Differentiated circuits: The ecologies of knowing and securing life

Steve Hinchliffe & Stephanie Lavau

Geography, College of Life and Environmental Sciences, University of Exeter, Amory Building, Rennes Drive, Exeter, EX4 4RJ, UK

Forthcoming in *Environment and Planning D: Society and Space*.

Differentiated circuits: the ecologies of knowing and securing life

Steve Hinchliffe* and Stephanie Lavau

Geography
College of Life and Environmental Sciences
University of Exeter
Amory Building
Rennes Drive
Exeter EX4 4RJ

Stephen.Hinchliffe@Exeter.ac.uk
S.Lavau@Exeter.ac.uk

Acknowledgements

We would like to thank Richard Irvine (Animal Health Veterinary Laboratories Agency) and Ruth Cromie (Wildfowl & Wetlands Trust) for their assistance in the field and with the final drafting of this paper. Our colleagues John Allen, Nick Bingham and Simon Carter provided constructive criticisms on earlier versions. The research and paper were made possible on receipt of an ESRC research award 'Biosecurity Borderlands' RES-062-23-1882. The authors accept all responsibility for any errors, factual or otherwise.

Word Count 9396

Differentiated circuits: the ecologies of knowing and securing life

Abstract

The question of how to make life secure in a world of zoonotic disease threats is often answered in terms of an ever-tighter regulation of wild, domestic and human life, as a means to control disease. Conversely, in both theoretical and practical engagements with the business of making life safe, there is recognition of the circulatory and excessive qualities of life, its ability to overflow grids of intelligibility, and a requirement for knowledge practices to be responsive to a mutable world. In this paper we use empirical work on the field and laboratory practices involved in knowing life, specifically within the UK's avian influenza wild bird survey, in order to argue strongly for a form of biosecurity that does not seek to integrate life or the practices that make it intelligible into grids and closed circuits. Extending work by Latour, we argue that the truth-value of life science stems not solely from the circulation of references along a single chain of reference, but also from the productive alliance of knowledge forms and practices that are loosely brought together in this process. By demonstrating the range of practices, materials and movements involved in making life knowable we claim that it is the spatial configurations of knowledge practices, organisms and materials, their ongoing differentiation and not their integration, that makes safe life a possibility.

Introduction

On a cold November morning 2010, just at the break of day on a wetland in East Anglia, England, we corral hundreds of wild birds up a 'swan pipe'. The birds are to be tested for bird flu, and are carefully handled by professional and lay experts, each masked and wearing full personal protective clothing just in case the potentially deadly virus is already here. Many of the birds are migratory, arriving at this time of year from as far afield as Siberia, passing en route through countries and regions that are known to be positive for the highly pathogenic avian influenza (HPAI) that is causing concern. The scene is repeated around the country, and samples collected at these sites circulate to a laboratory for screening. Public health and the health of a £3.4 billion poultry industry (Dent, Kao et al. 2008) are at stake. The avian influenza wild bird survey (AIWBS) that we are witnessing here is designed to provide early warning of viruses that may well go on to circulate promiscuously and unpredictably within UK bird- and other life.

Figure 1. Herding birds up the swan pipe

The activity on the wetland is one manifestation of an attempt to provide some order or biosecurity in a bio-geographically promiscuous world (Clark 2005; Braun 2007: 361, see also ; Keil and Ali 2007; Hinchliffe and Bingham 2008). The emergence and mobility of infectious diseases in a global economy of exchange and circulation (Braun 2007: 7), where shifts in food production and animal husbandry contribute to an unstable political virology (Wallace 2009), make surveillance of wildlife part of a generalised attempt to secure life. In this paper we investigate this process by exploring the scientific practices that are involved in the Great Britain AIWBS. Our aim is to highlight the suite of activities and relations that make safe life a possibility. We trace a multi-disciplinary process involving birds, materials, ways of doing things, craft and institutions, a heterogeneous non-coherent assemblage (Law 2004), which undermines any sense that this instance of biosecurity is merely a technical matter of testing for viral presence. Rather, it is the productive alliance of knowledge forms and practices that are loosely brought together in this process that generates bio-security.

We start with a brief background to biosecurity and existing accounts of scientific knowledge practices and follow this with our ethnographic account of the wild bird survey. We end by expanding empirically and theoretically on the need to conceptualise both biosecurity and the production of scientific truth-value as enacted in multiple practices whose loose arrangement is, we argue, conducive to safe life.

Security, nonhuman life and circulatory space

Learning to live with nonhuman life has become a major motif of recent theoretical and empirically informed writing in geography and the social sciences (Bingham 2006; Whatmore 2006; Hinchliffe 2007; Haraway 2008). A wide body of posthumanist scholarship might effectively be summarised as an argument for a more responsive engagement with nonhuman worlds once human exceptionalism and triumphalism have been jettisoned. But emerging zoonotic diseases have seemed to make newly realised relatedness of human and nonhuman lives a problem rather than an opportunity. The result has often been a 'return to power', a Foucauldian power over life. Braun for example feared that ever increasing surveillance of wild lives marks a "capacity and desire to extend the unending examination of global populations across the animal kingdom in order to govern the 'global biological' as a single, integrated system containing emergent risks" (Braun 2007: 21). Biosecurity implied the "extension of forms of sovereign power by which life is ever more tightly integrated with law" (Braun 2007:14). Wilbert expressed a similar discomfort once the highly pathogenic H5N1 avian influenza virus reached UK shores. Suddenly "avian observation and knowledge of migratory routes [were] being reinvented as a kind of border patrol, a first line in veterinary surveillance" (Wilbert 2006: 2). Biosecurity, they feared, was a re-charged governance of human and nonhuman lives, an ever-extending power over life, and the integration of its circuits and circulations into secure frameworks.

As these authors know only too well, there is something disingenuous if not paradoxical about security posed in terms of an integration of lives and knowledge systems. Following Foucault (2004; 2007) we might summarise the issues as follows: First of all, life is characterised by its mutability and therefore its potential to outstrip any regulatory framework that is placed upon or around it. Security cannot therefore afford to be too rigid or based on fixed entities with known properties (see also Dillon and Lobo-Guerrero 2008). Second, the regulation of life always needs to be mindful of the requirement for living organisms to transact with their environments in order to live. Life cannot simply be contained and regulation must be of a specific quality that allows life to circulate and flourish while suppressing some of the dangers of doing so. In other words biosecurity involves promoting *and* regulating circulation. Finally, a security characterised by the regulation of flows and movement rather than barriers or prophylaxis, requires forms of knowledge that are responsive to a changing world. Within a continuously evolving realm both that which circulates and the knowledge necessary for regulation are open to transformation (Anderson 2011). These knowledge practices form the focus in this paper. How are living beings and knowledges enacted and arranged within the security process? In bringing together a concern over the qualities of security with work in STS and geography on knowledge practices, in particular their material and social heterogeneity, we seek to advance an understanding of how the seemingly incommensurable aspects of making life safe can be fostered.

