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Fruit Bats: Their Importance, Threats and Conservation

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ABSTRACT

Bats are nocturnal mammals which lives in large aggregations as colonies, hang their feet to twig of tree upward side, provide widespread ecological and monetary services via pollination, seed dispersal, rejuvenation of forests, guano as nutrient rich fertilizer and agricultural pest control. Different factors like exposure to heavy metals, pesticides, hunting, diminishing food supply, habitat destruction, forest fires and diseases are responsible for decreasing bat population, but urbanization greatly affects the composition and structure of inhabiting animal communities by transforming the natural habitats into environments dominated by human constructions. Micro bats feed on insect pests and help to reduce pesticide application in agricultural crops, whereas fruit bats feed on horticultural orchards like guava, ber and litchi thus act as pest. Bats are reservoirs of many pathogens like hendra, nipah, tioman, European lyssa and ebola viruses which cause several epidemic diseases among humans and domestic animals. Among 60 countries around the world, more than 200 bat species are considered to be threatened (critically endangered, endangered or vulnerable) by the International Union for the Conservation of Nature (IUCN). Using different eco-friendly methods like artificial lights and netting we can save our orchards and conserve fruit bats which will be helpful in the maintenance of ecological balance of nature.

KEYWORDS: Bats, conservation, ecological services, Indian flying fox, mammals

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1. INTRODUCTION

Bats account 20% of all known mammals and got second position after rodents (Bhandarkar and Paliwal, 2014). *Pteropus giganteus* Brunnich 1782, a polygynandrous species, commonly known as "Indian flying fox" and "Greater Indian fruit bat" is largest in its group, belongs to family Pteropodidae and order Chiroptera which is second largest order of class Mammalia, with meaning as "hand-wing". About over 1,117 species of bats occur in this order which is further subdivided into two sub-orders, Megachiroptera or "megabats" that includes 186 species of frugivorous bats (Simmons, 2005) and Microchiroptera, the smaller, echolocating and mostly insectivorous bats (Vyas and Upadhyay, 2014). India contains 11% of world's bat population (Simmons, 2005) and there are about 13 species of fruit bats (Srinivasulu et al., 2010) and 101 insectivorous bats (Bhandarkar andPaliwal,2014) but common ones are only three species, which includes Indian flying fox (*Pteropus giganteus*), Fulvous fruit bat (*Rousettus leschenaultii*) and Short-nosed fruit bat (*Cynopterus sphinx*). The Indian flying fox has a widespread range on the Indian sub-continent that extends from Pakistan to Southeast Asia and China, and South to Maldive Islands. Apart from India this species is also distributed in Bangladesh, Bhutan, Myanmar, Nepal and Sri Lanka (Molur et al., 2008).Bats are nocturnal in habit and lives in large aggregations as colonies from hundreds to thousands individuals depending on food availability (Williams et al., 2006) and mating season (Parry-Jones and Augee, 2001) and roost on large trees like, *Ficus bengalensis, F. religiosa, Tamarindus indica, Mangifera indica, Dalbergia sisso* and *Eucalyptus globulus*. Bats hang their feet to twig of tree upward side that type of posture of bats known as the roosting (Fenton, 2003). It roosts tropical forests and swamps along coasts and bodies of water. It is plant dependent means frugivorous i.e., mainly feeds on ripe fruits, such as mangoes, guava and bananas (Ali, 2012) or nectarivorous i.e., lick nectar, pollen from flowers, petals, bracts and leaves (Ali, 2014). The morphological characters of bat species become varied with the species. In case of mega or larger bat species have longer snout and eye sockets but in case of micro or smaller bats having short eye and short snout present for nectar-eating habitat other than this in case of Vampire bats have snout becomes reduced to make the larger teeth for blood-sucking from the body of prey animals. In frugivorous bats the cusps of the cheek teeth are adapted for break-down of the fruit pulps (Jones and Holderied, 2007). These species provide widespread ecological and monetary services via pollination, seed dispersal and agricultural pest control (Kunz et al., 2011). Under schedule V of Indian Wildlife Protection Act 1972 and International Union for Conservation of Nature (IUCN) Red List (Version 2014.1) this species is labeled as 'vermin' on the impression that it poaches ripe fruits from orchards and defecates in public places (Chakravarthy et al., 2008, Hassan et al., 2009) and causes heavy economic losses to guava (*Psidium guajava*) (20–28%), arecanut (*Areca catechu*) (18%), mango (*Mangifera indica*) (12–17%) and sapota (*Achrus zapota*) (12–30%) (Chakraverthy and Girish, 2003). Indian flying fox *P. giganteus* is widely distributed throughout India and other regions of Asian countries. The flying foxes are very conspicuous among tree roosting bats and thus many studies have been carried out on various aspects such as population ecology, reproductive behavior, roosting ecology (Gulraiz et al., 2015), distribution and conservation issues (Kumar et al., 2017). In this review we have tried to give information regarding fruit bats, their threats and conservation strategies so that ecological balance of nature may be maintained.

2. IMPORTANCE OF BATS

Bats directly feed on many harmful insect pest species which are very harmful to agriculture crops. This resulted lower application of pesticides on agricultural crops for protection from the insect pests and also decrease diseases over the crop plants (Weaver, 2008). Insectivorous bats in particular are especially helpful to farmers, as they control populations of agricultural pests and reduce the need to use pesticides. It has been estimated that bats save the agricultural industry of the United States from $3.7 billion to $53 billion year^{-1} by reduction in pesticide usage. This also prevents the overuse of pesticides which can pollute the surrounding environment and may lead to resistance in future generations of insects (Boyles et al., 2011). Bumrungsri et al. (2009) studied that pteropodids are major pollinators for some economically important fruit trees. In Northern Queensland, Spectacled flying fox *Pteropus conspicillatus* Gould plays a vital role in rainforest reproduction through pollination and although these bats may affect the fruit industry. Nectar and pollen are produced only at night by the majority of timber trees harvested on the East coast. This means that if flying fox populations decreases, fewer timber trees will join the logging cycle. Pteropodid bats play a major role in seed dispersal. Fighting over feeding territories (the squabbling heard at night) leads to the loser departing with a fruit in its mouth, and consuming it at a distance has been termed the 'raiders versus residents' seed dispersal model (Richards, 1990). McConkey and Drake (2006) in Tonga showed that once numbers of flying foxes declined below a threshold where there was no conflict over feeding territories, then seed dispersal ceased. Frugivorous species provide seed dispersal services and can play a role in the regeneration and pollination of some tree species (Caughlin et al., 2012). Bat dung, a type of guano, is rich in nitrates and is mined from caves for use as fertilizer (Weaver, 2008). They are very beneficial to the farmers because the guano of bats is used as fertilizer in many foreign countries. Guano contains rich amount of nitrogen and other micronutrient content which are very essential for plant body for their growth and cell division processes. During the US Civil War, saltpetre was collected from caves to make gunpowder; it used to be thought that this was bat guano, but most of the nitrate comes from nitrifying bacteria (Whisonant, 2001). The Congress Avenue Bridge in Austin, Texas is the summer home to North America›s largest urban bat colony, an estimated 1,500,000 Mexican free-tailed bats. About 100,000 tourists a year visit the bridge at twilight to watch the bats leave the roost (Christensen, 2016). Foraging behavior of three species of bats in relation to flowering of *Madhuca indica* was investigated during 2005 and a total of 1904 individual bats including *P. giganteus* (49.0%) *Cynopterous sphinx* (28.5%) and *Rousettus leschenaultia* (22.5%) were observed during flowering season. These three species were good pollinators of flowers of *M. indica* thus, providing an important ecosystem service (Wordley et al., 2014)."

