Tracking the bat research and conservation directions in the Philippines to identify future prospects and priorities

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Abstract

Empirical evidence is important to develop effective conservation policies. Documenting and assessing the status and threats towards a species and its habitat are essential steps towards developing appropriate policies to protect its population and mitigate existing to prevent future extinction. Here, we summarize recent bat research in the Philippines using a bibliographic approach to assess progress and gaps in both different bat research areas and efforts towards each species in the post-millennia period (2000-2017). An average of 7.9 bat studies is reported per year including grey literature, where only an average of 5.16 is published. Our analysis revealed that majority of bat studies conducted have been directed at community surveys in different areas. However, we found a disparity in research effort in terms of an average number of study per group, the "microchiropterans" (6.15) remains understudied compared to "megachiropterans" (13.78) for the past 18 years, and this reflects the lack of taxonomic studies in the country. While studies in "Ecology" remains low for the majority of species (i.e., 14% of all studies recorded). Interestingly, despite the lack of studies in many areas of bat research, there is a growing collaborative effort in bat conservation initiatives in the Philippines focused on the protection of many endemic and threatened species (e.g., flying foxes) and their habitats.

Keywords: Conservation, Islands, Philippine bats, Priorities, Research efforts

1. Introduction

The 7000 islands of Philippine archipelago hold more than 70 bat species belonging to seven families (Ingle & Heaney 1992; Heaney et al. 2010) (Figure 1). The majority of bat species in the country are found in tropical rainforests (Heaney et al. 2002, Heaney et al. 2006) and around thirty species are cave roosting (Ingle et al. 2011, Sedlock et al. 2014). Ingle and Heaney (1992) pioneered the comprehensive assessment of bats in the Philippines and the developed the first taxonomic key. Approximately half-known bat species in the

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Philippines are Pteropodids and the remainder are predominantly insectivorous bats. Insectivorous species include Vespertilionidae 32% (n= 25), Rhinolophidae (10 species), Hipposideridae (n=9), and other insectivorous species (Mollosidae (n=1), Megadermatidae (n=2), and Emballonuridae (n=3). In terms of endemism, 35% (n=27) is endemic in the country, and higher endemism can be found among Old-world fruitbats (Pteropodidae) which 60% are endemic in the country, restricted to Islands or single locality. In contrast to this, insectivorous families have a very low endemism (12%), though this is likely due to under-description of species present and large numbers of undescribed cryptic species. Many Protected areas have high diversity, high endemism, and many rare species (Heaney et al. 2006). Flying foxes (*Acerodon* and *Pteropus*), for example, are highly selective and largely thrive in primary to secondary forests (Van Weerd et al. 2003, Mildenstein et al. 2005, Stier & Mildenstein 2005).

The diversity of Philippine bats is undeniably high. However, unprecedented environmental change and the increasing human population in the Philippines poses a threat to many bat populations and their habitats (Posa et al. 2008, Wiles et al. 2010). Intensification of agriculture and other land-use changes has also meant ever-increasing demands on land areas. The increasing use of land for agriculture and commercial plantations has been associated with extensive loss and fragmentation of natural habitats and frequently the degradation of remaining habitats in the Philippines (Carandang 2005, Posa et al. 2008, Apan et al. 2017). Furthermore, according to Hughes et al. (2012), a significant change in the diversity and species richness of Southeast Asian bats is projected in the future as a response to different land-use and climate change in the future.

Therefore, to facilitate conservation and management bat research in the Philippines needs to provide an understanding of (1) species diversity and population patterns, (2) the role of bats in providing ecosystem services, (3) effects of current environmental changes to design effective conservation measures. The most recent review of Philippine bats was based on the 'Synopsis of the Philippine Mammals' by Heaney et al. (1998) and was updated in 2010. In 2011, Ingle et al. reviewed the status of cave bats including known roosting caves and karsts ecosystems. Their reviews have provided essential information on conservation status and threats; however, these reviews largely focus the distribution of species and diversity patterns, and further reviews are needed to identify conservation gaps in bat ecology and conservation in the Philippines. The synthesis from this review aims to not only allow researchers to identify future research prospects but to also serve as a guide in national and regional research allocation.

In this review, we applied a bibliographic approach in assessing recent bat studies in the Philippines. Here we provide quantified information on research effort towards species diversity, ecology, taxonomy, disease, and conservation using data from research publications and reports published since 2000. Using this approach is essential to quantify allocation of global or regional conservation efforts and resources (de Lima et al. 2011, for example, Conenna et al. 2017 on insular bat species; Vincenot et al. 2017 on Island flying foxes).

