Research Article

Foraging Niche and Food Preference of Selected Insectivorous Birds from Family *Monarchidae* and *Muscicapidae* (*Passeriformes*) in Girnar Wildlife Sanctuary, Gujarat, India

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ABSTRACT

This study examines the foraging behavior of seven insectivorous bird species from the *Monarchidae* and *Muscicapidae* families in Girnar Wildlife Sanctuary during the winter of 2020-2022. The aim is to understand how these birds utilize different foraging strategies and substrates to explore niche segregation. Data were collected on perch type, perching and foraging height, foraging substrate, foraging methods, and food preferences. This information was standardized and analyzed as percent use for comparative purposes. Foraging behavior was assessed through observation of perching height, attack maneuvers, and food capture locations. Flycatcher species predominantly perched and foraged at lower heights (0-3 m) and preferred shrubs and small trees. Sallying was the most frequently used attack maneuver (61.17%), with food capture occurring most commonly under leaves (50.33%). The Asian Paradise Flycatcher exhibited a preference for capturing prey in mid-air, likely due to its larger size relative to other species. Statistical analysis revealed that foraging height was the primary factor influencing behavioral variation, followed by attack maneuver and substrate composition. Study shows that foraging substrate choice and attack tactics contribute significantly to niche segregation among the studied insectivorous birds. These findings underscore the role of foraging strategies in reducing interspecies competition within a shared habitat

Keywords: Foraging, Insectivorous, Girnar Wildlife Sanctuary, Niche.

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INTRODUCTION

The relationship between animal communities and their habitats has been a focal point in the study of community ecology for several years. Avian foraging strategies represent a combination of intricate dynamics encompassing morphology, prey selection, foraging habits, habitat preference, prey abundance, and interplays with both predators and competitors.[1] Comprehending the interplay between prey availability and the diet of insectivorous birds holds crucial significance, especially amidst the prevailing challenges of habitat degradation and the alarming decline observed in both insect and bird populations. Variations in microhabitat and resource utilization among closely related avian species exist in the same geographic region have been widely documented in ornithological literature.[2-4] Exploring the distinct foraging tactics employed by sympatric species can offer insights into their coexistence within shared habitats.[5] By analysing these aspects of a species' foraging strategy, we can explain niche relationships,[6] understand patterns of habitat utilization, and effectively target conservation efforts based on community structure.[7] Insectivorous birds are often height generalists that rely on the composition of the plant species, the amount and dispersion of their prey, and interspecies competition. It altogether affects the foraging height selection of birds.[8,9] Even if

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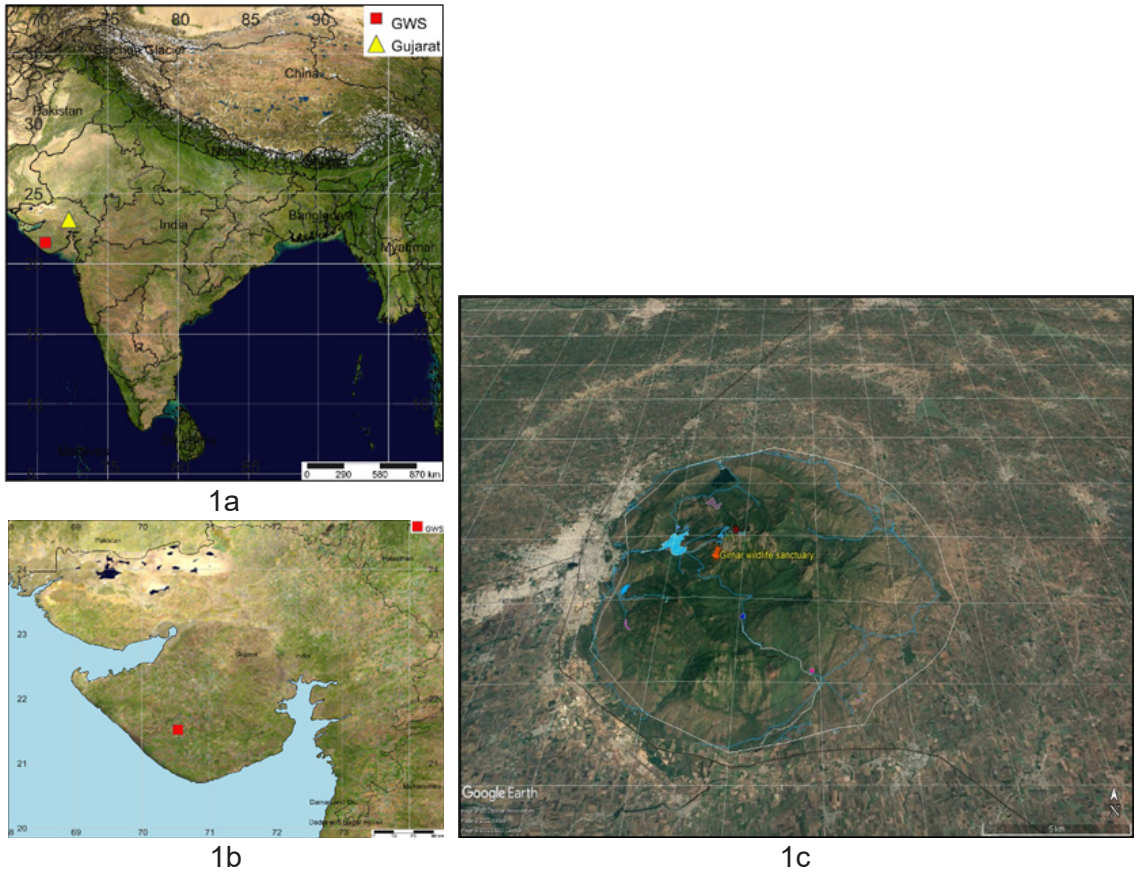

