Developing biodiversity indicators for African birds

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Abstract

Biodiversity indicators are essential for monitoring the impacts of pressures on the state of nature, determining the effectiveness of policy responses, and tracking progress towards biodiversity targets and sustainable development goals. Indicators based on trends in the abundance of birds are widely used for these purposes in Europe and have been identified as priorities for development elsewhere. To facilitate this, we established bird population monitoring schemes in three African countries, built on citizen science approaches used in Europe, aiming to monitor population trends in common and widespread species. We recorded >500 bird species from c450 2-km transects in Botswana, >750 species from c120 transects in Uganda, and >630 species from c90 transects in Kenya. Provisional Wild Bird Indices show a strong increase in bird populations in Botswana and a small decrease in Uganda. We also show comparisons between trends of habitat generalists and specialists, of birds within and outside protected areas, and between Afro-Palearctic migrants and resident birds. Challenges encountered included recruiting, training and retaining volunteer surveyors, and securing long-term funding. We show, however, that with technical support and modest investment (~US$30,000 per scheme per year), meaningful biodiversity indicators can be generated and used in African countries. Sustained resourcing for the existing schemes, and replication elsewhere, would represent a cost-effective way to improve our understanding of biodiversity trends globally, and measure progress towards environmental goals.

Keywords

land bird monitoring, national and international reporting, policy relevant, TRIM, wild bird index, population abundance, Aichi Targets.

Introduction

Countries need to conserve biodiversity and utilise natural resources wisely if they are to avoid, halt and reverse ongoing environmental degradation (Stephenson et al. 2016). To do so effectively, governments and their agencies need robust environmental data to make informed decisions. Yet in Africa, as elsewhere, that information is often lacking (Stephenson et al. 2016; Schmeller *et al*. 2017), partly due to insufficient support, investment and expertise in biodiversity monitoring. In this paper, we describe citizen-science based monitoring schemes for birds in three African countries that are beginning to deliver policy-relevant results.

Birds have many characteristics that make them useful indicators of environmental change: they occur in nearly all habitats, often reflect trends in other taxa, are moderately sensitive to environmental change, and our level of knowledge about their numbers, ranges and ecology is relatively high (Furness & Greenwood 1993; Gregory et al. 2005). Work in Europe and North America has shown that Wild Bird Indices (hereafter WBIs), combining trend data for multiple species, can be used to inform environmental and conservation decision-making and improve the management of natural resources. Specifically, WBIs are composite indicators describing the average trends in relative abundance of native species with each species trend weighted equally in the index (Gregory et al. 2005). Such composite indicators provide a simple way of measuring and communicating progress towards biodiversity targets and can communicate information on anthropogenic pressures, such as habitat change loss and climate change

(Stephens et al. 2016). Environmental degradation of this kind may have profound consequences for the lives of people by reducing natural resources and the ecosystem services upon which they depend, and thus WBIs are being used in many countries, particularly in Europe. However, such indices must be interpreted with care as many bird species are mobile and respond to environmental changes over large and often distinct areas, and they may use the environment in a different manner to other taxa.

Programmes to monitor populations of breeding birds, covering predominantly terrestrial habitats, have become established in many European and North American countries since the 1960s. Across Europe, there are currently 39 national monitoring schemes and the Pan-European Common Bird Monitoring Scheme (PECBMS, http://www.ebcc.info/pecbm.html) uses species indices from annual breeding bird surveys in 28 countries to produce European and European Union (EU) bird indices. These cover around 170 species, with the objective of using birds as indicators of the state of nature across Europe. The supranational multi-species indicators have been adopted as measures of progress towards the EU's biodiversity goals, including Structural, Headline and Sustainable Development Indicators (http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm).

Such indices are relevant to the Convention on Biological Diversity's (CBD) Strategic Plan for Biodiversity, specifically Strategic Goals B (reduce the direct pressures on biodiversity and promote sustainable use) and C (improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity), and to the Aichi Biodiversity Targets used to measure progress towards these goals (Targets 5, 7 and 12; www.cbd.int/sp/targets/), as well as to United Nations'

Sustainable Development Goal 15 (Butchart et al. 2010; Secretariat of the Convention on Biological Diversity 2014; Tittensor et al. 2014).

The WBI concept is being applied elsewhere, often in '*State of the Nation's Birds*' reports, for example, in North America (North American Bird Conservation Initiative, U.S. Committee 2014), Australia (O'Connor et al. 2015), and Uganda (Nature Uganda 2015). Although some land bird monitoring schemes are well developed and are becoming established elsewhere (e.g. Australia, China, India, Japan, South Korea, Taiwan), few other schemes exist, especially in the tropics where biodiversity richness is at its highest.

Following a review of the capacity of the African Partner organisations of BirdLife International in 2010, monitoring schemes were initiated in Botswana, and Kenya, and revised in Uganda. These countries were selected on the basis of the enthusiasm of national partners, volunteer capacity and a tradition of bird monitoring to expand upon. Here, we describe the progress of these schemes and illustrate what can be achieved in Africa in terms of biodiversity monitoring based on citizen science (public engagement in scientific research activities; European Commission 2014). The indices we present are provisional because the time series analysis is short, and more work is needed to refine and interpret the trends, but their potential is clear.

Methods

The establishment of the monitoring schemes is described in Supplementary Information S1, including details on field methods, sampling design and volunteer engagement. A semi-random sampling approach was preferred, owing to the low availability of observers, as it encourages participation in circumstances of uneven participant distribution. This is based on similar approaches that have been employed in Europe (*e.g.* Bulgaria). Line or point count transects were both considered as suitable survey techniques (Senyatso et al. 2008). The final decision on which technique to use in each country was based on local conditions and existing experience. In Botswana surveys involved walking a 2-km transect, undertaking a 5-minute count of all birds seen or heard at 11 points spaced every 200m. Surveys were undertaken twice a year, in February and November. In Uganda, a line transect method was used, recording all birds seen or heard along a 2-km transect, divided into 200-m sections. Surveys were undertaken twice a year, in January/February and July/August. The scheme in Kenya followed a similar approach to Botswana, with surveys undertaken twice a year, in February and August. The differing timings reflect the different peak times for the detection of resident and migrant species.

Species trends and indicator species selection

We conducted trend and indicator analyses with data from Botswana and Uganda, but not Kenya, as too few transects were surveyed in the first three years of the scheme (Table 1). We employed a standardised approach to identify reliable species trends. For many species, the frequency and number of individual birds recorded from the surveys meant that there was insufficient data to generate robust indices. For Botswana and Uganda, the most widespread species were selected by the mean number of occupied transects per annum. In Botswana, species recorded in ≥20 transects per year were selected, except for any species for which year-to-year indices increased or decreased by a magnitude greater than 10, or where the standard error of the multiplicative slope index was greater than 0.5 (following http://www.ebcc.info/index.php?ID=614). In Uganda, although fewer transects have been surveyed annually, there was a greater species abundance per tetrad. Here species recorded in ≥15 transects per year were selected, with the same caveats as defined above. This selection process allows for widespread species that are typically recorded in low numbers (*e.g.* Cape crombec *Sylvietta rufescens* in Botswana and African thrush *Turdus pelios* in Uganda) to be included, as well as those that are typically flocking or erratic in movements (e.g. gamebirds, marabou *Leptoptilos crumeniferus* and red-billed quelea *Quelea quelea*), which may only be recorded in a small proportion of transects but in large numbers. On this basis, we report trends for 95 and 78 species in Botswana and Uganda respectively.

