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Foraging Behaviour & Methods of *Acridotheres ginginianus* (Bank Myna): A Selective Review of Five Decades

Dr. Anuj Kumar Rajput¹, Vijay Kumar Shukla², Dr. Hemlata^{*3},

¹Department of Zoology, Gauri Shanker Dwivedi Mahavidyalaya, Jhijnhak, Affiliated to Chhatrapati Shahu ji Maharaj University, Kanpur, Uttar Pradesh, India

²Department of Biochemistry, Dr. Rammanohar Lohia Avadh University, Ayodhya, U.P., India

³Department of Zoology, Lalaram Sharma Memorial Degree College, Jarra Khera, Aligarh, Affiliated to Raja Mahendra Pratap Singh State University, Aligarh, Uttar Pradesh, India

* Corresponding author. E-mail address: hemaajsv@gmail.com

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ABSTRACT

The Bank Myna, *Acridotheres ginginianus* (Latham), is highly adaptable bird species, mainly foraging on the ground, belonging to the family Sturnidae, and wide spread throughout the Indian subcontinent. The species inhabiting fields of crops, banks of rivers, animals grazing near agricultural land, railways stations, roadsides and human settlements provides a good opportunity for studying adaptation behaviour both in natural and modified habitats. The present review summarizes findings about the foraging behaviour, feeding ecology and methods used in researching this bird species collected during around 50 years of studies. The findings show that the Bank Myna is omnivorous, consuming insects, grains, fruits as well as a great number of artificial foodstuffs. At the same time, insects play a vital role in the bird's diet especially during breeding period when animal food is profitable due to its higher protein content for birds' young. The bank mynas' activity varies in different parts of the day; surprisingly, the birds' feeding activity peaks in the morning and evening. Bank Mynas apply a wide range of methods in searching their food and obtaining it. Their living among animals and in agricultural habitats proves that they are characterized by a great behaviour adaptation. Earlier studies were mainly conducted through direct field observations, but modern researches use different methods such as instantaneous sampling, scan sampling, focal sampling, point counts, and direct counts. This review emphasizes that despite considerable advances in researching Bank Myna behaviour, e.g. by using video recording or using statistics, not enough work has been done. Therefore, it is high time to conduct more integrated studies.

Introduction

The Mynas belong to the Passeriformes order and Sturnidae family, making them a highly adaptable group of birds that can live in various natural and anthropogenic environments. Due to the present success of this particular group of birds to thrive within environments that have been modified significantly as a result of man's activity, the Mynas' adaptability, learning ability, and ability to communicate with one another all contribute to this success (Mock 1998). This adaptability among the various members within the *Acridotheres* genus has resulted in different geographical ranges and conservation statuses. The Bank Myna (*Acridotheres ginginianus*) is the Myna most commonly associated with the Indian subcontinent. The Bank Myna is listed as Least Concern, meaning this species is currently not being listed as Globally Threatened. Its geographical distribution extends over India, Bangladesh, Bhutan, Myanmar, Nepal, and Pakistan and adjacent areas. In addition, populations have established themselves beyond the historically recognized range of the Bank Myna (Kuwait) (Gregory & Al-Nasrallah 2001). In terms of the evolutionary relationship, the Bank Myna is closely related to the Common Myna (*Acridotheres tristis*) (Zuccon *et al.* 2008). The Bank Myna can easily be distinguished from other members of the *Acridotheres* genus, due to its bluish-grey body, large orange-red orbital skin, orange bill and legs, and faint wing and tail markings, and can be easily recognized within the field (Bose & Das 2012; Dhandhukia & Patel 2016). Different local names for the Bank Myna in different regions of India are indicative of the close association of this bird with humans and their associated habitats. The Bank Myna is found in many different habitats. The Bank Myna's range extends throughout much of northern and central India, occupying a wide variety of habitats. This is an Open Access article published under the Creative Commons Attribution 4.0 International License (CC BY 4.0)

from mountainous (*Himalayan foothills*) and plain landforms (Terai) to riverine systems and prey-rich environments (Anne and Ripley, 1983, 2007). Riparian and Riverine Habitat types represent important habitat types, as the diverse vegetation composition and open foraging areas provide habitat for Bank Mynas at landing sites. Riverine Systems and Riparian zones may affect both the abundance/density and reproductive success of Bank Myna populations (Bindiya *et al.*, 2017). An important feature of Bank Mynas is their tolerance of human-altered habitats. Bank Mynas are commonly found at train stations, on the tops of food storage cabinets, in urban areas, in farming areas, and in areas where food scraps are often discarded (Bose & Das, 2012). The large proportion of Bank Mynas present in these habitats is an indication that their feeding ecology cannot be separated from the human footprint on the landscape, nor the resultant alteration of that landscape.

Bank Mynas are ground-feeding omnivores, eating mostly grains, fruits, and the larvae of many invertebrates such as ants, caterpillars, grasshoppers, Termites, Bugs, Beetles, Millipedes, and Earthworms (Simwat & Sidhu, 1974; Feare & Craig, 1998; Rasmussen & Anderton, 2005). Farmers often observe Bank Mynas eating ripening Sorghum, Pearl Millet, Wheat, and Maize. Bank Mynas are also known to flock to grazing animals to take advantage of the insects stirred up by livestock and may feed on ticks found on livestock (Bhargava, 1981). Thus, the ecological function of Bank Mynas in the environment is both multi-faceted and complex. An insectivorous diet may assist in suppression of rural pest populations; consumption of fruits may promote the dispersal of seeds and thereby foster plant regeneration (Farid & Ahsan 2011; Mukhopadhyay & Mazumdar 2017). On the other hand, the omnivorous and opportunistic feeding habits of the Bank Myna(s) could lead to competition with other

animal species and possible crop depredation (Sengupta *et al* 1976; Narang *et al* 1984). While much research has focused on the behavioural aspects associated with foraging, nesting, roosting, movement, maintenance, vocalisations, and reproduction, little effort has been made toward developing a comprehensive understanding of these behaviours through a common methodological approach. Thus the current literature review combines study data collected during the past approximately five decades that contains emphasis on both the types of foraging behaviour and methodologies/technologies used to study Bank Myna(s).