Figure 1: 1a. Map of India shows location of Gujrat and Girnar Wildlife Sanctuary. 1b. shows the location of Girnar Wildlife Sanctuary in Gujrat. 1c. Girnar Wildlife Sanctuary. (Source:https://earth.google. com/web).

the foraging habits of bird populations have been well studied in other parts of the world, there is still much to be discovered in this area being investigated. No such study has been conducted on Indian avifauna and particularly for the Western parts of India. However, some studies discussed foraging of birds based on.[10]

Present study is the first investigation on foraging patterns and assemblages of avian community in Girnar Wildlife Sanctuary (GWS). The study was carried out with the importance of the area in mind in order to understand the underlying community pattern and distribution of resources among the bird species of GWS in order to establish the community structure of passerine birds.

MATERIALS AND METHODS

Study Area

Mount Girnar is the oldest and highest mountain range of Gujarat. The Girnar Hills are situated between parallels of latitude 21° 25' to 21° 35' N and meridians of longitude 70° 30' to 70° 40' E. Girnar Forest is described as "Type VII-A/c-1 Southern Tropical Dry Deciduous, Dry Teak Forest".[11]

Forest is divided into three parts including (a) the Teak Forest, largely found on the foothills adjoining the plains and on the lower slopes of Girnar, covering more than half of the entire forest; (b) the miscellaneous forests, found in the eastern outer periphery of Girnar; and (c) scrub forest, found in all the degraded patches in the plain area as well as on the hilltops along the ridges of Girnar (Figure 1). The dominant tree species of the area is *Tectona grandis* L.f 1782, but other species such as *Butea monosperma* (Lam., Taub 1894, *Haldina cordifoli* (Roxb.) Ridsdale 1978, *Holarrhena antidysenterica* (L.)Wall. 1829 *Pithocellobium dulce* (Roxb.) Benth. 1844, *Catunaregam spinosa* Thunb., Tirveng. 1979, *Zizyphus rotundifolia* (Burm.f.) Wight & Arn. 1833 and *Calotropis procera* (Aiton) W.T. Aiton 1811 are commonly found with other plants.[12] The climate of Girnar is semi-arid with a mean temperature of 25.7°C and mean annual precipitation of 827 mm.[13]

Methods

Field survey was carried out for a period of winter (November 2020-February 2021 and November 2021-February 2022). The survey was made twice a week for the entire study period. Data collection has

been done during the most active periods of the day, i.e., mornings (06:00 to 10:00 hr) and late afternoons (16:30 to 19:00 hr). Birds were monitored for as long as it was possible to keep them in sight, but for statistical analysis, only the independent observations, or the first sighting of a certain species, were considered to avoid problems with non-independent data. Identification of birds and their occurrence were noted using a Nikon 10×40 binocular and Nikon Coolpix P900 camera. Pray items were also observed and identified by literature till family/genus level. 30 independent observations were taken for each bird species for accuracy of the data.[14,15]

