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1 **The co-benefits of biodiversity conservation programmes on wider**
2 **ecosystem services**

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14 Abstract

15 While multiple ecosystem service benefits are increasingly emphasised in policy as an outcome for
16 land management, most conservation management and legislation is currently focused on
17 conserving specific species and habitats. These management interventions may provide multiple co-
18 benefits for other ecosystem services but more information is needed on where these synergies
19 occur in order to realise these benefits. In this paper, we use expert data obtained from structured
20 interviews with key stakeholders to examine the perceived impacts of 11 species-specific
21 conservation schemes on wider ecosystem services in Scotland, UK. With some exceptions, impacts
22 were perceived to be mostly positive or neutral, suggesting that there are many potential
23 opportunities when looking to manage for the delivery of multiple ecosystem services.
24 Unsurprisingly, 'wild species diversity' and 'environmental settings' are the ecosystem services
25 perceived to benefit the most from species conservation management. Despite the clear benefits of
26 aligning biodiversity conservation and ecosystem service objectives, many challenges remain and
27 future policy and associated management will need to tackle issues of scale as well as the
28 distribution of costs and benefits.

29 Keywords: Agri-environment, Expert data, Habitat management, Interview, Management
30 interventions, Species Action Framework

31

32 **1. Introduction**

33 Since the release of the Millennium Ecosystem Assessment (MA, 2005) there has been a growing
34 interest in the use of ecosystem services frameworks when looking for policy solutions that aim to
35 maximise ecosystem benefits from our landscapes. In particular, there is policy and practitioner
36 interest in designing management approaches consisting of multiple interventions that can address
37 multiple outcomes (e.g. biodiversity conservation, food security, water quality, natural flood
38 management, climate change mitigation and adaptation), and acknowledge and potentially minimise
39 conflict and trade-offs. This is especially relevant given that both natural and financial resources with
40 which we have to produce these essential ecosystem services are limited (Maskell, 2013).

41 Despite this interest, if the concept of ecosystem services is to be integrated more fully into land
42 planning and management, there are still many barriers that need to be overcome (de Groot et al.
43 2010). In particular, there is a need for increased understanding of how we can manage our
44 landscapes to deliver multiple ecosystem benefits given that in the past, the focus has often been to
45 produce large quantities of only a few ecosystem services, mainly timber, fibre, and food. We also
46 need to understand how ecosystem services interact so that trade-offs can be minimised and
47 synergies can be maximised in order to optimise benefits to ecosystems and society (Bennett et al.
48 2009; Howe et al, 2014). Identifying where these synergies exist in-line with how the land is
49 currently managed for certain ecosystem services is therefore essential for incorporating ecosystem
50 services more widely within existing land management practices.

51 While multiple ecosystem services are increasingly emphasised in policy as an outcome for land
52 management, most of the conservation management and legislation currently practised is tightly
53 focused on management interventions for conserving specific species and habitats (Maes et al. 2012;
54 Pearson, 2016). Nevertheless, many management interventions intended to benefit the
55 conservation of a particular species or habitat may bring multiple benefits in terms of the diversity of
56 other, wider ecosystem services provided (Bradbury et al. 2010; Rhymer et al. 2010; Fisher et al.

57 2011; Eastwood et al. 2016), especially if overall levels of biodiversity are enhanced (Rey Benayas et
58 al. 2009; Whittingham, 2011). Indeed, evidence suggests that the relationship between biodiversity
59 ecosystem service provision is often positive, although this relationship can be complex and service
60 dependent (Harrison et al. 2014).

61 Therefore, the co-benefits of managing for biodiversity may offer many opportunities for synergies
62 between traditional species conservation management and the delivery of a wide range of
63 ecosystem services but we need to understand these relationships much better in order to realise
64 these benefits in terms of optimised management (Mcfadyen, 2012; Whittingham, 2011; Ekroos et
65 al. 2014). We especially need to ask, which interventions can support multiple objectives, which
66 other objectives will continue to require bespoke action, and how this mix of multi-functional and
67 bespoke actions can be planned within a landscape.

