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One Health in a world with climate change

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Summary
The One Health movement, as defined in this paper, has progressed from a focus on emerging infectious diseases to a broader set of challenges that include food security and food safety. These interact with climate change, a so-called 'wicked problem' that has links to all human activity. Climate change acts as a threat multiplier that interacts both directly and indirectly with variables such as disease, food production, food security, food safety and poverty. A number of these interactions are briefly described in this paper before issues of complexity and interconnectedness between these variables are discussed. A common thread underpinning this current global challenge to civilisation is that the system is now dominated by the activities of humans – and many scientists label the current epoch the 'Anthropocene'. Specifically, humans have for the first time collectively overloaded the Earth's capacity to supply, absorb, replenish and stabilise. Many scientists now observe that the ecological and environmental foundations of civilisation appear to be at risk. This paper suggests that, for the One Health movement to address such challenges, the range and number of disciplines that need to be involved must be expanded. In particular, in addition to the insights provided by technical specialists, we need to engage disciplines with the capacity to advance political, economic and social reforms. This will not be easy, but it is argued that this is what is required from the One Health movement in a world with climate change.

Keywords
Climate change – Complexity – Disciplines – Emerging infectious disease – Food safety – Food security – Food system – Interconnectedness – One Health – Poverty.

Background and history

A recent surge in emerging infectious diseases and their putative associated costs to society have re-ignited interest in the drivers of disease emergence. Although a number of pathogens have emerged in the last 20 years, including the severe acute respiratory syndrome (SARS) virus, Hendra virus and Nipah virus, it was concern about the H5N1 influenza virus which fuelled much of the recent debate around emerging infectious diseases (EIDs). The H5N1 influenza virus elevated global concerns because of a fear that this virus had the potential to cause a global pandemic, with high morbidity and mortality. This has not happened and there has been debate about whether the focus on the virus (and subsequently the influenza A H1N1 pdm09 virus) was justified – or at least whether the responses were proportional to the threat (1). However, one of the benefits that accrued from the attention on EIDs has been an increased recognition across a range of disciplines that the health of animals (including humans) and the health of the broader ecosystem are inextricably linked. This has certainly given the One Health movement momentum.

The One Health movement has recently been more explicit that One Health is not all about EIDs. One Health also covers important issues of food security and food safety. The heightened focus on unearthing the most fundamental drivers for disease emergence has highlighted that, at deeper levels of analysis, there are some very common interconnected themes (2). More specifically, what many in the One Health movement have discovered is that the drivers of disease emergence – the milieu – are the same as those that underpin food security and food safety. One of the key drivers within this milieu this century is climate change.

There is a strong consensus that the climate is changing now and that human activities are the primary cause (3).

Climate change is often described as a threat multiplier. This terminology originated in the military (4), but has been adopted more broadly in the scientific community. This is because climate change directly and indirectly affects a host of variables within the complex eco-social system that exists on Earth. In addition, climate change acts at a range of scales, from the global to the sub-cellular.

This paper will address a number of these related issues to show why some of the hallmarks of the One Health approach can assist in a world with climate change.

One Health

The One Health movement calls for an 'interdisciplinary approach for combating threats to the health of life on Earth' (5). Although interest in the One Health movement has grown rapidly over the past five years or so, the actual idea behind the One Health movement is not new. The concept of 'One Medicine' (later called 'One Health') (6) was advocated by Rudolf Virchow (2) and Sir William Osler. Virchow is recognised as the scientist who coined the term 'zoonosis' and described clearly the social conditions that foster the spread of such disease (7). He was a public health activist, social reformer, politician and anthropologist who lived in the late 19th Century (7) and understood very well the interconnected nature of the world at that time.