The following data were recorded on each foraging bird encountered opportunistically: Perch types, perch height, foraging height (estimated height above the ground), Foraging substrate, Attack maneuver (Foraging Method) (Table 1).

a) **Perch type:** Trees, shrubs and ground and other objects.
b) **Perching height:** Height at which the bird was perched while feeding, was grouped into 0-3 m, 3-6 m, 6-9 m and 9-12 m.
c) **Foraging height:** 0-3 m, 3-6 m, 6-9 m and 9-12 m.
d) **Foraging substrate:** The material from which food is taken by the birds - classified into air, plants and ground.

Two multivariate analyses were conducted to discover distinct 'patterns', which represent linear combinations that characterize foraging behavior. PCA (Principal Component Analysis) is a method that reduces data by creating linear combinations of variables and condenses it into new synthetic variables known as principal components. Correspondence analysis, similar to PCA, is for visualizing numerical data and identifying similarities between the rows and columns of a data matrix. It was observed that correspondence analysis explained a greater portion of the variation in foraging data compared to other multivariate methods.[17] A hierarchical cluster analysis using Pearson's correlation coefficients was utilized to categorize species into distinctive guilds based on the frequency of use of all foraging parameters.[18]

Table 1: Description of attack maneuver used in this study.[16]

Attack Maneuver	Description
Glean	To pick food from a nearby substrate. Can be reached without full extension of legs or neck.
Stretch	To completely extend the legs and neck to reach the food items.
Hang	To hang head down in order to reach food not obtainable by any other perched position.
Hover	To maintain an airborne position by flapping wings and spreading tail.
Sally	To fly from a perch to attack a food item and then return to a perch.

RESULTS

643 independent observations were made on seven passerine bird species from family *Muscicapidae* and *Monarchidae* found in the study area. More than 30 independent foraging observations, ranging from

Table 2: Foraging height, foraging substrate, and attack maneuver variables utilised by flycatcher species. Data are given as percentages (%).

Foraging Parameters		Black-naped monarch n = 89	Indian paradise-flycatcher n = 98	Asian brown flycatcher n = 85	Brown-breasted Flycatcher n = 70	Tickell's blue flycatcher n = 156	Verditer flycatcher n = 73	Red-breasted flycatcher n = 72
Foraging Height	0-3 m	19.1	62.25	43.53	72.86	46.8	39.73	27.78
	3-6 m	24.72	29.59	52.94	27.14	39.74	57.53	44.44
	6-9 m	52.8	8.16	3.53	0	12.82	2.74	27.78
	9-12 m	3.38	0	0	0	0.64	0	0
Foraging Substrate	Leaf	69.66	18.37	58.83	62.86	36.54	60.27	45.83
	Branch	7.87	9.18	10.59	12.86	17.95	16.44	8.34
	Aerial	20.22	71.43	25.88	21.43	39.74	20.55	45.83
	Ground	2.25	1.02	4.7	2.86	5.77	2.74	0
Attack Maneuver	Glean	2.25	0	2.35	0	5.77	6.85	0
	Stretch	1.13	4.08	2.35	5.71	3.85	4.11	0
	Hover	16.85	26.53	25.89	32.86	32.69	23.29	29.17
	Sally	79.77	65.31	69.41	61.43	57.69	65.75	70.83
	Hang	0	4.08	0	0	0	0	0

