INTRODUCTION

The global diversity of vertebrate fauna comprises approximately 66,178 extant species. Further, species are highly diversified due to their habitation requirements and population abundance such as fishes (32,900 species), birds (10,425 species), reptiles (10,038 species), amphibians (7,302 species) and mammals (5,513 species) (Ceballos et al., 2015) and among the mammalian group, bat contributes more than 1300 species (Shi and Rabosky, 2015).

The global faunal diversity is known for its uniqueness, specialization, and characteristics. Presently, around 44% of the reported species are classified as nocturnal while diurnal are 26% and crepuscular or cathemeral mammals are 29% (Jones et al., 2009). During photoperiodic phase, diurnal animals can identify based on their morphology, behaviour, and habitation. However nocturnal animals became active during dark hours and displays behavioural activities hence, they are generally avoided and least studies species. One such an amazing but neglected species are bats (Order: Chiroptera). Therefore, very few information is available on their habitat ecology, foraging behaviour, population dynamics and threat variables (Mildenstein et al., 2005; Lacki et al., 2007; Plowright et al., 2011).

The most diverse order: Chiroptera evolved with several unique specializations such as well developed echolocation, highly sophisticated olfaction, sustained flight adaptation, capturing of prey while flying, fly with larger fruits than body mass, passively hang upside down and cosmopolitan habitation (Kunz and Fenton, 2005). They are long-living, placental mammal and also known as the largest and true flying mammal in the
world (Stier and Mildenstein, 2005). However, they share several characters, behaviour
and life strategies with other animals (Hall and Richards, 2000).

There is a paucity of information available on the diversity of order Chiroptera. Therefore, it remains unclear how many species actually coexist in this species-rich assemblage because existing inventories are inadequate. However, because investigation and identification of new species are difficult, but collectively its number may extend up to many in a year (Fenton and Simmons, 2015). Around a decade back, the global diversity of bats was estimated as 1,100 (Simmons, 2005; Wilson and Reeder, 2005) then 1,117 (Srinivasulu et al., 2010) and 1,232 species (Meyer et al., 2011; Picard-Meyer et al., 2014) but recently a new database reveals that there were more than 1300 species has been identified from the twenty different geographical location of the globe (Shi and Rabosky, 2015). Therefore, they maintained a remarkable position in mammalian community i.e. more than 20% of extant species (Wang et al., 2011). Therefore, field biologist showed curiosity to investigate the natural history of bats.

The world’s chiropteran fauna consists of two unequal sub-order i.e. the Megachiroptera (1 family) and the Microchiroptera (17 families) and they were immensely diverse in term of distribution and population size (Hutson and Mickleburgh, 2001; Wilson and Reeder, 2005). Historically, the distributional range of flying foxes ranges from East Indies to Australian Pacific Islands with the exception in the Antarctic and few other Oceanic Islands (Mickleburgh et al., 2002). They are one of the major species contribute to mammalian diversity as they represent around 20% species richness in both Paleo and Neotropical region (Mickleburgh et al., 2002). In term of species richness, around 75% of bats diversity are restricted with family Vespertilionidae,
Pteropodidae, Phyllostomidae, Molossidae, Rhinolophidae and Hipposideridae while rest belongs to family Desmodontidae, Emballonuridae, Furipteridae, Megadermatidae, Mystacinidae, Myzopodidae, Natalidae, Noctilioidae, Nycteridae, Rhinopomodidae and Thyropteridae, (Shi and Rabosky, 2015). In Asian countries, a total of 123 species have been observed, among them, 14 species are frugivorous while 109 are reported as insectivorous bats (Wordley et al., 2015).

Several studies have proven that bats are the keystone species and indigenous mammal for the ecological process in patchy and fragmented islands (Beggs and Wardle, 2006). The interaction of bats with foraging plants have considered as a very important component of the tropical ecosystems (Fleming, 2013). Throughout the globe, there were two families that have categorized as fruit-eating bats viz. Phyllostomidae and Pteropodidae (Kunz et al., 2011).

