Feeding preferences of Sunbirds in the selected habitats of Pernem Taluka, Goa

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Goa University

2022-2023

Feeding preferences of Sunbirds in the selected habitats of Pernem Taluka, Goa

A dissertation report for

ZOO 438D Dissertation

8 credits

Submitted in partial fulfilment of Master's Degree in Zoology

Goa University

by

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April 2023

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DECLARATION BY STUDENT

I hereby declare that the data presented in this Dissertation entitled "**Feeding Preferences of Sunbirds in the selected habitats of Pernem Taluka, Goa**" is based on the results of investigations carried by me in the Zoology Discipline at the School of Biological Sciences and Biotechnology, Goa University under the supervision of Dr. Minal Desai Shirodkar and the same has not been submitted elsewhere for the award of a degree or diploma by me. Further, I understand that Goa University or its authorities will not be responsible for the correctness of observations / experimental or other findings given the dissertation. I hereby authorize the University authorities to upload this dissertation on the dissertation repository or anywhere else as the UGC regulations demand and make it available to any one as needed

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COMPLETION CERTIFICATE

This is to certify that the dissertation entitled "**Feeding preferences of Sunbirds in the selected habitats of Pernem Taluka, Goa**" is a bonafide work carried out by **Ms. Tejashri Raghunath Mahale** under my supervision/ mentorship in partial fulfilment of the requirements for the award of the degree **Masters of Science in Zoology** in the Discipline Zoology at the School of Biological Sciences and Biotechnology, Goa University.

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ACKNOWLEDGEMENT

I am extremely thankful to the almighty Lord who has blessed, guided and protected me throughout. I would like to acknowledge all the people who have helped and guided me without which this project would have not been possible.

I express my sincere gratitude to my guide Dr. Minal Desai Shirodkar, Assistant Professor, Zoology Discipline, School of Biological Sciences and Biotechnology, Goa University for her constant guidance, help, support and encouragement throughout my dissertation work and for providing facilities to carry out the research work.

I am grateful to the Dean of School of Biological Sciences and Biotechnology Prof. Savita Kerkar for allowing me to carry out all the research work in the college premises.

I am most grateful to the Programme Director, Discipline Zoology Dr. Nitin Sawant for his constant guidance and encouragement throughout the dissertation period.

I would also like to thank my other professors, Dr. Avelyno D' Costa, Dr. Shanti Dessai, Ms. Gandhita Kundaikar, Dr. Shamshad Shaikh and Dr. Preeti Pereira for their valuable advice and suggestions.

I would like to express my deepest gratitude to my collegues Ms. Anchal Naik and Ms. Rashmi Anurlekar for their co-operation and suggestions.

I would also like to extend my gratitude to my parents, uncle and brother for their help and support both morally and financially. I am thankful to Ms. Prachi Talavnekar and Mr. Stephen Menezes for providing me with necessary pictures wherever needed. I wish to place on my deep sense of gratitude towards my friends to Ms. Prachi Gaonkar, Ms. Sanika Mahale, Mr. Rohan Kanolkar, Mr. Manish Malik, Mr. Rushikesh Bandodkar, Ms. Karishma Naik, Ms. Aishwarya Nene and Ms. Pooja Gaude for all the help they provided during the course of my study.

Ms. Tejashri R. Mahale

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CHAPTER 1: INTRODUCTION

A. INTRODUCTION

Birds are one of the most studied groups among the vertebrates. They contribute to the four types of services recognized by the UN Millennium Ecosystem Assessment which includes provisioning, regulating, cultural and supporting services. As members of the ecosystem, birds play several roles such as pollinators, scavengers, seed dispersers, nutrient recyclers, ecosystem engineers (Şekercioğlu 2006, Whelan et al. 2008, Wenny et al. 2011, Şekercioğlu et al. 2016) predators, seed predators (Christopher J Whelan et al., 2018) and are sensitive to the surrounding environmental changes. Birds are unique among other terrestrial organisms because they forage in a 3-D manner by moving vertically and horizontally in the search of food (Kooyman, 2012).

Globally, Sunbirds are known to be the pollinating birds for nectariferous plants. They are the important pollinators in Africa and Asia (A.J. Solomon Raju, 2008). Several pollination studies related to Sunbirds are conducted by Johnson (1996), Nicolson (2002), Solomon Raju (2008), Hobbahn (2015), Janecek (2015). Studies pertaining to the role of Sunbirds in the pollination of different plant species in India is done by Ali (1932), Frost et al. (1981), Davidar (1983), Sonawane et al. (2017). Work has been done on choice of flowers by Sunbirds with respect to different plant traits. The colour is the most studied plant trait (Solomon Raju, 1990; Davidar, 1983; Santharam, 1996). Choice of the flowers concerned to odour is studied by Klaing (2004) and Kaluthota et al. (2007). Vast studies are done on nectar intake by Johnson et al. (2008), Cruden et al. (1977), Rocea et al. (2010), Robert et al. (1976), Paton et al. (1989). Along with pollination, Sunbirds also show nectar robbing behaviour and studies concerned to nectar robbing are conducted by Kannah (1978), Santharam (1996), Arizmendi et al. (1996), Traveset et al. (1998). Few studies are done on choice of Sunbirds related to shapes and sizes of the flower (Subramanya et al., 1993, Bailey et al., 2018, N. Perera et al. 2020).

Sunbirds are a widespread group of species occurring in tropical and subtropical Africa and Asia (FUJITA, 2000). They are small passerines which belong to the family Nectariniidae. Sunbirds are

known to be the Old-World ecological equivalents of hummingbirds (Wolf, Hainsworth and Gill, 1975). Sunbirds are often brightly coloured with iridescent plumage and have slender, short or long and markedly curved bills. Sunbirds are vociferous, give calls while feeding and often sing chattering songs. They feed largely on nectar and other small insects (Burton and Burton, 2002).

Globally, 120 Sunbird species are known so far. Out of which 88 species are found in Africa, 33 are found in West African sub- continent, 80 species in Australasia while 27 occur in Nigeria (Mann, C. F., & Cheke, R. A., 2010). Recent study by (S. Dalvi) shows that there are 150 Sunbird species distributed along variety of habitats worldwide. *Nectarinia notata, Nectarinia souimanga, Nectarinia humbloti, Nectarinia dussumieri,* and *Nectarinia coquereli* are the five endemic Sunbird species generally found in western Indian Ocean region (Irwin, 1999; Louette, 1988).

India has 15 members of Nectariniidae, out of which 13 species are Sunbirds and 02 are spiderhunters (Sustain Team, (2022, May 18). *For the love of Nectar: The Dazzling Sunbirds of India*. Retrieved from https://roundglasssustain.com/photostories/sunbirds-india). According to Grimmett, R., Inskipp, C., & Inskipp, T. (2016), 13 species of Sunbirds are listed. Goa has five Sunbird species i.e. Purple- rumped Sunbird *Leptocoma zeylonica*, Crimson- backed Sunbird *Leptocoma minima*, Loten's Sunbird *Cinnyris lotenius*, Purple Sunbird *Cinnyris asiaticus*, Vigor's Sunbird *Aethopyga vigorsii* and a Little spiderhunter *Arachnothera longirostra* belonging to family Nectariniidae (Baidya P. and Bhagat M., 2017).

Each Sunbird has a distinct preferred diet. The activities such as probing, hovering and piercing are mostly used by the Sunbirds in acquiring the food. Hence, sum of these three activities are considered as the "feeding activities" (N. Perera et al. 2020). The strategy of resource and time allocation associated with foraging for food can strongly affect the animal's fitness. They need to make correct choice regarding resource and time allocation because it directly affects their survival and reproduction (Stephens and Krebs, 1986). The foraging strategies can be either short- term strategies (E.g.: seasonal) or long- term strategies (e.g.: across the life span or annual) (McNamara

and Houston, 2008: Arthur et al., 2016). Since nectar is an important part of the diet of Sunbirds, flower abundance, colour, morphology and nectar properties may affect their feeding behaviour (Wolf, Hainsworth, and Gill, 1975).

Territorial behaviour is often observed in Sunbirds (Ali, S. et al., (1983), Kannah, P., J. (1978) and Davidar, P. (1977). Since, nectar producing flowers are one of the best renewable resources (Gill and Wolf, 1975), they are often defendable by the Sunbirds in their food territory. Such territories mostly involve only one individual, intermittently coexisting with a female (Frank B. Gill et al. (1975). Both the genders of the species are known to guard their feeding and breeding territory (Cheke et al. 2001).

The morphological characters of the birds and flowers in particular, the bill of the former and corolla of the latter seem to dictate how birds handle nectariferous flowers (Gill and wolf, 1978). The feeding preferences of Sunbirds mostly depend on matching of length and morphology of the bill in nectar feeding birds with corolla length and morphology of the flower (Snow and Snow 1972, Wolf et al. 1975). Based on the morphology of a beak and tongue, Nectarinidae family (Sunbirds) can be labelled as specialized nectar feeders. This matching results in better pollination service (Christopher J Whelan et al., 2018). But certain plant traits alter the animal behaviour and their choices (Heystek et al., 2014). Ali, S.J., (1932).

The purpose of the present study was to document the plant species preferred by Sunbirds in different habitats, to examine their behavioural relationship with length of the corolla, colour, size, shape and odour of the flower and to visualize and describe their activity frequencies and foraging behaviour.

CHAPTER 2: REVIEW OF LITERATURE

B. REVIEW OF LITERATURE

One of the important ecosystem services provided by birds is pollination. Though most the plants are insect- pollinated, birds are also known to pollinate many of the plants. The pollinating birds in Australia are mostly Sunbirds, while in Africa and Asia it is mostly Sunbirds and white- eyes (A.J. Solomon Raju, 2008). Over 920 species of birds pollinate the plants (S. Subramanya et al., 1993, Raju J S Aluri et al. 1994, J. B. Atluri et al. 2000, Sjirk Geerts et al. 2008, William D. Newmark et al. 2020), including hummingbirds (Trochilidae) in the Americas, Sunbirds (Nectarinidae) in Africa, false-Sunbirds (Philepittidae) in Madagascar, flowerpeckers (Dicaeidae) and white-eyes (Zosteropidae) and Sunbirds (Nectariniidae) in Asia and Africa (A.J. Solomon Raju, 2008), honeyeaters (Melphagidae) and lories (Loridae) in Australasia and Hawaiian honeycreepers (Drepanididae) in Hawaii (Stiles 1981). The study revealed 58 Indian bird species from 16 different families and four orders to be involved in the pollination of 93 species of flowering plants belonging to 34 families and 20 orders. Bird features that aid in pollination and floral adaptation to bird pollination was studied. Wherein they found out that based on the morphology of a beak and tongue families such as Dicaeidae (flowerpeckers) Irenidae (leafbirds), Nectarinidae (Sunbirds) and Zosteropidae (white-eyes) can be labelled as specialized nectar feeders. The bird pollination is mostly considered as the supporting ecosystem service.

Procter and Yeo (1978) suggested that the evolution of ornithophily was followed by entomophily. But according to Indian and Western North American context in relation to the study of hummingbirds, suggest that more of the ornithophilous group of plants seem to be a sub-set of a much larger entomophilous plants (S. Subramanya et al.,1993). The ornithophilous plants of India include members of family Malvaceae, Bignoniaceae. Verbanaceae, Myrtaceae and Leguminoceae. The mistletoes (Loranthaceae) are widely studied ornithophilous plants in India and most of the Sunbird species eg: Vigor's Sunbird in Satpuda ranges of Maharashtra is seen to feed on mistletoes. (Ali, S., J. 1932, Laxminarayan Sonawane et al. 2017).

No major difference has been observed in the visitation pattern of Sunbirds on indigenous and exotic ornithophilous, entomophilous and chiropterous flowers (Kannah, 1978). Some studies validates that the no. of visits by Sunbird does not depend on the colour of the flower or plant species (N. Perera et al. 2020). However, the plants epitomized for having unscented flowers, reddish colouration and high volume of dilute nectar are more favoured for pollination by birds (Van der Pijl 1961). A study on foraging behaviour of purple Sunbird shows that they are attracted to red flowers (Taher Ghadirian et al., 2008) which may have no smell (Klasing, 2004). While, the ornithophily by Sunbirds wherein they forage on blue flowers of *Acanthus ilicifolius* and purple flowers of *Anisomeles sp.* shows that birds also prefer flowers other than red colour (A.J. Solomon Raju, 1990). The preference on colour of the flower may sometimes depend upon the amount of nectar present inside. In *Helicteres isora*, the red flowers have more nectar than the blue ones (V. Santharam, 1996, A.J. Solomon Raju, 2008) which may be one of the reason why red flowers are favoured in some of the plant species such as *Hibiscus rosa- chinensis* (Taher Ghadirian et al. 2008). It is also figured out that the nectar of the flowers visited by Sunbirds (specialist nectarivores) is different from that visited by generalist nectarivores. However, there's not much difference in the nectar preferred by Sunbirds and hummingbirds (Johnson and Nicolson 2008).

Birds that forage on nectar of the flowers can be divided into specialist nectarivores and generalist nectarivores. Hummingbirds (Trochilidae, Apodiformes) in America, Sunbirds (Nectariniidae) in Africa, South Asia and Australasia, sugarbirds (Promeropidae) in South Africa, honeyeaters (Meliphagidae) in Australasia, and flowerpeckers (Dicaeidae, all Passeriformes) and lorikeets (Psittacidae, Psittaciformes) in South Asia and Australasia are mainly the specialist nectarivores (Collar 1997, Schuchmann 1999, Cheke and Mann 2008a, 2008b, Higgins et al. 2008). However, these contrast with opportunistic generalist nectarivores, which consume nectar only periodically (in the Old World and the New World) and belong mainly to the Passeriformes, for example white-eyes, weavers, bulbuls or orioles (Cruden and Toledo 1977, Johnson and Nicolson 2008, Rocca and Sazima 2010).

