Animals' mobilities

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Abstract
This paper draws together animal and mobility studies to develop the concept of animals' mobilities. It identifies the parallel intellectual interests in these fields that provide the intellectual foundations for this synthesis, in: mobility (over movement), affect, relational space, and ordering practices. It explores what configures an animals' mobility, knowledge practices for researching and evoking animals' mobilities, and how animals' mobilities are governed. The conclusion highlights what these fields gain from this synthesis, and identifies the empirical, political and conceptual contributions that this concept makes to geographical research. The argument is illustrated with examples of large, terrestrial mammals, especially bears.

Moving animals

The home range of a polar bear can exceed 350 000 square km. Bears can travel over 30 km a day for many days in a row and have been known to swim over 100 km. They move with the seasons, can go several months without eating, and live in diverse social and spatial formations (Mulvaney, 2011). Some polar bears have learnt to forage at garbage dumps. They come into conflict with people and have been subject to translocation and training programmes designed to remove, deter, or train troublesome animals (Archibald, 2017). Polar bears are charismatic animals and popular subjects for safaris and zoos. Knut – a polar bear born at Berlin zoo in 2004 – increased visitor numbers by 30% and generated €5m in revenue (Espinoza, 2008). Yet bears often fare poorly in captivity. They pace repeated loops around their enclosures. Many get hot, fat, and bored. Some are given antidepressants, and they often die young (Clubb and Mason, 2003).

This paper continues our series on concepts for animals' geographies. The apostrophe is important. We use it to foreground a distinction between considerations of how animals have been spaced by humans, and animals' own lived geographies and experiences. We follow the distinction made by Philo and Wilbert (2000) at the re-founding of the field of animal geography, between 'animal spaces' and 'beastly places', while noting the marked emphasis on the former (how animals are spaced by human actions) within animal geography research during much of the past two decades (Hodgetts and Lorimer, 2014). In a previous paper (Lorimer et al., 2018), we developed the concept of animals' atmospheres to describe the affective intensities that shape animals' lives. In this paper we turn to the concept of animals' mobilities.

In doing so we develop a conceptual approach that prioritises the lived patterns and embodied experiences of animals. Animals' mobilities extends the concept of mobilities to animals by first asking how animal movements are shaped by human actions (Adey, 2017; Bull, 2011). Whereas the notion of animal 'movement' in biology simply describes a shift in spatial coordinates, 'mobility' refers to the politics (and ethics) of animal movement (or stillness). That is, the conceptual shift from 'movement' to 'mobilities' recognises that animal movements are always produced within (and are productive of) relations of power between various actors. But, second, the notion of mobility in human-focussed geographies goes further, emphasizing not only how movements are shaped, but also how the resulting mobilities are experienced and gain meaning. It might be assumed that extending the

concept of mobility to animals would automatically emphasize these embodied and lived experiences. But given the historical tendency to overlook animal subjectivity in accounts of their geographies, we emphasize this facet of mobilities with an apostrophe. We suggest a tactical distinction might be made between *animal mobilities* and *animals' mobilities* (see Table 1), where the latter (with the apostrophe) emphasizes how movement (or its lack) is experienced by animals themselves. We recognise that animal and animals' mobilities are inherently interwoven in the ubiquitous, anthropogenic ecologies of the Anthropocene. In this paper, however, we focus primarily on animals' mobilities, as they are less developed in the geographical literatures.

Table 1. Concepts of Animal Movement and Mobilities

Animal movements	**Animal mobilities** *Tactical distinction made herein between:*	
	Animal mobilities	**Animals' mobilities**
Animal shifts in Euclidean space	The movement (or stillness) of animals as shaped by the actions of various actors, particularly humans.	The embodied, affective, and lived animal experience of mobilities

We first introduce animal and mobility studies, tracking four parallel developments that provide foundations for intellectual synthesis. Readers desiring a fuller treatment of these two fields might explore progress reports published in this journal (Cresswell, 2011; 2012; 2014; Merriman, 2015; 2016; 2017; Buller, 2014; 2015a; 2015b) as well as book-length treatments (Cresswell, 2006; Urry, 2007; Urbanik, 2012; Adey, 2017). We next present the concept of animals' mobilities in three parts, which outline: i) what configures an animal's mobility; ii) knowledge practices for researching and evoking animals' mobilities; and iii) how animals' mobilities are governed. In conclusion, we demonstrate that both animal and mobility studies have much to gain from this encounter and identify three contributions that the concept of animals' mobilities makes to geography. The paper focuses on large,

terrestrial mammals, especially bears, elephants, and wolves. There are limitations that arise from this decision. But this focus on familiar animals, with similar biologies and geographies to humans, provides the readiest means for illustrating our concept. We hope this paper provokes future investigations of more alien animals' mobilities.

Mobility studies and animal studies

Mobility and animal studies have experienced a comparable rise to prominence over the last 30 years. They have shared in, and been marked by, conceptual turns that cut across the social sciences. It is surprising, therefore, that conversations and cross-fertilisation between these two fields have been rather limited. Here we identify four areas where this parallel evolution seems most striking, and where we see most promise for future development. We focus on shared concerns with: i) mobility, over movement; ii) affect; iii) relational understandings of space; and iv) ordering practices.