In order to do this we firstly outline the circulations of life and knowing that are relevant to our ethnographic account of the wild bird survey.

Two circulations

Avian influenza (AI) is a common condition of wild and domestic birds and a component of porcine and human influenza. It is a disease that can circulate within and beyond dense populations of wild and domestic birds, drifting, mutating and reassorting as it does so. The population densities and the ensuing inter and intra-population circulation of AI virus may well have been increased in recent decades. Certainly, domestic numbers and concentrations of susceptible domestic birds have increased markedly (Davis 2005; Pew Commission 2008; Liebler, Otte et al. 2009), and it may well be that overall decline in available habitat for wild birds has changed patterns of viral traffic in previously discrete flocks. The broader point is that avian life and its pathologies now circulate in ways that were unimaginable 50 years ago before the emergence of a high throughput poultry industry with a standing global population of around 19 billion birds (FAOSTAT 2009). This new avian landscape is also of course marked by host-pathogen transactions that can and will produce shifts in the genotype and phenotype of the avian influenza virus (Capua and Alexander 2006). As a result, previously low pathogenic strains of AI can develop into highly pathogenic strains, something that has demonstrably occurred within poultry houses and within laboratory settings. This possibility presents a real and potential threat to poultry, wildlife and people, and as a result the possibility for wild birds to pick up and transmit viruses from and to poultry, often sub-clinically and at low levels of infection, is a major concern for biosecurity. International bird migrations can form one of a number of links between disease regions while daily movements or weather related flock displacements draw farms, poultry keepers, wetlands and other habitats together. It is this geography of disease that forms the background to the investment in wild bird surveillance. These are, however, not the only circulations that constitute biosecurity. We now turn to a second set of circulations, those of knowledge.

As scholars in science and technology studies (STS) have long argued, knowledge is required to circulate in order to have effects (Latour 1987). Science in practice is characterised by Latour (1999; 2007; 2010) as material transformations and translations, which allow knowledge to move from worlds to words, from referents to references. In this deambulatory understanding of knowledge generation, worlds are not simply *represented*, they are progressively and carefully *transformed* along a chain of translations (into numbers, charts, words and so on) that preserve something of their character, whilst economically reducing their complexity to matters that are transportable and compatible. Truth-value is hence produced through a series of transformations of things into forms, and forms into things, allowing “a state of affairs to be loaded into a statement” (Latour 1999: 48) whereby “each stage is matter for what follows and form for what precedes it” (Latour 1999: 74). Knowledge in this account is made from a *heterogeneous* set of things and signs, which are both joined and separated by the translations, transformations and transcriptions that characterise science in practice. As a result, traditional divides between writing and things, representations and worlds, signs and referents, are unsettled. As Latour puts it, these forms and materials exist side by side and “[O]ne never travels directly from objects to words, from referent to the sign, but always through a risky intermediary pathway" (1999: 40).

These chains need to be *reversible*. The reference needs to 'bring back' a world to a reader. References achieve this by allowing the transportation of elements of a world into, for example, laboratory spaces, while preserving an ability for laboratory spaces and their products to be traced back to the worlds of which they speak. Each transformation therefore takes us further away from a world, but at the same time produces knowledge of that world – a double movement involving closeness and distance. Crucially, for Latour (2004; 2010), the circulation of references is a *normative* account of knowledge generation. Reference designates the *quality* of the circuit in its entirety, with truth-value generated where and when a circuit turns. "Truth-value *circulates* here like electricity through a wire, so long as this circuit is not interrupted" (Latour 1999: 69, original emphasis).

While Latour's account of circulation is compelling, and we make use of it in what follows, we are also conscious of the practices and materials that are *integral to but do not become integrated within* knowledge making. Beyond the heterogeneity of the circuit, we're also interested in other circuits that may smooth the passage of or even interfere with the production of knowledge. The focus here will be on those knowledges, lives and practices which retain an outsider-ness despite being integral to security.

To summarise, biosecurity requires knowledge of that which circulates. This is enacted through scientific practices, which themselves produce another form of circulation, that of references. As we will show, to keep the circuit turning, these references often require other circuits and other practices. It is the heterogeneity within *and* outside the circulation of references that, we argue, produces truth-value. Moreover, it is this mixture of practices that becomes crucial to the successful implementation of biosecurity. If, as we argue, biosecurity requires openness to the new, rather than a tightly integrated policing of life, then it is through such an ecology of intersecting knowledge practices that life may be made safe. By following the various stages of the avian influenza wild bird survey in Great Britain, we trace the circulations of references through which knowledge is generated of the disease risk of wild birds. We ask how circulations of wild birds and their potential pathogens are loaded into statements about avian influenza, and what kinds of matters are, in the process, required for or sometimes obscured from this account of infection and disease. Our method has been to observe and participate in many of the processes we describe – bird catches, reserve management, laboratory work – as well to discuss our observations with key actors.

Knowing birds

The British Isles, lying on the edge of the Eurasian land mass and warmed by the Gulf Stream, is a particularly favourable destination for winter migratory visitors from northern Europe, Siberia, Canada and Iceland (Newton 2010: 40). Along with weather dependent migrations, these seasonal movements of birds provide one component of a circulation of avian and viral life, linking the UK to continental Europe and beyond this to areas where highly pathogenic avian influenza is increasingly thought to be endemic. In 2006, in line with other EU states, an AI Order was issued in England (with legal equivalents in the devolved assemblies in the UK) requiring there to be an assessment of "the risk of spread of influenza of avian origin by wild birds" (DEFRA 2006: 10). We now detail how this assessment was translated into a survey of wild birds.