The experiment conducted by Robert Schlamowitz et al. (1976) concluded that the rate of nectar intake by *Nectarinia kilimensis* from an artificial feeder decreased with increase in the corolla length as a result of less nectar obtained per lick due to the morphological difference, even though the Sunbirds protrude their tongues beyond the bill length. (Paton and Collins, 1989). Based on the morphology of a beak and tongue, families such as Dicaeidae (flowerpeckers) Irenidae (leafbirds), Nectariniidae (Sunbirds) and Zosteropidae (white-eyes) can be labelled as specialized nectar feeders among the Birds found in India (Kannan, P., J. 1978). The families including Dicaeidae and Nectariniidae harvest more nectar from tubular flowers because of their long bills as compared to the body size (S. Subramanya et al.,1993).

The plant traits alter the animal behaviour and their choices (Heystek et al., 2014). Ali, S.J., (1932) noticed that some flowers require external pressure to open, as that of family Loranthaceae and Sunbirds and flowerpeckers help in pollination and fertilization by exerting such pressure on these flowers. Davidar, P., (1983) concludes that flowerpeckers mostly prefer closed flowers of mistletoes and do not visit opened flowers, wherelse Sunbirds prefer flowers which are opened. White- eyes opputunistically visit opened and closed types of mistletoes. Purple- rumped Sunbird showed a significant correlation with the corolla length and no. of the flowers, while long- billed Sunbird showed a significant correlation with glucose concentration. Both Sunbirds preferred different feeding plants because of their bill length which allows them to share a common habitat (N. Perera et al. 2020).

Though Sunbirds are considered as good pollinators, Kannah (1978), they also show illegitimate visits. The illegitimate visit shown by robbers (birds or insects) mostly have negative, no effect (Zhang et al., 2007) or rarely show a positive effect on the plant (Singh et al., 2014). When birds feed on the nectar as primary nectar robbers, they make a hole in the flower tube or at the base of the corolla (Mcdada & Kinsman 1980, Feinsinger et al. 1987, Thompson et al. 1996, Arizmendi et al. 1996, Ueda & Karaki 1997, Traveset et al. 1998, Ueda 1999).

Kannah (1978) observed 31 species of plants out of which at least 21 were frequently robbed off their nectar through a short- cut method of nectar robbing. Various visitors to the plants behave in different ways in-order to harvest the nectar/ pollen. Inouye D.W. (1980) classified these visitors into pollinators (P), thieves (T) and robbers (R). Pollinator is the one that profits the plant by transferring pollen grains from stamen to stigma of same or another flower. A thief derives the benefit from the plant without harming the morphology of the flower nevertheless prevents pollination due to mismatch of the morphologies. However, robbers also preclude pollination by destroying the flower. An index of relative usefulness of the visitors to *H. isora* was determined by V. Santharam (1996) wherein *Turdoides striatus* dominantly visited (748 flowers) and was the main pollinator, followed by *Nectarinia zeylonica* but it was categorised as thief along with *Nectarinia asiatica.* Both the Sunbirds accounted for 24% of the visit but did not make any contact with the anther. Blossom- headed parakeet was the most destructive among the robbers.

The cheating/ nectar robbing behaviour, generally executed by insects or birds, may not always have a detrimental effect on plant reproductive success (Arizmendi, Domínguez & Dirzo 1996; Morris 1996) but has led to decrease in the seed set in many of the cases (A. Traveset et al., 1998, P. D. Kamala Jayanti et al. 2015, Radhamani Dhanya et al. 2012). The phenomenon of nectar robbing by nectivorous species among the long tubular flowers is wide- spread (Mcdada & Kinsman 1980, Roubik et al. 1985, Feinsinger et al. 1987, Traveset et al. 1998). Traveset et al. 1998). This phenomenon is known from both native as well as introduced and decorative flower species. (Vogel et al. 1984, Thompson et al. 1996, Ueda & Karaki 1997, Ueda 1999). When birds feed on the nectar as primary nectar robbers, they make a hole in the flower tube or at the base of the corolla (Mcdada & Kinsman 1980, Feinsinger et al. 1987, Thompson et al. 1996, Arizmendi et al. 1996, Ueda & Karaki 1997, Traveset et al. 1998, Ueda, 1999). The same has been observed for *Canna generalis* from Cannaceae and *Gardenia sp*. from Rubiaceae (Kaoru FUJITA, 2000).

Though nectar is a good source of energy, mostly ornithophilous flowers are poor in essential amino acids and predominantly contain thiamine and isoleucine. Hence, even the specialized

nectarivorous birds like that of Sunbirds consume animal matter to meet their protein requirement. (Ali, S. et al. (1987) and Snow, D.W. (1981). Since the nestlings in purple Sunbird are altricial, they require protein during their rapid development (Klasing 2004). In-order to satisfy this need, adults feed their nestlings with small insects. In Indian subcontinent, the purple Sunbirds are known to feed on insects and spiders, but majorly on flower nectar (Ali 2002). Nectar passes more rapidly through the digestive tract (Roxburgh and Pinshow, 2002) hence majority of the visits are in the search of nectar. The calyx water of *Spathodea companulata* is rich in amino acid and are easily harvested by birds with pointed beak (Bahadur, B. et al., 1986). Along with the flower nectar, fruit nectar is also preferred by Sunbirds. V. Jain et al. (2011) reported that *Nectarinia zeylonica* and *Nectarinia asiaticus* visited *Bombax ceiba* in Southern Rajasthan to feed on the nectar of the flowers and fruits. Fruits of *Cordia myxa* and *Phoenix dactylifera* are also preferred by Sunbirds in late spring and summer.

The hummingbirds of family Trochilidae with long pointed wings, short leg and straight bill are adapted to hover more while feeding as compared to the Old-world nectivorous passerine birds with shorter wings, bigger feet and curved bills (Pyke 1981). Yet, most of the Sunbird species suck the nectar from the flowers by hovering like that of hummingbirds rather than perching on a branch close to the flowers or hanging upside-down in- order to feed on the flower's nectar. The benefit of hover- feeding could be decrease in the foraging time (Collins and Paton 1989). The heavier Malachite Sunbird was seen to hover more frequently on *Nicotiana glauca* (Geerts and Pauw 2009), *Salvia* and *Lycium* flowers (Petra Wester 2013) which indicates that body mass doesn't limit the hovering behaviour. Hovering is mostly induced when flowers lack the perch or are directed to the open spaces. Old World nectarivorous birds were very rarely seen hovering in-order to feed on indigenous plants and three species of Old-World Sunbirds behaved like hummingbirds and hover-fed when they were presented with a New World plant adapted for hover-pollination (Sjirk Geerts et al. 2008). The coral trees of the genus *Erythrina* (Fabaceae) is an ideal example wherein 42 Old World and 15 New World species are adapted to perching birds and the adaptations

for hover-pollination occur in a paraphyletic assembly of 65 species restricted to the New World (Bruneau 1997).

Except for three studies of Sunbirds visiting introduced plants, American tree tobacco *Nicotiana glauca* (Solanaceae) introduced to South Africa (Geerts and Pauw 2009), American ornamental firecracker bush *Hamelia patens* (Rubiaceae) in India (Reuben 1986) and as well as a native plant *Impatiens sakeriana* (Balsaminaceae) in Cameroon (Janeček et al. 2011), there have been no quantitative studies of Sunbird hovering behaviour. A detailed observations of hovering behaviour while foraging in two Sunbird species (Malachite Sunbird *Nectarinia famosa* and Southern Double-collared Sunbird *Cinnyris chalybeus*) at flowers of three Salvia species (*Salvia africana-lutea*, *S. lanceolat*a and *S. africana-caerulea*; Lamiaceae) and one natural hybrid as well as *Lycium afrum* (Solanaceae) in South Africa is an additional study in hovering by Sunbirds (Petra Wester 2013).

CHAPTER 3: MATERIALS AND METHOD

C. MATERIALS AND METHODS

C.1. Study Species:

1. **Purple- rumped Sunbird** *Nectarinia zeylonica* - It occurs throughout South Asia from the Persian Gulf to Southeast Asia (Firouz 2005). It is a common resident in the Indian Subcontinent and can be found in peninsular India from south of north-western Maharasthra, through Madhya Pradesh, and Bihar (Ali & Ripley 1999; Cheke & Mann 2001). It is relatively smaller in size and have short down-curved bill. Males are easily distinguished from females because of their contrasting colour. They have dark maroon upperparts with bluish- green crown that glimmer at certain angles, bright green shoulder patch and violet to purplish patch in the throat region. Females have relatively light yellowish breast as compared to male and olive to brownish upperparts. They often give "*ptsiee ptsit"* or twittering calls and at the same time the closed wings are flirted upwards and the tail opened and shut (Henry). They feed on nectar, small insects, soft caterpillars, spiders, etc. The beak length (from the skull) of *Nectarinia zeylonica* is 1.7- 1.8 cm in males and 1.6- 1.8 cm in female (Ali, S. and Ripley D. 1999). (**Figure 12)**

2. **Purple Sunbird** *Cinnyris asiaticus* – It is a small (<10 cm length), highly vocal bird with distinct sexual dimorphism. It is widely distributed from West Asia through the Indian subcontinent and into Southeast Asia. Male have two different plumages, breeding or courting being glossy metallic purplish black on the upper parts and an eclipse plumage (non- breeding) with dark brown wings, yellow underparts with a dark median line down the centre of throat and breast (Porter et al. 1996). The female is olive brown on the upper-parts and yellowish below. They have markedly down-curved bill with brush-tipped tubular tongues that helps in nectar feeding. Their singing notes are melodious followed by ringing, metallic notes including a "*chwit*" or "*chwing*!" (Information about Birds).

Purple Sunbird feeds majorly on nectar, honey, insects and mistletoes (Ali 1992). The beak length (from the skull) of *C. asiaticus* is 2 to 2.2 cm (Ali, S. and Ripley D. 1999). (**Figure 13)**

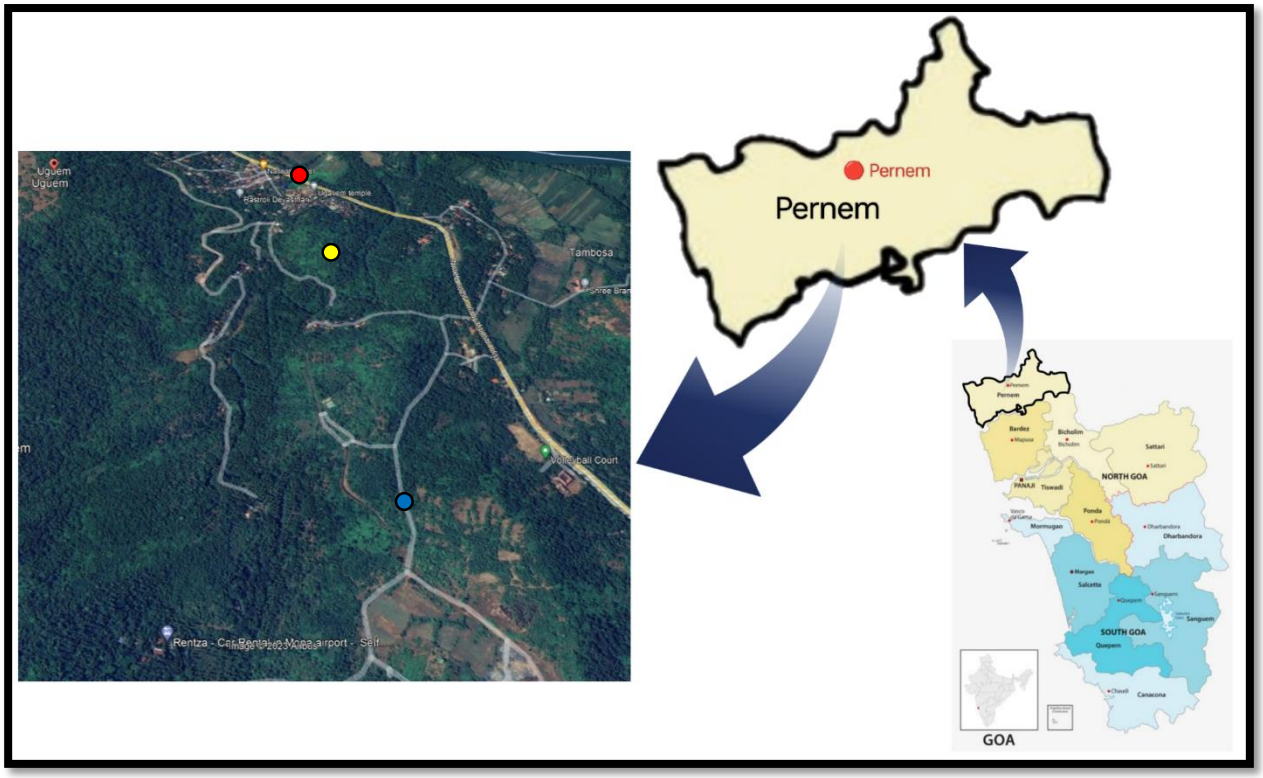
3. **Crimson – backed Sunbird** *Leptocoma minima* - It is tiny about 8cm in size hence also known as small Sunbird. It is endemic to Western ghats of India. Male is very similar to *N. zeylonica* but an adult male have velvety red mantle, reddish upperparts instead of chestnut,absence of metallic shoulder- patch, broader red breast band, shiny green crown and pinkish- violet patches on the throat and rump. A black edge seperates the yellow on the underside. The female is olive brown on upper- side, dull yellow belly and rump is distinctly red in colour. They give longer "*chee- chee- which- chee"* calls to shorters notes of "*chik"* calls. The beak length (from the skull) of *L. minima* 1.2 is 1.5 cm (Ali, S. and Ripley D. 1999, Robert A. Cheke et al. 2001). (**Figure 14)**

