Chapter 18
Threats to Bats and Educational Challenges

Merlin D. Tuttle

Abstract Like most animals, bats are threatened by habitat loss and degradation. However, they are also uniquely threatened almost universally by humans. In this chapter, I will emphasize the educational issues I believe will be most important to the next generation of bat conservationists. Though threat levels and possible solutions vary widely, the importance of addressing unfounded fear cannot be ignored. Putting disease concerns in perspective has been essential throughout the history of bat conservation efforts and is currently a resurgent issue that threatens the educational progress that has been made in recent decades.

18.1 Introduction

18.2 Early Challenges in North America

Needs for bat conservation were first officially recognized by scientists at a meeting of the American Association for the Advancement of Science (1971) where researchers concluded that bats were rapidly disappearing, ecologically essential, and in need of immediate help (Henshaw 1972). Leading newspapers and magazines published intensely scary stories that often bore no resemblance to reality (Cox 1980; Okie 1979; Remsburg and Remsburg 1977), creating extreme fear of bats (Brass 1994) that became highly profitable for pest and public health industries (Gallager 1977; U.S. Environmental Protection Agency 1980; Strohm 1982; Anonymous 1984).

M.D. Tuttle (✉)
5000 Mission Oaks Blud., #41, Austin, TX 78735, USA
e-mail: merlintuttle@gmail.com

R.A. Adams and S.C. Pedersen (eds.), *Bat Evolution, Ecology, and Conservation*,
DOI 10.1007/978-1-4614-7397-8_18, © Springer Science+Business Media New York 2013

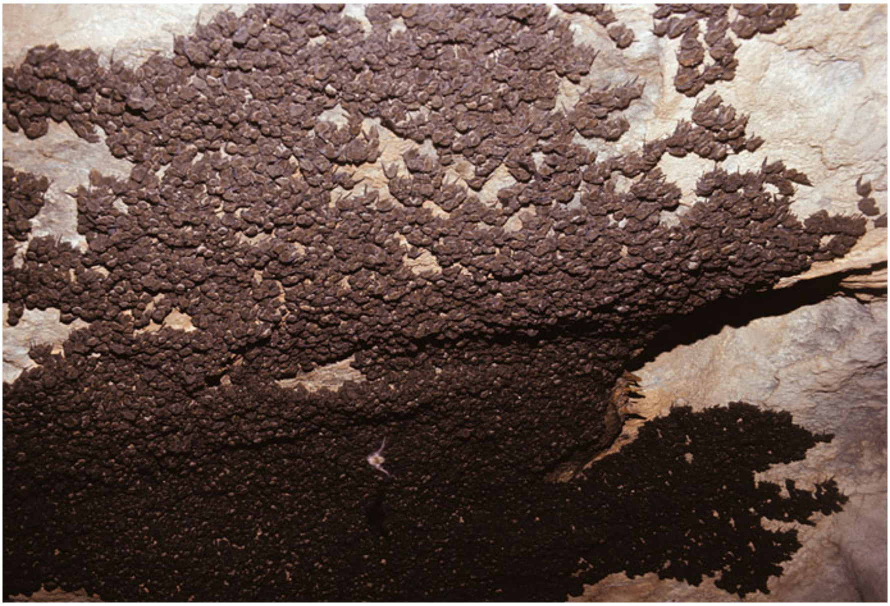

Fig. 18.1 Hibernating gray bats (*Myotis grisescens*) in Hubbards Cave, Tennessee. Protective gates have enabled this once nearly extirpated population to rebuild to more than 500,000

In May 1976, the US Centers for Disease Control and Prevention (CDC) began officially issuing DDT for poisoning bats in buildings that not only needlessly harmed bats but created far greater public health risks than the bats themselves (Barclay et al. 1980; Brass 1994; Kunz et al. 1977; Trimarchi 1978). Denny Constantine, the leading authority on bat rabies, condemned the nationwide drive to create hysteria and the resulting use of exceptionally dangerous chemicals to kill bats. He concluded that "The public health problems posed by bats are relatively insignificant compared to the public health problems usually initiated by those who publicize bats as problematic, typically resulting in an exaggerated, inappropriate response, damaging to the public health" (Tuttle 1988a).

By the time I founded Bat Conservation International (BCI) in 1982, most Americans believed that bats were frequently rabid and would attack people and pets. Bat killing was not limited to those living in buildings (Gillette and Kimbrough 1970; Mohr 1972) but also in natural caves (Fredrickson and Thomas 1965) that housed endangered species (i.e., gray bats) wherein entire colonies were exterminated (Tuttle 1979), resulting in a federal listing as endangered in 1976 (Fig. 18.1).

Help for bats would be impossible without first dispelling widely believed public health myths. Since virtually everyone already "knew" bats were dangerous, our first priority was to present an exceptionally well-documented case to rebut almost universal propaganda. We published a thorough and complete, peer-reviewed paper distributed to US state health departments (Tuttle and Kern 1981). We provided workshops and seminars and collaborated with honest experts who helped gain passage of state legislation in Wisconsin outlawing pesticide use against bats (Wisconsin State Assembly Bill 630). We also shared our experience and information widely through BCI members, empowering them to gain similar progress in additional states; exaggerated claims would be rebutted. Using positive photographic portrayal of bats, we provided pro-bat articles to most of America's leading wildlife magazines and published a layman's handbook *America's Neighborhood Bats* that put risks and benefits in perspective and clearly explained how to solve bat problems or identify honest pest control companies (Tuttle 1988a).

Putting risk into perspective, we noted that rabies from bats kills one or two Americans annually (Johnson et al. 2010), whereas the risk of death from driving 1 mi. in a motor vehicle is greater than the per-year risk of death from rabies in America (Tuttle 1999), and falling vending machines, shaken by irate customers, kill more Americans each year than does bat rabies (Olnhausen and Gannon 2004). Periodically, Americans still experience dire warnings about bats, usually by states with the largest, unjustifiable budgets for rabies control. States that have "passive" rabies prevention programs, wherein people are informed of bite risks, the need for pet vaccinations, and timely reporting of any bites, suffer no more human rabies mortality than states with "active" programs supported by large budgets for surveillance and prevention. In fact, it is extremely unlikely that stricter guidelines or warnings about bats could further reduce this consistently rare problem (Canada Communicable Disease Report 2009; Tuttle 1999).

A 1996 "Bat Rabies Alert" in New York illustrates how counterproductive such campaigns can be. Despite only one bat-transmitted case of human rabies in the state's history, a "bat rabies alert" was declared, and tens of thousands of posters, stickers, and other warning materials were distributed at schools, camps, and fairs, resulting in media stories claiming that bat rabies can be transmitted without contact (Tuttle 1999). New York health officials began vaccinating people who reported seeing bats fly through their yards. Dr. Brendon Brady (Chairman, Board for Finger Lakes Community Care, NY) documented a staggering 398 % jump (46 in 1996 to 183 in 1998) in rabies vaccinations (~$2,000 per person) and wrote, "I am outraged that the Health Department policy is wasting millions to prevent the rarest disease in New York" (Tuttle 2000).

Participants at the 29th Annual North American Symposium on Bat Research (1999) unanimously passed a resolution stating no credible support (Mlot 2000) for the CDC's policy advising postexposure prophylaxis of "persons potentially exposed to bats even where a history of physical contact cannot be elicited" (CDC MMWR 1995). Public health studies from Oregon, Connecticut, and Canada (Cieslak et al. 1998; Serres et al. 2009) independently concluded that CDC's policy had negligible impact in preventing rabies. Oregon found that by following CDC's advice, they would, on average, prevent no more than a single human death per 75 years at a cost of more than $180 million (Cieslak et al. 1998). Canada's National Advisory Committee on Immunization (NACI) abandoned CDC's policy even though bat-transmitted rabies rates are similar to the USA, just 6.7 cases per billion person years (CCDR-NACI 2009).

Worldwide, more than 50,000 humans die of rabies each year (Johnson et al. 2010) with 99 % coming from dogs. And human infection from other lyssaviruses accounted for just five human deaths in Africa, two in Australia, three in Europe, and none in Asia or the Pacific Islands (Johnson et al. 2010).

18.3 Current and Future Challenges

18.3.1 Emerging Diseases

Due to increased reporting of rare but potentially problematic zoonotic diseases, fear of bats is reemerging as a major threat to their conservation. Bats occupy a wide variety of ecological niches, so it is not surprising that diverse viruses have coevolved with them. Most of these bat-borne viruses are probably harmless to humans, but circumstantial evidence suggests that, in addition to rabies, bats may be reservoirs or intermediate hosts for rare but frightening diseases such as Hendra, Nipah, Marburg, and Ebola viruses that can cause lethal encephalitis or hemorrhagic fever in humans (Carrington et al. 2008; Calisher et al. 2008; Wibbelt et al. 2010).

