Chapter 1
Bats in the Anthropocene

Christian C. Voigt and Tigga Kingston

Abstract Humans have inadvertently changed global ecosystems and triggered the dawn of a new geological epoch, the Anthropocene. While some organisms can tolerate human activities and even flourish in anthropogenic habitats, the vast majority are experiencing dramatic population declines, pushing our planet into a sixth mass extinction. Bats are particularly susceptible to anthropogenic changes because of their low reproductive rate, longevity, and high metabolic rates. Fifteen percent of bat species are listed as threatened by the IUCN, i.e., they are considered Critically Endangered, Endangered or Vulnerable. About 18 % of species are Data Deficient, highlighting the paucity of ecological studies that can support conservation status assessments. This book summarizes major topics related to the conservation of bats organized into sections that address: the response of bats to land use changes; how the emergence of viral and fungal diseases has changed bat populations; our perception of bats; and drivers of human–bat conflicts and possible resolutions and mitigation. The book ends with approaches that might advance bat conservation through conservation networks and a better understanding of human behavior and behavioral change.

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1.1 The Emergence of a New Geological Epoch: The Anthropocene

The world in which we live is fragile; a small layer of organismic activity covers the planet like a microbial film on top of a large boulder. Nonetheless, humans treat the Earth as if anthropogenic impacts on this delicate biological layer may be absorbed by unfailing natural buffers. Yet, convergent and overwhelming evidence from all over the world underlines that mankind has already changed and continues changing the face of our planet. Among the many transformations humans imposed on our planet, some of the most severe appear to be (1) the addition of more than 550 billion metric tons of carbon to the atmosphere which are the main drivers of global climate change and ocean acidification (Gray 2007; Ciasi and Sabine 2013), (2) the alteration of the global nitrogen cycle by the use of artificial fertilizers (Canfield et al. 2010), (3) the routing of more than one third of global primary production to human consumption (Krausmann et al. 2013), (4) the ongoing mass extinction of species (Barnosky et al. 2011), and (5) the globalization of transport which has resulted in the spread of invasive species and pathogens (Lewis and Maslin 2015). It is now widely recognized that global ecosystem services may be inadvertently suffering from human action, because human-induced environmental impacts are overriding natural process that have dominated our planet for millions of years (Steffen et al. 2011).

In the face of lasting human impacts on the Earth's geological conditions and processes, many scientists, beginning with Paul Crutzen and Eugene Stoermer in 2000, now posit that our actions have brought us to the dawn of a new geological epoch—the Anthropocene. The pros and cons regarding this definition, which literally means "Human Epoch" and would succeed the Holocene, are still heavily debated (Monastersky 2015). Yet skeptics are declining in number, and much of the current debate focuses on the exact beginning of the Anthropocene, generally considered to be c. 1800. The Anthropocene working group of the Subcommission on Quaternary Stratigraphy reports to the International Commission on Stratigraphy with a proposal to formalize the Anthropocene in 2016. For the purpose of this book, we do not refer to an exact starting point of the Anthropocene, but merely acknowledge the fact that humans have an impact on virtually all global ecosystems and that wildlife species such as bats (order Chiroptera) have adjusted to these changes, experienced substantial population declines, or gone extinct.

1.2 Bats in the Anthropocene: The Conservation of a Nocturnal Taxon

Bats (order Chiroptera) include more than 1300 extant species, forming the second largest mammalian order, and are unique among mammals in their evolution of powered flight. Although the common ancestor of living bats dates back to the K/T

boundary (c. 70 mya), the most rapid radiation of any mammalian order resulted in all 18 extant families by the end of the Eocene c. 37 mya (Teeling et al.2005). Moreover, although the majority of bat species are insectivorous, trophic diversity is extraordinary for a single order, with frugivores, nectarivores, piscivores, sanguinivores, and carnivores represented. Bats currently inhabit all continents except Antarctica, and in many parts of the world, especially the tropics, are the most species-rich mammalian group at a given locality, with alpha diversity reaching about 70 species in the Paleotropics (Kingston et al. 2010) and over 100 in the Neotropics (Voss and Emmons 1996; Rex et al. 2008). From any perspective, bats are an evolutionary and ecological success story. Nonetheless, bat populations are under severe threat in many regions of the world (Racey and Entwistle 2003). The last recorded case of a bat species driven to extinction is that of the Christmas Island pipistrelle, *Pipistrellus murrayi* (Lumsden and Schulz 2009; Lumsden 2009; Martin et al. 2012), yet this species is most likely not the last one to vanish from our planet.

