GRASSROOTS JOURNALS

Grassroots Journal of Natural Resources, Vol.8 No.3 (December 2025)
ISSN: 2581-6853 | CODEN: GJNRA9 | Published by The Grassroots Institute
Website: https://grassrootsjournals.org/gjnr | Main Indexing: WoS, CABELL, EBSCO

ISSN 2581-6853 | 8(3) December 2025

00615 | Research Article

Utilization of Vegetation and Avian Indicators for Wetland Health Assessment at the Driefontein Ramsar Site, Zimbabwe

Augustine Mureri*[1], Pascal Manyakaidze[2], Tinashe Muteveri[3], Regis Musavengane[4], Caston Muchadudza Makaka[5]

[1]Department of Land and Water Resources Management, Faculty of Agriculture, Environment and Natural Resources Management, Midlands State University, Gweru, Zimbabwe; Department of Geography, Faculty of Social Sciences, Midlands State University, Gweru, Zimbabwe. Email: augurmureri@gmail.com | ORCID: https://orcid.org/0009-0009-6214-1224

[2a]Department of Geography, Faculty of Social Sciences, Midlands State University, Gweru, Zimbabwe. Email: manyakaidzep@staff.msu.ac.zw | ORCID: https://orcid.org/0000-0003-0355-4239

[2b]Centre for Information, Learning and Knowledge Transfer, Local Initiatives and Development (LID) Agency, Donga Rural Service Centre, Shurugwi, Zimbabwe.

[3]Department of Applied Biosciences and Biotechnology, Midlands State University, Gweru, Zimbabwe. Email: tinashe.muteveri@gmail.com | ORCID: https://orcid.org/0000-0002-4773-7259

[4]Department of Geography, University of the Free State, Bloemfontein 9301, South Africa; Centre for Information, Learning and Knowledge Transfer, Local Initiatives and Development (LID) Agency, Donga Rural Service Centre, Shurugwi, Zimbabwe. Email: regmuss2000@yahoo.com | ORCID: https://orcid.org/0000-0002-5276-7911

[5]Department of Applied Biosciences and Biotechnology, Midlands State University, Gweru, Zimbabwe. Email: makakac@staff.msu.ac.zw | ORCID: https://orcid.org/0000-0001-8615-9036

**Corresponding author*

How to cite this paper: Mureri, A., Manyakaidze, P., Muteveri, T., Musavengane, R. and Makaka, C.M. (2025). Utilization of Vegetation and Avian Indicators for Wetland Health Assessment at the Driefontein Ramsar Site, Zimbabwe. *Grassroots Journal of Natural Resources*, 8(3): 367-393. Doi: https://doi.org/10.33002/nr2581.6853.080315

Received: 22 October 2025
Reviewed: 11 November 2025
Provisionally Accepted: 13 November 2025
Revised: 20 November 2025
Finally Accepted: 25 November 2025
Published: 31 December 2025

Abstract

The high rate of wetland degradation, which has reached over 40 percent in the past 30 years, has raised conservation concerns worldwide. The role of local communities in assessing wetland health has not been integrated with scientific approaches, and efforts are needed to harmonise these perspectives. This study examines the health of the Driefontein wetlands, a Ramsar site, by evaluating the distribution and composition of vegetation and bird species as indicators of wetland health during the dry season. Five 10 m x 50 m zones were established around each of five selected pools and subdivided into quadrants for sampling wetland indicator vegetation, in accordance with the Environmental Management Agency's Wetland Species Indicator Guide. Bird counts were conducted twice a day, once a week, over four months during the dry season. Findings revealed variations in vegetation richness and diversity across various zones, with species richness and diversity decreasing as distance from the water source increased. The 10-20 m and 20.1-30 m zones exhibited the highest species richness (R=14) and diversity (Shannon indices of 2.216 and 2.188, respectively), while the 40.1-50 m zone had the lowest (R=10, Shannon = 1.2). Dominant species in the 10-20 m zone included *Typha latifolia* subsp. *capensis* (31.5%) and *Phragmites australis* (17%). Species richness declined with distance, with some species failing to thrive beyond 30 m. Bird counts indicated dominance by egrets (66.9%) and cranes (15.3%), with *Bubulcus ibis* (49.2%) being the most prevalent indicator of wetland birds. The combined use of vegetation and avian indicators for wetland health assessment offers greater opportunities to inform development and conservation efforts.

Keywords

Wetland health; Sustainable community-based management; Avian indicator; Vegetation richness

Introduction

Wetlands are among the world's most productive and vital ecosystems, providing indispensable services including carbon sequestration, flood mitigation, groundwater recharge, and water purification (Kaul and Kumar, 2019). Their role in receiving and purifying upstream water and waste flows has led to their description as the 'kidneys of the landscape'. At the same time, their high biological diversity and complex food webs have led to their designation as 'biological supermarkets' (Chakraborty, Sanyal and Ray, 2023). Healthy wetlands also provide an aesthetic value and support a wide range of recreational, social, and cultural activities. They are also ecosystems of interest to the World Food Programme (WFP), as they provide immediate relief to food-insecure families in rural communities by providing nutritious food and purified water (Atiim, Alhassan and Abobi, 2022). Despite their vital ecological and socio-ecological values, these ecosystems are simultaneously among the most threatened habitats in the world.

Wetlands occupy approximately 6% of the world's land surface (Mutyavaviri, 2006). Zimbabwe accounts for 1.28 million hectares of wetlands, which translates to 3.6% of the country's total area (Dube, 2012). The sizes of individual wetlands in Zimbabwe vary, with the smallest ranging from 0.1-1.0km wide to 0.5-5.0km long, which makes them prone to being overlooked in development and conservation planning, ignoring that in total they translate to a vast area (Dube, 2012). Despite the numerous benefits and functions provided by the wetlands, policymakers and politicians have, to a greater extent, ignored wetland conservation. This is because they have often wrongly regarded them as wastelands that can be sacrificed for other "more pressing needs" (Dube, Dube and Marambanyika, 2023). In addition, local communities, the immediate beneficiaries of wetland conservation, still have limited knowledge of sustainable wetland management, wetland health-monitoring strategies, and the interlinkages between wetland health and service provision.

Effective monitoring of wetlands is essential for their conservation, yet a significant challenge persists in moving beyond a singular matrix to a holistic health assessment. Wetland health monitoring requires a comprehensive evaluation of three dimensions, including ecosystem integrity, functional performance, and conservation value (Das, Das and Singha, 2025). In relation to wetland health, the ecosystem integrity dimension encompasses structural attributes, including wetland indicator species, biodiversity, and richness (Faber-Langendoen *et al*., 2019). The conservation value dimension refers to the wetland's ability to support sensitive and ecologically significant species. The functional performance dimension of wetland health monitoring encompasses the system's capacity to sustain major biogeochemical processes, water purification, and recycling of nutrients (Liu *et al*., 2020). In Sub-Saharan Africa, where livelihoods are directly dependent on natural resources, the deterioration of wetland health poses threats to biodiversity and human well-being. The Driefontein Wetlands in Zimbabwe, recognised as the Ramsar Site of international importance, serve as a crucial stronghold of biodiversity as well as a vital resource for the local community. However, traditional wetland health monitoring and assessments often rely on limited physico-chemical data, which usually provide an incomplete picture of the wetland's overall health condition (Rawat *et al*., 2025). There is a growing need for bioindicator-based approaches that can assess the health of wetlands across all three dimensions.

Several studies have been conducted regarding the mismanagement of wetlands; however, less attention has been given to the development of a communal wetlands' health assessment tool, which utilizes the composition and seasonal distribution of threatened and/or endangered wetland indicator birds and vegetation species. The distribution of sensitive vegetation species in and around water bodies can be used to develop a locally applicable wetland health monitoring tool that the local community can easily utilise to monitor and estimate wetland health status for informed managerial decision-making (Shannon *et al*., 2022; Wu *et al*., 2018). This study posits that the synergistic use of avian and vegetation communities provides a robust integrated approach to rural community wetland health monitoring. Wetland indicator vegetation distribution or structure is a direct indicator of wetland integrity and a key driver of wetland functional performance (Manyakaidze *et al.,* 2025). In contrast, avian populations in wetlands, especially waterbirds, serve as excellent proxies for both conservation value and functional performance due to their high sensitivity to changes in habitat and food resources. An assessment of vegetation and avian wetland health indicator groups enabled evaluation of the Driefontein Wetlands' structural integrity, inferring its functional capacity, and assessing its conservation significance for avian biodiversity. This provided a validated framework for rapid and effective wetlands monitoring, which guides conservation strategies for Driefontein wetlands and similar vulnerable wetlands globally.

The monitoring tools are based on the understanding that different species respond uniquely to fluctuations in moisture levels, as well as varying conditions of degradation or conduciveness. As the wetland dries up or degrades gradually, those species that need more water are affected (show symptoms or dry up) first, followed by those that need less water, and as this happens, the services that were obtained from the wetland also decrease (Duan *et al*., 2021). For example, when the wetland indicator species found far from the water source are increasing, it means the wetland is still wet and conducive enough to sustain all other species that survive within the radius between the water and the observed species. This, on the other hand, means that when near-water species are no longer thriving well, it indicates that those far from water or beyond the radius under observation suffered worse, which suggests deteriorating wetland health. It is thus important that a baseline study on the distribution of wetland indicator vegetation species and threatened or endangered birds is undertaken to serve as a future reference point. However, no such study has been done on the Driefontein wetlands. Therefore, the study aimed to establish the baseline species richness, distribution, and composition of indicator birds and vegetation species in the Driefontein wetland. It also aimed to develop a locally applicable wetland health estimation tool to monitor and estimate Driefontein wetland degradation, thereby informing community-based wetland conservation strategies (using the Bottom-Up Approach).

Materials and Methods

Description of the Study Area

The study was conducted in the Driefontein wetlands (19°30′E, 30°64 ′S) in Zimbabwe. The Driefontein wetlands are located in the Zambezi River basin (Figure 1), approximately 200 km southwest of Harare. Driefontein wetlands are a Ramsar Site covering approximately 201,194 ha. It is situated at an elevation of around 1435 m above sea level. The wetlands stretch for 9 km, covering parts of the Midlands, Masvingo, and Mashonaland East Provinces. However, much of the wetland is located in the Chirumhanzu District of the Midlands Province.

