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Synthesis

Ecohealth and resilience thinking: a dialog from experiences in research and practice

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ABSTRACT. Resilience thinking and ecosystems approaches to health (EAH), or ecohealth, share roots in complexity science, although they have distinct foundations in ecology and population health, respectively. The current articulations of these two approaches are strongly converging, but each approach has its strengths. Resilience thinking has developed theoretical models to the study of social–ecological systems, whereas ecohealth has a vast repertoire of experience in dealing with complex health issues. With the two fields dovetailing, there is ripe opportunity to create a dialog centered on concepts that are more thoroughly developed in one field, which can then serve to advance the other. In this article, we first present an overview of the ecohealth and resilience thinking frameworks before opening a dialog centered on seven themes that have strong potential for cross-pollination between the two approaches: scale interactions, regime shifts, adaptive environmental management, social learning, participation, social and gender equity, and knowledge to action. We conclude with some future research suggestions for those interested in theoretical and practical applications at the intersection of environment and health. In particular, closer collaboration between these two fields can lead to addressing blind spots in the ecosystem services framework, complementary social-network analysis, the application of resilience heuristics to the understanding of health, and the development of a normative dimension in resilience thinking.

Key Words: *complexity; ecohealth; ecosystem approaches to health; health; resilience thinking; social–ecological systems*

INTRODUCTION

Health and disease are increasingly understood as the product of interrelated ecological, cultural, social, and economic situations. For example, among the Inuit peoples of Nunavut and Nunavik (Canada), the consumption of traditional "country foods"—such as raw fish and meat—has been positively linked to feelings of health and well-being, whereas rapid cultural change has been flagged as a reason for the increase in mental health problems among Aboriginal Canadians (Kirmayer et al. 2009). At the same time, this is not a one-way influence; health also shapes social and ecological outcomes. For instance, poverty has been found to be a significant driver of increased exposure to malaria, and conversely, economic development is impacted by malarial incidence (Sachs and Malaney 2002). Likewise, the ramifications of disease outbreaks are not purely a matter of public health but have important economic consequences. For example, the 2003 global outbreak of Severe Acute Respiratory Syndrome (SARS) had an economic impact in the millions of dollars (Keogh-Brown and Smith 2008).

In what concerns the ecosystem–health nexus, there is now a wealth of evidence connecting ecosystem change with health impacts (Butler and Oluoch-Kosura 2006). Indeed, ecosystems provide basic material needs, regulate the spread of disease (Patz et al. 2004, Myers and Patz 2009) and can provide emotional fulfillment (Barton et al. 2012). Often, these connections become more apparent when there are negative consequences for humans, some examples are how recent outbreaks of vampire bat rabies in Brazil and Peru were associated with land-use change caused by gold mining prospecting (Schneider et al. 2009), or how unusual precipitation patterns in the United States have been linked to outbreaks of waterborne diseases (Curriero et al. 2001).

The study of the relationships between ecology and human health with the aim of searching for socially appropriate responses has given rise to the field broadly known as ecosystem approaches to health (EAH) or ecohealth, which we use interchangeably here. Ecohealth is one of several integrative approaches that consider health and environmental interactions. However, although there is a degree of overlap between these approaches, they are in fact distinct. For example, there is a broad-scoped literature in the field of environmental health, which tends to emphasize linear, cause-and-effect thinking rather than complex systems thinking (Parkes et al. 2003). There is also ecosystem health, which applies the concepts of resilience, vigor, and organization to the study of the integrity of ecosystems (Costanza and Mageau 1999). However, in ecosystem health, health is used as a metaphor, whereas ecohealth seeks to understand and promote the physiological and psychosocial health and well-being of humans in the context of complex social and ecological interactions (Waltner-Toews 2009). A more complete characterization of these approaches and their historical convergence is outside the scope of this paper but can be found in Parkes et al. 2003, 2005, and Webb et al. 2010.

