Infrastructure and nonhuman life: a wider ontology

Maan Barua

University of Cambridge, UK

Abstract

This paper develops a wider ontology of infrastructure. Firstly, focusing on circulations, it argues that infrastructures not only hasten the flow of materials but produce nonhuman (im)mobilities radically altering the dynamics of life. Secondly, it shows how natural and infrastructural ecologies meld as infrastructures become a medium of life, with important consequences for design, architecture, planning and governance. Thirdly, it fleshes out how nonhuman life itself is cast as infrastructure, tracking the biopolitical implications of this move. An infrastructural ontology moving beyond anthropocentric familiars generates new analytics and critical openings for the politics of governing human and nonhuman life.

Infrastructure and nonhuman life

Termites outnumber humans ten to one. Some species have become cosmopolitan as infrastructure – containers, cargo, ships and railways – has moved them around the world. Tunneling and foraging in buildings, infesting train tracks and bridges, termites inhabit infrastructure, rendering the latter into an Isopteran world. Gnawing through wood, infrastructure becomes food, metabolized by these creatures and their microbial companions. Causing substantial damage, termites have sparked an entire bioeconomy of eradication closely entwined with their arthropod lives and deaths. The complex structures termites build through 'swarm intelligence' are hailed as a paradigm for artificial intelligence and the future of

automated responses to infrastructural glitches. Investments pour in to harness their lively potentials: 'everything termites do, the military would like to do, too' (Margonelli, 2018; p.219).

Termites, like a suite of other creatures, tell an uncanny story of the social, political and material lives of infrastructure. They reorient how one might think of the mobilities infrastructures generate by accelerating movement (Graham and Marvin, 2002), the built environments infrastructures produce as they move materials around (Amin and Thrift, 2017; Murphy, 2017), and the bioeconomies infrastructures foster by rendering life into a locus of accumulation (Barua, 2018b; Rajan, 2006; Lemke, 2015). These more-than-human enfleshments, and

enmeshments with infrastructure, where corporeality and substrate meld or the habitat and habits of living beings get inexorably entangled with those of infrastructural environments, point to a wider infrastructural ontology, one where a suite of entities, potentials and forces animate, and have bearings upon, the circulation, assembly and contestations of infrastructure. Yet, barring a small and nascent body of work attentive to circulation (Amin and Thrift, 2017; Banoub and Martin, 2020; Mitchell, 2002), sensing and mediation (Gabrys, 2014; Parks, 2017), and multispecies assemblages (Doherty, 2019; Carse, 2012; Wakefield and Braun, 2019), scholarship on infrastructures remain largely anthropocentric in their outlook.

Infrastructures might be understood as 'objects that create the grounds on which other objects operate', their 'peculiar ontology' lying in the fact that 'they are things and also the relation between things' (Larkin, 2013; p.329). As dynamic socio-technical formations with multiple, distributed parts, 'infrastructure is a structure of contact' situated in particular material conditions and simultaneously cutting through the economic, the cultural and the political (Amin and Thrift, 2017; p.35). Scholarship on infrastructure is a wide conversation that spans geography (Furlong, 2011), anthropology (Appel et al., 2018), architecture (Easterling, 2014) and media studies (Parks and Starosielski, 2015). There is a diverse array of conceptualizations of infrastructure, ranging from the systemic (Graham, 2010), to the networked (Graham and Marvin, 2002), the hidden (Anand, 2017), to the spectacular (Larkin, 2013), from the everyday (McFarlane and Silver, 2017; Lemanski, 2020), to the monumental (Barry, 2013), but three broad currents pertaining to the material and political life of infrastructure stand out. Firstly as architectures of circulation, encapsulated in Larkin's oft-repeated dictum that infrastructures are 'matter that enable the movement of other matter' (Larkin, 2013; p.329), they undergrid modern societies and cause alterations on such a scale that 'infrastructure is no longer an effect

but a cause' (Amin and Thrift, 2017; p.39). Secondly, infrastructures are a 'system of substrates' albeit formed and knowable only through relations (Star, 1999; p.380), and which generate ambient environments of everyday life. Pipes (Anand, 2015), energy grids (Luque-Ayala and Silver, 2016), and roads (Harvey and Knox, 2012), not only subtend human life but become contested sites of design and assembly, variance and breakdown (Appel et al., 2018). Thirdly, infrastructures settle and habituate routines of social order, becoming frames to recast and rethink the political. Metrics (Criqui, 2016) and meters (von Schnitzler, 2018), are read as techniques and apparatuses of liberal government that administer and regulate populations. They modulate markets, lead to novel forms of economic assembly and improvisation, which can stem from people's everyday activities in the city (Simone, 2004; McFarlane and Silver, 2017; Amin, 2014).

Whilst closely interrogating the material lives of infrastructure – as both the 'matter of government' and 'the government of matter' (Lemke, 2015; p.16) – there is little that tells us about the relations between other-than-human life and infrastructure. An anthropocentric 'ontology of infrastructure' centers 'on built things, knowledge things, or people things' (Larkin, 2013; p.329). Here building, and the built environment, are primarily products of human assembly or of deviance from intended plan and script. Knowledge is configured as a human capacity alone, leaving little room for other modes of knowing or knowledge*abilities* that might be differently distributed across bodies and human-nonhuman divides (Whatmore, 2009). Social relations that are configure and are configured by infrastructures are confined to those between people alone, paying little heed to the heterogeneous collectives within which lives unfold. This ontology of infrastructure, irrespective of whether infrastructures are viewed as a socio-technical condition (Star, 1999), a political economic formation (Graham and Marvin, 2002), or a heterogeneous configuration (Lawhon et al., 2018), are

relational but anthropocentric. In lieu, this paper formulates a more expanded articulation of the constitution, effects and promises of infrastructure and, consequently, proposes a wider infrastructural ontology. It does so through three interconnected themes, moving from the effects infrastructures have on the distribution and mobility of life, to infrastructures as a medium of life and, finally, how nonhuman life itself is rendered infrastructural. These themes derive from central currents of the contemporary infrastructural condition – infrastructures as architectures of circulation, as substrates generating the environments of everyday life, and as technologies of regulation and government; currents that the paper reworks in a more-than-human vein through insights and synthesis of concepts from diverse fields including critical phenomenology, animal ethology, architecture and media studies.[1]

A wider infrastructural ontology is advanced in three sections which proceed along a spectrum of increasing intensity at which other-than-human life and infrastructures get enmeshed. In the next section, the paper examines modes of nonhuman mobility and immobility induced by infrastructure, arguing that the latter's circulatory effects extend beyond the familiar terrain of freight, transport and cargo. Architectures of circulation, tracked through roads and shipping, dictate the scope of contemporary ecological assemblages, how such assemblages congeal and the political/ecological effects they set in motion. It then turns to nonhuman lifeworlds in infrastructural environments to argue that infrastructures are not only background substrates subtending human life but become the very medium of nonhuman inhabitation. To do so, the paper develops the concept of infrastructure as nonhuman 'habitus' (Bourdieu, 1977) and argues that this concept is vital for understanding how 'natural' and infrastructural ecologies meld and the biopolitics and cosmopolitics they invoke.[2] Examined differentially through repurposing, spontaneity and deliberative design, habitus

opens up the category of infrastructure to multiple agencies and forces that have largely remained invisible in anthropocentric iterations (Appel et al., 2018). The subsequent section attends to the rendition of nonhuman life itself *as infrastructure*, critically appraising how practices of 'infrastructuring' animals are becoming a mode of biopower and a political technology of capital. These arguments are developed through a specific set of animal species rather than the gamut of life encompassed by the term 'more-than-human', as they offer a productive grammar for generate questions and concerns. The paper concludes by bringing these themes together to discuss what analytical and political purchase a wider ontology of infrastructure, refracted through the more-than-human, offers up for specifying infrastructures within geography and the wider social sciences.

Infrastructural circulation: nonhuman mobility and immobility

A key effect of infrastructures is that they hasten the world. Architectures of circulation, whether road networks, shipping, railways or air freight, have received considerable attention in scholarship on infrastructure (Martin, 2016; Harvey, 2012b; Harvey and Knox, 2012). Yet, barring certain seminal exceptions (Mitchell, 2002), the latter seldom registers their effects on the mobility of other-than-human life. Attending to the animal-infrastructure enmeshments or infra-ecologies produced by such architectures of circulation can provide insights into some of the hidden mobilities induced by infrastructure, opening up ground for inter- and intra-disciplinary conversations between studies of socio-technical systems (Larkin, 2013), invasive species ecology (Simberloff et al., 2012) and mobility (Cresswell, 2014). Whilst these themes have continually haunted more-than-human geography and political ecology (Crosby, 2004; Clark, 2013; Clark, 2002; Robbins, 2004), infrastructure has seldom been a vital thread, although it is critical for asking questions of mobile natures

in the Anthropocene/Capitalocene/Plantationocene (Carse, 2019; Amin and Thrift, 2017; Haraway, 2015), and the concerns of 'scale, rate/speed, synchronicity, and complexity' it evokes (Haraway, 2016; p.99).

Architectures of circulation, as the subsequent examples of road networks and shipping illustrate, work upon the more-than-human at a number of scales, from individual animals to entire assemblages. They front stage different agencies spurring mobility, from unintentional movement via circulating infrastructures to purposive mobility through transport architectures. Rendering visible some of these hidden effects of architectures of circulation has significant implications for how animals' mobilities might be comprehended and known (Hodgetts and Lorimer, 2018), as they bring to the fore an important but neglected dynamic of contemporary, mobile natures: becoming hypermobile and immobile – being stuck, cut off, isolated (Cresswell, 2012; Khan, 2016) – at the same time. Furthermore, animate mobilities spurred by infrastructures now increasingly come back to bear upon infrastructural circulation and flow, thus bringing to fore a much more complex world immersed in, and constituted through, movement.

