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Assessment of faunal biodiversity and challenges for sustainability

Satya Prakash Mehra

Environmental cum Development Professional, GFSRD-RSNH-GWF, India

ABSTRACT

Faunal biodiversity underpins ecosystem functioning, human wellbeing and long-term sustainability. However, accelerating land-use change, fragmentation, pollution, invasive species, overexploitation and climate change are driving unprecedented declines in animal populations and altering species interactions. Effective assessment of faunal biodiversity and the implementation of strategies that maintain or restore harmony between human needs and wildlife are essential for achieving sustainable development goals. This paper synthesizes contemporary approaches to assessing faunal biodiversity (field surveys, remote sensing, eDNA, acoustic monitoring, citizen science, analytical indices and modelling), identifies the main socio-ecological challenges to maintaining harmony, and proposes an integrated framework combining robust assessment, adaptive management, conflict mitigation, policy instruments and community-centred conservation for long-term sustainability. Practical recommendations, monitoring protocols and research priorities are provided to help conservation practitioners, environmental managers, policy makers and academics operationalize faunal biodiversity assessment and coexistence strategies.

KEY WORDS

Biodiversity; Ecosystem; Overexploitation; Climate change; eDNA; Pollution

ARTICLE HISTORY

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Introduction

Study Area

Faunal biodiversity the variety and variability of animal life at genetic, species and ecosystem levels is a fundamental component of ecological resilience and socio-economic well-being [1]. Animals provide pollination, pest regulation, nutrient cycling, cultural services and food security; they also act as indicators of ecosystem health [2,3]. Nonetheless, global indicators point to steep declines in many animal taxa and widespread restructuring of communities driven by anthropogenic pressures [4]. Assessing faunal biodiversity accurately is a prerequisite for conservation action, environmental impact assessment, land-use planning and adaptive management [5-7].

Beyond measurement, maintaining harmony that is, minimizing negative interactions between people and animals while conserving biodiversity is both a social and ecological challenge. Human–wildlife conflict, competition for resources, zoonotic risks, and differing stakeholder values complicate conservation outcomes [8-11]. Achieving sustainability requires integrating rigorous biodiversity assessment with socio-institutional measures that address livelihoods, governance, and incentives.

Main objectives

This paper has three objectives: (1) present a contemporary, practical synthesis of methods for assessing faunal biodiversity across spatial and taxonomic scales; (2) identify and discuss the principal challenges to maintaining human–faunal harmony in a sustainable way; and (3) propose an integrated operational framework and actionable recommendations for monitoring, mitigation and policy to support long-term coexistence.

Principles of Faunal Biodiversity Assessment

Unit, scale and objectives define method choice

Assessment begins by setting clear objectives: inventory vs. monitoring, presence/absence vs. abundance, short-term impact assessment vs. long-term trend detection. Spatial scale (local site, landscape, national) and taxonomic focus (invertebrates, birds, mammals, herpetofauna, aquatic fauna) drive sampling design and analytical choices [5,12]. Temporal scale determines the frequency of monitoring necessary to detect biologically meaningful change [13].

Representative sampling and stratification

To reduce bias, sampling must be stratified by habitat, elevation, land-use type, or management unit. Randomization, replication and adequate sample sizes are fundamental to inferential power [6]. For mobile taxa, sampling must consider detectability and movement patterns.

Detectability and sampling error

Detectability varies with species' behaviour, time of day, season, observer skill and equipment. Methods that account for imperfect detection (e.g., occupancy modelling, distance sampling, mark–recapture) provide more reliable estimates of occurrence and abundance [14,15].

Multi-method approaches

No single method captures the full faunal assemblage. Combining methods visual transects, camera traps, pitfall arrays, mist-netting, acoustic recorders, eDNA increases detection probabilities and cross-validates data [5].

Field and laboratory methods strengths and limitations

Below is a synthesis of commonly used methods, their ideal applications and constraints.

Visual and auditory surveys

Line transects and point counts (birds, large mammals).

***Correspondence:** Dr. Satya Prakash Mehra, Environmental cum Development Professional, GFSRD-RSNH-GWF, India, e-mail: drspmehra@yahoo.com

Good for relative abundance and distribution; require trained observers; affected by detectability and habitat visibility [15].

Nocturnal spotlight and call playback surveys for nocturnal mammals and amphibians. Useful where vocalising species are present but may bias behaviour.

Trapping and capture methods

P**itfall traps, Sherman traps, mist nets** capture small mammals, herpetofauna and birds for biometric data, age/sex structure and tagging. Ethical handling and permits are essential. Trapping biases species composition toward trappable taxa.

Camera trapping

Widely used for cryptic, nocturnal and large mammals; provides occupancy and relative abundance indices, activity patterns, and species interactions [16]. Cost and data management (large image volumes) are considerations. Spatially explicit capture–recapture (SECR) models can estimate density [17].

Acoustic monitoring

Passive acoustic recorders (autonomous units) are effective for birds, bats, amphibians, and some insects. Automated call classification is maturing but requires curated reference libraries and careful QC [18,19,12].