72 to 156 observations, were recorded for each focal species (Table 2). The species studied were Black-naped monarch *Hypothymis azurea* (Boddaert, 1783), Indian paradise-flycatcher *Terpsiphone paradisi* (Linnaeus, 1758), Asian brown flycatcher *Muscicapa dauurica* Pallas, 1811, Brown-breasted Flycatcher *Muscicapa muttui* (E.L. Layard, 1854), Tickell's blue flycatcher *Cyornis tickelliae* Blyth, 1843, Verditer flycatcher *Eumyias thalassinus* (Swainson, 1838) and Red-breasted flycatcher *Ficedula parva* (Bechstein, 1792). These species feed mainly on insects and other small invertebrates. Asian brown flycatcher, Brown-breasted Flycatcher, Verditer flycatcher and Red-breasted flycatcher are migratory species and are present in the study area between October and March. Though, foraging activity of resident species was not significantly affected by the presence of migrant species. All species use the sally maneuver, capturing prey by flycatching from one perch to another. However, there are slight variations among them in terms of foraging height, substrate preference, perching height, and perching type. These species occasionally exhibit hovering behavior, maintaining an airborne position by flapping their wings and spreading their tail for a short period. Most frequently used foraging height was 0-3 m (39.44%) followed by 3-6m (39.44%), 6-9 m (15.40%) and 9-12 m (0.57%). Six species out of the seven prefers to forage in lower strata (0-6 m) except Black naped monarch forage in higher strata 6-9 m. All four-forage substrate were used by all the species. They mainly prefer to forage aerially by hover in the air and catch flying insects, followed by forage on the leaves to catch the prey from the undersides of the leaf. Attack maneuver were used by birds are glean, stretch, hover, sally and hang all the flycatcher species used sallying to obtain the food. Other than sallying they use hover over the food and collect. Less preferred methods were stretch, glean and hang (Table 2).

Perching heights were seen to varied from 0-12 m, in general 0-3 m (40.66%) preferred by all seven species. They preferred scrub as a perching object followed by tree (branch, bark, leaves and trunk). Other objects (power lines, poles, walls, walls, dead tree and rock) are preferred less by the flycatchers (Table 3).

Corresponding analysis of the foraging parameters shows two dimensions that together explained 80.82% variation in the data Axis 1 explained 51.57% of data variation was weighted on foraging height. Axis 2 explained 29.25% of data variation was weighted on foraging height and foraging substrate (Figure 2).

The Principal Component Analysis (PCA) shows 91.07% of variation in all parameters data. PC1 explained 81.19% was weighted on foraging height. PC2 9.88% of the data variation and was weighted on Attack maneuver (Figure 3).

Cluster analysis illustrated the niche overlap of studied species reflecting their spatial variables selection (Figure 4). The analysis was consistent with Corresponding analysis results and effectively divided the species based on preference of foraging height, foraging substrate and attack maneuver.

During the study period we observed that birds are feeds mostly on flying insects from the orders Dipterans, hemipterans, coleopterans, lepidopterans and Odonata and Araneae (Table 4).

The present study reveals difference between the various perching and foraging parameters among the seven insectivorous birds in study area.

The degree of niche overlap among insectivores displayed variability across numerous species, particularly

Table 3: Perching height and perching variables utilised by flycatcher species. Data are given as percentages (%).

Perching Parameters		Black-napped monarch n = 89	Indian paradise-flycatcher n = 98	Asian brown flycatcher n = 85	Brown-breasted Flycatcher n = 70	Tickell's blue flycatcher n = 156	Verditer flycatcher n = 73	Red-breasted flycatcher n = 72
Perching Height	0-3 m	38.2	34.69	54.12	48.57	44.23	31.51	33.33
	3-6 m	46.07	55.1	34.12	50	31.41	64.38	50
	6-9 m	2.25	0	2.35	0	1.92	0	5.56
	9-12 m	13.48	10.2	9.41	1.43	22.44	4.11	11.11
Perching Type	Tree	16.85	20.41	29.41	70	46.79	26.03	31.94
	Shrubs	25.84	29.59	55.29	27.14	42.31	61.64	54.17
	Ground	51.69	36.73	11.77	2.86	7.69	8.22	5.56
	Other objects	5.62	13.27	3.53	0	3.21	4.11	8.33