As infrastructure, roads are both monumental and mundane. Besides transporting vehicles, increasing speed and fostering connectivity, roads are a technology of government, rendering places and provinces legible and bringing them into the ambit of administration (Scott, 1998). Much of the anthropocentric scholarship on road infrastructures shows how they are plural spaces, as much sites of expectation and promise (Harvey and Knox, 2012; Harvey and Knox, 2015), as they are about mobility and transport. Roads become vehicles of Modernity that 'form us as subjects', mobilizing 'affect and the senses of desire, pride and frustration' (Larkin, 2013, p.332). Yet, with their global reach closing in on 25 million kilometres, enough to circumvent the earth

600 times (Laurance and Arrea, 2017), roads also have ecological and evolutionary effects, thereby foregrounding a whole other set of questions on the animacy and agency of infrastructure.

Road infrastructures are actively used by animals. They become habitat corridors directing the movement of organisms through less hospitable habitat (Benítez-López et al., 2010), altering biogeographic patterns. In southern India, the Rhesus macaque crosses major biogeographic barriers via highways and bridges and has spread into areas formerly inhabited only by Bonnet macaques. Unable to outcompete the more aggressive Rhesus, Bonnets have been displaced from urban habitats to forest areas (Kumar et al., 2013). New socio-ecological formations are beginning to emerge, with mixed troops of the two species coalescing in certain locales, within which Bonnets are relegated to subordinate positions within intra-troop hierarchies (Kumar et al., 2011). Roads are not just conduits of movement but also become habitat, drawing certain species to their vicinity with significant effects on animals' behavioural profiles. In Southern India, forest-dwelling Bonnet macaques have begun to gravitate towards roads where they get food from passing vehicles. Some individuals even stop cars by adopting bipedal begging postures – a novel behaviour that only emerges in infrastructural environments (Sinha, 2005).

But as ethnographies of roads remind us, highways and motorways are topological, connecting and separating at the same time (Harvey, 2012b). Roads impede animal movement and can reduce animal densities, particularly when traffic volume and velocity is high (Benítez-López et al., 2010). Motorways become biogeographic barriers, setting in motion a whole other geography of stillness and stuckness emerging from the breakdown of dispersal. Immobility generated by architectures of circulation are thus crucial for nascent calls to develop appreciations of animals' mobilities, which have tended to focus on movement (Hodgetts and Lorimer, 2018), as its effects are not just in terms of pattern but

process as well. Evolutionary effects of infrastructure-induced immobility are poignant in the case of New York City's White-footed mouse populations where roads have carved up their once continuous urban distribution into isolated pockets. Each isolated population now carries its own genetic signature and is an exemplary case of infrastructure-induced evolution (Munshi-South and Nagy, 2014).

There is a folded geography of animal-infrastructure mobility and immobility, for animals can repurpose infrastructures to overcome the very barriers to movements they generate. Rhesus macaques using electric wires to cross busy roads in Indian cities are a striking case (Barua and Sinha, 2017). By 'exapting' electric infrastructure for their own simian movements, macaques have shifted from a rural terrestriality to an urban arboreality, with all kinds of implications for the social and material life of electric grids. Power outages caused by macaques tripping wires in Indian cities are not uncommon (Anon., 2011); in Kenya, a monkey that fell into a transformer triggered a blackout that spread across the entire country (Anon., 2016). The effects macaques' arboreality has on infrastructures' intended functioning for humans has resulted in modifications in practices of infrastructural repair and maintenance. Electricity providers work with wildlife rescue NGOs, drawing on their expertise in dealing with macaques, especially in situations where members of a troop prevent linemen from coming close to individuals entangled in wires (Anon., 2018). Actually-existing urban practices are thus beginning to recognize rather than efface animal-infrastructure enmeshments, and acts of infrastructural repair are, in some instances, becoming cosmopolitical as they entail responding to other-than-human affects and not just technicalities of the electric grid.

Being attentive to such a non-anthropocentric infrastructural ontology demands synergies between ethnographies of road infrastructure (Harvey and Knox, 2015), the burgeoning sub-field of road ecology (Van Der Ree et al., 2015), and 'etho-geographies' that bring insights from critical phenomenology, ethology and human geography into conversation (Barua and Sinha, 2017). Ecologists, for instance, are beginning to view development infrastructure such as roads as 'keystones' (Johnson et al., 2019). An inversion of the traditional keystone species concept, it is now infrastructure, or rather infra-ecologies constituted through the enmeshment of animals and infrastructure, that effect ecosystem function and trigger trophic cascades. A recognition of the keystone role of infrastructures has resulted in efforts to modulate animal mobilities through 'reconciliation infrastructures' – underpasses, tunnels and crossings designed keeping other-than-humans in mind – discussed later in the paper. Similarly, roads might themselves be seen to be 'animate', drawing connections and proliferating rhizomatically with a life of their own (Rest and Rippa, 2019). These points of convergence between ethnography and the material politics of road-building, road ecology and keystone effects, as well as etho-geographies attentive to *animals'* mobilities signpost future avenues for developing a political *ecology* of infrastructure that goes beyond the routine misadventures of environmental impact assessments.

The iterative dynamic between nonhuman mobility and immobility, and the itinerations between structures of circulation and their routes, are crucial elements of a non-anthropocentric infrastructural ontology. Yet, questions of scale, speed and complexity raised herein become different if one looked into other architectures of circulation: shipping. The economic significance of a global cargo-carrying fleet of 50,000 ships, transporting more than 90% of all traded commodities worldwide (Hulme, 2009), are well known, but their under acknowledged ecological effects are hard to ignore. There is little deliberate animal movement using ships, but closer scrutiny shows how shipping fleets, as mobile infrastructures, are beginning to dictate nonhuman movement at unprecedented scales and speed. Ships become habitat, witnessed in

the case of that key figure of Anthropocene ecosystems: the humble rat. Maritime trade, resulting in the latter becoming cosmopolitan, has triggered ecological cascades and extinction events world-over (Pattemore and Wilcove, 2012). Differential scales of mobility are folded into the ship. The shipping container, an invention without which economic globalization or the deindustrialization of the United States would be unimaginable (Martin, 2016), and the ballast tank are perhaps two most important devices shaping Anthropocenic biogeographies. Modern trans-oceanic shipping's movement of several billion tonnes of ballast water annually accounts for the transport of 10,000 species each day (Streftaris et al., 2005). What is moved are not just individual animals but entire assemblages, intensifying both the volume and taxonomic diversity of biotic flows, and transforming the very composition of aquatic ecosystems.

Social and political effects of infrastructure-induced circulation of biota is most poignantly drawn out by Timothy Mitchell in his classic chapter *'Can the Mosquito Speak?'* In a convincing analysis going beyond social constructivist explanation of phenomena, Mitchell shows how the largely sedentary malaria-causing *Anopheles* mosquito spread in Egypt with the help of infrastructure. The arthropod probably arrived by boat and other architectures of transport, whilst colonial river control and irrigation projects 'enabled the mosquito to jump barriers from one region to the next'. Irrigation also altered the temperature and chemistry of the water, resulting in a proliferation of curly pondweed – an invasive aquatic plant – on which mosquito larvae 'piggy-backed' to spread. *Plasmodium*, the malaria parasite needing human bodies to reproduce, took advantage. Transport infrastructures and engineering works set in motion a cascade of other-than-human mobilities that in turn had significant bearings on ecology, populations and health. 'The surest way to restore the health of the Egyptian population,' the colonial British Government conceded, 'would be to destroy dams and return to basin irrigation' (Mitchell, 2002; p.23). Mitchell's analysis shows how animal-infrastructure enmeshments reorient notions of power and the capacity to act as questions rather than an answer known by the analytical social sciences in advance.

Infrastructures thus simultaneously generate hypermobile and immobile worlds: they become a vital thread in understanding the intensity and scale of other-than-human movement in addition to animals' subjectivities and their collective circumstances (Hodgetts and Lorimer, 2018). What is significant about infrastructure-induced mobility is that species with no 'natural mechanism capable of global transport' (Ricciardi, 2007; p.331), are now being dispersed. They produce 'biogeographies of the Anthropocene' where 'compositional dissimilarities among distant regions' have been significantly reduced (Capinha et al., 2015; p.1250). At the same time, for other creatures, immobility is deepened. There is thus significant scope for interdisciplinary articulations of such biogeographies (Stallins and Kelley, 2013; Lorimer, 2010), which ought to be written not so much in terms of roots but more along routes for, independent of what transported, *infrastructural movement itself* – ports visited, routes taken, the volume and speed at which goods are moved by architectures of circulation – are now beginning to define what constitutes a biogeographic assemblage at any juncture. Infrastructure-induced movement and their uneven, heterogeneous effects have bearings on a number of domains, from conservation to the governance of populations and the administration of life. An infra-ecological world of movement brings new obligations and responses into being, bringing the commonplace valuing of mobility over immobility into question.

Infrastructure as medium: nonhuman habitus

Enmeshments between life and infrastructure become even denser when we turn to infrastructure as a medium for nonhuman life. The latter is crucial for developing an expanded infrastructural ontology as it reworks another central current of thinking on infrastructure: as a system of substrates that generate ambient environments of everyday life (Star, 1999). Whilst scholarship gravitates toward showing how infrastructures, as 'built things', operate as structures of contact and generate the very ground through which other objects operate (Larkin, 2013), there is a tendency to focus on the built environment as solely one of humanist assembly. The kinds of lives infrastructures summon and the publics they spark (von Schnitzler, 2018), the effects infrastructures produce when deviating from script (Appel et al., 2018), or when form is loosened from technical function (Larkin, 2013), are inflected through specific sets of human actors. A suite of other bodies and entities that work upon infrastructures from within, whether generating the glitches (Berlant, 2016) and breakdowns (Graham and Marvin, 2002) that render background infrastructural work visible, find little room in the story.

