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Conservation priorities for birds and biodiversity: do East African Important Bird Areas represent species diversity in other terrestrial vertebrate groups?

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An urgent question in biodiversity conservation is the extent to which priority areas for one well-known indicator group, like birds, "capture" species within other groups. The first tests of this question have indicated that capture is high. BirdLife International's "Important Bird Areas" (IBAs) work on this assumption. We test this for East African IBAs using databases on the distribution of all Afrotropical birds, mammals, snakes and amphibians, compiled at the Zoological Museum of the University of Copenhagen and mapped on a 1-degree grid in the software WORLDMAP. We assess how well the IBAs capture terrestrial vertebrate species in the region, and find that absolute capture is high. Moreover, capture of regionally endemic and threatened species is also very high. We indicate those few important species and areas not covered by IBAs. However, the IBAs do not generally capture other groups significantly better than do random selection sets of areas covering the same extent. Further, systematically selected near-minimum sets of areas can capture more species in considerably less area. Nevertheless, these near-minimum sets take into account neither ecological processes (in particular, avian migration) nor actual land-use patterns. As data become available to incorporate these factors and other taxa into quantitative priority-setting techniques, IBAs may be able to be planned with added area-efficiency. For now, though, we suggest that IBAs are not only very effective on-the-ground priorities for the conservation of birds but they also represent the majority of other terrestrial vertebrate diversity.

INTRODUCTION

Priority-setting for conservation

Current species extinction rates are at least 1000 times as great as those typical of the earth's history (Pimm *et al*. 1995). This is largely because threats to biodiversity are disproportionately concentrated in centers of endemism where many species with small ranges co-occur (Myers 1988). Thus, traditional conservation targeting areas of scenic or cultural significance cannot be expected to conserve biodiversity effectively (Pressey 1994). Further, it will not be efficient or effective to conserve one species at a time (Pitelka 1981). Only for two classes - birds (Collar *et al*. 1994) and mammals (Baillie & Groombridge 1996) - do we have a good idea of the conservation status of each species. Conservation must set priorities that enable multiple species to be conserved simultaneously (Ehrlich 1992).

The most obvious way of doing this is to conserve concentrations of species richness (Prendergast *et al*. 1993). However, this approach may select ecotones with high alpha diversity at the expense of rare species (Pressey & Nicholls 1989). Thus, concentrations of restricted-range (Terborgh & Winter 1983) or threatened (Collar 1994) species, or both (Myers *et al*. 2000) may be better conservation targets. An alternative approach relies not just on the numbers of species in an area, but on the identity of these species relative to those in other areas. This is complementarity, which aims to select sets of conservation areas holding the most species overall, rather than individually (Pressey *et al*. 1993). This approach has considerable theoretical merit but is data-hungry and so has been little used in practice except in the temperate zone (Pimm & Lawton 1998).

A further shortfall of each of these approaches is that in applications to date they only represent pattern - species disitributions - and do not target processes promoting persistence (Nicholls 1998). An excellent example of such a process is migration - migratory species must be conserved in different places at different times of year (Gómez de Silva Garza 1996). Others range from tiny (e.g. pollination) through medium (e.g. predator-prey dynamics) to huge (e.g. resilience to climate change) scales (Cowling *et al*. 1999). Techniques are only just beginning to be developed to incorporate such processes into conservation priority-setting (Williams 2000). Finally, it is essential that priority-setting exercises incorporate not just irreplaceable features (in both pattern and process) but also are sensitive to how vulnerable a particular area is (Margules & Pressey 2000).

Indicator taxa for conservation priorities

A potentially major constraint for any prioritization of areas for the conservation of biodiversity is that most biodiversity remains unknown (May 2000). Systematic priority-setting must therefore rely on samples of well-known taxa on the assumption that such taxa represent biodiversity generally (Gaston 1996). Some studies have suggested that this assumption may be valid (Pearson & Cassola 1992) but at local scales there appears to be very little direct correlation in patterns of richness between major taxa (Lawton *et al*. 1998). This may well be due to scale-dependence (Pomeroy 2000), maybe because species within a single major taxon are unlikely to share similar fine-grained habitat with species in other major taxa (Reid 1998). To circumvent this problem, Faith & Walker (1996) suggested that congruence between complementary sets of priority areas for indicator taxa might be a better measure. However, van Jaarsveld *et al*. (1998) found that complementary sets for eight taxa in the Transvaal, South Africa shared few selected areas.

Nevertheless, even if diversity patterns and conservation priorities do not directly correspond between taxa, indicator taxa may still be useful in practice if priority areas for the conservation of one taxon also represent ("capture") many species in others (Balmford 1998). A test of this idea showed that, despite poor cross-taxon congruence in species richness or conservation priority areas, key areas for five taxa in Ugandan forests performed remarkably well at capturing species from the other groups (Howard *et al*. 1998). Burgess *et al*. (2000) supported this conclusion for forest birds and mammals on a 1-degree grid across Africa, finding that complementary sets of areas to represent birds captured 77% of mammals and that complementary sets of areas for mammals captured 94% of birds.

The Important Bird Areas programme

Birds are the single major taxon most commonly used to set conservation priorities, because they are widespread, diverse, easily-surveyed, taxonomically well-known, and have a broad popular appeal (ICBP 1992). BirdLife International, in particular, has pioneered the use of birds in conservation planning, through four programmes (in the tropics). The first is the Red Listing programme, for which global Red Data Books are being compiled (e.g., Collar & Stuart 1985) and for which many regional and national Red Lists are also now available (e.g. Bennun & Njoroge 1996). The second is the Endemic Bird Areas (EBAs) programme, for defining all areas to which two or more bird species with globally restricted ranges of <50 000 sq. km are completely restricted (Stattersfield *et al*. 1998). Third, particular attention is paid to the conservation of migratory species (Salathé 1991), especially, in response to the Ramsar convention, waterbirds (Rose & Scott 1994).

Fourth, the Important Bird Areas (IBAs) programme has been developed to combine the priorities set by the other programmes in specific sites for conservation action on the ground. IBAs have already been defined for Europe (Heath *et al*. 2000) and the Middle East (Evans 1994), and the IBA programme is now well-underway in Africa (Bennun & Fishpool 2000). Specifically, IBA inventories have been completed for southern Africa (Barnes 1998) and now for East Africa (EWNHS 1996; Bennun & Njoroge 1999; Baker & Baker in press; Byaruhanga *et al*. in press).

IBAs are defined as sites of significance for birds in any one of four categories (Bennun & Fishpool 2000): globally threatened species (Collar *et al*. 1994); restricted range species (Stattersfield *et al*. 1998); "biome-restricted assemblages" - being a category defined *ad hoc* to represent species (regardless of range size) but endemic to a particular biome; and particular congregations of individual birds. This fourth category is subdivided into four criteria: >1% of the biogeographic population of a waterbird; >1% of the global population of other species; >20 000 individuals of waterbirds or seabirds; or other thresholds (defined species by species) for migratory species at bottleneck sites.

