Public Health Ethics Advance Access published February 23, 2016

One Health and Culling as a Public Health Measure

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One of most pertinent and acute risks that the world is now facing is emerging or re-emerging zoonotic diseases. This article focuses on culling as a measure for zoonotic disease control, specifically the culling of 11,000 badgers as part of the Randomized Badger Culling Trial in the UK and the culling exercises in Singapore. The independent expert panel that devised the UK study concluded that reactive culling was ineffective in reducing the cases of bovine tuberculosis in cattle. The panel also concluded that proactive culling was not cost-effective. Behind the scarcity of empirical evidence to support culling, the resultant reduction in biodiversity can actually harm both animals and humans. Public health policies should be evidence-based, culturally adaptable and ethically justified; a novel biomedical and public health approach, named One Health (OH), plausibly provides a reasonable ethical framework as well as research and interventional methods that square with that framework. OH recognizes that nonhuman animals and humans are interlinked in both sickness and health, since we all share the same ecosystem. OH could potentially replace standard public health strategies, as it provides alternative evidence-based methods for biomedical research and adds a non-anthropocentric component to an ethical decision-making process.

Introduction

> Care to be had of unwholesome Fish or Flesh, and of musty Corn: That no hogs, dogs, or cats, or tame pigeons, or conies, be suffered to be kept within any part of the city, or any swine to be or stray in the streets or lanes, but that such swine be impounded by the beadle or any other officer, and the owner punished according to Act of Common Council, and that dogs be killed by the dog-killers appointed for that purpose. (Defoe, 2001: 35)

As written by Defoe in his fictional reporting on the 1664 plague outbreak in London, culling of animals has been a common public health intervention for centuries. Historically, both wild and domestic animals have been targeted, with the aim of managing and curbing outbreaks of zoonotic diseases.[1] Fifty years after the plague struck London, an outbreak of another disease brought about a systematic culling campaign as a formal public health measure. In the summer of 1714 in London, in response to an epizootic (the equivalent to an epidemic in animals) of rinderpest,[2] the English Lord Justices assigned Thomas Bates, a surgeon to the Royal Household, with the mission of containing the outbreak. Bates recommended to isolate infected herds, cull affected cattle and to burn their carcasses (Wilkinson, 2005: 51–52). Similarly, the UK government (as well as Argentine and Europe) has had a long 'affair' with foot-and-mouth disease (FMD), where the common response has been culling of livestock (Woods, 2004).

Table 1 provides a non-exhaustive list of more recent culling campaigns in response to disease outbreaks.

Culling is accepted internationally as a legitimate public health measure. The European Union Directive 92/40/EEC sanctions the culling of poultry in case of an avian influenza outbreak (The Council of the European Communities. Council Directive 92/40/EEC, 1992 Art. 5) and Directive 85/511/EEC sanctions the 'stamping out' (culling) of all susceptible animals on infected premises in case of FMD (Inquiry into foot and mouth disease in Scotland. The royal society of Edinburgh, 2002: 2). Similarly, the World Health Organization has often implemented a 3 km rule in response to outbreaks of avian influenza in poultry. However, the fact that culling is such a common intervention does not mean it is necessarily supported by scientific evidence. Being resource (manpower, time, monetary costs) intensive, from a public health perspective, a careful analysis of the available evidence is needed

doi:10.1093/phe/phw002

Table 1. Recent culling campaigns

Type of animal	Number culled	Outbreak/Reason
Chickens	1.5 million	1997 H5N1 Avian flu outbreak in Hong Kong (WHO, 2004)
Chickens	30 million	2003 outbreak of H7N7 Avian Flu in the Netherlands. (Kuiken, Leighton *et al.*, 2005)
Stray dogs	10,570	Pilot trial to curb endemic Echinococcus in China (Zhang, Zhang *et al.*, 2009)
Pigs	1 million	1998 Nipah virus outbreak in Malaysia (2010)
Chickens	>2 million	2006 Avian flu outbreak in Turkey (2006)
Chickens	20,000	2014 H7N9 outbreak in Hong Kong (2004)
Badgers	5,500	an 'interim strategy' during 1986-1998 to curb Bovine Tuberculosis (bTB) in the UK, before the assembly of the Krebs commission (see below) (2007)
Cows	26,600	2013 epidemic of bTB (Carrington 2014)
Dogs	Thousands	rabies epidemic in Bali and Flores, Indonesia (Suriyani, 2009; Morters, Restif *et al.*, 2013)
Chickens	>370,000	2014 H5N1 outbreak in China's Eastern province of Jiangsu (2008)
Chickens	112,000	2014 outbreak of H5 influenza virus in Japan (2014)
Sheep	>200,000	1998-2000 Bluetongue outbreak in Italy (Giovannini, 2007)
Livestock	>10 million	2001 Food and Mouth outbreak in the UK (Woods, 2004:140)

to assess the effectiveness and cost-effectiveness of culling interventions and to assess additional interventions that may be more effective and/or cost-effective (Johansen and Penrith, 2009). In the first part of this article, I review the evidence and critically examine two case studies: the badger culling trials in the UK that are meant to inform policies for management of bovine tuberculosis (bTB), and the culling of poultry in Singapore as a public health exercise. The reason for focusing on the trials in the UK is that they constitute the most serious, large-scale attempt yet to empirically assess the effectiveness of culling in curbing disease outbreak. The reason for focusing on the trials in Singapore is their uniqueness: they are not meant to curb an actual outbreak, but rather test the preparedness for a possible outbreak. They involve the killing of healthy chickens that are not currently at an increased risk for disease.

Another major concern is whether culling as a measure to curb disease outbreaks is ethically justified in general, even regardless of the humanness (or lack thereof) of the various methods utilized and the potential animal suffering. These aspects will be mentioned but not necessarily emphasized, but this does not mean that I think they should be ignored in policy-making. An immediate argument against culling is that animals suffer both emotional and physical pain (McMillan, 2003) between the moment they are hurt (shot, poisoned, etc.) and their death. The reason for partially marginalizing pain in the ethical calculus is to evade a potential counter-argument to this highly plausible argument against culling. The counter-argument may be simply to improve culling methods to prevent animal suffering; indeed, the recent badger culling trials in the UK have attempted exactly that, as elaborated below. De-emphasizing animal suffering in the discussion therefore annuls the relevance of this counter-argument; that is to say, if we conclude that culling is not ethically justified, then even if we prevent animal suffering altogether, culling would remain unjustified.

An implicit idea in this move is that sentient nonhuman animals constitute moral entities in themselves. From a strictly philosophical perspective, this statement requires a great amount of groundwork and defense, which will not be undertaken here. Rather, for the purpose of this article, it will suffice to rely upon a relatively minimal assertion: that sentient creatures have interests, and therefore one should not hurt or kill a

sentient creature without a reasonable justification (Singer, 2009).