From movement to mobility

In spite of its theoretical heterogeneity (Adey, 2009), mobilities scholarship is united by an understanding that mobility is not a mere synonym for movement (Cresswell, 2010). Whilst attending to the manner, styles, capacities for and impediments to movement led to important insights in human geography, a focus on mobilities also emphasizes the various forms of cultural meaning that cohere in and through such processes (Cresswell, 2006). Mobilities are thus movements and stillnesses that are socially shaped, experienced (by human actors, in most accounts), and that have meanings for those involved. Movement is a term now reserved for shifts in Euclidean space, understood in terms of spatial coordinates. In a similar fashion, much work in animal studies[i] takes issue with the approaches to animal movement that were prevalent in 20th century zoology. While these have provided rich means for understanding aggregate autonomous animal movements (that we draw on below), critics argue that they are premised on mechanistic models of behaviour that do not account for animals' subjective interpretation and experience of movement and stasis (Bekoff, 2002; Ingold, 2011; cf Adey 2008 on reductionist understandings of human movement). Recent work in animal studies starts from the premise that animals inhabit meaningful worlds, and in so doing it rejects the essentialist claim of humanist epistemologies that meaning is the sole preserve of human subjects. It recognises the

hermeneutic capacities of animal life and the rich social lifeworlds in which animals are entangled (Despret and Buchanan, 2016; de Waal, 2016). While this work has done much to foreground animals' lived experience, it has yet to engage explicitly with the concept of animals' mobilities (though see Hodgetts, 2017).

Affect

A second, related concern that links mobility and animal studies is with the non-representational dimensions of human and animal life, and how these come to shape, and be shaped by, mobilities. Work in mobility studies has been central to the development of the geographies of affect (McCormack, 2014) and has focused on the multisensory, embodied practices, skills, and experience of different modes of moving – from walking to aeromobility (Adey et al., 2014). This work has attended to the lived experiences of disability, immobility and spatial exclusion (Hall and Wilton, 2017). It has mapped the affective intensities that shape mobilities across a range of places and the 'interspaces' through which they are connected (Adey et al., 2013). In these accounts, the affective dimensions of mobility emerge from encounters within material assemblages (see below). And only a limited subset of the materials that configure affect and shape meaning are understood to require the textual modes of representation (books, films, etc.) that were so central to previous forms of humanist enquiry. Such concerns with assemblages, affect, and the non-representational dimensions of life have also become central to work in animal studies and animal geography, as these fields underwent a parallel shift away from the textual focus of the cultural turn (Whatmore, 2006; Weil, 2006). This turn to affect in thinking about animals' mobilities is best illustrated in work that explores proximal, multispecies modes of cohabitation and captivity, especially those premised on choreographed human-animal movements; for example, as found in studies of animals as transport (Game, 2001), livestock (H Lorimer, 2006), pets (Goode, 2007), and as sensory prostheses (Hodgetts and Hester, 2017). This turn to affect in animal studies is especially indebted to feminist scholarship on the geographies of embodiment and encounter, especially Haraway's (2008) writings on laboratory animals (see Greenhough and Roe 2011). While the focus of this work still tends to be the human subject, some attention has been paid to the shared and contrasting ways in which animals' mobilities (and immobilities) are felt and made meaningful.

Relational space

Mobility and animal studies are concerned with the ways in which spaces are enacted (often unequally) by different groups of actors (Cresswell, 2006; Philo and Wilbert, 2000). Concepts and methods have been developed for 'following the things' – tracing the passage of a range of human and nonhuman actors along the networks of globalisation (Cook, 2004). A key concept here is the assemblage: an expansive new materialist term that seeks to capture the socio-technical ecologies in and through which human and animal lives move. This work is concerned ultimately with questions of topology – mapping the different, but interrelated, spatial formations and temporal rhythms along which bodies move, and within which human and animal mobilities are enabled and constrained (Murdoch, 2006; Whatmore, 2002). A shift from movement to mobility is strongly associated with a pluralisation of conceptions of space. This departs from a 'regional' or 'Cartesian' understanding to recognise more reticular and volumetric topologies, as well as those configured by different socio-ecological intensities (Hinchliffe, 2007). In mapping assemblages, mobilities theory has focused on the agency of nonhuman actors (mostly technologies) in co-configuring the spatialities of human movement (Merriman, 2016). Assemblage tracing in animal studies focuses on the circulation of disembodied animal representations, body parts or incarcerated specimens and is concerned with the networks (and other topological forms) along which animals travel (Whatmore and Thorne 2000). This work explores how mobile animals shape human mobilities, and how they transgress human bordering practices (Philo and Wilbert 2000; Dobson et al 2013). Others have addressed the rhythms and intensities of human-animal (and especially microbial) relations in farms and cities, mapping hotspots of human-animal interaction that account for the emergence of novel ecologies, often with pathological potential (Hinchliffe et al., 2016; Brown and Kelly, 2014). Strands of this work engage critically with zoological methods for tracking aggregate animal movements (Keck, 2015).

Ordering practices

A final, shared concern is with the spatial ordering (or bordering) practices that come to configure differential human and animal mobilities. Mobility and animal studies have conceived spatial power with reference to concepts from political economy, for example in

work on intensive agriculture (Hinchliffe et al., 2016; Neo and Emel, 2017). This includes a growing interest in the concepts of animal capital, work, and labour (Barua, 2017; Blanchette, 2015; Shukin, 2009). But these fields have arguably been more strongly influenced by engagements with the work of Michel Foucault and Gilles Deleuze, and the concepts these theorists offer for understanding the ordering of movement or the processes of territorialisation. To paraphrase extensive literatures, we can identify three post-structuralist approaches to ordering practices that have had most influence on the relational approaches to mobility and animal studies we introduce above. The first is forms of sovereign power, associated with the totalising control over the movement of life. The second is disciplinary power and the forms of governmentality through which the mobilities of individual human and animal subjects are enabled and constrained. The third is with modes of biopolitics, in which the mobilities of aggregations of human and animal bodies are governed as part of broader programmes for making live and letting die. These include an emergent, shared concern with environmental modes of biopower in which political attention is directed towards modulating the circulation of socio-ecological systems to deliver systemic properties like resilience, growth, biosecurity, and ecosystem services. We expand, reference, and develop this tripartite framework in the section on governing animals' mobilities below.