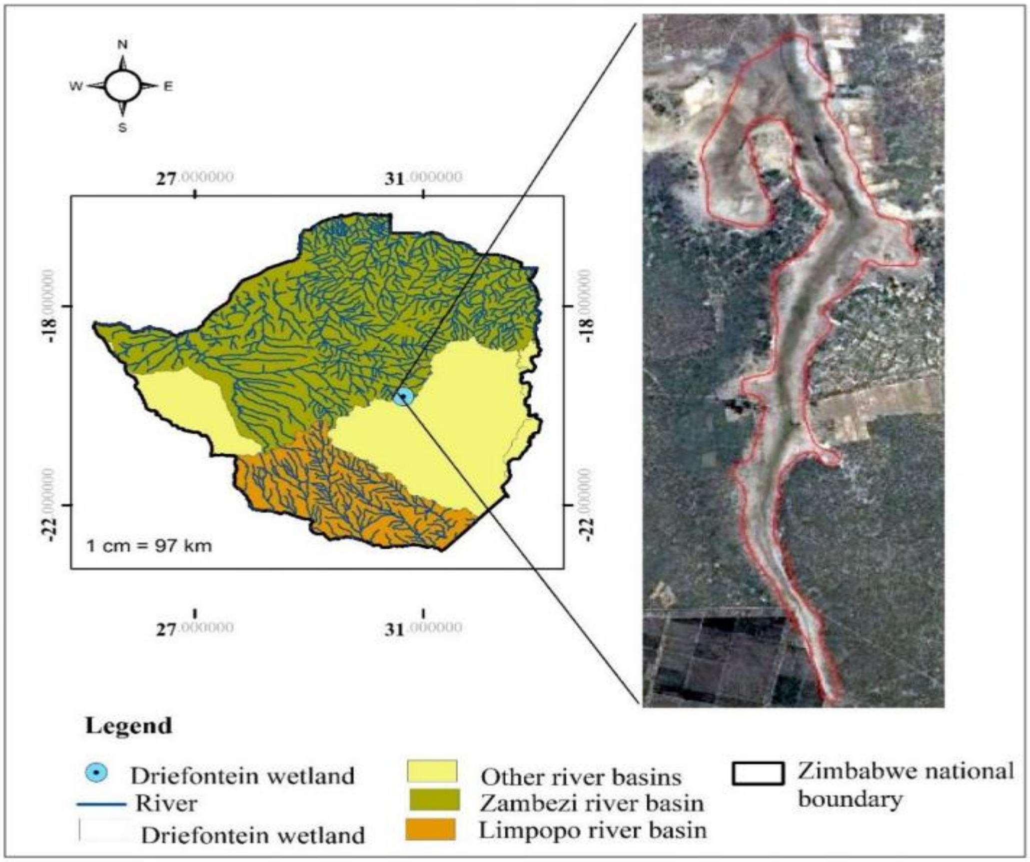

Figure 1: Location of Driefontein Wetlands in Zimbabwe

Major rivers that feed into the wetlands are Shashe, Nyororo, and Chinu. The watershed wetlands also form the headwaters of five major rivers, including Mutirikwi, Deure, Chivake, Popoteke, and Shashe. Driefontein wetlands have gently sloped terrain dominated by sandy loamy soils with a high infiltration rate, allowing high subsurface water to spread across the terrain. The high infiltration rate, high subsurface water spread, and the presence of an impermeable layer beneath allow the wetland to remain wet throughout the year (Ramsar Information Site, 2014). The Driefontein wetlands are also referred to as the Driefontein Grasslands by the Ramsar Convention, due to the dominance of extensive grasslands across the wetlands.

The Environmental Management Agency (EMA) and the Chirumanzu Rural District Council (RDC) are the responsible authorities for the conservation of wetlands, with assistance from local traditional leadership, including chiefs, village heads, headmen, WADCO, and VIDCO. These local traditional leaders are the recipients of conservation strategies from the government, Non-Governmental Organisations (NGOs), or experts,

Doi: https://doi.org/10.33002/nr2581.6853.080315 Open Access

using a Top-down Approach, so that they can cascade these strategies and ideas to their subordinates. Communal farmers sustainably use the wetland's peripheral areas, while the core is set aside (protected) for conservation purposes. The wetland was once fenced before fast-track land reform, which later exposed the fence to vandalism by native households who were forcibly resettled in Fairfields near Mteo Plantations during the colonial era. For the sustainable conservation of the wetland, LID Agency and BirdLife Zimbabwe are non-governmental organisations that established four Local Conservation Groups (LCGs) to spearhead the sustainable conservation and/or management of the Driefontein wetlands.

Research Design, Population, and Sampling Procedure

The study adopted a quantitative research approach. Sampling was conducted during the hot dry season. Both faunal and floral species were included in this research, as they complement each other in assessing wetland health. However, the study focused only on those species referred to as '*wetland indicator species*' according to the A Field Guide to Wetland Identification Using Indicator Plants in Zimbabwe (Environmental Management Agency, n.d).

Flora wetland indicator species sampling

A total of five permanent natural plunge pools (Table 1) were selected along the Chinu River, which passes through the Driefontein wetlands.

Table 1: Location of plunge pools used to determine vegetation species distribution and richness

Water Source Number	*Latitude*	*Longitude*	*Altitude (m)*
1.	19°.31′21″	30°.64′56″	1432
2.	19°.30′35″	30°.68′68″	1418
3.	19°.32′83″	30°.70′59″	1435
4.	19°.32′51″	30°.70′53″	1430
5.	19°.32′31″	30°.70′48″	1431

Five zones at 10-m intervals from the stream bank and extending 50 m along the stream were demarcated at each selected water point (Table 2). Tape measures and pegs were used to measure and mark points of focus outside the water source.

Table 2: Zones from which quadrants were randomly selected

Strip Number	*Distance from the stream bank (m)*	*Length along the stream bank (m)*	*Zone Area (m^2)*
1	0 to 10	50	500
2	10.1 to 20	50	500
3	20.1 to 30	50	500
4	30.1 to 40	50	500
5	40.1 to 50	50	500

Each of the five zones was divided into five quadrants, each measuring 10 m × 10 m. One quadrant was randomly selected from each zone for vegetation sampling, and the baseline study covered 20 percent sample area in line with the species-area relationship (Desmet and Richard, 2004). Transect walks were conducted in the selected quadrants for each water source, recording species present and the number of wetland indicator vegetation species using the EMA field guide (Environmental Management Agency, n.d.). Where necessary, photos of those species that could not be identified on site were taken for identification by expert taxonomists.

The sample band strategy was designed to capture the moisture gradient from the water body, revealing a decrease in hydrological influence with increasing distance. Bands were set perpendicular to the Chinu River bank at 10-m intervals (0-10 m, 10-20 m, etc.), aligning with natural pool morphology and minimising anthropogenic impacts. This gradient-based approach follows EMA guidelines to represent soil moisture zonation. For quality control in species identification, all vegetation was identified in the field using the EMA Wetland Indicator Species Guide, with photos taken of ambiguous specimens. An expert taxonomist from the Zimbabwe National Botanical Gardens verified these within 48 hours, and the identifications were cross-checked against herbarium samples. Additionally, 10% of quadrants (3) were independently resampled by a second observer to ensure greater than 95% inter-observer agreement. The counts were conducted non-destructively and yielded average counts over two separate bird-drinking hours.

Enumeration of Wetland Indicator Bird Species

The water point bird count technique was used for bird sampling, and the species-area relationship by Southwood and Henderson (2009) provided the guidelines. Wetland bird indicator species were counted from selected water stations (Table 3). Sampling sites were selected with the assistance of local stakeholders (personnel from the Environmental Management Agency, Forestry, Traditional leaders, Local Authority, Agritex Department, village heads, WADCO, and VIDCO). Bird species visiting the drinking water points were observed twice a day (in the morning and afternoon) once a week for four dry-season months. Birds were identified to species level using identification guides by Volpato (2009), and wetland indicator bird species were counted. Photographs of birds that could not be identified in situ were taken for verification by expert taxonomists.

Table 3: Location of water points used in bird species counting

Source Number	*Village of location*	*Latitude*	*Longitude*	*Altitude (m)*
1	Aldby	-19.31210	30.64564	1432
2	Welstead 1	-19.30444	30.68138	1432
3	Welstead 2	-19.30949	30.68930	1444
4	Good Hope 1	-19.34987	30.70761	1456
5	Good Hope 2	-19.32316	30.70487	1431

Key informant interviews, bird sounds, and bird droppings and footprints were also used to map the distribution of wetland indicator birds. Key informants were interviewed on the distribution of birds, anthropogenic activities affecting the wetland, and the possible measures that can be adopted at the communal level to reduce degradation of wetland health and biodiversity.

Data Analysis

MS Excel was used to generate graphs that analyse the distribution of the wetland indicator vegetation and bird species. The Statistical Package for Social Sciences (SPSS version 21, IBM) was also used to analyse data collected from key informant interviews and discussions using themes and codes. Qualitative data were analysed through thematic analysis and pattern identification. A systematic and comprehensive record of the coding and themes raised in the interviews and observations was created. The six standard stages of thematic analysis were followed. These stages include the following: familiarisation with the data, assigning preliminary codes to the data for content description, searching for patterns or themes in codes across the different interviews, reviewing themes, defining and naming themes, and producing a report.

In addition to descriptive statistics (proportions, Shannon index), inferential tests were applied to strengthen causality claims. Quadratic regression analyses were used to model distance-species relationships, with distance midpoints (5 m, 15 m, 25 m, 35 m, 45 m) as predictors for richness and diversity. Multivariate analysis included PERMANOVA (using Bray-Curtis dissimilarity on species presence/absence data across zones) to test for differences in vegetation composition. For birds, generalised linear models (GLMs) with Poisson distribution were used to link counts to habitat drivers. Community leaders provided informal consent for the researcher. The study was deemed not sensitive and non-destructive to the ecosystems, and permission was granted by the project implementing stakeholders.

