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Integrating Local Ecological Knowledge for Waterbird Conservation: Insights From Kavango-Zambezi Transfrontier Conservation Area, Zimbabwe

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Abstract

Weaving local and scientific knowledge systems is important to enhance understanding, practice, and ethics toward natural resources sustainable utilization. We focused on wetlands and waterbirds and used local knowledge and perceptions by key informants in and around a protected area in Zimbabwe to investigate (a) trends in rainfall and water quality, (b) waterbird trends and associated uses, and (c) drivers, mechanisms, and impacts behind waterbird trends, to understand waterbird ecological dynamics. We confronted these perceptions to available data locally and globally. Furthermore, we explored local ideas to improve waterbird survival. Associations between informant variables and trends in water quality were tested using the χ^2 test while multiple correspondence analyses were used to explore drivers, mechanisms, and impacts of bird trends. Wildfowl were cited the most (48.7% of all citations), probably linked to their use as food, and they were negatively driven by human predation but would increase when left to follow natural processes. Changes in natural processes and wetlands drove large piscivores into decline, but their populations would increase when predation was controlled. Generalist species responded positively when climate and resources were not limiting. We then discus the feasibility of the suggested waterbird conservation remedies: education, increasing surface water, law enforcement, sustainable use guidelines, and modified drinking troughs for large herbivores. Local knowledge and available local trends data were inconsistent with International Union for the Conservation of Nature trend status. The local sources of knowledge were not correlated but broadly consistent. We also discuss the scale discrepancies and how the sources of information can be complementary.

Keywords

waterbirds, waterpans, trends, perceptions, local knowledge

Introduction

Humans are the main drivers of the biodiversity crisis, and understanding how people interpret changes and ecosystem dynamics in their social, ecological, and economic context is critical for biodiversity conservation (Gutiérrez, Wood, Redpath, & Young, 2016; Turvey et al., 2013). Native people may be interested in conserving and enhancing biodiversity because they often rely on local environments for a variety of resources (Gadgil, Berkes, & Folke, 1993). Conservationists can utilize ideas from a local community perspective (*emic*) and elsewhere outside the concerned community (*etic*, knowledge) (Morris, Leung, Ames, & Lickel, 1999). Knowledge held by indigenous people can therefore be

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useful in monitoring resource trends and managing ecosystem processes and functions (Berkes, Colding, & Folke, 2000; Guerbois & Fritz, 2017). Some traditional knowledge and management systems use local ecological knowledge (LEK) to interpret and respond to feedbacks from the environment to guide the direction of resource management as directed through various leadership structures (Gadgil et al., 1993). This knowledge can therefore contribute to the conservation of biodiversity, rare species, sensitive sites, and ecological processes (Berkes et al., 2000; Gadgil, Olsson, Berkes, & Folke, 2003).

As wetlands are threatened ecosystems, efforts are increasingly directed toward linking what people actually know and value about wetlands and their associated species (Kentula, 2000). Waterbirds are ecologically dependent upon wetlands, are used by humans for provisioning and cultural services (Freese, 1997), and are indicators of environmental and climatic changes (Ogden et al., 2014). Wetlands are often nested within larger landscapes that experience wide ranges of anthropogenic and climatic pressures (Ramachandran, Kumar, Gopi Sundar, & Bhalla, 2017). Exploring drivers of waterbird trends in wetlands from a local community perspective can give conservationists an opportunity to measure their perception of the impacts of natural and anthropogenic changes (Bosma, Glenk, & Novo, 2017; Dias & Belcher, 2015; Taylor, Howard, & Begg, 1995).

Dynamics of waterbirds may be driven by natural processes such as predation, rainfall patterns, and diseases (Cumming et al., 2011; Davis et al., 2015; Gaidet et al., 2007; Guillemain, Arzel, Legagneux, & Elmberg, 2007) as well as anthropogenic disturbances such as habitat alteration, persecution, and consumption (Lin et al., 2012; Lukasiewicz & Dare, 2016; Vonbank, Hagy, & Casper, 2016). Although people are increasingly becoming aware of climate changes and their implications (Adger, Barnett, Brown, Marshall, & O'brien, 2013), the use of local knowledge for fostering waterbird conservation has been poorly explored at the edges of protected areas (PAs; Gutiérrez et al., 2016). This is particularly true in southern Africa, a region supporting a wide range of resident waterbirds and contributing to the persistence of migratory species (Dodman & Diagana, 2006). This study is set in northwest Zimbabwe, at the eastern end of the Kavango-Zambezi Transfrontier Conservation Area (KAZA). A variety of wetlands can be found in this area (Matiza & Crafter, 1994) which makes it a very important breeding habitat for several waterbird species in southern Africa (Godfrey, 1992).

In this study, we investigated people's knowledge related to waterpans and waterbirds as well as the perceived relative weight of climate change, anthropogenic pressure, and natural processes on the observed status and trends of waterbirds. We hypothesized that people's knowledge on waterbirds will be greater for locally abundant species or species with cultural importance or popular local uses. Second, we expected the perceived trends of species used for consumption to be more often associated with anthropogenic drivers than climatic or natural. Third, we thought that local people in our area would have greater knowledge about waterbirds, their trends, and wetlands status compared to people who are nonlocal. We combine perceived trends and knowledge related to annual rainfall, surface water availability, and quality, with ecological knowledge on waterbird species, their dynamics, and uses. We used rainfall records from a representative gauging stations in the study area to confront local people's perceptions on rainfall patterns. We then compared cited waterbird trends to (a) those derived from long-term monitoring in Hwange National Park (HNP) and (b) those documented on the International Union for the Conservation of Nature (IUCN). We also compared local perceptions on drivers of waterbirds trends with those documented by the IUCN. As part of a proactive investigation to improve waterbird conservation and wetland management, we also explored the remedial actions identified by people and used this information to discuss conservation implications, challenges, and opportunities.