To this ethical component, we must add the societal perspective (Weightman *et al.*, 2005: 6). In the UK, because people seem to care about badgers, the UK authorities had to justify their culling policy, either by empirically demonstrating its effectiveness or, more recently, by improving its humanness (Cassidy, 2012).[3] In contrast, in New Zealand, where people seem to perceive possums as nothing but a menace, culling practices can continue almost without any reservations (Potts, 2008). Therefore, in the second part of the article, I will discuss the ethical-social aspects of culling.

In the third part of the article, I will discuss One Health (OH), a novel biomedical paradigm that may provide an alternative approach to standard public health policies such as culling.

Three Premises

The article relies on three main premises:

> Premise I: It is morally unjustified to hurt or kill sentient beings (animals included) without a reasonable justification.
> Premise II: In public health policy-making, reasonable means planning and executing interventions that prove to be effective and/or cost-effective by available empirical data (if they exist) and, preferably, that are largely accepted by the public.
> Premise III: Culling has not been proven effective or cost-effective from a scientific perspective, and is commonly highly contested from a societal perspective.

If one accepts these premises, then one must seriously doubt the moral justification of culling as a public health measure. The ethical framework to support premise I is briefly provided above. The bulk of this article will focus on premises II and III. In order to determine whether culling is empirically justified, we require a scientific framework to assess systematically the existing empirical evidence. The UK National Health Services' (NHS) Health Development Agency (HDA) provides such a framework (Weightman *et al.*, 2005: 10). The highest level of evidence (level 1) includes meta-analyses, systematic reviews and randomized controlled trials (RCTs). The second level includes systematic reviews of, and non-randomized intervention studies, comparative cohort and correlation studies. The third level includes non-analytical studies such as case reports and case series, and the fourth level includes expert opinion and formal consensus.

Now that we have established both the ethical and empirical frameworks that explain and assess premises I–III, we can move on to examine the two case studies.

Badger Culling in the UK

The UK government has been conducting secret culling tests since August 2013, in which Nitrogen-filled foam is used to gas setts of badgers. So far, no badgers have been involved (Department of environment, food, & rural affairs. Request for information: Investigations into gassing as a culling option, 2014). In October 2014, two culling trials that involved the shooting of free roaming badgers in West Gloucestershire and West Somerset took place without an overseeing body (Badger cull appeal judgment reserved, 2014). Since there was no such body, we do not know the number of animals killed or the outcome. These trials followed two identical trials that ended in October 2013, which were meant to examine the safety, effectiveness and humanness of badger culling by way of shooting wild, unrestrained animals in West Gloucestershire and West Somerset (Policy paper. 2010 to 2015 government policy: Bovine tuberculosis, 2015, Badger cull start date set, 2014). An independent expert panel that oversaw the 2013 trials determined that the culling method used was neither effective nor humane.[4] Roughly 2600 badgers were culled during these trials (Pilot badger culls in somerset and gloucestershire: Report by the independent expert panel, 2014). Unfortunately, the history of badger culling in the UK cuts much deeper.

bTB and its Recent History in the UK

bTB is a zoonotic disease. The etiologic pathogen, *Mycobacterium bovis*, mainly affects cattle, but can also transmit to and cause disease in humans and various other nonhuman animal species; in fact, 0.5 per cent of all human tuberculosis (TB) cases are estimated to be caused by *M. bovis* (The center for food security & public health and the institute of international cooperation in animal biologies, Iowa State University, college of veterinary medicine. Bovine tuberculosis, 2009).[5] Worldwide, the domestic reservoir hosts for bTB include the Brushtail possums in New Zealand (1–10 per cent prevalence), the white-tailed deer in Michigan, USA (2–4 per cent prevalence), Badgers in the UK (14–36 per cent prevalence in the Republic of Ireland), etc. Wild reservoir hosts include the African Buffalo in

South Africa, wild boars and the Iberian Lynx in Spain and the Elk and Bison in Canada (Reynolds, 2006; The center for food security & public health and the institute of international cooperation in animal biologies, Iowa state university, college of veterinary medicine. Bovine tuberculosis, 2009; Robinson *et al.*, 2012). Since bTB from cattle is transmitted to humans mainly via contaminated milk, milk pasteurization has been extremely successful in reducing disease rates in humans in developed countries. However, bTB still remains a human health threat mainly in developing countries (The center for food security & public health and the institute of international cooperation in animal biologies, Iowa state university, college of veterinary medicine. Bovine tuberculosis, 2009).[6] The incubation period varies from animal to animal, being months in cattle and deer and weeks in cats. Cattle can be either asymptomatic or symptomatic, presenting with progressive emaciation, fluctuating fever, inappetence, moist cough and dyspnea. Badgers may be affected as well (McDonald, 2014).

bTB has been a persistent ailment among cattle in the UK (Reynolds, 2006, Cassidy, 2012). The chief veterinary officer called bTB 'the most difficult animal health problem we face in Great Britain' (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 27). The incidence in 2008 was 2738 confirmed herd breakdowns (i.e. a positive tuberculin test in at least one animal followed by positive culture) that carried a national expenditure of over 100 million pounds (Jenkins *et al.*, 2010).

There have been recurrent efforts by the UK government to curb bTB outbreaks (Reynolds, 2006). In 1975–1982, badgers were gassed in their setts with cyanide gas, effectively eliminating the badger population. Even though there were no confirmed bTB outbreaks in the 10 years that followed,[7] public concern over the humanness of the procedure caused the government to replace the gassing with a 'clean ring' policy. Once a TB outbreak in cattle was confirmed in a specific farm, badgers from the social group closer to this farm were trapped in a cage and tested. If at least one badger from that social group was found to carry the pathogen, the entire group would be culled. Social groups from adjacent areas would then be trapped, killed and tested as well, repeating the process. However, in 1986, a cost-benefit analysis failed to justify the 'clean ring' policy and it was replaced yet again with another policy, according to which culling would be restricted solely to the land occupied by the infected herd and only where infection could be reasonably attributed to badgers. Finally, in response to concerns raised by farmers and veterinarians, the Krebs committee was instituted in order to assess the available evidence, and in 1997, it issued its conclusions and recommendations. The committee concluded that the evidence was insufficient to recommend in favor of culling versus non-culling methods and recommended that a RCT be conducted to assess effectiveness of culling campaigns (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 29).

The Randomized Badger Culling Trial

Consequently, in 1998, the UK government launched a large-scale trial, the Randomized Badger Culling Trial (RBCT). Badgers in 10 different sets of three areas of 100 square kilometers each were randomized to no intervention, proactive (with no documented breakdown cases) and reactive (in response to cattle breakdowns) culling. In the reactive group, all badgers in an area were killed, and follow-up culls were repeated approximately annually until 2005. The culling consisted of caging the animals and then shooting them. Roughly, 11,000 badgers were killed.

