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Economic Contribution of Fruit Bats (Family Pteropodidae) Through Durian Fruit Production in the Agroecosystem in Java Island

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ABSTRACT

The Farmers in agroecosystems generally do not know that the existence of fruit bats in agroecosystems is very important because of their function as pollinators for various types of horticultural crops with high economic value, such as durian and other plants that are chiropterophilic. The purpose of this paper is to determine the types of fruit bats (Family Pteropodidae), their role in the agroecosystem, and their role as durian pollinators and their economic contribution to Java. The procedure for preparing this paper, data is collected and selected from relevant literature with the subject matter of the study, then the data is analyzed descriptively-qualitatively-comparative, then the annual economic value is calculated from the durian production produced. It turns out that Java Island is inhabited by fruit bats of 8 genera and 12 species, namely *Macroglossus minimus, M. Sobrinus; Eonycteris spelaea; Aetalops alecto; Chinorax melanocephalus; Cynopterus brachyotis, C. horsfiledii and C. titthaecheil; Megaerops kusnotoi*; *Pteropus vampyrus*; *Rousettus amplexicaudatus and R. leschenaulti.* Five (5) types of which are found in the agroecosystem of Kokap District, Kulonprogo Regency, Yogyakarta. The positive role of fruit bats in the largest agro-ecosystem in Java Island is as a pollinator. Fruit bats have been shown to exclusively pollinate durian plants. On the island of Java, there is only 1 type of durian Durio zibethinus naturally found and in various areas different local durian cultivars are cultivated. The durian trade is very popular, especially during the durian season and starting in 2019 Indonesia does not import durian. If the price of durian at the farmer level is IDR 10,000 / kg, then in 2019, the economic value of durian in Java Island is at least more than 6 trillion rupiah / year), and in Kokap District, Kulonprogo Regency it is more than 10 billion rupiah / year. In conclusion, the annual local economic contribution of fruit bats in the agro-ecosystem is important, especially when the economic value of other chiropterphilus plants is added, such as petai, kapok randu. This information should be disseminated to agro-ecosystem farming communities to inspire their active roles in efforts to preserve the existence of fruit bats in their respective areas.

Keywords: *Economic Value of Biodiversity, Fruit Bats (Family Pteropodidae), Durian (Durio zibethinus), Chiropterophilus, Agroecosystems in Java.*

1. INTRODUCTION

A wildlife must be able to survive to reproduce, and it must reproduce so that the next generation can continue its evolutionary journey through its ability to adapt to changes in its habitat. The pressure of natural selection is getting stronger when natural habitats change rapidly such as when land is converted to agroecosystems. One example of a wildlife group that is able to survive in an agroecosystem is the types of fruit bats, members of the Pteropodidae family. In natural ecosystems, many plants in the forest depend on fruit bats for their pollination and seed distribution. In agro-ecosystems, fruit bats play an important role in the pollination of various types of cultivated plants with high economic value, but there is very little attention to the existence of fruit bats, they are even hunted and considered detrimental because they eat fruits [1]. This

occurs because most farmers in agro-ecosystems do not know that the existence of fruit bats exclusively pollinate various types of horticultural crops that are chiropterophilus which have high economic value.

The purpose of this paper is to determine the types of fruit bats (Family Pteropodidae), their role in the agroecosystem, their role as pollinators and their economic contribution in Java.

The results of this research paper are expected to be used as material to convince bureaucrats, planning officials for wildlife protection and the community that the existence of fruit bats in the agro-ecosystem is not detrimental and is even very beneficial for the community economically.