Methods

Study Area

The study was conducted in the south-eastern part of KAZA (TFCA), Zimbabwe. This area is also in the Hwange socioecological system (SES) comprising HNP (centered on 19°00′S, 26°30′E; communal areas [CAs], Ngamo and Silewu wards) and Sikumi Forest Area (SFA, a photographic and hunting area) as shown in Figure 1. CAs in Tsholotsho and Hwange Districts are under the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE). The Hwange SES is in a semiarid area with a mean annual rainfall of 600 mm and a wet season that stretches from October to April (Chamaille-Jammes, Fritz, & Murindagomo, 2006). This area is characterized by poorly drained Kalahari sands giving rise to a system of around 40,000 mostly shallow seasonal pans (Childes & Mundy, 2001; Godfrey, 1992). In addition, there are dams and artificially pumped waterpans that were constructed to meet wildlife (in the PAs), agricultural, and domestic needs (in the CAs). Over 122 waterbird species have been recorded in waterfowl counts recorded in HNP (BirdLife Zimbabwe [BLZ], 2013). There are no waterbird surveys conducted in the CAs, but monitoring has been done inside HNP since 1992.
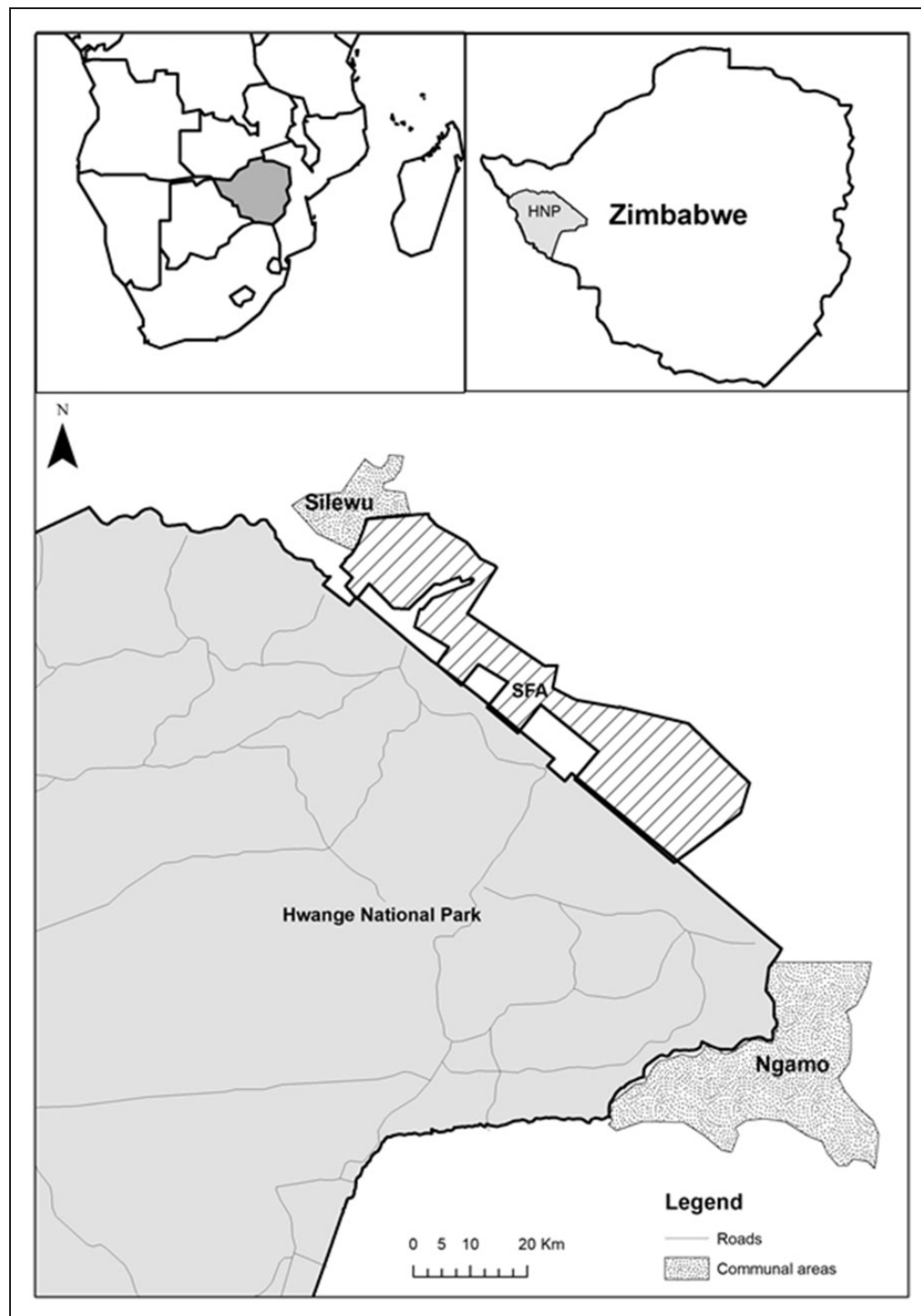
Figure 1. The study area in the south-east KAZA TFCA showing Hwange National Park and the adjacent land uses.

The people in the CAs rely primarily on subsistence farming (fields and gardens) and natural resource harvesting. Main crops include maize (*Zea mays*), sorghum (*Sorghum bicolor*), and pearl millet (*Pennisetum glaucum*) (Guerbois, Dufour, Mtare, & Fritz, 2013) while cattle (*Bos* species) and Matebele goats (*Capra* species) are also kept. The Hwange SES benefits economically from tourism activities such as safaris and sport hunting, and the human population in the CAs has been increasing (Nhongo, 2014). Extraction of resources from HNP by local people is prohibited by law. In SFA, waterpans within 3 km from CAs are accessed by people for their

livestock, but hunting is prohibited (Guerbois et al., 2013). People working in HNP and SFA were recruited from neighboring CAs (can be considered as local people) and elsewhere (nonlocal). In CAs, access to natural resources (e.g., the use of water from wetlands, area for gardens, and hunting waterbirds) are governed loosely by traditional leaders (Matiza & Crafter, 1994). The locals in CAs often use domestic dogs (*Canis familiaris*) and catapults while hunting. Ethnolinguistic categories of locals in the study area are Nambya, Ndebele, Dombe, Tonga, and Shona. The first four ethnolinguistic groups have been living in the same district as those under study before the establishment of HNP in 1928 while the Shonas are mostly people who have worked in HNP, SFA, and surrounding townships after 1928 (Nhongo, 2014).

Sampling

Our sampling targeted people living within the PAs and also CAs adjacent to them. Permission was granted from relevant authorities (Rural District Councils, chiefs, village heads, Forestry Commission, and Parks and Wildlife Management Authority) to conduct our study. We obtained a written informed consent from the district administrator as well as verbal agreement from all participants to use the information they provided in our survey. People's knowledge about waterbirds may be influenced by their origins and length of residence in a local area (Gilchrist, Mallory, & Merkel, 2005), level of education, and occupation (Higgins, Naugle, & Forman, 2002). We therefore used a stratified purposive sampling technique (across HNP, SFA, and CAs), with the help of traditional leaders where relevant, to identify and select the first set of informants with valued knowledge about waterbirds and wetlands in the Hwange SES. We complemented this first set using the snowballing technique

by asking our informants to identify other people with valuable knowledge. In the PAs, our sample consisted of employees from the Parks and Wildlife Management Authority, Forestry Commission, nongovernmental organizations and researchers with a range of occupations: rangers, ecologists, wildlife officers, tourist attendants, picnic attendants, and tour guides ($n = 49$). In the CAs, we targeted potential local knowledge holders, including employees from the education sector (primary and secondary school teachers), kraal heads, chiefs and religious leaders, cooperative leaders, CAMPFIRE officers, traditional healers, people involved in ecotourism, outstanding farmers (with large herds of cattle and those who cultivate large pieces of land), livestock herders, and people working at veterinary offices ($n = 54$).

Data Collection and Processing

We collected data on local knowledge through semi-structured interviews from February 2015 to February 2016. Interviews were conducted in local languages (Nambya, Ndebele, Dombe, Tonga, and Shona) by trained local assistants, and the average time of administration was 35 mins. Initially, we conducted a pilot study with assistants in the team to make sure that procedure was standardized and to reduce interviewer bias. Responses to open questions were recorded by exhaustively writing all the details given by informants to avoid *a priori* bias in data processing. A thematic analysis was then conducted *a posteriori* to minimize the number of modalities for each variable of interest while gleaning as much information in line with our hypotheses.

Sociodemographic data were collected, and the latter were categorized according to different variables recognized to have an influence on ecological knowledge (Table 1). The attributes of our informants are summarized in Table 2. Informants were asked to express their

Table 1. Categorization of Informant's Sociodemographic Variables Used in This Study.

Variable	Modality	Description
Place of residence	PA	People working for SFA/HNP or living in their facilities
	CA	People living in the Ngamo and Silewu wards
Origin	Local	People born in the same district (Hwange or Ngamo)
	Nonlocal	Not born in the same district they were working/ living at the time of the interviews (Fried, 1982)
Length of residence	Short term	The informant spent less than 15 years in the Hwange SES (Gandure et al., 2013)
	Long term	Stayed for more than 15 years
Highest level of education	Primary	Primary level or below of the Zimbabwe education system
	Secondary	Attended school after the primary level but no tertiary qualifications were done
	Tertiary	Attained any training after secondary education (certificate, diploma or degree)
Main occupation	Environment	Farming, tourism, ecological research
	Nonenvironment	Engaged in the business and education sectors

Note. CA = communal area; PA = protected area; HNP = Hwange National Park; SFA = Sikumi Forest Area; SES = socioecological system.

