Interim progress report on estimating costs of Target 11 and 12

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This report summarises progress to date of a collaborative project between BirdLife International, Royal Society for the Protection of Birds, United Nations Environment Programme World Conservation Monitoring Centre and the University of Cambridge Department of Zoology, funded by the Cambridge Conservation Initiative. **Cost figures mentioned below are provisional and may well change as analyses are finalised.**

Target 12: Costs of preventing extinctions and conserving threatened species

Using a structured questionnaire to relevant experts (identified from information held by BirdLife International), we collected information on recent and required expenditure on conservation actions for as many Critically Endangered bird species as possible (excluding those for which there are no known populations) and for a sample of Endangered and Vulnerable species (stratified by distribution size and mean GDP of countries within each species' distribution). Red List categories were taken from BirdLife International (2011).. For the required expenditure, we first defined a target in terms of the change in status necessary to qualify the species for downlisting to a lower Red List category of extinction risk, determining the minimum such change necessary given each of the Red List criteria under which the species qualified (e.g. reduction of the decline rate below 80% over three generations for a species qualifying as Critically Endangered under criterion A2 alone, or an increase in population size to above 250 mature individuals for a species qualifying as Endangered under criterion D1 alone). We then developed a list of actions necessary to achieve the status change, drawing on those identified in BirdLife International (2011). Respondents were invited to modify and/or expand (with justification) the listed actions, and, for each one, to provide minimum and maximum estimates of (a) the annual cost needed to achieve it, (b) the number of years (up to 10) required to complete it, and (c) the likelihood of it being successful. For each cost estimate, respondents were asked to score their confidence that the true figure lies within the stated range and to provide information on the sources of their estimates. We checked each completed questionnaire against a number of quality control criteria, clarified any uncertainties with the respondent, and then adjusted the minimum and maximum values to scale all respondents' estimates to a standard degree of confidence. We then multiplied the adjusted minimum annual cost by the minimum number of years, and the adjusted maximum annual cost by the maximum number of years, summing across all actions to generate an overall range of estimates for each species.

In total, 237 completed questionnaires were returned covering 211 threatened species (17%), comprising 105 Critically Endangered, 67 Endangered and 39 Vulnerable species. To extrapolate costs to species without data, we modelled the median cost (the mid-point between the sum of minimum costs and the sum of maximum costs) weighting by the inverse of the range of costs, so that estimates with narrow ranges were given higher weight. We assumed that the costs of species conservation might be a function of species' traits and of the economic development of the countries it occurs in, and that costs would not be independent of range size (distribution extent). We therefore modelled $\log_e$ (median cost / range size) as a function of a number of species traits (2011 IUCN Red List category, migratory status [yes/no], forest dependence [high/medium/low/does not occur in forest], island endemism [endemic to island(s)/not], all from BirdLife International 2011 and data held in BirdLife's database) and a number of economic indicators of the countries it occurs in (GPS, per capita GDP, GDP per square km [an index of land values] and Purchasing Power Parity (PPP) [an estimate of the relative cost of living in each country]). All possible combination of these explanatory variables were fitted using the 'dredge' function in the MuMIn package in R for model selection and multi-model inference, and used model averaging to assess the relative contribution of each explanatory variable. Red List category, island endemism, forest dependence, GDP per sq km and PPP and an interaction between island endemism and Red List category all had significant independent explanatory power, whereas migratory status, GDP and per capita GDP did not (Table 1). The models provided a reasonable fit to the data, with a correlation coefficient of 0.57 between actual and fitted costs. The best model was then used to extrapolate costs to the remaining threatened species.

