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Research Article

Ecological assessment of semi-arid wetlands in Patan district, Gujarat: Implications for migratory bird conservation and wetland management

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Abstract

Wetlands are critical ecosystems that sustain biodiversity, regulate hydrological cycles, and provide essential ecological services, yet they are increasingly threatened by anthropogenic pressures. This study conducted a comprehensive ecological assessment of semi-arid wetlands in the Patan district, Gujarat. A total of 138 wetlands were identified and surveyed during the migratory season (November 2020 to February 2021). Avifaunal assessments recorded 206 bird species, with a significant proportion comprising migratory (47%) and wetland-dependent species (7%). Based on composite ecological scoring that integrated species richness, migratory bird presence, threatened species occurrence, bird abundance, and habitat integrity, 23 wetlands were prioritized for conservation action. Remote sensing analysis using the Modified Normalized Difference Water Index (MNDWI) revealed a modest increase in wetland extent between 2017 and 2020, primarily through conversion from adjacent grassland and vegetated areas, although localized wetland shrinkage was also detected due to anthropogenic pressures. Based on these findings, recommendations include targeted habitat protection for priority wetlands, invasive species management, regulation of grazing pressures, community engagement for conservation, and the establishment of long-term monitoring programs integrating field surveys with remote sensing tools to ensure the ecological sustainability of Patan's wetland ecosystems.

Keywords*:* Wetlands, Patan, Migratory Birds, Biodiversity, Conservation, GIS, Habitat Monitoring

Introduction

Wetlands are among the most dynamic, productive, and diverse ecosystems on the planet. They play fundamental roles in maintaining ecological balance by supporting biodiversity, regulating hydrological cycles, recharging groundwater aquifers, sequestering atmospheric carbon, buffering floods, and purifying water (Mitsch & Gosselink, 2007; Ramsar Secretariat, 2013). Although wetlands occupy only about 6% of the Earth's terrestrial surface, they are estimated to support nearly 40% of all known species of plants and animals, making them vital nodes of global biodiversity (Keddy, 2000). Furthermore, wetlands contribute significantly to human well-being by providing ecosystem services essential for food security, livelihood sustenance, cultural identity, and climate change mitigation (Millennium Ecosystem Assessment, 2005).

Despite their immense ecological and socioeconomic importance, wetlands are among the most threatened ecosystems globally. It is estimated that over 35% of global wetland areas have been lost since 1970, and the rate of wetland degradation continues to exceed that of any other ecosystem type (Davidson, 2014; Ramsar Global Wetland Outlook, 2018). Major drivers of wetland loss include land-use change for agriculture and urbanization, overextraction of water resources, pollution from agricultural runoff and industrial effluents, invasion by exotic plant species, and the impacts of climate variability (Gopal, 1992; Finlayson et al., 2019). Semi-arid wetlands, in particular, face acute threats owing to the fragile balance between limited water availability and increasing anthropogenic pressures (Dube et al., 2023).

In India, wetlands are integral to ecological resilience and cultural traditions. The country hosts a wide diversity of wetland types, ranging from high-altitude glacial lakes of the Himalayas to coastal mangroves, freshwater marshes, estuaries, floodplains, and inland saline depressions (Prasad et al., 2002). The Ministry of Environment, Forest and Climate Change (MoEFCC) has estimated that India's wetlands cover approximately 7.6 million hectares, but this figure likely underrepresents small, seasonal, and non-perennial wetlands that are critical for local biodiversity

(ENVIS, 2020). Several wetlands in India have been designated as Ramsar sites of international importance, yet a vast number of ecologically significant wetlands, particularly in semi-arid and arid regions, remain poorly studied and inadequately protected.

Gujarat, located in western India, presents a mosaic of inland, coastal, and estuarine wetlands shaped by unique geomorphological and climatic factors. The state lies at the intersection of the Central Asian and West Asian-East African migratory flyways, making it a globally significant region for migratory bird conservation (BirdLife International, 2020). The wetlands of Gujarat, particularly the saline desert ecosystems of the Rann of Kachchh and adjacent areas, provide critical wintering, staging, and breeding grounds for a diverse assemblage of migratory waterbirds, including globally threatened species such as the Sarus Crane (*Grus antigone*), Greater Flamingo (*Phoenicopterus roseus*), and Dalmatian Pelican (*Pelecanus crispus*) (Islam & Rahmani, 2004; Ganpule, 2016).

The Patan district, situated in northern Gujarat, encompasses a landscape of semi-arid grasslands, saline flats, ephemeral river channels, and anthropogenic reservoirs. The district shares ecological connectivity with the Little Rann of Kachchh, thereby supporting an array of wetland habitats critical for migratory and resident bird species. Seasonal wetlands formed through monsoon inundation, village tanks, irrigation reservoirs, and natural depressions together create a heterogeneous wetland complex across the district. These wetlands not only harbor biodiversity but also support local agrarian economies, livestock grazing, and traditional fishing practices. However, the ecological integrity of Patan's wetlands faces mounting threats. Increasing agricultural intensification, expansion of settlements, groundwater extraction, invasion by *Prosopis juliflora*, and unsustainable livestock grazing have been observed to degrade wetland quality and reduce available habitats for waterbirds (Patel & Dharaiya, 2016). Despite their importance, Patan's wetlands and waterbirds have received limited research compared to adjacent districts (Chaudhary et al., 2022a, 2022b; Judal et al., 2024; Prajapati et al., 2023. In terms of birds, available information is mainly focused on non-wetland birds (Kalwani et al., 2024; Patel et al., 2021; Patel et al., 2024), resulting in a significant gap in understanding the ecological status, avian usage patterns, and habitat dynamics of wetlands of Patan.

