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Research Article

DIVERSITY AND FUNCTIONAL MORPHOLOGY OF BIRD CLAWS IN THE SRIKAKULAM REGION, ANDHRA PRADESH, INDIA

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ABSTRACT

Avian claw morphology provides vital information on ecological adaptations related to locomotion, foraging strategies, and habitat specialization. This study offers a comprehensive field-based survey of bird claw diversity across the heterogeneous landscapes of Srikakulam District, Andhra Pradesh, India, conducted during the post monsoon period (June to December 2024). We recorded 74 bird species spanning wetlands, forests, agricultural fields, and urban environments, using direct observations complemented by high resolution photography. Species were classified into nine functional claw types based on curvature, toe arrangement, and substrate interaction. Perching claws dominated (29.7%), followed by wading, swimming, and raptorial forms. Strong associations emerged between claw morphology and habitat use, reinforcing established functional adaptation frameworks. These results contribute valuable insights into avian ecomorphology within tropical ecotones and establish a critical baseline for future conservation driven morphological and behavioural research in the biologically rich yet understudied eastern peninsular region of India.

Keywords: Avian claw morphology, Functional adaptation, Habitat specialization, Srikakulam birds.

INTRODUCTION

The remarkable diversity in avian claw morphology reflects the interplay of ecological niche specialization, behavioural adaptation, and evolutionary history across bird lineages. Composed primarily of keratin over a bony core, claws fulfil essential functions including climbing, perching, prey capture, swimming, and grooming, making them critical indicators of both survival strategies and habitat relationships throughout the avian class. Key morphological aspects such as claw curvature, length-to-width ratio, and cross-sectional structure have emerged as reliable predictors of ecological roles and behavioural repertoires among birds (Thomson & Motani, 2023; Hedrick *et al*., 2019).

Avian claw shape has been repeatedly shown to correlate with ecological demands and behaviour. Raptors such as eagles and falcons possess robust, sharply curved talons for prey immobilization, while perching birds exhibit moderately curved claws that provide stability on branches (Birn-Jeffery *et al*., 2012; Thomson & Motani, 2021). Ground-dwelling species like pheasants show relatively straight claws adapted for terrestrial traction, whereas climbing birds such as woodpeckers display pronounced curvature and asymmetry that enable adherence to vertical substrates (Pintore *et al*., 2023). Aquatic species often exhibit flattened or modified claw structures that aid propulsion and manoeuvrability (Greenwold *et al*., 2014; Carril *et al*., 2024). Comparative analyses further highlight how claw form integrates with feeding, locomotion, and grasping strategies, reflecting a balance between ecological specialization and evolutionary constraints (Sustaita *et al*., 2013; Martin & Sherratt, 2023).

Recent morphometric and biomechanical studies underscore the importance of standardizing measurements when interpreting ecological roles, as claw morphology can vary substantially within taxa (Tinius & Russell, 2017). Moreover, 3D modelling approaches reveal that the keratin sheath responds dynamically to ecological pressures, while the bony core retains phylogenetic signals, providing

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palaeontologists with valuable insights into extinct taxa (Hedrick *et al*., 2019; Carril *et al*., 2024). This duality illustrates how claw morphology integrates functional adaptation with evolutionary history. Habitat-specific studies also confirm strong links between claw form and substrate use, with tropical understorey birds showing highly recurved claws for vertical perching, and open-habitat species displaying broader, flatter claws for balance on varied surfaces (Siri *et al*., 2020; Pintore *et al*., 2023).

While global research has advanced understanding of avian ecomorphology, there remains a paucity of detailed surveys focusing on the functional diversity of bird claws within tropical and subtropical regions, particularly in eastern India. The Srikakulam district of Andhra Pradesh, positioned between the Eastern Ghats and the Bay of Bengal, encompasses a mosaic of riverine, wetland, forest, and agricultural habitats that support rich avifaunal diversity. Yet, systematic documentation and analysis of claw types, with emphasis on habitat, behaviour, and conservation value, are notably lacking.

