1 · *Eating Wild Animals*

1.1 Introduction

Wild animals, plants and their products are harvested for purposes ranging from food to medicine. Humans have exploited wild animals and plants throughout their evolution (Hill 1982) and contemporary aboriginal and rural peoples still rely on them for their daily needs (Wilkie *et al.* 2005). The meat of wild animals or wild meat (see Box 1.1) is still a crucial part of the staple diet of millions of families in the tropics and subtropics since it is often the most available and widely used source of animal protein (Abernethy *et al.* 2013; Fa *et al.* 2003), and is also important for its micronutrient content (Golden *et al.* 2011; Sarti *et al.* 2015; Sirén & Machoa 2008). Wild meat is central to the livelihood strategies of the poor since it can constitute a significant source of revenue, especially for rural families (Brown & Williams 2003; Milner-Gulland & Bennett 2003). It is also consumed regularly by urban peoples more as a commodity product than as a necessity.

In this book, we use the Coad *et al.* (2019) definition of wild meat as any non-domesticated terrestrial mammals, birds, reptiles and amphibians harvested for food. We concentrate on the consumption and trade of wild animals as food and the implications of these activities on the fauna in the region of the globe found within a band on either side of the equator from 23.5°N, and 23.5°S; the Tropic of Cancer and the Tropic of Capricorn, respectively. This portion of the world known more generally as the tropics is important in not just harbouring most of the Earth's biodiversity but also millions of peoples who still depend on wild animals for their food security and livelihoods. A more detailed description of the extent and characteristics of the tropics and subtropics are given in Chapter 2.

Although other animals comprise important dietary items in the tropics and subtropics, in this book we focus only on vertebrates because they constitute most of the terrestrial wild animal biomass consumed by

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Box 1.1 *What is wild meat?*

For some time, the term bushmeat was used as a catchall phrase for the meat of wild animals. The term, which originated in Africa, referred to the meat from animals found in forests and savannas; these habitats are commonly referred to as 'bush', hence the name bushmeat. The expression is assumed to have originated in British colonial times but may pre-date this era. The native catechist, T. C. Brownell, in south-east Liberia, mentioned he was offered on 29 March 1857 something to eat by the head-man of the interior village of Nyambo 'which he called bush meat, but it had such a human aspect that I laid it aside, and awaited the repast which was preparing' (quoted in Scott 1858, p. 295). Liberia was the first African republic to proclaim its independence in 1822.

Nasi *et al.* (2008) defined bushmeat as any 'non-domesticated terrestrial mammals, birds, reptiles and amphibians harvested for food''. Insects, crustaceans, grubs, molluscs and fish are excluded from this classification. But, although the term has been employed to refer to the meat of wild animals from regions other than Africa, there has been a recent move towards using the more generic term 'wild meat', since it has no geographical associations. Thus, following its adoption by the IUCN-World Conservation Union General Assembly Resolution 2.64 (IUCN World Conservation Congress 2000), Coad *et al.* (2019) use the term wild meat as terrestrial animals used for food in all parts of the world. However, the Convention on Biological Diversity 's (CBD) (2012) description of wild meat hunting as 'the harvesting of wild animals in tropical and subtropical countries for food and for non-food purposes, including for medicinal use' is imprecise since wild meat is only one of the products derived from the hunting of wild animals anywhere in the world.

humans in these regions. Mammals make up the largest proportion of all animals eaten and traded, both in terms of weight (biomass) and numbers. The cultural preference for wild meat is not due to a lack of awareness or entrepreneurship but ultimately relates to the low productivity of domestic livestock in many tropical and even subtropical conditions. For poor farmers in tropical environments, as seen in the Brazilian Amazon (Carvalho *et al.* 2020), raising livestock for their meat has high

risks and investment costs, making successful livestock husbandry rarely a feasible option. In situations where livestock can be kept, such as the ever-present domestic chicken, these animals are often more a form of reserve banking, or to satisfy cultural needs. In contrast, wild meat is a resource that is freely available for use, so the cost of its procurement is always lower than the cost of raising livestock. However, in recent decades the exploitation of wild animals for their meat has moved from just being a source of food and income for rural communities or Indigenous Peoples, to a commodity exploited for profit-making reasons by supplying the urban areas. Such increase in demand for wild meat has been brought about by accelerating population growth, use of more modern and efficient hunting techniques, and opening of remote areas to commercial hunters by extractive industries. As will be documented in detail in this book, there is an accumulation of evidence that this is seriously threatening wild animal populations and human food security in many areas.

For the millions of Indigenous and non-Indigenous communities in tropical and subtropical environments, often among the world's rural poor, wild meat is frequently the most consumed source of protein, vitamins and minerals (Van Vliet *et al.* 2017). Wild animal meat can also be traded by and between rural communities and transported beyond its point of extraction. Because of its value-to-weight ratio and great transportability if smoked, the wild meat trade has risen dramatically, fuelling in some cases unsustainable extraction rates (Chapter 6) as shown for West and Central African countries (Fa *et al.* 2003; Fa & Peres 2001). Commercial hunting for wild meat has grown in importance in recent decades (see Section 1.7), with increasing numbers of hunters currently either earning or supplementing their incomes with the sale of meat (Milner-Gulland & Bennett 2003). This intensifies hunting levels and reduces the sustainability of numerous wildlife species, largely because it enlarges the population density of consumers eating meat from a given habitat area (cf. Bennett & Robinson 2000). Hunting of wildlife is still the single most geographically widespread form of resource extraction in the tropics (Fa *et al.* 2002, 2005; Milner-Gulland & Bennett 2003).

Hunting refers to the act of pursuing and taking wild animals by several means and for different purposes. Wildlife can be hunted for food, trophies (most often skins, teeth, antlers and horns), medicines and other traditional uses (most hard and soft body parts) and as pets (especially primates, birds and reptiles). Hunting occurs in a variety of habitats worldwide (Nasi *et al.* 2008). Vulnerability of hunted species

varies according to their biological characteristics and the state of the habitats they are found in. Coupled with threats from habitat loss (Laurance *et al.* 2006; Wright & Muller-Landau 2006), overhunting can result in the extinction of species, especially of larger-bodied species of mammals and birds that have a naturally low intrinsic rate of population increase (see Chapter 5 & 6). This process, referred to as defaunation (Chapter 2; Dirzo *et al.* 2014) is an anthropogenically driven cause of species and population extirpations and, critically, of declines in local species abundance of seed dispersers and 'habitat landscapers' such as in tropical forests. This changes the long-term dynamics and structure of these ecosystems and ecosystem services (Chapter 6).

As we show in Chapter 2, tropical and subtropical landscapes are heterogeneous, containing diverse animal and plant species that make up a variety of wildlife communities that differ in their dynamics, including contrasting human pressures. Important intercontinental differences exist between tropical and subtropical areas worldwide, but there are significant contrasts in how the faunas in each continent have been affected by unsustainable hunting. In Asian tropical forests, already more than 12 large vertebrate species are known to have become extinct in countries such as Vietnam (Bennett & Rao 2002). The problem is perceived to be presently more acute in the heartlands of West and Central Africa, but progressively worsening even in the remotest parts of Latin America (Peres 2001). Such dissimilar trajectories in actual and potential faunal loss between continents follow the major impacts of development and forest loss, essentially linked to human population growth that drive agricultural expansion, logging, development and other human activities. The situation in Asia is also unlike other continents, because of the reliance on large-scale wildlife trade involving long-distance, international supply chains (Duckworth *et al.* 2012). Demand for land, timber and non-timber forest resources has exploded throughout Asia as a result of rapid economic growth (Bennett & Rao 2002). The region is a key supplier to the international wildlife market, both legal and illegal. Despite there being intercontinental dissimilarities, at a global scale there is now sufficient evidence to highlight that the plight of many species, in particular mammals, is primarily due to overhunting (see Ripple *et al.* 2016 p. 20016). We discuss the impact of unsustainable hunting in Chapters 2 and more in detail in Chapter 6 in this book.

We begin this introductory chapter with a description of the importance of hunting and meat eating to humans and how this has influenced

the evolution of the species. This is followed by a brief review of how prevailing ecological conditions influence dependence on plants or animals to survive at different latitudes. We then document which animal species and groups are currently hunted and used for food, discuss the issue of wild meat markets especially in Africa and present our current understanding of wild meat consumption by diverse groups of people in different parts of the world. The chapter ends with the reasons for writing this book and explains how we can use the accumulated knowledge on this subject to help reduce wild meat exploitation and ways of balancing human and wildlife needs in the future.

1.2 Meat Eating and Hunting in Human Evolution

Similar to modern chimpanzees, the earliest hominins consumed large quantities of fruit, leaves, flowers, bark, insects and some meat (Watts 2008). By at least 2.6 million years ago (YA), a remarkable expansion in this diet occurred; some hominins began incorporating meat and marrow from small to very large animals into their diet. Arguably, it was not until at least one million YA that hominids actively hunted animals for food (Potts 1996; Walker & Shipman 1996). Eating meat from hunted animals or from carcasses provides more calories per unit of search time than the collection of plant products (Hill 1982). Carrion is thought to have been an early source of high-quality protein for hominids (Binford 1981; Blumenschine *et al.* 1987), who may have lacked appropriate technology to capture vertebrate prey. However, populations of chimpanzees and baboons are known to hunt cooperatively (Stanford & Wrangham 1998). This suggests that hominids may also have been social hunters who shared the obtained prey, in addition to actively stealing carcasses, as do other carnivores.

Human hunters have followed a complex evolutionary process. Bipedalism provided greater autonomy for the search and transport of food. The development of intelligence favoured in the first instance the theft of carcasses from other predators, the formation of groups that operated in a coordinated manner to access larger prey, the sequential development of tools to work the carcasses and weapons to defend and hunt, and the establishment of rules for an equitable distribution of the obtained meat (Stanford 2001). Competition with other carnivores could have induced the observed increase in body size of primitive hunters (Arsuaga *et al.* 2014), strategic cooperation, diurnal habits, rapid manipulation of prey and selective capture of smaller ones, in parallel with the

progressive expansion of the neocortex and the improvement of cognitive skills and intragroup communication (Pearce *et al.* 2013; Van Valkenburgh 2001).

