Disaster management takes to the skies

Enns, Charis; Bersaglio, Brock; Karmushu, Ramson

DOI:
10.1016/j.polgeo.2022.102732

Political Geography 98 (2022) 102732

Contents lists available at ScienceDirect

Political Geography

journal homepage: www.elsevier.com/locate/polgeo

Full Length Article

Disaster management takes to the skies: How new technologies are reconfiguring spatialities of power in desert locust management

Charis Enns [a], Brock Bersaglio [b,*], Ramson Karmushu [c]

[a] Global Development Institute, University of Manchester, Manchester, UK
[b] International Development Department, University of Birmingham, Birmingham, UK
[c] Indigenous Movement for Peace Advancement and Conflict Transformation, Nanyuki, Kenya

ARTICLE INFO

Keywords:
Earth observation technologies
Necropower
Volumetric space
Desert locust
Disaster management
Kenya

ABSTRACT

This article explores how new technologies – such as drones and satellites – are incorporated into disaster management and questions the implications for power relations between disaster authorities and subjects. This is a critical area of research, as the proliferation of aerial and networked technologies has made their use in disaster management and response more common. Although concerns have been raised about the potential use of aerial and networked technologies in the surveillance and spatial discipline of populations by commercial and government actors, few have considered the implications for disaster management. In response, this article turns to geographical literature on necropower, verticality, and planetary spatialities to analyse technological innovations in responses to desert locust upsurges in Kenya. Drawing from qualitative research carried out between February 2020 and January 2021, we explain how desert locust control operations have shifted from horizontal to vertical to networked and planetary in nature through experimentation with new technologies over the past century. We argue that aerial and networked technologies have led to a volumetric shift in desert locust management and response, giving remote and increasingly automated actors who operate 'above' greater power over the life and death of populations 'below'. In making this argument, we adopt a more-than-human perspective to account for how nonhuman entities and lifeforms shape and are subjected to necropolitical disaster management and responses. We conclude by reflecting on what this analytical approach has to offer the study of vertical and volumetric geographies.

1. Introduction

In 2019, desert locust swarms began to spread from the Arabian Peninsula across the Greater Horn of Africa, posing "an extremely alarming and unprecedented threat to food security and livelihoods" (Food and Agriculture Organisation of the United Nations (FAO), 2020a; par. 1). Desert locusts are considered one of the world's most dangerous migratory pests, as swarms – containing up to 80 million individuals in a single km^2 – can cause substantial pasture and crop damage. Throughout 2018 and 2019, successive rounds of breeding took place in the Empty Quarter of the Arabian Peninsula, as insecurity and insufficient resources hampered survey and control operations. By late-2019, swarms of desert locust had formed, migrated, and begun to arrive in northern Kenya, marking the beginnings of the worst desert locust upsurge in the country in 70 years.

Habitual to arid and semi-arid regions in Africa, the Middle East, and Southwest Asia, desert locusts have posed a formidable threat to human societies since ancient times. Historically, efforts to contain desert locusts occurred largely on the ground. In northern Kenya, controlled fires were ignited to decimate swarms, as well as breeding and feeding sites, and people banged metal objects to scare mature swarms away from crops and pasture. Over time, governments and regional organisations assumed management of desert locust control operations, traveling by foot, camel and, later, vehicle, to control swarms using pesticidal baits and sprays. Today, efforts to control desert locusts happen primarily from above. Satellites are used to identify locations where desert locusts are likely to swarm; smartphone apps are used by citizens to report swarming once it begins; drones are used to monitor swarms as they migrate and roost; and airplanes fitted with ultra-low volume sprayers are used to disperse pesticides. The spaces of desert locust control are no longer just two-dimensional or horizontal in orientation; rather, desert locusts are increasingly viewed from above and managed from afar.

* Corresponding author.
E-mail address: b.d.bersaglio@bham.ac.uk (B. Bersaglio).

https://doi.org/10.1016/j.polgeo.2022.102732
Received 16 June 2021; Received in revised form 17 January 2022; Accepted 27 July 2022
Available online 29 August 2022

This volumetric shift in desert locust management is not unique to pest control, but can be observed in response to many other types of hazards and disasters. Whether one considers wildfires, floods, or hurricanes, information about these events and the destruction they cause is increasingly generated using aerial technologies, such as drones and satellites, producing digital information that is transferred across the globe through antennas, dishes, fibre-optic cables, and microchips. This information feeds into disaster responses that are also increasingly executed by air; for example, with aircraft that carry and disperse chemical flame retardants, pesticides, or even emergency food supplies to end or mitigate crises. Despite the fact that disaster management no longer unfolds on a flat plane, 'horizontalism' remains predominant in disasters literature and geographical scholarship more broadly. Drawing inspiration from literature that seeks to move beyond "'flat' ontologies" of geographical knowledge (Steinberg & Peters, 2015), this article explores how new technologies are being incorporated into disaster response and considers what the implications are for how power is enacted and experienced among humans and nonhumans affected by disasters.

In this article, we make use of a case study that focuses on technological adaptations and advances in desert locust management in northern Kenya and the Greater Horn of Africa. Our analysis suggests that desert locust control operations have shifted from largely horizontal to vertical to networked in nature as a result of experimentation with new technologies over the past century. We argue that volumetric shifts in desert locust management have enabled authorities to gain new forms of control over space, risk, and populations 'from above', with implications that exacerbate asymmetrical power relations with those 'below'. More specifically, we highlight three ways that volumetric shifts in desert locust management risk exacerbating power asymmetries: changing technologies and authorities involved in calculating and conducting control operations, including Artificial Intelligence (AI) and private companies; greater degrees and volumes of separation between desert locust authorities and those intimately affected by upsurges; and ongoing experimentation with technologies designed to improve the efficacy of calculated biopolitical and necropolitical interventions. Our analysis is framed using insights from geographical literature on biopolitics, necropolitics, and disasters (Foucault 1998; Mbembe, 2003; Lawrence and Weibe, 2017), as well as that on verticality, novel technologies, and automation (Adams, 2018; Elden, 2013; Tripodi, 2020).

For nearly a century, entomological and pest management studies have been carried out on desert locusts in the Greater Horn of Africa often without being subjected to critical scrutiny. Our analysis in this article is informed by these studies, including research articles, policy documents, and images from the region on locusts produced between the 1930s and the present, as well as news stories, social media posts, and webinars during the most recent desert locust crisis. Analysis of these sources was conducted between February 2020 and January 2021. This analysis is supplemented and triangulated with insights from interviews with people in northern Kenya involved in the desert locust response or impacted by the upsurge and response. In total, 95 people participated in the research, including representatives from civil society organisations (n = 5), government bodies (n = 6), and communities (n = 84). Interviews were carried out between July and October 2020 by eight community-based researchers embedded in counties affected by desert locusts, including Isiolo, Laikipia, Marsabit, and Samburu. Community-based researchers also collected photographic data, including animals, plants, and landscapes affected by swarm activity. All research activities followed the COVID-19 protocols of the Government of Kenya and the World Health Organisation, taking place outdoors with personal protective equipment and social distancing or virtually using mobile phones and WhatsApp.

In the next section, we turn to geographical literature concerned with the biopolitics and necropolitics of disasters as well as geographical literature that seeks to move beyond flat ontologies through engagement with verticality and novel technologies that make possible planetary spatialities. We then introduce our case study and proceed with our analysis of different volumetric shifts that have occurred in desert locust management in northern Kenya over the past century or so. Before concluding, we discuss the changing forms of authority and enactments of power that have occurred alongside these shifts and outline some of the ways in which the increasingly volumetric nature of disaster management is at risk of exacerbating existing power asymmetries.