68 In particular, there is a need for data on the type and costs of conservation management actions and
69 the outcomes of the management at a species, habitat and ecosystem service level. But there is
70 currently little empirical evidence on the effectiveness of different interventions in achieving these
71 co-benefits. Monitoring of outcomes is not always implemented, and where it is, it is rarely designed
72 to measure benefits in terms of wider ecosystem service provision (Raffaelli and White 2013). Where
73 empirical data on impacts are lacking, informal knowledge from stakeholders and other experts is
74 being used increasingly in the assessment of management interventions implemented as part of
75 conservation programmes (Cullen 2013). But with some exceptions (Austin et al., 2015; Laycock et
76 al. 2009, 2011, 2013) there are few studies that have used such information as part of a critical
77 assessment of the effectiveness or cost-effectiveness of species-specific conservation programmes,
78 regarding either their original objectives or the potential impacts of the schemes on ecosystem
79 service delivery.

80 In this paper, we use data obtained from structured interviews with expert stakeholders to examine
81 the perceived impacts of a number of species conservation schemes on wider ecosystem services in

82 Scotland, UK. We capture the perceived co-benefits of the conservation schemes on a pre-defined
83 list of ecosystem services, assess the strength of the impact, and whether it leads to an increase or
84 decrease in ecosystem service provision. Supplementary qualitative data were collected to examine
85 how and why these impacts are occurring, and how they might arise as a result of any specific
86 management interventions within the conservation programme. We use the quantitative and
87 qualitative data to identify potential synergies between traditional species management and the
88 delivery of wider ecosystem services in order to increase understanding of how we can manage our
89 landscapes to deliver multiple ecosystem benefits. Conservation schemes available within Scotland
90 form the focus of the study, but the approach and interpretation are relevant to the evaluation of
91 other biodiversity conservation programmes where information on ecosystem service co-benefits
92 are limited.

93 **2. Methods**

94 2.1. Identifying target species

95 The species conservation schemes considered in this paper (Table 1) were undertaken through a
96 number of elements of the Scotland Rural Development Programme (SRDP), which helps to deliver
97 the European Union's Rural Development Regulation in Scotland, in addition to other historic
98 funding programmes such as the Scottish Natural Heritage's (SNH) Natural Care programme.
99 Together these programmes contribute to the implementation of the Scottish Biodiversity Strategy,
100 which in is in turn pursuant to overall UK biodiversity commitments. The SRDP under consideration
101 covered the period 2007-2013.

102 To help deliver the Scottish Biodiversity Strategy, SNH recognised that there was a need to prioritise
103 species management, focusing on those where significant gains to overall biodiversity were
104 expected. As a result, a Species Action Framework (SAF) produced in 2007 set out a strategic
105 approach to species management in Scotland. It also identified a 'Species Action List' of 32 species

106 that were the focus of new, targeted management interventions between 2007 and 2012
107 (<http://www.snh.gov.uk/protecting-scotlands-nature/species-action-framework/>).

108 The species selected for this study were drawn from the SAF and include a mix of native bird,
109 mammal, amphibian, insect, fungi and plant species of conservation interest (black grouse,
110 capercaillie, hen harrier, sea eagle, red squirrel, great crested newt, marsh fritillary butterfly, slender
111 scotch burnet moth, hazel gloves fungus, and water vole). These species were those for which we
112 could identify observable conservation actions and monitoring taking place, which was not the case
113 for all species within the SAF. One of our selected study species (corncrake) was not included in the
114 SAF, but was included in our study due to the scale of conservation action being undertaken,
115 including targeted options within the SRDP. The range of species selected and the diversity of
116 habitats they occupy also provide an opportunity to examine a wide variety of management
117 interventions when considering their perceived impacts on ecosystem services (Table 1).

118 2.2. Stakeholder interviews

119 Semi-structured interviews were conducted with expert advisors for each case study species to
120 examine the perceived impacts of these selected species conservation schemes on wider ecosystem
121 services. Key contacts were identified for each species by the project team and included species
122 leads and advisors from public agencies (SNH, Forestry Commission); conservation NGOs (Royal
123 Society for the Protection of Birds, Game and Wildlife Conservation Trust, Butterfly Conservation
124 Scotland); land owner and other stakeholder groups (Scottish Land and Estates, SAC Consulting).