The IUCN Bat Specialist Group is in the process of reassessing the Red List status of bat species, with the current assessments of 1150 species mostly completed in 2008, with 34 species assessed since. From these assessments, five species were assessed as Extinct (giant vampire bat (*Desmodus draculae*), dusky flying fox (*Pteropus brunneus*), large Pelew flying fox (*P. pilosus*), dark flying fox (*P. subniger*), and Guam flying fox (*P. tokudae*)). The giant vampire bat is known only from the fossil and subfossil records, and the causes of its extinction are unknown. However, the four island *Pteropus* spp. are all victims of the Anthropocene, with hunting and habitat loss as the main drivers of extinction. Fifteen percent of bat species are listed in the threatened categories [Critically Endangered (CE), Endangered (EN), and Vulnerable (VU)] and 7 % are Near Threatened (Fig. 1.1). Around 18 % of species are Data Deficient (DD), and there have been a wealth of new species discovered since the last assessment. The pattern of vulnerability is fairly consistent across families (Fig. 1.2), with the notable exception of the Pteropodidae with 36 % of species extinct or threatened, probably because of their size, their appeal as bushmeat and for traditional medicine,

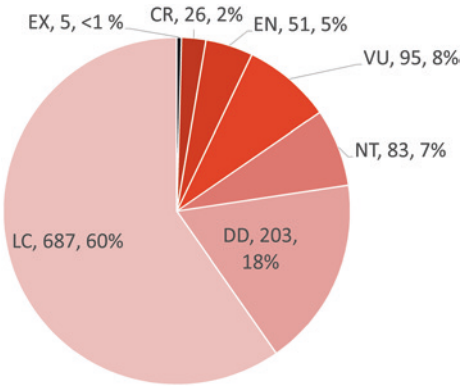

Fig. 1.1 *Red* List status of the 1150 bat species assessed 2008–2014 (IUCN 2015). IUCN categories are *EX* Extinct, *CR* Critically Endangered, *EN* Endangered, *VU* Vulnerable, *NT* Near Threatened, *DD* Data Deficient, *LC* Least Concern. Number of species and percentage of all species given as labels

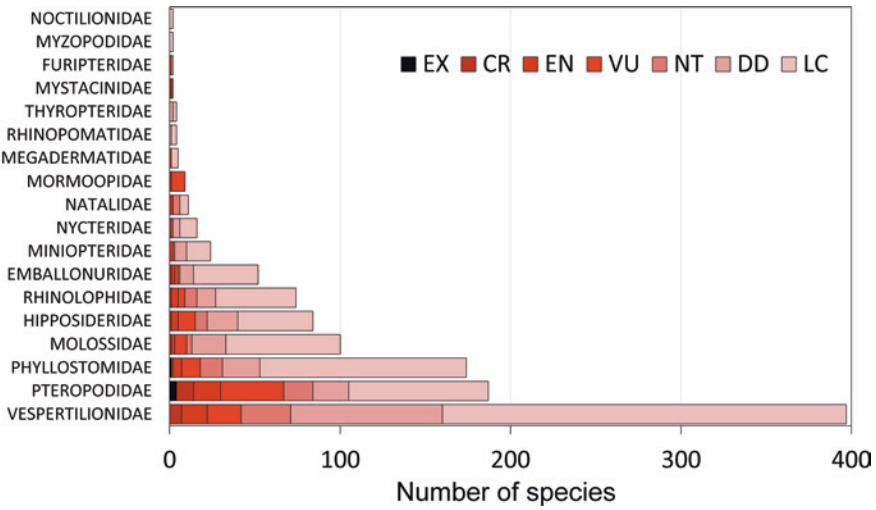

Fig. 1.2 *Red* List status of bats by family. Abbreviations as for Fig. 1.1

and because many form susceptible island populations. Even this depicts only part of the picture; populations are only considered stable in 21 % of all species and increasing in less than 1 %. Of the remaining species, populations are decreasing (23 %) or the trend is unknown (55 %). Moreover, of the 687 species assessed as Least Concern (LC), current specific threats were identified for about 27 % of species. Declining populations and identified threats suggest a bleak future, and it is probable that more species will satisfy the rigorous criteria of the threatened categories in the coming years.