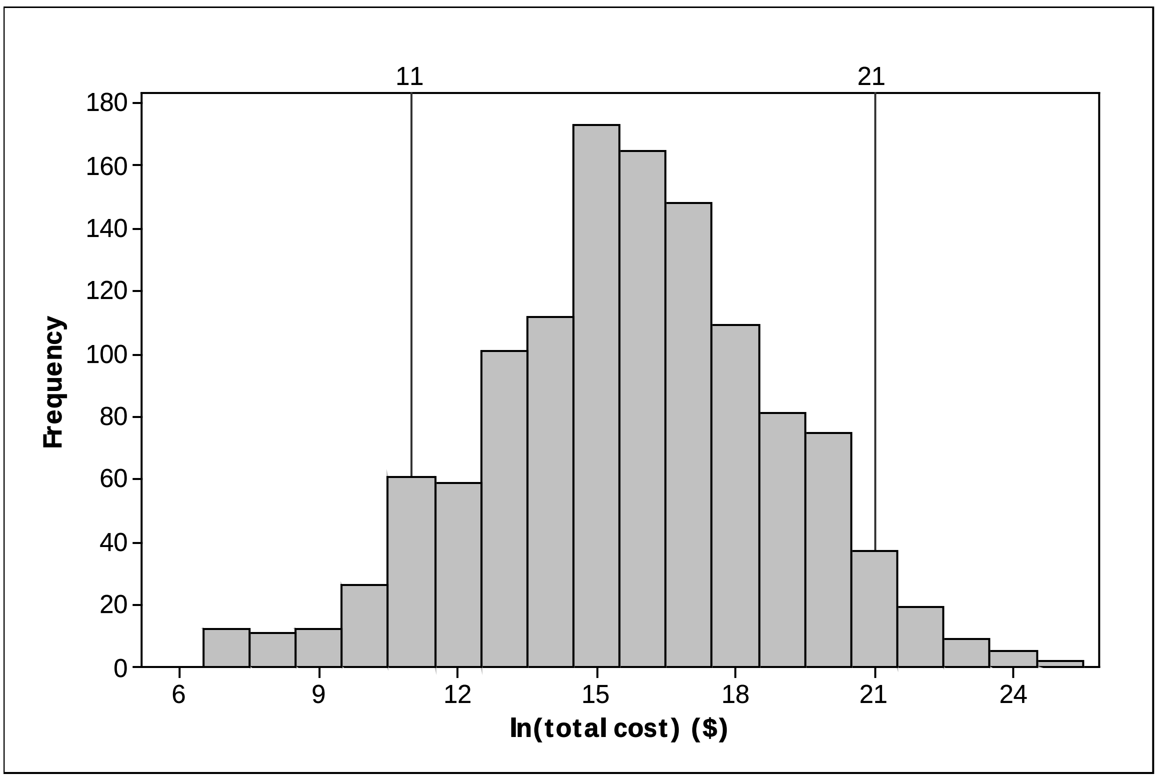
Table 1. Top three competing models of median costs (RL = a 3-level Red List category; Island = binary factor scoring yes or no for island endemism; Forest is a 4-level factor: non-forest species, low, medium and high forest dependence); GDP/km^2 = mean GDP for countries within the distribution divided by range size; PPP = mean Purchasing Power Parity of countries within the distribution). Models containing other explanatory variables received little support.

RL	Island	Forest	GDP/km^2	PPP	RL*Island	AICc	Weight
+	+	+	+	+	+	1184.2	0.754
+	+	+	+		+	1187.9	0.117
+	+	+	+	+		1188.4	0.090

The model indicated that required costs per sq km were greater for Critically Endangered species than for Endangered or Vulnerable species, but since the former have on average smaller range sizes, total costs did not differ systematically across Red List categories. Required costs for island endemics were higher per sq km than for mainland species, but again their range sizes were smaller on average and their total costs were significantly lower than mainland species ($F_{1,1215} = 5.13$, $P < 0.05$). Required costs were lower for species with low forest dependence and non-forest species than for species with high forest dependence, and were significantly higher for species occurring in countries with higher GDP per sq km and with lower PPP.

Modelled costs were generated as estimates of $\log_e(\$/km^2)$. These were back-transformed and multiplied by range size to derive a total cost per species. Because of the wide range of costs and their strongly skewed nature, total values were again log-transformed for some analyses. Because species could vary from the sampled species in their combination of values for the explanatory variables, extrapolated required costs could greatly exceed or fall below the distribution of observed required costs (Fig. 1). Such cases were therefore converted to the minimum or maximum observed values as appropriate.

Figure 1. Histogram of modelled estimates of total required costs for downlisting threatened bird species. The vertical lines represent the range of values reported in the sample.



