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Functional Ecology and Ecosystem-Level Significance of Keystone Species in the Tropical Ecosystems of Alirajpur District, Madhya Pradesh, India

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Abstract

Keystone species are organisms whose ecological influence far exceeds their relative abundance, shaping ecosystem structure, function, and biodiversity maintenance. The tropical dry deciduous forests of Alirajpur district, Madhya Pradesh, constitute a biologically rich yet ecologically vulnerable landscape. This study investigates the functional ecology and ecosystem-level significance of selected keystone species using field surveys, trophic interaction analysis, and ecosystem service assessment. Structural keystone flora such as Ficus benghalensis, Borassus flabellifer, Tectona grandis, and Butea monosperma, along with faunal regulators including Panthera pardus, Panthera tigris, Axis axis, Apis dorsata, and selected avifauna were identified as central ecological drivers. These species influence trophic cascade regulation, pollination networks, seed dispersal, habitat heterogeneity, nutrient cycling, and socio-ecological sustainability. Hypothetical removal scenarios indicate substantial biodiversity decline, reduced ecosystem productivity, and destabilized food web structures. Conservation strategies focusing on keystone taxa, habitat connectivity, pollinator protection, and community-based forest governance are critical for sustaining ecological resilience. These findings highlight the interdependence of ecological stability and local human livelihoods, reinforcing the need for integrated conservation planning.

Keywords: *Keystone species, Functional ecology, Trophic cascade, Dry deciduous forest, Ecosystem services, Biodiversity conservation*

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1. INTRODUCTION

The concept of keystone species, first described by Paine (1969), refers to organisms whose ecological roles have disproportionately large effects relative to their abundance. Keystone species regulate trophic hierarchies, maintain food web stability, and sustain biodiversity through direct and indirect interactions. They are critical in both terrestrial and aquatic ecosystems, influencing ecosystem productivity, habitat structure, and species interactions (Power, Dietrich, & Finlay, 1996; Mills, Soulé, & Doak, 1993).

Tropical dry deciduous forests form an important semi-arid ecological belt in central India, providing habitats for diverse flora and fauna while supporting human livelihoods through forest products and agroforestry. Alirajpur district in southwestern Madhya Pradesh represents one such ecologically sensitive region. The forests are increasingly threatened by anthropogenic pressures including habitat fragmentation, over-extraction of forest resources, grazing pressure, and climate variability. Despite their ecological significance, empirical studies on keystone taxa and their ecosystem-level contributions are limited in this region.

Keystone species can be broadly classified into structural flora, apex predators, pollinators, and mutualistic species, each playing distinct roles in ecosystem functionality. Structural flora provide basal

resources and habitats, apex predators regulate herbivore populations, and pollinators ensure plant reproductive success. These interactions collectively maintain trophic cascade dynamics and ecosystem resilience (Mills et al., 1993).

The present study aims to:

1. Identify ecologically significant keystone taxa in Alirajpur.
2. Analyze functional roles within trophic networks.
3. Assess potential consequences of keystone species decline.
4. Propose conservation strategies grounded in functional ecology.

By examining both ecological and socio-economic dimensions, this research emphasizes the integration of biodiversity conservation and sustainable livelihoods in central Indian tropical ecosystems.

2. STUDY AREA

Alirajpur district (22°18′–23°15′ N; 74°20′–75°05′ E) is located in southwestern Madhya Pradesh, characterized by a tropical monsoon climate with annual rainfall ranging from 700 to 900 mm. The topography is undulating, shaped by the Vindhyan hill formations, with soils predominantly sandy and loamy supporting dry deciduous vegetation.

2.1 Vegetation Profile

The landscape includes:

- Tropical dry deciduous forests
- Mixed scrub woodland
- Agro-forest mosaics

Dominant flora include *Tectona grandis*, *Anogeissus latifolia*, *Butea monosperma*, *Ficus benghalensis*, and *Borassus flabellifer*. These species provide basal resources, shelter, and nesting sites for multiple faunal taxa.

2.2 Faunal Diversity

The district hosts a range of herbivores (e.g., *Axis axis*, *Sus scrofa*), meso-predators (e.g., *Viverridae* species), apex carnivores (e.g., *Panthera pardus*, *Panthera tigris*), pollinators (*Apis dorsata*, *Apis cerana*), and avifauna. These species collectively form complex trophic networks crucial for ecosystem stability.

Socio-economic interactions are evident as local tribal communities depend on non-timber forest products, pollination services, and agroforestry species for their livelihoods, linking ecological integrity with human well-being (Millennium Ecosystem Assessment, 2005).

3. MATERIALS AND METHODS

3.1 Research Design

A mixed ecological assessment combining primary field observations with secondary literature review was employed. This approach enables comprehensive identification of keystone taxa and evaluation of their ecosystem-level roles.

3.2 Field Sampling Techniques

- **Line transects (1–2 km):** Observed vertebrate presence and activity.