In total, 228 IBAs have been identified in East Africa (Table 1). In addition to these, Ethiopia has eight potential IBAs (EWNHS 1996) and Kenya five (Bennun & Njoroge 1999). Note that since the publication of EWNHS (1996), the number of IBAs in Ethiopia has increased to 73 (with areas delimited for 38 of these); these data have yet to be published and so we do not include them here. The size of the Ethiopian IBAs relative to those in the other three countries is primarily driven by seven IBAs each larger than a million hectares; the Awash River Valley [ET12] at 11 370 000 ha and the Baro River [ET17] at 38 400 000 ha are particularly huge (EWNHS 1996). Only five other East African IBAs are larger than a million hectares. The area of 47 IBAs, particularly large IBAs and particularly in Ethiopia, has yet to be delimited.

TABLE 1. Numbers and areas of East African IBAs, and their coverage as a percentage of national areas. Data are from EWNHS (1996), Bennun & Njoroge (1999), Byaruhanga et al. (in press) and Baker & Baker (in press) respectively.

	Number of IBAs (with data)	Known	Known total area (ha)	Known Mean area (ha)	Known Median area (ha) %
Ethiopia	62 (36)	70 868 538	1 968 571	106 284	63
Kenya	60 (59)	5 503 250	93 275	18 000	10
Uganda	30 (24)	1 164 008	48 500	27 800	6
Tanzania	76 (62)	15 767 688	254 318	46 850	17
Total	228 (181)	93 303 484	515 489	32 000	32

The aim of this study is to assess how well these 228 East African IBAs perform as "Important Biodiversity Areas", for terrestrial vertebrate biodiversity, at least. Specifically, we ask how well IBAs represent mammal, snake and amphibian species. We aim to identify species not represented in IBAs and suggest sites for their conservation, and then draw general conclusions as to the potential of IBAs for conserving biodiversity overall.

METHODS

The ZMUC databases

Over the last five years, data have been compiled at the Zoological Museum of the University of Copenhagen (ZMUC) on the distribution of all currently-recognized species of birds (terrestrial and freshwater), mammals, snakes and amphibians found in mainland sub-Saharan Africa south of 20°N (Burgess *et al*. 1998). Data are derived from secondary sources wherever possible, although for many small mammals, snakes and amphibians it was necessary to compile primary point locality data. Where this was the case we consulted with taxonomic specialists to extrapolate ranges across suitable habitat; only the least known species were plotted without extrapolation. These data have been mapped onto a 1-degree grid (1957 cells each approximately 105 km on the side) and entered into the program WORLDMAP (Williams 1996). This is a dynamic database into which new grid-cell data-entries are added almost daily. Nevertheless, it already comprises the most complete cross-taxonomic species distributional database for any tropical continent. Hereafter we refer to these species collectively as "terrestrial vertebrates" for convenience, always remembering that it has not been possible to include all reptiles in the databases. In Figure 1a-c we illustrate the East African portion of the databases. We give full details of data sources for taxonomy and distribution in Brooks *et al*. (in press).

Allocating IBAs to grid cells

In order to analyze the representation of mammal, snake and amphibian species in IBAs, it was first necessary to take the central coordinates for each IBA and allocate each to their respective grid cell. For Ethiopia (EWNHS 1996), numerous IBAs were located by ranges of coordinates; we took the mid-point, guided by the national map (EWNHS 1996: 13) for these to locate them on our grid. We corrected a few coordinates which were askew in the accounts.

Two potential problems exist in this method of allocating IBAs to grid cells. One is that some species present in a particular grid cell may be absent from the part of that grid cell covered by an IBA (errors of commission). Conversely, some IBAs are larger than a single grid cell and so species from multiple cells may actually be present in the IBA (errors of omission). Here, we assume that *on average* these problems should cancel out. Although we only have data on the area of 181/228 IBAs (Table 1), the mean IBA area per cell (i.e. amalgamating multiple IBAs where they lie in the same cell; we have data for 102/122 IBA grid cells) is 914 142 ha, i.e. ~10 000 sq. km. This is equivalent to approximately one 1-degree grid cell, although note that the median is considerably smaller, at 109 284 ha, only a tenth of a 1-degree grid cell. Species not covered in one IBA but counted in our database as represented should therefore be balanced by species covered by other IBAs in reality but not in our database. However, this may not be true to the extent that errors of omission are caused mainly by a few very large Ethiopian IBAs whereas errors of commission are caused by many, more widely scattered IBA.

We carried out all analyses in the four-nation East African block of Ethiopia, Kenya, Uganda and Tanzania. This region covers a total of 277 1-degree grid cells, an area of just under 3 million hectares, or about 15% of Sub-Saharan Africa. It holds 1516 bird, 574 mammal and 490 snake and amphibian species. Clearly, restricting our analyses to this politically-defined region leads to the bisection of some biogeographically important areas, such as the Albertine Rift. Further, because it is bounded by the edges of 1-degree grid cells, it includes small portions of each of the neighbouring countries. We therefore excluded from the database the 60 bird (Dowsett & Forbes-Watson 1993), 29 mammal (Wilson & Reeder 1993), 20 snake (Uetz & Etzold 1996) and 39 amphibian (Frost 1985) species occurring only in these neighbouring countries within the 277 cell region.

RESULTS

Absolute and percentage representation in IBAs of all species, endemic species and threatened species of terrestrial vertebrates in the region.

We first assessed the numbers and proportions of East African terrestrial vertebrate species represented in the IBA network (Table 2a). We did this for birds, mammals, snakes and amphibians together, and all species combined. Representation of species in IBAs is high, over 90% in all cases. The results for birds (and, to some degree, those for all species - because these of course include birds) are essentially trivial. Given that the IBAs are defined by the distributions of birds, and much of the data used in compiling the ZMUC bird databases was also used in defining the IBAs, we expect East African IBAs to adequately represent the region's birds. These results were included merely to give an indication of the proportions of peripheral species that - even for birds - the IBAs are not seeking to represent. Such species are better conserved elsewhere.

TABLE 2. a) Absolute and percentage representation in 122 IBA grid cells of all species, endemic species and threatened species of terrestrial vertebrates in the region. b) Mean absolute and percentage (±2.5% tail) representation in 1000 random sets of 122 cells of all species, endemic species and threatened species of terrestrial vertebrates in the region. c) Number of cells required to represent all species, all endemic species and all threatened species of terrestrial vertebrates in the region by a simple greedy complementary area-selection algorithm. d) Number of cells required to represent all species, all endemic species and all threatened species twice.