The median estimated cost required to downlist threatened species to a lower category of extinction risk was $0.69 million annually, but ranged from a few hundred dollars to over $7 billion annually (Fig. 1), although these extremes are likely to arise from extrapolation of the model to species with combinations of explanatory variables outside the range of those in the sample from which the predictive model was built. Capping these extreme values to the minimum ($7,150) and maximum ($662 million) total required annual costs recorded in the sample led to an estimated total cost of $15 billion annually to downlist all the world's 1,253 threatened bird species by one Red List category, assuming no shared benefits. However, only around 15-20% of the required costs for the sampled species were for species-specific action, such as captive breeding. Most costs were for site and habitat protection likely to benefit co-occurring species.

By comparison, for 19 Critically Endangered species that were successfully downlisted to lower categories of threat during 1988-2008, the mean annual cost was $356,000 (median $140,000): considerably less than the estimates of required funding discussed above. However, these species are likely to represent the easiest and cheapest cases, and may not be representative; it is also likely that these estimates under-represent the cost of research and planning that underpins successful conservation interventions. By contrast, the total spent on individual endangered species by federal and state wildlife agencies in the USA during 1989-2002 was $5.196 billion (Male and Bean 2005), although spending was highly skewed towards a small number of species.

Next steps

1. Use bootstrapping to generate confidence limits around estimates of required costs for each species.

2. Account for shared costs among co-occurring species through a GIS analysis in which the total estimated cost for each species minus the fraction that is for species-specific actions (estimated from the means for each category for those species with costs extrapolated from the model) is divided by the number of grid cells overlapping with the species' distribution. Then sum the maximum cost for each cell globally, and add to the sum of unshared costs across all species.

3. Estimate costs for developed and developing countries separately.

4. Extrapolate to all threatened taxa based on the fact that threatened birds comprise 6.4% of all known threatened species. Refer to literature on costs in other taxa to show how they compare to those for birds. Consider that the costs of some actions will be shared across taxonomic groups.

5. Separate the costs for Critically Endangered species only ('preventing extinctions'), and consider how much more would be required to downlist all species to non-threatened status.

Target 11. Costs of expanding protected areas to cover sites of particular importance for biodiversity.

Given that the wording of Target 11 calls for protected area expansion to cover "areas of particular importance for biodiversity", and that expanding current protected areas (PAs) to cover unprotected Important Bird Areas (IBAs) would increase terrestrial PA coverage to just over 17% (the threshold for terrestrial coverage called for in the target) (Butchart et al. 2012), we attempted to obtain a robust estimate of the total financial resources required to protect and effectively manage the global IBA network, based on a sampling approach.

Methods

We combined data on required funding for effectively managing PAs from Bruner et al. (2004) (converted to 2012 US$ and matched to IBAs) with additional data for 184 sites from 15 countries (7 of which were not covered by the 41 countries in the earlier model). Information for these additional sites came from a range of sources including published estimates and grey literature, and, for 5 countries, data were compiled by BirdLife Partners using structured questionnaires. After removal from the Bruner et al. dataset of 108 sites (out of 297) that did not overlap spatially with any IBAs, our dataset included site-level management cost data for 373 sites across 48 countries.

To generate estimates for each site for variables that may explain variation in management costs, we overlaid polygons of IBA boundaries with several global-scale spatial datasets. For IBAs for which only point locations were available, circles of appropriate area were used, centred upon the given IBA location. Values for each of the variables were calculated for both the IBA itself and the surrounding 25 km buffer. We calculated mean human population density (per km2) using the GPWv3 data for 2000 at 1/4 degree resolution. Using GLC2000 global landcover maps (Bartholomeé and Belward, 2005), we calculated the proportion of each IBA (and the surrounding buffers) covered by artificial (non-natural/human-dominated) landcover. In order to measure ease of access/accessibility and pressure, we calculated the density of roads (total length of both primary and secondary roads) surrounding each IBA using data from VMap0, and mean terrain ruggedness within each IBA (following Sappington et al. 2007) based upon 30 arcseconds global SRTM data, and a 3 by 3 cell area. Other variables were: site area, gross domestic product (GDP) standardized by country area (IMF, 2012), Purchasing Power Parity (PPP; IMF, 2012), and HDI (Human Development Index) rank (UNDP, 2011).