Review of Literature

The Bank Myna (*Acridotheres ginginianus* (Latham)) is an extensively-distributed member of the Sturnidae family of passerines, and occurs in all northern and central regions of the Indian subcontinent. Many aspects of its life history have been studied over the last five decades by several research teams, including feeding and foraging behaviour, nesting, breeding, roosting, locomotion, vocalisations, social behaviour, and ecological impacts. Existing literature on the Bank Myna(s) indicates that researchers often study only specific behavioural components of the species and do not generate an integrated assessment of the full behavioural potential of the species. Earlier studies primarily included descriptive observational data, while later studies used an increasing amount of systematic behavioural sampling, quantitative data analyses, and geographical information system (GIS) applications. The present paper chose for the literature that has been reviewed therefore will provide an essential background for understanding both the ecological behaviour of the Bank Myna; its methodology for its study. Ali and Ripley (1983, 2007) presented significant general information regarding the distribution, identification and general biology of the birds of India, including the Bank Myna. The Bank Myna mainly occupies the northern and central parts of India and has been reported to occur in the Himalayan foothills, and the lower Himalaya areas south as far as the line joining Mumbai and Balasore. Beyond India, the greater distribution includes Bangladesh, Bhutan, Nepal, Pakistan, Myanmar and many of the neighbouring countries. Bank Mynas have even been found farther afield than the regular distribution for South Asia. For example, Gregory and Al-Nasrallah (2001) reported the establishment of a breeding population of Bank Mynas in Kuwait. Habitat usage of the Bank Myna is characterized by a significant degree of ecological flexibility; the Bank Myna can inhabit cultivated fields, the open area around rural habitation, banks of rivers, wetlands, urban areas, the area around railway stations and along the roadsides, as well as areas where food is available through human activity. Bose and Das (2012) concluded that Bank Mynas are a common feature of both urban and rural areas and that they are routinely found foraging for food in the area around railway stations, roadside restaurants and food stands. Their findings were milestones in demonstrating that the Bank Myna can adapt its feeding behaviour and social behaviour to human-influenced habitats. Riparian habitats and habitats along rivers are critical for Bank Mynas. Variability in vegetation and environmental conditions along the river/hillsides can increase vegetation heterogeneity and enhance availability of foraging and nesting opportunities. It is likely that the ability of the Bank Myna to utilize both natural habitats and landscape modified by humans is one of the main mammalian ecological characteristics that have enabled them to thrive in a broad geographical area. *A. ginginianus* is one of several species of Indian mynas that has had the greatest emphasis on foraging as one of its many behavioural elements. Simwat & Sidhu (1974) were among the first researchers to provide a thorough analysis of Bank Myna's developmental timeline and eating habit(s) in Punjab. Their findings established a valuable foundation upon which others have since based their work, as well as provided data regarding how an organism's feeding habits will reflect variations based on both biological factors and environmental influences. As with most species of mynas, the Bank Myna is an omnivorous ground feeder. The Bank Myna is found to consume both plant-based and animal-based food sources, such as grain, fruits, and the insect & other invertebrate types. In addition to insects such as ants, caterpillars, grasshoppers, termites, true bugs, beetles, and millipedes, Bank Mywas have also been reported to utilize earthworms as a food source as well (Simwat & Sidhu 1974,