4. **Vigors's Sunbird** *Aethopyga vigorsii* - is a resident, endemic species of the Western Ghats (Rahmani et al. 2013) but has also been reported in Nilgiris (Rasmussen PC & JC Anderton, 2005). It feeds chiefly on nectar and also on insects and spiders. Son is described as a chirping trill. Vigors's Sunbird mainly in smaller flocks in upper levels of foothills, forest and forest edge.The adult male has scarlet throat and breast, while the underparts are grey and have a bottle green tail. The upper-parts of female are dark olive and underparts are grey. A juvenile male is similar to the female, but has a dull scarlet throat and breast. The beak length (from the skull) of *Aethopyga vigorsii* is 1.9-2.1cm (Ali, S. and Ripley D. 1999). (**Figure 15)**

C.2. Study Area:

The present study was conducted from June 2022 to April 2023 in three selected habitats of Pernem Taluka, Goa; namely a vegetation near human habitation (15°45'11" N 73°50'09" E) at Ugavem, a roadside habitat at Mopa (15°45'37" N 73°50'49" E) and a mixed plantation of *Areca catechu* and *Cocus nucifera* in Ugavem (15°45'10" N 73°50'17" E) **(Figure 1).**

Figure 1. Map of the study area (● - indicates Vegetation near human habitation at Ugvaem, ● - indicates Mixed plantation of *Cocos nucifera* and *Areca catechu* at Ugvaem, ● - indicates Roadside habitat at Mopa)



C.3. Method:

The study was carried out weekly in the morning hours for about 30 minutes at each site when the Sunbird activity was high. Focal sampling method was used to collect the data (Altmann, 1974; Martin, Bateson and Bateson, 1993, N. Perera and C.S. Wijesundara, 2020). In each of the site, the focal individual was observed from a single point of observation 10m away from the clump. For observing Sunbirds, 8x40 Celesteron binoculars were used. The detailed activities were dictated through verbal description on the phone's recorder (N. Perera & C.S. Wijesundara, 2020). The following details were noted down such as date, time period, type of habitat, Sunbird species encountered, total no. of species, total number of males, females and juveniles. Sunbird species visiting the clump, plants used for feeding and perching, etc. Android phone's stopwatch was used to calculate the time budget from the total amount of time spent by the Sunbird feeding, flying, perch changing, preening (Stiles, 1971). Total of 1080 minutes were spent in-order to observe the Sunbirds throughout the study period. The time spend by Sunbird in 1st and later visits after leaving the clump and returning after a time lapse was noted down. Behaviour of the Sunbird was classified into hopping, perching, probing, hovering, piercing, interspecific aggression, intraspecific aggression, preening, flitting, rubbing of the beak, (Remsen & Robinson, 1990) and flying. The feeding behaviour was classified into i) **Legitimate visits**- those making contacts with stigmas and anthers and ii) **Illegitimate visits**- robbing the nectar by piercing the corolla from the sides (Sjirk Geerts et al. 2008). The visitors to the plants were classified as pollinators (P) and robbers (R) according to Inouye D.W. (1980).

The plants species visited by birds was identified using a field guide such as e-flora of India. Parts of the parts (leaves, flower, bud) was collected and pictures were taken of the whole plant, bark, stem, etc wherever required for ease in identification. Features of the flowers such as colour, shape, size, length of the corolla and odour was noted down. The length of the corolla and other parameters of the flower was measured using digital vernier calliper and a measuring ruler

wherever required. The observations on presence and foraging activity by other bird species was also recorded.

C.4. Data Analysis:

One- way ANOVA test was used to find the relationship between no. of visits by Sunbirds and plant species, relationship between Sunbirds with features of the flower (colour of the flower, size of the flower, length of the corolla and shape of the flower), total no. of visit by Sunbirds in different months, no. of Sunbirds with respect to different habitats and type of food preferred by the Sunbird.

Student t- test was used to find the correlation of Sunbirds with odour of the flower and type of visit (either legitimate or illegitimate). These two tests were conducted using GraphPad Prism software.

CHAPTER 4: OBSERVATIONS

D. OBSERVATIONS

Table 1. List of plant species utilised by Sunbirds and their presence in different habitats (+ indicates present, - indicates absent) (HU= Vegetation near human habitation at Ugavem, RH= Roadside habitat at Mopa, MP= Mixed plantation of Coconut trees and Areca nut at Ugavem).

Sr. No.	**Scientific Name**	**Common Name**	**Family**	**Habitats**		
				VH	**RH**	**MP**
1	*Phyllanthus reticulatus* var. *glaber* Mull.Arg.	Black-honey shrub	Phyllanthaceae	+	-	-
2	*Calotropis gigantea* (L.) W.T.Aiton	Giant milkweed	Asclepiadaceae	-	+	-
3	*Musa acuminata* Colla	Banana	Musaceae	+	-	-
4	*Clerodendrum paniculatum* var. *diversifolium* (Vahl) C.B.Clarke	Pagoda flower	Lamiaceae	+	-	-
5	*Hibiscus rosa-sinensis* L.	Chinese hibiscus	Malvaceae	+	-	-
6	*Thespesia populnea* (L.) Sol. ex Corrêa	Portia tree	Malvaceae	+	-	-
7	*Rotheca serrata* (L.) Steane & Mabb.	Blue fountain bush	Lamiaceae	-	+	-
8	*Impatiens balsamina* L.	Balsam	Balsaminaceae	-	+	-

9	*Cocos nucifera* L.	Coconut tree	Arecaceae	+	-	+
10	*Thespesia lampas* (Cav,) Dalzell & Gibson	Ananza lampas	Malvaceae	-	+	-
11	*Cheilocostus speciosus* (J.Koenig) C.D.Specht ,	Crepe ginger	Costaceae	-	+	-
12	*Helicteres isora* L.	Indian screw tree	Malvaceae	-	+	-
13	*Heliconia psittacorum* Sessé & Moc.	Parrot Heliconia	Heliconiaceae	+	-	-
14	*Tithonia diversifolia* (Hemsl.) A.Gray	Mexican sunflower	Asteraceae	+	-	-
15	*Calliandra sp.*	Powder puff	Fabaceae	+	-	-
16	*Syzygium sp.*	Rose apple	Myrtaceae	+	-	-
17	*Tamarindus indica* L.	Tamarind tree	Fabaceae	+	-	-
18	*Tectona grandis* L.f.	Teak tree	Lamiaceae	+	-	-
19	*Caesalpinia pulcherrima* (L.) Sw.	Peacock flower	Fabaceae	-	+	-
20	*Ixora coccinea* Comm. ex Lam.	West indian jasmine	Rubiaceae	+	-	-
21	*Moringa oleifera* Lam.	Drumstick tree	Moringaceae	+	-	-

22	*Spathodea campanulata* Buch.-Ham. ex DC.	African tulip tree	Bignoniaceae	+	-	-
23	*Justicia adhatoda* L.	Malabar nut	Acanthaceae	+	-	-
24	*Dendrophthoe falcata* (L.f.) Ettingsh.	Honey suckle mistletoe	Loranthaceae	+	-	-
25	*Macrosolen capitellatus* (Wight & Arn.) D anser	South indian mistletoe	Loranthaceae	+	-	-
26	*Bombax ceiba* var. *ceiba* A.Robyns	Malabar silk cotton tree	Malvaceae	-	+	-
27	*Anacardium occidentale* L.	Cashew tree	Anacardiaceae	-	+	-
28	*Samanea saman* (Jacq.) Merr.	Monkey pod tree	Fabaceae	-	+	-
29	*Peltophorum pterocarpum* (DC.) Backer ex K.Heyne	Yellow flame	Fabaceae	+	-	-
30	*Calycopteris floribunda* (Roxb.) Lam.	Getonia	Combretaceae	-	+	-
31	*Chromolaena odorata* (L.) R.M.King & H.R ob.	Chromolaen a	Asteraceae	-	+	-
32	*Combretum indicum* (L.) Jongkind	Rangoon creeper	Combretaceae	+	+	-

33	*Butea monosperma* (Lam.) Taub.	Palash tree	Fabaceae	-	+	-
34	*Mangifera indica* Wall.	Mango tree	Anacardiaceae	+	-	-
35	*Vitex negundo* L.	Chinese chastetree	Lamiaceae	+	-	-
36	*Ocimum tenuiflorum* L.	Holy basil	Lamiaceae	+	-	-
37	*Ziziphus rugosa* Lam.	Wild jujube	Rhamnaceae	-	+	-
38	*Lannea coromandelica* (Houtt.) Merr.	Indian ash tree	Anacardiaceae	-	+	-
39	*Artocarpus heterophyllus* Lam.	Jack fruit tree	Moraceae	+	-	-
40	*Lantana camara* L.	West Indian lantana	Verbenaceae	+	+	-
41	*Pachystachys spicata* Ruiz & Pav.	Cardinal's guard	Acanthaceae	+	-	-
42	*Areca catechu* L.	Areca nut	Arecaceae	-	-	+

Table 2. Plants utilised by Sunbirds for feeding (+ indicates present, - indicates absent).

Sr. No.	Plant species	Sunbird species			
		Purple-rumped Sunbird	**Purple Sunbird**	**Crimson - backed Sunbird**	**Vigor's Sunbird**
1	*Phyllanthus reticulatus* var. *glaber* Mull.Arg.	+	-	-	-
2	*Calotropis gigantea* (L.) W.T.Aiton	+	+	-	-
3	*Musa acuminata* Colla	+	+	-	-
4	*Clerodendrum paniculatum* var. *diversifolium* (Vahl) C.B.Clarke	+	-	-	+
5	*Hibiscus rosa-sinensis* L.	+	-	-	-
6	*Thespesia populnea* (L.) Sol. ex Corrêa	+	+	-	-
7	*Rotheca serrata* (L.) Steane & Mabb.	+	+	-	-
8	*Impatiens balsamina* L.	+	-	-	-
9	*Cocos nucifera* L.	+	-	-	+
10	*Thespesia lampas* (Cav,) Dalzell & Gibson	+	-	+	+
11	*Cheilocostus speciosus* (J.Koenig) C.D.Specht ,	-	-	-	+
12	*Helicteres isora* L.	+	+	-	-
13	*Heliconia psittacorum* Sessé & Moc.	+	-	-	-

14	*Tithonia diversifolia* (Hemsl.) A.Gray	-	+	-	+
15	*Calliandra sp.*	+	+	+	+
16	*Syzygium sp.*	+	-	-	-
17	*Tamarindus indica* L.	+	+	-	+
18	*Tectona grandis* L.f.	+	-	+	+
19	*Caesalpinia pulcherrima* (L.) Sw.	+	-	-	-
20	*Ixora coccinea* Comm. ex Lam.	-	+	-	-
21	*Moringa oleifera* Lam.	+	-	-	-
22	*Spathodea campanulata* Buch.-Ham. ex DC.	+	-	-	+
23	*Justicia adhatoda* L.	-	+	-	+
24	*Dendrophthoe falcata* (L.f.) Ettingsh.	+	-	+	-
25	*Macrosolen capitellatus* (Wight & Arn.) Danser	+	-	+	+
26	*Bombax ceiba* var. *ceiba* A.Robyns	+	+	-	-
27	*Anacardium occidentale* L.	+	+	-	-
28	*Samanea saman* (Jacq.) Merr.	+	-	-	-
29	*Peltophorum pterocarpum* (DC.) Backer ex K.Heyne	+	-	-	-
30	*Calycopteris floribunda* (Roxb.) Lam.	+	+	-	-
31	*Chromolaena odorata* (L.) R.M.King & H.Rob.	-	+	-	-
32	*Combretum indicum* (L.) Jongkind	+	-	-	+

33	*Butea monosperma* (Lam.) Taub.	+	-	-	-
34	*Mangifera indica* Wall.	+	-	-	-
35	*Vitex negundo* L.	-	+	-	-
36	*Ocimum tenuiflorum* L.	-	+	-	-
37	*Ziziphus rugosa* Lam.	-	+	-	-
38	*Lannea coromandelica* (Houtt.) Merr.	+	+	-	-
39	*Artocarpus heterophyllus* Lam.	+	-	+	-
40	*Lantana camara* L.	+	-	-	-
41	*Pachystachys spicata* Ruiz & Pav.	-	-	-	+
42	*Areca catechu* L.	+	-	-	-

Table 3. Results of One- way ANOVA showing variations utility of colour, shape, size of the flower and length of the corolla by Sunbirds.

Sr. No.	**Sunbird species**	**Colour of the flower**		**Shape of the flower**		**Size of the flower**		**Length of the corolla**	
		F	**P value**	**F**	**P value**	**F**	**P value**	**F**	**P value**
1	Purple-rumped Sunbird	3.942	0.0019 **	10.69	<0.0001 ****	6.01	<0.0001 ****	8.78	<0.0001 ****
2	Purple Sunbird	1.076	0.385	1.799	0.1118	1.77	0.0665	2.459	0.0083
3	Crimson-backed Sunbird	1.505	0.1891	1.012	0.4248	0.9404	0.5046	0.7888	0.6508
4	Vigor's Sunbird	1.515	0.1859	2.409	0.0357	0.8833	0.5587	0.093	0.093

Table 4. Results of One- way ANOVA showing the variations in utility of plants, habitat, food items and the activities of Sunbirds.

