BLOSSOMING TREASURES OF BIODIVERSITY

In defence of the world’s most reviled vertebrate animals: part 1: ‘lower’ species (sharks, snakes, vultures, frogs & toads)

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ABSTRACT

Biodiversity is vital to the welfare and survival of humans, but public support for conservation of most animal species is appallingly limited. Vertebrates make up less than 5% of the world’s documented animal species, but are viewed far more sympathetically than invertebrates. This is because humans are empathetic with the appearance and behaviour of many of them, particularly the charismatic superstars like pandas and tigers that currently are the mainstays of biodiversity fundraising. Conversely, just as such attractive icons are effective ambassadors of biodiversity conservation, so certain detested and sometimes dangerous vertebrate pests have greatly compromised the public image of biodiversity. Some of these species, admittedly, are responsible for significant damage to health and economic welfare. Nevertheless, this paper shows that all play important ecological roles, they have compensating economic values, their harm has often been exaggerated, and their very negative public images are undeserved. This first installment deals with the most reviled ‘lower’ vertebrate species: sharks (representing fish); frogs and toads (representing amphibians); snakes (representing reptiles); and vultures (representing birds). The next contribution will deal with mammals.

Introduction

Biodiversity is useful in many respects to humans: as resources (especially food, medicine, fibre, and fuel), for ecological services (such as pollination, stabilization of water supplies, and carbon sequestration to prevent excess CO₂ from affecting the atmosphere and climate), and for entertainment and education. In addition, there are ethical reasons why people should respect other species. Regardless of these rational considerations, humans have decided preferences for other species, some being admired and respected, others detested and shunned, and this hugely (often predominantly) determines biodiversity conservation efforts (Small 2011, 2012; Figures 1–2). In short, ‘charismatic wildlife species are likely to obtain more public funding for efforts to conserve them than less charismatic ones’ (Tisdell and Nantha 2006; Figure 3). Unfortunately for invertebrates, aside from butterflies and bees there are very few that are charismatic (Small 2019). Many vertebrates are charismatic, but their level of support depends on just how charismatic they are (Bellon 2019).

This paper is concerned with conservation aspects of vertebrate animals that are detested, and therefore least likely to receive support. A parallel paper (Small 2019) examined conservation aspects of reviled invertebrates. ‘Vermin’ refers to animals that are perceived as being so detrimental to human health or welfare that they warrant extermination. Lack of sympathy, indeed blind hatred for such species, sometimes has some justification, but it lessens respect for biodiversity in general and control measures often endanger thousands of innocent species. The goal of this paper is to generate understanding of the economic values and useful roles the world’s most reviled vertebrates play in nature, in order to minimize the disrespect for biodiversity that they generate.

About 70,000 species of vertebrates (animals with a spinal cord surrounded by cartilage or bone) have been named. Vertebrates include fish, amphibians, reptiles, birds, and mammals, many of which are highly threatened by possible extinction (Ripple et al. 2017; Table 1). Vertebrate animals receive much more targeted biodiversity research and conservation than do invertebrates (Donaldson et al. 2016; Titeley et al. 2017), but are nevertheless in desperate need of attention (Ceballos, Ehrlich, and Dirzo 2017). Hoffmann et al. (2010) identified the main drivers of biodiversity loss in vertebrates as agricultural expansion, logging, overexploitation, and invasive alien species. Ducatez and Shine (2017) similarly examined the harmful effects of habitat alteration, invasive species, climate change, and overexploitation (Table 1; Figures 4 and 5).
Part 1 of this paper deals with the most vilified ‘lower’ vertebrate species, i.e. those that aren’t mammals, but represent fish, amphibians, snakes, and birds (Figure 4). Part 2 of this paper (in press) will deal with the most vilified mammal species. Fish, amphibians, snakes, and sometimes also birds are often considered ‘lower’ because they are evolutionarily older, or simply because they aren’t mammals, reflecting human arrogance that we belong to the ‘highest’ group of animals (Figure 5). Cooper (1977) noted that some zoologists term both birds and mammals (which are warm-blooded) as ‘upper vertebrates’, but he restricted the word to include only mammalian vertebrates, while employing the phrase ‘lower vertebrates’, as in this paper, to cover birds, reptiles, amphibians, and fish. The Collins English Dictionary defines ‘lower vertebrates’ as ‘relatively simple and primitive vertebrates’, giving birds...
Table 1. Comparison of key economic and psychological considerations bearing on human relationships with the groups of vertebrates.

| Group                          | Fish | Amphibians | Reptiles | Birds | Mammals |
|-------------------------------|------|------------|----------|-------|---------|
| IUCN species assessed         | 19,239 | 6794 | 7829 | 11,147 | 5850 |
| IUCN species assessed as     | 2674 | 2200 | 1409 | 1486 | 1244 |
| "Threatened"                  |      |          |          |       |         |
| Percentage assessed as        | 13.9 | 32.4 | 18.0 | 13.3 | 21.3 |
| "Threatened"                  |      |          |          |       |         |
| Domesticated pets              | Popular | Limited popularity | Limited popularity | Very popular | Extremely popular |
| (‘companions’)                 |       |           |           |          |          |
| Domesticated livestock         | Few but large potential | Few & limited importance | Few but high importance of chickens | Many & of high importance | High |
| Harvested value                | Huge | Low | Low | High | Very high |
| (wild & cultured)             | Low | Very low | Very low | Very high | Very high |
| Charisma                      |      |          |          |       |         |

*Source: International Union for Conservation of Nature (IUCN), Table 3a: Status category summary by major taxonomic group (animals), https://www.iucnredlist.org/redlist/content/attachment_files/2019_3_RL_Stats_Table_3a.pdf; this table also shows numbers of extinct species. ‘Threatened’ includes species assessed as ‘Critically Endangered’, ‘Endangered’, and ‘Vulnerable’.

Figure 4. The most vilified ‘lower’ vertebrates (sharks, frogs & toads, snakes, and vultures). Painting by Jessica Hsiung.

and reptiles as examples, and excluding mammals (https://www.collinsdictionary.com/dictionary/english/the-lower-vertebrates). Most people are indifferent to fish, except as food and aquarium pets, but sharks are widely hated. Most people find amphibians, particularly frogs, to be unattractive and, of all vertebrates, amphibians are particularly imperilled (Table 1). Most people are afraid of reptiles, particularly snakes. Most birds (now known to be derived from reptiles) are widely admired, but vultures are considered repulsive. The predominantly cold-blooded (exothermic) vertebrates (fish, amphibians, and reptiles) have much lower public appeal than birds and mammals, and are relatively neglected in conservation programmes (Textbox 1). In the same vein, it is much easier to enact legislation eradicating cold-blooded pests than warm-blooded (endothermic) pests (Fenoglio, Boano, and Delmastro 2018). Citing George Orwell’s ‘All animals are equal, but some animals are more equal than others’, Mather (2019) commented ‘There is a huge bias in favor of mammals, which is not consistent with their frequency... 0.2% of those on the planet'. Reasons for these biases are discussed in Small (2011, 2012).

Textbox 1. Charismatic species dominate conservation funding to the detriment of most endangered vertebrates.

The interrelationship between public interest in endangered species and the attention they receive from the conservation community is the ‘flywheel’ driving much effort to abate global extinction rates. Yet big international conservation non-governmental organizations have typically focused on the plight of a handful of appealing endangered species, while the public remains largely unaware of the majority... interest was higher for mammals and birds at greater risk of extinction, but this was not so for fish, reptiles and amphibians. Our analysis reveals a global bias in popular interest towards vertebrates that is undermining incentives to invest financial capital in thousands of species threatened with extinction. Raising the popular profile of these lesser known endangered and critically endangered species will generate clearer political and financial incentives for their protection.

– Davies et al. (2019)

Sharks

‘Fish’ is the conventional plural for a group of specimens or individuals all belonging to the same species (although employing ‘fishes’ in this situation is debatably a misspelling – e.g. Jesus fed the crowd with five loaves and two fishes). However, ‘fishes’ is appropriate to referring to a group of more than one species, and this is frequent in scientific publications (although employing
‘fish’ would not usually be considered an error). When referring to fish(es) in general in expressions like ‘all the fish(es) in the sea’, ‘he sleeps with the fish(es)’, the shorter form of the plural tends to be preferred.