This study addresses this gap by systematically categorizing and analysing avian claw diversity in the Srikakulam region. It links claw morphology with habitat use, feeding strategies, and ecological adaptation across local bird communities, utilizing direct field observations and photographic documentation. By highlighting patterns of claw specialization and abundance, the research aims to inform conservation efforts, raise regional awareness, and contribute to the broader discourse on avian functional morphology and adaptation.

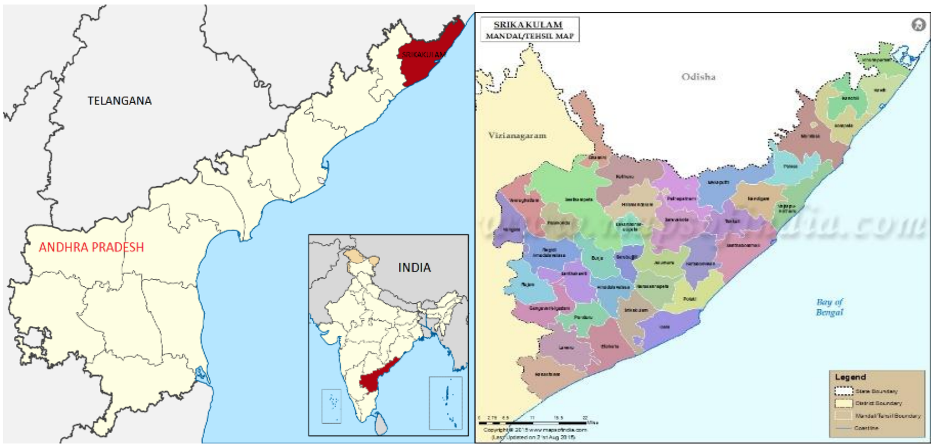

Figure 1. India-Andhra Pradesh-Srikakulam.

MATERIALS AND METHODS

Study Area

The study was conducted in Srikakulam District, located in the northeastern part of Andhra Pradesh, India. Geographically, the district spans between 18°20′N to 19°10′N latitude and 83°25′E to 84°50′E longitude (Figure 1). Situated within a transitional zone between the Eastern Ghats and the coastal plains of the Bay of Bengal, Srikakulam exhibits remarkable ecological diversity and supports a rich avifaunal community. Five major rivers Vamshadhara, Nagavali, Suvarnamukhi, Mahendratanaya, and Bahuda, originate in the Eastern Ghats and flow eastward across the plains before emptying into the Bay of Bengal. These river systems are accompanied by an extensive network of over 8,000 irrigation tanks, replenished seasonally by rainfall and channel fed irrigation. This intricate hydrological infrastructure creates a mosaic of perennial and seasonal aquatic habitats integral to bird diversity in the region.

Study Period and Site Selection

Fieldwork for this study was conducted from June to December 2024, covering the late pre-monsoon, monsoon, and post-monsoon seasons in the Srikakulam region. Surveys spanned diverse habitat types within Srikakulam District, including wetlands, forest patches, agricultural lands, riverbanks, and coastal stretches, selected based on bird abundance, habitat diversity, and accessibility to encompass a full range of ecological niches.

Sampling Method

Birds were recorded through a combination of systematic transect walks and point counts across representative habitats. Transects of 1–2km were established in forest edge, wetland, and urban locations, with observers moving slowly and noting all visually or aurally detected bird species. Stationary point counts of 10-minute intervals were deployed in marshes and dense vegetation, where visibility was limited. Additional opportunistic observations outside primary sampling hours further enriched the species list.

Bird Observation and Photography

Bird species were identified and documented using a Nikon D3500 DSLR camera with a 70–300mm telephoto lens, enabling clear visualization of foot and claw structures. Observations were conducted during early morning (06:00–09:30 hrs) and late afternoon (15:30–17:30 hrs), coinciding with peak avian activity. Binoculars (8×42 and 10×50) were used for close field observation, and targeted photographs were taken for later examination of pedal morphology, ensuring that ventral and lateral views of claws were captured during perching, feeding, or flight.

Species Identification

Species identification followed standard field guidelines, including: Ali, S. (2002). *The Book of Indian Birds*. Bombay Natural History Society. Grimmett, R., Inskipp, C., & Inskipp, T. (2011). *Birds of the Indian Subcontinent*. Helm Field Guides. Scientific names and taxonomic classifications were cross checked against the Bird Life International database and IOC World Bird List v13.1 (Gill *et al*., 2023).