Economising

In order to develop a risk assessment of wild birds and their influenza viruses, bird life first needed to be made manageable. A group of ornithological and veterinary experts were contracted to develop a targeted approach and the resulting report included "biology spreadsheets" for the 573 wild bird species found in Britain, descriptions of their flocking tendencies, flyway population, migratory habits, habitat preferences, and AI status (Crick, Atkinson et al. 2006). These descriptions as well as a migration-mapping tool, tested on 12 species, drew on data from the national ringing scheme, operated by the British Trust for Ornithology (BTO), in which each year over 2,600 volunteers ring around 900,000 birds, of which around 10,000 are re-sighted or re-captured. This information about the location and abundance of wild birds was combined with data from the newly implemented national poultry register to identify areas of significant co-distribution of wild birds and domestic poultry. The research report thus identified high-risk wild birds and at risk places. Surveillance resources and efforts were subsequently targeted at certain species of duck, geese, swans, gulls and waders, located at wetlands and wildlife reserves in regions where poultry production was more marked (Snow, Newson et al. 2007).

This progressive reduction of a potentially pathological world to wild birds and then to a subset of those birds and to particular locations, an 'economising' as Latour (1999) would see it, involved drawing together various knowledges. The flocking behaviours of birds and their population structure in flyways, their local migratory paths, feeding habits, frequency of visits to farmland and geographical distribution within Britain were used as proxies for the potential threat of disease to poultry flocks. In assembling this knowledge, ornithologists, ringing techniques, databases of ring recovery and resighting, volunteer ringers, wildlife reserves and wetlands, bird counts, behavioural studies were mixed with qualitative risk assessments, virologists, and veterinary epidemiologists, to formulate probabilities of infection and design high priority surveillance areas. While the end result, the survey, is clearly about attempts to systematically categorise and order the world, using probabilities as means to predict with a view to controlling and eradicating disease, it is worth noting that this knowledge is informed by practices that have some interesting and counter-veiling histories. The provenance of bird watching, of observations, has rather different affective orientations to the world than those of disease surveys and surveillance.

Once certain species and wetland habitats had been targeted, the set of risky birds needed to be reduced again to a manageable sub-set. This involved supplementing the routine monitoring of found sick or dead birds with a strategy for sampling apparently healthy birds, the latter ideally helping to "assess background levels and identify strains… of avian influenza circulating in wild bird populations" (Birdlife International 2006: 3). To be effective as an early warning system the survey would ideally require a large sample in order to be confident of a negative result, as infection rates can be very low even when AI is being transmitted within wild bird populations. In practice though, the sample was limited to a maximum of around 4000 birds per annum, a number that took into account resource constraints as well as the need to minimise disturbance to wild bird populations. In effect, rather than being amenable to statistical forms of verification, the live bird survey would always be reliant on supplementary evidence and expert judgement in order to develop robust knowledge.

Much of this expertise was deeply rooted in avian and reserve knowledge practices. So for example, there was already a rich understanding of bird life, health and well being within birding organisations. Through regular bird counts and daily bird feeds; through experience of knowing where birds go, on the reserve and beyond; through observing bird behaviour, recording the lives of individuals and their families, and noting the dates of migrations: the people who work on reserves inhabit the landscape in ways that produce a rich understanding of avian life. Wardens know which birds are unwell; they can spot a bird that is out of place or out of sorts. They listen, watch, smell, touch, as they live with and know birds. There is a suite of practical, quite intimate, understandings of the landscape, soundscape and movement spaces of birds. These knowledge practices were not necessarily central to the survey, nor did this intimate knowledge circulate formally in the circuit of references, but together they provided an embodied expertise that made the circuit operational, and constituted a unique source of avian understanding that would be required, as we will demonstrate, in any assessment of safe life.

With practical targets set, and in recognition of the legal and practice-based need for expert ornithologists to undertake the survey, the Wildfowl & Wetlands Trust (WWT) were contracted to perform the live catches. The most frequently used method involved a baited trap called a swan pipe, a built form resembling medieval, game keepers' duck decoys (figure 1). Each catch was a highly organised event, requiring monitoring of weather conditions, bird welfare, as well making sure a team of avian specialists arrive at remote locations in the early hours of the morning to assist in shepherding birds up the pipe and then 'processing' the catch before releasing birds back onto the water.

Partial Transformations

Once a reasonable sample of birds have been tempted into the swan pipe, a mesh curtain is quickly triggered and the previously concealed catching team hurriedly assemble to herd the birds up the pipe. At the end of the pipe swans are sexed, wrapped in green plastic jackets (to protect the birds but also the handlers) and laid on a straw bed in a pen. Other species are carefully placed in crates and await processing. Each bird is carried by a handler through a series of stations where they are numbered, measured and swabbed before being released. On the first trestle table, new catches are ringed and re-catches have their individually numbered ring recorded. These additions to the bodies of the birds enable the birds and their numbers to circulate in different spaces. The numbered birds will be returned to the wetland as quickly as possible, leaving the transcribed bird numbers to circulate along the chain of reference that is the bird survey. In this sense, while the birds become numbered and in some senses 'informed' (Barry 2005), their circulation remains distinct from their reference. To be sure, the two circulations (of birds and references) are articulated or joined by numbers, but they are neither integrated nor somehow structured by one another. In other words, and as we will emphasise throughout, the articulation also performs differentiation, and is thereby a partial one.

Alongside the birds' identification numbers, biometrics (age, sex, weight and wing length) are recorded. Some of these numbers follow individual bird identifiers to take part in the AI survey, but others also circulate within the birding organisations' own, longstanding, knowledge networks. Each numbered bird has an electronic history of sightings, catches, offspring, arrivals and departures which can be combined to yield time-series trends to provide life expectancies, breeding success, and migratory habits. This other circulation is one example of the detailed avian knowledge that is generated on the reserve and within birding organisations but does not necessarily circulate, formally at least, with the survey. Others include the detailed and long standing study of species like the Bewick's swans who are known individually, and by name and history: Winterling, the bird with a limp, who at age 27 holds the joint record for the longest-lived bird to visit the reserve; Croupier, son of Casino who brought 32 cygnets back to the reserve during her long life; or Saruni and Sarindi, theirs being only the second recorded swan divorce. This intimate knowing has its own history. From the late 1950s, having successfully attracted migrating Bewick's swans to Slimbridge, on the Severn in Gloucestershire, the WWT's founder Peter Scott started to sketch these swans as they made their annual visit to the reserve (figure 2). The drawing led to an ability to recognise individual birds on the basis of their unique bill patterning, and so started one of the longest running single species studies in the world. Scott and those who have followed his pioneering observational work have noted each bird's arrival, habits and social behaviour for over 40 years. In glass fronted offices overlooking the reserve, staff quickly make sketches, their schematic, diagrammatic form allowing for a knowing that is suited to the process of identifying a busy, moving bird from all angles and in different lights (see Law and Lynch 1990). From these observations, involving over 4000 birds, certain staff can, by memory and by reference to their notebooks and record sheets, identify a bird in seconds (even if un-numbered or when, as is often the case, their numbered legs remain submerged in the water). Identifying birds makes it possible to track their day-to-day feeding behaviours, their noisy territorial displays, their health, their family relations, their pairings and their offspring.