This gap in systematic ecological assessments limits the ability to develop evidence-based conservation strategies, designate Important Bird and Biodiversity Areas (IBAs), or prioritize wetlands for restoration and management interventions under frameworks such as the Wetlands

(Conservation and Management) Rules, 2017. Furthermore, in the context of accelerating climate variability and anthropogenic pressures, regular monitoring of wetland dynamics using remote sensing tools has become indispensable for detecting landscape changes and informing adaptive management approaches (Xu, 2006; Finlayson et al., 2019). In light of these challenges, the present study was undertaken to provide a comprehensive ecological assessment of the wetlands of Patan district. The specific objectives of the study were to: (i) compile a district-wide inventory of wetlands through field surveys and remote sensing, (ii) document the avifaunal diversity and seasonal usage patterns of these wetlands, (iii) identify wetlands of high conservation priority based on composite ecological metrics, and (iv) analyze spatiotemporal changes in wetland extent between 2017 and 2020 using the Modified Normalized Difference Water Index (MNDWI). By integrating field-based ecological assessments with satellite-based spatial analyses, this study aims to contribute to the conservation planning and sustainable management of semi-arid wetlands in Gujarat.

Materials and Methods

Study area

Patan district, located in northern Gujarat, spans an area of approximately 5740 km², between latitudes 23°23'–24°09' N and longitudes 71°02'–72°29' E (Figure 1). The region experiences a predominantly dry climate, characterized by an average annual rainfall of approximately 548 mm, mostly confined to the southwest monsoon season (June–September). The landscape comprises saline flats, ephemeral river channels, seasonal natural depressions, and numerous man-made reservoirs and tanks (Kalwani et al., 2024; Patel et al., 2024).

Administratively, the district is divided into nine talukas, with Radhanpur, Santalpur, and Sami being notable for their higher density of wetlands due to their geographical proximity to the Little Rann of Kachchh (Fig. 1). These hydrological and geomorphological conditions make Patan an important region for wetland-dependent biodiversity.

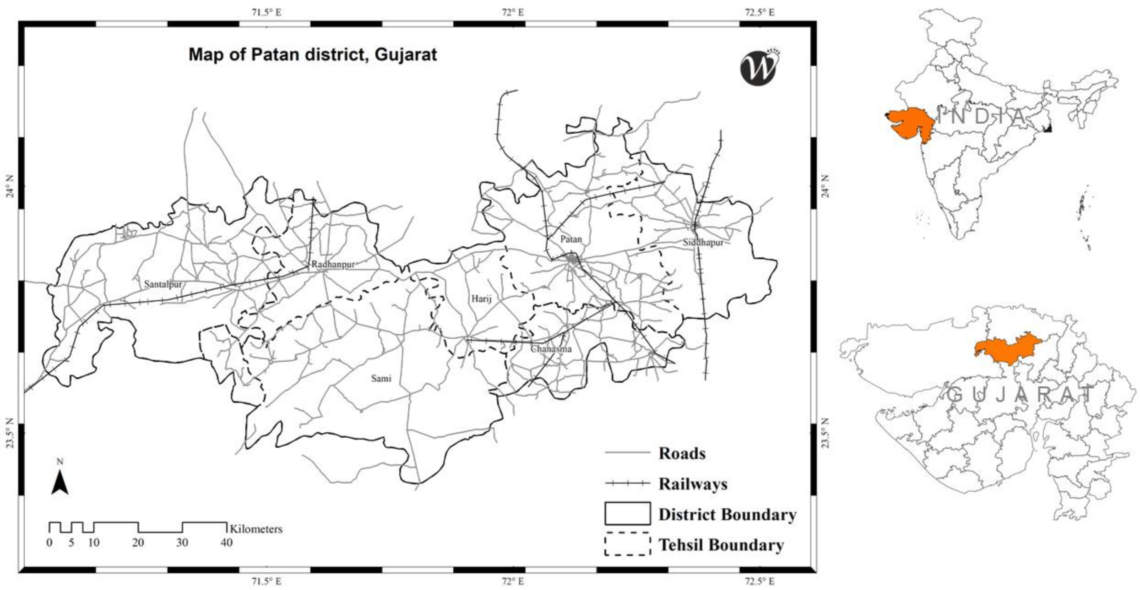

Figure 1. Location map of Patan district, Gujarat, with administrative boundaries

Wetland Dataset Compilation

A comprehensive wetland inventory was created using a combination of satellite imagery (Sentinel-2B, Landsat-8), topographic maps, and secondary datasets from the Gujarat Forest Department and the ENVIS Wetlands Portal (2020). Field surveys were conducted to ground-truth satellite interpretations, assess accessibility, and record ecological characteristics. Each wetland was classified into one of three categories: natural inland wetlands (e.g., lakes, marshes), man-made wetlands (e.g., tanks, reservoirs), or saline/seasonal wetlands.