Classification of Claw Types

Claw types were categorized primarily through direct field observation of foraging birds, with behavioural clues such as perching, climbing, wading, and swimming guiding morphological assignment. Where possible, photographs were taken for confirmation and measurement. For elusive or less visible species, published literature and regional field guides (e.g., Rasmussen & Anderton, 2012; Ali & Ripley, 1987) supplemented and validated claw type assignment. No museum specimens were examined as part of this study. Functional claw categories were adapted from current ecomorphological frameworks (Birn-Jeffery *et al*., 2012; Hedrick *et al*., 2019), considering features such as claw curvature, length to width ratio, digit arrangement (e.g., Anisodactyl, Zygodactyl), and substrate interaction behaviour. Each species was assigned to one of the following types based on photographic analysis and field observations (Table 3): Perching claws, grasping claws (raptors), Climbing claws, wading claws, Ground foraging claws, Scratching claws, Swimming claws, Clinging claws (arboreal), Specialized claws (e.g., fish catchers, pectinate for grooming).

Data Recording and Analysis

A total of 74 bird species representing multiple orders (Passeriformes, Accipitriformes, Charadriiformes, etc.) were recorded. For each species, data on claw morphology, habitat type, and behavioural context were documented. The photographic dataset was analysed using ImageJ software to measure claw curvature (arc angle), total length, and arc depth where possible. Associations between claw type and habitat type were summarized in tabular form. Data interpretation was primarily qualitative, with plans for morphometric analysis in future studies.

Functional classification of avian claws and feet

The morphology of avian feet and claws reflects evolutionary adaptations to ecological niches and locomotor behaviours. On the basis of functional characteristics, the observed bird species in the study area could be broadly classified into the following claw foot types:

Cursorial (Running) Feet

Cursorial birds, such as bustards and ostriches, possess elongated and muscular legs adapted for terrestrial locomotion. Typically, these species exhibit reduced digits; the hind toe is diminished or absent, and the remaining anterior toes are aligned forward to support fast running. The ostrich (Struthio camelus) uniquely possesses only two toes, with the larger inner toe bearing a nail for propulsion (Ziswiler, 1965).

Perching Feet

Common among passerines (e.g., sparrows, bulbuls, robins, and mynahs), perching feet results in three forward pointing toes and a reversed hallux (hind toe), forming a strong grip for securely clasping branches. This anisodactyl arrangement allows dynamic stability during perching and roosting.

Scratching Feet

As observed in birds such as fowl, quail, and pheasants, these feet are robust, with thick claws and an emphasis on ground interaction. Males often possess bony spurs on the tarsus, which are used for both foraging and territorial combat (Collias & Collias, 1967).

Raptorial Feet

Predatory species (e.g., eagles, hawks, owls, kites) exhibit powerful, curved talons on all digits and are designed to pierce, grasp, and immobilize prey. The presence of tylari fleshy pads on the ventral side of toes enhances grip. In fish eating raptors such as the osprey (*Pandion haliaetus*), sharp keratinous spines replace tylari to prevent slippage during prey capture (Hertel, 1995).

Wading Feet

Species such as herons, jacanas, and snipes display elongated toes and legs adapted for navigating wetlands and marshes. These feet are usually nonwebbed or slightly webbed, allowing a balance between floating vegetation and mudflats (Prum, 1990).

Swimming Feet

Aquatic birds are adapted for propulsion in water via various foot modifications: Ducks and teals: possess palmate feet (three front toes connected by full webbing). Grebes and coots: Lobate feet, where each toe has a separate skin flap, improving underwater thrust. Cormorants and pelicans have totipalmate feet, with all four toe webbeds (Livezey, 1990).

Climbing Feet

Seen in parrots and woodpeckers, these feet are zygodactylous, with two toes facing forward and two facing backwards, enhancing the vertical grip and manipulation of surfaces or food.