A productive entry point for analyzing and specifying how infrastructure becomes a medium of life is to conceptualize *infrastructure as nonhuman habitus*. To do so, one might draw upon and extend Bourdieu's (1977; p.72) concept of habitus, broadly understood as 'systems of durable, transposable *dispositions*' produced by 'a particular type of environment' or the 'material conditions of existence', which structure and are structured by 'regulated and regular' practices. Habitus is the melding of habit and habitat and provides vital entry points for understanding how infrastructures and animal lifeworlds coalesce. Infrastructures configure a creature's lifeworld by modulating *habit* – its sensory and sentient world-making activities and rhythms, and by furnishing *habitat* – a creature's dwelt environment and its very medium of inhabitation. An expanded understanding of habitus to include other-than-human worlds needs to be in conversation with work on how animal bodies are themselves mediatic (Parikka, 2010), capable of sensing worlds according to their own propensities and rhythms. The import of this move is that it broadens the retinue of sentient subjects through which infrastructures are relationally 'known' (Star, 1999), and provides vital inroads for understanding contemporary conditions that are becoming 'medianatures', where a 'natural ecology is entirely entangled with' a 'technological one' (Parks, 2017; p.144).

Critical development of the concept of nonhuman habitus demands working with affiliated bodies of work that engage with animal lifeworlds, habits and modes of sensing. This includes readings derived from critical phenomenology to formulate animals' atmospheres: the relational configuration of an animal's *umwelt* via their molecular and neurological bodies, socio-ecological rhythms and enveloping, volumetric landscapes (Lorimer et al., 2017); geographies of the built environment that 'disturb the agential apartheid' of human bodies being the sole beholder of landscape (Whatmore and Hinchliffe, 2012; no page); and affective interpretations of architecture that attends to ways in which animals respond to, and repurpose, the built environment along and against the tide of planning and design (Smailbegović, 2015; Ingold, 2013; Metzger, 2016). A further counter to the hylomorphism running through some of the more anthropocentric work on infrastructure comes from the burgeoning field of urban ecology that shows how animals adapt to the built environment through a number of life-history strategies (Schilthuizen, 2019), and behavioural innovations (Sinha, 2005; Barua and Sinha, 2017). Together, they provide a relational grammar for grasping infrastructures as a medium of nonhuman life.

To further elucidate the concept of habitus, the paper turns to three modes of animal-infrastructure enmeshments. Each of these relate, differently, to the notion of design,

a concept that has been pivotal to formulations of urban form and media infrastructure (Parks and Starosielski, 2015; Larkin, 2008; Gandy, 2016). The first entails *repurposing*, where affordances of infrastructural substrates are realized by other-than-humans *along and against the grain of design*. The section then turns to *recombinance*, where infrastructural environments throw up surprises, invoking questions of spontaneity via nondesign or emergence *in spite of design* (Jasper, 2018; Gandy, 2013b). The paper then attends to an emerging set of *reconciliation* infrastructures *actively designed* to accommodate nonhumans (Holder, 2018), albeit with their own biopolitics of modulating other-than-human life (Parks, 2017). These three modes provide useful cuts for a comparative account of the diverse agencies encapsulated in animal-infrastructure enfleshments, pointing not just to commonalities but divergences and differences in how infrastructures become a medium of nonhuman life.

Repurposing Infrastructures

Termites are perhaps the test case for understanding how infrastructures are repurposed, not along a humanist axis of calibration but through the realization of infrastructural affordances by Isopteran bodies. Drywood termite colonies, by extending foraging activities and territories into built infrastructure through a series of reticulate tracks (Su and Scheffrahn, 2000), incorporate pilings, bridges, railway sleepers and buildings into their Isopteran worlds. 'Foraging tubes' and mounds which the arthropods create, modify and continually repair, funnel the movement of air currents and eddies that in turn guide termite movement. Rhizomatic trails laid out by termites generate a 'sort of external memory', leading some entomologists to argue that their structures themselves ought to be considered as living (Margonelli, 2018; p.51). Termites are thus not just enmeshed or entangled in infrastructures, but enfleshed in that it is difficult to separate where one body ends and the other begins or, for that matter, where the divisions between corporeality and substrate lies.

Termite-infrastructure enfleshments strike at the heart of notions of the 'built environment', symptomatic of certain strands of urban studies and urban political ecology that remain tethered to humanist notions of construction (Rademacher, 2018). They render infrastructural substrates into landscapes of inhabitation (Hinchliffe, 2003) or media infrastructures at once sensed and sentient (Parikka, 2013). Repurposing, which works with and counter to the ambit of design, is a two-way process. Termites 'in-form' materials albeit by working with 'materials and forces' rather than 'imposing properties upon matter' (Deleuze and Guattari, 1986b; p.98). At the same time, infrastructural environments bear upon their habits, directing termite reproduction, movements and flows. Termites are mediatic bodies rendering infrastructures knowable in other-than-human ways. Their abilities to sense infrastructural environments are in part configured by their *umwelts*, where perception is not just about audition, olfaction and vision, but through metabolic means as well. Eyeless, termites use their antennae to feel for smoothness, removing everything that is rough. Their metabolization of infrastructure into food is a mediatic process, unmaking infra-space as they render external architectonic environments into an internal one.

Repurposing brings a whole other geography of infrastructural accretion, withering and repair to the fore. Examining processes of repurposing, which is done by a suite of creatures that inhabit infrastructures, although termites are a striking example, can enable new synergies between urban ecology and architects' work on 'subtraction' that runs parallel to the expansion of infrastructure and accumulation of capital (Easterling, 2014). The scale of damage drywood termites inflict upon infrastructure, running into billions of dollars worldwide are a case in point. The work of maintenance and repair becomes one of working with and against the grain of termite

action. Furthermore, repurposing and means to control it are caught up in wider political entomologies. In the US, for instance, decommissioning of railroads and their subsequent burial led to a spate of termite infestations. Abandonment and sunk capital resulted in an increase in rotting infrastructural substrates and, consequently, led to an expansion of the creature's habitat. In spite of protracted eradication measures, many termite colonies could not be moved. Privatization of railroad infrastructure further aggravated the problem. Sleepers were resold to recuperate investment costs, enabling Isopterans to proliferate even more widely (Austin et al., 2008), moving into infrastructural substrates from where they were earlier absent.

Recombinant Infrastructures

If repurposing encapsulates a nonhuman habitus which runs counter to infrastructural design, recombinance entails novel compositions that have to do with spontaneity and emergence. Recombinant systems are usually characterized by no-analog assemblages that have no past evolutionary history of co-composition (Lundholm, 2015). They are often products of infrastructure-induced mobilities outlined earlier, where species from different parts of the world are brought together or new compositions of native species with no ecological memory of cohabitation are constituted from scratch (Meurk, 2011). Equally, recombinant substrates can be generated by infrastructures radically altering abiotic environments and, therefore, the very conditions under which ecosystems reproduce. Recombinance is a process where infrastructure becomes the very medium of life, adding, deleting or re-sorting species frequently in excess of human deliberation and design. In the latter sense, recombinant infrastructural substrates are akin to 'unintentional landscapes', which are spontaneous and unfixed, emerging in spite of planning and design (Gandy, 2016; Jasper,

2020), or they can be deliberative, achieved through landscape gardens or restoration projects, that is more akin to a form of 'entropy by design' (Gandy, 2013a; p.275).

One of the best-known examples of recombinance is the Peppered moth (*Biston betularia*) which, in the 19th century, which quickly evolved a dominant, dark form with cryptic colouration to disguise itself in smoky, sooty environments generated by the industrial revolution. The moth's emergence was a case of co-evolution with *Lecanora conizaeoids* or pollution lichen, virtually unknown before levels of sulphur dioxide rose in the air and substrates were modified by industrial chemicals. Distinct 'lichen zones' soon emerged around towns, cities and industrial complexes, where *Lecanora* replaced leafy lichens. As a result, populations of the Peppered moth proliferated. Both the moth and the lichen, as mediatic bodies, sense and respond to polluted atmospheres and infrastructural substrates. Furthermore, the relations moths compose with infrastructure is contingent upon lichen, thus rendering habitus into a question of both an enmeshment and an enfleshment with infrastructure and the assemblages it throws up. Decreasing sulphur dioxide levels since the 1970s has led to reductions of pollution lichen, which is now confined to acidic tree barks such as the Scots pine. Concurrently, dark forms of the Peppered moth are as rare as they were in the early 19th century (Schilthuizen, 2019; Rotherham, 2017).

Recombinance shows how infrastructures operate as media infrastructures (Parks, 2017), mediating other-than-human life and the conditions of life's reproduction. Ecologists proclaim that recombinance is increasingly becoming a feature across the world and that 'we have recombinants whether we like it or not' (Meurk, 2011; p.215). Yet, as emerging work on 'chemical infrastructures' and 'distributed reproduction' (Murphy, 2017), is beginning to show, recombinance comes with a fraught biopolitics of abandonment, settler colonialism and the military-capital complex. Chemical

infrastructures refer to the 'varied pathways' of 'industrially produced chemicals', which connect 'moments of production and consumption' whilst permeating and structuring 'both human and nonhuman' life (Murphy, 2013; no page). As much as recombinant infrastructural substrates give rise to novel assemblages, often communities of exotic and pollution-tolerant species (Rotherham, 2017), valued (or not) for their entropic and nondesign aesthetics, there is also a slow violence enacted as industrial chemicals permeate life. Harms are unequally distributed as the molecular manifestations of chemicals come back to mark the most vulnerable bodies, whose impacts can take generations to see. As actually-existing political ecologies have continually pointed out, multiple layers of capitalist, colonial and environmental destruction reside amidst the rubble of recombinant infrastructures. They increasingly shape the 'susceptibilities and potentials of future life' (Murphy, 2017; p.497), dictating which lives might flourish and which ones are abandoned.

