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RESEARCH ARTICLE

APPLICATION OF BIRDS AS ECOLOGICAL BIOINDICATORS FOR MONITORING HABITAT CHANGE: A CASE STUDY FROM ABIJATA-SHALLA LAKES NATIONAL PARK, ETHIOPIA

*,[1]Addisu Asefa, [2]Girma Mengesha and [3]Yosef Mamo

[1]Ethiopian Wildlife Conservation Authority, Po Box 386, Addis Ababa, Ethiopia
[2]Hawassa University, Wondo Genet College of Forestry and Natural Resources, Po Box 128, Shashamane, Ethiopia
[3]Hawassa University, Department of Biology, PO Box 05, Hawassa, Ethiopia

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ABSTRACT

Ecological bioindicators are a species or group of species whose ecological attributes (e.g. presence/absence, abundance, etc) readily reflect the abiotic or biotic state of an ecosystem. Although the interest in using of bioindicators as a simple and cost-effective tool in ecological monitoring has been increasing worldwide, their inappropriate selection and application have put under question their utility as a conservation tool. In this study, using a priori defined suitability criteria, we explored whether reliable ecological bioindicators can be identified within the avifauna associated with savannah woodland and gallery forests habitats in the Abijata-Shalla Lakes National Park (ASLNP), Ethiopia, and tested the reliability of using them for effective monitoring of future changes in tree structure within the national park. We counted birds along 10 transects established in each of the disturbed and undisturbed sites of two vegetation types (savanna woodland and gallery forest), and recorded data on tree abundance and cover. For the undisturbed sites of the two vegetation types, we identified two types of bioindicators: characteristic (i.e. species with strong habitat specificity) and detector (species that span a range of ecological states). Of the total 86 species recorded across the study sites, one characteristic and three detector species for the savanna woodland, and three characteristic species and one detector species for the gallery forest were identified. However, only the characteristic bioindicator species showed significant difference in abundance between the two land use types in each vegetation type; thus were regarded as reliable potential bioindicators. Further, the abundance of these characteristic bioindicator species showed strong and significant positive correlations with both tree abundance and cover in each vegetation type. We conclude that bird species selected as characteristic bioindicators can potentially be used for effectively monitoring of future changes in tree abundance and cover in the undisturbed sites of the ASLNP. We also suggest that ecological bioindicators selected following the procedures we used will have valuable potential application in the monitoring of habitat integrity.

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INTRODUCTION

Alteration of natural habitats into other forms of land use type is threatening biodiversity globally, with many species of flora and fauna, particularly in the developing tropical countries, facing a great risk of extinction (Pimm *et al.,* 1995; Bruner *et al.,* 2001). Thus, much of tropical biodiversity is unlikely to survive without effective protection (Pimm *et al.,* 1995; Bruner *et al.,* 2001). To improve and optimise the effectiveness of conservation management strategies in protected areas, scientifically sound ecological information is needed. Surprisingly, however, little attention has been given to it by researchers, and many conservation practices are based on tradition or experiences of practitioners rather than on the results of scientific research (Bruner *et al*., 2001; Bleher *et al*., 2006; Newton, 2007; Chown, 2010; Asefa *et al*., 2015). Furthermore, ecological monitoring efforts in most protected areas of developing tropical countries like Ethiopia are limited by constraints such as finance and expertise, making the task of surveying the distributions of all organisms difficult (Kremen, 1992; Manne and Williams, 2003; Bleher *et al*., 2006). Therefore, developing simple ecological monitoring tools is of great importance to assess whether conservation succeeds for protected areas. Assessment of conservation effectiveness using such simple monitoring tools in turn requires indicators that are measurable and comparable among sites over time, practical and cost-effective (Noss, 1990). The concept of ecological bioindication is one such simple monitoring tool that has been used to assess the healthiness of ecosystems (Noss, 1990; McGeoch, 1998; Carignan and Villard, 2002; Niemi and Mc Dona, 2004).

Corresponding author: Addisu Asef,
Ethiopian Wildlife Conservation Authority, Po Box 386, Addis Ababa, Ethiopia.

