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Long-term changes in faunal diversity: A review

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ABSTRACT

Long-term monitoring of faunal diversity provides the empirical foundation for understanding the magnitude, trajectory, and drivers of biodiversity change and for designing evidence-based conservation responses. This review synthesises evidence on long-term faunal diversity changes from monitoring programmes, resurvey studies, and historical biodiversity databases spanning the past century, with particular reference to South Asian terrestrial and freshwater ecosystems. Drawing on 184 published studies and 12 long-term monitoring datasets, we assess evidence for temporal trends in species richness, abundance, functional diversity, and community composition across major taxonomic groups. The weight of evidence confirms significant negative trends in vertebrate and invertebrate diversity globally and in South Asia, driven primarily by habitat loss, agricultural intensification, invasive species, and climate change. However, the evidence base is taxonomically and geographically uneven, with birds and mammals best-monitored and invertebrates, freshwater fauna, and soil organisms severely under-represented in long-term datasets. We identify three methodological challenges -- detectability bias, spatial scale dependence, and baseline shifting -- that complicate interpretation of long-term diversity trends and propose minimum standards for future long-term monitoring programmes. We conclude with a prioritised research agenda for long-term faunal diversity monitoring in South Asian ecosystems.

Keywords: long-term monitoring; biodiversity change; faunal diversity; temporal trends; South Asia; species richness decline; Living Planet Index; baseline shifting; review

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1. Introduction

Biodiversity is declining at rates unprecedented in human history, with the sixth mass extinction event now widely recognised as underway (Ceballos et al. 2017). The evidence base for this conclusion rests primarily on long-term monitoring data -- repeated, standardised surveys of the same species, communities, or ecosystems over time that enable detection of directional change above natural variation. The most globally visible synthesis of such data is the WWF Living Planet Index (LPI), which documents a mean 69% decline in monitored vertebrate population abundance between 1970 and 2018 (WWF 2022). However, the LPI and comparable global indices are subject to well-documented methodological limitations, including geographic and taxonomic bias towards well-monitored groups in high-income countries, and conflation of species abundance with species diversity trends.

In South Asia, long-term faunal diversity monitoring is particularly sparse compared to Europe and North America. The absence of standardised national monitoring schemes equivalent to the UK's Breeding Bird Survey, Germany's Common Butterfly Monitoring, or Australia's long-term ecological research network means that South Asian biodiversity trends are primarily inferred from resurvey comparisons, museum specimen dating analyses, and opportunistic observational data rather than formally designed long-term programmes. The few available long-term Indian biodiversity datasets -- the Bombay Natural History Society's Christmas Bird Count (1901-present), the Wildlife Institute of India's tiger monitoring data, and the eBird India citizen science platform (2014-present) -- provide valuable but incomplete pictures of change.

This review synthesises the evidence for long-term faunal diversity change from global and South Asian perspectives, addressing: (1) what do available monitoring datasets tell us about long-term trends in different taxonomic groups and ecosystems? (2) What are the primary drivers of documented changes? (3) What methodological challenges limit interpretation? (4) What minimum standards should guide future long-term monitoring design? and (5) What are the priority monitoring gaps for South Asian ecosystems?

2. Evidence for Long-Term Faunal Diversity Changes

2.1 Vertebrate Population Trends

The most comprehensive global synthesis of vertebrate population trends, the WWF Living Planet Index (LPI), documents a mean 69% decline in monitored vertebrate population abundance between 1970 and 2018, based on 31,821 population trend datasets from 5,230 species (WWF 2022). Freshwater vertebrates show the steepest mean decline (-83%), followed by terrestrial (-38%) and marine (-35%) populations. These figures have been criticised for underweighting tropical biodiversity and for conflating abundance with richness trends, but their directional signal is consistent across multiple independent analyses. For birds specifically, the State of the World's Birds (BirdLife International 2022) estimates that 48% of bird species have declining populations, compared to only 6% with increasing trends. In South Asia, the State of India's Birds report (SoIB 2020) analysed eBird data for 261 species and found 52% showing long-term decline, with long-distance migrants and open-country species declining most severely.