2. New spaces and technologies of disaster management

2.1. Disaster management as biopolitical and necropolitical

Geographers have shown that disaster management is a biopolitical regime (Lawrence and Weibe, 2017), writing on topics such as climate-related hazards (Grove, 2014), toxic contamination (Davis & Hayes-Conroy, 2018), and disease (Braun, 2007). Biopolitics describes a political rationality that aims "to ensure, sustain and multiply life" and "to put this life in order" (Foucault, 1978, p. 138). The modern state exercises biopower through disciplinary techniques that operate on individual bodies and populations; for example, by collecting data on the populus through censuses and using this data to inform calculated programmes of intervention that aim to improve populations (Li, 2007). Such governmental interventions are pronounced in relation to crises and disasters, as the ability to protect life represents the ontological basis for modern forms of sovereignty (Bryan, 2015, p. 35). In the context of disaster management, calculated programmes of intervention are often informed by risk assessments, vulnerability mapping, modeling, and other approaches to collecting data on vulnerable populations in order to secure life in the face of uncertain and potentially calamitous futures (Grove, 2014).

At the same time, biopolitical understandings of governance regimes sometimes undertheorise the "centrality of death to the organization of socio-political life" (Kaur, 2021, p. 2). Drawing on work by Mbembe – who proposed the concepts of necropolitics and necropower to analyse "the creation of death-worlds" or "forms of social existence in which vast populations are subjected to conditions of life conferring upon them the status of living dead" (2003, 39–40) – many geographers are interested in how the infliction of harm and death upon certain populations is used to maintain socio-political control and liberal order. As Margulies explains, death and the threat of death is acknowledged in biopolitical literature, but necropolitical perspectives emphasise that "active political processes of death are just as necessary for the maintenance of other kinds of life under particular political regimes" (2019, 152). Concerning disasters, a necropolitical perspective recognises that some populations will be rendered killable during responses so that others may live (Anderson, Grove, Rickards, & Kearnes, 2020). This is well-exemplified by 'climate necropolitics' that legitimate violence against some people in climate change responses as serving the interests of *the rest* of the planet (DeBoom, 2020).

Although Foucault and Mbembe focused mainly on human concerns, a growing body of geographical literature aims to extend this work to the more-than-human world. Scholarship in this area demonstrates that nonhuman animals, plants, and other organisms both experience necropower and serve as conduits for necropolitical agendas (Crowley et al., 2018; Greenhough et al., 2018; Margulies, 2019; Wrigley, 2018). Some of this literature explains why non-human species are made live or made die in relation to disasters. This includes Collard's (2018) work on sea otters and environmental catastrophes; Stoddard and Hovorka's (2019) critique of how pigs may be kept confined and drowned during floods due to public health fears; and Chan's (2016) writing on the culling of cats during the 2003 SARS outbreaks due to their potential to spread the disease. These examples illuminate the dark entanglements that bind humans and nonhumans together in biopolitical and necropolitical governance regimes, as the destruction of nonhumans is justified as an effective means of sustaining human life. Mollett (2017) also cautions that in these dark entanglements, some humans may be rendered *less*-than-human and made die to maintain nonhuman populations deemed of greater value. Racist tropes leading to counter-poaching agendas and shoot-to-kill policies provide one example of the less-than-human politics at play in necropower (Lunstrum, 2017).

In building on this work, we advance and further develop a more-than-human perspective of the necropolitical entanglements that exist between humans and nonhumans in disasters and disaster responses. Our analysis of the desert locust upsurge in northern Kenya demands consideration for connections between human and nonhuman populations – including insect life, animal life, and plant life – and technological entities – including AI, drones, and satellites. Because of where these entities meet and how they are connected, we are led to look up towards the vertical and volumetric spaces where disaster management now unfolds.

2.2. Disaster management as vertical and volumetric

Geographers have traditionally thought of space as flat and the exercise of power as horizontal (Elden, 2013). However, it is now acknowledged that understanding the geographical workings of power requires consideration for fuller and vertically oriented volumes of three dimensional space – including the aerial (Adey, 2010b), oceanic (Steinberg & Peters, 2015) and subterranean (Bridge, 2013). As Foucault writes: "The vertical is not one of the dimensions of space, it is the dimension of power" (2007, 170). Mbembe (2003) too discusses 'vertical sovereignty,' describing how newfound abilities to exercise power from above the surface of the earth are resulting in a proliferation of sites of violence.

This volumetric shift in the exercise of power is both a result of and continues to demand technological advances that move power struggles from two-dimensional to three-dimensional spaces (Urry, 2003; Weizman, 2007; Gregory, 2011; Harris, 2015; Bracken-Roche, 2016; Garrett and Anderson 2017; Jackman & Squire, 2021). Writing about modern states, Mbembe explains:

> Occupation of the skies [has acquired] a critical importance, since most of the policing is done from the air. Various other technologies are mobilized to this effect: sensors aboard unmanned air vehicles (UAVs), aerial reconnaissance jets, early warning Hawkeye planes, assault helicopters, an Earth-observation satellite, techniques of "hologrammatization" (2003, 29).

These and many other technologies have changed how space is experienced, acting on terrains in ways that make populations below feel emotions of dread, fear, and nervousness not shared by those above (Gordillo, 2018). These affective attributes of vertical, volumetric space reflect the fact that decisions about who should live and who must die are increasingly made by those who hold the power to occupy or see the world from higher planes (Adams, 2019; Adey, 2010a, 2010b; Jackman & Brickell, 2021; Lockhart et al., 2021; Massé, 2018; Millner, 2020).

The 'volumetric turn' (Jackman & Squire, 2021) has occurred alongside another paradigmatic turn that is transforming modern spatialities of power. Tripodi (2020) describes this second paradigm shift as the expansion of the networked dimension: The popularisation of new technologies – including satellites, GPS, internet, and mobile technologies – has disintegrated certain spatial boundaries and allowed authorities to see, control, and dominate people and space at a planetary scale (Tripodi, 2020). Increasingly, authorities operate from the "point of view of the satellite" (Tripodi, 2020, p. 435), which has profound effects on how and where power struggles unfold. New technologies allow information to link and flow across space more efficiently, enabling remote actors and operators to make calculated decisions about the life and death of populations from whom they are geographically far removed. In some cases, these technologies appear to remove human authorities from the exercise of power altogether, as automated and artificially intelligent infrastructure are increasingly relied upon to monitor, observe and control populations without obvious human intervention (Cantrell et al., 2017; Garrett and Anderson 2017; Kitchin, 2020; Vukov, 2016).

Bringing together literature on the biopolitical and necropolitical governance of disasters with that on the shifting vertical politics of power, this article asks how new technologies of disaster management are altering how power is exercised and experienced by those involved in and affected by disasters. Our analysis shows how new earth observation technologies, in particular, are changing the spaces and dimensions on which power over life and death is exercised and experienced by both humans and nonhumans during disasters, as well as who is involved in exercising this power. The increasing availability and decreasing costs of new technologies are shifting disaster response from the ground to the air, and this volumetric shift is giving those with authority and expertise to operate vertically – including private security, technology, and AI companies – greater control over more types of space. This also affords these same actors new opportunities to surveil, control, and make calculated decisions on behalf of human and nonhuman populations. At the same time, new technological advances also mean that some aspects of disaster responses are automated, bypassing (or making redundant) encounters that might have otherwise occurred between authorities and the populations over which they seek to exercise bio- and necro-power. While these shifts have worrying implications for democratic processes and life itself, they also shift the dimensions and terrains of power struggles at a planetary scale.

3. Desert locust upsurges and management across space and time

Desert locusts (*Schistocerca gregaria*) belong to the same family as grasshoppers (*Acrididae*) and, under typical conditions, look and behave much like grasshoppers (Fig. 1). They have long slender bodies with large hind legs and primarily lead solitary lives. Desert locusts are most commonly found in low densities in arid and semi-arid regions that receive less than 200 mm of rain annually (Cressman, 2016; FAO 2020b). When in this solitary phase, desert locusts cause little trouble to humans or other forms of life. In fact, desert locusts often contribute positively to the functioning of healthy dryland ecosystems, as they cycle nutrients, enrich soil, and are consumed by a range of other living organisms (Le Gall et al., 2019).

