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Protected area gap analysis of important bird areas in Tanzania

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Abstract

Analyses of gaps in protected area (PA) coverage of species distributions have been carried out extensively for the past two decades, aiming to better locate new PAs and conserve species. In this study, progress to close gaps in the protection of the Important Bird Areas (IBAs) of Tanzania is assessed between 2002 and 2009, with a detailed GIS analysis from 2007 to 2009. Remaining gaps are ranked according to biological factors such as numbers of red list and restricted range avian species and social pressures such as human population, agriculture and density of the road network. Results show that there has been a 5.3% increase (7615.1 km^2) in protection of IBAs between 2007 and 2009. Of the 27 remaining IBA protection gaps, three are of high, nine of medium and fifteen of low priority for action. The current IBA 'gap area' of 17,133.3 km^2 contains around 26% forest, 13% shrubland, 9% grassland, 36% wetland and 12% agricultural land. This analysis provides a simple template for defining where further action to protect remaining IBA sites in Tanzania would lead to enhanced conservation of avian biodiversity in that country and provides a methodology for analysis leading to conservation action elsewhere in Africa.

Key words: biodiversity, extended gap analysis, GIS, important bird areas, protected areas, social pressures

Résumé

Des analyses des lacunes dans la couverture de la distribution d'espèces par des aires protégées furent réalisées de façon extensive au cours des deux dernières décennies, afin de mieux choisir l'emplacement des nouvelles aires protégées et de préserver les espèces. Dans cette étude, on évalue les progrès réalisés entre 2002 et 2009 pour combler les lacunes dans la protection des Zones importantes pour la conservation des oiseaux (ZICO) de Tanzanie, avec une analyse GPS détaillée depuis 2002. Les lacunes qui persistent sont classées selon des facteurs biologiques tels que le nombre d'espèces d'oiseaux sur la Liste rouge et d'espèces à l'aire de répartition restreinte, et les pressions sociales telles que la population humaine, l'agriculture ou la densité du réseau routier. Les résultats montrent qu'il y a eu une augmentation de 5,3% (7.615,1 km^2) de la protection de ZICO entre 2007 et 2009. Sur les 27 lacunes de protection de ZICO restantes, trois sont d'une haute priorité d'action, neuf d'une priorité moyenne et 15 d'une priorité faible. La « superficie des lacunes de couverture des ZICO » identifiée actuellement est de 17.133,3 km^2 et comprend environ 26% de forêts, 13% de broussailles, 9% de prairies, 36% de zones humides et 12% de terres agricoles. Cette analyse donne un modèle simple pour définir où de nouvelles mesures pour protéger des sites ZICO en Tanzanie pourraient conduire à une meilleure conservation de la biodiversité aviaire du pays, et elle donne une méthodologie d'analyse qui pourrait entraîner des actions de conservation ailleurs en Afrique.

Introduction

In response to commitments made under the Convention of Biological Diversity, governments across the world have invested in developing systems of protected areas (PAs). These are sites protecting biodiversity, natural resources, ecosystem services and associated cultural resources, managed through legal or other effective means (Dudley, 2008). Despite a remarkable increase in the land area covered by PAs (Coad *et al.*, 2008; Jenkins & Joppa, 2009), these measures have not slowed rates of species decline

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(Butchart *et al.*, 2010). Previous research has shown that PAs are often targeted at the conservation of charismatic and financially important megafauna and are skewed towards particular ecosystems, resulting in an inefficient representation of the full diversity of species and habitats within PA networks (Pressey *et al.*, 1993; Scott *et al.*, 2001; Beresford *et al.*, 2010). Global analyses of species distribution patterns and PA coverage have shown that PA networks do not cover the distribution of many threatened species, and hence, at a global scale, there are numerous 'gaps' in the PA network (Rodrigues *et al.*, 2004).

In Africa, gap analyses at regional scales have also shown that the coverage of biodiversity by existing networks of PAs is inadequate. For example, analyses at the 1 degree scale shows that around 197 threatened mammal species (Fjeldså *et al.*, 2004) and around half of 106 threatened birds (De Klerk *et al.*, 2004) occur outside PAs.

One of the most comprehensive approaches to defining areas of importance for biodiversity is the Important Bird Area (IBA) approach of BirdLife International (Bennun & Fishpool, 2000). These sites are of global importance for the conservation of bird populations, against a number of standard criteria, and IBAs have been used for prioritizing conservation efforts and expanding PA networks in many countries (BirdLife International, 2008a). The degree of coverage of IBAs by PAs is, furthermore, used to measure the progress of tackling biodiversity loss (Butchart *et al.*, 2010) and for tracking sustainable development towards the UN Millennium Development Goals (UN, 2010).