Ecohealth and resilience thinking are rooted in complexity science and, from an epistemological stance, both regard humans and nature as coupled, social–ecological systems. Because of these shared foundations, we suggest that combining insights from ecohealth and resilience thinking has the potential to contribute meaningfully to the understanding and improvement of human health and well-being in the face of changing environmental conditions. The goal of this paper is to explore similarities and differences between resilience thinking and ecohealth in order to identify opportunities for fruitful engagement and to propose key

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Table 1. Overview of resilience thinking and ecosystem approaches to health

	Resilience thinking	Ecosystem approaches to health
Principles	Complex adaptive systems Social–ecological systems Scale interactions	Complex systems thinking Transdisciplinarity Social and gender equity Participation Knowledge-to-action
Research foci	Dynamics of social–ecological systems	Links among health, ecosystems, and social systems
Origins/history	1970s Systems ecology and AEM 1990s Ecological resilience 2000s Social–ecological resilience	1970s Calls for integration of ecological, social, and health concerns 1990s Creation of IDRC's ecohealth program 2000s Creation of CoPEHs
Organization of the field	Nodes at universities and research centers throughout the world	Communities of practice throughout the world, with researchers and practitioners from various institutions

areas of joint research. This article is the result of two panel presentations and a series of discussions initiated at the EcoHealth 2010 Conference in London, UK and the Resilience 2011 Conference in Tempe, Arizona, USA.

We begin with an overview of the EAH and resilience thinking frameworks. We then open the dialog between the two approaches by exploring seven themes that are pertinent to both fields and have a strong potential for cross-pollination: scale interactions, regime shifts, adaptive environmental management (AEM), social learning, participation, social and gender equity, and knowledge to action. Each of these themes has received different degrees of attention in the two literatures, and we believe that by analyzing them from an integrative perspective it might be enriching for both. We conclude with some suggestions for future research for those interested in practical and theoretical work at the intersection of environment and health informed by a perspective based on complexity science.

OVERVIEW OF ECOSYSTEM APPROACHES TO HEALTH AND RESILIENCE

The goal of this section is to provide an overview of EAH and resilience thinking, considering their historical development, guiding principles, research foci, overarching social goals, and the organization of each field (see Table 1). When interpreting Table 1, one should recognize that many of the principles are indeed shared and cannot be easily assigned to one or the other, hence, the boundaries in Table 1 are permeable and should be understood as representative of the bulk of the literature in each field, but not of all the work in the field. Given the breadth and diversity of topics and research in ecohealth and resilience thinking, this is intended as a synoptic overview highlighting key elements within the two approaches that merit further integration.

ECOSYSTEM APPROACHES TO HEALTH

Ecosystem approaches to health focus on the social and environmental factors that shape human health. Complex systems thinking constitutes the theoretical foundation of EAH, which encompasses notions of self-organization, adaptability, nonlinearity, and cross-scale interactions (Kay et al. 1999, Waltner-Toews 2004, 2009). Principles that guide ecohealth research and practice include transdisciplinarity, participation, questions of gender and equity, and an emphasis on translating knowledge into action (cf. Forget and Lebel 2001, Lebel 2003, Waltner-Toews 2004, Rapport and Mergler 2004, Webb et al. 2010, Charron 2012). Transdisciplinarity considers the integration of different epistemologies, including local, traditional, and Indigenous knowledges, and different disciplines within the natural sciences, health sciences, social sciences, and the humanities (Rapport et al. 1998). Ecohealth builds upon participatory frameworks that move away from expert-led research toward a research process that includes relevant actors from problem definition to design to the interpretation and sharing of results (Whyte 1991, Mertens et al. 2005). Gender and social equity guide research questions, methods, and analysis. Underlying the use of an approach that is participatory and transdisciplinary and that considers gender and power relationships, is the notion that interventions for improving health can better respond to local realities and have a greater chance of translating knowledge into action (Dakubo 2011).

Health is defined as "not merely the absence of disease or infirmity" but rather a "state of complete physical, mental and social of well-being" (World Health Organisation (WHO) 1948). As such, EAH use an array of standard and case-specific measures to capture the multidimensional nature of health. For example, some studies use quantitative measures or aggregated indices coupled with conventional human health variables such as life expectancy, morbidity, or mortality. Others take a place-based approach, where health is specific to local cultural dimensions of perceived well-being (Panelli and Tipa 2007). Finally, some choose to integrate both conventional measures, such as mercury exposure levels, and perceptual measures, such as perceived quality of life, to assess the health of a population (Fillion et al. 2009).