In ecosystem, the flying foxes are categorically known as active pollinator and seed disperser. Ecologically and economically, fruit-eating bats have proven their importance in the Old World tropics, as they have a viable role in forest regeneration (Ingle, 2003; Nyhagen et al., 2005). Fruit bats foraging on night blooming plants during night hours (Hall and Richards, 2000; Hodgkison et al., 2004; Quesada et al., 2004; Fleming et al., 2009) and exchange pollen and disperse seeds between isolated and fragments islands and thus it helps in heterogeneity of tropical forests (Estrada and Coates-Estrada, 2002; Woinarski, 2004; Breed et al., 2010).

Pteropodids are stringent phytophagy of fruits, nectars, leaves, shoots, buds, flowers and pollen (Utzurrum, 1995; Barclay, 2002; Singaravelan and Marimuthu, 2004). Due to their considerable feeding plasticity, they interacted with a wide hierarchy of
plants diversity (Nakamoto et al., 2015) and plays a fundamental role in the maintenance of ecological processes (Kunz et al., 2011; Kasso and Balakrishnan, 2013). Generally, flying foxes prefer foraging on figs, bananas, palms, cashew, rambutan, durian and breadfruit etc. (Deshpande and Kelkar, 2015). Hence, pollen and seed of several flowering, fruiting trees are transferred via chiropterophily thus the reproductive alteration facilitate ecological succession throughout their geographical ranges (Hodgkison et al., 2003). Several studies confirmed that plants which are foraged by flying foxes have great medicinal and economic values (Singaravelan et al., 2009). In terms of economic importance, a little investigation has been carried out so that the details of ecosystem services and economical contribution needs further investigation for systematic analysis (Pennisi et al., 2004). As fruit bats are nomadic in foraging nature therefore, they actively engaged in the ecological process such as seed dispersal and pollination. Therefore, it was estimated that around 528 trees which belong to 64 families and 188 genera successfully maintained their diversity because of fruit bats (Kunz et al., 2011; Kasso and Balakrishnan, 2013).

Pteropodidae bats (186 species and 42 genera) exhibits largest species richness in the order Chiroptera (Mickleburgh et al., 1992; Simmons, 2005). The name “megabats” is abbreviated for them because of their body mass and wingspan. The flying foxes selected only well-exposed trees for roost because such trees are long lasting, spacious and mechanically stable however it also facilitates protection from predator, easier takeoff and landing room during flight (Granek, 2002; Gulraiz et al., 2015). Some other parameters such as plants density, types of vegetation, urbanization and availability of flowering and fruiting trees are also associated with roost (Pierson and Rainey, 1992;
Kunz and Jones, 2000). Flying foxes aggregated as much as possible during reproductive periods at day camps but they entirely dependent on groove size and tree characteristics. Flying foxes select roost generally associated with some principally important factors such as aspect, slope, the presence of water bodies, and groove size (Granek, 2002; Hahn et al., 2014). They generally occur close to human settlements and foraging on orchards, commercial crops and homestead garden as food resources. Some roosting colonies are long lasting even may retain for several decades (Hahn et al., 2014).

Most of the *Pteropus* spp. are colonial, gathered from few hundreds to many thousands of individuals called camps. Particularly, *P. alecto* and *P. scapulatus* colonies size range from 500 ± 10,000 individuals even may increase more in a maternal colony are quite common (Vardon and Tidemann, 1997). *Pteropus alecto* selected roost in mangroves, monsoon, floodplain, rainforest, Melaleuca open-forests, woodland and open forest (Press et al., 1995). The well-exposed trees have a significant role in food availability, social interaction, parturition, young rearing and protection (Lewis, 1996; Altringham and Senior, 2005).

The roosting sites of *Pteropus vampyrus* are reported in coconut groves, mangrove forests and primary forests (Kunz and Jones, 2000). Among them, the occurrence of roost sites is most frequent in mangrove forests and coconut groves due to abundance (Davis and Carter, 1962; Goodwin, 1979; Patterson et al., 1996; Cryan, 2003). In some cases, *P. vampyrus* mutually share maternal colonies with *A. jubatus* (Stier and Mildenstein, 2005). In this regards, *P. giganteus* prefer roost in tropical and sub-tropical areas, generally near to coastal areas (Zhang et al., 2010). The colonies size fluctuate
seasonally but at the time of reproduction, they gathered as several hundred in a single roost (Krystufek, 2009; Sugita et al., 2009).