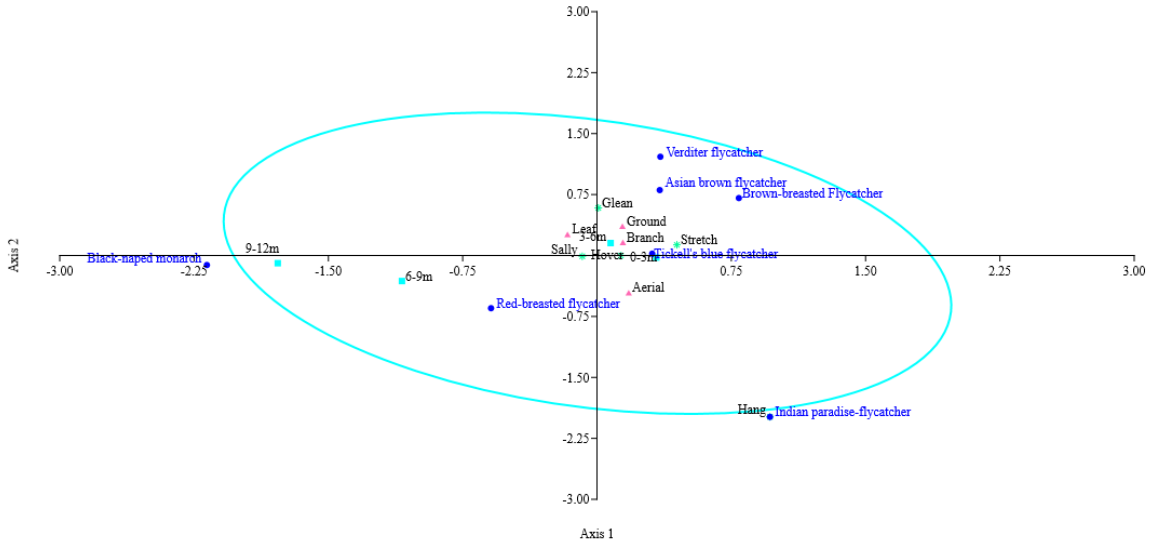

Figure 2: Correspondence plot of foraging variables (foraging height, substrate and attack maneuver). Ellipses indicate groups of bird species that were significantly correlated ($p < 0.01$) for any parameter according to a Pearson's correlation analysis.

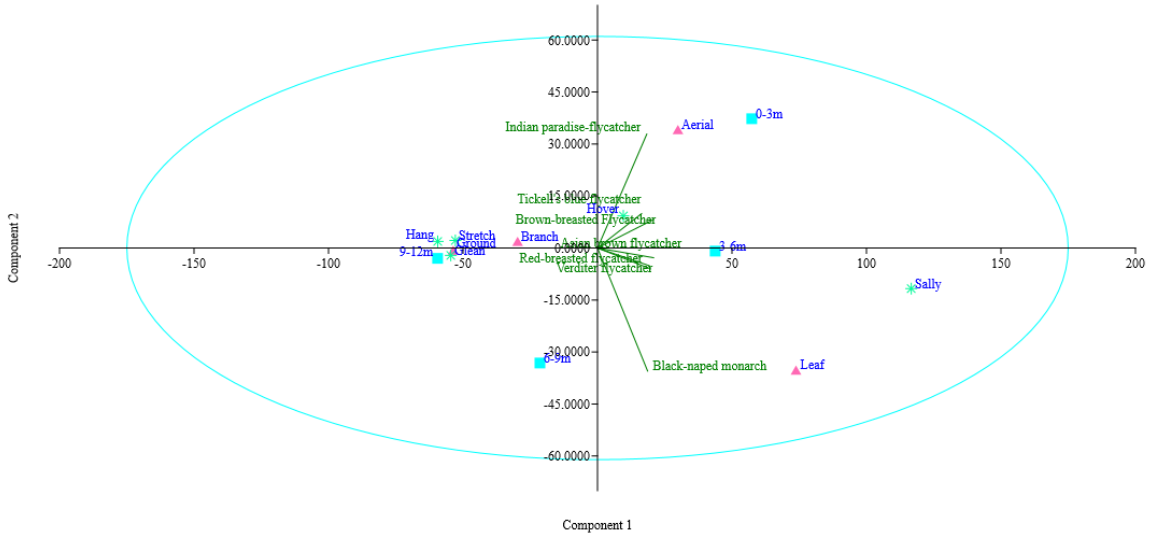

Figure 3: Principle components plot of foraging variables (foraging height, substrate and attack maneuver).

concerning foraging parameters such as foraging height, substrate, and attack maneuver.