The ecological importance of fruit bats is immense and the critical role played by them as pollinators and seed dispersers is now well established (Alvarez et al., 2002). Speakman (1991) observed that bats generally comprise a relatively small proportion of the diet of most predators. Bats represented only 0.003% of the diet of small falcons and hawks and 0.036% of the diet of owls in Great Britain. Although diurnal raptors feed on bats during twilight hours in some parts of the world, nocturnal predation by owls is the most significant predation pressure on bats in temperate regions. Strategies like low dependability to roost sites, selection of time and patterns of emergence from roosts and nocturnal activity are used to minimize the risk of predation (Madej et al., 2012). Particularly, beyond the economic value of plant pollination and seed dispersal services, plant-visiting bats provide important ecological services by facilitating the reproductive success and the recruitment of new seedlings. Many of these plants are among the most important species in terms of biomass in their habitats. For instance, bat-pollinated columnar cacti and agaves are dominant vegetation elements in arid and semiarid habitats of the new world (Kunz et al., 2011). Seed dispersal is a major way in which animals contribute for ecosystem succession by depositing seeds from one area to another. As 50–90% of tropical trees and shrubs produce fleshy fruits adapted for consumption by vertebrates, the role played by frugivorous bats in dispersing these seeds is tremendous. Countless tropical trees and understory shrubs are adapted for seed dispersal by animals, primarily by bats and birds. Particularly, night-foraging fruit bats are more compliant than birds by covering long distances each night, defecating in flight and scattering far more seeds across cleared areas (Duncan et al., 1999). Bat guano has a great ecological potential as bats sprinkle it over the landscape throughout the night and increases soil fertility and nutrient distribution. Thus, bats contribute a lot in nutrient redistribution, from nutrient rich sources (e.g., lakes and rivers) to nutrient-poor regions (e.g., arid or upland landscapes). For instance, a colony of one million Brazilian free-tailed bats (*T. brasiliensis*) in Texas can contribute to 22 kg of nitrogen in the form of guano (Buchler, 1975). Different types of seeds of trees and forest plant species extracted from ejecta of *P. giganteus* included Areca palm (*Areca catechu*), Coromandel ebony (*Diospyros melanoxylon*), Indian gaabh (*D. peregrina*), Lemon-scented gum (*Eucalyptus citriodora*), Chinese fan palm (*Livistona chinensis*), Sapodilla (*Manilkara zapota*), Mahwa (*Madhuca longifolia*), Indian lilac (*Melia azedarach*), Cajeput tree (*Melaleuca leucadendra*), Rambutan (*Nephelium lappaceum*), Guava (*Psidium guajava*) and Janbolanum plum (*Syzygium jambolanum*). *P. giganteus* is also a good helper of seed dispersel and transport of heavier seeds as these are mammal dependent for their dispersal. Jack fruit (*Artocarpus heterophyllus*) seeds were found the longest (40 mm) with maximum mean diameter (50 mm) and Rambutan (*N. lappaceum*) seeds were the heaviest having 3.4 g weight (Gulraiz et al., 2015).

Nearly 300 plant species in the Old World depend on fruit bats for their propagation (Fujita and Tuttle, 1991). During a study in Madurai (India), Venden and Kaleeswaran (2011) observed that a variety of seeds of different plant species were dispersed by bats in the vicinity of the roosting trees apart from the foraging trees. *Borassus flabellifer, Anacardium occidentale, Nerium indicum, Phoenix dactylifera, Prosopis juliflora,* and *Madhuca indica* were dominated in the surveyed roost sites and that species saplings were recorded as the maximum in the roosting vicinity confirming that *P. giganteus* indeed helps in seed dispersal to maintain the heterogeneity. At least 300 plant species of nearly 200 genera mainly rely on large populations of fruit bats for their propagation. These plants also produce approximately 500 economically valuable products (Fujita and Tuttle, 1991). During a study, Goveas et al. (2006) reported that in the guano of *P. giganteus*, there are nearly 70% banyan seeds that indicate their role in the dissemination of an important keystone plant species in our ecosystem. Wang and Smith (2002) studied the seed dispersal by bats and concluded that small bats like *C. sphinx* can carry large fruits much to their size while large fruit bats can carry more than 200 g. But it seems most of the larger fruit bats like to process the fruit in the fruiting trees and thus they tend to play an important role in maintaining the compositional heterogeneity of tropical forests as well as causing the secondary succession. Shanahan et al. (2001) indicate that among mammals, Pteropodidae are among the major consumers of figs. They contribute to long-distance dispersal of fig seeds and the recruitment of new trees in the forest as well as in isolated areas. Bats can swallow between 60–80% of the seeds present in a fig fruit which makes them very efficient fig consumers (Nakamoto et al., 2007). The fruit eating bat, *C. sphinx*, plays an important role in pollination and seed dispersal in many plants. In many places fruit bats are the only animal capable of carrying large seeded fruits and can be the single, most important pollinators, seed dispersers. At least 443 plant products useful to man are derived from 163 plant species that rely to some degree on bats for pollination or seed dispersal (Fujita and Tuttle, 1991). In Bihar, bats are known to keep under check of destructive rodent species in cultivated crops, godowns and houses (Sinha, 1999).

3. BATS AS PESTS

The extensive feeding of bats on tender twigs of Robusta coffee leads to drying of fruit bearing branches resulting in crop loss. The data indicated that the crop damage ranged from 5.9–9.48%. This made the farmers to develop a negative impact for bats and attempts were made to destroy the roosts which were near by the cultivated land (Verghese, 1998.). The fruit bats were estimated by the fruit growers to eat 50,000 kg of litchis annum^{-1} and that this damage is increasing at a rate of 10% annually (Oleksy et al., 2016). Under schedule V of Indian Wildlife Protection Act 1972 and International union for conservation of nature (IUCN) Red List (Version 2014.1) this species is labeled as 'vermin' on the impression that it poaches ripe fruits from orchards and defecates in public places (Chakravarthy et al., 2008, Hassan et al., 2009) and causes heavy economic losses to guava (*Psidium guajava*) (20–28%), arecanut (*Areca catechu*) (18%), mango (*Mangifera indica*) (12–17%) and sapota (*Achrus zapota*) (12–30%). Korine et al. (1999) showed that Egyptian fruit bat *Rousettus aegyptiacus* Geoffroy in Israel ate mainly non-commercial fruits and also to a lesser extent leaves and pollen, challenging the assumption that this species is a major agricultural pest. Out of 14 identified plant species comprising its diet, only four are grown commercially in Israel: persimmon (*Diospyros kaki*), loquat (*Eriobotrya japonica*), fig (*Ficus carica*) and date (*Phoenix dactylifera*), with the largest component consisting of figs (*Ficus* sp.). The perception of *R. aegyptiacus* as a pest led to conflict with farmers, resulting in extermination programs that reduced its population in the country (Hadjisterkotis, 2006). As these control measures involved widespread fumigation of caves by the authorities, using the chlorinated hydrocarbon lindane, many populations of cave-dwelling insectivorous bats were also drastically reduced. Other reports from Israel detail bats consuming commercial fruits such as apples, bananas, carobs (*Ceratonia siliqua*), dates, grapefruits (*Citrus paradisi*), litchi (*Litchi chinensis*), mandarins, pears and pomegranates (Izhaki et al., 1995). However, the overall extent of actual damage to fruit crops is unknown and requires further detailed investigation. In Lebanon, *R. aegyptiacus* was observed feeding on carobs, dates, and figs. Its preference for dates and figs in particular, which are also cultivated for human consumption, caused it to be the only bat species considered to be of economic importance there. Fruits such as dates could be protected by cloth bags or nets before ripening, this was seldom done. Some farmers were even known to starve populations of bats in caves by placing nets over the roost entrance. The damage over litchi crop was also observed in some regions. During a study in litchi crop, the damage to litchi fruits by *P. giganteus* accounts to be in the range from 6.85–8.93% of total fruit bearing on the trees of orchards. The average yield of litchi fruits was 7.09 kg tree^{-1}, out of which 5.59 kg fruit was damaged by fruit bats results an average economic loss of ₹ 32232.0/ acre^{-1} (Singh et al., 2022).