Clinging Feet

Birds such as swifts and hummingbirds exhibit pamprodactylous fe*et al*l four toes directed forward allowing them to cling to vertical surfaces such as cliffs or manmade structures. This unique configuration supports hovering or inverted rest (Collins, 2004).

Specialized Modifications

Some species present unique claw traits: Poorwill (*Phalaenoptilus nuttallii*) has a pectinate (comb like) claw used for grooming rich bristles. Ruffed grouse develops seasonal toe fringes (dermal expansions) that improve mobility over snow, akin to snowshoes. Larks exhibit elongated hind claws, possibly aiding in perching on flat, open terrain.

RESULTS AND DISCUSSION

A total of 74 bird species representing diverse avian families were recorded across a variety of habitats in Srikakulam District during the survey period from June to December 2024. These habitats included wetlands, forests, agricultural fields, and urban areas. Considerable variation in claw morphology was observed, allowing classification into nine distinct functional claw types linked to ecological roles. The distribution of species among claw types is summarized in Table 1 & Figure 2. Perching claws were the most common, followed by wading and swimming adaptations. The diversity of claw morphologies reflects functional adaptations to habitat specialization and behavioural needs (Figure 3).

Table 1. Perching claws were the most common, followed by wading and swimming adaptations.

Claw Type	No. of Species (n=74)	Percent (%)
Perching	22	29.7%
Wading	14	18.9%
Swimming	10	13.5%
Scratching	8	10.8%
Climbing	6	8.1%
Raptorial	7	9.5%
Other (Specialized)*	7	9.5%

*Includes clinging feet, seasonal adaptations, and pectinate claws.

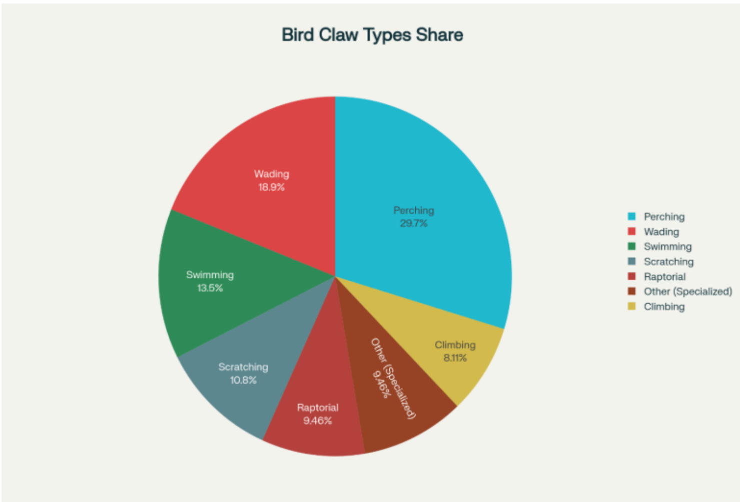

Figure 2. Pie chart illustrating the proportional distribution of claw types among the 74 species surveyed.

Claw types exhibited clear relationships with habitat preferences: Wetland species: Predominantly showed wading and swimming claws, facilitating navigation of marshes, mudflats, and water bodies. Urban and edge-dwelling birds: Exhibited primarily perching claws, supporting arboreal and substrate grasping in human modified landscapes. Forest species: Demonstrated raptorial claws (in raptors) and climbing claws (woodpeckers, parrots), reflecting adaptations to arboreal predation and locomotion.

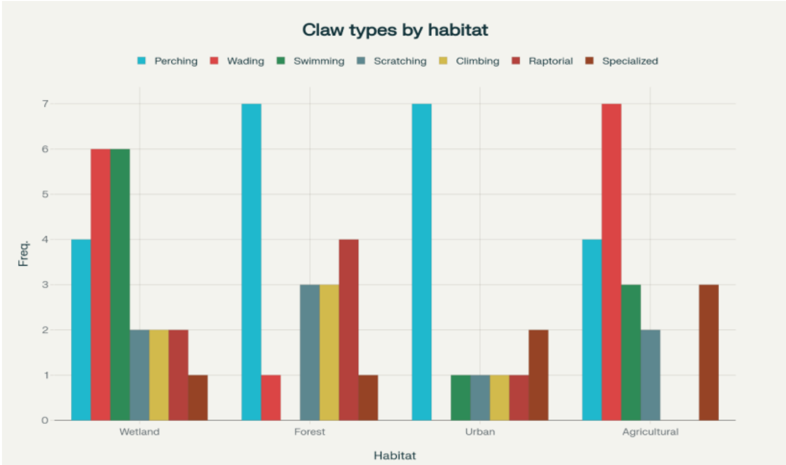

Figure 3. Bar chart showing the frequency of claw types across major habitat categories: Wetland, Forest, Urban, Agricultural.