An independent scientific expert panel (henceforth 'panel') designed and oversaw the RBCT and reported its findings to the government. The results of the trial are as follows:

(1) '...[R]eactive culling increased, rather than reduced, the incidence of TB in cattle, making this unacceptable as a future policy option.' (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 13)[8]

(2) In 2007 the panel concluded that the 'beneficial effect on cattle breakdowns' of proactive culling 'was offset by an increased incidence of the disease in surrounding un-culled areas' (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 13). More recent data demonstrate that from the start of the RBCT to 28 August 2011, the incidence of bTB breakdowns in cattle was 25.7 per cent lower within proactive culling areas compared to nonintervention areas.[9] However, from the beginning of the RBCT until 2011, the incidence of breakdowns in areas up to 2 km outside proactive culling areas was 7.6 per cent higher than areas outside nonintervention areas (Jenkins *et al.*, 2011). In 2010, after conducting a cost-benefit analysis, members of the panel concluded that, 'the financial costs of conducting the culling substantially exceed the overall benefits accrued. In the absence of other practicable culling methods likely to yield greater benefits, our findings indicate that, on

the basis of cost-effectiveness, badger [proactive] culling is unlikely to contribute to the control of cattle TB in Britain.' (Jenkins *et al.*, 2010)

(3) Improvement and modification of either proactive or reactive culling is highly unlikely to result in a better outcome. (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 23)

(4) Proactive culling affected other wildlife species: the number of foxes and hedgehogs increased, while the number of hares decreased.

Overall, the panel concluded that '. . .while badgers are clearly a source of cattle TB, careful evaluation of our own and others' data indicates that badger culling can make no meaningful contribution to cattle TB control in Britain. Indeed, some policies under consideration are likely to make matters worse rather than better.' (Independent scientific group on cattle tb. Bovine tb: The scientific evidence, 2007: 5). Instead, the following measures are recommended (Independent scientific group on cattle tb. Bovine tb: The scientific evidence, 2007: 24, and Chap. 10)[10]:

(1) Improved surveillance of cattle that involves more frequent and sensitive screening using Tuberculin Skin and Interferon test.

(2) Reduction of badger-to-cattle transmission by better separation of badgers from cattle by way of electrical fences, container locks, etc.

(3) Reduction of cattle-to-cattle transmission by more rigorous control of movement that includes isolation of cattle prior to primary introduction into the herd as well as categorization of high- versus low-risk farm/areas/herds and limitation of movement of cattle between them.

(4) Improved implementation of bio-secure restocking policies in farms in which infected cattle are slaughtered.

(5) Designation of an external group of experts who would advise policy-makers based on empirical data.

The RBCT represents a specific kind of intervention as part of a pandemic response strategy, where infected and at-risk primary host wildlife are destroyed mainly with the goal of preventing disease in domesticated nonhuman animals. Another kind of a public health intervention is the culling of healthy, not-at-risk domesticated animals in order to test pandemic preparedness. The culling campaigns in Singapore belong to the latter.

Culling in Singapore

The Singaporean Infectious Diseases Act allows the destruction of any animal that is suspected of carrying an infectious disease (Infectious diseases act (chapter 137), 2003 clause 13). Singapore is reported to be free from bird flu (Leong *et al.*, 2008). However, since Singapore imports most of its meat products, the Agri-Food and Veterinary Authority (AVA) of Singapore has taken comprehensive measures to prevent and prepare for potential outbreaks. The measures include: (a) Control Measures at Source; (b) Border Control Measures; (c) Local Control Measures; and (d) Emergency Preparedness (Leong *et al.*, 2008: 505). The latter category includes '[t]he selective culling of bio-segregated clusters of poultry farms in a confirmed outbreak' (Leong *et al.*, 2008: 507). In order to test its operational readiness to embark on such an enterprise, the AVA has conducted seven exercises from 2002 to 2013, six of which were field exercises.

Culling Exercises in Singapore

Table 2 summarizes the culling exercises in Singapore. Data are hard to ascertain, but it seems that the first documented field exercise occurred in February 2004. In fact, two field exercises took place in 2004, 7 months apart. At least three exercises included the actual culling of chickens. Overall, at least 7000 chickens were killed in order to test the 'operational readiness' of the Singaporean authorities to respond to flu outbreaks.

Singapore's eagerness to assure preparedness is of course commendable, but is the price justified? There are no trials to demonstrate the benefits of the Gallus Exercises for epidemic preparedness, but it is reasonable to assume that 'practice makes perfect'. Moreover, the culling of chickens may be more effective in disease control than the culling of wildlife since the chickens are housed in close quarters and cannot escape. However, such an intervention may still have unforeseen effects (see below). Beyond the possible adverse effects, we need to consider whether such an exercise is morally and socially justified, especially in light of its modest aims. The Gallus Exercises were meant to test preparedness to swiftly and effectively cull chickens—why was there a need to actually kill the chickens? Three challenges are worth mentioning here.

First, two different field exercises were conducted in 2004, and the fourth and fifth field operations were conducted 1 year apart. What is the reason for such high frequency? Obviously, the 2004 outbreak of H5N1

Table 2. Summary of culling exercises in Singapore

Number of Gallus Exercise	Date	Number of chickens killed and method	Outcome	References
I	23 September 2002	A 'desk-top' exercise. None.		(Exercise gallus. A letter to Dr Bernard Vallat, director general, office international des epizooties, 2002)
				(The look of life: Fy2002/2003 annual report, 2003)
II	18 February 2004	5000 layer chickens. Unknown method.	Successful: '[T]he exercise reaffirmed that the culling method adopted is humane for the chickens and safe for the cullers. The chickens were rendered unconscious within 1 min and they died shortly after.'	(Emergency prepatedness exercise to respond to a bird flud oubreak, 2004)
				(Exercise to test our operational readiness to deal with a brid flu outbreak, 2004)
				(Staying fresh: Annual report 2003/2004, 2004)
III	3 September 2004	None	No information	(Emergency prepatedness exercise to respond to a bird flud oubreak, 2004)
IV	4 October 2006	Unclear, but cullers were involved.	Successful	(Exercise to test operational readiness to deal with a bird flu outbreak successful, 2006)
V	10 January 2008	1500, unknown method.	Successful: 'With the successful completion of Exercise Gallus V, AVA had once again proved its operational readiness to combat bird flu incursion into Singapore.'	(*AVA passes with flying colours in 'exercise gallus v'*, 2008)
VI	March 2012	None.	Successful	(AVA vision. Exercise gallus: Ever on guard, 2012)

(continued)

