Important but not a priority? Conservation concerns & priorities for Philippine bats in the Anthropocene

Anthropogenic caused environmental changes coupled with rapid population growth are altering the Earth's biota at unprecedented rates, posing an alarming threat to the long-term persistence of many species of both animals and plants and so, a science-based prioritisation encompassing multiple dimensions is necessary. In the over 7000 Islands of the Philippine archipelago, a large proportion of bat diversity constitute the mammalian fauna of the country, which performs various ecological functions. However, many species are in need of high conservation attention yet the level and understanding of their vulnerability remain anecdotal. In this study, we aim to determine the vulnerability of Philippine bat species from different threats, which is important to establish effective conservation decision making and prioritisation in the future. We found that habitat loss and direct human-driven (e.g., hunting) is the main threat to more than half of the Philippine bat species. As expected, threatened and endemic species are facing higher levels of vulnerability with the strong positive relationship between Species Vulnerability Index (SVI) and Absolute Number of Threats. However, a weak relationship between Species-Research Effort Allocation (SREA) and SVI indicating a strong disparity in efforts and priorities among species. Given the high species richness, endemism, vulnerabilities, and disparity in efforts, the Philippine is indeed a conservation hotspot for bat biodiversity. We suggest that priorities should holistically consider multiple facets in knowledge paucity, levels of threats and species vulnerability for effective conservation process. Eyeing carefully on the emerging and unknown threats, increasing conservation education, and forging equitable partnerships and capacity building to bolster bat conservation in the Philippines.

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Important but not a priority? Conservation concerns & priorities for Philippine bats in the Anthropocene

Krizler Cejuela. Tanalgo[1, 2, 3, *] & Alice Catherine Hughes[1*]

[1]Landscape Ecology Group, Centre for Integrative Conservation, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, Mengla, Yunnan Province 666303, People's Republic of China; [2]International College, University of Chinese Academy of Sciences Beijing, 100049, PR China; [3]Department of Biological Sciences, College of Arts and Sciences, University of Southern Mindanao, Kabacan 9407, North Cotabato, the Republic of the Philippines

Abstract

Anthropogenic caused environmental changes coupled with rapid population growth are altering the Earth's biota at unprecedented rates, posing an alarming threat to the long-term persistence of many species of both animals and plants and so, a science-based prioritisation encompassing multiple dimensions is necessary. In the over 7000 Islands of the Philippine archipelago, a large proportion of bat diversity constitute the mammalian fauna of the country, which performs various ecological functions. However, many species are in need of high conservation attention yet the level and understanding of their vulnerability remain anecdotal. In this study, we aim to determine the vulnerability of Philippine bat species from different threats, which is important to establish effective conservation decision making and prioritisation in the future. We found that habitat loss and direct human-driven (e.g., hunting) is the main threat to more than half of the Philippine bat species. As expected, threatened and endemic species are facing higher levels of vulnerability with the strong positive relationship between Species Vulnerability Index (SVI) and Absolute Number of Threats. However, a weak relationship between Species-Research Effort Allocation (SREA) and SVI indicating a strong disparity in efforts and priorities among species. Given the high species richness, endemism, vulnerabilities, and disparity in efforts, the Philippine is indeed a conservation hotspot for bat biodiversity. We suggest that priorities should holistically consider multiple facets in knowledge paucity, levels of threats and species vulnerability for effective conservation process. Eyeing carefully on the emerging and unknown threats, increasing conservation education, and forging equitable partnerships and capacity building to bolster bat conservation in the Philippines.

Keywords: Anthropocene, Hunting, Islands, Philippines, Vulnerability

***Corresponding authors:** Email: KCT (tkrizler@gmail.com); ACH (ach_conservation2@hotmail.com)

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Introduction

Within Island tropical ecosystems, such as the Philippines, bats fulfil unique and crucial roles, and when displaced the entire structure and function of the ecosystem is likely to alter considerably (Cox and Elmquist, 2000; Jones et al., 2009; Kunz et al., 2011). Bat provides wide range of essential ecosystem services –from pollination, seed dispersal, pest control to tourism (Wiles et al., 2010; Kunz et al., 2011; Bumrungsri et al., 2013; Wanger et al., 2014) making these taxa as a good ecosystem health indicators for they respond to changes in habitat conditions (Medellin et. al. 2000 Russo and Jones, 2015). Regardless of their importance majority of the bat species and their populations are globally imperilled by diverse anthropogenic threats combined with unprecedented environmental change (Voight and Kingston 2016). Worldwide, the principal cause of bat mortality and extinction was anthropogenic-induced (O'Shea et al., 2015), particularly, habitat loss is one of the main threats to bats worldwide (Mickleburgh et al. 2002; Racey, 2013; Voigt and Kingston, 2016). In Southeast Asia, which is a centre for bat biodiversity and substantial percentage of bat fauna appears to be highly dependent on intact forest; relative deforestation rate may cause a consequence of forest loss of as much as 74% by the end of century (Sodhi et al., 2004; Lane et al., 2006; Struebig et al. 2008; Miettinen et al. 2011). The continuous habitat loss coupled with changing climate in the region is projected to result in the loss of >40% and global extirpation losses of estimated 23% of species by 2100 (Struebig et al., 2008; Hughes et al., 2012). In addition to land-use and climate change, the negative human perception, and lack of knowledge on bat ecosystem services hinder effective conservation implementations that drive the persecution of populations from colonies and hunting for bushmeat ((Hutson et al., 2001; Mickleburgh et al., 2009; Mildenstein et al., 2016).