125 These participants were selected for their expertise on the species concerned and their management
126 and not for their expertise on ecosystem services per se. This study was specifically focussed on the
127 perceived impacts of species conservation programmes and these experts were best placed to
128 comment on this as species lead advisors. However, the ecosystem service approach is increasingly
129 driving policy and strategy, so the interviewees in this study and their organisations (mentioned

130 above) will be extremely familiar with the approach. Finally, the interviews were given information
131 regarding ecosystem services well in advance of the interview and were given time at the start of the
132 interview to ask any questions and raise any queries regarding this approach, as explained below.

133 A total of 20 interviews were conducted with 16 interviewees between October and December
134 2012. A total of 18 interviews (involving 15 interviewees) were used further in the data analysis due
135 to incomplete answers. Of the 15 interviewees, three were interviewed regarding two species and
136 the remainder regarding one species each). The resulting number of interviews regarding each
137 species varied from one to four (Table 1). Each interview typically lasted between 1 and 2 hours
138 depending on the number of species under consideration. Interviewees were sent information
139 regarding the interview questions and topic areas prior to the interview, and were asked if they
140 understood all of the ecosystem service categories beforehand. These were explained further by the
141 interviewer if needed.

142 Face-to-face interviews were conducted where possible, although telephone or video conference
143 interviews were undertaken where necessary. Interviews were recorded with the permission of the
144 participants to support the extensive notes that were taken at the time of interview.

145 2.3. Assessment of wider ecosystem service co-benefits

146 The interviewees were first asked a series of questions relating to the type of management
147 interventions that were taking place for the conservation of the species. For each of our selected
148 species there was a range of applicable SRDP interventions either specifically targeting that species,
149 or that provided potentially relevant conservation actions. We identified the funding that was
150 directly related to our study species or linked to the species through published scheme literature.
151 The interviewees were asked to check the list of management interventions for their focal species(s)
152 and to rate their familiarity with those interventions. They were also asked questions relating to
153 relative costs and the effectiveness of the schemes in relation to specific objectives (full details of

154 these results are the subject of a previous paper, Austin et al 2015). The interviewees were then
155 asked to assess the wider effects of species interventions in terms of their impacts on different
156 categories of ecosystem services as classified by the UK National Ecosystem Assessment (Figure 1).
157 In particular, the participants were asked to consider the extent to which the biodiversity
158 conservation programmes (and associated management interventions) linked specifically to the
159 species that they manage, might lead to changes in the provision of these ecosystem services. They
160 were then asked whether, based on their expert judgement, impacts on these ecosystem services
161 might lead to slight or large increases in ecosystem service provision (scores of 1 or 2 respectively) or
162 lead to slight or large decreases in ecosystem service provision (scores of -1 or -2 respectively).
163 When participants were asked to give their score, they were also asked to explain the context
164 behind the score that they gave. For example, if a participant thought that management
165 interventions intending to benefit the species black grouse would lead to a decrease in the provision
166 of the ecosystem service category 'crops, livestock and fish', they were then asked to explain their
167 answer and include information on any specific impacts, specific management interventions and the
168 scale at which this impact was perceived to be taking place. (A summary of the main questions asked
169 at interview are listed in Supplementary information A).

170 **3. Results**

171 Our results show that across all of the species-related interventions examined in this study, the
172 greatest perceived co-benefits (on average) were associated with the ecosystem service categories
173 of 'wild species diversity', 'environmental settings' and 'pollination' (Figure 2). The lowest perceived
174 co-benefits (on average) were associated with the ecosystem service category 'water supply' and
175 there were no perceived co-benefits for the ecosystem service category of 'noise regulation' (Figure
176 2). These ecosystem services were therefore not examined further.

177 There were positive average impact scores associated with the species-related interventions on 10
178 ecosystem services overall, but this is subject to differing levels of variability for each ecosystem

179 service (Figure 2). The perceived impact scores differ for each ecosystem service according to focal
180 conservation species and in some cases there are perceived negative impacts associated with
181 species-related interventions for some ecosystem services (Figure 3a-3i).

182 Specifically, negative impacts were perceived in relation to some conservation management actions
183 for certain species with respect to 'wild species diversity' (Figure 3a), 'trees, standing vegetation and
184 peat' (Figure 3e), 'crops, livestock and fish' (Figure 3f) and 'disease and pest regulation' (Figure 3i).
185 Interventions intending to benefit hen harriers have perceived negative impacts across three of
186 these ecosystem service categories. The qualitative data collected enabled us to examine this further
187 (a summary of the qualitative data collected is provided in Supplementary Information B). According
188 to one interviewee, management for hen harriers may have a negative impact on the 'crops,
189 livestock and fish' due to the potential de-stocking of livestock to improve moorland habitat for this
190 species.