The conversion of primitive opportunistic hunters into systematic predators could have taken place in a scenario where optimal prey was abundant and predictable, the availability of other food was scarce or unpredictable and would have led to catches providing meat in surplus to the needs of the hunters (Rose 2001). Such a change would have required the possession of certain intellectual capacities to make decisions, develop cooperative strategies, and to manufacture and manage tools for capturing and processing game (Pearce *et al.* 2013), separating them from other primates (Hill 1982).

Cooperative hunting represents a stable evolutionary strategy from the moment Palaeolithic hunters became specialized in the pursuit of large animals (Boesch 1994) – those whose systematic capture is difficult to imagine without adequate technology and social organization (Hill & Hawkes 1983; Stiner 1994). As a consequence, this success gave rise to the adequate capture and processing of carcasses, and the selective transport and distribution of the most desirable parts before being consumed. All this process implies the adoption of decisions related to the management of prey species as can be verified from the fossil record and, with appropriate reservations, inferred from the behaviour observed in current hunter-gatherers.

Beginning around 10,000 BP however, the shift from hunting and gathering to domesticated food sources, both animal and plant, resulted in a narrowing of the diet (Larsen 2003). The consequences of this diet shift, from evidence from archaeological human remains worldwide, was a decline in health, including poorer dental health, increased occlusal abnormalities, increased iron deficiency anaemia, increased infection and bone loss (Larsen 2003). New dietary pressures introduced since the Industrial Revolution some 200 years ago have been the result of people's diets changing far more quickly than genetic adaptation is able to keep up with this change (Eaton *et al.* 1997). This discordance hypothesis postulated by Eaton *et al.* (1997) has been suggested to explain many of the chronic 'diseases of civilization'. Modern trends in human nutrition, especially after the Second World War, indicate a greater reliance on high-fat meats that, when eaten in excess, promote cardiovascular disease, especially in combination with the more sedentary lifestyles typical of many modern societies.

1.3 Importance of Wild Animal Foods in Human Diets

The relative importance of wild meat and plant consumption patterns can be determined from information obtained from modern-day hunter-gatherer societies (Box 1.2). The emerging patterns reflect regional and ecological specializations that in some groups probably date back to the late Pleistocene Epoch. Data on what types of food are eaten, and the importance of wild meat in particular, result from research conducted within a wide variety of disciplines. While most dietary data collected are behavioural and quantitative, human biological samples (e.g. urine, stool, saliva, serum, blood, dental calculus and hair) allow further insights into the physiological parameters of various modes of human subsistence (e.g. Gurven *et al.* 2016; Leonard *et al.* 2015; Pontzer *et al.* 2012).

Few hunter-gatherer or forager societies exist today, but many are well documented in the ethnographic record. Forager studies have become more popular over the last several decades, being of particular interest to evolutionary, sociological, demographic and human health science studies, as populations increasingly transition into a wage economy (Headland & Blood 2002). Earlier research on these groups was undertaken by anthropologists who assumed that the modern forager existence was a good analogue of the lifestyle that endured everywhere before 10,000 BP. However, one of the greatest obstacles to using foragers as analogues of our ancient ancestors is that virtually all foragers in the ethnographic record have complex technology compared to premodern hominins (Marlowe 2005). Moreover, as Lee and DeVore (1968) suggest, the foragers described may be a biased sample that have persisted because they occupied marginal habitats less coveted by agricultural people, although this contention has later been refuted. Using global remote sensing data to estimate habitat productivity for a representative sample of societies worldwide Porter and Marlowe (2007) showed that foraging societies do not inhabit significantly more marginal habitats than agriculturalists. Nevertheless, forager societies have not remained static, and many have changed their habits and diets because of their association with more food productive agricultural societies. This is clearly the case for some Pygmy communities in the Congo Basin (Dounias & Froment 2011).

Overview papers detailing contemporary hunter-gatherer diets have emerged as comprehensive and definitive sources of information on forager diets (Binford 2002; Cordain *et al.* 2000; Marlowe 2005). An important source of calculations of dietary patterns of surviving hunter-gatherer societies have resulted from George P. Murdock's Ethnographic

Box 1.2 *Hunter-gatherers*

The earliest definition of a 'forager' or 'hunter-gatherer' by Woodburn (1980) is entirely based on their subsistence mode, describing them as members of societies that obtain their food and other requirements directly from the wild. We use both terms interchangeably in this book. Others elaborated the definition as those peoples who specifically collect wild plant foods and game animals with 'no deliberate alteration of the gene pool of exploited species' (Panter-Brick *et al.* 2001). This definition is difficult to apply to all of the food consumed by a given population.

In the 1960s, based on diet alone, foraging populations worldwide (as those who consumed 100% of their diet from wild foods) were considered to account for less than 0.001% of the world's population (Lee & DeVore 1968). By the mid-1990s, since few of the remaining hunting and gathering groups depended on an entirely wild diet, a population of foragers was redefined as one that ate approximately 10–15% of domesticated foods (Kelly 1995). Presently, if the criterion that foraging populations must consume a diet of more than 90% wild foods is used, no population would meet the designation (Apicella & Crittenden 2015). Therefore, in the twenty-first century, almost all forager populations consume a mixed diet that includes varying degrees of farmed foods, wild foods, and in some cases nutritional subsidies from governments and aid organizations (Headland & Blood 2002).

Importantly though, hunter-gatherers have also been classified as peoples exhibiting unique social lives, which includes a degree of mobility, group size and/or kinship systems that impact of the use and sharing of resources (Lee 1992). Thus, depending on the environments inhabited in line with their social systems, foragers have been classified as 'generalized' or 'immediate return' *versus* 'complex' or 'delayed return.' Immediate return foragers consume their yield shortly after procurement and delayed return foragers store their food for varying lengths of time (Price & Brown 1985; Woodburn 1998).

Ecological factors that shape human population processes determine the distribution and abundance of hunter-gatherers worldwide. Using global ethnographic hunter-gatherer data from Binford (2001), Tallavaara *et al.* (2018) explored the effects of key environmental variables (net primary productivity, biodiversity and pathogen stress) on hunter-gatherer population densities. Primary and secondary

productivity were shown, at least regionally, to have positive effects on hunter-gatherer population density as well as on population home ranges. Hunter-gatherers access food directly from their surroundings (which can vary widely in energy availability) and thus depend on the productivity of wild plant and animal species, where they appropriate only a small fraction of the production. Additionally, biodiversity was shown to play an important role since it influences ecosystem stability – higher biodiversity is linked to temporal stability of aggregate ecosystem properties, such as biomass and productivity. For hunter-gatherers, increased stability of ecosystem-level biomass production decreases subsistence-related risk, and therefore positively affects hunter-gatherer population densities. In contrast, the effects of pathogens on hunter-gatherer abundance are, as expected, negative. Tallavaara *et al.* (2018) conclude that subtropical and temperate forest biomes in particular, rather than tropical forests, have the highest carrying capacity potential for hunter-gatherer populations as a result of the balance between disease risk and habitat productivity. These findings document that environmental factors play a key role in shaping global population density patterns of pre-agricultural humans.

Atlas; a database on 1,167 societies coded and published in 29 successive instalments in the journal *Ethnology*, 1962–1980. While valuable, some critics (e.g. Milton 2000) suggest that because the data used in these compilations are non-standardized tabulations from ethnically and geographically widespread human populations, this limits finer-scale comparisons. Despite several limitations, data contained in reviews such as Cordain *et al.* (2000) are a valuable entry point for discussion of variation among foragers from different latitudinal living environments. Listed populations are categorized by the percentage of their subsistence dependence on various categories of foods (i.e., wild plant foods and wild meat) even though no consistent unit of measurement has been used for each instance of data collection, as explicitly acknowledged by Cordain *et al.* (2000).

As expected, the composition of the human diet is extrinsically conditioned by biogeographical and ecological factors. The majority of hunter-gatherer societies, as used in Cordain *et al.* (2000), obtained 56–65% of their subsistence (energy) from animal foods (Fig. 1.1a), and predicted macronutrient energy intake ranges were carbohydrate

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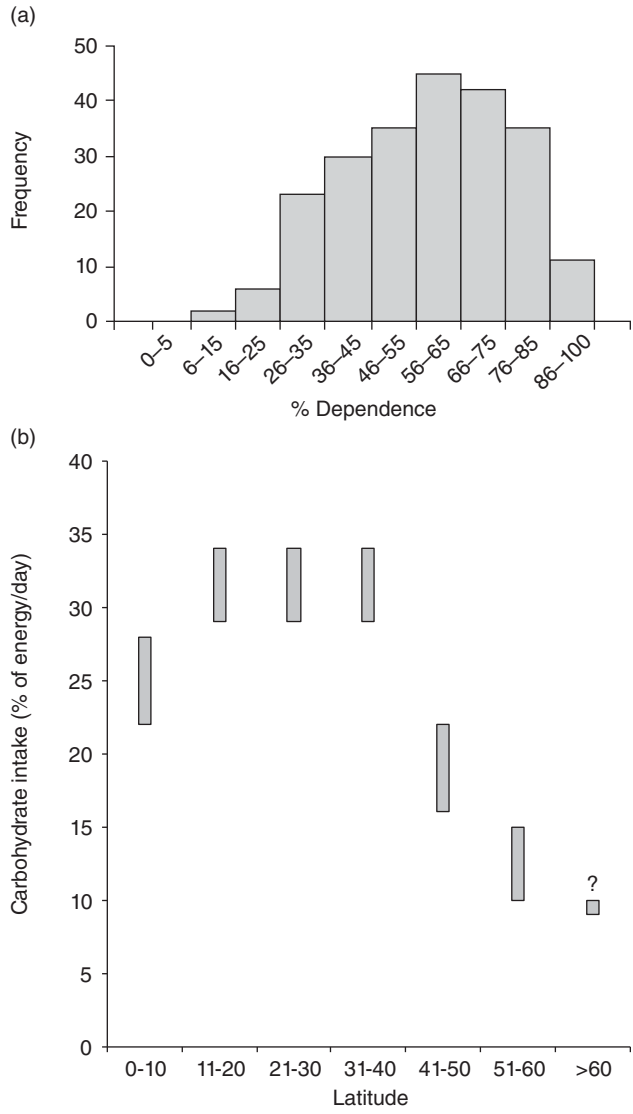

Figure 1.1 (a) Frequency distribution of subsistence dependence upon total (fished and hunted) animal foods in worldwide hunter-gatherer societies (n = 229). Frequency indicates the number of societies at that percentage dependence on animal foods. Median = 56–65%, mode = 56–65% (data from Cordain et al. 2000; figure adapted from Mann 2007 with permission from John Wiley & Sons). (b) Effects of latitude on carbohydrate intake (% of energy) for 229 hunter-gatherer diets shown as the minimum and maxiimum percentage recorded for each latitude intervals; maximum values were not available for >60 latitude (redrawn from data in Ströhle & Hahn 2011).

