The Wilson Journal of Ornithology 136(4):485–492, 2024 DOI: 10.1676/24-00052

Birds feeding on date palm sap during Bengali traditional sap harvesting on Nijhum Dweep, Bangladesh

Naim Khandakar,[1] Irin Sultana,[2] Farhana Akhtar,[3] Theunis Piersma,[4,5,6] and Delip K. Das[1,4,5]*

ABSTRACT—There is a Bengali tradition of consuming palm "jaggery" (unrefined sugar made from the sap of Indian date palms, *Phoenix sylvestris*) as a sweetener. To obtain jaggery, people tap Indian date palms to extract the energy-rich phloem sap during the winter. In Bangladesh, people commonly cultivate Indian date palms in traditional agroforestry. We explored which bird species capitalize on the jaggery tradition by consuming sap from tapped Indian date palms on Nijhum Dweep, an island in the Bay of Bengal. Once each day for 30 d between December 2019 and February 2020, we quantified the presence of birds on 120 tapped palms along a 1 km transect. We observed 37 bird species in the palms, and 18 of them (49%) were seen to consume sap. Seven species had not previously been recorded as sap feeders. Among the 18 sap-consuming species, we categorized 5 species (Chestnut-tailed Starling *Sturnia malabarica*, Asian Pied Starling *Gracupica contra*, Jungle Myna *Acridotheres fuscus*, Red-vented Bulbul *Pycnonotus cafer*, and Black Drongo *Dicrurus macrocercus*) as constant consumers of date palm sap; 11 species as accidental sap consumers, and 2 species as accessory sap consumers. Insectivorous and omnivorous species accounted for 78% of the sap consumers (39% each), with granivorous and frugivorous species accounting for the remaining 22%. This study highlights date palm sap as a potentially significant winter food source for resident birds, and demonstrates birds' ability to utilize tapped palms as an anthropogenic food resource. *Received 21 April 2024. Accepted 29 July 2024.*

Key words: avian guild, Bangladesh, foraging behavior, *Phoenix sylvestris*, sap feeding, tropical agriculture.

ABSTRACT (Bangla)—শীতকালে খেঁজুর গাছের রস থেকে তৈরি গুড় খাওয়া বাঙালির রসনা বিলাসের ঐতিহ্যের অংশ। এই রস (ফ্লোয়েম কলা বা টিস্যুর নির্যাস) বেশ শক্তি-সমৃদ্ধ যা গাছের কান্ড চেঁছে সংগ্রহ করা হয়। নানা প্রজাতির পাখি বাঙালির প্রথাগত খেঁজুর গাছের রস আহরণের প্রক্রিয়ার সুযোগকে কাজে লাগিয়ে রস পান করে থাকে। আমরা নিবিড়ভাবে বিষয়টি অনুসন্ধানের জন্য বঙ্গোপসাগরের নিঝুম দ্বীপে এক কিলোমিটার দীর্ঘ একটি সড়কে রস সংগ্রহের জন্য চাঁছা ১২০টি খেঁজুর গাছে আগত পাখি পর্যবেক্ষণ করি। ডিসেম্বর ২০১৯ থেকে ফেব্রুয়ারি ২০২০ এর মধ্যে সর্বমোট ৩০ দিন ট্রাঞ্জেক্ট লাইন প্রক্রিয়া অনুসরণ করে আমরা প্রতিদিন একবার করে গাছগুলো পর্যবেক্ষণ করেছি। গাছে আগত পর্যবেক্ষণকৃত মোট ৩৭ প্রজাতির পাখির মধ্যে, আমরা ১৮ প্রজাতির (৪৯%) পাখিকে খেঁজুর গাছের রস পান করতে দেখেছি। এই ১৮ প্রজাতির মধ্যে সাত প্রজাতির পাখির খেঁজুর গাছের রস পানের পূর্ববর্তী কোন নজির নেই, যা আমাদের গবেষণাতে প্রথমবারের মতো বেরিয়ে আসে। কাঠ শালিক, গো শালিক, ঝুঁটি শালিক, দেশি বুলবুলি এবং কালো ফিঙ্গে এই পাঁচ প্রজাতির পাখিকে নিয়মিত খেঁজুর গাছের রস পান করতে দেখা গেলেও বাকিদের উপস্থিতি ছিল কদাচিৎ। খেঁজুর গাছের রস পানে, দানাশস্যভুক ও ফলভুকদের তুলনায় পতঙ্গভুক এবং সর্বভুক পাখিরাই (৭৮%, ৩৯% করে প্রতিটি) সংখ্যাগরিষ্ঠ ছিল। আমাদের গবেষণা খেঁজুরের রসকে স্থানীয় পাখিদের জন্য একটি সম্ভাব্য গুরুত্বপূর্ণ শীতকালীন খাদ্য হিসেবে আলোকপাত করেছে। আরও দেখিয়েছে যে পাখিরা মানুষের দ্বারা খেঁজুর গাছ থেকে সংগৃহীত রসকে খাদ্য হিসেবে ব্যবহার করতে সক্ষম।

