METHOD FOR THE ASSESSMENT OF PRIORITIES FOR INTERNATIONAL SPECIES CONSERVATION

(MAPISCo)

Final Report

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1. Executive summary

Context. Biodiversity is declining at unprecedented levels globally, and meeting international targets aimed at halting these declines requires conservation efforts targeted not only at species but also at other aspects of biodiversity such as habitats, cultural values and ecosystem services. In spite of this wide range of targets requiring investment, resources available are declining. Against this backdrop, the UK Department for Environment, Food and Rural Affairs (Defra) sought, via this project, to develop a methodology for identifying species for which targeted conservation action would have the broadest consequential benefits (hereafter co-benefits) on other species, habitats, wider ecosystems, and ecosystem services.

Agreed scope and aims. The objective of the MAPISCo project was to develop a scoring method that enables species to be **ranked** based on their combined contribution to a selection of co-benefits linked to conservation targets (Aichi Targets). Concentration of conservation on these high-ranking species would, in theory, result in the largest associated biodiversity benefit. This methodology would be **expandable**, able to include further datasets should they become available, **adaptable**, with the weighting of co-benefits able to be altered in line with varying policy aspirations, and **usable**, ultimately able to be used by non-expert practitioners.

Selection of co-benefits. Five co-benefits were selected for inclusion in the methodology- (1) habitat and area conservation (Aichi Targets 5 and 7), sustainable harvesting of fish, invertebrates and aquatic plants (Aichi Target 6), (3) conservation of genetic diversity of wild relatives of cultivated plants and domesticated animals (Aichi Target 13), (4) protection of the provisioning of ecosystem services (Aichi Target 14) and (5) the prevention of species extinctions (Aichi Target 12). The selection of these co-benefits was based on the Aichi Targets of policy interest to Defra. They could also be linked in a scientifically defensible way with conservation effort on a species level AND have adequate data associated with them (from preliminary searches) to be related to species conservation lists, incurring as few taxonomic and geographic constraints as possible. However, it should be stressed that this methodological framework can be extended to include more co-benefits in the future, given, for example, specific policy needs (**expandable**).

Scoring. The methodology proposed here produces species lists ranked by their expected value in contributing to each of the five focal co-benefits under consideration. First, reliable data sources were identified that could be used to quantify the value of a given species to each of the five co-benefits. Species from these data sources were then added to a database and given a score for each of the five co-benefits. Details of how this was done are explained briefly in Table S1. The scores from each database were then combined to obtain an overall value that corresponds to species rank (see Box S1). Twelve data sources were found to be suitable for inclusion in the database at this stage. Many more were identified but later disregarded because of issues with data coverage and compatibility. The weighting, or importance, of each co-benefit can be adjusted in response to policy aspirations – this makes the methodology highly **adaptable.**

Results – example priority lists. The results generated by the database in its current format are constrained by data availability (e.g. only around 3% of all plant species have been categorised on the IUCN Red List while almost all bird species are included). For this reason in this section we present three different sets of results 1. All species, 2.Birds only (taxonomic case study) and 3. SE Asia only (geographic case study). The use of case studies allows us to focus on discrete sets of data, which, while not eliminating the constraints completely, allows a more meaningful demonstration of how the database can be used. For each set of lists we have outlined the main findings from the method followed by a discussion of how some of the key findings could be related to policy actions.

Generally, the results indicate that “politically interesting” or flagship species often championed by interest groups do not generally rank highly (e.g. Polar Bear *Ursus maritimus* 45625th and White Rhinoceros *Ceratotherium simum* 51510th), because they are associated with only a small number of the co-benefits considered here. There are 1064 species which occur in the top 500 regardless of changes in the co-benefit weightings, these include 502 birds, 161 mammals, 158 amphibians, 151 fish, 54 plants, 20 reptiles and 18 “other” species. This reflects the need for more data on plants, reptiles and invertebrates. Both the Habitat and Ecosystem Services co-benefits are significantly negatively correlated to Threat Status, meaning that more traditional approaches to conservation (based on extinction risk- the IUCN Red List) do not capture more recent concerns about protecting a range of co-benefits from each species. The MAPISCo methodology successfully prioritises both extinction risk and contribution to co-benefits.

Using the method. **Expandable**. We demonstrate how additional species or co-benefit data can be added to the database, and outline how such changes impact on the ranking of priority lists. **Adaptable**. We examine the effect changing individual co-benefit weightings (i.e. making certain co-benefits “more important” in the calculation of priority lists than others) has on priority list ranking. **Usable**. Here we outline the development of a web-based interface, which, using a variety of tabs and graphics, allows users to fully explore the priority lists created by the methodology under a number of different scenarios. Importantly, it also enables user to investigate how varying individual co-benefit weightings impact upon rankings. We view this as a critical feature of the Graphical User Interface (GUI), as it makes it extremely adaptable to policy aspirations. Further investment in this project could see this tool becoming available (open source) to interested parties

Discussion and project legacy. We conclude that we have delivered a methodology that can prioritise species for conservation based on their expected contributions to a selection of co-benefits. Thus, higher-ranking species should make greater contributions to meeting relevant Aichi Targets (5-8 and 12-14). This methodology is **expandable** – additional datasets can be added to it should they become available, **adaptable** – co-benefit weightings can be altered to fit with individual policy aims and **usable** – the development of a graphic user interface will allow non-technical users to use the method.

The original ambitious conceptual development of MAPISCo was rooted in the desire to embed science firmly in international species policy. The core issue was that biodiversity spending can tend towards projects focussed on charismatic animals with little evidence scientific justification for such action. The method we present here yields priority lists based on available scientific evidence but there are major caveats. The most important is the paucity of data available for some taxa (especially plants). Whilst our analysis based on a well-known taxon (birds) for which all species are assessed on the Red List does yield potentially usable results other prioritisation results based on combining taxa are inevitably strongly constrained by data availability.

As a consequence of this we therefore outline a road-map to overcoming the challenges of linking science and policy effectively in biodiversity governance in a way that will help ensure that MAPISCo strengthens the UK’s ability to maximise the wider value to biodiversity of its spend on international species conservation.

Conclusion. We have developed a methodology which provides a broad-brush mechanism for identifying species conservation priorities based on a selection of co-benefits. These co-benefits are based on currently available and accessible data that are accepted to be good quality and have the potential to be expanded as new data emerges. The project has demonstrated that the choice of co-benefits, the importance given to them and the data sources used has a strong effect on which species are identified as being higher priorities. Therefore, explicit policy decisions are required (and need to be documented) throughout the prioritisation process. This finding alone is a significant contribution to increasing engagement at the science-policy interface, because it shows how closely intertwined the two spheres are. This feature of MAPISCo is likely to make it more policy relevant than other prioritisation processes which are less sensitive to the practicalities of policy-making. Implied in the original project brief is an assumption of a relatively straightforward and linear science-policy interface, where policy asks a question, science answers it and then policy decides what action should be taken. In practice, while this assumption has proved broadly accurate, this must go hand in hand with meaningful dialogue between policy-makers and scientists so that the best information available is used to inform policy as soundly as possible. There is clear scope for Defra to build on the progress made in this project to allow scientific knowledge and practice to better support UK government objectives. Overall, there is significant potential for the methodology we have developed to become part of an iterative process where conservation science and policy continually inform each other to produce evidence-based scientific policy that is more relevant to society.

Table S1. *The data sources and scoring format used for each of the five co-benefits currently included in the methodology. With further development we envisage being able to include a greater number of data sources.*

Co-Benefit	Which data source do scores come from?	How were species scored? *
1. Habitat/area conservation	1) Important Bird Area (IBA)	1) Mean (average) number of co-occurring species of conservation concern (e.g. at high risk of extinction) in all of the IBA's in which a species occurs.
	2) Alliance for Zero Extinction (AZE)	2) Total number of species of conservation concern co-occurring with the target species in an AZE
2. Sustainable harvesting	3) "FishBase" data on commercial value in fisheries	3) 1-6 (1=no interest, 6=highly commercial
	4) IUCN Red List listed as affected by aquaculture	4) 1-3 (1=unknown, 3=industrial)
	5) "FishBase" for species used in aquaculture	5) 1 or 0 (1 if listed, 0 if not)
3. Conservation of genetic diversity	6) Database of crop wild relatives	6) 1 or 0 (1 if listed, 0 if not)
	7) Lists of wild relatives of domesticated animals	7) 1 or 0 (1 if listed, 0 if not)
	8) Plants listed as of medicinal use	8) 1-3 (least to most use)
4. Protection of ecosystem services	9) Carbon loss through deforestation (country-level)	9) Estimate of loss of carbon through deforestation (tonnes/year)
	10) Freshwater availability (country-level)	10) Availability of freshwater per capita per year (m^3/capita/year).
5. The prevention of extinctions	11) IUCN Red List (for animals) 12) SRLI (for plants)	11) & 12) 1-9 (1= extinct, 2= least concern, 9=critically endangered)

**These scores were rescaled to between 0 and 1 for the final ranking process and then standardized to give equal weighting between scores.*

Box S1: A worked example of the final priority score calculation

The final priority score for a species is the sum of the scores given for the five co-benefits. The method for calculating co-benefits scores is outlined below.

1) Mean taken of the scores assigned from original individual datasets (in this example, two different datasets).

2) The mean score calculated in step 1 is then standardised by taking away from it the mean of all the values in the entire co-benefit column, then dividing it by the standard deviation of that co-benefit mean (calculation of a "z score"). The resultant score will be positive if the individual species score is greater than the mean score and negative if the individual species score is smaller than the mean score.

Species	Habitat	Harvesting	Genetic diversity	Ecosystem Service Provisioning	Threat status	**Final Score**
Francolinus camerunensis	(0.136+0.789)/2 =***0.462***	(0+0+0)/3 = ***0***	(0+0+3)/3= ***0.333***	(0.323+0.975)/2 =***0.649***	max(0.778,0) = ***0.778***	((5.05)+(-2.58)+ (0.82)+(0.77) +(1.35)= **5.42**
	0.462-0.07 ***0.08*** ***= 5.05***	***0-0.25*** ***0.10*** ***=-2.58***	***0.333- 0.24 0.11*** ***=0.82***	***0.462-0.55*** ***0.11*** ***=0.77***	***0.462-0.45*** ***0.25*** ***=1.35***	
	5.05*1	***-2.58*1***	***0.82*1***	***0.77*1***	***1.35*1***	

3) The new co-benefit score is then multiplied by a weighting factor (in this case all co-benefits are weighted equally (i.e. weighting set to 1).

4) Final score calculated by adding together the 5 co-benefit scores. This score is then used to rank species in the priority list.

2. Introduction

***Capsule**.*

- *With biodiversity declining at unprecedented levels globally, the choice of where and how to invest biodiversity conservation effort is becoming increasingly difficult.*
- *This project seeks to develop a methodology by which species can be prioritised for conservation based not only on individual species benefits, but also on the contribution their conservation may make to other species, habitats, wider ecosystems, and ecosystem services.*
- *This project aims to help bridge the gap between the contrasting spheres of science and policy.*

2.1. Background

Biodiversity is declining at unprecedented levels globally: rates of species extinctions are increasing while natural habitats are declining. This is largely as a result of anthropogenic pressures (Butchart *et al.* 2010; Hoffmann *et al.* 2010). As a consequence, negative impacts on humans accrue, not only through intrinsic loss of wildlife but also as a result of declines in and loss of the ecosystem services healthy natural systems underpin and provide (Millennium Ecosystem Assessment 2005; Cardinale *et al.* 2012). The choice of where and how to invest biodiversity conservation effort is becoming increasingly difficult as available resources are shrinking and the number of targets to which to contribute is growing. Against this backdrop, the UK Department for Environment, Food and Rural Affairs (Defra) seeks through this project to develop a **scientifically robust and repeatable method to identify species for which targeted conservation action by the UK Government would have the broadest consequential benefits** (hereafter termed co-benefits) for other species (or taxa), habitats, wider ecosystems, and ecosystem services. Key conservation action aimed at such species will maximise contributions to international species conservation treaties such as the Convention on Biological Diversity's (CBD) Strategic Plan for Biodiversity 2011-2020, which established twenty international targets to safeguard global biodiversity. These are known as the Aichi Targets (COP 10 Decision X/2, see http://www.cbd.int/decision/cop/?id=12268), and aim to safeguard biodiversity in its broadest sense and at different levels. The targets of interest include **preventing extinctions, conserving habitats, controlling invasive species, sustainable harvesting, and protection of ecosystem services.**

As described in the original project brief (see Appendix 1), this method would involve the development of a scoring system where individual species are linked, via existing data sources (e.g. IUCN Red List, FishBase), to their expected contribution to various co-benefits (such as ecosystem service provision or genetic relatedness to domesticated plants and animals). Species recorded in the FishBase database, for example, as being important food sources would receive a high score for a "sustainable harvesting" co-benefit, whereas a species recorded as having little or no importance in harvesting would receive a low, or zero, score. This would enable individual species to be **ranked** within an overall priority list based on their contribution to all the co-benefits added together (the score for each co-benefit summed). **Conservation action aimed at species ranked at the top of this list would, therefore, be expected to have their greatest co-**

sequential benefits to the environment (based on the co-benefits selected for inclusion in the method).

This methodology should be 1) **expandable** allowing the incorporation of future data**,** 2) **adaptable** to changing policy aims and 3) **usable** by non-technical practitioners. This methodology would then be available to and usable by a range of practitioners, and be adaptable to a wide range of policy and conservation goals.

2.2. Why is this method necessary? The link between policy demands and scientific capability

One key goal of this project is to link policy goals (i.e. the addressing of Aichi Targets) to real conservation actions via sound scientific method. The fulfilment of this goal requires a smooth transition from policy to science and back to policy - that scientifically robust findings can be used to explore policy aspirations, and that the resulting policy is based on sound science and clear decisions (Figure 1).

However, as the science and policy “spheres” tend to have very different rationales, time-lines and objectives, the transition between them is often far from straightforward. Koetz *et al.* (2008) synthesise several authors in arriving at their view of the issues at the heart of the science-policy interface. They suggest that while science **objectively** deals with the generation of knowledge, policy tends to be concerned with making **subjective** choices between different arguments, often tackling interests and values that ultimately conflict (see also Appendix 5. *Rapid Assessment Report to support development of a Methodology for the Assessment of Priorities for International Species Conservation*, a report commissioned by this project, subcontracted to UNEP-WCMC).

This project aims to help bridge the gap between science and policy spheres by taking an **integrated approach**. While the inputs of the methodology will be policy-driven (i.e. the selection of co-benefits to which individual species conservation will be related and how these co-benefits are individually weighted), the methodology used to address these policy questions will be based on the best available scientific evidence. The development of a usable “front end” for this methodology should enable the scientific finding to be used by policy makers and applied directly to the policy sphere.

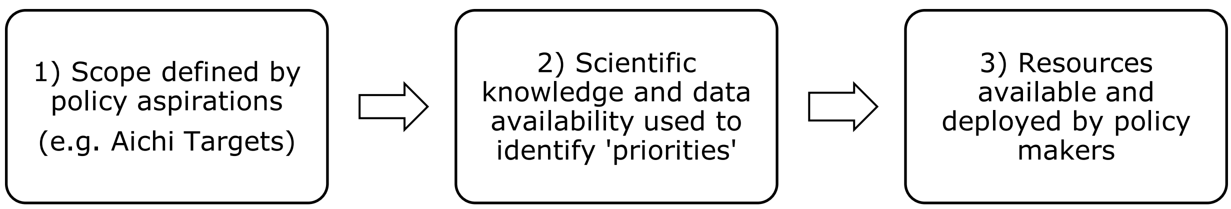

Figure 1. *Classic view of the science-policy interface*

2.3. Outline of the proposed project

The project brief underwent considerable development in the early phase of this project (see Appendix 1 and 2 for full details of the original brief and how it was amended). The final agreed aims of the project are as follows:

- To develop a scoring method which enables species to be **ranked** based on their contribution to a selection of conservation targets (or co-benefits), that would be **expandable** allowing the incorporation of future data**, adaptable** to changing policy aims and **usable** by non-technical practitioners.

- To test the results and usability of this methodology using case studies (taxonomic and geographic), testing the **expandability** and **adaptability** of the database with the addition of extra data sources and changes to co-benefit weighting.

- To develop a web-based tool (a graphical user interface GUI) so that the methodology can be demonstrated to and used by non-technical practitioners - **usability**.

- To consider the broader science-policy context in which MAPISCo sits and propose how it may become fully integrated in the future (the project legacy).

3. Development of the method

Capsule.

- *Co-benefits selected (by the steering group) for inclusion in the method: (1) Habitat and area conservation, (2) Sustainable harvesting of fish, invertebrates and aquatic plants, (3) Conservation of genetic diversity of wild relatives of cultivated plants and domesticated animals, (4) Protection of the provisioning of ecosystem services, and (5) Prevention of species extinctions.*
- *These co-benefits can be changed or added to - this makes the method expandable**.***
- *Scoring method developed which produces lists in which species are ranked by their expected value in contributing to each of the five co-benefits above.*
- *The weighting, or importance, of each co-benefit can be adjusted in response to policy**.***

3.1. Selection of co-benefits

The original aim of this project was to link the conservation of individual species to a large suite of ecosystem co-benefits that could be related directly to the relevant Aichi Targets. The targets of interest included preventing extinctions, conserving habitats, controlling invasive species, sustainable harvesting, and protection of ecosystem services. However, preliminary work indicated that for many species groups, sufficient data linking their conservation to many of the suggested co-benefits are either not available or not easily accessible. Moreover, the full range of co-benefits set out in the original brief was likely too large for the project timeframe.