Avifaunal Survey

Avifaunal surveys were carried out during the migratory season from November 2020 to February 2021. Each wetland was surveyed during early morning hours (08:00–11:00 hrs) and late afternoon hours (15:00–18:00 hrs), corresponding with peak bird activity periods. Birds were detected using direct visual count and block count methods. Field equipment included Olympus 10×50 binoculars and Nikon 20–60x spotting scopes. Bird species were identified using standard field guides (Grimmett et al., 1998), and records were maintained for species observed, flock sizes, foraging behaviors, and habitat characteristics. Diversity metrics, including Shannon-Wiener diversity index (H'), Simpson's index (1-D), Evenness (E), and species richness (S), were calculated using the software PAST v4.03 (Hammer et al., 2001).

Wetland Prioritization Framework

Each wetland was evaluated based on five key ecological parameters: total bird species richness, number of migratory species, presence of globally threatened species (as per IUCN Red List), bird abundance, and habitat integrity based on field observations. A scoring system ranging from 1 (low) to 5 (high) was employed for each parameter, and wetlands attaining a cumulative score ≥3 were classified as high conservation priority wetlands. Anthropogenic disturbances such as grazing intensity, fishing activities, vehicular movement, and the presence of garbage dumping were also recorded to provide a holistic assessment of vulnerability.

Habitat Change Analysis

Remote sensing-based analysis of wetland changes between 2017 and 2020 was performed using imagery from Landsat-8 OLI and Sentinel-2B MSI sensors. Pre-processing included radiometric correction and band stacking using QGIS and ESA's SNAP toolbox. The Modified Normalized Difference Water Index (MNDWI) was computed to enhance water feature detection. MNDWI was calculated using the formula:

$$MNDVI = Green - NIR/ Green + NIR$$

where Green corresponds to Band 3 and NIR corresponds to Band 8 in Sentinel-2 imagery. The MNDWI images were classified into water bodies, wetlands, and barren areas. Changes in wetland extent were mapped by overlaying classified raster images of 2017 and 2020, and wetland gain/loss was quantified.

Results

Wetland inventory of Patan district

A total of 138 natural and man-made wetlands were identified and surveyed across the Patan district, encompassing a diverse range of wetland types including natural lakes, marshes, irrigation tanks, reservoirs, and seasonal saline depressions (Figure 2). LULC also revealed that a total of 196.8 km2 of the district is occupied by the wetlands. The maximum number of water-logged areas is recorded in Santalpur taluka (34) followed by Radhanpur (25) and Sankheshwar (20). Whereas, Siddhpur taluka is recorded with the lowest number of wetlands (6) in Patan, followed by Harij and Sami taluka (Figure 3).