Horseshoe bats (*Rhinolophus*) are hypothesized to be the reservoir for the coronavirus that causes SARS. When a related virus was found in bats, it was presumed to have been transmitted from bats to civets caged in proximity in Asian animal markets. Unfortunately, the hypothesis was presented as fact (Fenton et al. 2006), triggering an onslaught of sensational media warnings of dangerous bats (McKie 2005). Because horseshoe bats are seldom sold in animal markets, the initially hypothesized route of transmission is unlikely. Furthermore, Janies et al. (2008) concluded that though horseshoe bats possibly were involved in the early evolution of SARS, it most recently appears to have spread from humans to civets and pigs.

Coronaviruses have been identified in bats worldwide (Dominguez et al. 2007; Quan et al. 2010; Tong et al. 2009; Watanabe et al. 2010). However, these viruses are also widespread in other animals from birds (Hughes et al. 2009) to whales (Mihindukulasuriya et al. 2008) and normally are benign or cause no more than common colds (Chua et al. 2008; Hun 2011). Most evidence linking viruses to bats is based on discovery of antibodies which does not establish infection or disease by that virus and also ignores what role, if any, bats play in that virus' natural cycle (Calisher et al. 2008).

Disproportionate emphasis on identification of bat reservoirs could prove counterproductive to disease prevention. Leroy et al. (2004) concluded that circulation of Ebola has involved many contamination events among animal species over long periods prior to modern detection and that multiple reservoirs may be involved, including some nonhuman primates, rodents, and shrews. Some experts speculate that filoviruses, such as Ebola and Marburg, may be of plant or arthropod origin with bats and other animals serving only as intermediate hosts (Calisher et al. 2008). Furthermore, Allela et al. (2005) found that up to 32 % of domestic dogs in outbreak areas had Ebola antibodies and could shed the virus without visible symptoms.

Fig. 18.2 Part of a massive colony of straw-colored flying foxes (*Eidolon helvum*) at Kasanka National Park in Zambia that consumes an estimated 6,000 tons of fruit and nectar per night. Their impact on seed dispersal and pollination is enormous, covering a huge area of equatorial Africa during annual migrations

During the 1994 human Ebola outbreak in northeastern Gabon, gorillas, monkeys, and bush pigs were dying and being scavenged for human food. That miners contracted Ebola was assumed due to associating with bats in the mines even though the outbreaks seemed most closely associated with humans scavenging bushmeat (Lahm et al. 2007). In only one instance has bat hunting appeared to be associated with a human case despite the fact that large numbers of straw-colored fruit bats (*Eidolon helvum*) are sold for human food (Leroy et al. 2009). Regardless of whether or not bats are reservoirs for Ebola, direct transmission from them to humans or livestock is exceedingly rare, if it occurs at all (Fig. 18.2).

Other sources of potential confusion are seen in the search for reservoirs of Hendra and Nipah viruses. Hendra has been hypothesized to be transmitted directly from bats to horses when horses eat flying fox placentas (Patterson et al. 2011), though this seems unlikely given that births normally occur in isolated roosting “camps” in forests and that horses are not known to scavenge. Experimental transmission has been demonstrated from cats to horses (Messenger et al. 2003), and barn cats would clearly scavenge placenta, potentially bringing the virus to horses. If true, horses might be protected by isolating them from cats rather than culling an endangered flying fox as proposed by horse breeders (Nolan 2011).

When Nipah virus was discovered in Southeast Asia, wildlife surveillance again focused primarily on bats (Chadha et al. 2006). Contamination of fruits or raw date palm juice by *Pteropus* was widely publicized, though bat biologists were skeptical

(Fenton et al. 2006) and subsequent attempts to isolate Nipah virus failed (Gurley et al. 2007). Human exposure histories varied greatly among outbreaks, suggesting the possibility of multiple sources (Homaira et al. 2010; Montgomery et al. 2008). Johara et al. (2001) reported that 46 % of 92 domestic dogs sampled near infected pig farms tested positive for Nipah antibodies.

We must be concerned about infectious diseases and the roles that wildlife, including bats, may play in their epidemiology. However, when public health is the focus, those who are concerned with conservation must insist on careful consideration of documented facts (Fenton et al. 2006). An editorial in the journal *Nature* cautioned that “The intrinsic conflict between the mandated need to inform the public of potential health hazards and the need of the media for sensational headlines is threatening to compromise the scientific process.” The warning was, in part, a response to exaggerated stories about bats (Ashby 1996).

Even if we were to lump all human deaths from Hendra, Nipah, Marburg, Ebola, and SARS viruses together and assume contact with bats to be the sole cause, bats still would be credited with fewer than 3,000 human fatalities globally in the past 40 years, mostly in remote areas where primitive health care is a major contributing factor. In the USA alone, foodborne illness causes an estimated 5,000 human deaths/year (Mead et al. 1999). Balancing public health versus conservation needs can be challenging (Messenger et al. 2003), especially because governments predominantly fund health issues that frighten us most, not necessarily those which pose the greatest threat (Finley 1998).

Lasting progress will require cooperation between virologists and bat biologists. Bats are simply too important to healthy ecosystems and economies for eradication to be considered (Brass 1994; Wibbelt et al. 2010). Furthermore, attempts to eliminate disease through wildlife control typically exacerbate problems while threatening ecosystem balance (Macdonald 1977) (Fig. 18.3).

Sensational coverage of potential risks from bat-borne disease has already created demands for flying fox eradication in Australia (e.g., Nolan 2011) and questioned the wisdom of allowing large colonies of straw-colored fruit bats to congregate in city parks of sub-Saharan Africa (Drexler et al. 2009). Attempts to evict such bats would likely expose them to unsustainable hunting pressures, threatening whole ecosystems that rely on their pollination and seed dispersal (Racey 2004; Chap. 23) (Fig. 18.4).

There is an urgent need to rein in the recent wave of sensational reporting (e.g., Hart 2006; Gilbert 2011). Despite the fact that millions of straw-colored fruit bats have thrived in city parks across Africa, there is no evidence of harm to humans. Nor does such evidence exist in Australia where large flying fox colonies occupy urban areas and rehabilitators care for hundreds of sick, injured, or orphaned flying foxes annually (Selvey et al. 1996).

Certainly, if bats were even remotely as dangerous as has been hypothesized in recent zoonosis literature, major disease outbreaks should have been documented long ago among the millions of people in Asia, Africa, and the Pacific and Indian Ocean Islands who have hunted, sold, or eaten a wide variety of bats throughout human history (Bergmans and Rozendaal 1988; Mickleburgh et al. 2011). Furthermore, since numerous bat populations have been in steady decline for

Fig. 18.3 Flying foxes are primary pollinators for many of Australia's most ecologically and economically important trees. This gray-headed flying fox (*Pteropus poliocephalus*) is pollinating a broad leaf apple tree (*Angophora subvalutina*)

Fig. 18.4 These young bat hunters earn a living shooting straw-colored flying foxes (*Eidolon helvum*) with sling shots in a city park in Abidjan, Ivory Coast, where bat-eating is very popular

decades as a result of overhunting, some being driven to extinction up to 100 years ago (Pierson and Rainey 1992; Racey and Entwistle 2003), it is unlikely that humans are at greater risk today than in the past. Surprisingly, not even guano mining in major, occupied bat caves has been identified as a source of human illness. Clearly, bats have a remarkable safety record.

The story of bats in Austin, Texas, provides an excellent example of how bats and humans can safely coexist when bat conservationists, educators, and public health officials cooperate in presenting a balanced message. In the early 1980s, as 1.5 million Brazilian free-tailed bats (*Tadarida brasiliensis*) began moving into newly created crevices beneath the Congress Avenue Bridge at city center, public health officials warned that they were rabid and dangerous. Sensational news stories made national headlines. People panicked, and the bats were nearly eradicated. BCI met with leadership individuals in the health department, city government, and local news media, gaining their cooperation to present a balanced educational message, not scaring people, but warning them not to handle bats. As a result, the community has benefitted greatly. The bats consume 15 tons of insects nightly and attract 12 million tourist dollars each summer. Furthermore, not one of millions of bat watching visitors has contracted a disease despite extraordinarily close association.

18.3.2 Vampire Control

Latin America is home to three species of vampire bats, one of which, the common vampire (*Desmodus rotundus*), has greatly overpopulated due to the introduction of livestock. Its bites are a primary source of rabies outbreaks that cost the cattle industry millions of dollars annually and kill approximately 50 humans (Acha and Alba 1988; Brass 1994; Schneider et al. 2009).

Not surprisingly, major efforts have been launched to eradicate vampires. Until recently, all bats were killed indiscriminately, threatening ecosystems and economies (Lord 1988; Tuttle 1988b; Brass 1994). Many thousands of bat caves and millions of bats were destroyed (Constantine 1970; Hutson et al. 2001). Such efforts have little or no impact in reducing vampire populations, since these bats typically live in colonies of less than 50 individuals, often unnoticed in wells (Brass 1994; de Oliveira et al. 2009). The most conspicuous bat colonies are highly beneficial but are the first to be eradicated. Even when vampire roosts are accurately identified, roost poisoning threatens entire species of beneficial bats that reclaim roosts after vampires are killed (Aguiar et al. 2010).