A study of the effectiveness of IBAs at conserving globally threatened birds in Africa (Beresford *et al.*, 2010) showed that IBAs were more effective than PAs at covering the distribution of globally threatened species of birds, which implies that PA gaps remain when analysed against the IBA network across Africa (Fishpool & Evans, 2001). In Africa, IBAs are threatened in various ways (BirdLife International, 2008b). The most important threat is habitat clearance for agriculture, which affects over 50% of IBAs, while selective logging or tree cutting affects 23% of IBAs, with degradation owing to firewood collection and forest grazing, and infrastructure development (including dam and road building) is a further key cause of habitat destruction, with 21% of IBAs affected (BirdLife International, 2008b). Transport networks play a leading role in economic development, but poor planning can have far reaching negative impacts on ecosystems, including destruction and fragmentation of habitats, spread of invasive species and direct mortality (Lin, 2005).

In Tanzania, 33% of the land surface is already designated as PAs (WDPA, 2009). It could therefore be expected that they cover all of the biological diversity in this country. Seventy-seven IBAs have also already been identified in Tanzania (Baker & Baker, 2002). These studies showed that around 10 years ago, 44 of the sites were already fully protected, but some 29 were unprotected and were thus gaps in the protected area network. These unprotected IBAs (IBA gaps) in Tanzania have become increasingly threatened by pressures of population expanding at 3% per annum and an economy growing at 7.4% per annum (NBS, 2009).

The aim of this study was to use the results of Baker & Baker (2002) to undertake a spatial analysis of trends in the protection of IBA sites in Tanzania over time. The work was designed to assess whether PA gaps for birds are being closed and to determine where the most critical conservation gaps for birds remain in this country and how threatened these are by land use and human development pressures. The analysis allows the prioritization of those locations where new PAs might be required to fill bird conservation priority gaps and hence provides a blue print for further conservation efforts in this country.

Materials and methods

Protected areas

The World Database on Protected Areas (WDPA) is maintained by the UNEP World Conservation Monitoring Centre (UNEP-WCMC) on behalf of IUCN World Commission on Protected Areas. The data gathering process has involved the world's governments and a consortium of conservation NGOs. The database includes the name, legal designation, IUCN management category, area, location (polygons) and the year of establishment. The WDPA for 2007 was obtained from UNEP-WCMC and for 2009 was downloaded from the WDPA website (http://www.wdpa.org/) (Fig. 1).

Important Bird Area database

Tanzanian IBA data were compiled by Baker & Baker (2002), and the species data and GIS layers were acquired for this study from BirdLife International, Cambridge (Fig. 2). The IBA database includes both points and polygon layers. For IBAs that had point and area information, but where no polygon was available, a circular buffer around the point was created with the same area as in the database.