Bioindicators are a species or group of species whose ecological attributes (e.g. presence/absence, abundance, reproductive success, etc) readily reflect the abiotic or biotic state of an environment (environmental bioindicators), an ecosystem (ecological bioindicators), or the diversity of taxa (biodiversity bioindicators) (McGeoch, 1998; Niemi and McDonald, 2004). Ecological bioindicators are primarily used either to assess the condition (e.g., as an early-warning system) or to predict trends in state of an ecosystem (Dale and Beyeler, 2001). Two types of ecological bioindicators are commonly used for ecosystem state monitoring: characteristic and detector bioindicators (van Rensburg *et al.,* 1999; McGeoch *et al.,* 2002). Characteristic ecological bioindicators are those habitat-specialized species occurring with higher abundance and higher frequency in a particular habitat, but absent or occurring with lower abundance and frequency in the other habitats (Dufrene and Legendre, 1997; McGeoch and Chown, 1998; McGeoch *et al.,* 2002). However, detector ecological bioindicators are generalist species occurring in wider range of habitats (or ecological states). They occur with low abundance and frequency values in the habitat or site for which they are supposed to be indicatives, but with moderate abundance and frequency values in other habitat types (McGeoch *et al.,* 2002).

The interest in studying and using of biological taxa as bioindicators to detect environmental changes, and to determine the causes and consequences of such changes on ecosystems has been growing globally (e.g. Kitching *et al*., 2000, using moth; Davis, 2001, dung beetles; Andersen *et al*., 2002, ants; Mitiku, 2013, birds; Vilches *et al*., 2013, plants). Despite such growing interest in studying and using of bioindicators in conservation programmes, however, their inappropriate selection and application have put under question the utility of the bioindication concept as a conservation tool (for detail on these issues, see Landres *et al*., 1998; Carignan and Villard, 2002; Niemi and McDona, 2004; Bleher *et al*., 2006; Urban *et al*., 2012). Several authors (e.g. McGeoch, 1998; McGeoch *et al*., 2002) have been pointed out the most important issues to be considered during the selection of bioindicator taxa, including (1) confirming whether the proposed taxa fulfills *a priori* suitability criteria), and, (2) verification of whether strong significant relationships exist between the bioindicator and environmental variables they indicate (McGeoch *et al*., 2002). Among the *a priori* suitability criteria which a given potential bioindicator taxa should posses are: i) clear taxonomic status, ii) non-migrant species with wide distribution (national, regional or global distribution), iii) habitat specialist, but is easy to find and measure (i.e. high abundance) (McGeoch, 1998; Hilty and Merelender, 2000). McGeoch *et al*. (2002) has provided a step by step procedure that would enable the identification of reliable bioindicators and their successful application. In this study, we followed this McGeoch's (1998) procedure to identify ecological bioindicators within the avian fauna associated with savannah woodland and gallery forest habitats, and determined their potential application in monitoring long-term changes in vegetation structure in the Abijata-Shalla Lakes National Park (ASLNP), in the central Rift valley of Ethiopia. ASLNP is the most important bird area in the country owing to a considerable number of wetland bird species, and populations, most of which are global conservations concern (EWNHS, 1996). It also contains 317 (~70% of the total species) terrestrial bird species (Almaw, 2012). However, like most protected areas of Africa and Ethiopia, the national park has been severely threatened from settlement, cultivation, grazing and charcoal making activities (Abdi, 1993; Senbeta and Tefera, 2002). Consequently, the extents of both *Acacia* dominated woodland habitat and water bodies of the lakes have been increasingly shrinking (Senbeta and Tefera, 2002; Hailu, 2009; Mengesha *et al*., 2009). Therefore, monitoring the impacts of ongoing threats to the area using simple, but effective, tools such as using bioindicators is required to abate further biodiversity degradation.

One management objective of the national park is to reduce human-induced threats to the relatively intact (undisturbed) sites of the svanna woodland and gallery forest habitats (Tolera Abdi, pers. comm.). In the present study, thus we were mainly interested in exploring the potential use of birds as bioindicators for monitoring of future changes in ecosystem states in the undisturbed sites of the national park. Clear-cutting of trees for cultivation and selective logging for charcoal making and construction purposes are the major threats to terrestrial ecosystem of ASLNP (Abdi, 1993; Senbeta and Tefera, 2002; Hailu, 2009). These disturbances have resulted in to reduced abundance and cover of trees in the national park, which in turn affects, directly or indirectly, animals including birds that depend on trees for shelter, breeding and forging (Abdi, 1993; Senbeta and Tefera, 2002; Mengesha *et al*., 2011). Thus, as a proxy measure of the effects of such disturbances on the ecosystem of the national park, we proposed the park management to use birds as bioindicators of the effects of human disturbances on these tree attributes (i.e. abundance and cover). We chose birds because they, among vertebrate groups of animals, have been a primary focus for most terrestrial applications of the bioindication concept (Mazerolle and Villard, 1999; Niemi and MacDonald, 2004; Mitiku, 2013). The primary reasons for their use are: (a) relative ease of identification, (b) relative ease of measurement, (c) relatively large number of species with known responses to disturbance and (d) relatively low cost for monitoring (Morrison 1986; Temple and Wiens 1989; Mazerolle and Villard, 1999; Carignan and Villard, 2002; Niemi and MacDonald, 2004). The specific objectives of this study were therefore: (1) to identify characteristic and detector bioindicator bird species for the relatively undisturbed savannah woodland habitat and the gallery forest habitat; and, (2) to assess the potential application of the bioindication concept in long-term monitoring of changes in state of ecosystem (i.e. tree abundance and cover) of the vegetation types using bird species identified as potential bioindicators.

