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Waterbirds persisted while terrestrial birds collapsed: contrasting habitat-guild responses to reservoir desilting in a wintering bird assemblage, western India

Soham Prajapati[1]
Sardar Patel University
Harsh Suthar[2]
Vitthalbhai Patel & Rajratna P.T. Patel Science College
Umang Sutariya
untamedumang01@gmail.com

Vitthalbhai Patel & Rajratna P.T. Patel Science College

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Abstract

Desilting and dredging are widely used to restore the storage capacity of shallow tropical reservoirs, and their ecological effects are usually assessed in terms of waterbirds. We monitored the bird assemblage of Pariyej reservoir, Gujarat, western India, across four consecutive wintering seasons (November–March, 2022–2023 to 2025–2026; ten visits per season) spanning a desilting programme during which the reservoir was drained from February 2024 and refilled after the following monsoon. Species were assigned to five habitat guilds, and seasonal comparisons used the November–February core wintering window. We recorded 154 species in 18 orders and 54 families. Per-visit richness fell from 117.1 ± 4.6 to 47.8 ± 2.3 species and recovered to 115.5 ± 3.1 (Kruskal–Wallis $H = 26.09$, $p < 0.001$; $\varepsilon^2 = 0.825$), with the first and last season's statistically indistinguishable. Sample coverage exceeded 99.9% throughout, so these changes were not detection artefacts. The decline was strongly guild-dependent and ran opposite to expectation: scrub- and tree-dependent birds lost 74% of per-visit richness and 88% of abundance, whereas open-water birds ended the study at 129% of baseline richness and 160% of baseline abundance. The wetland-dependent share of individuals rose from 63.9% to 89.0% during the works before returning to 65.9% ($H = 26.41$, $p < 0.001$). Season explained 87% of compositional variance (PERMANOVA pseudo-$F = 60.33$, $p = 0.0001$). The assemblage did not lose its waterbirds; it lost the terrestrial community dependent on fringing woody vegetation, which conventional waterbird-focused impact assessment would not have detected.

Introduction

Shallow reservoirs in the seasonal tropics accumulate sediment rapidly, and desilting is among the most common interventions used to restore their storage capacity. In Gujarat, western India, more than 221 lakh cubic metres of silt were removed from about 1,474 water bodies between 2022 and 2025 under a single state programme. Many of the water bodies treated in such programmes are simultaneously recognised as wetlands of conservation importance, so the same site can be an engineering asset and a protected habitat at once (Kingsford et al. 2016; Ma et al. 2010).

Where the ecological consequences of these interventions are considered at all, they are framed around waterbirds. This is understandable, since waterbirds are conspicuous, countable and the basis of most wetland designations, and they are widely used as indicators of wetland condition (Kushlan 1993; Green and Elmberg 2014). It also embeds an assumption: that the ecological value of a reservoir resides in its water, and that draining and dredging the basin will principally affect the birds that use open water and mudflat.

That assumption overlooks the structure of these sites. A reservoir in an agricultural landscape is not only a water body but a vegetated edge — reedbed, tall grass, scrub and scattered trees — that supports a terrestrial bird assemblage often richer in species than the waterbird assemblage itself (Pino et al. 2000; Şekercioğlu 2006). Desilting operations clear this fringe to provide access for machinery and to

dispose of excavated material, so the intervention alters two habitats at once while monitoring typically attends to only one.

Testing this requires a site surveyed consistently before, during and after such works, with species classified by the habitat they actually use rather than by taxonomic order alone. Pariyej reservoir in central Gujarat provides that combination. It is a wetland of national importance and an Important Bird and Biodiversity Area, it was surveyed with an unchanged protocol across four consecutive wintering seasons, and a desilting and remodeling programme was carried out within that window, with the reservoir drained from February 2024 (Government of Gujarat 2023; Ghai 2024).

We asked three questions. First, how did richness, abundance and diversity of the whole assemblage change across the four seasons, and was any recovery statistically complete? Second, did habitat guilds respond differently, and specifically did birds dependent on fringing woody vegetation decline more than bird's dependent on open water? Third, did the relative contribution of wetland-dependent and non-wetland birds shift during the works? We predicted that if the intervention acted principally through removal of water, open-water and mudflat guilds would decline most; if it acted principally through removal of fringing vegetation, scrub- and tree-dependent guilds would decline most and the assemblage would become more, not less, dominated by wetland-dependent birds.

Methods

Study area and management intervention

Pariyej reservoir (22°33'N, 72°38'E; Fig. 1) lies in Matar taluka of Kheda district, central Gujarat, western India. It is among the larger artificial freshwater wetlands of the region, with reported water depths averaging 2 m and reaching about 3.2 m (Parasharya and Jani 2006; Parmar and Acharya 2015). The reservoir supplies irrigation and drinking water, is designated a wetland of national importance by the Ministry of Environment, Forest and Climate Change, is recognised as an Important Bird and Biodiversity Area, and was ranked in the highest biodiversity priority class in the national inland wetland assessment (Vijayan 2004). Open water is bounded by submerged, floating and emergent hydrophytes and, beyond these, by a fringe of tall grass, scrub and scattered trees, with cropland forming the surrounding matrix.

The reservoir normally retains water through the year (Chaudhari et al. 2023) but underwent major engineering works during the present study. A desilting and remodelling scheme was taken up by the Irrigation Department, Government of Gujarat (Government of Gujarat 2023), and desilting and dredging were carried out through 2024. Contemporary reporting establishes that the reservoir had been drained from February 2024 and that dredging was still in progress in June of that year, when a fire in the exposed bed and fringing vegetation killed a mugger crocodile *Crocodylus palustris* and several turtles; rescuers described clearing tall grass along the reservoir edge (Ghai 2024). Standing water and fringing vegetation were therefore both reduced across the 2024 dry season, and the reservoir refilled after the following monsoon.

Survey design

Surveys covered four consecutive seasons: November 2022–March 2023, November 2023–March 2024, November 2024–March 2025 and November 2025–March 2026. Each season comprised five months surveyed twice per month, giving ten visits per season and 40 visits in total. Effort was constant across seasons in number of visits, seasonal timing, observers and protocol. Seasonal comparisons reported below use the November–February core wintering window (eight visits per season, 32 in total) so that the compared period is restricted to when migrants are established; March counts are retained and presented separately in the analysis of within-winter phenology, since March represents the departure period rather than the wintering period proper.

Birds were recorded using fixed-radius point counts distributed by stratified random sampling across the habitat zones of the reservoir, with each visit comprising a morning session from dawn until 10:30 h and an evening session from 16:00 h until dusk.

Observations used a 60× spotting scope and 8×42 and 10×50 binoculars, allowing distant birds to be identified without approach. Photographic vouchers were obtained with digital SLR and bridge cameras. Identification followed Grimmett et al. (2011) and Ali and Ripley (1983); automated tools were used only as a preliminary aid and every such record was confirmed by direct observation, photograph or an experienced observer. Behavioural notes followed ad libitum sampling (Altmann 1974) and checklists were archived on eBird.