Phloem sap, an energy-rich dietary resource, is consumed by several animal groups (Douglas 2006, Núñez Montellano et al. 2013). Sap consumption by birds presents an interesting ecological phenomenon, particularly observed in woodpeckers (Abdulali 1968, Eberhardt 2000, Schlatter and Vergara 2005, Pakkala et al. 2018) and hummingbirds (Southwick and Southwick 1980, Kevan et al. 1983, Macchi et al. 2011). Interestingly, some woodpecker species facilitate access to this hard-to-reach food source for

[1] Department of Zoology, Faculty of Life and Earth Sciences, Jagannath University, Dhaka, Bangladesh
[2] Centre for Integrative Ecology, School of Life and Environmental Science, Deakin University, Victoria, Australia
[3] Conservation Leadership, Department of Geography, University of Cambridge, Cambridge, United Kingdom
[4] BirdEyes, Centre for Global Ecological Change at the Faculties of Science & Engineering and Campus Fryslân, University of Groningen, Leeuwarden, The Netherlands
[5] Conservation Ecology Group, Groningen Institute for Evolutionary Life Sciences, University of Groningen, Groningen, The Netherlands
[6] NIOZ Royal Netherlands Institute for Sea Research, Department of Coastal Systems, Texel, The Netherlands
* Corresponding author: bisharga1095@gmail.com
Editor-in-Chief: Kristina L. Cockle

other opportunistic birds, including parakeet and passerine species (Daily et al. 1993; Blendinger 1999; Schlatter and Vergara 2005; Núñez Montellano et al. 2013, 2019). These birds use sap wells drilled by woodpeckers due to their inability to extract the nutrient-rich liquid by themselves (Belani et al. 2023).

Human activities can also facilitate sap-feeding birds, as documented in the USA (Kilham 1964), India (Rasal 2015), Guinea-Bissau (Gutiérrez et al. 2020), and Tunisian oases (Belani et al. 2023). Here we describe a case of human-facilitated sap feeding by birds in Bangladesh, where Indian date palm (*Phoenix sylvestris*; hereinafter date palm) is one of the most common palm species produced as a homestead crop (Rana et al. 2009, McKee et al. 2021). Consumption of fresh raw sap of the date palm and its derivatives (e.g., "jaggery," or unrefined sugar) is a common and traditional practice in Bangladesh (Ahmed et al. 2007). People harvest date palm sap from mid-October to mid-March (Nahar et al. 2010). For tapping the sap, they remove the rear leaves from the top edge of the date palm and expose the delicate inner tissue coat by removing the bark, the cut forming a "V". A small bamboo tube is inserted in the "V"- shaped area and positioned to collect sap from the date palm to drip into a pot placed under the tube. The traditional Bengali practice of sap collection for winter sweeteners creates access to energy-rich phloem sap for animals such as birds and bats (Nahar et al. 2010, Rasal 2015).

Fresh date palm sap is rich in proteins, minerals, and antioxidants, but it is mainly known for its high sugar content, primarily sucrose (Ben Thabet et al. 2007, 2009). When this sap ferments naturally, birds may ingest ethanol (Gutiérrez et al. 2020). Birds that consume fermenting fruits and nectar in the wild may be exposed to ethanol levels that could cause intoxication (Eriksson and Nummi 1982, Fitzgerald et al. 1990, Kinde et al. 2012). For some frugivorous and nectarivorous birds, the effects of drinking ethanol can be minimal (Mazeh et al. 2008). A few species may avoid date palm sap due to difficulties in digesting ethanol (Ben Thabet et al. 2007, 2009; Belani et al. 2023). Gutiérrez et al. (2020) reported that birds opportunistically feed on the sap of oil palms (*Elaies guineensis*), contrasting with Ali and Ripley's (1987) suggestion that sap consumption is not a common dietary habit among birds. However, migratory passerine birds may add date palm sap to their diet to meet migration needs (Belani et al. 2023). Gutiérrez et al. (2020) suggested that the ecological pressures leading to avian sap drinking behavior could differ between habitats, likely resulting in increased sap consumption by birds during dry seasons when water and food resources like arthropods and fleshy fruits are scarce. For example, White-fronted Woodpeckers (*Melanerpes cactorum*) in semi-arid forests drill trees year-round, but exhibit significantly higher sap consumption during dry seasons (Blendinger 1999; Núñez Montellano et al. 2013, 2019).

Here, we identify bird species that consume sap from tapped date palms at Nijhum Dweep in Bangladesh, quantify their frequency of occurrence of consuming sap, and describe the techniques they used to access this resource. As date palm sap is only available during the winter sap collection season, we expected that birds at Nijhum Dweep would opportunistically consume it.