Additionally, several other factors influence the preference for perch type, including species abundance, prey availability and type within a specific habitat, as well as morphological and behavioral characteristics of the bird species.[19]

The degree of niche overlap among insectivores varied for many species, with respect to foraging parameters, namely foraging height, substrate and attack maneuver. Several other factors also influence the preference of perch type which are species abundance, availability and

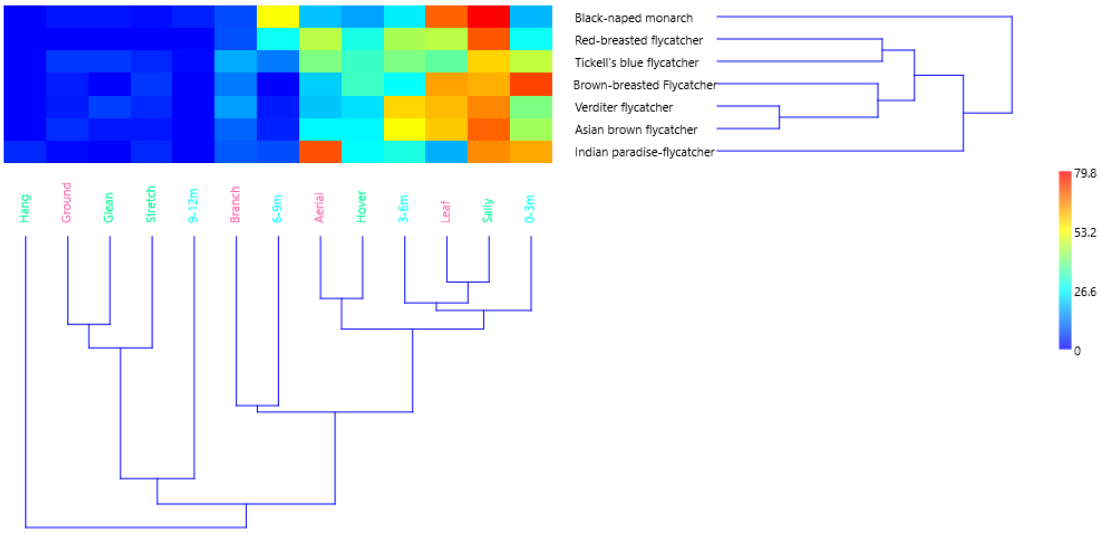

Figure 4: Interspecific relationships of seven insectivorous bird species, based on multivariate analyses of foraging height, attack maneuver and substrate.

Table 4: Observed prey items consumed by birds.

Sl. No.	Species Name	Scientific Name	Prey	Orders of prey items
1	Black-naped monarch	*Hypothymis azurea* (Boddaert, 1783)	Insects, including small butterflies and moths, grasshoppers, also small beetles and bugs, spiders	Lepidoptera, Orthoptera, Coleoptera, Hemiptera and Araneae
2	Indian paradise-flycatcher	*Terpsiphone paradisi* (Linnaeus, 1758)	Small winged insects; occasionally spiders. Capable of seizing very large prey, such as praying mantis (*Mantis*), grasshoppers, moths and *Pieris* and *Papilio* butterflies.	Dipterans, hemipterans, coleopterans, lepidopterans and Odonata and Araneae
3	Asian brown flycatcher	*Muscicapa dauurica* Pallas, 1811	Small invertebrates, including beetles, bugs, wasps, and larvae.	Coleoptera, Hemiptera, Hymenoptera and Lepidoptera
4	Brown-breasted Flycatcher	*Muscicapa muttui* (E.L. Layard, 1854)	Invertebrates, particularly flies and beetles.	Diptera and Coleoptera
5	Tickell's blue flycatcher	*Cyornis tickelliae* (Blyth, 1843)	Flying insects, Butterflies, Moths, Grasshoppers, Beetles and Bugs	Lepidoptera, Orthoptera, Coleoptera, Hemiptera, and Dipterans
6	Verditer flycatcher	*Eumyias thalassinus* (Swainson, 1838)	Small invertebrates, including sweatbees (*Trigona*), also ripe berries of *Macaranga* and *Mallotus*	dipterans, neuropterans, hemipterans, coleopterans, lepidopterans, Odonata and Araneae
7	Red-breasted flycatcher	*Ficedula parva* (Bechstein, 1792)	Insects and other invertebrates, especially beetles and spiders but also dragonflies and damselflies, grasshoppers, bugs, butterflies and moth and their larva, adult and larval flies, ants and wasps, earthworms and snails.	Coleoptera, Araneae, Odonata, Dipterans, Orthoptera, Hemiptera, Lepidoptera, Hymenoptera, Oligochaeta and Gastropoda

type of prey in a particular habitat, morphological and behaviour characteristics of the bird species etc.,[19]