For these reasons, a subset of five co-benefits was selected for inclusion in the development of the methodology (see Box 1). This selection was made based on the contribution these co-benefits made to Aichi Targets of policy interest to Defra, their links with conservation effort on a species level and adequate data being available (from preliminary searches) to link them to species conservation lists.

However, it should be stressed that further co-benefits could be included in the future to incorporate specific policy needs (***expandable***)**.**

Box 1. The five co-benefits selected for inclusion in the development of the methodology, and the Aichi Targets to which they contribute

1. Habitat and area conservation (Targets 5 and 7; hereafter termed “Habitat co-benefit”)
2. Sustainable harvesting of fish, invertebrates and aquatic plants (Target 6; hereafter “Harvesting co-benefit”)
3. Conservation of genetic diversity, in particular of wild relatives of cultivated plants and domesticated animals (Target 13; hereafter “Genetic Diversity co-benefit”)
4. Conservation of the provisioning of ecosystem services (Target 14; hereafter “ES co-benefit”)
5. Prevention of species extinctions (Target 12; hereafter “species extinction co-benefit”).

3.2. Focal co-benefits, data sets used and sources & category scoring

In the following sections, for each of the five co-benefits selected for inclusion we discuss (i) the rationale for links to conservation effort on a species level, (ii) data sets chosen to make this link and (iii) quantitative scoring used to integrate each data source in the prioritisation methodology.

A note on data sources

The majority of data sources were identified through discussions with experts at the project workshop (see Appendix 4). Many suggested data sources were unsuitable for use in the final methodology due to taxonomic or geographic biases in datasets, or general data accessibility issues. For example, for the habitat co-benefit, Biodiversity Hotpots (Myers *et al*. 2000) and the Global "200" Ecoregions project data (Olsen & Dinerstein 2002) could not be used as species associations made in the lists were taxonomically biased and the data were not easily available. For the harvest co-benefit, the Seas Around Us project (www.seaaroundus.org) was also rejected due to the data not being publicly accessible. For the genetic diversity co-benefit, the SEPASAL database (www.kew.org/ceb/sepasal) was rejected as data were both taxonomically and regionally biased as well as being difficult to access. Further examples of investigated but unsuitable databases are listed in Appendix 8, Table A8-1.

3.2.1. Habitat and area conservation (Aichi Targets 5 and 7)

Rationale

Target 5: "By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced."

Target 7: "By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity."

Both Aichi Target 5 and 7 relate to the conservation or sustainable management of natural and semi-natural habitats. Although conservation effort directed at species usually involves a degree of protection of the habitat(s) (Mace & Collar 2002), such contribution to habitat conservation is likely to be greater for some species than for others.

One way to link species-level conservation to habitat conservation is to focus on those species that are thought to be of disproportionate importance to their habitats or co-occurring species (i.e. "surrogate species" such as umbrella, keystone or indicator species; (Caro & O'Doherty 1999; Caro & Girling 2010). However, the effectiveness of surrogate species for conservation is widely criticised (e.g. Lindenmayer *et al.* 2002; Saetersdal & Gjerde 2011). More importantly, concrete evidence for the effectiveness of species as surrogates for habitats is limited and often highly context-dependent (Andelman & Fagan 2000), which means globally applicable lists of appropriate habitat surrogate species are not available.

Instead, in the current project we have chosen to link species to habitats by focussing on species that have previously been associated with, or used as "triggers" for the designation of Key Biodiversity Areas (KBAs) (Eken *et al.* 2004). Defined as "sites of global significance for biodiversity conservation "(Eken *et al*. 2004), KBAs are designated based on the conservation of habitat within them being important or even vital for the persistence of one or more target species (Eken *et al*. 2004). However, conservation effort directed at these target species is likely to benefit the wider habitat, making KBAs important areas for a wide and varied number of species. There is also a general consensus that the conservation of KBA sites has many wider benefits (e.g. in terms of cultural value or provisioning of ES (e.g. Butchart *et al.* 2012; Larsen, Turner & Brooks 2012).

Theoretically, conservation effort directed at a species recorded in a KBA will also benefit non-target species co-occurring in that KBA, as well as having other localised benefits (e.g. ecosystem service provision). Therefore, conservation effort directed at species recorded in species-rich KBAs is likely to produce higher levels of habitat co-benefits than conservation of a species that occurs in a species poor KBA.

A "habitat score" for each individual species is calculated as follows: for each species associated with a KBA, we use the mean number of other species known to co-occur in all KBAs in which that individual species occurs. This is, in effect, a proxy measure of the expected contribution a given species may make to habitat conservation overall.

Data sources

The linking of species and habitats necessary in this approach relies upon the availability of species inventories for individual KBAs. However, these inventories are not always available for all types of KBA, or for all species groups. For this reason we have decided to include data from the two types of KBA for which most data is readily available: Important Bird Areas and Alliance for Zero Extinction sites.

- *Important Bird Areas* (*IBAs)* are sites identified as being globally important for the persistence of one or more populations of endangered bird species. Identified using standardised criteria (http://www.birdlife.org/datazone/info/bacritglob [Accessed 22 August 2012]), a site qualifies for IBA status if it holds or is thought to hold significant populations (or parts of populations) of bird species (1) listed as endangered (Critically Endangered, Endangered or Vulnerable) on the IUCN Red List, (2) with a restricted range (e.g. endemics), (3) that are (largely) restricted to a single biome, or (4) that are migratory or congregatory and for which the site is important during particular parts of the year (BirdLife International 2008, http://www.birdlife.org/datazone/info/ibacriteria [Accessed 22 August 2012]). To date, over 10,000 IBAs have been identified globally (http://www.birdlife.org/datazone/site [Accessed 22 August 2012]), in which 4847 species are listed to occur. The number of bird species listed per IBA site ranges from 1 to 247, with an average of 9 per site.

- *Alliance for Zero Extinction (AZE) sites* are sites which hold the last remaining population(s) of highly threatened species of mammals, birds and/or selected reptiles, amphibians and conifers. To qualify as an AZE site, a site must (1) hold at least one species listed as Critically Endangered or Endangered on the IUCN Red List, (2) hold all or the majority (>95%) of the known population of the species, and (3) must be geographically and politically discrete (Ricketts *et al.* 2005). To date, 587 AZE sites containing 920 species have been identified. The number of species listed per AZE site ranges from 1 to 22, with an average 1.6 species per site.

Species-level score

All IBA and AZE inventories were sourced and the species included on them listed in a database in preparation for the assignment of a score.

For species listed as occurring in an IBA (or listed as a "trigger" species used to delineate an IBA), individual species scores were equal to the mean number of species recorded as co-occurring with that individual species across all IBAs for which there was a record. For example, if species A was recorded on three IBA inventories, and co-occurred with five species on one inventory, ten on another and twenty on the third, the score species A received would be mean of 5, 10 and 20 = 11.67. This resulted in each species receiving a value between 1 and 246, with a mean of 34.3.

Species listed as occurring in an AZE were attributed a score equal to the total number of species co-occurring with that species at the site in which it was recorded (not an average because, by definition, a given species occurs in only a single AZE site). This resulted in a score ranging from 1 to 22 (22 being the maximum number of species listed for one site) with a mean of 3.5. Species listed as occurring in both an IBA and an AZE were given the mean score. Those not listed as occurring in either an IBA or an AZE site were not allocated any score.[1]

For both scores, higher values indicate that, on average, a species occurs in AZE or IBA sites that hold larger numbers of other species. Conservation effort directed at species with such higher scores is therefore likely to both benefit their wider habitat as well as a larger number of co-occurring species.

3.2.2. Sustainable harvesting (Aichi Target 6)

Rationale

"*By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.*"

It was assumed (in discussion and agreement with the steering group) that conservation effort directed at harvested fish species or species involved in aquaculture production would contribute to this target. Moreover, we assumed that such contributions would be stronger for species that are seen as having greater economic value.

Data sources

Thus, we used three data sources to identify species relevant to this target:

1) *Commercial value of a species to fisheries*. FishBase (Froese & Pauly 2012) provides a qualitative assessment of the economic value of 3111 fish species across countries in which they are harvested. The overall economic value or importance of each species is categorised in one of six categories, ranging from "no interest" to "highly commercial". The definitions of the categories are given in Table 1.

2) *Species listed as affected by aquaculture on the IUCN Red List (IUCN 2012*). As well as conservation status and extinction risk, the IUCN Red List (2012.1) records types of threats faced by species. One of these threat classifications is aquaculture. We identified 269 species listed under Threat Classification (v.3.1) 2.4 (Marine & freshwater aquaculture), which distinguishes between species impacted by “Industrial” (Classification 2.4.2), “Subsistence/artisanal” (Classification 2.4.1.) and “Unknown” levels of aquaculture (Classification 2.4.3).

3) Species listed as used in aquaculture production on FishBase (204 species, C. McOwen pers. comm.).

Table 1. *FishBase commercial harvesting categories and scores attributed.*

Category	No. spp.	% spp.	Category score	Definition
Highly commercial	207	6.7	6	The species is very important to the capture fisheries (or aquaculture) of a country
Commercial	1416	45.5	5	The species is regularly taken in the capture fisheries or regularly found in aquaculture activities of a country
Minor commercial	1233	39.6	4	The species is of comparatively less importance in capture fisheries or aquaculture in a given country
Subsistence fisheries	210	6.8	3	The species is consumed locally only, mostly by the fishers themselves
Of potential interest	2	0.1	2	
Of no interest	43	1.4	1	

Species-level scores

All species were attributed a score for each of the three data sources listed above. First, species listed as commercially harvested in FishBase were attributed a score between 1 (for “no interest”) to 6 (for “highly commercial”), reflecting increasing conservation priority for species of greater economic interest (Table 1). Second, species listed as threatened by aquaculture on the IUCN Red List were attributed a score between 1 (for “unknown scale”) and 3 (for “industrial”) reflecting the increasing intensity of aquaculture threat and therefore the increasing potential for conservation effort directed at such species to benefit the target in question (Table 2). Third, species listed as used in aquaculture production on FishBase were attributed a score of 1, whereas other species were not attributed any value.

Table 2. *Species and classifications listed under Threat Classification (v.3.1) 2.4 (Marine & freshwater aquaculture) on the IUCN Red List (2012.1), and category scores attributed.*

Category	No. spp.	% of spp.	Category score
Industrial	27	10	3
Subsistence/artisanal	16	5.9	2
Scale unknown	226	84	1

3.2.3. Conservation of genetic diversity (Aichi Target 13)

Rationale

"By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimising genetic erosion and safeguarding their genetic diversity."

It was assumed (in discussion and agreement with the steering group) that conservation effort directed at species extant in the wild will contribute to the preservation of (unique) genetic diversity of the targeted species. Following the central tenet of this target, we chose to focus on wild relatives of crops and domestic animals, and further expanded our consideration into plant species with a known medicinal use.

Data sources

We used the following data sources to identify species relevant to this target:

1) A database of wild relatives of plant crop species. This database (Vincent *et al.* in prep.) lists 1385 high priority crop wild relative (CWR) species. CWR are wild species closely related to crop species which have the potential to contribute valuable traits (e.g. disease resistance) to crops in the future. Vincent *et al*. define CWR as those species which are sufficiently similar genetically to allow crossing (either naturally or in the laboratory; the "gene pool concept") or in some cases those species belonging to the same genus (the "taxon concept").

2) Lists of wild relatives of domesticated animal species, compiled from the FAO World Watch List for Domestic Animal Diversity (FAO 2000) and from (McGowan 2010). The former document identified avian and mammal species representing domestic animal genetic resources at risk of loss, based on a range of survey- and monitoring- efforts. From these, we identified those species extant in the wild and/or listed as at risk from hybridisation on the IUCN Red List (IUCN 2012, in total 210 species). Among birds, Galliformes are particularly important economically and we therefore added species from family and genera identified in McGowan 2010 and listed on the IUCN Red List (IUCN 2012) as relatives of domesticated animals (in total 323 species). It should be noted that in light of a recent review (Owens & McGowan in prep), neither Cracidae (chachalacas, guans and curassows

from Central and South America) nor Megapodidae (mound-builders from the Australasian region) receive scores for this co-benefit. This is because no successful hybrids between species from these families and domesticated poultry have been recorded (McCarthy 2006).

3) Plants species listed as used for medicinal purposes in the BGCI PlantSearch database (http://www.bgci.org/plant_search.php/ [Accessed 22 August 2012]) and Hawkins (2008). The BGCI PlantSearch database is compiled from information supplied by botanical gardens worldwide, including whether a given species has a medicinal use. The database holds 1788 species records listed as having medicinal use. Hawkins (2008) compiled information on many medicinal plant species from a range of sources and expert opinion questionnaires, and lists 429 medicinal plant priorities.

Species-level scores

All species were attributed a numerical score for each of the data sources outlined above. First, reflecting their status as CWR, species occurring in the CWR database were attributed a score of 1. Second, species occurring on our compiled list of relatives of domesticated animals were also attributed a score of one. Species not on either list were not attributed any score. The resulting binary scores reflect our limited ability using these data sources to distinguish further between the relevant species in terms of priority (e.g. a species either is a CWR or not). Third, species listed in the top 35 of Annex 5 of Hawkins (2008) were attributed a score of 3, remaining species in the same list were scored as 2 and other species with a known medical use (listed in the PlantSearch database) were scored as 1.

3.2.4. Protection of ecosystem services (Aichi Target 14)

Rationale

"By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable."

To maximise contributions to the protection of ecosystem services (ES) by conservation effort directed at a species level, evidence is required that shows the relative importance of species to the provisioning of ES. While it is widely recognised that ecosystems provide a range of services and benefits to humans, and indeed that groups of species can be associated with broad service provision (Millenium Ecosystem Assessment 2005; UK NEA 2011), the evidence base linking individual species to particular services is limited and evidence showing the relative value of different species for a given service even more so. Where such evidence is available, it is often limited to a single species in a particular context (e.g. Vira & Adams 2009; MAPISCo Project Team 2012). Such context-dependent examples do not constitute the solid evidence base necessary for the taxonomic and geographic scope required for the present methodology. Moreover, examples of broad species groups providing essential services are prevalent and often cited. However, in such cases, often large numbers of species are involved, and their relative importance to the provision of the service in different contexts is unclear. For example, although it is well known that many insects are vital as pollinators of economically important crop species, the value of *individual* pollinating species has, in the vast majority of cases, not been quantified. This inability to distinguish between such species in terms of their relative value to the service in question limits the use of such data in a species prioritisation methodology.

By contrast, there is a growing consensus that priorities for biodiversity conservation and for ES can be reconciled using *area*-based (as opposed to *species*-based) approaches, for example freshwater provisioning or carbon sequestration along with levels of biodiversity (Lamoreux *et al.* 2005; Goldman *et al.* 2008; Naidoo *et al.* 2008; Egoh *et al.* 2011; Fisher *et al.* 2011; Butchart *et al.* 2012). Thus, here we chose to make the link between species and the provisioning of a selection of ES by focusing on a larger, habitat- and country scale. The advantage of focusing on a country level is that broad measures of the provisioning of some ES are available at country level, and species occurrence data within broad habitats in countries is more readily available (and potentially more reliable) than finer-scale measures of distribution.

Data sources

We focus on two example ES – 1) estimated carbon loss through deforestation and 2) freshwater availability. We used the following data sets to link country-level measures of these two services to species level:

1) *Carbon loss through deforestation (tonnes/year).* To estimate this, we multiplied country-level estimates of (1) the stock of carbon in living forest biomass in 2010 (tonnes/hectare) with (2) the trend of the extent of primary forest between 2005-2010 (change in hectares), as available in the FAO Global Forest Resources Assessment 2010 (FAO 2010) database (http://countrystat.org/index.asp?ctry=for&HomeFor=for [Accessed 22 August 2012]).

2) *Freshwater availability*. As a measure of the availability of freshwater to people, we used the country-level estimated total renewable per capita freshwater supply in 2010, as obtained from the FAO AQUASTAT database (http://www.fao.org/nr/water/aquastat/data/query/index.html [Accessed 22 August 2012]). Lower values (<1000 m3/capita) indicate water scarcity (UNEP Vital Water Graphics: www.unep.org/geo/geo4/report/Glossary.pdf [Accessed 22 August 2012]).

3) *Habitat- and country- occurrence.* We used the data in the IUCN Red List (IUCN 2012) augmented by the Sampled Red List Index (SRLI) for plants (http://threatenedplants.myspecies.info/ [Accessed 22 August 2012], and S. Bachman pers. comm.) (to increase representation of plant species) to identify species occurrence in countries, and in (1) forest habitats (Habitat Classification 1) and wetland (inland) habitats (Habitat Classification 5). See **section 3.2.5** (page 20) for more information on the data used from the Red List and SRLI for plants.