Feare & Craig 1998, Rasmussen & Anderton 2005). This adaptability permits the Bank Myna to exhibit a significant amount of dietary flexibility due to the breadth of available food resources. Historically, descriptions of Bank Mynas in India have indicated that they are highly social birds that traditionally inhabit fields, open areas, and the vicinity of water bodies as well as the vicinity of animals and humans. Bank Mynas have been observed to follow animal "ploughing" (active placement of fertilized soil into the ground) and take advantage of exposed insect larvae resulting from disturbed soil and/or follow and take advantage of insects associated with the animal itself. The feeding ecology of the Bank Myna illustrates that its feeding behaviour is closely correlated with human-induced changes in resource availability due to urbanisation, agricultural practices, and livestock grazing. A particularly interesting aspect of feeding behaviour is the relationship between Bank Mynas and grazing animals. Bhargava (1981) reported that they have been observed to follow livestock and capture insects that have been disturbed due to the livestock's movement. Additionally, Bank Mynas have been seen to pick ticks from the bodies of livestock. Such associations help reduce the amount of time needed to find animals hidden away and demonstrate the opportunistic use of the resources made possible by other animals' activities. According to Feare and Craig (1998), insects play a role in the feeding habits of the Myna during the breeding season. Insects provide a particularly important animal protein source for young Myna chicks, while Myna adults also eat fruit, seeds, and all other forms of plant material. Therefore, it is believed that seasonal insect population differences will impact the feeding habits of the adult birds and their ability to reproduce successfully. People have been interested in the association of agricultural activity with the ecological impact of the Bank Myna. The Bank Myna can use insect pests found in crops, and this makes them suitable for use in biological pest control. Farid and Ahsan (2011) emphasized the value of insect-chewing birds in farming operations. Additionally, as stated by Mukhopadhyay and Mazumdar (2017), these birds play an important role in the ecological functions of pest control and the distribution of seeds. Furthermore, in addition to consuming insects, Bank Mynas will consume agricultural products that are ripening; for example, Sorghum, Pearl Millet, Wheat, Corn and other grains will be fed upon when available (Simwat & Sidhu, 1974). The Bank Myna has both a beneficial and a negative relationship with agriculture. Narang *et al.* (1984) demonstrated the potential for the Bank Myna to cause damage to economically important crops. Sengupta *et al.* (1976) further discussed how the omnivorous food behaviour of the Bank Myna can lead to interspecific competition for resources. Finally, the relationship between the Bank Myna and humans is an added dimension to the feeding ecology of the Bank Myna. According to Bose and Das (2012), the Bank Myna takes advantage of the food sources generated by humans by feeding at railway stations, road-side hotels, and food stalls. In their northern India research project, researchers established the presence of Bank Mynas in both urban and rural habitats, indicating a preference for insects where available, though they will regularly exploit discarded food and kitchen scraps. By switching between natural prey, agricultural resources and human-generated food sources, Bank Mynas have developed significant ecological resilience that enables them to maintain populations in landscapes characterised by fluctuating natural resources and substantial anthropogenic modification. Research on the daily activity of the Bank Myna has established that there is considerable variability in Bank Myna behaviour through the course of the day. Thakor *et al.* (2011) evaluated multiple categories of behaviour using observational techniques, and found that foraging activity tends to peak during the early morning and late evening hours of the day. Morning foraging is clearly biologically sensible for birds that have spent a prolonged period of inactivity during the night (due to being in a nocturnal roost). When birds awake from nocturnal roosting, they will consume food to restore their energy reserves. Morning environmental conditions may provide further opportunity to feed; moderate temperature and proper light levels in the morning are likely to provide improved opportunities for moving and searching for food, whereas increased temperature at mid-day may inhibit foraging activity. Noreen and Sultan (2021) also explored the relationship between food availability and the patterns of avian feeding behaviour. Thakor *et al.* (2011) indicated that resting frequently observed was highest in the afternoon. During the morning and evening, the amount

of locomotory activity was significantly greater compared to the mid-afternoon and that evening was a period of significant participation in maintenance behaviour. They reported that vocalisations tended to occur in the morning at times around 08:00 h, and those social activities generally increased during the morning and evening periods. Overall, these observations demonstrate that Bank Myna daily behaviours are organised temporally as opposed to being randomly distributed over the course of the day. The Bank Myna (*Acridotheres ginginianus*) will allocate its foraging, locomotion, and communication activities based upon energy demand as well as environmental conditions throughout each day. One of the more significant areas of research on Bank Mynas involves understanding their nesting ecology, as they are known for their colonial nesting habits and the use of cavities in natural and artificial environments. Historically, Bank Mynas have been reported nesting in banks of soil, side banks of rivers, inside wells, through holes in walls and under structures associated with the bridge. Ahsan and Kabir (2011) studied the Bank Myna's nesting habitat and reported that nesting occurred in riverbank areas, brickfields and holes in culverts. These data demonstrate that the Bank Myna has the ability to exploit both natural and artificially created nesting habitats for breeding purposes. Similarly, studies of breeding colonies reported that nesting occurred in steep riverbanks, along brickfield walls, inside culverts and artificial ditches, and on other exposed earthen surfaces. Bose and Das (2012) reported on colonial nesting of the Bank Myna and examined reproductive behaviours based upon natural photoperiods. Results of their study indicated that the main breeding season occurs during April through July, and that reproductive patterns in Bank Mynas are influenced by seasonal changes in reproductive structures as the length of daylight increases. Dhandhukia and Patel (2016) conducted a study focusing on the selection of nest sites by Bank Mynas and also provided additional details regarding dimensions of nests, which will help us better understand the types of site and environmental requirements for Bank Myna breeding. Overall, nesting studies of the Bank Myna demonstrate that the availability of suitable cavities is an important ecological requirement for this species. As a result, local populations of Bank Mynas may be greatly affected by the availability or loss of suitable nesting structures, even in the presence of an abundant food supply. As very social birds, Bank Mynas are often found in flocks of similar size and behaviour during periods of foraging. In relation to the social structure of Bank Mynas, the behaviour associated with roosting is among the most important components of their social behaviour. Based upon descriptions of a heterogeneous communal roost site, Chudasama *et al.* (2018) concluded that the communal roosting of Bank Mynas is a representation of extremely complex social structures. Explore and Find Food

Locomotory activity is directly related to feeding and exploring the habitat. Thakur *et al.* (2011) showed that there was greater locomotory activity in the morning and evening when most of the foraging activity was occurring. Since Bank Mynas primarily eat off the ground, they walk and run to look for food. The strength of their feet and bill enable them to eat a variety of foods.

Social Behaviour-In addition to the importance of locomotory behaviour, social behaviour through locomotion and vocalisation also plays a significant role in the social life of Bank Mynas. Thakur *et al.* (2011) reported that social interaction is high in the morning and evening and vocalisations were also dominant during the morning hours. Through interaction and communication, Bank Mynas can easily maintain their flock cohesion, establish territories, and communicate with flock mates about food locations and roosting sites.