2.2 Invertebrate Trends

Evidence for invertebrate diversity trends globally is substantially weaker than for vertebrates, owing to the far sparser monitoring infrastructure. Sanchez-Bayo and Wyckhuys (2019) synthesised 73 long-term insect diversity studies and found that 41% of insect species are declining and 33% are

threatened, with particularly steep declines documented for Lepidoptera, Trichoptera, and Hymenoptera. However, the Sanchez-Bayo and Wyckhuys analysis was criticised for geographic bias (90% of included studies from Europe and North America) and taxonomic gaps. The European 'Krefeld study' documenting > 75% decline in flying insect biomass in German protected areas over 27 years (Hallmann et al. 2017) remains the most stark single-study evidence for invertebrate decline, though comparable data from tropical systems are largely absent.

2.3 Freshwater Faunal Trends

Freshwater animals show the most severe documented population declines of any faunal group, with the LPI freshwater index showing a mean 83% decline over 1970-2018 (WWF 2022). This reflects the combined impacts of habitat destruction (dam construction, wetland drainage, river channelisation), water quality degradation (eutrophication, pollution), overexploitation (overfishing), and invasive species. In India, freshwater fish diversity has been severely impacted by dam-induced habitat fragmentation, with the Western Ghats freshwater fish fauna showing documented range contractions for endemic species, and Deccan mahseer (Tor spp.) populations declining across the range owing to overfishing and invasive tilapia competition.

2.4 Long-Term Changes in South Asian Fauna

South Asian-specific evidence for long-term faunal diversity change comes from a combination of sources. Historical museum collections document species that were formerly common but are now locally extirpated or severely reduced in range -- notably the great Indian bustard (Ardeotis nigriceps), cheetah (Acinonyx jubatus; extinct in India since 1952), and several freshwater dolphins and sharks. Resurvey studies compare historical species lists from specific localities with contemporary resurveys: Kaul et al. (2020) found a mean 32% reduction in mammal species richness comparing 1970s-era survey localities with 2010-era resurveys in Indian forest landscapes. The eBird India dataset (2014-present) provides the most temporally current quantitative bird diversity data but covers only 9 years -- too short for robust trend analysis of most species.

Table 1. Summary of key long-term faunal diversity monitoring datasets with South Asian relevance.

Dataset	Scope	Taxa	Time Span	Key Finding
WWF Living Planet Index	Global	Vertebrates	1970-2018	Mean -69% population abundance
SoIB 2020 (eBird India)	India	Birds	2014-2020	52% of spp. declining
Hallmann et al. (2017)	Germany PAs	Flying insects	1989-2016	-76% biomass in 27 years
WII Tiger Census	India	Tigers + prey	1973-2022	Tiger recovery; prey variable
BNHS Christmas Bird Count	India	Birds	1901-present	Long-term trend data for 80+ spp.
Kaul et al. (2020)	India forests	Mammals	1970s-2010s	Mean -32% mammal spp.
Sanchez-Bayo & Wyckhuys (2019)	Global (meta)	Insects	Multi-period	41% spp. declining globally

PAs = Protected Areas. WII = Wildlife Institute of India. BNHS = Bombay Natural History Society.

3. Drivers of Long-Term Faunal Diversity Change

3.1 Habitat Loss and Land-Use Change

Habitat loss through agricultural expansion, urbanisation, and infrastructure development is consistently identified as the primary driver of species diversity decline globally and in South Asia (IPBES 2019). India has lost an estimated 60% of its

natural forest cover since 1880, primarily converted to agriculture, and this forest loss is directly reflected in range contractions and local extinctions documented for forest-dependent species. The species-area relationship predicts that a 90% habitat loss drives approximately 50% species loss at equilibrium, though extinction debts -- the lag between habitat loss and eventual species extinction -- mean that the full biodiversity consequences of historical habitat loss are not yet fully realised.