Several effective approaches for controlling vampires are now available, but too often nothing is done till after livestock begin to die of rabies making it too late to prevent an outbreak from running its course. Vaccines can provide protection when administered prior to an outbreak, and application of an anticoagulant (often chlorophacinone, diphacinone, or warfarin) mixed with Vaseline, either to wounds where vampires return to feed or to the bodies of vampires captured and released, can be highly effective (Fig. 18.5). Application on bite wounds works best for campesinos with relatively few animals in that it kills only the offending individuals, whereas pasting captured/released vampires works best for larger ranches. Through mutual grooming one pasted bat can kill up to 40 others (Brass 1994; Lord 1988). The latter method should be utilized only by trained teams working in front of advancing rabies outbreaks to create barriers against further spread. Limited

Fig. 18.5 Pasting a common vampire bat (*Desmodus rotundus*) with an anticoagulant poison mixed with Vaseline in Cost Rica. With minimal training, this is an effective tool that can be highly specific in targeting only vampires that are harming livestock

studies have indicated negligible impacts on carnivores and scavengers who may eat poisoned vampires, though potential unintended consequences should be monitored (Brass 1994; Burns and Bullard 1979; Lord 1988). As is, most humans can be protected from vampire bits by screening windows or by mosquito nets, backed up by vaccination when bites occur (Lopez et al. 1992; Peters 2004; Schneider et al. 2009). Unfortunately, education on appropriate controls has lagged far behind scientific knowledge (Brass 1994; Lord 1988), even though education to easily identify vampire bats can be highly effective in solving most problems (Brass 1994). BCI recruited two of Latin America's foremost authorities on vampire control, Rexford Lord of Venezuela and Hugo Sancho of Costa Rica, to produce a 26-min video, titled *Control del Murcielago Vampiro y La Rabia Bovina*, that covered the best available techniques for controlling problem vampires while also showing the importance of protecting beneficial species (Walker 2002). Many vampire control personnel became collaborators in bat conservation.

Unfortunately, many poor campesinos still view all bats as vampires. To help, BCI collaborated with Rodrigo Medellin and associates in Mexico to develop a series of 20 highly entertaining 15-min radio programs, "Aventuras al Vuelo," narrated by a well-known commentator. These aired throughout Mexico and appeared to be highly effective.

Finally, we must keep in mind that wholesale elimination of vampires is neither feasible nor desirable (Lord 1988), and they play an important role in balancing forest animal populations, and rank among the world's most sophisticated mammals, providing numerous opportunities for scientific research (Tuttle 1988a, b).

Vampire saliva contains a veritable treasure trove of novel regulatory molecules, one of which is providing a greatly improved treatment for stroke victims (Medcalf 2012).

18.3.3 Bushmeat

Bats have been hunted and consumed as food throughout human history, especially in tropical and subtropical areas of the Old World. Early harvesting by indigenous people was mostly sustainable, but as human populations expanded, habitat was lost, demand increased, and hunting techniques improved. As early as 100 years ago, some island species began to succumb to extinction as appetites exceeded supply (Pierson and Rainey 1992).

In recent decades, use of firearms and the expansion of commercial hunting have proven especially problematic. Though poorly documented, many populations appear to have been unsustainably exploited, producing alarming declines (e.g. Epstein et al. 2009). Mickleburgh et al. (2011) documented a wide variety of both microchiropteran and megachiropteran bats being used, with the largest species in greatest demand, especially those that form conspicuous colonies in trees or caves. Flying foxes (mostly *Pteropus, Acerodon,* and *Eidolon*) are particularly prized and are highly vulnerable at roosts and when they aggregate at fruiting and flowering trees to feed. Unfortunately, they are most frequently killed while rearing young making losses especially impactful. Smaller fruit and nectar bats that form large cave-dwelling colonies (mostly *Rousettus* and *Eonycteris*) are clubbed at roosts during emergencies or are caught in fish nets or glue traps, and entire colonies may be killed quickly (Craven 1988).

Except for the relatively large *Hipposideros commersoni* and *Cheiromeles torquatus*, most microchiropteran bats are not sold commercially. However, in parts of Southeast Asia, all cave-dwelling species may be hunted (Racey and Entwistle 2003), resulting in severe population declines and biological irrelevancy (Fujita and Tuttle 1991; McConkey and Drake 2006; Mickleburgh et al. 2011). Flying fox hunting is often deeply embedded in cultural tradition (Pierson and Rainey 1992), making legislation nearly impossible to enforce unless supported by local communities. In Madagascar, Rahaingodrahety et al. (2008) noted that hunting laws were widely ignored and suggested that locally managed harvests of foraging bats might be a viable option.

When commercial hunting threatened the survival of *Pteropus samoensis* in American Samoa, I met the hunters as a fellow hunter interested in bats, even accompanying them on several hunts to better understand their reasons for hunting (Fig. 18.6). After learning they shared my concerns regarding the dramatic decline and that they were not hunting from economic necessity, paid big dividends. Teamed with botanist Paul Cox and private funders, Verne and Marion Read, we were able to enlist the hunters' enthusiastic collaboration in gaining hunting regulations and eventually a national park to protect the bats' habitat. Though we hated seeing these bats shot, protecting sufficient numbers for future generations to hunt was better than trying to force cessation of all hunting and almost certainly failing.

Fig. 18.6 Samoan flying fox (*Pteropus samoensis*) riding mid-day thermals above rain forest

Where private land owners control access to bat caves, simple education that allays fear and promotes understanding of bat values can be highly effective. Working with owners of caves occupied by endangered gray bats (*Myotis grisescens*), I will never forget one who asked me to kill all the bats. I picked up a handful of potato beetle wings the bats had discarded beneath their roost and, on exiting, asked if he knew what kind of insect they were from. I had noticed he was growing potatoes and corn nearby. Of course, he recognized some of his worst crop pests and was surprised that bats ate them. When he asked how many insects his colony ate, I estimated about 100 lb nightly but pointed out that they didn't just eat potato beetles. They likely also consumed corn-ear worm moths and mosquitoes. From then on, he was an ardent bat protector!

More recently, responding to an urgent call to BCI for help from Norma Monfort, whose family owned an important bat cave in the Philippines that housed 1.8 million *Rousettus geoffroyi*, we found that several nearby caves had suffered 95–100 % losses due to overhunting (Fig. 18.7).

The government wanted her land for agricultural use, thereby destroying the last major bat colony. Over the next 10 days, we documented area decline, prepared and presented a PowerPoint program for community leaders, and through photographs showed that this one colony could pollinate millions of durian flowers per night. Durian-loving participants, including the mayor, immediately signed a petition requesting critical wildlife habitat status protecting the bats. Norma later established an interpretive center near the cave that attracts thousands of visitors.

Community-level education is extremely important, especially where strong leaders or owners control roosting resources. When I visited Thailand in 1982,

Fig. 18.7 Norma Monfort educates visitors to her Philippine cave regarding the importance of its 1.8 million Geoffroy's rousette fruit bats (*Rousettus geoffroyi*) as vital pollinators of area durian crops. Without such knowledge, her cave would have been destroyed by government mandate

nearly all accessible bat caves had been decimated by overhunting, and formerly huge populations were persisting with only dozens or hundreds of individuals. The only large colony that showed stability was in a small, vulnerable cave but was protected by a guard, hired by its owner to ensure continued guano production.

Khao Chang Pran Cave, about 100 km west of Bangkok, was owned by Buddhist monks who supported their monastery by selling guano as fertilizer. The monks explained that guano sales had fallen by 50 % over 5 years. I found that commercial bushmeat hunters were concealing large nets near one of the entrances, capturing more than 10,000 *Rousettu*s and *Eonycteris* per month, selling them to restaurants (Fig. 18.8). Moreover, thousands of *Tadarida plicata* (Fig. 18.9) and other small, insectivorous species were being killed making the impact clearly unsustainable. I suggested hiring a game warden and by 1990 annual guano sales had risen from \$12,017 to \$88,660 USD. A thriving, bat-viewing tourist trade had also developed (Tuttle 1990). By 2002, annual sales had risen to US \$135,000, and the bats were consuming at least 4 tons of rice crop pests nightly (Leelapaibul et al. 2005). Local benefits undoubtedly included increased durian and petai production and reforestation supporting heavy charcoal demands. The immediate area was declared a no-hunting preserve with heavy fines for violatory.

In Myanmar, many large bat caves are protected from overhunting by local communities who rely on guano extraction (Bates 2003). In New Guinea and Nigeria, agreements permitted overhunted populations of *Dobsonia moluccensis* and *E. helvum* to recover following locally initiated limits on harvesting (Mickleburgh et al. 2011). In the case of *Dobsonia*, an important nursery cave was protected from

Fig. 18.8 Thai bat hunters preparing a night's catch of fruit bats (*Rousettus* and *Eonycteris*) for sale to local restaurants. Throughout the Old World tropics hundreds of thousands of pteropodid bats are caught and sold for human consumption annually without apparent harm to hunters or consumers, though many bat populations have been decimated

Fig. 18.9 Game warden hired to protect the bats of Khao Chang Pran Cave, in Thailand, watches millions of wrinkle-lipped bats (*Tadarida plicata*) emerge

hunting, and for *Eidolon*, hunting was permitted at a large tree-roosting colony but was confined to specific times and seasons. Initiation of restrictions need not be delayed till after detailed studies are conducted, and publicity of successes has far-reaching impacts for education and conservation.