2. FRUIT BATS IN THE ISLAND OF JAVA

2.1. The Diversity of Fruit bats in Java

Bats are a group of mammals that have the ability to fly and are active at night which are included in the Chiroptera Order. The number of bat species around the world is 848 species [2], and about 310 species inhabiting Indonesia [3]. The number of species in Indonesia may continue to grow because in recent years new species have been found in various regions in Indonesia, for example [4] [5]. The order Chiroptera includes two suborders, namely Suborder Megachiroptera (fruit bats), which includes only one family, namely Pteropodidae and Suborder Microchiroptera which includes several families. The revision results are based on morphological characteristics, behavior and molecular evidence, the suborder concept changes into two suborders, namely Yinpterochiroptera and Yangochiroptera [6] [7]. However, Fenton [8] questions the consistency of this new classification when viewed from the variation in the echolocation ability of its members. In this new classification the existence and position of the Pteropodidae family remains unchanged.

The family Pteropodidae is a group of bats that eat fruits, flowers and / or products of flowers, divided into 2 subfamilies, namely Macroglossinae and Pteropodinae [9][10], or into 4 subfamilia Macroglossinae, Pteropodinae, Harpyionycteridae and Nyctimeninae, however the last subfamily is not found on the island of Java. Members of the Subfamily Macroglossinae include 6 genera and 2 genera including *Macroglossus* and *Eonycteris* which are found on the island of Java, which are pollen and nectar-eating bats. Members of the Subfamily Pteropodinae in Java, represented by the genera *Aethalops, Cynopterus, Megaerops, Pteropus* and *Rousettus,* are fruit-eating bats that may also eat pollen and nectar [3].

The genus *Macroglossus* includes two types, namely *M. minimus* (E.Geoffroy, 1810) and *M.lagochilus* Matschie, 1899 [11]. The concept of this species changed where *M. minimus* Geoffroy, 1810 included *M.lagochilus* as one of the subspecies therein and raised the subspecies *M.m. sobrinus K.* Andersen, 1912 as a separate species [12]. Both are found on the island of Java [3]. *M. minimus* includes 5 subspecies, one of which is *M. minimus minimus* which is found on Java Island [13] and other islands and outside Indonesia [3], [5], and [11]. In Lombok Island, this species visited petai, banana and *Syzygium sp.* [14]. Meanwhile, *M. sobrinus* includes 2 supspecies and only *M. s. sobrinus* found on Java Island [3], and in Burma, Krakatau Island, Nias, Peninsular Malaysia, Sumatra and Thailand [13]. According to [13] in 1981 members of this subspecies are commonly found in gardens in Jakarta, and in Malaysia it is known to eat the pollen and nectar of three types of wild banana and soft fruits and mangroves *Duabanga grandiflora* (Sonneratiaceae) in dipterocarp and montane forests, and disturbed areas [15].

The genus *Eonycteris* includes 2 types and only *E. spelaea,* the cave bats, is found on Java Island [3]. This type includes 3 subspecies, and only *E. s. glandifera* in Java Island [3]), but according to [13] *E. s. spelaea* are also found on Java Island in the western part. In Lombok, this species is found in all types of habitat, but generally in banana gardens, near mango trees and on rivers that are either filled with water or dry [5], and in rock crevices such as caves and caves in coast [16]. In Malaysia, members can be found in agricultural lands and primary forests, seen eating flowers and nectar from bamboo, durian, petai, guava, jackfruit, *Barringtonia* spp. and mangroves that can be more than 38 km from the roosting site [17].

The genus *Aetalops* consists of only 1 species, namely *Aetalops alecto* which is divided into 3 subspecies and only *A.a. acypete* found in Java Island. Their life on the island of Java is not widely known, however, in Peninsular Malaysia it was found roosting in the mountain forests in small colonies consisting of 2-3 individuals. Its main diet is unknown, but it is thought to eat the soft fruit of trees and vines [3].

The genus *Chinorax* includes only one species namely *C. melanocephalus* which includes two subspecies, and only *C.m. melanocephalus* in Java [3]. In Kalimantan members caught under the canopy of dipterocarp forest [18], roosting in small groups in ferns and shallow caves in Peninsular Malaysia [19], allegedly eating fruit trees under tree canopies.