The Botswana transects were classified in terms of habitats as primarily grassland, savanna or (arid broadleaf) woodland, and the Uganda transects as primarily farmland (more intensive farming practices here meant that it was possible to define farmland as a separate category), grassland, (tropical) forest, savanna, or urban (although too few urban transects have so far been surveyed to enable analysis, and farmland and grassland transects were combined due to low sample sizes). These transect classifications were made by the respective scheme organisers using land cover maps.

We were also interested in understanding whether the trends of habitat specialists might differ from generalists, as has been reported elsewhere (Gregory et al. 2005). To do this, we used Juillard et al.'s (2006) Species Specialisation Index (SSI) to determine which species with reliable trends were habitat generalists or specialists. The SSI measures the variability of bird densities across habitat classes, using the coefficient of variation (standard deviation/average density).

We were also interested in the fate of Afro-Palaearctic migratory birds wintering in Africa, given the increasing conservation concern for this group on their breeding grounds (Vickery et al. 2014). Although to date 45 European migrant species have been recorded in the Botswana scheme and 57 species in the Uganda scheme, only six species in Botswana (European bee-eater *Merops apiaster*, red-backed shrike *Lanius collurio*, lesser grey shrike *Lanius minor*, barn swallow *Hirundo rustica*, willow warbler *Phylloscopus trochilus* and spotted flycatcher *Muscicapa striata*) and six in Uganda (European bee-eater, sand martin *Riparia riparia*, barn swallow, willow warbler, whinchat *Saxicola rubetra*, and yellow wagtail *Motacilla flava*), have been recorded in sufficient numbers to enable the calculation of reliable species trends.

Finally, the importance of Protected Areas (PAs) for biodiversity conservation has been the subject of much research (e.g. Chape et al. 2005; Gaston et al. 2008; Beresford et al. 2013), so we compared composite bird trends from our surveys within and outside PAs. To do so, transects in each country were identified as being within PAs or not, and a similar approach to the initial species selection was used (using the same statistical conditions for species inclusion). In each country, only species for which we had suitable trends for both within and outside PAs were included. For Botswana, species were selected that were recorded in ≥20 transects per year, within and outside PAs, resulting in 43 species for which we were able to calculate trends. For Uganda, to ensure that sufficient species were included, species were selected that were recorded in ≥14 transects per year, both within and outside PAs, resulting in 12 species.

Species composition, by country and indicator, is summarised in Supplementary Information S2.

Data analysis

Species trends were produced using the TRIM software programme (version 2.53) for analysing time-series of counts with missing observations using Poisson regression (van Strien et al. 2004). Counts were modelled as a function of site and year effects. Specifically, we used a TRIM change-point model with a change-point in every year, correcting for autocorrelation and over-dispersion. The multi-species WBIs were produced using the MSI tool R-script, which accounts for sampling error in the calculation of such indicators with bootstrapped confidence limits and tests for significance based on the Monte Carlo simulation (Soldaat et al. 2017). The script uses the species annual indices and standard errors from the TRIM output. Here, given the short time periods involved, we report linear trends only. For each indicator, 10,000 simulations were specified, the index set to 100 and the standard error set to zero in the first year. We use standard trend classifications and significance levels from the TRIM output and MSI tool output (Table S1).

Results

Coverage

For each country, transect coverage is summarised in Table 1. In Botswana, over 350 volunteers were registered and 170 have undertaken a count. Reliable species trends were calculated for 95 bird species (S2, S3). In Uganda, there were c100 regular participants, with 120 people participating in total. Reliable species trends were calculated for 78 bird species (S2). In Kenya, 160 people have participated in the count scheme so far, but it is too early to calculate trends.

Wild Bird Indices

In Botswana, the WBI has shown a significant strong increase of 65% between 2010 and 2015 (Fig. 4, Table 2), with 47 of the 95 species showing a significant increase, and only two species showing a significant decline (Table 2). In Uganda, the overall trend between 2009 and 2015 has been stable, although showing a small recent decline, with 15 of the 78 species showing a significant increase and 21 species showing a significant decline (Fig. 4, Table 2). This suggests tentatively that common bird populations are faring better in Botswana than Uganda. However, we stress that the monitoring period is short and the trend analysis is preliminary and relates to the more abundant species.

In Botswana, the most frequently recorded species was ring-necked dove *Streptopelia capicola* (present in 84% of transect counts), although the most abundant species was red-billed quelea (an overall count of at least 40,250 from 483 records between 2010 and 2015). In Uganda, common bulbul *Pycnonotus barbatus* was the most abundant (an overall count of >11,000 individuals from 713 records) and most frequently recorded species, in 91% of transects. Trend graphs for each species in the Botswana and Uganda WBIs are shown in S3.

Habitat generalists and specialists

We defined habitat specialists as those with an SSI >0.33 for Botswana and >0.40 for Uganda (to reflect the number of species and the distribution of values), which meant 34 and 21 species were classed as 'generalists', respectively. In order to allocate each of the specialists to a broad habitat, we used habitat-specific relative abundance (Julliard pers. comm.), as abundance *i*/overall mean abundance, within habitat *i*. Across the three broad habitat categories in Botswana and Uganda, the habitat with the highest habitat specific relative abundance score was selected as the 'preferred' habitat for each species. In Botswana, we identified 24 grassland, 16 savanna and 21 woodland specialists, and in Uganda, 17 farmland/grassland, 20 forest and 20 savanna specialists (see S2).

Habitat generalists in Botswana showed a significant strong increase between 2010 and 2015, with 20 of the 34 species showing a significant increase (Table 2, Fig. 5a). In Uganda, the trend was stable between 2009 and 2015, with four of the 21 species showing a significant increase, and five a significant decline (Table 2, Fig. 5b).

In Botswana, the indicators for grassland and woodland specialists showed significant strong increases between 2010 and 2015, with the trend for savanna specialists showing a significant moderate increase (Table 2). Of the grassland and woodland specialists, 50% and 57% respectively showed a significant increase, compared to just 19% of the savanna specialists (Table 2).

In Uganda, the indicator for farmland/grassland specialists showed a significant moderate increase (+17%) with 35% of species showing a significant increase and 18% a significant decline (Table 2). The indicator for forest specialists showed a significant moderate decline (-39%), with 45% of species showing a significant decline and none showing an increase. The indicator for the 20 savanna specialists in Uganda was stable.

Afro-Palearctic migrants

The overall trends of Afro-Palearctic migrants in Botswana and Uganda showed a significant moderate increase (Table 2, Fig. 6), with three species in Botswana (European bee-eater, barn swallow and spotted flycatcher) and four species in Uganda (sand martin, barn swallow, willow warbler and whinchat) showing a significant increase. Only yellow wagtail in Uganda showed a significant decline.

Within and outside Protected Areas

In Botswana, the trend within PAs was a significant moderate increase (+42%), that outside was a significant strong increase (+80%, Table 2, Figure 7). In Uganda, the trend within PAs was stable, but the trend outside was a moderate decline (-19%, Table 2).