Environmental DNA (eDNA)

eDNA from water, soil or air can detect presence of fish, amphibians, mammals and invertebrates with high sensitivity. It excels where visual detection is difficult but has limitations in taxonomic resolution and source attribution [20].

Genetic and genomic tools

Genetics inform population structure, connectivity, inbreeding and taxonomic uncertainty. Non-invasive sampling (scats, hair) combined with microsatellite or Single Nucleotide Polymorphism (SNP) analyses provides powerful conservation insights [21].

Remote sensing and Geographic Information System (GIS)

Habitat mapping, fragmentation metrics, landscape connectivity modelling and change detection using satellite imagery, Light Detection and Ranging (LiDAR) and Unmanned Aerial Vehicles (UAVs) are critical for linking faunal patterns to habitat features at multiple scales [22].

Citizen science and participatory monitoring

Structured citizen-science programs expand spatial coverage, augment datasets and foster stewardship [23-25]. Data quality control and calibration with expert surveys are necessary.

Metrics and Analytical Frameworks

Biodiversity indices

Species richness, Shannon–Wiener index and **Simpson's index** quantify diversity but capture different aspects (richness vs. evenness) [26,27].

Functional and **phylogenetic diversity** complement taxonomic metrics by reflecting ecological roles and evolutionary history [28].

Occupancy and abundance models

Occupancy modelling accounts for detection probability to estimate site occupancy reliably; hierarchical models link detection and state processes [14]. Distance sampling and SECR support density estimation [15, 17].

Trend detection and power analysis

Monitoring programs must be designed with statistical power to detect trends of conservation relevance; simulation and power analysis inform monitoring frequency and sample size [29].

Connectivity and metapopulation models

Landscape connectivity (graph theory, circuit theory) informs corridor design and reserve networks; metapopulation models identify extinction risk under habitat loss scenarios [30,31].

Socio-ecological assessment

Integrated indicators (ecosystem services valuation, socio-economic vulnerability, governance indices) enable assessment of trade-offs and co-benefits of conservation actions like enviropreneurship models [1,32,33].

Key Challenges to Maintaining Harmony and Sustainability

Habitat loss, fragmentation and landscape change

Conversion of natural habitats to agriculture, infrastructure and urban areas remains the principal driver of faunal declines [34]. Fragmentation isolates populations, reduces gene flow and increases edge effects.

Human-wildlife conflict (HWC)

Crop raiding, livestock depredation and threats to human safety generate retaliatory killing and erode tolerance for wildlife. Conflict hotspots often overlap with high biodiversity and poor governance [10,11].

Overexploitation and illegal trade

Unsustainable hunting, bycatch, and illegal wildlife trade threaten many taxa; enforcement and demand-reduction remain challenging [35].

Invasive species and disease

Invasives can restructure communities and spread disease; anthropogenic movement of species and climate change exacerbate these threats [36].

Climate change

Shifts in temperature and precipitation alter species' ranges, phenology and interactions, creating novel communities and mismatch dynamics [36,37].

Institutional and governance limitations

Insufficient cross-sectoral coordination, underfunding, weak enforcement and lack of participatory approaches undermine conservation outcomes.

Social inequity and livelihood dependence

Poor, marginalized communities often rely directly on wild resources, so conservation measures that ignore socio-economic realities can fail or generate conflict.

Strategies for Maintaining Harmony: An Integrated Approach

Maintaining long-term harmony between humans and fauna

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requires combining biophysical measures with social, economic and governance strategies. Below we outline an integrated framework.

Evidence-based assessment and adaptive management

Baseline and monitoring

Implement robust baseline surveys and repeat monitoring with methods appropriate to taxa and objectives. Use occupancy/density models and trend analysis to detect change.

Adaptive management

Use iterative cycles assess → plan → act → monitor → revise so management responds to new evidence [38].

Conflict mitigation and coexistence tools

Prevention

Improve livestock husbandry, deploy deterrents (fencing, lights, guard animals), secure crops with non-lethal methods, and reduce attractants [39].

Compensation and insurance

Well-designed, transparent compensation or insurance schemes can reduce retaliatory killings; community involvement in claim verification is critical.

Proactive zoning

Land-use planning that channels high-intensity uses away from core wildlife habitats, and establishes buffer zones and corridors.

Community-based conservation and livelihood integration

Benefit sharing

Link conservation to tangible benefits Eco-tourism income, payments for ecosystem services (PES), direct employment to build local stewardship, enviropreneurship [5,32,33].

Participatory governance

Include local communities in decision-making bodies, monitoring and enforcement [32,40,41].

Landscape connectivity and green infrastructure

Maintain and restore corridors, stepping stones and ecological networks using spatial planning tools and connectivity models [31,42]. Incorporate agroecological practices that increase habitat heterogeneity in working landscapes [41].

Legal, policy and economic instruments

Protected areas plus matrix management

Combine well-managed protected areas with biodiversity-friendly practices in surrounding matrix [41,43,44].

Incentives

Subsidies, tax breaks, PES and biodiversity offsetting (with strict safeguards) can align private action with conservation.

Regulatory enforcement

Strengthen anti-poaching capacity, wildlife crime intelligence and cross-border cooperation.