4. THREATS TO BATS

Song et al. (2000) studied the population of bats and concluded that fluctuation in carbon dioxide content, temperature, cave topography and dimensions that affects the diffusion of gases in the cave is caused by the inflow of the visitors which directly affect the bats causing disturbance in the population. The main threats to the bat population are described as under:

4.1. Exposure to heavy metals

Due to their large range across diverse habitats, flyingfoxes are potential bioindicator species for environmental metal exposure. Contamination in fruit bats is likely to be through atmospheric pollution, contact with contaminated foliage while searching for and eating food, which may be later ingested directly while grooming. Insectivorous bat species become contaminated mainly through bioaccumulation through the foodchain i.e., from water/soil/sediments/plants or other sources to insects and finally to the bats themselves. The additional routes of exposure to heavy metals may include contact with skin and inhalation (Allinson et al., 2006). Usually, upon oral ingestion, about 5–10% of the metal gets absorbed and about 99.5% of total ingested metal is excreted through faeces/guano, leaving only 0.5% to be deposited in various body tissues (Klaassen, 1976). Environmental contamination with heavy metals such as arsenic (As), lead (Pb), cadmium (Cd), and mercury (Hg) and trace elements such as copper (Cu) and zinc (Zn) (subsequently referred to as metals) has serious consequences for humans, animals and the environment (Zhijia and

Morrison, 2001, Martley et al., 2004, Anonymous, 2007, Callan et al., 2012, Gulson et al., 2012, Anonymous, 2013, Mackay et al., 2013). The effects of metal exposure have been best explored in rodent models and humans where both acute high-level and chronic low-level exposures have resulted in substantial negative consequences. According to these researches, hazardous metal concentrations can interfere with hepatic, renal and central nervous system function via physiological processes and irreversible cellular alterations that lead to necrosis (Needleman, 2004, Uriu-Adams and Keen, 2005, Zahir et al., 2005, Godt et al., 2006, Kapaj et al., 2006, Plum et al., 2010, Keil et al., 2011, Liu et al., 2013). Higher amounts of these metals can also impair innate and acquired immunological function, interfere with fecundity, cause endocrine disruption and some metals including As, Cd, Hg and Pb are carcinogens (Needleman, 2004, Uriu-Adams and Keen, 2005, Zahir et al., 2005, Godt et al., 2006, Kapaj et al., 2006, Plum et al., 2010, Keil et al., 2011, Liu et al., 2013). Pulscher et al. (2021) studied grey-headed flying-foxes (*Pteropus poliocephalus*) and black flying-foxes (*Pteropus alecto*) from the Sydney basin, Australia, using inductively coupled plasma mass spectrometry to trace concentrations of arsenic, cadmium, copper, lead, mercury, zinc and 11 other trace metals in their blood spots, urine, fur, liver and kidney samples. Due to fewer ambient lead emissions, kidney and fur had lower lead concentrations than amounts discovered in flying-foxes in the early 1990s. Cadmium contents (tissue) in flying foxes were higher than in prior investigations of flying foxes and other bat species, implying that they were exposed to unknown cadmium sources.Urine concentrations of arsenic, cadmium, mercury and lead were proportional to kidney concentrations. The study carried out by Rahman et al. (2020) to estimate presence of Zn, Cu, Mn and Fe in the tissues of four different organs (kidney, liver, lungs and patagium) of *Megaderma lyra* revealed that there was no significant difference in concentration of Zn and Mn whereas Cu and Fe varied significantly among the studied organs. Zn and Hg concentrations were high in the bat body compared to Mn and Cu. The data reported can be considered as baseline values for non-polluting sites because the critical trace elements in the body tissues of *M. lyra* were found to be within the threshold limits.

Johnson and Vincent (2020) in their study on bat guano indicated the presence of heavy metals such as mercury (Hg) and various other metals in varying concentrations. The concentration of metals like lead, cadmium and zinc, however, were below detection limits. Moreover, higher levels of contamination of Hg were found in urban areas to that of rural areas. The composition of guano also varied between the insectivorous and frugivorous bats and this was indicated by the presence of the elements Aluminium (Al) and Titanium (Ti) in insectivorous bat guano. It was also observed that the levels of copper (Cu), chromium (Cr), manganese (Mn) and nickel (Ni) were significantly different between the insectivores from Ernakulam (urban) and those from Irinjalakuda (rural) areas. Variability in the levels of metals found in bat bodies was influenced by their background environmental levels which in turn reflected the amounts accumulated. Metals may interfere with the normal functioning of the immune system, cause physiological and histological distress and thus increase the prevalence of parasites or wildlife infectious diseases (Hernout et al., 2016). Environmental pollution and contamination in turn can cause population declines in bats. Assessments of these contaminants thus help us to understand the levels that would harm humans. In the study carried out by Herndon and Whiteside (2017), the effects of CFA-type (Coal fly Ash) air pollution on bats were discussed which included hepatopathy, DNA damage, hemochromatosis and neurological disease. Eleven metals like arsenic, cadmium, cobalt, chromium, copper, mercury, manganese, nickel, lead, tin and thallium (all trace elements in CFA) are known to be potentially toxic to mammals including bats. Cadmium, lead and mercury are among the most commonly reported elements associated with toxicity in bats. Among the metals detected in bat tissues like liver and kidney, iron (Fe) is usually found at very high levels (Mansour et al., 2016). Iron storage illness is common in captive Egyptian fruit bats (*Rousettus aegyptiacus*) which are linked to increased infection rates and malignancy, particularly hepatocellular carcinoma (Leone et al., 2016). Environmental contaminants (such as persistent organic pollutants and metals) have been shown to impair iron homeostasis, resulting in negative biological impacts (Schreinemachers and Ghio, 2016). The discovery of fungal iron-gathering siderophores on bat wings using WNS shows that these molecules are involved in infection and/or tissue penetration (Mascuchet al., 2015). Brown fat, which is iron-rich and important in thermoregulatory activities in mammals has a limited distribution in the body. Brown fat thermogenesis is required for both arousal and hibernation maintenance in hibernating bats (Ito et al., 1991). The ferritin heavy heart (FHH) chain component of ferritin (the primary iron storage protein) has recently been shown to operate as a master regulator of organismal iron homeostasis, binding nutritional iron supply to redox homeostasis, energy expenditure and thermoregulation (Blankenhaus et al., 2019). Bats rely on brown adipose tissue for energy. Upon eating heavily polluted insect prey, the fatty acid profile in this tissue gets altered thus affecting mitochondrial function, torpor and energy consumption (Hill et al., 2016). Mansour et al. (2016) in his study on two insectivorous bat species *Taphozous perforatus* and *Rhinopoma cystops* studied 14 heavy metals using kidney, liver and guano samples. Liver of female *T. perforatus* contained significantly (p<0.05) higher levels of Ba and Pb than those of males while an opposite trend was recorded for Ba and Mn in liver of *R. cystops*. The guano samples contained much higher concentrations of the 14 metals than the tissues. It was concluded that accumulation of these contaminants in bat tissues seemed to be affected by factors such as species, gender and sampling time.