What configures animals' mobilities

In this section we present a typology of factors that configure animals' mobilities (table 2), that builds on the ontology of animals that we outlined in our previous paper on animals' atmospheres (Lorimer et al., 2018). We draw on insights from the field of movement ecology (Nathan et al., 2008), beginning with the animal subject, before moving out to explore an animal's collective zoological circumstances, and their ecological and abiotic context.

Analytical focus	Factor configuring mobilities
Animal subject	Bodily capacities
	Emotional experience

	Evolutionary and life history
Collective circumstances	Social relations
	Trophic relations
	Territories
Ecological and abiotic context	Habitat and infrastructure
	Climate / weather
	Atmosphere

Table 2. A list of factors that configure an animal's mobility

Animal subject

Our model of animals' mobilities requires an animal subject – that is, an animal that moves in relation to a world, is directed by extraneous influences, and experiences that movement subjectively. Elsewhere we (and others in animal studies) have outlined a model of animal subjectivity that focuses on an animal's umwelt, a concept which describes the affective relations between an organism and its environment that configure the possibilities and character of an animal's mobility (J Lorimer, 2007; H Lorimer, 2010; Adams, 2016). To describe an animal's umwelt, we need to understand the composition, comportment, and capacities of an animal's body.

Movement ecology provides us with rich means of identifying the properties of an animal that configure its motion capacity. We can start with the role played by animal anatomy and physiology, in particular their means of travel (legs, wings, fins, claws, etc.). For example, American black bears have a physiology that enables them to climb trees (a combination of effective claws and the right power to weight ratio); brown bears in North America, by contrast, are rarely able to follow (being too heavy) (Wilson and Mittermeier, 2009). Animals' bodies shape their ability to withstand varying climatic (cold, heat, wet and dry) and elemental (air, water, land) conditions (possession of lungs and gills). The cold of the boreal forest acts as a barrier for many animals, but those with thick fur may move with ease, and polar bears can even swim in freezing Arctic waters due to their dense fur and a

thick layer of fat (Stirling, 1998). An animal's diet, metabolism and life-cycle also enable or prevent its passage through diverse habitats, or the endurance of climatic extremes (via hibernation, metamorphosis, etc.). Animals use a panoply of senses to locate themselves and to navigate within their environments, by tracking a scent, orientating by the sun, or attuning to the earth's magnetic fields, for example. Bears have particularly effective olfactory capacities. Brown bears can track the scent of a carcass from miles away, while polar bears can smell seals through thick sea ice (Stirling, 1998).

Animal behaviourists study how movement is configured by differences in animals' cognitive abilities. They focus on spatial aptitudes and spatial memory, as well as an animal's bravery and curiosity (or neophilia/neophobia). They explore how these influence its reactions to an unfamiliar encounter – for example with a human or a piece of human infrastructure – and thus its ranging patterns in anthropogenic environments. The intensity and character of an animals' subjective experience of these movements will be affected by a range of cognitive factors that configure whether, and in what form, it experiences emotions. Animal emotion is a long-standing but contested field (Darwin, 1872; Dawkins, 2012). Many ethologists now accept that 'high-order' animals can experience a range of emotional states, including pain, pleasure, boredom, joy, grief, anger, and surprise (Bekoff, 2007), and research on captive animals has demonstrated that these emotions can be elicited by controlling an animal's movement. Differences in emotional responses will partly configure the contrasting experience of captivity for different species of bears (Clubb and Mason 2003; 2004).

Past animal movements come to shape future mobilities, on a range of temporal scales. Patterns of migration or hibernation may be evolved strategies for coping with climate variation (Nathan et al., 2008). Restrictions to these movements (like fencing or captivity) can cause an animal distress, even when the movement no longer serves a functional purpose. Animals' mobilities are also shaped by remembered life course experiences. Many animals learn to avoid sites associated with undesirable experiences – like predation or noise – and remember places associated with easy food provision – like garbage dumps or feeding stations for bears (Archibald, 2017). Elephant matriarchs learn the location of waterholes over many years of movement and are able to guide their families to little used-sources in times of drought. They also perform less obviously instrumental mobilities,

remembering where relatives die and returning to these 'graveyards' for communal acts of grieving (Bradshaw, 2009).

Collective circumstances

Animals' mobilities emerge from within dynamic social worlds and trophic relations that become territorialised in distinct animal places. We take these concepts of animals' sociabilities, trophic relations and territories in turn. Some animals live and move in spatially-compact assemblages that might be understood as 'societies' (Rubenstein and Kealey, 2010). Others live in scattered communities that only aggregate to breed, or perhaps to feed at abundant sites. Such groups are no less 'social', but theirs is a more spatially-diffuse from of sociality. Some animals live collectively in their youth, such as the many species of bear where the young tend to stay with their mothers for many months before dispersing, but then live more solitary lives in adulthood (Nowak and Walker, 1999). Others stay together for life; some go it alone from the get-go. The experience is often different for male and female animals. These sociabilities (or different forms of social living) reflect tendencies at the level of the species but can mask differences between individual animals. There are lone wanderers amongst the most gregarious species, and tight clans even amongst the independent. These social geographies come to configure animals' desires for companionship and/or solitude. They can have important emotional consequences, creating situations of boredom and loneliness when companions are missing, as well as anxiety amongst crowds or in close confinement with a dominant other.

The mobilities of any set of animals in the same location will also be strongly configured by their trophic relations, or position in the food chain. Animal interactions are characterised by a wide range of commensal, mutualistic, and parasitic relations with other animals (including humans). For example, the spatially overlapping mobilities of prey species (e.g. large herbivores) and predator species (e.g. large carnivores) will be meaningfully different based on their experience of hunting or being hunted (Berger 2009). Herbivores perform very different spatio-temporal rhythms for feeding, sleeping and socialising in the known absence of predators (Laundre et al., 2014), while those confined too close to their predators experience anxiety. The influence of such trophic relations on animals' mobilities is most starkly illustrated in multi-species societies in which humans are the 'apex predator'.

