crested Newts, a protected species under the Habitats Directive. Final Report [Defra Project Code WC1108].
12. Brand FS, Jax K (2007) Focusing the meaning(s) of resilience: resilience as a descriptive concept and a boundary object. Ecol Soc 12: 23. http://www.ecologyandsociety.org/vol12/iss1/art23/
13. Brenner N, Peck J, Theodore N (2010) Variegated neoliberalization: geographies, modalities, pathways. Global Net 10: 182-222. doi.org/10.1111/j.1471-0374.2009.00277.x
14. Cash DW, Clark WC, Alcock F, Dickson NM, Eckley N, Guston DH, Jäger J, Mitchell RB (2003) Knowledge systems for sustainable development. PNAS 100: 8086-8091. doi.org/10.1073/pnas.1231332100

15. Castella JC, Bourgoin J, Lestrelin G, Bouahom B (2014) A model of the science–practice–policy interface in participatory land-use planning: lessons from Laos. Landscape Ecol 29: 1095-1107. doi.org/10.1007/s10980-014-0043-x
16. Castree, N. (2008). Neoliberalising nature: the logics of deregulation and reregulation. Environ Plan A 40: 131-152. doi.org/10.1068/a3999
17. Collingwood Environmental Planning (2013) Monitoring and evaluation of Nature Improvement Areas: Year 1 (2012-13) Progress Report. Collingwood Environmental Planning Ltd, London
18. Collingwood Environmental Planning (2014) Updated Monitoring and Evaluation Framework for Nature Improvement Areas. Report to Defra [Defra project WC1061]. http://publications.naturalengland.org.uk/publication/5542385517854720, accessed 16 September 2019
19. Collingwood Environmental Planning (2015) Monitoring and Evaluation of Nature Improvement Areas: Final Report (2012-15). Report to Defra [Defra project WC1061], http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=220&ProjectID=18555, accessed 16 September 2019
20. Crooks KR, Sanjayan M (2006) Connectivity conservation. Cambridge University Press, Cambridge
21. Defra (2011) Competition opens to create bigger and better local wildlife areas. Defra Press Release, https://www.gov.uk/government/news/competition-opens-to-create-bigger-and-better-local-wildlife-areas, accessed 3 June 2019
22. Defra (2012) Report of the Habitats and Wild Birds Directives Implementation Review. Department for Environment, Food and Rural Affairs, London. http://www.defra.gov.uk/publications/2012/03/22/pb13724-habitats-wild-birds-directives/. Accessed 2 December 2013
23. Denzin NK, Lincoln YS (Eds) (2011) The SAGE handbook of qualitative research. Sage, Thousand Oaks, California
24. Dixon J (2014). Thirteen into Fourteen: New Year Message. https://peakchief.wordpress.com/2014/01/01/thirteen-into-fourteen-new-year-message/, accessed 27 October 2016
25. Douglas I (2014) The political filter in the local implementation of initiatives relating to urban ecology. Landscape Urban Plan 125: 312-319. doi.org/10.1016/j.landurbplan.2014.02.008
26. Eden, S. (2016) Environmental Publics. Routledge, New York and London.
27. Eggermont H, Le Roux X, Heughebaert A, Balian E, BiodivERsA partners (2013) The BiodivERsA database: Analysis of the competitive funding landscape for research on biodiversity and ecosystem services in Europe. BiodivERsA report. https://www.biodiversa.org/563/download, accessed 18 September 2019
28. Ellis, G., Hunter, R., Tully, M. A., Donnelly, M., Kelleher, L., & Kee, F. (2016). Connectivity and physical activity: using footpath networks to measure the walkability of built environments. Environ Plann B Plann Des 43: 130-151. doi.org/10.1177/0265813515610672
29. Fahrig L (2013) Rethinking patch size and isolation effects: the habitat amount hypothesis. J Biogeog 40: 1649-1663. doi.org/10.1111/jbi.12130
30. van Dijk N, Taylor S, Morecroft M, Darch G, Duffield S, Buckle R, Wright J (2013) Assessing and enabling climate change adaptation in Nature Improvement Areas. Natural

England Commissioned Report NECR119. http://publications.naturalengland.org.uk/publication/5935762914672640, accessed 16 September 2019.