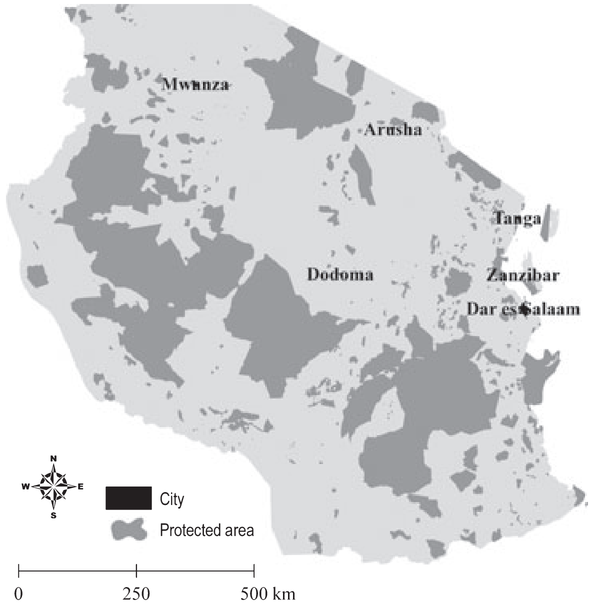

Fig 1 Distribution of protected areas Tanzania in 2009

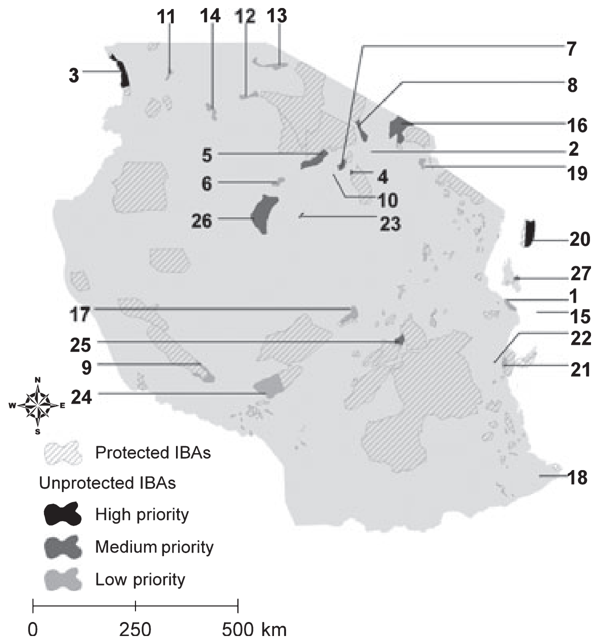

Fig 2 Distribution of Important Bird Areas (IBAs) and conservation priorities of 27 unprotected IBAs in Tanzania in 2009: 1, Dar es Salaam Coast; 2, Eluanata Dam; 3, Kagera Swamps; 4, Lake Burungi; 5, Lake Eyasi; 6, Lake Kitangire; 7, Lake Manyara National Park; 8, Lake Natron and Engaruka Basin; 9, Lake Rukwa; 10, Lake Tlawi; 11, Lake Victoria: Bumbire Islands; 12, Lake Victoria: Bunda Bay; 13, Lake Mara Bay and Masirori Swamp; 14, Lake Victoria: Mwanza Gulf; 15, Latham Island; 16, Longido Game Controlled Area; 17, Mtera Reservoir; 18, Mtwara District Coastal Forest; 19, Nyumba ya Mungu Reservoir; 20, Pemba Island; 21, Rufiji Delta; 22, Rufiji District Coastal Forests; 23, Singida Lakes; 24, Usangu Flats; 25, Uvidunda Mountains; 26, Wembere Steppe; 27, Zanzibar Island: East Coast

Population data

The latest human population census for Tanzania was for the year 2002. Population density data down to the ward level were obtained from the National Bureau of Statistics in Tanzania. The population pressure classification system suggested by Singh *et al.* (2001) was used to rank population pressure into three categories: (i) low, <25 people per km^2; (ii) medium, 25–100 people per km^2; and (iii) high, >100 people per km^2.

Land cover

A digital geo-referenced database on land cover for Tanzania was available through the Africover project (http://www.africover.org/). The Multipurpose Africover Database for Environmental Resources (MADE) is produced at a 1 : 200,000 scale. The original land-cover data consisted of twelve different categories. These categories were grouped into two simplified classes: agricultural area and nonagricultural area (Table 1).

Road network of Tanzania

Data for the road network were available from UNEP-WCMC. It was estimated by Noss (2004) that one mile of road construction consumes about 19.43 ha of habitat. Therefore, a buffer around the road network with an area equivalent to 19.43 ha was created.

Analysis

To avoid overestimation, overlapping PAs were merged in ArcMap (ESRI, Redlands, CA, USA). Variations between the reported size of the PA and that of the polygon corresponding to it were noted in this analysis. Hence, the analysis holds good only for the area of the polygon. To calculate the gaps in protection of Tanzanian IBAs, we overlaid the IBA layer onto the consolidated PA polygon layers for 2007 and 2009.

Spatial errors are always a possibility when combining multiple 1 : 1 m scale data sets for analytical purposes

Table 1 Classification of Africover land-cover classes into combined land-cover classes that comprise agriculture and nonagriculture land use

Combined cover class	Original Africover land-cover class
Agricultural area	Cultivated terrestrial areas and managed land – Herbs
	Cultivated terrestrial areas and managed land – Shrubs
	Cultivated terrestrial areas and managed land – Trees
	Cultivated aquatic or regularly flooded areas
Nonagricultural area	Natural and semi-natural aquatic vegetation
	Natural and semi-natural Terrestrial vegetation – Herbs
	Natural and semi-natural Terrestrial vegetation – Shrubs
	Natural and semi-natural Terrestrial vegetation – Trees
	Artificial surfaces and associated areas
	Bare area
	Inland water bodies
	Artificial water bodies

(CIESIN, 2009). For some IBA polygons, it was found that the PAs did not exactly match their edges, but the sites were clearly the same. The thin slivers of land that did not match were deleted using edit tool in ArcMap, thus forming the IBA gap layer.

The IBA gap layer was overlaid with three other categories of data; (i) population layer; (ii) land-cover layer; and (iii) road buffer layer separately. The resulting layers were projected using WGS 1984 UTM Zone 36S co-ordinate system, and the area for each unique polygon was computed. The attribute tables of the projected layers were exported as tabular data for statistical analysis. The tabular data set quantifies, for each gap, the total area of each of the three different categories of social attributes.