Pioneers of EAH sought to rethink the traditional biomedical health model, which emphasizes acute symptoms rather than systemic and underlying causes of illness and often fails to adequately address public health issues (Dakubo 2011). It became increasingly evident that poor health was linked to the larger political economy and to environmental degradation, with the

world's most marginalized often bearing the largest burden (Cole et al. 2006). In the 1970s, calls emerged for health-related policy, practice, and research to focus on the influence of natural and social environments on health outcomes (Lalonde 1974). Today, there are a variety of groups that practice and research ecohealth, such as the International Association for Ecology and Health and One Health. However, this article focuses on ecohealth as understood by the Canadian International Development Research Centre (IDRC), which funded Communities of Practice in Ecosystem Approaches to Health (CoPEHs) in Canada (www.copeh-canada.org), Latin America and the Caribbean (www.una.ac.cr/copehlac), Africa (www.copes-aoc.org), and the Middle-East, as well as a Field Building Leadership Initiative on Ecohealth in Asia. The CoPEHs provide learning and collaboration platforms for researchers and practitioners.

RESILIENCE THINKING

Resilience thinking offers a framework to understand processes of change and persistence. There are three key concepts that generally frame problems from a resilience perspective. First, resilience is most useful in examining complex adaptive systems, that is, systems whose components interact in complex ways and that have the capacity to learn, giving rise to adaptive behavior (Norberg and Cumming 2008). Second, as the components are social (such as labor, population, or institutions) as well as ecological (such as agricultural pests or the water cycle), these systems can also be considered coupled social–ecological systems (SESs) (Berkes and Folke 1998). The term is meant to emphasize that analyses of SESs are different from analyses of social systems or ecological systems alone (Westley et al. 2002). Finally, scale is important because complex adaptive SESs contain nested hierarchies (Gunderson and Holling 2002), and certain characteristics only manifest at particular levels within the spatial or temporal scales. Furthermore, key phenomena affecting the stability of the system may arise as the result of cross-scale interactions (Norberg and Cumming 2008).

The meaning of the term resilience itself has evolved over time. "Ecological resilience" was defined as the magnitude of disturbance that a system could absorb before shifting into an alternative steady state (Holling 1996). Later, "social–ecological resilience" was defined as having three components: (1) the amount of disturbance that a system can absorb and still remain within the same domain of attraction; (2) the capacity of a system to learn and adapt; and (3) the degree to which a system is capable of self-organization (Carpenter et al. 2001). Hence, social–ecological resilience follows similar lines to ecological resilience but it incorporates more centrally ideas about adaptation, learning, and self-organization (Folke 2006). The term "social resilience" (Adger 2000) has been coined to signal to the application of theoretical insights from resilience thinking to social systems; although it is widely recognized that insights from natural systems cannot be applied to social systems uncritically.

Resilience thinking emerged in systems ecology during the early 1970s as a way to understand nonlinear ecosystem dynamics. These understandings were applied to issues of resource management, such as insect outbreaks in the boreal forest, eutrophication of lake ecosystems, restoration of wetlands, management of grazed rangelands, or protection coral reefs (cf. case studies in Gunderson and Pritchard (2002)). In the 1990s, the concept began to be applied more broadly to the study of human–environment interactions, and there is now a wealth of regional case studies exploring how social–ecological systems deal with disturbance (Janssen et al. 2006). More recently, there has been a move toward the understanding of the impact of governance at multiple levels (Ostrom and Janssen 2005).

In terms of the organization of resilience as a field, initially, the bulk of resilience work came from a tightly knit group of researchers and practitioners who formed the Resilience Alliance in 1999 (formerly the Resilience Network), with the objective of exploring the dynamics of social–ecological systems. Subsequently, this group expanded to what now can be described as a series of concentric rings of resilience scholars located in 17 member nodes at universities and research centers (Parker and Hackett 2012).

WHY THE LINK BETWEEN ECOHEALTH AND RESILIENCE?