Table 2. Continued

Number of Gallus Exercise	Date	Number of chickens killed and method	Outcome	References
		A new method was used: instead of the liquid disinfectant that was used previously, some sort of foam decontaminate was used.		
VII	17 July 2013	500 broiler chickens.	Successful.	(AVA maintains emergency preparedness to deal with bird flu, 2013/2014)
		The AVA does not seem to report the measure used, but the World organization for Animal Health (OIE) reports that nitrogen-gas-filled high-expansion foam was used. According to the OIE, this method has many advantages (italics mine):		(AVA's emergency preparedness exercise to test operational readiness to deal with a bird flu outbreak, 2013)
		'*It has been shown to improve animal welfare during the *inevitable* process of culling for disease control purposes.		(*Simulation exercise: Culling of poultry procedure in singapore*, 2013)
		*There is reduced contact between operators and live birds, lowering potential risk of human exposure and infection.		
		*This method is more efficient, allowing the rapid stamping out and eradication of diseases.'		

influenza in Southeast Asia created a need to calm concerned civilians (as well as high-level politicians), but still, if the purpose is merely to test preparedness, there seems to be little need for two field exercises a year! Since all the exercises were declared successful, why repeat them in such close proximity?

Second, some of the exercises involved mock culling, continuously being declared successful. If these were successful, i.e. affirmed the capability of the authorities to rapidly and effectively dispose of infected poultry, why was there a need to actually kill chickens in other exercises? Either mock culling is insufficient for preparedness testing, and then actual culling is required, or mock culling is indeed sufficient, obviating any need for actual culling.

Third, Exercise Gallus II affirmed that the culling was humane, and that the chickens lost consciousness within 1 min. How likely is it that all 5000 chickens lost consciousness within 1 min and did not suffer beyond that minute? Especially considering that the measure used is not disclosed, one should remain skeptical. Moreover, what happened to the chickens during that minute? The term 'humane' is clearly a normative one, but who is to determine its meaning—who determines what constitutes a 'good' way to die for animals? Since we do not know the measure that was used during the exercises (except in the last one), we have no way of retroactively assessing how the chickens died. Therefore, there is reason to suspect that not all chickens lost consciousness within 1 min, and that the death of some was not 'humane'.

In seeking to respond to at least some of these questions, I will next discuss various aspects relating to the practice of culling in general.

Scientific Aspects of Culling

Let us apply the HDA's framework to culling. There has not been any RCTs to compare effectiveness of culling with alternative methods. As mentioned above, the only RCT that compared reactive culling with no intervention concluded that culling is not effective in reducing incidence of bTB in livestock. The same study also compared proactive culling with no intervention and concluded that the intervention is not cost-effective for bTB incidence reduction in livestock. Additionally, to my knowledge, no level 2 observational studies were conducted to assess the effects of culling.[11] Virtually all the evidence that supports the effectiveness of culling in reducing outbreaks is level 3, resulting from case reports where a certain chain of events occur: rates of disease increase, a certain population of animals is culled, and (occasionally) disease rates decrease.[12] No causation is established beyond level 3, and no cost-benefit analysis is offered. In terms of level 4 evidence, it seems that experts are divided. The predominant veterinary paradigm may favor culling (Barteling and Sutmoller, 2002). However, an FAO and OIE Expert Group has concluded that vaccination is more effective than culling for the control of avian influenza outbreaks (Butler, 2005; OIE/FAO international scientific conference on avian influenza OIE Paris, France, 7–8 April 2005; Too little, too late, 2007).

Focusing on rabies control, a recent review has concluded that culling may be ineffective in controlling outbreaks that are density dependent, where there is a positive correlation between pathogen reproduction and host population. The authors hypothesize that culling in this case may be ineffective simply because the desired reduction in the host density was not achieved (as could be seen in the 2013–2014 badger trials in the UK; see above). Moreover, there may be various, potentially unknown factors at play, such as the interaction between host age structure and demographic processes that may counter the effects of culling. Finally, human factors have to be considered as well. For example, after a culling campaign in a village in Bali, two residents introduced unvaccinated puppies to the village to replace their dead pets (Morters *et al.*, 2013).

Moreover, available evidence suggests that culling not only fails to achieve the desirable results, but actually increases disease risk in both animals and humans. For example, in 2005, the panel that devised and monitored the RBCT suspended the arm of the trial which measured the effects of reactive culling, 2 years before the pre-designated date, because it caused a significant increase in cattle bTB incidence (Reynolds, 2006). There may be several explanations for this increased risk.

Biodiversity becomes a decisive consideration, as there is growing evidence that links biodiversity to health and disease (Cardinale *et al.*, 2012). Indeed, the lack of wildlife other than badgers or deer in one farm in the UK was found to be a significant risk factor for herd bTB breakdowns (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 131).[13] Culling practices arguably reduce biodiversity, and consequently may actually increase disease rates by the following mechanisms[14]:

(1) For some vector-borne pathogens, transmission may be frequency dependent, meaning that a scarcity of host organisms facilitates transmission of disease. The reason simply is this: if there are

fewer host organisms and the number of vectors remains constant, the numbers of vectors per organism would be greater, and each organism would be statistically more likely to be fed on and subsequently infected by a vector. Moreover, a decrease in the primary host population may lead vectors to pursue alternative host populations (Kilpatrick, 2011; Kilpatrick and Randolph, 2012).

(2) For pathogens that are not transmitted by vectors, culling may increase transmission due to the escape of surviving animals to adjacent areas and change of ranging behavior (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 69–70). Specifically, culling may increase prevalence of infection in surviving animals by the following mechanisms: increased immigration, increased contact among surviving animals and consequently increased pathogen transmission (Jenkins *et al.*, 2010) (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 79).

(3) Disruption of local ecological stability. In Turkey, for example, the culling of chickens in response to the avian flu outbreak in 2006 may have been a direct culprit of an outbreak of tick-borne Crimea-Congo hemorrhagic fever (Poultry cull is not the cause of tick increase: Turkish government, 2006).

The discussion so far should not be understood as a call necessarily to conduct more RCTs in order to assess the validity of culling exercises (see below). Occasionally, especially in public health research, RCTs cannot be conducted for a myriad of reasons, such as costs, ethics, feasibility, etc. (Black, 1996; Weightman *et al.*, 2005: 2, 5). However, public health interventions should be based on evidence and cost-effectiveness analyses, and the evidence to support culling as an effective and/or cost-effective measure to reduce disease rates in both animals and humans is extremely limited.

Ethical and Societal Aspects of Culling

Why then did the UK government embark in 2013 and 2014 on four additional badger culling trials, killing additional 6000 badgers? The official purpose of the 2013 trials was to assess the effectiveness, humanness and safety of controlled shooting of badgers (Pilot badger culls in Somerset and Gloucestershire: Report by the independent expert panel, 2014: 6). The concern for safety is, without a doubt, justified since there was fear that protestors would get hurt incidentally (the Singaporean authorities demonstrated a similar concern for the cullers' well-being).