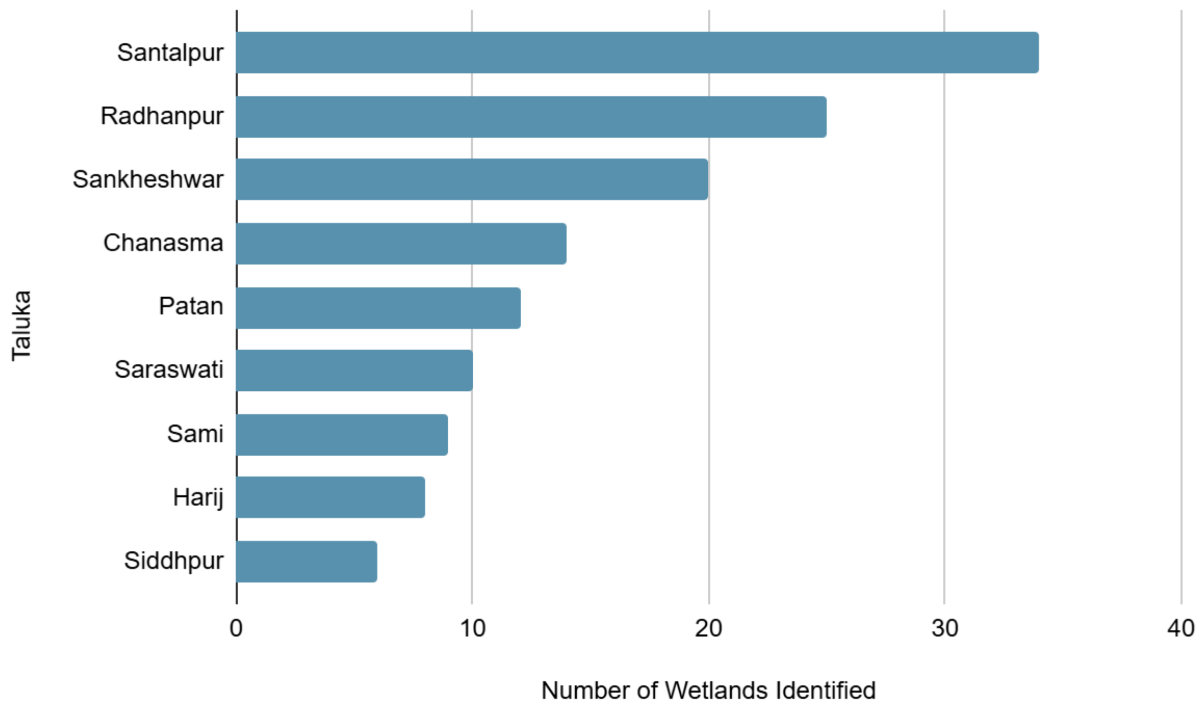

Figure 2. Taluka-wise distribution of wetlands in Patan district

Avifaunal diversity and composition

Across the 138 wetlands surveyed, a total of 206 bird species were recorded, representing 62 avian families and 138 genera. Among these species, 47% were classified as migratory, while the remaining 53% were resident species. Water-dependent bird species accounted for approximately 50% of the total observations, whereas the remaining species included terrestrial and semi-aquatic birds. The family Anatidae exhibited the highest diversity, with 19 species of ducks and geese reported. Other dominant families included Ardeidae, Scolopacidae, and Rallidae. Notable migratory species recorded included *Tadorna ferruginea* (Ruddy Shelduck), *Anas acuta* (Northern Pintail), *Grus antigone* (Sarus Crane), and *Pelecanus crispus* (Dalmatian Pelican).

The Shannon-Wiener diversity index (H') across the surveyed wetlands ranged from 2.01 to 3.15. The highest diversity value was recorded in Radhanpur taluka (H' = 3.15), followed by Sami (H' = 3.14) and Santalpur (H' = 3.12). The Simpson's Index (1-D) values ranged from 0.76 to 0.91, while Evenness values ranged between 0.81 and 0.93. Taluka-wise diversity patterns showed that the western talukas of Radhanpur, Santalpur, and Sami exhibited the highest species richness and diversity indices (Table 1).

Table 1. Summary of avifaunal diversity indices across talukas in Patan district.

Taluka	Number of Wetlands	Total Species	Shannon Index (H')	Simpson Index (1-D)	Evenness
Radhanpur	17	103	3.15	0.91	0.81
Santalpur	21	98	3.12	0.90	0.85
Sami	18	94	3.14	0.89	0.86
Chanasma	14	80	2.91	0.88	0.84
Saraswati	13	73	2.45	0.76	0.88

Important Wetlands

Based on the composite scoring system integrating species richness, migratory bird presence, presence of IUCN Red List species, bird abundance, and visual habitat integrity, a total of 23 wetlands were identified as high conservation priority sites. These wetlands consistently demonstrated higher avian diversity and abundance during the surveys. Important wetlands included Khokhala Wetland, Garamdi Wetland, Chhanasra-Rajusara Highway Wetland, Vadilal Dam, and Bolera-Sankheshwar Road Wetland. The distribution of these high-priority wetlands was concentrated predominantly in the western part of the district, encompassing talukas such as Radhanpur, Santalpur, and Sami (Fig. 3).