Fishes are classified in various ways, and the following is just one commonly recognized system. Twenty-seven thousand living species of fish have a skeleton that is made of bone, and are classified in class Osteichthyes. By contrast, only a little more than 1000 species have a skeleton made of cartilage (the flexible, light material prominent in human noses and ears), and they constitute class Chondrichthyes (Carrier, Musick, and Heithaus 2012). The term ‘shark’ is sometimes used in a broad sense to refer to all of the chondrichthyan fishes, but more commonly the word shark refers to a smaller subgroup (superorder or subdivision Selachii) of about 500 species (Ocean Portal Team 2018). Within class Chondrichthyes, the group of 500 or so sharks along with about 650 species of skates and rays make up the subclass Elasmobranchii or ‘plate-gilled’ fish (Figures 6–8).

The Whale Shark (*Rhincodon typus*; Figure 6) is the largest living shark, growing to over 18 m in length. It is a filter feeder, surviving on zooplankton and small fish. The extinct Megalodon (*Carcharocles megalodon*; Figure 7), the largest known shark, is thought to have reached 20 m in length (Figure 8). The Dwarf Lantern Shark (*Etmopterus perryi*) from the Caribbean matures at 16 to 19 cm, and is considered to be the world’s smallest shark. Sharks are carnivorous, feeding on

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**Figure 5.** Old perception of the comparative sequence of rank among the groups of vertebrates. Prepared by B. Brookes.

**Figure 6.** A 1912 postcard (public domain) showing a harvested Whale Shark (*Rhincodon typus*) in Miami, Florida, claimed to weigh 13.5 metric tonnes and to be 14 m long.
a wide range of prey. Most have several rows of teeth in their jaws. The teeth are constantly shed and replaced, and thousands of teeth are developed in a shark’s lifetime. Most sharks are cold-blooded (their temperature matching their environment), but several, including the Great White, can generate some heat. Most sharks are marine, occurring in all oceans, but a few can also survive in fresh water. The Greenland Shark (Somniosus microcephalus) is known to have reached an age of over 270 years, a record for vertebrates.

**Figure 7.** Artist impression of a Megalodon pursuing two extinct Eobalaenoptera baleen whales. Prepared by Karen Carr (public domain).

**Figure 8.** Comparative sizes of the extinct Megalodon, the Whale Shark, and the Great White Shark. Prepared by Scarlet 23 (CC BY SA 3.0).
Harmful aspects

Sharks well known for deadly attacks on humans are shown in Figure 9. Curtis et al. (2012) provide the following information.

Unprovoked attacks by sharks on humans are infrequent, but they can be extremely traumatic events. In general, the risk of shark attack is exceptionally low when compared with other dangers potentially encountered by beachgoers (e.g. drowning, rip currents, surfboard accidents, stingrays, jellyfish, etc.). However, similar to other animal attacks, they draw a disproportionate amount of public and media attention because of their dramatic circumstances. Millions of people engage in swimming, surfing, boating, snorkelling, or scuba diving in the ocean each year, providing billions of dollars in revenues to coastal communities worldwide. Repeated shark attacks within a certain area that result in injuries or deaths are not only extremely traumatic to those involved but can also lead to adverse economic impacts on coastal communities in close proximity to attack locations. This may result in considerable public pressure to take action to reduce the risk of shark attacks in such areas. There are over five hundred shark species in the world’s oceans, yet only about thirty species have been documented to attack humans . . . . White sharks have been implicated in a total of three hundred forty-six unprovoked attacks on humans worldwide since 1839, including 102 fatalities . . . the White Shark is most frequently cited as responsible where the identity of the attacking species is ascertained.

The Bull Shark (*Carcharhinus leucas*) and Tiger Shark (*Galeocerdo cuvier*) are also believed to be leading attackers of humans (Midway, Wagner, and Burgess 2019). Six global shark bite ‘hotspots’ have been identified: the West Coast of the United States, South Africa, Australia, Brazil, Reunion Island, and the Bahamas (Chapman and McPhee 2016). Shark bites of humans are claimed to have been increasing in recent years (see discussion in Midway, Wagner, and Burgess 2019, who point out that attacks seem to be decreasing in some areas). Increase in attacks has been attributed to several factors, including the rise in human population, habitat destruction, and climate change (Chapman and McPhee 2016). Forty percent of the world’s population lives within 100 km of a coast, contributing to an increased likelihood of shark–human meetings.

Beneficial aspects

Like all species, sharks are components of ecosystems in which many species have evolved natural balances. The large sharks that are of particular interest to the public are apex predators, which have been especially influential in shaping and maintaining marine ecosystems (Heupel et al. 2014).

It is highly ironic that sharks are widely regarded as ‘man-eaters’ (Neff and Hueter 2013), whereas in truth humans are ‘shark-eaters’. Sharks (as well as their chondrichthyan relatives) are commercially important for meat (Figure 10), and for shark fin soup (Figure 11(b)), a traditional and usually expensive (often over $100.00/bowl) delicacy in some Asian countries, especially China. ‘Finning’ frequently involves slicing off a shark’s fins (Figure 11(a)) and discarding the body at sea, and bans on this barbaric, wasteful practice have been instituted in some regions.

Biodiversity ecotourism – non-harmful observation of wild animals in their natural habitats – is potentially valuable for biological conservation efforts. ‘Shark ecotourism’ is the commercial practice of bringing tourists as close as possible to sharks in the wild without resulting in harm to either people or sharks (Klimley and Curtis 2006;

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Figure 9. Leading attackers of humans (at relative scale). (a) Bull Shark (*Carcharhinus leucas*). Photo (public domain) by Brenda Bowling. (b) Tiger Shark (*Galeocerdo cuvier*). Photo by Albert Kok (CC BY SA 3.0). (c) Great White Shark (*Carcharodon carcharias*), considered to be the most dangerous of sharks. Photo by Elias Levy (CC BY 2.0).
Figure 10. Harvested Shortfin Mako Sharks (*Isurus oxyrinchus*) on sale in the port of Vigo, Spain. The flesh taste is reminiscent of tuna. Photo by José Antonio Gil Martínez (CC BY 2.0).

Figure 11. Shark fins for food. (a) Harvested shark fins drying on a rack in Japan. Photo by Takonomakura (CC BY SA 3.0). (b) Shark fin soup. Photo by Cedric Seow (CC BY SA 2.0).

Figure 12. Sharks for ecotourism: people inside a shark-proof cage, with sharks swimming outside, in Hawaii. Photo by Kalanz (CC BY SA 2.0).
Gallagher and Hammerschlag 2011). Like whale watching, it can be conducted responsibly, but in reality there is an element of danger as well as the possibility of harm to natural ecosystems. Shark tourism has been touted as a means of reducing shark fishing in some regions, and promoting shark conservation (Cisneros-Montemayor and Sumaila 2014; Gallagher et al. 2015). Viewing of White Sharks underwater, wearing diving gear and from the safety of a shark cage, has become particularly popular (Figure 12). However, the sharks are typically attracted with ‘chum’ (a mixture of fish body fluids, oils, and macerated tissues), and even sometimes fed by the tourists, and there is concern that this practice conditions the sharks to approach boats and people (Bezerdi 2014).

Sharks have unusually robust physiology (they are resistant to diseases and heal quickly), and research on their biology has the potential to assist in developing medications and treatments for humans. However, claims that shark tissues, especially cartilage, can cure human cancers are unfounded (Posadzki 2011).

**Conservation aspects**

Textbox 2. Humanity’s destruction of its maternal aquatic ecosystem.

> It is a curious situation that the sea, from which life first arose, should now be threatened by the activities of one form of that life.  
>  
> – Rachel Carson (1951)

A key website for information on conservation of sharks is provided by the International Union for the Conservation of Nature Shark Specialist Group: https://www.iucnssg.org/. Sharks include the largest predatory fish in the oceans, with very few natural marine predators, but have become victims of human activities, like so much of marine life (Textbox 2). Sharks are threatened by deliberate overfishing (especially for fins), incidental or accidental catches (‘by-catch’ from becoming tangled in nets or caught on bait hooks not intended for them), pollution, habitat loss, and climate change (Dulvy et al. 2014). They are especially vulnerable because of their slow growth, late sexual maturity, and low reproductive output (Walker 1998). Perhaps 90% of large sharks have been eliminated. As top marine predators, long-lived sharks are significant bioaccumulators of pollutants such

Textbox 3. Economic and ecological harm associated with the decline of sharks.