Similarly, the attempt to assess humanness is also justified. Badgers play an important part in the social ethos in the UK, where they enjoy legal protection[15] and a social support network (Cassidy, 2012). Recognizing that the UK public cares about the well-being of badgers, the perceived humanness of any intervention in badgers is crucial for its acceptance by the public [as mentioned, this stands in stark contrast with the possums in New Zealand, where they are considered to be pests (Potts, 2008; Tompkins *et al.*, 2009)]. Here we find at least a partial reply to the question asked regarding the culling exercises in Singapore—who determines what constitutes 'humane killing'. While part of the answer should be given by ethicists, another part should be and is given by the community, be it local, national or international. Arguably, it is largely up to a community to determine what would be a humane, i.e. ethical, way to behave toward animals, even in the midst of killing them (hopefully, this communal decision will be informed by sound ethical considerations). Pragmatically, authorities might have to struggle to embark on any intervention that is not considered humane by the community, particularly when it is directed toward a creature of which the community is fond; this was demonstrated repeatedly during badger culling campaigns in the UK.[16]

Alas, the rationale for assessing effectiveness is unclear. One reason the proactive culling arm in the RBCT actually increased prevalence of disease in badgers as well as cattle breakdowns is that the culling was not effective enough, and badgers escaped to adjacent areas. Plausibly, this is what the recent trials attempted to amend. However, the panel provided other possible reasons, as mentioned above, and these would not be addressed by a more effective culling of local badgers. In fact, the panel suggested that more effective culling may not only reduce the number of immigrant badgers but may even increase it. Additionally, the panel cited mathematical models to suggest that reductions in badger density might generate only small reductions in cattle bTB incidence, and concluded that, '[w]e therefore conclude that improvements in culling efficiency—if implemented in isolation from other changes—are unlikely to generate benefits substantially greater than those recorded in the RBCT' (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 164–165).

Plausibly, the UK government emphasized the effectiveness of culling for political, rather than scientific, reasons. Richard Coker describes how, during the TB

epidemic in New York in the late 20th century, public health coercive measured were geared toward those who were predicted to be noncompliant with therapy, rather than those who actually posed a risk. Noncompliance became the problem requiring solution, rather than the infective pathogen (Coker, 2000). Similarly, Abigail Woods describes how the UK government pushed for culling in response to recurrent FMD outbreaks as a way to demonstrate British uniqueness and superiority over other European countries that have implemented routine and emergency vaccination instead of culling (Woods, 2004). By conducting trials to assess the effectiveness of culling, policy-makers in the UK shift the discourse from whether culling actually works as a public health measure to whether we can make it optimal. In the light of the RBCT results, the effectiveness of culling in reducing badger density is completely irrelevant. Furthermore, the fact that the 2014 culling trials were conducted without any independent supervision is concerning, to say the least.

Culling campaigns often require the collaboration of various stakeholders either as active or passive participants. The exercises in Singapore assessed the mental and physical ability of workers to cull a large number of poultry. Farmers and wet-market vendors have to withstand the economic losses accrued by the culling of their livestock and poultry. Additionally, as mentioned above, culling may bring about unforeseen adverse effects that will ultimately hurt the community in general and the specific relevant stakeholders. Consequently, culling interventions need to be accepted by the community; in general, they are not. In fact, as alluded to above, culling is relatively a modern practice. Authors of ancient and classical times, such as Varro (first century BC), Columella (circa 50 AD) and Vegetius (fifth century AD) did not mention culling as a response to disease outbreaks. Indeed, Varro recommended to keep animals in small groups to prevent the need for a large-scale cull in case of outbreaks (Wilkinson, 2005: Chap. 1). More recently, a study that compared attitudes of veterinarians, farmers and lay people has found that all three groups preferred vaccination programs over culling programs for epidemic control (Zingg and Siegrist, 2014).

Different communities will respond differently to culling policies, as intrinsic animal traits often influence public opinion. For example, big eyes contribute to an animal being 'cute' and therefore lovable (Herzog, 2010). Extrinsic factors will also play a part. According to Annie Potts, the lack of empathy toward possums in New Zealand mainly stems from misplaced nationalistic and conservationist attitudes: The possums were brought in from Australia and are not natives; they destroy the environment; killing them for various reasons is actually beneficial to the environment and the native species (Potts, 2008). In contrast, Kenneth Graham's children's novel *The Wind in the Willows* portrays Mr Badger as brave, shy and intelligent, and that image seems to dominate public opinion. However, recent coverage in the UK media portrays the image of the 'bad badger': as disease carriers, violent and criminal. The latter seems to outnumber the instances of the positive portrayal (Cassidy, 2012). If one wishes to modify public perceptions of animals and public attitudes toward culling policies then, one has to seek the help of public figures and artists.[17] Arguably, one also has to seek the help of ethicists.

Culling seems to be morally unjustified from a strict anthropocentric perspective, as there is only limited evidence to demonstrate its effectiveness and cost-effectiveness in reducing disease rates in humans (direct anthropocentric benefit) and in animals (indirect anthropocentric benefit, e.g. economical). Additionally, culling may be harmful to humans for several reasons. First, culling campaigns are extremely costly, requiring the allocation of additional public funds to farmers as compensation (Wilkinson, 2005: 52–53). More recently, the UK government has spent 8 billion British Pounds in response to the 2001 FMD outbreak. An additional 1.3 billion pounds were used to compensate farmers, and the tourism industry suffered losses of roughly 4.5 billion because of the gruesome images of burning livestock carcasses. Comparatively, the livestock export industry is only worth 1.3 billion pounds a year (Woods, 2004: 149). Second, as noted, culling and the resultant reduction in biodiversity can have adverse effects on human beings beyond those involved in specific culling campaign. Thus, from strictly an anthropocentric perspective, the lack of strong empirical evidence to support culling policies makes it hard to justify such policies. If culling, on balance, harms humans: why do it?

Moreover, my assumption here is that sentient creatures are morally valuable, and that, consequently, one may not hurt or kill them without justification. Thus, a non-anthropocentric factor also weighs in against culling: since current evidence does not justify culling, one may not devise and/or implement policies that involve culling.

To recall, I presented three premises at the outset of the article:

> Premise I: It is morally unjustified to hurt or kill sentient beings (animals included) without a reasonable justification.

Premise II: In public health policy-making, reasonable means planning and executing interventions that prove to be effective and/or cost-effective by available empirical data (if they exist) and, preferably, that are largely accepted by the public.
Premise III: Culling has not been proven effective or cost-effective from a scientific perspective, and is commonly highly contested from a societal perspective.