Some anthropologists suggest that domestication was the result of mutualistic relations between humans and a subset of an animal species that was best able to align its movements with those of an agricultural society and to temper its fear of people. They demonstrate that the gradual establishment of geographically settled human communities was enabled by, and reflected in, the selective breeding of animals to modulate, restrict, or remove their free-ranging tendencies (Clutton-Brock, 1999).

These social and trophic relations congeal to form animals' territories, which shape animals' mobilities. In biology, a territory is a selectively exclusive place that is created and enforced by an animal (Potts and Lewis, 2014). Territorial practices include signposting and scent-marking, border enforcement, and threats or acts of violence. Such practices can comprise a significant part of, and rationale for, many animals' daily movements. The detection, and subsequent circumvention or wilful transgression of another animals' territory will likely strongly configure an animals' experience of movement within a particular place. Another animals' territory can generate an ecology of fear, of curiosity or of anger, depending on the trophic and social relations involved (Berger 2009). The territoriality of an animal species varies greatly, even within taxonomic families. For example, adult giant pandas tend to occupy distinct areas, with the females intolerant of the presence of other females within their territories (Nowak and Walker, 1999). In contrast, polar bears, are 'only weakly territorial' (Sale and Michelsen, 2006, 391) but their mobilities can be strongly shaped by the territorial practices of human settlement, tourism and waste disposal (Finney, 2016).

Ecological and abiotic context

Landscape ecologists and invasion biologists have mapped and modelled how the spatial arrangements of habitat, geological features, and human infrastructure come to shape animal movement (Francis et al., 2016; Allen and Singh, 2016). Habitat determines the availability of food. It also helps configure the connectivity of a landscape and thus its relative connectivity and permeability for different groups of animals (Lindenmayer et al., 2006). Geological features (like oceans, rivers, or cliffs) and human infrastructure (like fences, roads, bridges, or planned wildlife corridors) similarly enable and constrain the movement of different groups of animals. For bears, these landscape features might include patches of vegetation that provide berries or garbage dumps hosting a different assortment

of nutritional items. Ursine mobilities might be restricted by roads, fences and pipelines, while centres of human settlement both deter and attract different species and individuals.

Climate and weather shape the possibilities for animals' mobilities though their effects on habitat and their influence on landscape structure and permeability (e.g. the presence/absence of ice). Anthropogenic climate change will shift the 'envelopes' in which species can exist (Thomas et al., 2004) with stark implications for animals' mobilities. Some animals will be forced to move. Long-standing and multi-generational habitual mobilities may be lost. Many vectors for adaptation will be constrained by anthropogenic and other landscape features on scales ranging from fences to oceans. For example, polar bears in Hudson Bay follow a seasonal cycle driven by the freezing and thawing of the sea. The ice brings times of plenty as the bears roam the frozen ocean for denning seals; but the melt may lead to times of hardship and famine. This annual cycle is being altered by climate change. The thaw comes earlier, the freeze later, and polar bears are having to seek out more food on land, which brings them into increased contact with humans (Dowsley and Wenzel, 2008).

Animals' mobilities are also shaped by a further range of atmospheric phenomena that may be less visible than hard infrastructure. These include the wavelength, intensity, and seasonal and diurnal timings of light energy, which serve as important cues and signposts for a range of animal movements. Anthropogenic influences on lightscapes – like lighthouses or urban street lighting – come to shape how, when, and where animals travel. Birds can be confused by lighthouses, or the transparency of plate glass (Van Doren et al., 2017). Some predators and scavengers have become nocturnal as a response to the ubiquity of urban street lighting (Gaston et al., 2013). The same is true for sound and smell, which different animals use to communicate, to detect the presence of others, and to navigate (by scent or sonar). Anthropogenic soundscapes, 'smellscapes' (Henshaw, 2013) and other biochemical alterations can interfere with animals mobilities, attracting, or more commonly deterring or confusing, animals. For example, through the effects of sonar on cetaceans (Wisniewska et al., 2018; Grebowicz, 2017), or antidepressant and contraceptive drugs on fish (Windsor et al., 2018).

How animals' mobilities can be known

In this section we outline a set of knowledge practices for researching animals' mobilities. We start with approaches for tracking and modelling autonomous, or self-willed, animal movements, add techniques for witnessing animals' affective experience, before discussing means for evoking animals' mobilities.

Tracking, sensing, and modelling

There is a long history of human fascination with live animal movement, that led to the development of sophisticated means for tracking animals across a range of spatial and temporal scales (Benson, 2010). Early techniques for visual identification, tagging and ringing, have been enhanced by more hi-tech methods (Kays et al., 2015). These include static camera traps and critter-cams (cameras attached to animals) alongside devices for remotely sensing animal movement, including radio tracking and Global Positioning System (GPS) tags and collars (Tomkiewicz et al., 2010). These technologies are embedded within global assemblages for animal surveillance and monitoring, which are orchestrated by thousands of skilled human bodies (J Lorimer, 2006). This endeavour has generated vast datasets (like movebank.org) and rich geographic information systems, which catalyse novel vernacular attachments to wildlife (Kirksey et al., 2018).

A second set of methods tracks animals' movement through a focus on parts of animals' bodies. Animal geographers have developed such methods for mapping anthropogenic animal mobilities – for example as meat (Emel and Neo, 2015), medicine (Hobson, 2007), data (Whatmore and Thorne, 2000), and imagery (Davies, 1999). Natural science offers further methods for tracing the autonomous movement of animals. Phylogeographers have used technologies from molecular biology to read long histories of animal movement from an animals' DNA (Avise, 2009; Hickerson et al., 2010). The analysis of the stable isotopes that are found in teeth and bones can be used to reveal an animals' diet and environmental exposures. This method has helped both archaeologists and law enforcement agencies fighting the illegal wildlife trade to trace the provenance and movement of animal specimens (Bowen et al., 2005).