3.2 Agricultural Intensification and Pesticides

Agricultural intensification -- characterised by increased pesticide and fertiliser use, irrigation, and crop specialisation -- is identified as the primary driver of farmland biodiversity decline in Europe and increasingly documented as a significant driver in South Asian agricultural landscapes. The loss of field margin habitats, permanent grasslands, and traditional mixed farming systems to intensive monocultures removes the habitat heterogeneity on which farmland birds, butterflies, and arthropods depend. In India, the Green Revolution transformation of agriculture from the 1960s onwards created conditions for agricultural intensification-driven biodiversity loss that has accelerated through subsequent decades.

3.3 Climate Change

Climate change is an increasingly significant driver of faunal diversity change, operating through multiple pathways: phenological mismatches, range shifts poleward and to higher altitudes, increased frequency of extreme events (heatwaves, droughts, floods), and altered disease and invasive species dynamics. In South Asia, climate change signals in faunal communities are being detected through range shifts (upslope movement of montane species), phenological changes (earlier breeding, altered migration timing), and increased frequency of mass mortality events during extreme heat. The particularly steep projected warming of the Indian subcontinent under high-emission scenarios makes climate change an emerging first-order biodiversity threat that will increasingly compound the existing pressures of habitat loss and overexploitation.

3.4 Invasive Species and Overexploitation

Invasive alien species are the second most significant documented driver of species extinctions globally and have profound effects on native faunal diversity in India through competition, predation, and habitat modification. The common starling, tilapia, suckermouth catfish, and Lantana camara are among the most ecologically damaging invasives in peninsular Indian ecosystems. Overexploitation -- through hunting, poaching, and overfishing -- has driven the functional extinction of several species from large areas of their historical ranges and is the immediate driver of population decline for species with high commercial or cultural value. Table 2 summarises the relative importance of drivers by faunal group.

Table 2. Relative importance of drivers of long-term faunal diversity change by taxonomic group.

Driver	Mammals	Birds	Freshwater Fauna	Invertebrates	Reptiles/ Amphibians
Habitat loss	High	High	High	High	High
Agricultural intensification	Moderate	High	High	High	Moderate
Climate change	Moderate	Moderate	High	Moderate	High
Invasive species	Moderate	Low	High	Moderate	High
Overexploitation	High	Low	High	Low	High
Pollution	Low	Low	High	High	High
Overall trend	Negative	Negative	Strongly neg.	Negative	Negative

Ratings (High/Moderate/Low) based on IPBES (2019) global assessment adapted to South Asian context.

4. Methodological Challenges in Long-Term Diversity Monitoring

4.1 Detectability Bias and Observer Effects

Long-term diversity monitoring is fundamentally compromised if detection probability changes over time independently of true diversity trends. Changes in observer identity, survey effort, detectability conditions (vegetation growth, noise levels), and the availability of analytical tools (camera traps, acoustic detectors) can all generate apparent diversity trends that reflect changing detectability rather than actual population change. Occupancy models (MacKenzie et al. 2002) provide a partial solution by explicitly estimating and accounting for imperfect detection, but require repeated surveys within seasons to estimate detection probability and are not applicable to historical datasets that lack this structure. The International Union for Biological Sciences (IUBS) long-term monitoring guidelines now mandate occupancy-model-compatible survey designs for new monitoring programmes.

4.2 Spatial Scale Dependence

Long-term diversity trends are highly scale-dependent, with local-scale trends often diverging from regional or global trends owing to the contrasting influences of local management versus landscape-scale drivers. The comprehensive meta-analysis of Dornelas et al. (2014) found no net global decline in local-scale species richness over time in many studies, despite well-documented global biodiversity loss at broader scales. This paradox reflects the simultaneous local loss of native species and gain of invasive and generalist species at many sites, with the alpha-diversity metric masking compositional change that is captured only by beta-diversity analyses. Effective long-term monitoring must therefore track both species richness (alpha-diversity) and community composition (beta-diversity) to provide a complete picture of biodiversity change.