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22–40%, protein 19–35% and fat 28–47% (Mann 2007). Because humans target different prey species depending on latitude and habitat type Marlowe (2005) suggests, from a trophic point of view, that they resemble different species more than conspecific populations. This adaptation of the diet to the regional and local availability is typical of predatory species that have a wide geographical distribution. As a corollary, plant-to-animal subsistence ratios vary significantly by latitude in response to differences in available primary productivity and biodiversity. Estimates of carbohydrate intake as a percentage of the total energy in 229 hunter-gatherer diets throughout the world vary from approx. 3% to 50% (Ströhle & Hahn 2011). Over a wide range of latitude intervals (11°–40° north or south of the equator) carbohydrate intake remains similar (30–35%) but decreases markedly from around 20% to 9% or less of the total energy with increasing latitude intervals from 41° to greater than 60° (Fig. 1.1b). Hunter-gatherers living in desert and tropical grasslands consumed the most carbohydrates (approx. 29–34% of the total energy). Diets of hunter-gatherers living in northern areas (tundra and northern coniferous forest) contained a very low carbohydrate content (≤15% of the total energy) where hunting and fishing predominate over the collection of plant products (Mussi 2007; Ströhle & Hahn 2011). Hunter-gatherers in higher latitudes, where plant growth is greatly curtailed, have adapted to living largely or entirely on raw animal matter, both meat and fat. As shown for the Indigenous Peoples in Greenland, the Inuit, genetic and physiological adaptations to a diet rich in polyunsaturated fatty acids are clearly reflected in their genome (Fumagalli *et al.* 2015).

1.4 Species Hunted for Wild Meat

Animals as small as caterpillars and land snails to the largest land mammal, the elephant, are consumed throughout the tropics and subtropics (Fig. 1.2). According to Redmond *et al.* (2006), a total of 2,000 different animals are hunted for wild meat across the world. Of these, as many as 55% are terrestrial vertebrates (amphibians, reptiles, birds, mammals), of which 638 species are hunted in the world's tropical and subtropical regions (Table 1.1). Almost 50% of all vertebrates used for wild meat are mammals, followed by birds (34.8%), then reptiles (13.8%) and amphibians (5.6%). The distribution of the different taxonomic groups by region reflects the biogeographic idiosyncrasies of each area of the world (Table 1.1). For example, because Oceania is composed primarily of

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Figure 1.2 Examples of animal species consumed by peoples in tropical forest areas in different parts of the world. (a) Frogs on skewers for sale at the Vientiane market, Republic of Lao (photo: J. M. Touzet); (b) Lowland tapir dressed for sale in Amazonia (photo: H. El Bizri); (c) Lizards for sale at the Vientiane market, Republic of Lao (photo: J. M. Touzet).

Table 1.1 *Number of terrestrial vertebrate species hunted and consumed for their wild meat in tropical and subtropical regions (data from Redmond et al. 2006)*

Vertebrate group	Oceania	South America	South/SE Asia	Sub-Saharan Africa	Total
Amphibians	3	3	14	16	36
Reptiles	0	6	76	6	88
Birds	34	53	75	60	222
Mammals	6	53	23	210	292

islands it is species-rich in birds but species-poor in reptiles and amphibians, with most mammals being bats. Also, as sub-Saharan Africa includes open, mammal-rich savannas, not common in Asia or South America (see Chapter 2), the numbers of mammal species hunted for wild meat in this region is significantly higher than in the others.

1.4.1 Mammals

Most hunted mammals are large-bodied primates, ungulates and rodents, with an average adult body mass equal to or greater than 1 kg (Robinson & Bennett 2004; Robinson & Redford 1991b). These species are considered to provide a greater return for the energy invested in hunting because of their size, but also because of their greater susceptibility to the more commonly used hunting techniques, such as snares and projectile weapons, particularly firearms (Chapter 3). As larger animals are often the most lucrative species to hunt, they are typically targeted first by hunters (Chapter 4). As populations of the larger animals decline, the time and effort required to hunt these species will eventually outweigh the potential gain. As a result, hunters change to targeting mid-size species until finally, if overexploitation is sustained, the hunt will primarily target small species (Jerozolimski & Peres 2003). However, throughout this process, the largest species will continue to be opportunistically captured whenever encountered, preventing their recovery, even though the primary target is now a smaller species (Robinson & Bennett 2004). In addition, snares, which are largely indiscriminate in what they catch, extensively deployed in Africa and Asia, are able to almost empty areas of a large number of animals in a short space of time (Fa *et al.* 2005; Harrison *et al.* 2016; Noss 1998b). The use of snares varies by continents in relation to the availability and

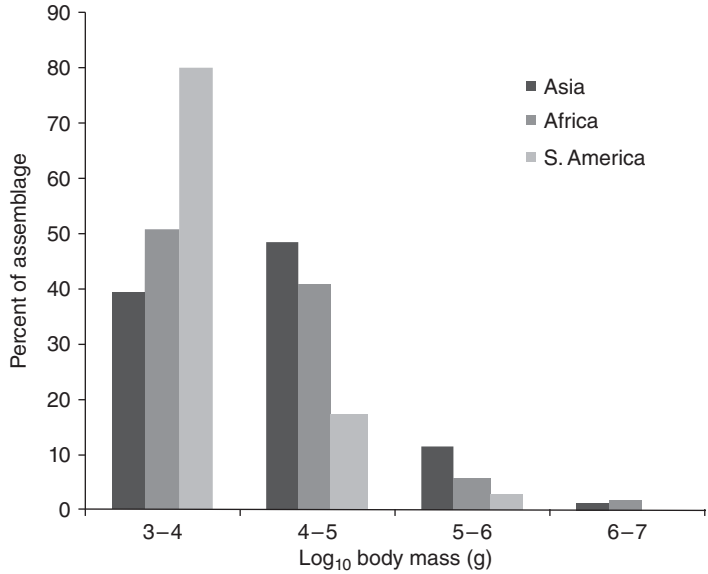

Figure 1.3 Distribution of body mass of hunted mammal species in Asian, African and South American forests (data from Corlett 2007 and Fa & Peres 2001).

distribution of ground and arboreal prey species. In South American moist forests, because there are relatively fewer abundant ground-dwelling species than in African and Asian forests, ground snares are consequently less profitable and not widely employed (see Chapter 2). The distribution of hunted mammals in South American, African and Asia moist forests clearly indicates the preponderance of smaller prey species in South America compared to Africa and Asia (Fig. 1.3, Corlett 2007; Fa & Peres 2001).

Thus, larger prey size and greater accessibility to hunters may explain the wider range of mammal species hunted in African forests compared to South American ones; 55% of a total of 284 African forest mammals are hunted in contrast to only 28% of the 192 species recorded in South American (Amazonian) forests (Fa & Peres 2001). The predominance of terrestrial large-bodied mammals in African forests can also explain their greater vulnerability to indirect hunting techniques, e.g. traps, nets, snares (Chapter 3). The use of snares has been a widespread practice in African forests, accounting for the extraction of more species (and biomass) than firearms (Kümpel 2006; Noss 2000, 1998b). Similarly, home-made snares are increasingly used across large areas of Southeast

Asia (O'Kelly 2013; Wilkinson 2016) with devastating effects on the fauna (Gray *et al.* 2018). In contrast, snare hunting is virtually absent in the Amazon Basin, probably because lower population densities recorded for Neotropical forest mammals render this trapping method relatively unprofitable (Fa & Purvis 1997; Peres 2000).

1.4.2 Birds

Primarily large but also smaller birds are hunted and eaten in tropical regions worldwide. In large areas of Latin America, some birds contribute significantly to the subsistence of rural families that depend on wildlife for their food. Groups such as cracids, large arboreal galliform birds (chachalacas, guans and curassows), are traditionally considered the most important birds for subsistence hunting for many Indigenous Amazonian communities. In a 5-year study of 35 Pano villages in Acre State, Brazilian Amazon, as many as 25 different bird taxa were hunted (Constantino 2016). Although the preferred prey were typically large species of ungulates, primates and reptiles, over the study period birds supplied 11% of all animals taken and 2% of all animal biomass hunted. Of all the bird taxa hunted, four species, the Spix's guan, large tinamou, pale-winged trumpeter and razor-billed curassow, contributed almost all the bird numbers and biomass. Macaws, parrots, toucans, rails, doves, wood quails, ducks, kites, aracari, jabiru stork and even harpy eagles were also recorded as hunted. In other areas of the Amazon, such as in the Pacaya-Samiria National Reserve (Peru) and its surroundings as many as 47 bird species are hunted for food (Gonzalez 2004). The most commonly hunted bird species included tinamou, anhinga, razor-billed curassow, Muscovy ducks and olivaceous cormorants but bird eggs are also an important source of food (Gonzalez 2004). In contrast to the moist forests regions, in the semi-arid habitats, the Caatinga in Brazil for example (de Albuquerque *et al.* 2012), although wild mammals still make up most of the animals and biomass hunted, doves, pigeons and tinamous are common birds used for food (Barboza *et al.* 2016).