A robust science-based evidence is critically looked-for to develop effective measures and bolster conservation progress. Mainly, to circumvent the risk of estimated future species loss and habitat reduction it is essential that conservation scientists should set achievable conservation targets in multiple dimension and scales (Rudd et al., 2011; Brum et al., 2017). Across the world, bat biologists proposed a strategic plan to address present and prevent future threats affecting multiple species at multiple sites, and protection of intact areas with highly diverse bat communities (Bat Conservation International, 2014). Although bat conservation knows no borders, conservation actions and protection are typically realised by geopolitical territories and threat levels and potential solutions widely vary (Tuttle, 2013; Verde Arregoitia, 2016). The dissimilarity on geopolitical priorities is a reflection of country's capacity, access, and availability of resources to address knowledge gaps and conservation processes (Ellison, 2005; Trimble and van Aarde, 2012) i.e., in the Philippines lack of capacity in other facets of bat research influence the disproportionate bat research diversity in the country (Tanalgo and Hughes, 2018). Thus, the enactment of priorities and conservation management should start in a local or national scale to compliment a large-scale target e.g., regional or global scales (Gärdenfors 2001; Kark et al. 2009; Rudd et al., 2011; Mazor et al., 2013; Beger et al., 2015).

The Philippines holds around 79 bat species distributed throughout over 7000 Islands of the archipelago, with an estimated >30% endemism and presumably higher (Heaney et al., 2010; Tanalgo and Hughes, 2018). Yet, a high proportion of species remains at risk of population declines from a wide range of threats and vulnerabilities. Tanalgo and Hughes (2018) recently published a comprehensive review of the state of knowledge of the Philippine bats aiming to identify gaps and future targets significant to heighten bat conservation in the country. Their review revealed the huge disparity of research allocation across research areas on Philippine bats i.e., there are a few numbers of studies towards species taxonomy, and conservation, and largely towards conservation-related studies. In addition, although, research effort toward threatened and endemic species do not differ significantly 87% of the species remains understudied. Nevertheless, the extent of threats across species remains unclear in their recent review; hence, we aim here to determine major threats and vulnerabilities to the Philippine bats and its relationship to information adequacy i.e., allocated research effort, which we believe both are equally important elements to develop effective regional and national conservation prioritisation (Tanalgo and Hughes 2018).

Methods and materials

We assessed the threats and vulnerabilities of the 79 species of Philippine bats using the same dataset from Tanalgo and Hughes (2018). We reviewed 142 studies published online (full articles=93, conference proceedings=30, and technical reports=19) 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 correspondence to bat scientists based in the Philippines. We used the latest International Union for Conservation of Nature Red List database (http://www.iucnredlist.org/) to supplement our assessment.

We classified the threats and vulnerabilities to 18 'classes' representing direct, indirect, and natural but we omit the intensity and range of threats to each species (e.g., size of population threatened), so, if a threat is recorded to be associated to the species it will be scored 1 (present). Consequently, we calculated the species vulnerability of each species based on the number and proportion of known threats and species biotic potential values adapted from the index of Tanalgo et al. (2018). Species vulnerability (SVI) is expressed as the product of sums of the means from threats/vulnerabilities multiplied to the species' biotic potential scores. The SVI is calculated using the equation: $SVI_{(species)} = [\sum (\bar{x}T_{dir} (.50)] + [\bar{x}T_{ind} (.40)] + [\bar{x}T_{nat} (.10))] * [\sum (BP_{cons} + BP_{E})]$. Where: SVI= Species Vulnerability Index; T_{dir}= direct anthropogenic threats (e.g., hunting, persecution); T_{ind}= indirect anthropogenic threats (e.g., deforestation, logging); T_{nat}= natural threats (e.g., typhoon and storms); BP_{Cons} = Conservation status values; BP_{E} = Endemism values (see Tanalgo et al., 2018 for values).

We used the non-parametric Kruskal-Wallis Rank Test or Mann-Whitney *U* Test to determine whether (i) the number threats/vulnerabilities varied among families, (ii) conservation status, (iii) and endemism. Moreover, we applied Pearson's *r* to test whether there is a relationship between Species Vulnerability Index (SVI), the absolute number of threats, and Species-Research Effort Allocation (SREA), which assess the adequacy of research efforts provided to species in a certain period. SREA can be calculated using the equation: SREA(x) = Ro/y. Where: SREA = Species-Research Effort Allocation; x = Species; Ro= the frequency the species (x) was recorded from publications/reports; yo= Number of years covered by the review or assessment (in this case 18 years). Values closer to 1.00 indicates higher effort is given to the species, and <1.00 indicates lower effort is provided. We used JASP Statistics v9.01 (JASP Team, 2018) for all statistical analyses and visualisations. We set all significance at $P = 0.05$.