Table 2. Attributes of Informants That Were Interviewed in PAs and CAs in the Hwange SES From February 2015 to February 2016.

Area	Area (N size)	Origin		Length of residence		Education level			Occupation	
		Local	Nonlocal	Long	Short	Primary	Secondary	Tertiary	Environment	Nonenvironment
PA	Forestry (10)	5	5	4	6	2	5	3	9	1
	HNP (32)	5	27	12	20	3	19	10	29	3
CA	Silewu (33)	21	12	26	7	9	17	7	22	11
	Ngamo (28)	16	12	23	5	12	9	7	16	12
	Total	47	56	65	38	26	50	27	76	27

Note. CA = communal area; PA = protected area; HNP = Hwange National Park.

perceptions relating to rainfall patterns from the time they started living in the area (the responses on rainfall patterns were categorized as erratic rains, dry spells, season shifts, and no observed change). Informants were also asked to list all the surface water points they knew in the area and their perception of water quality and quantity trends at each site. Surface water quality and quantity were broadly categorized as either decreased or not changed. To complement perceptions on rainfall, we used monthly records from the Parks and Wildlife Management Authority for HNP spanning spanning the longest length of residence by our informants (40 years).

We employed the free listing technique (Borgatti, 1999) to ask informants to mention all the waterbird species they knew and could recognize. Waterbird names were cited in English or vernacular languages. We verified the English names by probing the informant to describe the species they had cited (plumage colors, seasons normally seen, calls, and behavior). All waterbird species cited in vernacular languages were then translated to English after consultation with all local assistants and field guides (Hockey, Dean, & Ryan, 2005). Once the list was established, we asked informants to mention (a) the uses of the cited waterbird species, (b) the perceived changes in their population, and (c) the reasons attributed to such changes. Variables on uses were created based on informants' knowledge (from an *emic* perspective) and literature (from an *etic* one) (Morris et al., 1999). We differentiated birds that were eaten from those that were not; a bird was considered to be *eaten* if at least one informant mentioned *meat* as a use. The Common International Classification of Ecosystem Services as defined by Haines-Young and Potschin (2012) at the section level (constituted by regulation and maintenance, cultural and provisioning services) was used to categorize the uses. The regionally comprehensive *Roberts birds of southern Africa* (Hockey et al., 2005) was used to categorize birds into their functional types based mainly on key taxonomic groups, feeding behavior, ecology, and uses. We ended with four large enough groups to include in our

analyses: waders and wildfowl as typical waterbird taxa, and generalist feeders and large piscivores as multi-taxa groups (Appendix). For the list of species cited by our informants, we also noted the trends, uses and threats as documented on the IUCN website (http://www.iucnredlist.org). In addition, we also utilized waterbird surveys (done between 1992 and 2017) by BLZ that we analyzed for selected waterpans HNP. We recategorized informants' perceived population trends for each cited waterbird species as declining or not declining (including stable and increasing). We created a variable, "rDec," that expressed the ratio of informants mentioning declining to those citing not declining trends for each species. Another variable was created, "LEK_Decrease," in which we assigned a "1" when "rDec" was greater than 0.5 (i.e., generally perceived to be declining by more than 50% of informants), otherwise it was coded as "0." Likewise, the species trends from BLZ, "BLZ_Decrease" and IUCN, "IUCN_Decrease" were also coded as declining "1," and not declining "0." Finally, a local checklist for birds around Hwange National Park (BirdLife Zimbabwe, 2013) was then used to classify cited species as common or not common. We excluded from our data set the birds that were cited at the genus level when more than one species of that genus was found in our study area.

As we were particularly interested in distinguishing the sources of disturbances driving perceived population trends of waterbirds, we used cited causes for population trends to create a variable "drivers," taking three modalities: anthropogenic, climatic, and natural. We are aware that in some instances climatic drivers can be classified as natural (Ramachandran et al., 2017), but as we aimed to evaluate the contribution of changing rainfall patterns, we treated them separately. To investigate the mechanisms through which the species were affected by various disturbances, we created a variable "mechanisms" taking the following modalities: species' behavior, migration, predation, rainfall, habitat constraints, and other (Table 3). Furthermore, we sought to understand the waterbirds' life history traits that would be affected by the cited reasons for population

Table 3. Categorizations of Informant Responses Into Drivers, Mechanisms, and Impacts.

Category	Modality	Typical responses
Drivers	Anthropogenic	Disturbance by people, noise, dog kills, egg collection, poaching.
	Climatic	Climatic shifts, erratic rains, frequent droughts, rains not filling up wetlands.
	Natural	Food quantity, sex ratios, birth and death rates, survival rates, migrations, natural predation.
Mechanisms	Behavior	Always alert, easiness to catch, easiness to find eggs, tolerate people disturbance.
	Rain	Shifting rainfall patterns, climate change, rainfall amounts.
	Migration	Costs and benefits related to migration, shifted migration patterns.
	Predation	Dog kills, natural predation, human hunting, egg collection, increased human population.
	Wetlands	Good breeding habitat, surface water, aquatic food.
	Other	Chick survival rates, clutch size, protection inside protected areas, artificial water provisioning.
Impacts	Breeding	Chick production, survival rates, breeding habitat, egg destruction, breeding times.
	Occurrence	Migration, avoidance/tolerance to disturbances.
	Resources	Food and water available in and around wetlands.
	Survival	Human/natural related mortality, less demand for waterbirds meat.
	Other	Competition, individual fitness and vulnerability to diseases.

trends. Thus, we created a variable "impacts" in which responses were classified as breeding, occurrence, resources, survival, and other. We compiled the uses and threats for waterbirds documented by the IUCN. We then compared the trends from IUCN, local counts, and local informants as well as threats and uses published by the IUCN and those stated by our informants.

Informants were asked to state their opinions (as individuals and as a community) on the efforts they believed necessary or efficient to improve waterbird conservation. Such stated efforts were categorized into conservation education, law enforcement, increasing surface water, special water troughs, research, sustainable use, and doing nothing. We also created a variable "conservation target" for which we categorized cited efforts as direct (directed to the bird species) or indirect (those directed to their habitats or people).

Statistical Analysis and Presentation

Associations between sociodemographic variables of informants (place and length of residence, origin, education, and occupation) with perceived trends in (a) annual rainfall, (b) surface water quantity, and (c) quality of surface water were all tested using the χ^2 test (with $\alpha = .05$). To confront perceptions of rainfall trends and patterns, we tested if there was any relationships between time and annual rainfall, accumulated rainfall up to the end of November (when the tilling season is expected to have started), total rainfall received in January and February (mid-season months) using the Pearson correlations. We also used χ^2 tests to assess if mentioned drivers, mechanism, and impacts were associated with informant place and length of residence, origin, education, and occupation. We tested if informant's length of residence, origin, and employment were related to the number of waterbird species known using generalized linear models.

We explored the relationship between perceived drivers, mechanisms of waterbird trends, and the impacts using multiple correspondence analysis (MCA). We divided the waterbird perceptions data set in two samples: the first with waterbirds that informants cited as declining (mcaDecreasing) and the second for no decline (mcaNotDecreasing). Each subset was a species entry database (one row per species) in which the relative frequency of each "driver" (anthropogenic, climate, and natural) was calculated. For "mechanisms," we restricted our analyses to the habitat and the predation in accordance to our predictions. For "impacts," we included the relative frequencies of breeding, occurrence, resources, and survival. We also tested the effect of land use using the place of residence of the informants as a proxy.