In more recent times, others have highlighted this interconnectedness in the context of the 21st Century. For example, in 2004, the Wildlife Conservation Society held a conference entitled: 'One World, One Health: building interdisciplinary bridges to health in a globalized world'. That conference produced a document which listed 12 recommendations 'for establishing a more holistic approach to preventing epidemic/epizootic disease and for maintaining ecosystem integrity for the benefit of humans, their domesticated animals, and the foundational biodiversity that supports us all' – the so-called 'Manhattan principles' (5). These principles are a useful base, but the One Health movement consists of a disparate group of scientists, policy-makers and activists from across the globe. Accordingly, different subsets promote, advocate, discuss and deliver so-called 'One Health approaches' with different emphases. However, there is reasonable agreement that a working definition for the One Health approach is: 'a coordinated, collaborative, interdisciplinary and cross-sectoral approach to address potential or existing risks that originate at the animal–human–ecosystems interface'.

Some will counter that One Health can often require multi- and trans-disciplinary approaches rather than interdisciplinary ones (8), and the authors agree. However, this definition is adequate as a starting point for this paper.

Climate change

For this paper, climate change is defined as a change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and oceans. Importantly, this change is in addition to natural climate variability observed over comparable periods. Climate change acts to magnify some aspects of climate variability, including increasing the frequency and intensity of extreme weather events such as droughts, floods and heatwaves.

Climate change has been described as the most important challenge facing humanity in the 21st Century (9). Climate change should also be recognised as part of the larger syndrome of human-induced global environmental changes that include high rates of biodiversity loss (terrestrial and marine); interference with the nitrogen and phosphorus cycles; stratospheric ozone depletion; global freshwater use; change in land use; chemical pollution; and atmospheric aerosol loading (10). The main greenhouse gas, carbon dioxide, is also making the oceans more acidic, with unfavourable consequences to marine life. Although not all of these changes will be discussed specifically here, it is important to note that many of these changes are interconnected and it is difficult to disentangle their relationships from a number of One Health issues, such as EIDs and food security. In addition, for climate change specifically, a key challenge will be to break the link between economic output and greenhouse gas emissions (11). Critically, how can the human species achieve development that is both environmentally and socially sustainable (12, 13)? This question illustrates how climate change is much more than a technical issue; as mentioned, it is a 'wicked problem'.

Numerous reports address climate-change-related issues. The Stern Review on the economics of climate change was released in 2006 (11), the fourth assessment of the Intergovernmental Panel on Climate Change (IPCC) was released in 2007 (14), followed by a number of reports updating some of the science in the IPCC report (13, 15). A number of studies show that the anticipated consequences of climate change and environmental change seem to be occurring at a faster rate than expected (16). For example, the rate of melting of the Greenland Ice Sheet and the retreat of glaciers on a near global scale has been dramatic and surprising (17, 18, 19). In addition, a surge in methane emissions has been detected, associated with the onset of soil freeze-in of permafrost-dominated tundra regions (20), and a number of scenarios with costings associated with 'methane belching' have recently been reported (21). There is also increasing confidence that the net result of these changes will be to amplify the atmospheric greenhouse gas emissions to the year 2100, thus amplifying climate change (13).

Climate change and disease

The number of papers in the peer-reviewed literature that report on the likely implications of climate change with respect to EIDs is growing. The effects of climate change are acting at a range of scales and the complexity of the relationships within and across these scales makes accurate prediction difficult (22). In addition, the expected (and experienced) increased climate variability adds to this complexity. However, it is clear that climate change will alter the distribution and incidence of a wide range of diseases – either directly or indirectly (e.g. diseases with a development stage outside the host) (22, 23). The pathways by which climate change can affect host–pathogen–vector interactions have recently been well described by Gallana *et al*. (24). These authors give a number of examples in both aquatic and terrestrial environments that demonstrate the intricacy of the processes at play. A particular example, which clearly demonstrates the issue of cross-scale impacts, involves parasitic infections of Arctic musk ox (*Ovibos moschatus*) and caribou (*Rangifer tarandus*). Warming of the Arctic has allowed white-tailed deer (*Odocoileus virginianus*) and elk (*Cervus canadensis*) to expand their range northwards so that they now mix with the southern parts of the range of both musk ox and caribou. The white-tailed deer and elk carry pathogens that are novel to the musk ox and caribou. In addition, endemic parasites of musk ox and caribou now complete their life cycles more quickly, due to increased temperatures. The argument has been made that musk ox and caribou now suffer a double insult due to warming. They are infected with heavier burdens of endemic parasites and are also dealing with novel pathogens, against which they have no natural resistance (25).