Discussion

Robust environmental monitoring is essential in supporting global biodiversity reporting mechanisms (Secretariat of the Convention on Biological Diversity 2014; Butchart et al. 2010; Tittensor et al. 2014). It is encouraging that Botswana, Uganda and Kenya now have structured bird monitoring programmes in place to help inform their National Biodiversity Strategies and Action Plans under the CBD, and report against the Aichi Targets and Sustainable Development Goals. We hope that this will encourage other countries to invest in well-designed, citizen science-based biodiversity monitoring for land birds and other taxa, as highlighted by Schmeller et al. (2017), complementing other biodiversity monitoring schemes that have been established in Africa in recent years, such as the BIOTA project (Jürgens et al. 2011) and the

Southern African Birds Atlas Project (http://sabap2.adu.org.za/). The power of the information collected can only grow as more countries share common standards and knowledge, and share their data outputs – as we have seen in Europe and North America, where cooperation has formed the basis for important research (Pe'er et al. 2014; Inger et al. 2015; Gamero et al. 2016; Jørgensen et al. 2016; Stephens et al. 2016). We echo Stephenson et al. (2016) in calling on African government departments to work collaboratively to: enhance resources for monitoring and develop partnerships with donors; build capacity for data collection; improve co-ordination and collaboration for biodiversity data management; and produce and use more data-derived products that encourage data use, especially assessments that demonstrate the importance of biodiversity to economies and wellbeing.

We have shown how it is possible to establish bird monitoring schemes in Africa and we present the first provisional policy-relevant WBIs for Botswana and Uganda, and anticipate the same will be feasible for Kenya soon. Although the schemes are too young to assess changes over the long-term, the results suggest some emerging patterns that will bear careful scrutiny, and raise methodological issues for the schemes too. They also point to a series of common challenges that biodiversity monitoring programmes face and to some important considerations in terms of good practice. Like many long-term monitoring programmes, the schemes described here would be impossible to maintain without a citizen science approach, which is increasingly prevalent in global research (e.g. Cooper et al. 2014). While the use of volunteer scientists is not without problems (e.g. Conrad & Hilchey 2011, Crall et al. 2014), and must be accompanied by adequate scientific oversight (e.g. training, supervision and data verification (Buesching et al.

2014)), we believe that our work shows that this approach could be usefully extended elsewhere.

Developing the monitoring schemes

Developing motivated and skilled citizen scientists is key to the success of volunteer-based schemes. One challenge is a lack of tradition and culture in bird watching and systematic recording in Africa, as in other parts of the world.

In Botswana and Uganda, transects are generally closer to urban areas, as expected given the semi-random site selection (Figs. 1, 3), with some large areas, particularly in Uganda, that are so far devoid of any transects. Yet the stratified nature of transect selection has ensured that broad habitats have been represented and there has been a reasonable split in terms of transects located within PAs and in the wider landscape (Table S2). A future goal should be to target wider geographical coverage, as well as understanding to what degree the current sampling selection is representative of the land cover in each country, to inform targeted sampling and the development of stratified analysis to reduce bias.

A key issue is how each scheme can be funded over the longer term. It is crucial for each partner to secure a reliable source of in-country funding for the long-term operation and success of the programmes. This remains a challenge. We show that with technical support and a modest investment (~US$30,000 (20,000-40,000)) per year, meaningful biodiversity indicators can be produced to fulfill national, regional and international reporting obligations. Basic resources are needed to cover the full-time post of a national scheme organiser, printing and distributing survey forms, data and office costs, training workshops, the costs of promotional and training materials, and newsletters to feed back results to surveyors and other stakeholders.

Species trends and indicators

Although the African schemes cover only six to seven years, the results show a number of species with significant trends, both increasing and declining (Table 2). Our trend analysis is reasonably robust and is well established. However, the degree to which we might be able to generalize these findings is dependent on the sampling strategy, and the data are, for a number of practical reasons, spatially biased. We plan to investigate this in more detail and modify sampling and analysis accordingly.

That said, our analyses suggest differing trends in land bird populations in Botswana and Uganda that merits further investigation (Fig. 4). We found relatively little difference in species trends by major habitat, although the decline of forest specialist birds in Uganda is noteworthy (Fig. 5b). There were also differences in species trends in the PAs of each country (Fig. 7). Rather surprisingly, in Botswana, the indicators suggest that common bird populations are faring better outside of PAs (Table 2). In Uganda, the opposite was true (Fig. 7), as might be expected with presumed better habitat quality and conservation actions inside PAs. In time, these indices will be useful in assessing the performance of PAs in each country, at least in respect of these common bird populations and as part of a wider assessment. A study of the impact of the PA network in Europe concluded that these sites supported higher abundances of many common bird species (especially habitat specialists), but that the network was established too recently to assess its influence on population trends (Pellissier et al. 2013).

Policy use of the indicators

Bird monitoring data from Botswana, Kenya and Uganda will contribute usefully to wider biodiversity monitoring and reporting, and the *State of Uganda's Birds 2014* report is a good example of how this can be achieved (Nature Uganda 2015).

Data from the schemes have been made available to, and are already being used by, Government departments and agencies in each of the countries. In Botswana, data have been used to assist the Ministry of Agriculture to assess the distribution and abundance of red-billed quelea; an agricultural pest for which preventative measures are employed by governments to counter crop loss (Elliott 1990). In Kenya, house crow *Corvus splendens* abundance and distribution data are being used to advocate the control of this invasive species with the Kenya Pharmacy and Poisons Board. In Uganda, data from the National Biodiversity Data Bank (NBDB), including the scheme data, are being used in relation to Environmental and Social Impact Assessments for the oil industry. With longer-term datasets, it will be possible to look at bird populations in relation to other environmental factors, including land use pressures, climate change and PA management regimes. The indicators will also be useful for reporting against Aichi Targets 5 ('by 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced'), 7 (by 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity), and 12 ('by 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained), and Sustainable Development Goal 15 ('sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss'). Hence they are relevant to the CBD's Global Biodiversity Outlook, UNEP's Global Environment Outlook, and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services regional assessment for Africa.

Species trends of Afro-Palearctic migrants

Although sample sizes are small, the combined indices for Afro-Palearctic migrants are increasing, reflecting positive trends for most species. This result is perhaps surprising, given the well-established long-term and ongoing declines in their breeding population across at least western Europe (http://www.ebcc.info/index.php?ID=612), and may point to the difficulty in monitoring mobile and variable non-breeding populations and interpreting their trends, given incomplete knowledge of migratory connectivity and non-breeding ranges (Vickery et al. 2014). Only with more complete monitoring across African countries would we be able to capture and understand migrant bird trends, Afro-Palearctic, as well as, and importantly, intra-African migrant species too.