Results

Diversity and Distribution of Wetland Indicator Vegetation Taxa in Driefontein Wetlands

The results showed differences in species richness (R) and species diversity among ring zones around the water points. The 10.1-20 m and 20.1-30 m zones had the highest vegetation species richness (R=14), followed by the 0-10 m zone (R=13), and the lowest was the 40.1-50 m zone with 10 (Table 4). For species diversity, the 10.1-20 m circumference was the most diverse zone (Shannon index = 2.216), followed by the 20.1-30 m zone (Shannon index = 2.188), the 0-10 m zone (Shannon index = 2.023), and the least diverse was the 40.1–50 m zone (Shannon index = 1.2). Additionally, the results revealed that different wetland indicator plants or vegetation species thrived well under different moisture levels (Table 4). Wetland indicator vegetation species that were generally dominant close to the water bodies (less than 10 m) included *Typha latifolia* subsp. *capensis* (31.5%). *Phragmites australis* (Cav.) Steud (17%)*, Limnobium spongio* (15.1%), *Phragmites mauritianus* (Kunth) (10.3%), *Ludwigia stolonifera* (7.4%), *Colocasia esculenta* (5.1%), *Cyperus longus* (4.8%), and *Persicaria senegalensis* (1.9%) (Table 4). These plants occurred primarily within 1 m of the water bodies, but they were more dominant in the 20-m radius from the water's edge. The population density of these species also decreased with distance from the water points, with *C. esculenta* and *L.*

spongio absent beyond the 30-m radius. In contrast, *Cyperus longus, Phragmites australis* (Cav.), and *Ricinus communis* were rare outside the same radius. None of *T. latifolia* subsp. *capensis and Ricinus communis* occurred beyond the 40-m radius (Table 4). The species-area relationship (Southwood and Henderson, 2009) guided proportional estimates of species using the number of counted species and wetland coverage.

Table 4: Distribution of wetland indicator vegetation species by zone within 50 m of water sources

Species Scientific Name	*Proportion (%) of each species in the circumference ring*				
	0-10 m	*10.1-20 m*	*20.1-30 m*	*30.1-40 m*	*40.1-50 m*
Kyllinga melanosperma Nees	1.3	3.2	13.4	19.9	14.0
Cyperus difformis L.	0.3	2.3	15.3	54.4	66.7
Ricinus communis L.	0.0	5.4	3.5	0.4	0.0
Pycreus macrostachyos (Lam.) J. Raynal	3.5	4.1	6.4	6.9	4.1
Cyperus longus L.	4.8	6.3	1.0	0.4	0.6
Limnobium spongia (Bosc) Steud.	15.1	5.9	2.0	0.0	0.0
Colocasia esculenta (L.) Schott	5.1	4.5	0.5	0.0	0.0
Phragmites australis (Cav.) Steud	17.0	35.6	25.2	11.1	5.3
Phragmites mauritianus (Kunth)	10.3	5.0	1.5	0.0	0.6
Typha latifolia subsp. *capensis* Rohrb.	31.5	12.6	3.5	3.4	0.0
Ludwigia stolonifera (Guill. & Perr.) P.H.Raven	7.4	6.3	5.4	0.4	1.8
Eriocaulon matopense Rendle	0.6	1.4	8.4	0.4	1.2
Persicaria senegalensis (Meisn.) Soják	1.9	2.3	0.5	1.1	0.6
Persicaria attenuata (R. Br)	1.0	5.4	13.4	1.5	5.3
Species Richness	13	14	14	11	10
Shannon	2.023	2.216	2.188	1.398	1.2
Evenness	0.5813	0.6547	0.6369	0.3679	0.332
Simpson	0.8259	0.8319	0.8596	0.6456	0.5281
Wetland health estimate rating S	3.4	4.5	15.3	5.6	31.2
M	6.3	18.8	55.0	6.3	13.8
E	46.6	29.9	14.0	7.1	2.4

(S= Slight moisture stress or wetland degradation, M = Moderate moisture stress or wetland degradation, E = Extreme moisture stress or wetland degradation)

To assess differences in vegetation bands, we performed pairwise Mann-Whitney U tests on species richness and Shannon diversity indices across zones, using pools as replicates (n = 5 pools per zone). Our analysis revealed significant differences between inner zones (0-30 m) and outer zones (30-50 m) for species richness (U = 4.5, $p < 0.05$ for 0-10 m vs. 40-50 m; U = 3, $p < 0.05$ for 10-20 m vs. 40-50 m), indicating a decline in richness with distance. This trend was also evident in Shannon diversity, with significant differences between high-diversity zones (10-30 m) and the 40-50 m zone (U = 2.5, $p < 0.05$).

Eriocaulon matopense and *Persicaria attenuata* were mainly found between the 20-m and 30-m rings from water bodies, absent at the water's edge and beyond 30 m. *Pycreus macrostachyos*, *Cyperus difformis*, and *Kyllinga melanosperma* were concentrated in the last 20 m of the 50-m radius. While none of the wetland indicator species were abundant in the last 10 m of all five studied water bodies, 71.4% of the species had some representatives there. *Kyllinga melanosperma* (21%) and *Cyperus difformis* (33%) thrived in that area. Other species, including *L. stolonifera, P. australis*, and *Persicaria senegalensis*, were found from the water's edge to beyond the 50-m radius.

Deterioration of wetland health or moisture stress, based on wetland indicator vegetation species, can be rated as slight, moderate, or extreme. Table 4 presents the proportions of various soil moisture tolerance classes in vegetation species across different ring zones surrounding water margin pools. There was a general increase in the proportion of vegetation species associated with slight moisture stress, particularly with increasing distance from the water margins. On the other hand, the proportion of vegetation species associated with extreme moisture stress decreased with increasing distance from the water point margins.

Regression analysis indicated a quadratic relationship between both species' richness and distance from water sources (slope 1=0.238, p_1=0.02; slope 2=-0.006, p_2=0.003; R^2=52%; Figure 2), characterised by higher species richness at intermediate distances than at extreme distances. A similar, but less pronounced, trend was recorded for Shannon diversity (slope 1=0.058, p_1=0.05; slope 2=-0.001, p_2=0.05; R^2=17%; Figure 3). PERMANOVA on vegetation composition revealed significant differences among zones (pseudo-F = 3.25, $p < 0.05$, based on pooled species distributions), driven by spatial moisture gradients.

Composition of Wetland Indicator Bird Species in Driefontein Wetlands

Water-point bird counts and transect walks showed that ducks, storks, egrets, and cranes utilise the Driefontein wetlands. Egrets accounted for the highest proportion of the bird population (66.9%), followed by cranes and ducks at 15.3%, and storks at 6%.

The Driefontein wetlands host three of Zimbabwe's six known duck species, along with two species each of cranes, storks, and egrets. In a recent bird count, observed duck species included *Sarkidiornis melanotos* (knob-billed ducks), *Oxyura maccoa* (maccoa ducks), and *Anas hottentota* (Hottentot teal), contributing 2.2%, 2.7%, and 7.1% of the total wetland bird population, respectively. Only two crane species were found: the endangered *Bugeranus carunculatus* (wattle crane), contributing 6.6%, and the threatened *Balearica regulorum* (grey crowned crane), which contributed 8.7% to the total wetland indicator bird count.

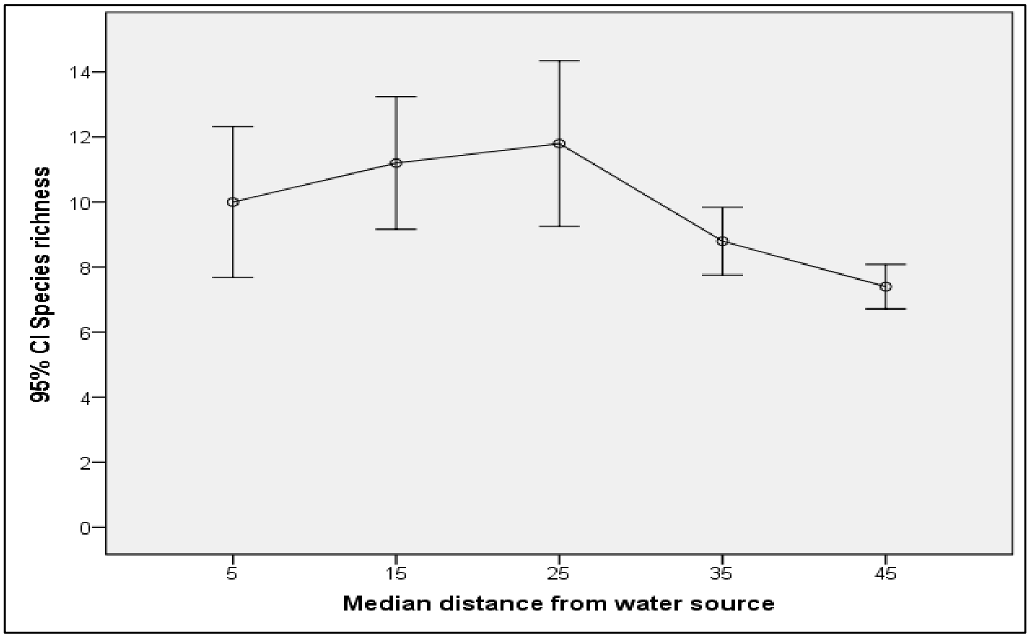

Figure 2: Vegetation species richness and distance from the source of water in the Driefontein Wetlands