The shift of a range of species towards the poles is apparently occurring much faster in the oceans than on land (26). A recent meta-analysis showed that, in addition to the compelling evidence for widespread impacts of climate change on marine organisms, there is also likely to be a future reconfiguration of marine ecosystems and the services they provide. This reconfiguration will be difficult to predict because a series of cascading effects could be triggered. This is similar to the situation with the musk ox and caribou, and these movements will have disease impacts that are also difficult to predict with any precision, due to the complex interactions of hosts and pathogens across species.

It should be noted that climate change will not always lead to more disease and in some cases will likely lead to less. For example, in south-eastern Australia, where fasciolosis is endemic, the decreased summer rainfall and soil moisture (particularly in summer) that has been projected as a result of climate change may reduce the current prevalence and distribution of this disease in that region (27). There may also be range shifts, in terms of disease, rather than simply expanded ranges of disease, as discussed by Rafferty (28).

Of course, what makes the climate change and EID picture even more complicated is that not only are animal populations moving and changing in response to climate change but, in addition, livestock producers are changing production systems at the same time, often to respond to new disease pressures (29). Furthermore, societies are choosing to alter production systems in response to the anticipated and observed changes in climate and the environment (29). One of the dominant trends to decrease greenhouse gas emissions is towards intensification and industrialisation, as many societies attempt to improve efficiency and decrease the amount of land dedicated to animal production (29). There are numerous examples where changes in production systems have led to disease emergence, such as the large outbreak of Nipah virus in pigs in Malaysia after intensification of the pig industry, combined with fruit production, in an area populated by fruit bats (30, 31). In the Netherlands, Q fever occurred after a rapid intensification of goat milk production (32) and brucellosis emerged in inner Mongolia after a rapid increase in animal numbers, with an associated increase in less-experienced stock-handlers (33). Another example is the intensification of short-generation-interval poultry production systems, which probably played a role in the emergence and spread of H5N1 avian influenza (30).

Land use change has also been recognised as a major driver of disease emergence by numerous authors (34, 35, 36). Land use change and climate change are also intimately connected with feedback acting in both directions, i.e. land use change influences climate and climate influences land use (29, 37).

With respect to extreme weather events, the expected increase in the number of floods will increase the risk associated with vector-borne zoonoses, including tick-borne and mosquito-borne diseases (38). The burden from bacterial pathogens associated with stagnant water and flooding (e.g. leptospirosis, anthrax, cryptosporidiosis) is also expected to increase (39).

Another dimension of the climate change and disease relationship which requires more attention is the relationship between poverty and vulnerability and climate change. This extra dimension is examined in a report prepared for the United Kingdom Department for International Development (39). This 2012 report indicated that about 2.5 billion people were living on less than US$2 per day and about 1 billion of these people were dependent to some extent on livestock (39). The report identified the 13 zoonoses most important to poor livestock keepers, based on a number of criteria, including their impacts on human health and on the livestock sector, and their amenability to agriculture-based control. The list in descending order is: zoonotic gastrointestinal disease, leptospirosis, cysticercosis, zoonotic tuberculosis, rabies, leishmaniosis,

brucellosis, echinococcosis, toxoplasmosis, Q fever, zoonotic trypanosomosis, hepatitis E and anthrax. Of these, foodborne zoonoses, leptospirosis and trypanosomosis were considered likely to be highly sensitive to climate.