We also performed MCAs to investigate the relationship between documented (IUCN) and perceived (informants) uses and threats for species with different trends (declining or nondeclining). As we expected the different functional types of waterbird species to be affected differently by disturbances, we used the guilds of waterbirds as illustrative variables in all the MCA plots. All statistical analyses were performed in the R statistical software (R Development Core Team, 2017), in particular we used the ade4 package (Dray, Dufour, & Chessel, 2007) for the multivariate analyses.

Results

Sociodemographic Variables

A total of 103 individuals (81 males and 22 females) were interviewed during the study. The majority (78.7%) of respondents with origins in the Hwange SES were in the

CAs. Most (75.4%) of the informants who stayed for long periods in this area were also from CAs. Sociodemographic variables are listed (Table 1), the sample distribution according to place of residence, origin, length of residence, education, and occupation categories is presented in Table 2. There was a significant association between education and occupation with most of the informants who attained primary and secondary education (80.3%) being occupied in environment-related jobs ($\chi^2 = 6.293$, $df = 1$, $p = .043$). Similarly, the association between occupation and place of residence was significant with more informants in the PAs (90.5%) engaged in environment-related jobs ($\chi^2 = 8.808$, $df = 1$, $p = .003$). There was no association between informant's occupation and their (a) origin and (b) length of residence ($p > .05$ in both cases).

Rainfall and Surface Water Trends

The majority of informants ($n = 99$, 96.1%) mentioned that rainfall amounts had decreased and the rest were not sure about patterns of change. The rainfall trends from HNP showed declining patterns, although it was not significant (Pearson correlation $r = -.178$, $p = .256$). Of the informants who cited a decrease in rainfall, 95% of them mentioned that rainfall had become erratic, with longer mid-season dry spells and the rains were coming late (Table 4). The records from HNP also show that accumulated amounts received by end of November are significantly declining ($r = .295$, $p = .049$). However, the HNP records did not show significant declines in rainfall received during the mid-wet season months ($r = -.061$, $p = .689$). Decreases or early drying of surface water was cited as main changes to wetlands by most informants (83%). Of the 63 informants who gave their knowledge on water quality, 76.1% perceived water quality as having deteriorated. Informant education was marginally associated with perceived surface water quality changes ($\chi^2 = 6.131$, $df = 2$, $p = .047$); those who only attained secondary education or below cited more changes compared to those with tertiary levels. However, informant's origin, place of residence, length of residence, and occupation were not significantly associated with perceptions on rainfall patterns or surface water (amount and quality) changes ($p > .05$ in all cases).

Birds Cited and Their Uses

A total of 48 waterbird species were cited by informants (Appendix). The citations for 11 species mentioned nine or more times by local and nonlocal informants are presented in Figure 2(a), while the perceived trends of these species are shown in Figure 2(b). Informants cited between 1 and 10 waterbirds (most often two species but mean of 4.1). The best model explaining number of cited species retained only informant's occupation; those engaged in environment-related activities mentioned more waterbirds (mean $= 4.33 \pm 0.28$ *SE*) compared to nonenvironment persons (3.09 ± 0.58) ($F = 4.569$, $df = 1$, $p = .035$). Wildfowl, large piscivores, generalists, and waders guilds (Appendix) constituted 48.7%, 21.5%, 15.5%, and 14.3% of the citations, respectively. The frequency of citation for individual waterbird species ranged from 1 to 40, with 41% of species being cited only once. Interestingly, 85% of species that were cited once were not eaten in the local area, although 70% of them have a "common" status in the south-east KAZA TFCA (examples being in families of herons, ibis, and plovers). The top four cited waterbird species were also eaten in the local area (these species represent about 38.5% of total citations): Spur-winged Geese (*Plectropterus gambensis*), Egyptian Geese (*Alopochen aegyptiaca*), Knob-billed Duck (*Sarkidiornis melanotos*), and Red-billed Teal (*Anas erythrorhyncha*) (Appendix). The order of citation for these four species

Table 4. Summary of Perceptions on Annual Rainfall Patterns and Surface Water Changes in the Hwange SES by Local and Nonlocal Informants.

Variable	Modality	Informant's Origin		Informant's Place of Residence	
		Local ($n = 47$)	Nonlocal ($n = 56$)	PA ($n = 42$)	CA ($n = 61$)
Rainfall patterns	Dry spell	9	20	16	13
	Erratic rains	7	11	5	12
	Season shifts	23	29	18	34
	No change	1	3	3	2
Surface water amounts	Decreased	43	43	32	54
	No change	0	5	4	1
	Not sure	4	8	6	6
Surface water quality	Deteriorated	27	24	18	33
	No change	4	12	8	8
	Not sure	16	20	16	20

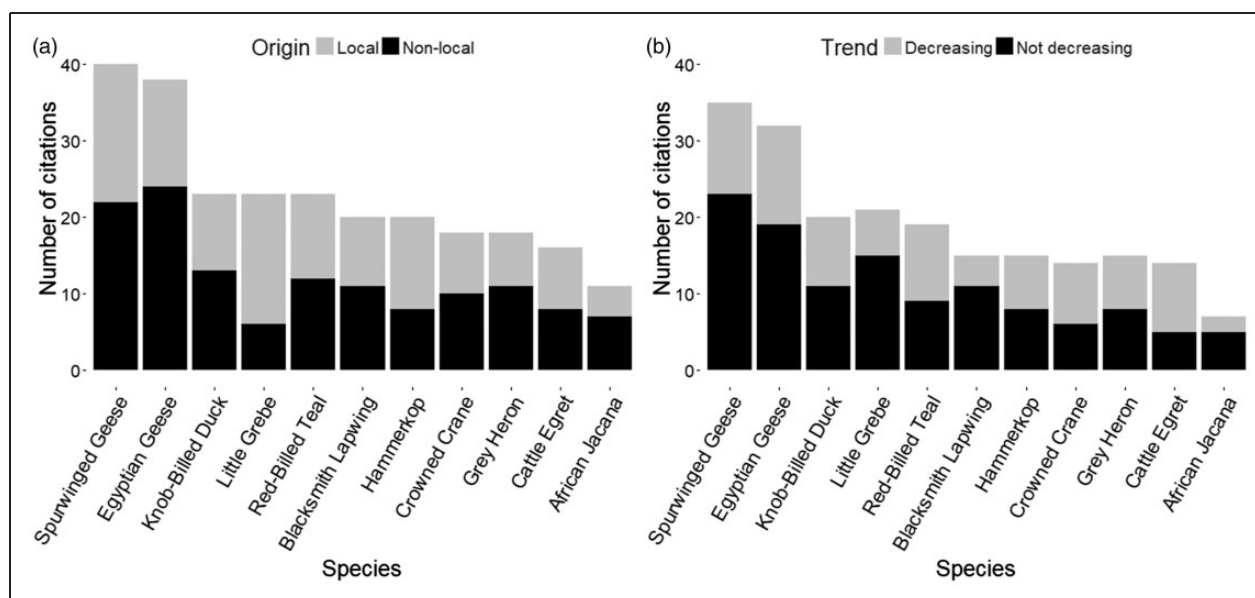*Note.* CA = communal area; PA = protected area.

Figure 2. Waterbirds that were cited nine or times, with (a) illustrating the contributions by informants with different origins and (b) illustrating people's perceptions about the species' trends in the Hwange SES.

follows a decrease in body weight. There were a few mismatches in species use in our study area in comparison to what is documented in Hockey et al. (2005) for the southern African region. The Little Grebe (*Tachybaptus ruficollis*), African Pygmy Goose (*Nettapus auritus*), White-faced Whistling Duck (*Dendrocygna viduata*), Black Stork (*Ciconia nigra*), and White Stork (*Ciconia ciconia*) were cited as not eaten, yet they are eaten in the region; the White-breasted Cormorant (*Phalacrocorax carbo*) was cited as eaten, but there is no documentation of it being eaten in the region. For cases where the question on uses was answered, informants described provisioning uses (for 63.4% of the cited uses), cultural (20%), and regulatory services (13.7%) while the remaining 2.9% of citations were not used (Appendix).