Species classification

Each species was assigned to one of five habitat guilds defined by the stratum in which it principally forages and shelters at this site (Table 1). Guilds were pooled into wetland-dependent (open water, shallow water and mudflat, marsh and reedbed fringe) and non-wetland (scrub and tree, open ground and aerial) categories. Residential status, feeding habit, order and family follow the authors' field classification; conservation status follows the IUCN Red List (IUCN 2025). The full annotated checklist is given in Online Resource 1.

Data analysis

For each visit, richness (S) was the number of species recorded and abundance (N) the total individuals counted. Diversity was expressed as Hill numbers, the effective number of species at orders q = 0, 1 and 2 (Jost 2006; Chao et al. 2014), and sample completeness was assessed as coverage-based sample coverage (Chao and Jost 2012). Differences among seasons in per-visit richness, abundance, guild richness and the wetland-dependent share of individuals were tested by Kruskal–Wallis tests with Dunn post-hoc comparisons and Bonferroni correction, with ε^2 reported as effect size. Assemblage composition was compared by permutational multivariate analysis of variance on Bray–Curtis

dissimilarities of relative abundance (9,999 permutations) and visualised by non-metric multidimensional scaling. Species contributions to the dissimilarity between the richest and poorest seasons were assessed by a SIMPER-type decomposition. Incidence-based Sørensen dissimilarity was partitioned into turnover and nestedness-resultant components following Baselga (2010). Community dissimilarity indices were calculated in R version 4.x (R Core Team, 2025) using the betapart package (Baselga & Orme, 2012). The package was used to partition overall Sørensen dissimilarity into its turnover and nestedness-resultant components, following the framework proposed by Baselga (2010).

Table 1 Habitat guilds used in this study, with definitions and the number of species assigned to each

Guild	Definition	Species	Category
Open water	Forages by diving or swimming in standing water away from the shoreline	14	Wetland-dependent
Shallow water and mudflat	Wades or dabbles in shallow water, on exposed mud or at the water's edge	38	Wetland-dependent
Marsh and reedbed fringe	Uses emergent vegetation, floating vegetation or wet grassland at the margin	14	Wetland-dependent
Scrub and tree	Depends on woody vegetation for foraging, perching or nesting	57	Non-wetland
Open ground and aerial	Forages on open ground, short grass, cropland or on the wing	31	Non-wetland
Total		**154**	

Results

Assemblage composition

We recorded 154 bird species in 18 orders and 54 families. Passeriformes was richest with 60 species, followed by Charadriiformes (21), Pelecaniformes (14) and Anseriformes (13) (Table 2). Non-wetland guilds accounted for 88 of the 154 species and wetland-dependent guilds for 66, so the site held more terrestrial than wetland bird species across the study as a whole (Table 1). Ten species of global conservation concern were recorded, four Vulnerable and six Near Threatened (Table 3).

Table 2 Ordinal composition of the bird assemblage recorded at Pariyej reservoir

Order	Families	Species	Order	Species
Passeriformes	25	60	Ciconiiformes	3
Charadriiformes	6	21	Suliformes	3
Pelecaniformes	3	14	Psittaciformes	3
Anseriformes	1	13	Galliformes	2
Accipitriformes	1	7	Bucerotiformes	2
Columbiformes	1	6	Piciformes	2
Coraciiformes	3	6	Podicipediformes	1
Gruiformes	2	5	Apodiformes	1
Cuculiformes	1	4	Strigiformes	1

Table 3 Globally threatened and near-threatened species recorded at Pariyej reservoir

Common name	Scientific name	IUCN	Status	Guild
Greater spotted eagle	*Clanga clanga*	VU	Migratory	Scrub and tree
Common pochard	*Aythya ferina*	VU	Migratory	Open water
River tern	*Sterna aurantia*	VU	Resident	Open water
Sarus crane	*Antigone antigone*	VU	Resident	Marsh fringe
Woolly-necked stork	*Ciconia episcopus*	NT	Resident	Shallow water
Painted stork	*Mycteria leucocephala*	NT	Migratory	Shallow water
Bar-tailed godwit	*Limosa lapponica*	NT	Migratory	Shallow water
Dalmatian pelican	*Pelecanus crispus*	NT	Migratory	Open water
Indian roller	*Coracias benghalensis*	NT	Resident	Scrub and tree
Alexandrine parakeet	*Psittacula eupatria*	NT	Resident	Scrub and tree

VU Vulnerable, NT Near Threatened.

Decline and statistically complete recovery

Per-visit richness differed strongly among seasons (Kruskal–Wallis H = 26.09, df = 3, $p < 0.001$; $\varepsilon^2 = 0.825$). It fell from 117.1 ± 4.6 species in 2022–2023 to 53.4 ± 2.8 in 2023–2024 and 47.8 ± 2.3 in 2024–2025, then returned to 115.5 ± 3.1 in 2025–2026 (Fig. 2a). Per-visit abundance followed the same

trajectory (H = 21.42, p < 0.001; ε^2 = 0.658), falling from 1,733 ± 379 to 896 ± 193 individuals and rising to a study maximum of 1,915 ± 419 (Fig. 2b). Season totals were 132, 58, 52 and 131 species.

Post-hoc comparisons located the effect precisely (Table 4). The first season differed from both depauperate seasons, and the final season differed from both, but the first and last seasons were statistically indistinguishable in richness (z = 0.53, p = 1.000) and in abundance (z = −0.64, p = 1.000). Recovery was therefore complete rather than partial.

Table 4 Kruskal–Wallis and Dunn post-hoc comparisons of per-visit richness, abundance and wetland-dependent share of individuals among wintering seasons

Comparison	Richness z	Abundance z	Wetland share z
2022–23 vs 2023–24	+2.89 *	+3.25 **	−2.80 *
2022–23 vs 2024–25	+4.46 ***	+2.51 ns	−4.50 ***
2022–23 vs 2025–26	**+0.53 ns**	**−0.64 ns**	**−0.48 ns**
2023–24 vs 2024–25	+1.57 ns	−0.75 ns	−1.71 ns
2023–24 vs 2025–26	−2.36 ns	−3.89 ***	+2.32 ns
2024–25 vs 2025–26	−3.93 ***	−3.14 **	+4.02 ***

Bonferroni-adjusted: *** p < 0.001, ** p < 0.01, * p < 0.05, ns not significant. Omnibus tests: richness H = 26.09, abundance H = 21.42, wetland share H = 26.41, all p < 0.001, df = 3. The first-versus-last comparison is shown in bold; it is non-significant on all three measures.

Hill numbers and sample coverage confirmed the pattern and excluded a sampling explanation for it (Fig. 7). Effective species numbers at q = 0, 1 and 2 all halved and recovered, while sample coverage ranged from 99.98% to 100.00% in every season, with at most three singleton species per season. The depauperate seasons were not incompletely sampled rich assemblages; the species were genuinely absent.