Methods

Study area

The study was conducted on Nijhum Dweep (Island), one of 11 coastal islands of the Nijhum Dweep National Park (22°03′52″N, 91°00′36″E), in the Bay of Bengal on the central coast of Bangladesh (Fig. 1; Das et al. 2020). The area is part of the Ganges-Brahmaputra-Meghna Delta, designated as an Important Bird and Biodiversity Area (IBA) by BirdLife International (2024). The total area of Nijhum Dweep is 4,873 ha, of which 1,735 ha is covered by a planted mangrove ecosystem (Hossain et al. 2016). Nijhum Dweep has a diverse ecosystem with 171 recorded bird species (MoEF and BFD 2014) and 152 plant species (Uddin et al. 2015). Many of these plant species are cultivated, including date palm, rain tree (*Samanea saman*), mango (*Mangifera indica*), jackfruit (*Artocarpus heterophyllus*), coconut (*Cocos nucifera*), areca palm (*Areaca catechu*), tali palm (*Borassus flabellifer*), koroi (*Albizia procera*), shilkoroi (*Albizia labbeck*), keora (*Sonneratia apetala*), baine (*Avicennia alba*), and geoa (*Excoecaria agallocha*). The roads in the study area pass through dense vegetation, and date palms are the most common (Uddin et al. 2015).

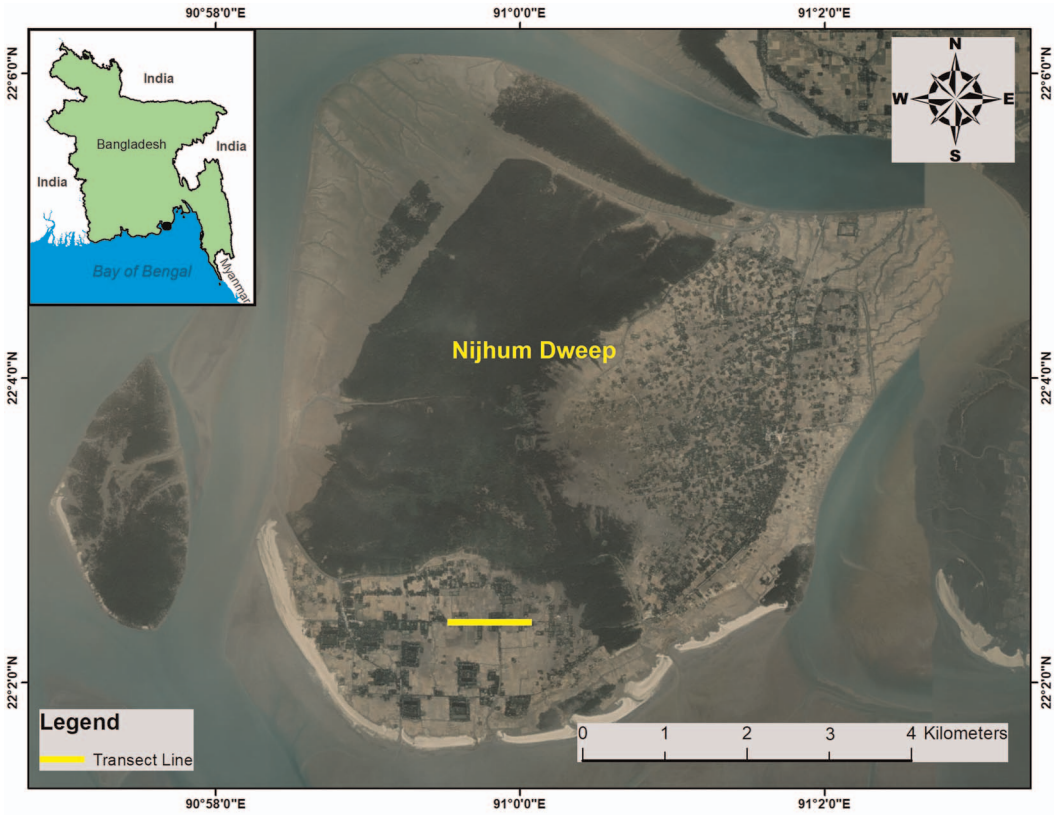

Figure 1. Study area in Nijhum Dweep National Park, located in the Bay of Bengal off the central coast of Bangladesh. The yellow line indicates a 1 km transect with 120 Indian date palms observed for recording sap-consuming birds from Indian date palms during the sap harvesting season in Bangladesh.