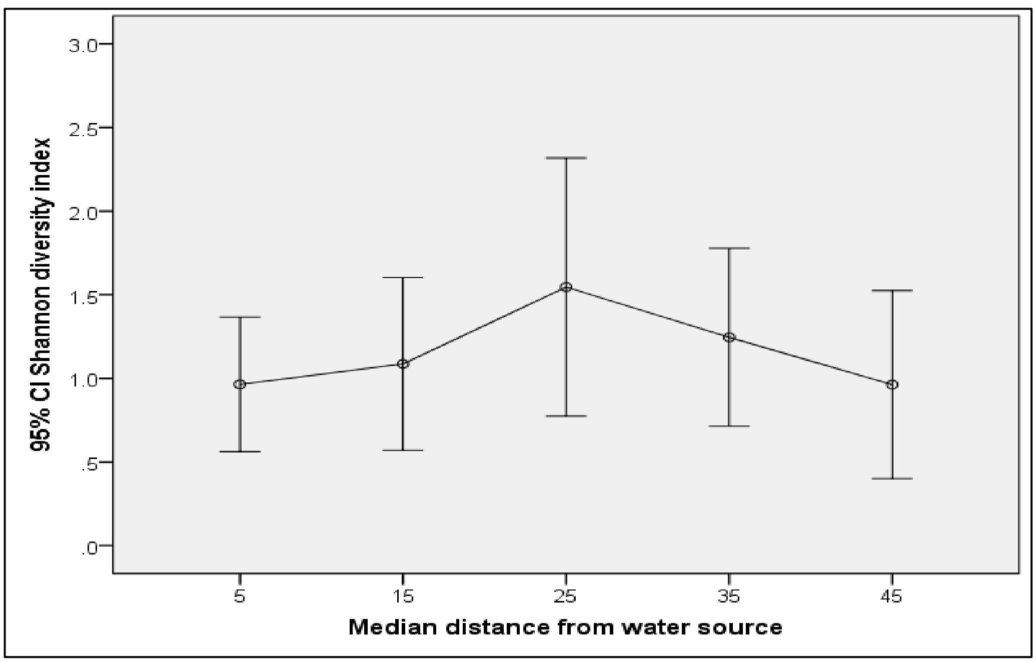

Figure 3: Vegetation Shannon diversity index and distance from the source of water in the Driefontein Wetlands

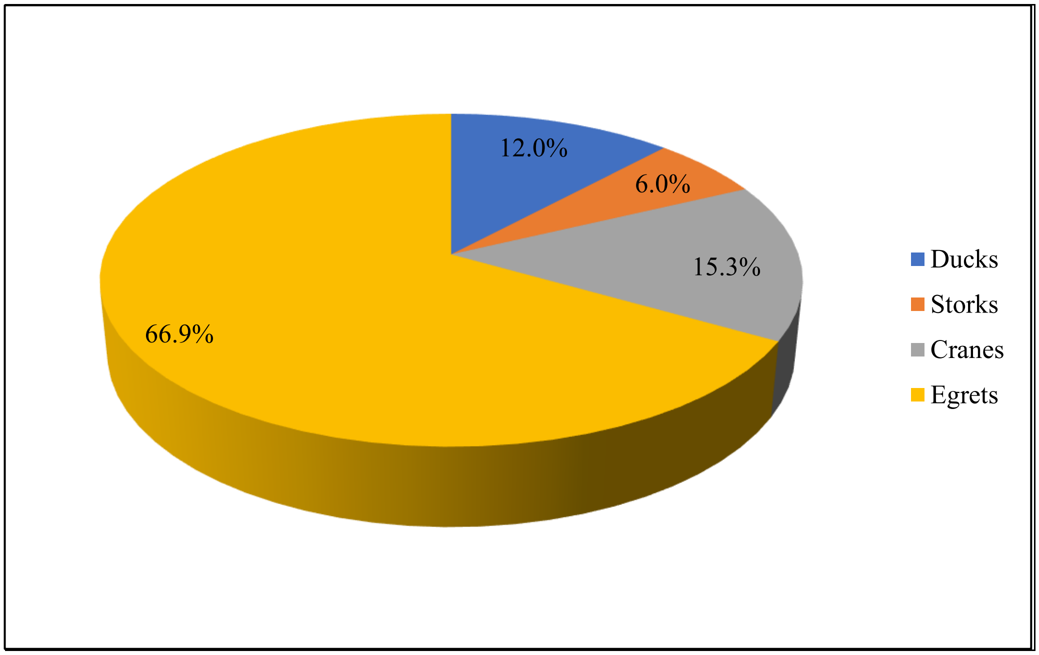

Figure 4: Proportion of various wetland indicator bird species at water points under study

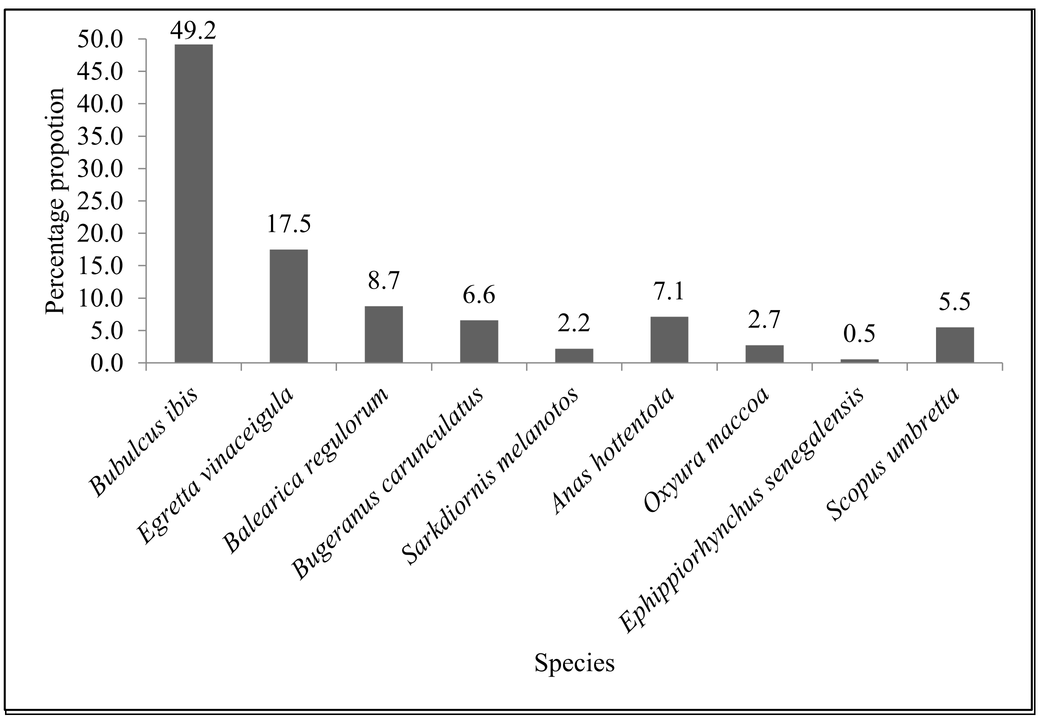

Figure 5: Proportion (%) of wetland indicator bird species to the total population of the counted species at water points under study

Bubulcus ibis (cattle egrets) were the most dominant species in Driefontein wetlands, contributing 49.2%, followed by *Egretta vinaceigula* (slaty egrets) at 17.5%. The stork species recorded were *Ephippiorhynchus senegalensis* (saddle-billed stork) at 0.5% and *Scopus umbretta* (hammerhead stork) at 5.5%. *Ephippiorhynchus senegalensis* had the lowest population.

Wetland Indicator Bird Species Distribution in Driefontein Wetlands

Drinking water points in Good Hope 1 village recorded the highest proportion of wetland indicator bird species (34.4%), followed by Aldby, Good Hope 2 (21.3%), Welstead 1 (14.8%), and Welstead 2 (11.5%) recorded the lowest proportion (Figure 6).

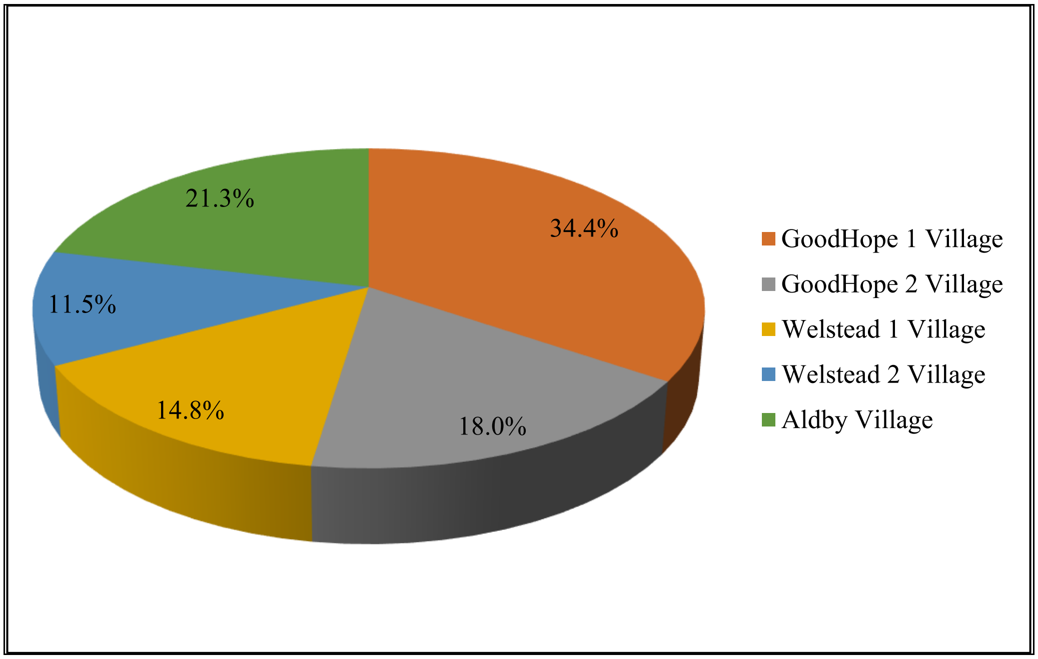

Figure 6: Proportions of various wetland indicator bird species in Driefontein based on observation at water points

Out of the five points chosen for wetland indicator bird species counting, Aldby and Good Hope 1 villages were frequently visited by all the wetland indicator bird species under study (Table 5). Good Hope 2, Welstead 1, and Welstead 2 stations were only visited by certain wetland indicator bird species, while others never used the drinking water points in these villages due to the source's seasonality, volume, and size. Egret bird species were the dominant wetland indicator bird species in Driefontein wetlands. *Bubulcus ibis* and *E. vinaceigula* were recorded in all villages' water points, with the highest proportion of *B. ibis* found in Good Hope 1 (30%), followed by Good Hope 2 (21.1%), Welstead 2 (18.9%), Aldby (15.6%), and Welstead 1 (14.4%) (Table 5). On the other hand, *E. vinaceigula* was most dominant on Welstead 1 (37.9%) and least on Welstead 2 (6.9%). *Bugeranus carunculatus*, *Sarkidiornis melanotos, Anas hottentota*, *Oxyura maccoa*, *E. senegalensis,* and *Balearica regulorum* were not encountered in Welstead 1 during the survey days (Table 5). The same species, except for the *B. carunculatus,* were never found at water points in Welstead 2. The three duck species (*S. melanoto, A. hottentota, and O. maccoa*) were not found at water points in the Good Hope 2, Welstead 1, and Welstead 2 villages.