This method identifies three kinds of gaps. (i) Gaps due to slight mismatch of WDPA polygons and IBA polygons. These are not real gaps and are caused by variations in mapping methods in GIS and were removed as described above. (ii) Partial gaps; for example, IBA polygons in the Eastern Arc Mountains range cover the entire mountain, while the WDPA covers only the reserve areas in the mountains. Therefore, the gaps found in that region are actually only partial protection gaps. (iii) Real gaps, where there is no WDPA polygon at all within the IBA boundary.

Relative ranking of IBA gaps

The four essential components of a relative ranking method are the dimensions of comparison along with the indicators for each dimension, a scoring method, and the weights assigned to different dimensions and indicators (Shi *et al.*, 2005). Four of these dimensions were used in this research (i) number of red list and restricted range avian species (BirdLife International, 2008b); (ii) human population pressure (Sanderson *et al.*, 2002); (iii) agricultural potential of the land (Gorenflo & Brandon, 2006); and (iv) road network pressure (Noss, 2004).

The first three dimensions, red list and restricted range bird species, human population pressure and agricultural potential of land, have two subdimensions; red list species and restricted range species, high population pressure and medium–low population pressure and agricultural and nonagricultural land. Hence, a total of seven indicators were developed for this project: (i) number of red list species in the unprotected IBA; (ii) number of restricted range species in the unprotected IBA; (iii) percentage of unprotected IBA under high population pressure; (iv) percentage of unprotected IBA under medium–low population pressure; (v) percentage of agricultural land in unprotected IBA; (vi) percentage of nonagricultural land in unprotected IBA; and (vii) percentage of road buffer zone in unprotected IBA.

In the relative ranking method, the mean value of each indicator for the 2007 and 2009 IBA gaps was calculated separately. For each IBA gap, the value of each indicator for a given gap was compared with the mean value of the indicator for all the IBA gaps. In this comparison, if the value of an indicator for a given IBA gap for items 1, 2, 3, 5 and 7 was greater than its mean value, the indicator was scored as 1; otherwise, it was scored as 0. Similarly, for the indicators of items 4 and 6, if the value of an indicator of a given IBA gap was less than its mean value, the indicator was scored 1; otherwise, it was scored as 0. On the basis of each indicator's score for a given IBA gap, a total 'gap score' was calculated, and the gaps were ranked accordingly (Table 2). Thus, this ranking method provided a relative ranking of the IBA gaps among the group of IBA gaps and not an absolute ranking (Shi *et al.*, 2005).

Table 2 Human population pressure, Agricultural land, Road network, Avian priority and Relative ranks for Important Bird Area (IBA) gaps in Tanzania: 28 in 2007 and 27 in 2009