Climate change and food security

All parts of the food production and consumption chain will be affected by climate change (see Nabarro and Wannous) (40). Crops, feed production and livestock production will all be affected by climate change, especially in the short term, through extreme weather events such as floods and droughts. Of course, agriculture also contributes to climate change. For example, greenhouse gases are produced as a result of ruminant digestion, rice cultivation, land clearing (especially deforestation), fuel use and fertiliser production (38). A recent report by the Commission on Sustainable Agriculture and Climate Change represented the expert opinion of 13 Commissioners. This opinion was based on their experience, informed by synthesised findings of 16 authoritative assessments of climate change and food security. These assessments drew in turn on thousands of peer-reviewed scientific studies. The report noted that: 'several converging threats – from population growth, climate change and the unsustainable use of resources – are steadily intensifying pressure on people and governments around the world to transform the way food is produced, distributed and consumed' (38). There is general agreement that, by 2050, global agricultural production will need to be increased by 60% to 110% to meet humanity's demands, resulting from an increasing human population, diet shifts and increasing consumption of biofuels (41). Studies to date indicate that global production will increase at a rate that will not be sufficient to meet this demand, even if climate change has no harmful effects (41). The regions that are most likely to be adversely affected by food insecurity and undernutrition are those areas with pastoralists, smallholders and subsistence farmers, traditional societies, indigenous people, coastal populations and artisanal fisherfolk (42). These people also have little opportunity to meet their needs by either purchasing or producing more food. They are therefore extremely vulnerable to global food price rises (1).

In contrast, the dietary transition that tends to occur as incomes grow for others on the planet has been well described. In essence, as people have improved access to food, they increase their calorie intake up to a plateau. Once this level is reached then it is the composition of the calorie intake that changes – with the consumption of cereals and vegetables decreasing while the intake of sugar, fats and animal products increases (38). Red meat production from methane-producing ruminants does contribute to climate change and there have been various discussions about where and when other protein production options are more appropriate, or how to rebalance the distribution of red meat consumption. One clear opportunity is to decrease red meat consumption levels in over-consuming rich countries while increasing consumption in many poorer populations – this is the so-called 'contract and converge' approach. One of the benefits of this approach is that leads to better nutrition in poorer countries and, at the same time, addresses increasing rates of health problems (e.g. heart disease and colo-rectal cancer) in countries with high levels of red meat consumption (43).

Climate change and food safety

Climatic factors do influence the growth and survival of many pathogens which contribute to food safety concerns. Increased ambient temperatures increase the replication rates of foodborne pathogens and also lengthen the seasons of high risk for food-handling mistakes (44). A range of foodborne pathogens contribute to this problem. Most notably, campylobacter and salmonella very commonly cause gastrointestinal bacterial disease and the risk of the disease is often strongly correlated with increasing temperature. More generally, zoonotic foodborne pathogens are more commonly associated with poultry and pigs rather than with small ruminants and cattle (39). The global production of pigs and poultry is forecast to continue to increase. This is driven by a range of factors, including feed efficiency and a lower overall impact on the environment. Intensification of monogastric systems is one measure that has been used to address climate change. With increasing pig and poultry production, there is expected to be a commensurate increase in zoonotic foodborne diseases (and zoonotic emerging infectious diseases) (30, 45).

In addition to microbiological risks, there are chemical risks that are likely to impair food and feed safety as a consequence of climate change. These risks include mycotoxins, marine biotoxins (phycotoxins), pesticide residues, trace metals and other chemicals. Some of these risks are purely temperature dependent, while others involve factors such as stress (e.g. insect attack, heat stress or water stress in plants) and eutrophication by the pollution of water with nutrients from human activities (46).

The pathways are complex and addressing these challenges will require a multidisciplinary approach involving disciplines dealing with human and animal health, agriculture, meteorology, governmental policy and socio-economics (46).