The gradual evolution of techniques used to study Bank Myna behaviour is a key aspect of the literature. Direct observation was the focus of some of the earliest studies, including Simwat and Sidhu (1974). Manual observations continue to provide significant ecological detail on the behaviour of Bank Mynas in present times as they are often seen in open areas and frequently seen close to human habitation. The development of systematic sampling methods represented a significant development in the methodology of Bank Myna research. The behavioural sampling methods proposed by Altmann (1974) have been widely used in behavioural studies and are currently included in studies of Bank Myna.

Thakur *et al.* (2011) used instantaneous sampling for their evaluation of foraging, resting, maintenance, locomotion, vocalisations, and social behaviours. Instant sampling can record the status of an animal's behaviour when it can be observed at regular intervals. This allows researchers to estimate how much time an individual spends doing different activities, or how long they spent eating well, or how long they were wandering around looking for food. Rahman *et al.*, (2019) conducted research on food preference and feeding modes using focal sampling, which allows researchers to observe a given subject(s) continuously or at fixed intervals. Focal sampling is particularly useful for understanding a sequence of behaviours in detail. Dhandhukia & Patel (2016) used scan sampling in nesting-related research, while Noreen and Sultan (2021) used point-count sampling to assess ecological impacts of various environmental variables.

The integration of quantitative and technological approaches in ecological research is becoming more common. Akhtar *et al.*, (2016) used GPS technology and computer-based statistical software to assess various ecological functions: GPS provides accurate spatial positioning and enables understanding of animal movement patterns, the use of their chosen habitats, and the relationships between different feeding areas.

Several statistical packages, such as SPSS, Statistix, and Minitab, have also been applied to analyse both ecological and behaviour data. Noreen & Sultan (2021) used a variety of quantitative techniques, including diversity analysis, to look at ecological systems and their habitats, while Shannon's Diversity Index (Shannon & Weaver, 1949) has also been widely used for comparative purposes.

There are still many areas where additional behavioural research on the Bank Myna is needed. The conclusion reached by the most recent behavioural review is that much of the behaviour of correctly identified Bank Myna species has been studied, but research on the behaviour of the other identified species, as well as unknown behaviours of more recently identified species, remains limited. The behaviour of the Bank Myna has been documented over the past five decades, with the available literature documenting many aspects of individual animal behaviour; however, also noted are the extensive gaps of knowledge yet to be filled.

Foraging behaviour has received the greatest attention among researchers; however, there is little research comparing and contrasting feeding behaviour with other behaviours, such as resting, locomotion, maintenance, vocalisation, social interaction, reproduction, and habitat use, simultaneously examined.

Another major limitation with regard to behavioural research on the Bank Myna is that of a lack of standardisation in method. Previously, behavioural methods used to research the Bank Myna have included: the method of direct observation, instantaneous sampling, focal sampling, scan sampling, point-count sampling, and the use of questionnaires, in addition to the use of direct counts of animals. Because of differences in sampling methodologies, comparisons between the results of different researchers are very difficult. Furthermore, in the source manuscript, the conclusion was made that there is no standardised or updated behavioural research method for the Bank Myna.

In addition, there should be a standardised use of ethograms for behavioural identification by researchers. Injuries related to observer bias could be minimised through the use of digital video recording, as these would provide a permanent record of animal behaviour that could be reviewed multiple times. Additionally, the use of automated systems for coding behaviours may also minimise observer bias. In addition, GPS and other types of tracking technology could also provide the researcher with the ability to better understand home-range size, movement between feeding and roosting sites, habitat selection, and the extent of disturbances from human activity.

Research should examine the interaction between behaviours and ecological and seasonal conditions, reproductive status, presence of livestock, habitat structure, and the extent of human disturbance over time. Long-term comparative research studies should also focus on various types of landscapes used by birds within different ecological zones: i.e., rural, urban, agricultural, and riparian. The literature has described the behaviour of the Bank Myna as flexible and adaptable; thus, it is likely that the Bank Myna's success in the ecosystem is highly correlated with the range of habitats used by the animal (wide variety of foods), social behaviour (opportunistic feeding strategies), and adaptability to human-modified environments. Nevertheless, these studies remain relatively sporadic. Therefore, a shift away from

isolated, descriptive observations towards standardised, quantitative, spatially explicit, and technology-assisted behavioural research on the ecology of the Bank Myna should occur to provide a complete and detailed understanding of the ecology of the bird.

Materials and Methods

2.1 Review Design-This study represents a selective narrative overview of the published literature on the behaviour of *Acridotheres ginginianus*, focusing primarily on research regarding its foraging behaviour, feeding ecology, activity patterns, habitat use, and the methods that have been employed to observe its behaviour. The literature reviewed spans around five decades, starting with the early studies of Simwat and Sidhu (1974) to the most recent research on foraging ecology and food availability (Noreen & Sultan, 2021).

2.2 Classification of Behavioural Literature-Information in the published literature has been categorized into different behavioural components. These components include foraging, resting, maintenance, locomotor activity, vocalizing, nest building, roosting, reproductive behaviours, and social interaction. The categorization of behaviours allows for comparison of how much attention has been given in the literature to each of the Bank Myna's behavioural components. Foraging has been given particular attention as foraging represents the dominant daily behaviour of the Bank Myna, and feeding activities are related to the type of habitat a Bank Myna occupies, its energy requirements, reproductive behaviours, and how they interact with agricultural landscapes.