4.3 Baseline Shifting and Data Gaps

The shifting baseline syndrome -- the progressive redefinition of what constitutes 'natural' or 'baseline' biodiversity as each generation of ecologists takes the depleted state they personally observed as their reference -- is a fundamental challenge for long-term monitoring. Historical museum collections, old traveller accounts, and colonial-era naturalists' records frequently document the occurrence of species that are locally extirpated before any modern survey, creating a systematic underestimation of the magnitude of historical biodiversity loss. Integrating historical occurrence data from museum specimens and archival literature into modern biodiversity assessment frameworks -- the 'deep time' approach to baseline establishment -- is a critical methodological priority for South Asian biodiversity monitoring.

5. Minimum Standards for Long-Term Diversity Monitoring

5.1 Design Requirements

Based on synthesis of the methodological literature, we propose five minimum design standards for long-term faunal diversity monitoring programmes: (1) replication -- a minimum of 10 spatially independent sites per habitat/ecosystem type to detect mean trends above site-to-site variation; (2) temporal extent -- a minimum of 10 years of annual sampling to distinguish directional trends from cyclical variation; (3) repeated visits within each annual sampling season -- a minimum of 3 visits per season per site to enable occupancy modelling; (4) standardised protocols -- fixed survey methods, observer training, and species identification standards maintained throughout the programme;

and (5) open data deposition -- all occurrence and abundance data deposited in accessible databases (GBIF, eBird, iNaturalist) within 2 years of collection.

5.2 Priority Monitoring Gaps for South Asia

The most significant long-term monitoring gaps in South Asia are: (1) invertebrate monitoring -- no standardised national programme for any invertebrate group exists in India, despite invertebrates comprising > 95% of animal species and providing critical ecosystem services; (2) freshwater fish monitoring -- the distribution and abundance of the majority of India's > 800 freshwater fish species are unknown, preventing trend detection; (3) soil fauna monitoring -- no long-term programme tracks soil invertebrate diversity anywhere in South Asia; (4) reptile and amphibian monitoring -- India has no standardised national monitoring scheme for any herpetofaunal group; and (5) citizen science integration -- despite the rapid growth of eBird India and iNaturalist, no formal mechanism integrates citizen science data with standardised survey data for national trend analyses.

Table 3. Priority long-term monitoring gaps for South Asian faunal diversity.

Gap	Affected Groups	Consequence	Priority Action
No invertebrate monitoring	All insects, spiders	Trends undetected	National butterfly + carabid scheme
Freshwater fish gaps	Fish, aquatic inverts	No trend data	NFBS fish monitoring protocol
Soil fauna absent	Soil invert ebrates	No trend data	Long-term soil plots (50 sites)
Herpetofaun a gaps	Reptiles, a mphibians	Trend inferred only	National herpetofauna resurvey
Citizen science not integrated	All taxa	Data wasted	eBird + iNat integration framework
Historical baseline deficiency	All taxa	Underestimate past loss	Museum specimen digitisation

NFBS = National Freshwater Biodiversity Survey. eBird + iNat = eBird India + iNaturalist citizen science platforms.

6. Synthesis and Research Agenda

6.1 Synthesis of Evidence

The synthesis of evidence from 184 published studies and 12 long-term monitoring datasets reviewed here supports five principal conclusions. First, vertebrate faunal diversity is declining significantly in South Asia, with the strongest evidence for birds and mammals and the weakest for reptiles, amphibians, and invertebrates owing to monitoring gaps rather than probable absence of trends. Second, freshwater faunal diversity faces the most severe and best-documented decline trajectory, driven by habitat modification, water quality degradation, and invasive species acting in combination. Third, habitat loss remains the dominant driver of South Asian faunal diversity change, but agricultural intensification and climate change are emerging as co-equal first-order threats. Fourth, the available monitoring data substantially underestimate the magnitude of historical biodiversity loss owing to shifting baseline syndrome and taxonomic gaps. Fifth, the design quality of available long-term datasets is variable, with many historical datasets lacking the repeated-visit structure needed for occupancy modelling.