Figure 2: A procession of swans, Peter Scott's sketches of the bill patterns of Bewick's swans visiting Slimbridge

The combination of shared field histories, pencil drawings and numbers helps in producing a "knowing around" (Hinchliffe, Kearnes et al. 2005) swans and other species that frequent British wetlands (see also Matless, Merchant et al. 2005). This knowing circulates less easily than numbers and vital statistics, it is slower to accumulate, and needs time and patience. Nevertheless, such observational practices and knowledges contribute to the ability to know birds and their pathologies.

Back to the survey, and the numbered birds now move along the processing line to the swabbing station. Birds are allocated two long handled dry swabs, which are bar-coded for easy recording. The attendant biologist carefully manoeuvres the swabs to remove a small amount of buccal material from the throat and faecal material from the cloaca (figure 3). The two swabs are then enclosed in their numbered tubes, secured together with an elastic band, and placed in a plastic container (a 'Pathopak') ready for shipment to the laboratory. The sampling site and the names of people who came in contact with this bird, the swabber and the handler, are added to the recording sheet.

Figure 3. Swabbing of a Bewick's swan

The mucus and other secretions, which adhere to the dry swab material, form more or less preserved biological samples and can now circulate in pairs with their numbered bird reference. The hope is that these swabs maintain enough of any avian disease ecology that exists within the throats and cloaca of wild birds. They are kept cool and couriered to the Animal Health Veterinary Laboratory Agency (AHVLA), Surrey, for testing.

Meanwhile, the birds that have been through the process line are released, quietly, back onto the wetland. It's done quietly so as not to alarm other birds. It's also a moment that staff and volunteers seem to enjoy most. Holding and then releasing a bird seems to express something of a caring comportment for wildlife, a letting go (on this spatial relation to care, see Hinchliffe 2008). This affective relation between staff and volunteers and the wild birds is something that doesn't circulate with the references, but it's something that is clearly important to everyone involved. While some of the birds and species are more difficult to handle than others, and there are clear favourites (swans known by name, teal appreciated for their plumage and diminutive size); this is more than simply getting close to individual birds. There is a care for bird life, a thrill that physical proximity to revered animals can momentarily be achieved and a satisfaction that the survey can take place with seemingly little disturbance to bird or ecology. To be sure, the birds are now freighted with references, but there is little sense of them or their human companions becoming integrated with the law. Instead of integration there are momentary and indeterminate inter-actions between circulations. An assemblage or actor network, in other words, where parts don't quite subsume one another and maintain their character even whilst being related.

Observation and surveillance

Before we follow the samples and numbers to the laboratory, we want to draw out some of the implications of the other modes of addressing birds that we have highlighted in our account so far. Here it is useful to remark on a difference between bird surveillance and observation. There is, in the ways in which birds are handled, in the attentiveness to birds as individuals and populations, in the landscape and interspecies knowledges that are learned and honed, something that is closer to observation than surveillance. At first blush the terms might sound roughly equivalent. From Julian Huxley's studies of the great crested grebe (Huxley 1968 (1912)) to Tom Harrison's translation of his bird observation experiences into positivist sociology and the Mass Observation movement, observing does in some sense evoke a rather ocular, disembodied science. For Michel Serres (2008: 39), though: "there is an immense difference between the observation of things and the surveillance of relationships". Observing, for Serres, involves an openness to and embracing of that which is looked at, watching with wonder and care, whereas surveillance watches with suspicion. Moreover, while observation tends to address and differentiate the world as things, something of which always escapes the relationship of the observer and the observed (Hinchliffe 2007; Bennett 2010), surveillance tends to address matters through a policing of their relationships. The focus on relationships tends to reduce relata to their relations alone, and in that sense gives a poorer account of the vitality of lives and matters.

In other words, we are dealing with two forms of watching over (birds). The first is watching over as in keeping a watch on, being on guard, being vigilant (from the Latin, vigilare = watchful, to the French, veiller = to watch, to sur-veillance); watching birds as threat. The second is watching over as in keeping safe, (from the Latin servare = to keep safe, through the French, to ob-servation); watching birds as threatened. Unsurprisingly, this second watching over shares its Latin roots with conservation and preservation. So whereas both observation and surveillance invoke a sense of careful(l)ness, one suggests care for/with those being watched, and the other care for/by those doing the watching.

To follow this etymological excursion a little further, the words observation and surveillance are also suggestive of different geographies of knowing. Ob-servation (the Latin ob- as toward, about, against) suggests watching amongst or amidst, whereas sur-veillance (from the Latin super- to the French sur-, as over, above) suggests watching from beyond, outside. Surveillance aspires to be all-knowing, deriving authority from the distance being made and re-made between subject and object. Perhaps ob-servation is more modest, more suggestive of "knowing around" rather than "knowledge of" (Hinchliffe, Kearnes et al. 2005: 653).

Finally, for Serres, to observe is to use more than sight. It is to use all senses, and only by doing so can it be adaptive, apprehending and comprehending the world. Surveillance privileges sight, which is pained by mixture, preferring to distinguish and separate (Serres 2008: 67). Observing makes sense with mixture, mingled bodies/senses as being amidst worlds rather than standing before the world. There is a set of practices, circulations and possibly other kinds of movement that are not best described as integrated circuits, that make AI surveillance possible but also exceed it. From learning to identify Bewick's swans, to knowing the avian landscape, to holding and letting birds go: knowing birds involves more than a single chain of reference. But before we expand on these points, we will follow the circulation of reference into the laboratory.