Shark and ray populations in many parts of the world’s oceans are in decline. These populations face a variety of threats, most notably from fishing, habitat degradation, pollution and climate change. These declines are exacerbated by their life history – slow growth, late maturity and small numbers of young relative to most other aquatic taxa – and as a result, populations have less potential to sustain fishing or to recover from depletion than do most teleost fish or invertebrates. Although no species of shark or ray are known to have become extinct in the wild, several species have been extirpated from large parts of their range, and 67 species are currently listed as Critically Endangered or Endangered on the IUCN Red List … . The loss of some shark and ray populations from aquatic ecosystems has socioeconomic and ecological consequences. First, sharks provide a source of protein, as well as a variety of other products (e.g. leather, fins, cartilage, liver oil) that are important to communities in both developing and developed nations. Whereas some fished populations are managed within sustainable limits (e.g. gummy shark, *Mustelus antarcticus*, in southern Australia), most are fished without knowledge of their sustainability or at levels above scientifically recommended limits. The lack of sustainable fishing practices for shark and ray populations will mean that this source of protein will need to be replaced by other sources, most of which are already at or above sustainable limits, or consumption will need to decline. Second, the decline of shark and ray populations has ecosystem consequences. The role of some shark species as top predators exerts top-down effects on ecosystems, and their loss or decline may have important direct and indirect effects on populations that can cascade through marine ecosystems. The loss of sharks may result in substantial changes to ecosystems that affect other organisms and the industries and human communities that rely on them.

– Simpfendorfer et al. (2011)

Figure 13. Whale Shark (*Rhincodon typus*) in the Georgia (U.S.) Aquarium. Photo by Zac Wolf (CC BY SA 2.5).
as mercury (Camhi et al. 1998). The reduction of sharks has deleterious economic and ecological consequences (Ferretti et al. 2010; Chapman 2017; Textbox 3).

Sharks are popular subjects for public and hobby aquaria (Morris, Livengood, and Chapman 2010; Grassmann, McNeil, and Wharton 2017; Figure 13), but like zoos, keeping animals in captivity may be beneficial or harmful to biodiversity (Lück 2007). Most species are unsuitable for aquaria, and hobbyists need to be cautious about offerings in the trade which may have been acquired from shrinking wild resources.

People are fascinated by large sharks that can eat humans, but this morbid interest is often unhelpful. For centuries, sharks have been depicted as extremely dangerous (Figures 14–15). Sensationalistic and often misinformed reports of gory shark attacks make it hard to view sharks sympathetically (Pearce 2015; Textbox 4), and to motivate the public to support conservation of sharks (Friedrich, Jefferson, and Glegg 2014). The expression ‘loan shark’ reflects the widespread villainous and heartless image of sharks. Similarly a ‘pool shark’ is a skilful billiards player who habitually takes advantage of

Figure 14. A typical historical depiction of sharks as extremely dangerous. Watson and the Shark, an oil painting (public domain image) by the American painter John Singleton Copley (1738–1815), showing a shark attack.

Figure 15. Cartoon showing the widespread conception that sharks are dangerous, bloodthirsty predators of humans. Prepared by B. Brookes.
Textbox 4. Lack of accurate and relevant knowledge harms shark conservation.

With the cultural shift toward environmentalism, public opinion about sharks has been changing. Popular culture now emphasizes that these animals are not a marine menace, but are instead stewards of the environment that play a critical role at the apex of marine food chains. The public is told in plaintive tones that sharks are misunderstood and that there is a need to study them because fisheries are depleting their numbers to such an extent that there will likely be dire consequences for marine ecosystems. As a result, a wave of instant ‘shark researchers’ has sprung up all over the world. Most seem to be associated with tourist diving operations using protective cages. These businesses often cater to a sense of adventure while offering clients the impression that they are contributing to a scientific understanding of these animals. Unfortunately, despite considerable press coverage and shifting public awareness, this has done little to promote much needed basic research.

– Naylor and Aschliman (2013)

Gaining support for shark conservation has been extremely difficult due to the negative preconceived notions the general public holds toward sharks . . . . The media . . . can play a significant role in promoting conservation, but unfortunately media coverage of sharks has been controversial recently with the airing of several non-factual, fake documentaries. To promote shark conservation the media’s message has to be unbiased, non-sensationalized, and accurate to ensure people are receiving the information necessary to build strong pro-shark conservation behaviours.

– O’Bryhim and Parsons (2015)

competitors. Regrettably for sharks, they are almost never pictured sympathetically as in Figure 16. The 1975 movie Jaws particularly reinforced fear of sharks, and indeed stimulated sports fishermen to deliberately eliminate them (Francis 2012). Nevertheless, the massive star of the film, an artificial mechanical contraption masquerading as a Great White, hardly represents the majority of sharks, which are no threat whatsoever to people. The widespread image of sharks as violent, bloodthirsty, unfeeling ‘eating machines’ has led to their persecution and senseless slaughter. ‘Despite its relative rarity, shark attack is a cultural phenomenon that draws intense public interest in the popular media with myths and misconceptions routinely perpetuated on television, in magazines and newspapers, and in the social media’ (Midway, Wagner, and Burgess 2019). Notable in this regard is ‘Shark Week’, an annual TV block (often week-long) which began in 1988 at the Discovery TV Channel, much criticized for sacrificing scientific accuracy for sensationalistic aspects related to sharks. Similarly the ‘Sharknado’ made-for-TV film series, starting in 2013, has dealt with waterspouts that lift sharks out of the ocean and deposit them on people with terrifying consequences. In fact, sharks are an insignificant hazard to humans: worldwide, about a dozen people are killed by sharks every year, while millions of sharks are killed by humans annually. Culling of sharks, often organized by governments, has been found to be ineffective, but in areas where sharks are known to pose risks, beach barriers and management techniques do reduce shark–human interactions (Curtis et al. 2012).

While there is conservation concern for sharks (Figure 17), to date international agreements to prevent overfishing have been very limited (Shiffman and Hammerschlag 2016). Many sharks are threatened, but for the most part researchers are concentrating on relatively common charismatic sharks and not the smaller, less interesting, but endangered sharks, which are much rarer (Momigliana and Hartcourt 2014). The three most dangerous sharks are in fact relatively protected in legislation: the White Shark is classified by the IUCN (International Union for Conservation of Nature) Red List as ‘Vulnerable’ while Bull and Tiger Sharks are evaluated as ‘Near Threatened’.

Figure 16. An unusual, sympathetic, humorous, anthropomorphic depiction of a shark befriending a sailor. Source: Holder and Jordan 1909. Photo credit: Freshwater and Marine Image Bank, University of Washington Libraries.
Frogs and toads

There are approximately 7000 living species in the vertebrate class Amphibia (the amphibians), which in addition to frogs and toads includes salamanders, newts, mudpuppies, and other groups (Pyron and Wiens 2011). Frogs inhabit all continents except Antarctica, and while a few reach the Arctic Circle, the greatest diversity occurs in the Tropics. They occupy most terrestrial and aquatic habitats, but avoid salt water. Frogs (and toads) mostly lay their eggs in water, the eggs develop into swimming tadpoles, and then transform into frogs (or toads) which may spend their adulthood mostly in water, on land, or in both (Figure 18).

The classification of frogs and toads is unsettled. There are about 6200 species that are called frogs and toads (Vitt and Caldwell 2013). Commonly, the ‘true frogs’ are placed in the family Ranidae. There are over 600 species of frogs found worldwide that are in this family. Other families that are often recognized include Bufonidae (the true toads), Ascaphidae (the tailed frogs), Pelobatidae (the spade foots), and Hylidae (the tree frogs).

The Goliath Frog (Conraua goliath) from Africa is the largest living frog, growing up to 33 cm in length and weighing up to 3.25 kg. The extinct ‘Devil Frog’ (Beelzebufo ampinga) of Madagascar may be the largest frog that ever

Figure 17. A display in favour of shark conservation. Photo by Socheid (CC BY SA 4.0).

Figure 18. Plate from a public domain nineteenth-century encyclopedia (Kirby and Schubert 1889) showing frogs and toads in their natural habitat. (a) Common Toad (Bufo bufo), (b) Natterjack Toad (Epidalea calamita), (c) Surinam Toad (Pipa pipa), (d) Edible Frog (Pelophylax esculentus), (e) Green Tree-frog (Hyla arborea).
lived. It grew to 41 cm in length and weighed about 4.5 kg. Paedophryne amauensis, from Papua New Guinea, may be less than 8 mm in length and is considered the world’s smallest known vertebrate (Rittmeyer et al. 2012).