	All species	Endemic species	Threatened species
a) Representation in 122 IBA grid cells			
Birds	1414/1456 (97%)	98/98 (100%)	53/55 (96%)
Mammals	525/545 (96%)	94/97 (97%)	72/80 (90%)
Snakes and amphibians	394/431 (91%)	121/131 (92%)	-
Total	2333/2432 (96%)	313/326 (96%)	125/135 (93%)

We repeated this analysis restricting ourselves to species endemic to the region of 277 1-degree grid cells covering East Africa (Table 2a). This should be of rather more significance than the analyses for all species: East African endemics can be conserved nowhere else. Representation is again over 90% in each case. Finally, we repeated the analysis considering only species included in the Red List (Baillie & Groombridge 1996) as globally threatened (Table 2a). No East African snakes or amphibians are considered globally threatened (probably a reflection of lack of assessment and knowledge rather than of actual conservation status). Once again, representation of threataned species in IBAs is very high. (Incidentally, using the newly-published *2000 Red List* http://www.redlist.org makes no difference to the representation of threatened taxa in IBAs.)

Which species are not represented in IBAs?

In Figure 1d-f we illustrate the distributions of all East African terrestrial vertebrates not represented in IBAs, and those of East African endemic and threatened species. The two threatened birds unrepresented in IBAs but apparently appearing in the region in our databases are in fact of only marginal occurrence. White-eyed Gull *Larus leucophthalmus* breeds along the Red Sea coast of Eritrea, but is only known to the south as a vagrant, and while Sociable Plover *Vanellus gregarius* winters in Eritrea, there are no confirmed records to the south (Urban *et al*. 1986). No East African endemic birds are unrepresented in the IBAs.

For threatened mammals, similarly, *Mormopterus acetabulosus* of Madagascar and the Mascarenes is only known from two mainland African reords, one from South Africa and one from Ethiopia (Baillie & Groombridge 1996). The once-widespread *Gazella rufifrons* occurred historically along the extreme northern border of Ethiopia, but there is no recent information on its survival here, and *Dorcatragus megalotis* has only been recorded twice in the region (in 1899 and 1972), on the Djibouti border (East 1998).

Thus the only characteristically East African threatened species not represented in IBAs are: *Taphozous hamiltoni* from extreme north-west Kenya and southern Sudan (Aggundey & Schlitter 1984); *Gerbillus cosensi* from Ngamatak on the Turkwel River in north-west Kenya (Lay 1983); *Myotis morrisi*, known from single specimens from Nigeria and Ethiopia (Largen *et al*. 1974); *Gerbillus bilensis* from Bilen in Ethiopia (Lay 1983); and *Ammodillus imbellis*, from Ethiopia and Somalia (Yalden *et al*. 1976). In addition, *Phacocheros aethiopicus*, listed by Baillie & Groombridge (1996) as threatened for the subspecies *delameri* (the nominate Cape subspecies is extinct), should be added to this list. The two *Gerbillus* are of particular concern, being endemic to the region, and a further unrepresented species, *G. dunni*, occurs only in Ethiopia and immediately adjecent Somalia (Lay 1983).

No threatened snakes or amphibians occur in East Africa (Baillie & Groombridge 1996). Of the 10 species apparently endemic to the region but unrepresented in the IBAs, three are known only from border regions: *Hyperolius discodactylus* from the DRC as well as Uganda (Laurent 1972a); *Bufo urunguensis* from Zambia as well as Tanzania (Poynton & Broadley 1988); and *Telescopus pulcher* from Somalia as well as Ethiopia (Scortecci 1935). This leaves seven exclusively East African endemics unrepresented in IBAs: *Hemisus brachydactylus* from southern Tanzania (Laurent 1972b); *Chilorhinophis carpenteri* from south-east Tanzania (Loveridge 1951); *Bitis parviocula* from several localities in central Ethiopia (Böhme 1977); *Ptychadena nana* from Arussi, Ethiopia (Perret 1980); *Phrynobatrachus minutus* from Duro, Ethiopia (Duellman 1993); *Coluber somalicus* from eastern Ethiopia (Largen & Rasmussen 1993); and *Leptotyphlops parkeri* from Degeh Bur, Ethiopia (Broadley 1999).

Comparison with random area selection

One method by which to evaluate the peformance of IBAs in representing terrestrial vertebrate species is to test how many species would be represented in an equivalent area to that covered by the IBAs but selected at random. We use the number of grid cells holding IBAs (122) as the area to represent species at random. Although this represents an area of ~1 220 000 sq. km, rather larger than the total documented area of IBAs at ~930 000 sq. km (Table 1), this latter figure does not include the areas of 47 (mainly large) IBAs, which we assume make up the difference. We therefore selected 122 cells from the East African total of 277 at random 1000 times (only cells holding species were included in the randomization), and considered the mean (±2.5% tail) representation of East African species, endemic species and threatened species in these random sets (Table 2b). The random sets represent between 81% and 98% of East Africa's species, endemic species and threatened species, generally capturing as many or only marginally fewer species than do IBAs.

Comparison with greedy complementary sets

Another method against which to evaluate the performance of IBAs is to compare them against sets of areas selected in a complementary fashion with the explicit goal of representing all species (Pressey *et al*. 1993). The simplest complementary area-selection technique is to select the first grid cell as that holding the largest number of species. All species represented within this first cell are then discounted, and the second cell is

TABLE 2. b) Absolute and percentage representation in 122 IBA grid cells of all species, endemic species and threatened species of terrestrial vertebrates in the region. b) Mean absolute and percentage (±2.5% tail) representation in 1000 random sets of 122 cells of all species, endemic species and threatened species of terrestrial vertebrates in the region. c) Number of cells required to represent all species, all endemic species and all threatened species of terrestrial vertebrates in the region by a simple greedy complementary area-selection algorithm. d) Number of cells required to represent all species, all endemic species and all threatened species twice.

	All species	Endemic species	Threatened species
b) Representation in random sets of 122 cells			
Birds	1418/1456 (97±2%)	93/98 (95±5%)	46/55 (83±12%)
Mammals	497/545 (91±3%)	95/97 (98±2%)	65/80 (81±9%)
Snakes and amphibians	377/431 (87±4%)	117/131 (89±7%)	-
Total	2290/2432 (94±3%)	278/326 (84±7%)	111/135 (81±8%)