Knowing viruses

So far a mass of wild birds has been transformed into numbered swabs. The birds, wetlands and skilled ornithologists are carried on these swabs to the laboratory, though as we have emphasised there are other references and forms of knowing that circulate elsewhere. The arrival of swabs signals a busy time for the labs. Every sample from a catch (anything from 40 to 400 arriving in one batch) needs to be processed. The urgency is palpable. The laboratory managers know that any failure to turn samples around quickly would be a disaster should there be a disease event or a positive result. A screening process enables rapid throughput of the materials, reducing the submitted swabs to a smaller sub-sample by ruling out negatives and ruling in those more likely to yield positive results. Like the transformation of birds into numbers and swabs, the process in the laboratory involves a series of further transformations in order to detect the presence of influenza. In detailing some of this activity and subsequent diagnoses, our argument again is that knowing viruses and disease requires more than one chain of reference and involves both surveillance and observation practices.

Viral surveillance

In the sample reception room, every sample is entered into the laboratory information management system (LIMS): swab barcodes are scanned and limited contextual information about the donor bird and the catch are keyed in. A new bar code identifier allows the samples to circulate smoothly within LIMS and within the laboratory, which is made up of a number of rooms including the reception, a sample preparation room, a room that contains the RNA (ribonucleic acid) extraction robot, another room that contains the Real-time Reverse Transcription Polymerase Chain Reaction (PCR) machines, and offices with computers used to compile results and generate reports. As references circulate through these spaces there are numerous changes in form (from swabs, to suspensions, to nucleic acids, to numbers and so on), as well as changes in lab coats for staff and ethnographers as they move between rooms. A constant identifier for each sample enables them to be tracked on LIMS as they proceed along the chain to eventually become a number suggesting presence or absence of influenza A virus.

The swabs are cleaned with alcohol and antibiotics (to remove bacteria), manually cut up and the viruses are inactivated. The mixture is centrifuged to separate non-viral from viral particles and the viral material is transferred to another room and placed inside an RNA extraction robot. The robot performs a series of routinised biochemical and physical procedures, including washes and vacuum filters, in order to extract RNA from the viral material. Some of this material is placed with reagents into the PCR machine. Inside, the chain reaction process converts the RNA that would code for the coat of influenza A virus (called matrix (M) gene) into a fluorescent DNA copy. The DNA is exponentially amplified through 40 cycles. If M-gene copies are present, a sensor will detect their fluorescence. The point in the chain reaction at which detection occurs is called the Ct (threshold cycle) value. A lower Ct score (below 34) signifies the presence of avian influenza: that is the quantity of influenza A virus in the bird was sufficient to yield enough M-gene RNA for DNA amplification and fluorescence after relatively few cycles. Ct values of over 35 are regarded as probable or unmanageable negatives.

This transformation from material on a swab – a lively mixture of avian cells and secretions, bacteria, and potentially viruses – to dead chains of ribonucleic acid and eventually a Ct value, is a physical, chemical and semiotic cleansing or purification as a means for circulation. In Latour’s (1999) terms, this reduction of the sample enables its simultaneous amplification, as it becomes transportable into new places.

In turn, the Ct values become the reference by which the virologists and vets can judge whether or not the LIMS-numbered sample refers to a ring numbered bird that is or is not potentially infected with AI.

The reduction and amplification of disease signal in this screening process is also dependent on a particular epistemology – one that is implicitly focused on single causes for a disease (for a history, see Attenborough 2011). The purification of materials into a dead strand of nucleic acid whose presence or absence codes for a diseased or healthy bird, and in turn for a nation in or out of danger, speaks to a world of fixed objects with clear properties. This is surveillance as Serres (2008) would see it, a practice devoid of complex objects or things, focusing only on the relations between fixed bodies. Potentially being foreclosed here are disease stories that relate to the cocktail of life forms present in any living tissue. Yet, in seeking to understand avian life and its pathologies, viral dynamics and mutability (and especially a possible mutation and/or reassortment into a pandemic influenza), the mix of life forms and tissues form an alternative 'object' of enquiry. In short, there may be an ecology to disease that, for the moment at least, cannot circulate in the laboratory. All this cleaning, killing, buffering, spinning, splitting, and filtering produces a material that circulates in a particular way. Even so, after the screen has been completed, and the mostly negative samples are discarded, a more observational science comes into play, and the chain of references for the potentially positive samples is once again wired less like circuit, and more like an investigative matrix (Waters 2012).

Viral observations

Suspect samples called 'non-negatives' are immediately re-extracted and re-tested within another set of laboratories with higher biosafety levels, to confirm and characterise probable viral presence. As well as further strain specific PCR based (molecular) tests, the samples also start to circulate in laboratories where classical rather than molecular virology using *in vitro* and *in vivo* methods and conventional virus isolation, culture and incubation take place. Here a sample will be inoculated into embryonated fowls' eggs, grown and then extracted, for further testing and characterisation. There's a step change in interactivity, samples no longer seem to "flow like electricity through a wire" (Latour 1999: 69), but proliferate such that the same sample becomes the subject of multiple simultaneous investigations. Again the

LIMS system is vital, but this time to draw together (rather than integrate) the material forms that the sample now takes. In this case, diagnosis is not simply a process of elimination, as we saw in the screening process; it is a suite of practices that produces new material forms that *may* gradually conform sufficiently to deliver a probable verdict (on the simultaneous nature of multiple forms see Mol 2002).

In contrast to the large rooms and clearly automated practices of screening, the diagnostic labs are small, packed full of well-used equipment, books, files and PCs, a busy working lab that can look chaotic to the outsider. Likewise, the number of simultaneous activities going on and their connections to one another make the laboratory space seem less coherent. This is not to say things are chaotic. This is what 'knowing between' (a literal translation of diagnosis) or even knowing around looks like. The whole process is held together by skilled scientists and virologists, LIMS and the ubiquitous use of timers and time-sheets, which tell a scientist that their results are ready for reading, or that the eggs need attention. There is a "choreography" (Cussins 1996) as the scientists navigate between preparing cultures, checking reagents, 'candling' eggs, extracting material from inoculated eggs for testing, re-inoculating material into new specified pathogen free eggs. Diagnosis is not so much a sequence of steps, producing a chain of reference, as a progressively multiple act: the greater the proliferation of techniques, the more signs, and hopefully the greater the degree of co-indication of result. In short, reference material starts to circulate in more than one chain, and the chains somehow have to be held together. Multiple material forms are made to cross reference to one another, to sometimes cancel one another out, or to build a case regarding the circulation of pathogens. This proliferation of *in vivo* and *in vitro* materials does not quite overturn the logic of looking for single viruses, but it does produce a different ecology of material circulations that doesn't necessarily flow easily down one chain of reference. Surveillance doesn't quite capture the nature of the labour involved in doing diagnosis or understanding disease. Observation again seems a better term for the complex of practices involved in the diagnostics laboratory.