Reconciliation Infrastructures

In contrast to repurposing and recombinance, reconciliation infrastructures are those that entail an active design of infrastructural environments to foster and modulate nonhuman life. It is a mode of designing- or planning-with animals and plants, where elements of the built environment are modified or assembled to foster nonhuman mobility, reproduction and even evolution. An active field of 'reconciliation ecology' underpins such imperatives. In contrast to reservation (i.e. setting up protected areas) and restoration (i.e. reinstating an erstwhile ecosystem state), which often resort to the old settlements of Nature and Society, reconciliation ecology is about conservation in the 'midst of human enterprise', an attempt to work with the promises and potentials of anthropogenic environments (Rosenzweig, 2003).

Reconciliation infrastructures incorporate ecology into architectural assembly and, in effect, are an imperative to modulate the habitus of the creature. At the level of assemblages, such infrastructures are designed to provide habitats for species. The engineering of living walls and roofs to enable plant and animal communities to thrive on grey infrastructure being a case in point (Francis and Lorimer, 2011). Often designed to simulate brownfield systems, living roofs can harbor rare taxa with specialized niches, although the effects of design are uneven and species with low dispersal capacities benefit less. Reconciliation projects offer up an infrastructural ontology that recognizes animal-infrastructure entanglements rather than efface them (Parks, 2017). However, they also raise questions as to whether such infrastructures ought to replicate 'natural' habitats or whether they should be experiments in creating spontaneous, novel and recombinant assemblages (Francis and Lorimer, 2011), a question that is political as much as it is ecological. In many instances, the line between infrastructures as 'experimental terrains' fostering new connections with nature via reconciliation and the 'looming logic of geo-engineering or techno-managerial fixes' is thinly drawn (Gandy, 2017; p.4). Reconciliation projects can become forms of greenwashing, enabling business as usual to continue unabated.

Reconciliation infrastructures entail synergies between critical phenomenologies of landscape, including how infrastructural environments are differentially sensed and inhabited by nonhumans, animal ethology and architecture. Wildlife bridges, overpasses and tunnels installed to facilitate animal movement are perhaps the fastest-growing examples of how design is now about modulating animals' habits and cultivating mobilities that the State and capital desire. Designs vary in terms of the species they target, but they are not hylomorphic. Rather reconciliation infrastructures attune designs to the *umwelt* of a creature, be they pipes under roadways for drawing in foxes and mice or canopy bridges

woven out of ropes for arboreal mammals to cross (Holder, 2018). Their architectures are about 'generating affordances' that might be realized by other-than-humans (Metzger, 2014; p.205). Deer, for instance, prefer clear sight paths to aid vigilance from predators, whilst smaller prey species need cover in order to go undetected. Underpasses for deer are designed with broad openings, kept clear of vegetation wherever possible so as to steer animals to their entrances. Reconciliation infrastructures strive to generate situations that enable animals to incorporate these structures into their own lifeworlds through habituation and use and are therefore interventions that aim to engineer worlds.

Jonathan Metzger's reading of planning through the idea of ethico-aesthetics (Guattari, 1995), 'associating *ethos* as 'habit' and understanding *aesthesis* as the capacity to act and be affected' (Metzger, 2016; p.583), is helpful for analyzing how such interventions proceed. Ecologists, architects and engineers designing wildlife passes and ecoducts aim to mimic ambient environments. Subtle variations in shape, moisture and light can lead to 'tunnel hesitation' and practitioners, therefore, experiment with atmospheres and manipulate affects in order to foster crossings (Andrews et al., 2015). Wildlife passes also generate affective intensities unanticipated in reconciliation infrastructures' inaugural assembly, notably by becoming predator traps. Predators such as mountain lions follow temporal and seasonal activity patterns of deer and increasingly haunt underpasses when deer utilize them. In response, many animals resort to using passes at times of the day when human activity and traffic levels are high so as to avoid predators (Caldwell and Klip, 2020). The modulation of an organism's habitus is thus caught up in a series of affective relations – an ecology of affect generated by and responding to worlds created by infrastructure.

The will to foster particular kinds of habitus through reconciliation infrastructures can be read as a mode of biopolitics, but such a reading requires both nuance and an attention to diverse currents at work. One strand here is the generation of connectivity as a means of fostering and administering life, where biopolitics shifts from the model of 'confinements', which are molds targeting populations, to 'controls' that are modulations, targeting mobilities and flows (Deleuze, 1995; p.178). The latter is an attempt to govern the aleatory through strategies to channelize and steer animal movement – practices that are 'regulatory and regulated' (Bourdieu, 1977; p.72), rather than creating enclosures and bringing about a strict separation of Nature and Society symptomatic of erstwhile spatialities of conservation (Brockington, 2002). Wildlife crossings in many parts of the Global North are a quintessential example. For instance, Canada's Banff National Park in Canada recorded more than 150,000 large mammal crossing events across its 38 passes in a span of four years (Holder, 2018). Funded by both the State and private capital, including automobile and petroleum companies, such reconciliation infrastructures have wider political implications. Large amounts of data generated in such venues serve strive to render animals trackable, and therefore amenable to calculation and control. They feed into imaginaries of 'data-behaviourism' where design is flouted as a means of governing futures through 'complexity' rather than democratic dispute (Grove et al., 2019), whilst global automobile industries and 'the fossil fuel-enabled circulation of goods and people characteristic of the Capitalocene' proliferate 'without disruption' (White, 2020; no page). Furthermore, reconciliation infrastructures can serve to render animal mobility into use-values for capital. The 'unpredictable movements' of wildlife are being tapped into by secondary automobile markets and deployed 'to catalyze and sustain subsidiary economies of fossil fuel industries, whether manufacturers of massive bumpers or motion-detecting vision machines' (Parks, 2017; p.150-151).

An alternative to such emergent forms of biopolitics might be to render infrastructures open to the dynamism of multiple agential forces and the morphologies

and materialities they (might) evoke. Of particular import are the cosmopolitical questions asked of planning and design when the scope of beings that count are expanded beyond the human. As Metzger evocatively argues, although wildlife passes reduce collisions by 75-80%, it still means collisions occur frequently, even when roads are fenced. Often, animals such as moose step over fences and end up in front of vehicles. As 'wronged subjects', moose spark affective publics into being and collisions become fiercely debated 'political' issues. They 'register protest', not by willfully colliding with speeding automobiles, but by providing a new lens on events. Collisions expose the limitations of data-behaviourism and bring forward the alternate possibilities of slowing down, including less consumptive futures and undoing the automobile industry's attempts to continue with business as usual via reconciliation infrastructures (Metzger, 2014).

In summary, the concept of habitus provides a crucial relational analytic for grasping how infrastructures furnish substrates for other-than-human life and the differential ways in which such life responds to a world increasingly configured by infrastructure. Repurposing, recombinance and reconciliation are useful entry points for parsing some of the diverse agencies at work and the forms of biopolitics that unfold through modulations of habitat and habit. Whilst repurposing works against the grain of planning and design, recombinant and reconciliation infrastructures are exemplars of how other-than-human life is subjected to constant infrastructural amendment, sometimes with particular aims of governance in mind. Infrastructure as habitus provides a set of complementary analytics to cognate takes on infrastructures as media ecologies (Parikka, 2013), and perspectives on infrastructure as substrates generating ambient environments of life (Star, 1999), to formulate a rich account of the bio- and

cosmopolitics at stake when infrastructures become the medium of other-than-human life. Habitus becomes crucial for grasping the ecologies and politics of infrastructure, taking it beyond the narrow ambit of the built environment and humanist infrastructural assembly.

Nonhuman life as infrastructure

Infrastructures are rapidly expanding to include nonhuman life. If biopolitical aspects of life-infrastructure enmeshments become evident with reconciliation and the design of infrastructures for other-than-humans, their effects are even more pronounced when animals themselves are cast as infrastructure. The deployment of animals as labour, as mediatic sensors, and as cyborg assistants in a range of actually-existing and promissory projects is a departure from the familiar effects infrastructures have on other-than-human life (Mitchell, 2002) and marks the advent of what popular commentators have called 'the age of animals as infrastructure' (Manaugh, 2015). The anticipatory logics and aspirations of infrastructuring – the act of rendering ecologies or assemblages into infrastructure – are varied. It can entail an economization of nonhuman life, where bio- and anatomo-politics function as elements in the development of contemporary capitalism (Lemke, 2011; Barua, 2018b; Wadiwel, 2018), converting life into the capacity to work (Federici, 2004), and bringing the very acts of ecological being and doing into the locus of accumulation (Negri, 2017). Equally, as others highlight (Wakefield and Braun, 2019), the installation of nonhuman infrastructures is a quest for managing and governing *human* life, especially in the face of futures cast as uncertain or turbulent. Yet, relations between capital and life are not given. Life can exceed attempts at infrastructuring or generate grounds for non-capitalist spaces and more-than-human commons. But taken thoughtfully, the infrastructuring of nonhuman life can serve as an analytic that opens up a suite of other

epistemological and political commitments glossed over when what is seen as infrastructure is recounted through anthropocentric familiars of built things, knowledge things and people things.

There are specific historicities to such infrastructuring: the explosion of new beasts of burden is subtended by the decline of others. Asian elephants are the quintessential example. Modes of transport, workers in plantations and forestry operations, symbols heralding modernity in colonial empire, elephants were vital for installing infrastructure and were themselves infrastructure. Infrastructuring proceeded through colonial bio- and anatomo-politics that included a seizure of the elephant trade, a regulation of human labour for their capture and care, as well as the generation of new knowledges for disciplining and managing proboscidean bodies (Saha, 2017). Elephant capture and management was an enterprise of generating profit, a biopolitics of rendering nonhuman life into a capacity to work, where divisions between constant and variable capital broke down as the animals reproduced as 'raw material' whilst simultaneously performing labour (Barua, 2016). The decline of draught work poses interesting questions regarding infrastructural obsolescence. Unlike machinery, elephants do not rust. In Thailand, logging elephants were taken to beg in cities after timber operations closed, before being redeployed in commercial ecotourism ventures (Paddock and Suhartono, 2020; Duffy, 2013). Other species, where avenues for performing productive work are limited, might even be let loose to go feral. Obsolescence not only poses the question what is infrastructure, but asks *when* other-than-humans count as infrastructure, for the latter can revert back to 'nature' when the activity of infrastructuring is no longer performed. As Carse points out, 'infrastructures can unbundle and run reverse if they are not maintained' (Carse, 2019; p.103).