Drivers, Impacts, and Mechanisms of Waterbird Trends

For all cases in which informants cited waterbird trends as having changed, the causal drivers were linked to natural (49.6%), climatic (30.4%), and anthropogenic processes (20%). Likewise, mechanisms behind the changes in waterbird trends were linked to rainfall (26.3%), predation, including human predation (12.5%), migration (7.2%), habitat constraints (5.9%), species intrinsic behavior (5.9%), and other mechanisms (Table 5). The perceived declining trends of waterbirds belonging to defined guilds ranged from 36.4% to 52.4% (Table 5). Overall, the cited impacts of these environmental changes and disturbances were linked to resources

(44.9%), survival (32.2%), occurrence (13.4%), and breeding (9.3%). We did not find any specific association between identified drivers, mechanisms, and impacts according to informant's place of residence, origin, and occupation (χ^2 tests, $p > .05$ in all cases).

We did not find any significant correlations between population trends as perceived by informants, the BLZ counts, and IUCN trends, with only 23% ($n = 7$) of species with concordant trends across the three trend sources. BLZ counts and informants perceptions were marginally more consistent with one another (55%), though not significantly correlated. Although the generalist and wildfowl species are more associated with declining IUCN trends (e.g., Abdimn stork *Ciconia abdimii*, Sacred ibis *Threskiornis aethiopicus*, and Little grebe *T. ruficollis*), large piscivores and waders (e.g., Black-winged stilt *Himantopus himantopus* and White-breasted cormorant *Phalacrocorax lucidus*) were more associated with declines from the BLZ counts as well as our informants perceptions. Species cited to be affected by habitat disturbance were significantly correlated to those used for arts locally, and those used as food globally ($r = .64$ and $.68$, respectively). Also, species cited as mostly hunted were significantly correlated to those used in arts ($r = .58$).

The first axis of the mcaDecreasing explained 41.1% of the variance in the data and correlated mostly with species whose survival was impacted by anthropogenic factors through predation (Figure 3(a)). Wildfowl (e.g., Spur-winged Geese, Egyptian Geese, and White-faced Whistling Duck) constituted a distinguishable group compared to the others along this first axis, their survival

Table 5. Summary of Percentages of Responses Mentioning Declining Species Trends, Drivers, Causes, and Impacts of Disturbances for Different Waterbirds Cited in the Hwange SES.

Guild	Drivers (%)			Mechanisms (%)						Impacts (%)					Citations Mentioning Decline
	Anthrop	Clim	Nat	Bev	Rain	Mig	Pred	Hab	Other	Br	Occur	Res	Surv	Other	
Wildfowl (*n* = 109)	23.2	26.8	50.0	7.8	28.9	6.7	14.4	4.4	37.8	8.9	11.1	33.3	34.4	12.3	42.4%
Generalists (*n* = 30)	18.2	45.4	36.4	3.7	37.0	7.4	18.6	7.4	25.9	3.7	11.1	40.7	18.5	26.0	52.4%
Large piscivores (*n* = 20)	0.0	44.4	55.6	0.0	13.3	13.3	0.0	6.7	66.7	0.0	13.3	33.3	0.0	53.4	40.7%
Waders (*n* = 16)	16.7	33.3	50.0	8.3	16.8	8.3	8.3	0.0	58.3	8.3	8.3	25.0	8.3	50.1	36.4%

Note. Anthrop = Anthropogenic; Clim = Climatic; Nat = Natural; Bev = Behavior; Rain = Rainfall; Mig = Migration; Pred = Predation; Hab = Habitat constraints; Br = Breeding; Occur = Occurrence; Res = Resources; Surv = Survival.
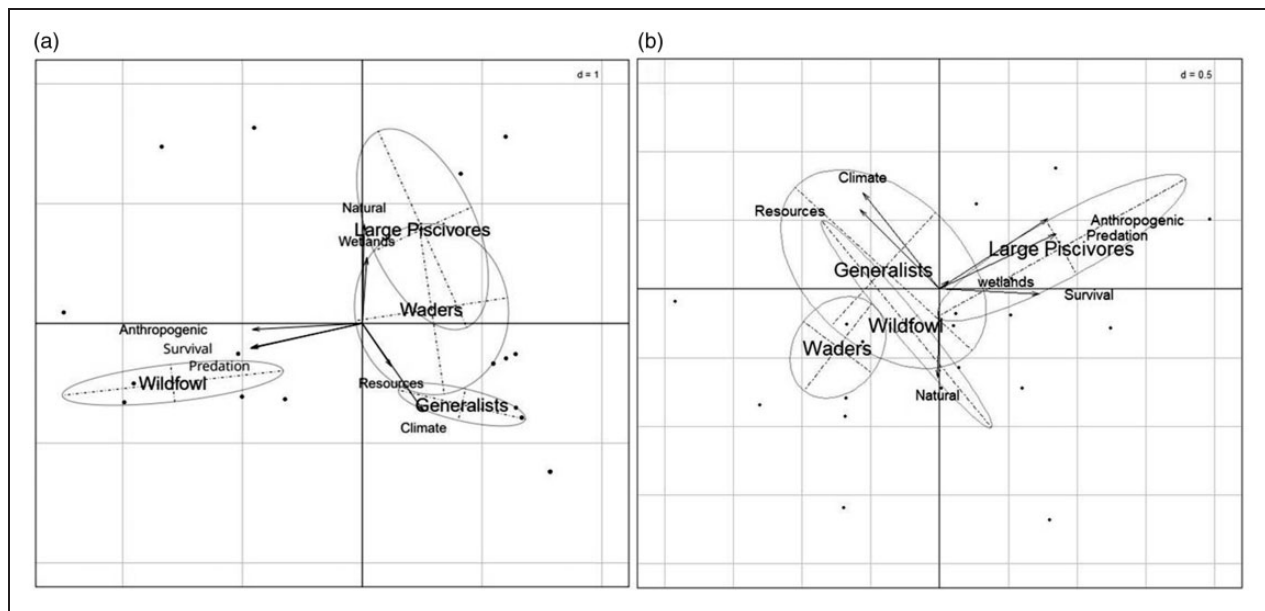
Figure 3. Plots of drivers, mechanisms, and impacts as perceived by people in the south-east KAZA TFCA for (a) declining and (b) stable and increasing waterbird trends.

and population changes being mainly influenced by human predation. The second axis which explained 24.8% of the variance illustrated natural drivers operating through wetland changes and negatively affecting large piscivores (such as White Storks). Climatic drivers were correlated to the declining generalist species like the Saddlebill *Ephippiorhynchus senegalensis*. Changes in waders were perceived to be more diverse, mostly responding to both climatic and natural drivers, and only remotely connected to anthropogenic predation and disturbances.

The first axis of mcaNotDecreasing contributed to 35.8% of total variance in the data and illustrated species that benefit from climatic and resource changes (e.g., African Openbill Stork *Anastomus lamelligerus* and Hottentot Teal *Anas hottentota*), opposing those experiencing less anthropogenic drivers and predation like the Goliath Heron *Ardea goliath* (Figure 3(b)).

The second axis which accounted for 23.8% of variance in the data was correlated to natural opposing anthropogenic drivers. Interestingly, species classified as large piscivores (e.g., White Stork) are perceived to benefit from changes in anthropogenic pressures, whereas generalist species seem to benefit more from climate change. Waders and wildfowl stability (or increase) seem to be associated with improvements in both natural processes and climate (e.g., African Jacana *Actophilornis africanus* and Spur-winged Geese).