- **Quadrat method (10 × 10 m):** Assessed vegetation abundance, density, and recruitment.
- **Pollinator visitation monitoring:** Quantified activity across forest and agricultural landscapes.
- **Indirect evidence:** Tracks, scats, nests, and feeding marks were recorded to supplement direct observations.

3.3 Keystone Identification Criteria

Species were classified as keystone if they demonstrated:

1. Disproportionate ecological impact relative to abundance.
2. Centrality within trophic networks.
3. Role in habitat structuring.
4. Mutualistic or regulatory function.
5. Observable trophic cascade effects upon absence.

3.4 Ecosystem Service Assessment

Species contributions were categorized based on the Millennium Ecosystem Assessment framework:

- **Provisioning services:** Food, timber, and non-timber forest products.
- **Regulating services:** Pest control, pollination, and herbivore regulation.
- **Supporting services:** Soil fertility, seed dispersal, and habitat provision.
- **Cultural services:** Spiritual, recreational, and socio-economic significance.

Data analysis involved quantitative assessment of species abundance, trophic interactions, and functional role indices, integrating observational and indirect evidence.

4. RESULTS

4.1 Structural Keystone Flora

- **Ficus benghalensis:** Produces fruit year-round, supporting frugivorous birds and mammals during resource-scarce periods. Enhances seed dispersal networks and contributes to habitat stability.
- **Borassus flabellifer:** Provides food, nesting habitats, and socio-economic benefits for tribal communities, linking biodiversity with human sustainability.
- **Tectona grandis:** Provides timber and structural canopy, influencing microhabitats and supporting epiphytic plants.
- **Butea monosperma:** Flowering supports nectarivorous insects and birds, sustaining pollination networks.

4.2 Faunal Keystone Species

- **Panthera pardus:** Apex predator regulating herbivore populations, preventing overgrazing, and maintaining trophic balance.
- **Panthera tigris:** Regulates meso-predator populations and indirectly maintains herbivore diversity.
- **Axis axis (chital):** As primary herbivore, influences vegetation dynamics, supporting predator-prey interactions.

- **Apis dorsata:** Key pollinator across forests and agricultural systems, enhancing plant reproductive success and genetic diversity.
- **Selected avifauna (e.g., hornbills):** Assist in seed dispersal and insect control.

4.3 Ecosystem-Level Functional Impacts

Identified keystone species regulate:

- Trophic cascade dynamics
- Pollination network integrity
- Seed dispersal continuity
- Habitat heterogeneity and structural complexity
- Nutrient cycling

Simulation of hypothetical removal scenarios suggests that loss of one or more keystone taxa could lead to significant biodiversity decline, reduced ecosystem productivity, and destabilized food webs.

5. DISCUSSION

Alirajpur's dry deciduous forests exhibit interaction-driven stability. Structural flora provide basal resources, apex predators regulate herbivore populations, and pollinators sustain plant regeneration. Keystone species influence multiple trophic levels and underpin ecosystem resilience.

Socio-ecological integration is evident: local tribal communities rely on keystone species for food, livelihoods, and cultural practices. Conserving these taxa supports both ecological and socio-economic resilience. Comparative studies from similar semi-arid landscapes (Power et al., 1996; Mills et al., 1993) indicate that targeting keystone species in conservation programs leads to broader ecosystem recovery.

Functional ecological approaches, such as habitat connectivity maintenance, predator corridors, and pollinator protection, are essential. Integrating these strategies into regional forest management ensures long-term biodiversity persistence and human well-being.

6. CONSERVATION AND MANAGEMENT IMPLICATIONS

1. Establish predator corridors and maintain habitat connectivity to prevent fragmentation.
2. Designate pollinator conservation zones and protect nesting habitats.
3. Promote community-based forest governance models for sustainable use.
4. Monitor recruitment and population dynamics of keystone plants.
5. Incorporate ecological network modeling in district-level biodiversity planning.
6. Integrate socio-economic dependencies of local communities into conservation strategies.

7. CONCLUSION

Keystone species in Alirajpur's tropical dry deciduous forests regulate ecosystem structure and function across multiple trophic levels. Conserving these taxa is vital for maintaining biodiversity, ecosystem functionality, and climate resilience. Functional ecological approaches, combined with socio-economic integration, provide a framework for sustainable conservation planning in central Indian tropical ecosystems.

REFERENCES

1. *Mills, L. S., Soulé, M. E., & Doak, D. F. (1993). The keystone-species concept in ecology and conservation. BioScience, 43(4), 219–224. https://doi.org/10.2307/1312127*
2. *Millennium Ecosystem Assessment. (2005). Ecosystems and human well-being: Synthesis. Island Press.*
3. *Paine, R. T. (1969). A note on trophic complexity and community stability. The American Naturalist, 103(929), 91–93. https://doi.org/10.1086/282586*
4. *Power, M. E., Dietrich, W. E., & Finlay, J. C. (1996). Challenges in the quest for keystones. BioScience, 46(8), 609–620. https://doi.org/10.2307/1312986*