Habitat guilds responded in opposite directions

All five habitat guilds declined significantly across seasons, but the magnitude of decline scaled with dependence on woody vegetation rather than on water (Fig. 3; Table 5). Scrub- and tree-dependent birds fell from 43.9 to 11.2 species per visit, a loss of 74% (H = 28.74, p < 0.001), and open-ground and aerial birds fell by 67% (H = 26.58, p < 0.001). Wetland guilds were considerably less affected: shallow-water and mudflat birds lost 42% (H = 23.62, p < 0.001), and open-water and marsh-fringe birds 52% each.

The contrast is starker in abundance and at the end of the study. Scrub and tree abundance fell by 88%, from 2,702 to 320 individuals per season, and recovered only to 81% of its baseline. Open-water

abundance fell by 40% but finished at 160% of baseline, and open-water richness finished at 129% of baseline. Shallow-water and open-ground abundance also finished above baseline, at 113% and 129% respectively. The reservoir therefore ended the study holding more waterbirds than before the intervention, while the scrub and tree assemblage had not fully returned.

Table 5 Habitat-guild richness and abundance across wintering seasons, with Kruskal–Wallis tests on per-visit richness

Guild	2022–23	2023–24	2024–25	2025–26	Loss at trough	Final vs baseline	H
Open water	8.1	3.9	4.8	10.5	52%	129%	26.31
Shallow water and mudflat	30.1	17.8	17.4	29.6	42%	98%	23.62
Marsh and reedbed fringe	10.9	5.2	6.4	11.2	52%	103%	25.74
Scrub and tree	**43.9**	**15.2**	**11.2**	**39.2**	**74%**	**89%**	**28.74**
Open ground and aerial	24.1	11.2	8.0	24.9	67%	103%	26.58

Values are mean species per visit. All Kruskal–Wallis tests df = 3, $p < 0.001$. Season abundance totals: open water 1,497 / 1,703 / 896 / 2,395; shallow water 5,775 / 2,775 / 5,238 / 6,529; marsh fringe 1,595 / 1,213 / 1,263 / 1,244; scrub and tree 2,702 / 613 / 320 / 2,180; open ground 2,296 / 868 / 573 / 2,973.

The assemblage became more wetland-dominated during the works

The clearest expression of the guild asymmetry is the changing balance of the assemblage itself (Fig. 4). The proportion of individuals belonging to wetland-dependent guilds rose from 63.9 ± 2.5% in 2022–2023 to 79.2 ± 1.5% in 2023–2024 and 89.0 ± 1.6% in 2024–2025, then fell back to 65.9 ± 3.9% in 2025–2026 ($H = 26.41$, $p < 0.001$). The first and last seasons did not differ ($z = -0.48$, $p = 1.000$). During the period when the reservoir was drained and dredged, then, nearly nine in ten birds present were wetland-dependent, against roughly six in ten before and after.

Compositional structure

Non-metric multidimensional scaling separated the four seasons into discrete, tight clusters with low stress (0.056), and the two species-rich seasons occupied adjacent regions of ordination space while the two depauperate seasons were widely separated from them and from each other (Fig. 5). Season

accounted for 87% of variance in Bray–Curtis dissimilarity (PERMANOVA pseudo-F = 60.33, R^2 = 0.866, p = 0.0001).

Species-level decomposition of the difference between the richest and poorest seasons identified the drivers directly (Fig. 6). The largest declines were in scrub- and tree-dependent species that disappeared entirely — rosy starling (90.2 to 0 individuals per visit), rose-ringed parakeet (59.6 to 0) and brahminy starling (49.1 to 0) — together with cattle egret (66.0 to 0), an open-ground forager. The largest increases were all in waterfowl and waders: northern pintail rose from 14.8 to 60.0 individuals per visit, ruddy shelduck from 27.1 to 53.2, common teal from 63.9 to 89.0 and Indian spot-billed duck from 12.4 to 29.6.

Ordered loss rather than species replacement

Partitioning of incidence-based dissimilarity showed that the depauperate assemblages were nested subsets of the rich ones rather than alternative communities (Fig. 8; Table 6). Between 2022–2023 and 2024–2025 nestedness accounted for 88% of total Sørensen dissimilarity (β_{sne} = 0.410 against β_{sim} = 0.058). The first and last seasons were almost identical in composition (Sørensen similarity 0.905, 119 species shared), whereas every other pair fell near 0.52. The final transition added 84 species and lost five.

Table 6 Pairwise partitioning of Sørensen dissimilarity between wintering seasons

Season pair	Shared	Unique	β sor	β sim	β sne	% nested
2022–23 vs 2023–24	49	83 / 9	0.484	0.155	0.329	68.0
2022–23 vs 2024–25	49	83 / 3	0.467	0.058	0.410	87.7
2022–23 vs 2025–26	**119**	**13 / 12**	**0.095**	**0.092**	**0.003**	**3.6**
2023–24 vs 2024–25	30	28 / 22	0.455	0.423	0.031	6.9
2023–24 vs 2025–26	49	9 / 82	0.481	0.155	0.326	67.8
2024–25 vs 2025–26	47	5 / 84	0.486	0.096	0.390	80.2

Within-winter phenology

Richness and abundance within each season rose from November to a peak in December and January, remained high in February and declined in March (Fig. 9). This was consistent across all four seasons despite the large differences in their absolute values, with peak richness of 120.5 species per visit in January 2023 and 119.0 in January 2026. The pattern was flattest in 2024–2025, when richness varied by only three species across the whole season, indicating that the depauperate assemblage was not only smaller but also less seasonally structured.

Discussion

The intervention acted through vegetation, not water

The central result is that the guild most damaged by draining and dredging a reservoir was the one least associated with its water. Scrub- and tree-dependent birds lost three-quarters of their per-visit richness and nearly nine-tenths of their abundance, while open-water birds ended the study richer and substantially more abundant than they began. Had the intervention acted principally by removing water, this ordering would have been reversed.

Two lines of evidence indicate that fringing vegetation was the mediating variable. First, the loss ordered itself along a gradient of dependence on woody and structural vegetation rather than on water depth: scrub and tree birds were worst affected, open-ground birds next, and the three wetland guilds least. Second, the species that vanished entirely were those requiring perches, cavities and canopy — starlings, parakeets, and among the raptors the whole of Accipitridae — rather than species requiring particular water depths. Independent reporting from the site describes fire in the fringing vegetation and the clearing of tall grass along the reservoir edge during the works (Ghai 2024), which is consistent with removal of this stratum.

The recovery of open-water birds to above baseline is explicable on the same reasoning. Desilting deepens a basin and restores storage, so a refilled reservoir may offer more open-water habitat than the silted one it replaced. Waterfowl responded accordingly, with northern pintail quadrupling and open-water abundance reaching 160% of baseline. The intervention was, for the waterbird assemblage, broadly beneficial in the medium term.