Using general linear models, we modelled required spend per hectare as a function of the socio-economic variables at the country level, and spatially explicit variables at the site-level. A priori selection of predictors was conducted through consultation of the literature to identify predictors of cost. Variables were log transformed to meet assumptions and tested to assess the degree of correlation between them. Where predictors co-varied by more than 0.7, the predictor with the strongest bivariate relationship with the response variable was selected. From the full model, which included all potential predictor variables, all combinations of the predictors were assessed (Grueber et al 2011) and an information theoretic approach was taken to identify the subset of models whose AIC value was not greater than the AIC +4 of the "best" model (Burnham &

Anderson 2004). A multimodel average was then taken to allow prediction based on the top set of models.

All of the best models included site area as a predictor. However, given the potential for detecting spurious negative correlations using such an approach, we also re-ran the models using total required spend as the dependent variable. To test whether the economies of scale found in our (and previous) models were spurious (Brett 2004; Armsworth 2011), we modelled the total required spend against the total area (both variables logged). The resultant coefficient of 0.23±0.03 confirms previous findings that costs per unit area decrease as total area increases (Armsworth et al 2011). We then added the other predictor variables and, using the same approach, identified the best set of models to describe total required costs. Again, the coefficient of less than one, with other predictor variables controlled for, confirms that economies of scale still occur. Using this alternative approach, all of the relationships remained virtually unchanged (with the exception of a change in sign for the coefficient on area). However, the explanatory power of the model was considerably reduced.

Results

We found that management costs are strongly correlated with site area (which varies over six orders of magnitude). As with previous global studies, we also found that both protected area size and purchasing power parity have a significant negative effect on costs, while GDP/km2 has a strong positive influence costs. Human population density around sites is an important predictor of costs, with higher costs associated with higher densities. Somewhat surprisingly, costs are lower for those sites surrounded by a greater proportion of human-dominated landcover. However, along with road density, this may simply reflect the importance of accessibility in determining costs, as more remote sites, although potentially less threatened, are also more costly to manage due to constraints on access. Furthermore, the type of land management in surrounding areas might be as or more important than lover cover within PAs in determining persistence of biodiversity.

Using the model to extrapolate to all existing protected areas within IBAs has yet to be fully completed. However, provisional results suggest a total annual cost in the region of $10-15 billion.

In addition to providing sufficient financial resources to existing protected areas, many IBAs remain unprotected and urgently require action to safeguard them from on-going threats. Of the total area of the IBA network, approximately 60% (6.3 million km^2) is currently unprotected. There are a number of options available for safeguarding unprotected/partially protected IBAs including (i) expanding one (or more) of the existing PAs that already (partially) overlap with or are adjacent to the IBA and/or (ii) establishing one or more new formal PAs or other forms of effective protection. The most appropriate form and its cost will depend on a range of contextual factors. For example, the cost of gazetting a new PA on publically owned land may be effectively zero, whereas establishing a protected area on privately owned land may require substantial compensation to be paid to those currently holding property rights to the land. However, for the purposes of this analysis we assumed that for all sites the full opportunity costs of conservation would need to be paid. To estimate these we obtained individual site-level opportunity costs per hectare from Naidoo and Iwamura (2007) (converted to 2012 US$) for 7,481 of these sites, and used country-level means for an additional 3,665 sites and regional-level means (for countries with available data) for a further 585 sites. This produced a total opportunity cost of $69.2 billion annually. This excludes the actual costs of establishment (e.g. capital investment in equipment/ infrastructure, costs of hiring/training staff, establishing management plans, demarcating boundaries etc.) or associated transaction costs (e.g. relating to stakeholder consultations/negotiations, legal fees and charges, land valuation studies, administrative costs etc.)

In order to obtain an estimate of the funding gap, we plan to estimate the current spending on site management globally using average country-level and/or regional data from a wide range of sources. Building on the dataset generated by James et. al. (2001), we have collected data for additional countries from national reports and management plans, GEF-UNDP project documentation (see Bovarnick, 2007; 2010), and additional estimates were provided by BirdLife Partners in 5 countries.

Next steps

1. Use the model to finalise extrapolated management costs for all currently protected IBAs globally, and for all currently unprotected IBAs.

2. Add system-level costs

3. Scale the results to cover all KBAs.

4. Consider establishment and transaction costs for new PAs

5. Compare required expenditure with published and collated estimates of country or regional-level average current expenditure and/or shortfalls in funding.

6. Compare results with past estimates of management and establishment/acquisition costs.

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