Roost are the fundamental place for social interaction hence, its regular monitoring may provide qualitative information on threat and population trends and conservation initiatives can be implemented accordingly (Kingston, 2010). At the same time, the population size of the particular colony can be estimated through focal observation (O'Shea et al., 2003). Generally, flying foxes don’t switch roost frequently and repeat year after year at the same geographical location (Fenton et al., 1985; Chaverri et al., 2007).

Flying foxes can travel around 3 – 166 km in a night for foraging (Roberts et al., 2012) and several kilometers (~ 1500 km) during local migration and reproduction (Richter and Cumming, 2006). They are exemplary species as they have evolved with a proficient tool i.e. olfaction for food identification and diet selection. However, they select only dull, large, structurally protected (Bollen and Elsacker, 2002), aromatic or musky and freshly ripped fruits at foraging (Elangovan et al., 2006). While foraging, they systematically bite on ripe fruits part, swallow only juicy contents and ejected fibrous portion as compact rinds (Nelson et al., 2005). Meanwhile, few bats refuse seeds intact at feeding roost or dropped while flying and possibly it might help in the propagation of several plants in the fragmented and isolated areas. Though, it has a high impact on the socio-economic development of the local populations (Fujita and Tuttle, 1991).

In addition, flying foxes are adapted to travel for long distance with large fruits and also capable of retaining the mass of seed in the guts for longer periods (5.5 – 7.5 h) (Shilton et al., 1999). Moreover, it has previously examined that the passed seeds from
bats intestine have a strong germination power and viability than birds (Medellin and Gaona, 1999; Naranjo et al., 2003). It has estimated that around 5% of fruits diversity and their 95% seeds are solely dispersed by frugivorous bats whereas birds and primates contribute merely 25% in their foraging territories (Medellin and Gaona, 1999). Therefore, fruit eating bats have a significant contribution to the seedlings establishment and forest regeneration (Fujita and Tuttle, 1991; Cox et al., 1992).

The fruit bats exhibits several unique strategies and behaviour while foraging. Few of them, prefers earlier foraging (e.g. *Epomophorus gambianus*), few are at periphery (e.g. *Eidolon helvum*), lower canopy (e.g. *Cynopterus sphinx* and *Rousettus leschenaulti*), dense canopy (e.g. *Epomops franqueti*) (Marshall, 1983) while few are reported as postponed forager on the peripheral canopy (e.g. *Pteropus giganteus*) (Nathan et al., 2009). Despite the foraging movements of *P. alecto* (Markus and Hall, 2004), feeding ecology of *P. rufus* (Bollen and Elsacker, 2002), odour based fruit selection of *P. pumilus* and *P. jagori* are well documented (Luft et al., 2003).

Throughout the world, flying foxes are considered as a pest of commercial crop (Aziz et al., 2016) but seed dispersal by them, boomed seed viability and also enhance the seed germination capacity (Djossa et al., 2008; Helbig-Bonitz et al., 2014; Baldwin and Whitehead, 2015). In this context, various studies suggested a fundamental difference between the foraging behaviour of bats and birds such as fruit bats prefer foraging on the fibrous fruits which may contain essential oils with hard rinds but generally birds mostly avoided such fruits while foraging (Galindo-González et al., 2000; Bianconi et al., 2007). Flying foxes systematically select and forage on freshly ripe fruits and drop food remnants underneath of feeding roost as ejected pellets. In some cases, they brought the
entire fruits at their night roost. Accidentally, it dropped on the flyway or sometimes reached up to the night roost (Muscarella and Fleming, 2007).

A study was conducted on the Ryukyu flying fox, *P. dasymallus* showed no apparent conflict with human dwellings (Lee et al., 2009; Nakamoto et al., 2009) while another study revealed a positive conflict with grove owner and *P. giganteus* in Myanmar. Further, it is also mentioned that *P. giganteus* accessed 24 plants as food amongst 13 fruits species also consuming by residing peoples (Win and Mya, 2015). The Rodrigues flying fox, *P. rodricensis* perceived as 36% damage of mango and lychee production in the Republic of Mauritius (Price, 2013). However, *P. giganteus* didn’t prefer to forage on orchards or commercial crops and 30% of the lychee crop damage by birds while bats accessed only 9.5% (Mahmood-ul-Hassan et al., 2010).

