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Geographies of conservation II: Technology, surveillance and conservation by algorithm

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Abstract
The wide range of wildlife tracking and surveillance technologies (radio and satellite tracking, cameras, and audio) that are being deployed in conservation have important implications for a geographical understanding of care for non-human nature. This report explores four dimensions of their influence. First, their detailed view of spatial dimensions of non-human lives affects conservation's demarcation and control of space. Second, the application of surveillance technologies to people is central to the rise of coercive conservation strategies. Third, such technologies enable the creation and commoditization of spectacular nature. Fourth, spatial digital data enables the automation of conservation decisions, a trend described here as 'conservation by algorithm'.

Keywords
animal geographies, camera traps, coercive conservation, conservation, conservation by algorithm, drones, radio-tracking, spectacle, surveillance, technologies, tracking

> She lived her life under near constant surveillance and was continually stressed by the interactions with the human world. She was tracked and logged as data. . . . We're watching her. She's watching us. And at the same time, we're watching ourselves. (Mendez and Allison (2012) *Bear 71*. National Film Board of Canada)

I Introduction

On 2 May 2009, scientists from the British Trust for Ornithology (BTO) and the Swiss Ornithological Institute caught a nightingale in a mist net on the eastern edge of the Cambridgeshire Fens, UK. A tiny electronic 'geolocator' tag was attached to its back, and the bird was released. A year later, it was recaptured in the same place and the tag was removed (BTO, 2016).

A geolocator consists of a battery, a light sensor, a clock and a chip. By recording light levels over time, it is possible to calculate latitude and longitude, and hence the bird's location. The tag recorded the nightingale's autumn migration to Africa, via the Pyrenees, Madrid and Lisbon to Senegal and Guinea. Somehow it made its way back, although the route was not recorded (BTO, 2016).

The nightingale, a bird laden with cultural associations (Mabey, 1993), declined in numbers in the UK by 91 per cent between 1967 and 2007 (Holt et al., 2012). Many long-distance

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migratory species are in decline, making them an urgent conservation priority internationally (Wilcove and Wikelsky, 2008; CMS, 2014). Effective conservation of such species is seen to demand better understanding of conditions on migration routes to target conservation action (Vickery et al., 2014; Marek, 2017; Hewson et al., 2016). It is to this end that the Cambridgeshire nightingale carried its geolocator to Africa.

In the last two decades, movement ecology has made significant contributions to conservation (Benson, 2016), supplying novel data used to increase the effectiveness of conservation action (Verma et al., 2016). Devices such as geolocators represent just part of a wider digital reshaping of conservation ideas and practice, involving monitoring, public engagement, citizen science, data analysis, and decision-support (Arts et al., 2015, Van der Wal and Arts, 2015, Verma et al., 2016). Computer and communication technologies such as low-cost sensors, smartphone 'apps', and the predictive analytics of 'big data' analysis are transforming biological field recording (August et al., 2015). Conservation organizations have been leading users of such technology, in pursuit of more robust and evidence-based conservation decisions (Sutherland et al., 2004; Adams and Sandbrook, 2013) and stronger public engagement and support.

The development and adoption of digital tracking and surveillance technologies in conservation have significance for human geographers interested in conservation in a range of ways. This report explores four of these: first, the implications of spatial data on animal movements for conservation's demarcation and control of space; second, the role of surveillance technology in the rise of coercive conservation strategies; third, the role of technology in the creation and commoditization of nature spectacles; fourth, the way in which digital data enables and encourages the automation of conservation decisions, a trend described here as 'conservation by algorithm'. Before this discussion, the report locates the role of technology as part of conservation's biopolitical regime, and sketches the range of tracking and surveillance technologies being deployed.

II Technologies of tracking and surveillance

There is an irony, perhaps, in the way in which the conservation of 'nature' requires the embedding of technology such as a geolocator among the feathers of a nightingale. Yet this harnessing of technology should come as no surprise. Whatever its diversity of ideology and concern (Sandbrook, 2015a), biodiversity conservation is a biopolitical regime, a form of governance whose aim is 'to secure the future of a valued life (both human and nonhuman) at the scale of the population' (Lorimer, 2015: 12). Conservation involves the exercise of power over both nature (keeping species and ecosystems within specific bounds in terms of state and location) and humans (determining who may take, kill or transform non-human lives and spaces). Technology is central to conservation's exercise of biopower, marshalling the 'productive and destructive processes through which life is made to live or left to die' (Lorimer, 2015: 13).