Why waterbird-focused assessment would have missed this

Had this site been monitored in the conventional way, by counting waterbirds, the conclusion would have been that desilting caused a temporary dip followed by improvement. That conclusion would be correct as far as it went and would have missed the larger part of the effect, because the assemblage that collapsed was terrestrial and the site holds more terrestrial than wetland bird species. This is a general risk wherever a water body is treated as synonymous with its water for assessment purposes, and it applies to a large number of sites: the Gujarat desilting programme alone covered around 1,474 water bodies, many in landscapes where reservoir fringes provide the only woody vegetation for some distance.

The practical implication is that impact assessment and post-works monitoring at wetlands of recognised ornithological value should cover the fringe as well as the basin. A guild-based classification of the kind used here is inexpensive, requires no additional fieldwork, and would have flagged the effect in the first season.

Recovery, resilience and what it required

Recovery was statistically complete for the assemblage as a whole: first and last seasons did not differ in per-visit richness, abundance or wetland-dependent share, and shared 119 of 131 species. Reassembly of this completeness within a single season requires that the habitat returned to a usable state and that a regional source pool persisted within colonising distance, and both evidently held. The nestedness result reinforces this, since the depauperate assemblages were ordered subsets rather than novel communities, so recovery involved the return of the same species rather than replacement by others (Baselga 2010; Ulrich et al. 2009).

Recovery was nonetheless not uniform. Scrub and tree birds returned to 89% of baseline richness and 81% of baseline abundance while every other guild met or exceeded its baseline, which is what would be expected if woody vegetation regenerates more slowly than water refills. Whether this residual shortfall closes is a question for continued monitoring.

Methodological strengths and limitations

Sample coverage exceeded 99.9% in every season, with at most three singleton species, so the differences reported here cannot be attributed to differential detection — a concern that applies to most comparisons of this kind and that is rarely tested. Effort was constant in visits, timing, observers and protocol. The effect sizes are large: season explained 87% of compositional variance and ε^2 for per-visit richness was 0.825.

Three limitations remain. First, no environmental variables were measured, so the association between the works and the assemblage rests on the coincidence of documented dates with the survey series rather than on a fitted relationship; water extent, depth and fringe vegetation cover were not quantified. Second, the design is a single site with four seasons and one intervention, so the generality of the guild asymmetry cannot be established here. Third, the timing is not an exact match: drainage is documented from February 2024, the final month of the 2023–2024 season, yet richness had already fallen in that season, implying either earlier preparatory works or an additional contributing factor.

Implications for management

Three recommendations follow. Desilting at wetlands of recognised ornithological value should be planned in consultation with the forest department, which at this site was not consulted despite a departmental facility on the reservoir edge (Ghai 2024). Where the engineering allows, works should be scheduled so that both refilling and fringe regeneration are advanced before the November to February wintering window. And fringing vegetation should be treated as a habitat to be retained in part rather than as an obstacle to machinery: retaining unburnt refugia along a portion of the perimeter would be expected to reduce the terrestrial loss substantially, at low cost to the engineering objective.

Declarations

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Ethics approval: This study was purely observational; no bird was captured, handled or disturbed.

Data availability: The datasets generated and/or analysed during the current study will be made available in a publicly accessible repository upon publication of the article or as requested by the editor or reviewer.

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Figures

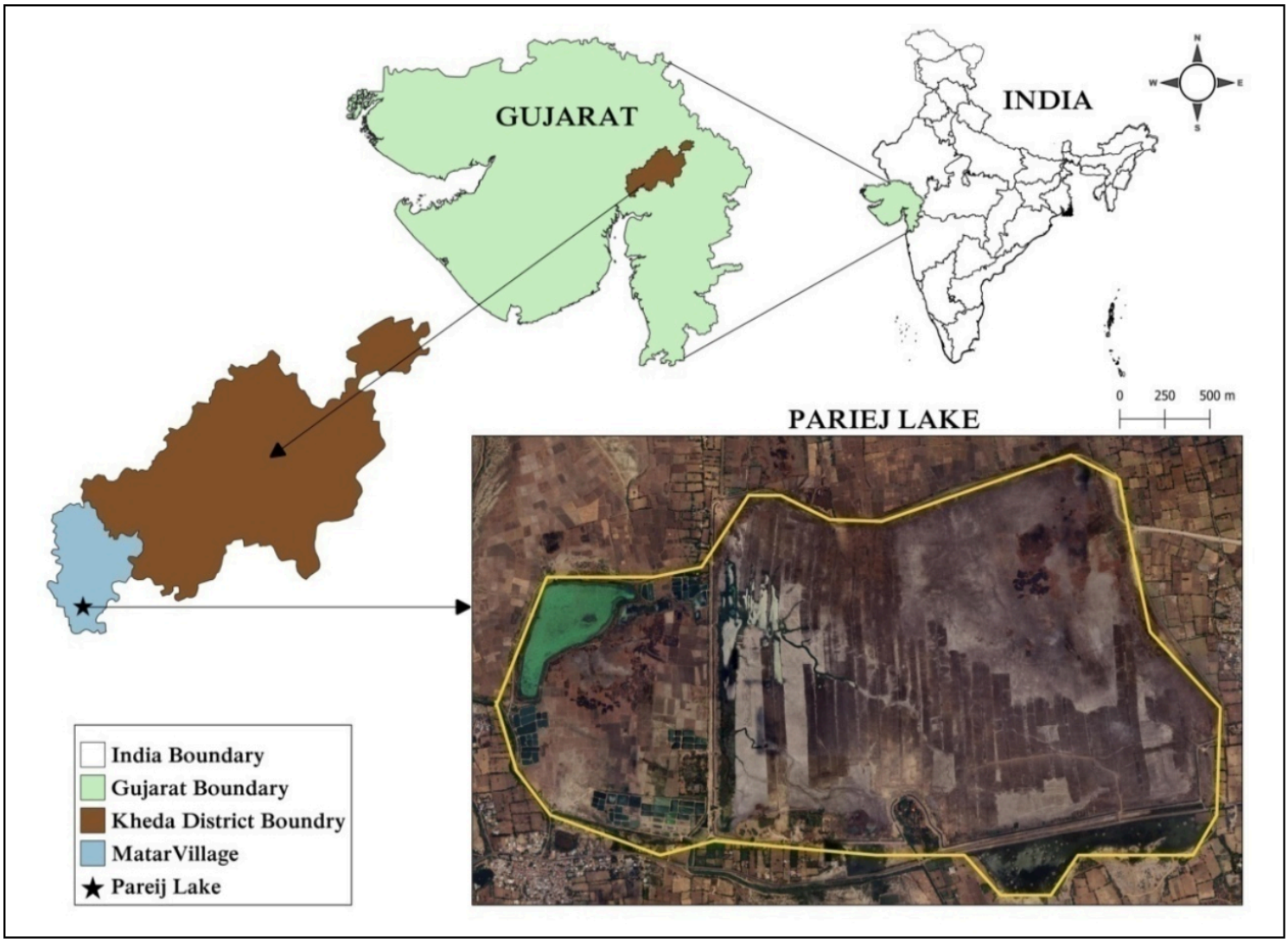


Figure 1

Location of Pariyej reservoir in Matar taluka, Kheda district, Gujarat, western India, showing open water, fringing vegetation, point-count stations and surrounding land use