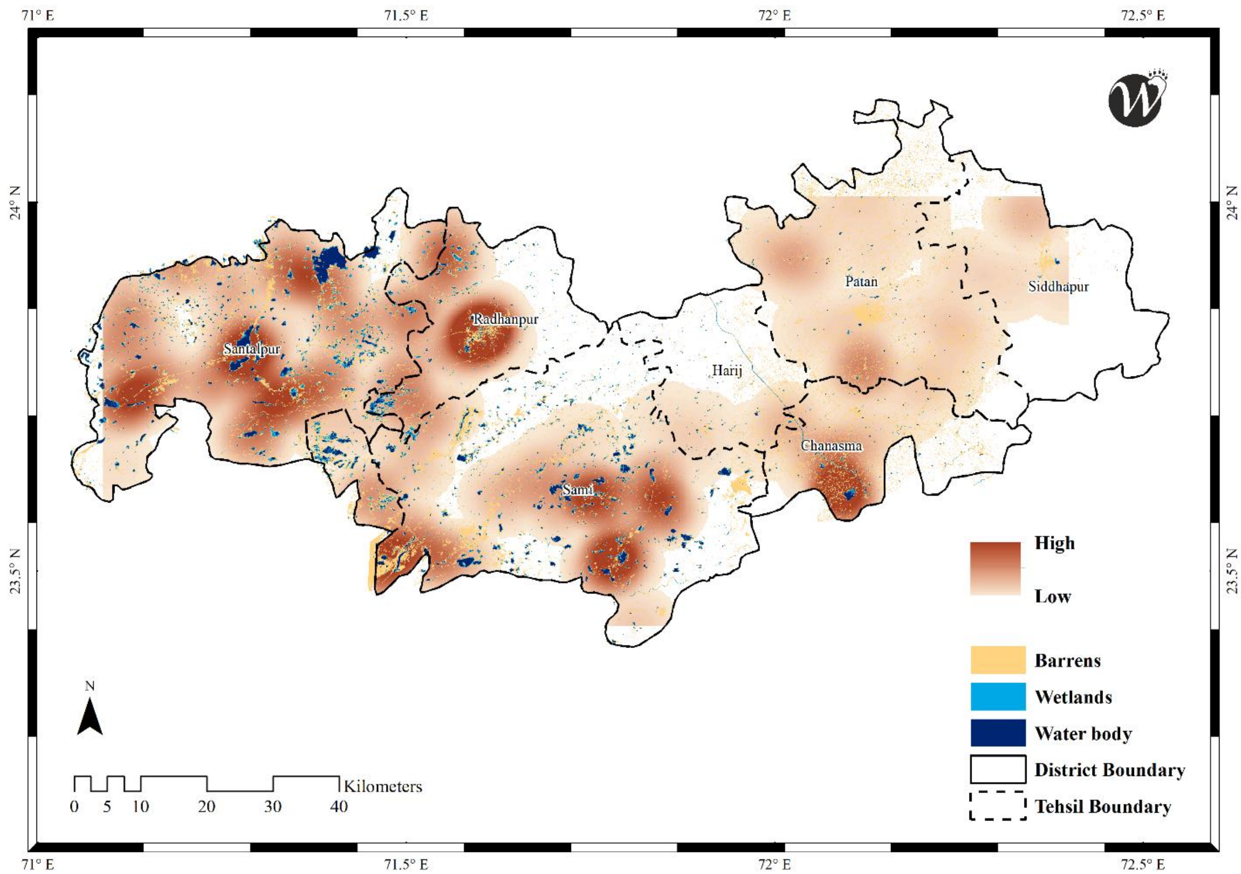

Figure 3. Map showing the location of high-priority wetlands based on avifaunal diversity scores in the Patan district.

Spatiotemporal change in wetland area

Remote sensing analyses using MNDWI revealed notable changes in wetland extents between 2017 and 2020 (Figure 4). An overall increase in wetland area by approximately 0.4% was observed, primarily attributed to conversion from adjacent grasslands and vegetated areas. In contrast, minor losses in wetland areas were recorded due to encroachment by barren lands and urban settlements, especially near peri-urban fringes. Talukas such as Santalpur, Sami, and Radhanpur demonstrated higher wetland retention and moderate expansion over the study period.