Emerging bestiaries of nonhuman infrastructures are heterogeneous but, for heuristic purposes, one might see these in four modes – provisioning, ecological, biosecurity and resilience infrastructures (Barua, 2020) – each of which harness lively potentials in different ways and are caught up with different iterations of contemporary capitalist biopolitics. Provisioning infrastructures map onto the role played by animals as ecosystem 'service providers' or as creatures carrying out metabolic labour (Barua, 2018a). These roles can be exposed through their breakdown, witnessed in the case of Cairo's pig cull, where the slaughter of 300,000 animals in the wake of a swine flu pandemic in 2009 resulted in rapidly growing piles of organic waste on the city's streets. An unofficial element of Egypt's 'waste-processing infrastructure', pigs' metabolic activities 'were tacitly relied upon as a key component' of the city's 'public sanitation regime' (Manaugh, 2015; no page). Often, scavenging animal bodies at the urban margins are relegated and 'rendered disposable' by state-centric views of infrastructure, casting them 'out from the imaginary of a clean, green, urban future' (Doherty, 2019, p.S000; Gutgutia, 2020). On the other hand, we are witnessing new ways of recruiting animals' metabolic labours into techno-political imaginaries of the automated, green city. Large-scale deployment of the black soldier fly in waste disposal is a case in point (Zhang, 2020).

Provisioning infrastructures render visible their own set of biopolitical imperatives. These can entail abandonment – the 'letting die' of biopolitics – where those immiserated by capitalist urbanization are left to deal with precariousness on their own accord and with minimal State support. Recent work on 'slum ecologies' shows how the urban poor eke out a living by enrolling the metabolic labours of animals in converting waste into value (Gutgutia, 2020). Provisioning infrastructures are also caught up with austerity, where eco-technologies that help fashion visions of the 'entrepreneurial city' go hand in hand with a reduction in public spending and reliance on voluntary labour to maintain infrastructures (Ernwein, 2017; Gabriel, 2016). Under regimes of austerity, infrastructuring animals can be read as a

capitalist politics of re-engineering society and privately appropriating the commons (Harvey, 2012a), but what is at stake is putting the unwaged labour performed by humans *and nonhumans* (Barua, 2018b) to work for the smart, entrepreneurial city. As ethnographic work is beginning to indicate, the infrastructuring of metabolic animal labour tends to naturalize 'the appropriation of nature and labour in the new green city' (Zhang, 2020; p.96). Animal infrastructures are once more becoming a component of the modern metropolis, but as a means of reorganizing work and fueling the creeping neoliberalization of infrastructures providing staples and public goods.

To fully grasp how contemporary forms of infrastructuring operate, one needs to attend to the ways in which organisms are recruited to modify, maintain or create habitats and act as controls on material flows. These are ecological infrastructures tallied to serve human (and capital's) needs. Reframing organisms as ecological infrastructure draws from a suite of 'mobilizing metaphors' in conservation biology (Barua, 2011), most notably the concept of 'ecosystem engineers'. Coined in the 1990s, the term ecosystem engineer became popular through efforts to put the concept to 'predictive use', including speculation that such engineers 'could someday be useful for protecting and resorting habitats' (Alper, 1998; p.1196). Ecologists distinguish between two types of ecosystem engineers: 'autogenic engineers' that change environments via their own living and dead tissues, and 'allogenic engineers' that alter environments by transforming living and non-living materials from one physical state to another via mechanical and other means.

The beaver is exemplary of the latter. 'By constructing dams,' beavers create 'wetlands that last far longer than the lifetime of an individual' animal (Caro, 2010; p.144). Beaver dams are becoming the 'fastest-growing stream restoration technique' in many parts of the US, and are also being promoted in the UK. They are being deployed to create wet meadows for vulnerable birdlife, rebuild

salmon streams and irrigate cattle pastures. Part of the allure of beaver dams is that they 'are cheap compared with other restoration techniques'. Unlike check dams, beavers delay, rather than prevent, water from flowing to downstream users. Instead of spending '$1 million per stream mile', the 'labor of a rodent' reduces costs of regulating and redistributing water flow by one-hundredth (Goldfarb, 2018; p.1059).

Ecological infrastructures are means of governing the aleatory – a form of governance associated with contemporary biopower that intervenes in circulations rather than proliferating via sovereignty or discipline (Lemke, 2015). As Foucault flags up in his reflections on environmentality, to govern the aleatory is to work with an ecological milieu, the flows of 'things and elements' rather than of individuals. The abiotic changes, physical flows and fate of other species that beavers dictate, along temporalities exceeding the lifetime of an individual animal, is a quest towards an 'allocation' of resources 'in space', literally 'a *canalization* of their circulation as well as the coding of their reciprocal relations' (Foucault, 2000; p.147–48, p.361). There are parallels here with the biopolitics of modulating animals' habits and mobilities through reconciliation infrastructures, but with some crucial divergences: animals, rather than architectonic substrates, are relied upon to carry out the work of modulation. Beavers, as ecological infrastructures, *canalize* the circulation of water, although the process is uneven and not always in ways desired by managers of ecosystems (Goldfarb, 2018).

Such infrastructuring of other-than-human life inverts the trope of deploying infrastructure to engineer animals' atmospheres into one of enrolling animals to sense and engineer atmospheres. As a result, *what* constitutes infrastructure shifts from built things and substrates to living beings and their mediatic capacities, harnessed for purposes of securing human life. Using canaries as 'biosensors' in underground mines is an oft-cited example (Wakefield and Braun, 2019), but contemporary, and often

promissory, iterations tap into living beings' vital powers even further. We are beginning to witness the emergence of 'cyborg' animal bodies (Haraway, 1991), that push anatomo-politics or the pole of biopower concerned with disciplining the body and integrating it into economic processes (Foucault, 1998), into new terrain. For instance, cockroaches, arthropods once associated with poor hygiene and pestilence, are now being equipped with sensors and trained to enter the rubble of collapsed buildings. Electric pulses steer the arthropods toward any movement they detect and these cyborg arthropods are being flouted as a means of finding human survivors. 'RoboRoaches' – speculative infrastructures developed through venture capital – are already available commercially (Ghorayashi, 2014). This form of 'cyborg anatomo-politics' is about modulating other-than-humans' mediatic capacities, reorienting animal bodies into technologies for dealing with shocks and turbulence.

The biopolitics of managing human life via nonhumans is becoming even more poignant with the infiltration of resilience, a term connoting responses to shocks and volatile situations, into urban, economic and environmental policy and practice. Here, nonhuman infrastructures are meant to 'cancel out and absorb events' (Wakefield and Braun, 2019; p.203). Oysters used as a layered line of defense to lessen the impact of waves along New York's coastline, and California's herd of one-thousand goats keeping down vegetation to prevent wildfires (Rivas, 2019), are two actually-existing examples. Both work to mitigate the peculiar nature of contemporary risks seen to threaten not only human lives but other infrastructures including transportation systems, financial institutions and energy networks. Through their metabolic activities and passage into death, oysters *build* infrastructures. Growing in response to ocean levels and dissipating risks, oysters *become* infrastructure, albeit in a rambunctious manner for the fouling of ships increases as an unintended side-effect (Wakefield and Braun, 2019). In a similar vein, by keeping vegetation

levels down, goats generate resilience infrastructures. Like pipes, cables and meters, they become a technology of government, working to secure *human* life in the face of a turbulent future where wildfires loom.

Resilience infrastructures are part and parcel of emerging forms of neoliberal biopolitics that is 'catastrophist', one where 'the future is increasingly being cast as unpredictable and dangerous' and where 'preparedness' become the watchword (Amin, 2013; p.140). Assigned with keeping uncontrollable catastrophes at bay, oysters and goats reveal 'a new relation to being, time and politics'. They fulfill the political function of what Carl Schmitt called the *katechon*: 'the permanent management of the present to hold back the force of chaos' (Wakefield and Braun, 2019; p.202). Here, the promissory trope of infrastructure heralding new futures or Modernity itself, synonymous with the term ever since its first use in relation to railway construction in the 1870s (Gandy, 2014), is turned on its head. Resilience infrastructures do not herald the future: they function 'to ward it off' (Wakefield and Braun, 2019; p.203).

Whilst many infrastructures emerge from or create grounds for capitalist accumulation, there are others in a 'minor' mode (Deleuze and Guattari, 1986a), that exceed the logics of accumulation and provide openings for non-capitalist spaces or even more-than-human commons (Nading and Fisher, 2020). Taking cues from AbdouMaliq Simone's (2004) articulation of 'people as infrastructure' that highlights how acts of improvisation and coalition become vital in subtending economic activities, there is a small but emerging body of work that is beginning to show how collaborations with animals become infrastructural for those immiserated by urban life (Barua, 2020; Jaffe, 2019; Ragavan and Srivastava, 2020). In cities such as Delhi, relations forged with macaques are vital for some communities whose only means of income is selling bananas to devotees wanting to feed the animals. These banana vendors take great pains to ensure that macaques are within the vicinity of their stalls, for the latter

are consumers of the commodities transacted, and are vital agents enabling the realization of value. Human-macaque coalitions furnish a scaffold for economic relations to take grip (Barua, 2020). Similarly, affective bonds formed between people living in informal settlements and street dogs facilitate and provision security for the urban poor (Ragavan and Srivastava, 2020).