Species-level scores

We assumed that conservation effort directed at forest species occurring in countries with higher estimated rates of carbon loss through deforestation is more likely to make contributions to targets to reduce carbon loss or increase carbon sequestration. Similarly, because wetland and forest habitats are particularly important in controlling both the supply and quality of freshwater (Millenium Ecosystem Assessment 2005; Larsen, Turner, & Brooks 2012), we assumed that conservation effort directed at forest or wetland species occurring in countries with lower levels of per capita freshwater supply is likely to make greater contributions to targets aiming to alleviate water scarcity or stress.

Accordingly, species occurring in forest habitats (IUCN Red List Habitat Classification 1) were attributed a score for the estimated carbon loss through deforestation, calculated as the average estimated carbon loss through deforestation across all countries in which the species occurs. Lower values indicate an association with higher rates of loss and therefore higher conservation priority. Similarly, species occurring in forest- or wetland habitats (IUCN Red List Habitat Classifications 1 and 5) were attributed a score for freshwater supply calculated as the average estimated supply across countries in which it occurs. Lower values indicate a greater association with higher levels of water scarcity, and therefore higher conservation priority.

3.2.5. Preventing species extinction (Aichi Target 12)

Rationale

"By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained."

As the present prioritisation methodology aims to maximise co-benefits of the conservation of species, we considered Aichi Target 12 to be our "focal" target and assumed that conservation effort directed at more highly threatened species would contribute most to it.

Since revisions from the IUCN Red Data Books (Mace & Lande 1991), the IUCN Red List has grown to become not only the most comprehensive data set on the extinction risk of a wide range of species from various taxonomic groups, but also represents an effective data source for species occurrence and habitat classifications (IUCN 2012). Red List threat status assessments are made by experts according to well-documented standards (IUCN 2001) (http://www.iucnredlist.org/technical-documents/categories-and-criteria/2001-categories-criteria [Accessed 22 August 2012]). Species are placed into one of nine threat categories representing increasing extinction risk, based on a range of criteria including (1) declines in population size, (2) restrictions in geographic range, (3) small absolute population size or (4) analytical evidence of high extinction risk.

Data sources and species-level scores

For each species listed on the IUCN Red List v. 2012.1 (IUCN 2012) and/or the SRLI for plants (http://threatenedplants.myspecies.info/ [Accessed 22 August 2012], and S. Bachman pers. comm.), the most recent threat status assessment was obtained. Each category was attributed a default numerical score on a linear scale, from 1 for the lowest category (Extinct) to 9 for Critically Endangered (this scale was set by the larger number of categories in the Red List data which has a "Lower Risk" category not present in the SRLI plant data), so that higher scores represent a greater risk of extinction. Species not occurring on either list were not attributed any score. The SRLI data had a "Not Evaluated" category, which was attributed a score of zero. Extinct in the Wild was treated as a higher priority category by attributing the second-to-highest score in both cases, with the view that the key goal of the prioritisation methodology is to achieve *in situ* conservation and species currently only persisting *ex situ* therefore require substantial conservation effort. For precautionary reasons, Data Deficient species were scored between Near Threatened and Least

Concern, which in both the Red List and SRLI scoring is near the middle of the score distributions. See Tables 3 and 4 for the default numerical scoring for the Red List and SRLI for plants, respectively.

Table 3. *Threat categories and number of species in the IUCN Red List (2012.1), and scores attributed. Species "Not Evaluated"(NE) were scored 0.*

Category code	Category	No. spp.	% of spp.	Category score
CR	Critically Endangered	3947	6.412	9
EW	Extinct in the Wild	63	0.102	8
EN	Endangered	5766	9.368	7
VU	Vulnerable	10105	16.417	6
NT	Near Threatened	3452	5.608	5
DD	Data Deficient	10497	17.054	4
LC	Least Concern	26922	43.738	2
EX	Extinct	801	1.301	1

Table 4. *Threat categories and number of species in the Sampled Red List Index (SRLI) for Plants, and scores attributed.*

Category code	Category	No. spp.	% of spp.	Category score
CR	Critically Endangered	1813	10.930	9
EW	Extinct in the Wild	31	0.187	8
EN	Endangered	2688	16.204	7
VU	Vulnerable	4998	30.130	6
NT	Near Threatened	752	4.533	5
DD	Data Deficient	1244	7.499	4
LR/cd	Lower Risk	223	1.344	3
LR/lc	Lower Risk	909	5.480	3
LR/nt	Lower Risk	677	4.081	3
LC	Least Concern	3162	19.062	2
EX	Extinct	91	0.549	1

Although both the relative scores among species and the scale used (e.g. linear, exponential) are inevitably largely subjective, the translation of threat categories into numerical scores used here is similar to that used in previous prioritisation studies (e.g. Rodriguez *et al.* 2004, Butchart *et al.* 2012). Because of the qualitative nature of these scores, we suggest that in the final version of the present prioritisation methodology these scores can be altered to suit changing expert opinion or policy aspirations.

In addition to conservation status assessments, from the RL and SRLI for plants we obtained lists of countries in which each species occurs, and lists of species occurring in forest habitats (IUCN Red List Habitat Classification 1) and wetlands (Classification 5).

3.3. Database & prioritisation

3.3.1. Database building

For a full explanation of the database structure see Appendix 6. Briefly, data from the sources described in **section 3.2**, page 13, were cleaned (errors removed) and compiled using R (v. 2.15.0, R Development Core Team 2012) and resulting tables stored in a SQLite relational database (v. 3.7.11). The resulting main output table contained one row per species, with either a relevant value for each data source, or a “blank” indicating the species does not occur in that data set.

3.3.2. Co-benefit weighting, re-scaling and priority score calculation

A worked example of how the final priority score for each species was calculated is provided in Box 2). Broadly, the score was calculated by following these steps

1) Individual species scores from each data set were rescaled to allow them to be compared on the same scale. First, each individual dataset score was divided by the maximum value for scores from that particular dataset. This allowed all scores to be assigned a value between 0 and 1. For example, a species receiving a score of 7 for the species extinction co-benefit (i.e. a threatened species) was rescored to 0.778 (raw score of 7 divided by the maximum score for that database of 9 [the score given to Critically Endangered species]), while a species scoring 2 for extinction risk (Least Concern) was rescored to 0.222 (raw score of 2 divided by the maximum score of 9). For database scores listed only as 0 or 1 (binary scores, such as those for “Aquaculture use” obtained from FishBase and species listed as “Crop Wild Relatives”) this transformation had no effect. For both ES data sources (estimated carbon loss through deforestation and freshwater availability) lower scores were associated with higher priorities, so their scales were inverted as well as rescaled.

2) Scores attaining to each co-benefit were then combined to create a “score per co-benefit”. For the prevention of species extinction (**section 3.2.5**, page 20), this co-benefit score equalled either the Red List conservation status score or the plant SRLI score, whichever was greater. All other co-benefits scores (Habitat, Harvesting, Genetic Diversity and ES Provisioning) were calculated by taking the mean of the individual dataset scores contributing to the co-benefit.

3) The overall co-benefit score for each species was then standardised. This was necessary because while the individual database scores were “rescaled” to between zero and one as described in 1), their position along this 0-1 scale was arbitrary. For example, for a species in receipt of a co-benefit score of 1 for harvesting (of which there could only be a score of 1 or 0 due to limitations in the data) and a score of 0.56 for extinction list, the harvesting score is not “twice” as important as the habitat extinction score – it is only twice as large as a result of the scoring method of the individual datasets. For scores to be standardised a z-score calculation was made – this is an accepted standardising technique. The quantity z represents the distance between the raw score and the population mean in units of the standard deviation. z is negative when the raw score is below the mean, positive when above. This means that the co-benefit scores will be related in terms of the overall mean score.

a. First, the mean and standard deviation of all the scores given to individual species was calculated for each co-benefit. It is important to note that this mean is calculated with empty cells being treated as missing data rather than as zero data (i.e. not included in the calculation of the mean). This is important, as the database contain a large percentage of “missing data” given few species receive scores in all databases. Treating them as “zeros” biases the database towards species that have scores for more co-benefits. By treating them as missing data this is a more accurate representation of what is known – i.e. it is not known if there is a relationship, rather than there is no relationship (p 45).

b. Each co-benefit score was then standardised by taking this mean score away from it, and dividing it by the standard deviation of this mean. The “z-score” was negative when the raw score was below the mean and positive when it was above.

4) The new score per co-benefit was then able to be modulated further by multiplying each by a weighting factor between 0 (no contribution) and 1 (maximum contribution). These weights can be modified based on policy decisions regarding the importance of each co-benefit. The default (as set in the database) is that all are equally important.

5) The final composite priority score per species equalled the sum of the weighted co-benefit scores.

The resultant list was sorted by decreasing final priority score. We used seven broad taxonomic groups to present the results below: amphibians (class Amphibia), birds (class Aves), fish (classes Actinopterygii, Cephalaspidomorphi, Chondrichthyes, Myxini and Sarcopterygii), mammals (class Mammalia), plants (kingdom Plantae), and reptiles (class Reptilia). These groups were chosen because they represent a wide range of taxonomic groups and are relatively well represented in the combined data sources used (e.g. as opposed to insects). The Red List was used as the primary source of taxonomic data, although for species not included on the Red List additional taxonomic data was used from the other data sets, where available, or inferred from the type of data. Species not belonging to any of the above groups were grouped as “Other” (mainly invertebrates).

Box 2: A worked example of the final priority score calculation

The final priority score for a species is the sum of the scores given for the five co-benefits. The method for calculating co-benefits scores is outlined below.

1) Mean taken of the scores assigned from original individual datasets (in this example, two different datasets)

2) The mean score calculated in step 1 is then standardised by taking away from it the mean of all the values in the entire co-benefit column, then dividing it by the standard deviation of that co-benefit mean (calculation of a "z score"). The resultant score will be positive if the individual species score is greater than the mean score and negative if the individual species score is smaller than the mean score.

Species	Habitat	Harvesting	Genetic diversity	Ecosystem Service Provisioning	Threat status	**Final Score**
Francolinus camerunensis	(0.136+0.789)/2 =***0.462***	(0+0+0)/3 = ***0***	(0+0+3)/3= ***0.333***	(0.323+0.975)/2 =***0.649***	max(0.778,0) = ***0.778***	
	0.462-0.07 ***0.08*** ***= 5.05***	***0-0.25*** ***0.10*** ***=-2.58***	***0.333- 0.24*** ***0.11*** ***=0.82***	***0.462-0.55*** ***0.11*** ***=0.77***	***0.462-0.45*** ***0.25*** ***=1.35***	((5.05)+(-2.58)+(0.82)+(0.77)+(1.35)= **5.42**
	5.05*1	***-2.58*1***	***0.82*1***	***0.77*1***	***1.35*1***	

3) The new co-benefit score is then multiplied by a weighting factor (in this case all co-benefits are weighted equally (i.e. weighting set to 1)

4) Final score calculated by adding together the five co-benefit scores. This score is then used to rank species in the priority list.

3.4. Inclusion of red list threat classification data

While Red List "threat category" (e.g. Critically Endangered, Near Threatened etc.) was included as a co-benefit in the methodology (from the Red List for animals and from the SRLI list for plants), the *nature* of that threat was not. The Red List "Threats Classification scheme" assigns a threat type to each of the species listed within it. The threats take a hierarchical format, with main threat categories subdivided into a number of subcategories, some of which are subdivided further (Table 5 and Appendix 8, Table A8-2 for full explanation of categories). The addition of this data to the overall database would allow the production of a) lists containing major threat classifications for particular species groups or geographical regions, and/or b) lists of species per threat classification.

Species data were downloaded from the IUCN Red List website for each major threat category (categories 1-12 Table 5). Only "first tier" threat classifications were used, rather than sub-categories, as these data were more robust. These data were then integrated into the main MAPISCo database using the unique binomial species name and or species identification number as a link between data tables. This enabled us to produce lists of threat data as shown in Table 6. Threat data was not scored in the current incarnation of the database because of uncertainties in the IUCN threat classification process for each focal taxon. Where data are better standardised (such as for the birds) there is the potential for these threats to be ranked and scored in accordance with policy aspirations (**expandable**).

Table 5. *The IUCN threat classification scheme categories (see Appendix Table A8-2 for full list and definitions)*

Main threat category	Sub-category (number of further sub-categories)
1 Residential & commercial development	1.1 Housing & urban areas 1.2 Commercial & industrial areas 1.3 Tourism & recreation area
2 Agriculture & aquaculture	2.1 Annual & perennial non-timber crops (4) 2.2 Wood & pulp plantations (3*) 2.3 Livestock farming & ranching (4) 2.4 Marine & freshwater aquaculture (3)
3 Energy production & mining	3.1 Oil & gas drilling 3.2 Mining & quarrying 3.3 Renewable energy
4 Transportation & service corridors	4.1 Roads & railroads 4.2 Utility & service lines 4.3 Shipping lanes 4.4 Flight paths
5 Biological resource use	5.1 Hunting & collecting terrestrial animals (4) 5.2 Gathering terrestrial plants (4) 5.3 Logging & wood harvesting (5) 5.4 Fishing & harvesting aquatic resources (6)
6 Human intrusions & disturbance	6.1 Recreational activities 6.2 War, civil unrest & military exercises 6.3 Work & other activities
7 Natural system modifications	7.1 Fire & fire suppression (3) 7.2 Dams & water management/use (11) 7.3 Other ecosystem modifications
8 Invasive & other problematic species, genes & diseases	8.1 Invasive non-native/alien species/diseases (2) 8.2 Problematic native species/diseases (2) 8.3 Introduced genetic material 8.4 Problematic species/diseases of unknown origin (2) 8.5 Viral/prion-induced diseases (2) 8.6 Diseases of unknown cause
9 Pollution	9.1 Domestic & urban waste water (3) 9.2 Industrial & military effluents (3) 9.3 Agricultural & forestry effluents (4) 9.4 Garbage & solid waste 9.5 Air-borne pollutants (4) 9.6 Excess energy (4)
10 Geological events	10.1 Volcanoes 10.2 Earthquakes/tsunamis 10.3 Avalanches/landslides
11 Climate change & severe weather	11.1 Habitat shifting & alteration 11.2 Droughts 11.3 Temperature extremes 11.4 Storms & flooding 11.5 Other impacts
12 Other options	12.1 Other threat

Table 6. *Example output of the MAPISCo database with threat classifications added*

Species	Taxonomic group	1. Residential	2. Agriculture	3.Energy	4. Transport	5. Resource use	6. Disturbance	7. System modifications	8. Invasive species	9. Pollution	10. Geological events	11. Climate change	12. Other	Threat status	Habitat	Harvesting	Gen. diversity	ES provisioning	Score	Rank
Francolinus camerunensis	birds	1	0	0	0	1	0	0	0	1	0	1	0	0.78	0.46		0.33	0.65	5.42	1
Caprimulgus prigoginei	birds	0	0	0	0	0	0	0	0	0	0	1	0	0.78	0.57			0.66	3.88	2
Afropavo congensis	birds	1	0	0	0	1	0	0	1	0	0	1	0	0.67	0.36		0.33	0.66	3.73	3
Craugastor polymniae	amphibians	1	0	0	0	0	1	0	0	0	0	1	0	1	0.50			0.62	3.58	4
Ecnomiohyla echinata	amphibians	1	0	0	0	0	1	0	1	0	0	1	0	1	0.50			0.62	3.58	4

4. Results - Example priority lists

***Capsule*.**

- *The results generated by the database in its current format are constrained by data (e.g. only around 3% of all plant species have been categorised on the IUCN Red List while almost all bird species are included).*
- *For this reason in this section we present three different sets of results*
  1. *All species*
  2. *Birds only (taxonomic case study)*
  3. *SE Asia only (geographic case study)*
- *These case studies allow us to focus on discrete sets of data, which, while not eliminating constraints completely, allows a more meaningful demonstration of how the database can be used.*
- *These results are then linked to policy actions.*

In this section we present species priority lists generated using the method outlined in **section 3.** However, we do so with an important caveat - **priority lists generated by the current version of the method are limited by the data used to calculate species scores.**

As described in **section 3.2** (page 13), only 12 data sources were deemed suitable for inclusion in the method. This has resulted in **constraints** on the database, both in terms of which species have been able to be included on the lists, and in terms of the numbers of co-benefits on which species on the lists can be scored. There are also geographical biases, with many more species being recorded from some regions than others.

If this method is to become fully integrated into conservation policy in the UK, these constraints must be addressed. The focus of further development should be on sourcing data for taxa and from regions which are under-represented by the current version of the database, and also on identifying those species groups within the lists which have small numbers of co-benefit scores (see Box 3, page 28, for full description of constraints in the database). This topic is further discussed in both **sections 5** (page 50) **and 6.4** (page 59).

For these reasons, in this section we have presented three different priority lists.

1. A list for all species included on this list
2. A list containing only bird species (taxonomic case study)
3. A list containing only data from SE Asia (geographic case study)

The use of case studies allows us to focus on discrete sets of data, which, while not eliminating constraints completely, allows a more meaningful demonstration of how the database can be used.

Box 3. Description of constraints incurred in the "all species" database

The coverage of the database (the number of species on the database as a percentage of all the species currently described globally) varies greatly between taxa. It is very good for birds (100.64%[4]), mammals (100.22%[4]) and amphibians (94.10%; Table B3-1), but poor for reptiles (38.39%) and fish (37.82%) and poorer still for plants (6.30%) and "other" species (1.02%; Table B3-1).