Flying foxes are large size and colonial species. Characteristically, noisy and open tree roost makes them more susceptible to threats such as hunting and roost harassment (Mickleburgh et al., 2002; Mildenstein et al., 2005). The population of *Pteropus* spp. is declining globally due to exponential growth of human population and ensuring food and house demands that are directly influencing the roost throughout their geographical ranges (Mildenstein et al., 2005; Jung and Threlfall, 2016). Therefore, around half of the flying fox diversity are categorized as threatened by IUCN. In compression to other regions, a number of fruit bats have been reported from the Indian Ocean but many are highly threatened (Mickleburgh et al., 2002).

Throughout the geographical ranges, the existence of flying fox colonies nearer to human dwelling have long practice for hunting. In Indonesia and Malaysia market, *Pteropus* spp. are tangibly hunted and sold as live or dead. In addition, *P. faunulus*
hunted for medicinal properties, *P. cognatus* teeth used in necklaces, *P. tonganus* for recreation in Vanuatu hotels (Voigt and Kingston, 2016), *P. mariannus* in auspicious occasions (Mildenstein, 2012) and consumed as a delicious dish as having nutritional constituents (Mbete *et al.*, 2011). It is also consumed by nomadic and localities to whom meat might be expensive stuff (Jenkins and Racey, 2008) and sometimes in spiritual starvation (Goodman, 2006). The Chamorro community gathered at party and ceremonial time and happily enjoy the bush meat of the flying foxes. In several parts of the western Pacific Ocean, the Guam flying fox, *P. mariannus* boiled in coconut cream as such and had complete as an appetizing dish (Fahn *et al.*, 2011). Already, *P. tokudae* have been extinct and now *P. mariannus* listed as endangered. However, the prevalence of amyotrophic lateral sclerosis outbreak was recorded as 50 – 100 times higher in Chamorros peoples due to flying foxes consumption (Cox *et al.*, 2003).

It is strongly believed that the bush meat of flying foxes cures diverse ailments such as night blindness (Goodman, 2006), menstrual problems in mammalian females (Walker, 2005), rheumatoid arthritis (Jain *et al.*, 2008), healing of external injuries and cough (Ghosh, 2009), fever (Jaroli *et al.*, 2010), kidney stones (Tuladhar-Douglas, 2008), oil in rapid hair growth (Lohani, 2011) and still in several places, it is hunted simply and eaten just because of the pleasure while it also considered as one of a preferable dishes for the Chinese and Manadonese communities (Harrison *et al.*, 2011).

Since the threats factors are increased exponentially, particularly in Islands. In this context, several studies have been carried out to reveal the causation of threat factors. Concretely, they explore that habitat depletion and hunting pressure arose as dominant population destructor of flying foxes. Presently, the flying fox of the Palau, Chuuk and
Pohnpei islands faced the dramatic period for survivability, though, they have a fundamental role as guardian for the natural process in the tropical forests particularly in patchy habitats (Pierson and Rainey, 1992).

Recent studies reveal that flying foxes are facing large exposure to metallic contamination (Zukal et al., 2015). It was argued that bats have longer life span than other species of similar body mass but higher level of roost fidelity, slow reproduction and long foraging movements, or even local migration during reproduction and harsh period showed lower level of extinction (Wilkinson and South, 2002; Barclay et al., 2003; Golden, 2009). On average, a flying fox can live up to 40 years with suitable habitation (Jurgens and Prothero, 1987; Healy et al., 2014) but highly sensitive to human disturbances or induced habitat changes and environmental stress (Parris and Hazell, 2005; Hayes and Loeb, 2007). Therefore, they strangely categorized as an ecological indicator of heavy metal and habitat quality (Kalcounis-Ruepell et al., 2007; Zukal et al., 2015).