31. Garmendia E, Apostolopoulou E, Adams WM, Bormpoudakis D (2016) Biodiversity and Green Infrastructure in Europe: Boundary object or ecological trap? Land Use Policy 56: 315-319. doi.org/10.1016/j.landusepol.2016.04.003

32. Görg C (2007) Landscape governance: The "politics of scale" and the "natural" conditions of places. Geoforum 38: 954-966. doi.org/10.1016/j.geoforum.2007.01.004

33. Harding S (2006) Science and Social Inequality: Feminist and Postcolonial Issues. University of Illinois Press, Chicago.

34. Hawker G, Burrell P (2006) Oxfordshire Conservation Target Areas mapping project draft report. https://www.wildoxfordshire.org.uk/wp-content/uploads/2014/02/CTA-report-Introduction1.pdf, accessed 21 March 2019

35. Hodgetts T (2018) Connectivity as a multiple: In, with and as "nature". Area 50: 83-90. doi.org/10.1111/area.12353

36. Hodgson JA, Thomas CD, Dytham C, Travis JM, Cornell SJ (2012) The speed of range shifts in fragmented landscapes. PLoS One e47141. doi.org/10.1371/journal.pone.0047141

37. Hodgson, J. A., Moilanen, A., Wintle, B. A., & Thomas, C. D. (2011). Habitat area, quality and connectivity: striking the balance for efficient conservation. J Appl Ecol *48*, 148-152. doi.org/10.1111/j.1365-2664.2010.01919.x

38. Isaac NJ, Brotherton PN, Bullock JM, Gregory RD, Boehning-Gaese K, Connor B, Crick HQ, Freckleton RP, Gill JA, Hails RS, Hartikainen M (2018) Defining and delivering resilient ecological networks: Nature conservation in England. J App Ecol, 55: 2537-2543. doi.org/10.1111/1365-2664.13196

39. Knight AT, Cowling M, Rouget M, Balmford A, Lombard AT, Campbell BM (2008) Knowing but not doing: selecting priority conservation areas and the research-implementation gap. Conserv Biol 22: 610–617. doi.org/10.1111/j.1523-1739.2008.00914.x

40. Lawton JH, Brotherton PNM, Brown VK, Elphick C, Fitter AH, Forshaw J, Haddow RW, Hilborne S, Leafe RN, Mace GM, Southgate MP, Sutherland WA, Tew TE, Varley J, Wynne GR (2010) *Making space for nature: a review of England's wildlife sites and ecological network.* Report to Defra. Defra, UK.

41. Moilanen A (2011) On the limitations of graph-theoretic connectivity in spatial ecology and conservation. J Appl Ecol 48: 1543-1547. doi.org/10.1111/j.1365-2664.2011.02062.x

42. Moon,K, Brewer TD, Januchowski-Hartley SR, Adams VM, Blackman, DA (2016) A guideline to improve qualitative social science publishing in ecology and conservation journals. Ecol Soc, 21:3. dx.doi.org/10.5751/ES-08663-210317

43. Moyse R, Rowsell E (2007) A model for an ecological framework for Kent and Medway. Report for Kent Wildlife Trust, Kent County Council http://www.swale.gov.uk/assets/Planning-General/Planning-Policy/Landscape-Character-Appraisal-Final-Sept-2011/Appendix-B-Living-Landscapes-Methodology.pdf, accessed 27 October 2016

44. Nassauer JI (2012) Landscape as medium and method for synthesis in urban ecological design. Landscape Urban Plan 106: 221-229. doi.org/10.1016/j.landurbplan.2012.03.014