Finally, if HPAI is confirmed, its presence is notifiable, ushering in legal duties on the part of the State (the AHVLA's role as an arm of a government department is now crucial). Reversal of the chain theoretically allows for the sample's location, species and ultimately individual bird to be identified. At this point, the rudimentary information in LIMS regarding the source of samples can be cross-referenced to the ornithological expertise in the field. While locating an individual bird in the field is feasible if often impractical for larger wildfowl, the main purpose of reversing the reference is to employ site-specific ornithological expertise to amplify the trace by suggesting population interactions and flock movements, and so provide a basis for disease management. However, at the point of reconnecting circuits, a significant tension between surveillance and observation can emerge. Conservation, welfare, educational and affective relationships between people and birds may conflict with any direct public- or animal-health based concerns which would seem to demand disease containment through capture and/ or culling. This tension between circulations may be finely balanced, but for now it is tilted towards the wild birds. In a situation of relatively low risk of viral transfer and with an acknowledged danger of disturbing and thereby dispersing wild populations in any attempted cull, there are few voices calling for a full integration of avian health through dis-integration of wild bird circulations. Indeed, in a case of H5N1 in mute swans in Dorset, England, efforts were made to anonymise the references in part to prevent Crown protected birds being targeted. Potential conflicts between ways of engaging avian life were circumvented partly as a result of refusing their integration, but, it must be noted that, as is the case currently in the UK for badgers and bovine tuberculosis (Enticott 2008), such conflicts may always turn out differently when or if risks to public and/ or animal health are suddenly amplified.

The survey, which was concerned with the risk of spread of avian influenza by wild birds, has indicated low levels of AI (a value of approximately 1% of wild birds sampled have yielded positive results for AI in the UK). At face value this might suggest a low risk, especially given the biosecurity measures taken on farms to reduce wild and domestic interactions. But the survey has not closed the debate. In other countries the proportion of positives is much higher in what are overlapping avian populations (6-20% in Sweden for example) (Mackenzie 2007). There is some discussion of different viral loads in different species, at different times of year, how young birds may be immunologically more susceptible to viruses than older birds, and in turn how different parts of the seasonal migration may yield higher infection rates than others (Wallensten, Munster et al, 2007). The methods themselves may also lead to under-reporting: faecal and salivary dry swabs are less reliable than blood samples, for example, and unlike the latter give no indication of an historical infection.

Listening to these discussion and debates we're reminded of all the knowledge that doesn't circulate in the survey, all the material that is not so much lost but forms a vital undercurrent to the circulating reference and importantly, keeps the circulation moving. The painstaking work of reserve staff, the daily counts, the detailed geographies of avian movements, the practices of viral diagnoses: few of these circulate along the whole length of the survey, but they do interweave with it and both unsettle its abstractions as well as enable its continuing movement. Making sense of survey results is, we would argue, only possible as a result of the knowledges and practices that inform the circulations. Survey results are, on their own, insufficient. They require interpretation, additional avian, ecological, virological, veterinary and epidemiological expertise. Their circulation and aggregation into European datasets and policy requires this continual work of levering in observations.

Indeed, beyond the temporary uncertainties involved in the survey, when Ct values can only indicate possible concern rather than high disease risk, the continual surfacing of observational knowledge suggests two things: first, that all the practitioners along the chain recognise the necessarily partial nature of a survey, the uncertainties embedded in selecting for single viruses, the sampling issues and so on; second, while seemingly robust in providing data on wildlife health, there is an attendant risk in ignoring this hinterland of experience and knowledge. As the vets and virologists attest, this is a partial picture set up to provide detection and early warning rather than furnish us with greater understanding of the ecologies of disease. But the real value of the survey is its mix of knowledges and practices, the generation of an ecology of practices, the heterogeneity of which can produce more informed approaches to avian life and its pathologies, and the affective labours that it has managed to assemble. In this sense it is more than a numerically based approach to risk; its value lies in its production of new kinds of differentiated and differentiating knowledge practices, the continual assembling of which is the mark of good security.

Conclusions

We started this paper by outlining the conceptual and practical difficulties associated with doing biosecurity, arguing for an approach which recognised the mutabilities of life as well as the multiplicities of knowledge, suggesting that security can itself be hampered by integration of circulations within a rigid framework. We have described two circulations, of avian lives and of knowledge, noting how fears relating to the former translate into targeted investments in the latter. Through detailing the Avian Influenza Wild Bird Survey, our purpose has been to describe how biosecurity surveillance is practised, and at the same time to draw out the heterogeneity of scientific practice. The aims relate closely, for scientific practice is more multiple and heterogeneous than a singular circulation model suggests, and this heterogeneity undermines any straightforward suggestion that life or indeed knowledge can be integrated into a secure apparatus. To expand on these conclusions we make the following three arguments.

First, knowing what circulates is vital to the process of security, but understanding the limitations of that knowing, its uncertainties and indeterminacies is just as important. This paper has started to suggest that far from being a straightforward measurement of circulations, good biosecurity involves an ongoing assembling of circuits, organisations, technologies, living beings and so on. Enacting biosecurity involves many agencies, knowledges and practices, which are drawn together but not quite aligned. NGOs, swans, governments and science are certainly not integrated through a survey, rather they interact in ways that are far from determined by a power over life.

Second, in Latour's (1999) own 'textbook' example of circulating reference there are claims to a simplified yet normative account of scientific practice and the production of truth-value. For Latour, a *single* thread holds multiple and heterogeneous elements of scientific practice together. Certainly, it is possible, possibly all too easy, to follow the thread that links a wild bird to a fluorescent signal of nucleic acid. The reference is good in the sense that it can be more or less reversed and flows by virtue of all manner of things (from Pathopak to barcodes) like "electricity through a wire" (Latour 1999: 69). We have interspersed our chain of reference with other movements not just to show discontinuities (which are there in Latour's version of heterogeneity) but to attend to the other circulations, the inter-references that make the survey possible, and that can often be relegated to a periphery as the circuit turns. Our point is that good science and truth-values might be even more heterogeneous than the single circuit suggests, relying on other movements, things and practices that can't, won't or aren't permitted to circulate, but that are necessary for circulation to occur.