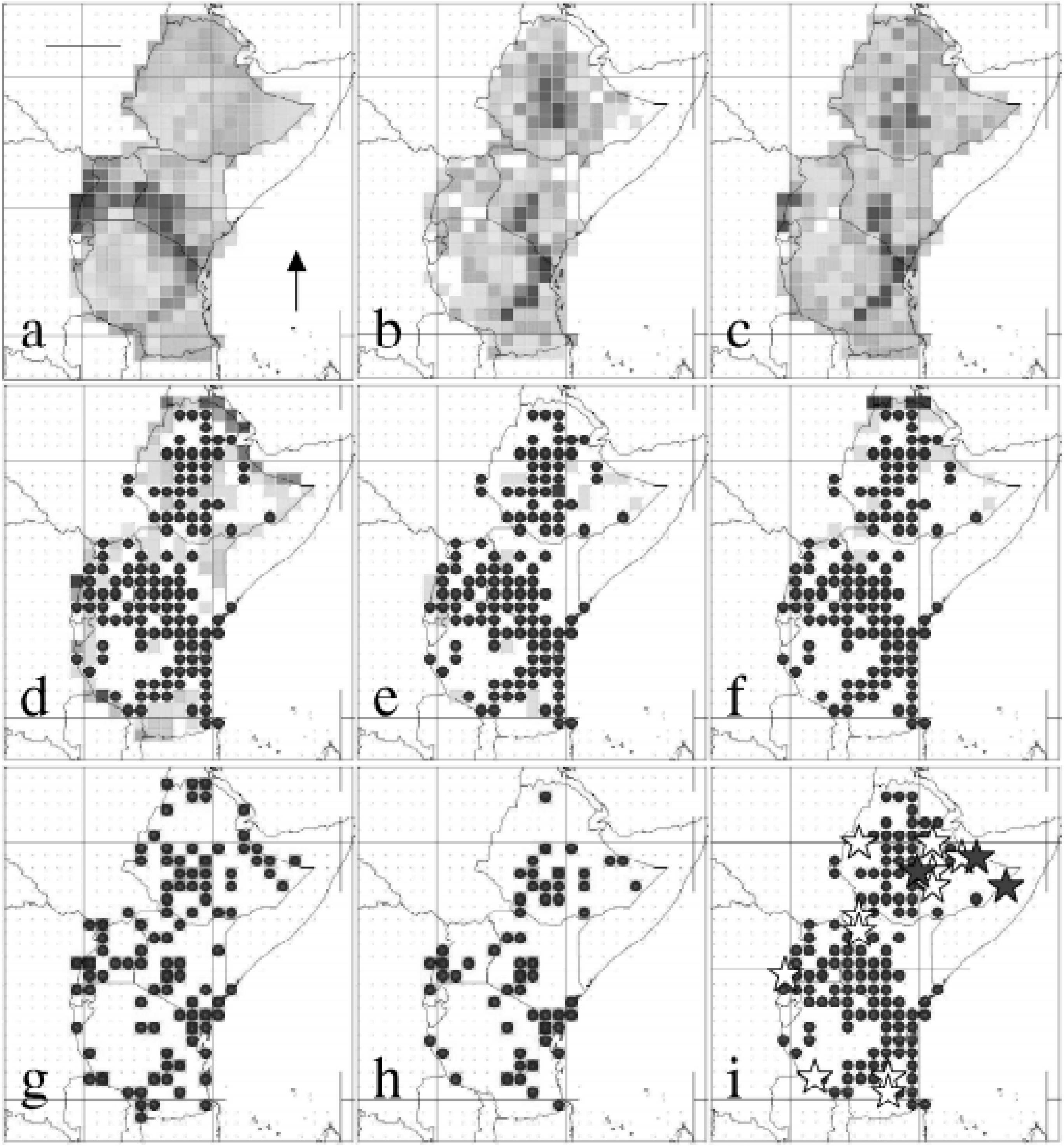

FIG. 1. a) Species richness of all terrestrial vertebrate species across East Africa. b) Species richness of all endemic terrestrial vertebrates across East Africa. c) Species richness of all threatened terrestrial vertebrates (which in practice are just birds and mammals) across East Africa. d) Distribution of all East African terrestrial vertebrate species unrepresented in IBAs. e) Distribution of endemic East African terrestrial vertebrate species unrepresented in IBAs. f) Distribution of threatened East African terrestrial vertebrate species (excluding the subspecies of Warthog *Phacocheros aethiopicus delameri*) unrepresented in IBAs. g) The greedy near-minimum complementary set of 1-degree grid cells representing all East African terrestrial vertebrates. 2423 species are represented in 97 cells. h) The greedy near-minimum complementary set of 1-degree grid cells representing all East African endemic terrestrial vertebrates. 326 species are represented in 57 cells. i) East African IBAs (grey circles) and the important areas for conserving East Africa's threatened, endemic or near-endemic terrestrial vertebrates which fall through the IBA network (stars). Only 14 additional areas would be necessary to represent these 17 species. Three areas (grey stars) hold two unrepresented species each, while the remaining 11 (white stars) hold single unrepresented species. Throughout, the large grid represents 10-degrees latitude and longitude, the scale bar 500 km, and the arrow north.

chosen as that holding the largest number of species unrepresented in the first cell. Next, all species represented within this cell are discounted to indicate where our third cell lies, and so on until we have represented every species desired in a near-minimum set of areas. This procedure is termed simple greedy complementarity, because it selects the area holding the largest number of unrepresented species at every step. Numerous other complementary methods exist, all of which achieve similar efficiency to simple greedy complementarity (Csuti *et al*. 1997).

We therefore use simple greedy complementarity to select near-minimum sets of areas for representing all species, all endemics and all threatened species of East African vertebrates. We give the sizes of these greedy sets in Table 2c. Probably the most informative of these sets are those for all four major taxa combined, because in these we maximize use of all the data available. In Figure 1g we therefore illustrate greedy near-minimum sets for all East African terrestrial vertebrates, and in Figure 1h those for all East African endemic terrestrial vertebrates - these latter are the species that can only be conserved within the region. In Table 2d we repeat the greedy near-minimum set selection, this time representing all species in the dataset in at least two areas.

DISCUSSION

Which additional conservation areas should be considered?

Given the marginal occurrence of those birds - especially threatened birds - occurring in East Africa (according to the ZMUC databases) but unrepresented in IBAs, we can state that the region's birds are fully represented by the East African IBA network. Maybe one of the most useful results of this exercise, however, is to suggest important areas for conserving those of East Africa's threatened, endemic and near-endemic terrestrial vertebrates which fall through the IBA network. That most of these species are desert specialists and that desert is poorly-represented within IBAs suggests that this lack of representation is real and not simply due to our limited knowledge of the species' distributions. In total, 14 additional areas would be necessary to represent these 17 species (Figure 1i), and in fact three of these probably already fall within two IBAs leaving just 11 additional areas necessary.

Three would represent two species each: the Warder Desert of south-east Ethiopia (6°N45°E) for *Ammodillus imbellis* and *Gerbillus dunni*; the Aware Desert of eastern Ethiopia (8°N44°E) for *Phacocheris aethiopicus* and *Telescopus pulcher*; and the Didda Plateau of central Ethiopia (7°N39°E) for *Bitis parviocula* and *Ptychadena nana*. Five of the remaining eleven areas representing one additional species each would be in Ethiopia: the Didessa River mouth (10°N35°E) for *Myotis morrisi*; the Bilen steppe (9°N41°E) for *Gerbillus bilensis*; the Degeh Bur desert (8°N43°E) for *Leptotyphlops parkeri*; the Duro mountains (7°N41°E) for *Phrynobatrachus minutus*; and the Imi steppe (6°N41°E) for *Coluber somalicus*. Two would need to be in Kenya: the Kaitherin Hills (4°N35°E) for *Taphozous hamiltoni* and the Kozibiri River (2°N35°E) for *Gerbillus cosensi*. One, for *Hyperolius discodactylus*, would be in the far west of Uganda (0°S29°E), and is probably actually represented in Bwindi-Impenetrable National Park [UG04]. Finally, three would need to be in Tanzania: the Urungu mountains (8°S31°E) for *Bufo urunguensis*; and the miombo woodland in the western portion of the Selous for *Hemisus brachydactylus* (8°S37°E) and *Chilorhinophis carpenteri* (9°S37°E) which are presumably already represented in the Selous Game Reserve [TZ18].