2.3 Behavioural Observation Methods-Methods previously developed by prior research studies are evaluated and categorised based on each method's most common observational strategies. Older studies primarily utilised direct/manual observations. More recent studies started using systematic behavioural sampling strategies (i.e. instantaneous sampling, focal sampling and scan sampling) based upon behavioural observation techniques developed by Altmann (1974). Ecological researchers also used point-count techniques to investigate animals, while those conducting research on communal roosting used direct counting techniques. Some researchers used survey questionnaires with field studies as a method of determining nesting behaviours and habitat preferences.

2.4 Technological and Analytical Approaches-Technological advancements relevant to psychological studies were included in this analysis, including GPS trackers or Global Positioning Systems, as well as statistical software systems (SPSS, Statistix, Minitab). In addition, some studies have incorporated ecological analysis tools (e.g. Shannon's Diversity Index) and CLAM software. In addition to these analytical methods, foraging behaviour has also been categorised into components (search, attack, food-source movement/substrate, handling), wherein each of these five categories form a framework for studying the ways Bank Mynas identify, obtain and manipulate foods.

Results and Discussion

Table 1. Major studies on foraging behaviour of *Acridotheres ginginianus*

S. No.	Study Year	Major focus	Principal observation
1	Simwat & Sidhu 1973/1974	Feeding habits	Developmental period and month-wise feeding habits were examined
2	Dhindsa <i>et al.</i> 1988	Food searching	Road mortality associated with searching for food was considered
3	Feare & Craig1998	Diet composition	Fruits, seeds and insects were important foods; insects were particularly important for nestlings
4	Thakor <i>et al.</i> 2011	Daily foraging activity	Foraging was comparatively prominent during early morning and late evening

5	Bose & Das2012	Anthropogenic feeding	Birds were commonly observed at railway stations, roadsides and food stalls
6	Akhtar <i>et al.</i> 2016	Insectivory	Ecological role of insectivorous birds in biological control was investigated
7	Rahman <i>et al.</i> 2019	Food preference	Food preferences and feeding modes were examined
8	Noreen & Sultan2021	Food availability	Insects, fruits and grains were recorded as available food resources

The gradual evolution of research into the foraging behaviour of Bank Myna from an original focus on descriptions of the feeding behaviours of this species to temporal foraging activity, habitat utilization, food preferences and the ecological role played by this species is illustrated in Table 1. The initial studies of Bank Mynas mainly described their diets through direct observation of food intake; however, researchers increased their emphasis on studying artificial feeding habitats and the quantitative ecological relationships between habitat choice and foraging behaviour in subsequent years. In general the studies demonstrate that the foraging behaviours of *A. ginginianus* were both opportunistic and very flexible.

Table 2. Behavioural activities reported in Bank Myna

Behaviour	Major finding	Representative study
Foraging	Greater activity during morning and evening	Thakor <i>et al.</i> (2011)
Resting	Higher during afternoon	Thakor <i>et al.</i> (2011)
Maintenance	Comparatively higher during evening	Thakor <i>et al.</i> (2011)
Locomotory	Higher during morning and evening	Thakor <i>et al.</i> (2011)
Vocalization	Higher during morning, particularly around 08:00 h	Thakor <i>et al.</i> (2011)
Nesting	Riverbanks, brickfields and culvert holes used as nesting habitats	Ahsan & Kabir (2011)
Nesting	Colonial nesting reported	Bose & Das (2012)
Nesting	Preference toward artificial and natural wooden nests examined	Dhandhukia & Patel (2016)
Roosting	Heterogeneous communal roosting reported	Chudasama <i>et al.</i> (2018)
Reproductive	Reproductive activity studied under captivity	Bose & Das (2012)
Interaction	Higher interaction during morning and evening	Thakor <i>et al.</i> (2011)

According to existing research, Bank Mynas appear to have a specific pattern to their behaviours each day. Morning and evening are viewed as more important than other times for many of the behaviours associated with being active (foraging, roaming about and interacting), while the majority of rest occurs in the early afternoon hours. Studies have also shown flexibility in where Birds roost and nest, making them adaptable birds. However, each research article provides unique information regarding behaviours, so it may be impossible to draw any conclusions regarding the full behavioural spectrum of the Bird.

Table 3. Methods and technologies used in behavioural studies of *A. ginginianus*

Behaviour	Method/Technology	Representative study	Methodological basis/source reported in manuscript
Foraging	Direct observation	Simwat & Sidhu (1973)	Field observation
Foraging	Manual observation	Dhindsa <i>et al.</i> (1988)	Field observation
Foraging	Instantaneous sampling	Thakor <i>et al.</i> (2011)	Altmann (1974)
Foraging	GPS	Akhtar <i>et al.</i> (2016)	Garmin 72H
Foraging	Statistix 8.1	Akhtar <i>et al.</i> (2016)	Statistical analysis

Foraging	SPSS 16.0	Akhtar <i>et al.</i> (2016)	Nie, Bent & Hull (1970)
Foraging	Focal sampling	Rahman <i>et al.</i> (2019)	Altmann (1974)
Foraging	Point count	Noreen & Sultan (2021)	Evans & Love (1957)
Foraging	Minitab	Noreen & Sultan (2021)	Ryan <i>et al.</i> (1985)
Foraging	CLAM	Noreen & Sultan (2021)	Chao & Lin (2011)
Foraging	Shannon diversity index	Noreen & Sultan (2021)	Shannon & Weaver (1949)
Nesting	Questionnaire + field visits	Ahsan & Kabir (2011)	Field-based assessment
Nesting	Scan sampling	Dhandhukia & Patel (2016)	Altmann (1974)
Roosting	Direct count	Chudasama <i>et al.</i> (2018)	Direct enumeration