Sr. No.	Sunbird species	Plant		Habitat		Food item		Activity	
		F	P value	F	P value	F	P value	F	P value
1	Purple-rumped Sunbird	1.877	0.0012 **	1.86	0.1732	67.88	<0.0001 ****	25.73	<0.0001 ****
2	Purple Sunbird	0.6092	0.6092	1.01	0.3764	6.271	0.0053 **	3.495	0.0044 **
3	Crimson-backed Sunbird	1.373	0.0691	1.25	0.301	6.806	0.0037 **	5.094	0.0002 ***
4	Vigor's Sunbird	0.8645	0.7096	1.476	0.2446	6.285	0.0053 **	3.951	0.0018 **

Table 5. Results of Student t- test showing variation in preference to odour and types of visits by different Sunbirds.

Sr. No.	Sunbird species	Type of visit (Legitimate/ Illegitimate)		Odour of the flower (Present/ Absent)	
		P value	T	P value	t
1	Purple- rumped Sunbird	<0.0001 ****	8.161	>0.9999	0.000
2	Purple Sunbird	0.0125 *	2.743	0.9031	0.1233
3	Crimson- backed Sunbird	0.6657	0.4385	0.0168 *	2.609
4	Vigor's Sunbird	0.0287 *	2.358	0.0954	1.750