Data collection

We selected a road transect 1 km long and 20 m wide, with 120 date palms, to monitor birds feeding on date palm sap (Fig. 1). People tap date palms for sap extraction and consumption in Nijhum Dweep during the winter season, from December to February. Surveys were conducted for 30 d, between December 2019 and February 2020. During each survey, we walked along the same transect and observed the 120 date palms once per day in the late afternoon, from 1630 to 1730 h. During the surveys, we recorded the bird species present within the transect area and noted the species consuming sap from the date palms. We observed their sap consumption techniques, which included direct feeding from the bark or from bamboo collecting tubes. We observed birds with unaided eyes or with Nikon Aculon A211 8×42 binoculars. We took photographs with a Nikon P900 camera for documentation purposes. Bird identifications were later confirmed using the field guide of Grimmett et al. (2011).

We calculated the frequency with which each bird species consumed date palm sap using a constancy index (Dajoz 1973): $C = p_i \times 100/P$, where C is the constancy value for the species, p_i is the number of days in which species i was found consuming sap, and P is the total number of observation days. According to this index, if $C \geq 50\%$ the species is considered "constant," if $25\% \leq C < 50\%$ the species is "accessory," and if $C < 25\%$ the species is "accidental."

To understand the feeding strategies and dietary preferences of the bird species present in the transect area, bird species were grouped into 6 foraging guilds following Ali and Ripley (1987): carnivorous, omnivorous, frugivorous, nectarivorous, granivorous, and insectivorous. Additionally, to investigate date palm sap–feeding behavior in resident and migratory birds

Table 1. List of bird species visiting Indian date palms (either sap consumers or not) at Nijhum Dweep, Bangladesh. Birds were classified by their observed sap feeding technique (DFB = directly from bark, BT = from bamboo tube), feeding guild (Omn = omnivorous, Nect = nectarivorous, Gran = granivorous, Ins = insectivorous, Frug = frugivorous) (following Ali and Ripley 1987, Mukhopadhyay and Mazumdar 2017), and migration status (R = Resident, WM = Winter migrant) (following IUCN Bangladesh 2015).

Family name	Common name	Scientific name	Constancy index (%)	Sap feeding technique	Feeding guild	Migration status
Laniidae	Long-tailed Shrike*	*Lanius schach*	13.3	BT	Ins	R
Turdidae	Oriental Magpie Robin*	*Copsychus saularis*	6.7	BT	Ins	R
Zosteropidae	Oriental White-eye*	*Zosterops palpebrosus*	3.3	DFB	Ins	R
Sturnidae	Chestnut-tailed Starling	*Sturnia malabarica*	100	DFB	Omn	R
Sturnidae	Asian Pied Starling	*Gracupica contra*	100	DFB	Omn	R
Sturnidae	Jungle Myna	*Acridotheres fuscus*	100	BT	Omn	R
Sturnidae	Common Myna	*Acridotheres tristis*	23.3	BT	Omn	R
Pycnonotidae	Red-vented Bulbul	*Pycnonotus cafer*	100	DFB	Omn	R
Corvidae	Large-billed Crow	*Corvus macrorhynchos*	3.3	DFB	Omn	R
Corvidae	House Crow	*Corvus splendens*	–	–	Omn	R
Oriolidae	Black-hooded Oriole	*Oriolus xanthornus*	3.3	DFB & BT	Omn	R
Nectariniidae	Purple Sunbird*	*Cinnyris asiaticus*	6.7	DFB	Nect	R
Nectariniidae	Purple-rumped Sunbird	*Leptocoma zeylonica*	36.7	DFB	Nect	R
Estrildidae	White-rumped Munia*	*Lonchura striata*	3.3	DFB & BT	Gran	R
Psittacidae	Rose-ringed Parakeet	*Psittacula krameri*	6.7	DFB & BT	Frug	R
Psittacidae	Alexander Parakeet	*Psittacula eupatria*	–	–	Frug	R
Picidae	Black-rumped Flameback	*Dinopium benghalense*	3.3	DFB	Ins	R
Picidae	Fulvous-breasted Woodpecker	*Dendrocopos macei*	–	–	Ins	R
Picidae	Eurasian Wryneck	*Jynx torquilla*	–	–	Ins	WM
Cisticolidae	Common Tailorbird*	*Orthotomus sutorius*	23.3	BT	Ins	R
Cisticolidae	Plain Prinia	*Prinia inornata*	–	–	Ins	R
Dicruridae	Black Drongo	*Dicrurus macrocercus*	100	BT	Ins	R
Phylloscopidae	Greenish Warbler*	*Phylloscopus trochiloides*	26.7	DFB	Ins	WM
Phylloscopidae	Dusky Warbler	*Phylloscopus fuscatus*	–	–	Ins	WM
Meropidae	Green Bee-eater	*Merops orientalis*	–	–	Ins	R
Rhipiduridae	White-throated Fantail	*Rhipidura albicollis*	–	–	Ins	R
Muscicapidae	Taiga Flycatcher	*Ficedula albicilla*	–	–	Ins	WM
Motacillidae	Paddy-field Pipit	*Anthus rufulus*	–	–	Ins	R
Campephagidae	Large Cuckooshrike	*Coracina macei*	–	–	Ins	R
Acrocephalidae	Blyth's Reed Warbler	*Acrocephalus dumetorum*	–	–	Ins	WM
Paridae	Great Tit	*Parus major*	–	–	Ins	R
Passeridae	House Sparrow	*Passer domesticus*	–	–	Omn	R
Leiothrichidae	Jungle Babbler	*Turdoides striata*	–	–	Omn	R
Ploceidae	Baya Weaver	*Ploceus philippinus*	–	–	Gran	R
Cuculidae	Greater Coucal	*Centropus sinensis*	–	–	Omn	R
Columbidae	Spotted Dove	*Spilopelia chinensis*	–	–	Gran	R
Columbidae	Eurasian Collared-Dove	*Streptopelia decaocto*	–	–	Gran	R