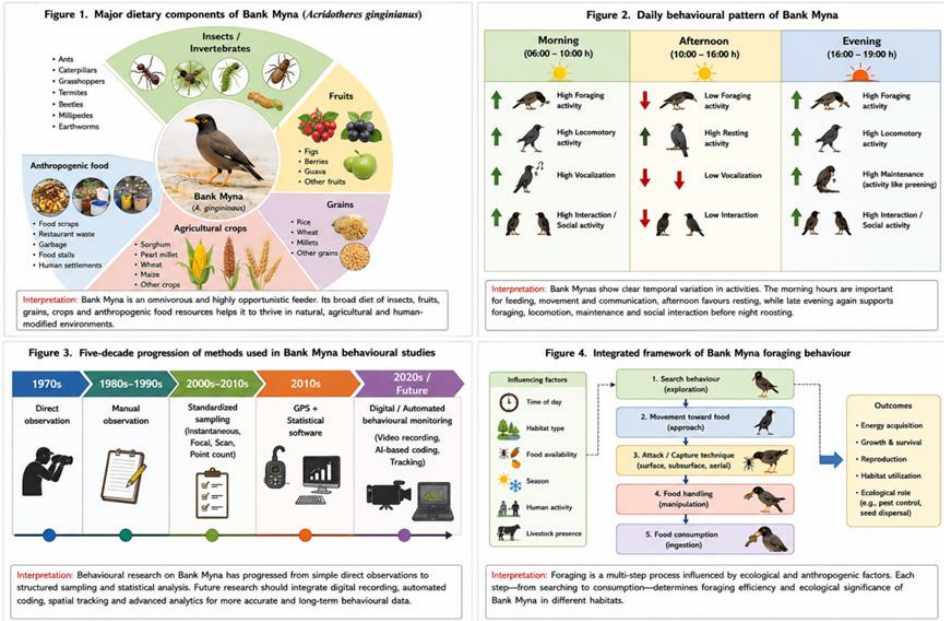
Table 3 illustrates how methodology has transitioned from a reliance on direct/hand-held documentation to a greater degree of spatial technology (i.e., GPS), statistical analyses, and structured sampling methods used to collect data. Whereas instantaneous, focus, or scan sampling methods enable behavioural records that are more defined, GPS also allows for the use of geospatial data when conducting ecological research. The original literature review indicates that even with the increased use of GPS in Bank Myna ecology, there is still a

lack of standardization in the way data is collected.

Table 4. Classification of major Bank Myna foraging components

Major component	Behavioural variables/categories
Search behaviour	Distance covered, number of stops, duration of stops, attack frequency, movement direction
Surface attack	Glean, reach, hang, lunge
Subsurface attack	Probe
Substrate manipulation	Gape, peck, hammer, chisel, flake, pry, pull, scratch
Site movement	Walk, hop, jump, run, climb, glide, flutter, fly
Aerial attack	Leap, sally, flutter-chase, flush-pursue, screen
Foraging site	Habitat, vertical position, horizontal position, foliage density, substrate

Foraging is a complex behaviour that consists of several components rather than just one behavioural event. Once the forager locates, approaches or attacks the food it is going to consume, it then must move around in the feeding area and then handle the food consumed. The classifications included in the manuscript serve as a framework for developing an ethogram that can be used in future studies of the Bank Myna; it also provides a means of quantifying each component of foraging. The quantification of these components will allow for comparisons of foraging efficiency of different types of habitat, different types of seasons and different food-resource types.



The illustration in Figure 1 indicates how Bank Myna’s diet consists mainly of animal- and plant-based sources as well as human-associated food sources, making them an omnivorous and opportunistic foraging bird. It is suggested that the extent of Bank Myna’s dietary niche allows them to successfully inhabit agricultural and semi-urban areas. Insects, grains, fruit, and domestic waste are the dominant sources of food identified by the manuscript as well as use of ripening plants. The data in Figure 2 indicate that the activity that occurs during each time period is dependent on the time of day. Based on available data, morning is an important foraging period as it coincides with the bird waking from a lengthy period of fasting during the night. In contrast, the afternoon is characterised as a more restful period of time, allowing the birds to take time for rest and recuperation from feeding and foraging at dawn. The late afternoon to evening periods sees a rise in the empirical data identifying the importance of feeding and locomotion as interest. Figure 3 proposes a timeline illustrating how the method for studying behaviour of the Bank Myna has evolved over the past 50 years. The first studies investigating behaviour of the Bank Myna relied on simple direct field observation while later studies relied on standardized sampling methods of specific behaviours of the Bank Myna through the use of quantitative analysis. More recently, the use of GPS has been incorporated into the ecological study of Bank Myna. The final future evolutionary stage of the digital/automated perspective of behaviour documenting methods represents a future avenue for behavioural researchers to pursue because the manuscript highlights the application of modern behaviour-coding

methodologies as an avenue to increase the accuracy of behaviour recording, however their widespread application has not yet occurred. Figure 4 presents an integrated model of Bank Myna foraging behaviour. The proposed model represents the major stages in the acquisition of food by the Bank Myna. Searching and mobilization are the first stages of acquiring food, and this is followed by the attack/capture of food and finally, the handling of it. Features associated with the habitat where Bank Myna are foraging as well as the availability of food influence the type of food obtained, the method of obtaining it and the manner in which they handle it and eat it. The manuscript has identified measurable variables associated with the action of searching, obtaining food through the process of attacks, methods of mobilizing, and substrates and manner of handling food allowing for future quantitative analysis.