Table B3-1 (from RL Stats Table 2 2012 IUCN Red List website)

Taxonomic group	Estimated number of described species	Number of species on the database	Coverage of the database (%)
Amphibians	6771	6371	94.10
Birds	10064	10128	100.64[4]
Fish	32400	12252	37.82
Mammals	5501	5513	100.22[4]
Other	1305250	13298	1.02
Plants	307674	19398	6.30
Reptiles	9547	3665	38.39

* note, the coverage for the database is greater than 100% for mammals and birds because some species listed on the database are not considered full species by all authorities, particularly those species that have been domesticated.

The database is also constrained by the number of co-benefits for which individual species have received scores (mean 2.29 for birds and 1.25 for plants; Table B3-2). This is significant because missing scores do not result from a "zero impact", but from missing data. There are also large differences for the individual co-benefits, with birds receiving by far the most scores for habitat, and fish for harvesting (Table B3-2).

Taxonomic group	Mean number of co-benefits scored (max = 5)	Proportion of species in each taxon scored on each co-benefit (%)				
		Threat status	Habitat	Harvesting	Genetic Diversity	Ecosystem Services
Birds	2.29	99.37	48.36	0.32	2.38	78.65
Amphibians	1.98	99.98	7.97	0.09	0	90.03
Mammals	1.77	99.78	3.01	0.33	3.66	69.73
Reptiles	1.63	99.97	0.46	0.08	0.49	61.47
Fish	1.57	84.57	0	26.03	0	46.89
Other	1.57	100.00	0.02	0.44	0	56.64
Plants	1.25	85.66	0.13	0.42	15.83	22.71

The case studies were selected, based on a range of different criteria, outlined below -

Taxonomic case study. Birds were selected for number of reasons: 1) birds are a very well-studied and understood group of species; 2) unlike for other taxa, there is only one Red List authority responsible for the prioritisation of all bird species (BirdLife International), which means the classification of species for the Red List is more uniform and more robust than for other taxa; 3) for birds, unlike for other taxa, all species are evaluated on the Red List. This is not the case for other taxonomic groups.

***Geographic case study. SE Asia*.** Given the constraints in data availability between taxa it is important to note that any region will be biased in its taxonomic coverage. However, we present an example based on one region as an example of the applicability of the method. We selected SE Asia as the case study region because large numbers of species on the “all species” database were recorded from this region. There was also good taxonomic coverage for these species (Figure 2). A further case study using UKOTs was also carried out (as described in the original contract specification), which is detailed in Appendix 7.

For each set of lists we have outlined the main findings from the method. This is followed, for the case studies (**sections 4.2**, page 36 **and 4.3**, page 44), by a discussion of how some of the key findings could be related to policy actions. This section has not been included for the “all species” section (**section 4.1**, page 30), as we believe there to be too much uncertainty in these results for them to be related directly to policy actions.

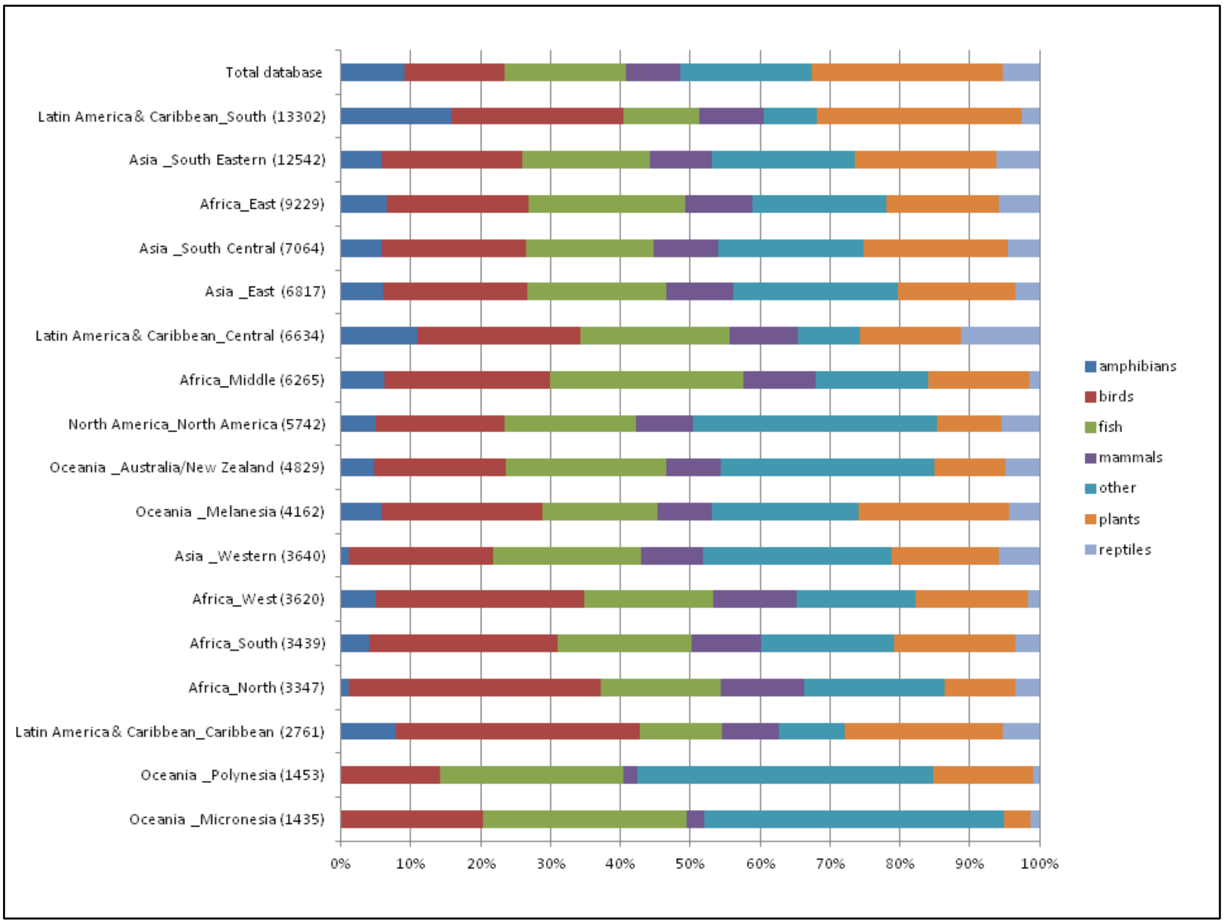

Figure 2. *The percentage contribution of each taxon (amphibians, birds, fish, mammals, plants, reptiles and other) to the MAPISCo database for each region (not including European regions). Regions are ordered by the number of species on the database they contain (shown in brackets). See Appendix 8, Table A8-3 for how countries were assigned to regions.*

4.1. Example 1: All species

4.1.1. Summary findings

Combining all data sources, and with all co-benefit weighting set to 1, the final output list consisted of 70625 species. The top 500 species from the list is shown in Appendix 9, Table A9-1.The top ten species in the list are *Francolinus camerunensis*, *Caprimulgus prigoginei*, *Afropavo congensis* (bird species), *Craugastor polymniae*, *Ecnomiohyla echinata*, *Megastomatohyla mixe*, *Plectrohyla calvicollina*, *Plectrohyla celata*, *Plectrohyla cyanomma*, *Plectrohyla sabrina* (amphibians) with priority scores ranging from 5.43 to 3.59 (Table 7). The score resolution[1] for the full list is 18.55% (13255 unique ranks for 70625 species).

4.1.2. Taxonomic composition

The overall list is made up of 14.34% birds, 27.47% plants, 7.81% mammals, 5.19% reptiles, 9.02% amphibians, 17.35% fish and 18.83% "other" species (Table 7). The highest scoring species for each taxon are shown in Table 7. This top 500 list consists of 116 (23.2%) amphibians, 242 (48.4%) birds, 36 (7.2%) fish, 79 (15.8%) mammals, 10 (2%) plants, 13 (2.6%) reptiles and 4 (0.8%) other species (Table 8).

4.1.3. Geographic composition

In the overall list 241 countries are represented, and 80 in the top 500. The ten countries for which the largest percentage of bird species on the list have been recorded are shown in Table 9. In the overall list, Indonesia has the largest percentage of species on the global list (2.05%) and Brazil has the largest percentage of species (19.12%) in the top 500 list.

4.1.4. IUCN threat categories and classifications

The threat status of species in the overall and top 500 lists are shown in Table 10. The makeup of the overall list mirrors the Red List, apart for species that have not been assessed by it (6.72%). The majority of species on the list are classed as Least Concern (40.01%), followed by Data Deficient (15.22%), Vulnerable (14.50), Endangered (8.33%) Critically Endangered (5.68%) and Near Threatened (5.14%). The remaining categories make up less than 6%. In the top 500, species classed as Critically Endangered contribute the biggest proportion (30.00%), followed by species classed as Endangered (26.20%), Vulnerable (21.20%), Least Concern and Near Threatened (10.40% each). Species in the remaining categories make up less than 2%. When the numbers of species falling in each Red List major threat category were compared with the top 500 list, 3.74% of all the bird species listed as Critically Endangered, 3.17% of species listed as Extinct in the Wild, 2.23% of species listed Endangered, 1.03% of species listed as Vulnerable and 1.43% of species listed as Near Threatened were also in the top 500.

[1] "Score resolution" refers to the ability of a given output list (priority list) to distinguish between species in terms of priorities: for example, some species receive the same final priority score, which results in the same rank (and therefore equal priority) for all these species. The score resolution is calculated as the number of unique ranks divided by the total number of species on a given list.

The threat classification which occurred most frequently in both the overall and top 500 lists was Biological resource use (23.94% and 46.0% of species respectively). This category includes hunting, fishing and logging activities. Agriculture and aquaculture was the threat category next most frequently recorded (17.02% and 40.8%), followed by Natural system modifications (10.86% and 19.4%), Residential and commercial development (10.43% and 16.2%), Pollution (10.41% and 10.2 %) and Invasive species (8.38% and 16.2%).The remaining six classifications made up less than 7% each (Table 11 and Figure 3). Looking at each species groups individually, the patterns are remarkably similar (Table 11). The top two threats across all species groups are Biological resource use and Agriculture and aquaculture. Beyond the top two, there are individual taxa variations. Birds, for example, are more threatened by Climate change than any other taxa in the list (9.36% vs. 7.16% and below); fish are more threatened by Pollution than any other taxa (13.49% vs. 11.81% and below) and amphibians by Residential and commercial developments (13.22% vs. 11.79% and below).

4.1.5. Co-benefits

In the overall list, 56.84% are scored for threat status, 32.34% for ES Provisioning, 4.84% for Habitat and Area Conservation, 2.92% for Sustainable Harvesting and 3.04% for Genetic Diversity. In the top 500 list, 33.53% of species are scored for conservation status and ES Provisioning, 24.28% for Habitat and Area Conservation, 2.62% for Sustainable Harvesting and 6.04% for Genetic Diversity.

Table 7. *Top 20 species listed in the database*

Species name	Taxonomic Group	Threat status	Habitat	Harvesting	Gen. diversity	ES provisioning	Score	Rank
Francolinus camerunensis	birds	0.78	0.46		0.33	0.65	5.43	1
Caprimulgus prigoginei	birds	0.78	0.57			0.66	3.89	2
Afropavo congensis	birds	0.67	0.36		0.33	0.66	3.74	3
Craugastor polymniae	amphibians	1.00	0.50			0.62	3.59	4
Ecnomiohyla echinata	amphibians	1.00	0.50			0.62	3.59	4
Megastomatohyla mixe	amphibians	1.00	0.50			0.62	3.59	4
Plectrohyla calvicollina	amphibians	1.00	0.50			0.62	3.59	4
Plectrohyla celata	amphibians	1.00	0.50			0.62	3.59	4
Plectrohyla cyanomma	amphibians	1.00	0.50			0.62	3.59	4
Plectrohyla sabrina	amphibians	1.00	0.50			0.62	3.59	4
Pseudoeurycea saltator	amphibians	1.00	0.50			0.62	3.59	4
Pseudoeurycea smithi	amphibians	1.00	0.50			0.62	3.59	4
Pseudoeurycea unguidentis	amphibians	1.00	0.50			0.62	3.59	4
Thorius aureus	amphibians	1.00	0.50			0.62	3.59	4
Thorius smithi	amphibians	1.00	0.50			0.62	3.59	4
Habromys chinanteco	mammals	1.00	0.50			0.62	3.59	4
Habromys ixtlani	mammals	1.00	0.50			0.62	3.59	4
Habromys lepturus	mammals	1.00	0.50			0.62	3.59	4
Calyptura cristata	birds	1.00	0.24			0.96	3.14	19
Duellmanohyla ignicolor	amphibians	0.78	0.50			0.62	2.68	20

Table 8. *Number, percentage, highest ranks and scores and highest-ranking species in the complete and top 500 species lists.*

Taxonomic group	No. spp.	% spp.	No. spp. in top 500	% spp. In top 500	Highest rank	Highest score	Highest scoring species
Amphibians	6371	9.02	116	23.2	4	3.59	*Craugastor polymniae, Ecnomiohyla echinata, Megastomatohyla mixe, Plectrohyla calvicollina, Plectrohyla celata, Plectrohyla cyanomma, Plectrohyla sabrina, Pseudoeurycea saltator, P. Smithi, P. Unguidentis, Thorius aureus, T. smithi*
Birds	10128	14.34	242	48.4	1	5.43	*Francolinus camerunensis*
Fish	12252	17.35	36	7.2	30	2.05	*Acipenser sturio*
Mammals	5513	7.81	79	15.8	4	3.59	*Habromys chinanteco*
Other	13298	18.83	4	0.8	149	0.08	*Elga newtonsantosi*
Plants	19398	27.47	10	2	149	0.08	*Devillea flagelliformis*
Reptiles	3665	5.19	13	2.6	89	0.69	*Ctenosaura oaxacana*

Table 9. *The top 10 countries in the overall and top 500 lists and the number and percentage of species which have been recorded as occurring within them.*

Overall list				Top 500 list		
Country rank	Country	No. spp.	% spp.	Country	No. spp.	% spp.
1	Indonesia	6298	2.05	Brazil	528	19.12
2	Ecuador	6116	1.99	Indonesia	99	3.59
3	India	5340	1.74	Mexico	85	3.08
4	United States	5245	1.71	India	62	2.25
5	China	5059	1.65	Congo, The Democratic Republic of the	55	1.99
6	Brazil	4867	1.59	China	54	1.96
7	Malaysia	4842	1.58	Cameroon	53	1.92
8	Mexico	4782	1.56	Thailand	44	1.59
9	Colombia	4651	1.52	Myanmar	43	1.56
10	Thailand	4522	1.47	Malaysia and Argentina	39	1.41

Table 10. *The proportion of species in the overall and top 500 lists and the IUCN threat category in which they are listed. The end column shows the proportion of bird species listed from each Red List category which occur in the top 500 list.*

	Overall list		Top 500		
Threat Status	No. spp.	% spp.	No. spp.	% spp.	% of all spp. in threat category on red list in top 500
CR	4009	5.68	150	30.00	3.74
DD	10672	15.11	6	1.20	0.06
EN	5882	8.33	131	26.20	2.23
EW	63	0.09	2	0.40	3.17
EX	801	1.13	0	0	0
LC	28258	40.01	52	10.40	0.18
LR/cd	255	0.36	0	0	0
LR/lc	1018	1.44	1	0.20	0.10
LR/nt	1015	1.44	0	0	0
NE	29	0.04	0	0	0
NT	3631	5.14	52	10.40	1.43
VU	10243	14.50	106	21.20	1.03
Not Assessed	4749	6.72	0	0	0

Table 11. *Percentage of species classified as threatened by each of the 12 IUCN threat classification categories, for the overall list and for each species group individually.*

	Percentage of species classified as threatened by each of the 12 categories								
	overall list	top 500	mammals	plants	birds	fish	reptiles	other	amphibians
Biological resource use	23.94	46.00	26.21	23.52	22.88	28.71	23.91	23.38	23.71
Agriculture /aquaculture	17.02	40.80	18.84	17.89	18.69	14.23	19.16	14.86	21.33
Natural system modification	10.86	19.40	10.51	12.28	12.60	11.29	9.90	10.73	8.56
Residential/commercial development	10.43	16.20	10.69	11.62	8.03	9.08	11.79	11.07	13.22
Pollution	10.18	10.20	8.90	9.91	7.44	13.49	10.01	11.81	10.03
Invasive species	8.39	16.20	7.87	8.31	8.98	8.12	8.58	9.17	8.55
Climate change	6.25	10.40	4.81	5.36	9.36	5.85	5.66	7.16	5.10
Human intrusions/disturbance	4.21	5.40	4.23	4.20	4.11	3.58	4.08	5.35	4.05
Energy production/mining	3.68	6.60	4.63	3.83	4.34	3.59	3.88	3.52	2.88
Transportation/service corridors	2.27	4.20	2.63	2.37	3.03	1.68	2.38	2.32	1.95
Geological events	0.48	1.20	0.59	0.57	0.51	0.27	0.49	0.51	0.55
Other threats	0.10	0.60	0.11	0.14	0.03	0.13	0.16	0.11	0.07