Comparisons of Uses and Threats of Waterbirds at the Local and Global Scales

Both the LEK and IUCN data set confirm that declines in wildfowl species (e.g., White-faced whistling duck) were mostly associated their use as food (Figure 4(a) and (b)); and generalist species were associated with
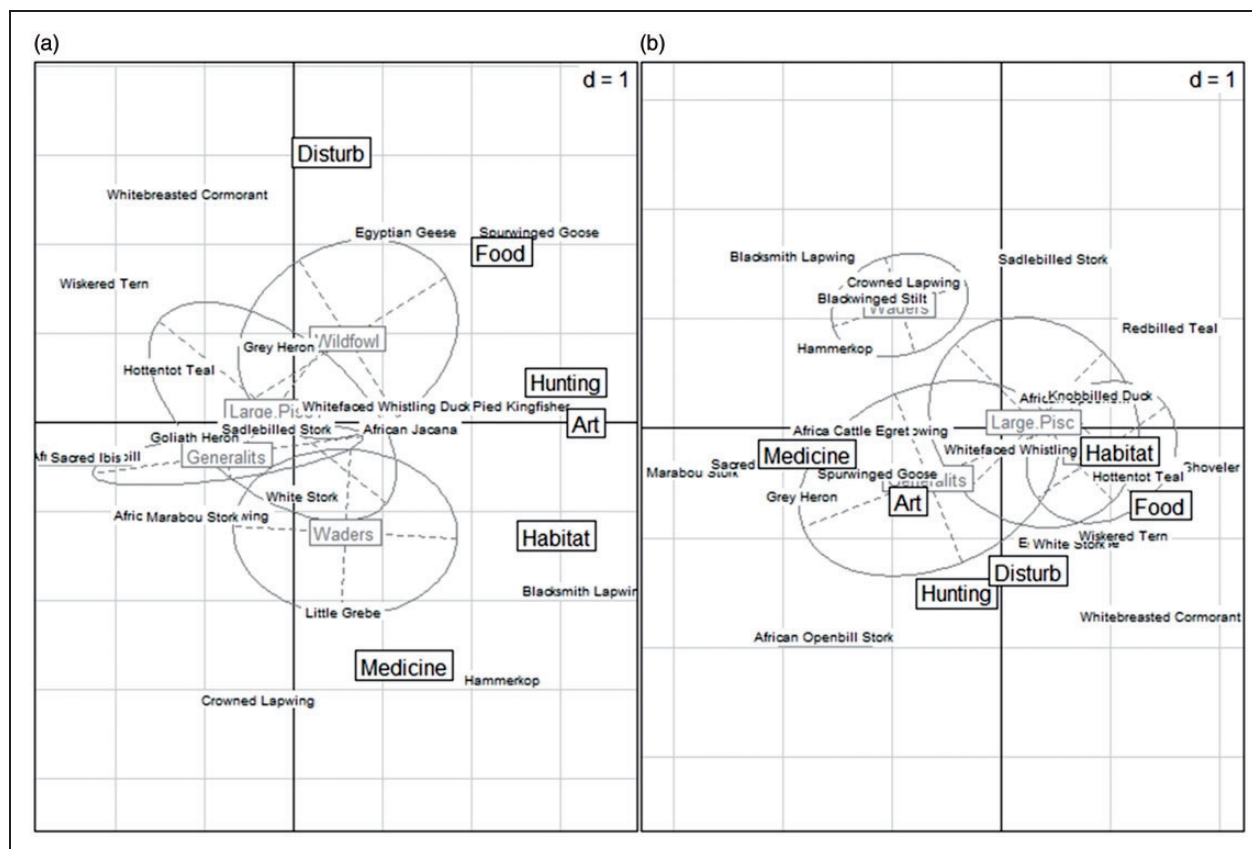
Figure 4. Plots of threats and uses associated with declining waterbird trends from (a) informant perspectives and (b) IUCN documentation.
Disturb = Disturbances.

threats to their habitats and hunting. Although the LEK data set illustrate that declines in large piscivores were associated with their use as medicines, IUCN trends suggest that they were not associated to any of the uses and threats we assessed. The IUCN data set suggests that declines in waders are associated with their use as medicines, but the LEK data set show that they are not associated to any of the variables we used.

Conservation Efforts to Improve Waterbird Survival

Ideas on improving bird survival (using efforts applied by the whole community) in our study area were mainly education and increasing surface water (29.7% and 27.5% of informants, respectively, as shown in Table 6). For efforts applied by individuals, 17.8% of informants thought that they could not do anything to improve bird survival. Interestingly, research, law enforcement, and conservation education were more frequently cited on efforts that could be applied by individuals (as compared to what could be done by the whole community) in improving bird conservation.

Table 6. Perceived Mitigation Efforts by Informants in the Hwange SES to Improve Waterbird Survival.

Mitigation Idea	Combined Community Efforts		Individual Efforts	
	Indirect	Direct	Indirect	Direct
Conservation education	6	20	17	14
Law enforcement	0	12	7	8
Nothing	0	0	10	5
Increase surface water	25	0	4	5
Research	2	1	5	1
Special troughs for livestock	2	0	0	0
Sustainable use	10	2	3	2

Note. Direct efforts were those targeting the waterbird species while the indirect ones were addressing either habitats or people.

Discussion

Our study used mostly LEK and opinions on waterbirds to investigate their uses, trends, and possible remedies to improve their survival. We are aware that some scientists are sceptical on using LEK in management

(Huntington, 2000) as they question its validity. However, we show that perceptions on rainfall mostly matched those of HNP. There were low concordance (55%) between perceptions of trends and BLZ trends, but this could be due to the fact that waterbirds counts were conducted only inside HNP, and 59% of our informants live in the neighboring CAs. We discuss this further later. We do not rule out the possibility of minor biases in species known because small, rare waterbirds could be more difficult to describe, for example, one informant cited the Crab Plover *Dromas ardeola* which has not formally been recorded in Zimbabwe. However, we believe that approaches used in this study allow us to make conclusions discussed in this section. We also believe that our sample was sufficient as snowballing did not yield any new informants (Noy, 2008).

Rainfall and Surface Water Trends

Our study has shown that in general LEK on rainfall revealed similar patterns to those recorded in rain gauges inside HNP. The prolonged mid-season dry spell was not detected from our data set, yet if it was strongly impacting local people's cropping activities it may be perceived more prominently. Actually, Chamaillé-Jammes, Fritz, and Murindagomo (2007) illustrated that drought severity and frequency have increased in this area. This suggest that the effects of climate change are increasingly becoming apparent to local people (Adger et al., 2013) and that LEK can be a useful tool to investigate such changes, and the associated adaptation responses by people (Berkes et al., 2000). The fact that informants with tertiary education and mostly engaged in nonenvironmental occupational activities seem to be less concerned or aware of any water quality change could be indicative of their loose dependence on surface water for daily life (Bouahim et al., 2015), compared to those with primary and secondary education or more involved in environmental activities. The quality of surface water was perceived to be the same across land uses, which can be attributed to similar pressures exerted on these water sources. The trends in rainfall and the high demand for surface water (drinking water for people and wildlife, extractions for tourism, and domestic purposes) can be seen as putting pressure on waterbird habitats.