Results

We assessed threats to Philippine-based on recent literature and IUCN Red List database. Out of 79 species, 16 (20%) are considered 'Threatened' based on IUCN standards (Vulnerable, Endangered, and Critically Endangered). Almost half of the Philippine bats are chiefly threatened by continuous deforestation (n=43, 54%), agriculture and logging (n=37, 47%). While, bushmeat hunting and harvesting of bats (n=33, 42%) is a major direct threat, particularly, in large flying foxes and cave-dwelling fruitbats. In caves, unregulated tourism threatens almost all known cave-dwelling bats (n=26, 33%) in the Philippines. Other threats include extractive industries such as mining and quarrying that threatens 22 species of both forest and cave-dwelling bats (Fig. 1).

Using Species Vulnerability Index (SVI) as our proxy to gauge the level of threats and vulnerability of taxa (species or family). Mainly, 36 (46%) species falls above the median (1.13) SVI value. We found that SVI values significantly differ among family (*Kruskal-Wallis*= 22.66, *d.f.*=6, P<.001). The Old-World Fruitbat Pteropodidae is the most threatened group ($\bar{x}_{SVI}$=2.148±1.30) among bat families (Table 1), for example, top species with highest SVI value includes the globally threatened and rare species *Acerodon jubatus* (SVI=5.295), *Dobsonia chapmani* (SVI=4.067), *Pteropus speciosus* (SVI=4.033), *Pteropus dasymallus* (SVI=3.720) and *Stylonycteris mindorensis* (SVI=3.200) (Table 2). Similarly, SVI differed significantly across conservation status (*Kruskal-Wallis*=24.54, *d.f.*=5, P<.001) and the levels of threats is highest among Critically Endangered ($\bar{x}_{SVI}$=4.067) and Endangered Species ($\bar{x}_{SVI}$=4.088). Whereas, in terms of endemism, endemic species experience higher threats ($\bar{x}_{SVI}$=1.97, Mann-Whitney U Test, P<.001) compared to non-endemic species ($\bar{x}_{SVI}$=.085). Lastly, we found positive correlation between SVI and species absolute number of threats (Fig 1.A) (r=.0725, n=79, P<.001), while there is a weak correlation between Species-Research Effort Allocation Index (SREA) Species Vulnerability Index (SVI) (r= -0.032, n=78, P=0.784) (Table 1; Fig 1.B).

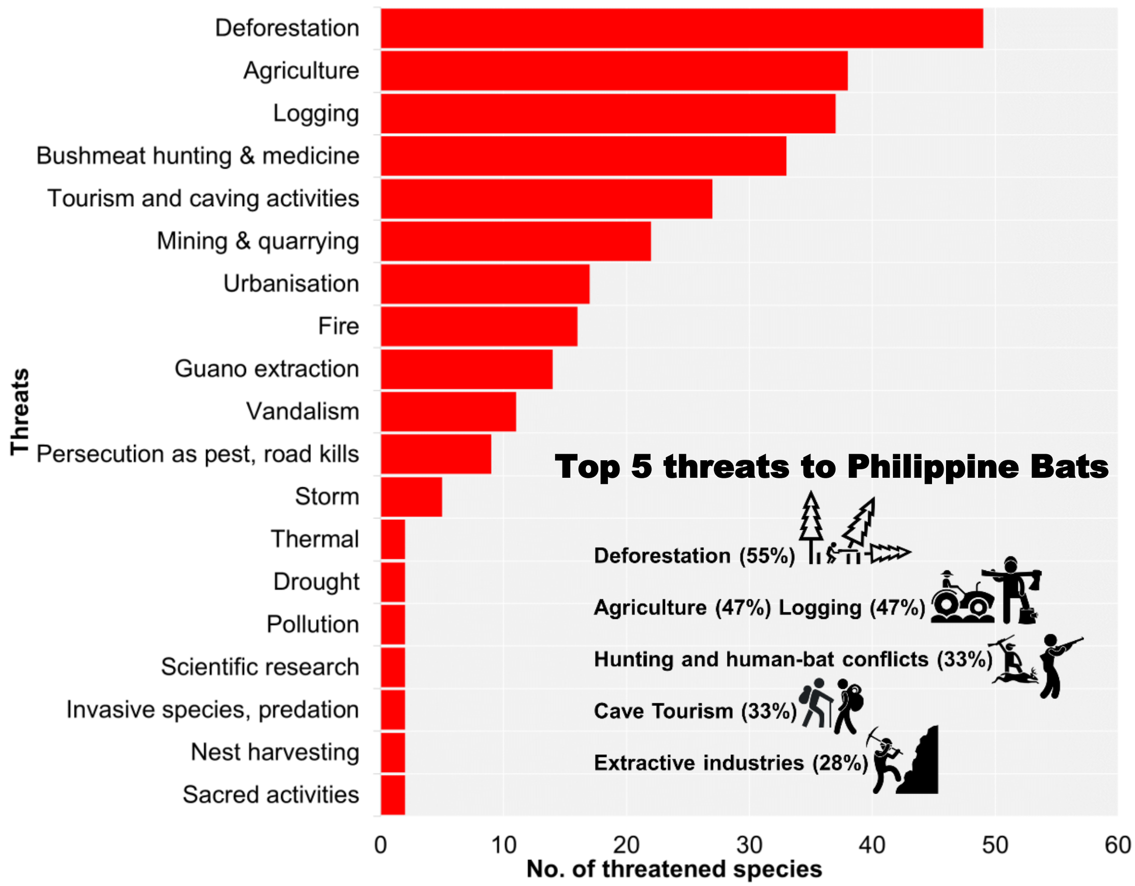

Figure 1. Main threats to Philippine bats. The threats to Philippine bats can be grouped under two main categories: habitat loss and human-induced.

