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Ecological Effects of Warfare on Wildlife

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1 INTRODUCTION

Wildlife – individuals, populations, and communities of animals and other organisms – can be either positively or negatively affected by the military, political, and socio-economic correlates of armed conflict.[1] However, a clear understanding of the conditions under which we can expect one outcome or the other has not emerged. Such clarity would be valuable for evaluating the extent to which wild animals require legal protection in wartime, for designing legal mechanisms to confer such protection, and for prioritising scarce conservation resources.[2]

As a point of departure for this chapter, we consider the intuitive hypothesis that armed conflict may generally (i) exacerbate exploitative harvesting (e.g., bushmeat hunting, wildlife trafficking) owing to food insecurity and the relaxation of law enforcement and social norms, but (ii) reduce habitat conversion (e.g., forest clearing for agriculture, extractive industry, and development) as economies slow and people emigrate from contested areas. Below, we review the evidence available for a first-level assessment of this idea. The few large-scale quantitative analyses conducted to date suggest that, on average, conflict tends to intensify both direct exploitation (Section 2) and habitat conversion (Section 3). However, there are notable local exceptions to this general pattern, as well as a persistent shortage of hard data about exactly how and why conflict affects wildlife. We discuss several major data deficiencies and biases that currently hinder a fuller understanding of the

[*] We thank Kaitlyn Gaynor for helpful conversations about these issues. We gratefully acknowledge research funding from the US National Science Foundation (IOS-1656527), the Greg Carr Foundation, the Cameron Schrier Foundation, and the Grand Challenges Program of the High Meadows Environmental Institute.

[1] Joseph P. Dudley et al., 'Effects of War and Civil Strife on Wildlife and Wildlife Habitats', *Conservation Biology* 16 (2002), 319–29; Thor Hanson et al., 'Warfare in Biodiversity Hotspots', *Conservation Biology* 23 (2009), 578–87; Kaitlyn M. Gaynor et al., 'War and Wildlife: Linking Armed Conflict to Conservation', *Frontiers in Ecology and the Environment* 14 (2016), 533–42.

[2] Edd Hammill et al., 'Factoring Attitudes Towards Armed Conflict Risk into Selection of Protected Areas for Conservation', *Nature Communications* 7 (2016) 1–9; Joshua H. Daskin and Robert M. Pringle, 'Warfare and Wildlife Declines in Africa's Protected Areas', *Nature* 553 (2018), 328–32.

ecological effects of warfare, and we identify opportunities to rectify some of these problems (Section 4). Last, we briefly survey emerging evidence that post-war interventions can rehabilitate wildlife populations and ecosystems on relatively rapid timescales (Section 5).

2 EXPLOITATIVE WILDLIFE HARVESTING DURING ARMED CONFLICT

Violence is often accompanied and aggravated by poverty and food insecurity.[3] Accordingly, animals that represent potential sources of food or income may be harvested at higher rates during a conflict. Ungulates and other large mammalian herbivores are highly desired as bushmeat, can feed many people, and are therefore frequently targeted by hunters for local consumption or local/regional trade. In places, firearms and especially automatic weapons become more available during conflicts, which increases the efficiency and scale of hunting.[4] Certain species are exploited both for meat and for the lucrative international trade in tusks, horns, skins, and other body parts, which makes them especially vulnerable. Many wars in Africa have been interwoven with illicit ivory trafficking, although the details of these clandestine actions and transactions are poorly documented.[5] Indeed, there is a paucity of information about the effects of war on wildlife populations in general.

To our knowledge, there have been only two large-scale quantitative assessments of the impacts of warfare on wildlife trends. The first was our own 2018 study, which analysed the population trajectories of 36 large mammalian herbivore species from 126 protected areas in 19 African countries between 1946 and 2010.[6] We found that populations generally declined in the presence of even a modest amount of armed conflict – and that the declines were greatest in areas with the highest frequencies of conflict. We expect that conflict-associated population declines are even more pronounced for mammals that occur outside of formally protected areas, but data to test this conjecture are scarce. The other was a global analysis showing that

[3] Ellen Messer and Marc J. Cohen, 'Conflict, Food Insecurity and Globalization', *Food, Culture & Society* 10 (2007), 297–315; Henk-Jan Brinkman and Cullen S. Hendrix, *Food Insecurity and Violent Conflict: Causes, Consequences, and Addressing the Challenges*, Occasional Paper No. 24 (Rome: World Food Programme 2001), 1–32.

[4] Franciany Braga-Pereira, Juliano André Bogoni, and Rômulo Romeu Nóbrega Alves, 'From Spears to Automatic Rifles: The Shift in Hunting Techniques as a Mammal Depletion Driver During the Angolan Civil War', *Biological Conservation* 249 (2020), 108744.