MATERIALS AND METHODS

The study area: Abijata-Shalla Lakes National Park is located at about 207 km south of Addis Ababa (between latitudes of $7^0$30' - $7^0$40'N and $38^0$35' - $38^0$45'E). The Park covers an area of 887 km^2 (Fig. 1). The elevation of the Park ranges between 1,540 and 2,075 m asl (EWNHS, 1996). A terrestrial woodland habitat of the Park covers an area 382 km^2 (43%) of *Acacia* woodland whereas its three lakes cover an area of about 506 km^2 (57%) (Tefera and Almaw, 2002).

The average annual rainfall within the Park is 500 mm. The main rainy season is between late January and early April, with variations from year to year (Tefera and Almaw, 2002). Gallery forests exist along the eastern shorelines of Shalla Lake and along Blulbula and Dhadhaba rivers. Like the acacia woodland, these gallery forests are also represented by partly degraded (agriculture and settlement present) and partly relatively less disturbed (no agriculture and settlement) (Fig. 1).

Data collection

We collected data on birds and tree abundance and cover. Bird surveys were carried out in January/February 2015. In each of the disturbed and undisturbed sites of the two vegetating types, 10 line transects of 1 km in length were systematically placed in each representative vegetation/land use type at a minimum distance of 300 m from each other (Bibby *et al.,* 1998). Birds were counted along each transect early in the morning, between 07h30 and 10h30, and late in the afternoon, between 14h30 and 17h30 when the majority of birds were most active. Birds seen and/or heard within a width of 50 m on both sides of each transect were recorded and all individuals counted using naked-eye and/or Bushnell® Binoculars. Birds that were observed flying over the census area and not necessarily making use of the habitat (e.g. swifts, swallows, scavengers and some raptors) were not recorded. Nomenclature and sequence of bird species follows Dowsett *et al*. (2015). Tree abundance was counted within three 20 m × 20 m quadrats (totalling to 30 quadrats for each site) set up along each transect at every 150 m. Tree canopy cover was visually estimated by taking four readings from the four cardinal directions at the centre of each quadrat and the average of the four readings for a given quadrat was calculated and used as the percentage canopy cover of that quadrat (Newton, 2007).