Although birds are less commonly hunted in African forests, a large number of species are killed and traded for both meat and traditional medicine. Petrozzi (2018) documented a total of 302 different species of 24 orders on sale in wild meat markets in 10 sampled West African countries. Most recorded species were Least Concern, with 23% Threatened according to the IUCN Red List. However, in a study of semi-permanent hunting camps in the Ebo Forest, Cameroon, birds

constituted 55%, more than mammals (43%) and other taxa (2%). The study recorded several species of birds rarely reported elsewhere (Whytock *et al.* 2016). Offtake of larger bird species was greater than for smaller taxa, but some bird species may be hunted more frequently than previous research suggests. This has important conservation implications for larger-bodied species such as raptors and hornbills (see Trail 2007).

1.4.3 Reptiles and Amphibians

Reptiles serve as an important source of animal protein for people around the world, but exploitation of this group for food is heaviest in the tropical and subtropical regions. By contrast, although amphibians are consumed on a smaller scale than reptiles, Mohneke *et al.* (2009) highlighted that at least 32 species (3 Urodela and 29 Anura) are used as food globally.

Of all reptiles, chelonians (turtles and tortoises) are the most heavily exploited (Klemens & Thorbjarnarson 1995). High levels of exploitation for food but also for pets and medicine are directly responsible for the precarious conservation status of as many as 11 (44%) of the 25 most threatened taxa (species and subspecies combined) of turtle and tortoise species in the world (Stanford *et al.* 2020). Crocodile and alligator meat are considered a delicacy in many parts of the tropics and subtropics (Huchzermeyer 2003), and are consumed extensively (Hoffman & Cawthorn 2012). The consumption of snakes is generally opportunistic, but in Asian countries (China, Taiwan, Thailand, Indonesia, Vietnam and Cambodia) and West Africa, these animals are important sources of wild meat (Brooks *et al.* 2010; Hoffman & Cawthorn 2012).

Within the Amazon region, a number of chelonian species, but also their eggs, are heavily exploited for food (Alves *et al.* 2012; Pezzuti *et al.* 2010). The giant Amazon River turtle, the largest South American river turtle, but especially the more abundant, yellow-spotted river turtle are widely harvested for their eggs and adults for food (Arraes *et al.* 2016). Similarly, in many tropical regions of sub-Saharan Africa, tortoises alongside other reptiles, but also amphibians, are collected for food. For example, in the Niger Delta in Nigeria, Akani *et al.* (1998) reported 4 frog species and 14 reptiles for sale in wild meat markets, that are consumed regularly; the latter group included two crocodiles, five snakes, one lizard and two tortoises. In this study, the Goliath frog, the

largest living frog, was commonly consumed, as reported in other parts of Africa (Gonwouo & Rödel 2008).

Information on reptile and amphibian consumption in Asia, although less formally documented, points to numerous species of chelonians, snakes and lizards being used as locally important food sources. By contrast, the medicinal trade of reptiles, especially turtles and snakes in Southeast Asia, poses a greater threat to this group than consumption.

1.5 Regional Differences in Species Hunted for Wild Meat

A meta-analysis of the characteristics of vertebrates hunted and consumed in West and Central African moist forests showed that a total of 129 species were recorded in the literature over a 40-year period (1971–2010) in five countries (Petrozzi *et al.* 2016). By class, significant differences in the number of species appeared; 91 mammals dominating, followed by reptiles (n = 19), birds (n = 14) and amphibians (n = 2). Mammals were also the most numerous in terms of the number of individuals and overall biomass traded, ungulates and large rodents in particular. Herbivores and frugivores were the most common trophic animal guild. Forest-specialists were the most abundant, and in riverine habitats reptile biomass was almost as important as mammals. Most species and individuals were non-threatened according to the IUCN Red List.

Information on species hunted for wild meat in African savannas has received comparatively little attention in comparison to forests (Lindsey *et al.* 2013). Because of their high abundance in these more open habitats, ungulates are the most hunted species (Lindsey *et al.* 2011b, 2011a). The more commonly hunted species in these habitats include abundant species such as impala and blue wildebeest but also plains zebra, as recorded in the Savé Valley Conservancy in the southeast Lowveld of Zimbabwe (Lindsey *et al.* 2011a). In a nationwide study in Tanzania, Ceppi and Nielsen (2014) showed that a total of 25 taxa were consumed in 10 tribal areas. Antelope was the most frequently mentioned type of wild meat in all ecoregions, with dik-dik and duikers making up the majority of records. This was followed by hare and Guinea fowl. Dik-diks and duikers make up most records but larger species such as the bushbuck and the African buffalo are consumed only rarely. The larger animals require more sophisticated hunting techniques and adequate firearms which are often limited and more difficult to acquire.

There is a large number of studies on the hunting and gathering of vertebrates in Latin America (Alves & Van Vliet 2018). In a meta-analysis of 78 different hunting studies, from sites in Central America, Amazonia and the Guiana Shield, a total of 90 hunted mammal species were recorded (Stafford *et al.* 2017a). This number included 12 genera of primates, 6 of ungulates and 8 rodent genera. As in Africa, ungulates and rodents make up the majority of the wild meat offtake in Neotropical communities. Within the Amazon Basin, the largest rainforest block in the world, much of the wild meat offtake is comprised of medium-sized ungulates such as white-lipped peccary, collared peccary, white-tailed deer and various brocket deer species, but also large rodents like the paca and agoutis (Fa & Peres 2001; Mesquita & Barreto 2015; Stafford *et al.* 2017b). Tapirs (South American tapir in lowland South American forests, Baird's tapir in Central America and Andean tapir in Andean forests) are the largest mammals in South and Central American forests (ca. 200 kg), and a sought-after prey species (Jerozolimski & Peres 2003; Nasi *et al.* 2011; Suárez *et al.* 2009). Primates are also the main targets for hunters in Central and South America, but overall standing biomass is less than ungulates and rodents combined. Typically, primates such as large cebid monkeys of which there are six Alouttinae monkey species and seven Atelinae species, are actively hunted for meat throughout their ranges (Ráez-Luna 1995). Species hunted and consumed will vary according to habitat and region but also according to the type of hunter involved. In the Amazon, colonists and Indigenous Peoples pursue different animals (Redford & Robinson 1987), the latter group concentrating on primates (Cormier 2006; Ojasti 1996). The Wai Wai indigenous communities in Guyana mostly hunt black spider monkeys, paca and curassow (Shaffer *et al.* 2017).

Regional differences in animals hunted occur, as observed in the different regions of Colombia (Vargas-Tovar 2012). For all regions pooled, only three species, the collared peccary, the tapir and the paca contributed more than half of all the hunted biomass, but other species such as caiman appear important in the Orinoco region and iguanas and white-tailed deer in the Pacific region (Vargas-Tovar 2012). A study by Van Vliet *et al.* (2017) of animals on sale in markets in the five main ecoregions in Colombia indicated that even though as many as eighty five different species were sold for food, three or four out of six main species for the entire country (the paca, red and grey brocket deer, capybara, armadillo and black agouti) dominated markets in each region. In the more open Brazilian cerrado, tapir, white-lipped and collared

peccary as well as various deer species (marsh deer, pampas deer, grey brocket deer, red brocket deer) and the giant anteater were commonly hunted (Welch 2014).

Information on wild meat extraction in Asian habitats remains scant (Lee *et al.* 2014) but some general patterns are available. According to Corlett (2007), over 160 species of mammal species of >1 kg are hunted in Asian forests where pigs contribute the largest proportion both in terms of individuals and biomass (Gray *et al.* 2018; Harrison *et al.* 2016; Morrison *et al.* 2007; Wilcove *et al.* 2013). As in other tropical and subtropical regions in Africa and the Neotropics, hunting of vertebrates, not just mammals in Asia and especially in Southeast Asia is common; hunting constitutes the greatest current threat to wild vertebrates in the region. This is primarily to supply ever-expanding local, regional and even global markets. Even in areas where good-quality forest remains intact, only a small proportion of the former vertebrate diversity and abundance is still found (Harrison *et al.* 2016). Only 1% of the land supports an intact fauna of mammals >20 kg (Morrison *et al.* 2007) and defaunation effects have been confirmed in a number of different localities (Aiyadurai *et al.* 2010; Johnson *et al.* 2003; Rao *et al.* 2010).

1.6 Indigenous and Rural Peoples Hunt Differently

Rural and Indigenous Peoples throughout the world still rely, to varying extents, on terrestrial animals (and fish) as food in the different habitats they inhabit. Levels of dependence on wildlife for food are affected by the ecological conditions in which people live. Where systematic comparisons have been undertaken for mammals in rainforest ecosystems, the most hunted group, in the Congo Basin in Central Africa and in the Amazon Basin in South America, inter-continental differences can be largely explained by the productivity of these ecosystems (see Chapter 2). However, because the standing biomass of mammals in Central African forests is considerably higher than in South America (Fa & Peres 2001), reliance on terrestrial wild meat is potentially greater for hunters in the former ecosystem. Yet, the high ratio of land area to rivers in the Amazon Basin, increases the possibility for penetration by inland fisheries and thus accounts for the higher proportion of fish. The possibility of exploiting more fish actually compensates for the lower contribution of mammalian meat in the diets of Amazonian peoples compared to those in Central African forests (Robinson & Bennett 1999b). Beyond the ecological reasons for the availability of wild meat for peoples living in

tropical environments, understanding the cultural and socioeconomic drivers of different hunter groups may help determine levels of wildlife extraction and the motives for these. In the following section, we describe the differences in prey species and extraction levels of Indigenous and non-Indigenous Peoples living in Amazonian and Congo Basin forests.