Key informant interviews indicated the unfavourable nature of the water sources in these villages, especially during the dry period.

However, it is important to note that the dominance of egrets, particularly *B. ibis* (49.2%), may partly reflect the agro-pastoral landscape around Driefontein rather than pure wetland health. Cattle egrets exhibit high habitat plasticity, thriving near livestock grazing in peripheral zones, which could decouple their abundance from degradation indicators like moisture loss (Marambanyika *et al*., 2021). This is evidenced by their presence across all sites, including seasonal ones, while more wetland-dependent species (e.g., cranes, ducks) are restricted to permanent habitats.

Table 5: Average number of each wetland indicator bird species observed per village water point used

Bird Group	*Species*	*Village Name*				
		Good Hope 1	*Good Hope 2*	*Welstead 1*	*Welstead 2*	*Aldby*
Egret Species	*Bubulcus ibis* Linnaeus	30.0	21.1	14.4	18.9	15.6
	Egretta vinaceigula Sharpe	13.8	13.8	37.9	6.9	27.6
Crane Species	*Balearica regulorum* E.T.Bennett	56.3	25.0	0.0	0.0	18.8
	Bugeranus carunculatus Gmelin	33.3	16.7	0.0	16.7	33.3
Duck Species	*Sarkidiornis melanotos* Pennant	75	0	0	0	25
	Anas hottentota Eyton	61.5	0.0	0.0	0.0	38.5
	Oxyura maccoa Eyton	60	0	0	0	40
Stork Species	*Ephippiorhynchus senegalensis* Shaw	100	0	0	0	0
	Scopus umbrette Gmelin	40	10	30	0	20

Ephippiorhynchus senegalensis (saddle-billed stork) did not occur at any of the water points except Good Hope 1, where only one individual was encountered.

Most (more than 50%) of key informants and focus group members indicated that the duck species were found in water bodies in earth-dams of Good Hope and Aldby village. Key informant interviews also established that *Bugeranus carunculatus*, *Scopus umbretta*, and *Balearica regulorum* used wetland grasslands as their prey grounds. However, they were sometimes observed in miombo woodland forests and thick small-forest habitats located in Aldby, Welstead 1, Welstead 2, Good Hope 1, and Good Hope 2. The GLMs testing bird-habitat links showed higher total bird counts in permanent sites (Good Hope 1, Aldby) than in seasonal ones (coefficient = 1.22, $p = 0.155$), though not significant. For ducks, a binomial GLM on presence/absence indicated a strong association with permanent habitats (coefficient = 2.45, $p = 0.10$), consistent with seasonality as a driver. These analyses reinforce that habitat permanence influences bird distribution, with weaker effects in degraded or seasonal areas.

Management Practices Suggested by the Locals to Conserve Driefontein Wetlands

The results indicated that the health and biodiversity of Driefontein wetlands are deteriorating. Wetland deterioration was reported by 79% of smallholder farmers, who raised concerns that the wetland no longer provided the services people used to receive in their youth. A large proportion (31%) of respondents cited the disregard for the wetland's sacred nature as the main cause of its deterioration.

About 97% of key informants attributed the disappearance of threatened migratory birds (*Bugeranus carunculatus, Ephippiorhynchus senegalensis*, and *Balearica regulorum*) to forced out-migration due to habitat and breeding-site destruction by veldt fires. Most key informants (93%) recommended a bottom-up approach because local people are custodians of sustainable solutions to local wetland health problems. More than half of respondents recommended several strategies, including the construction of weirs along streams (especially Chinu stream), having firefighting teams and wetland scouts for monitoring, use of paddocks or wetland fencing or controlled grazing, habitat management, afforestation or reforestation, and stopping the settlement of people in the wetland core as the chief solutions to restore wetland health.

Discussions

Wetland indicator vegetation and bird species are effective in monitoring and determining the health status of wetlands (Siddig *et al*., 2016). Native wetland indicator species are more effective in wetland health monitoring than the alien species (Fraixedas *et al*., 2020). According to Muneepeerakul *et al*. (2008), the distribution and concentration of indigenous species across wetland terrain are primarily determined by species' water requirements. This was supported by Qazi, Saqib and Zaman-ul-Haq (2022), who pointed out that dispersal agencies, such as wind, birds, and flowing water, have a less pronounced influence on the present-day vegetation species composition along a wetland terrain than the conduciveness of the destination sites. Moisture levels and seasonal fluctuations are the primary factors affecting the distribution of wetland vegetation, with terrain degradation a secondary influence (Ridolfi, D'Odorico and Laio, 2006).

The mechanism underlying the observed species zonation in Driefontein wetlands is primarily driven by gradients in soil moisture and hydrology, as influenced by the site's sandy loamy soils with high infiltration rates and an underlying impermeable layer that promotes subsurface water spread and year-round wetness (Ramsar Information Site, 2014). Species requiring high moisture, such as *Typha latifolia* subsp. *Capensis* and *Phragmites australis* dominate near water bodies (0-20 m) due to their consistent access to surface and shallow groundwater, while more tolerant species, such as *Pycreus macrostachyos* and *Cyperus difformis,* prevail in outer zones (30-50 m) where moisture levels decrease. This aligns with regional studies in semi-arid African wetlands, such as the Zoige Wetland in China (Wu *et al*., 2018), where soil hydrological gradients, measured via water table depth and infiltration, similarly dictate vegetation bands, with extreme moisture-stress species declining beyond 30m. Further, studies in the Okavango Delta (a comparable Ramsar site) confirm that impermeable layers enhance zonation by maintaining moisture differentials, supporting our findings that degradation reduces these gradients and shifts species distributions (Du Toit, Du Preez and Du Toit, 2021).

The Wetland Monitoring and Evaluation Tool is designed to be an accessible resource for local communities to monitor wetland degradation. However, it is most accurate when used in the specific wetland from which it was developed (Kotze *et al*., 2020). The tool's accuracy diminishes as the distance from the original wetland increases.

Additionally, variations in species composition across wetlands can limit the tool's applicability elsewhere. According to Irvine *et al*. (2022), for the tool to be effective in other wetlands, those wetlands should contain at least half of the species included in the tool's development. It is also essential to consult local communities when identifying species, as they possess valuable knowledge regarding the seasonality of local flora and the saturation levels of wetland areas.

The observed high abundance of the species *Ludwigia stolonifera, Typha latifolia* subsp. *Capensis, Phragmites mauritianus* (Kunth), *Phragmites australis* (Cav.) Steud, *Colocasia esculenta, Limnobium spongio, Cyperus longus,* and *Persicaria senegalensis* near water corroborate the findings of Qazi, Saqib, and Zaman-ul-Haq (2022). Their high abundance near the water is attributed to their high-water requirements. However, it is not always the case that species such as *Eriocaulon matopense* and *Persicaria attenuata* (R.Br), which were more concentrated in the 20-30 m ring, are always in that zone in all wetlands. Qazi, Saqib and Zaman-ul-Haq (2022) argued that differences in soil profile and type can lead to rearrangement of species distributions or to the extension of the radius they occupy from water ends in other wetlands. The nature of the soil profile can also lead to the presence of a temporary water table near the surface or in the topsoil. Differences in wetland soil profiles can cause roots to be in underground pools of water, allowing them to experience the same moisture abundance as those in surface water, even when located outside the 50-m radius (Ridolfi, D'Odorico and Laio, 2006). So, the use of permanent-radius occupation is effective only on the wetland of origin or on a wetland with similar characteristics (Du Toit, Du Preez and Du Toit, 2021).

The species *Pycreus macrostachyos, Cyperus difformis,* and *Kyllinga melanosperma* dominated the 30-50 m ring, most likely due to their low moisture or water use requirements. The water-requirement factor is also supported by Nikitina *et al*. (2020), who noted that vegetation distribution is generally strongly influenced by differences in water-use requirements, with those requiring more water occurring in water-ends and those requiring less water found at peak points. However, Qazi, Saqib and Zaman-ul-Haq (2022) disputed this point, highlighting that it only applies to perennial wetlands, and for seasonal species, there is a need to consider the change in moisture levels in seasonal wetlands, as the low water use requirement can be found on points previously occupied by the high-water use requirement species due to seasonal changes in moisture levels.

Results on the distribution and composition of Driefontein wetlands indicator birds showed that egret species dominated the wetlands. At the same time, only a few areas remained favourable for duck, crane, and stork bird species. However, a healthy wetland is characterised by high productivity, a high species population, high species richness, and the conduciveness of a larger part of the wetland to support the wetland indicator species at various trophic levels (Chatterjee *et al*., 2020b). This point was supported by Kahl *et al*. (2022) and Mariyappan *et al*. (2023), who highlighted that ecosystem health is measured by the number of trophic levels present, giving equal weight to the proportions of each level's population. This implies that higher-biodiversity wetlands are healthier because they have a higher probability of supporting active producers, consumers, and decomposers, which form trophic levels that create a balanced food chain or web within a wetland ecosystem. When considering the number of active trophic levels, the outcome for the Driefontein wetlands is increasingly becoming less conducive, as evidenced by declining species populations.

Wetland indicator bird distribution in Driefontein is influenced by sub-habitat characteristics beyond water point seasonality, including water depth, shore length, shore quality, vegetation cover, and nekton availability (Irvine *et al*., 2022). Permanent pools in Good Hope 1 and Aldby, with deeper water (>1m) and longer, vegetated shores (e.g., *Typha* stands), support higher duck and crane populations due to abundant prey (e.g., fish, insects) and nesting sites (Chatterjee *et al*., 2020a). In contrast, seasonal pools (Welstead 1, 2) with shorter, degraded shores and sparse vegetation limit these species, favouring adaptable egrets such as *Bubulcus ibis* (Irvine *et al*., 2022). Nekton scarcity in drying pools further reduces stork presence, as seen with *Ephippiorhynchus senegalensis* (Irvine *et al*., 2022).