Yet, under certain climatic conditions, the behaviour and physiology of desert locusts can change, which in turn changes how they interact with wider ecosystems and ecologies. Periods of drought can lead desert locusts to congregate in larger-than-usual numbers in areas with remaining vegetation. When rains eventually come to these areas, creating moist soil and producing more vegetation, desert locusts reproduce quickly. Under these conditions, desert locusts shift from a solitary lifestyle into a group lifestyle called the 'gregarious' phase

Fig. 1. Mature desert locust, Kenya. Photo credit: Ramson Karmushu.

Fig. 2. Swarm of mature desert locusts, Kenya. Photo credit; Ramson Karmushu.

(Fig. 2). When in the gregarious phase, the colour and body shape of desert locusts change, their brains grow, and their endurance increases (Le Gall et al., 2019). Left unchecked, gregarious desert locusts can undergo successive breeding seasons and spread across entire countries and regions – known as an 'upsurge' – or even across multiple regions and continents – known as a 'plague'.

Moving about in swarms that can travel up to 150 km per day, gregarious desert locusts consume large amounts of vegetation quickly. A 1-km^2 swarm can contain up to 150 million adults (Symmons & Cressman, 2001). Desert locusts often feed on crops and pastures that support human livelihoods and needs and a small swarm has the capacity to consume the same amount of daily food as 35,000 people (Food and Agriculture Organisation of the United Nations (FAO), 2015). In the gregarious phase, desert locusts also become destructive of the ecosystems they might otherwise contribute to positively, and therefore risk bringing harm to other nonhuman organisms by damaging vegetation and being consumed when bearing pesticide (Knight, 2020).

3.1. Horizontal responses to desert locust upsurges

Between 1860 and 1963, a desert locust plague was experienced somewhere on the planet four out of every five years (Van Huis et al., 2007). During this period, the arrival of desert locust swarms usually signified large-scale famines. In order to stave-off hunger and food insecurity, affected communities would attempt to control desert locust swarms on the same plane where locusts bred, fed, and roosted. In northern Kenya, communities would mobilise to scare locusts away with loud noises, including making high-pitched cries, beating drums, banging metal, blowing horns, starting engines, and firing blanks (Interview 1, Samburu, August 2020). Fires and smoke were also used to repel swarms and destroy breeding sites (Interview 2, Samburu, August 2020). Across parts of the Greater Horn of Africa where surveillance is scant and control operations are often slow to arrive, these same tactics continue to be used to this day. Such measures scare the swarming insects from one location to another, enabling communities and local authorities to prevent excessive damage to grazing land and crops; however, they do not end upsurges or plagues altogether.

When Kenya was colonised in the 1880s, desert locusts became a significant concern for colonial authorities because of the economic threat they posed to agriculture production and trade across the British East Africa Protectorate (George, 1954, p. 1). The colonial administration admitted that "little was known about why or where outbreaks of the desert locust started" (Desert Locust Survey, 1948–1962). In fact, for many years, colonial authorities believed that desert locusts in solitary and gregarious phases were different insects (Cressman, 2016). In attempting to learn more about the species, teams were sent by camel across the Protectorate to look for locusts and record observations, as "motor transport equipment could not be employed in such rough country" (George, 1954, p. 5).

Patrol teams were also tasked with managing desert locust swarms encountered by using dusting equipment and dry bran laced with pesticides, such as Arsenic and Lindane (Bellehu, 1979). During the early 1950s "some 4000 hopper bands were destroyed under the [Desert Locust Survey and Desert Locust Control] Organisation's advice by a force of 14 Italians, 800 Somalis, 270 camels" (George, 1954, p. 5). "The value of local experience was also borne out", as young men in affected regions were enrolled in response measures (George, 1954, p. 5). Elders in northern Kenya remember colonial officials arriving and mandating assistance from young men in locust control operations by carrying supplies and navigating the terrain as "they could walk for days without growing tired" (Interview 3, Samburu, July 2020).

Despite these efforts, desert locusts were seen as a persistent threat to British interests in East Africa and wider empire. Colonial authorities felt that part of the difficulty they experienced in managing desert locusts was that swarms often went unnoticed for too long, as reliance on ground transportation and tactics made it challenging to access difficult terrains and higher elevations where desert locusts reproduced. As Rainey et al. explains:

> [R]eporting of locusts is inevitably and strikingly biased by the distribution of human populations and particularly of cultivation; thus for example, a single small swarm among cultivations is commonly reported several times daily (e.g. in the Kitui area of Kenya, January 1954) in contrast with a large swarm which in early February 1955 was followed by aircraft for eight days over the uninhabited hinterland of Mombasa without ever being reported from the ground at all (1979, 324).

Such observations led to more coordinated and better resourced desert locust operations in the colonies from the 1950s onwards.

In 1950, the Desert Locust Control Organisation (DLCO) was formed as a department of the East African Common Services Organization and was financed by Kenya, Tanganyika, Uganda, and the United Kingdom (DLCO-EA n.d.). Originally headquartered in Nairobi, the organisation had "a field laboratory in Eritrea, a unit investigating [juvenile] hopper behavior, two basic reconnaissance units, mobile specialised units investigating the behaviour and movement of adult locusts and various ad hoc units to conduct field research and experiments" (George, 1954, p. 2). Personnel were tasked with "maintain[ing] constant watch, plotting the location of all major concentrations of locust, giving warning of any tendency to commence swarming and carry[ing] out control measures" (Desert Locust Survey, 1948–1962). To compensate for the difficulty of vehicle travel to affected regions, base camps were established to host personnel in the field, which were equipped with canteens, mess halls, showers, and even tennis and squash courts.

Throughout the colonial era, desert locust control operations would remain primarily horizontal in their operations. Responders traveled great distances, often by camel or on foot, and established outposts far removed from colonial settlements in seeking to monitor and control swarms. The technology used to surveil and spray desert locust swarms also operated on a horizontal plane, including animal transport, 4 × 4 vehicles, and hand-held equipment for dispersing pesticides. However, as independence from Britain neared and passed and new technologies became more accessible, the planes of desert locust response in Kenya would become increasingly vertical in orientation.

3.2. The shift toward vertical locust control operations

In the second half of the 20th century, the frequency and duration of desert locust plagues began to decrease, with plagues occurring every 10–15 years and lasting an average of three years (Cressman, 2016). This is partly because efforts to control desert locusts became more coordinated with the formation of a regional organisation, the Desert

Locust Control Organisation for Eastern Africa (DLCO-EA), in 1962. Under the DLCO-EA, experimentation with new technologies made vertical approaches to surveilling and controlling desert locust swarms more common. For desert locust upsurges to occur, successive rounds of breeding must take place under appropriate climatic and environmental conditions (Waloff, 1966). The uptake of vertical technologies during the latter half of the 20th century made it easier for authorities to disrupt successive breeding seasons by spraying adult locusts and their breeding grounds with pesticides – preventing larger upsurges.

Before the mid-20th century, the primary measures used to control desert locusts were insecticidal baiting and ground dusting and spraying with handheld tools, such as exhaust nozzle sprayers (Bellehu, 1979). During the 1930s and 1940s, experimental efforts used aircraft to detect and survey locust swarms and carry out locust control operations (Rainey & Sayer, 1953). However, little effort was made to reproduce these experiments on a large scale as reliance on aircraft was considered expensive and substantial improvements were also needed to equipment, insecticides, and tactics in order for aerial tools and technologies to be effective (Rainey & Sayer, 1953). Technological advances in the 1950s made aerial methods of desert locust surveillance and control more feasible (Rainey et al., 1979).