Differences in the types of prey species hunted by Indigenous Peoples and rural communities have been studied in Neotropical and African settings. Using an index of the number of animals taken per consumer year, Redford and Robinson (1987) and later Redford (1993) described contrasts in the nature and intensity of hunting by Indigenous Peoples and colonists in tropical and subtropical forests in South America. For Indian communities in the Amazon, mammals constituted the most important type of game, with birds second and reptiles third; during a comparable time period, data for colonists, mammals were first, reptiles second and birds third. However, indigenous groups took on average a higher number of animals per consumer year than did colonists. Moreover, preferences between Indian and colonist groups in the types of mammals hunted were different, with primates being the most frequently taken order for Indians and rodents for colonists. In another meta-analysis in the Congo Basin, Fa *et al.* (2016) showed that there were significant differences in species hunted and extraction rates between indigenous Pygmy and non-Pygmy groups. Overall, Pygmies hunted a smaller range of taxa but took a higher proportion of prey of a greater mean body mass than non-Pygmies. Harvest rates, animals per inhabitant, were almost twice as high in non-Pygmy sites than in Pygmy sites, as were extraction rates, the number of animals hunted per unit area. There were no significant differences in biomass values, due to the higher body mass of species hunted by Pygmies. However, when converted to extraction per hunter per km^2, non-Pygmy sites harvested more per unit area than Pygmy groups.

The general picture that emerges from these two contrasting studies is that although variation in what Indigenous Peoples and other groups hunt may be to some extent explained by differences in the ecological context and hunting technologies used by each group, contrasting preferences for prey animals can also account for such variation. Although estimates of hunting impact by indigenous *versus* non-indigenous groups in different parts of the world are still lacking, Fa *et al.* (2016) have shown that given their lower numbers and estimated extraction rates, Pygmies in the Congo Basin have a substantially lower impact on prey populations

than other groups. The most alarming difference between these two groups is in the proportion of hunted animals that are traded for profit with significantly higher volumes of game sold by non-Pygmies than by Pygmies (Fa *et al.* 2016).

1.7 Understanding Urban Wild Meat Markets

The sale of hunted animals, often to neighbours or passersby, is motivated by the need to earn some income for the family to buy goods (Nasi *et al.* 2008; Ávila Martin *et al.* 2020). In other circumstances, hunters can be driven or choose to sell their quarry to middlemen for sale beyond their immediate neighbourhoods. If hunters enter the broader and more elaborate commercialization of wild meat, they participate in a commodity chain driven primarily by demand by urban residents who are willing to pay a premium (Bowen-Jones *et al.* 2003). Although reliable information on the scale of the international wild meat trade is still patchy, in Europe some studies suggest that the amount of wild meat imported here is substantial (Chaber *et al.* 2010; Falk *et al.* 2013). For example, in a survey at Roissy-Charles de Gaulle airport (Paris, France), 7% of the inspected passengers from West and Central African countries were carrying wild meat (over 20 kg on average and up to 51 kg), and 25% had domestic meat (average 4 kg) in their luggage (Chaber *et al.* 2010). These and more recent studies (Gombeer *et al.* 2021) indicate that wild meat is not only imported for personal use but also to supply an organized illegal luxury market for African wild meat in many cities in Europe. Moreover, as suggested by Morrison-Lanjouw *et al.* (2021) in the Netherlands and Walz *et al.* (2017) in the USA, culture, taste preferences, the perception that wild meat is more healthy than other meats (and therefore of lower disease risk) as well as an increase in disposable income may all be driving the local demand for African wild meat in expatriate communities.

There is little evidence that exports of wild meat from Latin America or Asia are significant. Even though the international wild meat trade may be minimal in these continents, there is growing proof that there has been a clear rise in commercial hunting within tropical countries. Although urban wild meat was originally considered a more important issue in the African context, increased urbanization within other parts of the tropics is resulting in a greater demand for wild meat from cities and large towns. In South America, for example, the consumption of wild meat in urban centres had been considered minimal compared to in

Africa (Nasi *et al.* 2011; Rushton *et al.* 2005). However, recent studies suggest that there are non-negligible city markets in which a large number of wild animals are sold for human consumption (Bodmer & Lozano 2001; Chaves Baía Júnior *et al.* 2010; Parry *et al.* 2014; Van Vliet *et al.* 2015, 2017). In a recent study in cities in Amazonas, Brazil, El Bizri *et al.* (2019) demonstrated that wild meat is an important item in the diet of residents in urbanized Central Amazonia since a very large proportion of interviewees in the study ate wild meat and large numbers of animals are harvested every year to supply urban consumers. But, as shown in a study of the availability of wild meat and domestic meats in Kinshasa and Brazzaville – the two capital cities in Central Africa accounting for around 15 million inhabitants (Fa *et al.* 2019) – wild meat consumption can be considerable, despite the offer of domestic meat. The often-repeated suggestion that the solution could be the replacement of wild meat by domestic meat at more affordable prices, as suggested by Rushton *et al.* (2005) and others, may not be sufficient to solve the problem.

The greatest impact of commercial hunting on native vertebrate fauna is arguably occurring in Central Africa. In this region, populations of many hunted species are rapidly extirpated and sanctuaries for wildlife are dwindling since almost all Central Africa's forests are now accessible to hunters (Abernethy *et al.* 2013). Based on wild mammal meat removal rates estimated for the Amazon and Congo Basins (Nasi *et al.* 2011), Central African forests are subjected to four times higher extraction of wild animals than in the Amazon. This contrast is not just a reflection of the greater standing mammalian biomass in African moist forests but the higher density of people which drives the demand for wild meat. Historic data on changes in hunting pressure in Central Africa are not available but hunter numbers are likely to have increased relative to the rise in overall human population densities. In parallel, while only 1 in 10 people lived in urban areas in 1900, almost half of all sub-Saharan inhabitants now live in towns and cities (United Nations 2014). Urban inhabitants, especially those recently arrived from rural areas into cities, have a desire to carry on consuming wild meat (because it something they are accustomed to) even though domestic meats are more available and for most families affordable (Cowlishaw *et al.* 2004; Cronin *et al.* 2015; Wilkie *et al.* 2005). Consequently, urban wild meat markets thrive in Central Africa, even in countries where it may be illegal to sell some wild species as food. As a result, demand for wild meat in towns and cities has increased and is expected to grow even more with increasing

urbanization. The urban population in Africa is projected to rise to 1.339 billion in 2050 from 395 million in 2010, 21% of the world's projected urban population (Güneralp *et al.* 2017). Much of the upsurge is taking place in small- and medium-sized provincial towns in mid-latitude Africa, as rural youth leave to seek a better life (Lwasa 2014). This demographic change implies a much greater demand on domesticated and wild food production systems, which can have far-reaching impacts.

Urban consumers of wild meat live either in (a) provincial towns close to sources of wildlife where livestock production is uncommon and market access makes imported animal source foods unavailable or unaffordable, or (b) large metropolitan areas far from sources of wildlife where wild meat is no longer a dietary necessity and more a cultural desire to connect to a rural past (Wilkie *et al.* 2005). Vigorous trading of wild meat to satisfy urban demand is widespread in all major West and Central African cities (Bennett Hennessey & Rogers 2008; Chausson *et al.* 2019; Edderai & Dame 2006; Luiselli *et al.* 2017; Malonga 1996; Mbayma 2009; Mbete *et al.* 2011) and the purchase of wild meat is common in even relatively small towns. The certainty of demand, ease of entering the market and low risk of penalties have encouraged villagers in subsistence economies across the region to use local wildlife as a cash crop.

In large metropolitan cities in Africa, consumers usually have the choice of several sources of domestic animal protein, but many opt for wild meat for reasons other than its nutritional importance. City dwellers may eat wild meat as a means of culturally reconnecting to their place of origin, where they or their parents consumed wild meat (Luiselli *et al.* 2017, 2018, 2019). Although consumers in some provincial towns (particularly isolated ones) may buy wild meat because it is the cheaper meat and more readily available (Fargeot *et al.* 2017; Van Vliet *et al.* 2010b), wild meat in metropolitan cities throughout the tropics for some groups of consumers is more of a luxury item and status symbol (Cao Ngoc & Wyatt 2013; Shairp *et al.* 2016; Wilkie *et al.* 2016). As a luxury commodity, city dwellers pay higher prices than rural consumers for the same animal. Urban consumer willingness to pay relatively high prices encourages rural hunters to increase the amount they take and the proportion they sell to gain income as well as food (Bennett *et al.* 2007; de Merode *et al.* 2004; Grande-Vega *et al.* 2016). It also encourages non-local hunters to enter the market. Perhaps more significantly, many rural peoples have shifted from being traditional subsistence hunters to supplying cities.

Although there are clear multigenerational issues affecting consumption of wild meat in cities, younger generations are less predisposed as shown in a study in West African cities by Luiselli *et al.* (2018, 2019), most people eat wild meat because they prefer its taste. The perception that wild meat is a luxury item is often cited but studies such as Kümpel *et al.* (2007) in the city of Bata in Equatorial Guinea, showed that consumption of fresh foods, including wild meat, increased with income while eating of frozen produce tended to decline. In some situations, however, such as in post-depletion scenarios (see Cowlishaw *et al.* 2005), wild meat is consumed as a bonus. In Ghana, wild meat was more expensive than domestic meat or fish since wild meat production was low in volume and occurred at considerable distances from urban centres, whereas domestic meat production was high in volume and near city markets (Cowlishaw *et al.* 2005). In Nigeria and Gabon, wild meat is also a luxury item, more expensive than imported beef, for which individuals are willing to pay a premium over other sources of animal protein (Ladele *et al.* 1996; Starkey 2004). Wealth is known to affect wild meat consumption in some rural settings where intake was higher in wealthier households (de Merode *et al.* 2004; Wilkie *et al.* 2005) because poorest households could not afford hunting tools or somebody able to hunt. In contrast, in cities like Kisangani in the Democratic Republic of Congo (DRC) where households no longer have access to free natural resources, the poorest seek the most inexpensive source of protein available in the market. Smoked wild meat is one of the cheapest sources of protein year-round but other sources of animal protein, except pork and caterpillars, are significantly more expensive. In the Kisangani market, wild meat was sold in small piles costing <USD 0.10 each, whereas domestic meat was sold in piles of 500 g to 1 kg (Van Vliet *et al.* 2012). Despite the existence of sharp socioeconomic structuring between rural and urban consumers, but also within them, there is the acceptance that the burgeoning urban populations, not just in Africa (see El Bizri *et al.* 2019 for the Amazon), fuels an ever-increasing, lucrative trade of wild animals from rural and protected areas (Chapter 5). This trade is now the most significant immediate threat to wildlife but also to the food security of people who have hunted them. Subsistence hunting and fishing do not usually pose a significant threat at low human densities to the abundant wildlife species living around rural forest communities.