45. Nassauer JI, Opdam P (2008) Design in science: extending the landscape ecology paradigm. Landscape Ecol 23: 633-644. doi.org/10.1007/s10980-008-9226-7
46. Nowotny H, Scott P, Gibbons M (2003) Introduction: Mode 2'revisited: The new production of knowledge. Minerva 41: 179-194. doi.org/10.1023/A:1025505528250
47. O'Brien K (2013) Global environmental change III: Closing the gap between knowledge and action. Prog Hum Geog 37: 587-596. doi.org/10.1177/0309132512469589
48. Opdam P (2018) Exploring the Role of Science in Sustainable Landscape Management. An Introduction to the Special Issue. Sustainability 10: 331. doi.org/10.3390/su10020331
49. Opdam P, Coninx I, Dewulf A, Steingröver E, Vos C, van der Wal M (2016) Does information on landscape benefits influence collective action in landscape governance?. Curr Opin Env Sust 18: 107-114. doi.org/10.1016/j.cosust.2015.12.006
50. Opdam P, Nassauer JI, Wang Z, Albert C, Bentrup G, Castella JC, McAlpine C, Liu J, Sheppard S, Swaffield S (2013) Science for action at the local landscape scale. Landscape Ecol 28: 1439-1445. doi.org/10.1007/s10980-013-9925-6
51. Pinto-Correia T, Kristensen L (2013) Linking research to practice: The landscape as the basis for integrating social and ecological perspectives of the rural. Landscape Urban Plan 120: 248-256. doi.org/10.1016/j.landurbplan.2013.07.005
52. Plummer R, Armitage DR, de Loë RC (2013) Adaptive comanagement and its relationship to environmental governance. Ecol Soc 18: 21. dx.doi.org/10.5751/ES-05383-180121
53. Pullin AS, Knight TM (2005) Assessing conservation management's evidence base: A survey of management-plan compilers in the United Kingdom and Australia. Conserv Biol 19: 1989–1996. doi.org/10.1111/j.1523-1739.2005.00287.x
54. Salomaa A, Paloniemi R, Hujala T, Rantala S, Arponen A, Niemelä J (2016) The use of knowledge in evidence-informed voluntary conservation of Finnish forests. Forest Policy Econ 73: 90-98. doi.org/10.1016/j.forpol.2016.09.004
55. Snäll T, Lehtomäki J, Arponen A, Elith J, Moilanen A (2016) Green infrastructure design based on spatial conservation prioritization and modeling of biodiversity features and ecosystem services. Environ Manage 57: 251-256. doi.org/10.1007/s00267-015-0613-y
56. Somerset Wildlife Trust (2016) Somerset's Ecological Network: Mapping the components of the ecological network in Somerset. https://www.somersetwildlife.org/hres/Somerset%20Ecological%20Networks%20Report%202016.pdf, accessed 17 September 2019.
57. Swindon Borough Council (2011) A Green Infrastructure Strategy for Swindon 2010-2026. Available at https://www.swindon.gov.uk/download/downloads/id/3269/swindon_borough_open_space_audit_and_assessment_2014_part_a.pdf, accessed 30 Jan 2019.
58. Swyngedouw E (2005) Governance innovation and the citizen: The Janus face of governance-beyond-the-state. Urban Stud 42: 1991-2006. doi.org/10.1080/00420980500279869
59. Taylor S, Knight M, Harfoot A (2014) National biodiversity climate change vulnerability model. Natural England Research Report NERR054. http://publications.naturalengland.org.uk/publication/5069081749225472, accessed 17 September 2019.

60. Termorshuizen JW, Opdam P, Van den Brink A (2007) Incorporating ecological sustainability into landscape planning. Landsc Urban Plan 79: 374-384. doi.org/10.1016/j.landurbplan.2006.04.005

61. Toomey AH, Knight AT, Barlow J. (2017) Navigating the space between research and implementation in conservation. Conserv Lett 10: 619-625. doi.org/10.1111/conl.12315

62. UE Associates (2010) Green Infrastructure Strategy for the Partnership for Urban South Hampshire. Available at http://www.push.gov.uk/push_gi_strategy_adopted_june_10-2.pdf, accessed 19 October 2016

63. Villard MA, Metzger JP (2014) Beyond the fragmentation debate: a conceptual model to predict when habitat configuration really matters. J Appl Ecol 51: 309-318. doi.org/10.1111/1365-2664.12190

64. Von Haaren C, Reich M (2006) The German way to greenways and habitat networks. Landscape Urban Plan 76: 7-22. doi.org/10.1016/j.landurbplan.2004.09.041

65. Vos C, Berry P, Opdam P, Baveco H, Nijhof B O'Hanley J, Bell C, Kuipers H (2008) Adapting landscapes to climate change: examples of climate-proof ecosystem networks and priority adaptation zones. J Appl Ecol 45: 1722-1731. doi.org/10.1111/j.1365-2664.2008.01569.x

66. Watts K, Eycott A, Handley P, Ray D, Humphrey J, Quine C (2010) Targeting and evaluating biodiversity conservation action within fragmented landscapes: an approach based on generic focal species and least-cost networks. Landscape Ecol 25: 1305-1318. doi.org/10.1007/s10980-010-9507-9

67. Wu J (2013) Key concepts and research topics in landscape ecology revisited: 30 years after the Allerton Park workshop. Landscape Ecol 28: 1-11. doi.org/10.1007/s10980-012-9836-y.]