In biodiversity conservation, humans have in effect become 'curators of wildlife' (Verma et al., 2016: 77). Classic 'command and control' conservation (Holling and Meffe, 1996) borrows techniques, skills and devices from other kinds of more-than-human biopolitical management (hunting, fishing, forestry, disease or pest control; Lorimer, 2015). In its locally intensive policing of nature, conservation routinely cuts, burns, poisons, shoots and traps (Woodworth, 2013), seeking to establish or enhance species here (those characteristic or in decline) and control or extirpate others elsewhere (especially those classed as 'alien invasive species'; Pearce, 2015; cf. Hobbs et al., 2013). In its deployment of technologies of control, conservation draws on longstanding science-based modes of understanding nature, including its own academic disciples in game management (Leopold, 1933) or the bespoke missionary field of conservation biology (Meine et al., 2005).

Technologies that extend the capacity of humans to observe and record the presence of other organisms act essentially as prosthetic devices that extend human abilities to perceive and observe other lives (Lorimer, 2007, 2015). Key technologies in terms of geographies of conservation are those that allow individual organisms to be identified at particular locations and times. Such tracking and surveillance devices can be thought of in two categories: first, those attached to individual animals, and second, those that are remotely deployed.

In terms of animal-borne devices, the oldest is probably bird ringing (or banding, USA), developed at the end of the 19th century, which consists of attaching a unique numbered metal ring to the leg of a captured wild bird, in the hope that this will be returned when the bird is killed or recaptured (Robin, 2001; Bircham, 2007). Techniques were developed to identify individuals visually, for example the use of bird rings of different colours, or, for other taxa, visible marks or tags attached to ears, flippers or fins.

The invention of transistors in 1947 revolutionized the tracking of wild animals (Benson, 2010). The development of radio telemetry in the USA in the 1950s benefitted from close Cold War links to military scientific networks, technology and funding (Benson, 2010). It began to be routine to attach transmitters whose unique radio signal could be detected by fixed or movable aerials, to collars or harnesses (mammals and birds), or by suckers or darts into the body (e.g. fish and marine mammals).

Since the 1950s, radio telemetry devices have grown steadily smaller and more powerful, with improved battery life. Detection has become possible from greater distances, from aircraft, helicopters and even satellites (Pennisi, 2011). GSM mobile phone technology allows location to be captured continuously via a mobile phone network, giving advantages in terms of spatial accuracy (a few metres), size, cost and battery life (e.g. Graham et al., 2009). Miniaturized satellite tags weighing below 5 g can be fitted to birds such as turtledoves and cuckoos weighing as little as 100 g (Hewson et al., 2016). Tags as light as 1.6 g have now been developed (Marek, 2017). Digital data on animal movement is widely collected, and increasingly it is shared in standardized format through centralized open-access archives such as Movebank (https://www.movebank.org/).

Digital technologies have also revolutionized remote surveillance. Remote sensing platforms and sensors have evolved continuously and become standard conservation tools. Panchromatic (black and white) photography from balloons and aeroplanes was developed for military use in the First World War, and transformed by stereo photography in the second. Post-war, colour photography, and film stock sensitive outside the visible spectrum (e.g. infrared) began to be used for land systems and ecological mapping. From the 1970s, multispectral digital imaging from satellite sensors provided civilian environmental scientists with relatively affordable and frequent-repeat imagery of much of the earth's surface within and beyond the human visual spectrum. This made continental scale ecological mapping possible. Such images and data are now widely available for download from the internet.