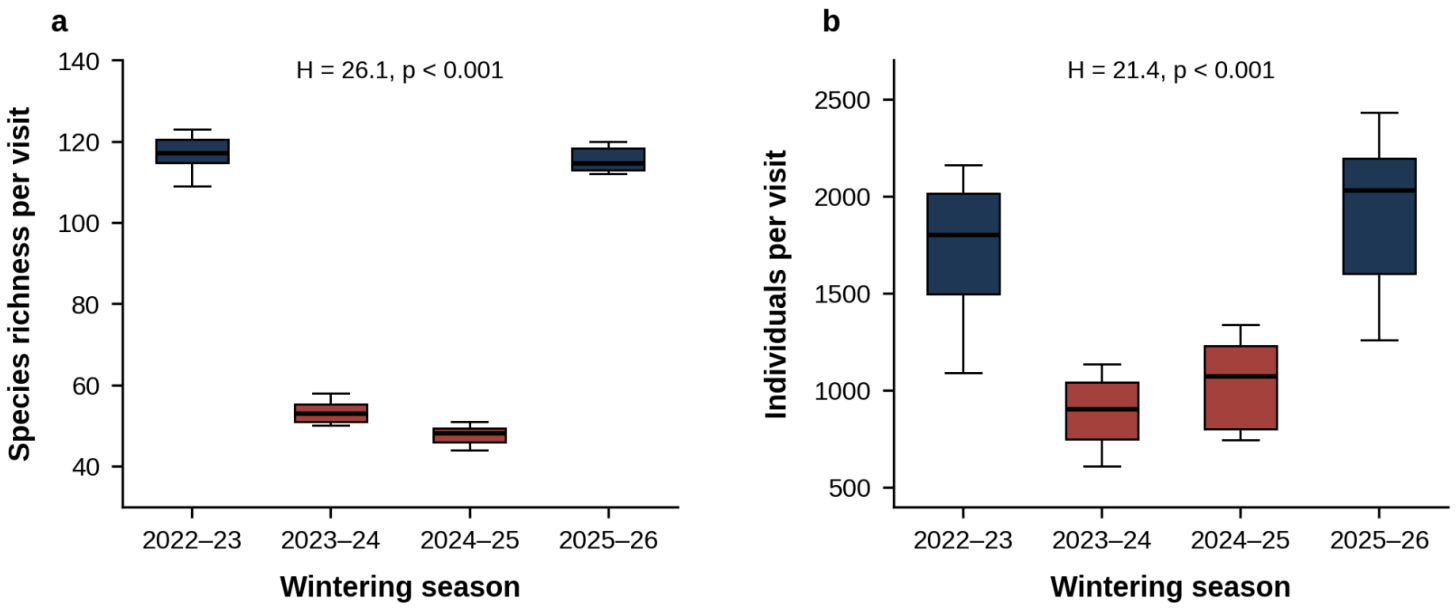


Figure 2

Per-visit a species richness and b abundance in each wintering season (November–February, eight visits per season). Boxes show median and interquartile range, whiskers the range

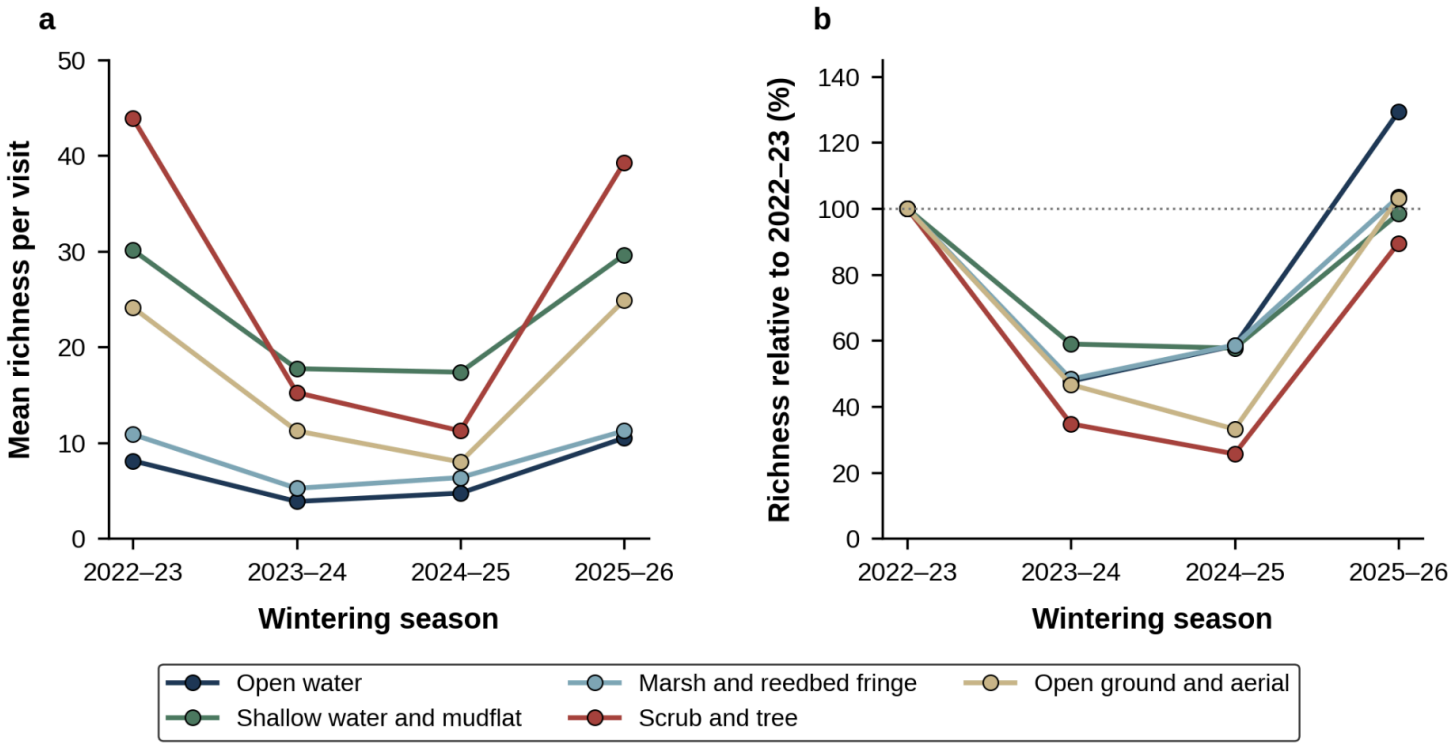


Figure 3

Mean per-visit richness of five habitat guilds across wintering seasons, shown a in absolute terms and b relative to the 2022–2023 baseline. Wetland-dependent guilds declined least and open-water birds