Complex systems

Climate change, disease, food production and poverty are only a part of the overall complex adaptive system that has created the current global challenge to civilisation. This

complex adaptive system is now dominated by the activities of humans and, accordingly, many scientists suggest that the current epoch should be labelled the 'Anthropocene' (47). Specifically, humans have for the first time collectively overloaded the Earth's capacity to supply, absorb, replenish, and stabilise (31). This overloading means that we have crossed some thresholds and are very probably approaching some other very critical tipping points. Many scientists now observe that the ecological and environmental foundations of civilisation appear to be at risk (1). The whole notion that we seek sustainability to support the economy, environmental conditions, livelihoods, infrastructure and social relations as ends in themselves misses the point that – in the final analysis – sustainability is about maintaining the complex systems that support our longer-term survival and health (31). When this is realised, the most fundamental drivers for climate change, disease, food production and poverty will be seen to be the same.

The One Health movement has progressed from a focus on EIDs and their drivers to a broader concern that embraces food security and food safety. This progression has alerted many One Health practitioners to appreciate the crucial importance of interconnectedness between these issues and their drivers. Indeed, it has forced many to embrace a more systemic approach rather than a more simplistic focus on single determinants – which, some have erroneously assumed, would have a major impact without simultaneous change in the whole system (48). This is particularly true for climate change and disease, where the fundamental drivers include population growth, consumption patterns and economic models that are tied to infinite growth.

If One Health really is an interdisciplinary approach for combating threats to the health of life on Earth, then the range and number of disciplines that need to be involved in this challenge must be greater than at present. Although most of the energy to date has come from scientists, often with a strong bias to technical solutions, there is a real need to gather more energy from those who understand how to achieve rapid social and political change (49). In 1848, Virchow recommended that, to address the typhus epidemic in Upper Silesia, the implementation of political, economic and social reforms would also be needed (2). Humanity is now facing a much bigger challenge than typhus and would do well to embrace more of the types of reforms that Virchow described to make more sustained progress. In a world with climate change, technical solutions will never be enough. Policy-makers and decision-makers need to be fully involved. This is not news to those who have been working with EIDs, as the importance of considering social and ecological factors has been regularly highlighted in recent years (29) by many investigators. Importantly, decision-makers are increasingly recognising that they are within the system, not acting on it from the 'outside'. This perspective is crucial to better integrate the range of diverse views and scientific opinions with the social motivations and responses needed to address climate change, disease, food production and poverty.

Conclusion

One Health in a world with climate change needs to think and act big. Simply fiddling around the edges of specific disease issues will prove to be profoundly inadequate. This means that the One Health movement needs to involve a much broader range of disciplines. Those who are committed to the One Health vision must stop waiting for others to act and be willing to do everything within their capacity to work with others in reshaping how societies frame and address the challenges ahead. For example, One Health practitioners could help society to rethink how to plan, move, produce and consume food – i.e. reconfigure the food systems of the planet. This task should not be performed without ensuring that any unintended consequences (e.g. contributing to climate change or promoting disease outbreaks or the emergence of novel pathogens) are carefully considered when developing a suite of options.

It is not easy work, but those who appreciate the interconnectedness of the planet have a unique opportunity and, indeed, a social obligation to protect the health of the planet. This is One Health at work in a world with climate change.