Although agencies at work might be diverse, what is common is that both sets of minor infrastructures entail forms of collaboration and improvisation that provide collective platforms for reproducing everyday life. Here, the mediatic capacities of nonhuman bodies are put to ends other than those of capitalist expansion: to generate 'alternate infrastructures of care' in the metropolis by tapping into 'the collective labours of diverse coalitions' both human and other-than-human (Alam and Houston, 2020; p.7). Furthermore, minor infrastructures make evident that there is nothing inherently capitalist or neoliberal about more-than-human infrastructures: they are amenable to capture but the latter does not always have to be the default position. As collective platforms, such infrastructures open up other possibilities for life, one that eschews capitalist biopower to herald forms of commoning (Gibson-Graham et al., 2016).

A wider infrastructural ontology

The main thrust of this paper, by moving beyond the usual suspects through which the grammar of infrastructure has come to be forged, has been to foreground a wider infrastructural ontology. The three interrelated themes – infrastructures as modalities of circulation, as a medium of life and the infrastructuring of nonhuman life – are less about bringing diverse agencies and potentials under a singular term and more to do with what is a plural conversation around infrastructure and how it might be opened up to the more-than-human, and on which it has significant bearings. Analytically, there is much shared between this approach and takes

on media infrastructures, STS and emergent multispecies ethnographies of infrastructure. However, an emphasis on differential forms of nonhuman agency, the immanence of nonhuman life and infrastructure, and the lively political economies associated with infrastructuring life, also marks its departure.

The paper has shown how this approach reveals a very different kind of understanding of the social, material and political life of infrastructures than those that are more anthropocentric in their outlook, and which gravitate toward built things, knowledge things and people things, thus pushing more familiar ideas on infrastructure in new and unexpected directions. This includes a re-evaluation of infrastructures as systems that forge worlds by accelerating mobilities (Larkin, 2013), to structures of contact and circulation that generate altered, cosmopolitan biogeographies, producing hypermobility and immobility of nonhumans at the same time. Furthermore, by unveiling the ways in which infrastructures become a medium of nonhuman, and not just human (Star, 1999), life, the paper front stages emerging forms of contemporary biopower that take nonhumans as its target. The concept of nonhuman habitus, refracted through the triad of repurposing, recombinance and reconciliation, provides a crucial analytic for understanding diverse the diverse agencies constituting life-infrastructure enmeshments and for parsing the different strategies of rendering life amenable to modulation and control. The deployment of infrastructures to administer life becomes even more poignant when moving from more-than-human geographies *of* infrastructure to *more-than-human infrastructures*, for not only does this reorient what constitutes infrastructure, but reveals a whole set of biopolitical and economic strategies at work glossed over by mainstream infrastructural scholarship and its emphasis on technologies of liberal government tethered to the human (Appel et al., 2018).

If infrastructures imply both things as well as a relation between things (Larkin,

2013), a wider infrastructural ontology broadens who or what composes these relations, expanding the ways through which infrastructures are relationally 'known' (Star, 1999), and adding a whole new raft of questions regarding infrastructural being, temporality and politics; one that sees infrastructures as emergent, continually folded into intra-actions with more-than-human company (Parks, 2017); one that locates infrastructuring as a continuous negotiation of the nature-infrastructure boundary where natural and infrastructural ecologies meld but also where infrastructures revert back to nature (Carse, 2019); one where the promissory Modernist trope of infrastructure (Gandy, 2014) is inverted into keeping the future at bay; and one where understandings of infrastructural improvisation, subtending everyday lives amidst precariousness (Simone, 2004), is opened to more-than-human collaborations. A wider ontology reworks the very notion of 'the infrastructural' and calls for very different forms of ethnographic and analytical rapprochement than those currently on record in geography and the wider social sciences.

What this means in terms of an established protocol or method cannot be reified, but a number of basics can be put in place. First, it invites analysis of the dynamics of nonhuman (im)mobility and flow, where long-standing engagements with cosmopolitan faunas (Clark, 2002; Crosby, 2004), can be brought into conversation with phenomenological takes on animals' mobilities (Hodgetts and Lorimer, 2018; Lulka, 2013), and the wider biopolitics of governing bio-circulations (Braun, 2007). Second, it draws attention to a whole new arena of planning and design that seek to administer other-than-human life and actualize worlds, whether in a mode that is techno-managerial (Grove et al., 2019), or cosmopolitical (Metzger, 2019). Here, further investment in understanding animals as mediatic bodies, how they sense infrastructural worlds and are being deployed as sensing infrastructures, can be generative. Such a programmatic would entail re-

invigorating more-than-human geography's inaugural concerns of attending to spaces of embodiment, motion and relation and how they are constituted through traffic at the feverish borders between human and animal, flesh and information, body and machine (Whatmore, 1999). Fourth, it demands taking seriously emerging trends of infrastructuring nonhuman life and the political economies surrounding vitality, an endeavour crucial for addressing calls for providing correctives to some of the new materialist accounts of agency that dispense with a critical politics in their recuperation of elusive material ecologies (Gandy and Jasper, 2017; Braun, 2015; Klinke, 2019). A wider infrastructural ontology can in fact furnish ground for another kind of politics where nonhuman life might subvert capitalist capture and or be opened up to form new coalitions for commoning.

Notes

1. Charting a wider ontology of infrastructure requires both conceptual innovation and a plural perspective that is not limited by an academically reified canon, largely because actually-existing conditions and developments are heterogeneous, not confined to any single set of domains. To this end, the paper builds cumulatively from a number of perspectives and, to the possible ire of purists, without necessarily lugging the baggage some of these concepts bring with them. This ambitious move is necessary for dealing with the promiscuity of the topic at hand: no single discipline or conceptual lineage on its own is sufficient. Of particular import are notions of infrastructuring developed in STS; non-hylomorphic understandings of the built environment drawn from architecture and anthropology; the concept of habitus in sociology; and cognate takes on sensing elucidated in critical phenomenology and media studies. What these concepts share in common is their relational grammar and they are put to work synthetically to query contemporary biopower and political economies of nature in novel, and often

unexpected, ways. For reasons of brevity, the paper curtails the scope of idiographic detail, and shifts the emphasis to the nomothetic in order to foster debate and chart avenues for further rapprochement.

2. I distinguish between cosmopolitan and cosmopolitics as follows: the former refers to a condition where biotic fauna become 'globalized' as a result of trans-territorial circulation (Barua, 2014); cosmopolitics on the other hand is about opening up the political from the narrow confines of give-and-take in an exclusive human club to a host of other-than-human interlocutors who co-configure political situations and outcomes (Stengers, 2010).

Funding

References

Alam A and Houston D (2020) Rethinking care as alternate infrastructure. *Cities* 100: https://doi.org/10.1016/j.cities.2020.102662.

Alper J (1998) Ecosystem "engineers" shape habitats for other species. *Science* 280(5367): 1195-1196.

Amin A (2013) Surviving the turbulent future. *Environment and Planning D: Society and Space* 31(1): 140-156.

Amin A (2014) Lively Infrastructure. *Theory, Culture & Society* 31(7-8): 137-161.

Amin A and Thrift N (2017) *Seeing Like a City.* Cambridge, UK: Polity Press.

Anand N (2015) Leaky States: Water Audits, Ignorance, and the Politics of Infrastructure. *Public Culture* 27(2 (76)): 305-330.

Anand N (2017) *Hydraulic city: Water and the infrastructures of citizenship in Mumbai.* Durham: Duke University Press.

Andrews KM, Nanjappa P and Riley SPD (2015) Roads and Ecological Infrastructure: Concepts and Applications for Smal Mammals. Baltimore: Johns Hopkins University Press.

Anon. (2011) Monkey tangle trips electricity supply. *Indian Express*, 26 June 2011.

Anon. (2016) *Kenya nationwide blackout caused by rogue monkey*. Available at: https://www.bbc.co.uk/news/world-africa-36475667 (accessed 23 October 2019).

Anon. (2018) Monkey entangled in telephone wire on 80-feet-tall tree rescued. *The Hindu*, 01 March 2018.

Appel H, Anand N and Gupta A (2018) Temporality, Politics and the Promise of Infrastructure. In: Anand N, Gupta A and Appel H (eds) *The Promise of Infrastructure*. Durham: Duke University Press, pp.1-40.

Austin JW, Glenn GJ and Gold RE (2008) Protecting Urban Infrastructure from Formosan Termite (Isoptera: Rhinotermitidae) Attack: A Case Study for United States Railroads. *Sociobiology* 51(1): 231-247.

Banoub D and Martin SJ (2020) Storing value: The infrastructural ecologies of commodity storage. *Environment and Planning D: Society and Space* DOI: 10.1177/0263775820911942.

Barry A (2013) *Material politics: Disputes along the pipeline.* Oxford: John Wiley & Sons.

Barua M (2011) Mobilizing metaphors: the popular use of keystone, flagship and umbrella species concepts. *Biodiversity and Conservation* 20: 1427-1440.

Barua M (2014) Circulating elephants: unpacking the geographies of a cosmopolitan animal. *Transactions of the Institute of British Geographers* 39(4): 559-573.

Barua M (2016) Lively Commodities and Encounter Value. *Environment and Planning D: Society and Space* 34(4): 725-744.

Barua M (2018a) *Animal Work: Metabolic, Ecological, Affective*. Available at: https://culanth.org/fieldsights/1504-animal-work-metabolic-ecological-affective (accessed 16/11/2018).

Barua M (2018b) Animating capital: work, commodities, circulation. *Progress in Human Geography* DOI: 10.1177/0309132518819057.

Barua M (2020) *Nonhuman Life as Infrastructure*. Available at: https://www.societyandspace.org/articles/nonhuman-life-as-infrastructure (accessed 19/12/2020).

Barua M and Sinha A (2017) Animating the urban: an ethological and geographical conversation. *Social & Cultural Geography* DOI: 10.1080/14649365.2017.1409908: 1-21.

Benítez-López A, Alkemade R and Verweij PA (2010) The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. *Biological Conservation* 143(6): 1307-1316.

Berlant L (2016) The commons: Infrastructures for troubling times. *Environment and Planning D: Society and Space* 34(3): 393-419.