The endangered *Bugeranus carunculatus*, the threatened *Balearica regulorum*, and the threatened *Ephippiorhynchus senegalensis* were found at only a few sites. However, the community elders noted that the birds used to be found in all villages. The decrease in population sizes of endangered species, such as *Bugeranus carunculatus* and *Balearica regulorum*, is attributed to climate change and habitat loss (Londe *et al*., 2023; Li *et al*., 2025). However, Mukherjee *et al*. (2022) also highlighted metal toxicity as an important factor. Climate change and habitat loss are most likely to have caused the decline in the crane population in the Driefontein wetlands, as only a few small, isolated bushes remain. Encroachment by new smallholder farmers into the wetland core has forced the crane species out of the wetlands, as they are shy. These findings align with those of Wang *et al*. (2023), who noted that if their breeding sites or habitats are disturbed, cranes can migrate permanently over thousands of kilometres to new wetlands with better habitats and breeding sites. However, climate change is a significant factor in the decrease of bird species in wetlands (Li *et al*., 2025), and the crane population is projected to decrease further as wetland health continues to degrade (Ramsar Information Site, 2014). The results of this study confirm the projected decrease in population size as they indicate a notable decrease in the population sizes of bird species in the Driefontein wetlands.

Marambanyika *et al*. (2021) identified habitat loss as a more significant factor in the decline of wetland bird species than climate change. The once perennial Chinu Stream and surrounding earth dams have transformed into seasonal aquatic habitats. This shift likely explains the absence of duck species such as *Sarkidiornis melanotos*, *Anas hottentota*, and *Oxyura maccoa*, which are typically found in permanently aquatic environments; these ducks either migrated or perished due to habitat loss. Consequently, ducks are now only observed in the Shashe River, Good Hope village, and Mapondela earth dams during the summer season. Additionally, the bird species *Ephippiorhynchus senegalensis* and *Scopus umbretta* are likely to have been indirectly affected by a decline in fish and other prey availability. Sathe and Pawar (2021) projected a decrease in the populations of these birds, citing that the ongoing drying of previously perennial wetland pools poses a threat to the African hammerkop (*Ephippiorhynchus senegalensis*), *Scopus umbretta*, various kingfisher species (*Alcedinidae*), and other birds that rely on aquatic organisms for food.

While habitat loss from anthropogenic activities (e.g., veld fires, encroachment) is emphasised, climate drivers, such as shifts in rainfall, are also critical, as noted by key informants who attribute bird disappearances to forced migration. Historical data indicate a 10% decline in annual rainfall over the last century (Mazvimavi, 2010), with average precipitation at 670 mm (1991-2020) showing high variability due to ENSO; El Niño phases reduce rainfall by up to 30% during October-March. Recent trends (2000-2024) reveal an increasing unpredictability, with drier-than-average conditions in southern Africa, including record dryness in Zimbabwe during 2023-2024, linked to El Niño and a positive Indian Ocean Dipole (NOAA, 2024; WMO, 2025). In the Midlands Province, this exacerbates wetland drying, as highveld areas (>1200m, with historical rainfall of >800 mm) face reduced infiltration and seasonal streamflow (e.g., the Chinu River).

The bird species used to estimate wetland health are the *Bubulcus ibis* and *Egretta vinaceigula* egrets. The results of the study showed that *Bubulcus ibis* and *Egretta vinaceigula* were the most abundant wetland indicator bird species in the Driefontein wetlands, indicating that the wetlands remain healthy. This pattern was initially counterintuitive, as these species increased while other wetland birds declined. However, Kahl *et al*. (2022) and Ntongani and Andrew (2013) argued that the *Bubulcus ibis* species has a mutual relationship with livestock, especially cattle, in the Driefontein wetlands, which also implies the possibility of an indirect mutual relationship with people or herdsmen. Thus, habitat destruction by people can quickly affect the birds *B. ibis* and *Egretta vinaceigula* to the extent of forcing them to migrate permanently to new wetlands. The frequent disturbance by people or human encroachment into the core of the wetland did not affect the breeding of *B. ibis* and *E. vinaceigula,* which was also attributed to their undisturbed population growth.

Marambanyika *et al.* (2021) also noted that people in the communities surrounding the Driefontein wetlands do not eat egrets, as they regard them as unpalatable. Thus, their reproduction is not affected by illegal hunting, which also impacts other wetland indicator birds, such as ducks, which are consumed by local communities. Shannon *et al*. (2022) posit that using *B. ibis* and *E. vinaceigula* species populations to assess wetland health is unreliable because a healthy wetland is highly productive and can provide food or prey for every food chain or web level. Additionally, Wang *et al*. (2023) and Sathe and Pawar (2021) opine that *B. ibis* do not entirely depend on prey in wetlands because they also feed on teaks from grazing livestock. Thus, these birds can survive well and multiply in the Driefontein wetlands, even as the wetland deteriorates towards its peak stage.

Results of focus group discussions on the rehabilitation and conservation of Driefontein wetlands indicated the community's willingness to improve the wetland's health. If well-trained, the firefighting team can effectively mitigate habitat loss, prevent the extinction of certain species, and reduce soil erosion across the wetlands. These findings corroborate those of Marambanyika *et al.* (2021), who noted the need to include fireguards, as they yielded better results in Chebvute wetland and habitat restoration. Guarding the wetlands against wildfire can also improve ecosystem biodiversity, making them healthy and productive and a conducive destination or habitat for many species. Disaster Risk Reduction Committees (DRRC) report that fireguards can stop fires, even when outbreaks occur at night. However, there is a need for continuous maintenance of fireguards to prevent fire breaches, as occurred in the Mteo plantation, which has poorly maintained fireguards. However, constructing fireguards in the Driefontein wetlands can be challenging due to the wetland's size.

Construction of weirs along streams can help to maintain moisture in the Driefontein wetlands throughout the year. However, traditional leaders highlighted that their ancestors did not allow the use of cement in the wetland. Afforestation can enhance habitats for wetland species, as observed in many environmental conservation studies (Spieles, 2022). However, successful afforestation and reforestation are rarely achieved in Zimbabwe's wetlands due to a general disregard for environmental requirements. Surrounding communities lack wetland conservation awareness. Pyke *et al*. (2018) highlighted that for wetland conservation processes to succeed, the responsible communities need to be educated on the interrelationship between their livelihoods and the health of the environment. Although fencing of the wetland core is effective in controlling the loss of Driefontein wetland species, Spieles (2022) argued that surrounding communities often fail to implement the project due to a lack of financial resources. Results from previous wetland fencing projects indicate that successful fencing can only be achieved with government and donor support. This underscores the importance of involving all stakeholders in wetland conservation planning from the outset (Kumari *et al*., 2020). Therefore, wetland conservation requires a multidisciplinary approach that incorporates all relevant approaches and stakeholders in decision-making.

Recommendations

To strengthen community-based management, we suggest annual training programs for Local Conservation Groups (LCGs) and village committees (VIDCO/WADCO) focused on wetland monitoring using the developed vegetation and bird indicator tool. Training will include species identification, data collection, and fire management, facilitated by EMA, LID Agency, BirdLife Zimbabwe, and other stakeholders involved in wetland conservation. We also recommend establishing community-managed eco-tourism for birdwatching, with 60% of revenues allocated to local households through VIDCO-led funds for livelihood improvements, such as access to clean water for communities involved in conservation. Different avenues, including carbon trading and private-sector engagement, can be used for providing sustainable wetland conservation funding to protect the hydrological zones that attract concentrations of wetland species and to finance socio-economic conservation programmes. Additionally, implement equitable quotas for sustainable resource harvesting to benefit vulnerable groups and encourage conservation. These actions aim to reduce biodiversity loss by empowering local communities, drawing on successful models from other Zimbabwean wetlands (Marambanyika *et al*., 2021).

The study recommends a bottom-up approach for managing the Driefontein wetland, in which local people, traditional leaders, and local leaders collaborate to develop management strategies that minimise resistance. Experts must provide the Wetland Health Monitoring and Evaluation Tool and facilitate the conservation processes, rather than imposing the strategy on the locals, as this is likely to result in silent resistance.

Figure 7 illustrates a framework for community-driven governance of Driefontein wetlands. Local stakeholders, including traditional leaders and community members, identify conservation needs through participatory processes. They design and implement tailored strategies, such as fire management and weir construction, with support from experts like the Environmental Management Agency. Continuous monitoring of vegetation and avian indicators enables adaptive management, while community-led eco-tourism and equitable resource harvesting support local livelihoods.

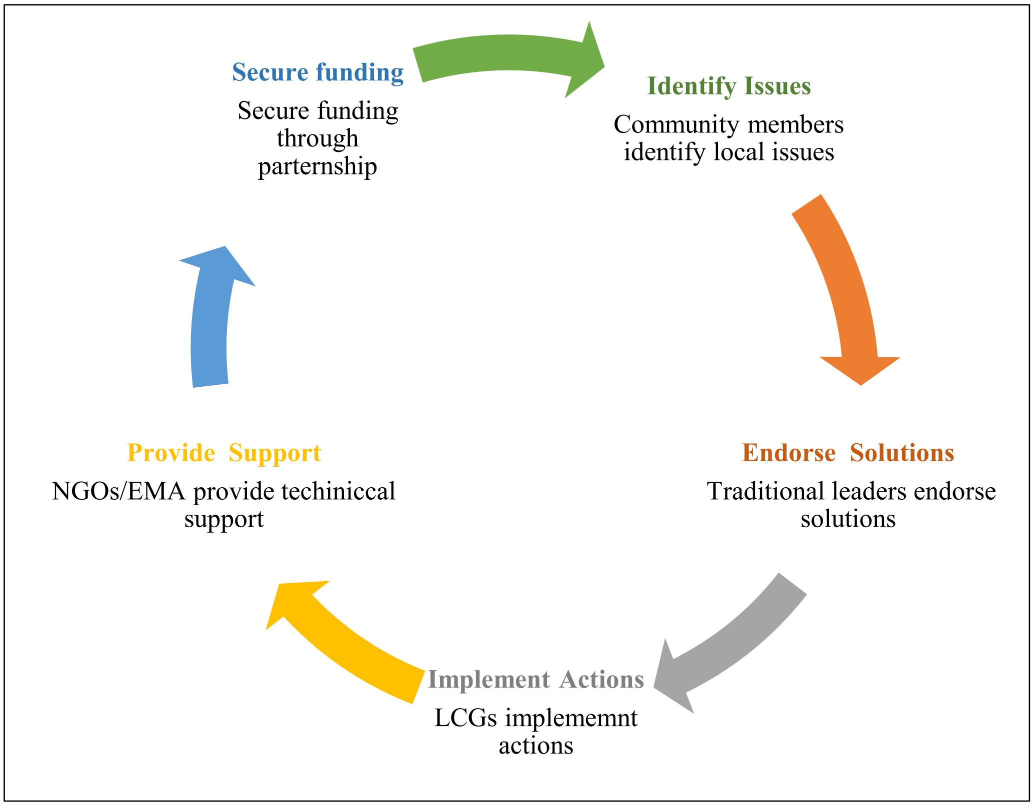

Figure 7: Wetland Community-driven Development Framework

This study has some methodological limitations that should be considered when interpreting the results. The findings of this study cannot be generalized to suit wetlands outside the Midlands Province. A Wetland Health Monitoring and Evaluation Tool tailored to each wetland's needs has to be formulated and provided to local communities (in their local language) so they can utilise it in their decision-making. Further research is required to address seasonality, the lack of hydrological measures, and sample size limitations.