68. Wyborn C (2015a) Co-productive governance: A relational framework for adaptive governance. Global Environ Chang 30: 56-67. doi.org/10.1016/j.gloenvcha.2014.10.009

69. Wyborn C (2015b) Connecting knowledge with action through co-productive capacities: adaptive governance and connectivity conservation. Ecol Soc 20: 11. 1. dx.doi.org/10.5751/ES-06510-200111

70. Wyborn C (2015c) Cross‐Scale Linkages in Connectivity Conservation: Adaptive governance challenges in spatially distributed networks. Environ Policy Gov 25: 1-15. doi.org/10.1002/eet.1657

71. Youn H, Gastner MT, Jeong H (2008) Price of anarchy in transportation networks: efficiency and optimality control. Phys Rev Lett 101: 128701. doi.org/10.1103/PhysRevLett.101.128701

72. Žlender V, Thompson CW (2017). Accessibility and use of peri-urban green space for inner-city dwellers: A comparative study. Landscape Urban Plan 165: 193-205. doi.org/10.1016/j.landurbplan.2016.06.011

List of table captions

Table 1. Themes used in the analysis and examples of codes.

Table 2 A selection of quotes from conservationists pointing to the resources issues they have grouped according to resource type.

Table 3 Actors involved in preparing GI strategies, frameworks and plans in England, 2005-2015. Data compiled by the authors from a list of 58 documents available online (see supplementary material Table 1)

Table 1

Theme	Codes in theme (examples)
Concepts of connectivity	Functional connectivity; structural connectivity; planning concepts of connectivity (e.g. footpaths, cyclepaths)
Methods of connectivity assessment	Ecology based; planning based; graph-based methods; Fragstats; GIS-based; systematic methods
Criteria for method choice	Scientific legitimacy; resources; understanding of the method; connectivity analysis is simple
Implementation barriers	Resources, irrelevance of science

Table 2

Resource	Quote
Equipment (including software)	*We don't have access to GIS.*
	Some of them [NIAs] *are very capable, or others don't have any GIS capabilities.*
Personnel	*If this was done 10 years ago, I am sure I would have a team of 5 people, he would have a team of 5 people ... now we don't do in depth analysis, we do it quite broad brush.*
	We lost Ranger's Services ... from 11 staff now it's only 2
	We might be using a Fragstats approach, but no time for now.
Time	*The timescales were so quick and we were so pressurised so we had to be based on expert knowledge.*
	In two years you cannot do more than the baseline.
Budget	*The only way we measured connectivity is mean distance between occupied patches ... We don't have the resources to do more than that.*

Table 3

Type of organisation	Number of GI documents
Consultants	21
Consultants with business partnership	6
Consultants with district, local or county council	6
Consultants in a multi-stakeholder partnership*	6
County/District/Local Councils	10
Third sector	1
University	2
Community Forest	2
Partnership	1
Unknown	3

* Typically these multi-stakeholder partnerships are very diverse and include governmental or quasi-governmental organisations (e.g. Natural England), NGOs, local councils, development agencies, or even other partnerships.

List of figures

Figure 1. *Top Left*: Public spending in biodiversity as percentage of GDP, from http://jncc.defra.gov.uk/page-4251.*Top Right*: Absolute number of Natural England staff from the years leading up to the crisis up to now. Data compiled by the authors from Natural England annual reports and accounts, available at: https://www.gov.uk/government/collections/natural-england-annual-reports-and-accounts. *Bottom*: Full-time equivalent number of Forest Research staff from the years leading up to the crisis up to now. Data compiled by the authors from Forest Science annual reports and accounts, available at https://www.gov.uk/government/collections/forestry-commission-annual-reports. Increase of staff between 2016 and 2017 due to the "internal" move of 44 FT-equivalent staff from the Forestry Commission to Forest Research.