[5] Ross Reeve and Stephen Ellis, 'An Insider's Account of the South African Security Forces' Role in the Ivory Trade', *Journal of Contemporary African Studies* 13 (1995), 227–43; Robin Thomas Naylor, 'The Underworld of Ivory', *Crime, Law & Social Change* 42 (2005), 261–95; Varun Vira and Thomas Ewing, *Ivory's Curse: The Militarization & Professionalization of Poaching in Africa* (Washington, DC: Born Free USA 2014); Shane C. Campbell-Staton et al., 'Ivory Poaching and the Rapid Evolution of Tusklessness in African Elephants', *Science* 374 (2021), 483–7.

[6] Daskin and Pringle, 'Warfare and Wildlife' (n. 2), 328–32.

roughly 80 per cent of all terrestrial mammal and bird species overlapped with a conflict between 1989 and 2018, and that these overlaps were associated with population declines among threatened species.[7]

Most published anecdotes and case studies are in line with this general trend. The Democratic Republic of Congo (DRC) – part of the biodiversity-rich but conflict-plagued Congo Basin – provides several noteworthy examples. In eastern DRC, rebels killed hundreds of hippos (*Hippopotamus amphibius*) around Virunga National Park in the mid-2000s.[8] In central DRC, endangered bonobos (*Pan paniscus*) were hunted at higher rates during conflicts between 1990 and 2010.[9] In north-eastern DRC, the last surviving population of northern white rhino (*Ceratotherium cottoni*) was extinguished from Garamba National Park after anti-poaching efforts broke down during conflicts in the 1990s.[10] The final two northern white rhinos, Najin and Fatu, are living out their days in captivity in Kenya; both are females, meaning that they are the last of their kind.

Declines of large-mammal populations in wartime are thought to stem from a combination of subsistence hunting and commercial wildlife trafficking,[11] abetted by slackened law enforcement[12] and not infrequently by the active involvement of military forces and government officials in poaching and trafficking.[13] The fog of war provides cover for all manner of illicit activities, as evidenced by the literature on conflict ivory.[14] The same fog obstructs scholars' ability to reconstruct the tangled involvement of combatants, civilians, governments, and profiteers in wildlife harvest and sale. Brian Huntley's (2017) account of the Angolan Civil War provides an unusually in-depth portrait of how conflict-associated corruption, poverty, and chaos nearly exhausted that country's wildlife.[15] Sometimes animals are sacrificed as political pawns. In the DRC, charcoal producers controlled by local militias killed endangered mountain gorillas (*Gorilla beringei beringei*) in a gambit to destabilise

[7] Uttara Mendiratta, Anand M. Osuri, Sarthak J. Shetty, and Abishek Harihar, 'Mammal and Bird Species Ranges Overlap with Armed Conflict and Associated Conservation Threats', *Conservation Letters* 14 (2021), e12815.

[8] Joe Bavier, 'Congo Militia Threaten to Kill Rare Gorillas', *Reuters* (21 May 2007), available at https://reut.rs/3HaGWaW, accessed 22 February 2022.

[9] Janet Nackoney et al., 'Impacts of Civil Conflict on Primary Forest Habitat in Northern Democratic Republic of the Congo, 1990–2010', *Biological Conservation* 170 (2014), 321–8.

[10] Kes H. Smith, 'Status of Northern White Rhinos and Elephants in Garamba National Park, Democratic Republic of Congo, During the Wars', *Pachyderm* 31 (2001), 79–81.

[11] Gaynor et al., 'War and Wildlife' (n. 1), 534.

[12] Peter Zahler and Peter Graham, 'War and Wildlife: The Afghanistan Conflict and Its Effects on the Environment', *International Snow Leopard Trust Special Report* (2001), 1–3.

[13] Jeffrey A. McNeely, 'Conserving Forest Biodiversity in Times of Violent Conflict', *Oryx* 37 (2003), 142–52; Peter Smallwood, Chris Shank, Alex Dehgan, and Peter Zahler, 'Wildlife Conservation . . . in Afghanistan?', *BioScience* 61 (2011), 506–11.

[14] Patience Akumu, 'Illegal Ivory Trade Funding Lord's Resistance Army Rebels', *Independent* (7 June 2013), available at https://bit.ly/3G3rbTl, accessed 22 February 2022; Rene L. Beyers et al., 'Resource Wars and Conflict Ivory: The Impact of Civil Conflict on Elephants in the Democratic Republic of Congo – the Case of the Okapi Reserve', *PLoS One* 6 (2011), e27129.