The distinction between what should be included in ‘frogs’ in its most comprehensive sense and ‘toads’ in its comprehensive sense is debatable. In practice, frogs have smooth, moist skin (which may appear slimy), a narrow body with round bulging eyes, and long hind legs designed for lengthy, high jumps. Frogs usually live near and are often found in water, and have many predators. By contrast, toads have rough, dry, bumpy skin, a wide body with oval eyes which do not bulge as much as the eyes of frogs, and short hind legs designed for small hops rather than jumps. Frogs usually have teeth, toads usually do not. Toads can live in dry situations away from water, and their bitter-tasting skin deters predators. These differences do not hold for all species called frogs and toads. Moreover, the word ‘frog’ is often used in a comprehensive sense to refer to both frogs and toads. Regardless of technical classifications, frogs and toads share an unmistakable appearance (Figure 13), characterized by short, tailless bodies, broad, flat heads, big mouths, and long, muscular hind legs.

**Harmful aspects**

Toxins on the outer parts of frogs often protect them from predators. The skin of many frogs (indeed, of numerous amphibians) may contain tiny glands that secrete a variety of toxic chemicals (Daly 1995). Many toads and some frogs also have large glands on the side of their heads behind the eyes, that manufacture defensive toxins which are secreted externally. Various terms have been applied to these glands (Tyler, Buron, and Bauer 2001). They are best called parotoid glands (or alternatively, paratoid glands). However, they have also frequently been termed parotid glands (even in technical zoological literature), which is confusing because the latter phrase is also applied to a different kind of gland that occurs in mammals. In mammals, parotid glands excrete saliva within the mouth.

Many frogs accumulate toxic alkaloids from the animals they consume, and some are able to synthesize their own toxins (Saporito et al. 2012; Santos, Tarvin, and O’Connell 2016). The toxins of ‘poison dart frogs’ are employed in South America to produce poison to add to darts, and such species are so poisonous that they merit avoidance. Some are so toxic that one drop of their skin secretions can kill an adult human. Many toxic frogs are brilliantly coloured, to warn away predators (Figure 14). Some frog secretions are hallucinogenic, and are occasionally unwisely employed by people to get high.

![Figure 13. Plate from a public domain nineteenth-century encyclopedia (Brockhaus 1892) showing frogs and toads. (a) Litoria peronii (Australia). (b) Bombina bombina (Europe). (c) Ranitomeya fantastica (Peru). (d) Leptopelis flavomaculatus (Africa). (e) Allobates femoralis (South America). (f) Bufo japonicus (Japan). (g) Phyllomedusa hypochondrialis (South America). (h) Bufo balearicus (Italy). (i) Pelophylyx lessonae (Europe).](image)

The Cane Toad (Rhinella marina; Figure 21) is the world’s largest ‘toad’. This native of South and mainland Central America has been introduced to islands throughout Oceania and the Caribbean, and Northern Australia. Imported in some places to control agricultural pests (especially in Sugarcane, hence ‘cane’ in the name), it has become an invasive pest, and a serious threat to native species (Tingley et al. 2017). The skin of Cane Toads is very toxic, and dogs attacking them have died. Cane Toads are reviled in Australia where they seem to be unstoppable, despite merciless programmes of extermination (Shine 2018).

**Beneficial aspects**

Frogs and toads in their natural ecosystems play important roles as predators and prey. They consume agricultural pests and disease carriers, and are an important food source for birds, snakes, and other animals. Vast
numbers of insects are destroyed, some species known to eliminate thousands of mosquitoes in a single night. Tadpoles are usually aquatic and those consuming algae assist in keeping waterways clean. In parts of the world frogs are eaten and provide a significant source of protein. Where there are very large supplies of frogs or toads, their skins are sometimes harvested for leather. Frogs are also employed in traditional medicine to treat many conditions. Frogs are also used to a degree in Western medicine. They are common subjects of laboratory experimentation, including manipulations by schoolchildren (a subject that raises ethical issues, and usage is decreasing due to animal welfare concerns). The African Clawed Frog (*Xenopus laevis*) was extensively employed in the past in pregnancy testing (urine from a pregnant woman injected into a female frog causes it to lay eggs). The skin of amphibians often contains defensive biological compounds, which have potential to contribute to pharmaceuticals against infective microorganisms. Sometimes frogs are kept as pets, but it should be understood that amphibians often carry salmonella bacteria, so handling them could produce intestinal discomfort.

**Conservation aspects**

Amphibians worldwide are facing numerous threats to their existence (Heatwole and Wilkinson 2012; Tapley et al. 2015; Textbox 5; Figure 22). The Amphibia are proportionally the most threatened group of vertebrates. A very high percentage of frogs and toads – 30% – is...
Textbox 5. The threat to survival of frogs and toads.

Amphibians appear particularly vulnerable to global change as the world enters its sixth mass extinction event. Because of their roles as important prey and predators, susceptibility to water-soluble toxins through permeable skin, and a life history that straddles aquatic and terrestrial environments, amphibians are good indicators for environmental degradation and community stability in the face of the major drivers of species loss. Although the causes of amphibian declines are diverse and interactive, individual mechanisms include habitat loss, environmental contamination, global climate change, disease and pathogens, spread of invasive species, and overharvesting.

– Warkentin et al. (2009)

classified as ‘Severely Threatened’ (Morrison et al. 2012; IUCN 2017); by comparison, 22% of mammals and 13% of birds have this status. About 150 species of frogs are believed to have gone extinct in recent history (Vitt and Caldwell 2013). The skin of frogs and toads is thin and permeable to water (‘semi-permeable’ to infiltration of many compounds in water), facilitating entry of harmful pollutants. Many wild populations are in serious decline due to harmful chemicals in their environment. Indeed, because of their sensitivity to pollution, frogs have been likened to the canary in the coal mine that indicates environmental danger. Frogs are considered by ecologists to be a particularly good indicator of the health of ecosystems, and the current rapid reduction in their numbers coupled with the frequent development of physical malformations (such as extra legs) is viewed with alarm. Many breeding ponds are being filled in because of housing development or polluted by agricultural pesticides. Large numbers are killed on roads, especially toads. Some species are threatened by collection out of nature for the trade in living animals. The introduction of more competitive foreign species is another factor, and so is climate change. As if amphibians didn’t have enough problems, a deadly parasitic chytrid (Batrachochytrium dendrobatidis; chytrids are usually interpreted as fungi) is rapidly eradicating amphibians throughout the world (Skerratt et al. 2007; Bacigalupe et al. 2017; Figure 23).

Frog-legs (frogs’ legs) are a prominent dish in many national cuisines, particularly in France and China (Figure 23). Although frogs are farmed in China, Vietnam, and Taiwan, the vast majority that end up on a plate are harvested from the wild. Many countries have severely restricted local collection, but huge quantities are exported from Asia, mostly from

Figure 23. A dish of frogs’ legs. Photo by Anagoria (CC BY 3.0).

Figure 22. Stubfoot Toads (Atelopus of Central and South America). These have become highly diminished by habitat loss, pollution, introduced species, and disease. Source (public domain): Franz et al. (1918).
Indonesia. Currently, about a billion frogs are exported annually to the United States, about two billion to Europe (Warner 2011). Many environmentalists are opposed to consumption of frog legs in view of the general decline of amphibians (Warkentin et al. 2009). While it has been assumed that a very small number of species are being harvested from nature, it appears that in fact a broad range of frogs are being taken from the wild (Ohler and Nicolas 2017). The Mountain Chicken (Leptodactylus fallax), a native of the Caribbean islands of Dominica and Montserrat, has become critically endangered because of overcollection for its legs which are said to taste like chicken (Schuessler 2016).

Attitudes by the public towards frogs and toads are quite polarized, and this is critical in determining support for conservation. Many people think frogs and toads are just ugly and disgusting. A plague of frogs was one of God’s punishments in the Old Testament. On the whole, historical attitudes to frogs and toads have been rather mixed, many fairy tales depicting amphibians favourably, others not. According to a particularly common myth, touching warty toads (or any frog) gives one warts. ‘The Frog Prince’ fairy tale (especially a version by the Brothers Grimm) involves a Princess kissing a frog which causes it to transform into a handsome prince (Figure 24). Fortunately, many people find frogs to be cute, and there are many illustrations of frogs and toads appearing to behave like humans (Figure 25).