Cited Waterbirds, Uses, and Factors Affecting Them

Although our sample was derived from people with different origins and lengths of residence, the cited waterbirds and associated uses were similar across informants' origins. This result differs from classic findings by Atran et al. (2002) where awareness of ecological complexity involving animals, plants, and practices in Maya (Spain)

were linked to people's origins. This could be linked to the LEK on the waterbird species that may be common at provincial or even national scales especially those used for protein and present in myths. Also, the knowledge about waterbirds and their habitats in the Hwange SES could have been passed on to nonlocal residents (through environment-related job training and other business networks) as tourism is the major economic activity in the area. Already our results suggest that people working in environment-related jobs know more waterbird species. In concordance with our hypothesis on cited waterbirds and their uses, the frequency of citations was highest for wildfowl species such as the ducks and geese which are eaten in the local area, and those birds used for other purposes such as regulatory services were less frequently cited (only 14% of the total citations). Interestingly, a large number of waterbird species that have the "common" status in the south-east KAZA TFCA system (BirdLife Zimbabwe, 2013), but are not used as food, had low frequencies of citations (with the majority being cited once). This result is classic in the "Cultural domain analysis" (Borgatti, 1999) where semantic categories, such as birds, often have a core and periphery structure, with few items cited by many informants and many items cited by few informants. This also suggests that local knowledge of waterbirds in our study area is culturally founded (based on consumption) more than ecologically so, and that anthropogenic pressure might be high on these frequently cited species. We also illustrated that declining wildfowl species trends are often used for food, which may be driving most of them to decline, as was also documented by Freese (1997). The other species with high citations were the more conspicuous and attractive ones such as large piscivores (e.g., Grey Heron *Ardea cinerea*), and those that symbolize things in local culture, such as Hammerkop *Scopus umbretta* which is associated with bad omens (Muiruri & Maundu, 2010).

There were some mismatches between local and international scales and also between local counts and LEK. The mismatch between perceived trends of waterbirds in our study area and global trends (IUCN) could be indicative of differences in local conditions when compared to pressures elsewhere. Our recent work with the BLZ trends is also revealing disjointed patterns at various scales, with species having more stable or increasing trends in HNP compared to Zimbabwean scale. In general, conditions seem more favorable around Hwange than elsewhere. The discrepancies between local counts and perceived trends are likely to be due to the very little spatial overlap between the areas counted and the areas where people live. This call for further validity checks but certainly suggests that there is a large amount of information that can be gained from LEK in places

that have been ignored by historical monitoring. The wetlands outside PAs may actually play a crucial role in the conservation of these waterbird species (Guillemain, Fritz, & Duncan, 2002).

There were also mismatches on what local people cited as eaten species and what is documented for the region. Although members of storks (such as *C. nigra* and *C. ciconia* in our case) are consumed in parts of Africa (Boere, Galbraith, & Stroud, 2006; Nikolaus, 2001), they are generally not eaten in Zimbabwe (Ewbank, 2014). However, the case of the mismatch on wildfowl species (*T. ruficollis, N. auritus*, and *D. viduata*) is interesting as they are widely eaten elsewhere in Zimbabwe. We think that this could be linked to how difficult it is to catch them for meat (especially for *T. ruficollis*) or that they occur in low abundance locally (especially *N. auritus*, BirdLife Zimbabwe, 2013) such that people generally would not actively hunt them but maybe if our sample was larger, we could have encountered informants who eat these species.

The perceived contribution of natural, anthropogenic, and climatic drivers to waterbird trends varied across functional types. People in our study area perceived that declining trends of wildfowl (42.4% of stated citations) are mainly being driven by human predation and that they would increase when allowed to follow natural processes. Although in their analysis, Long, Székely, Kershaw, and O'Connell (2007) concluded that human exploitation was not the major driver of wildfowl trends worldwide, its local influence can have far-reaching consequences on populations and behavioral adjustments (Bloom, Howerter, Emery, & Armstrong, 2013; Thiebault & Tremblay, 2013). Declines in large piscivores (40.7% of informants' citations) were mostly associated with loss of wetlands and associated changes in natural processes. The wetland conditions included the declining surface water and quality as was cited by most informants. The large piscivores (mainly the storks, cormorants, and herons) were perceived to increase when survival is promoted by changes in human drivers, especially those that control predation. Such species can be affected by domestic dogs which often suppress populations and displace them from favored habitats (Banks & Bryant, 2007). The contribution of this fear of domestic dogs in CAs could be high especially in places where they may be free roaming (Morters et al., 2014) or used in hunting (Butler & du Toit, 2002).

The generalist species (which had 52.4% of their citations mentioned as declining) were perceived to respond mostly to climate and resources, with a tendency to decrease when these factors are either stable or deteriorating. As resources for generalists such as food (e.g., invertebrates, small vertebrates and plant material as outlined in Hancock, Kushlan, & Kahl, 2010) and surface water are tightly linked to climate (Long et al.,

2007), they would increase if climate was not a constraint for them. Interestingly, the perceived uses and threats for wildfowl and generalist species are similar to those experienced globally. This implies that such species could be facing greater pressures locally and globally, and mitigation measures against their declines should be prioritized. From our data, it is difficult to pinpoint major factors affecting waders (that had 36.4% of citations mentioning decline), as both climatic and natural drivers had an influence on them (through wetlands mechanisms that impact on resources). This could be because waders are a very diverse group that have a significant proportion of their members surviving some pressures in the environment through migrations (Kilpatrick et al., 2006) and probably contains some of the smallest waterbirds that people in most cases would not have specific knowledge on (Jóhannesdóttir, Alves, Gill, & Gunnarsson, 2017).

Remedies to Improve Waterbird Conservation

Informants in our study area suggested actions that can alleviate most of the drivers and mechanisms that were unfavorable for species survival. Informants think that shortages of surface water could be alleviated by augmenting surface water (through work involving pumping, scooping/deepening of waterpans). This remedy was mostly suggested at the community level (Table 6), and it is most probably linked to high costs involved. It is tempting to accept this option, as it benefits not only the waterbirds but also tourism in general (Smit, Grant, & Devereux, 2007), but other factors like herbivore distribution and possible groundwater changes, given the reduction in rainfall for our study area (Chamaillé-Jammes, Valeix, & Fritz, 2007), must challenge management authorities how the resulting water sources (if implemented) would be distributed across the landscape.

Other people (17.8% of informants) thought that they could not take any action to improve waterbird survival. Although previous researchers have explored the causes of such views (Mukamuri, 1995), including challenges of management of natural resources in CAs (Matiza & Crafter, 1994), we believe that there is need for intervention by all stakeholders to avert some of the declining waterbird species' trends. However, it was encouraging to note that a few individuals (12.9% of responses) demonstrated higher commitment and "willingness to pay" (Dias & Belcher, 2015) by offering to construct small water sources even in their gardens! Also of interest was the option to modify existing water sources which would allow separation of points used to water livestock from those which could be used by waterbirds to minimize possible disturbances. Expanding on this idea, access to selected surface water sources can be

negotiated in CAs which would result in reduced water quality deterioration and disturbances to waterbirds associated with them. We see these as noble ideas, although their implementation needs to consider other herbivores involved, as waterpans accessed by elephants (*Loxodonta africana*) may face damages.

About 40% of informants also believed that education would improve waterbird survival particularly targeting the reduction of anthropogenic drivers. Our informants believed that such education efforts must target not only the species but also the habitats used, suggestions that have also been made by other scholars (Gadgil et al., 2003; Gandure, Walker, & Botha, 2013). Dealing with illegal hunting of species has been a recurrent issue in conservation (Byg, Martin-Ortega, Glenk, & Novo, 2017), and unsurprisingly, only 18.8% of informants think that law enforcement could be employed to limit human effects on waterbirds and their habitats. The success of law enforcements may rely on good perceptions from all stakeholders (Mutanga, Vengesayi, Muboko, & Gandiwa, 2015) and the motivation being driven by local people (Byg et al., 2017). In that regard, 13.2% of informants actually believe that management should allow access to waterfowl resources (as evidenced by those who cited sustainable use). Such management would first need proper medium- to long-term monitoring of the trends of wildfowl in the CAs, including modeling under different land use and climatic scenarios as discussed by Davis et al. (2015), but to our knowledge such monitoring efforts have not been put in place. We therefore concur with the informants who mentioned that there is need for general research to explore the ecology of waterbirds in our study area, but we also think that at CA level, local people can be trained in simple waterbird monitoring especially if the idea on setting aside some surface waterpoints/special water troughs is adopted. This will promote knowledge sharing and should foster greater stewardship from local people which will also reduce illegal harvesting.