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2. Review Approach

Published literature was searched between January 25 and April 20, 2017. A dataset was created based on the literature published from 2000-2017 obtained from Web of Science (Thompson Reuters), Google Scholar (https://scholar.google.com), self-archived ResearchGate (https://www.researchgate.net) and personal communications with bat experts working in the Philippines. We used the following keywords to screen the literature from 2000-2017: (bat* OR Chiroptera) AND (Philippine* OR Luzon OR Visayas OR Mindanao) AND (Species OR diversity OR Taxonomy OR species composition OR conservation* OR threat* OR ecosystem service* seed dispers* OR pollinat* OR parasite* OR disease*) AND (Threat* OR Hunting OR trade OR bushmeat*) AND (Land-use* OR Plantation* OR Oil Palm OR Rubber*). To maximize the output for our dataset, we included studies published online from conference proceedings from biodiversity societies in the Philippines (i.e. Biodiversity Conservation Society of the Philippines [formerly Wildlife Conservation Society of the Philippines], Philippine Society for Study of Nature, Philippine Society of Taxonomy and Systematics, etc.). Technical reports published online from NGO's and Government offices were also included. To avoid incomplete and biased data sampling, the unpublished thesis was excluded from the review. Since most universities in the Philippines do not have an online library of the thesis to access, we excluded thesis and dissertations from the review.

Initially, our search returned 142 studies (Published article =93, Proceedings of conferences=30, Technical Reports =19). We screened these papers for the following criteria: (1) Research areas, (2) Distribution of research efforts per Island and per study site, (3) Habitat type where the study was conducted, and (4) Number of studies, which recorded the species.

To quantify research efforts by research areas, five categories were set: Diversity, Conservation, Ecology, Diseases, and Taxonomy and Systematics. Each category was divided into sub-areas to differentiate all studies to a more specific area (description is in Table 1). We counted the number of studies conducted within each main and sub-theme and the distribution of bat research was quantified based on where the study was conducted in the main Islands of the Philippines (Luzon, Visayas, and Mindanao). The distribution of studies based on habitat type (e.g., including caves and karst, forest, forest and cave, forest and land-use types, land-use and urban sites) were also assessed.

Lastly, we quantified research efforts per species by evaluating every study and the target species including those species listed and surveyed. This is to assess the attention and research effort given to each species; therefore we set criteria to determine priority species. The frequency of Philippines bats records in studies dated from 2000 to present was assessed and used to rank species effort allocation. Species were ranked using a simplified method using the equation Species Effort Allocation (x) = f / y (where: x= species; f= frequency of species records; y= number of years or coverage of the review). A species with a value equal to 1.00 indicates an average effort per year relative to all species, while <1.00 indicates that higher effort is given to the species, and >1.00 means lower effort is provided.

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3. Results and discussion

3.1. Bat research in the Philippines

Our analysis of bat research effort from 2000-2017 revealed that there is an average of 7.9 (±4.53) bat studies reported per year, where only an average of 5.16 is published in peer-reviewed journals. The majority of the bat research is from Luzon (n= 54, 37.8%), followed by Mindanao (n=49, 34.2%), Visayas (n= 34, 23.8%) and lowest number of studies were conducted across the whole country (n=6, 4%) (Figure 2). Most of the bat studies focused on forest habitats, of which the majority is from Luzon Island (n=42). In caves and karst ecosystems, the majority of the studies were from Mindanao (n=17) and Visayas (n=14) (Fig. 3). In Mindanao, important bat surveys and inventories were made in the recent years increasing the number of known cave-dwelling species in the Philippines. In the Visayas, major studies were conducted in karst areas of the Island especially on the Island of Bohol (see Sedlock et al. 2014, Phelps et al. 2016) and coastal areas of Panay Island (Mould 2012). Nevertheless, there is an inadequate number of studies in the westernmost part of Southern Philippines (e.g., Sulu, Tawi-Tawi, and Zamboanga) (Fig. 4). A comparative study of bat diversity across different habitat types, which is important to understand the impacts of land-use and environmental changes to bat communities is also lacking.

3.1.1. Research allocation per species and understudied taxa

An average of 2.10 (±0.59) studies was published per species per year (species effort/year) from 2000 to present. In general, fruitbats are the most well-studied bat groups in the Philippines with the majority of the species are beyond average effort per year (SEA values <1.00) including the widespread species *Cynopterus brachyotis, Rousettus amplexicaudatus* and *Ptenochirus jagori* (Table 2; Fig. 6).