On the other hand, some people are pathologically afraid of frogs and toads. Phobic fear of frogs, toads or other amphibians is called batrachophobia or ranidaphobia (the latter term sometimes restricted just to frogs). Extreme fear of toads has been termed bufonophobia. Fear of frogs is basically irrational, but it is real, and people with this condition need sympathetic, professional guidance.

There are efforts being made to save frogs and toads. Many schools now teach that these, as well as snakes, deserve to be protected. Almost 7% of all amphibians are represented in zoos, where they receive a measure of protection against extinction (Murphy and Gratwicke 2017). There are also international efforts to limit the trade in frogs collected from the wild (Figure 26).

**Snakes**

The vertebrate class Reptilia, with about 10,000 species, is classified in different ways by different authorities. In addition to snakes, other creatures accepted as reptiles include turtles, lizards, crocodiles, and others (Pinheiro-Donoso et al. 2013). Some include birds, which in fact are known to be derived from reptiles (Modesto and Anderson 2004). Snakes are assigned to suborder Serpentes (the word serpent is synonymous with snake). There are about 3600 species of snakes living today. Snakes occur on every continent except Antarctica, but are absent from some islands, notably Greenland, Iceland, Ireland, and New Zealand (although sea snakes often visit coastal areas). Most snakes are terrestrial, but about 70 marine species, which are extremely venomous but docile, live in the Indian and Pacific oceans. So-called thread snakes – blind, burrowing, worm-like animals – are as short as 10 cm in length. The longest snake is the Reticulated Python growing to about 7 m in length (the extinct Titanoboa cerrejonensis grew to almost 13 m). The Green Anaconda is not the longest, growing to over 5 m, but is believed to be the heaviest of living snakes, approaching 100 kg. Snakes are ‘cold-blooded’ (poikilothermic), i.e. unable to generate their own heat metabolically, and in freezing climates they overwinter in a dormant condition, in sheltered, above-freezing situations, sometimes denning communally with hundreds, even thousands of other individuals. Snakes are scaly (covered by overlapping scales), but contrary to frequent belief, are not slimy. Snakes are of...
considerable interest to science, and there are many popular books (e.g. Mehrtens 1987; Mattison 2007; Lilywhite 2014; O’Shea 2018). Many snakes are quite beautiful (Figure 27).

Harmful aspects

Some biologists arbitrarily state that no snake is ‘poisonous’ when a poison is defined as a substance that is ingested or inhaled – which excludes injection. In any case, the venom (which is based on modified saliva) is usually a combination of many chemicals and can be quite toxic. The compounds present may include proteolytic enzymes (which break down proteins), myotoxins (which destroy muscle tissue), neurotoxins (which block or destroy nervous system tissues), and hemorrhagic toxins (which attack the circulatory system and prevent blood clotting). The principal function of venom for snakes is prey subjugation, but venom also serves as a deterrent to predators (Jackson and Fry 2016; Jackson, Jouanne, and Vidal 2019). Most snakes are nonvenomous (at least, they do not have significantly toxic saliva), but about 725 species are venomous, and of these about 250 can kill a human with a single bite. The internet abounds with lists allegedly representing the world’s most venomous or dangerous snakes, but there is considerable disagreement about how to make such judgements (Silva 2013; Walls 2013), and snake identification is sometimes erroneous leading to false records. Examples of particularly poisonous snakes are shown in Figure 28. Some snakes, such as many of the sea snakes (Figure 29), have extremely toxic venom – i.e. very little is required to kill – but they very rarely attack humans. Aggressive venomous snakes that are common and likely to encounter people are responsible for most snakebites. Walking barefoot in snake-infested regions is frequent in Developing Countries, particularly in parts of Asia and Africa, where casualties are highest. Due to lack of treatment facilities coupled with occurrence of venomous snakes, it has been estimated that about

Figure 25. Anthropomorphic depictions of frogs and toads – shown in human-like activities. (a) Toads Tea-Party by English author, illustrator, mycologist, and conservationist Helen Beatrix Potter (1866–1943; her published works entered the public domain in 2014). (b) A toad in morning dress, holding an umbrella and a bunch of flowers. Drawing by G. Hope Tait, ca. 1900. Credit: Wellcome Collection (CC BY 4.0). (c) Chorus of Frogs, a vintage postcard (public domain) from the early twentieth century. (d) Frog fishing, from Beatrix Potter’s The Tale of Mr. Jeremy Fisher.
93 million people are at greatest risk, including many in sub-Saharan countries, Indonesia, and other parts of southeast Asia (Longbottom et al. 2018).

Snakes with major clinical importance belong to the families Elapidae (African and Asian cobras, Asian kraits, African mambas, American coral snakes, Australian and New Guinean venomous snakes, and sea snakes) and Viperidae (Old World vipers, American rattlesnakes and pit vipers, and Asian pit vipers). (Gómez-Betancur et al. 2019)

A detailed geographical guide to the principal venomous snakes is found in World Health Organization (2016). Approximately 100,000 people die annually from snake bites, and every year 400,000 suffer permanent disabilities such as amputations and permanent neurological damage (Williams et al. 2019;Textbox 6). Anti-venom reduces mortality from venomous snakes by 90%, but is frequently unavailable in poor countries, accounting for the large number of deaths. By comparison, hippos, the deadliest land mammal, kill an estimated 500 people annually. Shark bites attract far more attention, but claim as little as five deaths worldwide yearly. Snakes are natural predators of wild animals, but they also sometimes victimize livestock and pets. Occasionally very large nonvenomous snakes also kill humans and domesticated animals.

Textbox 6. Snakebite harm occurs mostly in poor, tropical countries.

Snakebite envenoming (SBE) affects as many as 2.7 million people every year, most of whom live in some of the world's most remote, poorly developed, and politically marginalized tropical communities. With annual mortality of 81,000 to 138,000 and 400,000 surviving victims suffering permanent physical and psychological disabilities, SBE is a disease in urgent need of attention. Like many diseases of poverty, SBE has failed to attract requisite public health policy inclusion and investment for driving sustainable efforts to reduce the medical and societal burden.

– Williams et al. 2019

Textbox 7. Invasive snakes contribute to biodiversity loss.

Invasive species are considered to be among the major causes of biodiversity loss. . . . Increasing urbanization creates a desire for contact with nature for people living in towns and cities, and keeping pets is one way of fulfilling this need. The popularity of reptiles as pets has been growing steadily since the second half of the 20th century. Unfortunately, reptiles can have enormous negative ecological impacts, e.g. invasion of the brown tree snake (Boiga irregularis) on Guam island caused the extinction of 77% of the island’s native birds and 75% of its native lizards. Also, other direct impacts on humans (e.g. venomous snakes or power outages caused by these snakes).

– Kopecký et al. 2019

Some introduced snakes are causing considerable harm to natural ecosystems (Kraus 2015). The most widely cited example is the Brown Snake introduced to Guam, where it climbs trees and decimates native birds not expecting it (Textbox 7). The Burmese Python (Python bivittatus or Python molurus bivittatus) is currently invading the Florida Everglades with widespread reductions of native animals (Dorcas, Pittman, and Willson 2017; Willson and Driscoll 2017; Figure 30).

Beneficial aspects

Most snakes are beneficial because they control rodent and other pests. Without snakes, expanding rodent populations would significantly increase property damage, spread of infectious diseases, and destruction of agricultural products. Species such as garter snakes also feed on typical garden pests such as slugs and snails,
and some snakes consume insects like grasshoppers and crickets that damage crops. Snakes are prey for larger animals such as hawks, owls, and herons. Snakes are a key component contributing to the maintenance of ecosystems.

Snakes are exploited in several ways by humans, especially as food, pets, and (especially in Afro-Brazilian religions) in traditional medicine and magic/religious ritual (Alves and Filho 2007). Snake skin, especially from large snakes such as pythons, is employed to make a premium leather (Figure 31). Snake venom is under investigation as a potential source of pharmaceuticals (Estevão-Costa et al. 2018; Munawar et al. 2018). The venom of particularly toxic snakes is harvested in order to produce antivenoms to treat snakebite (Figure 32). Antivenom is produced by injecting small amounts of venom into a domestic animal, and after the animal’s blood produced antibodies, collecting and purifying the antibodies.