The genus *Cynopterus* includes 4 types, and three of them, namely *C. brachyotis, C. horsfiledii* and *C. titthaecheilus,* are found in Java. C. brachyotis includes 6 subspecies [3] or 9 subspecies [13] which in Java Island is only represented by *C.b. javanicus* Andersen,

1910. Members were caught in gardens in Jakarta and the Bogor Botanical Gardens [13]; in Kalimantan, habitat includes all habitat types including montane forest, dipterocarp forest, home gardens, mangroves and coastal vegetation [19],[20]; and in Lombok caught in a wide variety of habitats, both natural and cultivated [5]. Its diet is fruit, nectar and pollen [21] from about 27 plant genera with a large portion being from Ficus [22]. These animals consume fruits and flowers *Durio zibethinus* and *Sonneratia* spp; and flowers and fruit of *Musa* spp. [20], [21], [23]. *C. horsfiledii* includes 6 subspecies [3] or 4 subspecies [13], and in Java Island it is represented by *C.h. horsfiledii*. In Lombok this species is found in most habitat types, especially in cultivated areas [5]; in Peninsular Malaysia it is found in the lowlands, in habitats such as gardens, moorlands, rubber plantations and other cultivated areas than in forests [19]. *C. titthaecheilus* includes 3 subspecies, and in Java Island only *C.t. titthaecheilus* [13]. In Java this species is found from the lowlands to an altitude of 1600 m asl in habitats that are no longer natural [5].

The genus *Megaerops* only includes *M. kusnotoi* which is not divided into subspecies and is only found in Java [3]. This species was first identified and proposed by Hill & Boeadi in 1978 based on specimens caught at an altitude of 700 m at Hanjuang Ciletuh, Lengkong, Sukabumi Selatan, West Java. His life is still a mystery [12]. [13] put *M. kusnotoi* population in Priority Class: 6 (Rare), because there is still a lack of information about the status of the population and its forms of sustainability threats, it is proposed that a study be carried out on population status and forms of threats to sustainability, especially in protected areas.

The genus *Pteropus* on the island of Java is only represented by Pteropus vampyrus. This type includes 7 subspecies, and only *P. v. vampyrus* in Java Island [13]. In Timor, this species is found in large numbers in mangrove forests, and was found eating *Ficus* fruit along with other species of bats; in Kalimantan it is found along the coast, the lowlands, sometimes in groups invading the interior or flying long distances to eat flowers and fruits, including nectar and fruit such as rambutan and mango and durian flowers [19]. In Sumatra, its members eat fruits, flowers and nectar of various plants such as durian, rambutan, banana, langsat and other garden plants [13].

The genus *Rousettus* in P. Jawa is represented by *Rousettus amplexicaudatus* and *Rousettus leschenaulti. Rousettus amplexicaudatus* includes 3 subspecies and only R. a. infumatus spread across Java [3], [13]. Its members are abundant in Kalimantan [19], in Timor it is quite abundant in various types of habitats from the coast to an altitude of about 400 m above sea level and was found eating *Muntingia* sp. [15]. They are able to travel up to 25 km per night in search of food [23]. *Rousettus leschenaulti* includes 3 subspecies *R..l. leschenuilti* and only *R. l. shortridgei* scattered in Java Island [3], and other islands [13]. Members of this type explore the area between roosting sites, consuming various kinds of fruits, both cultivated and wild plants [25], consuming *Anarcardium occidentale, Annona reticulata,* A. *Squamosa, Heterophragma roxberghii, Oroxylum indicum, Radermachera xylocarpum, Adansonia digitata, Ceiba petandra* and *Mdhuca indicad* flowers and fruits and they also consume the flowers and fruits of *Psidium guajava, Syzygium cumini* and *Mimitaops hexandra* [26]. and reported that in Sri Lanka this species consumed the flowers and fruits of *Psidium guajava, Musa sp., Eriobotrya japonica, Annona muricata and Ceiba petandra* [27].