191 However, there were also negative perceived impacts on ecosystem service provision as a result of
192 management for other species. According to one interviewee, the management interventions
193 associated with the conservation of great crested newts can result in a loss of natural vegetation
194 which may impact negatively on the ecosystem service of 'trees, standing vegetation and peat' at
195 the local scale (Figure 3e). Management interventions associated with black grouse conservation
196 may lead to de-stocking of livestock and may therefore have a small negative impact on this
197 ecosystem service, as can management for sea eagles according to the interviewee(Figure 3f).
198 However, the sea eagle management plan has been introduced by SNH to support livestock farmers
199 if this occurs.

200 Despite these negative perceived impacts, for many of the species-related interventions, the
201 perceived impacts on ecosystem services are mostly neutral or positive. In particular we found that
202 management interventions intended to benefit three of the bird species (black grouse, capercaillie
203 and corncrake) had mostly positive perceived co-benefits for all ecosystem services (Figures 3a-3i).

204 This is with the exception of black grouse impacts on livestock as mentioned above. The qualitative
205 data collected were essential in understanding these findings. For example, our interviewees
206 explained that conservation management interventions for black grouse and capercaillie may
207 include planting trees - which may lead to increases in the provision of this ecosystem service which
208 will have knock-on implications for the provision of the ecosystem service of 'environmental
209 settings' (as native forestry increases, more people may visit the area). In addition, the other
210 management interventions associated with this species (such as the creation of species rich
211 grassland) may also lead to increases in other non-target bird species and greater pollination
212 provision. For the corncrake, management interventions such as late mowing and cutting
213 management are likely to have positive co-benefits for wider species diversity (especially butterflies
214 and wildflowers), pollination (as a result of more pollinators) and the ecosystem service category
215 'environmental settings'.

216 **4. Discussion**

217 Empirical data relating to ecosystem service co-benefits from species conservation management are
218 rarely collected, and we have therefore utilised informal expert knowledge from key stakeholders
219 and managers. We did not seek to quantify the amount of service provision, either in absolute terms
220 for each category or in relative terms across categories. This reflects our need to apply the
221 assessment scheme across a range of species, and that on the whole, the scoring was undertaken by
222 different people for each species (some interviewees considered multiple species). These
223 participants were selected for interview as they were identified as the key advisors for each species
224 and their related conservation schemes. The quantitative and qualitative data that they gave
225 regarding the related impacts on ecosystem services reflect years of experience and expert opinion
226 based on related data regarding each species. Nevertheless, our results are based on stakeholder
227 perceptions (sometimes from one participant for an individual species conservation programme) and

228 not directly from empirically derived data, and this should be considered when interpreting the
229 results.

230 In this paper, we have found that the perceived co-benefits of some key species-specific
231 conservation interventions are clearly leading to impacts on wider ecosystem services. With some
232 noted exceptions, such co-benefits were positive (or neutral) for many species-specific interventions
233 suggesting that there are many potential areas for synergies when looking to manage for the
234 delivery of multiple ecosystem services. In particular, we found that the current habitat
235 management interventions for the three bird species (black grouse, capercaillie and corncrake) may
236 offer many other positive co-benefits, as supported by previous studies (Wilkinson et al, 2012)
237 Unsurprisingly, 'wild species diversity' and 'environmental settings' are likely to benefit the most
238 from the current conservation interventions practised for these species. However, there is now a
239 need to understand more about the processes that lead to these co-benefits in order to ensure that
240 potential ecosystem service benefits are achieved.

241 Since this study was undertaken, the subsequent Scottish Rural Development Programme (2014-
242 2020) has incorporated the potential for any one conservation scheme to provide multiple
243 environmental benefits into the approach <http://www.gov.scot/Topics/farmingrural/SRDP>).
244 Nevertheless, at the time of writing, the issue of monitoring outcomes still needs to be resolved.
245 Arguably, if adequate ecosystem service indicators can be developed and measured at sufficient
246 temporal and spatial resolution, then we may also be able to indirectly determine the potential
247 effectiveness of conservation schemes.