18.3.4 Crop Damage

Fruit growers frequently report crop losses due to flying foxes. In the 1920s, complaints were so numerous in Australia that the governments of Queensland and New South Wales hired a distinguished British biologist, Dr. Francis Ratcliffe, to spend 2 years with a goal of finding a "wholesale method of destruction." He concluded, "The assumption that the flying fox is a menace to the commercial fruit industry is quite definitely false, and cannot be cited as a valid reason for expenditure of public money on its control." He also reported "a good deal of exaggeration," wherein fabrication and embellishment were common (Ratcliffe 1931).

Nearly 70 years later, I visited Jim Trappel, who had grown peaches and nectarines in New South Wales for 30 years. He initially referred to flying foxes as "black devils" that could wipe out a crop in just a few nights. However, he later admitted that he and his fellow growers had greatly exaggerated losses and that flying foxes seldom harmed his crops. He had suffered significant losses just three times in 30 years, wherein 80, 50, and 30 % of his crop was lost. Those were years when gum trees, the bats' preferred local food, had failed to flower. By comparison, he estimated that cute rosella birds (*Platycercus eximius*), which he liked, were damaging roughly 10 % of his unprotected fruits annually. Averaged over time, these birds cost him nearly twice as much as flying foxes, but when bat problems occurred, they posed greater short-term hardships.

To solve both problems, Trappel invested in netting to cover entire orchards, and he enthusiastically reported that the netting had additionally protected his crops against hail damage and led to earlier fruit ripening and higher market prices. With this excellent return on investment, he became a netting distributor. A government-commissioned study confirmed Trappel's basic assessment, both of damage and remedies (Fleming and Robinson 1987), and the government now offers low-interest loans to assist with exclusion netting. Some of the greatest opportunities to further the conservation of bats begin when we genuinely investigate real or perceived nuisance problems, and although many claims are based entirely on misperceptions, these should not be denied without careful investigation.

One of the most harmful, yet widespread and firmly held misperceptions, is that flying foxes harm durian crops by preventing fruit set. Durian trees (*Durio zibethinus*) produce large numbers of flowers that are highly reliant on bats (Fig. 18.10) for pollination (Bumrungsri et al. 2009) after which flowers drop petals, presumably helping hungry bats locate receptive blossoms. When farmers see large numbers of bats triggering a steady rain of flower parts, they assume the bats are destroying flowers.

Fig. 18.10 A dawn bat (*Eonycteris spelea*) pollinating durian (*Durio zibethinus*). Several pteropodid bat species are the exclusive pollinators of this king of Southeast Asian fruits

Even after I convinced them that bats are essential pollinators, some still insisted that they must be harming their crops by sometimes knocking off whole flowers. At that, I point out that the weight of too many large fruits could break branches and that by preventing some fruit development, those remaining have improved quality.

While conducting bat research along the Mombasa Coast of Kenya, I repeatedly heard that bats were a scourge to mango (*Mangifera indica*) and other fruit crops (Tuttle 1984). I examined thousands of mangos during harvest, interviewed growers, and conducted controlled experiments of fruit ripeness preferences of bats. Although many mangos were eaten nightly in orchards, none of them were commercially harvestable nor would captive bats of six species consume harvestable fruit even when deprived of other food (Fig. 18.11). Akberkhan Khan, the largest mango exporter in Kenya at the time, explained that mangos ripe enough to attract bats are too ripe for harvest, and by removing those mangos, bats reduce breeding opportunities for fruit fly and fungal pests. Some growers often mistook bush baby and monkey tooth marks in harvestable fruit for bats. In Malaysia and Indonesia, growers of rambutan (*Nephelium lappaceum*), langsat (*Lansium domesticum*), and water chestnut (*Eugenia aquea*) reported that bats threatened crops only for the last few nights prior to harvest and that most problems could be avoided by using bright lights or fires (Fujita and Tuttle 1991).

Fig. 18.11 An Egyptian fruit bat (*Rousettus aegyptiacus*) eating a ripe mango, missed during harvest. Removal of such fruits aids growers in reducing harmful fruit flies and fungi

When growers and government officials lack knowledge, serious harm can be inflicted. In 1958, Israeli government officials began fumigating caves used by *Rousettus aegyptiacus* using ethylene dibromide and later lindane, in response to fruit grower complaints. Entire cave ecosystems were lost as were approximately 90 % of insect-eating species followed by population explosion of noctuid moths that caused major crop damage (Makin and Mendelssohn 1985). Massive eradications were also carried out in Cyprus (Hadjisterkotis 2006). Unfortunately, fruit bats are still classified as vermin (Singaravelan et al. 2009) even in countries like Australia where much progress has been made. The New South Wales Farmers Association recently called for a government cull of endangered flying foxes (Cox 2011). Objective documentation and education continues to be of paramount importance in dealing with fruit damage.

18.3.5 Environmental Degradation

Agricultural pesticides and herbicides, industrial and sewage discharges, light pollution, monoculture farming and forestry, and even campfire smoke in parks likely influence bat health and survival, but these impacts are seldom monitored and remain poorly understood.

Despite minimal investigation of insecticide impacts on bats, it is clear that populations have been harmed (Clark et al. 1978; Clark 1981, 2001; Mohr 1972; Reidinger 1972; Sasse 2005). Sublethal effects could seriously compromise immune functions, impair flight, and intolerably increase hibernation metabolism

(O'Shea and Clark 2002), and the spraying of forests for gypsy moths harms nontarget insects that bats consume (Sample and Whitmore 1993). In the UK, bats showed a clear preference for feeding over organic versus conventional farms (Wickramasinghe et al. 2003).

Fortunately, when optimal roosts have been protected, or new ones provided, bat populations typically have grown. The fact that the endangered *M. grisescens* has undergone dramatic recovery based solely on roost conservation, despite mortality from agricultural insecticides (Clark et al. 1978, 1983), clearly indicates that environmental degradation has not yet become a primary cause of decline for this species (Tuttle 1986), and there is no evidence to suggest differently for the endangered Indiana bat (*Myotis sodalis*) (O'Shea and Clark 2002). The industrialized world is on a treadmill that constantly demands stronger pesticides in ever larger quantities to kill increasingly resistant pests (Isenring 2010). When DDT was banned in Missouri, it was replaced with aldrin which also was banned, only to be replaced by heptachlor, then endrin, both of which were banned. All killed bats (O'Shea and Clark 2002; Sasse 2005).

Modern neonicotinoids are so effective at killing insects that insect-eating birds are declining (Gabel 2010). Bat guano may be the most sensitive indicator for environmental monitoring (Clark 1988; Sasse 2005). At every opportunity, conservationists need to help educate a naïve public regarding the benefits of reduced use of pesticides, including Bt toxins (Altieri and Nicholls 2001; Pemsl et al. 2007; Turnbull and Hector 2010). Collaboration with organic growers presents a variety of excellent opportunities for bat conservationists.

18.3.6 Elephant Overpopulation

In Africa, I have found no greater threat to bats than the devastation of their woodland habitats by overpopulated elephants that have nowhere left to go due to human overpopulation. Healthy populations of elephants provide essential ecosystem services, but because they have been pushed into small, restricted parks, overpopulation has led to a crisis. As early as 1983, Barnes noted that overpopulation had caused dramatic reduction in woodlands and that regeneration was no longer possible, raising concerns regarding how the biodiversity of parks and nature reserves could survive (Cumming et al. 1997; Grant et al. 2011) and in some cases damage that cannot recover in a 100 years or more has expanded across vast areas of Southern Africa.

In Botswana, I visited bat roosts in huge, hollow baobab trees in 2000 that had been totally destroyed by 2003. It was sobering to see how quickly giant trees of such vital ecological importance could be entirely eliminated from a large area. There is an urgent need for wildlife managers to establish humane, ethical procedures to control elephant populations. Unfortunately, culling elephants may at times be necessary, but this does not provide a long-term strategy for controlling populations. Contraception may be effective (Delsink et al. 2006) and should be relied upon wherever feasible.

18.3.7 Feral Cats

Feral and unsupervised domestic cats kill a wide variety of wildlife (Dauphine and Cooper 2009), and their numbers have more than doubled since 1970 (Clarke and Pacin 2002). They are especially effective at catching bats as they return to roosts. Their impact can be serious because most bats produce only one young per year. Bat conservationists should support efforts to humanely control feral cats and collaborate in educating the public to keep cats indoors, contributing greatly to the safety of both cats and wildlife. Land managers should be informed regarding the potential threat of cats at bat roosts, especially in front of protective gates that if built in narrow cave entrances force bats to slow and circle, an invitation to unnatural predation. Plans are available for gates that permit safe entry for bats, improving the odds of escaping unnatural predators (Fant et al. 2009).

18.3.8 Habitat Loss

Habitat loss is a well-documented threat, though the specific needs of bats are complex and often poorly understood. Most species require multiple roosts of varied temperature, a mosaic of foraging habitats, and lengthy nightly and seasonal travel may be required to access food or roost resources (Racey and Entwistle 2003). Simply encouraging landowners and managers to protect woodlots, wetlands, hedgerows, multiage forests, and small ponds can be very helpful.