By the 1960s, aerial desert locust control operations were proving far more effective than other approaches. Following the establishment of DLCO-EA, an air unit was developed and equipped to service the entire East Africa region. Aircraft used for locust control were fitted with equipment that could be used to spray a powerful oil solution of the insecticide Dieldrin (Rainey & Sayer, 1953). Once sprayed, this formula stayed on the ground with persistent, lethal effects for locusts and other species that could last 30–40 days on vegetation and much longer in soil (Sharma, 2014). Even if insects were not hit directly by the spray, they would be killed after coming into contact with soil and vegetation in treated areas. Each aircraft had the ability to treat 2000 ha per day in just five to 6 h of flying time; whereas, ground vehicles could only treat 300–500 ha per day depending on the nature of the terrain, vegetation cover, and winds (Food and Agriculture Organisation of the United Nations (FAO), 1962).

Following this initial period of experimentation, aircraft also began to be used for preventive purposes. Low flying aircraft were used to surveil and detect pre-swarm infestations in difficult to reach places and to identify vegetation patches from the air that might serve as suitable roosting and breeding grounds (Rainey et al., 1979; Rainey & Sayer, 1953). Authorities also began experimenting with radar to support air reconnaissance of locust swarms and to plot swarms and their migratory routes, adapting technologies developed and used for military combat in World War II for pest management.

3.3. Automated, networked technologies and desert locust management

There is growing evidence to suggest that desert locust gregarization may once again be on the rise due to climatic changes being experienced globally, "such as increases in temperature and rainfall over desert areas, and the strong winds associated with tropical cyclones, [which] provide a new environment for pest breeding, development and migration" (Salih et al., 2020, p. 584). The most recent desert locust upsurge in the Greater Horn of Africa has been attributed to three cyclones over the Arabian Peninsula between 2018 and 2019 that left warm, sandy, and wet soil conditions in the Empty Quarter of Saudi Arabia ideal for desert locust breeding (Devi, 2020; FAO 2020b). Typically, the Arabian Sea might go multiple years without a single cyclone event. Moreover, temperature rises in the western Indian Ocean also contributed to severe flooding across the Greater Horn of Africa, which created ideal conditions for successive breeding seasons on the continent (Parker 2019).

Although the risk of desert locust upsurges and plagues may be rising, there have also been notable technological improvements in the detection, surveillance, and control of locusts in recent years. Until the mid-1990s, field data were plotted and analysed manually using paper maps, transparencies, and coloured pencils and then transmitted back to authorities using Telex. Today, a purpose-built technology, called eLocust, is used to support this process. The eLocust system allows for the recording of field observations and transmission of data by satellite in real time to the Food and Agriculture Organisation of the UN (FAO) (Cressman, 2014) – which is coordinating the desert locust response in partnership with the DLCO-EA and national governments. During past upsurges and plagues, the eLocust system was mainly used by field officers with tablets. However, during the most recent emergency, a smartphone application was developed that could be downloaded and used by anyone to report locust sightings. The app uses a satellite data communicator so that reports can be submitted from areas with no network and it also makes use of AI to rapidly identify and remove unwanted data, such as reports of tree locusts (*Anacridium melanorhodon*), which are not within the FAO's mandate to control. Once this data is received by the FAO, it is shared back with national control teams so they can target and spray swarms.

Satellite technology has also been a game changer in recent efforts to control desert locusts. Satellites cannot yet detect locust swarms; however, they can be used to provide important information on ecological and meteorological conditions that can be used to predict where locusts are most likely to breed, swarm, and migrate. The FAO is currently making use of three satellites as part of its control operations in the Greater Horn of Africa. Two satellites provide information on rainfall and vegetation while the third detects soil moisture beneath the earth's surface. Combined, this information can be used to determine where locusts are likely to swarm. Partners ranging from NASA to the European Space Agency to the World Meteorological Organisation have all been involved in assisting the FAO in improving and refining the use of remote sensing imagery for desert locust monitoring and forecasting.

Two further technological breakthroughs have also occurred during the latest upsurge in the Greater Horn of Africa. First, a pre-existing software, called EarthRanger, has been adapted and adopted by the FAO to integrate and display all field data of desert locusts in real time. EarthRanger was initially developed to enable conservationists to collect, integrate, and display remote sensing data on wildlife movements across any given ecosystem. This software was already in use in and around some of Kenya's most well-known private wildlife conservancies. As a result of aircraft and pilot shortages at the outset of the upsurge, personnel and equipment from wildlife conservancies were requested to participate in the desert locust response. As they joined the response, conservationists suggested adapting and fine tuning their own software for desert locust control operations.

EarthRanger aggregates reports of locust swarms from the eLocust system with real-time monitoring of the locations where ground and aircraft control operations are being carried out. This provides a complete picture of both the upsurge and response activities, resulting in better-coordinated operations (Food and Agriculture Organisation of the United Nations (FAO), 2020c). Based on information available in EarthRanger, a private security company that specialises in security for wildlife conservancies in Kenya, called 51 Degrees, has been directing and managing aerial operations. As FAO's senior locust forecaster explains:

> Before we were just operating in the dark. With EarthRanger you can see exactly the path the aircraft has taken and where it has sprayed. It has led to a more effective use of the aircraft, and more efficient control operations. I'm sure that is a major factor which contributed to the decline in the upsurge which we are seeing now (Cressman, as cited by Food and Agriculture Organisation of the United Nations (FAO), 2021).

EarthRanger has proven so valuable for managing desert locusts in Kenya that the FAO has expanded and consolidated its partnership with both EarthRanger and 51 Degrees for control operations in other affected countries in the Greater Horn of Africa.

The second technological breakthrough being developed for desert locust control operations during the most recent upsurge is drones. The long-term ambition of the FAO is to have drones equipped with mapping sensors and sprayers to identify locusts and then control small infested areas or areas that are difficult to access by ground. According to the FAO's Senior Desert Locust Forcaster:

> This is highly desirable and advantageous because it makes control operations much safer and more precise. Field officers would avoid coming into contact with the chemicals as drones would be doing the spraying. Spot control would involve spraying only the specific locust infestation rather than treating the entire area, thus reducing pesticide usage and protecting the environment (Cressman, 2021, 775).

At the moment, drones are somewhat restricted in terms of the volume of pesticides they can carry and the distances they can cover due to their size and limited battery life (Matthews 2020). However, the FAO is working with government authorities to develop and test drone technology built for this purpose. AI companies, such as HEMAV, have also been involved in this process, producing an innovative drone, known as the 'dLocust', for use in desert locust control operations (HEMAV, 2016).

Another application of drones in desert locust surveillance and control is to complement satellite imagery, providing higher resolution images of areas identified as potential swarming sites and images of swarms in the early stages of development. This promises to reduce the areas that need to be checked by ground teams and other aircraft. Once an area is identified as requiring surveillance using satellite imagery, ground teams would travel to these areas and deploy the dLocust to collect further data. This data would then be transmitted to eLocust to enable authorities to determine if further action is needed. Similarly, it has been suggested that drones could be used for post-disaster mapping, providing high resolution images and informing more accurate assessments on vegetation and crop loss following desert locust invasions.

4. Shifting planes of power in desert locust management

Before colonial administrations became involved in the management of desert locust populations in East Africa, responses to upsurges and plagues were highly localised and occurred on a horizontal plane. This horizontalism persisted in desert locust control operations for decades, with patrol teams sent by the colonial administration traversing vast landscapes on camel or by foot – and later by 4 × 4 vehicles – to set up camps and conduct operations on the ground. With the involvement of the colonial government, desert locust response came to represent a clear example of biopolitical population management. The lives and deaths of desert locusts became imbricated with the lives and deaths of human populations, as authorities devised interventions to prevent or at least minimize the vulnerability of certain human populations to locust swarms.