2.2. Fruit Bats in Yogyakarta

Yogyakarta, which is located in the southern part of the island of Java, is one of the provinces in Indonesian with a relatively small area compared to other provinces on the island of Java, but has a relatively complete type of ecosystem that can represent Java Island starting from the coast, alluvial plains, mountains and mountains, and has a relatively complete type of agroecosystem, starting from rice fields, yards, moor, mixed forest and production forest. Yogyakarta also produces quite large durians and even has a famous local variant of durian, including the durian menoreh, so Yogyakarta is quite representative for a study on durian production which cannot be separated from the existence of fruit bats

The species of fruit bats found in rural and urban agro-ecosystems in Yogyakarta are different. The results of research on the diversity of fruit bats in rural agroecosystems carried out during the durian flowering season showed that in all villages in Kokap District, Kulonprogo Regency, there were 4 types of fruit bats, all of which were found in durian pollen, namely *Cynopterus branchyotis, Cynopterus horsfieldi, Rousettus amplexicaudatus* and *Macroglossus. minimus* [28]. Some people in the area consider that the existence of fruit bats is considered detrimental because they see fruit bats eating fruits such as duku and suck sap from coconut tree tubers that farmers have installed to make sugar. The results showed that there were three types of fruit bats visiting and sucking coconut tree sap, namely *Cynopterus branchyotis, C. horsfieldi* and *R. amplexicaudatus*. Two other fruit bats that do not suck the coconut tree sap in the area are *M. minimus* caught with mistnets, and *Pteropus vampyrus* which was observed directly in the canopy of tall trees and was not caught with mistnets [29]. The results of research in urban agroecosystems conducted at the Gadjah Mada University campus showed that there were 2 types of fruit bats, namely *Cynopterus brachyotis and Cynopterus horsfieldii* [30]. It seems that both types are

widespread in Yogyakarta, both in rural agro-ecosystem and urban agro-ecosystem.

3. THE ROLE OF BATS IN AGROECOSYSTEMS IN JAVA

Most of Java Island is an agro-ecosystem area. Apart from rice fields, [30] describes the condition of land cover in Java which includes forests, talun, mixed gardens, moor, gardens and yards. Judging from the degree of environmental health [31] when compared to natural ecosystems, agroecosystems have lost the ability to organize themselves and lose the ability to sustain their identity in a sustainable manner. The level of diversity and complexity is very important to determine the health degree of agroecosystems.

The role of several types of biota in agroecosystems in providing significant direct or indirect ecological services, such as fruit bats. Fruit bats utilize agrosystems as feeding and roosting habitats, but on the other hand, some plant species cultivated for fruit will not succeed without their presence as pollinators, so the presence of these pollinators has a positive impact on the agroecosystem [33]. The biota that helps the process of pollinating plants at night apart from moths (invertebrates) are bats (Order Chiroptera), which in Indonesia are represented by members of the Pteropodidae family. Horticultural plants whose pollination depends on the presence of bats (chiropterophilous) cultivated in agroecosystems in Java, including *Agave* sp., *Musa* sp., *Ceiba* sp., *Durio* sp., and *Parkia* sp. [34], mango and coconut [17] which some of them are very important for the economy of farming communities on dry land.

Agroecosystems are used by bats to eat fruits planted by the community, giving rise to the perception that their existence is detrimental. Discussions about the decline in horticultural yields in agroecosystems due to being attacked by vertebrate pests, the magnitude of the damage and the decline in economic value have been widely found in the literature, for example by [35]. Some types of fruit bats forage in the form of ripe fruit. The term ripe fruit contains 3 meanings: first, ripe fruit to be harvested, for example bananas (*Musa paradisiaca* L.); second, ripe fruit for sale that must be stored for at least 4 days before human consumption, for example avocado (*Persea americana* Mill.), sapodilla (*Achras zapota* L.), guava (*Psidium guajava* L.), papaya (*Carica papaya* L.) ; and third, ripe fruit on the tree, which is ready for consumption, but if stored for more than 3 days, it will rot. Fruit bats mostly eat ripe fruit in the third category (not in the first and second categories), although in fact very ripe or overripe fruit tends to be overgrown with mushrooms and not suitable for sale.