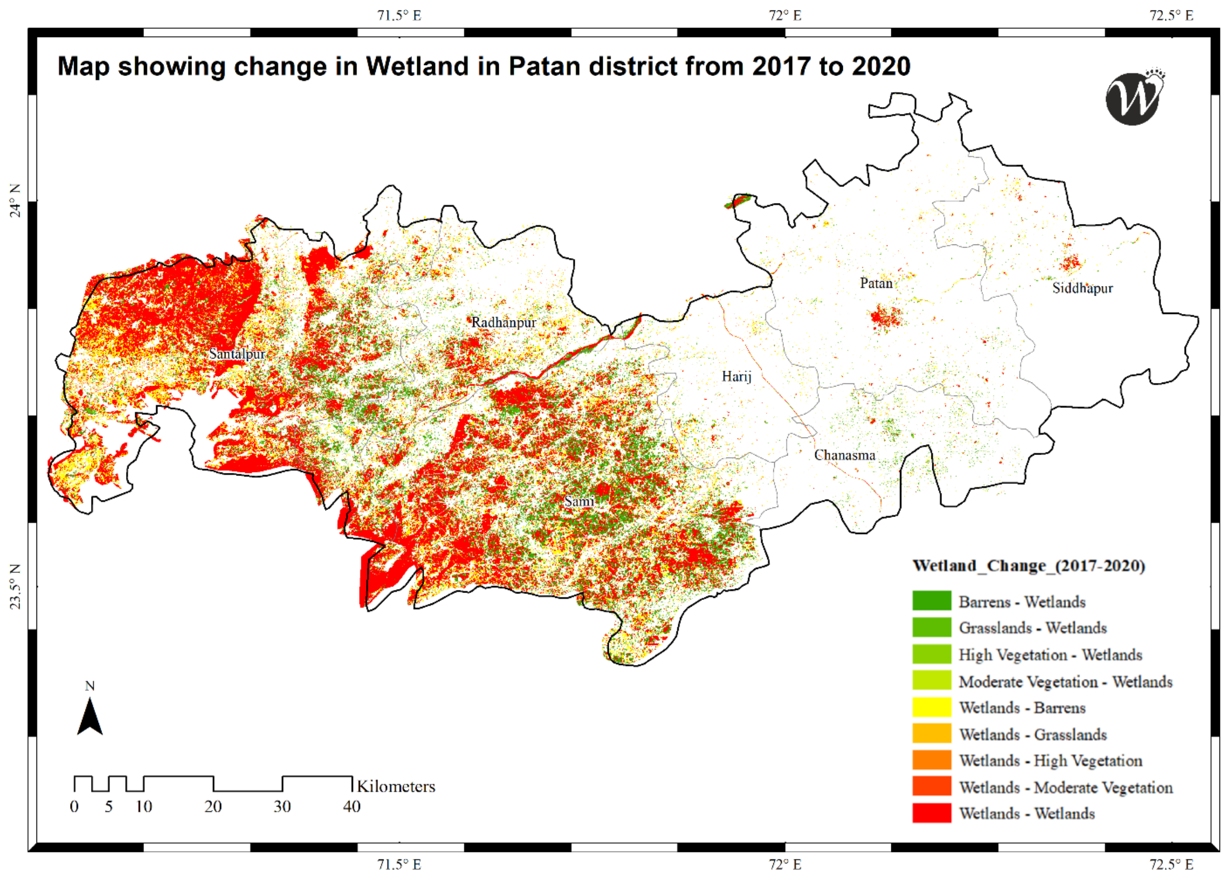

Figure 4. Map showing the changes in wetland area between 2017 to 2021

Discussion

The present study provides a comprehensive ecological assessment of semi-arid wetlands in Patan district, Gujarat, revealing these ecosystems as critical biodiversity hotspots within an otherwise arid landscape. Our documentation of 206 avian species across 138 wetlands, with 47% comprising migratory taxa, strongly supports the hypothesis that these wetlands function as vital stopover, wintering, and breeding habitats along the West Asian–East African Flyway. This finding aligns with previous research highlighting the importance of Gujarat's wetlands within this global migration corridor (BirdLife International, 2020; Mundkur et al., 2017). The presence of globally threatened species, including Sarus Crane (*Grus antigone*), Dalmatian Pelican (*Pelecanus crispus*), and Oriental Darter (*Anhinga melanogaster*) not only elevates the conservation value of these wetlands but also positions them as potential candidates for international designations such as Ramsar sites or Important Bird and Biodiversity Areas (IBAs) as suggested by Kumar et al. (2017) and Rahmani et al. (2016).

Spatial heterogeneity in avian community metrics reveals distinct ecological patterns across the study area. Western talukas (Radhanpur, Santalpur, and Sami) consistently exhibited higher Shannon-Wiener diversity indices (H' > 3.1) and species richness compared to eastern counterparts. This pattern can be attributed to their proximity to the Little Rann of Kachchh, reduced anthropogenic disturbance, and complex hydrological regimes that create habitat mosaics favoring diverse avifauna (Vijayan et al., 2004). These findings support Sebastián-González and Green's (2016) assertion that shallow, seasonally inundated wetlands with varied salinity gradients typically support higher richness of migratory waders and omnivorous water birds. The evenness indices (0.81–0.93) across sites indicate equitable species distribution with minimal dominance effects characteristic of relatively undisturbed wetland ecosystems with functional trophic networks (Azeria, 2004; Báldi, 2008). The predominance of omnivores and insectivores in the assemblage further suggests intact food webs and ecological resilience, serving as bioindicators of wetland health as noted by Cintra et al. (2007) and Ma et al. (2010).

Our prioritization framework identified 23 high-priority wetlands deserving immediate conservation attention based on multiple ecological criteria. This science-based approach follows contemporary best practices in wetland conservation planning, where multi-parameter ecological assessments increasingly inform site-specific interventions under global frameworks such as the Ramsar Convention and CBD's Aichi Targets (Davidson and Finlayson, 2018). The precarious protection status of many high-priority sites often classified as revenue land or lacking designated buffer zones renders them particularly vulnerable to degradation and encroachment. Similar vulnerability patterns have been documented across South Asian wetlands, where ambiguous land tenure and classification systems undermine conservation efforts (Bassi et al., 2014; Kumar et al., 2017).

Remote sensing analysis using Modified Normalized Difference Water Index (MNDWI) between 2017 and 2020 revealed a modest overall increase (0.4%) in wetland area. However, this apparent expansion warrants cautious interpretation, as field observations suggest much of this change reflects ephemeral inundation of adjacent terrestrial habitats rather than restoration of degraded wetland basins a limitation of satellite-based surface water detection in semi-arid environments noted by McFeeters (2013) and Zhai et al. (2015). Concurrent wetland contraction along peri-urban margins and encroachment of barren land into historical wetland boundaries highlights the spatially heterogeneous impacts of land-use change, consistent with patterns documented by Guo et al. (2017) in similar landscapes. These findings underscore the importance of integrating field-based and remote sensing approaches when monitoring dynamic wetland systems in arid environments (Ozesmi and Bauer, 2002).

Anthropogenic pressures on Patan's wetlands were evident throughout our surveys. Overgrazing emerged as a prevalent threat, with livestock trampling degrading shoreline vegetation and accelerating siltation processes that diminish water retention capacity and alter avian habitat structure (Marty, 2005). The aggressive spread of *Prosopis juliflora* at numerous wetland margins represents another significant ecological concern. This invasive species alters soil chemistry, outcompetes native vegetation, and provides suboptimal habitat for wetland-dependent birds (Kaur et al., 2012; Shackleton et al., 2014). Additionally, fishing practices employing fine-mesh nets were observed to cause incidental mortality among diving birds. Improper waste disposal, particularly near roadside wetlands and settlements, introduces additional stressors including water contamination and disturbance from feral dogs and opportunistic scavengers.