These natural science methods deliver vast amounts of data, which have come to inform a wide range of models that are designed to both explain and to predict animal movement. Modelling animal movements is a popular subject for machine learning algorithms and other modes of artificial intelligence, for example for the automation of species and individual animal recognition using the vast existing libraries of camera trap images (Yu et al., 2013). They have become analytically and political powerful tools for those charged with animal management (Adams, 2018). For example, data from GPS-collared grizzly bears has been combined with habitats maps to identify and predict the types of human habitat disturbance they avoid (Stewart et al., 2012) and the landscape linkages they prefer for movement (Proctor et al., 2015). These enable management recommendations regarding the spatial location of future human developments and conservation areas.

Ethology and multispecies ethnography

Methods for tracking autonomous animal movements can be complemented by those that witness animals' experiences of (im)mobility. Here we review methods from ethology and multispecies ethnography that are now well established in animal studies (Kirksey and Helmreich, 2010; Buller, 2015a). There are extensive literatures considering the contested epistemic status of animal emotions (cf. Bekoff, 2007; Dawkins, 2012) and of anthropomorphism (Buller, 2012). Here we focus on approaches that recognise animal emotions and deploy modes of 'critical anthropomorphism' (Johnston, 2008), developing the epistemic potential that comes from recognising both the affinities and the differences between the motile lifeworlds of humans and other animals.

Some of the most compelling accounts of animals' experience of mobility come from laboratory experiments that use animal models (mostly rats and mice) as surrogates for human cognitive processes and pathologies. These experiments either constrain an animals' movement as a known way of inducing stress, or they take changes in animal movement as symptoms of a disease state (Davies, 2010; Despret, 2015). Animal affect is measured through both invasive techniques to monitor changes in blood chemistry, heartbeat, etc. as well as close observation of animal behaviour. Comparable ethological research on farms has explored animals' experience of agricultural (im)mobilities (Wemelsfelder et al., 2012). Perhaps the best-known example would be the work of the autistic animal behaviour

scientist Temple Grandin (2006). By virtue of her condition, Grandin claims to be able to 'think like a cow' and attune to the bovine experience of passing through the slaughterhouse. Grandin accounts for how the architecture and atmosphere of the slaughterhouse affects cow mobilities and offers practical advice on improving such facilities in the interests of both animal welfare and productivity (Grandin, 2015; cf Donovan 2013 for a critical assessment of Grandin's approach and influence). In another example, Marion Dawkins and her colleagues' observations of chickens' affective experience of intensive farming informed the development of an 'automated tracking' system, in which an algorithm analyses aggregate visual data of chicken movement to assess their welfare (Colles et al., 2016).

These observational methods have also been used by ethologists and multispecies ethnographers to explore the experience of free-ranging animals. Notable examples include work on urban hyenas (Baynes-Rock, 2015), reindeer herding (H Lorimer, 2006), dairy farming (Holloway et al., 2014), bird migration (van Dooren, 2014), human-bear cohabitation (Boonman-Berson et al., 2016), and elephant crop raiding (Barua, 2014). These studies develop multisensory and kinaesthetic methodologies through which the researcher 'learns to be affected' (Despret, 2004) by their target organism, developing a 'somatic sensibility' (Greenhough and Roe, 2011) that helps attune to the animals' experience of mobility. Such approaches may involve embodied, skilful practices of moving alongside animals. Often social scientists work with animal experts to understand how animals sense and orientate themselves in landscapes, and how their movement through different places leads to palpable shifts in animals' moods. These methodologies borrow from comparable approaches to researching affect that have been developed in mobility studies (Dowling et al., 2017; Spinney, 2015).

Such techniques would allow ethologists to describe the mobilities of bear cubs sliding in the snow as joyful play, and to report some ursine experiences of captivity as boring, or even traumatic. But doing so requires care and reflexivity. Movement can be misleading, and misinterpretation is always a possibility in multi-species ethnographic research (Kirksey and Helmreich, 2010). For example, American black bears do not show a movement response to the presence of drones (unmanned aerial vehicles) being used to monitor them;

but they do exhibit stress in a strong physiological response, measurable as an elevated heartbeat (Ditmer et al., 2015).

Evocation

The long popular interest in animal movement is evidenced by the extensive multimedia archive of representations of moving animals. Moving animals figure prominently in poetry, in literature, and in art. But many critics have argued that the medium best equipped to evoke animal movement is film (Lippit, 2000; Burt, 2002). Animal movement has been central to the history and development of moving imagery, from the early work of Eadweard Muybridge, through to the technological innovations associated with blue chip natural history film-making (Chris, 2006). We have reviewed the broader potential of moving image methodologies for evoking animals elsewhere (J Lorimer, 2010b), here we focus on three genres of moving imagery (and other media) that seek to evoke animals' mobilities.

The first are efforts to popularise the data generated by animal tracking methods to inform and engage publics with wildlife. This might involve the generation of open source and online GIS platforms that aggregate tracking data and help visualise real time animal movements. Popular projects include those that follow bird migrations (like the *Animal Tracker* app) or websites that allow users to follow wolves and other terrestrial mammals.[ii] This zoological interest extends to creative art projects that provide compelling visualisations of big data on animal movement (Cheshire and Uberti, 2016). In contrast, *YouTube* offers a more ludic, anarchic, and scatological selection of amateur and pirated videos of animals on the move. The platform bears witness to popular enthusiasms for comic domestic cats, feral urban foxes and raccoons, and high-speed and violent wild animal deaths, amongst others (Cahill, 2015).