Semi-automated mapping of vegetation and other natural features was made possible by computerized data and analysis. Geographical information systems allowed data derived from various sources to be superimposed and the resulting maps analysed, published and disseminated. Recently, drones, or unmanned (sic) aerial vehicles (UAVs), have brought the cost of such surveillance down dramatically, broadening its accessibility, and triggering numerous experiments in ecology and environmental science (Anderson and Gaston, 2013). Satellite and airborne radar provide other forms of data which can also be integrated into conservation assessments, for example LIDAR mapping of the topography of forest canopies, and associated estimates of vegetation density, and hence biomass, and therefore stocks of carbon relevant to carbon offsetting schemes (Asner et al., 2010; Simonson et al., 2012).

Remote photographic surveillance of individual organisms has also been transformed by digital technology. Animal photography with automatically triggered camera flashes was pioneered at the end of the 19th century (Shiras, 1936). Technological advances included the replacement of cumbersome plate cameras with film, and from the 1930s small cameras using 35 mm cinema film stock. The 1980s saw the development of infrared motion detection, and the 1990s the development of digital images. Camera traps are widely used in wildlife biology (Ancrenaz et al., 2012; O'Connell et al., 2011; McCallum, 2013), many operating beyond the human visual range (e.g. infrared). Close-circuit video is also now commonly deployed at conservation sites (Chambers, 2007; Verma et al., 2015, 2016).

Digital audio sensors allow animals to be located and identified using sound, including sound beyond the range of human hearing (e.g. the ultrasonic calls of bats). Software can identify and separate species automatically (Robinson Willmott et al., 2015). Sonic surveillance can also be conducted underwater (e.g. passive acoustic tracking of migrating humpback whales; Stanistreet et al., 2013).

This quick sketch of technologies for animal tracking and surveillance indicates their extraordinary scope. The gaze of field biology, and conservation, is not yet panoptic, but the intent – and perhaps the capacity – is clear. Let us turn to its significance for geographies of conservation.

III Surveillance and conservation geographies

The first important aspect of digital tracking and surveillance technologies for geographies of conservation lies in the levels of detail and intimacy of their view of non-human lives, and their capacity to individuate, to isolate the movement of the individual from the broad patterns of the population. This has attracted the attention of animal geographers (Hodgetts and Lorimer, 2015; Buller, 2015). Thus Barua (2014: 916) sees tracking technologies as central to the development of 'lively' or 'intradisciplinary' biogeographies, demonstrated by his analysis of the 'dwelt political ecology' of elephants among the forests and tea estates of Assam. It is not just the geographies of animals, but the geographies of particular animals, that are opened to the scientific gaze. That gaze, enabled by digital technologies, is inherently spatial.

Digital tracking allows the construction of 'wildlife cartographies', mapping of species distributions and using those representations to enable 'effective, targeted conservation measures' (Verma et al., 2016: 81). In particular, it provides the evidence base for territorial claims in the form of new protected areas. Thus Benson (2016) shows how animal tracking not only changes understanding of the way the individual animals and populations use land, but also therefore conservation's ability to lay claim to that land. American wildlife biologist Helmut Buechner studied Uganda kob (an antelope) in the 1950s, using tranquilizing darts and drugs, plastic collars, identifying tags, and moving films. This 'spatial-biopolitical expertise' (Benson, 2015: 138) allowed him to demonstrate the territorial behaviour of the kob, and convert this into a conservation argument about the need for protected areas. The 'territorial claims of endangered species' could therefore be pressed in the face of competing land use demands, legitimated by other kinds of colonial scientific expertise (Benson, 2016: 137).

Surveillance not only intensifies conservation territorialization in terms of the demarcation of spaces for nature and for people, but also the management of the resulting boundaries. If animals can be tracked, their boundary-crossings become not only something that can be, but must be, managed, as for example when elephants with GPS collars cross virtual 'geo-fences' in the landscape to engage in crop raiding, or break electric fences built to protect smallholder farms (Graham et al., 2010; Evans and Adams, 2016). Tagged animals can be seen by the public as the responsibility of those who know their movements, and can be at risk when they move close to people (Cooke et al., 2017). Thus an endangered great white shark killed in Western Australia because it was judged an 'imminent threat' to a bathing beach was only known to be present because of an acoustic tag fitted by scientists (Meeuwig et al., 2015).