Which IBAs are the highest priority for representing all taxa?

A useful way to assess which of the IBAs are of the highest priority for representing not just birds but also mammals, snakes and amphibians is to compare the greedy complementary set of areas for representing all endemic species (Figure 1h) with the IBAs. The greedy complementary set for all species, as opposed to that for just endemics, is less useful because it picks so many peripheral sites, where species are occurring at the very edge of their ranges, although note that techniques are now being developed to avoid this problem (Araújo & Williams 2000). Of the 57 1-degree grid cells within the near-minimum greedy complementary set to represent all endemics, 43 also hold IBAs (101 IBAs in total): 13 in Tanzania (29 IBAs); 12 in Kenya (39 IBAs); 12 (16 IBAs) in Ethiopia; and 6 (17 IBAs) in Uganda.

The near-minimum set includes all but three of the 19 Kenyan IBAs scored as "critical" by Bennun & Njoroge (1999). The missing three IBAs are all in the far west of Kenya and are all extremely important in the national context: South Nandi Forest [KE55] (Waiyaki 1998), the Busia Grasslands [KE57] (Nasirwa & Njoroge 1997) and Kakamega Forest [KE58] (Bennun & Waiyaki 1992). However, their only species not widely-represented in the rest of East Africa is the threatened Turner's Eremomela *Eremomela turneri*, present in KE55 and KE58 (Collar & Stuart 1985). This is otherwise known in East Africa only from historical records from Nyondo forest in Uganda (Chapin 1953) and South Nandi appears to be its global stronghold (Kosgey 1998).

The top ten cells of the near-minimum set (which between them represent nearly three-quarters of the region's endemics)

TABLE 2. c) Absolute and percentage representation in 122 IBA grid cells of all species, endemic species and threatened species of terrestrial vertebrates in the region. b) Mean absolute and percentage (±2.5% tail) representation in 1000 random sets of 122 cells of all species, endemic species and threatened species of terrestrial vertebrates in the region. c) Number of cells required to represent all species, all endemic species and all threatened species of terrestrial vertebrates in the region by a simple greedy complementary area-selection algorithm. d) Number of cells required to represent all species, all endemic species and all threatened species twice.

	All species	Endemic species	Threatened species
c) Number of cells required to represent all taxa			
Birds	51	23	17
Mammals	58	29	29
Snakes and amphibians	58	38	-
Total	97	57	38

TABLE 2. d Absolute and percentage representation in 122 IBA grid cells of all species, endemic species and threatened species of terrestrial vertebrates in the region. b) Mean absolute and percentage (±2.5% tail) representation in 1000 random sets of 122 cells of all species, endemic species and threatened species of terrestrial vertebrates in the region. c) Number of cells required to represent all species, all endemic species and all threatened species of terrestrial vertebrates in the region by a simple greedy complementary area-selection algorithm. d) Number of cells required to represent all species, all endemic species and all threatened species twice.

	All species	Endemic species	Threatened species
d) Number of cells required to represent all taxa twice			
Birds	88	43	33
Mammals	92	45	51
Snakes and amphibians	95	54	-
Total	151	86	66

TABLE 3. Occurrence of IBAs defined by each of four categories in the greedy near-minimum set of areas to represent all East African terrestrial vertebrates. * significant P < 0.05.

	Threatened	Restricted range	Biome-restricted	Congregations
Occurs	76	57	65	28
Does not occur	88	37	79	45
Expected to occur	73	42	64	32
Chi-squared (1 d.f).	0.28	10.17*	0.04	1.70

are the West Usambara-Mkomazi complex [TZ16 and 71], Ethiopia's Didda Plateau, the central Kenyan Rift Valley [KE1, 3, 4, 46, 48, 49 and 52], the Uluguru-Mikumi complex [TZ6, 68 and 72], the Udzungwa National Park [TZ66], Samburu National Park [KE33, 34 and 54], the Addis Ababa region [ET32 and 36], Rwenzori Mountains National Park [UG5, 6, 7 and 9], Arabuko-Sokoke forest [KE7 and 8] and Nechisar National Park [ET55].

An additional interesting question is to ask how IBAs defined by each of the four categories (Bennun & Fishpool 2000) are distributed in the greedy near-minimum set of cells that represent all East African endemic terrestrial vertebrates (Table 3). We assessed whether the occurrence in the near-minimum set of each of the four categories was significantly different from that expected at random (i.e., the overall proportion of IBAs in the set, 101/228). Significantly more IBAs wholly or partly defined by restricted range species were represented in the near-minimum set than expected. There was no significant difference between the proportion of IBAs defined by threatened or biome-restricted species, or by congregations, occurring and not occurring in the near-minimum set. This result is unsurprising: restricted range bird species by definition occur in very few grid cells (no more than a maximum five 1-degree grid cells), and each have to be represented at least once in the greedy near-minimum set.

Possible future refinements

A key difficulty with conducting this exercise is the resolution at which data are available. This makes it impossible to tell conclusively from the ZMUC databases whether or not a species is actually represented within an IBA. This could have dangerous consequences: species which are considered to be fully represented within the IBA network could actually only occur outside of (albeit close by) the areas, and suffer conservation neglect in consequence. It seems unlikely that this is a major problem, because most of East Africa's habitat is heavily modified (Hannah *et al*. 1995) while most IBAs and presumably most surviving populations lie together in what remains unmodified. Nevertheless, it is clear that there is an urgent need to collect and compile finer resolution biological distributional data (da Fonseca *et al*. 2000). One short-cut towards this could be building deductive environmental models of species distributions based on satellite imagery - such data are already available for large African mammals (Boitani *et al*. 1999). Ultimately, though, the most effective data for incorporation into priority-setting will be that collected at "point" localities representing actual land management units, especially existing protected areas (e.g., Howard *et al*. 2000); such work is now underway for non-forest IBAs in Uganda, for example.

A second important field of research should involve collecting data on other groups to test the degree to which conservation priorities set for one group, like birds, are effective more generally. Such work is already underway for plants (Lovett *et al*. 2000). Clearly, freshwater and marine taxa, and ecological processes, which until now have not been adequately represented by pattern-based terrestrial priority-setting, must be the focus of specific efforts (Balmford *et al*. 1998). It is likely that IBAs actually represent these relatively well for birds, due to the inclusion of a category for congregations of migratory species (often waterbirds or seabirds). However, as data become available to represent such processes into quantitative priority-setting techniques, it may be possible to increase the area-efficiency with which they are represented in IBAs.