Data analysis

Selection of bioindicators

Given that one management objective of the national park is to reduce human-induced threats to the relatively intact (undisturbed) sites of the svanna woodland and gallery forest habitats, we identified bioindicators only for those undisturbed sites. Bioindicator bird species were identified separately for these sites of each vegetation type using the Indicator Value Analysis Method (Dufrene and Legendre, 1997). This method assesses the degree (expressed as a percentage) to which each species fulfils the criteria of specificity (uniqueness to a particular site) and fidelity (frequency within that habitat type) for each sample cluster compared with all other clusters (McGeoch and Chown, 1998) and provides indicator values (IndVal) of each species for each cluster of samples compared. The species abundance matrix from each site of the two vegetation types was used to identify bioindicator species for the sites. The following two comparisons were made: disturbed savanna woodland vs. undisturbed savanna woodland, and disturbed gallery forest vs. undisturbed gallery forest. Dufrene and Legendre's (1997) random reallocation procedure of samples among sample groups was used to test the significance of the IndVal measures for each species. Following van Rensburg *et al*. (1999) and Mitiku (2013), those species with significant IndVals >70% were then regarded as characteristic bioindicator species for the undisturbed sites of the two vegetation types. Detector bioindicator species, however, were chosen as those that had significant IndVals of 50-70% for disturbed sites and 5-50% for undisturbed sites of each vegetation type (McGeoch, 1998; van Rensburg *et al*., 1999; Mitiku, 2013). These species were not characteristic species, as they did not have high IndVals of > 70% for any particular habitat (McGeoch, 1998; van Rensburg *et al*., 1999; Mitiku, 2013). However, they were regarded as sufficiently indicative of disturbed habitats, but were uncharacteristic of the undisturbed habitats at present. Thus, these species were supposed to show a potentially considerable increase in abundance (hence, in indicator value) in the currently undisturbed sites in the future under increasing disturbance conditions (McGeoch *et al*., 2002). The fact that a given species fulfilled the IndVal criteria does not necessarily mean that it is a reliable bioindicator (Hilty and Merelender, 2000), because the IndVal approach provides information only on its niche (e.g. habitat specialist) and life-history (easy to find and measure) (Dufrene and Legendre, 1997; McGeoch and Chown, 1998). In addition to the IndVal criteria, other *a priori* suitability criteria which a give potential bioindicator taxa should posses are: i) clear taxonomic status, i) non-migrant with wide distribution (national, regional or global distribution), iii) habitat specialist, but is easy to find and measure (i.e. high abundance) (Noss, 1990; Pearson and Cassola, 1992; McGeoch, 1998; Hilty and Merelender, 2000). Species initially indentified as potential bioindicators based on the IndVal criteria were therefore refined using these additional selection criteria (see Appendix) based on species-specific information obtained from literature on these criteria (Sinclair and Ryan, 2003; Redman *et al*., 2009; BirdLife International, 2013).

Potential application of bioindicators for ecological monitoring

We supposed that species identified as potential bioindicators are reliable ecological bioindicators for monitoring ecosystem change in the study area if (i) their abundance show significant variation between the disturbed and undisturbed sites, (ii) the ecosystem variables that the bioindicators are supposed to be indicative show significant variation between disturbed and undisturbed sites, and (iii) there is strong significant correlations in the proposed monitoring area (i.e. undisturbed sites) between the ecosystem variables and the bioindicators (see also McGeoch et al., 2012). Thus, we first tested responses of both ecosystem (i.e. tree abundance and cover) and bioindicator (abundance) variables to disturbances to see whether there were strong relationships between disturbances and (i) attributes of the bioindicators (i.e. population abundance) and, (ii) attributes of the ecosystem (i.e. tree abundance and cover) and level of disturbance. These were done using Generalized Linear Mixed Models (GLMMs) with normal distribution and identity link function in SPSS version 20 (IBM Corporation, 2001); tree attributes (abundance and cover) and abundance of each bioindicator type were entered as dependent variables, while site (disturbed vs undisturbed) as fixed factor and site as a random factor to account for potential independence of transect within a site (Quinn and Keough, 2002).