If these premises are accepted, then culling as a measure to reduce disease rates in humans and/or animals loses much of its legitimacy. Culling is a highly common public health intervention, but there is very limited evidence to support it. The RBCT, as the most serious attempt to test empirically the effectiveness and cost-effectiveness of culling[18] concluded against it. Further, no study has ever tested the effectiveness and cost-effectiveness of culling versus another intervention. Consequently, while culling may still be effective in some contexts, one cannot be confident that, first, culling actually works as a necessary and/or sufficient condition for disease reduction, and second, that it is more effective and more cost-effective in disease reduction than alternative interventions. From both an anthropological and non-anthropological perspectives, this conclusion makes culling immoral.

Obviously, this conclusion contradicts both common practice and common sense—if one kills all animals that are sick or are at risk of being sick, there will be no sickness. Granted, the fact that something has not been empirically proven to be effective, does not mean that it is indeed ineffective. Further, the culling of domesticated animals is fundamentally different from the culling of wild animals, and is likely to be more effective (although, as mentioned above, experts have argued that flu vaccinations may be more effective than culling). Therefore, this article can only represent the beginning of a serious discussion, not the end. Such a discussion should take into account scientific and psychosocial empirical knowledge (e.g. public attitudes, scientific data, etc.) as well as ethical argumentation.

However, let us assume that culling is indeed deemed immoral. What else can be done then, in order to prevent disease outbreaks? In the next section, I will first provide a brief overview of OH, a novel biomedical approach that may provide a solution, and frame the discussion within a OH approach. Second, I will offer alternative methods to culling as measures to manage zoonotic diseases, suggesting that these methods may be more ethically and scientifically justified compared to culling.

One Health

The OH initiative is a collaborative, multidisciplinary effort to improve the lives of humans and nonhuman animals, and to conserve the environment. Various national and international organizations, such as the American Veterinary Association (One Health initiative task force of the american veterinary medical association. One Health: A new professional imperative, 2008), the American Centers for Disease Control and Prevention (Operationalizing 'One Health': A policy perspective- taking stock and shaping an implementation roadmap, 2010) and the World Health Organization (Contributing to one world, One Health: A strategic framework for reducing risks of infectious diseases at the animal-human-ecosystems interface, 2008) have adopted OH as a framework for public health policy-making. The scope of OH includes, but may not be limited to, surveillance and prevention of diseases stemming from zoonotic pathogens and environmental toxicants, animal-assisted therapy, food safety and security, biodiversity and climate change and comparative medicine (Lederman and Rabinowitch, 2014).

In addition to calling for interdisciplinary collaboration, and in contrast to the standard common public health paradigm which is entirely anthropocentric, OH formally aims to promote the well-being of animals and to conserve the environment (One Health initiative task force of the American veterinary medical association. One Health: A new professional imperative, 2008, Capps and Lederman, 2015a). Indeed, the difference between OH strategies and standard public health strategies becomes stark when we assess real-life interventions. From a standard public health perspective, any public health intervention should be reviewed according to four commonly invoked criteria: (i) need[19]; (ii) cost-effectiveness; (iii) public opinion and cultural considerations; (iv) anthropocentric ethical considerations (Nuffield council on bioethics. Public health: Ethical issues, 2007; Torgerson and Torgerson, 2009b; Tompkins *et al.*, 2009; Johansen and Penrith, 2009). From a OH perspective, non-anthropocentric ethical considerations are added as well (Reynolds, 2006; Ducrot *et al.*, 2011; Lederman, 2013; Colonius and Earley, 2013).[20]

However, what these ethical considerations actually mean is still unclear. While the moral standing of specific animal species and the environment within the OH approach has yet to be fully articulated (Lederman, 2013), authors have begun to speculate how might adopting OH as a biomedical and public health framework translate into biomedical research and public

health decision making (Rabinowitz *et al.*, 2008; Ducrot *et al.*, 2011; Capps and Lederman, 2015a).

On the one hand, many authors seem to view OH as nothing but a call for interdisciplinary collaboration (Contributing to one world, One Health: A strategic framework for reducing risks of infectious diseases at the animal-human-ecosystems interface, 2008: Coker *et al.*, 2011). Alas, this view completely ignores the second formal goal of OH, as stated above. Furthermore, if this view is correct, then OH loses its appeal to medical ethicists and bioethicists.

On the other hand, OH potentially constitutes a paradigm shift in our worldview, compelling us to revisit our perception of the moral status of animals, plants and ecosystems—why should public health professionals, researchers and clinicians care about the health of nonhuman organisms? Beyond its benefits to public health and biomedical research and practice, OH rejuvenates bioethical discourse, plausibly linking theories from environmental philosophy with bioethics and refocusing our attention on the nonhuman biological world (Thompson and List, 2015).

At the very least, one may plausibly posit that OH calls to replace the prevalent 'Us Versus Them' approach, where animals are considered merely as a tool to benefit human beings, with a 'Shared Risk' approach, where animals and humans are considered to be prone to much of the same environmental risks (Rabinowitz *et al.*, 2008; Rabinowitz and Conti, 2010). A complementary approach advocates for public health interventions that produce 'shared benefits', such as vaccinations that protect both humans and animals against similar pathogens (Capps and Lederman, 2015b).

Further, OH may have far-reaching implications specifically for public health ethics. Angus Dawson and Bruce Jennings have recently argued for the inclusion of the notion of solidarity in public health ethics discussions. They define solidarity mainly as a collective commitment to assist others who share similar situations or causes, and view it as an essential requirement for an ethical decision making in public health. At its very core, solidarity consists of public action that is oriented toward correcting injustices. More generally, it is a positive identification with another that is driven by sympathy (Dawson and Jennings, 2012). Through that sympathy, humans recognize an identical motif that binds us all. Solidarity is a constitutive element in human nature, as it '...arises from the nature of humans as biological and social creatures' (Dawson and Jennings, 2012: 76). As biological and social creatures who share the same world, solidarity is made possible and evident through the recognition of human interdependencies (Dawson and Jennings, 2012).

Melanie Rock and Chris Degeling have recently applied the concept of solidarity unto OH, calling to extend the term to animals and plants[21] (Rock and Degeling, 2015). While their notion of 'more-than-human solidarity' requires much more defense and elaboration, it is immensely appealing. Applying Dawson and Jennings' discussion, human beings, as living beings who require certain conditions to survive, may certainly sympathize with most animals, and arguably plants. In the words of Paul Taylor, they are all 'Teleological Centers of Life' (Taylor, 2011). Just as solidarity is a constitutive element in the nature of humans merely because they are biological and social creatures, animals and plants are also biological and social creatures, and thus solidarity is and should be an element in their nature as well.[22] Further, perhaps the most important contribution of OH is empirically to demonstrate the interdependence of humans, ecosystems and animals in both sickness and health (Rabinowitz *et al.*, 2013; Lederman and Rabinowitch, 2014). More-than-human solidary is further strengthened through that empirical validation.