In addition, research should continue into other possible short-cut techniques for conservation priority-setting. One technique, that of conserving flagship species with the aim of representing all species (Ryti 1992) has now been shown to be rather ineffective (Williams *et al*. 2000). Another alternative is research into environmental surrogates for conservation planning (Faith *et al*. 1996). This strategy may be more effective for representing ecological process than are pattern-based approaches (Olson & Dinerstein 1998). The danger with such planning is that without explicit attention to species, even highly-valued vertebrate species may be lost if they happen to be unrepresented within the ecoregional net (Noss 1987).

Overall performance of IBAs

East Africa's IBAs appear to represent other terrestrial vertebrate species effectively. Overall, representation of vertebrates is over 90%, and that for mammals and birds even higher. The capture of endemic species is even higher, which is particularly important given that these can be conserved nowhere else in the world. Further, threatened vertebrates, the most immediate targets for conservation action, are also well represented, with only five regularly occurring threatened East African species (all mammals) unrepresented in IBAs.

When compared with quantitative techniques, however, the degree to which IBAs capture other groups of species is less surprising. The performance of IBAs is significantly better than random only for each group of threatened species, and for all endemic vertebrates (although it is never significantly worse than random). In addition, simple greedy complementary techniques could represent all East African species in considerably less area than is covered by the IBAs at present, although the degree to which this is true must vary by country because three-quarters of all of the IBA area of East Africa lies in Ethiopia alone. Simple greedy complementarity can even represent all taxa twice in only 25% again more area than covered by the IBAs. One possible explanation is that the "extra" area required by IBAs is due to their representation of concentrations of individual birds. Table 3 provides some evidence for this. In addition, much of the "efficiency" of the near-minimum sets is achieved by the selection of peripheral areas where species from different regions meet (Figure 1g-h). Such areas may well be ecologically unviable or politically undesirable to conserve. Third, the IBAs do not aim to represent species in a minimum number of areas, and actually aim to represent some (e.g., threatened) species in as many sites as possible.

The IBA strategy has other key advantages which cannot be evaluated by species representation alone. An obvious one is the explicit incorporation of ecological process (avian migration) into the priority-setting (Williams & Araújo 2000). While vulnerability is not an explicit factor in determining IBAs, degree of threat is increasingly being used to rank IBAs in priority order for action (e.g. Bennun & Njoroge 1999). Of course, the incorporation of threats and processes for birds does not necessarily mean that these are incorporated for other groups. For example, the representation of Elephants *Loxodonta africana* in IBAs will not lead to their conservation unless the IBAs are managed not just for birds but also for allowing seasonal movements and preventing poaching of the species. Another advantage over species representation is that the IBA process focuses on actual land management units, increasing the feasibility of conservation action based on the strategy (Lombard *et al*. 1997). Thus, IBAs concentrate on "conservation -efficiency" more than area-efficiency. Least tangible, the IBA priority-setting process is a consensual one, involving considerable fieldwork and public outreach by local organizations; this is particularly important because action is only likely to be taken on the ground if people in the area are sufficiently motivated (Mittermeier *et al*. 1995).

To conclude, while IBAs do not represent biodiversity pattern with the maximum efficiency possible, they have considerable (although unquantified) other advantages which explain this. Further, it is clear that all species from other taxa will not be represented in priority sets unless information about those taxa is incorporated into the priority-setting process. Nevertheless, IBAs do not only represent bird species extremely well, but also capture enough mammals, snakes and amphibians for us to have confident that they are in practice effective sites for the representation of nearly all terrestrial vertebrate biodiversity.

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REFERENCES

Araújo, M.B. & Williams, P.H. 2000. Selecting areas for species persistence from occurrence data. Biological Conservation 96: 331–345.

Baillie, J. & Groombridge, B. 1996. 1996 IUCN Red List of Threatened Animals. The IUCN Species Survival Commission, Gland, Switzerland.

Baker, N. & Baker, E. (in press) Important Bird Areas in Tanzania. Wildlife Conservation Society of Tanzania, Dar es Salaam, Tanzania.

Balmford, A. 1998. On hotspots and the use of indicators for reserve selection. Trends in Ecology and Evolution 13: 409.

Balmford, A., Mace, G.M. & Ginsberg, J.R. 1998. The challenges to conservation in a changing world: putting processes on the map. In: Mace, G.M., Balmford, A. & Ginsberg, J. (eds.). Conservation in a Changing World. Cambridge University Press, Cambridge, UK.

Barnes, K.N. 1998. The Important Bird Areas of Southern Africa. BirdLife South Africa, Pretoria, South Africa.

Bennun, L.A. & Waiyaki, E.M. 1992. An ornithological survey of Kakamega Forest. Research Reports of the Centre for Biodiversity, National Museums of Kenya: Ornithology 2.

Bennun, L. & Njoroge, P. 1996. Birds to watch in East Africa: a preliminary Red Data list. Research Reports of the Centre for Biodiversity, National Museums of Kenya: Ornithology 23.

Bennun, L. & Njoroge, P. 1999. Important Bird Areas in Kenya. NatureKenya, Nairobi, Kenya.

Bennun, L.A. & Fishpool, L.D.C. 2000. Important Bird Areas in Africa. Ostrich 71: 150–153.

Böhme, W. 1977. Eine neue Art der Gattung *Bitis* (Serpentes, Viperidae) aus Äthiopien. Monitore Zoologico Italiano, N.S., Supplemento 9: 59–68.

Boitani, L., Corsi, F., De Biase, A., D'Inzillo Carranza, I., Ravagli, M., Reggiani, G., Sinibaldi, I. & Trapanese, P. 1999. AMD African Mammals Databank - A Databank for the Conservation and Management of the African Mammals. Istituto di Ecologia Applicata, Rome, Italy.

Broadley, D. 1999. A new species of worm snake from Ethiopia (Serpentes: Leptotyphlopidae). Arnoldia Zimbabwe 10: 141–144.

Brooks, T., Balmford, A., Burgess, N., Fjeldså, J., Hansen, L.A., Moore, J., Rahbek, C. & Williams, P. (in press) Towards a blueprint for conservation in Africa. BioScience.

Burgess, N., Fjeldså, J. & Rahbek, C. 1998. Mapping the distributions of Afrotropical vertebrate groups. Species 30: 16–17.

Burgess, N., de Klerk, H., Fjeldså, J., Crowe, T. & Rahbek, C. 2000. A preliminary assessment of congruence between biodiversity patterns in Afrotropical forest birds and forest mammals. Ostrich 71: 286–290.

Byaruhanga, A., Pomeroy, D. & Kasoma, P. (in press) Important Bird Areas in Uganda. NatureUganda, Kampala, Uganda.

Chapin, J.P. 1953. The birds of the Belgian Congo. Part 3. Bulletin of the American Museum of Natural History 75A.