To be fair, elsewhere Latour has written of truths that do not involve a central role for reference. Religious belief, for example, requires not so much a chain of reference whereby successive signifiers change form as the circuit turns, but a repetitious communication of the same reality in various formats, a "procession of angels" (Latour 2001: 222). Truth is not conveyed by reference, but by continual renewal of a message. Likewise, in political spheres, Latour (2003) highlights a logic of spin rather than a logic of circulation, and in law, the aim is to form a case without the encumbrances of a particular reference (Latour 2010). But even within this multiple engagement with truth-makings, there is a strong tendency to treat these movements as distinct practices, wedded to particular institutional forms (be they science, politics, religion or law). Our point is that other circuits, processions and translations are part of and not separate to the scientific process. Bird watching, a sensing of swans, the multiplication of materials in laboratory diagnostics: these all occur within or alongside the wild bird survey. The ways in which this heterogeneity is handled is an important means to judge what the wild bird survey can and can't say. Circulating references, no matter how aligned they may be, do not by themselves communicate truth-value. Their relations to other circuits and movements help us to see what kinds of truth are being generated.

Finally, the strength of the survey might not *only* be judged on its ability to transform wild birds into percentage incidences of influenza, itself a feat of circulation. Its strength lies rather in the drawing together of a suite of practices, observations and forms of knowing that continue to question disease aetiology, ecology, epidemiology and forms of scientific knowing. Indeed, the circulation of references is only possible as a result of this range of experience, this ecology of practices. It may be, then, that this strength lies not in integration but in the weak ties formed between social groups (Granovetter 1973) and, we would add, between people and companionable species

(Haraway 2008), from viruses to birds. If an aim is to generate understanding of the role that wild birds might or might not play in a highly dynamic, complex ecology wherein viruses co-infect, mutate, re-circulate and so on, then the continuing circulation of references and all those observations and other movements that allow the circulation to keep turning need to fostered. So when decisions are made on the future of such surveys, it might be that the truth-value of the survey should be judged by its ability to assemble knowledges as well as organise references. This kind of science would be more observational than surveillant, more of an accumulation of non-coherent parts than a single thread of evidence. As observational practice, it would be "ready to be not be ready" (Derrida 2002: 361), prepared for unusual events (see also Hagglund 2010: 302). Expanding the survey to allow for its heterogeneity to speak of wild birds and their pathologies might be the more prudent course of action. To do so would not involve integration of wild life, or indeed, any life, and it should not proceed through simple aggregation or integration of knowledge practices. As Foucault reminded us, "it is not that life has been totally integrated into techniques that govern and administer it; it constantly escapes them" (Foucault 1981: 143; see also Anderson 2011). It is this ability to take flight that a geography of knowledge, attendant to the heterogeneous materials, practices and sites of knowing, can foster. By attending to differentiated rather than single circuits, geographers and STS scholars can highlight the interactions that make a looser kind of knowing both possible and more suitable in the pursuit of safe life or biosecurity.

References

Anderson, B. (2011). "Affect and biopower: towards a politics of life." Transactions of the Insititue of British Geographers.

Attenborough, F. (2011). "The monad and the nomad: medical microbiology and the politics and possibilities of the mobile microbe." Cultural Geographies **18**(1): 91-114.

Barry, A. (2005). "Pharmaceutical matters: the invention of informed materials." Theory, Culture and Society **22**(1): 51-69.

Bennett, J. (2010). Vibrant Matter: A Political Ecology of Things. Durham, NH, Duke University Press.

Bingham, N. (2006). "Bees, butterflies, and bacteria: biotechnology and the politics of nonhuman friendship." Environment and Planning A **38**: 483-498.

Birdlife International (2006). Surveillance of wild birds. http://www.birdlife.org/action/science/species/avian_flu/pdfs/surveillance_of_wild_birds.pdf.

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

Capua, I. and D. J. Alexander (2006). "The Challenge of Avian Influenza to the veterinary community." Avian Pathology **35**(3): 189-205.
Clark, N. (2005). "Ex-orbitant Globality." Theory, Culture and Society **22**(5): 165-185.
Crick, H. Q. P., P. W. Atkinson, et al. (2006). Avian Influenza Incursion Analysis (through wild birds): a report of the British Trust for Ornithology, Wildfowl & Wetlands Trust and Veterinary Laboratories Agency to the Department for Environment, Food and Rural Affairs. Thetford, Norfolk, BTO.
Cussins, C. (1996). "Ontological choreography: Agency through objectification in infertility clinics." Social Studies of Science **26**(3): 575-610.
Davis, M. (2005). The Monster at our Door: The Global Threat of Avian Flu. New York, The New Press.
DEFRA (2006). The Avian Influenza and Influenza of Avian Origin in Mammals (England) (No.2) Order 2006. London, HM Stationary Office.
Dent, J. E., R. R. Kao, et al. (2008). "Contact structures in the poultry industry in Great Britain: Exploring transmission routes for a potential avian influenza virus epidemic." BMC Veterinary Research **4**(27): 1-14.
Derrida, J. (2002). Hospitality. Acts of Religion. G. Anidjar. London, Routledge.
Dillon, M. and L. Lobo-Guerrero (2008). "Biopolitics of security in the 21st Century." Review of International Studies **34**(2): 265-292.
Enticott, G. (2008). "The Spaces of Biosecurity: Prescribing and Negotiating Solutions to Bovine Tuberculosis." Environment and Planning A **40**(7): 1568-1582.
FAOSTAT. (2009). "FAOSTAT http://faostat.fao.org/." Retrieved 25/5/11, 2011.
Foucault, M. (1981). The History of Sexuality, Volume 1: An Introduction. Harmondsworth, UK, Penguin.
Foucault, M. (2004). Society must be defended. London, Penguin.
Foucault, M. (2007). Security, Territory, Population: Lectures at the College de France 1977-78. London, Palgrave Macmillan.
Granovetter, M. S. (1973). "The Strength of Weak Ties." American Journal of Sociology **78**(6): 1360-1380.
Hagglund, M. (2010). "A Non-ethical Opening of Ethics: A response to Derek Attridge." Derrida Today **3.2**: 295-305.
Haraway, D. (2008). When Species Meet. Minneapolis, University of Minnesota Press.
Hinchliffe, S. (2007). Geographies of Nature: Societies, Environments, Ecologies. London, Sage.
Hinchliffe, S. (2008). "Reconstituting Nature Conservation: Towards a careful political ecology." Geoforum **39**(1): 88-97.
Hinchliffe, S. and N. Bingham (2008). "Securing life - the emerging practices of biosecurity." Environment and Planning A **40**: 1534-1551.
Hinchliffe, S., M. Kearnes, et al. (2005). "Urban wild things: a cosmopolitical experiment." Environment and Planning D: Society and Space **23**(5): 643-658.
Huxley, J. (1968 (1912)). The Courtship Habits of Great Crested Grebe. London, Jonathan Cape.
Keil, R. and S. H. Ali (2007). "Governing the sick city: Urban governance in the age of emerging infectious disease." Antipode **39**: 846-873.
Latour, B. (1987). Science in action: How to follow scientists and engineers through society. Cambridge, Mass., Harvard University Press.