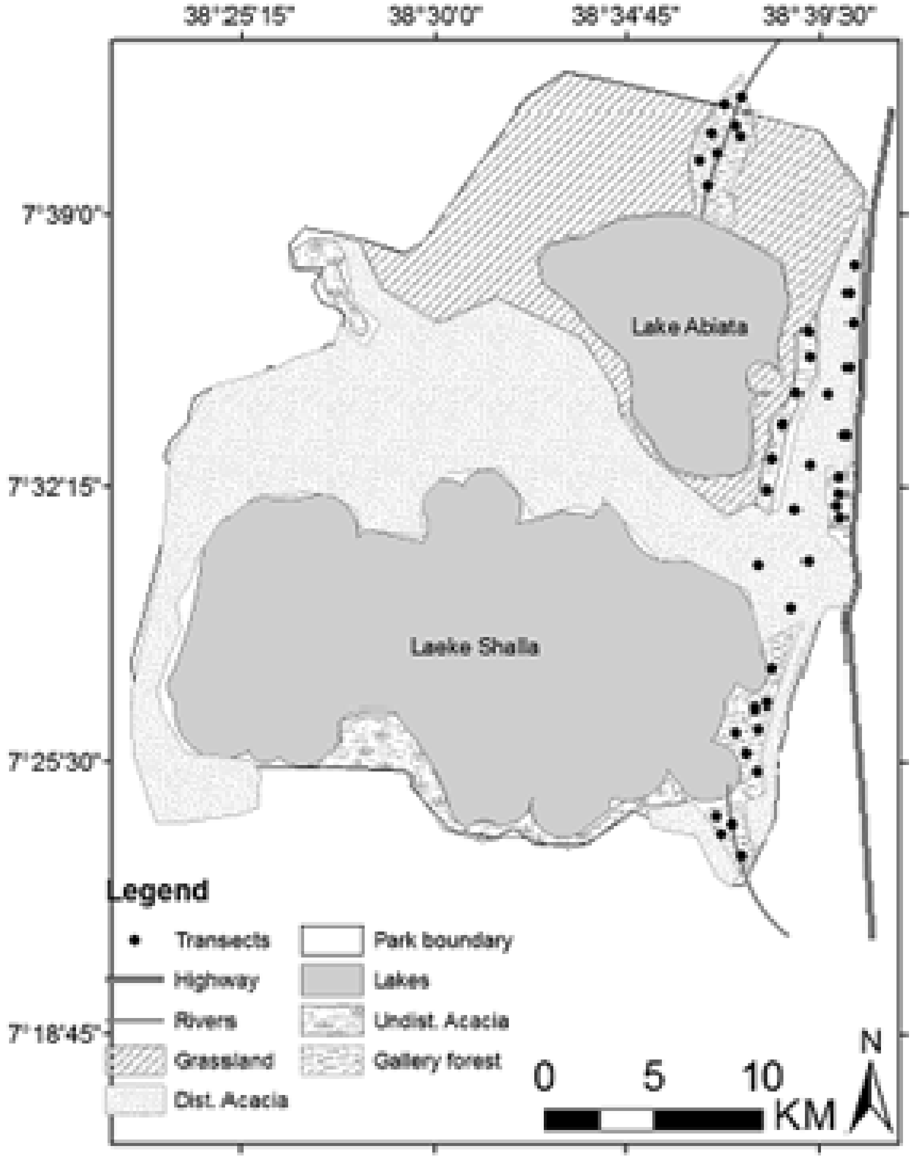
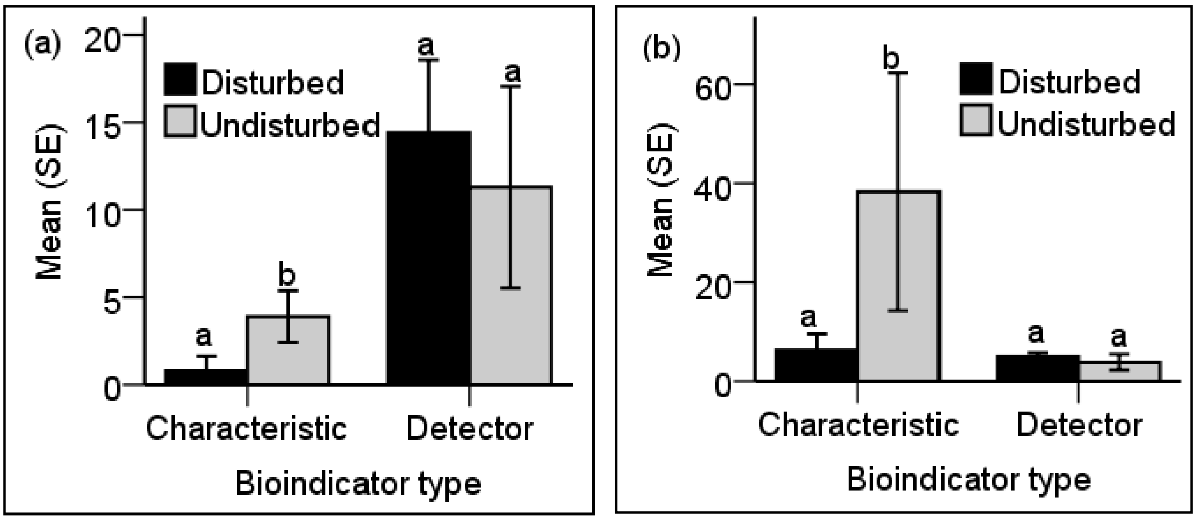


Fig. 1. Map of the study area showing the different vegetation types and sampling sites



(a) (b)

Fig. 2. Mean (± SE) abundance of the characteristic and detector bioindicators in the disturbed and undisturbed sites of the savanna woodland (a) and gallery forest (b). Means with different letter in each series are significantly different at P = 0.05

We then used a simple linear regression model to develop predictive models relating each tree variable and abundance of each bioindicator type selected for the undisturbed sites of the two vegetation types; tree abundance and tree cover were treated separately as response variables, while abundance of bioindicators as predictors. When two or more characteristic or detector species were selected for a given site, we used their summed abundance, rather than individual species' abundance, as an input in the regression analysis, following De Cáceres *et al*. (2010).