Whereas resilience thinking and EAH have distinct roots in ecology and population health, respectively, there is a strong convergence between the current articulations of these two approaches, specifically around complex social–ecological systems as a common epistemological and methodological foundation. With the two fields dovetailing, there is ripe opportunity to create a dialog centered on concepts that are more thoroughly developed in one field, which can then serve to advance the other. This was the original impetus behind the two panels presented at the EcoHealth 2010 and the Resilience 2011 conferences (chaired by the lead author) that served to inform this article. In particular, we believe that the complexity-informed approach to health developed in EAH and the thinking tools developed by resilience thinking offer synergies to address human health issues.

Resilience research has focused extensively on the study of change and persistence in ecosystems with the underlying purpose of maintaining ecosystems in a desirable state, that is, in a state where the ecosystem continues to provide the goods and services upon which human well-being depends. Indeed, managing for resilience —understood in its broadest sense as the management of processes of persistence, adaptation, and transformation—is seen as enhancing our ability to improve ecosystems, society, and human well-being (Folke et al. 2010). Although health is considered a component of well-being (Millennium Ecosystem Assessment (MA) 2003), there are very few examples within the resilience literature focused specifically on health (Berkes et al. 2012). Thus, there is little guidance in dealing with specific health issues save counted exceptions such as Janssen and Martens (1997), Cumming (2010), and Cumming et al. (2011). Here is where an approach to health that is rooted in systems thinking but that emphasizes equity, participation, and knowledge-to-action can be useful for resilience thinkers wishing to be more explicit and empirical in their treatment of well-being and health and move from theory to practice.

On the other hand, it is widely recognized in the EAH community that the challenges that we face in relation to human and animal health—accelerated environmental change, declining ecosystem services (MA 2005), population growth, or globalization—constitute so-called wicked problems (Brown et al. 2010). Wicked problems are difficult to define precisely, conflicting views are

held by multiple stakeholders, solutions tend to be partial or temporary, and each situation is often distinctly unique (Rittel and Webber 1973). Systems thinking has been hailed as a way to address wicked problems in health (Kreuter et al. 2004), however, there is a lack of unifying heuristics to do so although there are examples such as the diamond diagram schematic (Kay et al. 1999), the Adaptive Methodology for Ecosystem Sustainability and Health (Waltner-Toews and Kay 2005), or the prism framework (Parkes et al. 2003, 2010). Here is where we feel that tools such as those employed in adaptive environmental management and synthetic concepts such as scale interactions (panarchy) and regime shifts can help to add precision to EAH.

COMMON GROUND AND OPPORTUNITIES FOR CROSS-POLLINATION

We now turn our attention to the seven aforementioned themes, highlighting common ground between resilience and ecohealth as well as opportunities for cross-pollination.

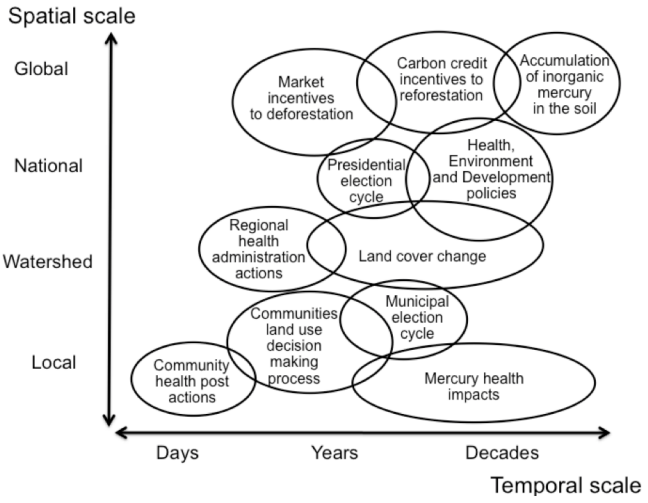
Scale Interactions

One of the heuristics used in resilience thinking is panarchy. The idea of panarchy is that complex social–ecological systems contain nested hierarchies (Gunderson and Holling 2002), and certain characteristics of the system only manifest at particular levels and scales. Scale is defined as "the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon" (Cash et al. 2006). For instance, in a forest ecosystem, there can be processes pertaining to leaf stomata, whole trees, or an entire tree stand; these processes might last seconds or span centuries. Likewise, within a given society, processes can occur at the level of a single individual, a family, a neighborhood, or an entire city. Although spatial and temporal scales are most commonly used, one can think of other social scales based on administrative, institutional, or economic parameters that are helpful in framing an issue.