248 This study highlights the potential for and direction of impact regarding the co-benefits (or dis-
249 benefits) of species biodiversity conservation on ecosystem service provision. We have seen within
250 our results that managing for biodiversity may not always result in positive impacts for some
251 ecosystem services. For some ecosystem services, evidence suggests that increased levels of
252 biodiversity can lead to increases in the levels of service provision (Harrison et al. 2014). However, in

253 some cases, the diversity needed to provide certain services may be low compared to those required
254 by biodiversity conservation objectives. For example, monocultures or exotic species can be more
255 effective at providing certain ecosystem services when compared to a diverse community of native
256 species (Bullock et al, 2011). While there may be situations where multiple objectives can be
257 achieved simultaneously, future landscape planning policy and practice will need to acknowledge
258 any trade-offs when looking to deliver multiple ecosystem services (Howe et al, 2014).

259 Many of the perceived ecosystem service impacts associated with biodiversity conservation schemes
260 that were captured in this study are occurring on a local scale and are therefore more difficult to
261 observe at the regional level across which policy operates. This is not to say that impacts from local-
262 scale management interventions are not contributing to ecosystem services at a larger scale, but
263 they may have a greater impact if they were applied at the landscape level rather than on individual
264 sites without taking into account the surrounding management (Mckenzie et al, 2013). This issue of
265 scale creates further challenges when it comes to beneficiaries and who pays for the management
266 interventions. In this study we have examined biodiversity conservation schemes which encourage
267 landowners to manage their land for the benefit of wildlife and the environment. Currently,
268 landowners are only compensated for the management interventions that contribute to local
269 impacts on biodiversity and not for their contribution to wider-scale ecosystem services, but the
270 beneficiaries of those ecosystem services will be the wider community and the public, in addition to
271 local private landowners (Macfadyen et al, 2012). A more comprehensive understanding of the
272 beneficiaries and providers of management interventions, and their distribution in space and time,
273 would help to underpin the development of new strategies that seek to optimise ecosystem services
274 and biodiversity conservation delivery.

275 **Conclusions**

276 It is clear that existing biodiversity conservation schemes targeted at certain species have both
277 positive and, in some cases, negative impacts on wider ecosystem services. We have identified

278 where synergies between biodiversity conservation schemes and their co-benefits for wider
279 ecosystem services are likely to occur, but further empirical data from monitoring studies would be
280 useful to support specific recommendations for integrative management to deliver multiple
281 biodiversity and ecosystem service objectives from landscapes. We have focused on conservation
282 schemes within Scotland to examine these issues, but the approaches used and interpretations
283 drawn could be applied to the assessment of other biodiversity conservation programmes where
284 potential impacts on wider ecosystem services are unknown. A universal consideration is that
285 despite the clear benefits of aligning biodiversity conservation and ecosystem service objectives,
286 many challenges remain. Any future policy and associated mechanisms for optimising both
287 objectives will need to tackle issues of scale as well as the distribution of costs and benefits..

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293

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369

370

Table 1. Examples of management interventions undertaken as part of conservation schemes for the selected species (non-exhaustive list). Examples of the habitat where the species occurs are also provided (non-exhaustive list). The number of interviewees who gave information on each species conservation scheme is listed in the final column.

Species	Examples of species habitat	Examples of management interventions	Number of interviewees
Black grouse (<i>Lyrurus tetrix</i>)	Mosaics of moorland and heathland, early stages of coniferous plantations, rough grazings and traditionally managed meadows.	Creation and management of species-rich grassland, moorland grazing management, native woodland creation.	4
Capercaillie (<i>Tetrao urogallus</i>)	Native pinewoods, with dense ground cover of blaeberry and heather, but will also use commercial conifer plantations and small numbers remain in a few upland oak woods in Tayside.	Native woodland creation, woodland management (restructuring, woodland grazing, livestock removal, reducing deer impact etc), mammal and bird predator control.	3
Hen harrier (<i>Circus cyaneus</i>)	Hen harriers breed on moorlands, peatlands and conifer plantations usually below 500m. Grasslands provide valuable foraging habitats. In winter, birds move to open countryside (lowland farmland, marshland, fenland, heathland and river valleys).	Moorland management including de-stocking of sheep, mammal and bird predator control, woodland management (restructuring, woodland grazing, livestock removal, reducing deer impact etc), supplementary food provision.	1