The study by Leone et al. (2016) on captive Egyptian fruit bats (*Rousettus aegyptiacus*) to determine the tissue distribution of iron storage and the incidence of intercurrent neoplasia and infection in them which may be directly or indirectly related to iron overload due to increased amounts of hepatic iron was done using tissue sections. Iron was regularly found in the liver and spleen but significant levels were also found in the pancreas, kidney, skeletal muscle and lung. The most common neoplasm was hepatocellular carcinoma (HCC) followed by cholangiocarcinoma. Bronchioloalveolar adenoma, pulmonary carcinosarcoma, oral sarcoma, renal adenocarcinoma, transitional cell carcinoma of the urinary bladder, mammary gland adenoma and parathyroid adenoma were among the extrahepatic neoplasms. Three poorly differentiated carcinomas, a poorly differentiated sarcoma and a neuroendocrine tumour were among the metastatic neoplasms of unknown initial origin. HCC was shown to be substantially more common in bats with hemochromatosis than in bats with hemosiderosis. Cardiomyopathy was diagnosed in 35 of the 77 bats with evaluable heart tissue however there was no link between cardiac damage and the quantity of iron discovered in the liver or heart. Multiple bats developed hepatic abscesses but there was no evidence of a link between hemochromatosis and bacterial infection. Other studies revealed the concentrations of mercury (Hg) in fur of both frugivorous (*Megaerop* sp. and *Cynopterus* sp.) and insectivorous (*Rhinolophus* sp. and *Hipposideros* sp.) bat species residing at Temenggor lake and Kenyir lake in peninsular Malaysia. Higher concentrations of mercury were reported from the insectivorous bats at Kenyir Lake with *Hipposideros* sp. showing higher concentrations (Syaripuddin et al., 2014). Flache et al. (2015) conducted a study to determine heavy metal concentration by ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometer) in hairs of three bat species (*Myotis daubentonii*, *Nyctalus noctula* and *Pipistrellus pipistrellus*). In *P. pipistrellus*, a slightly higher concentration of Cd along with highest concentration of Pb and Zn was observed. *N. noctula* displayed the highest contents of Cu and Mn. Significant results were reported between the concentrations of Cu and Mn and those of Pb and Cd. Zukal et al. (2015) aimed to study heavy metal concentration on wild bats using different organs as kidney, liver, guano and whole-body carcass. Four out of 65 species were analysed more than five times and heavy metals such as Cr, Cu, Cd, Zn and Pb were reported in frugivorous/nectarivorous species. Both frugivorous/nectarivorous species and guano have a greater mean contaminant value in time than insectivorous bats. Scholars carried out a study to analyse the heavy metal concentration (Cd, Cu, Pb and Zn) in various organs like liver, kidney and heart of micro and mega bats from Northern and Central Punjab (Pakistan) by using atomic absorption spectrophotometry. Maximum concentration of heavy metals was observed in kidney as compared to liver and heart and following the order Zn>Pb>Cu>Cd.

4.2. Exposure to pesticides

Pesticides are used to protect crops and cattle from numerous pests, diseases, weeds, and parasites there by contributing to agricultural production. Organochlorines, organophosphates, pyrethroids, carbamates, neonicotinoids, chlorophenoxyacids, triazines and glycines are the chemical classifications for these items. Within each chemical group are various types of commercial products with different purposes such as insecticides (for the control of insects), acaricides (to control mites), nematicides (to control plant parasitic nematodes), molluscicides and rodenticides (rodents). In addition, there are two separate chemical groups; the herbicides whose purpose is to control weeds and fungicides, bactericides used to prevent fungal and bacterial diseases (Banaszkiewicz, 2010). While target organisms absorb a major fraction of pesticides, a significant quantity is nevertheless spread in the environment via air and water and is discovered in soil, surface water and groundwater on a regular basis. Non-target animals particularly creatures that play critical ecological roles in ecosystems are constantly exposed to pesticide residues or by-product impacts when pesticides persist and build in the environment.

Bats are diverse group of animals that occupy practically every continent. They play vital ecological and economic roles as seed dispersers in natural habitats and insect control agents thereby reducing insect damage to commercial crops (Boyles et al., 2011). Pesticide concentrations are highest in the adipose tissue of bats followed by the liver and brain. Bioaccumulation of pesticides in bats can be 30 times more sensitive than in rodents (Shore et al., 1996). Aside from pesticide effects in cells and tissues, some chemicals interfere with non-target creatures' endocrine systems thereby affecting hormone secretion, transit and/or binding totarget cells. Given the aforementioned considerations, we conclude that bats are pesticide sensitive and could serve as a model for pesticide risk assessment programmes (Stahlschmidt and Bruhl, 2012). The necessity of analysing pesticide impacts in key bat species is heightened by specific traits such as high metabolic rate, lifespan and oxygen consumption. Recent research has suggested that bats may be more vulnerable to pesticide exposure than previously thought. Bats can be exposed to pesticides through contaminated food and drink as well as skin contact in their roosting locations. Residues can bioaccumulate in their tissues causing health risk. Low breeding rates and seasonal reductions in food availability are two variables that contribute to bat species' vulnerability to pesticide exposure (Stahlschmidt and Bruhl, 2012, Stechert et al., 2014).

Furthermore, they discovered that there are still significant gaps in the number of studies depicting the impacts of pesticides on bats and that they are concentrated in temperate regions of the world. Although certain countries in Central and South America have used a lot of pesticides in the previous ten years, little is known about how they affect Neotropical bat populations. Due to their position at the top of the food chain, bats that eat insects are thought to be more vulnerable to pesticides. Insect-eating bats aid in the control of insect populations including disease vectors such as dengue, fever, leishmaniasis and malaria as well as agricultural pests. Insect-eating bat declines in North America have resulted in a loss of billions of dollars in agricultural production (Cleveland et al., 2006, Boyles et al., 2011, Lopez-Hoffman et al., 2014). Insect-eating bats end up bioaccumulating pesticide residues in their tissues when they feed on pesticide-contaminated food (insects, arthropods and others) (Gerell and Lunderg, 1993, Stahlschmidt and Bruh, l 2012). Organochlorines, dieldrin, endosulfan, lindane, pyrethroids, organophosphates and carbamates were found at residual amounts in different tissues of insect-eating bats (Clark and Krynitsky, 1983, Fernandez et al., 1993, Gerell and Lunderg, 1993, Kannan et al., 2010, Lilley et al., 2013, Stechert et al., 2014, Eidels et al., 2016). Fruit-eating bats, on the other hand, are huge seed dispersers who help with forest conservation and replanting (Altringham, 1996). These animals are also constantly exposed to environmental toxins and their almost entirely fruit-based diet makes them ideal markers of pervasiveness and occurrence of pesticide contamination (Valdespino and Sosa, 2017). Along with food, water is also a source of exposure to pesticide contamination in bats. Contamination can occur directly through the use of contaminated water or indirectly through the consumption of contaminated insects. Furthermore, water quality is a selection factor for the species as some individuals may choose to graze in less polluted areas than others (Korine et al., 2015). Despite the importance of water quality for the species, there were no studies that showed a direct link between pesticide residues in water bodies and bioaccumulation in bat tissues despite research involving heavy metals demonstrating such a link (Zocche et al., 2010, Naidoo et al., 2015, Hill et al., 2016). Some researchers link the reduction of bat populations in some parts of the world to pesticide bioaccumulation in their tissues (Bennett and Thies, 2007, Dennis and Gartrell, 2015). Pesticides were found in significant amounts in the bodies of bats discovered in their roosting places in New Zealand and Spain (Fernandez et al., 1993, Dennis and Gartrell, 2015). Once ingested, xenobiotics are metabolically converted to more water-soluble compounds that are easier to excrete. This bio-transformation may alter the chemical's pharmaco-dynamic or toxic effect.