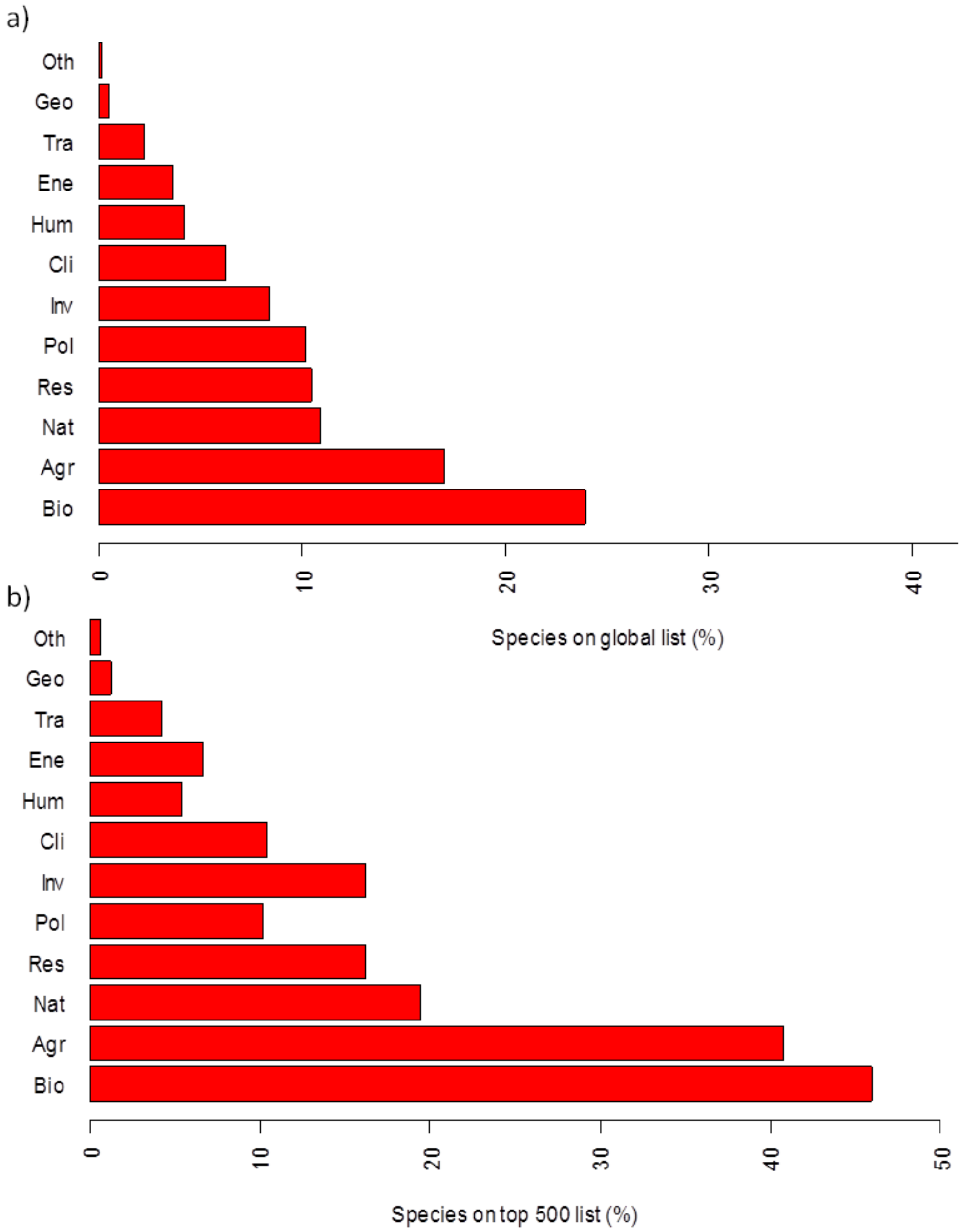

Figure 3. *Percentage of species classified as threatened by each of the 12 IUCN threat classification categories a) the overall list; b) the top 500. Full names for each threat category are given in Table 11.*

4.2. Example 2: Taxonomic case study – birds

4.2.1. Summary findings

The bird list contained 10128 species, 14.34% of the overall database (for the top 500 list see Appendix 9, Table A9-2). The score resolution for the overall list was 61.57% (6326 unique ranks for species) and for the top 500 list 89% (445 unique ranks). The top five species on the list are all Galliformes; Cameroon Francolin *Francolinus camerunensis* (scoring 6.53), Congo Peacock *Afropavo congensis* (4.62), Nahan's Francolin *Francolinus nahani* (3.39), White-breasted Guineafowl *Agelastes meleagrides* (2.30) and Swierstra's Francolin *Francolinus swierstra* (1.44) (for top 20 see Table 12).

4.2.2. Orders and Families

The overall list consisted of birds from 25 orders. Passeriformes were the most represented in the list at 57.73%, followed by Apodiformes (4.96%), Piciformes (4.63%), Psittaciformes (4.13%), and Galliformes (3.49%) (Table 13).

The top 500 list consisted of species from 19 orders. Of these, two made up almost three-quarters of the species listed – Galliformes (44.8%) and Passeriformes (33.6%), (Table 13). Sixty-eight individual families made up the top 500, with Phasianidae, making up the largest percentage (36.2%). The highest ranking species in each order is also shown in Table 13.

4.2.3. Country/region

Two hundred and thirty four countries are represented in the overall list, and 80 in the top 500. The ten countries for which the largest percentage of bird species on the list have been recorded are shown in Table 14. In the overall list, Colombia has the largest percentage of species on the global list (1.71%) and Brazil has the largest percentage of species (29.40%) in the top 500 list. The number and proportion of species recorded in each country, for both the overall and top 500 lists, is detailed in Appendix 9, Table A9-3.

4.2.4. IUCN Red List threat categories and classifications

The threat status of species in the overall and top 500 lists is shown in Table 15. The makeup of the overall list mirrors the Red List, apart for species that have not been assessed by it. The majority of species are classed as Least Concern (75.8%), followed by Near Threatened (8.69%), Vulnerable (7.18%), Endangered (3.84%) and Critically Endangered (1.95%). The remaining categories make up less than 3%. In the top 500, again species classed as Least Concern contribute the biggest proportion (36.6%), followed by species classed as Vulnerable (20.2%), Near Threatened (19.2%), Endangered (11.8%) and Critically Endangered (10.8%) followed by species in the remaining categories making up less than 2%. When the numbers in each category on the Red List were compared with the top 500 list, 27.41% of all the bird species listed as Critically Endangered by the Red List were in that top 500, 25% of species listed as Extinct in the Wild, 15.17% of species listed Endangered, 13.89% of species listed as Vulnerable and 10.91% of species listed as Near Threatened (Table 15).

In the overall list the threat classification against which the majority of species are listed is Biological resource use (22.33%). Agriculture and aquaculture (21.56%), Natural system modifications (14.28%), Climate change (12.42%), Invasive species (9.45%) and Residential/commercial development (4.79%) make up the next largest proportions. The remaining 6 categories make up the remaining 15% (see Table 16 for full list). For the top 500 list, the threat classification against which the majority of species are listed is also Biological resource use (23.90%) followed by Agriculture and aquaculture (22.54%), Natural system modifications (12.10%), Invasive species (9.53), Climate change (9.23%), Energy production and mining (5.59%), Residential and commercial development (4.99%) and Transportation and service corridors (4.54%). The remaining four categories made up less than 8% of the threats listed Table 16).

4.2.5. Co-benefits

In the overall list, 43.29% are scored for Threat Status, 33.67% for ES Provisioning, 20.62% for Habitat and Area Conservation, 0.68% for Sustainable Harvesting and 1.73% for Genetic Diversity. In the top 500 list, 31.83% of species are scored for Conservation Status and ES Provisioning, 29.79% for Habitat and Area Conservation, 0.57% for Sustainable Harvesting and 5.98% for Genetic Diversity.

4.2.6. Key findings and how they relate to policy

Species from the order Galliformes made up the majority of the top 500 bird species on the priority list. This is not surprising considering that the majority of Galliformes are scored on three co-benefits more (mean number per species = 3.10). As one of the most threatened group of birds, with over 25% of species in the group being classified as Vulnerable, Endangered or Critically Endangered, Galliformes score highly on Threat Status. Over two-thirds of the Galliformes in the top 500 have a score for Genetic Diversity; this reflects their close genetic relationship to the domesticated chicken, guineafowl, pheasant and quail. Over two-thirds have a score for Ecosystem Services and over half for Habitat, which reflects forest being the predominant habitat of Galliformes on the top 500 list. These characteristics are scored highly by the current co-benefit scoring system.

In order to maximise conservation benefit for Galliformes species (if we accept the inherent constraints in the MAPISCo prioritisation) policy-makers could target resources to countries with a high number of Galliformes species from the top 500 list. These countries (shown in Figure 4) include Indonesia, Brazil, The Democratic Republic of the Congo and Malaysia.

Table 12. *The top 20 highest scoring species, all in the order Galliformes, the country(ies) in which they have been recorded, scores each of the five co-benefits as well as resultant priority score and rank. Note that all values have been rounded to three decimal points. All co-benefit weighting factors set to 1 (default).*

Rank	Species name	English name	Country	Threat status	Habitat	Harvesting	Gen. diversity	provisioning	Score
1	*Francolinus camerunensis*	Cameroon Francolin	Cameroon	0.778	0.462	0	0.333	0.649	6.539
2	*Afropavo congensis*	Congo Peacock	Democratic Republic of Congo	0.667	0.361	0	0.333	0.659	4.625
3	*Francolinus nahani*	Nahan's Francolin	Uganda & Democratic Republic of Congo	0.778	0.245	0	0.333	0.640	3.389
4	*Agelastes meleagrides*	White-breasted Guineafowl	Cote d' Ivoire, Ghana, Liberia & Sierra Leone	0.667	0.230	0	0.333	0.606	2.301
5	*Francolinus swierstrai*	Swierstra's Francolin	Angola	0.778	0.116	0	0.333	0.626	1.436
6	*Guttera plumifera*	Plumed Guineafowl	Angola, Cameroon, Central African Republic, Congo, Democratic Republic of Congo, Equatorial Guinea & Gabon	0.222	0.340	0	0.333	0.584	1.400
7	*Agelastes niger*	Black Guineafowl	Angola, Cameroon, Central African Republic, Congo, Democratic Republic Congo, Equatorial Guinea, Gabon, Nigeria	0.222	0.330	0	0.333	0.597	1.380
8	*Tragopan satyra*	Crimson Horned-pheasant	Bhutan, China, India, Nepal	0.556	0.231	0	0.333	0.561	1.347
9	*Francolinus ochropectus*	Djibouti Francolin	Djibouti	1	0.026	0	0.333	0.619	1.233
10	*Lophura edwardsi*	Edwards's Pheasant	Vietnam	1	0.007	0	0.333	0.595	0.754
11	*Odontophorus capueira*	Spot-winged Wood-quail	Argentina, Brazil, Paraguay	0.222	0.151	0	0.333	0.795	0.642
12	*Lophura hoogerwerfi*	Aceh Pheasant	Indonesia	0.667	0.016	0	0.333	0.747	0.564

13	*Polyplectron schleiermacheri*	Bornean Peacock-pheasant	Indonesia, Malaysia	0.778	0.013	0	0.333	0.684	0.514
14	*Lophura inornata*	Salvadori's Pheasant	Indonesia	0.667	0.012	0	0.333	0.747	0.501
15	*Arborophila orientalis*	Grey-breasted Partridge	Indonesia	0.667	0.007	0	0.333	0.747	0.434
16	*Odontophorus melanonotus*	Dark-backed Wood-quail	Colombia, Ecuador	0.667	0.098	0	0.333	0.603	0.411
17	*Francolinus lathami*	Forest Francolin	Angola, Cameroon, Central African Republic, Congo, The Democratic Republic of Congo, Cote d' Ivoire, Equatorial Guinea, Gabon, Ghana, Guinea, Liberia, Nigeria, Sierra Leone, Sudan, Tanzania, Togo, Uganda	0.222	0.249	0	0.333	0.608	0.329
18	*Francolinus nobilis*	Handsome Francolin	Burundi, Democratic Republic of Congo, Rwanda, Uganda	0.222	0.225	0	0.333	0.629	0.177
19	*Cyrtonyx ocellatus*	Ocellated Quail	El Salvador, Guatemala, Honduras, Mexico, Nicaragua	0.667	0.069	0	0.333	0.617	0.124
20	*Odontophorus dialeucos*	Tacarcuna Wood-quail	Colombia, Panama	0.667	0.079	0	0.333	0.590	0.027

Table 13. *Proportion of species in the overall and top 500 species lists by Order, along with the highest rank and score per order and highest scoring species.*

Order	Overall list		Top 500		Highest rank	Highest score	Highest scoring species	Red List status
	No. spp.	% spp.	No. spp.	% spp.				
PASSERIFORMES	4763	57.73	168	33.60	207	-8.230	*Calyptura cristata*	CR
APODIFORMES	409	4.96	11	2.20	242	-8.960	*Schoutedenapus schoutedeni*	VU
PICIFORMES	382	4.63	8	1.60	306	-11.920	*Indicator pumilio*	NT
PSITTACIFORMES	341	4.13	30	6.00	249	-10.210	*Touit melanonotus*	EN
GALLIFORMES	288	3.49	224	44.80	1	6.530	*Francolinus camerunensis*	EN
FALCONIFORMES	275	3.33	5	1.00	261	-10.923	*Leptodon forbesi*	CR
COLUMBIFORMES	270	3.27	3	0.60	415	-12.990	*Columba albinucha*	NT
CHARADRIIFORMES	214	2.59	1	0.20	498	-13.560	*Charadrius thoracicus*	VU
CORACIIFORMES	207	2.51	3	0.60	447	-13.220	*Bycanistes cylindricus*	VU
STRIGIFORMES	181	2.19	10	2.00	245	-9.660	*Phodilus prigoginei*	EN
GRUIFORMES	177	2.15	3	0.60	295	-11.740	*Psophia viridis*	EN
ANSERIFORMES	159	1.93	18	3.60	21	0.001	*Cairina scutulata*	EN
CUCULIFORMES	152	1.84	2	0.40	422	-13.060	*Neomorphus squamiger*	VU
CICONIIFORMES	111	1.35	1	0.20	450	-13.212	*Bostrychia bocagei*	CR
CAPRIMULGIFORMES	100	1.21	2	0.40	201	-7.435	*Caprimulgus prigoginei*	EN
PROCELLARIIFORMES	55	0.67	3	0.60	340	-12.374	*Pterodroma magentae*	CR
TROGONIFORMES	44	0.53	0	0.00	587	-14.253	*Apaloderma aequatoriale*	LC
PELECANIFORMES	35	0.42	1	0.20	458	-13.300	*Fregata andrewsi*	CR
TINAMIFORMES	32	0.39	1	0.20	401	-12.895	*Crypturellus noctivagus*	NT
PODICIPEDIFORMES	22	0.27	0	0.00	821	-14.956	*Podiceps taczanowskii*	CR
STRUTHIONIFORMES	12	0.15	6	1.20	29	-0.238	*Casuarius casuarius*	VU
SPHENISCIFORMES	10	0.12	0	0.00	1548	-16.062	*Eudyptes robustus*	VU
PHOENICOPTERIFORMES	5	0.06	0	0.00	2663	-17.468	*Phoeniconaias minor*	NT
GAVIIFORMES	5	0.06	0	0.00	3509	-17.928	*Gavia adamsii*	NT
COLIIFORMES	2	0.02	0	0.00	3105	-17.689	*Colius castanotus*	LC

Table 14. *The top 10 countries in the overall and top 500 lists and the number and percentage of species that have been recorded as occurring within them.*

Country rank	Overall list			Top 500 list		
	Country	No. spp.	% spp.	Country	No. spp.	% spp.
1	Colombia	1835	1.71	Brazil	147	29.40
2	Peru	1814	1.69	DR Congo	27	5.40
3	Brazil	1766	1.65	Cameroon	18	3.60
4	Ecuador	1647	1.54	Indonesia	15	3.00
5	Indonesia	1600	1.49	India, Uganda	11	2.20
6	China	1269	1.19	Argentina, Liberia, Malaysia, Nigeria	10	2.00
7	India	1225	1.14	Colombia, Cote d' Ivoire, Ghana, Paraguay	9	1.80
8	DR Congo	1129	1.05	Gabon, Myanmar, Sierra Leone	8	1.60
9	Mexico	1103	1.03	Central African Republic, China, Congo, Equatorial Guinea	7	1.40
10	Kenya	1098	1.03	Angola, Guinea, Nepal, Thailand, Viet Nam	6	1.20

Table 15. *The proportion of species in the overall and top 500 lists and the IUCN threat category in which they are listed. The end column shows the proportion of bird species listed from each Red List category that occur in the top 500 list.*

	Overall list		Top 500		
Threat Status	No. spp.	% spp.	No. spp.	% spp.	% of all spp. in threat category on red list in top 500
CR	197	1.95	54	10.8	27.41
DD	60	0.59	4	0.8	6.67
EN	389	3.84	59	11.8	15.17
EW	4	0.04	1	0.2	25.00
EX	130	1.28	1	0.2	0.77
LC	7677	75.8	183	36.6	2.38
NT	880	8.69	96	19.2	10.91
VU	727	7.18	101	20.2	13.89
not classified	64	0.63	1	0.2	1.56

Table 16. *Red List threat classifications of the species in the overall and top 500 lists.*