Aust et al. (2017) reviewed the status of snake farming in China and Vietnam, where the reptiles are raised for meat, hides, and medicine. China and Vietnam are believed to be the largest and most important producers of, and markets for, snake meat. Aust et al. (2017) estimated that there are 4000 farms producing several million snakes of at least 15 taxa, including the Monocled Cobra (Naja kaouthia), the Chinese Cobra (Naja atra), the Oriental Rat Snake (Ptyas mucosus), and the King Cobra (Ophiophagus hannah) which are raised especially for meat. Snake farms usefully recycle low-value waste protein from the livestock and fishery industries. Aust et al. (2017) noted that ‘The livestock industry often attracts the attention of animal welfare groups because it advocates the intensive production of higher-order vertebrates’ but that this is less of a problem because ‘Snakes display markedly inferior cognitive abilities compared to endothermic species such as poultry and pigs’.

Figure 27. Beautiful snakes. (a) Blue Striped Garter Snake (Thamnophis sirtalis similis), slightly venomous, a Florida subspecies of the Common Garter Snake. Photo by Glenn Bartolotti (CC BY SA 4.0). (b) Texas Coral Snake (Micrurus tener), venomous, endemic to the southern United States and northeastern and central Mexico. Photo by L. A. Dawson (CC BY SA 2.5). (c) Rainbow Snake (Farancia euryphagma), nonvenomous, endemic to coastal plains of the southeastern United States. Photo by Charles Baker (CC BY SA 4.0). (d) Texas Long-nosed Snake (Rhinocheilus lecontei tessellatus), nonvenomous, endemic to the western United States and northern Mexico. Photo by L. A. Dawson (CC BY SA 2.5). (e) Coast Garter Snake (Thamnophis elegans terrestris), slightly venomous, one of numerous subspecies of this species of North American garter snake. Photo by Steve Jurvetson (CC BY 2.0). (f) Mud Snake (Farancia abacura), nonvenomous, endemic to the southeastern United States. Photo by U.S. Fish and Wildlife Service (public domain). (g) Southern Ringneck Snake (Diadophis punctatus), slightly venomous, southern phase of a species found in much of the United States, central Mexico, and southeastern Canada. Photo by Glenn Bartolotti (CC BY SA 3.0).
Despite the fear and loathing of many for snakes, they are favourite subjects of zoological displays. A ‘serpentarium’ (also known as an ophidiarum) is a zoo dedicated to snakes. A herpetarium is a zoo specializing in both reptiles in general as well as amphibians. Usually snakes are exhibited as sections of zoos and museums. Snakes are sometimes included in entertainment acts (Figure 33), which are sometimes unseemly, as noted in the following. Snake charming, most common in India, involves playing and waving...
around a wind instrument called a pungi in front of a snake (typically a cobra), which the audience is persuaded to believe becomes hypnotized (Figure 34). Strip-tease acts often involve snakes, a reflection of the association of the sexuality of women with the interpretation of snakes as phallic symbols of fertility (Foubister 2003). Some American Christian sects handle poisonous snakes, inspired by a passage of Scripture, Mark 16:15–18, which allegedly instructs followers of Christ to handle poisonous ‘serpents’ as a part of their worship, as a confirmation of their faith (an illegal practice in some states).

**Conservation aspects**

Snakes are the victims of habitat loss, particularly caused by urban sprawl, pollution, and deforestation (Mullin and Seigel 2009). About 100 species are listed by the IUCN Red List (https://www.iucnredlist.org/) as endangered. About 15% of sea snakes are either threatened with extinction or ‘Near Threatened’ (Elfes et al. 2013). Some rare species are threatened by over-harvesting (Alves and Filho 2007). Because snakes are predators, they are susceptible to the accumulation of environmental contaminants absorbed by their prey (Campbell and Campbell 2001).

There has been concern that snake farms may contribute to the overexploitation of wild species harvested from nature but represented as legitimately raised farm snakes (Lyons and Natusch 2011; Kasterine et al. 2012). Wild amphibians and rodents are often fed to farmed snakes, so there also needs to be attention to their conservation.

Snakes are heavily penalized by their bad reputations which have resulted in their being considered to be principal protagonists of humans (Figure 35).
Snakes are among the most persecuted of animals (Textbox 8). In addition to venom, snakes use constriction (Figure 30), or simply swallowing to kill their prey. All of these methods are repulsive to the human psyche. Moreover, numerous snakes are ambush predators, and so are by nature ‘sneaky’, further deteriorating the way humans perceive snakes. One of the dictionary definitions of snake is ‘a treacherous or deceitful person’. This view that snakes are wicked traces back at least to the story in the first book of the Bible of a serpent in the Garden of Eden persuading Eve to consume the forbidden fruit from the Tree of Knowledge (Figure 36). Western stories have often portrayed snakes as untrustworthy (Foubister 2003). On the other hand, snakes generally are respected creatures in most religions and in mythology (Stanley 2008; Sasaki, Sasaki, and Fox 2010; Figure 37).

‘Ophidiophobia’ refers to an irrational or extreme fear of snakes. However, it is not clear that fearing snakes is ‘abnormal’. Perhaps a third of people exhibit some fear of them, more commonly women (Rakison 2009). Some have theorized that humans, and indeed many other animals, have an innate
Textbox 8. Fear and ignorance as obstacles to snake conservation.

A surprisingly large number of persons in our society either cannot, or will not, accept the truth about one of our most useful forms of animal life – our harmless common snakes. This unfortunate attitude exists because it seems to be a characteristic of human beings to avoid learning anything that may cause them to consider something as harmful. They refuse to learn how to tell the harmless from the poisonous ones.

– Nelson (1960)

Due to an irrational, albeit subconscious, fear of snakes many snakes are killed needlessly. This could be avoided with a little understanding and education. Fear of snakes can be overcome regardless of its innate origins . . . However, overcoming this fear will first require an attitude of caring about our environment and its inhabitants followed by education about the reality of these misunderstood reptiles.

– Stanley (2008)

Though threatened by many of the same issues that affect other wildlife, including habitat loss, climate change and disease, negative attitudes may be the biggest barrier to snake conservation because it often impedes efforts to address other threats. For example, public outcry based on fear and misinformation recently halted a scientifically sound conservation plan for timber rattlesnakes. A similar project at the same location that involved releasing eagles was embraced by the community. Rattlesnakes are no less iconic or important to the ecosystem than eagles. In fact, they may help reduce the incidence of Lyme disease, which affects tens of thousands of people in the United States each year, by reducing the number of rodents that harbour this disease. But facts often play second fiddle to emotions where snakes are concerned. Snakes are important components of biodiversity, serving as both predators and prey in nearly every ecosystem on earth.

– Amarello (2017)

(instinctive) aversion to the sight of snakes acquired during evolution, as an adaptation to survive encounters with dangerous snakes (Kawai 2019). Indeed, there is even an indication that we are programmed to become alert when we hear snakes hissing (Erlich, Lipp, and Slaughter 2013). On the other hand, life experiences clearly condition some people to fear snakes. A more sophisticated view is that we have an inherent capacity to learn about characteristics that signal that an animal is dangerous, and that snakes trigger a lifelong fear response, perhaps as early as infancy (Souchet and Aubret 2016; Baynes-Rock 2017). It is clear that some animals are genetically programmed either to fear their predators from birth or to selectively become afraid of snakes (Cook and Mineka 1990). In studies of human infant responses, it can be difficult to tell whether snake-like stimuli are evoking a ‘fear’ response or simply ‘interest’ (Thrasher and LoBue 2016).

There are dozens of books written for children that sympathetically discuss snakes (e.g. Thomson and Wildlife Conservation Society 2006). Unfortunately, movies today often reinforce fear of snakes. The 1963 American epic movie Cleopatra included the suicide of the young queen of Egypt by a poisonous asp. The memorable line ‘Snakes, why did it have to be snakes’ was uttered by Indiana Jones in the 1981 film Raiders of the Lost Ark when he discovered that the Well of Souls was crawling with them. And the 2006 horror film Snakes on a Plane garnered a large cult following.

Vultures

Vultures are large birds that entirely or predominantly scavenge the bodies of dead vertebrate animals. They occur world-wide, except in Antarctica and Australia. There are 16 species of Old World vultures (examples
are shown in Figure 38). There are also seven species of New World vultures, including the Andean Condor and the endangered California Condor. Vultures are sometimes locally called buzzards, an ambiguous name that is also applied to some species that are not vultures. The Old World species (thought to have eagle ancestors) are not significantly related to the New World species (thought to have stork ancestors), so it is clear that their life style, of feeding almost entirely by scavenging dead bodies, evolved independently.