finished above baseline

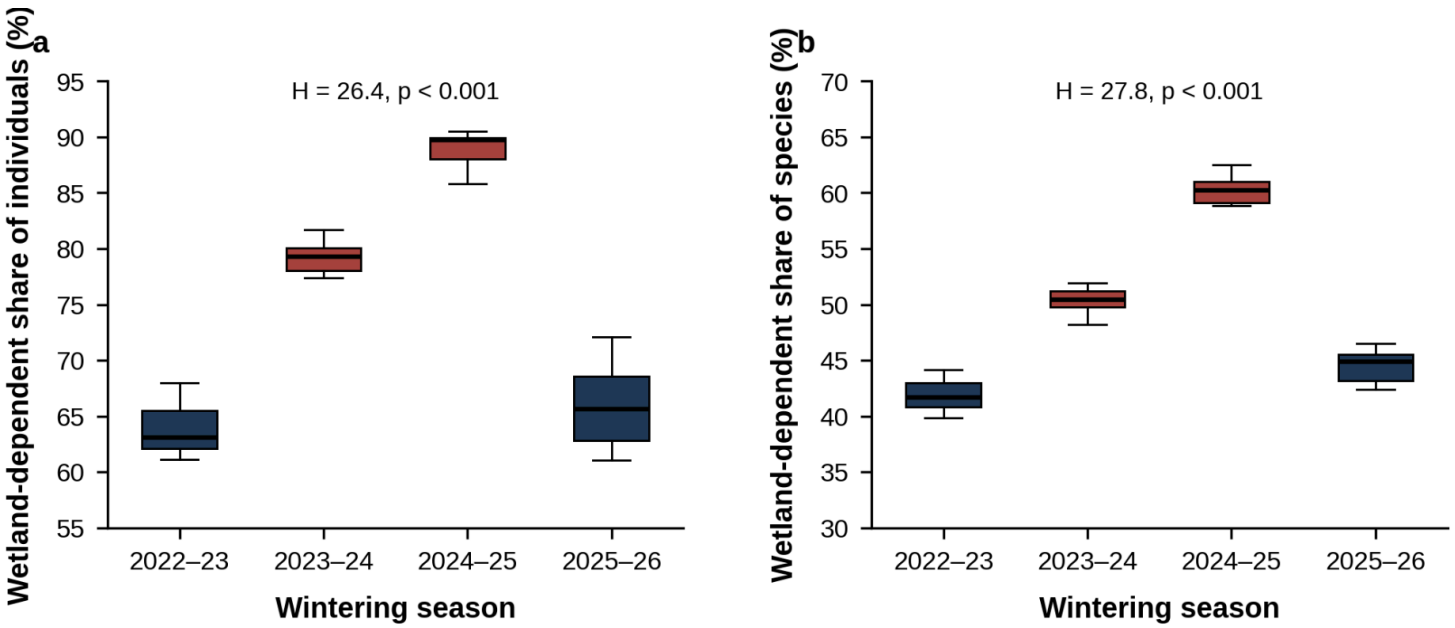


Figure 4

Wetland-dependent share of a individuals and b species recorded per visit in each wintering season. The assemblage became more wetland-dominated during the intervention, not less

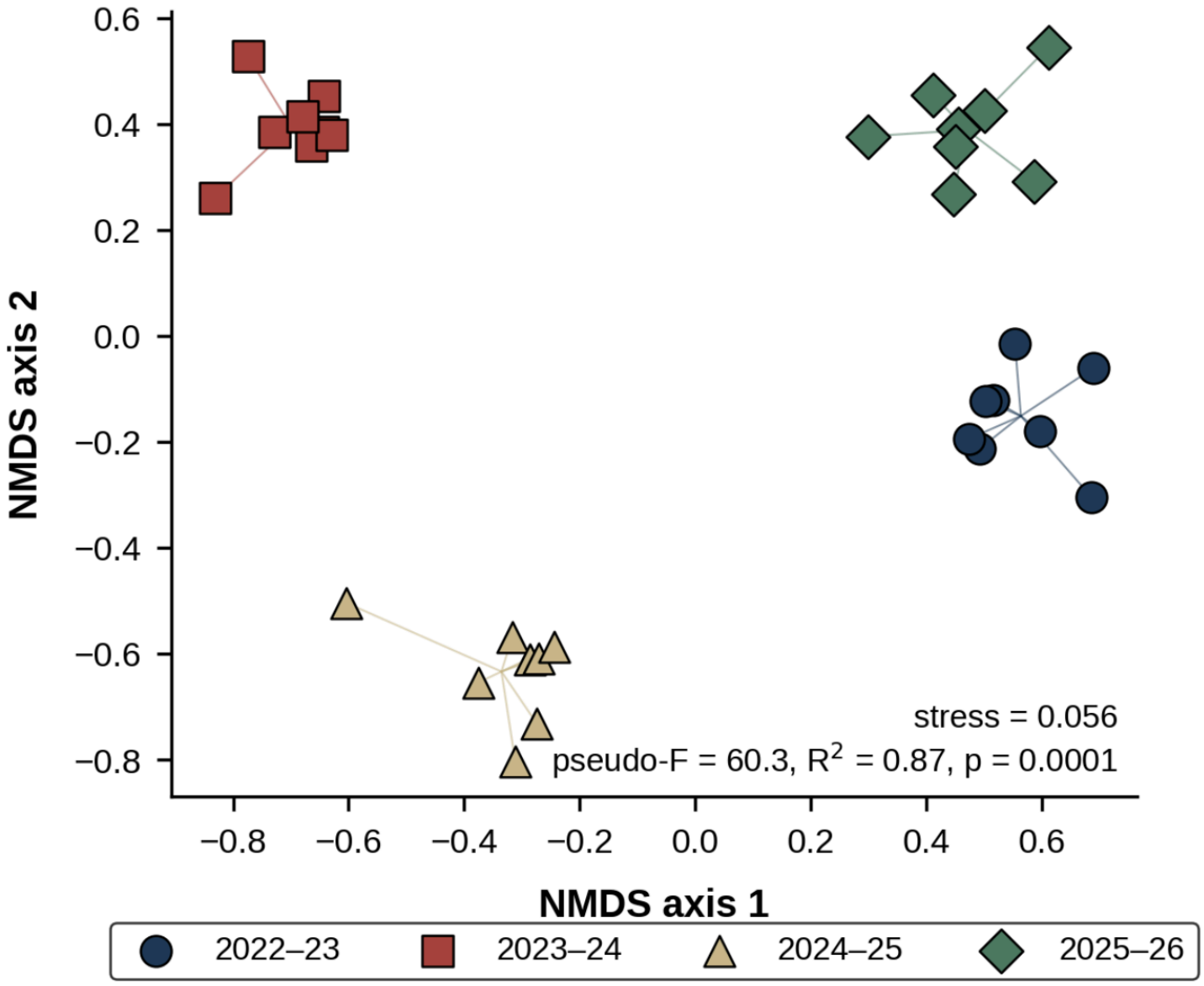


Figure 5

Non-metric multidimensional scaling of Bray–Curtis dissimilarity among 32 survey visits, with visits joined to their season centroid