				Area under Population Pressure (%)				Area under agricultural pressure (%)				Area under road network pressure (%)		Number of		Relative ranking[a]			
		Type of gap		High Population (Score)[b]		Low and Medium Population (Score)[c]		Agricultural Land (Score)		NonAgricultural Land (Score)		Road Buffer (Score)[d]		Red list species (score)[e]	Restricted range species (score)[e]	Total Score		Rank	
	IBA gaps	2007	2009	2007	2009	2007	2009	2007	2009	2007	2009	2007	2009			2007	2009	2007	2009
1	Dar es Salaam Coast	Partial	Partial	0.9 (0)	0.1 (0)	0.1 (1)	0.1 (1)	0.3 (0)	0.3 (0)	1.4 (1)	1.4 (1)	0.0 (0)	0.0 (0)	1 (0)	0 (0)	2	2	5	5
2	Eluanata Dam	Real	Real	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	0.5 (0)	0.5 (0)	99.5 (0)	99.5 (0)	0.0 (0)	0.0 (0)	0 (0)	0 (0)	0	0	7	7
3	Kagera Swamps	Partial	Partial	29.6 (1)	3.1 (1)	70.1 (0)	3.1 (1)	16.5 (1)	21.6 (1)	83.5 (0)	78.4 (0)	0.6 (0)	0.7 (0)	4 (1)	1 (1)	4	5	3	2
4	Kilombero Valley[f]	Partial	–	0.9 (0)	–	99.1 (0)	–	13.2 (1)	–	86.8 (0)	–	0.5 (0)	–	5 (1)	1 (1)	3	–	4	–
5	Lake Burungi	Real	Real	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	37.6 (1)	37.6 (1)	62.4 (1)	62.4 (1)	1.4 (1)	1.4 (1)	1 (0)	0 (0)	3	3	4	4
6	Lake Eyasi	Partial	Partial	0.0 (0)	0.0 (0)	100.0 (0)	7.6 (1)	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	0.0 (0)	0.0 (0)	2 (1)	1 (1)	2	3	5	4
7	Lake Kitangire	Real	Real	0.0 (0)	0.0 (0)	100.0 (0)	39.2 (0)	2.7 (0)	2.7 (0)	97.3 (0)	97.3 (0)	0.0 (0)	0.0 (0)	1 (0)	0 (0)	0	0	7	7
8	Lake Manyara National Park	Partial	Partial	45.8 (1)	34.8 (1)	54.2 (1)	7.0 (1)	0.4 (0)	0.4 (0)	99.6 (0)	99.6 (0)	0.6 (0)	0.6 (0)	3 (1)	2 (1)	4	4	3	3
9	Lake Natron And Engaruka Basin	Real	Partial	0.0 (0)	0.0 (0)	100.0 (0)	2.0 (1)	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	0.4 (0)	0.0 (0)	2 (1)	1 (1)	3	3	4	4
10	Lake Rukwa	Partial	Partial	0.0 (0)	0.0 (0)	100.0 (0)	13.5 (1)	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	0.3 (0)	0.3 (0)	1 (0)	0 (0)	0	1	7	6
11	Lake Tlawi	Real	Real	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	99.0 (1)	99.0 (1)	1.0 (1)	1.0 (1)	15.0 (1)	15.0 (1)	0 (0)	0 (0)	3	3	4	4
12	Lake Victoria: Bumbire Islands	Real	Real	7.6 (0)	7.6 (1)	0.0 (1)	0.0 (1)	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	0.0 (0)	0.0 (0)	0 (0)	0 (0)	1	1	6	6

Table 2 Continued

	IBA gaps	Type of gap		Area under Population Pressure (%)				Area under agricultural pressure (%)				Area under road network pressure (%)		Number of		Relative ranking[a]			
				High Population (Score)[b]		Low and Medium Population (Score)[c]		Agricultural Land (Score)		NonAgricultural Land (Score)		Road Buffer (Score)[d]		Red list species (score)[e]	Restricted range species (score)[e]	Total Score		Rank	
		2007	2009	2007	2009	2007	2009	2007	2009	2007	2009	2007	2009			2007	2009	2007	2009
13	Lake Victoria: Bunda Bay	Real	Real	14.4 (1)	0.2 (0)	8.0 (1)	8.0 (1)	14.3 (1)	14.3 (1)	85.7 (0)	85.7 (0)	0.6 (0)	0.6 (0)	0 (0)	0 (0)	3	2	4	5
14	Lake Victoria: Mara Bay And Masirori Swamp	Real	Real	5.3 (0)	0.7 (0)	69.4 (0)	32.0 (1)	11.1 (0)	11.1 (0)	88.9 (0)	88.9 (0)	0.2 (0)	0.2 (0)	0 (0)	0 (0)	0	1	7	6
15	Lake Victoria: Mwanza Gulf	Partial	Partial	7.6 (0)	0.5 (0)	0.0 (1)	0.0 (1)	12.0 (0)	12.0 (0)	88.0 (0)	88.0 (0)	0.1 (0)	0.1 (0)	0 (0)	0 (0)	1	0	6	7
16	Latham Island	Real	Real	0.0 (0)	0.0 (0)	0.0 (1)	0.0 (1)	0.0 (0)	0.0 (0)	0.0 (1)	0.0 (1)	0.0 (0)	0.0 (0)	0 (0)	0 (0)	2	0	5	7
17	Longido Game Controlled Area	Real	Real	3.5 (0)	0.4 (0)	96.5 (0)	24.5 (1)	2.4 (0)	2.4 (0)	97.6 (0)	97.6 (0)	1.3 (1)	1.3 (1)	2 (1)	1 (1)	3	4	4	3
18	Mtera Reservoir	Partial	Partial	0.0 (0)	0.0 (0)	100.0 (0)	52.0 (0)	1.5 (0)	1.5 (0)	98.6 (0)	98.6 (0)	0.5 (0)	0.5 (0)	0 (0)	0 (0)	0	0	7	7
19	Mtwara District Coastal Forests	Real	Real	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	0.0 (0)	0.0 (0)	1 (0)	0 (0)	0	0	7	7
20	Nyumba ya Mungu Reservoir	Partial	Partial	0.0 (0)	0.0 (0)	100.0 (0)	53.5 (0)	8.3 (0)	8.3 (0)	91.7 (0)	91.7 (0)	0.7 (0)	0.7 (0)	2 (1)	0 (0)	1	1	6	6
21	Pemba Island	Partial	Partial	67.1 (1)	1.2 (0)	1.1 (1)	1.1 (1)	67.0 (1)	67.0 (1)	9.0 (1)	9.0 (1)	1.0 (0)	1.1 (0)	2 (1)	4 (1)	6	5	1	2