Latour, B. (1999). Pandora's Hope: Essays on the reality of science studies. Cambridge, Mass, Harvard University Press.
Latour, B. (2001). ""Thou shall not take the Lord's name in vain" - being a sort of sermon on the hesitations of religious speech." Res **79**(39): 215-234.
Latour, B. (2003). "What if we talked politics a little." Contemporary Political Theory **2**: 143-164.
Latour, B. (2004). "How to Talk About the Body? the Normative Dimension of Science Studies." Body & Society **10**: 205-229.
Latour, B. (2007). A Textbook Case Revisited - Knowledge as a mode of existence. The Handbook of Science and Technology Studies. E. Hackett, O. Amsterdamska, M. Lynch and J. Wacjman. Cambridge, Mass., MIT Press**:** 83-112.
Latour, B. (2010). The Making of Law: An Ethnography of the Conseil D'Etat. Cambridge, Polity Press.
Latour, B. (2010). On the Modern Cult of the Factish Gods. Durham, New Hampshire, Duke University Press.
Law, J. (2004). After Method: Mess in social science research. London, Routledge.
Law, J. and M. Lynch (1990). Lists, field guides, and the descriptive organization of seeing: Birdwatching as an exemplary observational activity. Representation in Scientific Practice. M. Lynch and S. Woolgar. Cambridge, Mass., MIT Press**:** 267-299.
Liebler, J. H., J. Otte, et al. (2009). "Industrial food animal production and global health risks: exploring the ecosystems and economics of avian influenza." EcoHealth **6**: 58-70.
Mackenzie, D. (2007). "UK tests could miss bird flu in migratory birds." New Scientist **2604**: 12.
Matless, D., P. Merchant, et al. (2005). "Animal landscapes: otters and wildfowl in England 1945-1970." Transactions of the Insititue of British Geographers **30**: 191-205.
Mol, A. (2002). The Body Multiple: Ontology in Medical Practice. Durham, NC., Duke University Press.
Newton, I. (2010). Bird Migration. London, Collins.
Pew Commission (2008). Putting meat on the Table: Industrial Farm Animal Producition in America. Baltimore, Pew Charitable Trusts and Johns Hopkins Bloomberg School of Public Health.
Serres, M. (2008). The Five Senses: A Philosophy of Mingled Bodies. London, Continuum.
Snow, L. C., S. E. Newson, et al. (2007). "Risk-based surveillance for H5N1 avian influenza virus in wild birds in Great Britain." *Veterinary Record* **161**: 775-781.
Wallace, R. G. (2009). "Breeding Influenza: The Political Virology of Offshore Farming." Antipode **41**(5): 916-951.
Wallensten, A., V. J. Munster, et al. (2007). "Surveillance of Influenza A Virus in Migratory Waterfowl in Northern Europe." Emerging Infectious Diseases **13**(3): 404-411.
Waters, C. K. (2012). Why Genetics Succeeds: an Epistemology of Scientific Practice. Talk at Egenis, University of Exeter, 2012.
Whatmore, S. (2006). "Materialist returns: practising cultural geography in and for a more-than-human world." Cultural Geographies **13**(4): 600-609.

Wilbert, C. (2006). "Profit, plague and poultry: the intra-active worlds of highly pathogenic avian flu." Radical Philosophy **139**: 2-8.

Figure 1: Herding caught birds up the swan pipe

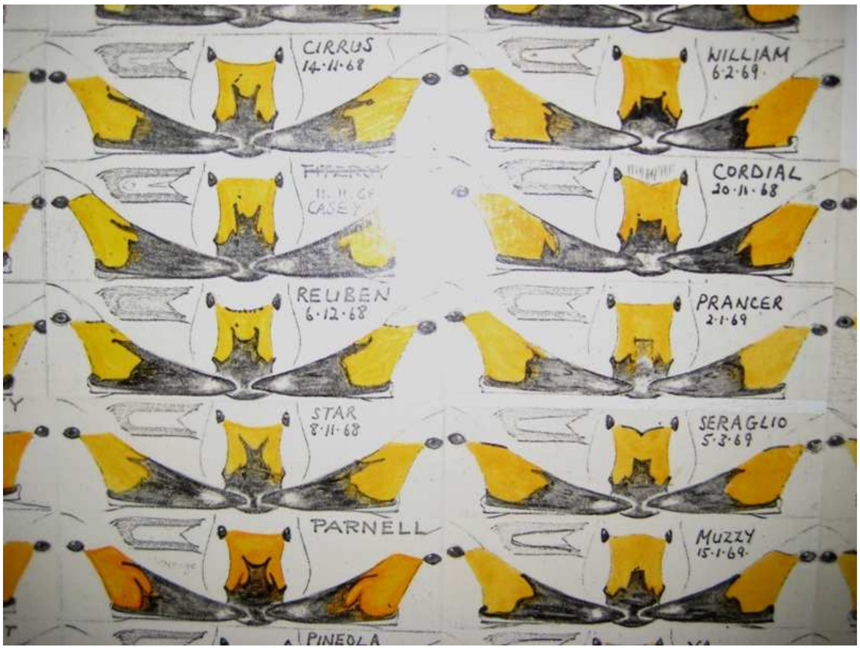

Figure 2: A procession of swans, Peter Scott’s sketches of the Bewick’s swans’ bill patters visiting Slimbridge

Figure 3: Swabbing of Bewick's swan