[15] Brian J. Huntley, *Wildlife at War in Angola* (Pretoria: Protea Book House 2017), 533–42.

and dismantle Virunga National Park.[16] Over 150 wildlife rangers in eastern DRC have been killed on the job since 1980, illustrating how efforts to enforce environmental laws can become conflicts within conflicts.[17]

Carnivores are rarely hunted for food, but they are hunted for skins, suffer from the depletion of their prey, and are often killed as bycatch in snares and traps set for other targets. Predators are inherently rarer than their prey – an area with 1,000 kilograms of prey will generally support only about 15 kilograms of carnivore[18] – and their populations are susceptible to total collapse. During the Mozambican Civil War (1977–92), large-herbivore populations declined by more than 90 per cent in Gorongosa National Park, but the populations nonetheless persisted.[19] In contrast, several species of top carnivores were locally eliminated and have only recently begun to recover with the aid of intensive management, extensive snare removal, and the translocation of individuals from other parts of Africa.[20]

Although most of the best-documented examples come from Africa, there are indications that populations of large animals have declined in response to conflicts elsewhere. The poaching of Indian rhino (*Rhinoceros unicornis*), tiger (*Panthera tigris*), and Himalayan blue sheep (*Pseudois nayaur*) spiked during the Nepalese Civil War (1996–2006), in concert with the diminished enforcement of conservation laws and international treaties such as the CITES.[21] In Cambodia, international demand for bushmeat and wildlife products fuelled intense hunting; endangered Asian elephants (*Elephas maximus*), Eld's deer (*Panolia eldii*), and hog deer (*Axis porcinus*), along with critically endangered kouprey (*Bos sauveli*) and Siamese crocodile (*Crocodylus siamensis*), were extirpated from habitats in the eastern part of the country during decades of conflict.[22] The intense poverty and lack of conservation programming throughout Afghanistan's long series of conflicts have left the country's snow leopards (*Panthera uncia*) and their prey vulnerable to being killed and sold by military and civilian hunters.[23] In Pakistan's Balochistan Province, screw-horned goat (*Capra falconeri*) and urial sheep (*Ovis orientalis vignei*) populations declined sharply as automatic weapons became widely available during the

[16] Stefan Lovgren, 'Congo Gorilla Killings Fueled by Illegal Charcoal Trade', *National Geographic* (16 August 2007), https://on.natgeo.com/3t3gqg3, accessed 22 February 2022.

[17] Bavier, 'Militia Threatens Gorillas' (n. 8).

[18] Ian A. Hatton et al., 'The Predator-Prey Power Law: Biomass Scaling across Terrestrial and Aquatic Biomes', *Science* 349 (2015), aac6284.

[19] Marc E. Stalmans et al., 'War-induced Collapse and Asymmetric Recovery of Large-Mammal Populations in Gorongosa National Park, Mozambique', *PloS One* 14 (2019), 1–18.

[20] Paola Bouley et al., 'Post-war Recovery of the African Lion in Response to Large-Scale Ecosystem Restoration', *Biological Conservation* 227 (2018), 233–42; David Quammen, 'How One of Africa's Great Parks Is Rebounding from War', *National Geographic* (May 2019), available at https://on.natgeo.com/3F2q05n, accessed 22 February 2022.

[21] Nabin Baral and Joel T. Heinen, 'The Maoist People's War and Conservation in Nepal', *Politics and the Life Sciences* 24 (2005), 2–11.

[22] Colby Loucks et al., 'Wildlife Decline in Cambodia, 1953–2005: Exploring the Legacy of Armed Conflict', *Conservation Letters* 2 (2009), 82–92.

[23] Zahler and Graham, 'War and Wildlife in Afghanistan' (n. 12), 1–13.

Soviet-Afghan War (1979–89); snow leopards were later hunted to local extinction when the depletion of their wild prey caused them to switch to eating livestock, prompting retaliation from herders[24] – an illustration of how human-human conflict can translate into human-wildlife conflict.

Other case studies, however, show that alternative outcomes are possible. For example, the 1970s Bush War in Zimbabwe was associated with prodigious growth of elephant populations, allegedly because the bush was too dangerous even for ivory poachers.[25] Are such exceptions as rare as they seem, or are they simply under-reported by scholars and journalists? The record is too sparse and fragmentary to provide a conclusive answer to this question.

3 HABITAT CONVERSION DURING ARMED CONFLICT

Impacts of conflict on animals that are not routinely hunted for food or body parts (which include most birds, reptiles, amphibians, and invertebrates) are more likely to result from changes in the availability and quality of habitat. The conversion of an ecosystem into concrete buildings or intensive agriculture annihilates the resident animal biodiversity of that ecosystem, and even less-intensive land uses can significantly erode the abundance and diversity of animal species. For example, selective logging of valuable timber species can eliminate the specialised birds, butterflies, and bees that eat and pollinate those trees, the specialised predators and parasites of those animals, and so on, with ripple effects throughout the food web – a phenomenon known as coextinction.[26]

It has been proposed that the reduction of human economic activity in conflict zones can decrease rates of habitat conversion.[27] Evaluating this proposition is easiest for forested regions, because deforestation is a relatively straightforward form of habitat conversion to quantify over large areas using aerial and satellite imagery. Contrary to this hypothesis, a recent analysis of deforestation throughout the tropics between 1992 and 2015 found that the rate of forest loss was twofold-to-fourfold greater in areas where conflicts occurred than in peaceful locations.[28] Although informative and pioneering in its scope, this study did not control for potentially confounding variables such as

[24] Javed Ahmed, Naseer Tareen, and Paind Khan, 'Conservation of Sulaiman Markhor and Afghan Urial by Local Tribesmen in Torghar, Pakistan', *International Union for the Conservation of Nature* (2001), 1–12.