Table 2 Continued

				Area under Population Pressure (%)				Area under agricultural pressure (%)				Area under road network pressure (%)		Number of		Relative ranking[a]			
		Type of gap		High Population (Score)[b]		Low and Medium Population (Score)[c]		Agricultural Land (Score)		NonAgricultural Land (Score)		Road Buffer (Score)[d]				Total Score		Rank	
	IBA gaps	2007	2009	2007	2009	2007	2009	2007	2009	2007	2009	2007	2009	Red list species (score)[e]	Restricted range species (score)[e]	2007	2009	2007	2009
22	Rufiji Delta	Partial	Partial	0.0 (0)	0.0 (0)	100.0 (0)	12.1 (1)	12.3 (0)	9.7 (0)	87.8 (0)	90.3 (0)	1.8 (1)	2.8 (1)	0 (0)	0 (0)	1	2	6	5
23	Rufiji District Coastal Forests	Real	Real	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	0.0 (0)	0.0 (0)	100.0 (0)	100.0 (0)	3.2 (1)	3.2 (1)	1 (0)	0 (0)	1	1	6	6
24	Singida Lakes	Real	Real	94.5 (1)	21.2 (1)	5.5 (1)	3.7 (1)	26.3 (1)	26.3 (1)	73.7 (1)	73.7 (1)	1.2 (1)	1.2 (1)	2 (1)	0 (0)	6	6	1	1
25	Usangu Flats	Partial	Partial	0.0 (0)	0.0 (0)	0.0 (1)	22.0 (1)	7.2 (0)	7.1 (0)	92.9 (0)	92.9 (0)	0.3 (0)	0.3 (0)	2 (1)	0 (0)	2	2	5	5
26	Uvidunda Mountains	Real	Real	0.0 (0)	0.0 (0)	100.0 (0)	62.8 (0)	3.8 (0)	3.8 (0)	96.2 (0)	96.2 (0)	1.2 (1)	1.2 (1)	2 (1)	8 (1)	3	3	4	4
27	Wembere Steppe	Partial	Partial	0.0 (0)	0.0 (0)	100.0 (0)	16.4 (1)	14.2 (1)	14.2 (1)	85.8 (0)	85.8 (0)	0.0 (0)	0.9 (0)	2 (1)	3 (1)	3	4	4	3
28	Zanzibar Island: East Coast	Partial	Partial	26.4 (1)	12.6 (1)	10.4 (1)	10.4 (1)	0.0 (0)	0.0 (0)	40.6 (1)	40.6 (1)	0.1 (0)	0.1 (0)	0 (0)	0 (0)	3	3	4	4
	Average			11.2	3.1	64.8	32.3	12.5	12.6	77.4	77.0	1.1	1.2	1.29	0.79				

[a]Score and rank are based on equal weights given to each dimension and indicator. If the value of the indicators (percentage of IBA gap under high population pressure, percentage of agricultural land in IBA gap and percentage of road buffer zone in IBA gap) was greater than its mean value, the indicator was scored as 1; otherwise, it was zero. Similarly, for the other two indicators (percentage of IBA gap under medium–low population pressure, percentage of nonagricultural land in IBA gap, number of red list species and number of restricted range species), if the value of an indicator was less than its mean value, then the indicator was scored as 1; otherwise, it was zero. On the basis of the indicator scores, the total score was calculated for each IBA gap, and the gaps were ranked on the basis of the total score.

[b]Human population density >100 km^{-2}.

[c]Human population density <100 km^{-2}.

[d]Buffer is 19.43 ha per mile of road.

[e]The same scores are added to both 2007 and 2009 as they do not change between 2007 and 2009.

[f]Kilombero Valley came under total protection in 2009.