Resource needs vary regionally. Where caves or large, hollow trees have long been available, many bats have become highly dependent upon them. In temperate regions, safe locations for winter hibernation are especially critical, and in tropical and subtropical climates, large populations may require caves year round. Loss of just one can have devastating regional impacts (Tuttle and Stevenson 1978; Stebbings 1988).

Caves and mines that provide the greatest volume and structural diversity have attracted the world's largest, most diverse bat populations because they provide wide temperature ranges and a large volume buffers against extreme weather variations. Caves having multiple entrances also help protect against predators. Unfortunately, such caves are highly used for commercial recreation.

The story of Mammoth Cave, Kentucky (Fig. 18.12), illustrates how huge bat populations have been lost in a manner making recovery exceedingly difficult. This cave once sheltered at least ten million bats and appears to have been dominated by the now endangered Indiana bat (*M. sodalis*), a species once ranked among America's most abundant mammals (Tuttle 1997). Like most caves used by major bat populations in eastern North America, Mammoth Cave was extensively altered during saltpeter extraction for gunpowder as early as the War of 1812 and again during the Civil War. Entrances were blocked to make the cave warmer for humans, and passages were widened for easier access. By 1820 additional alterations were

Fig. 18.12 Tour group entering Mammoth Cave in Mammoth Cave National Park. Millions of bats, dominated by the now endangered Indiana bat (*Myotis sodalis*), relied on this huge and diverse cave for winter hibernation prior to its early commercialization

made for commercial tourism. By the time Mammoth Cave National Park was founded in1941, the bats were gone (Toomey et al. 2002).

Due to the loss of key overwintering caves, Indiana bat populations plummeted from millions in the early 1800s to just 380,000 range-wide by 2001 and have failed to recover despite protection of caves sheltering the largest remaining populations. Unfortunately, early efforts to reverse decline focused almost entirely on protecting hibernation caves from human disturbance, with little or no regard for restoring altered microclimates. Also, substantial efforts were made to protect caves where relatively large numbers of desperate bats were barely surviving marginal conditions. When populations were compared over a 20-year period, those whose roosting temperatures fell within the species' preferred range increased, whereas those that did not declined alarmingly. In fact, some caves protected as "critical habitat" served as periodic death traps during widely spaced, but lethal, weather events.

Illustrative of the dramatic progress made when a bat's roosting needs are met, the endangered gray bat was in such precipitous decline in the 1960s and 1970s that extinction was predicted (Barbour and Davis 1969). Yet, through protection of key roosting caves, mostly with bat gates, millions of gray bats have been restored (Martin 2007). Bellamy Cave's (Tennessee) once large hibernating population had crashed due to intense human disturbance, but began recovering when I convinced the owner to prevent further disturbance. Numbers again plummeted when he partially obstructed airflow through the main entrance resulting in only 65 remaining gray bats in 1974. However, after the obstruction was removed, the hibernation area temperature dropped by an average of 2°C, and the population steadily grew to exceed 150,000 by 2010 (Samoray 2010). Early protective gates often did more harm than good by obstructing essential airflow and/or aiding predators (Tuttle 1977). However, new designs have succeeded in restoring previously declining bat populations (Fant et al. 2009).

Experience illustrates the extreme importance of educating cave owners and managers on how best to protect and manage bat roosts. Increasing numbers of private operators are finding bat conservation to be good business and are setting aside protected areas. Tour cave operators often are willing to cooperate enthusiastically in protecting bats and/or in educating the public to appreciate them. Some species, such as *Perimyotis subflavus*, are adapting to tolerate disturbance, allowing tourists as close as two meters, adding interpretive interest.

When we documented that Saltpetre Cave, a Kentucky state-operated tour cave, had been occupied by a large hibernation population of Indiana bats, managers enthusiastically ended winter tours. As a result, the Indiana bat population grew from 13 in 1999 to 6,088 by 2005. At Wyandotte Cave, Indiana, the once huge population recovered from 2,500 in 1977 to 45,500 in 2008 due to removal of an airflow-blocking gate and cessation of winter tours (Dunlap 2009). Even greater recovery could have been achieved if government administrators had permitted entrance restoration to prevent leakage of cold air (Tuttle 2005).

Although the largest, most complex caves and mines are typically best for bats, when contours provide cold versus warm air traps, even relatively small sites are important. Knowledge of bat needs and how structure impacts airflow and temperature in relation to recognition of stains in formerly occupied roosts are invaluable in selecting the best sites for protection (Tuttle and Stevenson 1978; Tuttle 1979). Rapid population growth in the protected Magazine Mine in Illinois, illustrates how quickly bats find and occupy even artificial sites with ideal conditions.

Hard rock mines, no longer used for mineral extraction, sometimes provide the only suitable refuges for bats displaced from caves. In North America the Bats and Mines Project, a partnership between Bat Conservation International, the mining industry, and government and private entities (Tuttle and Taylor 1998) has protected many important hibernating bat populations (Ducummon 2000; Dutko 1994; Tuttle 1993, 1996), including the most rapidly growing populations of endangered Indiana bats.

Fortunately, appropriate conditions are sometimes easy to restore or to provide artificially (Fig. 18.13). A wide variety of opportunities exist, including modification of existing caves and mines or construction of entirely new roosts ranging from artificial caves (Sander 1997; Locke 2003), to modified highway bridges (Keeley 1997; Keeley and Tuttle 1999), cinderblock towers (replacing ancient tree hollows) (Bayless 2006; Kelm et al. 2007) and bat house crevice roosts (Tuttle et al. 2005). Millions of American bats are now living in artificial roosts that provide the only hope of recovery for some species.

An extra large BCI-designed bat house, built on the University of Florida, Gainesville campus in 1991, now shelters a huge colony, mostly *T. brasiliensis*.

Fig. 18.13 (**a**) Tower roosts, built to provide alternative homes for Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) that have lost their original homes in extra large tree hollows at Mammoth Caves National Park, KY. (**b**) A maternity colony of the same species using an artificial roost in Trinity National River Wildlife Refuge, TX

Due to its popularity with bat watchers, a new roost that can accommodate 400,000 was built in 2010. The combined colony size is already 300,000 and growing rapidly (Reed 2012). More free-tailed bats now live in these two artificial roosts than are known from all the natural roosts in Florida combined, illustrating that loss of roosts is the key bottleneck to restoring bat populations of that area.

A final overriding need involves water. Bats have the greatest surface area per volume ratio of any warm-blooded animal, making them exceptionally susceptible to dehydration. They can lose up to 50 % of their body mass in water in a single day (O'Farrell et al. 1971), likely explaining why most nursery colonies are located near reliable water resources. Also, unlike other animals, most bats must drink in flight, typically requiring an unobstructed swoop zone of at least 3 m, some as much as 30 m (Fig. 18.14) (Taylor and Tuttle 2007). The availability of surface water and associated riparian habitat has declined alarmingly over the past 150 years (Adams 2003), and special watering devices for other animals often fail to meet bat needs.

If forecasts of climate change are correct, without prompt improvement of bat-friendly water resources, widespread extirpation is expected (Adams and Hayes 2008; Adams 2009a, b). The dramatic expansion of bat numbers when suitable roosts and water are provided, whether naturally or artificially, combined with the

Fig. 18.14 California myotis (*Myotis californicus*) drinking at livestock watering trough in arid southwestern US. On hot nights, bats often visited at rates approaching one per second

rapidly growing popularity of bat watching, gives hope for the future. Much remains to be accomplished in educating the public to support such efforts, but growing numbers of nature centers and commercial tour cave owners are now protecting bats because it is simply good business.

18.4 Priority Setting

Early conservationists had little choice but to focus on so-called glamor species, typically the largest or cutest animals. However, too often, multiple organizations competed to protect a few popular animals, while whole groups of ecologically essential species were ignored.

Even now, bats are often neglected despite a rapidly growing body of evidence confirming invaluable eco-services (Chap. 24). There is an urgent need to communicate research findings to conservation decision makers and the public at large (Kunz et al. 2011).

Most private donors, foundations, and government agencies want scientists to clearly define and rank priorities. Nevertheless, gaining objective consensus can be challenging, especially when those attempting to reach agreement stand to gain or lose funding based on how priorities are ranked.

Two approaches have worked for me. In recommending members for the endangered gray bat recovery team, I chose only highly respected bat research colleagues who had nothing to gain or lose from team decisions. We listened to arguments from those who did. Then, following objective discussion among team members, we established clear, quantifiable, and achievable priorities that won broad support.