The ability to track also influences conservation in its selection of priorities for action. Conservation organizations actively select charismatic species (cf. Lorimer, 2007) as flagships for technological projects. Focal species are selected to be 'easily recognisable, predictable, detectable, distinctive, larger, and yet unique' (Verma et al., 2015: 657). The 'trackability' of a species therefore influences its visibility in conservation strategies (Benson, 2016: 143), although some megafauna such as elephants offer both traditional photogenic charisma and trackability (Graham et al., 2009; Barua, 2016; Benson, 2016).

IV Surveillance and coercive conservation

A second implication of tracking and surveillance technologies for geographies of conservation is their role in the development of coercive conservation strategies (Peluso, 1993). People as well as other animals can be subjected to surveillance and control measures. Digital sensing and tracking devices (camera traps, drones and satellites) are widely used to monitor human activities for conservation law enforcement (e.g. to monitor illegal logging or poaching, collect evidence or catch perpetrators; Humle et al., 2014; Sandbrook, 2015b).

However, the use of surveillance technology in conservation has outstripped institutional frameworks for its governance – for example, little attention has been paid to the social risks of conservation drones (Sandbrook, 2015b). Furthermore, surveillance technology is fundamental to the militarization of conservation, such as Africa's 'war on poaching' (Duffy, 2000, 2014; Neumann, 2004), 'green militarization' (Lunstrum, 2014), or 'green violence' (Büscher and Ramutsindela, 2015). A discourse of 'poachers-as-terrorists' in Africa has made illegal hunters legitimate targets for counter-insurgency violence. Surveillance technologies such as camera traps, drones, helicopter-mounted infrared cameras and sniper rifle night sights are routinely used to combat poachers in Kenya (Haslam, 2016). The WorldWide Fund for Nature has collaborated with Google.org to develop a thermal and infrared camera and software system to detect people crossing a national park boundary (WWF, 2017). The ease with which technologies can be re-targeted between animals and people, and between warfare and securitized conservation, is an important dimension of the prosecution of 'war by conservation', in which conservation is drawn into a globalized security agenda (Duffy, 2016).

Conservation surveillance uses fear as a tool (Humle et al., 2014) to enforce environmentality on reluctant rural people (Agrawal, 2005). Such surveillance, and the sometimes-violent enforcement linked to it, offers the same challenges to rights and liberties as drones in the service of state security and warfare. It brings about what Shaw (2017: 9) calls 'atmospheric enclosure', creating 'biopolitical climates for human beings to dwell inside'. Shaw's focus is urban policing, but the skies are also increasingly threatening in conservation areas, both surveillant and even potentially directly weaponized.

To balance the growing evidence of the deployment of surveillant technology against citizens, it might be noted that digital technology can also be used by those disadvantaged by conservation territorialization and boundary-making. There is no reason (beyond cost and access) why technologies such as drones should not be used by communities in counter-mapping (Peluso, 1995). Butt (2015) describes how mobile phones help herders in Tanzania to subvert 'ever-tightening restrictions on access to land', sending warnings of the presence of game guards to enable grazing in areas incorporated into protected areas. Graham et al. (2012) describe the use of mobile phones by smallholder farmers to inform state wildlife managers when elephants cross the boundaries of wildlife conservancies and other areas where they are tolerated to raid growing crops.

V Surveillance, spectacle and commodity

The third aspect of tracking and surveillance technologies to which I want to draw attention is their capacity to create a spectacle of non-human lives (Igoe, 2010; Igoe et al., 2010). Spectacular nature has long been a commercial product, and one widely deployed by conservationists. The intimate gaze of the camera has been a feature of wildlife film and television since the 1930s (Mitman, 1999; Lorimer, 2015), and technology continues to extend its scope: the 2017 BBC wildlife blockbuster *Planet Earth II* drew heavily on the novelty of digital trail cameras, night vision photography and drones to provide its 'high-dose nature therapy' (Rose, 2017).