Three important insights emerge from considering scales in social–ecological systems. First, key phenomena affecting the stability of the system may arise as the result of interactions across or within scales (Holling 2001). Second, it is useful to separate a system's variables into slow and fast variables. Slow-changing variables tend to control ecological resilience, whereas social–ecological resilience can be controlled by either fast or slow variables (Walker et al. 2006). Third, scale mismatches between ecological and administrative scales might negatively impact management outcomes (Cumming et al. 2006).

The case of human mercury exposure in the Brazilian Amazon region, which has been studied extensively from an ecohealth perspective, serves to illustrate how scale can be considered more explicitly within the ecohealth framework. At the crux of the issue, deforestation leads to the erosion of the mercury-rich soils of the banks of the Tapajós River; the mercury propagates through the aquatic food chain, and human populations are then exposed through fish consumption (Guimarães and Mergler 2012). Figure 1 shows some of the different processes distributed along the spatial and temporal scales involved and how they interact. Some variables change rapidly, whether at the local level, such as tree removal by slash and burn practices, or at the global level, such as price fluctuations for soya or beef that influence the annual rate of deforestation (Malingeau et al. 2012). Other variables change at a slower rate, such as the accumulation of inorganic mercury in soils or the health impacts associated with mercury exposure.

Fig. 1. Interactions across spatial and temporal scales for mercury exposure in the Brazilian Amazon region.

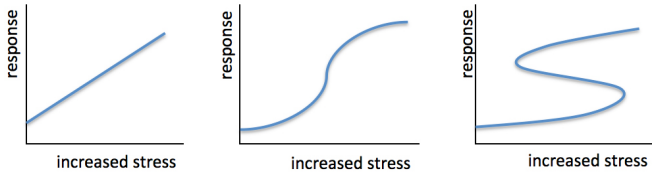


Considering wicked problems through a multiscale and multilevel perspective can highlight important scale mismatches, which is of relevance to ecohealth. For example, short national election cycles can trump the long-term planning required to locally manage the Amazon rainforest. A scalar perspective can therefore draw attention to relationships between variables at the national level that control the behavior or effectiveness of variables at the local level. In another example, local community efforts to reforest riverbanks at the microbasin level are ineffective in reducing mercury loads in the absence of a broader regional plan to decrease tree removal at the basin level. Here, a deeper understanding of scale interactions can assist in better coordinating efforts to improve human and ecosystem health.

Regime Shifts

The notion of regime shifts in resilience thinking evolved from the observation that ecosystems occasionally experience abrupt changes. Different pathways of change can be observed in an ecological system, as illustrated in Fig. 2 (after Scheffer 2009). An ecological system might respond to a stress or a change in conditions in a linear, gradual fashion (Fig. 2a). The system can also remain relatively unaffected as the conditions change and then respond strongly when the stress reaches a critical level (Fig. 2b). Lastly, the response of the system might have a catastrophe fold (Fig. 2c), meaning a system in the upper part of the sigmoid curve that experiences conditions beyond a threshold transitions very suddenly to the lower part of the sigmoid curve. This also implies that there are two alternative states, meaning that for the same set of external conditions the system can exist in two different configurations.

Fig. 2. Types of transitions observed in natural systems (based on Scheffer 2009).



Examples of catastrophic folds in ecological systems include the transition of lakes from oligotrophic to eutrophic states, of coral reefs from coral-dominated to algae-dominated states, or of woodlands from being dominated by herbaceous vegetation to being dominated by woody vegetation (Scheffer et al. 2001, Gunderson and Pritchard 2002, Folke et al. 2004). Although regime shifts have been documented in a diversity of ecosystems, they share several common characteristics: they are rapid, they are often triggered by an external event, they involve thresholds, and they indicate the presence of true alternative states (Scheffer 2009). For more examples of regime shifts, the Stockholm Resilience Centre is building an online database that can be accessed at www.regimeshifts.org/. Given the pervasiveness of regime shifts in ecological systems, and the fact that these arise as a consequence of their complexity, there is good reason to think that complex social–ecological systems might also experience regime shifts.