While there are understudied species, which have no records or studies documenting their occurrence in the country for the past 18 years. For instance, species like *Myotis ater, Pipistrellus stenopterus,* and *Cheiromeles parvidens*, though these species are recorded in other Southeast Asian countries and previously recorded pre-millennia in the Philippines their taxonomy and assessment remain unclear until present (Heaney et al. 1998; Heaney et al. 2005). Island endemic species with a narrow distribution such as *Acerodon leucotis, Desmalopex microleucopterus, Pteropus speciosus, Styloctenium mindorensis* are also understudied species in the Philippines (Table 2). The recently described pteropodid *S. mindorensis* and *D. microleucopterus* were discovered in 2007 in Mount Siburan, Mindoro Island. The rediscovered species *Dobsonia chapmani* (SEA=0.16 effort/year) in Cebu Island is also among the most understudied species. Other single-island species can only be found or have been recorded from few isolated localities, hence, mostly are Data Deficient.

Some species currently classified threatened (under IUCN Redlist standards) but are not considered understudied in terms of research allocation. The number of studies and records towards locally threatened large flying foxes

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Acerodon jubatus (SEA=.83 effort/year) and *Pteropus vampyrus* (SEA=1.00 effort/year) may have increased due to large funding allocation and monitoring in the past decades and have become significant groundwork to the protection of many of their roosting sites in the Philippines especially in Visayas and Luzon (i.e., Mildenstein et al. 2005).

We examined the research effort made per species according to research areas and found that it is in parallel with the Species Effort Allocation analysis. Most fruitbat species are well studied across themes. While most of the conservation studies are directed at species with high conservation concern. In terms of ecological studies, the majority of the research has studied the ecological aspect of foraging activities, roosting preference. Studies on disease (parasites and microbes) included other bat groups but still, the majority of records are within fruitbats (Fig. 6).

3.2. Species Diversity

Our analysis on research allocation per research area showed that the majority of the studies were conducted towards "Diversity: Community composition", accounting for the 56% (n=79) of the studies conducted and published since 2000 (Fig. 5). Despite the high number of species inventories and adding the factor of the archipelagic settings of the Philippines, there are only three newly described species (viz. *Desmalopex microleucopterus, Styloctenium mindorensis,* and *Dyacopterus rickarti*) and *Falsistrellus petersi* (Heaney et al. 2012) and *Kerivoula papillosa* (Duya et al. 2007) area new record in the Philippines Our analysis further showed that the majority of "microchiropterans" remains understudied compared to "megachiropterans" for the past 18 years in terms of an average number of studies per groups (microchiropterans= 6.15, megachiropteran= 13.78) (Fig. 7). This figure suggests that microchiropterans studies in the Philippines require more effort in future research (i.e., improving detection methods). In mainland Southeast Asia (e.g., Thailand, Vietnam, Cambodia), more taxonomic studies (e.g., Bumrungsri et al. 2006, Soisook et al. 2013, Tu et al. 2015, Soisook et al. 2017) have been conducted than in the Philippines, which resolved taxonomic issues and revealed new species and records of microchiroptera.

3.3. Ecological Studies

There are 21 (15%) out of 142 studies focused on the ecological roles and function of bats (Fig. 5). Though Sedlock et al. (2008) suggest that low bat species richness occurs in mixed agricultural habitats compared to tall secondary forests in the Philippines. In addition, Tanalgo et al. (2017) initially reported that bat diversity in small-scale mining areas is lower than pristine sites; and in caves, Phelps et al. (2016) revealed that surface disturbance in caves influences the roosting preference of cave-dwelling bats. There is still limited understanding of bat responses to different land-use types.

On the other hand, despite there is a clear understanding on the importance pteropodids in neighbouring countries in sustaining ecosystem services (i.e., Flying fox pollination durian in Malaysia, Abdul-Aziz et al. 2017), there is little information on this aspect of research across the Philippines. The

