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Forum

Need for Enhanced Environmental Representation in the Implementation of One Health

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Abstract: Issues of global environmental change, global health, emerging disease, and sustainability present some of the most complex challenges of the twenty-first century. Individual disciplines cannot address these issues in isolation. Proactive, innovative, and trans-disciplinary solutions are required. Recognizing the inherent connectedness of humans, animals, plants, and their shared environment, One Health encourages the collaboration of many disciplines—including human and veterinary medicine, public health, social science, public policy, environmental science, and others—to address global and local health challenges. Despite great progress in this shift toward transdisciplinarity, the environmental component of the One Health paradigm remains underrepresented in One Health discourse. Human and animal health issues are commonly discussed under the umbrella of the One Health paradigm, while upstream environmental drivers and solutions are less prominent. We assessed the current integration of environmental issues in One Health publications and leadership. There is room for enhanced integration of environmental knowledge in the implementation of One Health approaches. We discuss the potential benefits from the collaboration between One Health and ecohealth, and explore strategies for increased environmental involvement.

Keywords: One Health, ecohealth, transdisciplinary, ecology, ecosystem approaches to health, collaboration, zoonotic disease, ecosystem health

Introduction

One Health: A Necessary Approach in a Changing World

Population growth and globalization have resulted in a rapidly changing, highly interconnected world. Human population is on track to reach 9 billion by 2050, placing increasing demands on limited resources (UN 2011). Humans, animals, and the environment have always been connected; yet recent population pressures, resource depletion, and human mobilization have amplified the stress on global environmental systems that play a deterministic role in health and well-being. The consequences of this global change are costly for economies, ecosystems, and health systems. As highlighted by the World Bank, protecting against the negative impacts of these changes is a

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global public good (WB 2010, 2012). The complex nature and breadth of such threats demand transdisciplinary solutions that address the connections between human and animal health, and the underlying environmental systems upon which health relies. Over the past century, approaches to health have focused on anthropocentric interventions, such as pharmacotherapy or vaccination. One Health offers an alternative, enabling more systemic, preventive approaches that apply an understanding of social and environmental drivers of health and disease (Zinsstag et al. 2011; Barrett and Osofsky 2013).

One Health is a collaborative approach increasingly utilized by governments, intergovernmental agencies, academic institutions, and non-profits. One Health, broadly, can be defined as "the collaborative efforts of multiple disciplines working locally, nationally and globally to attain optimal health for people, animals and our environment (AVMA 2008)". It represents a paradigm shift in developing and implementing health interventions that proactively engage different health-related disciplines, such as human medicine, veterinary medicine, public health, and environmental health sciences (Osofsky et al. 2005a, b, 2008; AVMA 2008; WHO 2008). By integrating diverse approaches and perspectives, One Health aims to improve health for people, domestic animals, wildlife, and ecosystems simultaneously transecting spatial and temporal dimensions. This approach considers co-benefits and co-challenges so that solutions with multiple bottom lines can be achieved, whether they are for humans, animals, plants, or ecosystems.

The similarities and differences, and potential benefits of convergence, of One Health and ecohealth have garnered recent attention (Parkes 2012; Zinsstag et al. 2012). Ecohealth "strives for sustainable health of people, animals, and ecosystems by promoting discovery and understanding through transdisciplinary action-research" (EcoHealth 2008), and builds upon knowledge from the natural, social and health sciences, as well as the humanities (Charron 2012). Ecohealth has long incorporated environmental issues, having emerged from research aimed at understanding how ecosystems, environmental degradation, and unsustainable development impact health (Charron 2012). The origins of One Health are rooted in the management and emergence of zoonotic disease threats, and as discussed, have a less robust foundation in environmental sciences. Both ecohealth and One Health espouse a holistic understanding of health and champion transdisciplinary, systemic approaches. While great overlap and benefit from collaboration exists, we focus explicitly in this paper on the One Health approach, which traditionally has been lacking in effective environmental representation. We think there is great opportunity for ecohealth practitioners to add valuable environmental expertise to One Health research and interventions.