[25] John B. Hallagan, 'Elephants and the War in Zimbabwe', *Oryx* 16 (1981), 161–4.

[26] Lian Pin Koh et al. 'Species Coextinctions and the Biodiversity Crisis', *Science* 305 (2004), 1632–4.

[27] McNeely, 'Forest Biodiversity in Conflict' (n. 13); Elsa M. Ordway, 'Political Shifts and Changing Forests: Effects of Armed Conflict on Forest Conservation in Rwanda', *Global Ecology and Conservation* 3 (2015), 448–60; Pablo Jose Negret et al., 'Need for Conservation Planning in Postconflict Colombia', *Conservation Biology* 31 (2017), 499–500; Dolores Armenteras, Laura Schneider, and Liliana María Dávalos, 'Fires in Protected Areas Reveal Unforeseen Costs of Colombian Peace', *Nature Ecology & Evolution* 3 (2019), 20–3.

[28] David M. Landholm, Prajal Pradhan, and Juergen P. Kropp, 'Diverging Forest Land Use Dynamics Induced by Armed Conflict Across the Tropics', *Global Environmental Change* 56 (2019), 86–94.

human population density and accessibility; additional continental- and global-scale studies are needed to address lingering uncertainties.

Many other studies have focused on the relationship between conflict and deforestation at sub-continental scales. This topic has recently garnered particular attention in Colombia after the signing of a peace accord to end five decades of hostilities.[29] During the Colombian conflict, forced migration of millions of people, mostly from rural to urban areas, created large swaths of abandoned land.[30] Some smaller municipalities experienced net forest regrowth on these disused farms.[31] Moreover, militias required that up to 30 per cent of forests be spared from clearing to limit access, conceal the position of the militants, and provide cover for coca cultivation and weapons trafficking.[32] Nonetheless, many regions rich in mineral resources or suitable for cattle ranching and coca production were deforested during the conflict.[33] Thus, in Colombia, the evidence suggests that conflict had locally variable but overall negative effects on forest cover.

Subsequently, the movement towards peace in Colombia has brought new threats. From 2017 to 2018, fires increased by 600 per cent inside formerly rebel-controlled protected areas, and overall forest disturbance surged – in part because provisions of the peace agreement granted lands for agricultural clearing, commercial development, the harvest of natural resources, and the return of displaced persons in forests that were previously under de facto protection by militants.[34] Thus, researchers analyzing the effects of armed conflict on wildlife must also consider the aftermath, a point to which we return in Section 5.

Conflict-driven habitat degradation is also well-documented in African and Asian regions. Displaced persons in the central DRC fled into and cleared protected forests at twice the peacetime rate,[35] while those fleeing the Rwandan civil war, genocide, and aftermath deforested parts of Nyungwe National Park and much of Giswahiti Forest Reserve.[36] In Afghanistan, conflict has hindered the development

[29] Brigitte Baptiste et al., 'Greening Peace in Colombia', *Nature Ecology & Evolution* 1 (2017), 1–3.

[30] Negret et al., 'Planning Postconflict Colombia' (n. 27), 499–500.

[31] Landholm et al., 'Forest Land Use and Armed Conflict' (n. 28), 86–94.

[32] Paulo J. Murillo-Sandoval et al., 'The End of Gunpoint Conservation: Forest Disturbance After the Colombian Peace Agreement', *Environmental Research Letters* 15 (2020), 1–12, available at https://iopscience.iop.org/article/10.1088/1748-9326/ab6ae3, accessed 22 February 2022.

[33] Ana María Sánchez-Cuervo and T. Mitchell Aide, 'Consequences of the Armed Conflict, Forced Human Displacement, and Land Abandonment on Forest Cover Change in Colombia: A Multi-scaled Analysis', *Ecosystems* 16 (2013), 1052–70; Negret et al., 'Planning Postconflict Colombia' (n. 27), 499–500; Armenteras et al., 'Fires in Colombian Protected Areas' (n. 27), 20–3; Landholm et al., 'Forest Land Use and Armed Conflict' (n. 31), 86–94.

[34] Armenteras et al., 'Fires in Colombian Protected Areas' (n. 27), 20–3; Murillo-Sandoval et al., 'The End of Gunpoint Conservation: Forest Disturbance after the Colombian Peace Agreement' (n. 32), 1–12.

[35] Janet Nackoney et al., 'Impacts of Civil Conflict on Primary Forest Habitat in Northern Democratic Republic of the Congo, 1990–2010', *Biological Conservation* 170 (2014), 321–8.