* indicates new record of sap feeding.

occurring in Nijhum Dweep during the winter migration season, birds were classified as either resident or winter migrant, following IUCN Bangladesh (2015).

Results

We observed 37 avian species along the transect (Table 1). Among these, 18 (49%) were recorded as consumers of sap from the date palms (Table 1). The constancy index classified 5 bird species (Chestnut-tailed Starling *Sturnia malabarica*, Asian Pied Starling *Gracupica contra*, Jungle Myna *Acridotheres fuscus*, Red-vented Bulbul *Pycnonotus cafer*, and Black Drongo *Dicrurus macrocercus*) as constant consumers of date palm sap. Eleven species (Black-rumped Flameback *Dinopium benghalense*,

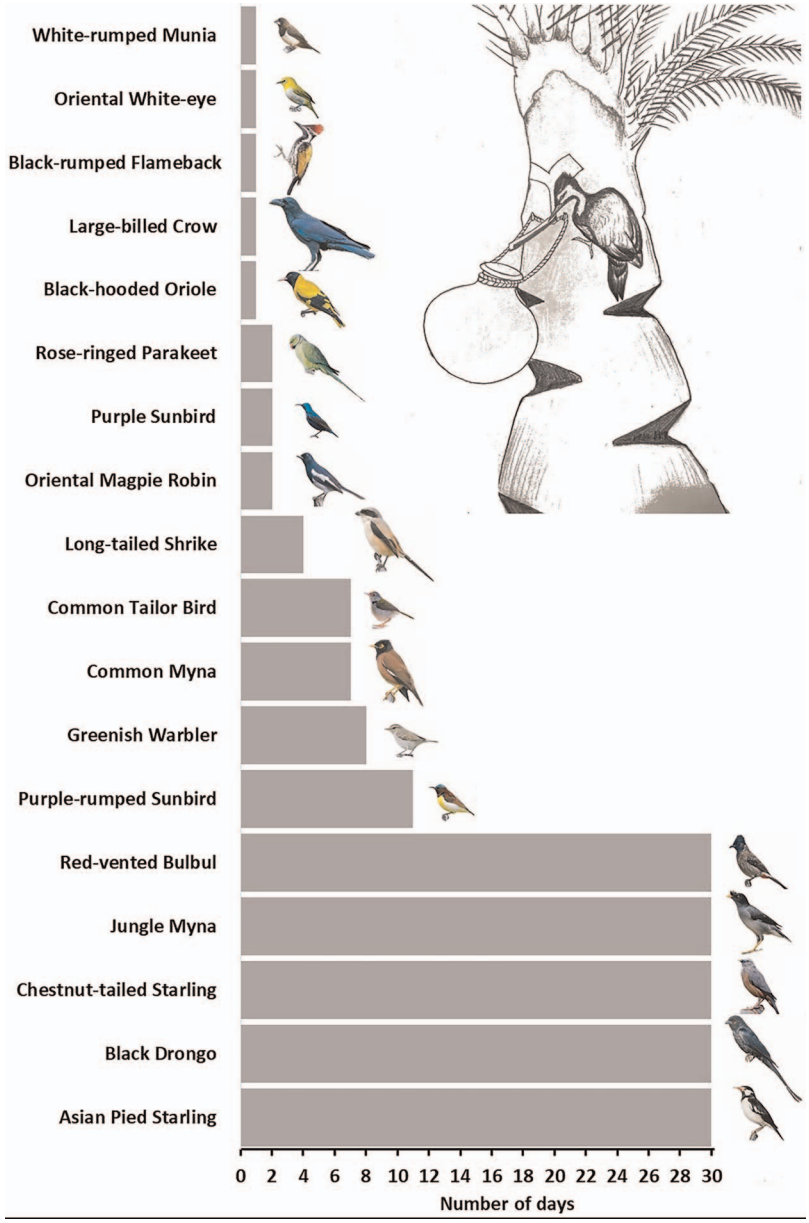

Figure 2. Gray bars indicate the number of days that we recorded each bird species consuming date palm sap, out of 30 observation days. An illustration of sap tapping from the Indian date palms in Nijhum Dweep, Bangladesh, is shown inside the graph. (Drawing by Farhana Akhtar)