Discussions

Threats to the bats of Philippine Islands

In nearly two decades, there is no substantial amount of studies and evidence explicitly elucidating the impacts of different threats and vulnerabilities to bats. Nevertheless, most of the bat studies and assessments suggest two main potentials drivers of population declines to many species. Land modification and loss, and human-bat conflicts are among concerns that impend not only species but as well as to their critical habitats.

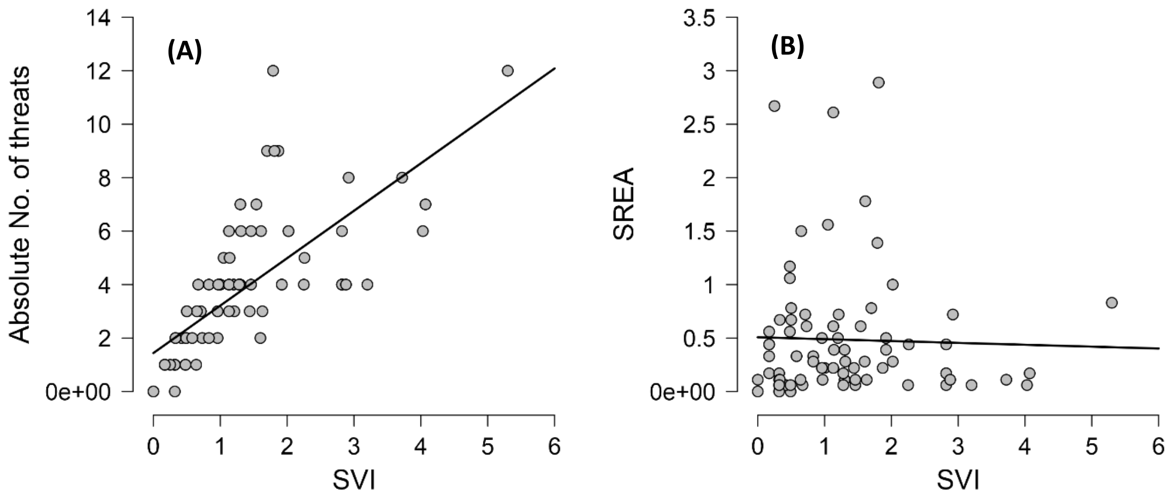

Figure 2. The relationship of Species Vulnerability Index (SVI) to absolute total number of threats (A) and Species-Research Effort Allocation (SREA).

1. Habitat loss and modification

Although, in general, there are there are no clear and extensive understanding of the impacts and dynamics of deforestation and land conversion to bat population and communities in the Philippines. One considerable factor of this is a very few numbers of studies that demonstrated threat interactions to species diversity. In this present work, we noted that extensive land uses, agriculture, and commercial plantations are among the significant threat to the majority of Philippine bat species. Out of 79 species, 43 (54%) species are threatened by deforestation, followed by agriculture/cultivation (n=37, 47%), and commercial logging (n=36, 45%). Currently, an estimated 90% of lowland forests in the Philippines have disappeared. The country's forest biodiversity has grown by 2.1% (100,000 ha) annual forest loss from 2000-2005. Land use in the Philippines has reached 70% to 20% of decline rate in the forest over the 20th century, with an estimated 9.8 million ha of forest altered from 1935 to 1988 (Carandang, 2005; Suarez & Sajise, 2010; Forest Management Bureau, 2013; Apan et al., 2017). Deforestation for mostly industrialisation and infrastructure occurs heavily and may highly affect many important roosting and foraging sites in the country especially for forest-dependent species. In many forested areas including few areas of protected areas, the continuous illegal logging, slash and burn activities (*Ka-*

ingin), and the conversion of natural forests to agricultural and plantations are among the highest threats to forest bats (Ingle 2003; Jakosalem et al., 2005; Heaney et al., 2006; Nuneza et al., 2015). Recent studies on Philippine bats on different land-use types have demonstrated that bat diversity varies significantly between natural forest and degraded habitats (e.g., plantations) (Sedlock et al., 2008; Tanalgo et al., in prep). A comparative study of species richness and activities between tropical rainforests and agropastoral habitats in a protected area in Northern Philippines revealed lower species richness in mixed agricultural sites compared to tall secondary forests (Sedlock et al., 2008).