	Overall list		Top 500	
Threats	No. spp.	% spp.	No. spp.	% spp.
Biological Resource use	1847	22.33	158	23.90
Transportation and service corridors	296	3.58	30	4.54
Pollution	294	3.55	26	3.93
Other threats	0	0	0	0
Natural system modifications	1181	14.28	80	12.10
Invasive species	782	9.45	63	9.53
Human intrusions and disturbance	281	3.40	21	3.177
Residential and commercial development	396	4.79	33	4.99
Geological events	35	0.42	3	0.45
Energy production and mining	349	4.22	37	5.59
Agriculture and aquaculture	1783	21.56	149	22.54
Climate Change	1027	12.42	61	9.23

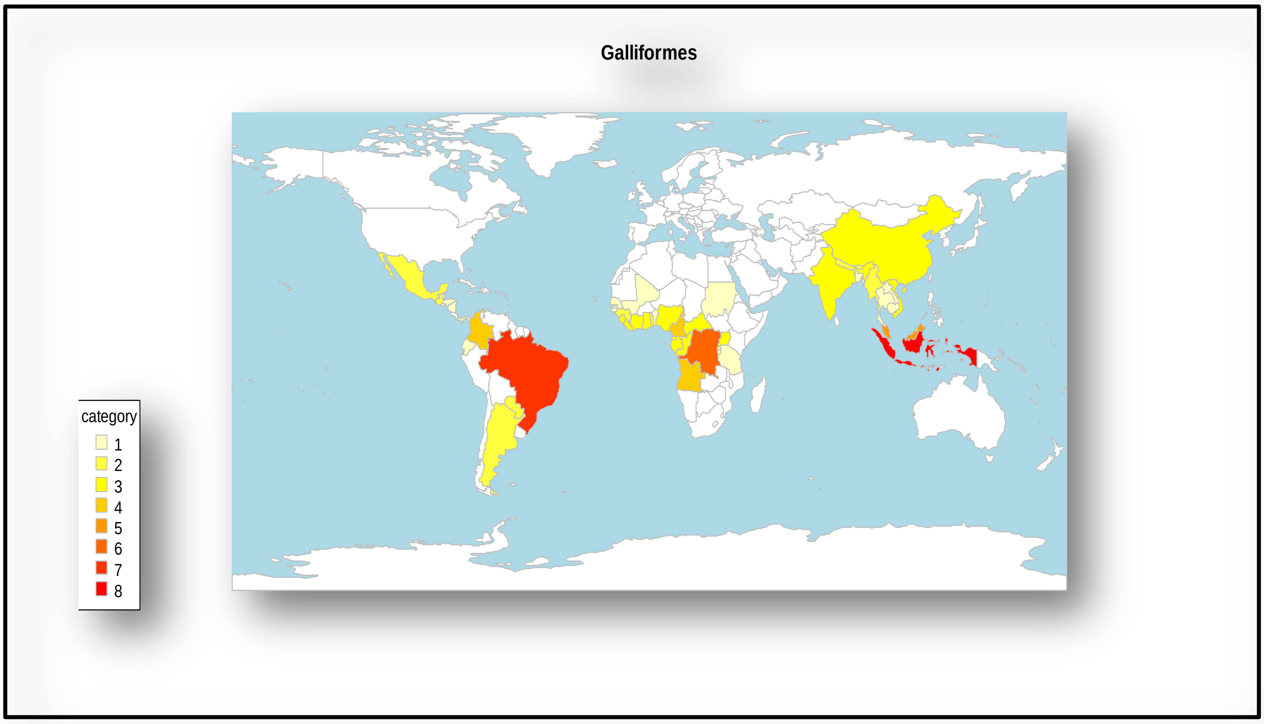

Figure 4. *The global distribution of Galliformes species in the top 500 birds list. The categories relate to the number of Galliformes species (in the top 500) that are found in each country. Countries coloured white have no Galliformes listed in the top 500. (The map was produced using the package rworldmap South, A. (2011) rworldmap: A New R package for Mapping Global Data. The R Journal Vol. 3/1: 35-43.)*

4.3. Example 3: Geographic case study – SE Asia

4.3.1. General findings

The final output list for SE Asia contains 12496 species, which is 17.7% of the overall database. The score resolution for the full list is 23.66% (2956 unique ranks for 12496 species) and for the top 500 is 49.20% (246 unique ranks). The five highest priority species are the Togian Islands Babirus *Babyrousa togeanensis* (0.782), Anoa *Bubalus depressicornis* (0.782), Mountain Anoa *B. quarlesi* (0.782), Javan pig *Sus verrucosus* (0.782) and Aceh pheasant *Lophura hoogerwerfi* (0.503) (see Table 17 for the top 20 species).

4.3.2. Taxonomic composition

The overall list consists of 20.42% “other” species (2552 spp.), 20.27% plants (2533 spp.), 20.09% birds (2510 spp.), 18.17% fish (2271 spp.), 8.86% mammals (1107 spp.), 6.24% reptiles (780 spp.) and 5.95% amphibians (743 spp.) (Table 18). The top 500 list has a rather different composition, with birds and mammals contributing the largest proportions (36.8 %, 184 spp. and 35.0%, 175 spp. respectively), followed by plants (10.4%, 52 spp.), “other” species (6.8%, 34 spp.), amphibians (4.8%, 24 spp.), fish (4.2%, 21 spp.) and reptiles (2.0%, 10 spp.). The highest scoring species in each taxon are shown in Table 18. The highest scoring mammals, birds and fish are all in the top 20, while the highest scoring amphibian *Duttaphrynus sumatranus* is ranked at 86, “other” species *Protosticta gracilis* at 107, plant *Taxus wallichiana* at 44 and reptile *Emoia ruficauda* 193.

4.3.3. Geographic composition

The species in the overall and top 500 lists have been recorded in 11 countries - Brunei, Cambodia, Indonesia, Lao, Malaysia, Myanmar, Philippines, Singapore, Thailand, East Timor and Viet Nam. In the overall list, the greatest proportion of species have been recorded in Indonesia (18.28%) followed by Malaysia (14.05%), Thailand (13.13%), Viet Nam (11.42%), Myanmar (10.15%), Philippines (9.72%), Cambodia (6.40%), PDR Lao (6.39%), Singapore (5.64%), Brunei (3.55%) and East Timor (1.27%) (Table 19). In the top 500 list the country in which the largest proportion of species have been recorded is Indonesia (32.41%), followed by Malaysia (11.18%), Myanmar (10.15%), Thailand and Viet Nam (both 9.44%), Philippines (7.28%), Cambodia (6.46%), Myanmar (6.83%), Lao PDR (6.36%), Brunei (2.77%), Singapore (2.67%) and East Timor (1.85%) (Table 19). The top ranked species in each country are listed in Table 20.

4.3.4. IUCN Red List threat categories and classifications

The threat status of the overall and top 500 lists is shown in Table 21. The majority of species in the overall list are classed as Least Concern (47.7%), followed by Data Deficient (18.55%), Vulnerable (13.43%), Near Threatened (6.55%), Endangered (4.64%) and Critically Endangered (4.03%). The remaining categories make up less than 6%. In the top 500 list, species classed as Vulnerable made up the largest proportion (29%), followed by Critically Endangered (27%), Endangered (22%), Least Concern (14.2%), Near Threatened (6.6%), and Data Deficient (1.2%). No species in the top 500 were classed in the any of the remaining categories. In the overall list, the threat classification against which the majority of species are listed is Biological resource use (29.90%) followed by Agriculture and aquaculture (13.25%), Pollution (11.95%), Residential/commercial development (11.82%), Natural system modifications (8.46%), Climate change (7.34%), Human intrusions/disturbance (6.55%), Invasive species (6.18%), Energy production and mining (2.74%). The remaining four categories make up less than 4% (see Table 22 for full list). For the top 500 list, the threat classification against which the majority of species were listed is also Biological resource use (25.6%), followed by Agriculture and aquaculture (20.79%), Natural system modifications (11.60%), Residential and commercial development and invasive species (both 8.35%), Climate change (7.64%), Pollution (5.20%), Energy production and mining (4.95%), Human intrusions and disturbance (3.68%), Transportation and service corridors (3.11%) and Geological events (0.71%) (Table 22).

4.3.5. Co-benefits

In the overall list, 100% are scored for Threat Status, 66.12% for ES Provisioning, 7.18% for Habitat and Area Conservation, 5.27% for Sustainable Harvesting and 1.58% for Genetic Diversity. In the top 500 list, 100% of species are scored for Conservation Status, 99.8% for ES Provisioning, 28.6% for Habitat and Area Conservation, 8.8% for Sustainable Harvesting and 13.6% for Genetic Diversity.

4.3.6. Key findings and how they relate to policy

In the top 500 list, the country in which the largest proportions of species have been recorded is Indonesia (32.41%). These 316 species (138 mammals, 112 birds, 23 plants, 20 amphibians, 11 fish, 9 “other” species and 3 reptiles) share similar threats (37.34% of these species are threatened by Biological resource use and 29.43% by Agriculture and aquaculture). For the highest ranked 10 species in the top 500 list (all from Indonesia), hunting and/or habitat destruction are the major threats listed by the IUCN Red List. Conservation actions that reduce habitat destruction and target unsustainable hunting of species in Indonesia should therefore benefit these priority species. Several species on the list, e.g. Javan warty pig *Sus verrucosus* and Sulawesi babirusa *Babyrousa celebensis* are illegally hunted in protected areas and therefore better community engagement and conservation law enforcement would benefit these species.

Table 17. *The top 20 highest scoring species, the order to which they belong, the country(ies) in which they have been recorded, scores each of the five co-benefits as well as resultant priority score and rank. Note that all values have been rounded to three decimal points. All co-benefit weighting factors set to 1 (default).*

Rank	Species	English name	Taxon	Country	Threat status	Habitat	Harvesting	Gen. diversity	ES provisioning	Score
1	Babyrousa togeanensis	Togian Islands Babirusa	mammals	Indonesia	0.778			0.333	0.747	0.782
1	Bubalus depressicornis	Anoa	mammals	Indonesia	0.778			0.333	0.747	0.782
1	Bubalus quarlesi	Mountain Anoa	mammals	Indonesia	0.778			0.333	0.747	0.782
1	Sus verrucosus	Javan Pig	mammals	Indonesia	0.778			0.333	0.747	0.782
5	Lophura hoogerwerfi	Aceh Pheasant	Birds	Indonesia	0.667	0.016		0.333	0.747	0.503
6	Lophura inornata	Salvadori's Pheasant	Birds	Indonesia	0.667	0.012		0.333	0.747	0.441
7	Arborophila orientalis	Grey-breasted Partridge	Birds	Indonesia	0.667	0.007		0.333	0.747	0.374
8	Babyrousa babyrussa	Babiroussa	mammals	Indonesia	0.667			0.333	0.747	0.275
8	Babyrousa celebensis	Sulawesi Babirusa	mammals	Indonesia	0.667			0.333	0.747	0.275
8	Callosciurus melanogaster	Mentawai Squirrel	mammals	Indonesia	0.667			0.333	0.747	0.275
11	Polyplectron schleiermacheri	Bornean Peacock-pheasant	Birds	Indonesia, Malaysia	0.778	0.013		0.333	0.684	0.251
12	Bubalus mindorensis	Mindoro Dwarf Buffalo	mammals	Philippines	1.000			0.333	0.608	0.208
12	Sus cebifrons	Visayan Warty Pig	mammals	Philippines	1.000			0.333	0.608	0.208
14	Lophura edwardsi	Edwards's Pheasant	Birds	Viet Nam	1.000	0.007		0.333	0.595	0.172
15	Bos sauveli	Grey Ox	mammals	Cambodia, Lao PDR, Thailand, Viet Nam	1.000			0.333	0.597	0.082
16	Epinephelus coioides	Estuary Cod	Fish	Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam	0.556		0.611		0.614	-0.119
17	Sus celebensis	Celebes Pig	mammals	Indonesia	0.556			0.333	0.747	-0.233
18	Cairina scutulata	White-winged Duck	Birds	Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Thailand, Viet Nam	0.778	0.017		0.333	0.622	-0.407
19	Melanoperdix niger	Black Partridge	Birds	Brunei Darussalam, Indonesia, Malaysia, Singapore	0.667	0.020		0.333	0.660	-0.441
20	Lophura erythrophthalma	Crestless Fireback	Birds	Brunei Darussalam, Indonesia, Malaysia, Singapore	0.667	0.019		0.333	0.660	-0.448

Table 18. *Proportion of species in the overall and top 500 species lists by taxonomic group, along with the highest rank and score per group, highest scoring species and the country in which it is found.*

Taxonomic group	Overall list		Top 500		Highest rank	Highest score	Highest scoring species	Country (ies)
	No. spp.	% spp.	No. spp.	% spp.				
Amphibians	743	5.95	24	4.8	86	-2.056	Duttaphrynus sumatranus Sumartrian toad	Indonesia
Birds	2510	20.09	184	36.8	5	0.503	*Lophura hoogerwerfi* Aceh pheasant	Indonesia
Fish	2271	18.17	21	4.2	16	-0.119	*Epinephelus coioides* Estuary Cod	Brunei Darussalam; Cambodia; Indonesia; Malaysia; Myanmar; Philippines; Singapore; Thailand; Viet Nam
Mammals	1107	8.86	175	35	1	0.782	*Babyrousa togeanensis* Togian Islands Babirusa	Indonesia
Other	2552	20.42	34	6.8	107	-2.375	*Protosticta gracilis* Arthropod	Indonesia
Plants	2533	20.27	52	10.4	44	-0.842	*Taxus wallichiana* Himalayan Yew	Indonesia; Myanmar; Philippines; Viet Nam
Reptiles	780	6.24	10	2	193	-3.334	*Emoia ruficauda* Red-tailed Swamp Skink	Philippines

Table 19. *The 11 countries which feature in the overall and top 500 lists and the number and percentage of species which have been recorded as occurring within them.*

Country rank	Overall list			Top 500 list		
	Country	No. spp.	% spp.	Country	No. spp.	% spp.
1	Indonesia	6298	18.28	Indonesia	316	32.41
2	Malaysia	4842	14.05	Malaysia	109	11.18
3	Thailand	4522	13.13	Myanmar	99	10.15
4	Viet Nam	3934	11.42	Thailand	92	9.44
5	Myanmar	3498	10.15	Viet Nam	92	9.44
6	Philippines	3347	9.72	Philippines	71	7.28
7	Cambodia	2205	6.40	Cambodia	63	6.46
8	Lao PDR	2202	6.39	Lao PDR	62	6.36
9	Singapore	1944	5.64	Brunei	27	2.77
10	Brunei	1223	3.55	Singapore	26	2.67
11	East Timor	436	1.27	East Timor	18	1.85

Table 20. *The top ranking species in each country.*

Country	Highest Priority score	Rank	Species
Brunei	-0.119	16	*Epinephelus coioides*, Estuary Cod
Cambodia	0.081	15	*Bos sauveli,* Grey Ox
Indonesia	0.782	1	*Babyrousa togeanensis*, Togian Islands Babirusa
People's Democratic Republic of Lao	0.081	15	*Bos sauveli,* Grey Ox
Malaysia	0.251	11	*Polyplectron schleiermacheri, Bornean Peacock-pheasant*
Myanmar	0.356	28	*Epinephelus coioides*, Estuary Cod
Philippines	0.207	12	*Bubalus mindorensis, Mindoro Dwarf Buffalo*

Table 21. *The proportion of species in the overall and top 500 lists and the IUCN threat category in which they are listed.*

	Overall list		Top 500	
Threat Category	No. spp.	% spp.	No. spp.	% spp.
CR	503	4.03	135	27.00
DD	2318	18.55	6	1.20
EN	580	4.64	110	22.00
EW	2	0.02	0	0.00
EX	7	0.06	0	0.00
LC	5960	47.70	71	14.20
NT	819	6.55	33	6.60
VU	1678	13.43	145	29.00
not evaluated	122	0.98	0	0.00
LR/cd	122	0.98	0	0.00
LR/lc	378	3.02	0	0.00
LR/nt	129	1.03	0	0.00

Table 22. *Red List threat classifications of the species in the overall and top 500 lists.*

	Overall list		Top 500	
Threats	No. spp.	% spp.	No. spp.	% spp.
Biological Resource use	4371	29.90	181	25.60
Transportation and service corridors	224	1.53	22	3.11
Pollution	1747	11.95	37	5.23
Other threats	6	0.04	0	0.00
Natural system modifications	1236	8.46	82	11.60
Invasive species	903	6.18	59	8.35
Human intrusions and disturbance	957	6.55	26	3.68
Residential/commercial development	1728	11.82	59	8.35
Geological events	34	0.23	5	0.71
Energy production and mining	401	2.74	35	4.95
Agriculture and aquaculture	1937	13.25	147	20.79
Climate Change	1073	7.34	54	7.64

5. Using the method

Capsule.

- ***Expandable.*** *We demonstrate how additional species or co-benefit data can be added to the database, and outline how such changes impact on the ranking of priority lists.*
- ***Adaptable.*** *We examine the effect changing individual co-benefit weightings (i.e. making certain co-benefits "more important" in the calculation of priority lists than others) has on priority list ranking.*
- ***Usable.*** *Here we outline the development of a web-based interface, which, using a variety of tabs and graphics, allows users to fully explore the priority lists created by the methodology under a number of different scenarios. We view this as a critical feature of the GUI, as it makes it adaptable to policy aspirations.*

5.1. Expandable –How does the does the priority list respond to the inclusion of additional co-benefit data? A plant example.