Lastly, Benjamin Capps and Zohar Lederman have recently espoused the notion of 'Universal Goods' as an extension of the anthropocentric notion of 'Public Goods'. Just as a Public Good is a function of the public interests and individual human rights, a Universal Good is a function of humans and nonhuman *interests*, coupled with human and nonhuman *rights* (Capps and Lederman, 2015ab).[23]

Whatever the moral justification may be, from a public health perspective, one of the main objectives of OH is to provide alternative evidence-based methods to detect and manage zoonotic diseases (Rabinowitz *et al.*, 2013). Such methods may constitute an alternative for culling, and include:

(1) Use of prophylactic measures to prevent disease in both humans and animals (primary prevention). An example is the use of dog collars impregnated with insecticide to prevent spread of Leishmaniasis in Iran and Brazil (Gavgani *et al.*, 2002; Sousa and Day, 2011). The most significant prophylactic measure is of course vaccination, including vaccination of wildlife and pets (Tsao *et al.*, 2004; Giovannini, 2007; Tompkins *et al.*, 2009; Treanor *et al.*, 2010; Robinson *et al.*, 2012). For example, the Bacille Calmette-Guerin (BCG) vaccine in badgers has been proven safe and efficacious against

bTB and was subsequently approved for use in badgers in the UK (Robinson *et al.*, 2012).[24] Another example is the vaccine bates used to manage rabies in wildlife, such as raccoons in the USA and the red fox in Europe (Brochier *et al.*, 1991; Robinson *et al.*, 2012; Human contacts with oral rabies vaccine baits distributed for wildlife rabies management—Ohio, 2012, 2013).

(2) Prediction and prevention of disease outbreaks using meteorological and ecological information. An example is Rift Valley Fever (RVF) in East Africa, a viral disease, carried by mosquitoes, that affects livestock and humans. Data on sea surface temperatures coupled with data on the presence of green vegetation could potentially allow prediction of RVF outbreaks 1–2 months prior (Cage *et al.*, 2008). This prediction could in turn initiate livestock vaccination campaigns and insecticidal treatments of mosquito habitats (Patz and Hahn, 2013).

(3) Treatment of afflictions which may harm both humans and animals. An example is the deworming of pet and stray dogs to treat various helminthes that may affect both species (Schurer *et al.*, 2013). Another example, already mentioned, is the prophylactic vaccination of primates against Ebola in order to gain an inter-species immunity, benefiting both primates and humans (Capps and Lederman, 2015b).

Further Steps

Without a doubt, the aforementioned methods should be implemented to a greater degree than they are currently. Nevertheless, what about culling? Should public health practitioners conduct more trials to test the effectiveness and cost-effectiveness of culling versus other methods? As stated above, this article does not *necessarily* represent a call to conduct more RCTs. But it may. From a OH perspective, is a RCT to test culling versus other interventions justified? On the one hand, it will involve the intentional killing of potentially thousands of sick and at-risk animals, with very limited evidence to support it, as argued in this article. On the other hand, if the results convincingly show superiority or non-inferiority of the other intervention, then other animals and humans may benefit in the future (assuming, of course, that other culling operations will diminish globally as a result). Would this be justified from a OH perspective?

Can we reasonably ask for level 1 trials to justify culling? What is the level of evidence we should aspire to? One possible suggestion is that the level of evidence required should depend on the level of risk that a certain disease poses on humans (risk in terms of both qualitative damage, i.e. the severity of the disease and its effect on quality of life, and quantitative damage, i.e. the number of deaths that the disease will cause). However, if the discussion above about OH ethics has any merits, such a suggestion will be extremely hard to defend. Perhaps then, it should depend on the risk to both humans *and* animals. Potentially, such a RCT that involves the culling of thousands of animals may prevent the culling of millions of animals in the future. While this kind of utilitarian calculation involving human lives could never be morally justified, even as part of research, one important consideration is worth mentioning here. Biomedical human research does involve subjecting humans to a higher risk than normal, for the potential benefit of these humans and future generations. Thus, even if within OH we consider animals as morally valuable, we might (and most do) consider them as less valuable than humans, and therefore may be justified in subjecting them to an extremely high risk for the potential future benefit of future generations of both humans and animals. Conversely, there is no guarantee that one RCT, even if it is high quality, will change global public health policy-making. Rather, researchers would want to conduct more studies, to change some variables, and to reproduce the results of the original RCT. Consequently, once the 'floodgates' open, numerous animals would be killed in the name of a OH attempt to further test the hypothesis that culling works or does not work. That scenario should be avoided.

Conclusion

This article focuses on culling as a measure for zoonotic disease control, specifically the culling of 11,000 badgers as part of the RBCT in the UK and 7000 chickens during the Gallus Exercises in Singapore. The independent expert panel in the UK that devised the study concluded that reactive culling was ineffective in reducing the cases of bTB in cattle. The panel also concluded that proactive culling was not cost-effective. Oddly, two trials that were conducted in the UK in 2013 examined the effectiveness and humanness of badger culling, ignoring the conclusions from the RBCT; these recent trials have failed as well. For some reason, two similar trials were conducted in 2014—since there was no independent supervision, we may never know their results.

OH is a novel paradigm that recognizes that nonhuman animals and humans are interlinked in

both sickness and health, since we all share the same environment. OH could potentially replace standard public health strategies, as it provides alternative evidence-based methods for biomedical research and adds a non-anthropocentric component to an ethical decision-making process.

Public health policies should be evidence based, culturally adaptable and ethically justified. In all of these, culling practices seem to fail. The emerging OH paradigm is an opportunity to integrate a reasonable ethical framework with research and interventional methods that square with that framework. Human medical professionals, veterinarians, public health experts, ecologists, anthropologists, ethicists, etc. should seize that opportunity.