Sea eagle (<i>Haliaeetus</i>)	Found in coastal areas and reintroduced to Scotland in 1975. A self-sustaining population has now formed on the west coast of Scotland	Management of coastal areas, wetland, moorland grazing, sustainable management of native woodlands.	2
Corncrake (<i>Crex crex</i>)	In Scotland (April – September), corncrakes live in tall vegetation in hayfields and farm grasslands	Grass mowing and cutting management, management of cover for corncrakes, traditional cropping of Machair.	1
Red squirrel (<i>Sciurus vulgaris</i>)	Conifer and broadleaf woodland	Control of grey squirrel for red squirrel conservation, creation and management of woodlands.	2
Great crested newt (<i>Triturus cristatus</i>)	Areas of lowland that contain medium sized ponds, rough grassland, scrub and woodland	Create, restore and manage wetland, manage grass margins, scrub and tall herbs.	1
Marsh fritillary butterfly (<i>Euphydryas aurinia</i>)	In Scotland, the main habitat is coastal grasslands with temporary colonies in large (>1 ha) woodland clearings and in other grasslands	Management of habitat mosaics, creation and management of species-rich grassland, grazing management of cattle.	1
Slender Scotch burnet moth (<i>Zygaena loti</i>)	Species rich grassland areas close to the coast	Management of habitat mosaics, creation and management of species-rich grassland, grazing management of cattle.	1

Hazel gloves fungus <i>(Hypocreopsis rhododendr)</i>	Atlantic Hazel woodland	Management of scrub and tall herb communities, sustainable management of native woodlands.	1
Water vole <i>(Arvicola amphibious)</i>	Densely vegetated banks of slow flowing rivers, ditches, lakes and marshes where water is present throughout the year	Control of the invasive species mink, management of wetland (create and restore).	1

Figures

Figure 1: Final ecosystem services and ecosystem goods. *Source: UK NEA (2011), adapted from Fisher et al (2008).*