When it came to cooperation between bat conservationists and the wind industry, a diverse group of stakeholders formed the Bats and Wind Energy Cooperative (BWEC, http://www.batsandwind.org). A governing Oversight Committee is composed of one member each from the five entities who provide primary financial support (American Wind Energy Association, Bat Conservation International, U.S. Department of Energy, U.S. Fish and Wildlife Service, U.S. National Renewable Energy Laboratory). This committee works in close collaboration with a Project Coordinator, under advisement of a six-member Scientific Advisory Committee and a six-member Technical Advisory Committee. The Oversight Committee organizes face-to-face planning meetings, led by a professional facilitator, at approximately 3-year intervals. Progress is reviewed and budgets fine-tuned at least once annually. By assigning final priority setting to a relatively few highly respected individuals, with professionally facilitated input from both scientific and technical advisory committee members, extraordinary consensus has gained broad financial support and commensurate progress.

A final area of conservation planning that deeply concerns me involves finding a balance between priorities for endangered and ecologically essential species. Too often, decision makers focus so heavily on endangered species that the old adage “an ounce of prevention is worth a pound of cure” is ignored. It is now clear that important eco-services can be lost long before a formerly abundant species is endangered (McConkey and Drake 2006).

Just as conservation of biodiversity hotspots has emerged as a strategic planning priority, so should protection of key populations of eco-service providers. A single roost can shelter bats whose loss could threaten regional ecosystem health and thus caves, mines, etc., urgently need to be inventoried and prioritized for conservation. Once protected, these resources can play pivotal roles in conservation with implications extending far beyond bats.

References

Acha PN, Alba AM (1988) Economic losses due to *Desmodus rotundus*. In: Greenhall AM, Schmidt U (eds) Natural history of vampire bats. CRC Press, Boca Raton, FL

Adams RA (2003) Bats of the Rocky Mountain West. University Press of Colorado, Boulder, CO

Adams RA (2009a) Bat reproduction declines when conditions mimic climate change projections for western North America. Ecology 91:2437–2445

Adams RA (2009b) The threat of climate change. BATS 27:1–4

Adams RA, Hayes MA (2008) Water availability and successful lactation by bats as related to climate change in western regions of North America. J Anim Ecol 77:1115–1121

Aguiar LMS, Ludmilla MS, Brito D, Machada RB (2010) Do current vampire bat (*Desmodus rotundus*) pose a threat to Dekeyser’s nectar bat (*Lonchophylla dekeyseri*) long-term persistence in the Cerrado? Acta Chiropterol 12:275–282

Allela L, Boury O, Pouillot R, Yaba P, Kumulungui B, Rouquet P, Gonzalez JP, Leroy EM (2005) Ebola virus antibody prevalence in dogs and human risk. Emerg Infect Dis 11:385–390
Altieri MA, Nicholls CI (2001) Ecological impacts of modern agriculture in the United States and Latin America. In: Solerig OT, Paarberg R, Di Castri F (eds) Globalization and the rural environment. David Rockefeller Center for Latin American Studies, Washington, DC
Anonymous (1984) Fraudulent bat control outlawed. BATS 1(2):2–3
Ashby J (1996) Mad cows, bats and baby milk. Nature 382:109
Barbour RW, Davis WH (1969) Bats of America. University Press of Kentucky, Lexington, KY
Barclay RMR, Thomas DH, Fenton MB (1980) Comparison of methods used for controlling bats in buildings. J Wildl Manage 44:502–506
Bates PJJ (2003) Conservation status of the bat and bird fauna of the limestone karst areas of Mon and Kayin States, Myanmar (Burma). Unpublished report for Fauna & Flora International 100% Fund, Fauna & International, Cambridge, U.K.
Bayless M (2006) Designing homes for forest bats. BATS 24:9–11
Bergmans W, Rozendaal FG (1988) Notes on collections of fruit bats from Sulawesi and some off-lying islands (Mammalia, Megachiroptera). Zool Verhandel 248:1–74
Brass DA (1994) Rabies in bats: natural history and public health implications. Livia Press, Ridgefield, CT
Bumrungsri S, Sripaoraya E, Chonfsiri T, Sridith K, Racey PA (2009) The pollination ecology of durian (*Durio zibethinus*, Bombacaceae) in Southern Thailand. J Trop Ecol 25:85–92
Burns RJ, Bullard RW (1979) Diphacinone residue from whole bodies of vampire bats: a laboratory study. Bull Pan Am Health Organ 13:365
Calisher CH, Holmes KV, Dominguez SR, Schountz T, Cryan P (2008) Bats prove to be rich reservoirs for emerging viruses. Microbe 3:521–528
Canada Communicable Disease Report, National Advisory Committee on Immunization (NACI) (2009) Recommendations regarding the management of bat exposures to prevent human rabies. ACS 7:1–28
Carrington CVF, Foster JE, Zu HC, Zhang JX, Gavin GJD, Thompson N, Auguste AJ, Ramkissoon V, Adesiyun AA, Guan Y (2008) Detection and phylogenetic analysis of group 1 coronaviruses in South American bats. Emerg Infect Dis 14:1890–1893, http://www.nc.cdc.gov/article/14/12/08-0642.htm
Centers for Disease Control and Prevention (CDC) (1995) Human rabies, Alabama, Tennessee and Texas, 1994. MMWR Morb Mortal Wkly Rep 44:269–272
Chadha MS, Comer JA, Lowe L, Rota PA, Rollin PE, Dellini WJ, Ksiazek TG, Mishra AC (2006) Nipa virus-associated encephalitis outbreak, Siliguri, India. Emerg Infect Dis 12:235–249
Chua KB, Voon K, Crameri G, Tan HS, Rosli J, McEachern JA, Suluraju S, Yu M, Wang LF (2008) Identification and characterization of a new orthovirus from patients with acute respiratory infections. PLoS One 3:1–7
Cieslak PR, DeBess EE, Keene WE, Fleming DW (1998) Occult exposures to bats in Oregon: Implications for rabies post-exposure prophylaxis, vol 58. Abstract from the International Conference on Emerging Diseases, Atlanta, GA
Clark DR Jr (1988) Northern Alabama colonies of the endangered gray bat *Myotis grisescens*: Organochlorine contamination and mortality. Biol Conserv 43:213–225
Clark DR Jr (2001) DDT and the decline of free-tailed bats (*Tadarida brasiliensis*) at Carlsbad Cavern, New Mexico. Arch Environ Contam Toxicol 40:537–543
Clark DR Jr, LaVal RK, Swineford DM (1978) Dieldrin-induced mortality in an endangered species, the gray bat (*Myotis grisescens*). Science 199:1357–1359
Clark DR Jr (1981) Bats and environmental contaminants: a review. U.S. Fish and Wildlife Service, Special Scientific Report, Wildlife 235:1–27
Clarke AL, Pacin T (2002) Domestic cat "colonies" in natural areas: a growing exotic species threat. Nat Areas J 22:154–159
Constantine DG (1970) Bats in relation to the health, welfare and economy of man. In: Wimsatt WA (ed) Biology of bats, vol II. Academic, New York, NY

Cox C (1980) The nightmare house. Fam Circle 93:64–94

Cox L (2011) Farmers stick to their guns on bats. Central Western Daily, April 16

Craven I (1988) Finding solutions. BATS 6:12–13

Cumming DHM, Fenton MB, Rautenbauh IL, Taylor RD, Cumming MS, Dunlop JM, Ford AG, Hovorka MD, Johnston DS, Kalcounis M, Mahlangu Z, Portfurs CVR (1997) Elephants, woodlands and biodiversity in southern Africa. S Afr J Sci 93:231–236

Dauphine N, Cooper RJ (2009) Impacts of free-ranging domestic cats (Felis catus) on birds in the United States: A review of recent research with conservation and management recommendations. In: Rich TD, Arizmendi D, Demarest D, Thompson C (eds) Proceedings of the Fourth International Partners in Flight Conference: tundra to tropics, McAllen, TX

de Oliveira PR, Silva DAR, Rocha JH, de Melo SMA, Bombonato NG, Carneiro e Silva FO (2009) Survey, registration and population estimate of hematophagous (vampire) bat habitats, before and after control activities in the county of Araguari, MG, Brazil. Arq Inst Biol (Sao Paulo) 76:553–560

Delsink AK, Van Altena JJ, Grobler D, Bertschinger H, Kirkpatric J et al (2006) Regulation of a small, discrete African elephant population through immunocontraception in the Makalali Conservancy, Limpopo, South Africa. S Afr J Sci 102:403–504

Dominguez SR, O'Shea TJ, Oko LM, Holmes KV (2007) Detection of group 1 coronaviruses in bats in North America. Emerg Infect Dis 13:1295–1300, http://www.nc.cdc.gov/eid/article/13/9/07-0491.htm

Drexler JF, Corman VM, Gloza-Rausch F, Seebens A, Annan A, Ipsen A, Kruppa T, Muller MA, Kalko EKV, Adu-Sarkodie Y, Oppong S, Drosten C (2009) Henipa RNA in African bats. PLoS One 4:1–5

Ducummon S (2000) The Great Lakes initiative. BATS 18:6–11

Dunlap K (2009) Population trends of Indiana bats in Indiana. In: IKC Update (Quarterly publication of Indiana Karst Conservancy) No. 95, 25 pp

Dutko R (1994) Protected at last: the Hibernia mine. BATS 12:3–5

U.S. Environmental Protection Agency, Region V, in the matter of Bradley Exterminating Co., Richfield, Minn. 1980 Docket no. I.F. & R. V-604-c, Marvin E. Jones, Admin. Law Judge. May 8, 1980