Table 2. Detailed field observations enabled classification of claw types in commonly encountered species, combining ecological context with morphology.

S. No	Common Name	Scientific Name	Claw Type	Habitat Type
1	Indian Peafowl	*Pavo cristatus*	Scratching	Forest Edge
2	House Sparrow	*Passer domesticus*	Perching	Wetland Edge
3	Grey headed Swamphen	*Porphyrio poliocephalus*	Climbing	Wetland
4	White throated Kingfisher	*Halcyon smyrnensis*	Perching	Freshwater Marsh
5	Indian Pond Heron	*Ardeola grayii*	Wading	Freshwater Marsh
6	Rose ringed Parakeet	*Psittacula krameri*	Climbing	Urban
7	Common Myna	*Acridotheres tristis*	Perching	Forest Edge
8	House Sparrow	*Passer domesticus*	Perching	Freshwater Marsh
9	Little Cormorant	*Microcarbo niger*	Swimming	Wetland
10	White throated Kingfisher	*Halcyon smyrnensis*	Perching	Wetland Edge

Indian Peafowl (*Pavo cristatus*): Displays scratching claws ideal for terrestrial foraging and roosting. House Sparrow (*Passer domesticus*): Classic perching feet conducive to branch grasping in urban/agricultural habitats. Grey headed Swamphen (*Porphyrio poliocephalus*): Adapted climbing claws for dense wetland vegetation. White throated Kingfisher (*Halcyon smyrnensis*): Perching claws suited for grasping exposed perches near water. Indian Pond Heron (*Ardeola grayii*): Wading feet optimized for marshy habitats. Rose ringed Parakeet (*Psittacula krameri*): Curved claws enabling arboreal climbing. Common Myna (*Acridotheres tristis*): Versatile perching claws enabling urban adaptability. Little Cormorant (*Microcarbo niger*): Swimming feet with webbing aiding aquatic propulsion. The present study provides a comprehensive analysis of avian claw morphology linked with habitat utilization across 74 bird species in the ecologically diverse Srikakulam District, Andhra Pradesh. The observed diversity of claw types from perching and wading to raptorial and climbing reflects clear functional adaptations consistent with global avian ecomorphological patterns and

underscores the intricate relationship between morphology, behaviour, and environment. The predominance of perching claws (29.7%) in our datas*et al*igns well with global data indicating that passerines with anisodactyl foot arrangements dominate many terrestrial bird communities (Martin & Sherratt, 2023). This prevalence illustrates the versatility of perching adaptations, facilitating arboreal locomotion and the exploitation of a broad range of habitats, including rapidly changing urban agroforestry landscapes. However, continued urban expansion and habitat fragmentation in the region pose risks by potentially reducing adequate perching substrates, which could negatively impact these species (Figure 3).

Wading claws, comprising 18.9% of species, were strongly associated with wetland habitats, especially herons and moorhens. Their elongated toes allow weight distribution over unstable substrates, which is pivotal for survival amid mounting hydrological stresses from altered water regimes and wetland degradation (De Mendoza *et al*., 2024). The conservation of wetland integrity is thus essential to maintain the ecological functions supported by such specialized morphologies. Swimming claws, accounting for 13.5%, correspond with Srikakulam's network of tanks and reservoirs, supporting water adapted species like cormorants and coots. Their palmate and totipalmate feet exemplify morphological trade-offs: optimized for aquatic propulsion but less efficient on land (Tyler, 2023). These adaptations highlight the need to safeguard aquatic habitats not just for bird abundance but for maintaining functional biodiversity.