[36] Samuel Kanyamibwa, 'Impact of War on Conservation: Rwandan Environment and Wildlife in Agony', *Biodiversity and Conservation* 7 (1998), 1399–406; Ordway, 'Political Shifts and Forests' (n. 27), 448–60.

of sustainable economies as the country's human population has grown enormously;[37] in turn, livestock have overgrazed grasslands and trees have been cleared for fuel and timber, diminishing habitat quality for wild ungulates and reducing their availability as prey for snow leopards and other threatened carnivores.[38] In southeast Asia, the application of defoliants and herbicides such as Agent Orange by the US military in the 1960s and 1970s damaged forests and polluted soils and wetlands.[39] Iraq destroyed 600 oil fields in retribution for attacks by US troops during the First Gulf War in 1991, which contaminated habitats hundreds of kilometres south into the Persian Gulf and killed seabirds, fish, and other marine animals.[40]

Yet, again, there are conspicuous exceptions to the general pattern of conflict-associated degradation. One of the most famous positive side effects of conflict for wildlife is the de facto protected area created by the Korean Demilitarized Zone, which is now home to many at-risk species, including white-naped cranes (*Grus vipio*), Asiatic black bears (*Ursus thibetanus*), and Amur goral (*Naemorhedus caudatus*).[41] In Malaysia, the Royal Belum State Park was recently created in areas that were previously closed to civilians and industrial activity during hostilities with neighbouring Thailand.[42] In Sierra Leone, rebel army bases and combat events were both associated with reduced deforestation rates between 1990 and 2000.[43] An economic downturn during the civil war in El Salvador reportedly slowed agricultural development and forest clearing in the 1980s.[44]

In sum, the available evidence suggests broad similarities between impacts of war on hunting and habitats. Negative effects predominate, but more neutral or even positive outcomes for wildlife sometimes emerge. That conflict can at least occasionally provide a shield for wildlife and their habitats speaks volumes about the reference state: humankind has many ways of destroying, and biodiversity needs protection in both war and peace. Further progress in our understanding of these issues will require both (i) additional large-scale quantitative assessments that build on recent continental and global analyses[45] and (ii) additional finer-scale assessments that capture the kinds of context-specific information that larger-scale syntheses inevitably

37 Smallwood et al., 'Wildlife Conservation in Afghanistan' (n. 13), 506–11.
38 Ibid. See also Zahler and Graham, 'War and Wildlife in Afghanistan' (n. 12), 11–13.
39 Arthur H. Westing, 'Ecological Effects of Military Defoliation on the Forests of South Vietnam', *Bioscience* 21 (1971) 893–8.
40 Severin Carrell, 'Gulf States Fear Iraqi Oil Sabotage', *Independent* (9 February 2003), available at https://bit.ly/3n2phLo, accessed 22 February 2022.
41 Ke Chung Kim, 'Preserving Biodiversity in Korea's Demilitarized Zone', *Science* 278 (1997) 242–3.
42 McNeely, 'Forest Biodiversity in Conflict' (n. 13), 142–52.
43 Robin Burgess, Edward Miguel, and Charlotte Stanton, 'War and Deforestation in Sierra Leone', *Environmental Research Letters* 10 (2015), 1–10.
44 Susanna B. Hecht and Sassan S. Saatchi, 'Globalization and Forest Resurgence: Changes in Forest Cover in El Salvador,' *BioScience* 57 (2007), 663–72.
45 Landholm et al., 'Forest Land Use and Armed Conflict' (n. 28), 86–94; Daskin and Pringle, 'Warfare and Wildlife' (n. 6) 328–32.

obscure. Such situational knowledge is necessary to understand when and where conflict will endanger wildlife, to predict when and where exceptions are likely, and to untangle which agents and what proximate causes (e.g., food insecurity, governance issues, military activities, forced migration) determine the direction and magnitude of war's impact on wildlife. An essential raw ingredient for such studies is greater knowledge about the diversity and abundance of wildlife in warzones.

4 DATA DEFICIENCIES: GEOGRAPHIC AND TAXONOMIC BIASES

A major limitation of the presently available data is the heavy geographic skew in biological field studies. Biodiversity data are generally scarcer and of lower quality in tropical countries than temperate ones, in poorer countries than richer ones, and in conflict-prone regions than peaceful ones.[46] In part, these knowledge gaps reflect the predilections of Northern/Western biologists, who gravitate towards localities that are safe, comfortable, and well-equipped.[47] They likewise reflect the systematic underdevelopment of local capacity and expertise in the Global South, which tends to be especially pronounced in countries with histories of conflict, instability, and poverty.[48]

These data deficiencies are pronounced even for charismatic large mammals, which attract disproportionate attention and funding and are comparatively easy to count (Figure 3.1(A)). They are undoubtedly much worse for other types of animals, (e.g., invertebrates, reptiles, fishes). The Living Planet Index – a global metric of vertebrate species abundance[49] – is the basis for many studies that examine patterns of wildlife population trajectories.[50] In this database, 81 per cent of the data on African large herbivores, carnivores, and primates come from just five countries: South Africa, Tanzania, Kenya, Zimbabwe, and Uganda. A similar bias is present in published studies

[46] Laura J. Martin, Bernd Blossey, and Erle Ellis, 'Mapping Where Ecologists Work: Biases in the Global Distribution of Terrestrial Ecological Observations', *Frontiers in Ecology and the Environment* 10 (2012), 195–201; Kerrie A. Wilson et al., 'Conservation Research is Not Happening Where it is Most Needed', *PLoS Biology* 14 (2016), e1002413; James T. Stroud and Kenneth J. Feeley, 'Neglect of the Tropics is Widespread in Ecology and Evolution: A Comment on Clarke et al.', *Trends in Ecology & Evolution* 32 (2017), 626–8.