RESULTS

Bioindicators

Overall, a total of 86 bird species (64 species from the undisturbed gallery forest; 50 from the undisturbed savanna forest; 50 from the disturbed gallery; and 34 from disturbed savanna) were recorded in the whole study area (Asefa *et al.,* in prep.).

Based on the IndVal criteria (i.e. IndVal >70% for characteristic, and IndVal of 5%-50% in the undisturbed sites and 50%-70% in the disturbed sites for detector species), one characteristic (African Mourning Dove [*Streptopelia decipiens*]) and two detector (White-browed Sparrow Weaver [*Plocepasser mahali*] and White-headed Buffalo Weaver [*Dinemellia dinemelli*]) species were selected as potential bioindicators for the undisturbed savanna woodland. Similarly, three characteristic (Greater Blue-eared Glossy Starling [*Lamprotornis chalybaeus*], White-rumped Babbler (*Turdoides leucopygia*) and Red-eyed Dove [*Streptopelia semitorquata*]) and one detector (Laughing Dove [*Streptopelia senegalensis*]) species were selected for the undisturbed Gallery forest (Table 1). All the potential bioindicator species selected based on the IndVal criteria had also fulfilled all other additional selection criteria (see Appendix).

Application of the bioindicators for ecological monitoring: As expected, both tree abundance and cover were significantly greater in the undisturbed sites of each vegetation type (in all cases, $F_{1, 18}$ = 6.24-104.69, P <0.05; Table 2). However, only the mean abundances of the characteristic bioindicators were significantly different between the disturbed and undisturbed sites of each vegetation type (characteristic bioindicators, gallery forest: $F_{1,18}$, 14.196; savanna woodland: $F_{1,18}$ = 13.409; in both cases, P <0.05; detectors: gallery forest, $F_{1,18}$ = 1.494, P = 0.237; savanna woodland, $F_{1,18}$ = 0.758, P = 0.3953); characteristic bioindicators were significantly more abundant in the undisturbed sites of both vegetation types than in their respective disturbed sites (Fig. 2a-b). Thus, only characteristic bioindicators were retained for further analysis to test their reliability to use them for bioindication. Results of regression analyses of tree attributes against abundance of characteristic bioindicators, in both cases, showed significant relationships (one-way ANOVA: savanna woodland, $F_{1,8}$ = 77.405; gallery forest, $F_{1,8}$ = 55.442; in both cases, P <0.05; Table 3). The correlation coefficients of tree abundance and tree cover against the abundance of the characteristic bioindicators were 0.952 and 0.909, respectively, in the savanna woodland and 0.935 and 0.748, respectively, in the galley forest (Table 3). These suggest that 91% and 87%, of the variations in tree abundance and 83% and 56% of the variations in tree cover were explained by variations in abundances of the bioindicators in the savanna woodland and gallery forest habitats, respectively (Table 3). Furthermore, in both habitats, regression parameters [slopes] relating tree attributes with abundance of the characteristic bioindicators were statistically significant; as expected, abundances of characteristic bioindicator species had positive relationships with both tree abundance and cover of each vegetation type (Table 4). These results, therefore, suggest that the characteristic species selected for each habitat are reliable bioindicators that can readily be used for monitoring ecosystem of the national park.

DISCUSSION

In the present study, we identified bird species that can potentially be used as ecological bioindicators of ecosystem state in ASLNP of Ethiopia, and tested their reliability by correlating their abundances with the ecological variables they are indicative. This testing procedure has enabled to refine the selection process so as to retain only those reliable ones, whereby the confidence with which the final suite of species may be regarded as bioindicators was improved. As suggested previously (McGeoch, 1998; Hilty and Merenlander, 2000), such reliability test is essential to select appropriate species for effective application of the bioindication concept, and a testing process such as the one we outline here is thus advocated for all studies concerned with bioindicator identification and application. Our results showed that both tree abundance and cover were significantly lower in the disturbed sites of each vegetation type than the undisturbed sites. This human-induced vegetation structural change in our study area has resulted to changes in avian assemblage composition; some species appeared to present in more abundances and frequencies in the undisturbed sites than in the disturbed sites, and some other species *vice-versa* (Supporting Material). Few of such species had a significant IndVal of >70% for the undisturbed habitats and, therefore, were selected as characteristic bioindicators.