Agroecosystems are used by bats as roosting habitats where during the day the fruit bats rest and sleep (roost) in trees or in caves. If a large number of bats live in cultivated trees, their existence is considered to be very detrimental because the trees are dead or damaged, but on the other hand, the population should not be completely lost from the area because it is useful to help pollinate cultivated plants [36]. Caves in the agroecosystem on the island of Java are generally inhabited by bats belonging to the Subordo Microchiroptera with a relatively far greater number of individuals than members of the Subordo Megachiroptera which are only 2 species and the number of individuals of population is relatively low, namely *R. amplexicaudatus* and *E. spelea* [3]. The caves where the roosting of the bats are abundant can produce a large amount of guano and can be harvested regularly resulting in an economic contribution to the local community. Because the existence of fruit bats provides ecological services as seed dispersal, and provides economic services in the form of guano production, their existence must be well managed [37].

In general, the role of fruit bats as plant seed dispersers in agro-ecosystems in Java Island is low. After eating the fruit, the bats release the seeds through their feces so that they accidentally scatter the seeds, which, if the medium is suitable, can grow into new plants. Unlike in natural ecosystems, in agroecosystems where most of the plant species found on the land are selected, maintained and managed by humans. If there is a type of plant living in the land that is not desired by the land owner, then that plant is removed.

4. THE ROLE OF FRUIT BATS AS POLLINATORS AND THEIR ECONOMIC CONTRIBUTION IN JAVA ISLAND

4.1. Fruit Bats as Pollinators for Durian Plants

In the Southeast Asia region, the durian fruit is nicknamed the King of Fruit because of its large size (1-3 kg), the taste and smell is very distinctive and the price is relatively expensive, but at the same time it is a controversial fruit because it is very popular with some people but is avoided by some other people. Durian fruit is classified as a true fruit of the simple type (simple fruit), dried fruit (siccus), which breaks (dehiscens) and is classified as a true capsule [38]. The process of forming the fruit begins with the pollination process (the attachment of pollen to the pistil) then continues with the process of fertilization and a fruit is formed which is an organ of continued development of the ovary (ovary). The pollination process includes cross-pollination (alogamy) which is assisted by animal pollinating agents (zoidogamy), namely fruit bats which also pollinate many other plant genera [39].

The plant that bats cultivate is called *chiropterophilus* which is very common in the tropics, and one example is the durian (*Durio zibethinus*). It is characterized by flowers, blooming and receptive at night; flowers are relatively open - growing on tree trunks (cauliflory), are white, cream, or pale yellow which makes them easy to see in the dark; has a strong odor similar to a bat or fruit-like odor; flower structure - long, strong pistil and with large openings, dense anthers so that the head and chest of the bat can be affixed with pollen. In return for the bats pollinating the flowers, flowers provide nectar for these flying mammals which require high energy. The advantage of pollination carried out by bats over birds, bats carry on average ten times more pollen than birds; bats also carry pollen in distances of up to tens of kilometers than birds that are only hundreds of meters [40].

The name durian in a broad sense includes all types of plants belonging to the genus *Durio*. Its members are spread across Southeast Asia, totaling 27 species [41], of which 20 species are scattered in Indonesia, and only 1 species naturally occurs in Java Island, namely D. zibethinus. Nine of the 27 species were reported as edible fruits, including *D. zibethinus* (durian) [42]. Not all species of the genus *Durio* are pollinated exclusively by bats. Research on the pollination of each species of the genus *Durio* is still rare, so it is not certain that each species is *non-chiropterophilus*, *mix pollination*, or *pure chiropterophilus*. According to [43], three types of flower pollination of Durio's members are *non-chiropteriphilus*, which is carried out by birds, namely *D. grandiflorus, D. oblongus*, and *D. kutejensis*. So far, there is no known member of the genus **Durio** whose pollination is carried out by animals during the day and night, but there are other members of the genus that are *chiropterophilus* but are also pollinated by birds [44].