Over time, desert locust control operations grew more reliant on aircraft and radar, shifting the spatiality of desert locust management. Technological advances enabled new "vertical visualities" (Adey, 2010a) that altered the ways that authorities understood and responded to desert locust upsurges. In turn, the increasingly vertical nature of desert locust control operations altered spatial orientations of power among those involved in and affected by responses. Those with access to a "view from above" (Adey, 2010a) were less encumbered in their efforts to mobilise and respond quickly to certain threats posed by desert locusts because they could routinely surveil large spaces with greater ease and because difficult terrain and local populations became less of an obstacle. In short, those managing disasters and those living through disasters began to experience greater degrees of separation from one another as technical advances improved the efficacy of control operations.

In the past decade, a further paradigmatic shift has also occurred with reliance on other novel technologies in desert locust management. These technologies have again changed the way experts see locust swarms and position themselves in relation to upsurges. Increasingly, authorities operate one step ahead of desert locust populations in space and time, predicting where desert locusts are likely to feed, roost, and breed, with the goal of intercepting swarms before they are able to do so. If the first volumetric shift in desert locust management can be described as moving the battle to monitor, contain, and eliminate locusts from a two-dimensional to a three-dimensional plane, this more recent shift involves the introduction of a fourth, time-related dimension that allows for predictive anticipatory action to be taken. This latest shift has been made possible by technologies that create a networked disaster response that operates through a planetary spatiality rather than being constrained by Cartesian and physically bound spatial coordinates (Tripodi, 2020).

This shift towards the networked dimension has enrolled new actors in disaster management and response. Specifically, private actors with expertise in and access to innovative technologies are now heavily involved in surveillance operations and in making decisions on behalf of human and nonhuman populations affected by desert locusts. Although global and national authorities still play key roles in conducting desert locust control operations, private actors and companies also play increasingly central roles in disaster management. In Kenya, 51 Degrees has been granted authority to make decisions about how to secure the life of human and wildlife populations by pursuing the death of locusts across the Greater Horn of Africa. This reflects a larger global trend towards privatization (i.e. the contracting of public goods and services to private entities) and 'government by proxy' (i.e. the provision of government goods and services by non-governmental agents empowered through contracts, grants, and tax subsidies) in disaster response (Gotham, 2012). As corporate actors with novel technologies promise expedient solutions to complex disasters, we are bearing witness to the transference of biopower and necropower between public and private spheres.

It is worth noting that shifting planes of power in desert locust management have not erased the horizontal and two-dimensional aspects of control operations altogether. Tactics and technologies that have contributed to desert locust management for many decades continue to factor into response activities. For example, over 500 members of Kenya's National Youth Service and other representatives of grassroots communities across northern Kenya have been trained as scouts to observe and report on swarm activity and other information of use to authorities coordinating the response (Food and Agriculture Organisation of the United Nations (FAO), 2020c). Even Kenya Defence Forces have participated in control operations in parts of northern Kenya deemed too insecure for nonmilitary personnel. The information gathered through this groundwork is fed upwards and outwards towards public and private authorities that manage and operate new systems and technologies to control desert locusts from afar.

5. The implications of volumetric shifts for power asymmetries

In this final section, we reflect on the implications of the shift from horizontal to vertical to networked disaster management through experimentation with new technologies over the past century. Here, we show that with each volumetric shift in desert locust management, authorities have gained new forms of control over space, risk, vulnerability, and populations from 'above' with implications for populations 'below' that need to be interrogated. More specifically, we highlight several ways that the shifting planes of disaster management risk exacerbating power asymmetries between those with the authority to respond to disasters and those most intimately affected by disasters.

The incorporation of new technologies in desert locust operations has automated many elements of the disaster response. For example, the eLocust system acquires information through crowdsourcing but makes use of AI to rapidly identify and remove unwanted reports, such as reports of tree locusts. Concerns held by local populations about growing tree locust numbers are not just left unaddressed by authorities; they are automatically erased by this advanced software upon receipt in order to ensure data being used to calculate response action are 'clean'. There have also been new developments with drone technology, earth observation satellites, and other software systems that further automate the desert locust response. NASA is even experimenting with interactive maps that use machine learning to detect and predict breeding grounds before outbreaks begin based on wind, humidity, surface temperatures, and vegetation index data collected by earth-observing satellites.

The automation of disaster response provides yet another example of how technologies originally designed for military use are being trialed, reimagined, and commercialised for use in other sectors and at new sites and scales (Garrett & Anderson, 2018; Jackman & Brickell, 2021). This transfer of technology is driving new innovations and agendas, such as advances in creating autonomous, artificially intelligent systems that are able to recognise the behaviours, movements, and rhythms of non-human entities. The technologies being developed and used to respond to desert locusts are effectively being trained to think like locusts so that they can predict and respond to future swarms on the basis of statistical data. Similar examples can be seen in response to other disasters, such as new types of AI that can detect wildfires or predict floods. By experimentally generating and learning what data to bring to the attention of authorities, these technological innovations provide information far beyond what was previously possible within human capacities (Adams, 2018; Amoore & Raley, 2017). Similar to what can be seen in other sectors – like in conservation or logistics – disaster authorities now "participate in a techno-fetishist agenda positing drone [and other surveillance] technology as a privileged and panacea agent of futurity, while often eliding its implication" (Jackman and Jablonowski, 2021, 1).

Yet, just like the trend towards nonhuman, automated decision-making in other sectors (Amoore & Raley, 2017), the automation of decision-making in disaster response has wide-ranging impacts – many of which are not positive. Similar to algorithmic war (Amoore, 2009) and conservation by algorithm (Adams, 2018), disaster response by algorithm has a tendency to shift response operations to places "where data is managed, where its analysis is understood and where the results can be debated among experts" (Adams, 2018, p. 2). This results in decision-making by those who have little first-hand knowledge of the landscape where information is collected. In the case of desert locust control, those operating some of the technologies used in the response work from an exclusive private wildlife conservancy in Kenya while those interpreting this data may be as far away as Rome, working from offices located at the FAO headquarters.

In this sense, growing reliance on new technologies in the desert locust response deepen and extend the space between disaster authorities and subjects. Decisions about how to manage disasters are less likely to be tested through political debate or subjected to public scrutiny. Rather, the use of automated and networked technologies shifts the power to inform and direct desert locust management above and away from affected communities and into the hands of remote decision-makers and technical experts. It is often assumed that the proliferation of affordable technologies – such as the crowdsourcing technologies being used in the most recent desert locust response through the eLocust smartphone app – will assist in democratisation. However, there is a risk that instead, authorities have gained the ability to make expedient, calculated decisions concerning populations below at the expense of inclusive, democratic, or transparent processes of decision-making.

This stands in contrast to how decisions were made and action was taken during desert locust outbreaks in the past. Historically, interactions between desert locust personnel and localised populations across northern Kenya were somewhat inevitable. As former Director of DLCO explained, "Local and tribal [*sic*] authorities as well as the central government are often prerequisite to effective operations" (George, 1954, p. 8) while "the refusal of tribal [*sic*] authorities to permit the application of insecticides by machinery" meant that control operations could not move ahead as planned (George, 1954, p. 5). Similarly, Adfris Bellehu, the current Director of the DLCO-EA, describes how field officers went to great lengths to convince local populations that spraying activities were safe during the early days of spraying: "During [Lindane's] introduction I shall never forget tasting and eating the bait myself to convince the owners of camels and cattle that it was harmless; then they would let us use it on their lands" (Bellehu, 1979, p. 17). In short, when disaster response activities were oriented along a horizontal plane, it was easier for local populations to interact with those involved in coordinating and carrying out control operations in both invited and uninvited ways.