Figures

Figure 1

UK % spend of GDP on biodiversity

Natural England staff (number)

Staff numbers Forest Research (FT equivalent)

UK % spend of GDP on biodiversity

Natural England staff (number)

Staff numbers Forest Research (FT equivalent)
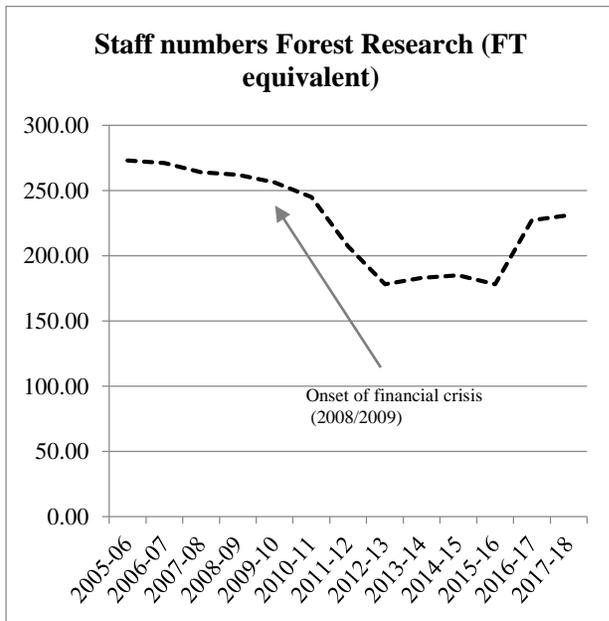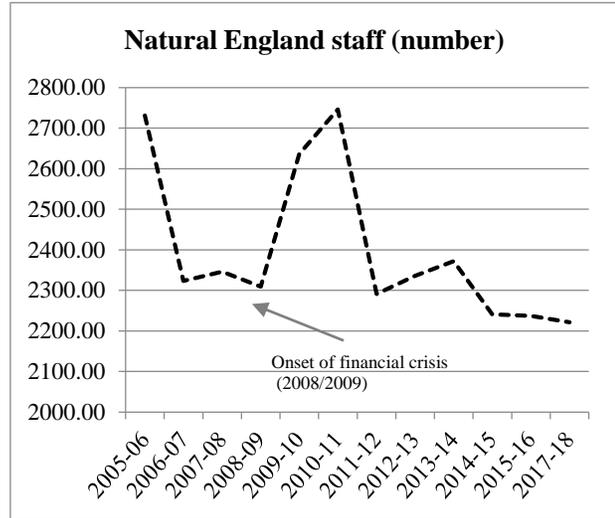