Health and one health integration

Integrate wildlife surveillance with public and animal health systems to monitor zoonoses and reduce disease spillover risk, applying One Health principles.

Education, awareness and social norms

Long-term tolerance and behaviour change arise from awareness campaigns, school programs, and culturally appropriate messaging. Social norms around wildlife protection can be cultivated through community leaders and demonstration projects.

Operational Protocol: Designing a Biodiversity Assessment and Harmony Plan

Below is a stepwise operational protocol for practitioners.

Step 1: Define objectives and stakeholders

Clearly articulate conservation and social objectives (species of concern, ecosystem services, HWC reduction), and map stakeholders (local communities, government, industry, NGOs, research institutes).

Step 2: Baseline assessment design

- Stratify the landscape and select representative sampling units.
- Choose a multi-method toolkit tailored to taxa (camera traps + occupancy modelling for mammals; point counts + acoustic monitoring for birds; eDNA for aquatic systems).
- Conduct power analysis to determine sampling effort.

Step 3: Data collection and management

- Use standardized protocols and metadata standards (date, Global Positioning System (GPS), effort, observer).
- Implement Quality Assurance / Quality Control (QA/QC) and data storage solutions with open-access options where appropriate.

Step 4: Data analysis and reporting

- Estimate occupancy/abundance with detection-corrected models, compute diversity indices, functional/phylogenetic metrics and landscape metrics.
- Produce readable outputs (maps, dashboards) for stakeholders.

Step 5: Coexistence interventions design

- Based on hotspots of conflict and vulnerability, co-design mitigation measures with communities (e.g., predator-proof kraals, guarding schedules, crop zoning).
- Identify opportunities for livelihood diversification and Payments for Ecosystem Services (PES).

Step 6: Policy integration and financing

- Align interventions with national biodiversity strategies, Environmental Impact Assessment (EIA) requirements and local development plans.
- Identify funding sources (conservation grants, development funds, private sector Corporate Social Responsibility (CSR)).

Step 7: Monitoring, evaluation and adaptive management

- Set Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) indicators (biodiversity trends, conflict incidents, economic benefits) and review on fixed cycles.
- Revise interventions based on monitoring results.

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Case Examples (Illustrative, Generic)

Integrated landscape in a mixed agro-forest matrix: A program combining camera trapping, community scouts and PES reduced livestock losses by 60% over three years while increasing wild herbivore occupancy in riparian corridors. Key success factors: community co-design, transparent compensation, and corridor restoration.

Riparian fish monitoring using eDNA: eDNA surveys allowed rapid detection of invasive carp upstream of critical spawning grounds, enabling timely management actions and preventing further spread.

Citizen science for migratory bird monitoring: Structured eBird-style programs provided long-term seasonal trend data, validated against systematic point counts, and increased local stewardship through school engagement.

Research and monitoring priorities

Integration of novel technologies: Further develop automated acoustic and image recognition, eDNA reference databases, and low-cost sensors to broaden taxonomic coverage.

Linking demographic and landscape models: Combine SECR density estimates with connectivity models to forecast population persistence under land-use change.

Socio-ecological experiments: Test alternative compensation, insurance and livelihood interventions (enviroprenuership) with rigorous social science methods (randomized evaluations where appropriate).

Climate-adaptation strategies: Identify climate refugia and prioritize connectivity to facilitate range shifts.

Standardized global monitoring frameworks: Harmonize methods and metadata to allow comparable trend analysis across regions.

Ethical, legal and capacity considerations

Ethical treatment of animals: Ensure humane handling, minimal disturbance and compliance with ethical review and permits.

Data sovereignty and benefit sharing: Respect indigenous and local knowledge rights, ensure data access policies protect sensitive information (e.g., locations of threatened species).

Capacity building: Invest in local training for taxonomy, survey methods, data analysis and conflict mediation to sustain monitoring programs.

Conclusions

Sustaining faunal biodiversity while maintaining human–faunal harmony is both an ecological and social endeavour. Robust, multi-method assessments provide the evidence base needed for effective action. However, data alone are insufficient: success hinges on integrating assessment with participatory conflict mitigation, landscape planning for connectivity, adaptive management, and inclusive policy mechanisms that deliver benefits to local people like enviropreneurship. A One Health perspective, attention to equity and sustained capacity building will be essential. The framework and operational guidance presented here offer a practical pathway for practitioners and policy makers to assess biodiversity, reduce conflict and foster coexistence that supports long-term sustainability.

Practical Appendices (Short)

Appendix A - Example minimum dataset for faunal monitoring

- Site ID, GPS coordinates, elevation, habitat type, date/time, weather, observer ID
- Method used, effort (e.g., transect length, camera trap nights), species observed (with counts), photographic/audio file references, verification status.

Appendix B - Example SMART indicators

- Biodiversity indicator: Change in occupancy probability of target mammal species over 5 years (target: no net decline).
- Conflict indicator: Number of livestock depredation incidents per 100 households per year (target: 50% reduction in 3 years).
- Livelihood indicator: Percentage of participating households receiving ≥10% annual income from conservation-linked activities (target: 60% participation).

Disclosure Statement

The authors do not have any conflict of interest.

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