Conversion of intact and secondary forests to plantation have intensified in the recent years across Southeast Asia including in the Philippines (Fitzherbert et al., 2008; Hughes, 2018). Although, agricultural areas may support many bat species in the Philippines (Heaney et al., 1998), a rapid assessment study of bat diversity between lowland protected areas and commercial plantations (Oil Palm and Rubber) revealed that higher bat diversity remains to occurs in protected areas (in lowland forests) (Bello et al., 2010; Achondo et al., 2014). The more generalist species e.g., *Cynopterus brachyotis* was found to be common and abundant in both pristine and degraded habitats but lower endemism was found in plantations. These findings suggest that plantations are least suitable habitat for endemic and specialised bat species in the Philippines, however, can still support common and widespread yet important species. This is further supported by recent findings from Tanalgo et al. (in prep.) showing that fruitbat population differs significantly across the season between two plantation types (rubber and oil palm) in lowland Mindanao. They found that common fruitbats abundance is higher in rubber plantation compared to oil palm but species richness remains low. The conversion of natural habitats to agriculture and its current expansion rate and development in previously forested or protected areas is a widespread threat to Asian biodiversity (Hughes, 2017; Hughes, 2018). Common cash crops such as Oil Palm and Rubber are presently dominating wide land areas in the Philippines and is displacing lowland forest (Villanueva, 2011). Although, the Philippines is not a major Oil Palm producer in the Asian region (Shiel et al., 2009) it has a consistently produced more than 100 thousand metric ton of palm oil in 2009 to 2012 (Index Mundi, 2018). Nevertheless, it is set to change in the future as the country set to convert large land areas for oil palm plantation in the future. At present, the Philippines has roughly 90 thousand hectares of palm oil producing lands and concentrated in Mindanao Island, south of the Philippines (The Agriculture, 2018), with a projection of almost million land area for potential land production (Philippine Bureau of Agricultural Statistics, 2012). While, Rubber dominates around 222,601 hectares of land areas (as of 2016) (Philippine Statistics Authority, 2016). In the first quarter of 2018, rubber production has increased by 4.4% (47.36 metric tons) compared to the same quarter in 2017 (45.37 metric tons) (Philippine Statistics Authority, 2018). The major contributor of rubber production in the country is chiefly from Mindanao Island.

The alarming expansion rate of plantations in the Philippines particularly Oil Palm (Reyes, 2014), which is more dreadful and unsustainable (Mendoza, 2007; Miler, 2017), prompts to establish a long-term investigation in commercial plantations using bat populations as surrogate bioindicators (Russo and Jones, 2015). Increasing comparative studies within agricultural areas and forest ecosystems using novel approaches (e.g., mist nettings, harp traps, and echolocation calls) would greatly help understand deeper the effects of changing landscapes to bat population that is relevant to implement conservation measures (Sedlock et al., 2008).

2. Extractive industries

Extractive industries such as mining and quarrying threaten 22 species (27%) of Philippine bats, but this is an underestimated number as many mining areas in the country remains under assessed due to the difficulty of security access (personal observation). Mineral mining activities and the establishment of mining road for the survey are prominent in few protected areas with high bat biodiversity (e.g., Mt. Hamiguitan, Relox et al., 2009). A preliminary work on bat diversity in a small-scale gold mining adjacent to lowland forest in Southern Mindanao showed that bat diversity and activity is very low (Tanalgo et al., 2017). The absence of pristine vegetation and foraging sites due to vegetation removal contributes to this negative status of bats in the area. The same study also observed the capture rates were lower during the dynamite blasting in mining holes compared to non-blasting periods, however, the short period of sampling period makes the result inconclusive and warrants to a more comprehensive monitoring. Mining operations are rampant in the southern part of the Philippines' Mindanao Island, which imperils a large proportion forested areas (Responsible Mining Research in Mindanao http://stprmm.carsu.edu.ph/content/responsible-mining-research-mindanao, 2014). The contribution of the mining and quarrying sector to the country's gross domestic product (GDP) has increased from 1% to 5% in 2013 to 2014 respectively. While, cement production extracted from karsts areas of the country has increased around 9% to 22 metric tons from 20.1 metric tons in 2013 (Mines and Geosciences Bureau, 2015; Fong-Sam 2017). In the total land area of more than 30 million hectares of the Philippines, the Mines and Geosciences Bureau of the Philippines has estimated a proportion of about 9 million hectares as potential high mineral content site. As of 2012, an estimated of around 3.8 per cent of the Philippine land area was already covered by mining tenements and around 30 firms are operating for metallic mines (Mines and Geosciences Bureau of the Philippines, 2012). Most of these areas are in forested areas or if not, it is adjacent to protected areas. Habitat alteration is the main effect of mining in the study area among of the associated activity is road construction in the middle of the forested area. Establishment of road channels in the area destroys many of bats' feasible roosting area and food sources preventing species to interact with each other, also preventing other ecological and biological processes of the species (Berthinussen and Altringham, 2011). The Department of Environment and Natural Resources legislated the Philippine Extractive Industries Transparencies Initiative (PH-EITI) to improve the accountability and transparency in the Philippine mining sector (Agub, 2013; Jamasmie, 2014), however, this do not mainstream biodiversity conservation. In response, at present, the government's new strict environmental policy "Integrating biodiversity conservation in mining project cycle would surely help mining companies restore, possibly to near-original condition, mining-affected forests in the country" (Villanueva, 2017). Nevertheless, given that mining and quarrying create nuclear impacts on the ecosystem, hence, an all-encompassing biodiversity monitoring not only for bats but also for all natural resources, as a whole is a needed.