Wild meat is sold as fresh carcasses or smoked meat in markets, at roadsides, in hunters' homes or as cooked dishes in restaurants. In all continents where wild meat is traded, it is available at several entry points

in the commercial chain, where it passes from the hunter to the consumer. In some situations, hunters may sell their kill as whole animals to a trader or directly to a restaurant operator, who then retails it in smaller pieces. Hunters may also dress the carcass and sell pieces direct to consumers in their village. But, more commonly hunters or their emissaries may carry the meat to the point of sale, often the nearest town or city, though in the case of professional hunters operating from hunting camps, traders may travel to the camp to buy the smoked meat.

The main concentration sites for the sale of wild meat, on a regular basis, are without any doubt within markets. In Africa, such public gatherings, where the buying and selling of merchandise, including wild meat take place, occur in almost every sizeable village or town. Here, wild meat can be traded and displayed on makeshift counters, or in larger cities on more permanent stalls within purpose-built market buildings. Some, like the Atwemonon market in Ghana (Crookes *et al.* 2014; Ntiamoa-Baidu 1997), are highly organized and the wild meat trade and associated chain of small restaurants, known as chop bars, are handled as small-scale family businesses handed down from parents to children. In all studied areas in Africa (Cowlishaw *et al.* 2005; East *et al.* 2005; Fa 1999), there are five main actor groups identified in the wild meat trade: farmer hunters or mainly subsistence hunters, commercial hunters, wholesalers, market traders and small restaurant operators. Commonly, hunters and intermediaries are men, whilst sellers are women (Tagg *et al.* 2018). Hunters live and work in rural areas and capture their prey using snares and shotguns. Commercial hunters depend entirely on wild meat for their livelihood, whereas farmer hunters sell wild meat to supplement their income from agricultural produce. The women traders – wholesalers, market traders and restaurant and bar operators – live and work in the city. Wholesalers work from home. They buy meat in bulk from the hunters and sell to the retailers: the market traders and small restaurants or bars. Market traders operate from stalls in the market, whereas chop bars, a term used in West Africa for small establishments, are scattered across the city. Women form the main clientele for market traders, whereas men are more likely to frequent chop bars. The primary route of trade is from commercial hunters to restaurants and bars via wholesalers, although there is also substantial trade along other routes. Each trader has her own set of hunters who supply her with meat and whom she rewards by granting loans. The trade provides income for a large number of people – hunters and traders – but it is a fairly closed system. Most wild meat markets are largely unregulated by either state or local institutions.

In a number of countries, some wildlife species (e.g. endangered species) nominally protected from hunting by legislation are still consumed as wild meat. Wild meat sold openly to the public is a typical feature of many African countries, and markets are found in almost every village or town in the region. Wild meat markets are particularly well developed in West and Central Africa, which is also the area where the trade has been best documented since as long ago as the 1970s (see Asibey 1977; Jeffrey 1977).

The study of wild meat markets in urban and rural spaces can provide researchers with relatively easily obtainable data on carcass numbers and price by species, and sometimes information on the origin of the meat (see e.g. Dupain *et al.* 2012). Such data has been used to infer hunting sustainability although there are limitations to their use (Chapter 5). This is because there are varying reasons why animals are traded or retained by hunters e.g. the hunters need for cash (de Merode *et al.* 2004) or the relative prices of wild meat species and domestic meat (Wilkie *et al.* 2005; Wilkie & Godoy 2001) and transport costs to town (Crookes & Milner-Gulland 2006). As a result, the numbers and species appearing in markets is a subset of the total hunted in the production habitats. Despite potential drawbacks, the data emerging from wild meat market studies can be informative in assessing trends, such as the impact of Ebola on consumption of different species (Funk *et al.* 2021) and as argued by Fa (2007) if large market numbers can be monitored, these represent the best compromise between economy of collection effort, and precision and accuracy of estimates based on population indices. By standardizing data collection protocols and optimal sampling periods (as indicated in Fa *et al.* 2004) comparisons between areas and with other studies are possible. Data quality ultimately depends on the continued dedication and adequate training of observers, the cooperation of various agencies and the rapid and accurate compilation of results.

The sale of wild meat in different parts of the tropics and subtropics merits particular attention since this activity has important implications for the livelihood strategies of the poor, and it is relevant to wider issues of public governance (Brown & Williams 2003). Although these issues will be discussed further in Chapter 5, in this section we focus on the phenomenon of wild meat trade from the viewpoint of who sells wild meat and which wild meat is commercialized. At a landscape level, at least in tropical forest areas, evidence points to wild meat consumption and hunting being positively associated with increasing forest cover (both correlated with greater animal prey availability) which in turn is

often negatively related with access to markets. As demonstrated by Carignano Torres *et al.* (2018) for households in post-frontier Amazonia, people living in remote, forested areas are likely to be the most dependent on wild meat. However, those living in more populous, peri-urban areas are likely to be the actors contributing most to total hunting effort, due to the greater market access. Market access also increases the opportunity for hunters to transition from a barter-based to a monetary economy, leading to greater wealth and livelihood diversification for them (Chaves *et al.* 2017). By increasing the supply of wild meat to markets, these hunters are effectively changing consumer behaviour, ultimately boosting the demand from consumers.

Data on actual wild meat volumes for sale, taken from the literature, generally indicate a very large variation in amounts traded per site. From more extensive, multiple-site studies (Fa *et al.* 2006; Starkey 2004; Wilkie *et al.* 2005) amounts traded ranged from about 100 to 9,000 carcasses per annum. When wild meat volume traded per site is adjusted by the number of inhabitants in each site (data from Fa *et al.* 2006), about 20 kg (median 7.7, range 0.1–392) is available per person per annum, but highly skewed, as 45% of all studied sites had between 0 and 4 kg of wild meat per inhabitant per annum. The more populated sites did not have more wild meat on sale (in fact, wild meat availability fell with larger settlements), but wild meat volume on sale per site was negatively correlated with mean body mass of the animals on sale (Fa 2007).

Market studies encompassing large numbers of monitored sites, as in the Cross-Sanaga region of Nigeria and Cameroon (35,000 km^2), estimated that over a million carcasses were traded in 89 urban and rural markets in a year (Fa *et al.* 2006). Typically (see Section 1.4), almost all animals traded were mammals, of which around 40% were ungulates (duikers and pigs), 30% rodents and close to 15% were primates. Information on wild meat volume traded within other markets in African forest areas has been published for Ghana (Cowlishaw *et al.* 2005; Crookes *et al.* 2014; Ntiamoa-Baidu 1997), Bioko (Cronin *et al.* 2015; Fa *et al.* 1995), Rio Muni (East *et al.* 2005; Fa *et al.* 1995), DRC (Colyn *et al.* 1987), the Cross-Sanaga region of Nigeria and Cameroon (Fa *et al.* 2006) and Gabon (Starkey 2004). From these sources, most markets sell largely ungulates and rodents, but primates can constitute more than 20% (Fig. 1.4). As indicated above, these three taxonomic groups are the most important for human consumption in all areas where the trade has been documented (see also studies in Bennett & Robinson

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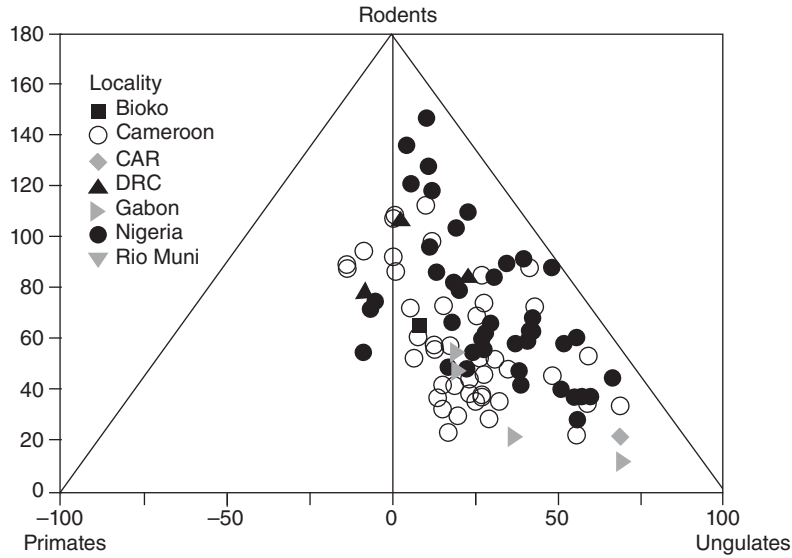

Figure 1.4 Ternary plot of proportions of the three most common mammal taxa for sale in wild meat markets in West and Central Africa. A ternary plot is a specialization of a barycentric plot for three variables, which graphically depicts the ratios of three proportions. (Data sources: Bioko, Fa et al. 1995; Cameroon, Fa et al. 2006; Central African Republic (CAR), Noss 1995; Democratic Republic of Congo (DRC), Colyn et al. 1987; Gabon, Steel 1994; Nigeria, Fa et al. 2006; Rio Muni, Fa et al. 1995; figure from Fa 2007, adapted with permission from John Wiley & Sons.)

2000), but significant variation in the proportions of ungulates, rodents and primates is typical. The relative contributions of these taxa are highly uneven, as often a limited number of taxa alone – small duikers such as blue duiker in Central Africa and Maxwell's duiker in West Africa, large rodents such as the cane rat and the brush-tailed porcupine – constitute over 50% of the total weight traded.