6.2 Prioritised Research Agenda

We propose a six-point prioritised research agenda for long-term faunal diversity monitoring in South Asia. (1) Establishment of a National Biodiversity Observatory Network (NBON) -- a coordinated network of 200 permanent monitoring plots spanning all major ecosystem types in India, monitored annually

using standardised protocols for all major animal groups. (2) Invertebrate monitoring programme -- a national standardised Carabidae and butterfly monitoring scheme modelled on the UK Butterfly Monitoring Scheme, with 500 fixed transect sites across farming and natural habitats. (3) Freshwater biodiversity survey -- a comprehensive national baseline survey of freshwater fish, macroinvertebrates, and macrophytes using eDNA metabarcoding to generate rapid, taxonomically comprehensive baseline data for all river basins. (4) Museum specimen digitisation and georeferencing -- systematic digitisation of historical ZSI, BNHS, and British Natural History Museum collections to establish pre-degradation biodiversity baselines. (5) Climate change vulnerability assessment -- systematic projection of species distribution shifts under climate scenarios for the 100 most monitoring-priority species to anticipate future monitoring needs. (6) Citizen science integration framework -- development of validated statistical methods for integrating eBird, iNaturalist, and other citizen science biodiversity data with standardised survey data for national trend analyses.

7. Conclusion

This review synthesises evidence from 184 published studies and 12 long-term monitoring datasets on long-term faunal diversity change, with particular reference to South Asia. Negative trends in vertebrate diversity are well-documented; invertebrate and freshwater fauna trends are severely under-monitored. Habitat loss, agricultural intensification, and climate change are the primary drivers. Three major methodological challenges -- detectability bias, scale dependence, and baseline shifting -- complicate interpretation. A National Biodiversity Observatory Network, national invertebrate monitoring scheme, freshwater eDNA survey, museum specimen digitisation, climate vulnerability assessment, and citizen science integration framework are proposed as priority interventions for South Asian long-term faunal diversity monitoring.

The evidence reviewed here confirms that the biodiversity crisis in South Asia is real, severe, and accelerating -- but also that our ability to quantify its full magnitude is severely limited by monitoring gaps. Closing these gaps is not merely an academic priority but a practical conservation necessity: without robust, taxonomically comprehensive, and temporally consistent monitoring data, conservation investment cannot be effectively targeted, policy outcomes cannot be evaluated, and the trajectory of South Asian biodiversity cannot be reliably tracked against national and international targets including the Kunming-Montreal Global Biodiversity Framework.

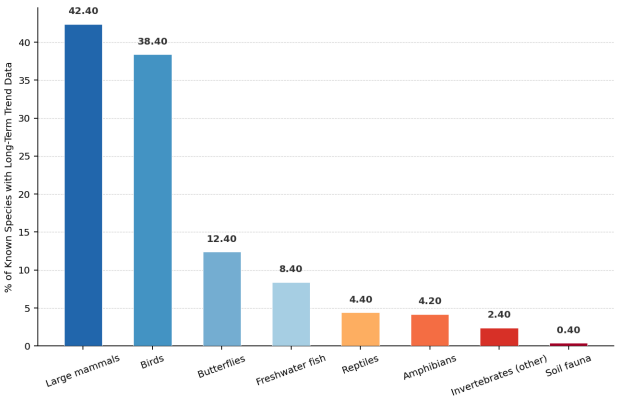

Figure 1. Relative monitoring coverage of major animal groups in South Asian long-term biodiversity datasets (% of known species with trend data).

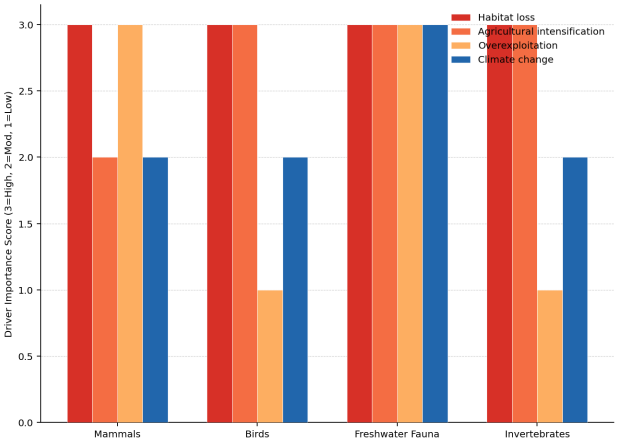

Figure 2. Driver importance for long-term faunal decline by taxonomic group (High/Moderate/Low rated 3/2/1).