Epstein JH, Olival KJ, Pulliam JRC, Smith C, Westrum J, Hughes T, Dobson AP, Zubaid A, Rahman A, Basir MM, Field HE, Daszak P (2009) Pteropus vampyrus, a hunted migratory species with a multinational home-range and a need for regional management. J Appl Ecol 46:991–1002

Fant J, Kennedy J, Powers R, Elliott B (2009) Agency guide to cave and mine gates. Amer. Cave Cons. Assoc., Bat Cons. Intl. and Missouri Dept. Cons. St. Louis, MO

Fenton MB, Davison M, Kunz TH, McCracken GF, Racey PA, Tuttle MD (2006) Linking bats to emerging diseases. Science 311(5764):1098–1099

Finley D (1998) Mad dogs. Texas A&M University Press, College Station, TX

Fleming PJ, Robinson D (1987) Flying fox (Chiroptera: Pteropodidae) on the north coast of New South Wales damage to stone fruit crops and control methods. Aust Mammal 10:143–145

Ford WM, Britzke ER, Dobony CA, Rodrigue JL, Johnson JB (2011) Patterns of acoustical activity of bats prior to and following white-nose syndrome occurrence. J Fish Wildl Manag 2:125–134

Fredrickson LE, Thomas L (1965) Relationship of fox rabies to caves. Public Health Rep. 80:495–500

Fujita MS, Tuttle MD (1991) Flying foxes (Chiroptera: Pteropodidae); Threatened animals of key ecological and economic importance. Conserv Biol 5(4):455–463

Gabel DA (2010) Modern insecticides' devastating effects. 20th European Biomass Conference & Exhibition. http://www.enn.com/top_stories/article/42009

Gallager J (1977) Bat's fate hangs on destroying the sinister myths. Tempo-Chicago Tribune, February 16, pp 15–17

Gilbert N (2011) West Africans at risk from bat epidemics. Nature http://www.nature.com/news/2011/110922/full/news.2011.545.html?WT.ec_id=NEWS-20110927

Gillette DD, Kimbrough JD (1970) Chiropteran mortality. In: Slaughter BH, Walton DW (eds) About bats. Southern Methodist University Press, Dallas, TX

Grant SJ, Cumming GS, Cumming DHM, Mahlangu Z, Altwegg R, Semour CL (2011) Large termitaria act as a refugia for tall trees, deadwood and cavity-using birds in a miombo woodland. Landsc Ecol 26:439–448

Gurley ES, Montgomery JM, Hossain MJ, Bell M, Azad AK, Islam MR, Molla AR, Carroll DS, Ksiazek TG, Rota PA, Lowe L, Comer JA, Rollin P, Czub M, Grolla A, Feldmann H, Luby SP, Woodward JL, Breiman RF (2007) Person-to-person transmission of Nipah virus in a Bangladeshi community. Emerg Infect Dis 13:1031–1037

Hadjisterkotis E (2006) The destruction and conservation of the Egyptian fruit bat *Rousettus aegyptiacus* in Cyprus: a historic review. Eur J Wildl Res 52:282–287. doi:10.1007/s10344-006-0041-7

Hart L (2006) After rabies death, dark days for bats. Los Angeles Times http://articles.latimes.com/2006/aug/14/nation/na-bats14

Henshaw RE (1972) Cave bats: their ecology, physiology, behavior and future survival. Bull Natl Speleo Soc 343:31–76

Homaira N, Rahman M, Hossain MJ, Nahar N, Khan R, Rahman M, Podder G, Nahar K, Khan D, Gurley ES, Rollin PE, Comer JA, Ksiazek TG, Luby SP (2010) Cluster of Nipah virus infection, Kushtia District, Bangladesh, 2007. PLoS One 5(10):1–5

Hughes LA, Savage C, Naylor C, Bennett M, Chantrey J, Jones R (2009) Genetically diverse coronaviruses in wild bird populations of Northern England. Emerg Infect Dis 15:1091–1094, http://www.nc.cdc.gov/eid/article/15/7/09-0067.htm

Hun R (2011) Coronaviruses, colds and SARS. Microbiology and immunology on-line pathmicro.med.sc.edu/virol/coronaviruses.htm

Hutson AM, Mikleburgh SP, Racey PA (eds) (2001) Global action plan for microchiropteran bats. IUCN, Gland, Switzerland

Isenring R (2010) Pesticides and the loss of biodiversity. Pesticide Action Network Europe, London, 26 p

Janies D, Habib F, Alexander B, Hill A, Pol D (2008) Evolution of genomes, host shifts and the geographic spread of SARS-CoV and related coronaviruses. Cladistics 24:111–130

Johara MY, Field H, Rashudi AM, Morrissy C, van der Heide B, Rota P, bin Adzhar A, White J, Daniels P, Jamaluddin A, Ksiazek T (2001) Nipah virus infection in bats (Order Chiroptera) in Peninsular Malaysia. Emerg Infect Dis 7:439–441

Johnson N, Vos A, Freuling C, Tordo N, Fooks AR, Miller T (2010) Human rabies due to lyssavirus infection of bat origin. Vet Microbiol 142:151–159

Keeley B (1997) Bats in bridges. BATS 15:8–10

Keeley BW, Tuttle MD (1999) Bats in American bridges, vol 4. Bat Conservation International Inc., Austin, TX, pp 1–41

Kelm DH, Wiesner KR, von Helversen O (2007) Effects of artificial roosts for frugivorous bats on seed dispersal in a neotropical forest pasture mosaic. Conserv Biol 8:1–9

Kunz TH, Anthony ELP, Rumage WT III (1977) Mortality of little brown bats following multiple pesticide applications. J Wildl Manage 41:476–483

Kunz TH, de Torrez EB, Bauer D, Lobova T, Fleming TH (2011) Ecosystem services provided by bats. Ann N Y Acad Sci 1223:1–38

Lahm SA, Kombila M, Swanepoel R, Barnes RFW (2007) Morbidity and mortality of wild animals in relation to outbreaks of Ebola haemorrhagic fever in Gabon, 1994–2003. Trans R Soc Trop Med Hyg 101:64–78

Leelapaibul W, Bumrungsri S (2005) Diet of wrinkle-lipped free-tailed bat (*Tadarida plicata* Buchannan, 1800) in central Thailand: insectivorous bats potentially act as biological pest control agents. Acta Chiropt 7(1):111–119

Leroy EM, Telfer P, Kumulungui B, Yaba P, Rouquet P, Roques P, Gonzalez JP, Ksiazek TG, Rollin PE, Nerrienet E (2004) A serological survey of Ebola virus infection in Central African nonhuman primates. J Infect Dis 190:1895–1899

Leroy EM, Epelboin A, Mondonge V, Pourrut X, Gonzalez JP, Muyembe-Tamfum JJ, Formently P (2009) Human Ebola outbreak resulting from direct exposure to fruit bats in Luebo, Democratic Republic of Congo, 2007. Vector Borne Zoonotic Dis 9:1–6

Locke R (2003) Bats at last. BATS 21:6–7

Lopez A, Miranda P, Tejad E, Fishbein DB (1992) Outbreak of human rabies in the Peruvian jungle. Lancet 9:809

Lord RD (1988) Control of vampire bats. In: Greenhall AM, Schmidt U (eds) Natural history of vampire bats. CRC Press, Boca Raton, FL

Macdonald DW (1977) The behavioural ecology of the red fox. In: Kaplin C (ed) Rabies, the facts. Oxford University Press, Oxford

Makin D, Mendelssohn H (1985) Insectivorous bats victims of Israeli campaign. BATS 2:1–2

Martin CO (2007) Assessment of the population status of the gray bat (*Myotis grisescens*). U.S. Army Corps of Engineers Environmental Laboratory, Engineer Research and Development Center Final Report, ERDC/EL TR-07-22, 97 pp

McConkey KR, Drake DR (2006) Flying foxes cease to function as seed dispersers long before they become rare. Ecology 87:271–276

McKie R (2005) Warning: bats can seriously damage health. The Observer, http://www.guardian.co.uk/science/2005/oct/09/research.highereducation

Mead PS, Slutsker L, Dietz V, McCaig LF, Bresee JS, Shapiro C, Griffin PM, Tauxe RV (1999) Food-related illness and death in the United States. Emerg Infect Dis 5:607–625

Messenger SL, Rupprecht CF, JS Smith (2003) Bats, emerging virus infections, and the rabies paradigm. In: Kunz TH, Fenton MB (eds) Bat ecology. Univ Chicago Press, IL

Medcalf RL (2012) Desmoteplase: discovery, insights and opportunities for ischaemic stroke. Br J Pharmacol 165:75–89

Mickleburgh S, Waylen K, Racey P (2011) Bats as bushmeat: a global view. Oryx 43:217–234

Mihindukulasuriya KA, Wu G, St. Leger J, Nordhausen RW, Wang D (2008) Identification of a novel coronavirus from a beluga whale by using a panviral microarray. Am Soc Microbiol 82:5084–5088