Scavengers are species that include in their diet dead animal or plant material that they did not kill or collect, such as animals that died naturally, or the remains of prey that was abandoned. While numerous scavengers will spend
at least some of their time hunting and killing live animals or foraging on living plants, vultures are the only vertebrates that are obligate (full-time) scavengers, although sometimes they kill wounded, dying, newborn, or small and weak animals. There are also several obligate invertebrate scavengers, such as Blowflies, and various deep-sea creatures, including some fish, that are thought to rely mainly if not exclusively on scavenging. ‘Necrophagy’ refers to feeding on corpses (dead bodies) or carrion (bodies that are decaying, but not too extensively), and such animal tissues almost always provide high-quality food.

The biology of vultures has been studied extensively (see Campbell 2015 for an excellent review). Dead animals putrefy (similarly dead plant materials decay), and the causal microorganisms frequently produce toxins. Vultures specialize on corpses (some occasionally consume rotting fruit), and their bodies are adapted to such feeding and to withstand the associated toxic germs. The ‘bald’ head and often the neck of vultures is mostly or entirely bare of feathers to facilitate thrusting their heads into the carcasses while avoiding contaminated flesh and blood accumulating on head feathers. An alternative, somewhat speculative interpretation is that the lack of feathers facilitates cooling in hot environments (Ward et al. 2008). The feet of New World vultures are adapted to walking on ground, rather than grasping and killing prey. (Old World vultures have talons, like their eagle and hawk relatives.) Large wings allow soaring with minimal expenditure of energy, and along with keen vision this facilitates the location of dead bodies. Sharp, hooked beaks are designed to rip meat apart. Vultures of the genus Cathartes (including Turkey Vulture, Greater Yellow-headed Vulture, and Yellow-headed Vulture) also have a well-developed sense of smell that aids in the detection of carrion as far away as 2 km. Stomachs of vultures are capable of withstanding extremely corrosive acidity, which is necessary to kill the large intake of bacteria. Strong immune systems

Figure 38. Some Old World vultures. (a) Palm-nut Vulture (Angolan Vulture; Gypaetus angolensis). Colour lithograph, ca. 1875. (b) Bearded Vulture (Lammergeier; Gypaetus barbatus). Chromolithograph by W. Greve after A. Thorburn, ca. 1885. (c) Cinereous Vulture (Vultur monachus). Chromolithograph by W. Greve, after A. Thorburn (1860–1935), ca. 1885. All from Wellcome Trust (CC BY 4.0).
further serve to survive infections from contaminated meat. The Egyptian Vulture has learned to drop stones on ostrich eggs to open them. Bearded (Lammergeier) Vultures (Figure 38(b)) drop bones on rocks to break them open, and use their specialized tongues to extract the marrow.

**Harmful aspects**

Textbox 9. Pest problems caused by the two most common North American vultures.

Black and Turkey Vultures cause problems in several ways. The most common problems associated with vultures are structural damage, loss of esthetic value and property use related to offensive odours and appearance, predation to livestock and pets, and air traffic safety . . . . Livestock losses to black vultures are a major concern for many producers. Black Vulture predation of livestock involves killing or injuring animals that are sick, weak, or otherwise unable to defend themselves. This usually involves newborn calves, piglets or lambs and the associated heifers, sows, and ewes . . . . Property damage, especially from Black Vultures, includes tearing and removing window caulking, screen enclosures, roof shingles, vinyl seat covers from boats and tractors, windshield wipers and door seals on cars, and plastic flowers at cemeteries. Droppings of Turkey and Black Vultures create nuisance conditions, especially when the birds loaf on roofs of houses, office buildings, communication towers, and electrical transmission structures. The accumulation of droppings on electrical transmission towers causes arcing and power outages. Vultures pose hazards to aircraft, especially when landfills, roosts, or other congregating sites are located near approaching or departing flight paths . . . . In addition, vultures can cause human health and safety problems by contaminating water sources with their droppings. Contamination has occurred when coliform bacteria from droppings entered water towers or springs from which residences drew water. Many people consider vultures a nuisance because of the white-wash effect their droppings leave on trees and structures at roost sites, the ammonia odour emanating from roost sites, and a general feeling of doom when vultures congregate nearby . . . . Black vultures often plunder dumpsters and garbage cans, and they frequent waste transfer stations, zoos, and any place where food scraps are regularly available.

— Avery and Lowney (2016)

The two most common species of vultures in North America (the distributions of both extend to South America) are the Turkey Vulture (*Cathartes aura*; Figure 39(b)) and the Black Vulture (*Coragyps atratus*; Figure 39(a)), and both are significant pests, their sharp nails, strong beaks, and corrosive droppings capable of considerable damage (Textbox 9; Figure 40).

As noted in the next section, vultures play important roles in limiting the spread of diseases from carcasses. However, while some bacteria are destroyed in a vulture’s digestive tract, some bacteria could be transmitted on the bird’s feathers and feet. Thus, while vultures can reduce the spread of most infections in a locality, they also could introduce infections into new areas. (Avery and Lowney 2016)

In fact, Old World vultures have recently been demonstrated to be carriers of disease (Meng et al. 2017), including histoplasmosis and salmonella. Nevertheless, the risk of disease transmission to humans seems low (Marin et al. 2014).

**Beneficial aspects**

Despite the bad reputation of scavengers in general and vultures in particular, they are very beneficial to ecosystems (Wilson and Wolkovich 2011; Ogada, Keesing, and Virani 2012; Devault et al. 2016; Figure 41). Of particular ecological importance is the role of vultures in controlling diseases that can be transferred from carrion (Markandya et al. 2008; Santangeli et al. 2019). Carcasses may be sources of many diseases, including rabies, anthrax, bubonic plague, mad cow disease, and foot and mouth

**Figure 39.** The two most common New World vultures, painted by J. J. Audubon (1785–1851) for his monumental four-volume work *The Birds of North America* (Audubon 1827–1838). (a) Black Vultures (*Coragyps atratus*; plate 106) feeding on a mule deer. (b) Turkey Vulture (*Cathartes aura*; plate 151).
disease. Vultures have extremely acidic stomachs (pH = 1) where very few viruses and bacteria can survive. Bacteria contaminating the surfaces of vultures have likely served to protect them from predators, which would likely become sick if they ate them. In ranching areas of North America, vultures were once killed in the belief that they carried and transmitted anthrax and hog cholera, but these disease organisms do not survive passage through a vulture’s digestive system.

Reductions of vultures in areas of Asia have resulted in increased accumulation of carcasses. Feral dogs have increased dramatically in parts of Asia because of the increased supply of corpses. The presence of vultures serves to suppress this problem, as well as the associated danger of rabies (Ogada et al. 2016).

The practice of leaving the dead in designated places for vultures to eat (termed ‘air burial’ and ‘sky burial’) traces to the Zoroastrianism religion, probably beginning in the first millennium BCE in ancient Persia. This still occurs in certain parts of Asia, but sometimes there just aren’t enough vultures available to dispose of the bodies (MaMing et al. 2016).

Conservation aspects

About 70% of vultures are listed as ‘Threatened’ or ‘Near Threatened’ by the International Union for Conservation of Nature (Ogada et al. 2016). Vultures have declined catastrophically over the last three

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**Figure 40.** Black Vultures (*Coragyps atratus*) damaging cars in Everglades National Park, Homestead, Florida. The birds rip off windshield wipers and weather-stripping. Photo by Judy Gallagher (CC BY 2.0).

**Figure 41.** Painting (public domain) by Thomas Baines (1820–1875) showing a dead buffalo being approached by vultures. Baines, an English painter, produced many paintings showing landscapes of southern Africa.
decades, especially in Asia and Africa, and are now the most threatened group of birds in the world (Buechley and Sekercioglu 2016a, 2016b; Textbox 10).

Textbox 10. The ecological role and conservation plight of vultures.

Vultures are nature’s most successful scavengers, and they provide an array of ecological, economic, and cultural services. As the only known obligate scavengers, vultures are uniquely adapted to a scavenging lifestyle. Vultures’ unique adaptations include soaring flight, keen eyesight, and extremely low pH levels in their stomachs. Presently, 14 of 23 (61%) vulture species worldwide are threatened with extinction, and the most rapid declines have occurred in the vulture-rich regions of Asia and Africa. The reasons for the population declines are varied, but poisoning or human persecution, or both, feature in the list of nearly every declining species. Deliberate poisoning of carnivores is likely the most widespread cause of vulture poisoning. In Asia, Gyps vultures have declined by > 95% due to poisoning by the veterinary drug diclofenac, which was banned by regional governments in 2006. Human persecution of vultures has occurred for centuries, and shooting and deliberate poisoning are the most widely practiced activities. Ecological consequences of vulture declines include changes in community composition of scavengers at carcasses and an increased potential for disease transmission between mammalian scavengers at carcasses. There have been cultural and economic costs of vulture declines as well, particularly in Asia. In the wake of catastrophic vulture declines in Asia, regional governments, the international scientific and donor communities, and the media have given the crisis substantial attention.