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majority of bat ecological studies focused on the seed dispersal ecology of frugivorous bats. Ingle (2003) investigated seed dispersal of frugivorous bats in different landscapes in lowland montane in Mindanao and Gonzales et al. (2009) in the lower successional area in Luzon. In Subic, roosting and foraging ecology of flying foxes (*Acerodon jubatus* and *Pteropus vampyrus*) are well understood through series of surveys and radio-tracking studies conducted in the area since the early 2000s (Stier & Mildenstein, 2005, Mildenstien et al. 2005, Mildenstein et al. 2014). Despite the fact there is a substantial number of studies on the role of the endemic *Ptenochirus jagori* as a seed disperser in the forest in the central Philippines (e.g., Curio et al. 2002, Reiter 2002, Reiter et al. 2004, Reiter et al. 2006) the proportion of other species is still low. All of the studies mentioned above provided substantial evidence on the ecosystem services provided by frugivorous bats as seed dispersers. However, there are no documented studies on the flower visitation of nectarivorous bats, unlike many other SE-Asian countries (e.g., Bumrungsri et al. 2013, Acharya et al. 2015; Stewart et al. 2015; Abdul-Aziz et al. 2017; Lim et al. 2017). Bat biologists from Thailand have clearly documented the ecosystem function of the Old-world fruit bats as pollinators (e.g. *Eonycteris spelaea*) to many economically important plant species from Thailand and across Southeast Asia such as Durian and Petai (Bumrungsri et al. 2013, Acharya et al. 2015, Sritongchuay et al. 2016, Stewart et al. 2016) and as seed disperser in degraded habitats (Sritongchuay et al. 2014). In Malaysia, nectarivorous bats are also documented as pollinators of mangrove species (Mohamed et al. 2016), and Abdul-Aziz et al. (2016) utilized a molecular approach to understanding the pollination roles of *Pteropus hypomelanus* in wild durian (Abdul-Aziz et al. 2017). All of these studies from neighbouring territories have clearly highlighted the significant role of bats in sustaining ecosystem process and have become important in the protection of populations and their habitat.

There are only two studies (out of 6 ecological studies) focusing on the foraging ecology of species of species other than Pteropids. Balete (2010) investigated the diet and foraging behaviour of false vampire bat *Megaderma spasma* in Mt. Makiling, revealing this species consumed at least 10 insect orders, though almost 90% comprised of the Orders Coleoptera, Hemiptera, and Orthoptera. While, Sedlock et al. (2014) explored the diet of *Rhinolophus inops, R. arcuatus, R. virgo,* and *Hipposideros pygmaeus* using molecular techniques and found the complex diet relationship among taxa.

There are only 2 papers on the reproductive phenology of only three species of 78 species in the Philippines viz. *Eonycteris spelaea, Macroglossus minimus,* and *Rousettus amplexicaudatus* (Heideman & Utzurrum 2003, Delpopolo et al. 2014). The reproductive phenology and its relationship to foraging and environment have been widely explored in other Southeast Asian countries. Nurul-Ain et al. (2017) comprehensively documented the reproductive patterns of 11 Malaysian bat species and the ecological factors such as diet and climate affecting them. Furey et al. (2011) have pioneered the documentation of the reproductive patterns of cave-dwelling bats in relation to cave conditions and climate in Vietnam. Both studies have shown the

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relationship of reproductive phenology on climatic patterns and availability of food resources.

3.4. Disease and Parasites

The diversity of disease occurrence in bats has been recently explored in Philippine bat population. A total of 16 studies was recorded focused on both microbe association and parasites to bats (Fig. 5). Arguin et al. (2002) pioneered to study Lyssavirus infections among bats in the Philippines. Jayme et al. (2015) revealed that Reston ebolavirus virus (RESTV) is present in multiple bat taxa. At the same time, the presence of anti-RESTV antibodies was found from the Philippine endemic *Acerodon jubatus*. However, the low prevalence and low viral load suggest broader investigations assess the geographic occurrence of ebolavirus groups in Philippine bats are needed. Recently, Taniguchi et al. (2017) isolated and characterized Pteropine orthoreovirus (PRV) from four Philippine fruitbats (all are non-endemic). In humans, this virus causes respiratory tract illness (RTI). Their findings showed that roughly 90% of the bats sampled tested positive with neutralizing antibodies to PRVs. Furthermore, the risk of PRVs to infect human remains vague and further surveillance is necessary.

Aside from viruses associated with bats, the presence of other microbes (bacteria and fungi) were also studied in selected bat species. Hatta et al. (2016) detected the presence of *Campylobacter jejuni,* bacteria that causing diarrheal illness in human (Coker et al. 2002), were detected from rectal swabs from *Rousettus amplexicaudatus.* Furthermore, Jumao-as et al. (2017) revealed the presence of important agro-economic fungi (e.g. Aspergillus, Penicillium) from fruitbats common to orchards.

Interestingly, studies in bat ectoparasites are increasing and relatively higher on Luzon Island. Alvarez et al. (2015) contributed new host and distribution records of batflies from Mt. Makiling and Mindoro Island (Alvarez et al. 2016), and Amarga et al. (2017a, 2017b) recorded batflies from cave-dwelling bats from Marinduque Island with new records for the Philippines.