Naturalistic film makers have developed a variety of narrative and cinematographic techniques to present the evolutionary and ecological rationales for aggregate animal movement, and to evoke the affective intensities of animals on the move. The shift in focus from education to entertainment in blue chip wildlife documentaries (Davies, 2000) has seen a rise in more immersive individuated accounts of animals' experience (Mitman, 2005).

The predominant 'affective logic' (Carter and McCormack, 2006) has shifted from a dispassionate curiosity with objective movement, to an embodied empathy with subjective animal mobilities. This shift has been enabled by new mobile technologies like critter cams, drones, and other remotely operated devices, alongside new slow-motion, microscopic and infrared cameras.[iii] These take filmmakers into hitherto inaccessible spaces (like the ocean depths, amidst the herd, or in close proximity to dangerous predators), or allow them to track previously intractable spatio-temporal rhythms and durations (like the night, the sociabilities of the swarm, or the life-cycle). Eva Hayward (2010) argues that such technologies extend the 'fingery-eyes' of film, generating new affective visualisations of animal movement.

The narrative arcs of these blue-chip stories of animal mobility tend towards the familiar, tracing seasonal and diurnal rhythms, or individual struggles in the face of adversity. A third genre of animal evocation provides more disconcerting accounts of (im)mobility. Examples of this genre focus on animals in captivity, and feature shocking images of aggregate animal crowding, violent spatial confinement, and a selection of animal behaviours and expressions that even untrained viewers would recognise as painful – like stereotypic pacing, crying, and howling (J Lorimer, 2010b). More nuanced accounts take the viewer into the lifeworlds of animals who are baffled and disorientated by their encounters with humans and their infrastructure (Hayward, 2005). A compelling ursine example would be Bear 71 (Mendes and Allison, 2012). This interactive web documentary (and subsequent virtual reality work) traces the experience of a radio collared grizzly bear in Banff National Park, whose entire life is captured on the Park's trail cameras. The visual experience takes viewers into her debilitating and ultimately lethal mobile encounters with various humans and their infrastructure (Castellano, 2018). These multimedia efforts are redolent of recent literary experiments at 'being a beast' (Foster, 2016. See also Thwaites, 2016; Cowen, 2016), in which a variety of authors, assisted by varying degrees of technology and expertise, seek to emulate the mobilities of their chosen animals to explore the animal experience of moving within fragmented, anthropogenic 'linescapes' (Warwick, 2017).

How animals' mobilities are governed

Human shaping of animal movement and mobilities has arguably been the central concern of animal geographies (Wolch and Emel, 1998), alongside a broader body of work in anthropology, zoology, ethology, and other parts of animal studies. These literatures give us a great variety of ways of conceiving of how animals' mobilities are governed and provide copious data on animals' experience of living in human-shaped worlds. The primary focus of this work in animal studies has been on human sovereign power (after Agamben, 2004) and its effects upon individual animals and the aggregations they comprise (social groups, breeds, species, biodiversity, or ecologies). In this context, sovereign power describes the power to take life and let live (Foucault, 2003): the disproportionate ability of (some) humans to eradicate other animals, or to achieve absolute control over their movements through technologies of spatial confinement like the fence, the cage, the net, or the tank (Netz, 2004). This work reveals the dramatic anthropogenic diminishment of the diversity of animals' mobilities through extinction (Kolbert, 2014), and widespread reductions in global animal vagility due to the rise of both intensive animal agriculture and of landscape impermeability (Tucker et al., 2018). These are aggregate patterns that mask the novel global mobilities of a small number of invasive 'global swarmers' (Bright, 1998) equipped to navigate the networked biogeographies of the Anthropocene.

Animal governmentality

These trends are well reported. In this section, we would like to focus on other forms of human power over animals that involve working with animals' mobilities. Here we borrow from recent engagements in animal studies with Foucault's concepts of disciplinary power and biopower (Chrulew and Wadiwel, 2016), where the former is concerned with human shaping of individual animal mobilities, while the latter focuses on the modification and modulation of aggregations of animal bodies and their collective properties (Biermann and Mansfield, 2014; Asdal et al., 2016). Those working in animal studies were initially wary of applying Foucauldian concepts of disciplinary power (and governmentality) to animals. The application of these ideas in the humanities and social sciences tended to focus on discursive technologies of subjectification, like scientific classification, media representation, or economic valuation. These are especially humanist political technologies that regulate human behaviours through shaping human identities and social norms. While discursive technologies have significant implications for shaping how humans interact with

animals, they are not usually understood to operate on the animals directly: it makes little difference to a bear's sense of identity if a powerful human describes it as American, cute, or tasty. The utility of these concepts became clearer as analysis turned to the non-discursive dimensions of disciplinary power (Philo, 2012), especially the roles of technology and architecture, and affect and embodiment (Anderson, 2012). Latterly, animal geographers have demonstrated how the mobilities of some animals are shaped by the disciplinary practices of training. These involve forms of human-animal communication, and are enabled by technologies, like whistles, bits and bridles, and whips and electric prods. Dogs, cows and horses provide the best documented examples (Holloway, 2007; Włodarczyk, 2016; Patton, 2003), but there are also histories of training bears for human entertainment and deterrence (Forsyth, 2016).

Disciplinary training has been central to the rise of intensive animal agriculture, in which animals are subjected to a range of infrastructure designed to rationalise bodies and behaviours in the interests of maximising production (Holloway 2007), in ways that are directly comparable to the disciplining of human mobilities within Fordist and other production systems (Cresswell 2006). Discipline also enables human co-existence with relatively free-ranging animals. To deter pest species through fear, people have long used guard dogs (Shivik, 2014; Haraway, 2008), scarecrows (Lorimer, 2013), and other modes of manipulating local affective atmospheres. For example, any polar bears caught entering the city of Churchill are chased away; but if they won't budge, they are darted, and then transported to the polar bear pound where they are kept without food for a month before being released. The intention is to teach them a lesson (Finney, 2016). Comparable practices have been used to train free-ranging elephants (J Lorimer, 2010a), bears (Boonman-Berson et al., 2016), hyenas (Baynes-Rock, 2012), and cougars (Collard, 2012) to co-exist peacefully with humans. In comparison, Rosemary Collard documents a suite of training interventions associated with wildlife rehabilitation that seek to engender misanthropy (Collard, 2014). Fearsome animals – like dogs – have also long been used to shape human mobilities (Cherkaev and Tipikina, 2018; Skabelund, 2008; Wall, 2016).