Bourdieu P (1977) *Outline of a Theory of Practice.* Cambridge: Cambridge University Press.

Braun B (2007) Biopolitics and the molecularization of life. *Cultural Geographies* 14: 6-28.

Braun B (2015) New Materialisms and Neoliberal Natures. *Antipode* 47(1): 1-14.

Brockington D (2002) *Fortress Conservation: The Preservation of the Mkomazi Game Reserve, Tanzania.* Oxford: Currey.

Caldwell MR and Klip JMK (2020) Wildlife interactions within highway underpasses. *The Journal of Wildlife Management* 84(2): 227-236.

Capinha C, Essl F, Seebens H, et al. (2015) The dispersal of alien species redefines biogeography in the Anthropocene. *Science* 348(6240): 1248-1251.

Caro TM (2010) *Conservation by Proxy.* Washington DC: Island Press.

Carse A (2012) Nature as infrastructure: Making and managing the Panama Canal watershed. *Social Studies of Science* 42(4): 539-563.

Carse A (2019) Dirty Landscapes: How Weediness Indexes State Disinvestment and Global

Disconnection. In: Hethertington K (ed) *Infrastructure, Environment and Life in the Anthropocene.* Durham: Duke University Press, pp.97-114.

Clark N (2002) The Demon Seed: Bioinvasion as the Unsettling of Environmental Cosmopolitanism. *Theory, Culture & Society* 19(1-2): 101-125.

Clark N (2013) Mobile Life: Biosecurity Practices and Insect Globalization. *Science as Culture* 22(1): 16-37.

Cresswell T (2012) Mobilities II: still. *Progress in Human Geography* 36(5): 645-653.

Cresswell T (2014) Mobilities III: Moving on. *Progress in Human Geography* 38(5): 712-721.

Criqui L (2016) Delhi: Questioning Urban Planning the Electrification of Irregular Settlements. In: Luque-Ayala A and Silver J (eds) *Energy, power and protest: geographies of the electric city*. Abingdon and New York: Routledge, pp.86-111.

Crosby AW (2004) *Ecological imperialism: the biological expansion of Europe, 900-1900.* Cambridge: Cambridge University Press.

Deleuze G (1995) *Negotiations.* New York: Columbia University Press.

Deleuze G and Guattari F (1986a) *Kafka: Toward a Minor Literature.* Minneapolis, MN: University of Minnesota Press.

Deleuze G and Guattari F (1986b) *Nomadology: the war machine.* New York: Semiotext(e).

Doherty J (2019) Filthy Flourishing: Para-Sites, Animal Infrastructure, and the Waste Frontier in Kampala. *Current Anthropology* 60(S20): S321-S332.

Duffy R (2013) The international political economy of tourism and the neoliberalisation of nature: Challenges posed by selling close interactions with animals. *Review of International Political Economy* 20(3): 605-626.

Easterling K (2014) *Subtraction.* Berlin: Sternberg Press.

Ernwein M (2017) Urban Agriculture and the Neoliberalisation of What? *ACME: An International Journal for Critical Geographies* 16(2): 249-275.

Federici S (2004) *Caliban and the Witch: Women, the Body, and Primitive*

Accumulation. Brooklyn, NY: Autonomedia.

Foucault M (1998) *The History of Sexuality: The Will to Knowledge, Vol 1.* New York: Penguin.

Foucault M (2000) *Power: Essential Works of Michel Foucault, 1954-1984.* New York: The New Press.

Francis RA and Lorimer J (2011) Urban reconciliation ecology: The potential of living roofs and walls. *Journal of Environmental Management* 92(6): 1429-1437.

Furlong K (2011) Small technologies, big change: Rethinking infrastructure through STS and geography. *Progress in Human Geography* 35(4): 460-482.

Gabriel N (2016) "No place for wilderness": Urban parks and the assembling of neoliberal urban governance. *Urban Forestry & Urban Greening* 19: 278-284.

Gabrys J (2014) Programming Environments: Environmentality and Citizen Sensing in the Smart City. *Environment and Planning D: Society and Space* 32(1): 30-48.

Gandy M (2013a) Entropy by design: Gilles Clément, Parc Henri Matisse and the Limits to Avant-garde Urbanism. *International Journal of Urban and Regional Research* 37(1): 259-278.

Gandy M (2013b) Marginalia: Aesthetics, ecology, and urban wastelands. *Annals of the Association of American Geographers* 103(6): 1301-1316.

Gandy M (2014) *The Fabric of Space: Water, Modernity and the Urban Imagination.* Cambridge, Massachusetts: MIT Press.

Gandy M (2016) Unintentional Landscapes. *Landscape Research* 41(4): 433-440.

Gandy M (2017) Habitat and Living in Plural Cities: a Critical Reflection. Reportno. Report Number|, Date. Place Published|: Institution|.

Gandy M and Jasper S (2017) Geography, materialism, and the neo-vitalist turn. *Dialogues in Human Geography* 7(2): 140-144.

Ghorayashi A (2014) *Cyborg cockroaches home in on sounds of distress*. Available at: https://www.newscientist.com/article/dn26525-cyborg-cockroaches-home-in-on-sounds-of-distress/ (accessed 23/10/2019).

Gibson-Graham JK, Cameron J and Healy S (2016) Commoning as postcapitalist politics. In: Amin A and Howell P (eds) *Releasing the Commons: Rethinking the futures of the commons*. London and New York: Routledge, pp.192-212.

Goldfarb B (2018) Beavers, rebooted. *Science* 360(6393): 1059-1061.

Graham S (2010) Disrupted cities: When infrastructure fails. Abingdon, Oxford: Routledge.

Graham S and Marvin S (2002) *Splintering urbanism: networked infrastructures, technological mobilities and the urban condition.* Abingdon, Oxford: Routledge.

Grove K, Krivý M, Rickards L, et al. (2019) Interventions on design and political geography. *Political Geography*. https://doi.org/10.1016/j.polgeo.2019.1004.1009.

Guattari F (1995) *Chaosmosis: An Ethico-aesthetic Paradigm.* Bloomington: Indiana University Press.

Gutgutia S (2020) *Pigs, Precarity and Infrastructure*. Available at: https://www.societyandspace.org/articles/pigs-precarity-and-infrastructure (accessed 19/12/2020).

Haraway D (1991) *Simians, Cyborgs, and Women: The Reinvention of Nature.* London: Free Association Books.

Haraway D (2015) Anthropocene, capitalocene, plantationocene, chthulucene: Making kin. *Environmental Humanities* 6(1): 159-165.

Haraway D (2016) *Staying with the trouble: making kin in the Chthulucene.* Durham: Duke University Press.

Harvey D (2012a) *Rebel cities: From the right to the city to the urban revolution.* London: Verso.

Harvey P (2012b) The topological quality of infrastructural relation: An ethnographic approach. *Theory, Culture & Society* 29(4-5): 76-92.

Harvey P and Knox H (2012) The enchantments of infrastructure. *Mobilities* 7(4): 521-536.

Harvey P and Knox H (2015) *Roads: Ann anthropology of infrastructure and*

expertise. Ithaca, NY: Cornell University Press.

Hinchliffe S (2003) Inhabiting: landscapes and natures. In: Anderson K, Domosh M, Pile S, et al. (eds) *The Handbook of Cultural Geography.* London: Sage, pp.207-226.

Hodgetts T and Lorimer J (2018) Animals' mobilities. *Progress in Human Geography*. DOI: 10.1177/0309132518817829. DOI: 10.1177/0309132518817829.

Holder S (2018) *Animals need infrastructure too.* Available at: https://www.citylab.com/life/2018/07/wildlife-crossings-bridges-tunnels-animals-roads-highways-roadkill/566210/ (accessed 23/10/2019).

Hulme PE (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology* 46(1): 10-18.

Ingold T (2013) *Making: Anthropology, archaeology, art and architecture.* Abingdon, Oxford: Routledge.

Jaffe R (2019) Urban uncertainty and animals-as-infrastructure. In: Silver J and Meth P (eds) *Speculative Infrastructure and cities-in-the-making*. Sheffield: Urban Institute/SIID, pp.49-50.

Jasper S (2018) Sonic refugia: nature, noise abatement and landscape design in West Berlin. *The Journal of Architecture* 23(6): 936-960.

Jasper S (2020) *Abandoned Infrastructures and Nonhuman Life*. Available at: https://www.societyandspace.org/articles/abandoned-infrastructures-and-nonhuman-life (accessed 19/12/2020).

Johnson CJ, Venter O, Ray JC, et al. (2019) Growth-incuding infrastructure represents transformative yet ignored keystone environmental decisions. *Conservation Letters* DOI: 10.1111/conl.12696.

Khan N (2016) Immobility. In: Salazar N and Jayaram K (eds) *Keywords of Mobility: Critical Engagements*. Oxford: Berghahn, pp.93-112.

Klinke I (2019) Vitalist temptations: Life, earth and the nature of war. *Political Geography* 72: 1-9.

Kumar R, Radhakrishna S and Sinha A (2011) Of least concern? Range extension by rhesus macaques *(Macaca mulatta)* threatens long-term survival of bonnet macaques *(M. radiata)* in peninsular India. *International Journal of Primatology* 32: 945-959.

Kumar R, Sinha A and Radhakrishna S (2013) Comparative Demography of Two Commensal Macaques in India: Implications for Population Status and Conservation. *Folia Primatologica* 84: 384-393.

Larkin B (2008) *Signal and Noise: Media, Infrastructure, and Urban Culture in Nigeria.* Durham, NC: Duke University Press.

Larkin B (2013) The politics and poetics of infrastructure. *Annual Review of Anthropology* 42: 327-343.

Laurance WF and Arrea IB (2017) Roads to riches or ruin? *Science* 358(6362): 442-444.

Lawhon M, Nilsson D, Silver J, et al. (2018) Thinking through heterogeneous infrastructure configurations. *Urban Studies* 55(4): 720-732.