Implications for Conservation

Although a lot of work has been done in the southern African region (Hockey et al., 2005), monitoring of local waterbird trends in the CAs is at its early stage. We believe that this will improve our understanding of waterbird community dynamics and their conservation, as well as the management of wetlands in these semi-arid savannah systems. While building these waterbird databases, we can benefit from LEK as it was advocated in adaptive conservation orientated management in many circumstances (Brook & McLachlan, 2008; Gilchrist et al., 2005) and has become part of the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services vision today (Tengö et al., 2017). As argued by Brook and McLachlan (2008), appropriate depiction of LEK systems are needed to ensure that holders of such knowledge will continue participating in ecological research aimed at conservation, and the scale at which the knowledge is related needs to be explicitly defined.

It will be worth trying to implement the idea of lessening disturbances around wetlands by negotiating livestock access to selected waterpans in CAs (or creation of special troughs for livestock at sections of wetlands with potential to host wildfowl). We also advocate for greater enhancement of environmental awareness which is backed up by research and monitoring of waterbirds. We think that the community can organize themselves to conduct monitoring of waterfowl in (CAs) which will help management of the resource and increase stewardship of natural resources in their areas.

Appendix: Cited Waterbird Species and Assigned Functional Types in the Hwange SES Alongside the Categorized Uses.

Species Common Name	Scientific Name	Species Vernacular Names(s)	Functional Type	Number of informants				
				Cult	Prov	Reg	N.U.	N.Res.
Abdim's Stork	*Ciconia abdimii*	Ngauzane (Nd), Shuramurove (Sh)	Large piscivore	1	—	1	—	3
African Black Duck	*Anas sparsa*	iDada (Nd)	Wildfowl	—	—	—	—	1
African Jacana	*Actophilornis africanus*	Otolo	Wader	1	1	1	—	8
African Openbill Stork	*Anastomus lamelligerus*	isiQhophamnenke (Nd)	Generalist	1	—	—	—	—
African Pygmy Goose	*Nettapus auritus*	iDada (Nd)	Wildfowl	—	1	—	—	1
African Skimmer	*Rynchops flavirostris*	—	Large piscivore	—	—	—	—	1

(continued)

Continued

Species Common Name	Scientific Name	Species Vernacular Names(s)	Functional Type	Number of informants				
				Cult	Prov	Reg	N.U.	N.Res.
African Spoonbill	*Platalea alba*	Imbemba (Nd)	Generalist	1	1	—	—	5
African Wattled Lapwing	*Vanellus senegallus*	Hurekure (Sh)	Wader	—	—	—	—	1
Black Stork	*Ciconia nigra*	uNowanga (Nd)	Large piscivore	—	—	—	—	3
Black-crowned Night Heron	*Nycticorax nycticorax*	—	Large piscivore	—	—	—	—	1
Blacksmith Lapwing	*Vanellus armatus*	—	Wader	3	4	2	—	11
Black-winged Stilt	*Himantopus himantopus*	Tekwane (Nd)	Wader	—	1	—	—	6
Cape Shoveler	*Anas smithii*	Sialwili (T)	Wildfowl	—	1	—	—	—
Cape Wagtail	*Motacilla capensis*	—	Wader	—	—	1	—	1
Cattle Egret	*Bubulcus ibis*	Amalanda (Nd) and Fudzamombe (Sh)	Generalist	2	1	11	—	2
Common Greenshank	*Tringa nebularia*	—	Wader	—	—	—	—	1
Common Moorhen	*Gallinula chloropus*	—	Generalist	—	—	—	—	2
Crab Plover	*Dromas ardeola*	—	Wader	1	—	—	—	1
Crowned Crane	*Balearica regulorum*	Mbowani (Nd) and Amahuruhwani (T)	Generalist	8	2	1	2	5
Crowned Lapwing	*Vanellus coronatus*	oGwelo (Nd) and Hurekure (Sh)	Wader	—	1	—	—	3
Egyptian Geese	*Alopochen aegyptiaca*	Amahansi (Nd) and Dhadha (Sh)	Wildfowl	2	26	1	—	9
Glossy Ibis	*Plegadis falcinellus*	—	Generalist	—	—	—	—	1
Goliath Heron	*Ardea goliath*	uNozalizingwenyana (Nd)	Large piscivore	—	—	—	—	1
Great Egret	*Ardea alba*	—	Generalist	—	—	—	—	1
Greater Painted Snipe	*Rostratula benghalensis*	—	Wader	—	—	—	—	1
Green Sandpiper	*Tringa ochropus*	—	Wader	—	—	1	—	—
Green-backed Heron	*Butorides striata*	—	Large piscivore	—	—	—	—	1
Grey Heron	*Ardea cinerea*	Ugogokamzokho (Nd)	Large piscivore	1	1	1	1	13
Hammerkop	*Scopus umbretta*	uTekwane (Nd)	Large piscivore	7	2	1	2	8
Hottentot Teal	*Anas hottentota*	—	Wildfowl	—	2	—	—	—
Knob-billed Duck	*Sarkidiornis melanotos*	Ingidiva (Nd)	Wildfowl	3	16	1	—	3
Lesser Jacana	*Microparra capensis*	—	Wader	—	—	1	—	—
Little Grebe	*Tachybaptus ruficollis*	Tsvitsvitsvi (Sh) and Tsviripolo (T)	Wildfowl	4	13	—	—	6
Marabou Stork	*Leptoptilos crumenifer*	—	Large piscivore	—	—	1	—	3
Pied Kingfisher	*Ceryle rudis*	isiXula (Nd) and Chinyururahove (Sh)	Large piscivore	2	2	—	—	2
Red-billed Teal	*Anas erythrorhyncha*	Amanewenewe (Nd)	Wildfowl	—	16	—	—	7
Reed Cormorant	*Microcarbo africanus*	uLondo (Nd)	Large piscivore	—	—	—	—	1
Sacred Ibis	*Threskiornis aethiopicus*	umXwagele (Nd)	Generalist	—	—	—	—	1
Saddlebill	*Ephippiorhynchus senegalensis*	—	Generalist	—	1	—	—	4
Southern Pochard	*Netta erythrophthalma*	iDada (Nd)	Wildfowl	—	—	—	—	1
Spur-winged Goose	*Plectropterus gambensis*	Makhlasi (Nd)	Wildfowl	2	34	—	1	3
Squacco Heron	*Ardeola ralloides*	—	Large piscivore	—	—	—	—	1
White Stork	*Ciconia ciconia*	Ingabuzane (Nd)	Large piscivore	—	—	1	—	4
White-breasted Cormorant	*Phalacrocorax carbo*	—	Large piscivore	—	1	—	—	1
White-faced Duck	*Dendrocygna viduata*	iDada (Nd)	Wildfowl	1	6	—	—	2
Wiskered Tern	*Chlidonias hybrida*	—	Large piscivore	—	—	—	—	1
Wood Sandpiper	*Tringa glareola*	—	Wader	—	—	—	—	2
Woolly-necked Stork	*Ciconia episcopus*	isiThandamanzi (Nd)	Large piscivore	—	—	—	—	2

Note. Cult = Cultural; Prov = provisional; Reg = regulatory services; N.U. = not used; N.Res. = no response given by informant. For vernacular names Nd = Ndebele; Sh = Shona; T = Tonga and those cited in English are marked by a dash (—).

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