3.1 Historical Development of Bank Myna Behavioural Research- The literature reviewed indicates that the study of the Bank Myna’s behaviour has gradually accumulated through multiple sources, rather than through a single, standardised investigative framework. Simwat and Sidhu (1974) published the first significant research regarding the Bank Myna’s development stages and feeding patterns and provided baseline data regarding its selection of food and relationships between the various stages of development. Subsequently, numerous other studies extended the ecological framework of behaviour related to foraging. Dhindsa *et al.* (1988), for example, reported mortality rates related to Bank Mynah searching for food in the vicinity of roadways and highlighted the dangers that birds face from taking advantage of anthropogenically influenced habitats. Feare and Craig (1998) addressed the Bank Myna’s varied diet, including fruits, seeds, and

invertebrates, and noted that invertebrate prey represents the most significant contribution to the nestling food supply. More recently, researchers began investigating Bank Mynah time budgets, habitat associations and quantitative data regarding their feeding behaviour. For example, Thakor *et al.* (2011) found that Bank Mynas foraged differently over time, and Bose and Das (2012) reported on the strong association of Bank Mynas with railway stations, roadside habitats and food stalls. More recent studies have investigated the Bank Myna's food preferences, modes of foraging and food availability in different types of habitat (Rahman *et al.*, 2019; Noreen & Sultan, 2021).

3.2 Foraging Behaviour and Temporal Activity-The feeding of Bank Mynas is a significant factor of the daily budgeted activity of the species. Individuals display the highest levels of foraging activity towards the beginning of the day, as birds start their foraging efforts shortly after they emerge from their roosts and during the morning, they have very high energy demands due to the stress of overnight roosting, in terms of environmental conditions, including the low temperatures and appropriate illumination of morning. On the other hand, a second peak in the foraging behaviours of Bank Mynas can occur in the late afternoon and/or early evening. This may represent a time of replenishment and preparation for sleeping in a communal or individual roosting situation for the night ahead. Thus, the feeding behaviour of Bank Mynas reflects not only the physiological demands of the birds but also their environmental surroundings and seasonal variations. Thakor *et al.* also observed other behavioural temporal partitioning within the species they studied, such as a greater proportion of time spent resting (afternoon) and increased locomotion (morning/evening). They reported a prominent amount of time spent maintaining their own conditions within their habitation in the evenings. Their observations on vocalisation indicated that Bank Mynas present the most vocalisation early in the morning when individuals have a peak ability to vocalise (e.g. at 08:00 hours), while later in the day, they have significantly reduced vocalise ability. All these observations indicate that the daily activity budgets of Bank Mynas and the associated behaviours (feeding, movement, communication and resting) are highly coordinated with the time of day that they occur.

3.3 Food Composition and Dietary Flexibility-Dietary flexibility is a key characteristic of Bank Mynas as indicated by the diets described in the reviewed studies. As an omnivorous species, Bank Mynas eat plants and animals, including: ants, caterpillars, grasshoppers, termites, bugs, beetles, millipedes, earthworms, and other invertebrates (Simwat & Sidhu, 1974; Feare & Craig, 1998; Rasmussen & Anderton, 2005). During the breeding season, the importance of insects to Bank Mynas is even more apparent than what was previously shown. The research of Feare & Craig (1998) demonstrates that although mynas utilize fruits, seeds, and insects for meals, the majority of food items delivered to nestlings include insects. Rapid growth and development of nestling Bank Mynas relies heavily on protein-rich invertebrate prey, making insect intake particularly vital during reproductive cycles. Bank Mynas obtain their plant materials from fruits, grains, and cultivated crops. Some examples include sorghum, pearl millet, wheat, and maize; thus, they have a direct relationship with agricultural production systems as both a pest and crop consumer. The relationship between Bank Mynas and agricultural production has both positive and negative effects. For example, the consumption of insect pests by Bank Mynas is beneficial to some agricultural crops; however, the consumption of economically important crops can create conflict (Simwat & Sidhu, 1974; Narang *et al.*, 1984).

3.4 Opportunistic Feeding and Association with Humans-The presence of Bank Mynas on railway stations, as well as their frequent visits to roadside eateries and other food vendors, suggests that they are taking advantage of anthropogenic foods that have been thrown away (Bose and Das, 2012). It is likely that such opportunistic foraging behaviours may be responsible for the success of Bank Mynas in natural landscapes near human habitation, including semi-urban areas. Additionally, though opportunities for food source acquisition exist within anthropogenic feeding environments, there are also corresponding risks associated with behavioural adaptations as they relate to increased road mortality associated with birds searching for food on and near roadways (Dhindsa *et al.*, 1988). Furthermore, as such adaptations

to environment change provide ecologically favourable conditions; they provide new sources of mortality for birds.

3.5 Association with Livestock-A second example of an unusual feeding strategy is that many types of birds can be seen following herds of large grazing mammals. As these animals move through the vegetation and soil, they disrupt various types of insects. By disrupting the vegetation, these large grazing mammals create more feeding opportunities for many birds because it provides access to more food sources. Bank Mynas are known to exploit these disturbed food sources and are also known to remove parasites from their host animal (Bhargava, 1981). This behaviour highlights the secondary ecological association that exists between birds and large grazing mammals, whereby when large mammals actively feed, they create more feeding opportunities for birds.