Several studies have shown that durian (*Durio zibethinus*) is pollinated by fruit bats. [1] stated that the pollination of durian was carried out by flying foxes, especially *Eonycteris spelea*. In the agroecosystem of Kokap District, Kulonprogo Regency, during the day, durian flowers are visited by bees and various insects and birds, while at night they are visited by fruit bats, namely *Cynopterus brachyotis*, *Cynopterus horsfieldi*, and *Roussetus amplexicaudatus*; and *Macroglossus minimus* [28]. Wasps, bees and birds suck the remaining honey and can sweep the pollen of durian flowers during the day which begins to wilt and the stigma is not receptive. While fruit bats visit flowers that bloom at night when the stigma is receptive to pollen germination, after circling the flowering durian tree, it lands on the tree trunk and inserts its tongue into the base of the flower to get nectar and pollen. The pollen moves from the anthers to their bodies, and when visiting other flowers the pollen will fall on the stigma causing pollination on other durian trees. [45] reports that pollination of semi-wild durian (*Durio zibethinus*) in agroecosystems as a commercial crop for small-scale farmers in Batetangnga village between October 2017 and 2018 was apparently carried out by 3 species of fruit bats, *namely Acerodon celebensis*, *Eonycteris spelaea* and *fPteropus alecto*. Furthermore, it was concluded that naturally without fruit bats there would be no durian fruit.

4.1. Contribution of Bats through Durian Fruit Production

Durian trade in Indonesia is increasing, public interest and the volume of durian trade are increasing from year to year. The types of durian that are sold are not limited to the local durian harvest but also imported from other regions. Durian fruit has also been processed into various variants of processed food. Purchases are served on line and sent via courier services. Increased interest in consuming durian cannot be separated from promotions in various regions by traders individually and together with the government through organizing durian festivals which are held regularly [46], [47], [48] and [49].

Durian fruit production in Indonesia tends to increase steadily. This cannot be separated from the attention of the government, which tries to spread superior seeds and encourage people to cultivate them. Based on data from the Central Bureau of Statistics [50], starting in 2017, durian production was a surplus, and the amount of the surplus continued to increase. In 2018, it was recorded that more than 1000 tons of Indonesian durian were exported to various countries such as Asian, Middle East and European countries. Since 2016, the Government has developed commercial durian fruit in 6 provinces / districts with a total area of 125 hectares, and dozens of national superior varieties have also been developed [51].

The durian trade at the consumer level has begun to experience a shift. Traditionally, durian sales units use units per fruit (grain). Now, the trade in durian with units of weight (kg) is now common. In 2017, the price of durian at the consumer level in Batam was around Rp. 25,000.00 / kg, and almost the same as the price in Jakarta [52]. In 2019, the price at the consumer level in Yogyakarta is slightly cheaper at Rp. 20,000.00 / kg, but the price of durian at the farmer level is around 50%, namely Rp. 10,000.00 / kg. The indirect economic contribution of fruit bats in an area can be calculated by the production of durian fruit multiplied by the price of durian at the farmer level. If durian production is priced at the farmer level, Rp. 10,000 / kg, then the value of the economic contribution: at the national level (11,698,015.71 kw) = Rp. 11,698,015,710,000; in P. Java (6,092,240.4 kw) = Rp. 6,092,240,400,000; Province in Yogyakarta (62,647 kw) = Rp. 62,647,000,000 [49]; in Kulonprogo Regency it is

46,520 kw = Rp. 46,520,000,000 [53]; in Kokap District, it is 10,162 kw = Rp. 10,162,000,000 [54].

5. CONCLUSION AND SUGGESTIONS

The economic contribution of the existence of fruit bats in Java Island and local areas at the sub-district level through its role as a pollinator for an agricultural commodity, namely durian fruit to farmers, is quite large, not including its services as a pollinator for other commodities such as petai, kapok randu etc. Information on the production of several high economic value commodities depending on the presence of fruit bats is suggested to be socialized to compulsory farmers in the agro-ecosystem so that they voluntarily participate in preserving their existence in their respective areas.

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