Developing a Global Wild Bird Index

The WBI project aims to encourage the development of land bird surveys in countries and regions where data are lacking, and seeks to synthesise relevant information on bird trends globally. As described above, bird monitoring programmes are being developed in a number of countries, raising the prospect of being able to chart the population trajectories of more species, and create more representative species trends over a wider area. If this were possible, such indicators would complement existing global biodiversity indices, such as the Living Planet Index (LPI: Loh et al. 2005; Collen et al. 2009; WWF 2016) and the Red List Index (RLI: Butchart et al. 2004, 2007), which are widely used in biodiversity assessments (e.g. Butchart et al. 2010; Tittensor et al. 2014). The WBI and LPI actually share similar index methods but differ in that the underlying trend data for the former come solely from systematically designed bird surveys, whereas for the latter they come from a wide range of sources reporting vertebrate trends. Note that bird trends from the WBI are routinely incorporated into the LPI (WWF 2016). The RLI is different, as it describes changes in the extinction risk of species derived from repeat assessments. However, the trend data produced by count schemes provide one of the key pieces of information required to assess the extinction risk and hence the Red List category of each species, and thereby help to underpin the production of RLIs at a variety of scales. In this way, WBIs complement and extend the current set of biodiversity indices, and we hope that their geographical coverage can be expanded.

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Author contributions

S.R.W. collated and analysed the data and drafted the paper

M.A.E. provided input to the analysis and the paper write-up.

D.S. provided input to the paper write-up.

F.B.M. organised collection of the Kenya data and provided input to the paper write-up.

I.J.B. provided input to the analysis and paper write-up.

S.H.M.B. provided input to the analysis and paper write-up.

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D.N.-W. organised collection of the Uganda data and provided input to the paper write-up.

P.K.N. provided input to the paper write-up.

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K.J.S. provided input to the paper write-up.

R.D.G. has had a major input to the analysis and paper write-up.

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Biographical sketches

S.R.W. oversees the current monitoring schemes as part of the Global Wild Bird Index project, which also involves M.A.E., I.J.B, P.K.N. and R.D.G. F.B.M. coordinates the monitoring scheme in Kenya, K.M. coordinates the monitoring scheme in Botswana and D.N.-W. coordinated the monitoring scheme in Uganda, until 2016. D.S. led on designing, establishing and developing the monitoring schemes from 2008, along with M.A.E., R.D.G, S.M.H.B, K.J.S. and D.P.. M.A.E., R.D.G. and S.M.H.B. established the overall GWBI programme.

Table 1. The number of transcects surveyed and bird species recorded during bird population monitoring in Botswana (2010-2015), Kenya (2011-2015) and Uganda (2009-2015), for all transects covered, transects within and outside Protected Areas.

Country	Year	All transects surveyed	Transects within PA	Transects outside PA	Total number of species recorded	Total bird count
Botswana	2010	128	62	66	309	20,713
	2011	242	100	142	411	61,355
	2012	316	128	188	385	84,942
	2013	232	97	135	362	64,227
	2014	283	116	167	411	80,219
	2015	244	92	152	392	60,404
	total	486	194	292	501	371,860
Kenya	2011	7	6	1	157	1,758
	2012	22	17	5	332	7,591
	2013	33	19	14	376	9,330
	2014	43	26	18	428	13,173
	2015	57	31	26	508	20,743
	total	92	49	43	638	52,595
Uganda	2009	65	37	30	507	10,090
	2010	58	31	29	446	9,766
	2011	59	28	33	487	11,778
	2012	73	37	38	597	11,762
	2013	71	38	35	517	9,349
	2014	81	45	38	617	12,774
	2015	64	26	40	448	7,259
	total	118	59	59	789	220,214

Table 2. A summary of the Wild Bird Indices showing the number of species significantly increasing, declining or uncertain trends within each indicator. Linear trend estimates (with standard error) in the Wild Bird Indices for Botswana and Uganda are also presented, with the percentage index changes shown for the whole time series. Significance levels are also shown (highlighted in bold).

Country	Indicator	Spp in indicator	Strong increase	Moderate increase	Stable	Uncertain	Moderate decline	Steep decline	Overall trend	% change
Botswana	WBI	95	26	21	2	44	1	1	1.087 (0.006) **strong increase**	64.6
Uganda	WBI	78	2	13	2	40	14	7	0.992 (0.004) stable	-15.0
Botswana	Habitat generalists	34	10	10	0	14	0	0	1.083 (0.009) **strong increase**	59.5
Uganda	Habitat generalists	21	0	4	0	12	3	2	0.988 (0.008) stable	-178.2
Botswana	Grassland specialists	24	6	6	0	11	1	0	1.097 (0.011) **strong increase**	75.8
Uganda	Farm/grassland specialists	17	2	4	1	7	3	0	1.032 (0.011) **mod. increase**	16.8
Botswana	Savanna specialists	16	2	1	1	11	0	1	1.058 (0.015) **mod. increase**	44.1
Uganda	Savanna specialists	20	0	5	1	10	4	0	1.014 (0.008) stable	-6.9
Botswana	Woodland specialists	21	8	4	1	8	0	0	1.105 (0.011) **strong increase**	77.3
Uganda	Forest specialists	20	0	0	0	11	4	5	0.944 (0.008) **mod. decline**	-38.8
Botswana	AP migrants	6	3	0	0	3	0	0	1.074 (0.022) **mod. increase**	46.6
Uganda	AP migrants	6	2	2	0	1	1	0	1.087 (0.028) **mod. increase**	59.7
Botswana	Within PAs	43	5	10	0	27	1	0	1.060 (0.008) **mod. increase**	42.7
Uganda	Within PAs	12	0	3	0	8	1	0	1.007 (0.010) stable	-5.3
Botswana	Outside PAs	43	12	10	0	21	0	0	1.102 (0.009) **strong increase**	79.5
Uganda	Outside PAs	12	0	1	1	5	4	1	0.973 (0.008) **mod. decline**	-19.0

Figure 1. The distribution of transects surveyed at least once in Botswana between 2010 and 2015. The black circles show transects located within Protected Areas and the white circles show transects outside. The dark shaded areas show the main Protected Areas in each country (from http://www.protectedplanet.net/).