Collar, N.J. 1994. Red Data Books, Action Plans, and the need for site-specific synthesis. Species 21–22: 132–133.

Collar, N.J. & Stuart, S.N. 1985. Threatened Birds of Africa and Related Islands. ICBP/IUCN Red Data Book, Part 1. Third edition. International Council for Bird Preservation, Cambridge, UK.

Collar, N.J., Crosby, M.J. & Stattersfield, A.J. 1994. Birds to Watch 2. The World List of Threatened Birds. BirdLife Conservation Series No. 4. BirdLife International, Cambridge, UK.

Cowling, R.M., Pressey, R.L., Lombard, A.T., Desmet, P.G. & Ellis, A.G. 1999. From representation to persistence: requirements for a sustainable system of conservation areas in the species-rich Mediterranean-climate desert of southern Africa. Diversity & Distributions 5: 51–71.

Csuti, B., Polasky, S., Williams, P.H., Pressey, R.L., Camm, J.D., Kershaw, M., Kiester, A.R., Downs, B., Hamilton, R., Huso, M. & Sahr, K. 1997. A comparison of reserve selection algorithms using data on terrestrial vertebrates in Oregon. Biological Conservation 80: 83–97.

da Fonseca, G.A.B., Balmford, A., Bibby, C., Boitani, L., Corsi, F., Brooks, T., Gascon, C., Olivieri, S., Mittermeier, R.A., Burgess, N., Dinerstein, E., Olson, D., Hannah, L., Lovett, J., Moyer, D., Rahbek, C., Stuart, S. & Williams, P. 2000. Following Africa's lead in setting priorities. Nature 405: 393–394.

Dowsett, R.J. & Forbes-Watson, A.D. 1993. Checklist of birds of the Afrotropical and Malagasy regions. Volume 1: Species Limits and Distribution. Tauraco Press, Liege, Belgium.

Duellman, W.E. 1983. Amphibians in Africa and South America: evolutionary history and ecological comparisons. In: Goldblatt, P. (ed). Biological Relationships between Africa and South America. Yale University Press, Newhaven, USA.

East, R. 1998. African Antelope Database 1998. IUCN - The World Conservation Union, Gland, Switzerland.

Evans, M.I. 1994. Important Bird Areas in the Middle East. BirdLife Conservation Series No. 2. BirdLife International, Cambridge, UK.

EWNHS 1996. Important Bird Areas of Ethiopia. Ethiopian Wildlife & Natural History Society, Addis Ababa, Ethiopia.

Ehrlich, P.R. 1992. Population biology of checkerspot butterflies and the preservation of global diversity. Oikos 63: 6–12.

Faith, D.P. & Walker, P.A. 1996. How do indicator groups provide information about the relative biodiversity of different sets of areas?: on hotspots, complementarity and pattern-based approaches. Biodiversity Letters 3: 18–25.

Faith, D.P., Walker, P.A., Ive, J. & Belbin, L. 1996. Integrating conservation and forestry production: exploring trade-offs between biodiversity and production in regional land-use assessment. Forest Ecology and Management 85: 251–260.

Freitag, S., Nicholls, A.O. & van Jaarsveld, A.S. 1996. Nature reserve selection in the Transvaal, South Africa: what data should we be using? Biodiversity and Conservation 5: 685–698.

Frost, D.R. 1985. Amphibian Species of the World: a Taxonomic and Geographical Reference. Association of Systematics Collections, Lawrence, USA.

Gaston, K.J. 1996. Biodiversity—congruence. Progress in Physical Geography 20: 105–112.

Gómez de Silva Garza, H. 1996. The conservation importance of semiendemic species. Conservation Biology 10: 674–675.

Hannah, L., Carr, J.L. & Lankerani, A. 1995. Human disturbance and natural habitat: a biome level analysis of a global data set. Biodiversity and Conservation 4: 128–155.

Heath, M.F., Evans, M.I., Hoccom, D.G., Payne, A.J. & Peet, N.B. 2000. Important Bird Areas in Europe: Priority Sites for Conservation. BirdLife Conservation Series No. 8. BirdLife International, Cambridge, UK.

Howard, P.C., Viskanic, P., Davenport, T.R.B., Kigenyi, F.W., Baltzer, M., Dickinson, C.J., Lwanga, J.S., Matthews, R.A. & Balmford, A. 1998. Complementarity and the use of indicator groups for reserve selection in Uganda. Nature 394: 472–475.

Howard, P.C., Davenport, T.R.B., Kigenyi, F.W., Viskanic, P., Baltzer, M.C., Dickinson, C.J., Lwanga, J., Matthews, R.A. & Mupada, E. 2000. Protected area planning in the tropics: Uganda's national system of forest nature reserves. Conservation Biology 14: 858–875.

ICBP 1992. Putting Biodiversity on the Map. Priority Areas for Global Conservation. International Council for Bird Preservation, Cambridge, UK.

Largen, M.J. & Rasmussen, J.B. 1993. Catalogue of the snakes of Ethiopia (Reptilia, Serpentes), including identification keys. Tropical Zoology 6: 313–434.

Largen, M.J., Kock, D. & Yalden, D.W. 1974. Catalogue of the mammals of Ethiopia. 1. Chiroptera. Monitore Zoologico Italiano, N.S., Supplemento 5(16): 221–298.

Laurent, R.F. 1972a. Amphibiens. Volume 22. (Exploration du Parc National des Virunga, Deuxième sèrie). Fondation pour favoriser les recherches scientifiques en Afrique, Bruxelles, Belgium.

Laurent, R.F. 1972b. Tentative revision of the genus Hemisus Günther. Annales du Musée Royal de l'Afrique Centrale. Série in Octavo, Sciences Zoologique 194: 1–67.

Lawton, J.H., Bignell, D.E., Bolton, B., Bloemers, G.F., Eggleton, P., Hammond, P.M., Hodda, M., Holt, R.D., Larsen, T.B., Mawdsley, N.A. & Stork, N.E. 1998. Biodiversity indicators, indicator taxa and effects of habitat modification in tropical forest. Nature 391: 72–76.

Lay, D.M. 1983. Taxonomy of the genus *Gerbillus* (Rodentia: Gerbillinae) with comments on the applications of generic and subgeneric names and an annotated list of species. Zeitschrift für Säugetierkunde 48: 329–354.

Lombard, A.T., Cowling, R.M., Pressey, R.L. & Mustart, P.J. 1997. Reserve selection in a species-rich and fragmented landscape on the Agulhas Plain, South Africa. Conservation Biology 11: 1101–1116.

Loveridge, A. 1951. On reptiles and amphibians from Tanganyika Territory collected by C. J. P. Ionides. Bulletin of the Museum of Comparative Zoology 106: 175–204.

Lovett, J.C., Rudd, S., Taplin, J. & Frimodt-Møller, C. 2000. Patterns of plant diversity in Africa south of the Sahara and their implications for conservation management. Biodiversity and Conservation 9: 33–42.