Figure 2. Occurrence of Sunbirds at different study sites

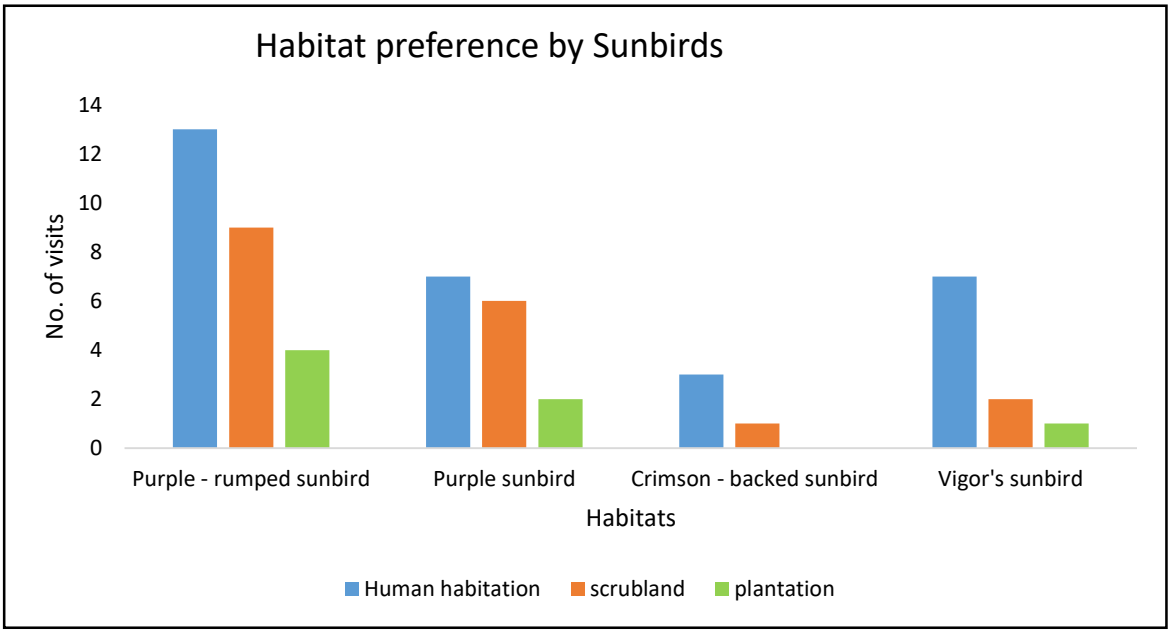


Figure 3. Frequencies of different Sunbird activities

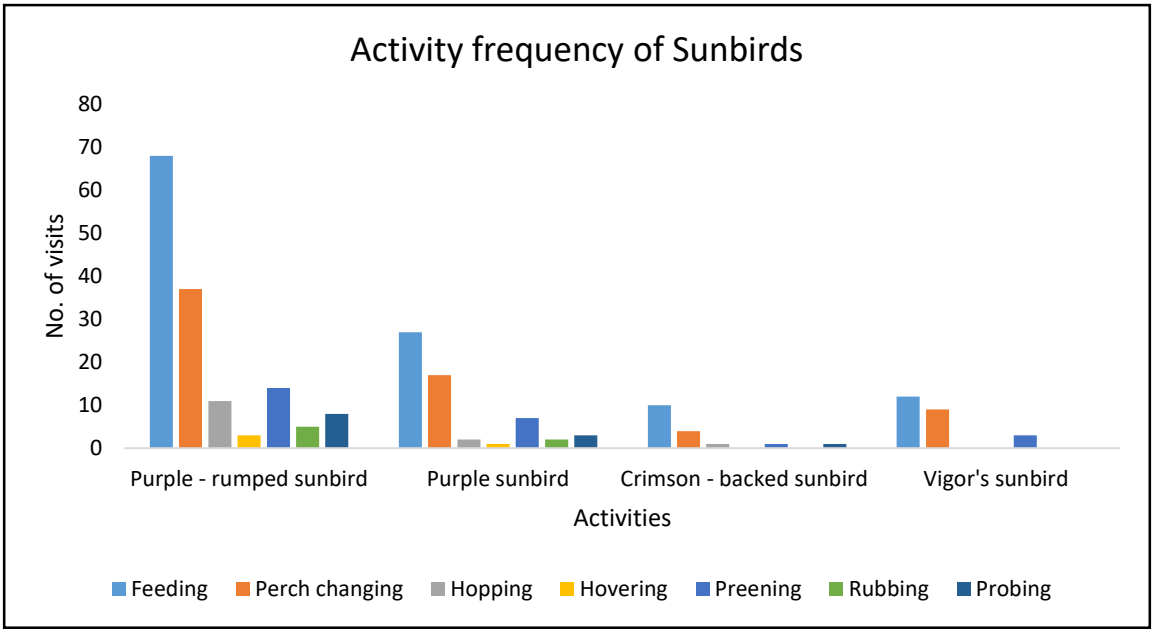


Figure 4. Types of visits by Sunbird

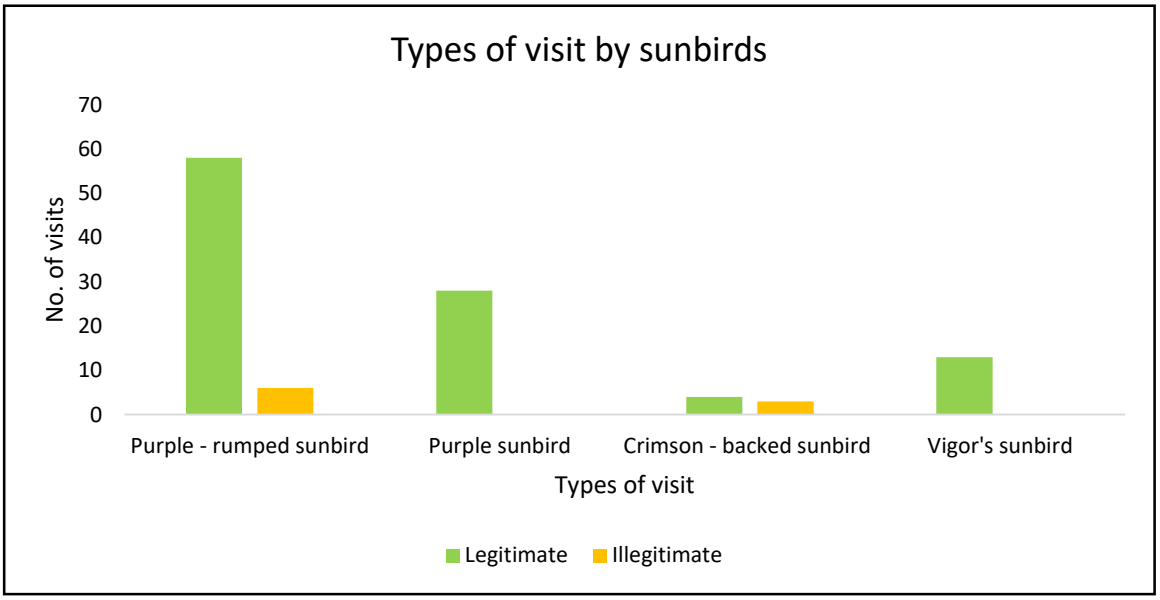


Figure 5. Type of food preferred by Sunbird

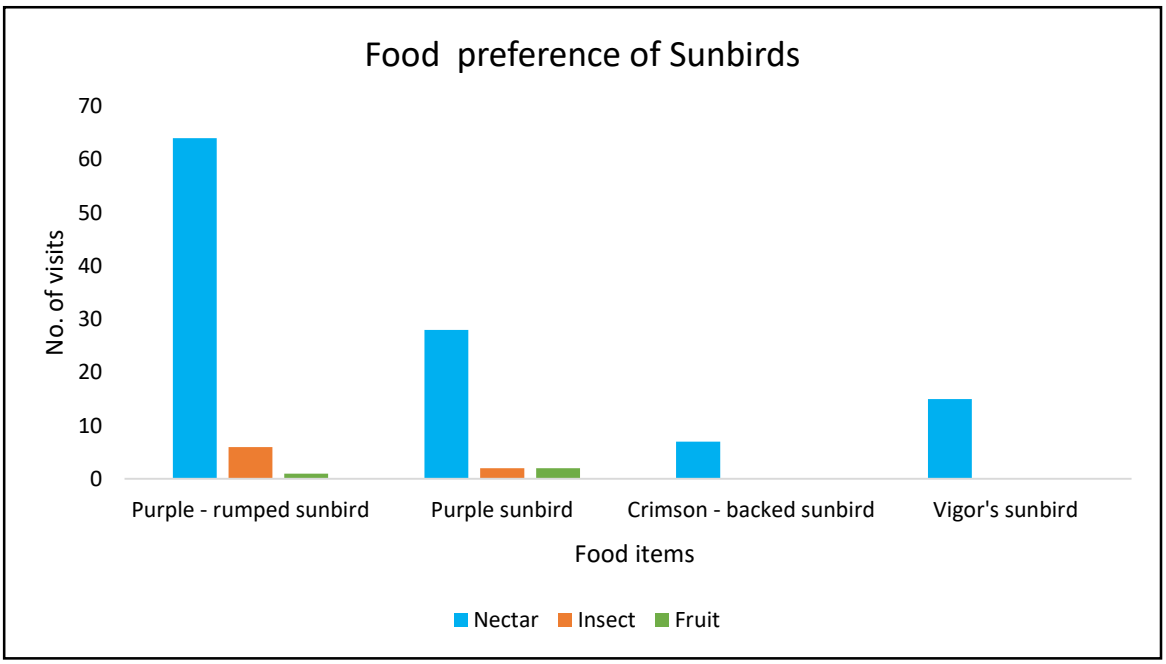


Figure 6. Colour of the flowers preferred by Sunbirds

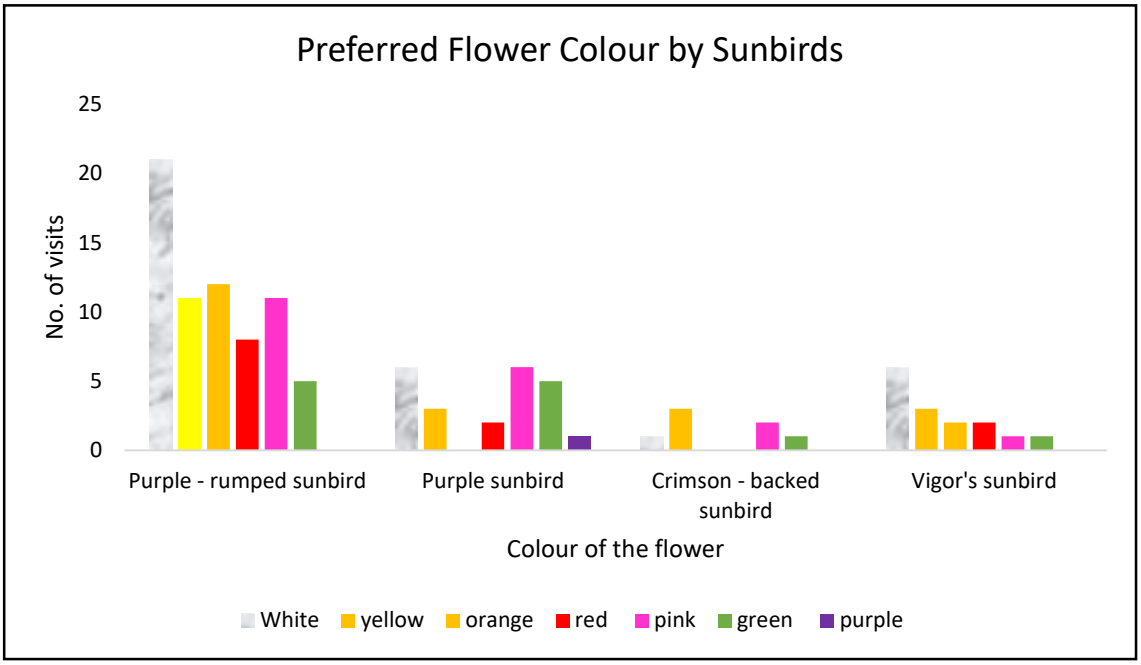


Figure 7. Shape of the flowers preferred by Sunbirds

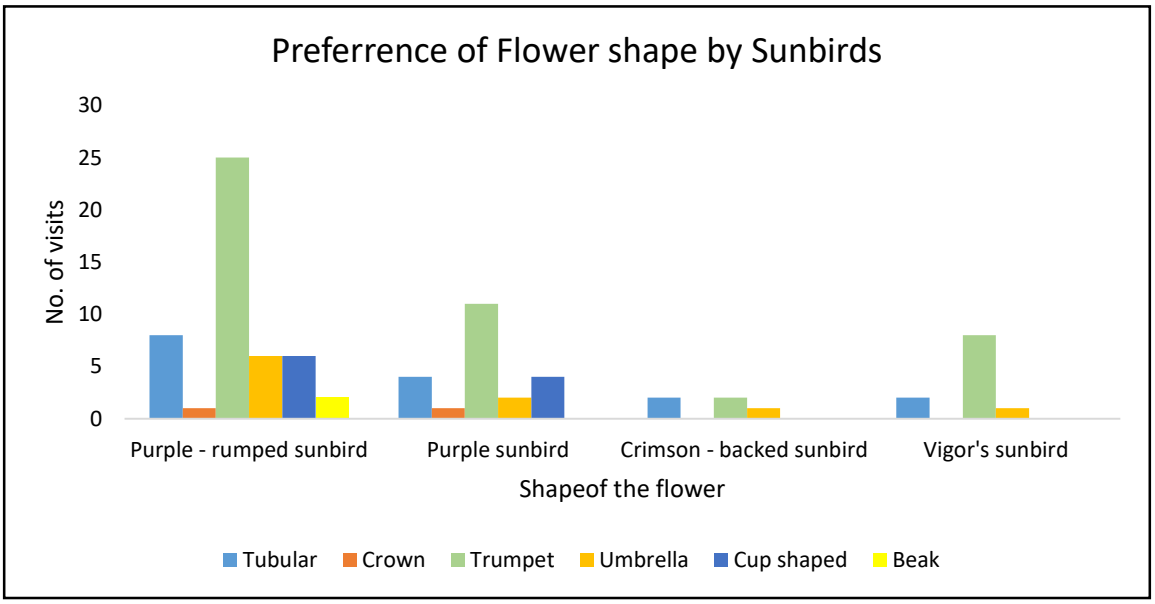


Figure 8. Size of the flowers preferred by Sunbirds

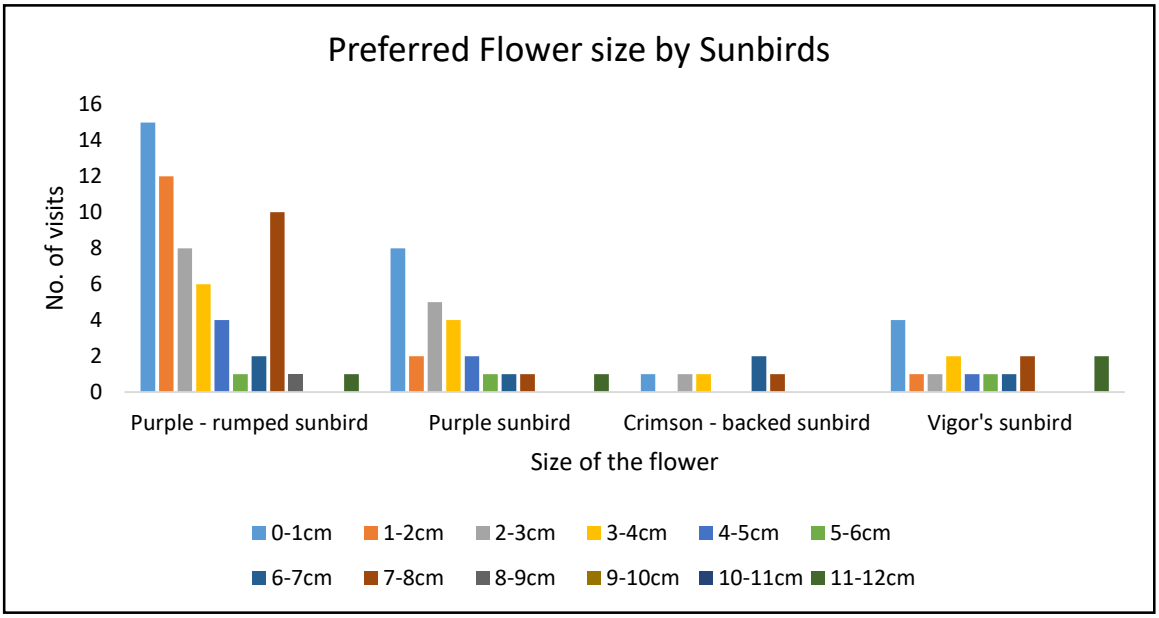


Figure 9. Length of the corolla preferred by Sunbirds

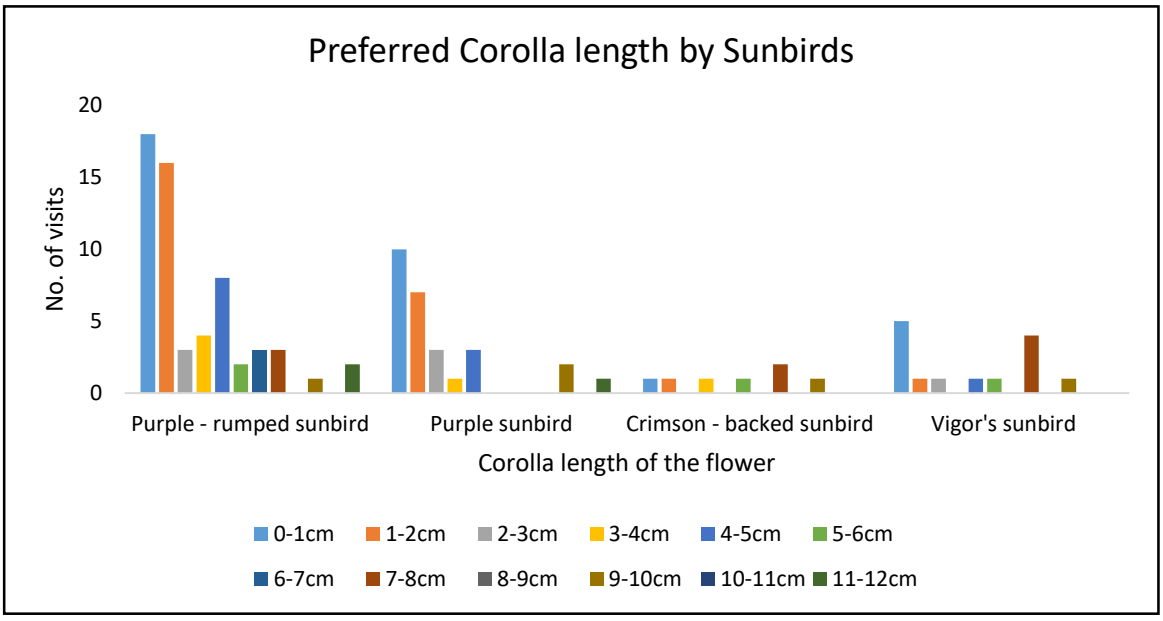
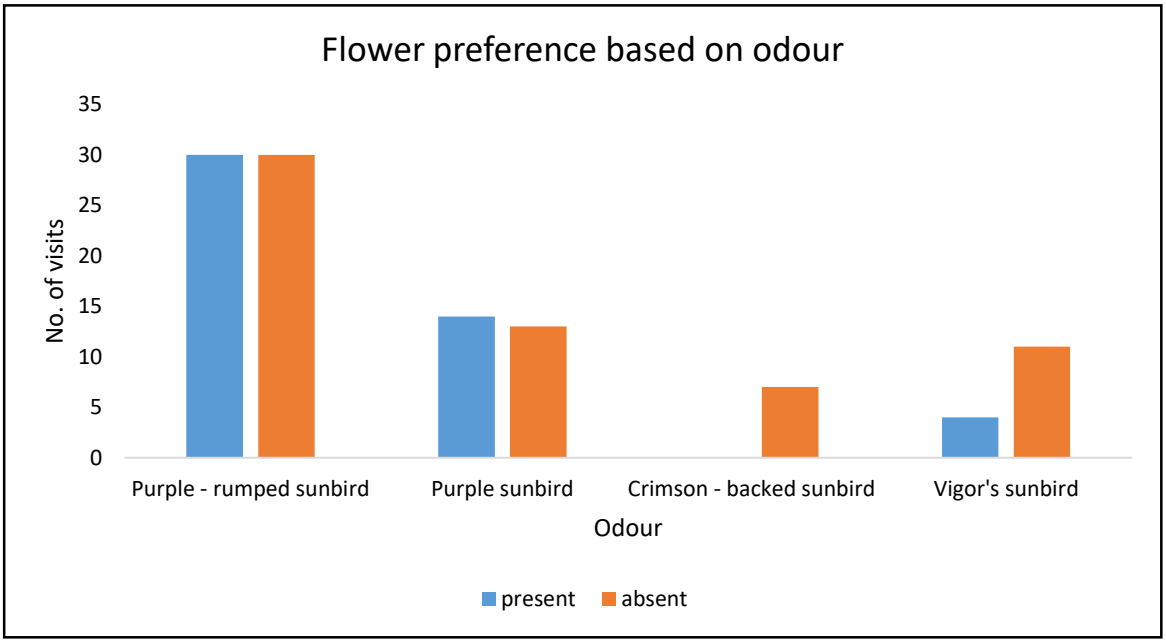
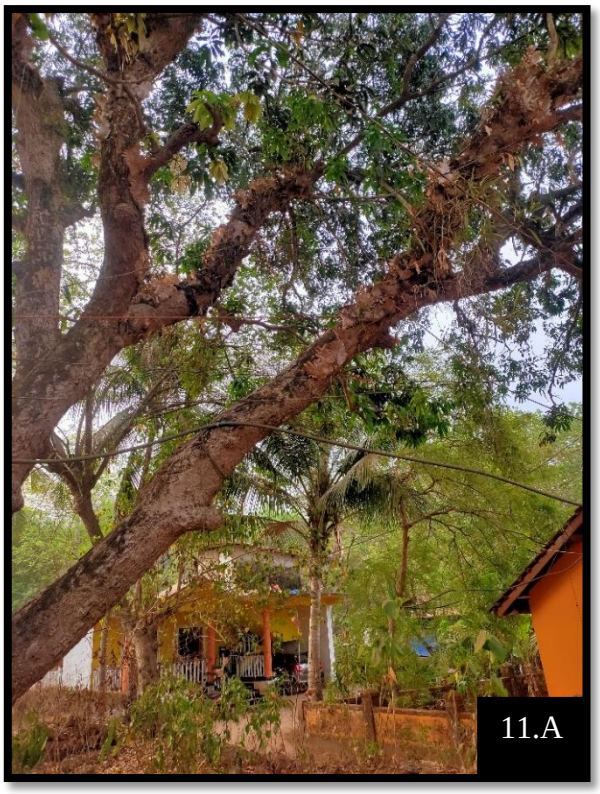


Figure 10. Odour of the flowers preferred by Sunbirds





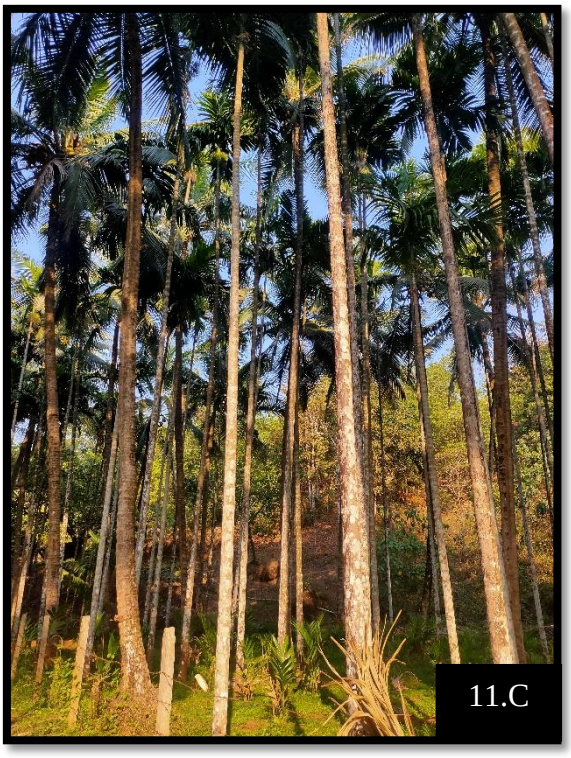
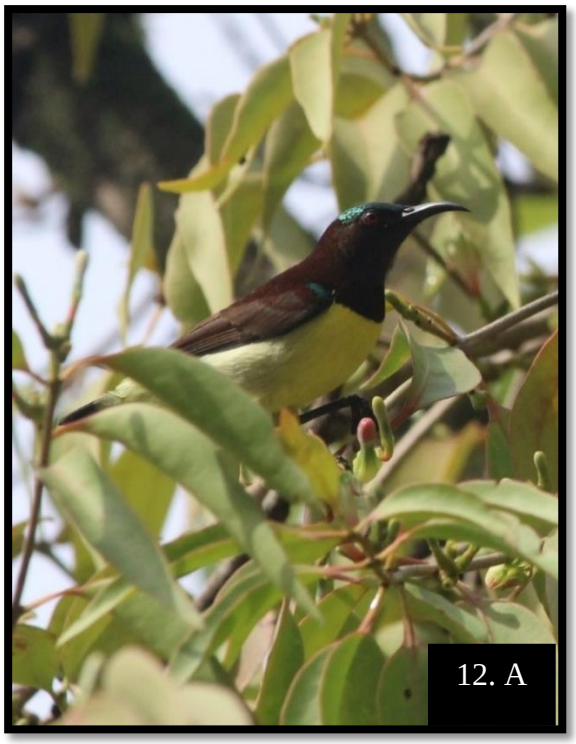


Figure 11: **Study sites** 11.A) Vegetation near human habitation 11.B) Roadside habitat 11.C) Mixed plantation of *Areca catechu* and *Cocos nucifera*.