Observed differences in the volume of wild meat traded may of course reflect hunting pressure, the number of hunters operating, which in turn may be related to the population status of the prey species in the area (Fa *et al.* 2005). As Ling and Milner-Gulland (2006) argue, because open-access hunting is a dynamic system in which individual hunters respond to changes in hunting costs and prices obtained for their catch, resulting offtakes will reflect human processes as well as ecological ones, for example, prey abundance. Assessing underlying factors rather than proximate outcome variables is complicated, but the trade-off in choosing to assess one or the other is between the potential for reduced monitoring

frequency due to longer-term predictions and greater uncertainty through the introduction of additional assumptions (Ling & Milner-Gulland 2006). Investing in characterizing supply and demand functions may not be essential if they are likely to change rapidly because of external economic or social processes or if effort and offtake can be manipulated directly. Assessing supply and demand, on the other hand, may be easier in a commercial market setting, because point demand is readily measured, and elasticity of demand can be inferred from knowledge of cultural and economic conditions. Ling and Milner-Gulland (2006) suggest that to determine sustainability reliably, some investment into modelling alternative monitoring and management strategies (with appropriate treatments of measurement error, system uncertainty and stochasticity), similar to those already being developed for fisheries, is necessary. Although this is an approach that definitely requires developing, its application may be more suited to small-scale analyses. In order to scale up to the level of large geographical areas, it may be necessary to sacrifice accuracy to gain a broader picture of the impact of hunting on wild meat species.

1.8 How Much Wild Meat Do People Eat?

Per capita wild meat consumption in different tropical regions has been measured in a number of studies in the Congo Basin and for Central and South America (Table 1.2). For Asia, there are no published studies on amounts of wild meat consumed by tropical forest peoples. Recent assessments of amounts of wild meat consumed by rural or indigenous communities in tropical and subtropical areas are scant. Most available estimates are dated (Table 1.2) and are somewhat problematic to compare since methods used differ in terms of level of accuracy of quantities eaten (ranging from less precise interview techniques such as 24-hour recalls to weighed amounts of foods consumed). Moreover, emerging values of wild meat consumed could reflect differences in the study population's dependence on game meat *versus* fish (or other non-vertebrate protein such as caterpillars), but also could reflect differences in the time of year in which the studies were undertaken. Often, there is not sufficient information reported to assess these potential sources of error. Despite these caveats, the data existing from the 40 published studies in Table 1.2 can be used to give an approximation of amounts of wild meat consumed per person per day by forest communities in South America and Africa. In general, we would assume that

Table 1.2 *Reported amounts of fresh edible wild meat and protein intake from hunting in selected rural South American and African communities. Values are in grams per person per day. We used a meat to protein conversion of 0.194 g of protein per gram of meat from Ojasti (1996)*

Group or locality	Country	Fresh meat	Protein	Source
South America				
Cuiba	Colombia	525.0	105.0	Arcand (1976)
Siona, Secoya	Ecuador	326.0	65.0	Vickers (1980)
Río Pachitea	Peru	299.0	49.5	Pierret and Dourojeanni (1966)
Jívaro	Peru/ Ecuador	278.0	56.0	Ross (1978)
Sharanahua	Peru	273.0	54.0	Siskind (1973)
Sirinó	Bolivia	219.0	44.0	Holmberg (1969)
Siona-Secoya	Ecuador	205.0	41.0	Vickers (1984)
Yékwana	Venezuela	159.0	32.0	Hames (1979)
Río Pachitea	Peru	153.0	20.6	Pierret and Dourojeanni (1966)
Yanomano	Venezuela	143.0	29.0	Hames (1979)
Trio	Suriname	130.0	26.0	Lenselink (1972)
Bari	Colombia	98.0	19.0	Beckerman (1980)
Kaingang	Brazil	95.0	19.0	Henry (1964)
Miskito	Nicaragua	86.0	17.0	Nietschmann (1972)
Jenaro Herrera	Peru	75.8	15.2	Ríos *et al.* (1975)
Río Ucayali	Peru	52.0	10.4	Pierret and Dourojeanni (1967)
Shipibo	Peru	47.0	9.0	Bergman (1974)
Río Ucayali	Peru	35.0	7.1	Pierret and Dourojeanni (1967)
Leonardo da Vinci	Brazil	31.0	6.2	Smith (1976)
Yukpa	Venezuela	28.0	6.5	Paolisso and Sackett (1985)
Nova Fronteira	Brazil	26.0	5.2	Smith (1976)
Rio Paragua	Venezuela	25.0	5.2	Ojasti *et al.* (1986)
Rio Aripuana, Dardanelos	Brazil	22.0	4.4	Ayres and Ayres (1979)
Coco Chato	Brazil	3.6	0.7	Smith (1976)
Africa				
Kola Pygmies	Cameroon	290.0	56.3	Koppert *et al.* (1993)
Liberia	Liberia	280.0	54.3	Anstey (1991)
Bomass	Republic of Congo	230.0	44.6	Auzel (1996)

Table 1.2 (*cont.*)

Group or locality	Country	Fresh meat	Protein	Source
Forest Mvae	Cameroon	200.0	38.8	Koppert and Hladik (1990)
Farmers, Campo Reserve	Cameroon	190.0	36.9	Koppert *et al.* (1993)
Ituri forest	DRC	160.0	31.0	Bailey and Peacock (1988)
Diba	CAR	160.0	31.0	Del Vingt (1997)
Ogooué-Ivindo	Gabon	140.0	27.2	Lahm (1993)
Ituri forest	DRC	120.0	23.3	Aunger (1992)
Oleme	CAR	120.0	23.3	Del Vingt (1997)
Dja	Cameroon	120.0	23.3	Del Vingt (1997)
Kenare	CAR	90.0	17.5	Del Vingt (1997
Coastal Mvae	Cameroon	90.0	17.5	Koppert *et al.* (1993)
Ekom	CAR	80.0	15.5	Del Vingt (1997)
Babenjele	CAR	50.0	9.7	Noss (1995)
Yassa	Cameroon	30.0	5.8	Koppert *et al.* (1993)

consumption of wild meat is likely to vary due to differences in: (a) the productivity and depletion levels of the landscape; (b) the price and availability of alternatives; (c) the wealth of the consumer and (d) consumer preference for wild meat.

For all South American tropical forest communities (Table 1.2), average amounts of wild meat were 138.9 ± 128.1 g/person/day (median = 96.5) or 27.0 ± 25.1 g/person/day (median = 19.0) of animal protein. In African communities, amounts of wild meat consumed (146.9 ± 75.9 g/person/day, median = 130.0) were higher than in the studied South American localities. Protein consumption in African sites was 28.5 ± 14.7 g/person/day (median = 25.2). Differences between the groups appear in both continental comparisons. In the South American sites, consumption varies from 3 to over 500 g/person/day, despite all localities occurring within similar tropical forest types. These disparities may be attributable to differences in the availability of wild meat. Availability of these resources will depend on the productivity of the habitat and perhaps more importantly on the existing or past hunting pressure. Hunting pressure is likely to be inversely correlated with the availability

of animal protein other than terrestrial game species (Jerozolimski & Peres 2003). In these terms, a settlement close to a highly productive river and enjoying a reliable source of fish would be less reliant on forest wildlife than those deprived of this resource (Calouro 1995; Endo *et al.* 2016; Ross *et al.* 1978). Although a few tribal communities of native Amazonians may acquire as much as 45% of their protein from fish, for most upland communities fish may be highly seasonal, and contributes only 20% or less of their protein intake (Balée 1985).

Differences in wild meat consumption in the Congo Basin are much more attributable to contrasts in lifestyles, although the effect of different habitats or hunting pressure cannot be overruled. For example, the amount of wild meat consumed by Efe foragers in the Ituri forest of northeastern DRC) was estimated at 160 g/person/day (Bailey & Peacock 1988); not that different to farmers reported to consume around 120 g/person/day (Aunger 1994). In contrast, estimates for different localities given in Chardonnet *et al.* (1995) show that amounts of wild meat consumed by different groups vary considerably, from an average of 104 g/person/day in foragers to 430 g/person/day in farmers. Similar differences between foragers and farmers can be seen when comparing Lahm's (1993) value's for wild meat consumption in the Ogooué-Ivindo, Gabon (100–170 g/person/day) with the much lower amounts eaten by Babenjele net-hunters in Mossapoula, Central African Republic (CAR) of 50 g/person/day (Noss 1995). Wild meat consumption in villages surrounding the Dja Biosphere Reserve in Cameroon, Odzala National Park in the Republic of Congo and the Ngotto forest in the CAR range from 80 to 160 g/person/day (Del Vingt 1997) while farmers in the Campo Reserve in southwestern Cameroon consume on average around 19 g/person/day (Koppert *et al.* 1993). The Yassa, Mvae and Bakola from coastal southern Cameroon consume between 20 and 200 g/person/day of wild meat (Koppert *et al.* 1993). Higher wild meat consumption rates have been reported by Auzel (1996) for families living in northern Congo (160–290 g/person/ day); by Koppert *et al.* (1993) for forest hunter-gatherers (290 g/person/day) and by Anstay (1991) for rural Liberians (280 g/person/day). Chardonnet *et al.* (1995) report that urban populations in Gabon, DRC and the CAR consumed, on average, 13 g/person/day – which is less than 10% of the wild meat eaten by hunter-gatherers living in the forest. However, total meat consumption was higher in urban areas compared with rural areas (Chardonnet *et al.* 1995), given their higher population density.