In interviews, elders old enough to remember previous upsurges explained how, in the past, colonial authorities would arrive in communities to discuss the crisis at hand and then "pick strong people to respond to such outbreaks, making them responsible for the work of chasing away the locust to avoid destruction" (Interview 5, Samburu, July 2020). In some cases, participation in desert locust control was done without compensation – accepted as a collective responsibility in response to the crisis (Interview 12, Samburu, July 2020) – while, in other cases, young people were provided payments for their service. In contrast, elders explained that "the new way of managing the locust was not involving communities" (Interview 13, Marsabit, August 2020). Instead, airplanes owned by wildlife conservancies "flew above our heads every day", sent to locate and spray the swarms (Interview, Marsabit 13, August 2020). As one elder described: "We hardly [saw] them controlling the spread, but they were speaking all over on radio counting figures of money used in controlling the swarms … We hear that aeroplanes are now spraying insecticides from above that might be killing our herds and birds to the sky but we have not witnessed the practice" (Interview 7, Marsabit, August 2020).

In addition to informing quick or anticipatory action by authorities with less room for public contestation, negotiation, and refusal, the automation of decision-making in disaster response also risks provoking fear and hostility amongst affected populations. Northern Kenya has a long history of perceived insecurity and government administrations have often used violent security operations to quell conflict and control illegal or illicit activity. As a result, there is already a high degree of fear and distrust towards the state. In recent years, security operations have become even more complex, as conservancy organisations have come to play an increasingly prominent role in securing the region on behalf of the state while also protecting their own economic and biopolitical interests in the landscape (Schetter et al., 2022). Hence, the use of conservancy-operated airplanes and drones in desert locust control – technologies which operate from above, hovering and spraying substances unbeknown to those below – risks amplifying 'volumetrics' of fear (Elden, 2013; Millner, 2020). Because such technologies can 'see without being seen' (Gordillo, 2018), they (re)produce landscapes of nervousness (Milner, 2020).

These technologies also sometimes 'see without noticing' (Gordillo, 2018) when they respond to disasters from above, resulting in actions that are misunderstood by those on the ground or that exert harm. There was no initial Environmental and Social Impact Assessment (ESIA) for the desert locust response in Kenya due to its classification as a national emergency (Interview 15, Samburu, August 2020). Although those responsible for using technologies to track and spray locusts were meant to be responsible for preventing the contamination of water sources and avoiding cultural and spiritual sites, the lack of an ESIA prior to operations beginning makes it possible that such sites were not always noticed by those working from above. Similarly, the FAO recommends people be informed about spraying on their land in advance and told how long to avoid the area after spraying. Yet, spraying often happened within hours of a swarm landing – generally at dawn before locusts begin to move – making it unlikely that all pastoralists grazing in an area marked for spraying were seen and given warning. As Amoore writes, algorithmic logics "make it possible to translate probable associations" (2009, 65) into actionable decisions; yet, the technologies used are not infallible or all-knowing and the associations made are not always correct, which can result in oversights and errors.

New innovations and technologies used in spraying also raise questions about the ongoing use of pesticides to control outbreaks. The specific formulations of pesticides used to control locusts under Kenya's early colonial administration were more harmful to human health and other forms of life than pesticides used today. In the past, pesticides were chosen because they were known to be persistent – meaning that they remained toxic on vegetation and soil, despite rain or sun, for a long time (Matthews, 2021). When baiting or hand spraying was the main approach used to disperse these pesticides, they were relatively limited in their reach. However, with the proliferation of aerial spraying techniques over the last several decades, the spatial and temporal reach of pesticides has become less constrained and more impactful. During the early stages of refining aerial control operations, which involved experimentation with 'curtain' or 'sheet' spraying, pesticides applied from the air were likely to drift from intended treatment sites and affect humans, animals, and plants that were not meant to be targeted. Recognising the implications of such diffuse spraying, the most persistent pesticides used in locust control, such as Dieldrin, were eventually banned altogether due to their carcinogenicity, hazards to wildlife, and other chronic effects (Matthews, 2021). However, the long-term consequences of spraying such pesticides in large quantities have been well-evidenced globally, with residues sometimes found many years after their disuse (Fig. 3).

Although the types of pesticides used in controlling locusts have become more regulated and the application of these pesticides has become more refined over time, there remain real concerns about the implications of using new technologies to increase the efficiency of spraying. As of March 2021, 475,000 gallons (1.8 million liters) of chemical pesticides had been sprayed over 4.35 million acres (1.76 million ha) (McConnell). This includes the spraying of Deltamethrin, Fipronil, Chlorpyrifos, and other insecticides – many of which are banned in other parts of the world as they act as "junior-strength nerve agents" for humans, are toxic to bees and fish, and contaminate water sources (Than 2013). Attempting to move away from more toxic means of control, during the 2020 desert locust upsurge, authorities experimented with a biopesticide, called Metarhizium, to control large, mature desert locust swarms for the first time. Although the results were potentially promising, its side-effects in real world environments are still not well understood. Thus, whether speaking of new ways of spraying or new things to spray, technological advances in desert locust management come with risks for humans and nonhumans. Moreover, without an ESIA and the free, prior, and informed consent of pastoralists, use of novel substances can also intensify the volumetrics of fear.

This may explain why there have been many unsubstantiated reports of pesticides causing harm to humans and animals following desert locust control operations. A recurring theme in interviews with people impacted by the desert locust upsurge was, in fact, the harm done rather than protection offered by pesticide use:

Fig. 3. Swarm of desert locusts killed by insecticidal spraying, Kenya. Photo credit: Ramson Karmushu.

> This time, people used spray and technology to locate the swarms … [These methods are] very effective in killing the swarms but it also killed our livestock. They poisoned the water we drink and killed many wildlife (Interview 8, Marsabit County, August 2020).

> Use of chemicals has changed the story and caused massive losses and endangered many lives … [Pesticides are] effective in killing swarms but costly to our livestock and wildlife (Interview 9, Marsabit County, August 2020).

Authorities have repeatedly denied any harm caused by the pesticides used during the most recent upsurge, including investigating and taking samples at sites where livestock have been found dead following spraying operations and attributing these cases to bloat. There are no confirmed cases of pesticides causing illness or death to livestock specifically. Yet, given that necropower does not only operate through outright killing, but also through slow biological degradation or wounding, the death of livestock is not the only form of harm that could be inflicted pastoral ecologies. Exposure to chemicals that are "driven inward, somatized into cellular dramas of mutation that – particularly in the bodies of the poor [marginalised and racialised]" – remain largely unobserved, undiagnosed, and untreated exemplifies necropower (Nixon, 2011, p. 6). Although the exact harm caused by these chemical and biological agents may not yet (or ever) be fully understood, and may not be deemed to outweigh the risks of not using them, the expectation that certain humans and nonhumans should accept toxic risk and inhabit toxic spaces even temporarily reflects calculated necropolitical action sanctioned by remote and, increasingly, automated authorities.

6. Conclusion

Advances in automated technology, earth observation technologies, and AI are radically changing how disasters are managed. From the biodiversity crisis to wildfires to plagues of desert locusts, innovations in technology and new classes of experts are giving authorities access to untapped vantage points of hazards and enhancing their ability to preempt and respond to potential threats with efficacy. In this article, we have shown that these technologies are changing the spatialities of disaster management. By this we mean, disaster management is increasingly less concerned with mobilising knowledge, personnel, and resources across horizontal, two-dimensional space as efficiently as possible. Disaster management has taken to the skies, literally and figuratively, and is increasingly vertical in its orientation and algorithmic in its approach. Although ground support can still play a vital role in disaster responses, the power to plan and conduct these interventions requires access to vertical technologies, such as aircraft, drones, and satellites. Moreover, we have shown that disaster management increasingly operates through a networked, planetary spatiality that includes a fourth time-related dimension. In this case, modeling software, real-time monitoring, and remote sensing enable authorities to better understand and respond to the rhythms and cycles of desert locusts, which in turn, allows them to calculate anticipatory action and responses. This type of technology-generated data is bound to become increasingly important to authorities as environmental change alters the temporalities of climate-related disasters and nonhuman entities and life forms (Edensor, Head, & Kothari, 2019).