Globally, the major threats to bat species identified by IUCN assessments are land use change (logging, non-timber crops, livestock farming and ranching, wood and pulp plantations, and fire), urbanization, hunting and persecution, quarrying and general human intrusions on bat habitats (Fig. 1.3). Bats are particularly susceptible to these human-induced perturbations of habitats because of their distinct life history. Bats are on the slow side of the slow-fast continuum of life histories (Barclay and Harder 2003). For example, they reproduce at a low rate (Barclay et al. 2004) and are long-lived mammals (Munshi-South and Wilkinson 2010; Wilkinson and South 2002). Thus, bat populations recover slowly from increased mortality rates. Despite their low reproductive rate and longevity, bats have relatively high metabolic rates owing to their small size which leads to relatively high food requirements (Thomas and Speakman 2003).

Lastly, bats are nocturnal animals with often cryptic habits. Even though they are present in many larger cities of the temperate zone, they often go unnoticed by their human neighbors. It is quite likely that perceptions of bats would be very different if *Homo sapiens* evolved as a nocturnal hominid. Or to put it in the words of Rich and Longcore: What if we woke up one morning and realize that we missed

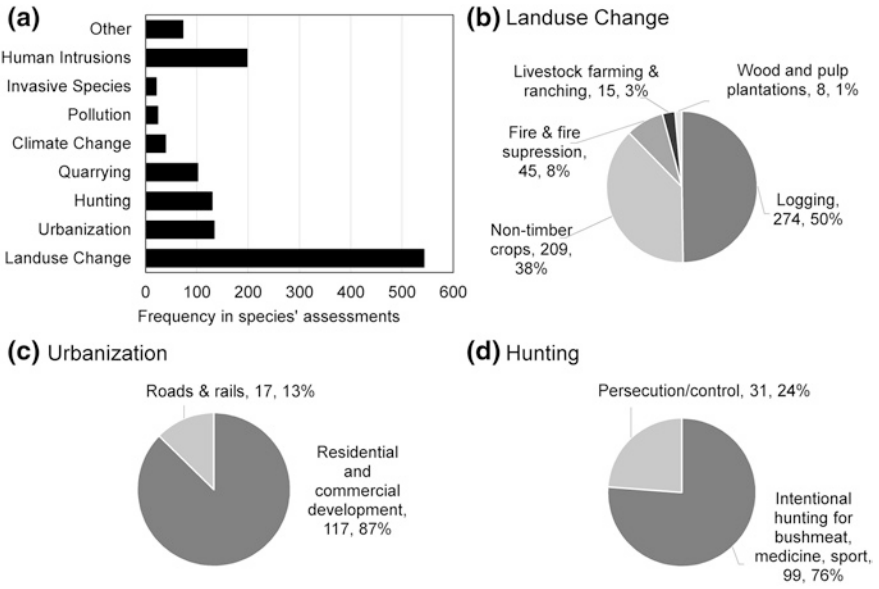

Fig. 1.3 Frequency of threats listed in the IUCN assessments of bat species. **a** Distribution of major threats across assessments. Land use changes, urbanization. and hunting are aggregations of IUCN listed threats given in **b–d**. Frequency of threat and percentage contribution are given

half of the story in our conservation efforts, namely the night part? (modified after Rich and Longcore 2004, p. 1). This brings up an important question: Do nocturnal animals benefit less from legal protection than diurnal animals? Are we more concerned about animals that we see and interact with during daytime? Do human societies perceive and evaluate, for example, fatalities of birds of prey at wind turbines in a different way than bat fatalities when both ought to benefit from the same level of protection? Do we consider recommendations to reduce light pollution for the sake of nocturnal animals such as bats, or does the expansion of the human temporal niche into the night come at high costs for all nocturnal animals? In summary, we speculate that bats as nocturnal animals might be particularly exposed to human-induced ecological perturbations because we are driven by our visual system and therefore tend to neglect the dark side of conservation, i.e., the protection of nocturnal animals.

1.3 Why Care About Bat Conservation?

The reasoning for the conservation of nature can be manifold, reaching from purely moral to monetary arguments and legal requirements. It may also vary according to the scale of the conservation approach, i.e., whether it is driven by

local, national, or international perspectives. Indeed, ethical considerations for the protection of species—although quite often neglected in modern civilization—should be the primary motivation; i.e., the obligation of humans to conserve nature for the simple reason of its existence and for the more selfish reason to make the diversity of biological life accessible and useable to following generations of humans. Lately, economic arguments for the conservation of nature are increasingly used, e.g., the importance of protecting water catchment areas to provide potable water or irrigation in agriculture. So-called ecosystem services of nature are highly valued in modern societies and therefore benefit from increasing protection.