Mlot C (2000) Bat researchers dispute rabies policy. Science 287:2391–2392

Mohr CE (1972) The status of threatened species of cave-dwelling bats. Bull Natl Speleol Soc 34:33–47

Montgomery JM, Hossain MJ, Gurley E, Carroll DS, Croisier A, Bereherat E, Asgari N, Formenty P, Keeler N, Comer J, Bell MR, Akram K, Molla AR, Zaman K, Islam MR, Wagoner K, Mills JN, Rollin PE, Ksiazek PG, Breiman RF (2008) Emerg Infect Dis 14:1526–1532

Nolan B (2011) Bat culls must be considered in Hendra fight. Sydney Morning Herald, July 12 issue

O'Farrell MJ, Studier EH, Ewing WG (1971) Energy utilization and water requirements of captive *Myotis thysanodes* and *Myotis lucifugus* (Chiroptera). Comp Biochem Physiol A Comp Physiol 39:549–552

O'Shea TJ, Clark DR Jr (2002) An overview of contaminants and bats, with special reference to insecticides and the Indiana bat. In: Kurta A, Kennedy J (eds) The Indiana bats: biology and management of an endangered species. Bat Conservation International, Austin, TX

Okie S (1979) Warning: sick bird may be a rabid bat. Washington Post, September 20

Olnhausen LR, Gannon MR (2004) An evaluation of bat rabies in the United States, based on an analysis from Pennsylvania. Acta Chiropterol 6:163–168

Patterson BJ, Mackenzie JS, Durheim DN, Smith D (2011) A review of epidemiology and surveillance of viral zoonotic encephalitis and the impact on human health in Australia. N S W Public Health Bull 22:99–104

Pemsl DE, Gutierrez AP, Waibel H (2007) The economics of biotechnology under ecosystem disruption. Ecol Econ 66:177–183. doi:10.1016/j.ecolecon.2007.08.022

Peters S (2004) Banishing the vampires of the jungle. BATS 22:1–3

Pierson ED, Rainey WE (1992) The biology of flying foxes of the genus Pteropus: A review. In: Wilson DE, Graham G (eds) Pacific Island flying foxes: Proceedings of an international conservation conference. US Fish Wild Serv Biol Rept 90:1–176

Quan P-L, Firth C, Street C, Henriguez JA, Petrosov A, Tashmukhamedova A, Hutchison SK, Egholm M, Osinubi MOV, Nigoda M, Ogunkoya AB, Briese T, Rupprecht CE, Lipkin WI (2010) Identification of a severe acute respiratory syndrome coronavirus-like virus in a leaf-nosed bat in Nigeria. MBio 1(4):e00208-10. doi:10.1128/mBio00208-10
Racey P (2004) Africa's best kept wildlife secret. BATS 22:1–5
Racey P, Entwistle AC (2003) Conservation ecology of bats. In: Kunz TH, Fenton MB (eds) Bat ecology. The University of Chicago Press, Chicago, IL
Rahaingodrahety VN, Andriafidison D, Ratsimbazafy JH, Racy PA, Jenkins RKB (2008) Three flying fox (Pteropodidae: Pteropus rufus) roosts, three conservation challenges in southeastern Madagascar. Madag Conserv Dev 3:17–21
Ratcliffe FN (1931) The flying fox (*Pteropus*) in Australia. Commonwealth of Australia, Council for Scientific and Industrial Research. Bull No. 53, 82 pp
Reed D (2012) University of Florida bat house and barn. Florida Museum of Natural History. http://www.flmnh.ufl.edu/bats/facts.htm
Reidinger RF Jr (1972) Factors influencing Arizona bat population levels. Dissertation, Arizona State University, Tucson, AZ
Remsburg C, Remsburg B (1977) Three years of terror. Good Housekeeping 184:83–134
Samoray S (2010) 2010 Survey of gray bat (*Myotis grisescens*) hibernacula in Tennessee. Unpublished report for the Tennessee Chapter of The Nature Conservancy, 18 pp
Sample BE, Whitmore RC (1993) Food habits of the endangered Virginia big-eared bat in West Virginia. J Mammal 74:428–435
Sander SM (1997) How to build a cave: A bold experiment in artificial habitat. BATS 15:8–11
Sasse DB (2005) Pesticide residues in guano of gray bats. J Ark Acad Sci 59:214–217
Schneider MC, Romijn PC, Uieda W, Tamayo H, Fernandes da Silva D, Belotto A, Barbosa da Silva J, Fernando Leanes L (2009) Rabies transmitted by vampire bats to humans: An emerging zoonotic disease in Latin America? Rev Panam Salud Publica 25:260–269
Selvey L, Taylor R, Arklay A, Gerrard J (1996) Screening of bat carriers for antibodies to equine morbillivirus. Commun Dis Intell 20:477–478
Serres GD, Skewronski DM, Mimault P, Quakki M, Maranda-Aubut R, Duval B (2009) Bats in the bedroom, bats in the belfry: reanalysis of the rationale for rabies postexposure prophylaxis. Clin Infect Dis 48:1493–1499
Singaravelan N, Marimuthu G, Racey PA (2009) Do fruit bats deserve to be listed as vermin in the Indian Wildlife (Protection) & amended acts? A critical review. Oryx 43:608–613
Stebbings RE (1988) Conservation of European bats. Christopher Helm, London
Strohm B (1982) Most facts about bats are myths. Natl Wildl 20:35–39
Taylor DAR, Tuttle MD (2007) Water for wildlife, a handbook for ranchers and range managers. Bat Conservation International, Austin, TX
Tong S, Conrardy C, Ruone S, Kuzmin IV, Guo X, Tao Y, Niezgoda M, Haynes L, Aganda B, Breiman RF, Anderson LJ, Rupprecht C (2009) Detection of novel SARS-like and other coronaviruses in bats from Kenya. Emerg Infect Dis 15:482–485, http://www.nc.cdc.gov/eid/article/15/3/08-1013.htm
Toomey RS, Colburn ML, Olson RA (2002) In: Kurta A, Kennedy J (eds) Paleontological evaluation of use of caves: A tool for restoration of roosts. The Indiana bat, biology and management of an endangered species. Bat Conservation International, Austin, TX
Trimarchi CV (1978) Rabies in insectivorous temperate-zone bats. Bat Res News 19:7–12
Turnbull LA, Hector A (2010) How to get even with pests. Nature 466:36–37
Tuttle MD (1977) Gating as a means of protecting cave-dwelling bats. In: Aley T, Rhodes D (eds) National Cave Management Symposium Proceedings 1976. Speleobooks, Albuquerque, New Mexico
Tuttle MD (1979) Status, causes of decline, and management of endangered gray bats. J Wildl Manage 43:1–17
Tuttle MD (1984) Fruit bats exonerated. BATS 1:1–2
Tuttle MD (1986) Endangered gray bat benefits from protection. BATS 4:1–3
Tuttle MD (1988a) America's neighborhood bats. University Texas Press, Austin, TX

Tuttle MD (1988b) Introduction to the natural history of vampire bats. In: Greenhall AM, Schmidt U (eds) Natural history of vampire bats. CRC Press, Boca Raton, FL

Tuttle MD (1990) Return to Thailand. BATS 8:6–11

Tuttle MD (1993) Crisis for American bats. BATS 11:6–8

Tuttle MD (1996) Wisconsin gains key bat sanctuary. BATS 14:3–7

Tuttle MD (1997) A mammoth discovery. BATS 15:3–5

Tuttle MD (1999) Rabies, economics vs. public safety. BATS 17:3–8

Tuttle MD (2000) The media blitz that threatens bats. BATS 18:5–8

Tuttle MD (2005) Balancing energy for survival. BATS 23:2

Tuttle MD, Kiser M, Kiser S (2005) The bat house builder's handbook (Revised). Bat Conservation International, Austin, TX

Tuttle MD, Kern SJ (1981) Bats and public health. Contrib Biol Geol 48:1–11

Tuttle MD, Stevenson DE (1978) Variation in the cave environment and its biological consequences. In: Zuber R et al (eds) 1977 National Cave Management Symposium Proceedings. Adobe Press, Albuquerque, NM

Tuttle MD, Taylor DAR (1998) Bats and mines. Bat Conservation International Resource Publ. No. 3, 50 pp

Walker S (2002) The vampire video. BATS 20:29

Watanabe S, Masangkay JS, Nagata N, Morikawa S, Mizutani T, Fukushi S, Alviola P, Omatsu T, Ueda N, Iha K, Taniguchi S, Fujii H, Tsuda S, Endoh M, Kato K, Tohya Y, Kyuwa S, Yoshikawa Y, Akashi H (2010). Bat coronaviruses & experimental infection of bats, the Philippenes. Emerg Infect Dis. http://www.nc.cdc.gov/eid/article/16/8/10-0208.htm

Wibbelt G, Moore MS, Shountz T, Voigt CV (2010) Emerging diseases in chiroptera: why bats? Biol Lett 6:438–440

Wickramasinghe LP, Harris S, Jones G, Vaughan N (2003) Bat activity and species richness on organic and conventional farms: impact of agricultural intensification. J Appl Ecol 40:984–993