Conclusions

This study demonstrates that the spatial distribution and composition of wetland indicator vegetation in the Driefontein wetlands serve as effective proxies for ecosystem health assessment, particularly during the dry season. Key findings reveal a clear zonation pattern aligned with hydrological gradients, characterised by moisture-dependent species such as *Ludwigia stolonifera* and *Typha latifolia* subsp. *capensis*, *Phragmites mauritianus*, *Phragmites australis*, *Colocasia esculenta*, *Limnobium spongia*, *Cyperus longus*, and *Persicaria senegalensis* dominate within a 20-m radius of water sources. At the same time, intermediate-moisture species such as *Eriocaulon matopense* and *Persicaria attenuata* prevail in the 20–30 m zone. Drought-tolerant species, including *Pycreus macrostachyos*, *Cyperus difformis*, and *Kyllinga melanosperma*, are concentrated in the 30–50-m outer zone. This pattern underscores that species with higher water requirements are confined to proximate zones and exhibit greater sensitivity to moisture stress, manifesting early signs of degradation (e.g., reduced richness and diversity) as hydrological conditions deteriorate.

Complementing vegetation indicators, avian surveys highlight the dominance of adaptable species such as egrets (*Bubulcus ibis* and *Egretta vinaceigula*), which comprised over 66% of observations, alongside declining populations of more specialised wetland-dependent birds like cranes (*Bugeranus carunculatus* and *Balearica regulorum*), ducks (*Sarkidiornis melanotos*, *Oxyura maccoa*, and *Anas hottentota*), and storks (*Ephippiorhynchus senegalensis* and *Scopus umbretta*). These trends reflect ongoing threats, including moisture stress, wildfires, deforestation, overgrazing, and illegal hunting, which exacerbate biodiversity loss and seasonal shifts in bird distributions. Birds aggregate around permanent earth dams in summer and migrate to forested areas along the Chinu stream in winter.

Integrating vegetation and avian indicators establishes a robust, locally relevant monitoring framework for monitoring wetland health. This approach allows for early detection of degradation and supports adaptive management strategies. Importantly, community perspectives underscore the effectiveness of a bottom-up approach, in which local stakeholders lead conservation efforts. These efforts can include activities such as forming firefighting teams, scouting wetlands, constructing weirs, reforesting areas, and implementing controlled grazing practices, all of which are supported by tools and training provided by experts. By strengthening indigenous knowledge and promoting inclusive governance, this strategy not only helps reduce biodiversity loss but also enhances ecosystem services essential to rural livelihoods in semi-arid regions. Future research should validate this tool across various wetland systems, incorporating long-term monitoring and climate projections to enhance its predictive accuracy and scalability.

References

Atiim, J.A.N., Alhassan, E.H. and Abobi, S.M. (2022). Evaluating the contribution of wetlands to food security and livelihoods improvement in the Savelugu Municipality, Ghana. *Wetlands Ecology and Management*, 30(3): 561-577. DOI: https://doi.org/10.1007/s11273-022-09889-x.

Chakraborty, S.K., Sanyal, P. and Ray, R. (2023). Ecosystem services and values of wetlands with special reference with east Kolkata wetlands. In: *Wetlands Ecology: Eco-Biological Uniqueness of a Ramsar Site (East Kolkata Wetlands, India)* (pp. 227-255). Cham: Springer International Publishing. DOI: https://doi.org/10.1007/978-3-031-09253-4.

Chatterjee, A., Adhikari, S., Pal, S. and Mukhopadhyay, S.K. (2020a). Community Structure of Migratory Waterbirds at Two Important Wintering Sites in a Sub-Himalayan Forest Tract in West Bengal, India. *The Ring*, 42(1): 15–37. DOI: https://doi.org/10.2478/ring-2020-0002.

Chatterjee, A., Adhikari, S., Pal, S. and Mukhopadhyay, S.K. (2020b). Foraging guild structure and niche characteristics of waterbirds wintering in selected sub-Himalayan wetlands of India. *Ecological Indicators*, 108: 105693. DOI: https://doi.org/10.1016/j.ecolind.2019.105693.

Das, M., Das, A. and Singha, S. (2025). Development of a comprehensive framework for wetland ecosystem assessment and management. *Geoscience Frontiers*, 16(3): 102036. DOI: https://doi.org/10.1016/j.gsf.2025.102036.

Desmet, P. and Richard C. (2004). Using the species–area relationship to set baseline targets for conservation. *Ecology and Society,* 9(2). Available online at: https://www.jstor.org/stable/26267668 [accessed on 23 October 2025].

Du Toit, M.J., Du Preez, C. and Du Toit, S.S. (2021). Plant diversity and conservation value of wetlands along a rural–urban gradient. *Bothalia-African Biodiversity & Conservation*, 51(1): 1-18. Available online at: https://journals.co.za/doi/abs/10.38201/btha.abc.v51.i1.4 [accessed on 23 October 2025].

Duan, J., Han, J., Cheung, S. G., Chong, R. K. Y., Lo, C. M., Lee, F. W. F. and Zhou, H. C. (2021). How mangrove plants affect microplastic distribution in sediments of coastal wetlands: Case study in Shenzhen Bay, South China. *Science of the Total Environment*, 767: 144695. DOI: https://doi.org/10.1016/j.scitotenv.2020.144695.

Dube, T. (2012). The impact of communal land use on dambos in Lower Gweru, MSc Dissertation, University of Zimbabwe. Available online at: http://www.alumni.uz.ac.zw/handle/10646/839 [accessed on 23 October 2025].

Dube, T., Dube, T. and Marambanyika, T. (2023). A review of wetland vulnerability assessment and monitoring in semi-arid environments of sub-Saharan Africa. *Physics and Chemistry of the Earth, Parts A/B/C*, 132: 103473. DOI: https://doi.org/10.1016/j.pce.2023.103473.

Environmental Management Agency (n.d.). A field guide to wetland identification using indicator plants in Zimbabwe. Wetland Identification Species Manual. 685/6 Lorraine/Faber Drive, Bluffhill Industrial Park, Harare. www.ema.co.zw.

Faber-Langendoen, D., Lemly, J., Nichols, W., Rocchio, J., Walz, K. and Smyth, R. (2019). Development and evaluation of NatureServe's multi-metric ecological integrity assessment method for wetland ecosystems. *Ecological Indicators*, 104: 764–775. DOI: https://doi.org/10.1016/j.ecolind.2019.04.025.

Fraixedas, S., Lindén, A., Piha, M., Cabeza, M., Gregory, R. and Lehikoinen, A. (2020). A state-of-the-art review on birds as indicators of biodiversity: Advances, challenges, and future directions. *Ecological Indicators*, 118: 106728. DOI: https://doi.org/10.1016/j.ecolind.2020.106728.

Irvine, K., Dickens, C., Castello, L., Bredin, I. and Finlayson, C.M. (2022). Vegetated wetlands: from ecology to conservation management. In *Fundamentals of Tropical Freshwater Wetlands*, 38(3): 589-639. DOI: https://doi.org/10.1016/B978-0-12-822362-8.00023-2.

Kahl, S., Navine, A., Denton, T., Klinck, H., Hart, P., Glotin, H. and Joly, A. (2022). Overview of BirdCLEF 2022: Endangered bird species recognition in soundscape recordings. In: *CLEF (Working Notes)*. *Conference and Labs of the Evaluation*

Forum, Bologna, Italy. pp. 1929-1939. Available online at: https://agritrop.cirad.fr/611524/1/611524.pdf [accessed on 20 October 2025].

Kaul, S. and Kumar, R. (2019). Wetland Conservation Ethos. New Delhi: Wetlands International South Asia. pp. 64. Available online at: https://indianwetlands.in/uploads/6.%20Wetland-Conservation-Ethos_2019_Wetland%20International%20South%20Asia.pdf [accessed 16 October 2025].

Kotze, D.C., Macfarlane, D.M., Edwards, R.J. and Madikizela, B. (2020). WET-EcoServices Version 2: A revised ecosystem services assessment technique, and its application to selected wetland and riparian areas. *Water SA,* 46(4): 679-688. DOI: https://doi.org/10.17159/wsa/2020.v46.i4.9084.

Kumari, R., Shukla, S.K., Parmar, K., Bordoloi, N., Kumar, A., Saikia, P. (2020). Wetlands Conservation and Restoration for Ecosystem Services and Halt Biodiversity Loss: An Indian Perspective. In: Upadhyay, A., Singh, R., Singh, D. (eds), *Restoration of Wetland Ecosystem: A Trajectory Towards a Sustainable Environment*. Singapore: Springer. DOI: https://doi.org/10.1007/978-981-13-7665-8_6.

Li, X., Yang, Y., Zhao, P., Lv, D., Zhao, J., Lu, Z. and Zheng, H. (2025). Advancing a climate smart strategy for biodiversity conservation in protected areas on the Qinghai-Xizang Plateau. *Geography and Sustainability*, 6(3): 100264. DOI: https://doi.org/10.1016/j.geosus.2025.100264.