Recently, there have been a number of global One Health policy-relevant actions that have raised the profile of the approach and stimulated connections through fora for professional introductions and relationship-building. For example, in recent years, two International One Health Congresses have been held (Australia and Thailand), with a third planned for 2015 (the Netherlands); the Global Risk Forum initiated an annual One Health conference in Davos, Switzerland; two One Health Conferences in Africa have been hosted; the World Bank published its second volume of its One Health report, "People, Pathogens, and Our Planet," underscoring economic impacts and opportunities (WB 2012); the World Medical Association and World Veterinary Association co-signed a memorandum to collaborate on One Health (WMA 2012); and the World Veterinary Association released a position paper (WVA 2014). Notably in 2008, the World Organization for Animal Health (OIE), Food and Agriculture Organization (FAO), and the World Health Organization (WHO) released a joint strategic concept note in tri-partite partnership addressing infectious diseases at the animal–human–ecosystems interface, such as highly pathogenic avian influenza (WHO 2008; FAO/OIE/WHO 2010).

As One Health grows, it is important to understand its maturation; gauge environmental representation in One Health institutions, organizations, conferences, and publications; and suggest ways to enhance integration of environmental drivers, data, and disciplines into the future development of One Health. With policy and research coming to increasingly focus on issues of global environmental change, i.e., climate change, ocean acidification, urbanization, it is ever more important to build environmental perspectives into the One Health approach to maximize its relevancy and impact. Doing so will bring One Health into professional circles where its utility can be rediscovered, amplified, and applied.

Methods

Assessing Growth of One Health and Environmental Representation

To assess the expansion of One Health, and achieve a general sense for how integrated environmental disciplines are in the development of the field, we turned toward the

scientific literature and the disciplinary representation within two of the most robust, active, and multidisciplinary One Health organizations that include affiliated members. This analysis was designed to be a straightforward and illustrative exercise, allowing for a top-level description of disciplinary representation. It was not designed to be an exhaustive or statistically sophisticated analysis of the field.

First, we examined One Health's representation in the peer-reviewed scientific literature. We conducted a PubMed search on May 5, 2014. Search terms included "One Health" in the article's title or abstract. We limited the search to peer-reviewed journals, but included different article types, including research articles, reviews, letters, editorials, and interviews. Due to the incomplete representation of conference abstracts in PubMed, they were not included. The initial search results were individually validated for relevance to One Health, and a reduced number of records were included in the analysis. Journals were classified as primarily related to human medicine, veterinary medicine, environmental issues, public health, disease/microbiology, or transdisciplinary topics based on the journal's stated aims and scope. We used this information to calculate the percentage of One Health articles published in each of these disciplinary journal categories. The number of publications per year was also assessed; the publication count for 2014 was projected based on the daily rate of publications in 2014 as of May 5th.

To assess institutional representation of One Health, we examined the One Health Commission (OHC) and the One Health Initiative (OHI), two leading organizations in One Health advocacy. While there are many global organizations active in One Health, these two were chosen because they are member-organizations, enabling an analysis of the types of organizations involved. We assessed environmental representation on the OHC Board of Directors by examining the number and disciplinary affiliation of institutional members as published on their website as of May 19, 2014 (http://www.onehealthcommission.org/). To determine general organizational buy-in for One Health, we analyzed the proportion of environmentally related organizations signed on as OHI supporters (as of May 19, 2014).

Results and Discussion

Room for Increased Engagement of Environmental Disciplines in One Health

The increasing interest in and application of One Health are evinced by the rise of its representation in the scientific literature. The literature search yielded 1,270 records, which were then individually validated for relevance to One Health, leaving 287 final records that were included in the analysis. The first One Health article appeared in a peer-reviewed journal in 2004 (Fig. 1a). After slow but steady growth from 2004 to 2012, an inflection point occurred in 2013, when the number of articles more than doubled to 93. The year 2014 is projected to see 134 articles published, based upon the number of articles published as of May 5, 2014 ($n = 46$).

Despite this rapid growth in the number of One Health articles published, we found that a disproportionate number of articles were published within veterinary medicine (40%) and disease/microbiology-focused journals (29%) (Fig. 1b). Human medicine-focused journals and transdisciplinary journals have published the next highest percentage of One Health articles (11%). In comparison, relatively few One Health articles have been published within public health journals (5%) or environmentally focused journals (4%). Without One Health articles appearing in these journal venues, it will be more challenging to raise awareness of One Health within these disciplines. The environmental journals in which One Health articles have been published include: *EcoHealth*, *Frontiers in Ecology and the Environment*, *International Journal of Environmental Research and Public Health*, *Journal of Environmental Health*, *Journal of Environmental Quality*, and *Environmental Health Perspectives*. Eight percent of the 287 articles occurred in journals with a specific international focus, which may indicate a growing international community of One Health research and practitioners. We also noted an increasing representation of One Health topics in defense-focused journals such as *Biosecurity and Bioterrorism*, *Army Medical Department Journal*, and the *Journal of Special Operations Medicine*.