[47] Tatsuya Amano and William J. Sutherland, 'Four Barriers to the Global Understanding of Biodiversity Conservation: Wealth, Language, Geographical Location and Security', *Proceedings of the Royal Society B* 2013 280, 1–7; Ana L Reboredo Segovia, Donato Romano, and Paul R., Armsworth, 'Who Studies Where? Boosting Tropical Conservation Research Where it is Most Needed', *Frontiers in Ecology and the Environment*, 6 January 2020. The latter authors report that 'US scientists still respond negatively to safety concerns,' echoing the findings of the former authors that conflict-prone regions are less-well represented in biodiversity databases.

[48] Wilson et al., 'Conservation Research' (n. 46), e1002413.

[49] Ben Collen et al., 'Monitoring Change in Vertebrate Abundance: The Living Planet Index', *Conservation Biology* 23 (2009), 317–27.

[50] David Vačkář et al., 'Review of Multispecies Indices for Monitoring Human Impacts on Biodiversity', *Ecological Indicators* 17 (2012), 58–67; Megan D. Barnes et al., 'Wildlife Population Trends in Protected Areas Predicted by National Socio-economic Metrics and Body Size', *Nature Communications* 7 (2016), 12747.

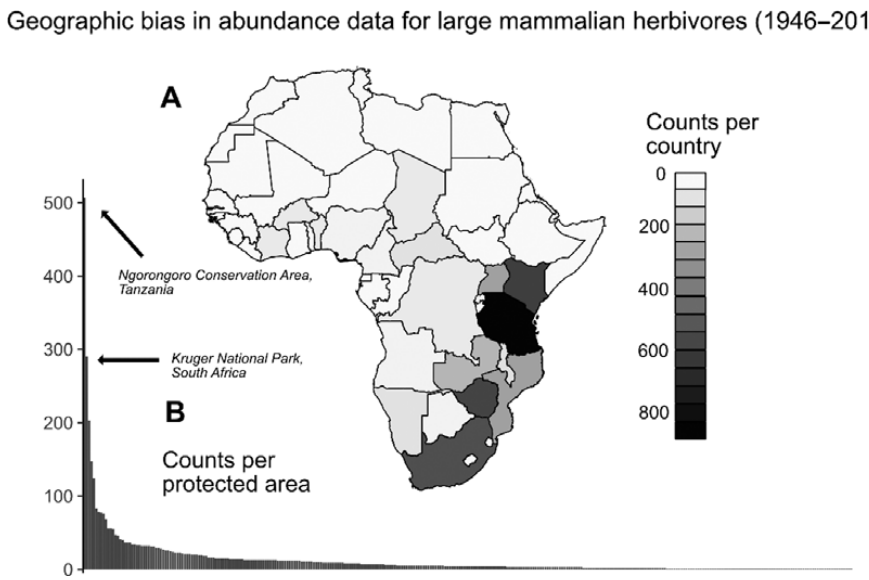

FIGURE 3.1 The number of times large mammalian herbivore populations were counted in (A) each African country and (B) 322 African protected areas between 1946 and 2010. Data from Daskin and Pringle (2018), 2.

that have compiled data from primary sources; in one landmark study of large mammal population trajectories in African protected areas, 76 per cent of the data came from four of the best-studied countries (South Africa, Tanzania, Kenya, and Uganda).[51] Throughout the rest of the continent, there are few if any reliable quantitative data on mammal abundances – notably so for large swaths of West Africa, the mega-diverse Congo Basin, and adjoining countries such as Gabon and South Sudan that are rich in wildlife (at least historically). Even within the few comparatively well-studied countries, a handful of protected areas receive the vast majority of attention. There have been hundreds of wildlife counts in renowned conservancies such as Ngorongoro Crater in Tanzania and Kruger National Park in South Africa, whereas many lesser-known, lesser-staffed, and less-visited protected areas remain essentially unstudied (Figure 3.1(B)).