Common Tailorbird *Orthotomus sutorius*, Long-tailed Shrike *Lanius schach*, Oriental Magpie Robin *Copsychus saularis*, Oriental White-eye *Zosterops palpebrosus*, Common Myna *Acridotheres tristis*, Large-billed Crow *Corvus macrorhynchos*, Black-hooded Oriole *Oriolus xanthornus*, Purple Sunbird *Cinnyris asiaticus*, White-rumped Munia *Lonchura striata*, and Rose-ringed Parakeet *Psittacula krameri*) were accidental sap consumers and 2 species (Purple-rumped Sunbird *Leptocoma zeylonica* and Greenish Warbler *Phylloscopus trochiloides*) were accessory sap consumers (Fig. 2, Table 1).

Half of the sap-consuming bird species consumed the sap from the bark of the date palm. One-third consumed sap from bamboo tubes, and one-sixth of species consumed using both techniques (Table 1, Supplemental Fig. S1). Of the 18 sap-consuming bird species, 78% were insectivorous and omnivorous (39% each). Among the sap-consuming bird species, most were residents, with only one species, Greenish Warbler, being a winter visitor to Bangladesh (Table 1).

Discussion

Birds are rarely documented feeding on date palm sap, but along our transect on Nijhum Dweep, nearly half of the bird species we observed consumed sap from date palms. To our knowledge, this is the first published report of birds in Bangladesh consuming date palm sap. Although Black-rumped Flameback can gain phloem sap by excavating holes in the bark of living trees, the remaining species would typically not have access to sap in their natural habitat. The sap-feeding behavior was made possible by the Bengali tradition of tapping date palms to collect sap during the winter season.

Constant consumers of sap were mainly insectivorous and omnivorous. We observed that the insectivorous Black Drongo was a regular sap consumer, highlighting the opportunistic nature of avian foraging strategies. Insectivorous species like the Common Tailorbird and Greenish Warbler also consumed sap, indicating a broad dietary flexibility. Omnivorous bird species incorporate both plant-based and animal-based foods in their diet (Salim 1941, Mayntz 2019). We found 4 omnivorous species to consistently consume date palm sap (Table 1). Our findings suggest that sap could serve as an alternative winter food source for birds, with the dietary shifts following seasonal variation in food availability and nutritional needs (Arslangundogdu 2010). Sap may provide a reliable, if seasonally temporary, food source (Núñez Montellano et al. 2019).

For 7 of the bird species we observed consuming sap—Common Tailorbird, Greenish Warbler, Long-tailed Shrike, Oriental Magpie Robin, Oriental White-eye, Purple Sunbird, and White-rumped Munia—we could not find previously published evidence of sap feeding. These species belong to families with diets based on insects, seeds, nectar, and pollen (Salim 1941, Ghadirian et al. 2007). The findings expand our understanding beyond traditional diets and highlight the opportunistic foraging strategies of these birds (Salim 1941, IUCN Bangladesh 2015).

Our observations of Black Drongo, Rose-ringed Parakeet, and Common Myna consuming sap from thin bamboo collecting tubes align with a previous study by Rasal (2015). Moreover, we observed 6 additional bird species—Common Tailorbird, Long-tailed Shrike, Oriental Magpie Robin, Jungle Myna, Black-hooded Oriole, and White-rumped Munia—obtaining sap from bamboo collecting tubes. This suggests a common feeding strategy among different bird species, the convenience of accessing sap overriding their various ecological or morphological characteristics.

Except for the Greenish Warbler, a winter migrant, all species observed feeding on date palm sap were resident. In contrast, Belani et al. (2023) recorded only migrant species feeding on date palm sap in Tunisian oases. Although we observed several winter migrants along our transect (Eurasian Wryneck *Jynx torquilla*, Dusky Warbler *Phylloscopus fuscatus*, Blyth's Reed Warbler *Acrocephalus dumetorum*, and Taiga Flycatcher *Ficedula albicilla*), we did not see them consume date palm sap. Some migratory passerine species may avoid consuming date palm sap, perhaps because they have difficulty digesting sucrose or ethanol (Ben Thabet et al. 2007, 2009; Belani et al. 2023). Birds have been observed to exhibit ethanol avoidance behaviors (Mazeh et al. 2008, Belani et al. 2023).

Date palm sap consumption has been associated with the transmission of Nipah virus diseases from bats to humans (Aidoo et al. 2006, Luby et al. 2006, Nahar et al. 2010, Luby 2013). *Pteropus* spp. bats carry Nipah virus and contaminate the sap with their saliva, urine, and excreta while consuming sap from the tapped bark and sap collecting pots (Chua et al. 2002, Wacharapluesadee et al. 2005, Khan et al. 2010). Considering that wild birds such as sparrows and finches can harbor various pathogens that may pose health risks

to humans (Thomas et al. 2008), the large number of bird species accessing sap, and thus connecting with humans, may warrant some degree of disease surveillance as it may expose humans to bird-carried infectious diseases via the sap extraction tools.