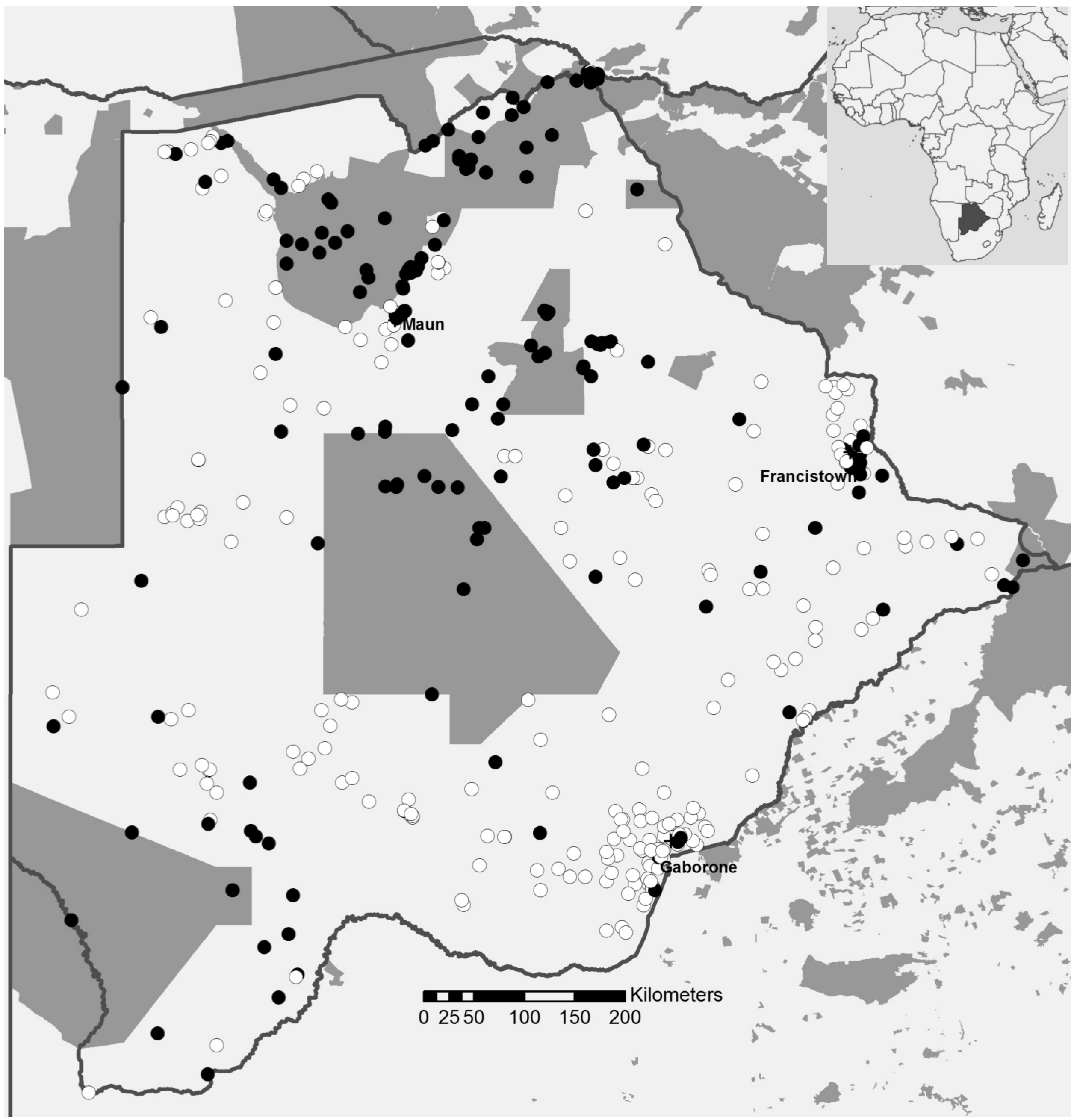


Figure 2. The distribution of transects surveyed at least once in Kenya between 2011 and 2015. The black circles show transects located within Protected Areas and the white circles show transects outside. The dark shaded areas show the main Protected Areas in each country (from http://www.protectedplanet.net/).

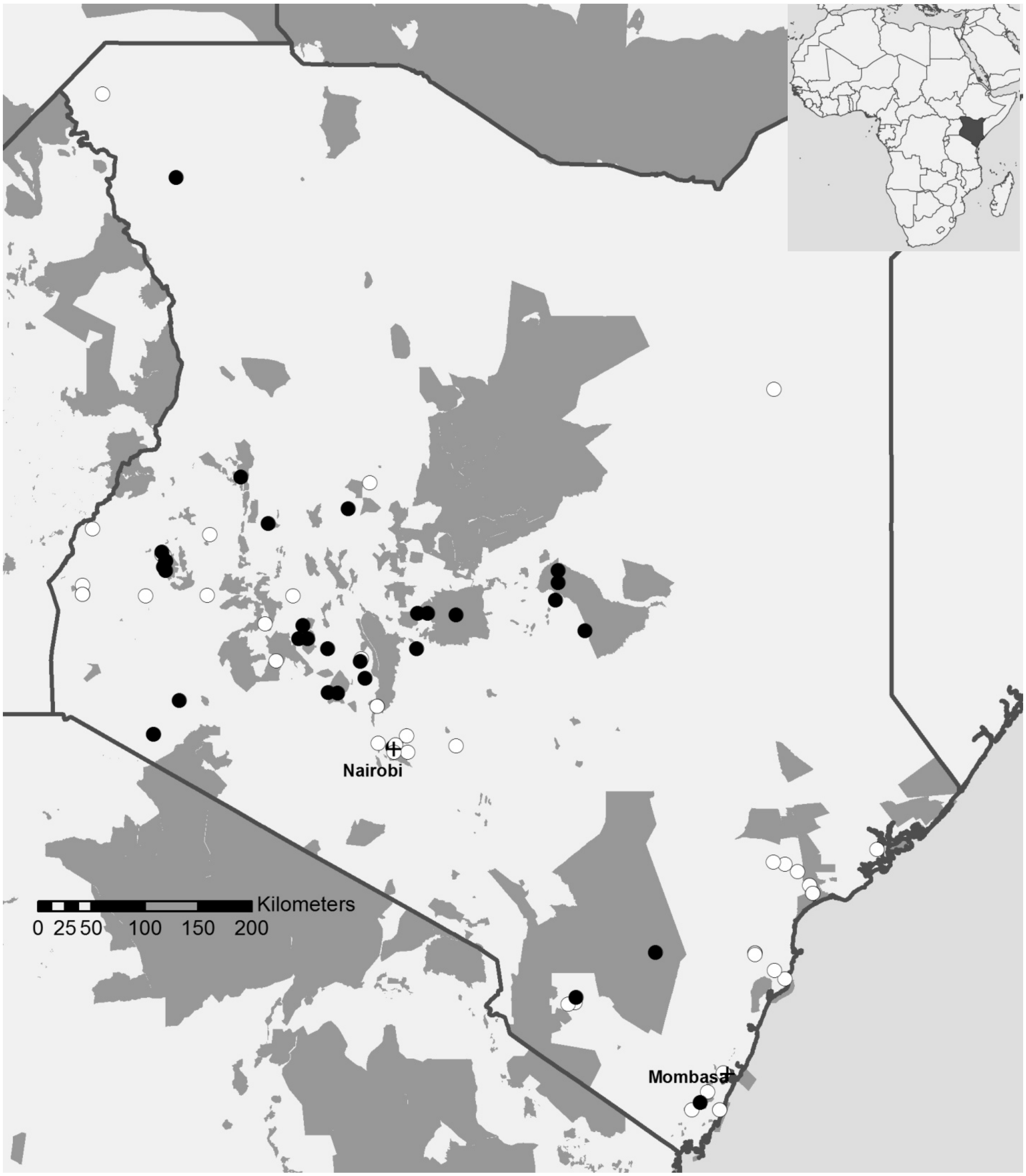


Figure 3. The distribution of transects surveyed at least once in Uganda between 2009 and 2015. The black circles show transects located within Protected Areas and the white circles show transects outside. The dark shaded areas show the main Protected Areas in each country (from http://www.protectedplanet.net/).

