Scoping Review of the Bats and their ecosystem Services in Indonesia

Tatag Bagus Putra Prakarsa[1*], *Rizka* Apriani Putri[1], and *Kartika* Ratna Pertiwi[1]

[1]Prodi Biology, Faculty of Mathematic and Natural Science, Universitas Negeri Yogyakarta
Jl. Colombo No 1, Yogyakarta, 55281

Abstract. Bats have an important role in the ecosystem as seed spreaders, pollinators, insect controllers, and nutrient recyclers. However, there is no comprehensive review that evaluating the role of bats across biogeography in Indonesia. The purpose of this study is to study the role of bats as insect controllers, seed dispersers, and pollinators based on the results of research over the last 2 decades in Indonesia. The data collected by research to published research with different keywords that covers different ecosystem of the bats. This review summarizes the importance of conserving bat populations and the ecological services they provide. It is reviewed bat-related literature published over the past two decades, with a total of 46 relevant literatures of the total literature, 47.8% studied bat diversity, 13% diversity and ecology, 17% studied its role as a pest control, 13% studied its role as a pollinator, and 8.7% studied its role as a seed disperser. The findings show that bat-related research in Indonesia has experienced an upward trend since 2003-2023. This study can be used as a basis for sustainable conservation efforts and aiming at achieving the goals of SDGs.

1 Introduction

Bats have a major contribution in maintaining ecosystem stability through the provision of ecosystem services which include insect pest control, pollination, seed dispersal, and guano production as the main energy source in the cave ecosystem [1-3]. But this important role is often ignored [4,5]. So, it is important to measure the ecosystem services that bats provide to humans as a conservation effort. Recent studies have shown that the role of bats as agricultural pest control is critical for food production [6]. Bats as efficient pest insect population controllers. Some of the insect pests that bats control include: Coleoptera, Diptera, Hemiptera, Odonata, Isoptera, dan Lepidoptera [7-12]. This role can lower the cost of pest control. According to [13] who provide examples in their study, *the species Tadarida brasiliensis* can reduce costs of up to US $ 741,000 per year in cotton production in Texas. In their study [11] said *Tadarida plicata* in Thailand helped reduce the loss of thousands of tons of rice in one year. The role of bats as scatterers and pollinators is very important. Bat-bats can help with forest succession. Blight is known to pollinate hundreds of species of Angiosperms, some are plants with high economic value such as durian, jackfruit, and cactus [14-16]. Bats are also producers of guano. Guano has two important roles, first as the main

* Corresponding author: bagusprakarsa@uny.ac.id

energy source in the cave ecosystem, second as a natural fertilizer [2, 17]. Although bats provide important ecosystem services, some are under threat, population trends are declining, and some data is lacking. The main threats faced by bats are habitat loss and poaching [18]. Currently, the problem that is being faced is the information gap between developed countries (America and Europe) with other countries that have high bat diversity such as Indonesia. Therefore, it is urgent to prioritize the long-term preservation of bats. One attempt to affirm the importance of bats to humans is to adequately measure the impact of the ecosystem services that bats provide. The purpose of this study is to study the role of bats as insect controllers, seed dispersers, and flower pollinators based on the results of research over the last 2 decades in Indonesia.

2 Materials and Method

This study is a scoping review of the literature. This study was carried out by searching scientific literature related to bats published between 2000 and 2023 in the Google Scholar, Scopus and ScienceDirect databases. The year range used is because it is before 2000, bat studies in Indonesia were very rare and it was difficult to track down articles/study evidence. The articles we are looking for are in English and Indonesian. Articles used include research articles (journals), proceedings or preprints, dissertations or theses, and books. The keywords used in the search are: insectiv∗, frugivor∗, nectarivor∗, pollinat∗ or in combination with bat∗ or Chiroptera and role * or diversity. These keywords and combinations were chosen to cover the maximum number of published studies, which often use a variety of terms to describe the ecosystem services that bats provide. The search is limited to papers from experimental results with clearly stated research questions or hypotheses. We updated taxonomic information from literature search to Simmons and Cirranello [19] Taxonomic and geographic database for bats https://batnames.org/) [19]. We grouped all studies based on the type of study from the article (bat diversity, pest control, pollinator, seed dispersion, and bat ecology). The bat diversity group includes studies that only show bat diversity. The pest control group includes bat studies that act as insect pest controllers. The pollinator group includes the study of bats and their role as pollinators. The seed dispersion group includes studies of bats and their role as seed dispersers. The bat ecology group includes the study of populations, behavior and habitat. Data are generally analyzed descriptively. To compare bat diversity research and research related to its role, we used one way anova analysis ($p = 0.05$). Statistical analysis is performed with PAST software (PAleontological STatistics) ver 4.13 [20].