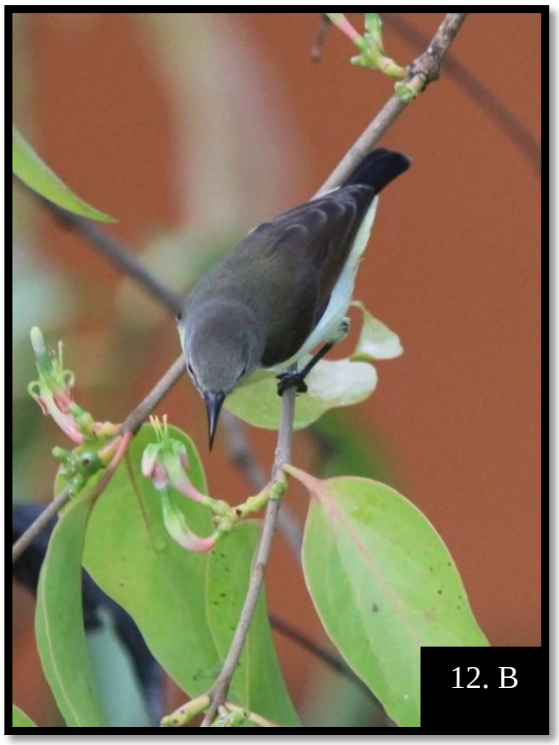


Figure 12: **Study species 1- *Leptocoma zeylonica*** 12.A) Male 12.B) Female 12.C) Neck of the male showing iridescent plumage.

Figure 13: Study species 2 - *Cinnyris asiaticus* 13.A) Male 13.B) Female 13.C) Male in eclipse plumage

Figure 14: **Study species 3- *Leptocoma minima*** 14.A) Male

Figure 15: Study species 4- *Aethopyga vigorsii* 15.A) Male 15.B) Female 15.C) Juvenile male

Figure 16: **Activities of Sunbird** 16.A) Rubbing of a beak 16.B) Preening

Figure 16: **Activities of Sunbird** 16.C) Hovering 16.D) Perching

Figure 17: **Feeding activities of Sunbird** 17.A) Feeding on flowers of *Cocos nucifera* 17.B) Feeding on fruits *of Ziziphus rugosa*

Figure 18: **Types of visits shown by Sunbird** 18.A) Legitimate visit 18.B) Illegitimate visit (Robbing of nectar by piercing a hole on the sides of corolla)

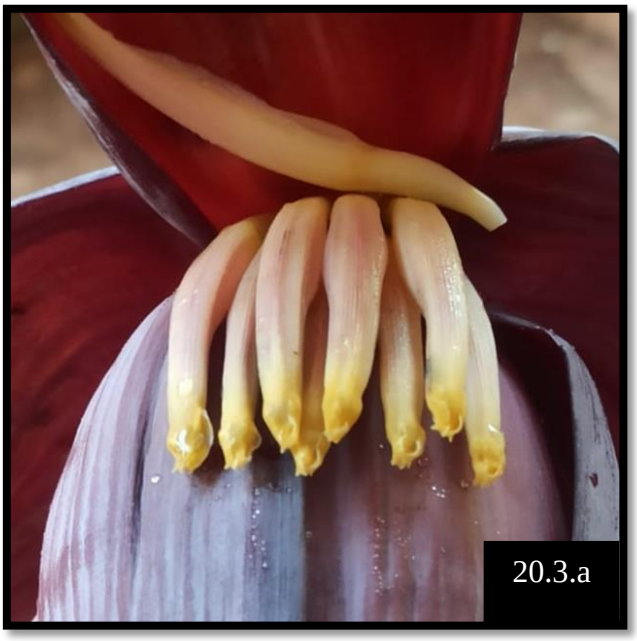
Figure 19: **Measurement done using Vernier calliper and Ruler** 19.A) Measuring flower size of *Justicia adhatoda* 19.B) Measuring corolla length of *Thespesia lampas*

Family: Phyllanthaceae

Family: Asclepiadaceae

Figure 20: **Plant species utilised by Sunbirds** 20.1.a) *Phyllanthus reticulatus* 20.2.a) *Calotropis gigantea*

Family: Musaceae



Family: Balsaminaceae

Figure 20: **Plant species utilised by Sunbirds** 20.3.a) *Musa acuminata* 20.4.a) *Impatiens balsamina*

Family: Lamiaceae

Figure 20: **Plant species utilised by Sunbirds** 20.5.a) *Clerodendrum paniculatum* 20.5.b) *Ocimum tenuiflorum* 20.5.c) *Rotheca serrata* 20.5.d) *Tectona grandis* 20.5.e) *Vitex negundo*

Family: Malvaceae

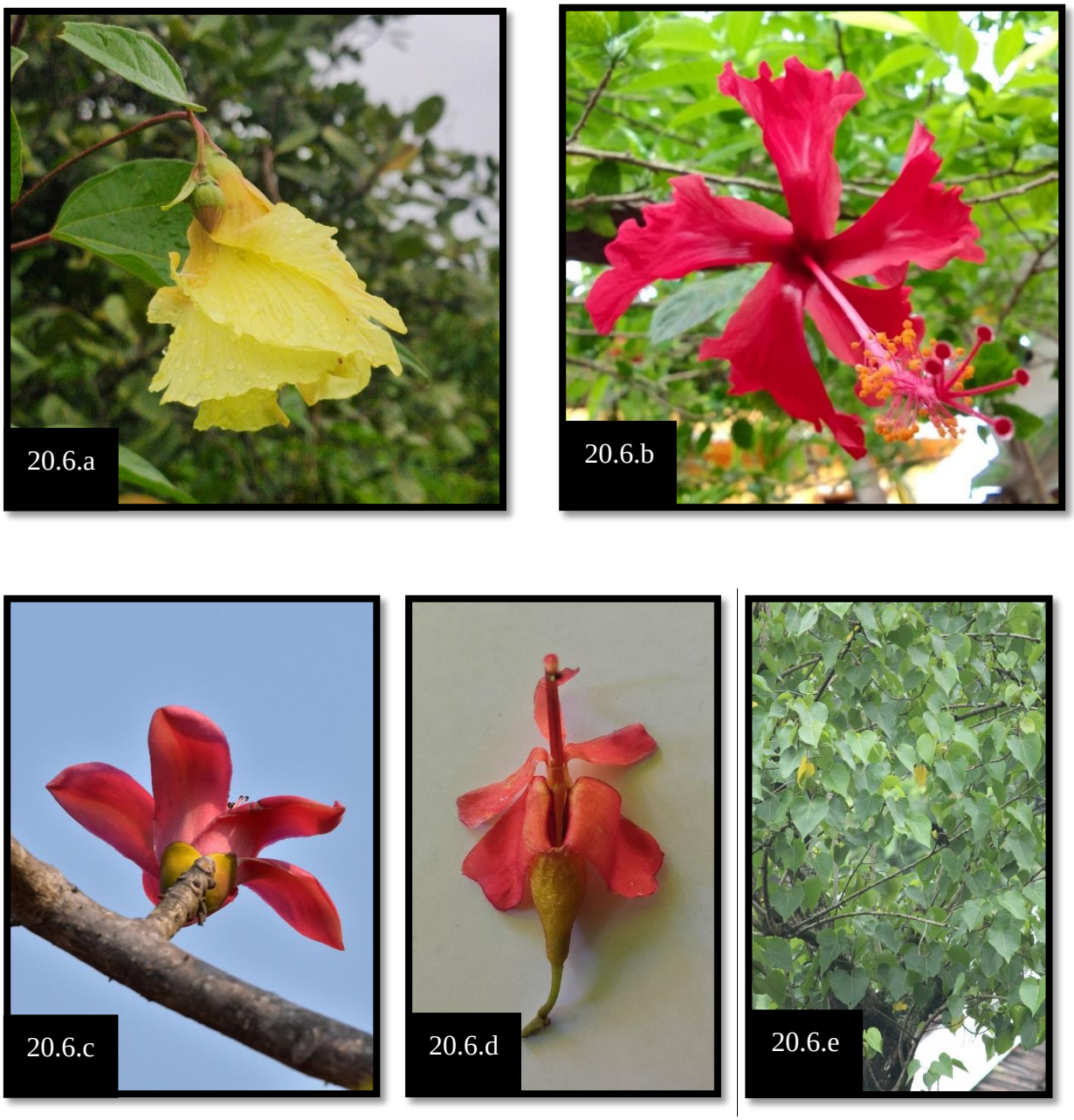


Figure 20: **Plant species utilised by Sunbirds** 20.6.a) *Thespesia lampas* 20.6.b) *Hibiscus rosa- sinensis* 20.6.c) *Bombax ceiba* 20.6.d) *Helicteres isora* 20.6.e).*Thespesia populnea*

Family: Arecaceae

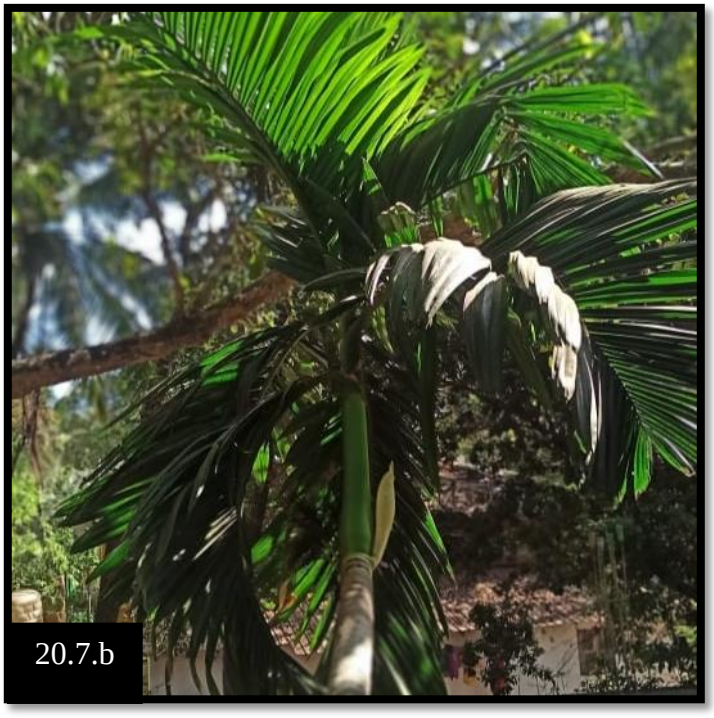


Figure 20: **Plant species utilised by Sunbirds** 20.7.a) *Cocos nucifera* 20.7.b) *Areca catechu*

Family: Asteraceae

Figure 20: **Plant species utilised by Sunbirds** 20.8.a) *Tithonia diversifolia* 20.8.b) *Chromolaena odorata*

Family: Costaceae

Family: Heliconiaceae

Figure 20: **Plant species utilised by Sunbirds** 20.9.a) *Cheilocostus speciosus* 20.10.a) *Heliconia psittacorum*

Family: Loranthaceae

Figure 20: **Plant species utilised by Sunbirds** 20.11.a) *Macrosolen psittacorum* 20.11.b) *Dendrophthoe falcata*

Family: Myrtaceae

Family: Rubiaceae

Figure 20: **Plant species utilised by Sunbirds** 20.12.a) *Syzygium sp.* 20.13.a*) Ixora coccinea*

Family: Moringaceae

Family: Bignoniaceae

Figure 20: **Plant species utilised by Sunbirds** 20.14.a) *Moringa oleifera* 20.15.a) *Spathodea campanulata*

Family: Acanthaceae

Figure 20: **Plant species utilised by Sunbirds** 20.16.a) *Justicia adhatoda* 20.16.b) *Pachystachys spicata*

Family: Fabaceae

Figure 20: **Plant species utilised by Sunbirds** 20.17.a) *Samanea saman* 20.17.b) *Peltophorum pterocarpum* 20.17.c) *Tamarindus indica* 20.17.d) *Caesalpinia pulcherrima* 20.17.e) *Calliandra sp*. 20.17.f) *Butea monosperma*

Family: Anacardiaceae

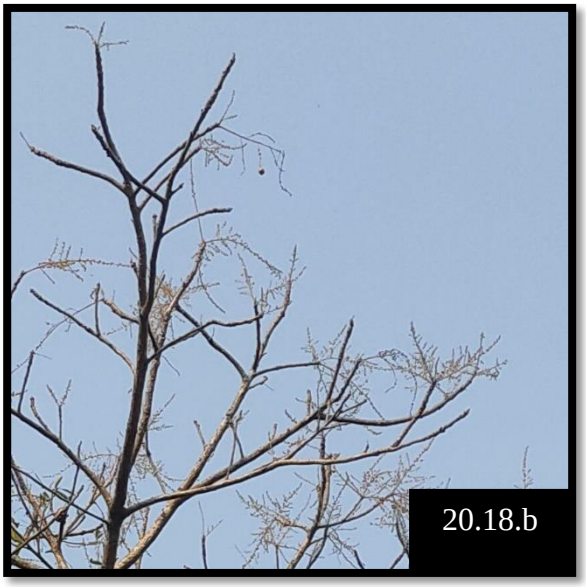


Figure 20: **Plant species utilised by Sunbirds** 20.18.a) *Anacardium occidentale* 20.18.b) *Lannea coromandelica* 20.18.c) *Mangifera indica*

Family: Combretaceae

Figure 20: **Plant species utilised by Sunbirds** 20.19.a) *Combretum indicum* 20.19.b) *Calycopteris floribunda*

Family: Rhamnaceae

Family: Moraceae

Figure 20: **Plant species utilised by Sunbirds** 20.20.a) *Ziziphus rugosa* 20.20.b) *Artocarpus heterophyllus*