Results

Increasing coverage of IBAs by protected areas

The IBAs defined in 2002 cover 167,132 km^2 of land and water. In 2002, 44 IBAs were in protected areas, four had part of their extent protected and 29 had no official (legal) protection (Table 3). Conspicuous among those unprotected were Lake Natron, the Kitulo plateau and most of Usangu flood plain in southern Tanzania, and the complex of Wembere steppe, Lake Kitangire, Lake Eyasi in the Eastern Rift Valley. Our spatial analysis shows that by 2007 protected areas covered 29.2% of the total land area of Tanzania and encompassed 85.2% of the IBA area. Between 2007 and 2009, the WDPA shows a 12.1% increase (31,170 km^2) of land falling within PAs. However, the increase in IBAs under protection is lower, with only 5.3% extra area (7615.1 km^2) protected. In 2007, there were 28 IBA gaps and this fell to 27 gaps in 2009. Of the total number of gaps occurring in 2009, thirteen were real gaps and fourteen partial gaps, so there was a decrease in gap area in four IBAs (Table 4).

Table 3 Changes in the number of fully protected, partly protected and unprotected Important Bird Area (IBA) sites in Tanzania over time [2002 data from Baker & Baker (2002) and 2007 and 2009 data from our GIS analysis]

Protection status	2002 (n)	2007 (n)	2009 (n)
Fully protected IBA	44	49	50
Partially protected IBA	4	14	14
Unprotected IBA	29	14	13

Human population, agricultural and road network pressure of IBA gaps 2007

Human population covered 39.2% of the area in 28 gaps in 2007, with 11.2% under high population density (Table 2). Only twelve of the gaps were entirely under high-density population pressure. In another fourteen gaps, more than 100% of the land was occupied by low- and medium-density populations. Lake Tlawi and Pemba Island gaps had more than 65% of agricultural land. Fifteen gaps had 80% of nonagricultural land, while six gaps had 100% of the same. Lake Tlawi showed the highest percentage for land under road network pressure – 15% of land under road network pressure, which was the highest among all other gaps. Seven gaps remained unaffected by the road network.

Human population, agricultural and road network pressure of IBA gaps 2009

In 2009, 17.65% of the remaining gap land was under human population density (Table 2), which equated to eleven gaps under high-density population pressure. The Lake Manyara National Park gap had the highest human occupancy, with 34.8% of the gap containing high human population density. Low- and medium-density population occupied the whole extent of five gaps. Two gaps had 50% of land under agriculture of which Lake Tlawi gap had 99% of the land under agriculture. Fourteen gaps had 75% of nonagricultural land, while six gaps were entirely nonagricultural. In terms of roads, eight gaps were not affected by a road network. The Lake Tlawi gap had the largest amount of land affected by a road network.

Table 4 Changes in IBA gap area in four key wetland sites between 2007 and 2009

	IBA Gap	Gap area 2007 (km^2)	Gap area 2009 (km^2)	Difference in area (km^2)	Change in gap type
1	Kilombero Valley	5683.14	0.00	5683.14	Partial to no gap through inclusion of Kilombero Valley Ramsar site within WDPA
2	Lake Natron and Engaruka Basin	2260.06	507.80	1752.26	Real to Partial gap through inclusion of Lake Natron Ramsar site within WDPA
3	Kagera Swamps	1432.57	1091.03	341.54	Partial to Partial gap through inclusion of Kimisi Game Reserve within WDPA
4	Rufiji Delta	422.10	257.33	164.76	Partial to Partial gap through inclusion of Rufiji Mafia Kilwa Ramsar site within WDPA

IBA = Important Bird Area; WDPA = World Database on Protected Areas.

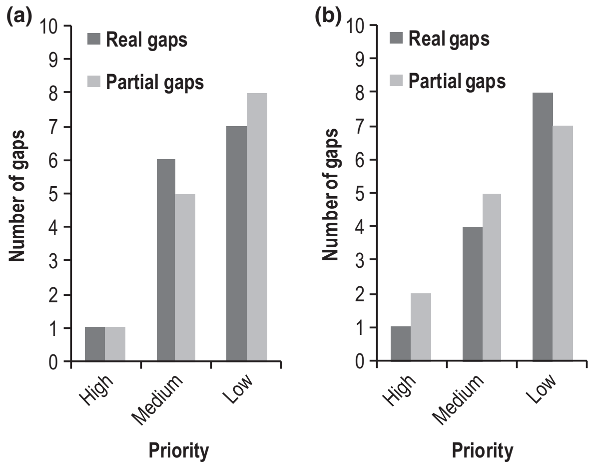

Fig 3 (a) Frequency of high, medium and low priorities in 28 Important Bird Area (IBA) gaps in 2007. (b) Frequency of high, medium and low priorities in 27 IBA gaps in 2009

Relative ranking

On the basis of the summed score for the five threat indicators, and assuming each indicator has the same weight, all gaps were ranked and grouped into three priorities for conservation action: high-priority gap (rank 1 and 2), medium-priority gap (rank 3 and 4) and low-priority gap (rank 5, 6 and 7). On this basis, the Singida Lakes and Pemba Island gaps were high-priority gaps for conservation action in both 2007 and 2009.