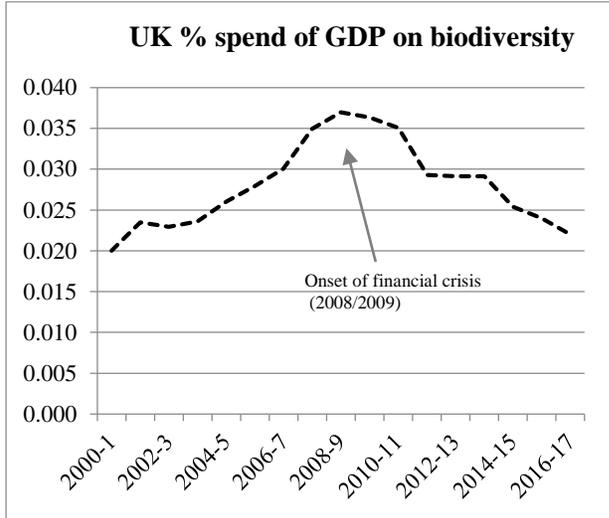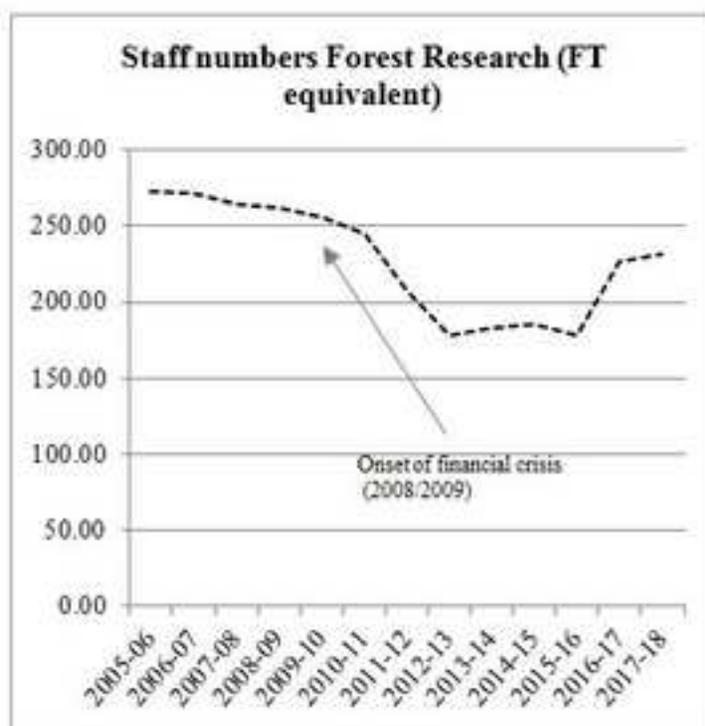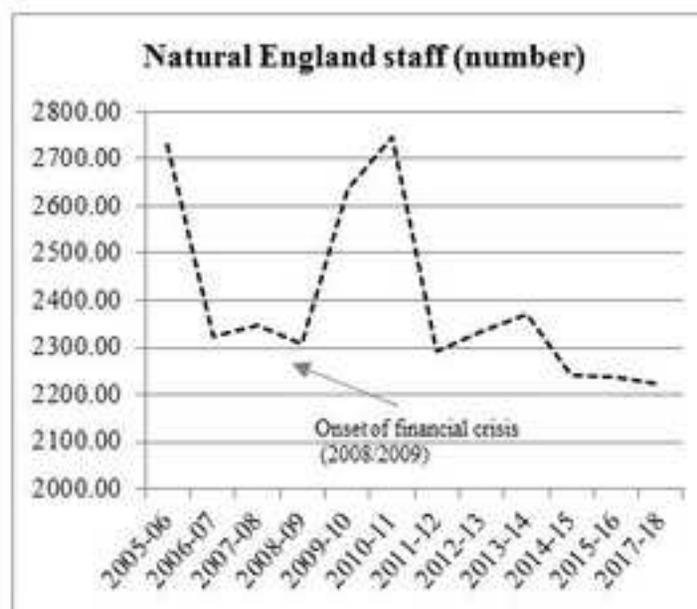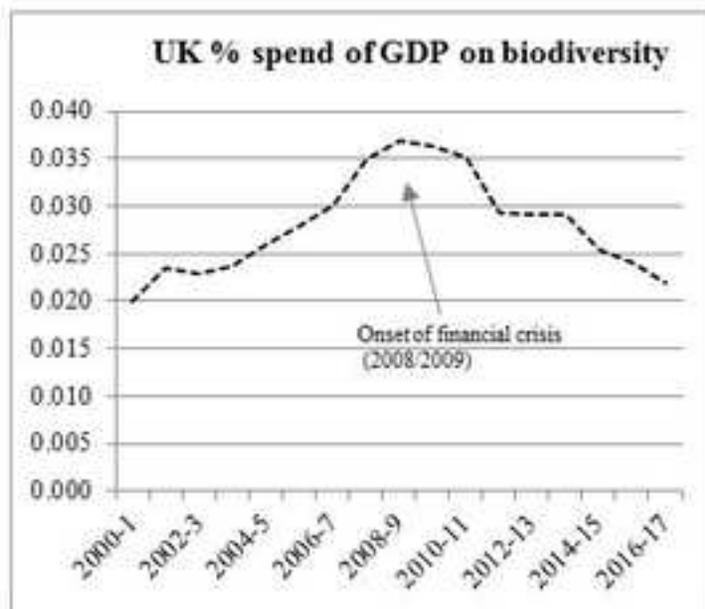
Click here to access/download
Supplementary material
supplement_LE.docx

Click here to access/download

Supplementary material

GI_locations.kml