Presently available estimates indicate that 5–8 million people in South America (ca. 1.4–2.2% of the total population) regularly rely on wild meat as a protein source, with many being amongst the poorest of the region (Rushton *et al.* 2005). Among the Caiçaras people in the Atlantic forest of Brazil, the dependency on wild meat is not constant throughout the year, but occasional hunting represents a complimentary source of animal protein (Nasi *et al.* 2008). In Venezuela, a study by Señaris and Ferrer (2012) found that hunting fulfilled mainly subsistence purposes in indigenous communities and contributed between 40% and 100% of the meat consumed, whereas in mestizo (mixed heritage) communities, wild meat contributed to 10–30% of meat intake. In semi-arid regions, such as the Brazilian Caatinga, wild mammal meat can be a vital source of animal protein for human communities since freshwater fish is limited in the region. Here, wild meat can be especially critical during the early drought periods, when crops are scarce and domestic animals may die from starvation and dehydration (Alves *et al.* 2009; Barboza *et al.* 2016; Fernandes-Ferreira *et al.* 2012; Miranda & Alencar 2007; Pereira & Schiavetti 2010). Similarly, in the Yucatan Peninsula of southern Mexico, a less arid area but still water-limited because of the predominant limestone soils which restrain the occurrence of surface water bodies and agriculture, wildlife is an important food resource for people living in small, isolated and poor villages surrounding extensive forest areas (Santos-Fita *et al.* 2012). Because hunting is also practiced to prevent or mitigate crop damage by wildlife, a high proportion of abundant and generalist species, such as doves, armadillos, coatis, collared peccaries and white-tailed deer, are taken in agricultural areas, surrounding fallows, gardens and forest patches (Santos-Fita *et al.* 2012). Several studies have shown that wild meat from the most commonly hunted Neotropical species contributes to healthy diets (see Van Vliet *et al.* 2017 for a review) and that the nutritional content of wild meat is difficult to replace by most affordable sources of meat from domestic and industrial origin (Gálvez *et al.* 1999). In addition, wild meat constitutes what could be called a festival food (León & Montiel 2008; Sirén 2012; Van Vliet *et al.* 2015), understood as a food choice that may be related to identifying with one's ethnic background (Chapman *et al.* 2011), or as a comfort food consumed in positive social contexts and resulting in an affirmative association between food and emotional well-being.

Estimates of wild meat consumption by a number of rural communities in the Amazon and the Congo Basin in Nasi *et al.* (2011) suggest

that as much as 63 kg/year/person (170 g per day) and 51 kg/year/person (140 g/person/day) of wild meat is consumed respectively. The authors indicate that the total protein requirement is almost entirely satisfied by wild meat for these communities. A study by Fa *et al.* (2003) calculated that meat supply from wild meat hunting in Central Africa might be higher (at 48 g/person/day) than the non-wild meat protein supply locally generated or imported (34 g/person/day) in the region. These general approximations of the importance of wild meat to people's food security can be reinforced by making comparisons between the recommended daily amounts of protein required to maintain a healthy person and the reported amounts of wild meat protein consumed, albeit with known methodological limitations.

According to the FAO/WHO/UNU Expert Consultation on Protein and Amino Acid Requirements in Human Nutrition (FAO/WHO/UNU 2007) the dietary reference intake (DRI), is 0.8 g of protein per kilogram of body weight. This amounts to 56 g/day for the average sedentary man and 46 g/day for the average sedentary woman. From the available information in Table 1.2, we note that the minimum requirement is unmet in 20 out of the 24 studies for South America, and not covered in any sites for Africa, except one. As mentioned above, it is possible that the DRI for Amazonian sites in Table 1.1 is likely met given the importance of fish these Amazonian communities. Thus, the consumption of wild meat by rural communities in South America, and even throughout Latin America, is not high in terms of quantity, but remains an important component of household food security, and a key element in diet, income diversification, and socially and culturally.

1.9 The Aim of This Book

As suggested at the beginning of this chapter, the overexploitation of wild meat in many parts of the world is a concern for conservationists, development scientists, policy makers and NGOs dealing with wildlife exploitation and human livelihoods issues. In the tropics and subtropics, increasing human populations and the rising trade of wild meat from rural to urban areas, often compounded by the lack of any sizeable domestic meat sector, drive unsustainable hunting levels. Evidence from the Congo and Amazon Basin forests suggests that annual levels of wild meat extraction in these environments are unsustainable. Solving this worldwide problem is one that must embrace ecological, socio-economic and cultural perspectives. These priorities need to be in

balance in order to ensure that wild meat consumption does not lead to the extirpation of wildlife, and that its ongoing rational use continues to provide food security and livelihoods for the millions of rural and Indigenous Peoples that still depend on it. The study of wild meat use in all parts of the world is therefore as important as disciplines relating to the dynamics of disease, wildfire, carbon sequestration, invasive species and biogeochemical cycles (Terborgh & Estes 2010). 'Wild meat biology', if we were to give this discipline a name, is not just understanding the impact of global, local or functional extinction of animal populations or species on ecosystem functioning – defaunation processes primarily driven by overhunting (Chapter 2) – but also the consequences on food security of those still dependent on wild meat as a source of food.

Research on any aspect of wild meat use and hunting has been distributed over a large number of academic journals. As of 31 December 2021 a total of 1,243 papers have been published containing the key words 'bushmeat' or 'wild meat' as a topic in the Web of Science. These papers were published in 308 academic journals. A total of 284 journals published eight or fewer papers whilst only 24 journals published more than eight (Fig. 1.5).

Although all publications focused on wild meat, quite a broad spectrum of academic disciplines is involved. The first research paper was published in 1983. Since the turn of the millennium, the yearly number of papers has increased steadily and has now reached over 100 per annum (Fig. 1.6). Additionally, there are many papers that deal with the consequences of wild meat hunting, especially zoonotic transmission of diseases (e.g. anthrax, HIV/AIDS, Ebola, monkeypox, SARS, COVID-19 and many more). Moreover, numerous papers in the hunting literature deal with wild meat without explicitly mentioning 'bushmeat' or 'wild meat' in the title or abstract, and thus are not included in Fig. 1.5 or Fig. 1.6.

Early studies were mostly descriptive, but the assortment of subjects covered has increased considerably. Alongside this burgeoning scientific interest, there has been much interest in advancing policies and actions that remedy the growing concern for the loss of biodiversity due to overexploitation of species for food. Campaigns around the so-called 'bushmeat crisis', that emerged in the early 1990s (e.g. the Bushmeat Task Force, Eves *et al.* 2008) were primarily ensconced in protectionist measures toward wildlife consumption or an understandable concern for the fate of great apes. These initiatives have been replaced with

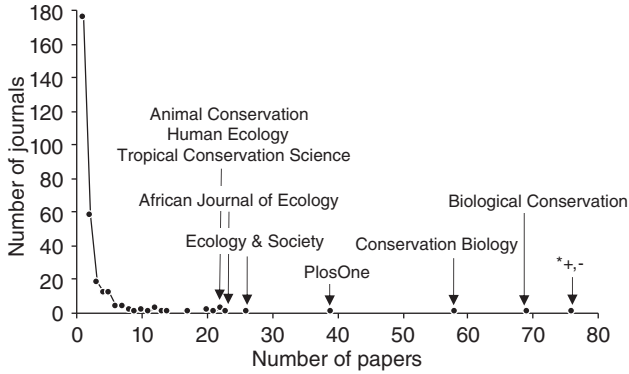

Figure 1.5 Number of scientific articles published on bushmeat and wild meat from 1983 until 2021 appearing in different journals (data from citations in the Web of Science). The most important journals in terms of papers published are shown on the graph.

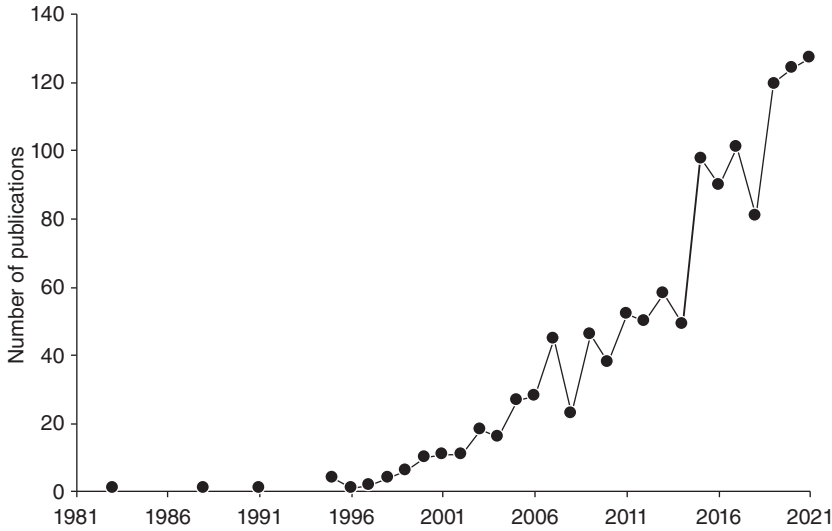

Figure 1.6 Annual number of papers published relating to wild meat or bushmeat since 1983 (data from citations in Web of Science).

those that seek to develop alternative livelihoods to replace the demand for wild meat (Alves & Van Vliet 2018; Wicander & Coad 2018) and to discover more comprehensive and context-specific biological and policy responses to prevent wildlife declines and to promote human well-

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being (CBD 2017; Nasi & Fa 2015). Technical documents have summarized our knowledge of the wild meat issue, such as Robinson and Bennett's (1999a) seminal book. Bakarr's *et al.* (2001) collection of papers on wild meat use in West and Central Africa has been followed by others aimed at providing guidance for better governance towards a more sustainable wild meat sector (Coad *et al.* 2019; Nasi *et al.* 2008). The latter document was presented to the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), to the CBD at their 21st meeting, 11–14 December 2017, with recommendations for consideration by the Parties to the Convention.

This book summarizes a large volume of information related to what is known about wild meat use in tropical and subtropical regions of the world (Chapters 1, 2 and 3). It also focuses on two key biological and sociological topics: what decisions hunters make when hunting (Chapter 4) and on the more intractable subject of how to measure sustainability (Chapter 5). The following chapters reviews what we know of the impact of overhunting on wildlife and the people that depend on it (Chapter 6) and the link between zoonotic diseases and wild meat (Chapter 7). We end the book (Chapter 8) by offering reflections on how best science and policy can intertwine to come up with possible solutions to the problem at hand. This textbook is not a policy recommendation document but a more updated primer that can find itself in the hands of students and of practitioners who are still developing their paradigms and perspectives.