3. *Exploitation of cave and cave-dwelling bats*

Caves and underground habitats are important for almost half of global bat species (Furey and Racey, 2016; Tanalgo and Hughes, in. prep.). In the Philippines, more than 30 bat species are cave dwelling and dependent from caves for their life histories (Ingle et al. 2011; Sedlock 2014; Phelps et al., 2016; Alviola et al., 2015; Tanalgo & Tabora 2015). Smaller caves can even host multiple species and some caves can host millions of individuals, for example, the Monfort Cave Sanctuary in Samal Island in Mindanao was recorded as the largest single species colony of *Rousettus amplexicaudatus*, accounting for almost 2.3 individuals in single cave site (Carpenter et al., 2014). Yet, large proportion of 1,756 (258 surveyed by DENR-PAWB) known caves in the Philippines are understudied and may be facing diverse anthropogenic threats such as mineral mining, hunting for bushmeat, recreation, bird's nest harvesting, and unregulated cave tourism are placing many cave-dwelling bats imperilled (Ingle et al., 2011; Sedlock et al., 2014; Alviola et al, 2015; Phelps et al., 2016; Tanalgo et al., 2016). Recent findings showed evidence on the impacts of human exploitations on caves and underground ecosystems in the Philippines. Natural caves closer to the settlements have shown high bat population declines in short periods due to susceptibility to illegal hunting, trade, and higher visitation from tourism and recreation (Sedlock et al., 2014; Tanalgo and Tabora, 2015). Caves in Southcentral Mindanao, for example, showed drastic declines in bat populations based on historical and present surveys (Tanalgo and Tabora, 2015). Hunting is common on these caves, large fruitbats such as *Rousettus amplexicaudatus* and *Eonycteris spelaea*, and large insect bats *H. diadema* are hunted from large colonies for food and exotic menus (Tanalgo and Tabora, 2015; Tanalgo et al., 2016). While in Central Philippines, smaller bats are hunted for recreation (Phelps K., personal correspondence). Local communities harvest large bat colonies by leaving wide fishnets on cave opening and introducing loud noise from pistols, smoking using coconut torch, and directly disrupting roosting bats. Hunted bats are decapitated and skinned which then sold in local households at 2.00 to 3.00 (US$ .06) pesos per piece (Tanalgo et al., 2016). In a similar case in Bohol (Central Philippines), human disturbance in caves (e.g., hunting, tourism) may have caused some bat species to abandon their roosting colonies. The majority of the caves surveyed in Bohol have experienced both current and historical human-induced disturbances, generally by bird's nest collection, bushmeat, and guano extraction, which led to drastic declines in population. For instance, in 2001, there were an estimated 500,000 bats in Canlunsong cave but a population landslide to 200 bats observed in most recent surveys (Sedlock et al., 2014).

Regardless of the importance of caves for a large proportions of Philippine bats, most of the country's cave ecosystems lack scientific studies (Ingle et al., 2011; Alviola et al., 2015) at the same time facing great threats due to lack of specific statutory protection, this may be because protecting caves are expensive and time-consuming. The existing policy, National Cave and Cave Resources Management and Protection Act (Republic Act 9072), aims to identify and protect cave biodiversity and geological importance, although important it often focuses on tourism potential and economic values and undermines the protection of cave-dwelling bats and cave biodiversity as a whole (PAWB-DENR, 2008). Thus, developing strategies to effectively conserve and monitor caves in the Philippines using a holistic and uniform procedure is an important step forward and to facilitate the paucity of information on the vulnerability of cave-dwelling bats in the Philippines (Tanalgo et al., 2018).

4. Human-bat conflicts

Apart from habitat alteration, direct human interactions to bat populations are more severely contributing to the declines in populations. In areas where poverty is high, many locals rely on hunting and consumption of bushmeat to satisfy/compensate limited access to food sources and income i.e., in areas where agriculture and livelihood is poorly established (Scheffers et al., 2012; Tanalgo et al., 2016; Tanalgo, 2017), particularly in remote protected areas (Heaney et al., 2006; Raymundo and Caballes, 2016; Tanalgo, 2017). In the country, large flying foxes and fruit bat are highly vulnerable to hunting pressures for food and medicine e.g., indigenous people in Mt. Apo National Park hunt flying foxes for subsistence (Tanalgo, 2017). While, smaller fruit bats like *Cynopterus brachyotis, Ptenochirus jagori, Rousettus amplexicaudatus* and *Eonycteris spelaea* are hunted by locals for meat and trade in protected areas in Luzon Island (Scheffers et al., 2012) and Mt. Matutum Protected Landscape in Mindanao (Nuneza et al., 2015). In Subic Bay, apart from hunting for food, urban residents hunt large fruit bats and flying fox (e.g., *Acerodon jubatus* and *Pteropus vampyrus*) for sport and recreation (Mildenstein et al., 2016). Overhunting has even led to the drastic decline and local extinction of threatened species, for example, *Dobsonia chapmani* in Negros Island (Raymundo and Caballes, 2016).