Some metabolites derived from the original compounds can also bio-accumulate in tissues and induce immunotoxicity, oxidative stress, endocrine disruption and reproductive failure in wild animals even after the exposure period (Berny, 2007). In several bat species, organochlorines were found to increase the basal metabolic rate with a consequent reduction in body energy reserves (Swanepoel et al., 1999, Kannan et al., 2010, Brinati et al., 2016). Energy reserves mobilization, especially from lipids, increases blood concentration of pesticides which increases its effects in more sensitive tissues such as liver and brain (Boyd et al., 1990). In the brain, organochlorines can compromise the regulation of several processes such as hibernation (Chen et al., 2008) and prey capture during flight (Schwartz and Smotherman, 2011, Wenstrup and Portfors, 2011). In the liver, this class of pesticide can compromise the detoxifying ability (Hill et al., 2016). Moreover, the reduction of energy reserves may also impair reproductive processes particularly in females and make awakening of torpor difficult (Eidels et al., 2016). Decreased energy reserves may also induce an increase in foraging time which involves higher energy expenditure and make individuals more susceptible to predation (Swanepoel et al., 1999, Allinson et al., 2006). Organochlorines typically interfere with acetylcholinesterase activity which may impair their echolocation performance (Eidels et al., 2016, Hsiao et al., 2016). Considering the importance of this feature for bat navigation, this single effect can impair a wide variety of their nocturnal activities. In reality, among insect-eating bat species monitored in agricultural areas with different degrees of herbicide exposure, populations observed foraging in organic crop areas showed a higher foraging time and greater species richness when compared to those found in areas near crops treated with pesticides (Barre et al., 2018). Exposure to organochlorines also caused several pathologies in liver of bats such as vacuolization, necrosis and apoptosis (Amaral et al., 2012, Oliveira et al., 2017). In addition, they induced oxidative stress (Oliveira et al., 2018) and decreased the total hepatic antioxidant capacity (Oliveira et al., 2017) which depending on the severity of the liver lesions can cause death (Dennis and Gartrell, 2015). Besides the effects of pesticides in cells and tissues, some chemicals also interfere with the endocrine system of non-target organisms thus impairing hormone secretion, transportation and/or biding to target cells. Several organochlorines and pyrethroid insecticides are considered endocrine disrupters that alter the reproduction axis mediated by testosterone in rats (Thies and McBee, 1994, Thies et al., 1996). In bats, only a few studies have been contributing to this important area including the reported incidence of several testicular and epididymal pathologies followed by the exposure to the fungicide tebuconazole in Neotropical fruit-eating bats (Machado-Neves et al., 2018). Immuno toxicological effects of pesticides are also a neglected area regarding studies with bats although the white-nose syndrome has been killing millions of bats in temperate regions. Pesticide toxicity leads to immune suppression and makes the individual more susceptible to infections by pathogenic organisms (Afonso et al., 2016). A direct association to pesticides exposure was suggested by Kannan et al. (2010) which reported a reduced complement system activity induced by organochlorine bioaccumulation in insect-eating bats (Kannan et al., 2010, Lilley et al., 2013).

4.3. Effect of urbanization on bat population

Bats likely form the most diverse group of mammals remaining in urban areas (Jung and Kalko, 2011). The studies conducted in urban landscapes showed that overall bat activity and species richness are greatest in more natural areas and decrease with increasing urban influence (Lesinski et al., 2000). However, certain bat species may better be able to adapt to urban landscapes (Duchamp and Swihart, 2008). Coleman and Barclay (2011), nevertheless, cautioned that most researchers have worked in forested regions directing less attention to other biomes including grasslands. They argue that because urban tree cover is fairly constant (<30%) in all cities, urbanization in tree-rich regions implies deforestation and thus reduced tree cover may cause the negative effect of urbanization. Under the results of Gehrt and Chelsvig (2004) upon investigating the response of bats in and around the highly populated city of Chicago, USA, it was found that species diversity and occurrence were higher in habitat fragments within urban areas than in similar fragments in rural areas. Though the large, forested parks in the region may offset the habitat loss caused by urbanization and hence mitigate any negative impacts to bats at the regional scale. The majority of studies on bats in urban environments come from the temperate regions of Europe and North America. Many studies focus on the response of bats to differently structured areas within the urban environment including historic and newly built city districts (Pearce and Walters, 2012), illuminated and non-illuminated areas, industrial areas, small and larger parklands and areas that receive wastewater (Park et al., 2012). Most of these studies report relatively high bat activity and species richness in areas with remaining vegetation such as older residential areas, riverine habitats or parklands. Certain bat species appear to thrive in these urban environments and success has been linked to species-specific traits (Duchamp and Swihart, 2008). In particular, bat species with high wing loadings and aspect ratios so presumed to forage in open areas which also roost primarily in human structures appeared to adjust to urban environments provided that there was sufficient tree cover (Dixon, 2012). Many of these studies imply that protecting and establishing tree networks may improve the resilience of some bat populations to urbanization (Hale et al., 2012). Population and assemblage level responses along gradients of urbanization reveal that generally foraging activity of bats seems to be higher in rural and forested areas than in urban areas (Lesinski et al., 2000). However, it is important to note that some species might be highly flexible in their habitat use. The European bat *Eptesicus nilsonii*, for example, spends a much higher proportion of its foraging time in urban areas after birth of the juveniles than before (Haupt et al., 2006).

In the Neotropics, most studies concerning bats and environmental disturbance have concentrated on fragmentation effects due to logging or agricultural land use. Persistence of bats in fragmented landscapes has been associated with edge tolerance and mobility in phyllostomids along with the predominant use of open space as foraging habitat for aerial insectivorous bats (Meyer and Kalko, 2008). Of the few studies focusing on urban areas, most report an overall decrease in species richness and relative abundance of bats in urban areas compared to forested areas (Jung and Kalko, 2011). Predominantly, insectivorous bats remain in large urban environments (Filho, 2011). Of these, it is typically members of the molossidae, which are known to forage in the open spaces above the tree canopy that seem to tolerate and potentially profit from highly urbanized areas (Jung and Kalko, 2011). Besides, many buildings in cities provide potential roost sites that resemble natural crevices and are known to be readily occupied by molossid bats (Scales and Wilkins, 2007). In a smaller urban setting in Panama where mature forest compensates very restricted urban development, a high diversity of bats occurred within the town and bats frequently foraged around street lights (Jung and Kalko, 2011). Recent investigations from large metropolitan urban centres in Australia concluded that suburban areas can provide foraging habitat for bats (Threlfall et al., 2012) and support greater bat activity and diversity than urban and even forested areas (Luck et al., 2013). Studies from regional urban centres in Australia concluded that any urban land cover, even if low-density residential can decrease bat activity and species richness and can deter some species of bats (Luck et al., 2013). Evidence also suggests that species adapted to open spaces and edges such as those within the molossid family do not display the same response to urbanization in small regional versus large metropolitan urban centres indicating subtle behavioural differences among species with similar eco-morphology. The few studies that have investigated species-specific foraging, roosting requirements and bat displaying high roost site fidelity within urban areas, it was reported that species differ in their ability to forage successfully on aggregations of insects across the urban matrix reflecting variation in flight characteristics and sensitivity to artificial night lighting (Threlfall et al., 2013). In a study, large pteropodid bats were under threat from direct human impacts via hunting and human land-use alteration and hence it was reported that any impact of urbanization may directly affect the populations of pteropodid bats. However, increasing land-use change and growing urban populations have been stated as the cause of dramatic declines of many bat species (including pteropodids) in Singaporewhere it was reported that the declines may reflect the declining status of bats in South-East Asia more broadly (Lane et al., 2006). In a study conducted in Pakistan, bat species distribution in relation to increasing urbanization was studied where greater bat capture success was recorded in urban areas in comparison to sub-urban and rural areas (Nadeem et al., 2013). Demographic changes in human populations of many countries are turning rural areas into areas nearly devoid of humans. As a result, buildings are abandoned and due to a lack of maintenance, they deteriorate over time. Shortly after abandonment, many synanthropic bat species benefit likely due to the reduced disturbance by humans. Deserted buildings may provide new roosting structures for bats like for *Hipposiderosni cobarulae* in Myanmar (Douangboubph et al., 2011). In a long run, synanthropic bats may vanish from these sites when buildings deteriorate (Sachanowicz and Wower, 2013). Another effect of demographic changes involves movement and concentration of people in urban areas. Following this, previously unused buildings even in industrial areas or unoccupied space under the roof of buildings are converted into houses or apartments to host the influx of people in cities. This may cause losses of roosting opportunities for synanthropic bats. In China, a vast number of old buildings were demolished during the process of modernization which reduced the density of roosts significantly for synanthropic bats (Zhang et al., 2009).