Recent attempts to critically review the ecosystem services provided by bats have revealed that many species offer unique and large-scale monetary benefits to agricultural industry (Kunz et al. 2011; Ghanem and Voigt 2012; Maas et al. 2015). For example, flowers of the Durian tree are only effectively pollinated by the Dawn bat, *Eonycteris spelaea*, in Southeast Asia (Bumrungsri et al. 2009). Durian is a highly valued fruit in Asia with Thailand producing a market value of durians of almost 600 million US$ annually (Ghanem and Voigt 2012). Other bats consume large amounts of pest insects, thereby offering services that could save millions of US$ for national industries (Boyles et al. 2011; Wanger et al. 2014). However, the monetary approach for protecting bat species is a double-edged sword, since bat species without apparent use for human economy may not benefit from protection compared to those that provide some ecosystem services. Moreover, arguments based on economic or utilitarian values of wildlife may appeal to self-interest motivations and suppress environmental concern (Kingston 2016). In this context, it is important to note that we have just started to understand the ecological role bats fill in natural ecosystems. For example, bats have been recently documented as top-down regulators of insect populations in forest habitats of the tropics and temperate zone (Kalka et al. 2008; Boehm et al. 2011) and also in subtropical coffee and cacao plantations (Williams-Guillen et al. 2008; Maas et al. 2013). Finally, bats are protected by law in some countries. For example, they are covered by the Habitat Directive of the European Union and thus strictly protected in E.U. countries. Also, migratory bats benefit from some level of protection because they are covered by the UN Convention for the Protection of Migratory Species. Countries that have signed this convention are obliged to support conservation actions that are beneficial for migratory species. CITES (The Convention on International Trade in Endangered Species of Wild Fauna and Flora) protects threatened species through controls of international trade in specimens. The precarious conservation status of the flying foxes is apparent. Currently, *Acerodon jubatus* and ten *Pteropus* spp are on CITES Appendix I, with trade only permitted in exceptional circumstances, and the remaining *Acerodon* and *Pteropus* species on Appendix II, by which trade is controlled to avoid utilization incompatible with their survival.

1.4 About This Book

The idea to publish a book about bat conservation was stimulated by the "3rd International Berlin Bat Meeting: Bats in the Anthropocene" in 2013. The overall goal is to provide a summary of the major threats bats are facing in a rapidly changing world. The book is organized in four major sections: (1) bats in anthropogenically-shaped landscapes, (2) emerging diseases, (3) human–bat conflicts, and (4) conservation approaches. The basic concept of chapters in all of these sections is to review the literature that is available in peer-reviewed journals. We are aware that many topics related to bat conservation have also been addressed in brochures or books published by non-governmental or governmental organizations. Sometimes these sources have been cited in the corresponding chapters, yet in most cases authors of this book have focused on the aforementioned sources of information.

From our editorial perspective, the chapters cover the majority of relevant topics in bat conservation. However, we acknowledge that at least three topics are missing in this book. First, this book misses a chapter on "bats and global climate change," because Jones and Rebelo (2013) published a recent review on this topic and the body of literature about this topic has not largely increased since then. Second, we did not commission a chapter on "Bats and chemical pollutants," as current knowledge of heavy metals was recently synthesized by Zukal et al. (2015) and information for other pollutants is sparse. That said, the subject is referenced in several chapters (Williams-Guillen et al. 2015; Korine et al. 2015; Voigt et al. 2016). Third, we did not include a chapter on "island bats," although many of them are endangered and some even are threatened by extinction, as Fleming and Racey (2010) provide a detailed overview of this topic in their recent book. Finally, authors integrate successful interventions into their accounts and make specific recommendations for future research, but additional evidence-based evaluations of the success of conservation interventions per se are found in Berthinussen et al. (2014).

The Anthropocene has gained momentum. It is a geological epoch that is not in equilibrium but is constantly changing by the action of mankind. For a handful of bat species anthropogenic changes may prove beneficial, but for the vast majority our actions precipitate drastic population declines that must be slowed if we are to conserve the extraordinary diversity of this unique mammalian order. We hope that this book will stimulate new directions for research and support conservation interventions that will keep the night sky alive with bats in the Human Epoch.

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