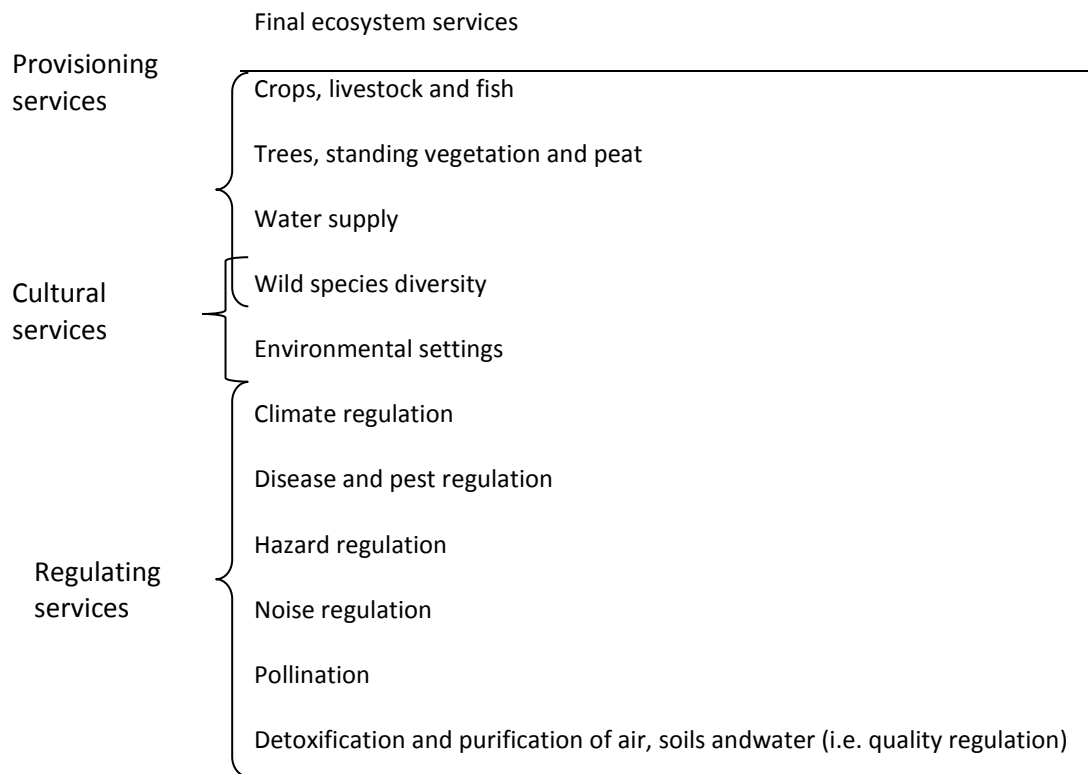


Figure 2. Average perceived impact scores on ecosystem services across all species conservation programmes. An average of all final impact scores for each species relating to each ecosystem services was calculated to show average impacts for each ecosystem service category. Scores for individual species can be positive or negative in relation to impacts on different ecosystem services (see Figure 3). Therefore, all means were positive but some species actions had negative impacts on some ecosystem services. Standard error bars are shown for each ecosystem service category to show variation within the data.

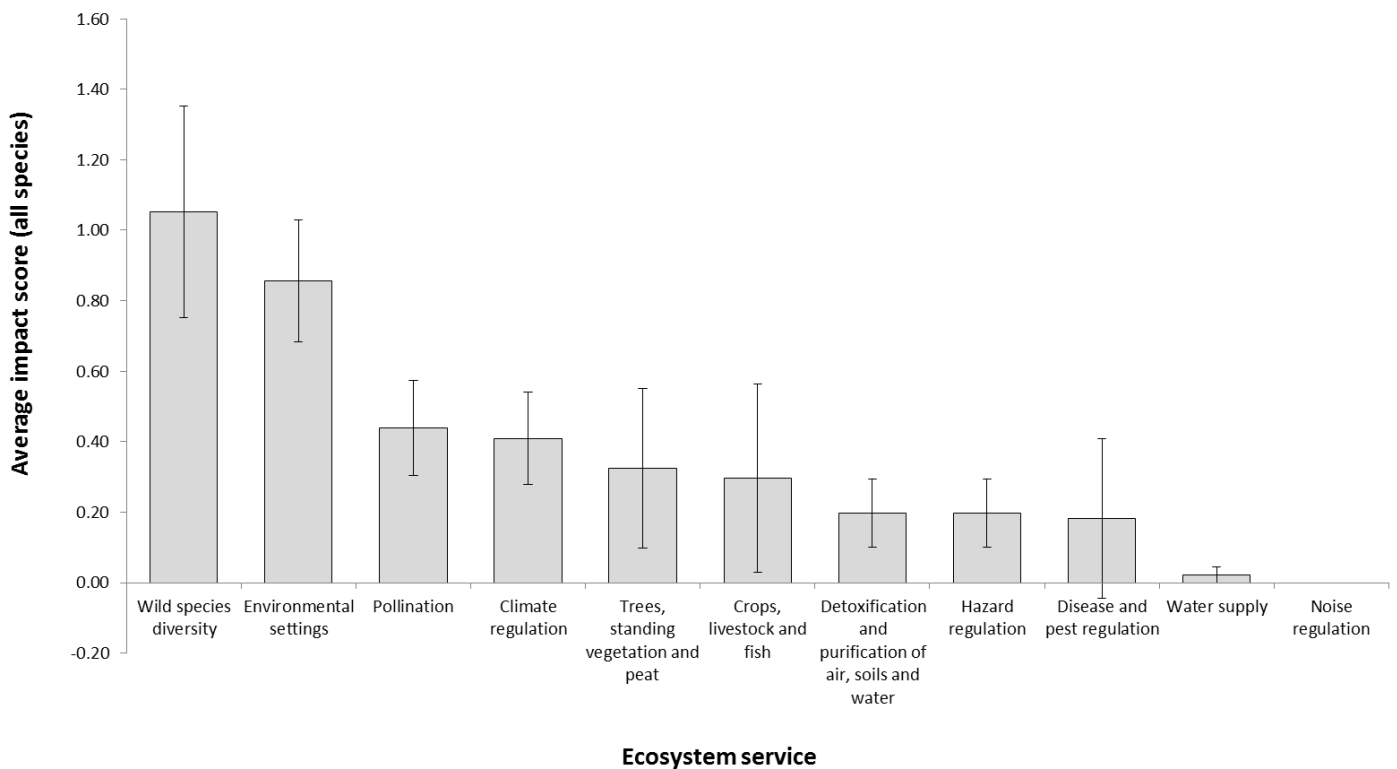
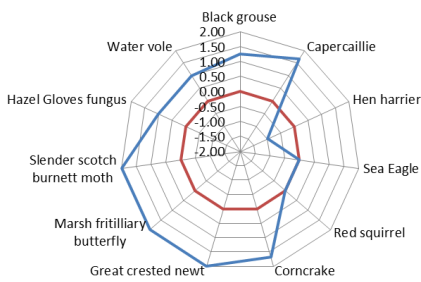