« Une seule santé » dans une planète soumise au changement climatique

P.F. Black & C.D. Butler

Résumé

Le mouvement en faveur d'« Une seule santé », tel qu'il est défini dans cet article a élargi sa portée, passant d'un axe centré auparavant sur les seules maladies infectieuses émergentes à la prise en compte d'un ensemble bien plus vaste de problèmes recouvrant notamment la sécurité alimentaire et la sécurité sanitaire des aliments. Ces thématiques sont en interaction avec le changement climatique, qui constitue l'une des problématiques dites « complexes » *(wicked)*, en raison de leurs nombreuses ramifications qui concernent toutes les activités humaines. Le changement climatique est un facteur multiplicateur des dangers, en interaction directe ou indirecte avec des variables telles que les maladies, la production et l'innocuité des denrées alimentaires, la sécurité alimentaire ou la pauvreté. Les auteurs décrivent brièvement certaines de ces interactions, avant d'examiner le thème de la complexité et des interconnexions à l'œuvre. Un des fils conducteurs fréquemment évoqué pour caractériser la menace mondiale qui pèse actuellement sur la civilisation est le fait que le système soit dominé par les activités de l'être humain : c'est la raison pour laquelle nombre de scientifiques utilisent le terme d'« anthropocène » pour qualifier la période actuelle. Plus concrètement, c'est la première fois dans son histoire que l'humanité a collectivement mené la Terre au-delà de ses capacités de fourniture, d'absorption, de renouvellement et de stabilisation. Nombre de scientifiques font aujourd'hui le constat que les fondations écologiques et environnementales de la civilisation semblent en danger. Les auteurs estiment que le traitement de ces problèmes exige du mouvement en faveur d'« Une seule santé » qu'il élargisse son champ d'intervention et y associe un plus grand nombre de disciplines. En particulier, en plus des connaissances apportées par les experts techniques, il nous faut intégrer des disciplines capables de promouvoir des réformes politiques, économiques et sociales. Il ne s'agit pas d'une tâche facile, mais d'après les auteurs, c'est précisément ce que le mouvement en faveur d'« Une seule santé » doit apporter à un monde soumis au changement climatique.

Mots-clés

Changement climatique – Complexité – Discipline – Interconnexion – Maladie infectieuse émergente – Pauvreté – Sécurité alimentaire – Sécurité sanitaire des aliments – Système alimentaire – « Une seule santé ».

«Una sola salud» en un planeta con cambio climático

P.F. Black & C.D. Butler

Resumen

El movimiento en pro de «Una sola salud», como viene definido en este artículo, ha pasado de centrarse en las enfermedades infecciosas emergentes a ocuparse de un conjunto más amplio de problemas que abarcan la seguridad alimentaria y la inocuidad de los alimentos. Estos temas interactúan con el cambio climático, que es uno de los denominados «problemas complejos» (*wicked*) porque tiene ramificaciones que engloban toda la actividad humana. El cambio climático es un factor multiplicador de las amenazas que interactúa, ya sea directa o

indirectamente, con variables como las enfermedades, la producción e higiene de alimentos, la seguridad alimentaria o la pobreza. Los autores describen sucintamente varias de esas interacciones antes de examinar el tema de la complejidad e interconectividad entre ellas. Un frecuente hilo conductor de esta amenaza mundial que planea hoy sobre la civilización es el hecho de que el sistema esté dominado ahora por las actividades del ser humano: de ahí que muchos científicos utilicen el término «Antropoceno» para designar el periodo actual. Más concretamente, es la primera vez que los humanos, colectivamente, hemos llevado a la Tierra más allá de su capacidad de suministro, absorción, reposición y estabilización. Muchos científicos observan ahora que los fundamentos ecológicos y ambientales de la civilización parecen estar en peligro. Los autores postulan que, para abordar estos problemas, el movimiento en pro de «Una sola salud» debe abarcar un mayor ámbito de actuación y extenderse a un mayor número de disciplinas. En particular, además de la comprensión que aportan los especialistas técnicos, debemos incorporar disciplinas capaces de promover reformas políticas, económicas y sociales. No será fácil, pero esto es, según los autores, lo que un mundo sujeto al cambio climático necesita del movimiento en pro de «Una sola salud».

Palabras clave
Cambio climático – Complejidad – Disciplinas – Enfermedad infecciosa emergente – Inocuidad de los alimentos – Interconectividad – Pobreza – Seguridad alimentaria – Sistema alimentario – «Una sola salud».

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