Acknowledgments

The authors are thankful to Jagannath University in Bangladesh and the National Centre for Biological Sciences in India for financial support; and the Bangladesh Forest Department and the IUCN Bangladesh for logistical support during this study. We sincerely thank the anonymous reviewers and editors for their valuable comments that greatly improved the manuscript.

Literature cited

Abdulali H. 1968. Sap sucking by Indian woodpeckers. Journal of the Bombay Natural History Society. 65:219–221.

Ahmed R, Islam ANMF, Rahman M, Halim MA. 2007. Management and economic value of *Schumannianthus dichotoma* (Murta) on rural homesteads in the Sylhet region of Bangladesh. International Journal of Biodiversity Science and Management. 3:252–258.

Aidoo KE, Nout MJ, Sarkar PK. 2006. Occurrence and function of yeasts in Asian Indigenous fermented foods. FEMS Yeast Research. 6:30–39.

Ali S, Ripley SD. 1987. Compact handbook of birds of India and Pakistan together with those of Bangladesh, Nepal, Bhutan, and Sri Lanka. New Delhi (India) and Oxford (UK): Oxford University Press.

Arslangundogdu Z. 2010. Presence of insectivorous birds in the forest area of Istanbul University, Turkey. Journal of Environmental Biology. 31:197–206.

Belani F, Cuervo JJ, Selmi S. 2023. Human-facilitated feeding on date palm *Phoenix dactylifera* sap by trans-Saharan warblers during spring stopover in a Tunisian oasis. Bird Study. 70:260–268.

Ben Thabet I, Attia H, Besbes S, Deroanne C, Francis F, et al. 2007. Physicochemical and functional properties of typical Tunisian drink: Date palm sap (*Phoenix dactylifera* L.). Food Biophysics. 2:76–82.

Ben Thabet I, Attia H, Besbes S, Deroanne C, Francis F, et al. 2009. Physicochemical characteristics of date sap "lagmi" from deglet nour palm (*Phoenix dactylifera* L.). International Journal of Food Properties. 12:659–670.

BirdLife International. 2024. Important Bird Areas factsheet: Ganges-Brahmaputra-Meghna delta [cited 13 Mar 2024]. http://www.birdlife.org

Blendinger PG. 1999. Facilitation of sap-feeding birds by the White-fronted Woodpecker in the Monte Desert Argentina. Condor. 101:402–407.

Chua KB, Koh CL, Hooi PS, Wee KF, Khong JH, Chua BH. 2002. Isolation of Nipah virus from Malaysian Island flying-foxes. Microbes and Infection. 4:145–151.

Daily GC, Ehrlich PR, Haddad NM. 1993. Double keystone bird in a keystone species complex. Proceedings of the National Academy of Sciences USA. 90:592–594.

Dajoz R. 1973. Ecologia general. 3rd edition. Petrópolis (Brazil): Vozes.

Das DK, Khandakar N, Ali MS. 2020. Large-billed Crow depredates wintering waders on the coast of Bangladesh. Wader Study. 127:165–168.

Douglas A. 2006. Phloem-sap feeding by animals: Problems and solutions. Journal of Experimental Botany. 57:747–754.

Eberhardt LS. 2000. Use and selection of sap trees by Yellow-bellied Sapsuckers. Auk. 117:41–45.

Eriksson K, Nummi H. 1982. Alcohol accumulation from ingested berries and alcohol metabolism in passerine birds. Ornis Fennica. 60:2–9.

Fitzgerald SD, Sullivan JM, Everson RJ. 1990. Suspected ethanol toxicosis in two wild Cedar Waxwings. Avian Diseases. 34:488–490.

Ghadirian T, Qashqaei AT, Dadras M. 2007. Notes on feeding and breeding habits of the Purple Sunbird *Nectarinia asiatica* (*Cinnyris asiaticus*) in Bandar Abbas, Hormozgan, Southern Iran. Podoces. 2:122–126.

Grimmett R, Inskipp C, Inskipp T. 2011. Birds of the Indian Subcontinent. 2nd edition. New Delhi (India): Oxford University Press.

Gutiérrez JS, Catry T, Granadeiro JP. 2020. Human facilitation of sap-feeding birds in the Bijagos archipelago, West Africa. Ibis. 162:250–254.

Hossain KT, Tanim IA, Saluddin M. 2016. Change detection of forest cover: A study Nijhum Dwip National Park, Hatiya, Noakhali. Journal of Life and Earth Sciences. 2:54–90.

IUCN Bangladesh. 2015. Red List of Bangladesh–Volume 3: Birds. Dhaka (Bangladesh): International Union for Conservation of Nature, Bangladesh Country Office.