4.4. Overhunting of bats

Milner-Gulland and Bennett (2003) in their study concluded that human communities have long exploited bat populations for consumption and current hunting pressure was likely to be much greater than historical pressure because of increased human population density, greater accessibility to natural areas, technological advances in bat capture methods and transport options along with relaxed adherence to cultural taboos. Bat hunting is likely to be unsustainable (Bradshaw et al., 2009), especially when coupled with other anthropogenic stress. Overhunting (commonly also "unregulated" hunting, although not all unregulated hunting is neither unsustainable nor regulated hunting sustainable) is a globally recognized threat to many wild species of animals (Milner-Gulland and Bennett, 2003). For bats, overhunting has been a conservation concern for over three decades (Anonymous, 2014). Twenty years ago, the conservation status of nearly half (78/160) of the Old-World fruit bats was unknown due to a lack of data (Mickleburgh et al., 1992). Today only 11% (21/183) of the extant Old World fruit bat species on the Red List are considered data deficient (Anonymous, 2014). This general increase in knowledge about bats includes a better understanding of the extent of hunting pressure. In the first conservation review, 49 (31% of the total 160 known) Old World fruit bat species were recognized as hunted. Two decades later, nearly twice as many species (92) are known to be hunted, representing over half of the183 recognized species of Old-World fruit bats. Although there has been relatively little research explicitly focused on quantifying hunting impacts, the general level of concern about hunting effects on bat conservation has increased. Using Old World fruit bats as an example, in the first review, hunting was not considered a threat for most (60%) of the hunted species (Mickleburgh et al., 1992). Five of these hunted species (25/30, 83%) have been moved up to a higher threat status because of perceived pressures that hunting causes (Anonymous, 2014). Overhunting is the main factor in the loss of three of the now-extinct fruit bat species and a cause behind local extirpations within species' historic distributions like Polynesian sheath-tailed bat *Emballonura semicaudata* from Vanuatu (Helgen and Flannery, 2002). Similarly, the declines of seven of the ten fruit bat species listed as critically endangered are attributed directly to hunting; the remaining three species are still virtually unknown (Anonymous, 2014). Seven hunted bat species previously assumed to be unaffected by hunting now have hunting listed as a major threat (Mickleburgh et al., 1992). Most (68%) of the species that are hunted are listed as threatened by hunting while only 15% of the hunted species are expected not to be affected. However, it should be pointed out that for the remaining 38% of hunted species, reviews remain ambivalent about whether hunting is a problem or not. Similarly, in the review of bats as bush meat carried out in 2004 (Mickleburgh et al., 2009), 59% of questionnaire respondents said bat hunting occurred in their region and over half (54%) of those species hunted were perceived to be negatively affected. Epstein et al. (2009) and Harrison et al. (2011) reported that fruit bats are hunted for food and medicine extensively (including commercial trade) leading to rigorous declines throughout their range. Lane et al. (2006) studied deforestation rates in South-East Asia project and concluded that many pteropodids may happen to globally extinct by the end of this century.

5. BATS AS VECTOR OF DISEASES

The fruit bats are important reservoirs of many pathogens, some of which have been reported to be associated with many diseases like rabies, which cause direct death of bats (Brussow, 2012), European lyssa virus (Fooks et al., 2002), Hendra (Halpin et al., 2000) and Menangle (Bowden et al., 2001). Other virusesalso cause infection and death of bats such as Nipah and Tioman viruses in Malaysia (Chua et al., 2002) and hanta viruses in Korea. They can easily spread these to other mammalian species because they are longer life span and more mobile in nature. Ejecta of the fruit bats supports a great diversity of organisms including arthropods, fungi, bacteria and lichens (Ferreira and Martins, 1998) and are most common sources of pathogenic and other mycofauna distribution. White Nose Syndrome disease (WNS) has spread rapidly and by 2014 was found in 25 U.S. States and five Canadian Provinces. A confirmed case of WNS is defined by the presence of cupping erosions on the skin caused by infection of *Pseudogymnoascus destructans*, which is determined by histopathological examination (Meteyer et al., 2009). There are currently seven hibernating species in North America that have been confirmed with infections characteristic of White Nose Syndrome disease, including Little brown bat *Myotis lucifugus* Le Conte, Northern long eared bat *Myotis septentrionalis* Trouessart, *Myotis sodalist* Miller and Allen, Eastern small footed bats *Myotis leibii* Audubon and Bachman, Gray bat *Myotis grisescens* Howell, Big brown bat *Eptesicus fuscus* Beauvoisand Tricolored bat *Perimyotis subflavus* Cuvier. There are several additional species for which *P. destructans* has been detected on skin tissues using swab sampling and quantitative PCR (Polymerase Chain Reaction) methods (Muller et al., 2013), but that have not been confirmed with characteristic skin lesions that define the disease. Two of the species confirmed with White Nose Syndrome disease (*M. sodalist* and *M. grisescens*) were already listed as federally endangered under the U.S. Endangered Species Act before White Nose Syndrome disease emerged and several other species have been predicted to go globally or regionally extinct due to mortality from White Nose Syndrome disease (Thogmartin et al., 2013). The U.S. Fish and Wildlife Service listed *M. septentrionalis* as federally threatened in 2015 due to the risk of extinction from White Nose Syndrome disease associated mortality. A status review of *M. lucifugus* was conducted by Frick et al. (2010) to determine whether listing as federally endangered is warranted of this once common species. In Canada, three species, *M. lucifugus, M. septentrionalis* and *P. subflavus* were listed as endangered in 2015. The rapid spread and extensive mortality associated with White Nose Syndrome disease raise serious concerns about population viability for species that are being impacted by this disease. Challenge or inoculation studies (Warnecke et al., 2013, Wilcox et al., 2014) and comparative studies of bats from affected versus unaffected hibernacula (Reeder et al., 2012) have led to progress in our understanding of mechanisms underlying White Nose Syndrome disease. The wings of bat are physiological active tissue involved in gas exchange and fluid balance. In general, results of physiological studies are converging on a consensus that cutaneous infection of the wings accounts for the physiological and behavioral effects of White Nose Syndrome disease (Cryan et al., 2010). Rahman et al. (2012) studied that direct transfer of Nipah virus from bats to people occurs in Bangladesh nearly every year through consuming date palm sap, mostly tainted with feces, saliva or urine from infected *P. giganteus*. Nahar et al. (2010) has used some preventive measures to block bats' access to date palm sap collection pots and reduce the risk of Nipah virus transmission. It has been hypothesized that bats and gorillas may share Ebola virus through association at shared fruit resources, but this has not been verified and additional research is needed to better understand the ecological connections between bats and other mammal hosts in the transmission of these diseases (Olival and Hayman, 2014). Due to the close proximity of bats with humans and domestic animals, it is possible that they had important role in the epidemiology and zoonoses. The contact of bats with humans and domestic animals are either direct or indirect, for example through many hematophagus arthropods such as mosquitos, ticks and cone-nosed bugs feeds on bats, domestic animals and man. They are thought to be transferring half of the communicable diseases in man and act as a reservoir, intermediate host or vector of various pathogens. The fungi related to bat excreta are mostly limited to the places where bat guano is frequently abundant. Most bat species are favourable hosts and vectors of diseases anddue to their high mobility, broad distribution, long life spans, live in colonies and their social behavior bats also carry more zoonotic viruses as compared to Rodents (Castro, 2013). Bats are also well known as a natural reservoir of many zoonotic viruses, including Lyssa virus (causative agents of rabies), Henipa virus, severe acute respiratory syndrome (SARS) corona virus and Ebola virus. They may also be responsible for spreading diseases particularly the Nipah virus which causes illness and death in humans (Kunz and Racey, 1995, Marimuthu, 1998, Thatcher, 2004). Flying foxes are natural reservoirs of fatal viruses like Henipa and Corona (Epstein et al., 2008). Their ability to host different viruses is enabled by their wide geographical distribution, migratory and feeding habits and in many cases, high population density (Wibbelt et al., 2009). Following are some the major outbreaks of viruses:

Rabies virus (family Rhabdoviridae, genus Lyssavirus, serotype 1/genotype 1) transmitted between mammals including bats primarily through the bite inoculation of rabies virus present in the saliva of infected individuals (McKendrick, 1941). The dual characters of transmitting rabies virus and being hematophagous (vampire bats) have cast a shadow on bats. Bats of three species; *Diphylla ecaudata* (hairy-legged vampire bat), *Diaemus youngi* (white-winged vampire bat) and *Desmodus rotundus* (commom vampire bat) are known vampires and have been found to be involved in transmission of rabies virus although available evidence indicates that only the vampire bat is important in this regard (Turner, 1975). Globally, a vanishingly small proportion of the approximately 55,000 annual human deaths caused by rabies virus are caused by variants of virus associated with bats (Knobel et al., 2005). Five viruses have been placed in the taxon Filoviridae. Four of them (Ebola Zaire virus, Ebola Sudan virus, Ebola Ivory Coast virus and Ebola Reston virus) comprise the genus Ebola virus and Marburg virus comprises the genus Marburg virus. The natural reservoir hosts of these viruses have not yet been identified. However, Ebola virus RNA has been detected in terrestrial mammals in the Central African Republic (Morvan et al., 1999). Experimental infections of the Angola free-tailed bat (*Mops condylurus*), little free-tailed bat (*Chaerephon pumilus*) and Wahlberg's epauletted fruit bat (*Epomophorus wahlbergi*) with Ebola Zaire virus led to replication of virus in these bats (Swanepo el et al., 1996). Recently, Ebola virus RNA was detected in liver and spleen tissues of three fruit bats; the hammer-headed fruit bat (*Hypsignathus monstrosus*), Franquet's epauletted bat (*Epomops franqueti*) and little collared fruit bat (*Myonycteris torquata*) (Leroy et al., 2005). In 1994, an outbreak of an acute respiratory illness occurred in humans and horses in Hendra, Brisbane (Australia). Twenty-one horses and two humans (trainer and a stable hand) were infected (Murray et al., 1995). Four additional outbreaks during 1994, 1999 and 2004 infected five horses and two humans, killing all but one human (Selvey et al., 1995, Hooper et al., 1996, Rogerset al., 1996, O'Sullivan et al., 1997, Field et al., 2000). A virus family paramyxoviridae, genus Henipavirus (named after Hendra and Nipah viruses) was shown to be the etiologic agent of this disease (Murray et al., 1995). The natural hosts and probable reservoirs of Hendra virus are fruit bats of the genus *Pteropus* including the black flying fox (*Pteropus alecto*), gray-headed flying fox (*P. poliocephalus*), little red flying fox (*P. scapulatus*) and spectacled flying fox (*P. conspicillatus*). Concurrent serologic surveillance of Indian flying foxes in India during 2003 found that 54% had neutralizing antibodies to Nipah virus suggesting that Nipah virus or a closely related virus was widespread across the range of Indian flying foxes. Chadha et al. (2006) recently reported the occurrence of Nipah virus infections in humans in India in 2001.

Corona virus was not reported to cause severe disease in humans before the onset of severe acute respiratory syndrome (SARS) (Wang and Anderson, 2019). The SARS outbreak in 2002–03 remains as one the most impactful pandemic outbreaks of the 21st century mainly due to the fact that the aetiology was totally unknown during the outbreak which made accurate diagnosis and effective control impossible (Peiris et al., 2003, Wang and Eaton, 2007). The outbreak lasted more than six months with rapid spread of the virus from Southern China to more than 30 countries on all major continents and resulted in more than 8000 human infections and 774 deaths (Wang and Eaton, 2007). Multiple international teams spent the next decade hunting for the origin of SARS-CoV and serendipitously found many SARS-CoV related viruses in bats, most abundantly from the genus Rhinolophus (horseshoe bats) (Lau et al., 2005, Li et al., 2005, Hu et al., 2018). The main bat species that carry SARSr-CoVs are families of Rhinolophidae and Hipposideridae, two insectivorous bats that are distributed widely in the world. Therefore, it is expected that bat SARS-CoVs should also be found in a wide range of countries (Geng and Zhou, 2021). So far, this viral family has been reported in China, South Korea, Japan, India, Burma, Thailand, Italy, Slovenia, Bulgaria, Kenya, Brazil and Australia i.e., across five major continents in the world (Lau et al., 2005, Li et al., 2005, Tong et al., 2009, Drexler et al., 2010, Lau et al., 2010, Rihtaric et al., 2010, Wacharapluesadee et al., 2015, Lecis et al., 2019). The novel corona virus SARS-CoV-2 from Wuhan, China was discovered in December 2019 (Laskar and Ali, 2021). Since its emergence, it has developed into a global epidemic (Rothan and Byrareddy, 2020). The SARS-CoV-2 is different from earlier corona virus outbreaks, severe acute respiratory syndrome (SARS) coronavirus in 2002 and Middle East respiratory syndrome (MERS) corona virus in 2012 predominantly due to its extremely high transmission rates (Peiris et al., 2004, Zaki et al., 2012, Sun et al., 2020). The SARS-CoV-2 belongs to genus beta-corona virus and subgenus sarbeco virus with possible origin in bats supported by its similarity to two bat-derived corona virus strains, bat-SL-CoVZC45 and bat-SL-CoVZXC21 (Lu et al., 2020, Zhou et al., 2020). Yadav and his colleagues detected the presence of COVs in *Rousettus* sp. and *P. medius* species of bats from seven different states of India and found that upon screening the specimens of eight *Rousettus* sp. and 21 *Pteropus* sp. were found positive for CoVRdRp gene (Yadav et al., 2020).