The idea of regime shifts has found use in the study of poverty traps (cf., Carter et al. 2007, Barrett 2008, Enfors 2013), and we hypothesize that this can be extended to ecohealth to better frame and understand disease outbreaks. For instance, Morrison et al. (2008) explored outbreaks of ciguatera fish poisoning (CFP), a food-borne disease caused by the biomagnification of benthic toxins, in several coastal communities in Cuba. They suggest that the presence of ciguatoxic fish is linked to a shift in the reef from a coral-dominated to algae-dominated state, due to a variety of social and ecological factors. They found that communities where the reefs had been degraded (algae-dominated) also experienced sudden increases in CFP occurrences. Although there are ample opportunities to explore regime shifts in health, it is important to note that regime shifts are often discovered a posteriori. Much work remains to develop indicators of thresholds that would allow enough lead time for interventions to prevent a regime shift toward an undesirable state (Biggs et al. 2009).

Adaptive Environmental Management of Natural Resources

Adaptive environmental management (AEM) is the expression of resilience theory as it applies to the management of ecosystems and is pivotal to resilience thinking. AEM emerged in the late 1970s in reaction to conventional management efforts that usually focused on reducing the natural variability of ecosystems in order to obtain predictable outcomes. Following this logic, food production systems shifted from traditional multicropping to monocultures, single-species stands replaced forest ecosystems, rivers were channelized to reduce periodic floods, and so on. Although the homogenization and simplification of ecosystems led to short-term gains, they also compromised the ability of the system to continue to produce benefits in the long term— a situation termed "the pathology of command-and-control" (Holling and Meffe 1996). In essence, the ecosystem managed though command and control behaves predictably over a decreasing range of conditions but becomes increasingly unstable while becoming vulnerable to surprises arising from complex nonlinear dynamics. By contrast, AEM was developed with the explicit purpose of embracing and managing under conditions of uncertainty. Acknowledging that ecosystems are complex, AEM combines assessments with management actions in an iterative fashion (Holling 1978, Walters 1986, Lee 1993). The exercise is twofold: first, to gain knowledge of the dynamics of the system and second, to understand how human intervention will affect it (Gunderson et al. 2008). Thus, in AEM policies are seen as hypotheses and management actions as experiments.

Early examples of applied AEM include the restoration of hydrological patterns in the Florida Everglades for recovery of the wading bird populations (Walters et al. 1992), the restoration of salmon and trout fish in the Columbia River basin after decades of hydropower development (Lee and Lawrence 1986), the management of forests in British Columbia (Taylor et al. 1997), or the restoration of the longleaf pine habitat in the Eglin Air Force Base, Florida, which led to a 40% increase in the population of red-cockaded woodpeckers (Hardesty et al. 2000, Peterson 2002). Benefits of AEM include the identification of key uncertainties and gaps in knowledge, that allow for the comparison of alternative outcomes and enhance communication and transparency (Taylor et al. 1997).

Ecohealth recognizes the strong connection between environmental conditions and human health to the point that some argue that human health is an outcome of effective ecosystem management (Parkes et al. 2003, Bunch et al. 2011). Still, whereas ecohealth recognizes the importance of ecosystem management as a determinant of health and shares many of the theoretical foundations of AEM, only AEM has well-developed and unified environmental management tools to this end (Hess et al. 2012). These include stakeholder workshops (usually with experts), dynamic modeling to hash out policy interventions—ranging from computer simulations to scenarios—and monitoring in an iterative fashion. Such concrete management tools may be of use for ecohealth scholars and practitioners wishing to operationalize its principles and work with the uncertain and complex connections between health and ecosystem integrity. These could be of use, for example, in contexts where land-use change has been linked to the (re)emergence of infectious diseases (Patz et al. 2004, Chivian and Bernstein 2008). We do not wish to imply that AEM is a silver bullet; there are indeed valid concerns about the challenge of implementing AEM, such as the risk involved in large-scale management experiments (Walters 1997) or the reticence of natural resource management organizations to institutional change (Allan and Curtis 2005).