Digital technologies are fundamental to the work that conservation does to frame affective relations between people and non-human nature. Close-circuit television (CCTV, or the 'wildlife-cam') has become a routine adjunct of visitor experience at conservation sites and online (Chambers, 2007; Verma et al., 2015). Cameras positioned at the nests of rare birds such as peregrine falcons (e.g. Derby Peregrines, 2017) or by an African stream (e.g. Explore, 2017) and linked to the web provide continuous streaming of 'live' images. Conservation organizations routinely use CCTV to capture interest, and create emotional 'connection' with members of the public (Verma et al., 2015), to educate, create the sense of the need for care, and to generate financial and other forms of support.

CCTV and wildlife film appear to offer an unedited view of the life of wild animals, free from human 'intrusion' (Verma et al., 2015). Yet the sense of proximity relies on a physical and technological separation between watchers and watched, creating a complex hybrid of real and virtual. CCTV transforms animal bodies into digital images that can be stored (and can be re-run as 'highlights'), and restricts sensory interactions to the visual (there are no 'live' smells or noises). This makes 'CCTV-assisted bird watching' and similar spectacles paradoxically geographically distancing (Chambers, 2007). Digital video epitomizes 'technological nature', mediating, augmenting and simulating physical nature (Kahn, 2009). Virtual natures are increasingly pervasive, (for example in conservation games; Sandbrook et al. 2014; Dorward et al., 2016). Some fear that the lure of virtual nature (particularly to young people) will erode authentic experiences of non-human nature (e.g. Louv, 2005; Ellard, 2015).

At the same time, footage from wildlife cams does not always invoke passivity in viewers. Verma et al. (2015) record the highly emotional responses of people viewing webcams (for example a peregrine falcon trying to feed a dead chick), and Brulliard (2016) reports aggressive response of American viewers watching starving chicks on nest cams of birds of prey.

Büscher (2015) notes how viewers of wildlife cams in South Africa used social media to demand intervention by conservation managers, for example if an animal appeared injured.

Tracking technologies also create new possibilities for the creation of spectacle, and facilitate new networks of care, based on the identification of individual animals. Thus in Scotland, the locations of satellite tagged red kites were combined with other data to create a weekly 'blog' describing the movements of four birds on a 'BloggingBirds' website, using natural language technology (http://redkite.abdn.ac.uk; Van der Wal et al., 2015). Similarly, the British Trust for Ornithology publishes the locations of satellite tagged cuckoos on their migration to Africa to publicize their scientific work and the challenges of cuckoo conservation (Verma et al., 2016).

Spectacular images of nature have everywhere become an indispensable part of conservation's engagement with capitalism (Igoe, 2010; Igoe et al., 2010). Corporate brands are linked to conservation causes, using 'images of landscapes, exotic people and animals to raise financial support for conservation interventions' (Igoe, 2010: 378). Thus, in the case of the BTO's tagged cuckoos, an attempt has been made to monetize these data streams through sponsorship. The BTO website offered the opportunity to 'sponsor a cuckoo' (BTO, 2017) in return for an information pack, a choice of gift item, regular email updates on the cuckoos and their name on a list of sponsors.

As conservation increasingly embraces market-based models, nature that is threatened or saved is alike represented in 'dramatic, technologically mediated and circulated performances' (Sullivan, 2012: 202). Conceptual devices used to stabilize, monetize and market non-human nature (such as carbon credits or biodiversity offsets) depend on spectacular digital representations of nature as 'products' that can be bought and sold (Sullivan, 2012, 2013). Social media create and circulate 'new virtual forms and manifestations of nature and its conservation' (Büscher, 2013: 1). In 'Nature 2.0' applications, nature is increasingly to be '"saved" through mouse-clicks and double-taps' (Büscher, 2016: 727). Surveillance and spectacle are respectively the preferred method and core product of global conservation.