Family: Verbenaceae

Figure 20: **Plant species utilised by Sunbirds** 20.21.a) *Lantana camara*

Figure 21: **Colour of the flower utilised by Sunbirds** 21.a) White flower of *Justicia adhatoda* 21.b) Yellow flower of *Thespesia lampas* 21.c) Orange flower of *Ixora coccinea* 21.d) Red flower of *Helicteres isora* 21.e) Pink flower of *Impatiens balsamina* 21.f) Green flower of *Calycopteris floribunda* 21.g) Purple flower of *Vitex negundo*

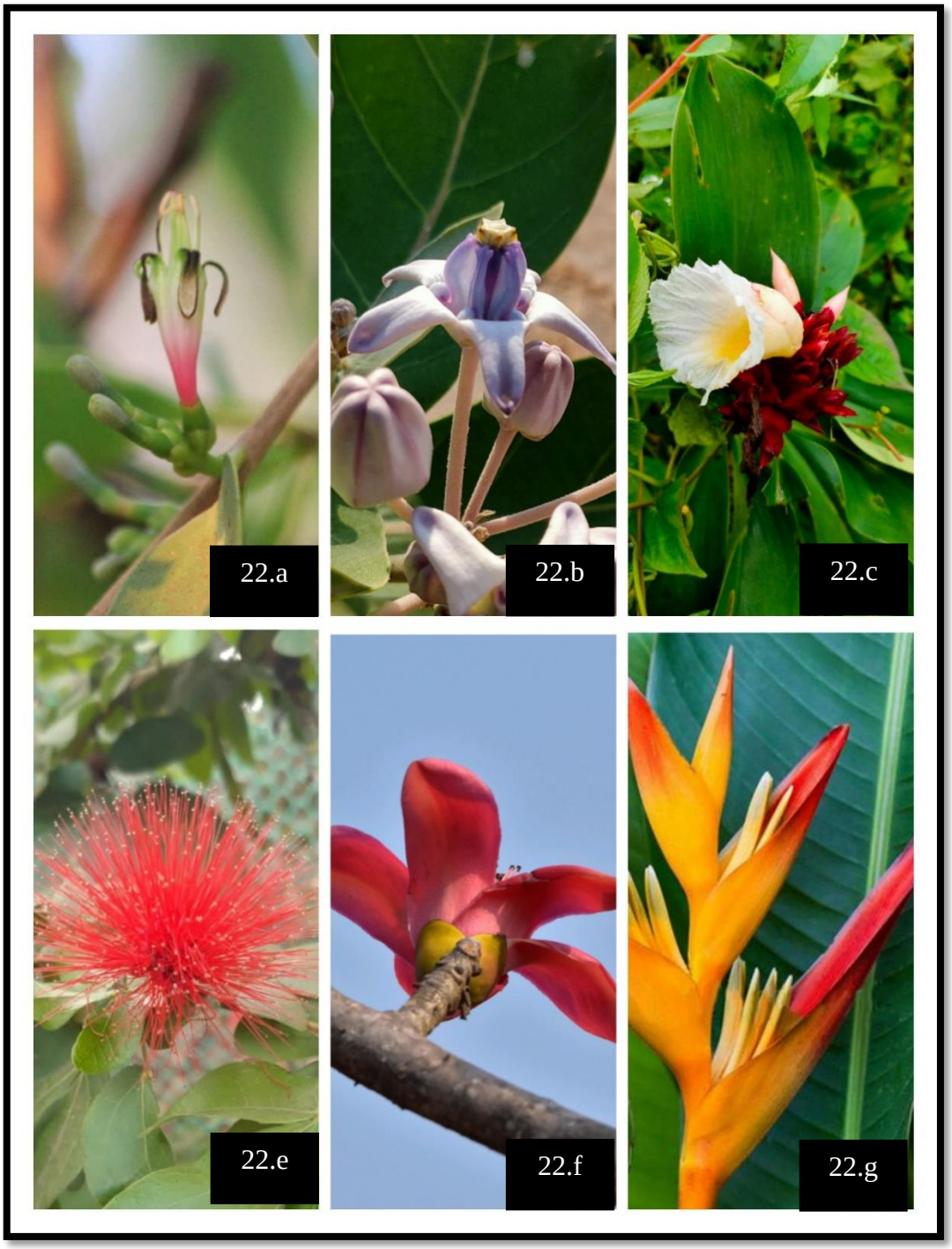


Figure 22: **Flower shapes utilised by Sunbirds** 22.a) Tubular flower of *Macrosolen capitellatus* 22.b) Crown shaped flower of *Calotropis gigantean* 22.c) Trumpet/ funnel shaped flower of *Cheilocostus speciosus* 22.d) Umbrella- shaped flower of *Calliandra sp.* 22.e) Cup- shaped flower of *Bombax ceiba* 22.f) Beak-shaped flowers of *Heliconia psittacorum*

I. Purple- rumped Sunbird

1. Shape preference

Purple- rumped Sunbird preferred trumpet/ funnel shaped flowers more significantly as compared to other shapes ($F= 10.69$, $P < 0.0001$). Trumpet shape was used 25 times followed by tubular shape (7 times). Cup- shaped and umbrella shaped flowers were moderately preferred in equal number (6 times). Least preference was given to beak shaped followed by crown shaped flowers.

2. Colour preference

Purple- rumped Sunbird preferred white coloured flowers more significantly as compared to other colours ($F= 3.942$, $P= 0.0019$). White coloured flowers were used 20 times followed by pink and yellow colour (11 times), orange flowers (6 times) and green were utilised 5 times. Purple coloured were not preferred at all by Purple- rumped Sunbird.

3. Size preference

Purple- rumped Sunbird preferred flower size 0-1cm (15 times) more significantly than other sizes. ($F= 6.01$, $P < 0.0001$). Size 0-1cm was favoured more followed by 1-2cm (12 times) and 8-9cm (10 times). Sizes 2-3cm and 3-4cm were moderately preferred. Least preference was given to sizes 5-8cm and 11-12cm. The sizes ranging between 9-11 were not preferred at all. Nectar robbing behaviour was observed on the flower 11-12cm due to mismatch in beak and flower morphology.

4. Corolla length preference

Purple- rumped Sunbird preferred flowers having corolla length 0.2-1cm (18 times) more significantly than other corolla lengths ($F= 8.78$, $P < 0.0001$). Size 0.2 -1cm was followed by 1-2cm (16 times). Size 4-5cm was moderately utilised (8 times). Corolla length having the size of 8-9cm and 10-11cm was not preferred at all.

5. Odour preference

Purple- rumped Sunbird didn't show any significance with respect to odour of the flower (P > 0.9999, t= 0.000). Purple- rumped Sunbird exploited equal number of flowers with and without odour (30 times).

6. Type of visit

Purple- rumped Sunbird preferred legitimate visits more significantly as compared to illegitimate visits (P= < 0.0001, t= 8). Legitimate visits were seen 56 times while illegitimate visits were seen for 6 times.

7. Habitat preference

Purple- rumped Sunbird didn't show any significance with relation to number of visits in different habitats (F= 1.25, P= 0.301).

8. Plant preference

Purple- rumped Sunbird preferred *Cocos nucifera* more significantly as compared to other plant species (F= 1.877, P= 0.0012).

9. Food preference

Purple- rumped Sunbird preferred nectar more significantly as compared to insects and fruit (F= 6.806, P= 0.0037). Nectar was utilised 7 times while fruit and insects were not preferred during the study period.

10. Activity preference

Purple- rumped Sunbird preferred feeding activity more significantly as compared to other activities (F= 5.094, P < 0.0001). The feeding activity was seen 10 times followed by perch changing (4 times). Hopping, rubbing and probing activities were not observed.

II. Purple Sunbird

1. Shape preference

Purple Sunbird utilised flowers having tubular, crown, trumpet, umbrella and cup shaped, though no significance was observed with respect to the shapes of the flower. The beak shaped flowers were not picked up by Purple Sunbird (F= 1.799, P= 0.1118).

2. Colour preference

Purple Sunbird exploited flowers having white, yellow, red, pink, green and purple colours, though no significance was observed with reference to colour of the flower (F= 1.076, P= 0.385). Orange coloured flowers were not preferred by Purple Sunbird.

3. Size preference

Purple Sunbird used flowers having size ranging from 0.6 -8 cm and 11-12cm, though no significance was observed regarding size of the flower (F= 1.77, P= 0.0665). Size ranging from 9-11 cm was not preferred.

4. Corolla length preference

Purple Sunbird preferred corolla length 0.2-1cm (10 times) more significantly than other corolla lengths (F= 2.459, P= 0.0083). Size 0-1 cm was followed by 1-2cm (7 times). Size 5-9 and 10-11 cm was not chosen at all.

5. Odour preference

Purple Sunbird didn't show any significance with respect to odour of the flower (P=0.9031, t= 0.1233). Purple Sunbird preferred flowers with odour for 14 times and that of without odour (13 times).

6. Type of visit

Purple Sunbird preferred legitimate visits more significantly as compared to illegitimate visits (P= 0.0125, t= 2.743). Legitimate visits were seen 28 times while illegitimate visits were not observed.

7. Habitat preference

Purple Sunbird didn't show any significance concerned to number of visits in different habitats (F= 1.01, P= 0.3764).

8. Plant preference

Purple Sunbird was seen feeding on 22 plant species out of 42, though no significance was observed regarding no. of visits on each plant species. (F= 0.6092, P= 0.6092)

9. Food preference

Purple Sunbird preferred nectar more significantly as compared to insects and fruit (F= 6.285, P= 0.0053). Nectar was exploited 28 times while fruit and insects were preferred twice during the study period.

10. Activity preference

Purple Sunbird preferred feeding activity more significantly as compared to other activities (F= 3.495, P= 0.0044). The feeding activity was seen 27 times followed by perch changing (17 times). Preening was moderately observed for 7 times. Probing was observed for 3 times and hopping and rubbing was seen twice followed by hovering.

III. Crimson- backed Sunbird

1. Shape preference

Crimson- backed Sunbird choose tubular, trumpet and umbrella shaped flowers, though no significance was observed with reference to the shape of the flower. The beak, crown and cup-shaped flowers were not used by Crimson- backed Sunbird (F= 1.012, P= 0.4248).

2. Colour preference

Crimson- backed Sunbird picked up white, yellow, pink and green coloured flowers, though no significance was observed regarding colours of the flower (F= 1.505, P= 0.1891). Orange, red and purple coloured flowers were not preferred by Crimson- backed Sunbird.

3. Size preference

Crimson- backed Sunbird used flowers having size ranging from 0.6-1, 2-4 cm and 6-8 cm, though no significance was observed regarding size of the flower (F= 0.9404, P= 0.5046). Illegitimate visits were observed on the size ranging from 6-8 cm due to mismatch in the morphologies of flower and bill.

4. Corolla length preference

Crimson- backed Sunbird utilised flowers of 0.2-2 cm, 3-4cm, 5-6cm, 7-8 cm and 9-10cm, though no significance was observed with reference to corolla lengths (F= 0.7888, P= 0.6508).

5. Odour preference

Crimson- backed Sunbird preferred odourless flowers more significantly than those with odour (P=0.0168, t= 2.609). Odourless flowers were favoured 07 times while those with odour were not favoured at all.

6. Type of visit

Crimson- backed Sunbird favoured legitimate visits as well as illegitimate visits, though no significance was observed regarding types of visit (P= 0.6657, t= 0.4385). Legitimate visits were seen 04 times while illegitimate visits were observed 03 times.

7. Habitat preference

Crimson- backed Sunbird didn't show any significance related to number of visits in different habitats (F= 1.25, P= 0.301).

8. Plant preference

Crimson- backed Sunbird was seen feeding on only 05 plant species out of 42, though no significance was observed with respect to no. of visits on each plant species. (F= 1.373, P= 0.0691)

9. Food preference

Crimson- backed Sunbird preferred nectar more significantly as compared to insects and fruit (F= 6.806, P= 0.0037). Nectar was preferred 14 times while fruit and insects were not prioritized during the study period.

10. Activity preference

Crimson- backed Sunbird preferred feeding activity more significantly as compared to other activities (F= 5.094, P= 0.0002). The feeding activity was seen 20 times followed by perch changing (08 times). Preening, probing and hopping were the least observed activities. Hovering and rubbing of the beak were not seen during the study period.

IV. Vigor's Sunbird

1. Shape preference

Vigor's Sunbird preferred trumpet shaped flowers more significantly as compared to other shapes (F= 2.409, P= < 0.0357). The trumpet shaped flowers (08 times) were followed by tubular shape and umbrella shaped flowers. The beak shape, crown shape and cup- shaped flowers were not used by Vigor's Sunbird.

2. Colour preference

Vigor's Sunbird exploited white, yellow, orange, red, pink and green coloured flowers, though no significance was observed regarding colours of the flower (F= 1.515, P= 0.1859). Purple coloured flowers were not preferred by Vigor's Sunbird.

3. Size preference

Vigor's Sunbird choose flowers having size ranging from 0.6-8 cm and 11-12 cm, though no significance was observed with respect to size of the flower (F= 0.8833, P= 0.5587).

4. Corolla length preference

Vigor's Sunbird gave more weightage to corolla length of 0.2-2 cm, 4-6 cm, 5-6cm, 7-8 cm and 9-10, though no significance was observed with reference to corolla lengths (F= 0.093, P= 0.0.093).

5. Odour preference

Vigor's Sunbird used flowers with and without odour, though no significance was observed regarding odour of the flower (P=0.0954, t= 1.750). Vigor's Sunbird preferred odourless flowers 12 times and those with odour 04 times.

6. Type of visit

Vigor's Sunbird preferred legitimate visits more significantly as compared to illegitimate visits (P= 0.0287, t= 2.358). Legitimate visits were seen 13 times while illegitimate visits were not observed.