Despite these challenges, the strong socio-cultural connections between local communities and many wetlands present opportunities for participatory conservation approaches. Several surveyed wetlands particularly irrigation tanks and community ponds retain cultural significance and provide livelihood services to nearby villages. These existing human-nature relationships offer foundations for community-based conservation models that integrate traditional ecological knowledge with scientific management, an approach increasingly advocated in wetland governance literature (Finlayson et al., 2019). Successful examples from other semi-arid regions demonstrate that engaging local stakeholders as wetland stewards can yield sustainable outcomes through practices such as regulated resource harvesting, ecotourism development, and participatory monitoring (Everard and Kataria, 2011).

From a policy perspective, our findings underscore the urgent need for formal recognition of semi-arid wetlands within existing conservation frameworks. Despite their demonstrated biodiversity value, most wetlands in Patan remain outside the purview of the Wetlands (Conservation and Management) Rules, 2017 a legislative gap attributable to size thresholds, documentation deficiencies, and the historical undervaluation of arid zone wetlands. The ecological evidence presented here, particularly regarding high-priority sites and migratory bird usage, provides compelling justification for their inclusion under national protection mechanisms and potential nomination for international designations like IBAs or Ramsar sites. Furthermore, the systematic threat documentation and spatial monitoring methodologies developed through this study offer tools for implementing adaptive management strategies resilient to increasing climate variability and anthropogenic pressure.

Conclusion

This study highlights the ecological significance of semi-arid wetlands in Patan district, documenting high avifaunal diversity with 206 species, including a substantial proportion of migratory and globally threatened birds. The spatial analysis revealed that while some wetland areas have expanded modestly between 2017 and 2020, multiple wetlands remain vulnerable to anthropogenic pressures such as invasive species encroachment, overgrazing, and habitat degradation. Based on these findings, several recommendations are proposed. Priority conservation actions should focus on the 23 identified high-value wetlands, ensuring habitat protection, regulating livestock grazing, and managing invasive species such as *Prosopis juliflora*. Wetland boundaries must be legally secured to prevent encroachment and unsustainable land-use changes. Community-based initiatives should be encouraged to promote sustainable use and stewardship of wetlands, integrating local livelihoods into conservation frameworks. Additionally, the establishment of a long-term ecological monitoring program combining field surveys with remote sensing analyses is essential to track wetland dynamics and guide adaptive management strategies. Recognizing and protecting these wetlands under national conservation frameworks and potentially nominating key sites for Ramsar designation would further enhance their ecological security.

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References

Assessment, M. E. (2005). Ecosystems and human well-being: wetlands and water. World resources institute.

Azeria, E. T. (2004). Terrestrial bird community patterns on the coralline islands of the Dahlak Archipelago, Red Sea, Eritrea. Global Ecology and Biogeography, 13(2), 177-187.

Báldi, A. (2008). Habitat heterogeneity overrides the species–area relationship. Journal of Biogeography, 35(4), 675-681.

Bassi, N., Kumar, M. D., Sharma, A., & Pardha-Saradhi, P. (2014). Status of wetlands in India: A review of extent, ecosystem benefits, threats and management strategies. Journal of hydrology: Regional studies, 2, 1-19.

BirdLife International. (2020). State of the world's birds and their habitats. BirdLife International.

Chaudhary, S. V., Desai, P. G., & Dharaiya, N. A. (2022a). An annotated checklist of bird diversity of Kheralu, Mehsana, Gujarat. Species, 23(71), 74–85.

Chaudhary, S., Rana, P., & Desai, P. (2022b). Avifaunal diversity of M. N. College, Visnagar, Gujarat. ZOO's PRINT, 37(6), 31–36.

Cintra, R., Sanaiotti, T. M., & Cohn-Haft, M. (2007). Spatial distribution and habitat of the Anavilhanas Archipelago bird community in the Brazilian Amazon. Biodiversity and Conservation, 16, 313-336.

Davidson, N. C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. Marine and Freshwater Research, 65(10), 934–941. https://doi.org/10.1071/MF14173

Davidson, N. C., & Finlayson, C. M. (2018). Extent, regional distribution and changes in area of different classes of wetland. Marine and Freshwater Research, 69(10), 1525-1533.

Dube, T., Dube, T., & 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.

ENVIS. (2020). Wetlands of India – Gujarat. ENVIS Centre on Wildlife and Protected Areas, MoEFCC.

Everard, M., & Kataria, G. (2011). Recreational angling markets to advance the conservation of a reach of the Western Ramganga River, India.

Finlayson, C., Everard, M., Irvine, K., McInnes, R. J., Middleton, B. A., van Dam, A., & Davidson, N. (2018). The wetland book I: Structure and function, management and methods. Springer.

Ganpule, P. (2016). Observations of probable Taimyr Gulls *Larus fuscus taimyrensis* at Okha, Gujarat, India. Indian BIRDS, 12(1), 1-4.

Gopal, B. R. I. J. (1992). Tropical wetlands: degradation and need for rehabilitation. Ecosystem Rehabilitation, 2, 277-96.

Grimmett, R., Inskipp, C., & Inskipp, T. (1998). Birds of the Indian Subcontinent. London, UK: Christopher Helm.