The architects of the One Health movement have acknowledged the importance of the environment from the outset and repeatedly attempted to emphasize its role, notably through the important Manhattan Principles (Cook et al. 2004). There is also some precedent of environmental professionals reaching out to health professionals to build One Health collaborations, as well as the development of truly transdisciplinary approaches to health and the environment (Nicole 2014). A few prominent examples include: the Animal & Human Health for the Environment And Development (AHEAD) Project, the Health for Animals and Livelihood Improvement (HALI) Project, and the Health & Ecosystems: Analysis of Linkages (HEAL) project and the Emerging Pandemic Threats

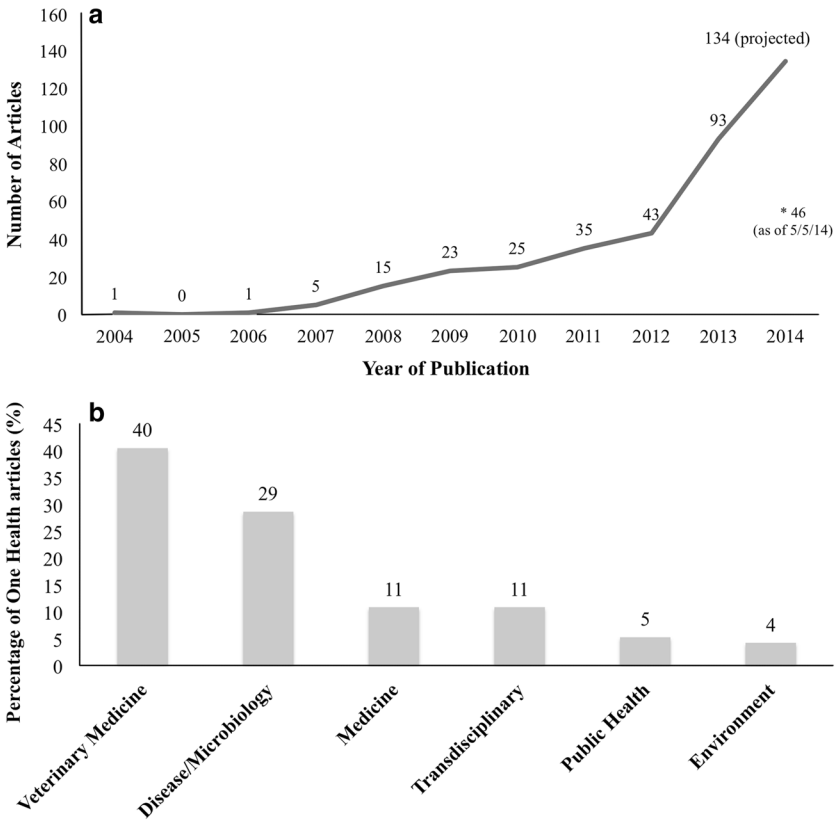

Figure 1. (**a**) The number of One Health-related articles published each year has steadily increased since 2004, totaling 287 as of May 5, 2014. Projections estimate that 134 One Health articles may be published in 2014. (**b**) One Health articles have appeared in journals of diverse disciplinary types, including: veterinary medicine, disease/microbiology, human medicine, transdisciplinary, public health, and environmental. The percentage of articles published in each type of journal is presented.

PREDICT project. Additionally, the One Health Initiative has welcomed the inclusion of environmental language into their mission and descriptions, and the One Health Newsletter actively seeks out environmentally oriented stories to include in the quarterly newsletter. Despite these efforts, environmental issues and experts remain generally underrepresented in One Health dialogue.

To illustrate this point, we examined environmental representation in a number of prominent One Health organizations. The OHC is a "globally focused organization dedicated to promoting improved health of people, domestic animals, wildlife, plants and the environment" and "informing all audiences about the importance of transcending institutional and disciplinary boundaries, and transforming the way that human, animal, plant, and ecosystem health professionals, and their related disciplines, work together to improve the health of all living things and the environment." We applaud this commitment; yet, found that of the 15 institutional members of the Board of Directors of the OHC, only one institutional representative had an indirect environmental relationship (Georgia Aquarium). Of the 71 organizations that have officially signed on as supporters of One Health with the One Health Initiative, only 9 (13%) are environmentally related organizations.