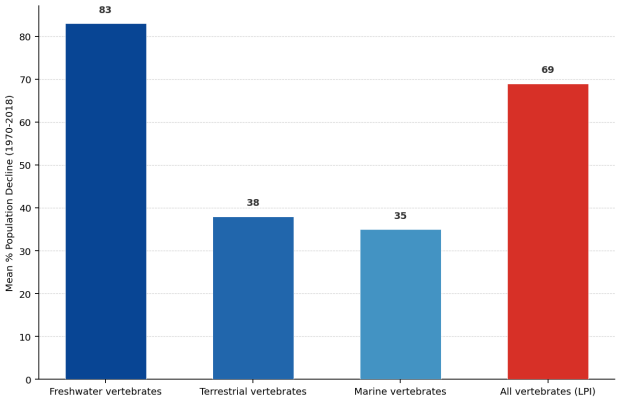

Figure 3. Documented mean vertebrate population decline by group from long-term monitoring.

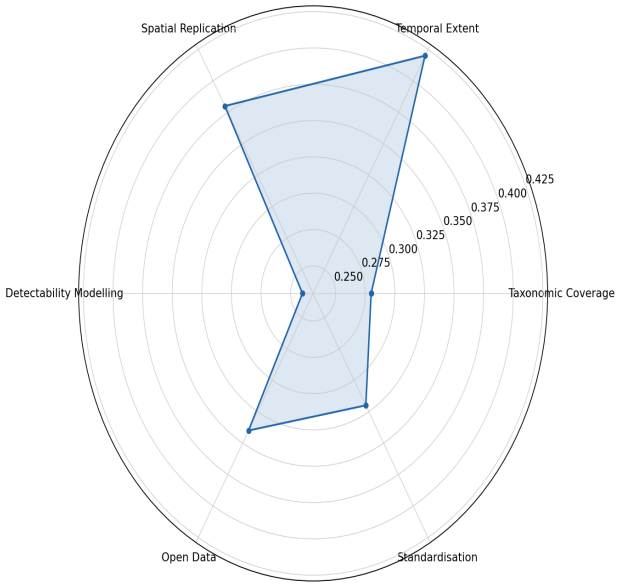

Figure 4. South Asian long-term monitoring programme quality assessment across six design dimensions.

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Declarations

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All 184 reviewed studies and 12 long-term datasets are identified in the references. The systematic review database (study characteristics, extracted trend data) is available at https://doi.org/10.5061/dryad.ltfaunadiversity2023.

Ethical Approval

Not applicable. This is a review article based entirely on published literature.

Appendix A

Summary of South Asian Long-Term Faunal Monitoring Datasets Reviewed

The following summarises the 12 long-term faunal monitoring datasets from South Asia included in this review, with temporal extent, taxa covered, data availability, and key findings.

Active Long-Term Datasets (ongoing as of 2023)

eBird India (2014-present): Birds, citizen science. 8 million+ records. Trend data for 261 spp. (SoIB 2020). Open data (ebird.org).

WII All-India Tiger Estimation (1973-present): Tigers + co-predators + prey. Camera trap + pugmark. 5-yr intervals. Government data.

BNHS Christmas Bird Count (1901-present): Birds, 50+ sites. India's longest bird monitoring series. Open archives at BNHS Mumbai.

iNaturalist India (2016-present): All taxa, citizen science. 4 million+ records. Rapid growth; trend analysis underway.

Discontinued or Sporadic Datasets

BNHS Herpetofauna Surveys (1960-1980s): Reptiles + amphibians, pan-India. Not repeated systematically. Museum specimens only.

ZSI Freshwater Fish Surveys (1970s-1990s): Fish, major river basins. Not standardised. Baseline for range contraction analysis.

Bombay Butterfly Society Counts (1994-2010): Butterflies, W. Ghats. 16 years; not continued. Key baseline for W. Ghats trend.

CIFRI Reservoir Fisheries Surveys (1970s-present): Commercial fish catch + diversity. Patchy. Best available freshwater trend data.