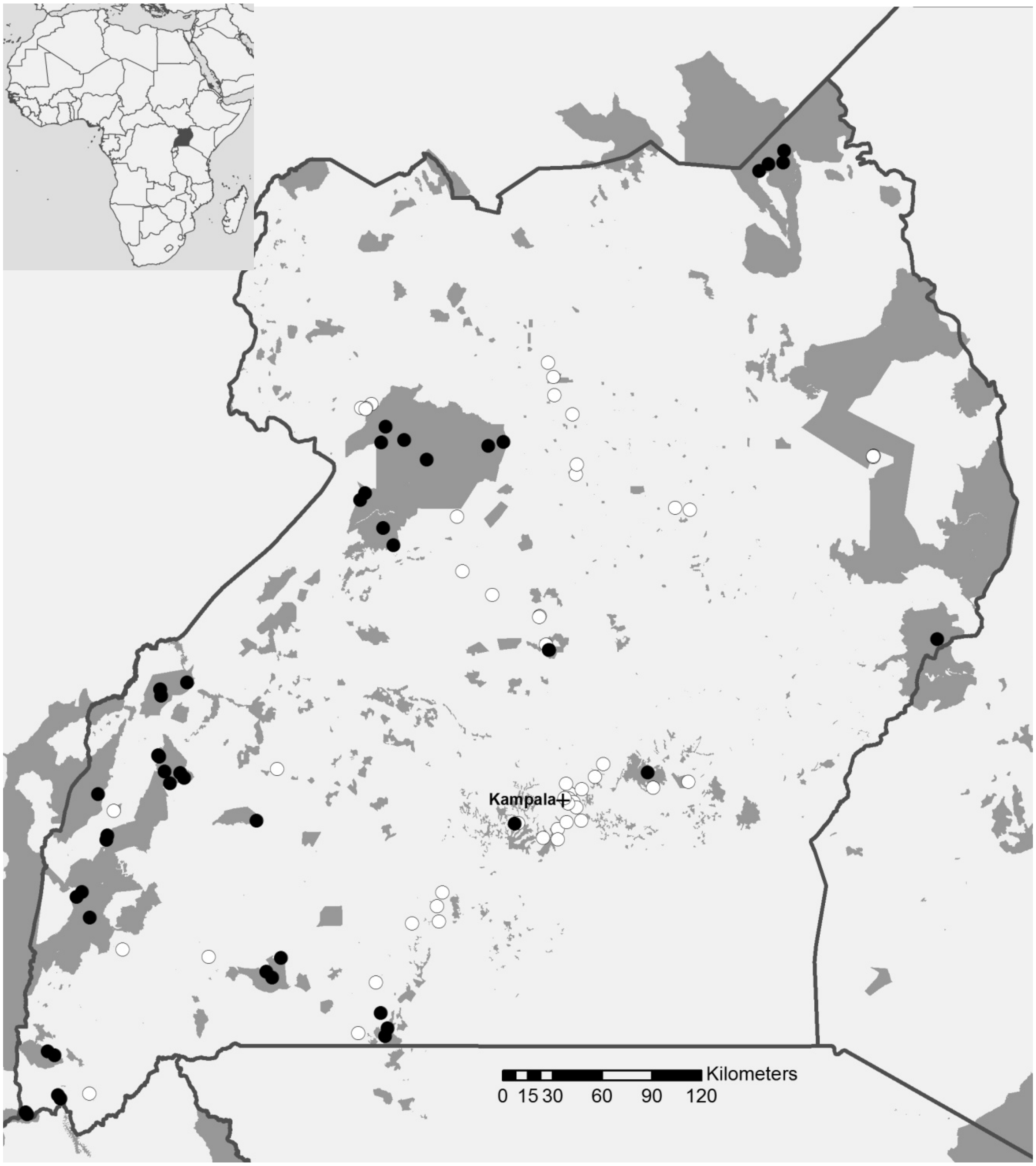


Figure 4. Wild Bird Indices for Botswana (95 species, grey line) and Uganda (78 species, black line, with 95% confidence limits). For each indicator, the proportion of the species within each TRIM significance classification is also shown in the bar chart below.

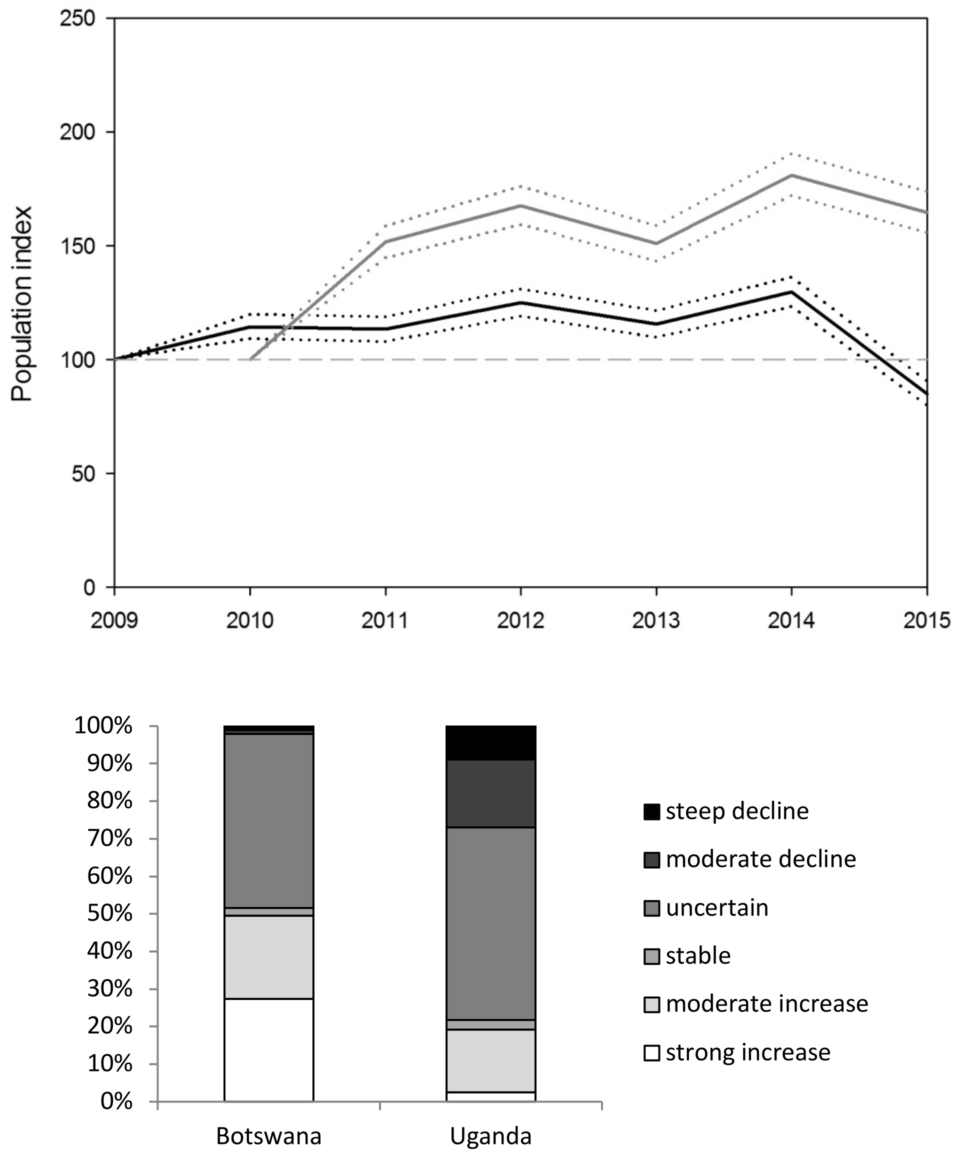
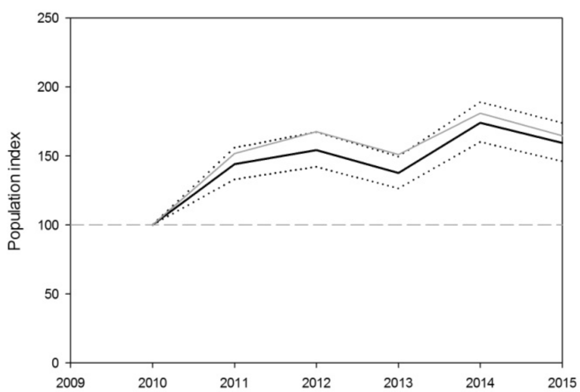