3.5. Conservation research and initiatives

Alongside increasing bat research, the effort to conserve bat populations and their ecosystems is increasing in different regions in the Philippines (Bat Conservation International 2015). An example of a successful flying fox species conservation project (initiated in the late 1990's) is "Bat Count Philippines". The project aims to provide baseline information and capacity building towards the conservation of flying foxes particularly *A. jubatus* and *Pteropus vampyrus*, and was piloted in the Northern Part of the Philippines and later in the central Philippines (Mildenstein 2002, Mildenstein et al. 2012). In 2012, the 'Filipinos for Flying Foxes' project was initiated by the same investigators and new collaborators Project expansion in the Southern Philippines is still a challenge and may be due to the lack of research capacity, access (i.e., security and safety of fieldwork), the existence of initial communicated information, and concrete evidence of their occurrence to the areas where flying foxes were thought to exist.

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There are also policies, which enforce bat conservation in the Philippines, for instance for bat caves there is National Cave Committee, which functions to identify and protect important caves based on biodiversity and geological importance. However, this policy often overlooked because of the lack of bat cave biologists working with the committee and it focuses more on caves' potential for tourism and economic purposes (Phelps et al. 2016) as evident to the current number of cave bats under protection by the policy (Ingle et al. 2011). To address the current situation in bat cave conservation in the Philippines as well as in a larger region of Southeast Asia, the Bat Cave Vulnerability and Conservation Mapping Initiative (https://tropibats.com/about-the-bcvi/) was initiated to develop standardized and easy-to-use strategy for cave conservation and to identify important bat cave hotspots in the tropics (Tanalgo et al. 2017).

4. Future priorities in bat research in the Philippines: Addressing current issues

This study is the first to provide a quantified assessment of recent bat research in the Philippines. The findings of this review suggest that there are limited studies in different areas of research i.e., ecological studies to understand ecosystem function and services of bats. In the Philippines, there are many studies that have been carried out but many may have remained as reports, Masters, or PhD theses, and others are in local journals, which is different to access online. Due to this, global species assessment (i.e. IUCN red list) of Philippine bats are challenging especially the assessment of threat intensity per species (Mildenstein et al. 2016). Thus, bat biologists and conservationists in the country are encouraged to diversify bat research and make their information accessible (e.g. publish data and findings) to fill in many gaps in bat research in the country.

Future prospects for bat research should not only focus on 'community-composition' or species inventories but should explore the taxonomy and systematics of different species to resolve those species that belongs complex and unresolved groups (e.g. families Hipposideridae and Rhinolophidae) as many insectivorous bats remain undetermined and Data Deficient (Sedlock et al. 2008, Sedlock 2016). Accurate taxonomic examination or identification of a species is essential in assessing the state of biodiversity as well as the assigning correct conservation status (Dubois 2003) and hence it is the foundation of all bat research and conservation initiatives. The promotion of integration of novel technologies to increase ecological and taxonomic studies should also be prioritized since to address gaps in lack of research in species identification i.e. call library for echolocating species (Sedlock 2016).

The elucidation of bat ecosystem services from different ecosystem types should be another top priority in Philippine bat research since there are only limited studies that have been made in this area. This will represent another important step to develop a concrete basis for the species and habitat conservation. The impacts of deforestation, human intrusions in habitats, and other land-use changes on bat populations and their ecological dynamics should also be explored alongside. Regional studies on the impacts of climate change

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on current and future distribution of Philippine bats especially those with very narrow distribution are also imperative in order to heads-up conservation actions and mitigation.

The interactions of human and bats including its habitat is also an interesting aspect of bat research to explore in the region. Illegal hunting and trade of bats from forests and caves for food, bush meat, and trade is an emerging threat to bats in many regions especially protected areas but the lack of quantitative information warrants rigorous investigations (Scheffers et al. 2012, Tanalgo et al. 2016, Tanalgo 2017). While, consumption of bat meat is quite common across the country and although studies on disease associated with bats were studied in some species in the Philippines, investigations on the risk of disease spillovers from bat species remain unexplored (Watanabe et al. 2010).

Consequently, to address the gaps in bat research in the Philippines it is essential to highlight and strengthen research and conservation capacity among local researchers from the academia, NGO's and other institutions concerned to attain effective and sustainable conservation especially in biodiversity hotspots for bats (Racey 2013). Most importantly is to encourage and train young bat researchers in the region to sustain the need for conservationists and advocates in the future.

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