— Ogada, Keings, and Virani (2012)

Vultures are threatened by a variety of factors, some of them common to many birds (Campbell 2015; Ogada et al. 2016; Textbox 10). Collisions with electrical lines, wind turbines, windows, and aircraft occur. Sanitation measures, such as burying dead animals, while beneficial for human health, has not been helpful for vultures in some places. (Conversely, increases in road kill have been good for vultures.) Agricultural chemicals are another source of harm. DDT is still used in some regions, and new organochlorine pesticides are dangerous for vultures. Plaza, Martinez-López, and Lambertucci (2019) state that the chief current threat to vultures is pesticides. By the early 2000s, more than 95% of India’s vultures had vanished, due particularly to the use of diclofenac in cattle. This veterinary anti-inflammatory drug has been widely employed to treat pain and swelling in sacred cattle, but is very toxic to vultures, causing kidney failure. The drug is now banned in much of Asia, and vulture populations appear to have stabilized. Lead in ammunition (currently banned in some regions) has induced toxicity (the strong acid in the digestive systems of vultures dissolves lead to a greater extent than in most other birds). When carcasses are poisoned to kill livestock predators, vultures sometimes become innocent victims. In sub-Saharan Africa, poisoning of carcasses to eliminate pests such as hyenas and jackals, has greatly decreased vulture populations. Many animals are attracted to carcasses or dying animals by the presence of vultures hovering above, and wildlife officers are similarly made aware of protected animals killed illegally. To avoid attracting game wardens, poachers sometimes poison carcasses to eliminate vultures (University of Utah 2016). Safford et al. (2019) argue that poisoning (from all sources) is the chief cause of vulture decline. Other factors harming vulture survival include trade in traditional medicines made from vultures, and killing them for food (‘bushmeat’). The slow reproductive rates of many vultures makes them susceptible to population decrease. Climate change may benefit some species, harm others such as the Hooded Vulture in Africa where desertification, in combination with urbanization and habitat alteration, is decreasing the supply of corpses.

Among vultures, condors (Figure 42) have a privileged position in the eyes of most people. The simple fact that condors do not have the word ‘vulture’ in their names strongly reduces the very negative image conjured up by this label. Another significant advantage is their size: they are massive, the wing spans sometimes exceeding 3 m. Condors are the largest flying land birds in the Western Hemisphere, and among the largest birds in the world that are able to fly (but see Figure 43). It is a truism that large animals very strongly tend to be idolized by humans (Small 2011, 2012). The Andean Condor (Figure 42(b)) has been a respected icon for millennia among indigenous peoples of South America, and is currently a national symbol of six countries throughout its range. Similarly the California Condor (Figure 42(a)) is a traditional esteemed symbol among California native peoples. The enormous wing spans of condors greatly helps in keeping them aloft, but limits them to windy areas where they can glide on air currents with little effort. Andean Condors are confined to Andean mountains, coasts that also supply strong ocean breezes, and deserts with strong thermal air currents. In parallel, the California Condor is currently restricted to the western coastal mountains of the United States and Mexico and the northern desert mountains of Arizona (the species once ranged from Mexico to Canada). Persecution by hunters and farmers greatly reduced numbers of condors (Haemig 2012). By 1982, there were only 22 birds
of the California Condor left alive. Intensive conservation efforts led to the species rebounding, and there are now hundreds in California, Arizona, Utah, and Baja California (Mexico). The Andean Condor, currently considered ‘Near Threatened’, has similarly benefitted from conservation and re-introduction policies.

Vultures, often referred to as ‘nature’s clean-up crew’, are like garbage collectors (indeed, they are highly attracted to garbage) and undertakers – indispensable to health, but nevertheless viewed with discomfort, even revulsion. Eating unsanitary decaying corpses is disgusting from a human perspective. The birds have been interpreted as bad luck omens. They are stereotypically associated with impending disaster, such as in cartoons depicting circling vultures as a harbinger of death. Vultures are often added to horror movies, and scenes showing human carnage shortly after a war. Language also indicates the lack of esteem in which vultures, indeed scavengers in general, are viewed. The word ‘scavenger’ is often applied to humans in

Figure 42. The two species of New World condors. (a) An old male California Condor (*Gymnogyps californianus*), painted by J. J. Audubon (1785–1851) for his monumental four-volume work *The Birds of North America* (Audubon 1827–1838). Source (public domain): vol. 4, plate 426. (b) Andean Condor (*Vultur gryphus*), shown attacking a lamb on a rock. Males like this can easily be identified by the large comb (caruncle) on the head and the wattle on the neck that is formed by folds of skin. Coloured etching prepared by W. Panormo (1796–1867) after a drawing by H. Smith (active 1858). Source: Wellcome Trust (CC BY 4.0).

Figure 43. Giant Teratorn (*Argentavis magnificens*), an extinct (as of 6 million years ago) predatory bird of Argentina, believed to be a relative of the condors. Among the largest flying birds ever to exist, it is speculated to have had a wing span reaching 7 m and a weight that exceeded 70 kg. Credit: Stanton F. Fink (CC BY SA 3.0). Outline of woman added for scale.
a very pejorative sense to refer to a person who searches refuse for food, so all scavengers tend to be held in low esteem. The word ‘vulture’, as well as ‘buzzard’ often used as a synonym, have some even more pejorative meanings, such as ‘a contemptible or rapacious person’, ‘a mean or cantankerous person’, and ‘a contemptible person who preys on or exploits others’. Expressions like ‘vulture capital’, ‘vulture investment’, and ‘legal vulture’ reflect these predatory meanings. ‘Vulture funds’ are private investment funds that trade in the defaulted or soon-to-default debts usually issued by the world’s most heavily indebted poor countries, providing creditors opportunities to extract exorbitant fees to extend payment schedules.

Historically, attitudes to vultures have ranged between approval and hatred. Some spiritual traditions were quite respectful of vultures (Kushwaha 2016), but they have also been associated with witchcraft and demons. Often, vultures have been considered to be quite undesirable, and have been persecuted. Some vultures defend themselves by vomiting foul-smelling material on attackers (a practice that also reduces the weight of the birds, facilitating escape). Some vultures prevent overheating by ‘urinating’ (i.e. emptying their cloaca) on their legs, with subsequent evaporative cooling (a behaviour which seems less repugnant under the technical term ‘urohidrosis’). These habits do not serve to endear the birds to humans.

Most people are very sympathetic to birds, and find their appearance and life styles to be very attractive. However, most vultures are the complete opposite of the ‘cute and cuddly’ charismatic species that easily attract conservation support. Even Charles Darwin, perhaps the greatest student of biodiversity, upon observing a Turkey Vulture from the deck of the Beagle in 1835, called it a ‘disgusting bird’ whose bald head was ‘formed to wallow in putridity’ (quoted in Royet 2016). Many vultures have been described as having faces that only a mother could love. The King Vulture, at least, is exceptionally colourful and is quite impressive in flight (Figure 44). Moreover, some artists have succeeded in depicting vultures in quite attractive poses (Figure 45).

Figure 44. King Vulture (Sarcoramphus papa) of Central and South America. (a) Photo by Renato Augusto Martins (CC BY SA 4.0). (b) Photo by Eric Kilby (CC BY SA 2.0). (c) Photo by Weltvogelpark Walsrode (CC BY SA 3.0).
Despite their morbid reputation and appearance, vultures have managed to attract some official safeguarding, at least in in Western countries, where they have legislative protection (Balmford 2013). Shooting vultures in North America and the European Union is now illegal. In the United States, the Migratory Bird Treaty Act protects vultures, which are managed by the federal government, and can be killed only with a Migratory Bird Depredation Permit from the U.S. Fish and Wildlife Service (Avery and Lowney 2016). Farmers have frequently been the cause of vulture decline, and it is particularly important to educate the farming and ranching communities that on balance vultures are highly beneficial (Cailly Arnulphi, Lambertucci, and Borghi 2017).

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Disclosure statement

No potential conflict of interest was reported by the author.

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