VI Conservation by algorithm

The fourth and final aspect of digital tracking and surveillance technology to which I wish to draw attention is its role in the automation of conservation decisions. Digital devices, especially using online or mobile phone-based interfaces (August et al., 2015; Teacher et al., 2013; Van der Wal et al., 2016), are transforming the field collection of biological data. These technologies generate more, better, faster and cheaper data capture from sensors, with continuous and geographically located data over a larger spatial extent and in previously inaccessible locations (Arts et al., 2015). Digital tracking and surveillance sensors bring advantages of continuous flows of data, lower costs of capture, reduced costs in data transfer and storage in shared multi-species databases (Benson, 2016). However, perhaps the greatest significance of digital technologies lies in the ease with which data can be fed directly into computational algorithms. As Joppa (2015: 525) observes, the way in which computational technology provides 'tools and infrastructure to monitor, model, and safeguard biodiversity in entirely new ways' is starting to revolutionize the practice of conservation.

Technical advance means that conservation data collection is increasingly being automated, bypassing (or making redundant) scientifically skilled conservation workers. Fixed sensors can record continuously and download data without human intervention. Automation also allows new kinds of data to be recorded. For example, algorithms can automatically identify individual tigers from stripe patterns on photographs (e.g. Yu et al., 2013) and distinguish different species of bats from the characteristics of their ultrasonic calls from continuous digital recordings, an impossibly daunting task for human analysis (Adams et al., 2010).

Computer-aided taxonomy enables reliable biological data to be derived from the observations of even unskilled citizens. In the *Google Play* store, Jepson and Ladle (2015) find numerous apps for automated species identification, for example automated acoustic species detection and identification, and the use of image recognition software to automatically identify tree species from their leaves. Data quality from citizen observers can be improved by automated feedback (Van der Wal et al., 2016). The eBird website (http://ebird.org/) converts observations by amateur ornithologists into a centralized database usable by scientists (Wood et al., 2011).

People can also be made to provide data of conservation importance unconsciously, scraped from social media or recorded by specialized apps. For example, *Google Trends* data can track natural events such as the flowering of asthma-producing plants, or the occurrence of biting insect species (Proulx et al., 2013), and data on the health and mood of smartphone users can be linked to location to analyse how people interact with nature and protected areas (Teacher et al., 2013).

Not only data collection but also data cleaning can be automated. Modelling techniques from engineering and computer science are being applied in ecology to perform quality control procedures to filter out erroneous data (Porter et al., 2012). Swinnen et al. (2014) describe an automated processing protocol to sort video recordings from trail cameras, set to record beavers, that were empty, or recorded other species, without having to watch the recordings. Price-Tack et al. (2016) have developed automated image processing to identify animal presence in time-lapse camera trap images, reducing personnel time and costs.

In part, the automation of analysis is an inevitable concomitant of the deployment of digital sensors (what Gregory (2011: 194), in the context of drone warfare, describes as the 'image surge'). The volume and rate of flow of data from environmental sensor networks are challenging traditional systems of data management (e.g. transport, storage, quality control and assurance, gap filling and analysis), and driving a new field of ecological informatics or ecoinformatics (Porter et al., 2012). As in the drone warfare, automated software systems are required to analyse data streams to identify significant patterns (cf. Gregory, 2011). Automated analysis of surveillance data for conservation is becoming feasible in real time. Thus Robinson Willmott et al. (2015) describe a novel system of linked thermal, acoustic and ultrasound sensors to monitor bird and bat movements in the eastern USA, with a view to temporary shut-downs of wind turbines to reduce mortality from collisions.

Digital tracking and surveillance technologies are important elements in automated analysis and planning in conservation. Automatically cleaned and checked data are transferred to information management systems where scientific workflows provide quality assurance and additional metadata, before analysis (Porter et al., 2012). Digital data fed directly into algorithms and models (Benson, 2016) in turn support conservation decisions and policy prescriptions.

Increasing dependence on digital tracking and surveillance can therefore be seen as a new conservation regime, one of 'conservation by algorithm'. In security and military contexts, digital data are routinely handled by algorithm, translating probable associations between people into 'actionable security decisions' (Amoore, 2009). Drone killing involves the deployment of autonomous algorithms that automate target recognition (Allinson, 2015). Algorithmic rules of association have become the basis for everyday securitization in what

Amoore (2009) calls ‘algorithmic war’. Conservation applications are therefore quickly following models that eerily copy the automated military kill chain. Thus a wildlife concession in Tanzania uses a reconnaissance drone fitted with photographic recognition software ‘to pick up and differentiate potential threats like poachers and cattle from naturally occurring objects [*sic*] like wildlife’. If a potential threat is identified, an ‘ops room technician’ reviews the footage and any threat is registered in the computerized Domain Awareness System (DAS) and ‘law enforcement assets are immediately dispatched to deal with the problem’ (Singita Grumeti Fund, 2017).