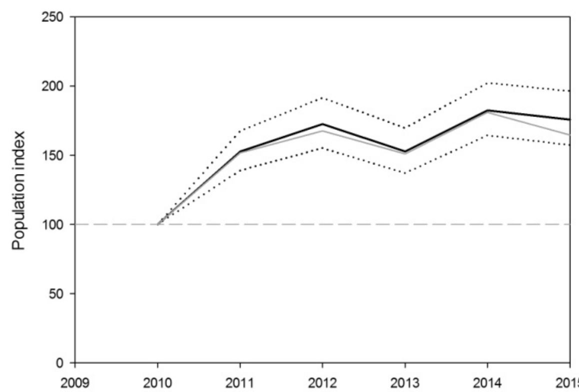
Figure 5. Wild Bird Indices for habitat generalists and specialists in (a) Botswana and (b) Uganda (with 95% confidence limits). For each indicator, the proportion of the species within each TRIM significance classification is also shown in bar chart below. As a comparator the overall Wild Bird Index for each country is shown as a grey line.

(a) Botswana

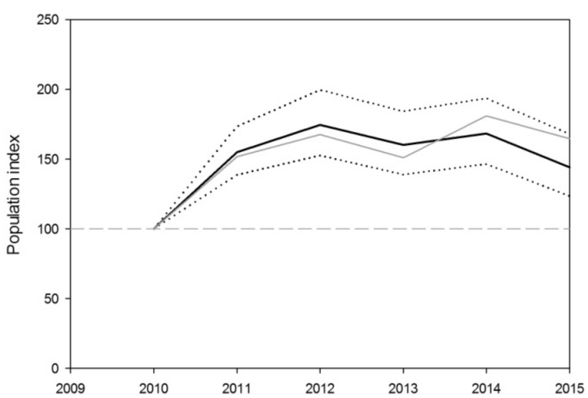
Generalists (34 species)



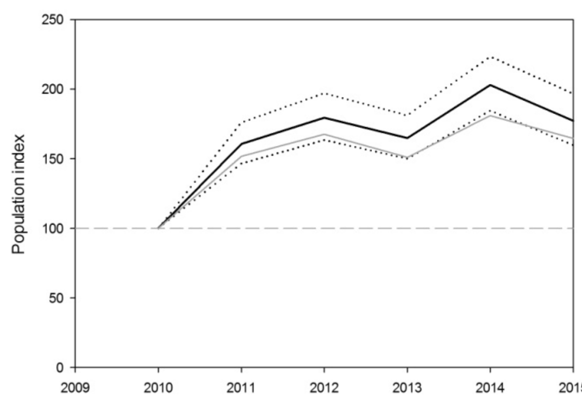
Grassland (24 species)

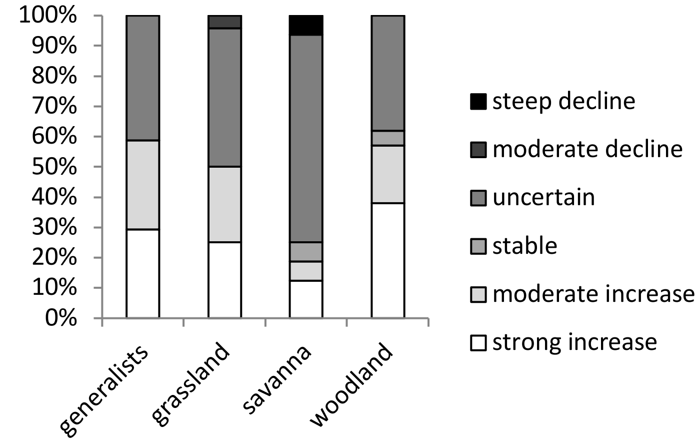


Savanna (16 species)



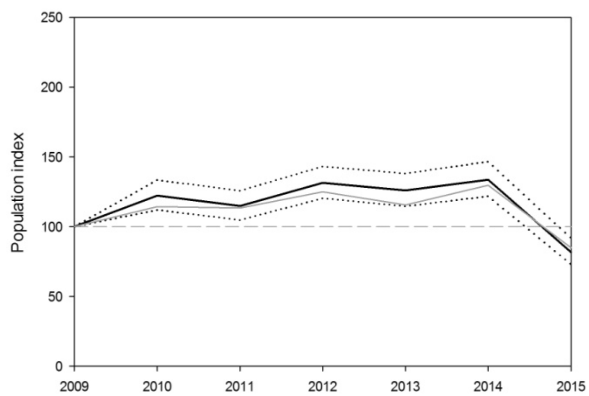
Woodland (21 species)



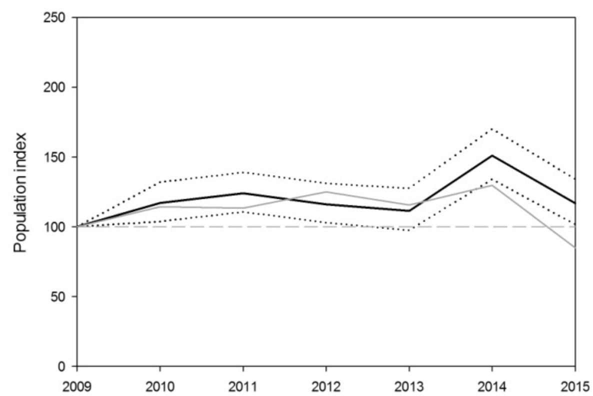


(b) Uganda

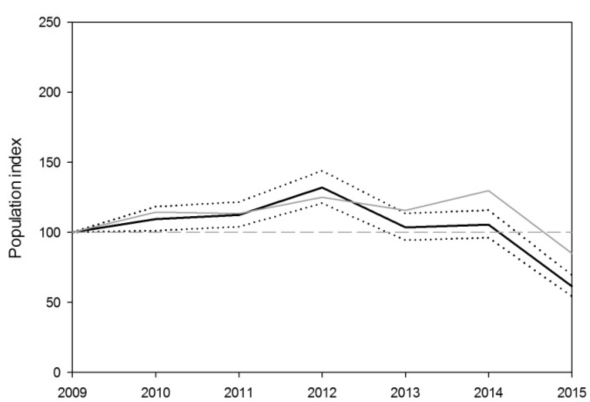
Generalists (21 species)