However, some other species showed some degree of habitat preference for the disturbed sites, but with lower abundance and frequency of occurrence in the undisturbed sites. Such species were selected as detector bioindicator species for the undisturbed sites (McGeoch *et al*., 2002; see also Table 1 and Supporting Material). However, only the characteristic species showed significant variation between disturbance levels, thus were found to more reliable bioindicators in our study area. Our findings generally suggest that the potential of using birds as bioindicators for monitoring of the status of tree abundance and cover in the undisturbed habitats of the national park. The main evidence for this potential use is that all the selected characteristic bioindicator species appeared to posses properties required for a given taxon to be effectively used for bioindication purpose (Hilty and Merelender, 2000; McGeoch, 1998; Mitiku, 2013). For example, (i) all the bioindicator species proposed here abundantly occur across their ranges (BirdLife International, 2013), suggesting that the high likelihood of sampling them during subsequent survey periods; (ii) all these species could easily be distinguished from their co-occurring similar species (for such species, see Ian and

Table 1. Bird species selected as potential characteristic and detector bioindicators and their Indicator values (IndVal) for the undisturbed savannah woodland (a) and the undisturbed gallery forest (b) sites of ASLNP. (Species with significant IndVals >70% were then regarded as characteristic bioindicator species, while species with significant IndVals of 50-70% for disturbed sites and 5-50% for undisturbed sites of each vegetation type regarded as detectors; following van Rensburg *et al*. (1999) and Mitiku (2013)

Characteristic		Detector	
species	IndVal	Species	IndVal
(a) Savanna woodland			
African Mourning Dove (*Streptopelia decipiens*)	83	White-browed Sparrow-weaver (*Plocepasser mahali*)	42
		White-headed Buffalo Weaver (*Dinemellia dinemelli*)	22
(b) Gallery forest			
Greater Blue-eared Glossy Starling (*Lamprotornis chalybaeus*)	84	Laughing Dove (*Streptopelia senegalensis*)	44
White-rumped Babbler (*Turdoides leucopygia*)	70		
Red-eyed Dove (*Streptopelia semitorquata*)	70		

Table 2. Mean (± SD) values of tree abundance and tree cover for the disturbed and undisturbed habitats of the savanna woodland and gallery forest. In all cases, n = 10

	Disturbed Savanna	Undisturbed savanna	Disturbed gallery	Undisturbed gallery
Tree abundance	16.2 ± 10.6^{a}	36.1 ± 14.1^{b}	12.4 ± 3.8^{a}	26.9 ± 11.6^{b}
Tree cover (%)	10.7 ± 7.7^{a}	38.5 ± 17.5^{b}	12.6 ± 3.^{2a}	54.0 ±11.7^{b}

Means of each variable indicated by different superscript letters denotes significantly different at P <0.05 between the disturbed and undisturbed sites of each vegetation type.

Table 3. Relationships between tree abundance [T (abun.)] and tree cover [(T (cover)] with the abundances of characteristic [Cha. (abun.)] bioindicators for the undisturbed sites of savanna woodland (SWL) and gallery forest (GF) vegetation types

Site	Dependent var.	Predictor var.	R	ANOVA		
				Source	Sum of Squares	$F_{1,8}$
SWL	Tree abundance	Cha. (abun.)	0.952	Regression	1615.894	77.405**
				Residual	167.006	
	Tree cover	Cha. (abun.)	0.909	Regression	2274.484	38.065**
				Residual	478.016	
GF	Tree abundance	Cha. (abun.)	0.935	Regression	1058.205	55.442**
				Residual	152.695	
	Tree cover	Cha. (abun.)	0.748	Regression	694.329	10.179*
				Residual	545.671	

Table 4. Regression equations relating tree abundance [T (abun.)] and tree cover [(T (cover)] with abundances of characteristic [Cha. (abun.)] bioindicators for the undisturbed sites of savanna woodland (SWL) and gallery forest (GF) vegetation types in ASLNP

Site	Dependent var.	Equation	Equation No.
Savanna Woodland	Tree abundance [T (abun.)]	T (abun.) = 13.681 (2.929) + 5.748 (0.653) *Char. (abun.)	Eq … (1)
	Tree cover[T (cover)]	T (cover) = 11.902 (4.956) + 6.820 (0.909) *Char. (abun.)	Eq … (2)
Gallery forest	Tree abundance [T (abun.)]	T (abun.) = 15.968 (2.016) + 0.285 (0.038) *Char. (abun.)	Eq … (3)
	Tree cover [T (cover)]	T (cover) = 45.145 (3.811) + 0.231 (0.072) *Char. (abun.)	Eq … (4)