Human perception of the importance or role provided by bats widely varies across the region but chiefly lacks understanding. The long existence of negative perception and misbeliefs are among important drivers of declines or in the poor conservation attention by citizens towards bats in the country (Raymundo and Caballes, 2016). In an unpublished survey on fruit grower and fruitbat interaction in orchard dominated area in the Philippines showed low awareness among fruit growers towards the ecosystem services provisions of bats (i.e., fruitbats as pollinators of main fruit crop industries) (K.C. Tanalgo et al., unpublished data). Instead, bats are perceived as pest and nuisance that causing damage to fruit crops such as durian *(Durio* spp.*)*, rambutan *(Nephelium lappaceum)* and lanzones *(Lansium domesticum)* and income loss during the peak fruiting season (June to August). In response to this misbelief, growers mitigate bats by persecution i.e., establishing fishnets around orchards to exclude bats from coming in the fruit orchard. In some cases, growers intentionally shot flying foxes from their roosting colonies to prevent them from visiting orchards. In village localities, locals associate bats to a folklore *Aswang* (a local half human, half bat monster creature) and because of fear many large colonies are exterminated (i.e. cave smoking, shotgun) (Tanalgo et al., 2016).

The negative bat-human relationship in the county may be implicated in the lack of information on the ecosystem services provisions of bats to different ecosystems in the country, especially in the economic perspective. According to the recent review, bat research in the country towards ecosystem services remains lacking particularly on the understanding the bat pollination to important crops (e.g., durian) (Tanalgo and Hughes, 2018). Mainstreaming bat ecosystem services provisions through establishing science-based evidence and increasing outreach education programs will considerably change their negative connotations and will progress conservation directions (Trewhella et al., 2005; Abdul-Aziz et al., 2017a; Abdul-Aziz et al., 2017b).

5. *Changing climate: an unknown threat to the Philippine bats*

The changing climate will certainly imperil global bat species (Sherwin et al. 2012; O'Shea et al., 2016), however, the knowledge on the projected impacts of global changing climate to the Philippine bats remains lacking (Tanalgo and Hughes, 2018). Although, Hughes et al. (2012) projected the impact of climate change and land-use change on bat species diversity in mainland Southeast Asia. The study has projected the effects of future climate scenarios on bat diversity and predicted changes in range size for 171 bat species throughout mainland Southeast Asia. Chiefly, it is a significant reduction in species richness in all regions with current high species richness between 2050-2090 it is the severe scenario of continuously increasing human population size, regional changes in economic growth and the greenest scenario, global population peaking mid-century. In 2050 and 2080, those scenarios set by the IPCC together with the climate change factors have predicted that 3-9

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% of the species would lose its niche, 2-6 % of species may have no suitable niche space in 2050-2080. Synergistically, vegetation loss and climate changes combined results to only 1 % of species showed no variability in 2050 predictions. Expansion of ranges was also projected in some species however due to barriers to dispersal especially species with poor dispersal capacity expansion is impossible. Under bioclimatic scenarios, 1-13% of species showed no projections in their current range. To circumvent expected biodiversity loss in the future efficient and effective facilitation of range shifting for dispersal-limited species it through landscape connectivity improvement (Hughes et al., 2012). Synergistically, land-use and climate change have led to substantial range contraction and increase extinction probability in the decades (Root & Schneider, 2002; Thomas et al., 2004). Apart from monitoring, it is imperative to have a robust measure of climate and land-use change impacts to Philippine bats and to identify areas where highest conservation protection is needed and evade future species loss.

6. *Scientific (over) collections for disease research and public perception: an emerging threat for Philippine bats?*

Scientific collection and disease surveillance are not currently but may emerge as a main threat in the future due to an increasing trend of bat-associated diseases studies in the Philippines over the past 2 decades (Tanalgo and Hughes, 2018). Despite numerous surveillance on their diseases, no clear evidence on the incident of bat mortality, transmission to human or livestock that associated bat-microbes (e.g., virus, bacteria, and fungi) (Tanalgo and Hughes, 2018). Globally, around 13% of 222 recent studies collected bats for disease surveillance and dominantly coming from the tropics (Russo et al., 2018). Although only a small number of species are currently at risk of scientific collection, the number of species and individuals collected for disease research if not regulated may pose a significant threat. Thirty-five species (n=35, 44%; 7 endemic species) of Philippine bats have been identified for disease research. Most of these studies have euthanised numerous individuals, for example, single nationwide studies have sampled 1047 individuals (brain of 821 individuals) from 14 species to examine for the associated virus, and other studies may have even executed 21 species (see Tanalgo and Hughes, 2018 for a list of studies). Most of the species collected (and killed) for disease surveillance in the Philippines are not classified threatened based on the global red list. However, it is important to take note that there are some non-threatened species that are facing higher threats in local scale i.e., *Rousettus amplexicaudatus*, despite globally considered least concerned, in the Philippines it is at risk with multiple threats from habitat loss and extensive hunting. In addition to over collection of bats, disease-related studies have significantly contributed to the negative image of bats and undermine lifelong efforts to conserve and protect many bat populations (López-Baucells et al., 2017; Tuttle 2017; Racey et al., 2018). Therefore, disease studies that deals with collecting bats should essentially consider the conservation implication of their collections and surveillance, and should clearly enforce educational progress and the conservation importance of such studies.