Although novel technologies and experts are improving the efficacy of disaster response, volumetric shifts occurring in disaster management also have implications for power that flag concerns. Based on our case study, the desert locust upsurge in northern Kenya, the increasingly vertical and four dimensional orientation of disaster management can be seen as making existing power asymmetries more pronounced in at least three ways: granting new actors and technologies more authority and ability to calculate decisions about control operations and response interventions; creating greater degrees and volumes of separation between authorities, subjects, and the socioecologies in which disasters and responses play out; and, finally, making experimentation with new technologies – ranging from biopesticides to crowdsourcing to drones – imperative to the pursuit of ever more expedient interventions. Growing reliance on such technologies comes with the risk of consolidating power over life and death in the hands of a relatively small number of remote technical experts working with information that has been created, screened, and cleaned by AI. We do not wish to downplay or demonise the efforts of those involved in humanitarian responses to desert locust upsurges through our analysis. We simply mean to flag pressing questions about the implications that some novel technologies in disaster management have for power relations.

In theorising about the broader implications of volumetric shifts in disaster management, we bring literature on verticality and planetary spatiality into conversation with that on biopower and necropower. This helps us emphasise that disaster management is not just about making certain human populations live. Rather, disaster management is also about making populations of humans and nonhumans die – and imbuing certain human-nonhuman entanglements with lethal toxicity or other forms of harm that extend beyond the spatial and temporal confines of disaster events. This aspect of our analysis points to a much wider unsettling trend in disaster management. Novel technologies are not only shifting the planes and volumetrics of disaster management, opening up new spaces dominated by new authorities on disasters. These technologies are also being mobilised to help calculate necropolitical disaster interventions – sometimes automatically with limited human input – profoundly altering how and by whom sovereign power over life and death is enacted, encountered, and contested.

Beyond contributing to understanding of disasters and disaster responses, this article builds on wider literature on vertical, volumetric geographies. Existing scholarship in this area critically engages with how volumetric shifts and innovations in aerial, automated technologies shape how and where power is enacted and experienced and by who – focusing mainly on social inequalities and power asymmetries among humans. Yet, our article underscores the ongoing need to pay greater attention to how changing spatialities and technologies of power play out in a more-than-human world with implications for humans and nonhumans. As we have shown, as AI is programmed to think like locusts, the insects themselves – along with the biological and meteorological conditions that cause them to behave and function in particular ways – contribute to innovations in remote sensing, machine learning, and drone and other surveillance technology. These technological innovations are not confined to desert locust control operations, but are taken up and used to further adapt related technologies in other contexts and sectors and virtually all domains of life and death. It is only by shifting nonhuman lifeforms and entities closer to the centre of our analytical gaze that we are able to 'see' and 'learn' these intimate connections and appreciate the complexities and nuances of biopower and necropower.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This article was made possible by Rapid Response Funds from the Global Challenges Research Fund. The following individuals contributed to data collection: Philip Lkuumei, Mairie Sakui, Evans Mesahami, Raphael Lenaruti, Grace Lolim, Rose Orguba, Silole Vivian. We are grateful for their efforts and time. We would also like to thank participants in the Drone Ecologies workshop organised by Naomi Milner (University of Bristol) for their constructive feedback on an earlier version of the article. Finally, many thanks to the anonymous reviewers for their useful feedback which helped to improve the article.

References

Adams, W. M. (2018). Conservation by algorithm. *Oryx, 52*(1), 1–2.
Adams, W. M. (2019). Geographies of conservation II: Technology, surveillance and conservation by algorithm. *Progress in Human Geography, 43*(2), 337–350.
Adey, P. (2010a). Vertical security in the megacity: Legibility, mobility and aerial politics. *Theory, Culture & Society, 27*(6), 51–67.
Adey, P. (2010b). *Aerial life: Spaces, mobilities, affects*. Hoboken: John Wiley & Sons.
Amoore, L. (2009). Algorithmic war: Everyday geographies of the war on terror. *Antipode, 41*(1), 49–69.
Amoore, L., & Raley, R. (2017). Securing with algorithms: Knowledge, decision, sovereignty. *Security Dialogue, 48*(1), 3–10.
Anderson, B., Grove, K., Rickards, L., & Kearnes, M. (2020). Slow emergencies: Temporality and the racialized biopolitics of emergency governance. *Progress in Human Geography, 44*(4), 621–639.
Bellehu, A. (1979). the Desert locust control organization for eastern Africa (DLCOEA) and its background. *Philosophical Transactions of the Royal Society of London B Biological Sciences, 287*(1022), 265–268.
Bracken-Roche, C. (2016). Domestic drones: The politics of verticality and the surveillance industrial complex. *Geographica Helvetica, 71*(3), 167–172.
Braun, B. (2007). Biopolitics and the molecularization of life. *Cultural Geographies, 14*(1), 6–28.
Bridge, G. (2013). Territory, now in 3D! *Political Geography, 34*, 55–57.
Bryan, J. (2015). War without end? Military humanitarianism and the limits of biopolitical approaches to security in Central America and the caribbean. *Political Geography, 47*, 33–42.
Cantrell, B., Martin, L. J., & Ellis, E. C. (2017). Designing autonomy: Opportunities for new wildness in the Anthropocene. *Trends in Ecology & Evolution, 32*(3), 156–166.
Chan, Y. K. (2016). No room to swing a cat? Animal treatment and urban space in Singapore. *South East Asian Studies, 5*(2), 305–329.
Collard, R. C. (2018). Disaster capitalism and the quick, quick, slow unravelling of animal life. *Antipode, 50*, 910–928.
Cressman, K. (2014). Desert Locust survey and control data recording and transmission by satellite in real time. *Rome: Food and Agriculture Organisation of the United Nations*.
Cressman, K. (2016). Desert locust. *Biological and Environmental Hazards, Risks, and Disasters*, 87–105.
Cressman, K. (2021). 'Technical innovations in global early warning in support of desert locust area-wide management. In *Area-wide integrated pest management* (pp. 765–778). Boca Raton: CRC Press.
Crowley, S. L., Hinchliffe, S., & McDonald, R. A. (2018). Killing squirrels: Exploring motivations and practices of lethal wildlife management. Environment and Planning E: *Nature and Space, 1*(1–2), 120–143.
Davis, S., & Hayes-Conroy, J. (2018). Invisible radiation reveals who we are as people: Environmental complexity, gendered risk, and biopolitics after the Fukushima nuclear disaster. *Social & Cultural Geography, 19*(6), 720–740.
DeBoom, M. J. (2020). Climate necropolitics: Ecological civilization and the distributive geographies of extractive violence in the Anthropocene. *Annals of the Association of American Geographers*, 1–13.
Desert Locust Control Organisation for Eastern Africa (DLCO-EA). (No date). DLCO-EA History. DLCO-EA. Available at. https://www.dlco-ea.org/index.php/component/sppagebuilder/55-dlco-ea-history.
Devi, S. (2020). Locust swarms in east Africa could be 'a catastrophe'. *The Lancet, 395* (10224), 547.
Edensor, T., Head, L., & Kothari, U. (2019). Time, temporality and environmental change. *Geoforum, 108*, 248–255.
Elden, S. (2013). Secure the volume: Vertical geopolitics and the depth of power. *Political Geography, 34*, 35–51.
Food and Agriculture Organisation of the United Nations (FAO). (1962). *Report of the Seventh session of the FAO desert locust control committee: Held in Addis ababa*. Ethiopia, from 16-19 April 1962. Rome: Food and Agriculture Organisation of the United Nations.
Food and Agriculture Organisation of the United Nations (FAO). (2015). *FAO desert locust information services (DLIS) helps countries to control desert locust*. FCC-EMPRES Information Sheets. Rome: Food and Agriculture Organisation of the United Nations.
29 January Food and Agriculture Organisation of the United Nations (FAO). (2020a). *Alarm over Desert Locusts increases as new generation of the destructive pests starts breeding in Horn of Africa*. Rome: Food and Agriculture Organisation of the United Nations http://www.fao.org/news/story/en/item/1258877/icode/.
5 October Food and Agriculture Organisation of the United Nations (FAO). (2020b). *Swarm breeding in northeast Africa and Yemen*. Rome: Food and Agriculture Organisation of the United Nations http://www.fao.org/ag/locusts/en/archives/briefs/2515/2516/index.html.
Food and Agriculture Organisation of the United Nations (FAO). (2020c). *desert Locust upsurge: Progress report on the response in the greater horn of Africa and Yemen: May-August 2020*. Rome: Food and Agriculture Organisation of the United Nations.
Food and Agriculture Organisation of the United Nations (FAO). (2021). A high-tech response is helping countries win battle against Desert Locusts. http://www.fao.org/news/story/es/item/1397940/icode/.
Foucault, M. (1978). *The history of sexuality*. New York: Pantheon Books.
Garrett, B., & Anderson, K. (2018). Drone methodologies: Taking flight in human and physical geography. *Transactions of the Institute of British Geographers, 43*(3), 341–359.
George, J. B. (1954). *The desert locust survey and control*. Nairobi: East Africa High Commission.
Gordillo, G. (2018). Terrain as insurgent weapon: An affective geometry of warfare in the mountains of Afghanistan. *Political Geography, 64*, 53–62.