Animal biopolitics

These individuated acts of disciplinary power must be understood as part of a broader collection of human efforts to govern the aggregate movements (or circulations, to use Foucault's 2007 term) of animals. These are forms of biopolitics that involve selective interventions by humans into animals' mobilities to make certain animals live and to let other animals die (Barker, 2015; Hodgetts, 2017). They might involve lethal acts of sovereign power upon individual animals, but the primary aim is to govern the reproduction and circulation of aggregations of animals' bodies. A central concern within this literature has been the biopolitics of animal confinement and selective breeding, especially those associated with agricultural systems. Anthropologists have explored how domestication (of both humans and animals) involved the preferential selection of animals with greater tolerance for more sedentary (i.e. less mobile) and more crowded conditions (Clutton-Brock, 1999). This process has been accelerated with new genetic knowledges and biotechnologies (Holloway et al., 2009) and reaches its current apogee in the breeds of chicken designed to survive life in the battery farm. Scholars have borrowed concepts from the biopolitics literature to critique these developments (Shukin, 2009; Twine, 2010; Taylor, 2013). Some draw analogies with 20th century eugenics and the 'thanatopolitics' (Agamben, 1998) of the Nazi concentration camps (see discussion in Wolfe, 2012). Activists advocate for a range of spatial solutions, from forms of 'animal liberation' (Singer, 1990) to more reformist models of 'free-range' agriculture (Cole, 2011).

Animal geographers would suggest that such affirmative biopolitical projects for animal free-ranging or liberation must be informed by spatial imaginaries that are both species-specific and ecologically nuanced. These have been developed in a second body of work that maps the spatialities of wildlife conservation, on the one hand, and of biosecurity, on the other, and identifies tensions between their shared interests in governing the circulations of animals (Dobson et al., 2013). Facilitating migration has long been a concern of international conservation policy (Matthews, 1993), while the recognition of the deleterious effects of habitat fragmentation, and the growing interest in ecological adaptation, have led to the rise of 'connectivity' and 'permeability' as logics for environmental and planning policy (Worboys et al., 2010; Crooks and Sanjayan, 2006). Connectivity thinking grants more prominence to ecological networks, over discrete territories, and operates across a range of scales (Hodgetts, 2018). The 'Yellowstone to Yukon' is exemplary of a set of high-profile

international and transboundary connectivity schemes that emerged in the 1980s and 1990s. This initiative links protected areas across thousands of miles of mountainous landscape. It facilitates large mammal movements by protecting habitat corridor and installing 'bear bridges' across highways (Chester, 2006).

At the same time, there are established concerns about the enhanced mobilities of a small number of animals that: i) spread zoonotic disease; ii) are well adapted to the networked biogeographies and disturbed ecologies of the Anthropocene; and/or iii) proliferate as a result of human land use change and the easing of population controls. These animals transgress human orderings and have become framed as biosecurity risks. Their mobilities are the focus of careful management involving a range of bordering practices (Dobson et al., 2013). In the UK, for example, the risk of badgers spreading tuberculosis to cattle has led to controversial control efforts (Enticott, 2008), as have the ecological and agricultural impacts of 'invasive' mammalian species like the grey squirrel (Crowley et al., 2018). Resurgent 'native' species like deer, boar, and rats, are flourishing as a result of illegal reintroductions, diminished hunting, and changes in pest control techniques (Hodgetts, 2017; Buller, 2008). In many cases like these, the character of the bio that is threatened and in need of security is not clear cut, nor is it that simple in either ecological or political terms to differentiate native and invasive species. The mobilities of different species can be both valued and feared by different groups, and there is a politics as to which human and animal interests come to be favoured (Crowley et al., 2017; Lorimer and Driessen, 2013; Tsing 2017a; 2017b).

Practical solutions to these biosecurity situations enact a spatialised biopolitics of preferential mobility by drawing on the full range of forms of human power over animals, including the sovereign and disciplinary techniques reviewed above, alongside techniques for 'environmental' biopower (Anderson, 2012; Braun, 2014). This term describes interventions geared less towards securing the populations of species, and more towards the modulation of the functions and processes of a socio-ecological system (Hinchliffe et al., 2016). Rewilding schemes represent a prominent (if diverse) set of examples of this form of governance (J Lorimer 2017). Environmental historians provide the backstory to contemporary anxieties about biosecurity, identifying a subset of portable microbial,

vegetal, and animal 'shock troops' and 'camp followers' (Tsing, 2017b) that co-created the landscapes of the New World in the interests of European colonialism (Crosby, 2004). Contemporary conservationists now use 'keystone species' – animals with disproportionate ecological agency – as naturalistic tools for restoring or rebalancing ecologies that are understood to be dysfunctional (Lorimer, 2017). Wolves returning to Yellowstone created an 'ecology of fear' for many herbivores, whose terrified mobilities led to new grazing patterns that led, in turn to the resurgence of desired plant and animal species further down the food chain.

Contributions

This paper has developed the concept of animals' mobilities, as a contribution to work in animals' geographies. It has positioned this concept as a useful supplement to existing work on animal mobilities, enabling a focus on both the autonomous movements of animals and how these are experienced by animals themselves. The paper began by identifying parallel intellectual developments in recent work in mobility and animal studies. This concluding section summarises three contributions made by this concept to thinking mobility and animal studies together.