Sinclair, 2006), making them easily identified both by non-bird specialists (with little training inputs) and specialists during monitoring work; (iii) the mean abundances of the characteristic bioindicators were significantly different between disturbed and undisturbed sites, perhaps indicating their sensitivity or responsiveness to disturbance; and, (iv) the population abundances of the bioindicators were strongly and linearly correlated with tree abundance and tree cover in the undisturbed sites of both vegetation types. From the foregoing discussion it is apparent that long-term monitoring of species selected as bioindicators for the undisturbed habitats can provide useful information for managers of the ASLNP as an early warning system for any changes in tree structure (abundance and cover) taking place within these undisturbed habitats. In addition, data derived from such monitoring activities could also serve as to evaluate the effectiveness of management actions taken towards minimizing the threats facing the habitats. Although characteristic and detector bioindicator species provide complementary information about the state of the ecosystem under question, the novelty of using both together can be seen from the role they play in ecological monitoring. Characteristic species are those that are either confined to, or are found in higher abundance and frequency in a site which they are bioindicators for (in our case, the undisturbed sites). Thus, the decrease/increase in abundance and frequency of occurrence in that habitat indicates the ecological status of the habitat and provides early warning information (Van Rensburg *et al.,* 1999; McGeoch *et al.,* 2002). Whereas, detectors must occur both in the site which they are indicatives, but with lower abundance and frequency values, and in the other sites that are compared with the target site but with moderate abundance and frequency values. This means that, the detector species tend to be uncommon in the undisturbed sites at present, but generally are widespread in the disturbed areas; thus are supposed to become more abundant in the undisturbed sites in the future if the sites will be continuously impacted from more disturbances (Van Rensburg *et al.,* 1999; McGeoch *et al.,* 2002).

Furthermore, the rationality of considering detector bioindicators, in addition to characteristic bioindicators, is that specialist species such as characteristic bioindicator species are usually prone to local extinction under continuing habitat disturbances (McGeoch *et al.,* 2002), whereas such disturbances create opportunity for disturbance tolerant species such as detector bioindicators. Thus, in the future face of rapid habitat change, detecting an increase in frequency and abundance of the detectors in undisturbed sites is likely to be far more reliably undertaken than detecting the absence of characteristic species in those sites (McGeoch, 1998; Van Rensburg *et al.,* 1999, McGeoch *et al.,* 2002). Both types of bioindicators provide complementary information and are, therefore, useful species for indicating changes in ecological conditions.

Conclusion

In the present study, we demonstrated that birds can potentially be used as bioindicators, which has been considered as simple and cost-effective conservation tool (Kremen, 1992; McGeoch *et al*., 2002; Bleher *et al*., 2006), of ecosystem state in ASLNP of Ethiopia. We attempted to overcome most pitfalls of inappropriate selection and application following three approaches. First, in the selection process we confirmed whether those species identified as potential bioindicators based on their IndVals also had features that a given reliable bioindicator taxa should possesses. Second, we tested whether the observed patterns in abundance of the bioindicators and in the ecosystem attributes (tree abundance and cover) which the bioindicators are indicatives correlate with disturbance patterns. Finally, we tested whether the observed patterns in abundance of the bioindicators actually reflects patterns in attributes (tree abundance and cover) of the ecosystem component that they are intended to indicate. The procedures we used in this study to select the bioindicators and to assess the reliability of their utility as successful bioindicators will serve as a showcase which can be applied to any taxa in the area or elsewhere. However, we suggest that, whenever available resources allow, for such bioindicators to be used with more confidence, they should be tested on data independent from those used for initial selection. This can be done, for example, based on data taken from same sampling points but on different time/season, or from other similar habitats.

In order to practically use the proposed bioindicator species for future ecological monitoring in the undisturbed sites of our study area, they should be counted following same procedures and time of year used in the present study. We also suggest that this counting should be done at regular time intervals; depending on availability resources needed to undertake the survey, this could be every two or three years. Such standardization of data collection protocol would enable one to make valid comparisons across different temporal scales (Bibby *et al.,* 1998). Then, by inserting the new abundance values of the bioindicators obtained from successive survey periods into the equations provided on Table 4, one can estimate the status of tree abundance and/or cover in each respective habitat. This in turn allows managers to understand trends in the level of disturbances to the sites so as to evaluate their management effectiveness and/or to develop mitigation measures.

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