Liu, W., Guo, Z., Jiang, B., Lu, F., Wang, H., Wang, D. and Cui, L. (2020). Improving wetland ecosystem health in China. *Ecological Indicators*, 113: 106184. DOI: https://doi.org/10.1016/j.ecolind.2020.106184.

Londe, D.W., Davis, C.A., Loss, S.R., Robertson, E.P., Haukos, D.A. and Hovick, T.J. (2024). Climate change causes declines and greater extremes in wetland inundation in a region important for wetland birds. *Ecological Applications*, 34(2): e2930. DOI: https://doi.org/10.1002/eap.2930.

Manyakaidze, P., Musavengane, R. and Maponga, R. (2025). Rural Farmer-Managed Wetland Agroecosystems Promote Climate Resilience in Semi-Arid Savannah: Case of Nyororo Wetland, Mberengwa District, Zimbabwe. *Climate Resilience and Sustainability*, 4(1): p.e70011. DOI: https://doi.org/10.1002/cli2.70011.

Marambanyika, T., Mupfiga, U.N., Musasa, T. and Ngwenya, K. (2021). Local perceptions on the impact of drought on Wetland Ecosystem services and associated household livelihood benefits: the case of the Driefontein Ramsar Site in Zimbabwe. *Land*, 10(6): 587. DOI: https://doi.org/10.3390/land10060587.

Mariyappan, M., Rajendran, M., Velu, S., Johnson, A.D., Dinesh, G.K., Solaimuthu, K. and Sankar, M. (2023). Ecological role and ecosystem services of birds: a review. *International Journal of Environment and Climate Change*, 13(6): 76-87. DOI: https://doi.org/10.9734/ijecc/2023/v13i61800.

Mazvimavi, D. (2010). Investigating changes over time of annual rainfall in Zimbabwe. *Hydrology and Earth System Sciences Discussions*, 7(2): 2693-2715. DOI: https://hess.copernicus.org/articles/14/2671/2010/.

Mukherjee, A., Pal, S., Das, P. and Mukhopadhyay, S.K. (2022). Heavy metal exposure to a migratory waterfowl, Northern Pintail (Anas acuta), in two peri-urban wetlands. *Science of The Total Environment*, 851: 158238. DOI: https://doi.org/10.1016/j.scitotenv.2022.158238.

Muneepeerakul, C.P., Miralles-Wilhelm, F., Tamea, S., Rinaldo, A. and Rodriguez-Iturbe, I. (2008). Coupled hydrologic and vegetation dynamics in wetland ecosystems. *Water Resources Research*, 44(7): 2007WR006528. DOI: https://doi.org/10.1029/2007WR006528.

Mutyavaviri, F. (2006). Impact of cultivation on soil and species composition of the Monavale Vlei, Harare. Department of biological Sciences; U Z, Harare. Available online at: https://ir.uz.ac.zw/xmlui/bitstream/10646/878/1/Mutyavaviri_Fungai_Thesis.pdf [accessed 02 June 2025].

Nikitina, O.I., Dubinina, V.G., Bolgov, M.V., Parilov, M.P. and Parilova, T.A. (2020). Environmental flow releases for wetland biodiversity conservation in the Amur River Basin. *Water*, 12(10): 2812. DOI: https://doi.org/10.3390/w12102812.

Ntongani, W.A. and Andrew, S.M. (2013). Bird species composition and diversity in habitats with different disturbance histories at Kilombero Wetland, Tanzania, *Open Journal of Ecology*, 3(7): 482-488. DOI: https://doi.org/10.4236/oje.2013.37056.

Pyke, M.L., Toussaint, S., Close, P.G., Dobbs, R.J., Davey, I., George, K.J. and Clifton, J. (2018). Wetlands need people: a framework for understanding and promoting Australian indigenous wetland management. *Ecology and Society*, 23(3): 43. https://doi.org/10.5751/ES-10283-230343.

Qazi, AW., Saqib, Z. and Zaman-ul-Haq, M. (2022). Trends in species distribution modelling in context of rare and endemic plants: a systematic review. *Ecological Processes*, 11(1): 1-11. DOI: https://doi.org/10.1186/s13717-022-00384-y.

Ramsar Information Site, (2014). Ramsar Information Sheet: Driefontein Grasslands. *Ramsar Sites Information Service,* 1-22. Available online at: https://rsis.ramsar.org/RISapp/files/RISrep/ZW2104RIS_1602_en.pdf [accessed on 12 September 2025]

Rawat, M., Pandey, A., Gupta, P.K., Yadav, B. and Patel, J.G. (2025). A novel framework for wetland health assessment using hydro-ecological indicators and landscape metrics. *Modeling Earth Systems and Environment*, 11(3): 167. DOI: https://doi.org/10.1007/s40808-025-02371-6.

Ridolfi, L., D'Odorico, P. and Laio, F. (2006). Effect of vegetation–water table feedbacks on the stability and resilience of plant ecosystems. *Water Resources Research*, 42(1). DOI: https://doi.org/10.1029/2005WR004444.

Sathe, T. and Pawar, N. (2021). Migratory Bird Behaviour in a Changing World: Tracking and Modelling Long-Distance Journeys. *International Journal of Agriculture and Animal Production*, 02. DOI: https://doi.org/10.55529/ijaap.21.47.58.

Shannon, J., Kolka, R., Van Grinsven, M. and Liu, F. (2022). Joint impacts of future climate conditions and invasive species on black ash forested wetlands. *Front. For. Glob. Change,* 5: 957526, DOI: https://doi.org/10.3389/ffgc.2022.957526.

Siddig, A.A.H., Ellison, A.M., Ochs, A., Villar-Leeman, C. and Lau, M.K. (2016). How do ecologists select and use indicator species to monitor ecological change? Insights from 14 years of publication in Ecological Indicators. *Ecological Indicators*, 60: 223–230. DOI: https://doi.org/10.1016/j.ecolind.2015.06.036.

Southwood, T.R.E and Henderson, P.A. (2009). *Ecological methods*. John Wiley and Sons. Available online at: https://www.researchgate.net/profile/Peter-Henderson-8/publication/260051655 [accessed 09 August 2025].

Spieles, D.J. (2022). Wetland construction, restoration, and integration: A comparative review. *Land*, 11(4): 554. DOI: https://doi.org/10.3390/land11040554.

Volpato, G.H., Lopes, E.V., Mendonça, L.B., Boçon, R., Bisheimer, M.V., Serafini, P.P. and Anjos, L.D. (2009). The use of the point count method for bird survey in the Atlantic forest. *Zoologia (curitiba)*, 26(1): 74-78. DOI: https://doi.org/10.1590/S1984-46702009000100012.

Wang, G., Wu, H., Dai, J., Xiong, Y., Long, Y., Cai, X. and Liu, Y. (2023). Priorities identification of habitat restoration for migratory birds under the increased water level during the middle of dry season: A case study of Poyang Lake and Dongting Lake wetlands, China. *Ecological Indicators*, 151: 110322. DOI: https://doi.org/10.1016/j.ecolind.2023.110322.

Wu, C., Chen, W., Cao, C., Tian, R., Liu, D. and Bao, D. (2018). Diagnosis of wetland ecosystem health in the Zoige Wetland, Sichuan of China. *Wetlands*, 38: 469-484. DOI: https://doi.org/10.1007/s13157-018-0992-y.

Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*
Conceived and designed the research or analysis	Yes	Yes	Yes	Yes	Yes
Collected the data	No	Yes	No	No	No
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	Yes	No	No	No
Critical revision of the article/paper	Yes	Yes	Yes	Yes	Yes
Editing of the article/paper	No	Yes	No	No	No
Supervision	Yes	No	Yes	Yes	Yes
Project Administration	No	Yes	No	No	No
Funding Acquisition	Yes	No	Yes	Yes	Yes
Overall Contribution Proportion (%)	20	20	20	20	20

Funding
No financial support was received for the research and writing of this article.

Research involving human bodies or organs or tissues (Helsinki Declaration)
The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

Research involving animals (ARRIVE Checklist)
The author(s) solemnly declare(s) that this research has not involved any animal subject (body or organs) for experimentation. The research was not based on laboratory experiment involving any kind animal. The contexts of animals were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of ARRIVE does not apply in cases of this study or written work.

Research on Indigenous Peoples and/or Traditional Knowledge
The author(s) solemnly declare(s) that this research has not involved Indigenous Peoples as participants or respondents. The contexts of Indigenous Peoples or Indigenous Knowledge were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

Research involving Plants
The author(s) solemnly declare(s) that this research has not involved the plants for experiment and field studies. Some contexts of plants are also indirectly covered through literature review. Thus, during this research the author(s) obeyed the principles of the Convention on Biological Diversity and the Convention on the Trade in Endangered Species of Wild Fauna and Flora.

Research Involving Local Community Participants (Non-Indigenous) or Children
The author(s) solemnly declare(s) that this research has not directly involved any local community participants or respondents belonging to non-Indigenous peoples. Neither this study involved any child in any form directly. The contexts of different humans, people, populations, men/women/children and ethnic people were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or prior informed consent (PIC) of the respondents or Self-Declaration in this regard does not apply in cases of this study or written work.

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)
The author(s) has/have complied with PRISMA standards to an extent.

Competing Interests/Conflict of Interest
Author(s) has/have no competing financial, professional, or personal interests from other parties or in publishing this manuscript. There is no conflict of interest with the publisher or the editorial team or the reviewers.

Attribution and Representation
All opinions and mistakes are the author(s)' own and cannot be attributed to the institutions they represent. The publisher is also not responsible either for such opinions and mistakes in the text or graphs or images.

Declaration of the Use of AI
During the preparation of this work, the authors used AI to assists the script translation, language editing, grammar correction, reference management, improving readability and proof reading. The author(s) declared that the use of AI has not compromised originality, leading to plagiarism, or violating data privacy and copyright. Author(s) is/are responsible that AI use complies with ethical standards of research and publication. It is also declared that AI-generated content fabricating data, references or findings is strictly avoided and not included. Author(s) adhered the AI's upper usage limit of 15% as fixed by the journal.

Rights and Permissions

***

To see original copy of these declarations signed by Corresponding/First Author (on behalf of other co-authors too), please download associated zip folder [Declarations] from the published Abstract page accessible through and linked with the DOI: https://doi.org/10.33002/nr2581.6853.080315.