Given the risk and hardship of working in conflict zones, addressing these data deficiencies to better understand and mitigate the effects of war on wildlife will be challenging. There is an urgent need to couple emerging wildlife-monitoring technologies – which can help to offset the physical risks of conducting research in active warzones – with the cultivation of local capacity where it has been stifled by poverty, underdevelopment, and the tendency of Northern scientists and NGOs to

[51] Ian D. Craigie et al., 'Large Mammal Population Declines in Africa's Protected Areas', *Biological Conservation* 143 (2010), 2221–8.

https://doi.org/10.1017/9781009057301.004 Published online by Cambridge University Press

collect data in the tropics without contributing meaningfully to a foundation of local expertise. Technologies with rapidly advancing capabilities for wildlife monitoring include unmanned aerial vehicles (drones) and thermal sensors.[52] Motion-triggered camera traps and audio recorders can be placed in dangerous or inaccessible habitats to document wildlife activity.[53] A major logjam in the use of camera traps for wildlife monitoring is the immense effort required to extract data from hundreds of thousands of images, but multiple efforts are underway to process these data using machine-learning algorithms.[54] It is increasingly easy to envision a future in which the collection, analysis, and satellite transmission of sensor data are all fully automated,[55] requiring minimal human presence in dangerous environments. Similarly, the analysis of environmental DNA shed by organisms is an increasingly well-validated method for biomonitoring, and this approach too is on the path towards automation.[56] There are also many steps that can be taken before conflicts begin to facilitate subsequent analysis of the effects of war on wildlife,[57] such as investing in systematic large-scale surveys to generate baseline data (e.g., The Great Elephant Census).[58]

5 POST-WAR REHABILITATION AND REWILDING

Alongside the evidence that armed conflict generally has negative effects on wildlife and their habitats, there is evidence that natural systems are remarkably resilient in the wake of war – if given the chance. The post-war rehabilitation of Mozambique's Gorongosa National Park is perhaps the most dramatic example. Populations of elephant, hippo, buffalo, and diverse antelope species have all recovered dramatically since 2007 under the aegis of a pioneering public-private conservation

[52] Tracey Hollings et al., 'How Do you Find the Green Sheep? A Critical Review of the Use of Remotely Sensed Imagery to Detect and Count Animals', *Methods in Ecology and Evolution* 9 (2018), 881–92.

[53] J. Marcus Rowcliffe et al., 'Estimating Animal Density Using Camera Traps Without the Need for Individual Recognition', *Journal of Applied Ecology* 45 (2008), 1228–36; Zuzana Burivalova et al., 'Using Soundscapes to Investigate Homogenization of Tropical Forest Diversity in Selectively Logged Forests', *Journal of Applied Ecology* 56 (2019), 1365–2664.

[54] Mohammad S. Norouzzadeh et al., 'Automatically Identifying, Counting, and Describing Wild Animals in Camera-Trap Images with Deep Learning', *Proceedings of the National Academy of Sciences* 115 (2018), E5716–E5725.

[55] Sajid Nazir, Gorry Fairhurst, and Fabio Verdicchio, 'WiSE: A Satellite-Based System for Remote Monitoring', *International Journal of Satellite Communications and Networking* 35 (2017), 201–14; Paul Glover-Kapfer, Carolina A. Soto-Navarro, and Oliver R. Wearn, 'Camera-Trapping Version 3.0: Current Constraints and Future Priorities for Development', *Remote Sensing in Ecology and Conservation* 5 (2019), 209–23.

[56] David A. Bohan et al., 'Next-Generation Biomonitoring: Large-Scale, Automated Reconstruction of Ecological Networks', *Trends in Ecology & Evolution* 32 (2017), 477–87.

[57] Judy Oglethorpe et al, 'Overview C: Conservation in Times of War', in Richard Matthew, Mark Halle, and Jason Switzer (eds.), *Conserving the Peace: Resources, Livelihoods, and Security* (Winnipeg: International Institute for Sustainable Development 2002), 361–84.

[58] Michael Chase et al., 'Continent-Wide Survey Reveals Massive Decline in African Savannah Elephants', *PeerJ* 4 (2016), e2354.

initiative.[59] The precipitous decline of these species in the wake of the Mozambican Civil War had various knock-on effects for the ecosystem. Trees and invasive plant species became more abundant,[60] and the absence of top carnivores altered the behaviour of herbivores and their impacts on plants.[61] Yet the rapid recovery of large herbivores has already begun to reverse this habitat degradation; the abundance of a major invasive plant species has already been reduced to pre-war levels.[62] African wild dogs (*Lycaon pictus*) have recently been reintroduced; leopards appear to have recolonised the ecosystem on their own, and their numbers have since been augmented with translocated individuals.[63] These carnivores are re-establishing the predator-prey interactions that ecologists consider to be essential for the stability of eco systems. Similar efforts to 'rewild' conflict-impacted ecosystems are underway throughout Mozambique,[64] in Rwanda's Akagera National Park,[65] and elsewhere.