The disconnect between health and environmental fields is not unidirectional; health has been absent in a number of important environmental documents. For example, the original 1992 United Nations Framework Convention on Climate Change text has only two token mentions of health, the Kyoto Protocol has zero, and the Cancun Adaptation Framework has one, in a footnote.

How to Increase Environmental Representation in One Health: Drivers, Data, and Disciplines

To maximize environmental representation in One Health, we consider three facets of environmental research and practice that offer discrete avenues for involvement: environmental drivers, data, and disciplines.

Environmental Drivers

As the environment changes, so too does health; it can improve or deteriorate depending on shifts in environmental conditions (Fig. 2). The World Health Organization estimates that 24% of the global burden of disease in

humans, disproportionately felt in the developing world, is related to environmental factors (Prüss-Üstün and Corvalán 2006). In recent years, there has been increasing recognition of the value in tracing environmental drivers of disease. The MEA, for example, was critical in articulating the extent to which human well-being relies upon natural ecosystems and their services, while also emphasizing the challenges these ecosystems face in our era of rapid change. The IPCC's climate change and health work also enhanced the recognition of some of the most significant environmental and climate-related health impacts. The WHO has maintained a committed division focusing on health and environmental topics, including spheres as diverse as toxicology, zoonotic disease, and climate change.

In the future, investigation into the effects of environmental change on health will continue to be important, as will experimental studies that aim to disentangle and quantify the complex mechanisms behind environmental drivers of health. To aid in awareness of these issues and establish a basis for further research, environmental knowledge and fundamental ecological processes could be integrated into pre-professional, professional, and interprofessional training curricula, such as for medicine, veterinary medicine, and public health (Barrett et al. 2010; Beck et al. 2012). Equally, established environmental professionals can also be educated about how their research can offer insight to other disciplines that sit at the environmental health nexus.

Environmental Data

As transdisciplinary approaches to health issues grow, there will be an increasing demand for environmental data. In the era of Big Data, there is a need for placing new types of health and behavioral data within a relevant environmental context (Barrett et al. 2013). There are already many resources for accessing environmental data, yet few health projects utilize them. This could be due to a lack of awareness, inaccessibility, or differences in temporal or spatial scale and resolution. Comprehensive, consistent, and longitudinal data collection and dissemination across a wide range of ecological measures are essential. We outline examples of environmental data, indices, and publicly available data sources that could inform a diversity of health projects (see Supplemental Material, Tables S1, S2, S3).

As data collection capacity has increased, researchers in both environmental and health fields are accumulating

Figure 2. Human pressures on the environment result in global-scale environmental change, which can impact ecosystems services, and ultimately impact the health of humans, animals, plants, and the ecosystems they share.

datasets that can show change over time. Longitudinal indicators can focus data collection, evaluate the magnitude of change from baseline levels, assess the effects of interventions and be interpreted easily across different disciplines. Standard health indicators have been developed for assessing city, county, state, and even national level health (Koh 2011). The US-based Institute of Medicine published a report with 20 key heath indicators covering health outcomes, health-related behaviors, and health systems performance (IOM 2009). Environmental health indicators have also been explored in order to assess the effect of environmental change as well as provide insight for health assessments (IOM 2004). Useful indicators of ecosystem health are being developed to assess the ecological, social, and economic changes over space and time in both natural and urban systems (Wiegand et al. 2010). Ecological indicators can include measures such as water quality, tree canopy cover, soil organic matter, wildlife/bird populations, land use profiles, and vegetation characteristics (Muñoz-Erickson et al. 2010).

Environmental data are important to build into disease prediction models, such as those built by the EPT PREDICT program (PREDICT 2013). Additionally, there are current projects being developed among the WHO, World Meteorological Organization, National Oceanic and Atmospheric Administration, and National Aeronautics and Space Administration that are exploring the potential of early warning systems for disease outbreaks based upon monitoring climate data and projecting health impacts. Growing capacity for ambient environmental sensing, citizen science and the use of drones will expand access to remotely and passively captured environmental surveillance data (Boulos et al. 2011).