3 Result and Discussion

In total, we retrieved 54 articles from 2003 to 2023. The most types of publications are journal articles (43), followed by prosceesiding or preprint, then dissertation or thesis, and at least books. The types of publications in this study are shown in Table 1.

Table 1. The types of publications in this study

Types of Publication	N	Sample of publication
Journal (research article)	43	[10 21 22 23 24]
Proceeding or preprint	7	[25 26]
Dissertation or thesis	2	[10]
Book	2	[2]
Total Number of articles	54	

The total species of bats studied from these references are 46 species, belonging to 9 families and 20 genera. Most of them are insectivore bats or about 58.7%, while more are frugivores or nectar eaters. Details of such species are presented in Table 2.

Table 2. Bat species studied in this research (based on 54 articles studied)

Family	Genera	Species
Hippodideridae	*Hipposideros*	*H. Diadema*
		H. cervinus
		H. larvatus
		H. boeadii
		H. ater
Rhilophidae	*Rhinolophus*	*R.affinis*
		R. pusillus
		R. triofilatus
		R. sedulous
		R. euryotis
		R. simplex
		R. canuti
Minniopteridae	*Miniopterus*	*M. fuliginosus*
		M. magnetar
		M. pusillus
		M. australis
Mollosidae	*Tadarida*	*T. plicatus*
Nycterida	*Nycteris*	*N. javanica*
		N. tragata
Vespertilionidae	*Myotis*	*M. muricola*
		M. adversus
		M. ridleyi
	Kerivoula	*K. krauensis*
		K. lenis
	Murina	*M. rozendali*
Megadermatidae	*Megaderma*	*M. spasma*
Emballouridae	*Emballonura*	*E. Alecto*
Pteropodidae	*Pterophus*	*P. vampirus*
		P. Alecto
	Cynopterus	*C. brachyotis*
		C. spinx
		C. minutus
		C. horsfieldi
		C. taethachilus
		C. nusatenggara
	Rousettus	*R. leschenaultia*
		R. amplexicaudatus
	Macroglossus	*M. sobrinus*
		M. minimus
	Eonycteris	*E. spelaea*
	Sacolaimus	*S. sacolaimus*
	Dyacopterus	*D. spadiceus*
	Tylonycteris	*T. pachypus*
	Penthetor	*P. lucasi*
	Chironax	*C. melanocephalus*
	Acerodon	*A. celebensis*

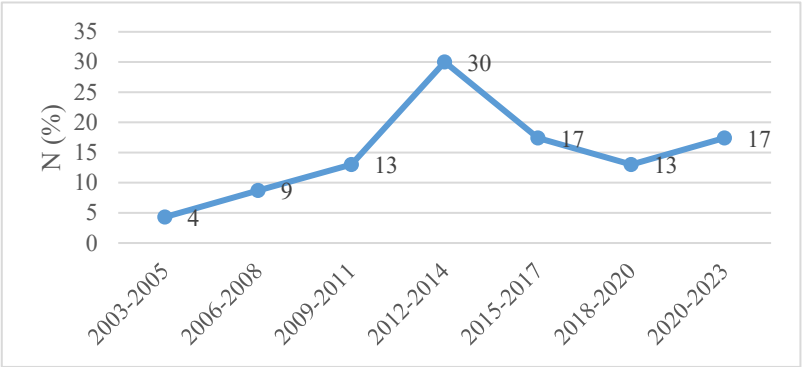

Fig.1. The trend on the number of publications from 2003-2023 on bat research in Indonesia based on Scopus and Google Scholar database