Flying foxes are exposed to all seasonal changes directly hence, they became susceptible to climate change. Therefore, the viability of physical parameters particularly temperature causes fragile death of flying foxes. In the year 2002, the temperature was raised at 42.8 °C in Australian pacific region as a result, around 3,500 individuals died from the nine colonies. Further, the maternal colony of flying fox decline 5 – 6 % of the population due to hyperthermia but the mortality rate was recorded as higher in *P. alecto* (10 – 13%) while lesser in *P. poliocephalus* (>1%). The overall death frequency was estimated that the young ones (23 – 49%) and females (10 – 15%) was major sufferer than adult males (3%) (Welbergen et al., 2008). Approximately 30,000 populations of
flying-foxes (including 24,500 *P. poliocephalus*) decreased due to 19 similar outbreaks since 1989 – 2001 in the Australian pacific region (Eby and Lunney, 2002).

Sometimes the natural calamities (typhoons and cyclones) raise natural food resources. Due to cyclones, the colony size of *P. samoensis* and *P. tonganus* population decreases 80 – 90% in the Samoan islands (Shilton *et al.*, 2008). In addition, several Islands are major losses *Pteropus* population due to the occurrence of typhoons (2 – 4 times in a century) causes major depletion of roosting and foraging trees on which *Pteropus* exclusively relay (Esselstyn *et al.*, 2006). Moreover, many species of flying foxes have become threatened due to over hunting such as *P. aldabrensis* and *P. rodricensis* (Mickleburgh *et al.*, 2009), *P. tonganus* (Hamilton and Helgen, 2008), *P. samoensis* and *P. tonganus* (Brooke, 2001) and *P. mariannus* (Esselstyn *et al.*, 2006).

It was noticed that the IUCN Red List of Threatened species has mentioned *P. giganteus* as a Least Concerned species (Venkatesan, 2007; Dey *et al.*, 2013). It has been reported that about 48% population of *P. giganteus* decline from a single roosting site due to anthropogenic activities in Assam, India (Ali, 2010). Since few decade back, deforestation increased exponentially and species diversity decreased proportionally. The available database on the IUCN showed that species such as *P. tokudae*, *P. brunnus*, *P. pilosus* and *P. subniger* have gone extinct. A number of studies reveal that about half of the flying foxes diversity are threatened due to deforestation and anthropogenic causes. Due to the anthropogenic activities, the flying foxes population coerced to seasonal migration (Struebig *et al.*, 2007; Avgar *et al.*, 2013).

In tropical forest, habitat depletion are considered as the potential damaging factors for faunal diversity. Therefore, it is crucial to understand threat factors and effect
on flying foxes. Therefore, various research suggested for species specific investigation for systematic conservation of threatened species (Myers et al., 2000; Williams-Guillén et al., 2016). However, a number of comparative studies have been carried on birds and mammals and they concretely suggested that the conservation initiatives have to start from slow reproducing and long living species within the confined area and biologically, it helps in the predation avoidance and estimation of threatened factors (Jones et al., 2002).

As the population flying foxes are drastically declining in Paleotopic coordinates, hence they have received exclusive attention by world chiropterologist. Since few decades several studies have been carried out with special consideration of the conservation priorities of winged keepers of the forest (Marshall, 1983; Fujita and Tuttle, 1991; Wilson and Graham, 1992). Though, threatened number of bats species are boomed as the deforestation, urbanization and human population enhanced regionally (Mildenstein et al., 2005). As a result, around the 25% of chiropteran diversity is threatened (O'Shea et al., 2003; Kingston, 2010). As the present situation of chiropteran diversity has been reached at the remarkable position hence, some novel methods for effective conservation which have to be implemented into extensive field survey (Breed et al., 2006). Further, it might be more reliable for minimizing the degree the habitat distraction throughout the habitation zones (Corlett, 2007; Rainho and Palmeirim, 2011). In addition, the effective conservation strategies of flying foxes can exaggerate the genetic variability through captive breeding and enhance the sustainability in natural conditions (O’Brien, 2005). In addition, the regular interaction with local masses as well
as occasional visitors throughout their roosting site may help as the primary steps towards sustainable conservation managements.