The method developed in this project has the capacity for additional datasets (either taxonomic or co-benefit) to be included within it should they become available. We see this expansion as a critical element of the method because at present, the number of datasets that contribute to the overall priority scores is relatively small (12 data sources). As discussed in **section 4** (page 27), this has resulted in taxonomic and geographic constraints on the lists, which must be considered before this method can become fully integrated in conservation policy. One way to address these constraints is to add new co-benefit data to the database. At present, we believe we have included all currently available, verified data, by focussing on either the transcribing of existing datasets into a format usable by the method, or on the collection of new data, additional data would make a huge improvement to the database. As described in **section 4** (page 27) this should focus on the taxa that are underrepresented in the current database - plants for example, are vastly underrepresented in the database in its current form – just 6.3% of all plants species currently described worldwide are on the priority list. This is not the case for other taxa, birds, the coverage for mammals and amphibians all approaching 100% (see Box 3 Table B3-1; page 28).

For this reason, we have chosen to investigate the effect additional plant data will have on the composition of priority lists

Method: To assess the effect of inclusion of further co-benefit data, we asked the IUCN SSC Palm Specialist Group (Bill Baker, Kew Gardens & IUCN-SSC Palm Specialist Group, pers. comm.) to use its specialist knowledge to score a selection of palm species based on their contribution to one of the five co-benefits – Harvesting. The group selected 64 species for inclusion in this assessment, based on the flagship species for palm conservation. However, only 52 of these species were already on the overall list. As this exercise was to address the addition of data to the list, we concentrated on these 52 species. The group were asked to score species on a scale of 0 to 2 where 0 is a species of zero value to harvesting and 2 is a species of the maximum value to harvesting. These values were then rescaled to fit with the original harvesting data. New co-benefit scores for harvesting were then calculated using these rescaled data set scores, following the procedure outlined in **section 3** (page 12). Final priority scores for the full list were then calculated.

Results: For the 52 palm species previously included on the priority list, inclusion of the new harvesting co-benefit scores results in harvesting co-benefit scores being increased (mean value from 0.111 to 0.414). The mean final priority score for these species in the overall list also increased, from -7.043 to -1.224. This had a significant change in the overall species ranking within the list. Firstly, two palm species now ranked equal first at the top of the overall list - *Carpoxylon macrospermum* and *Ceroxylon sasaimae* (both previously ranked 37816th). Secondly, inclusion of this new data set increased the representation of plants in the top 500 by 4% (from 10 to 30 species), largely at the expense of fish (-2.4%) and amphibians (-1.8%).

Discussion: These results show clearly that the expansion of the database through the addition of new information will have considerable effects on species priority lists.

5.2. Adaptable - How does the priority list respond to changes in co-benefit weightings?

The facility to change the relative weight given to of each co-benefit in is built into the database. **This allows the priority lists to be adapted to explore policy scenarios**. If, for example, a policy wished to prioritise species based on their contribution to ecosystem services, the weighting this co-benefit was given in the methodology could be increased in relation to the other co-benefits. This would then give an ecosystem service-centric list. We illustrate this adaptability using a sensitivity analysis and by carrying out a worked example.

5.2.1. Sensitivity analysis

The species represented in the top 500 list changes as the co-benefit weightings are varied. We can illustrate the strength of this effect across the five co-benefits by decreasing the weight of one co-benefit by 0.1 intervals from 1 to 0 whilst keeping all others constant (at 1). This gives a total of 51 combinations (10 decreases in weighting by 0.1, for each of the 5 co-benefits, in addition to all co-benefit weights set to 1).

Decreasing the weighting of each co-benefit (relative to all others held at a constant weight of 1) from 1 to 0.1 results in a similar pattern of absolute change in rank for each co-benefit (see Figure 5 below). The greatest absolute change in species in the top 500 list occurs when Ecosystem services is reduced to a weight of 0.1 (the mean change in rank is 1588.01). In the 51 combinations of weightings tested, a total of 1064 different species occur in the top 500, with some species occurring in many or all iterations (up to 51 times). The distribution of species occurrence in the top 500 is distinctly bimodal: 504 (41.6%) species occurred in the top 500 in more than 30 iterations and 602 (49.4%) occurred fewer than 10 times. This suggests a surprising degree of stability of species representation in the top of the list irrespective of modest levels of variations in weighting. This most likely reflects the non-independence of the co-benefits outlined above. Appendix 9, Table A9-4 shows the list of species occurring more than 30 times in the top 500.

5.2.2. Worked examples – threat status and ecosystem services

If policy-makers wish to **prioritise threat status** above all other co-benefits then they could adjust the weight applied to it allowing it to have a greater influence on the final priority score. By setting the weight of Threat Status to 1.0 and all other co-benefits to 0.5, this changes the priority list in the following ways;

1. The percentage of Critically Endangered species in the top 500 increases by 24.2% compared to when all co-benefits are equally weighted (1.0). The percentage of Vulnerable, Near Threatened or Least Concern species decreases, but the number of Endangered species remains constant (see Table 23).

2. The taxonomic focus of the top 500 does not change extensively, with birds continuing to contribute the largest proportion of species, followed by amphibians, mammals and fish (Table 23)

If policy-makers wish to **prioritise Ecosystem service provision** and adjust the weight applied to it as described above, this changes the priority list in the following ways;

1. The percentage of Critically Endangered species in the top 500 decreases by 14.2%, compared to when all co-benefits are equally weighted (1.0). The percentage of Endangered and Vulnerable species also decreases, while the number of Near Threatened and Data Deficient species increase. The number of Least Concern species remains relatively constant (see Table 24).

2. The taxonomic focus of the top 500 list shifts from birds (48.4 % of species when all co-benefits are weighted equally) to amphibians (42.4 %) (see Table 24).

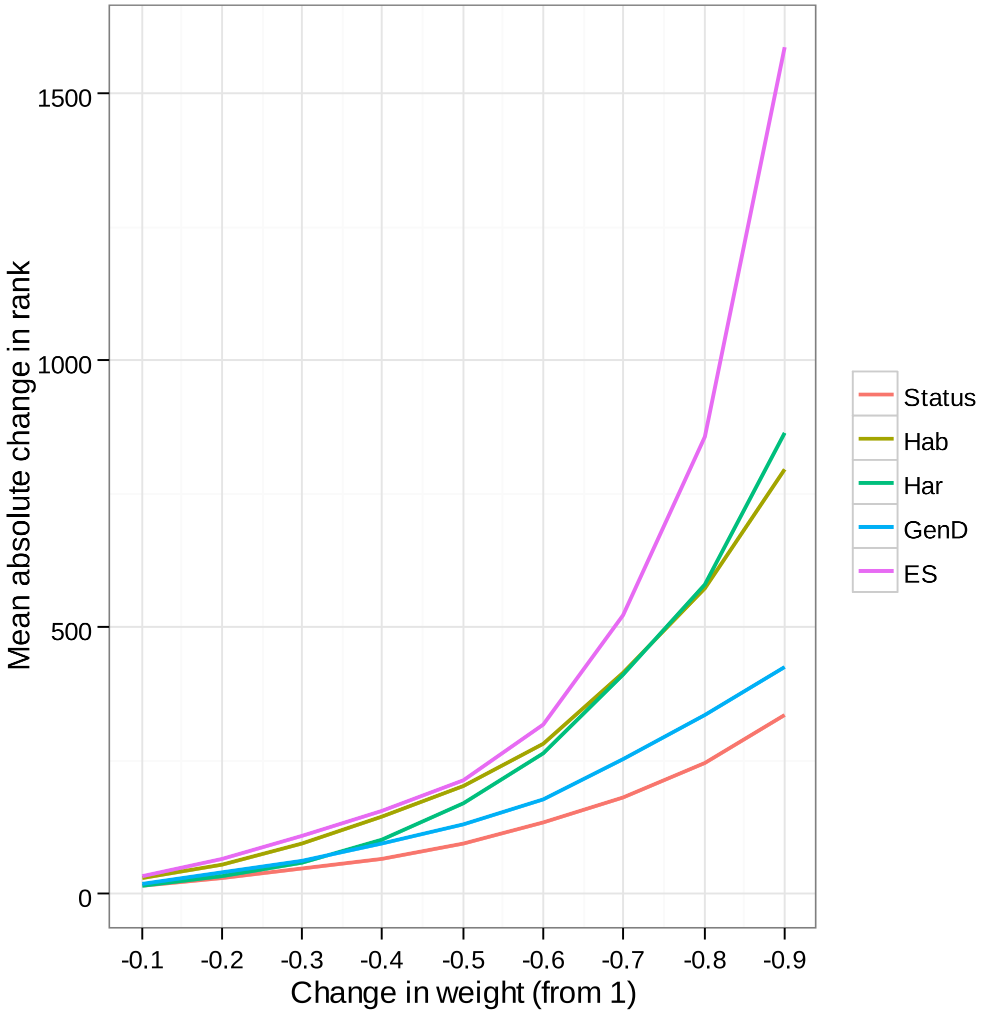

Figure 5. *Mean absolute change in the rank of species in the top 500, following decreases in co-benefit weightings.*

Table 23. *The proportion of species in the top 500 lists and the IUCN threat category in which they are listed when Threat Status or Ecosystem Services are given priority over other co-benefits (CBs).*

IUCN Red list Threat Status categories	Threat status weighted 1 (all other CBs weighted 0.5)	Ecosystem Services weighted 1 (all other CBs weighted 0.5)	All CBs weighted 1
CR	54.2 %	15.8%	30%
EN	26.6%	14.2%	26.2%
VU	12.6%	20.6%	21.2%
NT	5.6%	14.6%	10.4%
EW	0.4%	0.2%	0.4%
LC	0.4%	9%	10.4%
DD	0.2%	25.6%	1.2%

Table 24. *The proportion of species in the top 500 lists in each taxonomic group when Threat status or Ecosystem services are given priority over other co-benefits (CBs).*

Taxonomic group	Threat status weighted 1 (all other CBs weighted 0.5)	Ecosystem Services weighted 1 (all other CBs weighted 0.5)	All CBs weighted 1
amphibians	29.8	42.4	23.2
birds	40.6	35.2	48.4
fish	6.4	0.6	7.2
mammals	17.2	14	16
other	1.6	1.6	0.8
plants	2.2	4.6	1.8
reptiles	2.2	1.6	2.6

5.3. Usable - Development of Graphic User Interface (GUI)

A GUI is defined as “a type of user interface that allows users to interact with electronic devices using images rather than text commands”. In the context of the MAPISCo database, we see a GUI functioning as a way of enabling non-technical users to explore the data within it without having to individually alter each component manually. We envisaged the GUI using a combination of lists, graphs and maps to display the data in an easily interpreted form, allowing users to investigate questions such as: *What are the highest priority species*? *Where in the world does these species occur*? *What effect does altering particular co-benefit scores have on the overall ranking of the lists*? *Where does a particular species fall in the ranking*?

5.3.1. GUI Development

The GUI was developed using the same open-source statistical environment as the original database - R. This allowed user interface and analysis routines to be integrated easily. R also has rich graphical routines, a rapid development time, good transparency of method, and the potential for modification by other team members. R is freely available for all common operating systems, relatively easy to install, used in universities worldwide and increasingly by major commercial organisations such as Google and the New York Times. Using the new R Package ‘Shiny’, released in November 2012 for user interface development allows user interfaces to be run locally as well as on a web server. In the latter case users do not need to have R installed.

An initial prototype user interface was presented by the developer Andy South at the MAPISCo steering group meeting in November 2012.The initial prototype allowed users to select a species from the list and then choose one of the following display options (tabs):

- Graphic: the position of this species in the MAPISCo priority ranking (with all weighting factors set to 1), as a bar chart with each individual species represented by one bar. Bars are coloured according to taxonomic group.

- Map: a world map showing which countries this species occurs in and an option to label the countries with their names.

- Score co-benefits: shows how the priority score for this species is calculated from the five co-benefits. This allows the user to see, for example, whether a particular species receives a high priority score because of its values for Threat Status, Habitat or Harvesting.

A subsequent version was made available in time for the CITES COP at the start of March 2013. The new version added the following functionality requested at the steering group meeting.

- Two stage selection process: first allowing users to select a taxonomic group, continent and country. A species list is displayed based on these selections allowing the user to then select an individual species and view the outputs outlined above.

- Weightings sliders for each of the five co-benefits. The sliders can be moved between zero and one (with one being the default starting value). Changing the weightings leads to re-calculation of the priority scores and all other UI components update with the re-calculated rankings.

- Rank Table tab: displays a table of the selected species list ranked by priority scores. The table contains the scientific name, taxonomic group, English name and scores for each of the five co-benefits as well as the overall priority score.

- About tab: gives a brief outline of the project, contact details for project participants and acknowledgements.

The current, development version, of the GUI can be viewed and tried out at: www.mapisco.org.uk.

5.3.2. Constraints and legacy

The resources available for this part of the project have been limited relative to the usual resources required to develop a fully featured, robust, useable software product. 14 days of developer time for GUI development were available from project funds. Therefore, the GUI that has been produced should be seen as a prototype to be developed further. We are keen to develop the user interface when funds can be sourced.

5.3.3. Future development options

With relatively few extra days development time the following options can be added to the GUI in the short term. Costed proposals for these options were provided to the project steering committee in February 2013 (options that were taken up at that stage and are included in the implementation described above are not included here).

- Outputting priority lists as a PDF or CSV file including metadata detailing the user, time of creation and weighting options selected.

- Produce a version of the user interface targeted specifically at Overseas Territories (OTs), only including species occurring in OTs and allowing specific OTs to be selected.

- Allow output of a single reference page for a species chosen, giving text, map and graphics, including specifying the co-benefit values and which weightings options chosen.

- Creation of a reference document/atlas containing a page for all species subject to a maximum PDF size of ~2GB. The page would have text, map, and a scorings graph.

- Provide a button that will link to other databases (WCMC, IUCN Red List) and/or image search for the selected species.

- Creation of an R package containing the MAPISCo database and analysis routines, documentation and helpfiles. Submission to international repository. This will make the database and methods easily accessible to researchers worldwide and will help to ensure project legacy.

These short term development options could provide a bridge to longer term developments for which there is considerable potential.

5.3.4. Future hosting options

The beta-test version of the GUI is currently hosted on a test server and redirected from the www.mapisco.org.uk domain name. There is no guarantee how long this test server will remain available. To make the user interface freely available online in the long term there are two options. The first option is to make it available on a project specific server running R and shiny thus incurring no extra costs beyond hosting. The second option is to use the Shiny hosting service, which would incur an as yet unknown monthly fee. The related issue of where the database should be hosted is considered in **section 6.52**, page 61.

6. Discussion

Capsule

- *The method developed allows the prioritisation of species based on their contribution to five co-benefits - conservation effort directed at high ranking species is expected, therefore, to contribute most to biodiversity, via the selected co-benefits.*
- *The database that we have compiled contains information on 70000 species that has been consolidated from a suite of databases held by other organisations. Creating, curating and updating primary databases is time-consuming and expensive and so the coverage of species and co-benefit scores is variable across major species-groups. For example, birds are well-covered, plants much less so.*
- *There is clear scope for Defra to build on the progress made to date so that scientific knowledge and practice can better support UK government objectives. In order to do this, the database requires modest technical development and a permanent home, the scientific rationale linking species and co-benefits should be strengthened, and the policy arenas where it can be used should be defined more closely.*

6.1. Fit to original project brief

The original contract specification for this project required the creation of a methodology to prioritise species conservation effort for the greatest contribution to "*consequential benefits for other species (or taxa), habitats, wider ecosystems, and ecosystem services*". The methodology was to be: **expandable** allowing the incorporation of future data, **adaptable** to changing policy aims and **usable** by non-technical practitioners.

The methodology presented in this report meets the specification outlined above by focusing on a selection of five priority co-benefits (habitat conservation, genetic diversity, harvesting, species extinction risk and ecosystem services). The steps involved in developing a priority list of species for conservation investment included: (i) identifying 2-3 data sources which could be used to quantify the value of a given species to each co-benefit, (ii) computing standardised scores for each species on each co-benefit (across data sources), (iii) summing these scores to create a final ranked priority score, weighted as required. **In theory, conservation effort directed at species ranked highly on the priority list could be expected to contribute most to the selected co-benefits**. This would permit greater contributions to:

1) the prevention of species extinctions by on average focusing effort on more highly threatened species (**Aichi Target 12**),

2) the conservation of habitats by focusing effort on those species used to identify a selection of Key Biodiversity Areas in which larger number of species co-occur (**Aichi Targets 5 and 7**),

3) the promotion of sustainable harvesting by focusing on harvested species of the greatest economic value (**Aichi Target 6**),

4) the conservation of genetic diversity of species of economic or social value, by focusing on wild relatives of crops and domesticated animals, and medicinal plant species (**Aichi Target 13**) and

5) the protection of ecosystem service provisioning by focusing on species occurring in forest- and wetland habitats in countries with higher estimated rates of carbon loss through deforestation or lower freshwater availability (**Aichi Target 14**).