DISCUSSION

Most of earlier assemblage assignments of bird communities were mostly limited to looking at the groups at the trophic levels or diet since they relied heavily on existing information of the species' foraging activities.[20] In Girnar Wildlife Sanctuary, there were seven major groupings i.e. insectivorous, nectarivorous, granivorous and fruigivorous, carnivorous and aquatic among birds based on the food eaten.[21] The study discovered that ground foragers can be distinguished from species that feed on plants and the air by height and height-related traits. Three different foraging environments-the ground, plants, and air-are produced as a result of these variations. Microhabitats like wood and foliage are present in the plant environment and add to the habitat's complexity. The presence of different

plant types, such as shrubs, small trees, and tall trees, expands the vertical habitat's dimensions and offers supporting substrates like twigs, trunks, main branches, and foliage. The distinction between foraging above and below ground highlights the significance of foraging opportunities within these various habitats.[21]

The preference for the underside of leaves over the leaf surface is likely due to the tendency of some insects and their larvae to feed and seek shelter underneath leaves, as it offers protection from the sun and predators.[22] The niche separation observed among bird species provides clarity on the groups identified through cluster analysis. The presence of foraging height at the base of the cluster analysis diagram highlights its significance in the study area and gives the importance of maintaining a multi-level forest habitat. Such habitats offer more 'tropical space' for birds, thus supporting a larger diversity of species. The significance of foraging height likely reflects the distribution of insects across different vertical levels.[23] In this study, it was noted that the Asian Paradise Flycatcher mainly forages in the air, capturing flying insects, while the Black-naped Monarch tends to forage on the underside of leaves. The elongated tail and wings of the paradise-flycatcher enable its utilization of the air as the most optimal space for flycatching. Smaller wings and tails in species like the monarch and others make them more adept at foraging within dense vegetation cover, using sallying maneuvers and occasionally hovering on live green leaves. This aligns with previous findings indicating that paradise-flycatchers predominantly forage in the air while monarchs tend to forage on the undersides of leaves,[24] thus demonstrating specialization in foraging substrate associated with attack maneuver selection across different geographical areas. The slightly larger body size, including tail and wings, and long tail streamers in male paradise-flycatchers may hinder their ability to effectively forage on live green leaves with dense vegetation cover. While this niche separation facilitates resource partitioning among species, further research is needed to elucidate the specific prey items targeted by the birds across different foraging substrates.[25]

The utilization pattern of foraging height by birds reflects the availability of food resources, as well as the morphology and interspecific competition.[26] Foraging at different heights offers birds enhanced opportunities to locate prey across various vertical strata, thereby reducing competition among species. The hypothesis regarding the significance of height dimensions in bird species assemblages was initially proposed by [27] and has since been extensively studied.[28,29] Attack maneuvers and foraging substrates further improve the grouping of birds within the broader categories delineated by foraging height. Birds exhibit unique morphological adaptations that correspond to their specialized attack techniques for specific substrates. Species-specific morphology may restrict the utilization of certain attack maneuvers and foraging substrates.[30] This insight also suggests that parameters such as substrate type and attack maneuver play a significant role in shaping the specializations observed in certain bird species.

In the foraging ecology study, additional variables including foliage density, bird diets, and tree preferences could be helpful in providing a more thorough evaluation that organises the structure of the bird community.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

SUMMARY

This study examines the foraging behavior of seven insectivorous bird species from the *Monarchidae* and *Muscicapidae* families in Girnar Wildlife Sanctuary during the winter seasons of 2020 to 2022. Data on perch type, perching and foraging height, substrate, methods, and food preference were analyzed. Results reveal that all flycatcher species predominantly foraged at lower heights in shrubs and small trees. Sallying was the most common attack maneuver (61.17%), with food frequently captured from the underside of leaves (50.33%). Asian Paradise Flycatcher preferred mid-air hunting due to its larger size. Statistical analyses highlight foraging height as the primary factor, followed by attack maneuver and substrate composition, indicating niche segregation among sympatric species.

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