Publications related to bats from 2003-2023 generally experienced an increasing trend, although they decreased slightly after 2014. But increased again after 2018. The trend of publications related to bats in Indonesia between 2003-2023 is presented in Figure 1. Most bat studies in Indonesia (2000-2023) are limited to studying bat diversity, and only a few discuss their role and ecology. In detail, 47.8% studied bat diversity, 13% diversity and ecology, 17% studied its role as a pest control, 13% studied its role as a pollinator, and 8.7% studied its role as a seed disperser (Figure 2). So studies in Indonesia are mostly still studying diversity and ecology only (60.8%). Studies studying the role of bats in general are only 39.2%. In addition, when compared between studies that are limited to studying diversity with studies of each role, statistically significantly different ($p>0.05$). In detail the significance value of each study is presented in Table 3. Seeing this striking comparison, it will be difficult to use these studies to provide recommendations for area management. This is because the ecological services of bats are not known accurately. According to [11] a lot of data on the role of animals is needed to determine their ecological services. Regular and continuous monitoring can also provide accurate recommendations [13].

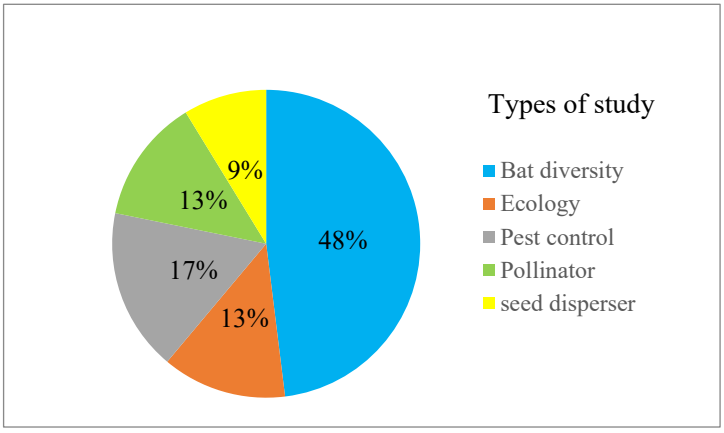

Fig.2. Details of bat study types in Indonesia

Based on these studies, actually in Indonesia more need comprehensive studies about bats and their ecological services that are beneficial to humans. This is considering the number of bat species in Indonesia (239 species) or almost 20% of the bats in the world and is one of the groups with the largest number of species in Indonesia [27, 28]. In addition, their habitat tends to be threatened, mainly by land use change and hunting [18]. This comprehensive

study is urgent considering the role of bats and competing with the rate of habitat decline/destruction. Insectivorous bats are the main insect controllers in agricultural systems [29-31]. Bat pollination is key for food production and forest ecology [32]. Besides that, bats are essential for reforestation because they disperse the seeds of many plant species far from the parent tree, thereby increasing the likelihood that the seeds colonize new patches of forest [33].

Table 3. The significance value of each study

	Div & Ecol	**Pest control**	**Pollinator**	**Seed disperser**
Div & Ecol		0.027*	0.044*	0.002*
Pest control			0.682	0.422
Pollinator				0.316
Seed diperser				

Note: The asterisk symbol shows a significant difference

3.1 Gap and Challenge for Future Studies of the Bats and their ecosystem Services in Indonesia

The literature research on bats and their role as ecological service providers shows that research related to this field in Indonesia has received great attention from 2003-2023. This trend may have been influenced by the status of Global Geoparks and political commitments around biodiversity conservation in the last 2 decades in Indonesia. From these findings, it can be concluded that most studies have placed limited emphasis on bat diversity and can be extended to the role of bats as providers of ecological services. Studies also need to be extended to areas that have not been studied so far. This can later be used as a basis for determining conservation strategies at landscape and sustainable scales [34].

4 Conclusion

This study shows that bat-related research in Indonesia has received significant attention from 2003-2023. However, most of it is still limited to biodiversity research, only a small number of studies comprehensively examine the role or ecological services of bats. Comprehensive study efforts still need to be improved in the future. This study can be used as a basis for sustainable conservation efforts and aiming at achieving the goals of SDGs.

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