Kevan PG, St. Helens SD, Baker I. 1983. Hummingbirds feeding from exudates on diseased scrub oak. Condor. 85:251–252.

Khan MSU, Hossain J, Gurley ES, Nahar N, Sultana R, Luby SP. 2010. Use of infrared camera to understand bats' access to date palm sap: Implications for preventing Nipah virus transmission. EcoHealth. 7:517–525.

Kilham L. 1964. The relations of breeding Yellow-bellied Sapsuckers to wounded birches and other trees. Auk. 81:520–527.

Kinde H, Foate E, Beeler E, Uzal F, Moore J, Poppenga R. 2012. Strong circumstantial evidence for ethanol toxicosis in Cedar Waxwings (*Bombycilla cedrorum*). Journal of Ornithology. 153:995–998.

Luby SP. 2013. The pandemic potential of Nipah virus. Antiviral Research. 100:38–43.

Luby SP, Rahman M, Hossain MJ, Blum LS, Husain MM, et al. 2006. Foodborne transmission of Nipah

virus, Bangladesh. Emerging Infectious Diseases. 12:1888–1894.

Macchi L, Blendinger P, Núñez Montellano MG. 2011. Spatial analysis of sap consumption by birds in the Chaco dry forests from Argentina. Emu-Austral Ornithology. 111:212–216.

Mayntz M. 2019. Bird diet types. Spruce [cited 19 May 2023]. https://www.thespruce.com/bird-diet-types-386612

Mazeh S, Korine C, Pinshow B, Dudley R. 2008. The influence of ethanol on feeding in the frugivorous Yellow-vented Bulbul (*Pycnonotus xanthopygos*). Behavioural Processes. 77:369–375.

McKee CD, Islam A, Luby SP, Salje H, Hudson PJ, et al. 2021. The ecology of Nipah virus in Bangladesh: A nexus of land-use change and opportunistic feeding behavior in bats. Viruses. 13:1–23.

[MoEF and BFD] Ministry of Environment, Forests and Bangladesh Forest Department. 2014. Nijhum Dwip National Park Management Plan 2015–2025. Strengthening Regional Cooperation for Wildlife Protection project. Dhaka (Bangladesh): Bangladesh Forest Department.

Mukhopadhyay S, Mazumdar S. 2017. Composition, diversity and foraging guilds of avifauna in a suburban area of southern West Bengal, India. Ring. 39:103–120.

Nahar N, Sultana R, Gurley ES, Hossain MJ, Luby SP. 2010. Date palm sap collection: Exploring opportunities to prevent Nipah transmission. EcoHealth. 7:196–203.

Núñez Montellano MG, Blendinger PG, Macchi L. 2013. Sap consumption by the White-fronted Woodpecker and its role in avian assemblage structure in dry forests. Condor. 115:93–101.

Núñez Montellano MG, Blendinger PG, Bodrati A, Salvador SA. 2019. Sap feeding by birds in southern Neotropical forests. Wilson Journal of Ornithology. 131:285–295.

Pakkala T, Piiroinen J, Lakka J, Tiainen J, Piha M, Kouki J. 2018. Tree sap as an important seasonal food resource for woodpeckers: The case of the Eurasian Three-toed Woodpecker (*Picoides tridactylus*) in southern Finland. Annales Zoologici Fennici. 55:79–92.

Rana P, Sohel S, Islam S, Akhter S, Chowdhury MS, et al. 2009. Traditional practice of palm husbandry in the southeastern region of rural Bangladesh: Status and potentials. International Journal of Biodiversity Science & Management. 5:155–161.

Rasal V. 2015. Sap-drinking by birds on tapped Indian date palm *Phoenix sylvestris*. Journal of the Bombay Natural History Society. 112:102–103.

Salim A. 1941. The book of Indian birds. 13th edition. Bombay (India): Bombay Natural History Society.

Schlatter RP, Vergara P. 2005. Magellanic Woodpecker (*Campephilus magellanicus*) sap feeding and its role in the Tierra del Fuego forest bird assemblage. Journal of Ornithology. 146:188–190.

Southwick EE, Southwick AK. 1980. Energetics of feeding on tree sap by Ruby-throated Hummingbirds in Michigan. American Midland Naturalist. 104:328–334.

Thomas NJ, Hunter DB, Atkinson CT, editors. 2008. Infectious diseases of wild birds. Hoboken (NJ): John Wiley & Sons.

Uddin MZ, Kibria MDG, Hassan MDA. 2015. Assessment of angiosperm plant diversity of Nijhum Dweep, Bangladesh. Journal of the Asiatic Society of Bangladesh, Science. 41:19–32.

Wacharapluesadee S, Lumlertdacha B, Boongird K, Wanghongsa S, Chanhome L, Rollin P. 2005. Bat Nipah virus, Thailand. Emerging Infectious Diseases. 11:1949–1951.