Synthesis: conservation priorities for Philippine bats

According to the IUCN standards, there are 16 species of Philippine bats considered as 'threatened'. In this study, we quantified the extent of bat priorities based on their conservation status, endemism, with a number of threats per species. A large percentage of the Philippine bats are presently at risk to various vulnerabilities. The most threatened groups are the frugivorous bats, in particular, the *Acerodon jubatus* (SVI=5.300), an endangered and endemic to the Philippine species. Imperilled by multiple threats this species is threatened by habitat loss to direct threats such as hunting and trade. The Golden-crown Flying Fox *Acerodon jubatus* is one of the important, key forest species in the Philippines, which provides various ecosystem services important for the sustainability and survival of many forest ecosystems, which both people and other species are dependent to as home and source of food and other needs (Mildenstein et al., 2005). While the *Dobsonia chapmani* (SVI=4.070) is also among the top priority in terms of species vulnerability. This species was previously assumed as 'extinct' after it was not recorded from its distributional until rediscovered last 2004. This species is an EDGE species and only known to occur in few localities in Central Philippines (e.g., Islands of Negros and Cebu) (Isaac et al., 2007; Paguntalan et al., 2008).

Reyers (2004) stated that recent attempts to streamline the identification of priorities requiring immediate conservation management (e.g., Connena et al., 2017) have urged the development of procedures for identifying species or population and regions for biodiversity importance that faces the largest threats in the near future (e.g., Hughes et al., 2012; Struebig et al., 2015; Tanalgo et al., 2018). In the Philippines, research effort is disproportionately distributed among habitat types i.e., the majority of the studies, for example, inventories are conducted in forest habitats or protected areas (Tanalgo and Hughes, 2018). Yet, it is also important to eye conservation prioritisation on 'cold spot' areas particularly those areas outside protected areas with potential high biodiversity and conservation value. Mildenstein et al. (2005) radio-tracked endemic *Acerodon jubatus* and found to forage around an entire 14,000 ha of protected areas but also recorded the species foraging in an adjacent forest outside the borders of protected areas in Subic Bay, Pampangga.

In this study, we found the number of threats is an important factor contributing to species vulnerability as evident to the strong positive relationship between the species vulnerability index (threats*conservation status) and absolute number of threats. Surprisingly, there is a weak relationship between research efforts and species vulnerability as measured by Species-Research Effort Allocation and Species Vulnerability Index, respectively. This finding suggests that species that conservation efforts and prioritisation should, but not limited to, keenly eye on both knowledge gaps (e.g., for species, habitats, and thematic areas) and conservation needs. Although we clearly found that threatened species experience more threats compared to non-threatened groups, it is important to take note that there are non-threatened species having values above the median SVI values, indicating they experience a high level of threats despite they are considered least concerned and they may be equally important to receive high conservation attention. In addition they may have the tendency to experience 'Passenger Pigeon Fiasco' effects, where a lesser threatened or commonly abundant species may gone extinct (or decrease in population) due to human-driven activities such as hunting for bushmeat and trade (Tanalgo and Hughes, 2018), especially that one of the main threats to Philippine bats are caused directly by human. Therefore, conservation allocation i.e., monetary budget to implement research or protection of habitat should carefully balance between threatened and non-threatened species.

Many species remains understudies and the present understanding of the species threats and vulnerabilities are ambiguous and ununiformed. Nevertheless, it should be taken into account that this current study gauged the threat levels based only on best available literature, authors' accounts, and the latest IUCN assessment. Very little number of the recent studies have evidently documented threats on their findings; this warrants that the future bat studies and assessments in the country must include an inclusive account of threats and disturbance associated to the species and its habitat based on a standardised comparable approach. The improvement of Philippine IUCN red list assessment especially of data deficient species is also crucial to advance the understanding the extent of threats and vulnerabilities across species and habitats. Here, we present another evidence supporting the recent review that the diversification of studies in different thematic areas i.e., bat ecology in changing environments or different land-use types must also be important priorities. Brum et al. (2017) highlighted that integrative biodiversity conservation encompassing not only species distribution, endemism, and vulnerability but also functional and evolutionary traits, to guarantee holistic priorities based on broad and multi-dimensions of diversity.

Take-home message

Along with the increasing number of bat studies relevant to Philippine bat conservation, yet there is clear disparity on the priorities persisting on research needs and species vulnerabilities. The understanding of Philippine bats in terms of its provision of different ecosystem services provisions and the impacts of a wide range of threats remains unknown. Essentially, it is a call to intensify diverse inclusive research through capacity building of geographically lacking regions, support next generations of scientists in the Philippines, promote equitable collaboration and partnerships, transparency, and open-data sharing and accessibility. We hope this ought not to hinder progress in Philippine bat conservation but instead be a challenge and opportunity especially for young and emerging bat scientists in the Philippines.

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