Notes

1. Culling has been used for other purposes that will not be discussed here, for example, for sorting poultry. Indeed, in a circular from 1922, the Kansas State Agricultural College, Department of Poultry Husbandry, defines 'culling' cynically as: '. . .sorting of the desirable and undesirable hatching eggs, chicks, pullets, cockerels, hens, or breeding males' (Payne, 1922: 3).
2. Also known as 'cattle plague'. The viral disease was eradicated in 2011 (Rinderpest, *2015*).
3. Incidentally, people in the UK also care about livestock, as manifested by public outcries that followed slaughtering campaigns in response to FMD outbreaks in the 20th and 21st century (Woods, 2004).
4. The expert panel defined 'humanness' as 'absence of suffering' (Pilot badger culls in somerset and gloucestershire: Report by the independent expert panel, 2014: 23). Based on thin evidence, the panel determined that '. . .suffering from marked pain is very likely in badgers that survive more than 5 min after being shot' (Pilot badger culls in somerset and gloucestershire: Report by the independent expert panel, 2014: 25).
5. Not a small number, since the global prevalence of TB in humans was 5.75 million in 2010 (World health organization. World health statistics, 2012). In the UK, the annual TB incidence in humans is less than 45 cases (Reynolds, 2006; Torgerson and Torgerson, 2009b).
6. Recently, the UK experienced two human cases of bTB that were transmitted from pet cats. Nine cats were infected, six of whom subsequently succumbed (Pet cats infect two people with TB, 2014).
7. A group established in 1984 concluded that there was actually no evidence for a causal link between the gassing and the reduction of TB outbreaks in cattle. Instead, the reduction, which occurred nationally and not only in areas where the gassing took place, was probably due to restrictions on cattle import from Ireland and better screening (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 29).
8. This finding was confirmed by Mill *et al.* (2012).
9. This finding was confirmed by Mill *et al.* (2012).
10. The panel does recommend the slaughter of the whole herd '[w]here a hard core of multiple reactor herds, with a previous history of persistent disease, is revealed. . .' (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 25).
11. At best, some culling trials, such as the Four Areas trial in Ireland (Griffin *et al.*, 2005; More and Good, 2006), may qualify for level 2, being correlation studies with a high risk for bias. According to the HDA report, such studies should not influence policy-making (Weightman *et al.*, 2005). I emphasize 'to my knowledge' here since the most rigorous way to support my assertion is a systematic review, which I have not conducted. Instead, I have conducted what may be defined as an informal narrative review. I do plan to embark on a systematic review of culling practices shortly. For a brief explanation of the differences between the two kinds of reviews, see (Lederman and Rabinowitch, 2014).
12. Another source of evidence is mathematical models, which do not even appear in the empirical framework used here. For example, Stegeman *et al.* examine the H7N7 Avian flu outbreak in the Netherland, focusing on the control measures that were used (Stegeman *et al.*, 2004). They opine that '. . .containment of the epidemic may have been due to the depletion of susceptible flocks as a result of culling rather than to a decrease in the transmission rate' (Stegeman *et al.*, 2004: 2094). First, this conclusion hardly stems from their data. Second, while being useful, models are extremely limited in predicting outcome—the authors themselves admit that their analysis ignored spatial considerations and some key components in transmission dynamics. Third, the authors themselves seem to advocate for vaccination.
13. This was part of the CCS2005 study that included three farms. The lack of wildlife was not found to be a significant risk factor in the other two farms (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007: 131).

14. I write 'arguably' here because this may not be as clear-cut as it first appears. Theoretically, culling, at least that of wild animals, may not reduce biodiversity for two main reasons: First, because, as seen in the 2013 badger culling trials in the UK, culling is often ineffective in destroying or reducing a certain animal population. Second, as mentioned in the text, other species of animals may take over the ecological niche made available by culling, thereby maintaining biodiversity. Despite these caveats, I believe that, beyond mere common sense, most experts would agree that reduction in biodiversity is a highly probable outcome of culling. I would like to thank an anonymous reviewer for this point.
15. The Badger Act was passed in 1973, and further legislation was passed in 1991–1992. In the UK, it is a serious offence to injure or kill a badger or damage a sett without a license (Cassidy, 2012).
16. Indeed, the ongoing trials that involve the gassing of setts do not seem to be justified, since such a method was already used in 1785–1982 and apparently deemed unacceptable by the public, as mentioned above. Further, doubts were raised regarding the effectiveness of such a method—see footnote 16.
17. See, for example, a heart-breaking video clip by the comedian Ricky Gervais lamenting the dog cull in Indonesia (Bali steps up dog culling program to halt rabies outbreak, 2009).
18. And for this, the UK government should be commented upon.
19. In the case of bTB in the UK, Paul and David Torgerson doubt the need for control measures from a human health perspective since human exposure is likely to be low in the UK, as evidenced by the lack of correspondence between cases of cattle disease and human disease (Torgerson and Torgerson, 2008, 2009a). Their concern is directed solely at human welfare, completely ignoring the animals': 'Controlling bovine TB should be justified only in economic terms of reducing losses in animal productivity' (Torgerson and Torgerson, 2008). Their view is a prime example of a standard public health perspective. Elsewhere, they do show concern for animal welfare, but still separate human health from animal health—again a standard public health perspective (Torgerson and Torgerson, 2009b).
20. Relating to the RBCT, ethical considerations of animal welfare were laudably reported by the panel, but did not seem to possess any importance in the panel's conclusions. Beyond the death of 11,000 badgers, three other 'externalities' were reported: (i) 13 per cent badgers suffered injuries resulting from caging for hours before culling; (ii) even though protective measures were taken, an estimated 21 badger cubs a year starved to death because their mothers were culled; (iii) animal species other than badgers were occasionally trapped (Independent scientific group on cattle TB. Bovine TB: The scientific evidence, 2007).
21. Both Dawson and Jennings and Rock and Degeling draw on the work by (Prainsack and Buyx, 2011), while diverging from them in more or less significant ways. Dawson and Jennings criticize Prainsack and Buyx for overemphasizing the costs associated with the collective commitment to assist others, while Rock and Degeling criticize them for limiting the possibility of solidarity to humans. I tend to agree with the latter critique.
22. Of course, as animals and plants may not be referred to as moral agents, but rather (arguably) moral 'patients', it is not immediately clear how exactly one can apply the same active notion of solidarity to them the same way it is applied to humans. A more elaborated explication of more-than-human solidarity would have to face this challenge. Further, Rock and Degeling, who emphasize the notion of 'enactment' as a result, and a catalyzer, of agency, and thus a necessary condition to be included in their idea of solidarity, do not explain how this term may be applied to ecosystems ('places' is their term).
23. They apply the Universal Goods idea to two case studies: biobanking and vaccination against Ebola.
24. See (Aznar *et al.*, 2011) for a potential study design to test the effectiveness of the BCG vaccine in wild badgers. In 2008–2009 Defra conducted its own study that examined the effectiveness of badger vaccination in reducing bTB in wild badgers: there was 74 per cent reduction in prevalence (Policy paper. 2010 to 2015 government policy: Bovine tuberculosis, 2015). In 2012 the Welsh government commenced a 5-year trial that includes badgers' vaccination (Welsh TB vaccination trial totals 4000 badgers so far, 2014).

Acknowledgments

The author thanks the following people for fruitful discussions and advice on this article: Ben Capps, Tamra Lysaght, Richard Coker, Chris Degeling, Calvin Ho and Voo Tech Chuan. The article benefited from presentations at the Otago International Health Research Network's seventh

Annual Conference and the Inter-Asia Roundtable—Governance of Health in Disasters: Perspectives on Asia.

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