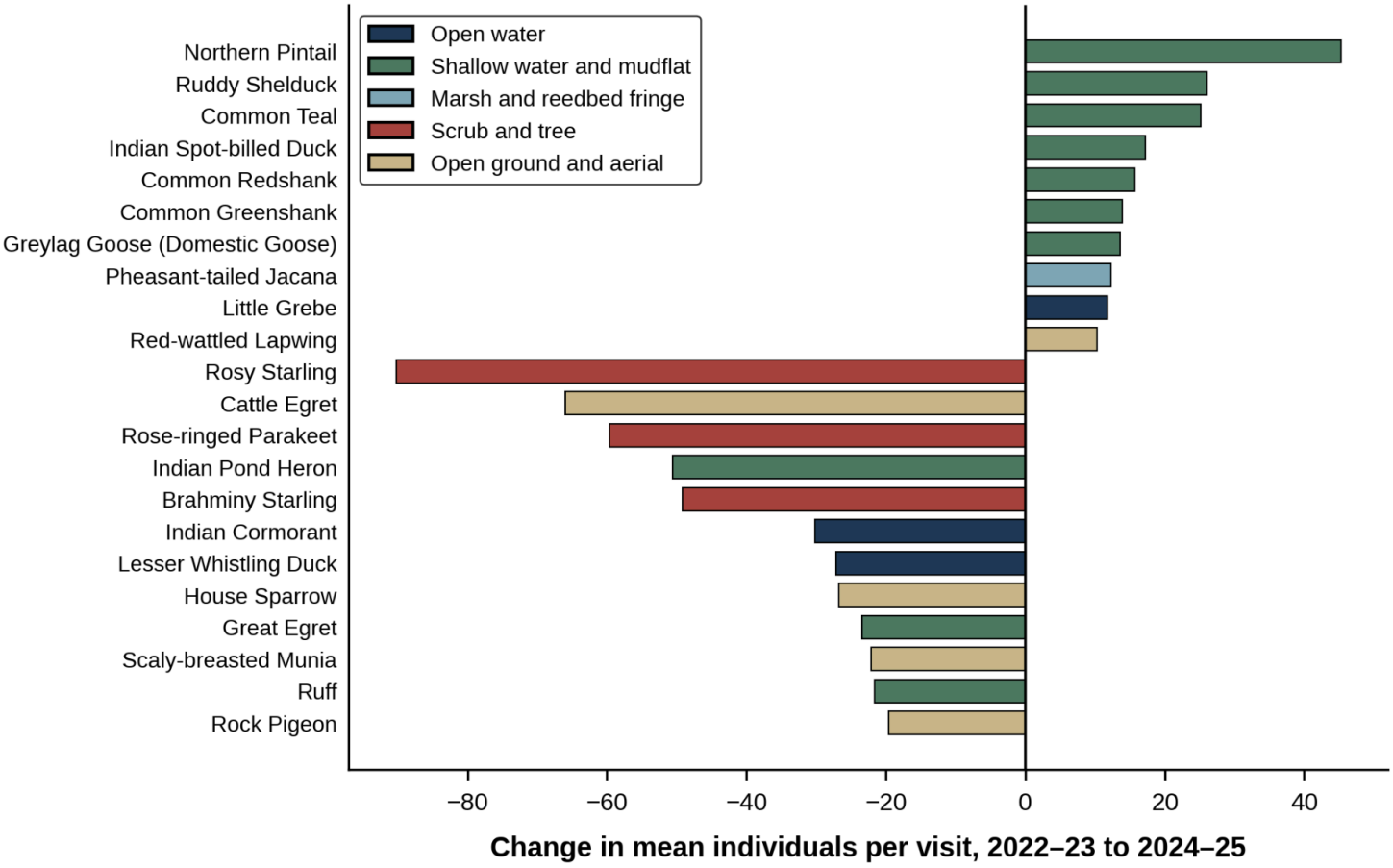


Figure 6

Species showing the largest changes in mean individuals per visit between 2022–2023 and 2024–2025, colored by habitat guild. Species gaining are dominated by waterfowl and waders; species lost are dominated by scrub, tree and open-ground birds

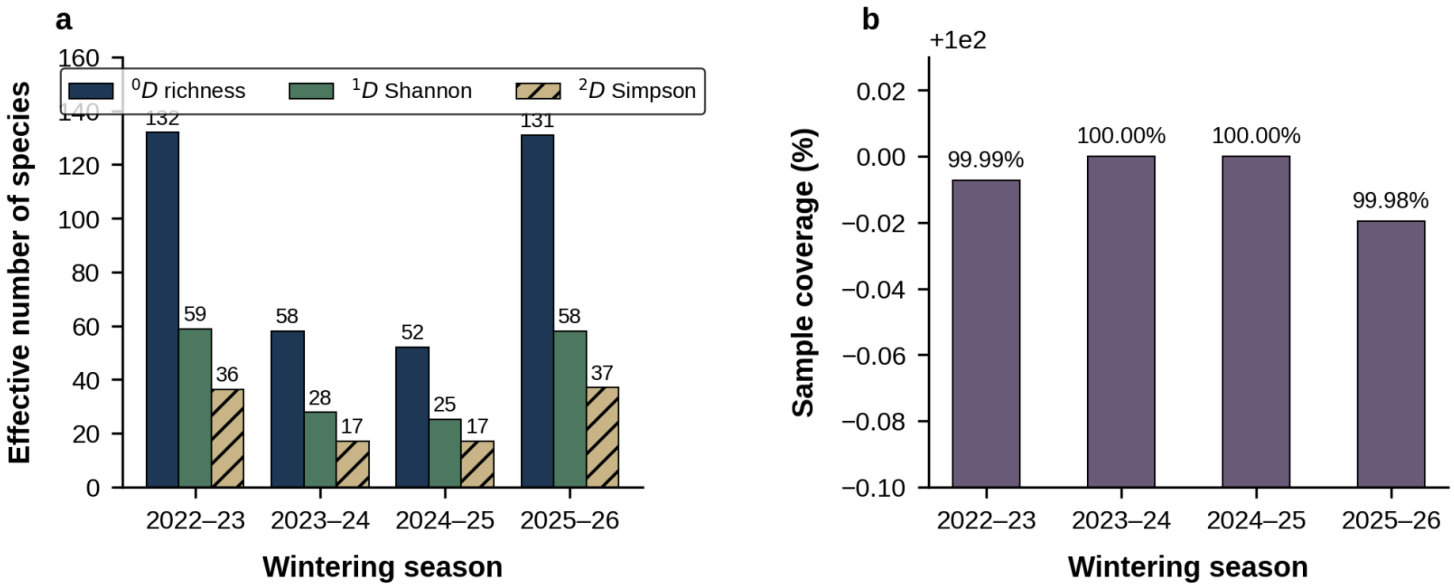


Figure 7

a Hill numbers at orders q = 0, 1 and 2 for each wintering season; b sample coverage, which exceeded 99.9% throughout