Guo, D.; Jin, H.; Gao, P.; Zhu, X. Detecting Spatial Community Structure in Movements. Int. J. Geogr. Inf. Sci. 2018, 32, 1326–1347.

Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica, 4(1), 1.

Islam, M.Z. & Rahmani, A.R. 2004. Important Bird Areas in India. Priority Sites for Conservation. Indian Bird Conservation Network, Bombay Natural History Society and BirdLife International (UK). Pp.xviii+1133

Judal, M., Bhalakiya, H., & Prajapati, S. (2024). A comprehensive checklist of avifauna in the vicinity of Dantiwada Reservoir with some notable records, Banaskantha, Gujarat. Munis Entomology & Zoology, 19(2), 862–877.

Kalwani, S., Chaudhary, S., Prajapati, N., & Dharaiya, N. (2023). Sighting of the Changeable Hawk-Eagle (Nisaetus cirrhatus) at HNG University, Patan, Gujarat, India. Prithivya (WCB Research Foundation Newsletter), 3(3), 4–8.

Kaur, R., Gonzales, W. L., Llambi, L. D., Soriano, P. J., Callaway, R. M., Rout, M. E., ... & Inderjit. (2012). Community impacts of Prosopis juliflora invasion: biogeographic and congeneric comparisons.

Keddy, P. A. (2010). Wetland ecology: principles and conservation. Cambridge university press.

Kumar, R., Tol, S., McInnes, R. J., Everard, M., & Kulindwa, A. A. (2017). Wetlands for disaster risk reduction: Effective choices for resilient communities. Ramsar Policy Brief, 1.

Ma, Z., Cai, Y., Li, B., & Chen, J. (2010). Managing wetland habitats for waterbirds: an international perspective. Wetlands, 30, 15-27.

Marty, J. T. (2005). Effects of cattle grazing on diversity in ephemeral wetlands. Conservation Biology, 19(5), 1626-1632.

McFeeters, S. K. (2013). Using the normalized difference water index (NDWI) within a geographic information system to detect swimming pools for mosquito abatement: a practical approach. Remote Sensing, 5(7), 3544-3561.

Mitsch, W. J., & Gosselink, J. G. (2007). Wetlands (4th ed.). Wiley.

Mundkur, T., Langendoen, T., & Watkins, D. (2017). The Asian Waterbird Census 2008–2015: results of coordinated counts in Asia and Australasia. Wetlands International, Ede, 146.

Ozesmi, S. L., & Bauer, M. E. (2002). Satellite remote sensing of wetlands. Wetlands ecology and management, 10, 381-402.

Patel S. and Dharaiya N. (2016). Inventory of aquatic birds with special reference to urban and desert wetlands ,. January, 29–36.

Patel, H., Gajjar, G., Bhatt, D., & Patel, K. (2021). An annotated checklist of avifauna from Hemchandracharya North Gujarat University campus, Patan, Gujarat, India. Journal of Biological Studies, 3(4), 121–131. https://doi.org/10.62400/jbs.v3i4.5441.

Patel, J., Desai, P., Patel, V., & Dharaiya, N. (2024). Factors influencing roost site preference of Rose-ringed Parakeets (Psittacula krameri, Psittacidae) in urban areas of North Gujarat, India. Journal of Animal Diversity, 6(2), 38–46.

Prajapati, S., Patel, D., & Rana, P. (2023). Study of bird diversity and distribution of Visnagar, Mehsana (Gujarat), India. International Journal of Fauna and Biological Studies, 10(3), 36–48.

Prasad, S. N., Ramachandra, T. V., Ahalya, N., Sengupta, T., Kumar, A., Tiwari, A. K., ... & Vijayan, L. (2002). Conservation of wetlands of India-a review. Tropical Ecology, 43(1), 173-186.

Rahmani, A. R., Islam, M. U., & Kasambe, R. M. (2016). Important bird and biodiversity areas in India: Priority sites for conservation (Revised and updated). Bombay Natural History Society, Indian Bird Conservation Network, Royal Society for the Protection of Birds and BirdLife International (UK), 1992.

Ramsar, P. (2013). The Ramsar Convention Manual: a guide to the Convention on Wetlands (Ramsar, Iran, 1971) Ramsar Convention Secretariat.

Sebastián-González, E., & Green, A. J. (2016). Reduction of avian diversity in created versus natural and restored wetlands. Ecography, 39(12), 1176-1184.

Shackleton, R. T., Le Maitre, D. C., Pasiecznik, N. M., & Richardson, D. M. (2014). Prosopis: a global assessment of the biogeography, benefits, impacts and management of one of the world's worst woody invasive plant taxa. AoB plants, 6, plu027.

Vijayan, V. S. (2004). Inland wetlands of India: conservation priorities. Salim Ali Centre for Ornithology and Natural History.

Xu, H. (2006). Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. International Journal of Remote Sensing, 27(14), 3025–3033.

Zhai, K., Wu, X., Qin, Y., & Du, P. (2015). Comparison of surface water extraction performances of different classic water indices using OLI and TM imageries in different situations. Geo-spatial Information Science, 18(1), 32-42.