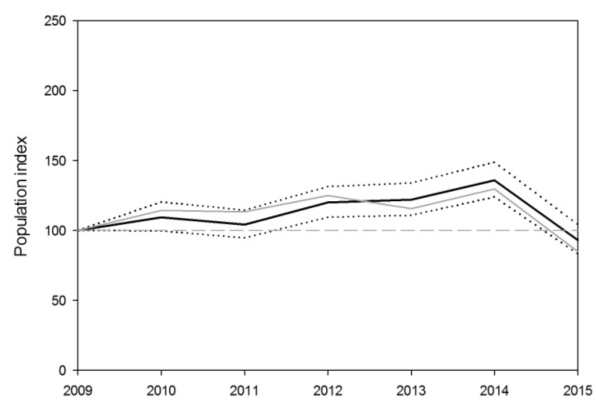
Farmland/grassland (17 species)

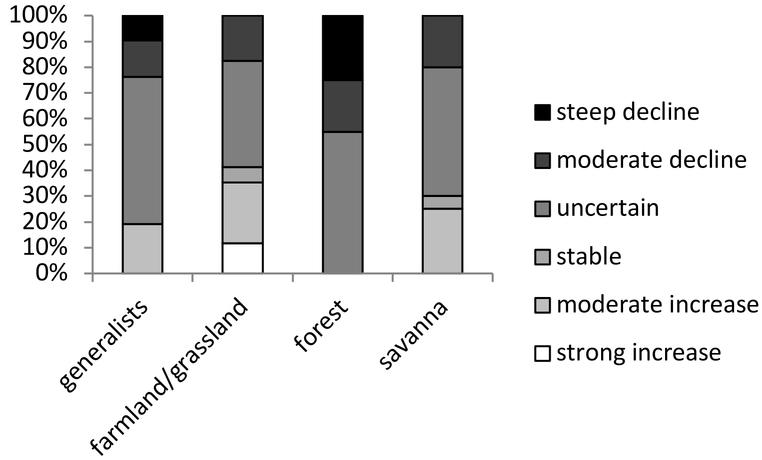


Forest (20 species)



Savanna (20 species)

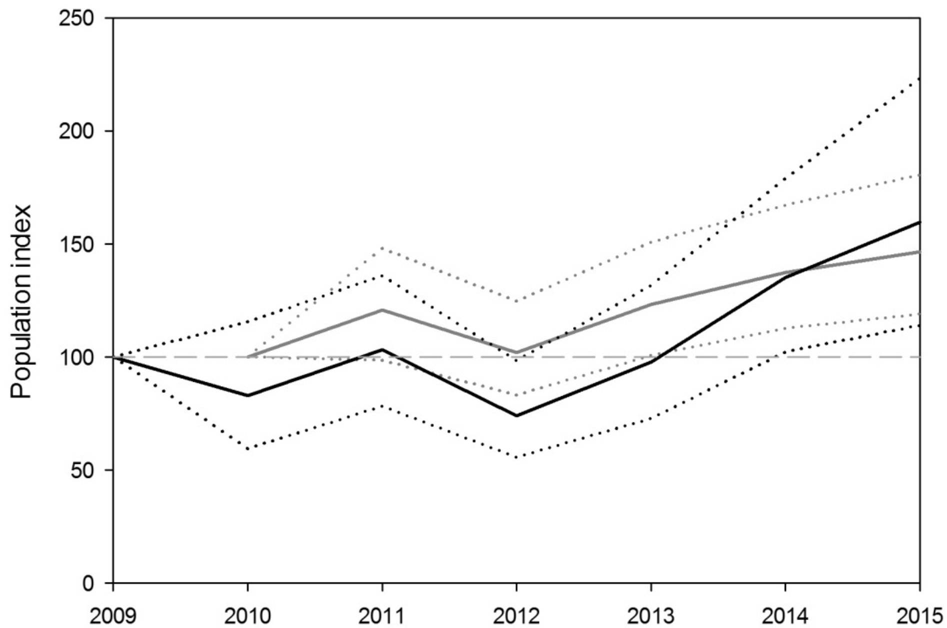



100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
generalists
farmland/grassland
forest
savanna
steep decline
moderate decline
uncertain
stable
moderate increase
strong increase

592 **Figure 6.** Wild Bird Index for Afro-Palearctic migrants in Botswana (grey) and Uganda (black)

593 with 95% confidence limits.

594

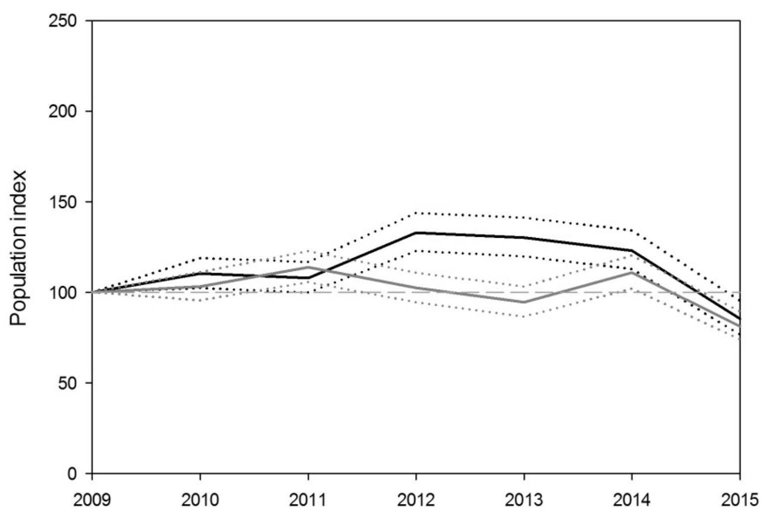


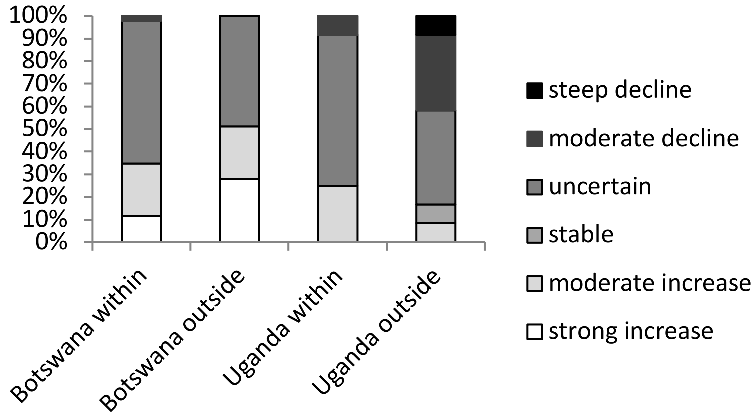
595

Figure 7. Wild Bird Indices within (black line) and outside (grey line) Protected Areas in (a) Botswana and (b) Uganda (with 95% confidence limits). For each indicator, the proportion of the species within each TRIM significance classification is also shown in the bar chart below.

(a)

(b)




100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Botswana within
Botswana outside
Uganda within
Uganda outside
steep decline
moderate decline
uncertain
stable
moderate increase
strong increase