Kosgey, D.K. 1998. Status and Habitat Choice of Turner's Eremomela *Eremomela turneri* (Van Someren 1920) in South Nandi Forest Reserve, Kenya. MPhil Thesis. Moi University, Eldoret, Kenya.

Margules, C.R. & Pressey, R.L. 2000. Systematic conservation planning. Nature 405: 243–253.

May, R.M. 2000. The dimensions of life on earth. In: Raven, P.H. & Williams, T. (eds.). Nature and Human Society: the Quest for a Sustainable World. National Academy Press, Washington, D.C., USA.

Mittermeier, R.A., Bowles, I.A., Cavalcanti, R.B., Olivieri, S. & da Fonseca, G.A.B. 1995. A Participatory Approach to Biodiversity Conservation: the Regional Priority Setting Workshop. Conservation International, Washington, DC, USA.

Myers, N. 1988. Threatened biotas: "hotspots" in tropical forests. The Environmentalist 8: 1–20.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. & Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853–858.

Nasirwa, O. & Njoroge, P. 1996. Status of the Blue Swallow *Hirundo atrocaerula* sites in Busia and Suba Districts, Kenya.

Research Reports of the Centre for Biodiversity, National Museums of Kenya: Ornithology 26.

Nicholls, A.O. 1998. Integrating population abundance, dynamics and distribution into broad-scale priority setting. In: Mace, G.M., Balmford, A. & Ginsberg, J. (eds.). Conservation in a Changing World. Cambridge University Press, Cambridge, UK.

Noss, R.F. 1987. From plant communities to landscapes in conservation inventories: a look at The Nature Conservancy (USA). Biological Conservation 41: 11–37.

Olson, D.M. & Dinerstein, E. 1998. The Global 200: a representation approach to conserving the earth's most biologically valuable ecoregions. Conservation Biology 12: 502–515.

Pearson, D.L. & Cassola, F. 1992. World-wide species richness patterns of tiger beetles (Coleoptera: Cicindelidae): indicator taxon for biodiversity and conservation studies. Conservation Biology 6: 376–391.

Perret, J.-L. 1980. Sur quelques *Ptychadena* (Amphibia, Ranidae) d'Ethiopie. Monitore Zoologico Italiano, N.S., Supplemento 13: 151–168.

Pimm, S.L. & Lawton, J.H. 1998. Planning for biodiversity. Science 279: 2068–2069.

Pimm, S.L., Russell, G.J., Gittleman, J.L. & Brooks, T.M. 1995. The future of biodiversity. Science 269: 347–350.

Pitelka, F.A. 1981. The condor case: an uphill struggle in a downhill crush. Auk 98: 634–635.

Pomeroy, D. 2000. Birds, hotspots and congruence: a question of scale? Ostrich 71.

Poynton, J.C. & Broadley, D.G. 1988. Amphibia Zambesiaca 4. Bufonidae. Annals of the Natal Museum 29: 447–490.

Prendergast, J.R., Quinn, R.M., Lawton, J.H., Eversham, B.C. & Gibbons, D.W. 1993. Rare species, the coincidence of diversity hotspots and conservation strategies. Nature 365: 335–367.

Pressey, R.L. 1994. *Ad hoc* reservations: forward or backward steps in developing representative reserve systems. Conservation Biology 8: 662–668.

Pressey, R.L. & Nicholls, A.O. 1989. Efficiency in conservation evaluation: scoring versus iterative approaches. Biological Conservation 50: 199–218.

Pressey, R.L., Humphries, C.J., Margules, C.R., Vane-Wright, R.I. & Williams, P.H. 1993. Beyond opportunism: key principles for systematic reserve selection. Trends in Ecology and Evolution 8: 124–128.

Reid, W.V. 1998. Biodiversity hotspots. Trends in Ecology and Evolution 13: 275–280.

Rose, P.M. & Scott, D.A. 1994. Waterfowl Population Estimates. IWRB Special Publication No. 29. International Waterfowl and Wetlands Research Bureau, Slimbridge, UK.

Ryti, R.T. 1992. Effect of focal taxa on the selection of nature reserves. Ecological Applications 2: 404–410.

Salathé, T. 1991. Conserving Migratory Birds. ICBP Technical Publication No. 12. International Council for Bird Preservation, Cambridge, UK.

Scortecci, G. 1935. Un nuovo genere e una nuova specie di Colubridi Opisoglifi della penisola dei Somali. Annali dell Museo Civico di Storia Naturale di Giacomo Doria 59: 1–5.

Stattersfield, A.J., Crosby, M.J., Long, A.J. & Wege, D.C. 1998. Endemic Bird Areas of the World: Priorities for Biodiversity Conservation. BirdLife Conservation Series No. 7. BirdLife International, Cambridge, UK.

Terbough, J. & Winter, B. 1983. A method for siting parks and reserves with special reference to Colombia and Ecuador. Biological Conservation 27: 45–58.

Uetz, P. & Etzold, T. 1996. The EMBL/EBI Reptile Database. Herpetological Review 27: 174–175.

Urban, E.K., Fry, C.H. & Keith, S. 1986. The Birds of Africa. Volume 2. Academic Press, London, UK.

van Jaarsveld, A.S., Freitag, S., Chown, S.L., Muller, C., Koch, S., Hull, H., Bellemy, C., Krüger, M., Endrödy-Younga, S., Mansell, M.W. & Scholtz, C.H. 1998. Biodiversity assessment and conservation strategies. Science 279: 2106–2108.

Waiyaki, E.M. 1998. An avifaunal survey of South Nandi Forest. Research Reports of the Centre for Biodiversity, National Museums of Kenya: Ornithology 30.

Williams, P.H. 1996. WORLDMAP 4.1. Priority Areas for Biodiversity. The Natural History Museum, London, UK.

Williams, P.H. 1998. Key sites for conservation: area-selection methods for biodiversity. In: Mace, G.M., Balmford, A. & Ginsberg, J. (eds.). Conservation in a Changing World. Cambridge University Press, Cambridge, UK.

Williams, P. & Araújo, M. 2000. Integrating species and ecosystem monitoring for identifying conservation priorities. European Nature 4: 17-18.

Williams, P.H., Burgess, N. & Rahbek, C. 2000. Assessing large 'flagship species' for representing the diversity of sub-Saharan mammals. In: Entwhistle, A. & Dunstone, N. (eds.). Priorities for the Conservation of Mammalian Diversity. Has the Panda had its Day? Cambridge University Press, Cambridge, UK.

Wilson, D.E. & Reeder, D.M. 1993. Mammal Species of the World: a Taxonomic and Geographic Reference. Smithsonian Institution, Washington, D.C., USA.

Yalden, D.W., Largen, M.J. & Kock, D. 1976. Catalogue of the mammals of Ethiopia. 2. Insectivora and Rodentia. Monitore Zoologico Italiano, N.S., Supplemento 8: 1–118.