There is a need to bring these disparate data sources together in geographic and temporal space. Data sharing platforms, such as The dotSkapes Project, based at the University of Wisconsin-Madison and EcoHealth Alliance, are developing a cloud application for One Health research. Cloud computing in this context refers to interacting with a web-based application and networked cyber-infrastructure to find, analyze, tag, and share research data (Preston 2012). Geographic Information Systems (GIS) also provide an essential platform for bringing different types of data together, situating it all in the same spatial reference, and then providing a framework for analysis. The emergence of open access, web-based geospatial platforms, such as Quantum GIS, Open Street Map, and Google Earth, as well as analytical capacity for Big Data, will promote the integration of multiple data sources (Boulos et al. 2011). Through geospatial analysis, we will be able to specifically explore the fine-scale interactions among the health of humans, animals, and ecosystems.

Environmentally Related Disciplines

Many environmentally related professionals add value and depth to any One Health collaborative team through knowledge of geography, geospatial analysis, environmental data resources, and ecosystem interactions. These professionals can be found within universities, government agencies at all levels (city, country, state, and federal), environmental consulting firms, NGOs, intergovernmental agencies, foundations, and businesses. We provide examples of relevant professions in Supplemental Table S4. We encourage health programs to reach out to environmentally trained professionals to incorporate environmental data and understanding into health research and practice. We support the idea that ecohealth, with its strong origins in environmental impacts on health, can help to further develop environmental representation in One Health through collaboration (Zinsstag et al. 2012).

To increase environmental engagement in One Health, the first step will require building communication and relationships via education and outreach campaigns within environmental communities. This could include publishing in high impact environmental journals (e.g., *EcoHealth*, *Frontiers in Ecology and the Environment*, *Environmental Health Perspectives*), and other transdisciplinary journals (e.g., *Science*, *Nature, Proceedings of the National Academy of Sciences*). With the recognition that researchers are often evaluated for tenure and job promotion based upon publication record in leading, disciplinary-relevant journals, there is some challenge in encouraging trans-disciplinary publication. Nonetheless, when added to existing portfolios of strong sectorial work, trans-disciplinary publication can enhance professional development through increased visibility and accolade for ground-breaking, particularly when considered with associated networking opportunities facilitated by peer review and conference presentation. Other approaches include extending invitations to One Health conferences and attending EcoHealth conferences, incorporating environmental graduate students into One Health training, and reaching out to environmental professional societies (e.g., International Association for Ecology & Health, Ecological Society of America, National Environmental Health Association). Increased environmental

disciplinary representation on One Health boards could also help. At the intergovernmental level, building upon the existing WHO-OIE-FAO relationship, the United Nations Environment Program could be added to create a new quaternary partnership with greater emphasis on specific environmental considerations.

Conclusions

Issues of global environmental change, global health, emerging disease, and sustainability present some of the most complex challenges of the twenty-first century (Barrett and Osofsky 2013). Individual disciplines cannot address these issues in isolation. The potential economic, health, and environmental consequences of inaction are enormous and the solutions virtually unlimited (WB 2010). One Health offers an integrated approach that recognizes the interconnected nature of human, animal, plant, and ecosystem health. The approach can inform policies, further scientific knowledge, enhance healthcare training and delivery, improve conservation outcomes, identify 'upstream' solutions, and address sustainability challenges. It uniquely focuses on preventive approaches that tackle the root causes of global health and environmental challenges. We are at a turning point in which the sustainability of future generations is increasingly reliant upon proactive, earnest global stewardship (Osofsky et al. 2000; Barrett and Osofsky 2013).

While challenges and barriers to the realization of One Health exist, this is an exciting and critical time in which to develop trans-sectoral approaches. Collaboration among practitioners in human health, animal health, ecohealth, environmental sciences, and other disciplines offers the potential to address challenges, design innovative solutions, and create co-beneficial health and environmental policies for our changing world. Diverse professionals are working together to find collaborative solutions at multiple scales (Binder et al. 1999; Parkes et al. 2005; Osofsky et al. 2008; Costello et al. 2009; Mazet et al. 2009). While the One Health approach has built support across many disciplines, particularly between human and veterinary medicine, it is imperative that environmental disciplines become even more involved. We urge the expanding nuclei of One Health project designers to ensure that environmental drivers, data, and disciplines are increasingly represented. Collaboration with ecohealth practitioners offers a valuable path to increased environmental representation in One Health (Zinsstag et al. 2012). Similarly, we urge environmental professionals to join their health counterparts to ensure that environmental bottom lines are maintained in the One Health equation.

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