3.6 Search, Attack and Movement Strategies-The way in which birds find food consists of two main behaviours: searching for food and attacking food. Searching can be measured by looking at distance travelled over time, how many times and how long the bird stops, the direction it moves in, and where it stops. These ways of determining how a bird searches for food can help determine how birds are using different areas to find food. The attacks the bird makes are many different types of movements based on how the bird sees its food and on what type of surface it is on. The various ways birds feed on surfaces may include gleaning and reaching, while the different types of food they might eat under the ground may include probing or moving the surface in some way. The way birds manipulate food may include pecking, hitting, shredding, pulling and shaving through the surface to get to it. The ways that birds can move in feeding locations may include walking, hopping, jumping, running, climbing, gliding, or falling from the air to get their food. The ways birds can catch food from the air will include sallying, among other means. This variety of behaviours shows the wide range of ways in which bird species can use their surroundings to obtain food, whether that food is located on the ground, in vegetation, or obtained by flying through the air. The various methods birds can use to manipulate their food are also determined by the type of food resource itself. The different types of food manipulation methods have been found to range from engulfing, gulping, striking, crushing, shaking, smashing, poking, rubbing, tearing, biting and drinking. Systematic recording of bird food manipulation can help to determine the relationship between bird food size, bird food type, bird food substrate and the energetic costs associated with the feeding process.

3.7 Methods Used in Bank Myna Behavioural Studies-Methodological development has been a prominent theme in research throughout five decades. The earliest publications on this topic by Simwat and Sidhu used observation-based methodologies, whereas Dhindsa *et al.* and Feare and Craig employed similar observational methodologies. As they allow for the assessment of avian behaviour in the wild under relatively low levels of equipment use, these methods are particularly good methods to continue to use, although they can be impacted by differences between observers, visibility and definitions of behaviours being observed. Thus, the development of standard sampling protocols represents an important step in the evolution of methodology. Thakor *et al.* (2011) conducted an instantaneous sampling approach to the study of foraging, resting, maintenance, locomotion, vocalisation and interaction behaviours. Instantaneous sampling captures what an animal does at set intervals, thus allowing researchers to develop activity budgets when systematic approaches are employed (Altmann, 1974). Focal sampling techniques have been used to study food intake behaviours as well (Rahman *et al.*, 2019); this technique allows researchers to obtain detailed information on feeding behaviour sequences and frequency as the animal is observed over a defined time period. Scan sampling methods have been used in studies of nesting behaviours, while point-count methodologies can be used to collect information on both the occurrence of birds and the relationship between habitat and bird occurrence patterns.

3.8 Incorporation of Technology and Statistical Analysis-Advances in technology and analytic tools have increased the potential for employing these tools in field studies of behavioural ecology. For instance, Akhtar *et al.* (2016) used GPS units within their field studies, demonstrating how they could accurately pinpoint the study subjects' locations on the earth's surface. GPS also opened up avenues to explore habitat usage, how animals move about their home ranges and where they obtain foods and how far they travel to

acquire those food items. Along with GPS, the statistical software that is available to researchers has increased greatly over the last several decades. In addition to using Statistix, SPSS and Minitab, ecological studies have also used Shannon's Diversity Index and CLAM software to quantitatively compare different habitats, food resources and different ecological communities. Analytic tools allow ecologists to conduct quantitative comparisons of habitats, food resources and diverse ecological communities; however, only a very limited number of behavioural research studies published in the literature review have utilized contemporary technology and analytic tools as was done in the aforementioned Bank Myna studies. Up until now, research on the Bank Myna's behaviours has primarily been conducted through direct observations. Thus, the future of research on behaviours of the Bank Myna will need to integrate the use of direct observations, automated recording devices and spatial technologies to provide researchers with additional data.

3.9 Ecological Significance—Although Bank Myna foraging may result in positive impacts on ecosystems, such as potentially supporting biological control and reducing insect pests through eating crop pests and supporting seed dispersal through fruit consumption, there are also negative impacts associated with this species. Bank Mynas compete with other bird species for food resources because of their omnivorous diets and they can inflict economic damage by feeding on farmed crops. The ecological role of the Bank Myna must, therefore, be determined on a case-by-case basis rather than classifying the species as wholly beneficial or harmful to the environment.

Conclusion

Over the last 50 years, literature has established a diverse foraging strategy used by *Acridotheres ginginianus* to exploit the many different types of natural, agricultural and human altered environments. Bank Mynas are an omnivorous species that rely primarily on ground feeding where they eat insects, fruits, grains, crops and food items associated with people, while the timing of feeding differs between the morning and evening. They show a range of feeding preferences that include associating with grazing animals for food resources, taking advantage of urban food items, and eating from a range of different prey types indicating their adaptability to a variety of available food items. The method of collecting data has advanced from using primarily observational techniques and manual counting to include real-time data collection using focal and scan sampling methods, point counts, GPS supported observations and various statistical techniques. However, the lack of standardization of data collection methods means that the body of literature does not reflect accurately the full range of behaviour, or all aspects of this species' behaviour. Future studies should incorporate both standardized field observations and video footage (or digital behaviour recording) to conduct automated coding, conduct spatial tracking and use quantitative analyses to evaluate results from multiple sites. Long-term, multi-habitat studies that examine the impact of urbanisation, increased agricultural production, food supply, and ecological change on the Bank Myna's behavioural response will help to determine the ecological significance of this widespread species and enhance the foundation of methodological approaches to ornithological behaviour in human-influenced ecosystems.

Conflict of Interest—The authors declare that there is no conflict of interest regarding the publication of this review article.

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