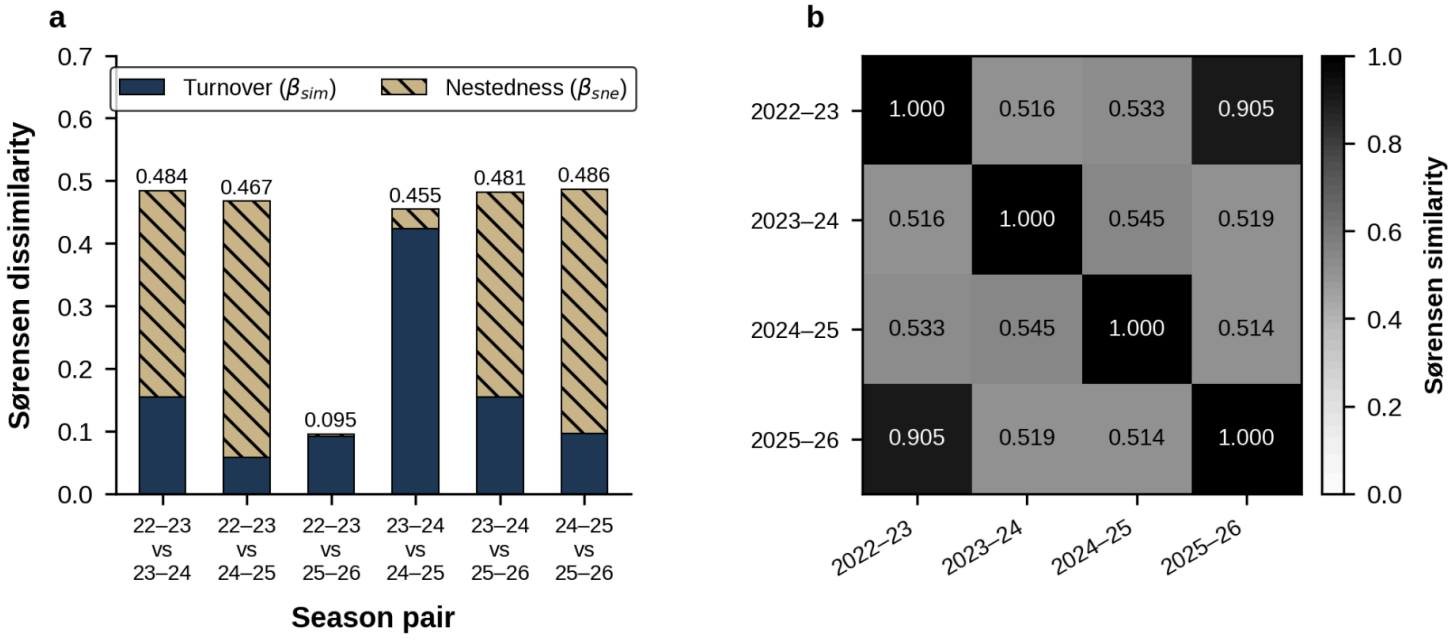


Figure 8

a Partitioning of Sørensen dissimilarity into turnover and nestedness components for each season pair; b matrix of Sørensen similarity among seasons

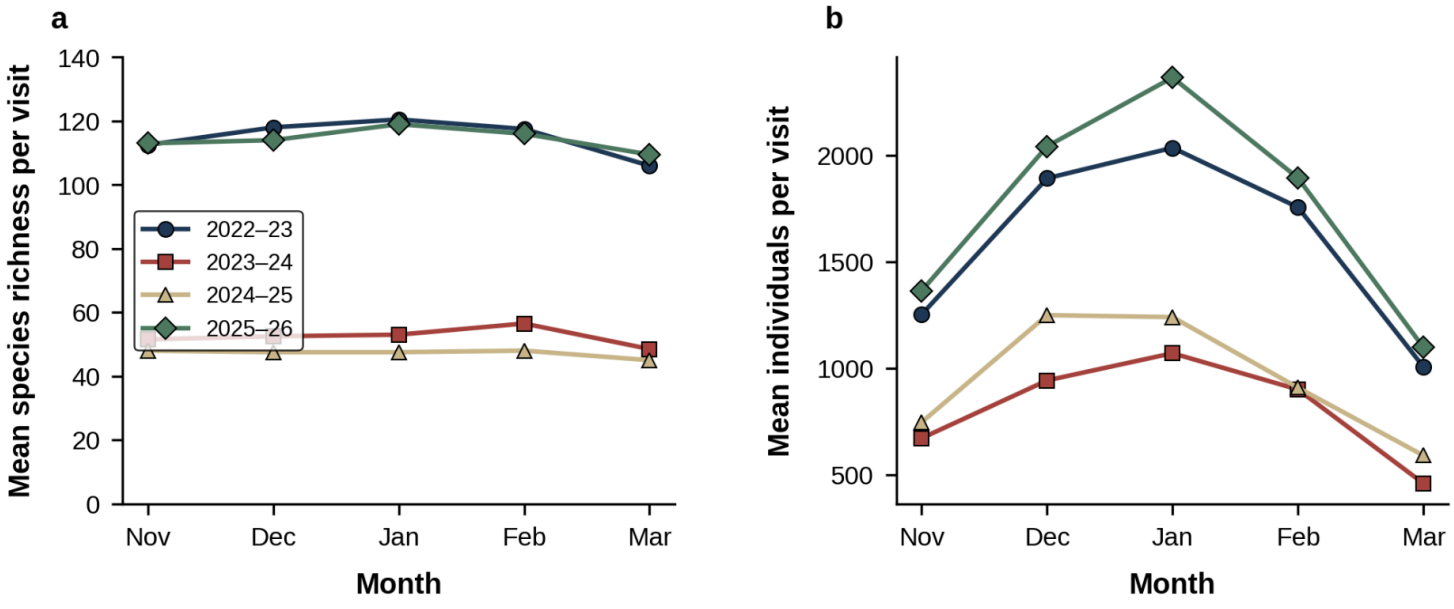


Figure 9

Within-winter variation in a mean species richness and b mean abundance per visit, November to March, in each of the four seasons