6. MANAGEMENT OF BATS

Full canopy netting is held permanently by a rigid structure of poles and tensioned cables over the entire orchard. Success levels are very high. The structure is expensive and prone to damage in regions that experience cyclones, high wind and hail. The smell of carbide was successful in deterring flying foxes during 1982 in North Queensland. However, flying foxes will become accustomed to the smell. Flashing strobe lights and bright light grids over orchards can be a successful tool to repel bats. Horizontal grid of electrified wires above the trees combined with droppers hanging down the side electric wires can be moderately successful.

Many effective methods have been introduced to prevent the damage caused by bats over the fruit orchards. One such method is full exclusion netting. Australia is the only country to deploy this netting method to a greater extent and gets a successful result, where some large fruit orchards are enclosed in nets supported by cables, frames or posts (Campbell and Greer, 1994). In Mauritius, entire litchi trees are netted and the government supports this by subsidizing 75% of the cost of 10 nets grower^{-1}. However, individual growers may have 200–300 trees and the method applies only to relatively low-growing orchard trees and not to the much older and larger 'backyard' trees which produce a significant proportion of the national litchi crop. Law et al. (2002) recommended planting trees with fruit in spring in Australia to relieve the flying fox damage faced by orchard owners at that time of year and these food trees should not be grown in the immediate vicinity of orchards but located away from commercial fruit growing areas. So, that the bats are attracted away from the orchards. The human built environment provides roosting opportunities for some species of bats and Common pipistrelle *Pipistrellus pipistrellus* Schreber is one of several species that have adapted to the built environment as natural roosts in Europe. Many avian predators will hunt bats which may be one reason why bats avoid flying in the day. For long term protection, three methods were recommended: planting non-commercial species of figs attractive to the bats; dividing orchards into smaller plots so that trees may be covered with sprigs of foliage, thatch or nylon net; and covering bunches of grapes with dry sprigs of foliage, netting, using firecrackers or electric fencing. In India, Verghese (1998) experimented with a successful results that erecting the nylon nets around the trellis-grown bower up to bower height, combined with using twigs and briers to cover canopy gaps in the bower will be helpful to protect the orchards against the fruit bats. In a study, Bicknell (2002) concluded that using smoke can act as an aversion agent for bats in Australia. Smoking the orchards will help to repel the bats away from the orchards. The success of several sonic deterrent devices in animal damage control, although most tests did not involve bats. They pointed out that the success of ultrasonic deterrents for bats was controversial and such devices had no practical value. They concluded that using distress or alarm calls was probably the most promising noise deterrent method. Mele (2008) studied that weaver ants are considered by entomologists and ecologists to be a potential biological control agent. In a study, Thiriet (2010) concluded that shooting is not an effective means preventing flying fox damage to fruit crops, particularly when their population is high in an area. Similarly, Martin and Mcllwee (2002) found that shooting will not stop bats from foraging as they have very high mobility, as a result the continuous stream of animals will move into the site from further field. The full exclusion netting is the most effective means of preventing the crop loss not just by bats but also by birds and hailstones. Use of artificial light is a very eco-friendly method for the management of fruit bats. Bat damage to litchi fruit crop was minimized by using lightening a non-lethal and non-polluting method (LED bulbs) having one time installation cost. After installation of 16 LED bulbs acre^{-1} of 30 watt at a distance of 50' from each other in upward position at a height of 8' above tree canopy in orchard having 72 trees planted at a distance of 25×25', we can reduce fruit bat damage to lower level and can give net economic return of ₹ 13448.0 acre^{-1} to litchi fruit growers which will increase their farm income and help in conservation of fruit bats (Singh et al., 2022).

7. CONSERVATION OF BATS

Bats live in urban regions and ingest large amounts of food relative to their body mass, are at risk of being poisoned due to the accumulation of trace metals. To determine species-specific trace metal contents in bats from urban environments, hair samples were analyzed by ICP-OES (Flache et al., 2014). Bat hunting is likely to be unsustainable (Bradshaw et al., 2009), especially when coupled with other anthropogenic stress. Overhunting (commonly also "unregulated" hunting, although not all unregulated hunting is neither unsustainable nor regulated hunting sustainable) is a globally recognized threat to many wild species of animals (Milner-Gulland and Bennett, 2003). For bats, overhunting has been a conservation concern for over three decades (Anonymous, 2014). Twenty years ago, the conservation status of nearly half (78/160) of the Old World fruit bats was unknown due to a lack of data (Mickleburgh et al., 1992). Today, only 11% (21/183) of the extant Old World fruit bat species on the Red List are considered data deficient (Anonymous, 2014). This general increase in knowledge about bats includes a better understanding of the extent of hunting pressure. In the first conservation review, 49 (31% of the total 160 known) Old World fruit bat species were recognized as hunted. Two decades later, nearly twice as many species (N=92) are known to be hunted, representing over half of the 183 recognized species of Old World fruit bats. Although there has been relatively little research explicitly focused on quantifying hunting impacts, the general level of concern about hunting effects on bat conservation has increased. Using Old World fruit bats as an example, in the first review, hunting was not considered a threat for most (60%) of the hunted species (Mickleburgh et al., 1992). Five of these hunted species (25/30, 83%) have been moved up to a higher threat status because of perceived pressures that hunting causes (Anonymous, 2014). Overhunting is the main factor in the loss of three of the now-extinct fruit bat species and a cause behind local extirpations within species' historic distributions e.g. Polynesian sheath-tailed bat *Emballonura semicaudata* Peale, from Vanuatu (Helgen and Flannery, 2002). Similarly, the declines of seven of the ten fruit bat species listed as critically endangered are attributed directly to hunting; the remaining three species are still virtually unknown (Anonymous, 2014). Seven hunted bat species previously assumed to be unaffected by hunting (Mickleburgh et al., 1992) now have hunting listed as a major threat. In 2001, the NSW government changed the listing of the grey-headed flying fox (*P. poliocephalus*) from protected to vulnerable under the NSW Threatened Species Conservation Act 1995. This resulted in negative reactions from the commercial fruit industry, as it resulted in socio-economic repercussions, particularly for small growers (Bower, 2002). Thiriet (2010) stated in his paper that the state government continued to allow shooting of the species for crop protection, but in 2008 the state banned all shooting of flying foxes, again due to concerns over animal cruelty. In India, all pteropodid species except the critically endangered Salim Ali's fruit bat *Latidens salimalii* Thonglongya are categorized as vermin and included as such in Schedule V of the Indian Wildlife Protection Act 1972. Singaravelan et al. (2009) has stated that the Indian government has ignored successive attempts by conservationists to have forest bats delisted. Improvements in legislation can be implemented at local, National and International levels. At the International level, Convention on International Trade in Endangered Species (CITES) protects species in international trade. The chiroptera specialist group considers that the successful implementation of CITES regulations is vital for the long-term survival of species in trade. However, endangered species may not be covered by CITES, either because they are not in trade or because their trade is not deemed international. In such cases, the promotion of adequate national protection for these species should be encouraged. On individual islands, local protection of roosts or habitat may be sufficient to ensure the survival of the species.

8. CONCLUSION

Fruit bats are second in population after rodents and are eco-friendly in nature. They have great importance in nature by helping in pollination, increase soil nutrition by guano, rejuvenation of forests and seed dispersal of those tree species which can't be done by humans. We have to reduce the threats faced by bats which tend to decrease their population. Although fruit bats are pests of horticultural crops, but we can reduce their damage by using eco-friendly methods for their conservation.

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