Gotham, K. F. (2012). Disaster, inc.: Privatization and PostKatrina rebuilding in new Orleans. *Perspectives on Politics, 10*, 633–646.
Greenhough, B., Dwyer, A., Grenyer, R., Hodgetts, T., McLeod, C., & Lorimer, J. (2018). Unsettling antibiosis: How might interdisciplinary researchers generate a feeling for the microbiome and to what effect? *Palgrave Communications, 4*(1), 1–12.
Gregory, D. (2011). From a view to a kill: Drones and late modern war. *Theory, Culture & Society, 28(7-8)-*, 188–215.
Grove, K. (2014). Biopolitics and adaptation: Governing socio-ecological contingency through climate change and disaster studies. *Geography Compass, 8*(3), 198–210.
Harris, A. (2015). Vertical urbanisms: Opening up geographies of the three-dimensional city. *Progress in Human Geography, 39*(5), 601–620.
HEMAV. (2016). Drones for desert locust project. https://www.youtube.com/watch?v=QmCznC6CbbE.
Jackman, A., & Brickell, K. (2021). Everyday droning': Towards a feminist geopolitics of the drone-home. *Progress in Human Geography*, 03091325211018745.
Jackman, A., & Squire, R. (2021). Forging volumetric methods. *Area*.
Kaur, R. (2021). Nuclear necropower: The engineering of death conditions around a nuclear power plant in south India. *Political Geography, 85*, 102315.
Kitchin, R. (2020). Civil liberties or public health, or civil liberties and public health? Using surveillance technologies to tackle the spread of COVID-19. *Space and Polity*, 1–20.
Knight, T. (2020). Locust invasion threatens wildlife and livelihoods in Kenya. *Fauna and Flora International*. https://www.fauna-flora.org/news/locust-invasion-threatens-wildlife-and-livelihoods-in-kenya.
Le Gall, M., Overson, R., & Cease, A. J. (2019). A global review on locusts (Orthoptera: Acrididae) and their interactions with livestock grazing practices. *Frontiers in Ecology and Evolution, 7*, 263.
Li, T. M. (2007). *The will to improve: Governmentality, development, and the practice of politics*. Durham: Duke University Press.
Lockhart, A., While, A., Marvin, S., Kovacic, M., Odendaal, N., & Alexander, C. (2021). Making space for drones: The contested reregulation of airspace in Tanzania and Rwanda. *Transactions of the Institute of British Geographers, early view*, 1–16.
Lunstrum, E. (2017). Feed them to the lions: Conservation violence goes online. *Geoforum, 79*, 134–143.
Margulies, J. D. (2019). Making the 'man-eater': Tiger conservation as necropolitics. *Political Geography, 69*, 150–161.
Massé, F. (2018). Topographies of security and the multiple spatialities of (conservation) power: Verticality, surveillance, and space-time compression in the bush. *Political Geography, 67*, 56–64.
Matthews, G. A. (2021). New technology for desert locust control. *Agronomy, 11*(6), 1052.
Mbembe, A. (2003). Necropolitics. *Public Culture, 15*(1), 11–40.
McConnell, T. (2021, March 23). A locust plague hit East Africa. The pesticide solution may have dire consequences. *National Geographic*. https://www.nationalgeographic.com/environment/article/locust-plague-hit-east-africa-pesticide-solution-may-have-dire-consequences.
Millner, N. (2020). As the drone flies: Configuring a vertical politics of contestation within forest conservation. *Political Geography, 80*, 102163.
Mollett, S. (2017). Irreconcilable differences? A postcolonial intersectional reading of gender, development and human rights in Latin America. *Gender, Place & Culture, 24*(1), 1–17.
Nixon, R. (2011). *Slow violence and the environmentalism of the poor*. Harvard University Press.
Parker, B.. (2019, 22 October). Indian ocean dipole spells flood danger for East Africa. *The new humanitarian*. Available at. https://www.thenewhumanitarian.org/news/2019/10/22/Indian-Ocean-Dipole-flood-danger-East-Africa.
Rainey, R. C., Betts, E., Lumley, A., & Rainey, R. C. (1979). The decline of the desert locust plague in the 1960s: Control operations or natural causes? *Philosophical Transactions of the Royal Society of London B Biological Sciences, 287*(1022), 315–344.
Rainey, R. C., & Sayer, H. J. (1953). Some recent developments in the use of aircraft against flying locust swarms. *Nature, 172*(4371), 224–228.
Salih, A. A., Baraibar, M., Mwangi, K. K., & Artan, G. (2020). Climate change and locust outbreak in East Africa. *Nature Climate Change, 10*(7), 584–585.
Sharma, A. (2014). Locust control management: Moving from traditional to new technologies–an empirical analysis. *Entomology, Ornithology & Herpetology, 4*(141), 2161–0983.
Steinberg, P., & Peters, K. (2015). Wet ontologies, fluid spaces: Giving depth to volume through oceanic thinking. Environment and Planning D: *Society and Space, 33*(2), 247–264.
Stoddard, E. A., & Hovorka, A. (2019). Animals, vulnerability and global environmental change: The case of farmed pigs in concentrated animal feeding operations in North Carolina. *Geoforum, 100*, 153–165.
Symmons, P. M., & Cressman, K. (2001). *Desert locust guidelines*. biology and behaviour. Rome: Food and Agriculture Organisation of the United Nations.
Than, K. (2013). Organophosphates: A common but deadly pesticide. *National Geographic*. https://www.nationalgeographic.com/culture/article/130718-organophosphates-pesticides-indian-food-poisoning.
Tripodi, L. (2020). Telescoping the city: Technological urbiquity, or perceiving ourselves from the above. *Space and Culture, 23*(4), 425–442.
Van Huis, A., Cressman, K., & Magor, J. I. (2007). Preventing desert locust plagues: Optimizing management interventions. *Entomologia Experimentalis et Applicata, 122*(3), 191–214.
Vukov, T. (2016). Target practice: The algorithmics and biopolitics of race in emerging smart border practices and technologies. *Transfers, 6*(1), 80–97.
Waloff, Z. (1966). The upsurges and recessions of the desert locust plague: An historical survey. *Anti-Locust Memoir, 8*, 1–111.
Weizman, E. (2007). *Hollow land: Israel's architecture of occupation*. London: Verso.
Wrigley, C. (2018). It's a bird! It's a plane! an aerial biopolitics for a multispecies sky. Environment and Planning E: *Nature and Space, 1*, 712–734.