Therefore, conservation of the species highlighted by our approach presents the greatest potential to contribute to Aichi 5-7 and 12-14, as well as being an effective way to help direct conservation policy to contribute to international conservation agreements.

6.2. How does the method compare with 'business as usual'?

One of the original drivers for this project was the perceived view that resources were often directed towards a few charismatic species. In the current methodology "politically interesting" or flagship species often championed by interest groups do not generally rank highly (e.g. Asian Elephant *Elephas maximus* is ranked 397th, African Elephant 553rd, Tiger 1759th, Giant Panda *Ailuropoda melanoleuca* 9473rd, African Lion *Panthera leo* 6724th, Eastern Gorilla *G. beringei* 3819th, Lowland Gorilla *Gorilla gorilla* 2741st, Black Rhinoceros *Diceros bicornis* 37816th, Polar Bear *Ursus maritimus* 45625th and White Rhinoceros *Ceratotherium simum* 51510th). This is because they are associated with only a small number, if any, of the co-benefits considered here. **The method we have devised is based on objective criteria which can be transparently adapted as policy aspirations change.** This can be done by putting more or less value on each co-benefit by varying the associated co-benefit weighting. For example, clearly using objective criteria based on a range of co-benefits places a few of the charismatic species illustrated here in context: they are less likely to fulfil a range of goals as set out in the Aichi Targets which we focus on than a large number of other species.

6.3 How do co-benefits relate to IUCN threat status?

An aim of the MAPISCo approach was to prioritise species based on the consequential benefits associated with their survival **in addition to** their IUCN Red List threat status. We would therefore expect that resulting priority lists are not simply a reflection of threat status.

To test this expectation we subdivided the overall database into four sub-databases – 1) one containing all species which score on Red List Threat Status AND Habitat Conservation, 2) one containing all species which score on Red List Threat Status AND Harvesting, 3) one containing all species which score on Red List Threat Status AND Genetic Diversity, and 4) one containing all species which score on Red List Threat Status AND Ecosystem Services. This meant that each sub database contained data only for species that score on Red List Threat Status and each of the other four co-benefits in turn. For each of these four databases we created three new priority lists based on -. 1) Red List threat category scores alone (for which the scores will be 1 for Critically Endangered, 0.88 for Endangered etc). This represents how prioritisation decisions could be made if the Red List alone was used to rank species. 2) Scores from the co-benefit in that database alone (e.g. scores for Genetic Diversity). 3) Scores from the threat category and co-benefit combined (the average of the two). The results of this are shown in Table 25 below.

Both the Habitat and Ecosystem Services co-benefits are significantly negatively related to Threat Status, meaning that more traditional approaches to conservation (based on extinction risk- the IUCN Red List) do not capture more recent concerns about protecting a range of co-benefits from each species.

When threat status and each co-benefit are combined, three of them (Habitat, Harvesting and Ecosystem Services) are positively correlated to threat status suggesting that the MAPISCo database does encompass extinction risk and these co-benefits as well. The exception is Genetic Diversity, which is negatively correlated to both IUCN status (although not significantly) and to IUCN status and Genetic Diversity suggesting that the relationship with this score and others is not straightforward. This is probably due to the scoring for this co-benefit which tends to be binary (either not related at all or quite highly related – **section 3.2.3.,** page 17).

Table 25. Spearman's rank correlation coefficient between IUCN status and each co-benefit (* = p < 0.05).

Priority score	IUCN status	Habitat (n = 5553)	Harvesting (n = 1504)	Genetic diversity (n = 811)	Ecosystem services (n = 38946)
Habitat	-0.154*				
Harvesting	0.013				
Genetic diversity	-0.066				
Ecosystem services	-0.60*				
IUCN status + Habitat	0.890*	0.246*			
IUCN status + Harvesting	0.862*		0.450*		
IUCN status + Genetic Diversity	0.902*			-0.328*	
IUCN status + Ecosystem services	0.863*				0.389*

6.4. Operating constraints

It is important to bear in mind that, in its current format, the method developed by this project is biased towards those taxa that have the greatest representation in the databases used to calculate priority scores. This is because some species and some co-benefits have been subject to more study and data collation than others. This issue is particularly acute for plants, which have a very low proportional representation in the current version of the database (this is discussed in full in **section 4**, page 27). This will inevitably result in the relative (overall mean) downgrading of plants in any species prioritisation process until more plants have been assessed on the Red List and in other databases. Therefore, we urge caution when using the method with all taxa: it is better to currently use it to ask specific questions such as prioritisation within well studied groups, such as birds.

6.5. Integration of MAPISCo into decision-making – next steps

As biodiversity issues become mainstream in political processes there is a recognition that the interface between science and policy must be strengthened (e.g. Koetz *et al.* 2008). Drawing on experience with the Intergovernmental Panel on Climate Change (IPCC), the necessary elements include research produced by bodies external to the policy body; a structure for collecting new data and observations; and an assessment body to make information and knowledge accessible for policy makers (Lariguaderie & Mooney 2010a;b). Perhaps most importantly, it is vital to recognise that developing science-based policy is an iterative and adaptive process that relies on improving knowledge so as to reduce uncertainty coupled with dialogue between the research and policy community (Koetz, Farrell & Bridgewater (2011).

Thus, use of the MAPISCo methodology should be seen as an iterative process (Figure 6). As discussed in **sections 4 and 5**, the use of data sources to inform the co-benefits should be continually assessed, improved and expanded, in response to (changing) expert opinion. Because the lists generated by the current method are based on a relatively small number of data sources (12), this expansion is crucial to give greater robustness to decision-making. It would be sensible, therefore, for Defra to give priority to supporting the efficient collation and curation (and even collection) of such data. It may also be possible to develop formal means to incorporate expert opinion in the way in which data sets are used and scored (e.g. Howes, Maron, & Mcalpine 2010; Aguilera *et al.* 2011) (as with the Palms example, **section 5.1**, page 50).

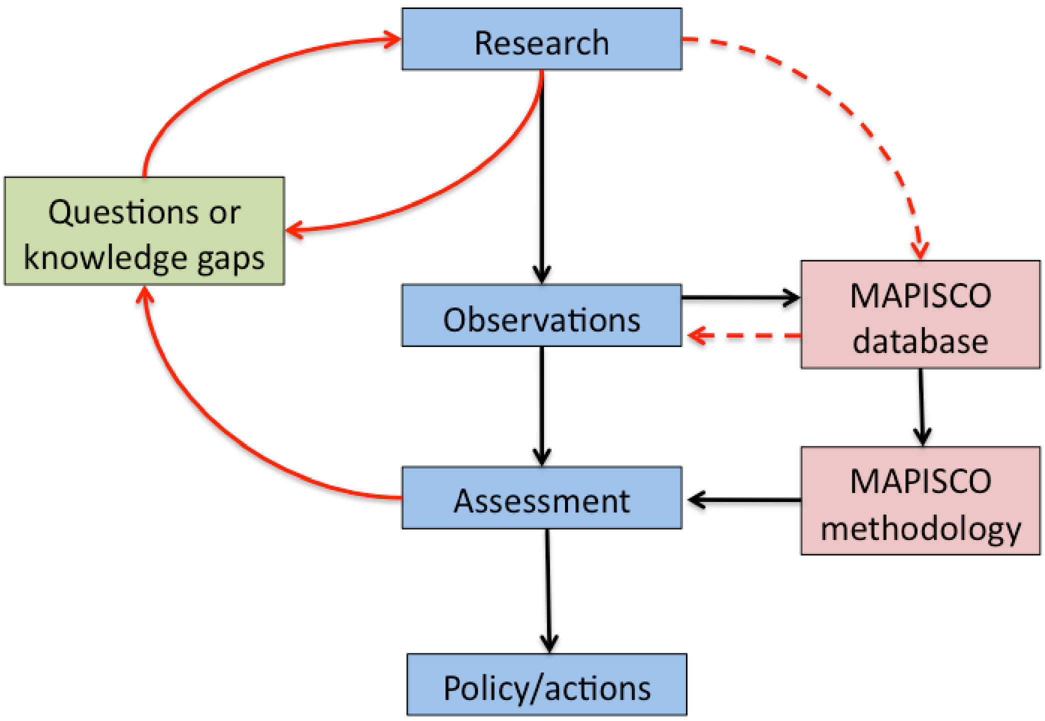

Figure 6. *Non-linear science-policy interface showing how MAPISCo may benefit from stronger dialogue between these two fields. Black arrows form part of the traditional "linear" interface, red arrows are the feedback required.*

To allow MAPISCo to be used successfully in the longer term, three areas require further attention: 1) **Science, 2) Practical** and **3) Policy.** This will put MAPISCo on a sustainable footing and enable it to contribute to policy development.

6.5.1. SCIENCE. Ensuring that the methodology fully accounts for scientific advances

Linking species data to co-benefits

Information on the links between conservation of individual species and co-benefits is varied. Thus the ability to prioritise conservation on the basis of some co-benefits will be more limited in some species groups than others (see **section 4**, page 27)**.** However, the knowledge base relating species conservation to co-benefits may improve in the future as interest in work on ecosystem services gains ground (including a thorough review commissioned by this project, see Appendix 3). If Defra is to progress with the MAPISCo method, further research may be appropriate refine the concepts and framework.

Conceptual advances

The analytical field of prioritisation in biodiversity conservation is moving rapidly and there are frequent advances in standardising variables and dealing with unknowns and uncertainty. It is important that relevant advances are tracked so that any necessary adjustments to the MAPISCo methodology can be made. Defra could achieve this by establishing a MAPSICo Secretariat, that undertakes the necessary surveillance or by commissioning regular updates.

Links to other Aichi Targets

The project has taken place within the context of Defra's desire to maximise overall conservation benefit from its spend on species. Currently five co-benefits, linked to four Aichi Targets are included in the methodology so the priority lists are only relevant within the context of these particular targets. Different species would be ranked more highly if contributions to Target 9 (control of invasive species) or others were to be included.

Non-independence of data sets

There is a degree of overlap in type of data used for the calculation of co-benefit scores (e.g. extinction risk as based on the IUCN Red List categories is used for Threat Status calculations, but is also used in the identification of e.g. IBA and AZE species). In statistical analyses, such interdependence would be considered a problem. However, in this case, this interdependence results from the co-benefits themselves (and the Aichi Targets from which they are derived) being non-independent. For example, by addressing Aichi Target 12 (preventing species extinctions), many species relevant to Target 13 (Genetic Diversity) would also be covered (as many of these are listed on the IUCN Red List).

6.5.2. PRACTICAL - Maintenance of database and incorporation of additional data. Where will the database be housed?

There is an immediate need to determine where the database will be housed and what form technical support will be required. There are several options for hosting the database either within

Defra, or with external hosts, such as the IUCN Red List Office (Cambridge), Newcastle University or UNEP-WCMC. The suitability of these options will depend on an assessment of the following factors:

- Cost;
- Capability;
- Ability to provide scientific support (see below);
- Understanding of Defra's policy needs and way of working; and
- Duration of hosting contract that Defra proposes.

Scientific support needs

Some level of ongoing scientific support to Defra may be required to allow the MAPISCO methodology to be fully operational. It may be that the standards and other documentation (see below) together with training in the application and use of the methodology to provide prioritisation lists would be sufficient, rather than an ongoing 'help desk' approach. Defra will need to consider what support it is likely to require, for how long and in what form.

Define standards and documentation

To ensure that the database and methodology are used appropriately and to best effect it is desirable to develop technical documents that define the standards to be used and specify in what format any outputs should appear. This is also important to show that all queries run in MAPISCo are transparent and that the decisions on weightings are documented fully. Good examples of how this can be done and how useful it may be can be drawn from the IUCN Red List which has standard definitions and classifications (see http://www.iucnredlist.org/technical-documents/classification-schemes and links therein) and also produces outputs of searches in a standardised way with a recommended citation. With some consideration, it would be possible to produce a similarly standardised output from the graphical user interface that gives all decisions made on weighting and identifies the person running the query as the author.

Incorporating new data and updating existing data

Data availability and accessibility is a concern. A very limited number of datasets exist which contain the information required for the MAPSICo methodology. Fewer still have been brought together, been adequately assembled and documented, and then made accessible. This is important because the availability and choice of data sources included in the database has consequences for the ranking of species. Thus, the ability to prioritise conservation on the basis of some co-benefits will be more limited in some species groups than others.

The paucity of data, for some taxa such as plants, means that small improvements in the availability of data can have a large impact on the resulting species priority list. The inclusion of specialist data on palm tree species into the database resulted in a considerable change in their place in the species ranking from no species in the top 2000; to two in the top five (see **section 5.2,** page 51). By exploring other scenarios where small improvements in the availability and/or quality of data linking species to co-benefits, it will be possible to focus resource investment in the gathering and/or collation of data that can maximise impact on prioritisation ability. In addition, the method derived here for 'within-group' prioritisation could be a useful way forward.

All suitable datasets have been incorporated in the current database. Addressing remaining gaps may require various approaches. For example, taxonomic coverage is not uniform, the specific content of the database (the data fields) vary and there is substantial need to improve the curation and accessibility of many datasets before they could be considered for inclusion in the MAPSICo database. Finally, there will be varying motivations of data holders to share their data with Defra on a gratis basis. A practical first step would be to look at institutions close to Defra (and current/future partners) and produce a detailed analysis of what their data holdings are and how they can be made accessible to MAPSICo. A strong candidate here would be Kew Gardens and the data currently being assessed by the IUCN Red List in Cambridge. Access to these sources may add significantly to the MAPSICo coverage. Filling other gaps would require a more strategic approach and this would depend on immediate Defra priorities.

6.5.3. Policy - Integrating MAPISCo into policy and resource allocation decisions

Demonstrating the potential of MAPISCo

MAPISCo would benefit from external review by scientists and policy-makers. Therefore, it is now very important to demonstrate the method to policy makers and senior officials in Defra and other potential users. This could involve a demonstration of how lists can be generated, the sorts of decisions that can be taken on co-benefit weightings and the impact varying these may have, and how the outputs can be used. One or more workshops with potential end users would likely be the best way to promote the method. If this could be combined with working through one or more current Defra species issues, it would be a very strong demonstration of the method.

Strengthening the ability of MAPISCo to underpin policy

The strengthening of links between both policy requirements and the framing of the scientific inputs, and between MAPSICo's outputs and the impact they have on policy decision-making will be key integrating MAPISCo into working policy. Providing a broader array of policy situations in which to demonstrate how the method may be used would be helpful, as this would allow the range of assumptions and decisions to be assessed through the range of weightings applied by policy makers to MAPISCo at the input stage. At the other, output, end of the process, it would allow much greater understanding of the range of uses to which the priority lists (and associated data) generated would then inform the decisions that have to be taken. Exploring this with a range of users in a variety of contexts would allow the potential and the limits of the method to be defined more clearly.

A further exploration and demonstration of the value of MAPISCo would be a clearly defined project in which priority lists would be generated with various weightings (reflecting different policy demands) and comparing these against existing Defra priorities. This would permit assessment of both how well aligned they are and, perhaps more informatively, reasons for variation between current priorities and various MAPISCo outputs. Such an assessment should help bring into sharp focus unstated assumptions or other factors that may need to be incorporated into the methodology to account for the full range of contexts in which it may be used.

Ease of use

The methodology is far more likely to be used if it is intuitive and clear. Therefore the interface (graphical user interface: GUI see **section 5.3**, page 54 for further discussion of GUI legacy) and the explanatory documentation needs to be easy to understand. The need here is for a short period of testing documentation and the GUI are a good fit to the users. There may be a need for refinement based on this testing.

6.6. Concluding remarks

We have delivered a first version of a methodology that can identify priorities for species conservation efforts based on expected contributions to a selection of five co-benefits. Our finding that around 1064 species are commonly ranked highly irrespective of variations in how the co-benefits are weighted, suggests that the proposed methodology does provide a blunt tool for identifying species where conservation effort could be expected to make significant contributions to the Aichi Targets.

This project is at the cutting edge of the science-policy interface. Although species prioritisation efforts are common, the vast majority of previous efforts are either geographically or taxonomically limited (e.g. Dunn, Hussell, & Welsh 1999; Knapp, Russell, & Swihart 2003; Rodríguez, Rojas-Suárez, & Sharpe 2004; Jimenez-Alfaro, Colubi, & Gonzalez-Rodriguez 2010), and are often limited to biological considerations only (Mace & Collar 2002; Mace, Possingham, & Leader-Williams 2006).

Although this project set out to establish clear objective criteria to determine how to prioritise species conservation investments, we have also shown that the choice of both co-benefit weighting and the data sources has a strong effect on which species are identified as higher priorities. As a result, the development of this methodology has brought the mismatch between the data requirements and data availability/accessibility for ambitious species prioritisation exercises into sharp focus.

Implied in the original project brief is an assumption of a relatively straightforward and linear science-policy interface, where science can directly meet policy needs and inform policy changes. Both the mismatch between the data required to fully service the original project brief and our results presented here highlight the need for a re-evaluation of this interface. As we have outlined above, at this stage of the methodology, further guidance and refinement of policy aims are required for science to make progress. In other words, a number of feedbacks from science into policy and back again need to be incorporated into a non-linear interface. As a result, the methodology described here becomes part of an iterative process where conservation science and policy meet and continuously refine each other’s needs, rather than a final answer to global species prioritisation problems.

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