The allocation of claw designs in scratching birds such as Galliformes, climbing species within Psittaciformes, and the raptorial curvature in Accipitriformes supports the idea of morphological modularity and niche partitioning seen worldwide (Kerschbaumer & Pfingstl, 2024). Raptors like *Milvus migrans* employ hypertrophied talons and specialized pads (tylari or spicules) to immobilize prey, illustrating a convergence of predatory adaptations across taxa. The less common but no less significant category of clinging and specialized claws (9.5%) reveals behavioural and structural innovation shaped by ecological demands. Notably, the pectinate claws of certain nightjars and grooming specialized claws in ground foraging larks provide examples of nonlocomotory functions of claws, emphasizing the multidimensional roles of pedal morphology, often overlooked in ecological surveys (Orkney *et al*., 2025). These specialized forms highlight evolutionary responses to unique ecological pressures and contribute to the morpho functional diversity within bird communities. Srikakulam's position as an ecotone between the Eastern Ghats uplands and Bay of Bengal coastal plains offers a distinctive biogeographic framework to examine adaptive radiation. The co-occurrence of forest associated birds with climbing and scratching claws alongside aquatic birds with wading and swimming adaptations suggests morphological convergence driven by diverse ecological opportunities a pattern reminiscent of adaptive radiations in Neotropical avifaunas (Claramunt *et al*., 2023). Moreover, the spatial and seasonal overlap of multiple species with differing claw morphologies may promote niche partitioning, reduce interspecific competition and facilitate coexistence through functional divergence. These findings corroborate recent research positing that habitat structure predicts claw morphologies more robustly than taxonomy alone (Picasso *et al*., 2025), underscoring the power of environmental filters in shaping morphological diversity.

This study is observational in nature and subject to the constraints of field-based identification and photographic documentation. The sample size, representing 74 species, limits comprehensive coverage of the region's avifauna, especially rare or seasonally migratory taxa. Quantitative morphometric analysis (e.g., measurements of claw curvature, length, and arc) was not performed, but could provide deeper insights into functional variation in future studies. Additionally, potential observer bias and sampling gaps may influence the representativeness of claw type prevalence. The diversity and prevalence of specific claw types reflect the distribution and health of corresponding habitats. For instance, declines in wading birds identified by specialized elongated claws could indicate wetland degradation or water regime changes. The presence or absence of swimming and perching claw types in urban or agricultural landscapes may serve as ecological indicators for habitat integrity and suitability for specialist and generalist birds. Monitoring claw type assemblages thus provides an indirect, but effective, tool for ecosystem health assessment and prioritization of conservation action. To further understand the evolutionary and ecological dynamics of avian claw morphology, integrative approaches are recommended. Future studies should combine detailed morphometric measurements using geometric morphometrics with molecular phylogenetic analyses to distinguish between adaptive convergence and inherited traits. Long term ecological monitoring, including the impacts of climate change on habitat distribution and bird communities, would be valuable. Linking claw morphology datasets with climate, land use change, and population trends could help predict shifts in functional adaptation and inform proactive conservation strategies.

CONCLUSION

This study presents one of the first comprehensive assessments of avian claw diversity in the Srikakulam District, documenting 74 bird species and categorizing their claws into nine distinct functional types. The findings reveal a robust link between claw morphology and habitat specialization, affirming established ecological and evolutionary principles. The dominance of perching claws among urban and edge species, coupled with the clear association of wading and swimming claws with wetland habitats, reinforces the role of foot structure as a reliable indicator of ecological behaviour and niche adaptation. Moreover, the discovery of specialized claw forms such as raptorial, clinging, and pectinate types highlights the evolutionary flexibility of avian morphology in response to environmental challenges and opportunities. Situated at the confluence of the Eastern Ghats and coastal plains, the Srikakulam region's complex habitats and rich bird diversity provide an invaluable natural laboratory to explore adaptive radiation and niche differentiation. This baseline dataset lays the groundwork for future morphometric, behavioural, and conservation focused research, which is critical in the face of accelerating habitat degradation and climate change. To further elucidate the intricate links between morphology and function, integrative studies involving detailed morphometrics, biomechanical analyses, and ecological modelling are strongly encouraged, especially for rapidly changing ecosystems across South Asia.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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