Lemanski C (2020) Infrastructural citizenship: The everyday citizenships of adapting and/or destroying public infrastructure in Cape Town, South Africa. *Transactions of the Institute of British Geographers* DOI: 10.1111/tran.12370.

Lemke T (2011) *Biopolitics: An advanced introduction.* New York and London: NYU Press.

Lemke T (2015) New Materialisms: Foucault and the 'Government of Things'. *Theory, Culture & Society* 32(4): 3-25.

Lorimer J (2010) Elephants as companion species: the lively biogeographies of Asian elephant conservation in Sri Lanka. *Transactions of the Institute of British Geographers* 35: 491-506.

Lorimer J, Hodgetts T and Barua M (2017) Animals' atmospheres. *Progress in Human Geography* DOI: 10.1177/0309132517731254.

Lulka D (2013) The Posthuman City: San Diego's Dead Animal Removal Programme. *Urban Geography* 34(8): 1119-1143.

Lundholm J (2015) The ecology and evolution of constructed ecosystems as green infrastructure. *Frontiers in Ecology and Evolution* 3(106): 1-7.

Luque-Ayala A and Silver J (2016) Energy, Power and Protest on the Urban Grid. *Energy, power and protest: geographies of the electric city.* Abingdon and New York: Routledge.

Manaugh G (2015) *New Urbanist: Our infrastructure is expanding to include animals.* Available at: https://www.newscientist.com/article/dn27465-new-urbanist-our-infrastructure-is-expanding-to-include-animals/ (accessed 23/10/2019).

Margonelli L (2018) *Underbug: an obsessive tale of termites and technology.* New York: Scientific American.

Martin C (2016) *Shipping Container.* London: Bloomsbury.

McFarlane C and Silver J (2017) Navigating the city: dialectics of everyday urbanism. *Transactions of the Institute of British Geographers* 42(3): 458-471.

Metzger J (2014) The moose are protesting: The more-than-human politics of transport infrastructure development. In: Metzger J, Allmendinger P and Oosterlynck S (eds) *Planning against the Political.* New York: Routledge, pp.203-226.

Metzger J (2016) Cultivating torment: The cosmopolitics of more-than-human urban planning. *City* 20(4): 581-601.

Metzger J (2019) A more-than-human approach to environmental planning. In: Davoudi S, Cowell R, White I, et al. (eds) *The Routledge Companion to Environmental Planning.* London: Taylor and Francis, pp.190-199.

Meurk CD (2011) Recombinant ecology of urban areas: characterization, context and creativity. In: Douglas I, Goode D, Houck M, et al. (eds) *The Routledge Handbook of Urban Ecology.* Abingdon, Oxon.: Routledge, pp.198-220.

Mitchell T (2002) *Rule of experts: Egypt, techno-politics, modernity.* Berkeley and Los Angeles, California: University of California Press.

Munshi-South J and Nagy C (2014) Urban park characteristics, genetic variation, and historical demography of white-footed mouse (Peromyscus leucopus) populations in New York City. *PeerJ* 2: e310.

Murphy M (2013) *Distributed Reproduction, Chemical Violence, and Latency.* Available at: http://sfonline.barnard.edu/life-un-ltd-feminism-bioscience-race/distributed-reproduction-chemical-violence-and-latency/ (accessed 23/10/2019).

Murphy M (2017) Alterlife and decolonial chemical relations. *Cultural Anthropology* 32(4): 494-503.

Nading A and Fisher J (2020) *Family Trees.* Available at: https://www.societyandspace.org/articles/family-trees (accessed 19/12/2020).

Negri A (2017) *Marx and Foucault: Essays Volume 1.* Cambridge, UK: Polity Press.

Paddock RC and Suhartono M (2020) *As Tourism Plummets in Thailand, Elephants Are Out of Work, Too.* Available at: https://www.nytimes.com/2020/03/24/world/asia/coronavirus-thailand-elephants.html (accessed 20/05/2020).

Parikka J (2010) *Insect media: An archaeology of animals and technology.* Minnesota: University of Minnesota Press.

Parikka J (2013) Insects and canaries: Medianatures and aesthetics of the invisible. *Angelaki* 18(1): 107-119.

Parks L (2017) Mediating Animal-Infrastructure Relations. In: Boucher M-P, Helmreich S, Kinney LW, et al. (eds) *Being Material.* Cambridge, MA: MIT Press, pp.144-153.

Parks L and Starosielski N (2015) Signal traffic: Critical studies of media infrastructures. Urbana, Chicago and Springfield: University of Illinois Press.

Pattemore DE and Wilcove DS (2012) Invasive rats and recent colonist birds partially compensate for the loss of endemic New Zealand pollinators. *Proceedings of the Royal Society B: Biological Sciences* 279(1733): 1597-1605.

Rademacher A (2018) Urban Political Ecology. *Annual Review of Anthropology* 44: 137-152.

Ragavan S and Srivastava S (2020) *Commoning Infrastructure*. Available at: https://www.societyandspace.org/articles/commoning-infrastructures (accessed 30/11/2020).

Rajan KS (2006) *Biocapital: The constitution of postgenomic life.* Durham and London: Duke University Press.

Rest M and Rippa A (2019) Road animism: Reflections on the life of infrastructures. *Hau: journal of ethnographic theory* 9(2): 373-389.

Ricciardi A (2007) Are modern biological invasions an unprecedented form of global change? *Conservation Biology* 21(2): 329-336.

Rivas K (2019) Over 1,000 goats needed to clear dry brush from California to help prevent wildfires. *ABC News*, 18 October 2019, https://abcnews.go.com/US/1000-goats-needed-clear-dry-brush-california-prevent/story?id=66368853.

Robbins P (2004) COMPARING INVASIVE NETWORKS: CULTURAL AND POLITICAL BIOGRAPHIES OF INVASIVE SPECIES*. *Geographical Review* 94(2): 139-156.

Rosenzweig M (2003) *Win-win Ecology: How the Earth's Species can Survive in the Midst of Human Enterprise.* Oxford, UK.: Oxford University Press.

Rotherham ID (2017) *Recombinant ecology-a hybrid future?* Dodrecht, the Netherlands: Springer.

Saha J (2017) Colonizing elephants: animal agency, undead capital and imperial science in British Burma. *BJHS Themes* 2: 169-189.

Schilthuizen M (2019) *Darwin comes to town: How the urban jungle drives evolution.* London: Quercus Editions.

Scott JC (1998) *Seeing like a state: How certain schemes to improve the human condition have failed.* New Haven, Connecticut: Yale University Press.

Simberloff D, Martin J-L, Genovesi P, et al. (2012) Impacts of biological invasions: what's what and the way forward. *Trends in Ecology & Evolution* 28(1): 58-66.

Simone A (2004) People as Infrastructure: Intersecting Fragments in Johannesburg. *Public Culture* 16(3): 407-429.

Sinha A (2005) Not in their genes: Phenotypic flexibility, behavioural traditions and cultural evolution in wild bonnet macaques. *Journal of Biosciences* 30(1): 51-64.

Smailbegović A (2015) AFFECTIVE ETHOLOGIES: monk parakeets and non-human inflections in affect theory. *Angelaki* 20(3): 21-42.

Stallins JA and Kelley L (2013) The Embeddedness of a North American Snake in the Wildlife Pet Trade and the Production of Assemblage Biogeographies. *Annals of the Association of American Geographers* dx.doi.org/10.1080/00045608.2013.765770.

Star SL (1999) The ethnography of infrastructure. *American behavioral scientist* 43(3): 377-391.

Stengers I (2010) *Cosmopolitics I.* Minneapolis, MN: University of Minnesota Press.

Streftaris N, Zenetos A and Papathanassiou E (2005) Globalisation in marine ecosystems: the story of non-indigenous marine species across European seas. *Annual Review of Oceanography and Marine Biology* 43: 419-453.

Su N-Y and Scheffrahn RH (2000) Termites as pests of buildings. In: Abe T, Bignell DE and Higashi M (eds) *Termies: Evolution, Sociality, Symbioses, Ecology*. Dordrecht and London: Kluwer Academic Publishers, pp.437-453.

Van Der Ree R, Smith DJ and Grilo C (2015) *Handbook of Road Ecology.* Oxford: John Wiley & Sons.

von Schnitzler A (2018) Infrastructure, Apartheid Technopolitics, and Temporalities of "Transition". In: Anand N, Gupta A and Appel H (eds) *The Promise of Infrastructure*. Durham: Duke University Press, pp.133-154.

Wadiwel D (2018) Chicken Harvesting Machine: Animal Labor, Resistance, and the Time of Production. *The South Atlantic Quarterly* 117(3): 527-549.

Wakefield S and Braun B (2019) Oystertecture: Infrastructure, Profanation, and the Sacred Figure of the Human. In: Hethertington K (ed) *Infrastructure,*

Environment and Life in the Anthropocene. Durham: Duke University Press, pp.193-215.

Whatmore S (1999) Hybrid Geographies: Rethinking the 'Human' in Human Geography. In: Massey D, Allen J and Sarre P (eds) *Human Geography Today.* Cambridge: Polity, pp.22-40.

Whatmore S (2009) Mapping knowledge controversies: science, democracy and the redistribution of expertise. *Progress in Human Geography* 33(5): 587-599.

Whatmore S and Hinchliffe S (2012) Ecological Landscapes. In: Hicks D and Beaudry MC (eds) *The Oxford Handbook of Material Culture Studies.* Oxford: Oxford University Press, pp.DOI: 10.1093/oxfordhb/9780199218714.9 780199218013.9780199210019.

White T (2020) *Road Ecology.* Available at: https://www.societyandspace.org/art icles/road-ecology (accessed 19/12/2020).

Zhang A (2020) Circularity and Enclosures: Metabolizing Waste with the Black Soldier Fly. *Cultural Anthropology* 35(1): 74-103.