7. Habitat preference

Vigor's Sunbird didn't show any significance with reference to number of visits in different habitats (F= 1.476, P= 0.2446).

8. Plant preference

Vigor's Sunbird was seen feeding on only 12 plant species out of 42, though no significance was observed regarding no. of visits on each plant species. (F= 1.373, P= 0.0691).

9. Food preference

Vigor's Sunbird preferred nectar more significantly as compared to insects and fruit (F= 6.285, P= 0.0053). Nectar was preferred 15 times while fruit and insects were not chosen during the study period.

10. Activity preference

Vigor's Sunbird preferred feeding activity more significantly as compared to other activities (F= 3.951, P= 0.0018). The feeding activity was seen 12 times followed by perch changing (09 times). Preening was least observed. Hovering, probing, hopping and rubbing of the beak was not seen during the study period.

Positive and negative interaction

Presence of some bird species didn't affect feeding of the Sunbirds. The presence of House crow and Nilgiri flowerpecker didn't affect feeding of Vigor's Sunbird and Purple-rumped Sunbird. Although it was observed that the niche was shared among Nilgiri flowerpecker and Purple Sunbird, alternate visits were noticed on *Zizipus rugosa*. The Common Iora was observed following Purple- rumped Sunbird (male) on *Artocarpus heterophyllus* and *Macrosolen capitellatus*, wherein the nectar foraging activity of the Sunbird on mistletoe causes disturbance to the insects which in- turn benefits the Iora. Inter- specific aggression was observed between Racket- tailed drongo and Purple- rumped Sunbird on *Spathodea campanulata*.

Territorial behaviour

Majority of the times the male of Purple- rumped Sunbird was seen chasing another male in flight in- order to show territorial behaviour. No territorial defence was seen between male and female of the same Sunbird species and both were known to guard their own territory. The male is also known to sing from a prominent perch and chase the intruders.

Feeding behaviour

Various plant traits alter the feeding behaviour of Sunbirds. Each sunbird showed some or the other distinct feeding approach. Purple- rumped Sunbird while feeding on the flowers of *Macrosolen capitellatus* and *Dendrophthoe falcata* inserted the beak in the closed tubular flower and wobbled the beak. The aggressive shaking of beak resulted in opening of the closed tubular flowers by an explosive flower opening method.

The other foraging activity used was hovering. Purple Sunbird and Purple- rumped Sunbird was seen hovering while catching insects. Most of the visits in- order to catch the insects was seen during the breeding season. The female of Purple Sunbird also hovered while collected the nesting

material. Purple Sunbird used to stay in an inverted position in- order to collect the insects present on the abaxial portion of the leaf.

Sunbirds were also noticed feeding on the flower sizes much larger than their beak. In the case of Purple- rumped Sunbird and Crimson- backed sunbird, the bill is short to reach the nectar through flower tube, hence they robbed the nectar by piercing a hole through the corolla of *Hibiscus rosa- sinensis* and *Thespesia lampas*. From the visual observation, it is obvious that the hole on the flower is made by the sunbird and not by any of the bee species.

CHAPTER 5: DISCUSSION

E. DISCUSSION

In the present study, *Cinnyris asiaticus* (Purple Sunbird), *Nectarinia zeylonica* (Purple- rumped Sunbird), *Leptocoma minima* (Crimson- backed Sunbird) *and Aethopyga vigorsii* (Vigor's Sunbird) were the four sunbird species studied during the study period. Sunbirds utilised total of 42 plant species belonging to 22 families.

1. Features of the flower

1.a Shape preference

The results of the study clearly showed that trumpet shape was most preferred by all four sunbirds followed by Tubular and Umbrella shaped flowers. The preference of the trumpet shaped flowers is because of long slender corolla tube that curves at the bottom, making it easier to be fed upon. A study done by Bailey, *et. al*. (2018) supports this finding, stating that sunbirds choose the length of flower over the diameter when determining the flowers for foraging. The members of family Nectariniidae harvest more nectar from tubular flowers because of their long bills as compared to the body size (S. Subramanya et al., 1993).

Purple- rumped Sunbird utilizes all the shapes of the flower, giving highest preference to trumpet shaped flowers and least preference to crown shaped flowers. Beak shaped flowers were utilised only by Purple-rumped Sunbird. Crimson- backed Sunbird showed equal preference to trumpet and tubular flowers.

1.b Colour preference

When flower colour was observed, all four Sunbird species we studied preferred white colour flowers and purple colour was least utilised. All four species of Sunbirds utilised white, yellow, pink and green coloured flowers for feeding. Orange colour was used only by Crimson-backed Sunbird. Many studies showed that specialist nectivorous birds prefer red colour flowers because of the abundant nectar in them (V. Santharam, 1996; A.J. Soloman Raju, 2008; Taher Ghadirian *et. al*., 2008), however red was barely used by the Sunbirds in our study. In our study, Purple Sunbird preferred white and pink flowers over others which differs from the results given by Taher Ghadirian *et. al*.,2008 which claims that they are attracted to red coloured flowers the most. Birds do not have much spectral sensitivity and hue discrimination towards the longer wavelength end of the spectrum (Stiles, 1981). In our findings, the reason for preferring more of white coloured may be due to abundance of white coloured flowers in the study site. Varied choices in flower colour might also be due to their learned preferences and sensory system as studied by Chittka, *et. al.*, 1999. Further studies can be done to test the amount of nectar in different coloured flowers.

1.c Odour preference

Purple- rumped Sunbird, Purple Sunbird and Vigor's Sunbird favoured flowers with as well as without odour in equal proportion. While Crimson- backed Sunbirds preferred only odourless flowers. Selection of the odourless flowers by Crimson- backed Sunbird is similar with other studies which shows that plants which have odourless flowers are favoured for pollination by birds (Van der Pijl, 1961). As per Klasing (2004), Purple Sunbird only feed on odourless flowers which opposes with our observation wherein Purple Sunbird was observed feeding on flowers bearing an odour as well as those without any odour in almost equal amount.

1.d Size preference

Most preferred flower size was 0.6 -2cm exploited by all four species of Sunbirds. This is because bill morphology corresponds with that of the corolla size of the flower. The corolla sizes ranging between 6-7 cm and 11-12 cm were the least utilised by Sunbirds. On the contrary, corolla length of size 10-11 cm was not used at all. The use of sizes longer than 2cm was due to the easy accessibility of nectar as a result of flower morphology like in that of *Syzygium sp., Calliandra sp., Samanea saman*, etc. Even though the Sunbird bill and corolla length of 11-12cm do not complement each other, Purple Sunbird and Purple- rumped Sunbird were seen feeding on it using nectar robbing behaviour. Purple- rumped Sunbird was seen utilizing all the sizes from 0-12cm, which is in- lines with the research done by N. Perera et. al. (2020), wherein they concluded that foraging strategies of Purple- rumped Sunbird shows significance with the corolla length of the flower similar to this study.

2. Habitat preference

From the results it is evident that there is no significance in the occurrence of Sunbird with respect to different habitats. The occurrence of Sunbirds in different habitats showed a decreasing trend from Vegetation near human habitation to roadside habitat. It was also observed that majority of the Sunbird occurrence was seen in human habitation even though human activities are high in this site as compared to other two. Similar conclusion was made in the study carried out by N. Perera (2020). The reason behind this could be due to high number of nectariferous plants in human settlements and least in mixed plantation. Purple- rumped Sunbird, Purple Sunbird and Vigor's Sunbird exploited all the three habitats whereas Crimson- backed Sunbird was seen only in Human habitation and at Roadside location.

3. Acitivity Frequency

In our study, all the Sunbirds were observed to spend their maximum time collecting nectar from the flowers, with least time invested in hovering in order to catch the insects. The reason behind this could be, availability of a greater number of nectar flowers in the study area. The other reason for giving least weightage to insects is because of their less availability as well as more energy consuming foraging technique. Similar observation of time expenditure was observed by Pyke (1979).

4. Feeding Strategy

A different type of feeding activity of Crimson- backed Sunbird and Purple- rumped Sunbird on *Macrosolen capitellatus* and *Dendrophthoe falcata* which belong to family Loranthaceae was seen. It was observed that these Sunbirds, inserted their beak into a closed tubular flower and shake its beak aggressively in order to open the petals of the tubular flower. Similar observation is made by Feehan (2008) and Heystek (2014), wherein Sunbirds use the technique of explosive opening of flowers by splitting the petal junction of tubular corolla to form window- like fenestrae. Though, in our study Sunbirds were seen feeding on closed flowers of mistletoes, another study contradicts this finding saying that Sunbirds mostly prefer open flowers of mistletoes for feeding.

Hovering activity of Sunbird was seen while feeding on insects. When feeding on insects the sunbird applies two strategies. One, it stays in inverted position and pecks on the lower side of leaves and other is to hover while catching its prey. The inverted position was preferred more due to less energy requirement. Hover feeding was favoured since it decreases the foraging time as said by Collins (1989). One more reason could be lack of perch while feeding on insects, as suggested by Reuben (1986), Geerts (2009), Janecek et. al. (2011) for the flowers directed to open spaces or the ones which lack the perch.

5. Food Preferences

Nectar was the most preferred food by all four sunbirds. Sunbirds are Nectarivorous birds which feed dominantly on nectar. A study by Roxburgh (2002), stated that nectar passes more rapidly through the digestive tract and hence majority of the visits are in search of nectar.

The second food preference followed by nectar was insects. Purple- rumped Sunbird and Purple Sunbird were the only two which preyed upon insects from the month of January to April which is known to be their breeding season. The reason behind this could be the higher protein content in insects essential for the development and growth of altricial nestlings of Purple Sunbird. The Purple- rumped Sunbird preferred insects for themselves in- order to fulfil their high energy requirement during the breeding period. An equivalent observation was made by Ali et. al. (1987), Snow (1981), Klasing (2004) where they mentioned that, although nectar is a good source of energy, most of the ornithophilous flowers lack essential amino acids and hence sunbirds consume animal matter to meet the protein demand.

Fruits were the least fed by sunbirds, with only two instances noticed. Purple- rumped Sunbird was observed feeding on fruits of *Phyllanthus reticulatus* only once during the month of June whereas, Purple Sunbird showed higher frequency of feeding on fruits of *Zizipus rugosa* during the months of March and April. The reason for preferring fruits over nectar near the roadside habitat may be because of less availability of nectar plants in late summer. No other studies show Purple Sunbird feeding on the fruits of *Zizipus rugosa*.

6. Number and Types of Visits on different Plant species

The study shows that among the total visits (112), majority were legitimate in nature. While only 09 visits were illegitimate. The plants favoured for illegitimate visits were *Hibiscus rosa-sinensis* and *Bombax ceiba* shown by Purple- rumped Sunbird, *Thespesia lampas* and *Artocarpus heterophyllus* shown by Crimson- backed sunbirds. A study conducted by Mcdada et al. (1980), Roubik et al. (1985), Feinsinger et al. (1987), Traveset et al. (1998) concluded that nectar robbing among the nectivorous species is common among the tubular shaped flowers which shows a similarity with our observation. The corolla width of Bombax ceiba being wide, sunbirds choose to rob the nectar rather than feeding in a legitimate way. Our observations show parallelism with the conclusion made by Celiwe et al. (2018) wherein the floral width is given less importance than floral length while determining foraging behaviour of sunbirds.

7. Territorial behaviour

Territorial behaviour is often observed in Sunbirds by Ali et al. (1983), Kannan (1978) and Davidar (1977). Our results show a similar observation wherein male to male aggression and chasing behaviour was observed in flight. Since, nectar producing flowers are one of the best renewable resources (Gill and Wolf, 1975), they are often defendable by the Sunbirds in their food territory. In our observation, no territorial defence was noticed between the female and male of same species. As concluded by Gill et al. (1975) and Cheke et al. (2001) such territories mostly involve only one individual, intermittently coexisting with a female.

CHAPTER 6: CONCLUSION

F. CONCLUSION

The study mainly focuses on the feeding preferences and occurrence of Sunbirds in different habitats. The foraging behaviour as well as the plant preference is essential to humans in many possible ways through the ecosystem services they provide. The sunbird and plant interaction plays a major role in pollination which needs special attention in day- to- day life wherein fragmentation of natural habitat is taking place in an enormous speed thereby affecting pollination of many useful plants. Therefore, to recover these fragmented areas Ecological Restoration should occur.

During the present study, four Sunbird species, namely *Cinnyris asiaticus* (Purple Sunbird), *Nectarinia zeylonica* (Purple- rumped Sunbird), *Leptocoma minima* (Crimson- backed Sunbird) *and Aethopyga vigorsii* (Vigor's Sunbird) were observed feeding on 42 plant species belonging to 22 families. From the observations, it is noticed that trumpet shaped flowers were most preferred by all the four sunbirds, followed by tubular and umbrella shape. With reference to colour, White coloured flowers are the first preference of Sunbirds followed by yellow and pink. The corolla length of the flower ranging between 0.2– 2cm was more exploited by the Sunbirds to feed upon. Purple Sunbird, Purple- rumped Sunbird and Vigor's Sunbird didn't show any specific preference concerned to odour of the flower, however Crimson-backed Sunbird favoured only odourless flowers.

Occurrence of Sunbirds is high in Vegetation near Human Habituated areas rather than along roadside or in areas with mixed plantations. Nectar is the best suited and most preferred food for sunbirds than insects and fruits. Sunbirds utilize most of their time feeding succeeded by perch changing. 103 legitimate visits of sunbirds were observed indicating that they play a vital role in pollination.

This is a preliminary study on Feeding ecology of Sunbirds in Goa. Further studies can be done on detailed aspects of role in pollination by different sunbirds on different flowers.

CHAPTER 7: BIBLIOGRAPHY

G. BIBLIOGRAPHY

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