Algorithms are as yet mostly having subtler effects in conservation. But there are nonetheless implications. While digital data collection may be distributed among a range of actors (even, potentially, shared with local people), conservation planning and decisions based on digital data streams tend to be concentrated in the hands of experts, remote from the field, in the offices of government, academic or non-governmental organizations (cf. Bryant, 2002; Fairhead and Leach, 2003). Advances in remote sensing, machine-based mapping and spatial analysis are fundamental to spatial conservation planning (Moilanen and Wilson, 2009) and the field of ‘conservation biogeography’ (Richardson and Whittaker, 2010; Ladle and Whittaker, 2012). Applications range from the prioritization of law enforcement effort using data on the spatial distribution of illegal activities (Plumptre et al., 2014) to the classification of land in terms of conservation importance and priority for protection, at any scale from local to global (e.g. Brooks et al., 2006). Site selection and decision-support algorithms identify areas that have the potential to maximize the achievement of conservation goals, whilst minimizing resources expended (Fajardo et al., 2014).

Of course, such as their name suggests, decision-support tools are supposed to inform and enable a planning system run by human decision-makers. Yet automation tools are increasingly mainstream. Thus the NatureServe network offers a range of specialized conservation planning tools and models such as ‘NatureServe Vista’ (‘A Powerful Scenario-Based Assessment and Planning Tool’), which can ‘automate complex GIS processes, keep track of your work, and deliver defensible, repeatable maps and reports’ (NatureServe, 2017). The deployment of such tools moves conservation decisions further away from people affected by them and further into the hands of remote decision-makers, or the technicians who devise the algorithms on which they rely. Algorithmic conservation involves a biopolitical regime operated remotely and autonomously that subjects both nature and society to discipline.

VII Conclusion

Tracking and surveillance technologies are shaping conservation in a range of ways of importance to geographers. They offer radical new insights into non-human lives, enabling and stimulating new regimes of management and control. They enable and justify coercion as a way of addressing conservation problems such as poaching, drawing on military methods, machines and mind-sets to change the balance of power in and around conservation zones. They offer new forms of spectacular nature, and new opportunities to monetize those data streams and interact with potential conservation supporters on the cusp between the virtual and physical world. Finally, they are a key part of the growing trend towards conservation by algorithm, where conservation decisions are automated and not tested through political debate.

Lorimer (2015) explores the possibility of conservation based on a more ‘cosmopolitical’ cohabitation with nature. But biodiversity conservation, increasingly scientific in method and neoliberal in ideology and structure (Brockington and Duffy, 2010; Büscher et al., 2012), is in many ways becoming less open and collaborative than Lorimer would wish. Conservation is a major beneficiary of the bulked out analytical power offered by tracking and surveillance technologies. These make it possible to address novel conservation problems, for example the protection of species migrating between regions and environments, or those experiencing range shifts due to climate change.

Yet the rise of algorithmic conservation could bring about profound change. To take just one rather wild example, Cantrell et al. (2017: 156) explore the potential for 'the automated curation of wild places'. They offer a conceptual design for a 'wildness creator', a fully automated and autonomous artificially intelligent infrastructure system 'to create and sustain non-human wildness without the need for continuing human intervention' (Cantrell et al., 2017: 161).

Tracking and surveillance technologies, and digital technologies more widely, have real implications for the social, political and environmental impacts of conservation. With advances in technology, reductions in cost, increases in the volume and diversity of data that can be collected and the range of algorithms that can be applied to it, conservation decisions increasingly move into the hands of experts and away from democratic oversight. The politics of future conservation geographies is increasingly shaped by technologies and algorithms. The question of who owns, programmes and controls them is of crucial importance.

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