The most obvious lesson of success stories like Gorongosa is that an ecosystem degraded by long-term conflict is not lost. This capacity for resilience suggests that efforts to secure protection for wildlife in wartime should consider not just the present and recent past, but also the post-conflict future. In Gorongosa, the park exists not only for wildlife management, but also as an engine of human development.[66] Educational, economic, medical, agricultural, and disaster-relief programming by the national park aims to support the region's populace, reducing their reliance on wildlife as food while bolstering their trust in and cooperation with the park. We believe that similar efforts elsewhere can help to create opportunities for coupled human-natural systems to recover and persist in perpetuity. Because the well-being of people and wildlife are joined in a feedback loop, we suggest that post-war relief efforts should incorporate environmental rehabilitation in addition to traditional human-oriented objectives. The Gorongosa Project provides one model that can be tailored to other circumstances.

59 Robert M. Pringle, 'Upgrading Protected Areas to Conserve Wild Biodiversity', *Nature* 546 (2017), 91–9.

60 Joshua H. Daskin, Marc E. Stalmans, and Robert M. Pringle, 'Ecological Legacies of Civil War: 35-Year Increase in Savanna Tree Cover Following Wholesale Large-Mammal Declines', *Journal of Ecology* 104 (2016), 79–89; Jennifer A. Guyton et al., 'Trophic Rewilding Revives Biotic Resistance to Shrub Invasion', *Nature Ecology & Evolution* 4 (2020), 712–24.

61 Justine L. Atkins et al. 'Cascading Impacts of Large-Carnivore Extirpation in an African Ecosystem', *Science* 364 (12 April 2019), 173–7.

62 Guyton et al., 'Trophic Rewilding' (n. 60), 1–13.

63 Natalie Angier, 'Mozambique is Using Science to Save One of Its National Parks from Destruction', *Independent* (25 July 2018); Natalie Angier, 'How This Spot (in Mozambique) Got Its Leopard', *New York Times* (10 January 2021). https://nyti.ms/3IrQcZT, accessed 22 February 2022.

64 Peace Parks Foundation, 'Conservation Triumphs' (2 December 2019) available at www.peaceparks.org/conservation-triumphs, accessed 22 February 2022.

65 Benedict Moran, 'Rwanda's War Nearly Destroyed This Park. Now It's Coming Back', *National Geographic* (5 May 2019), available at https://on.natgeo.com/3nohZYq, accessed 22 February 2022.

66 Pringle, 'Upgrading Protected Areas' (n. 59), 91–9.

The time needed for ecosystems and wildlife to recover can vary. Habitats recover slowly, but they do recover; tropical forests can regenerate substantially within the span of a few decades.[67] Among animals, time lags are longer for carnivores than for herbivores, but again the timescales are measured in years-to-decades – shorter than the span of a human career. In turn, recovering habitats and wildlife populations can rapidly revive ecosystem services, such as water provision, crop pollination, invasive-species control, and the employment of local people (including former combatants) in environmental management. International collaboration tied to local capacity-building is a key ingredient. With the collaborative assistance of the US Fish and Wildlife Service, urial and screw-horned sheep populations have rebounded in Baluchistan, Pakistan, in part because their conservation provided employment for game rangers and economic benefits from regulated trophy hunting.[68]

6 CONCLUSION

The accumulated evidence suggests that war generally exacerbates both intensive hunting and habitat conversion and is detrimental for individual animals and the populations, communities, and ecosystems of which the individuals are a part. Apparent exceptions to this general pattern are intriguing, and a fuller understanding of the circumstances that lead to exceptional outcomes may ultimately illuminate ways to mitigate the impacts of conflict on wildlife. We believe that the available data clearly suggest a need to consider mechanisms – legal and otherwise – to protect animals and their habitats in wartime. But the present state of knowledge about the ecological impacts of warfare is insufficient to precisely forecast the mechanisms by which conflicts will affect different aspects of biodiversity. Alleviating the current geographic and taxonomic biases in wildlife data is a challenging but crucial step that can be attacked progressively with the aid of emerging technologies. Understanding the social, economic, and political pathways through which war affects wildlife is equally important, and even more challenging. Figuring out how to design and justly enforce wildlife-protection laws in times when people are at their most vulnerable and desperate is undoubtedly most challenging of all.

Despite these hurdles, there is enormous unrealised potential to act in ways that resuscitate conflict-diminished wildlife populations, rehabilitate conflict-degraded ecosystems, advance human well-being, and enrich human experience. Access to a vibrant and intellectually stimulating natural environment is, we believe, a fundamental human right. It is rarely explicitly articulated as such. And yet it is an inextricable component of many widely accepted fundamental rights – to education, to mental and physical health, to participation in cultural life, to contemplation and creative activity, to an adequate standard of living. Many writers have

[67] Ibid.
[68] Ahmed et al., 'Conservation of Urial and Markhor' (n. 24), 1–12.

depicted wildlife conservation as a unique prerogative of the West and the North. It is hardly that. The thrill of safely observing an elephant or a tiger, the serenity of a walk in the forest – these things transcend culture. It is primarily the *access* to such pleasures that is concentrated in wealthy countries. By recognising the indispensability of non-human life to healthy human lives, it may be possible to link protections for people with protections for wildlife, both during and after armed conflicts.

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