The first is empirical. Animals' mobilities addresses an inadvertent humanist bias in mobility studies by enlarging the taxonomic scope of studied lifeforms. It provides much richer, multispecies descriptions of what is going on in any given place. It offers a vast expansion and diversification in understandings of the patterns and rhythms of movement in the world, and of the ways in which animal (including human) movement is experienced. This sub-disciplinary alliance would help geographers map the topological diversity of animal life and develop research on the 'interspaces' performed and inhabited by mobile bodies (Hulme and Truch, 2006). Research on animals' mobilities also develops current concerns with the embodied and affective dimensions of mobility. In this paper we have stayed close to animals 'big-like-us' (Hird, 2009), but rich pickings are visible amidst considerations of the mobilities of more alien animals, like the vampire squid (Flusser et al., 2012), as well as plants (Marder, 2015) and fungal spores (Tsing, 2014). The mobilities turn pushed the social sciences 'beyond' fixed territorial models of society (Urry, 2000). Such a shift would enhance a parallel relocation in multispecies studies towards an ecology beyond (fixed territorial)

ecosystems, so that it can better engage with the 'emergent ecologies' (Kirksey, 2015) of the Anthropocene.

Second, the concept of animals' mobilities has practical and ethical potential for those charged with governing the movements of animals (and of people). Those responsible for designing the architectures of animal management – from slaughterhouses, to domestic houses, to ecological networks – need to know how animals move, and how their lived experiences of these movements come to shape the efficacy and animal ethics of their design. Poorly designed animal housing and wildlife reserves can lead to animal death, suffering, and population decline – with implications for both human and animal livelihoods. Such pragmatic concerns are entangled with ethical imperatives. Individual animals, and their aggregations (families, herds, breeds, species, etc.) are greatly affected by the movement opportunities afforded to them, and to other animals. Many animals have suffered as a result of anthropocentric models of animal confinement and of preferred mobility. Some animals' lifeworlds have been damaged by the inadvertent release, introduction, or escape of another invasive animal. Yet the answer to an ethics of mobile animal flourishing does not necessarily lie in unfettered liberation, free-ranging, or rewilding (as some advocate). The joyful mobility of one animal or group of animals will often impact on the flourishing of another, leading to fear, pain or even extinction. As such the ethics of animal management is always political, riven by the incommensurable interests of different forms of mobile animal life. The concept of animals' mobilities provides valuable starting points for mapping these incommensurable spatialities to inform an animal ethics attuned to animal spatial difference.

Third, this interest in the politics of differential mobility foregrounds the longstanding interest in animal geography in the common political processes and technologies through which marginal human and animal lives are governed, and in how these ordering practices are lived and experienced. The concept of animals' mobilities invigorates this work by attuning to how diverse patterns and rhythms of movement are governed, and to how power is sensed, felt and (sometimes) given emotional expression (Lambert 2015). For example, we see scope for future work in 'one health' geography (Craddock and Hinchliffe, 2015) on the common human and animal experience of both the infectious and the non-

communicable diseases that characterise urban lives. While some animals flourish in the city, other people and animals living in precarious urban political ecologies experience common exposures to hotspots of infectious disease, hunger, pollution, and traffic accidents (Barua and Sinha 2017; Srinivasan, 2013). Mapping the entangled mobilities of street cattle, dogs, macaques and their people helps animate the city and understand the shared cross-species experience of urban health. Similarly, in more elite spaces, the trend towards sedentary mobilities, high-calorie diets, and antimicrobial drug use have been linked to increases in some inflammatory diseases amongst both companion animals and their owners (Chandler et al., 2017). Cats and dogs become obese, have allergies, diabetes and gut conditions comparable to humans (Sandøe et al., 2014). These trends show marked intra-species disparities in which it is the marginal humans and their pets that tend to get sick.

The concept of animal mobilities also helps explore the governance of aggregate human and animal movements. Geographers have demonstrated the discursive and material intersections between the marginal human and animal experience of the bordering practices of biosecurity regulation (Hinchliffe et al., 2016). In this multispecies 'politics of mobility' (Cresswell, 2010), fences, passports, visual surveillance, and forms of atmospheric deterrence work in equal measure to police human and nonhuman citizenship. Some humans and animals, such as those deemed sufficiently hard-working, enterprising, native, and/or entertaining experience smoothed global networks, assisted passage, and permeable borders. Others are kept at bay by deliberate exclusion (through human and nonhuman blacklists), or by the inadvertent effects of walls, fences and other bordering technologies. Inevitably, such efforts are incomplete. A subset of 'agile' (Tsing, 2017b) actors flow in and out alongside desired migrants, often establishing themselves in the most socially and ecologically ruined sites: the refugee camp, the informal settlement or the urban brownfield. Animals' mobilities demonstrate the analytical potential of thinking such animal and human mobilities as the shared and incomplete outcome of spatial modes of biopolitics, but it also cautions against uncritical modes of anthropomorphism. The nomadic experiences of a brown rat, panda, international banker, or child refugee all differ in ways that cut across lines of human-animal difference.

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[i] Animal studies is a fast growing, heterogeneous field that spans philosophy, geography and parts of biology. It is characterised by a range of conceptual framework and has its 'critical' variants. It is concerned with animal representations, animals-in-themselves, and the uses and abuses of 'animality' (for introductions see Kalof 2017, DeMello 2012)

[ii] US wolf tracking data was once available at www.wolf.org, but was taken down after concerns that it might be used by hunters to kill wolves. Likewise, Bison tracking data in the Netherlands was removed due to persistence human disturbance (see www.wisenten.nl). Other data streams include HerdTracker on the wildebeest migration.

[iii] See for example the BBC's recent *Animals with Cameras* series or the National Geographic *Crittercam*® series.