Figure 3. Web diagrams showing perceived impact scores (co-benefits) on ecosystem services for each of the species conservation programmes. Where there was more than one participant commenting on the impacts regarding management aimed at one particular species, an average has been taken. Where there is a no score, or a score of zero, this is taken to mean that there is no 'known' impact on the ecosystem service, according to the participant. The red line on each diagram marks where a score of zero would be and the blue line reflects the average impact scores given regarding each species conservation programme.

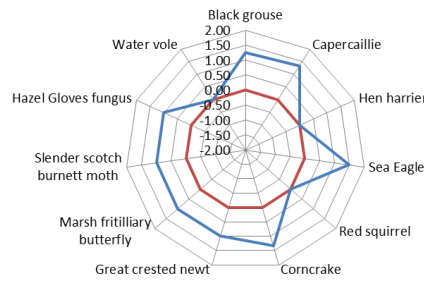
3a.

Wild species diversity



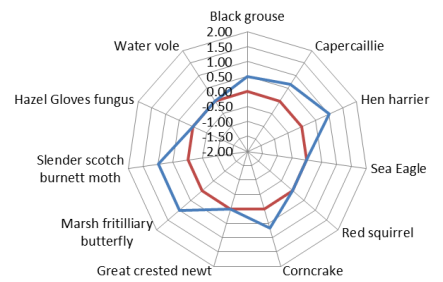
3b.

Environmental settings



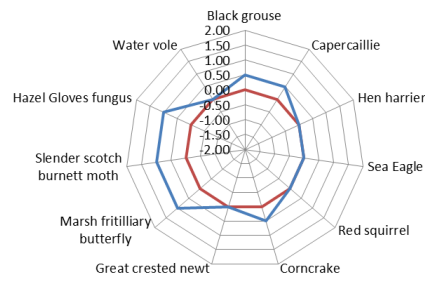
3c.

Pollination



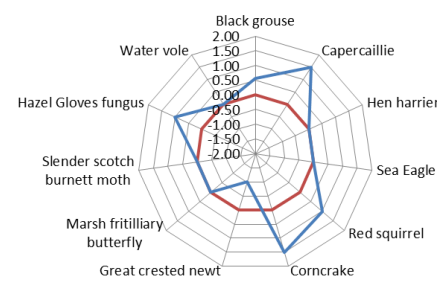
3d.

Climate regulation



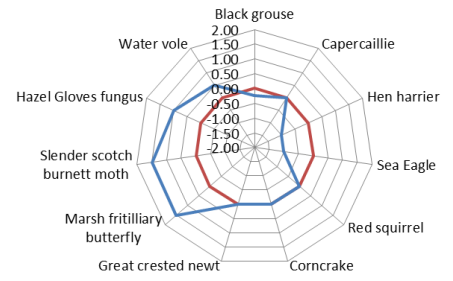
3e.

Trees, standing vegetation and peat



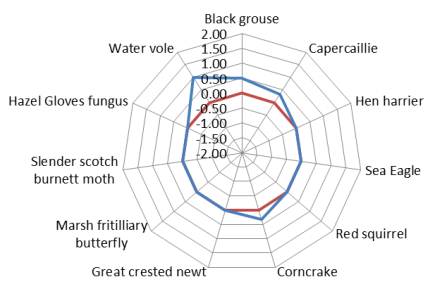
3f.

Crops, livestock and fish



3g.

Detoxification and purification of air, soils and water



3h.

Hazard regulation