Using the relative ranking method, two gaps, covering an area of about 1195.34 km^2, were high-priority gaps for conservation action in 2007, while six gaps (2461.77 km^2) were ranked similarly in 2009. In 2007, there was an equal number of real and partial gaps of high, priority for action (Fig. 3a), while 2009 had greater number of real gaps of low priority for action (Fig. 3b).

Taken together, these results imply that the PA network is being developed to cover the unprotected gaps in IBA coverage. However, this is not entirely due to changes that occurred on the ground between 2007 and 2009. The new Jozani NP on Unguja Island (Zanzibar) and the RAMSAR sites in Natron, Malagarasi, Rufiji and Kilombero Valley – which were declared in the 2004–2005 period – were only added to the WDPA after 2007. So while it remains true that the gaps in coverage of IBA sites are being closed by new PAs, the differences calculated between 2007 and 2009 are slightly artificial.

Discussion

In this paper, we have looked at the closure of gaps in IBA coverage by PAs in Tanzania. We show that some IBA gaps have been covered, reducing the amount of important biodiversity that is found outside of some form of protected land.

The UN Millennium Development Goals reporting uses coverage by IBAs to assess the degree to which key habitats for threatened species are adequately protected (UN, 2010). By 2007, 26% of IBAs were completely protected globally, which is a significant increase from 19% in 1990. The MDGs report recognizes that IBAs are critical sites for the conservation of the world's birds and other biodiversity and that protecting all of these areas would significantly contribute to the achievement of the Convention on Biological Diversity's target to safeguard areas of biological importance. However, the report states that, at present, more than two-thirds of these sites are unprotected or only partially protected.

In comparison, the protection of IBAs in Tanzania increased from 85.2% to 89.7% of their area between 2007 and 2009. This is an impressive achievement in a poor developing country. However, gaps still remain and targeted conservation efforts in those gap areas would achieve further gains for the conservation of biological diversity. The majority of the remaining unprotected IBA sites are forest patches located in mountain and lowland areas or sites with particular types of habitat – such as wetlands or upland grasslands – with either large congregations of birds of a few species or with assemblages of birds typical of these habitat types.

This paper used social data to rank the urgency of threats to some of the remaining gaps and hence the urgency for conservation action. This recognizes that biodiversity conservation policies and practices are inherently social phenomena, but the conservation community continues to look to the biological sciences to design these policies and practices (Shi *et al.*, 2005). Although biologists and practitioners, at least in recent years, have increasingly recognized that social factors are often the primary determinants of the success or failure of conservation efforts (Mascia *et al.*, 2003), biological criteria continue to dominate the literature on priority setting.

The key gaps remaining are in 27 different locations (Fig. 2). The gaps mainly fall within three broad habitat types: forests, savannah woodlands and wetlands

(Table 4). In the mountain forests, a gap is described from the Uvidunda Mountains, otherwise regarded as a part of the Rubeho range. In the lowland forests, gaps are known in the coastal forests of Rufiji district, Mtwara district and on the islands of Pemba and Unguja (Zanzibar). Here, forest patches support key bird habitat outside the PA network. These gaps are known to conservationists in Tanzania, and although not all of them are protected as yet, work is ongoing to close these gaps through gazettement processes aiming to create Nature Reserves, Forest Reserves or Village Land Forest Reserves. Within the savannah woodland areas, there are unprotected IBAs in the Lake Manyara National Park area and the former Longido Game Controlled Area. In Manyara, wildlife corridors are being developed using private lands (for example, Manyara Ranch) that will largely close the protection gap, and the Longido area has been gazetted as a Wildlife Management Area. The rest of the IBA protection gaps are in wetland areas or (especially) in lakes of various sizes or parts of Lake Victoria. These protection gaps have had less attention in recent years, and it is not expected that these gaps will be covered by PAs in the near future. In terms of the additional protection being applied to IBA sites in Tanzania, the new protection is generally within Village Forest Reserves or Wildlife Management Areas. These are both designations that concentrate management at the local level, involving villagers, and also seek to transfer benefits and management responsibilities down to the village level.

Finally, we recognize that there are challenges with some of the data sets – with the WDPA lacking some reserves and having inaccurate locations for others – and the Africover data set misassigning some vegetation types – as examples. Nevertheless, the broad pattern recovered in the analysis, which we believe is robust, shows the progress that is being made in Tanzania to develop a comprehensive protected area network for birds and the kinds of challenges that still remain in that regard.

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