Social Learning

Since Bandura's (1977) social learning theory, the idea that social contexts are the real schools for individuals has been used, developed, and applied to many domains. Considering the importance of "learning by doing" in AEM, the growing interest in social learning within the resilience literature comes as no surprise (e.g., Armitage et al. 2008, Tschakert and Dietrich 2010,

Johannessen and Hahn 2012). Social learning revolves around three intertwined aspects of individual and community learning: learning by doing through iterative cycles (Kolb 1984, Kato and Ahern 2008, Tschakert and Dietrich 2010), situated learning (Lave and Wenger 1991, Reed et al. 2010), and collaborative learning (Allen et al. 2001, Olsson et al. 2007).

Inspired by the idea of learning at different levels found in systems theory (Bateson 1972) and organizational learning theory (Argyris and Schön 1978, Swieringa and Wierdsma 1992), resilience scholars have explored single-loop, double-loop, and triple-loop learning. Single-loop learning refers to the simple correction of errors; that is, finding a solution to a specific problem. It is the most basic level of learning and does not, in itself, lead to systemic changes, rather to adaptations within a system. Double-loop learning questions the values, mental models and key relationships that underlie existing policies (Armitage et al. 2008). Double-loop learning may push stakeholders to engage with more complex understandings of a system, give them insights into their own group functioning, as well as favor a critical reflection on strategies and goals (Wildemeersch et al. 1998, Armitage et al. 2008, Johannessen and Hahn 2012). Finally, triple-loop learning is often understood as the learning that further questions the need for changes in governance or frames of reference (Armitage et al. 2008, Reed et al. 2010, Johannessen and Hahn 2012).

Given the centrality of participation in EAH, one would expect social learning to be well developed in this field. Indeed, research in the field addresses the idea of learning (Charron 2012), however, the exploration of social learning has not been as detailed as in resilience thinking. Recently members of two CoPEHs developed an evaluation framework for transdisciplinary groups that takes learning into account through an analysis of the coevolution of sociosemantics and social networks (Saint-Charles et al. 2013, unpublished manuscript). A sociosemantic network may be conceived of as a specific type of cognitive social network for which the relationships between individuals are constituted by their discourse similarities (Carley 1986, Monge and Contractor 2003, Newman 2004, Roth 2007). In transdisciplinary contexts that bring together individuals with different "thought-styles" (Pohl 2011), the way individuals understand the situation may vary greatly. Through their interactions, they influence one another and, hence, learning takes place at the individual as well as at the group level. The sociosemantic network analyses show how the way members "talking about" the situation is changing through time and in relation to the relationships they have with one another. Such analyses can be used by groups to reflect critically on their own development and types of learning (Saint-Charles et al. 2013, unpublished manuscript).

Participation

Ecohealth advocates prioritizing the voices and concerns of communities and stakeholders when examining health issues and their links with social and ecological variables (Waltner-Toews et al. 2003, Parkes et al. 2005, Dakubo 2011, Charron 2012). Participatory research creates partnerships for knowledge generation that rely on diverse framings of the same issue and that integrate various worldviews, including those coming from Indigenous and traditional knowledge systems, to create a common understanding of the problem and to promote power sharing (Parkes and Panelli 2001). In EAH, participation is integrated throughout the research process from the definition of research objectives and the development of questions (Guimarães and Mergler 2012) to the design of effective solutions (Fillion et al. 2011) and their implementation (Catalán-Vázquez et al. 2012).

Pragmatic benefits and limitations of participatory approaches have been tested in a wide spectrum of case studies, as in the case of watershed management for community health (Parkes and Panelli 2001) or the prevention of the spread of vector-borne diseases in rural and urban settings (Joshi et al. 2012, Monroy et al. 2012). The experience from EAH is that in the long run, a participatory process can directly and indirectly encourage stewardship of resources for sustainable use, empower marginalized groups through knowledge sharing and capacity building, and empower communities to take charge of environmental management actions based on research evidence (Betancourt et al. 2012). In other situations, the participation of local health officials has been essential in obtaining interinstitutional coordination that extends beyond the community to other governance levels (Monroy et al. 2012).

Some scholars in EAH have connected stakeholder participation to an increase of adaptive capacity (cf. Mertens et al. 2008 or Waltner-Toews et al. 2005). Similarly, within the resilience literature, a link has been drawn between participation and social–ecological resilience (Walker et al. 2002, Cundill et al. 2005, Lebel et al. 2006, Pahl-Wostl et al. 2008), particularly in studies focused on community-based management and comanagement (e.g., Berkes 2004, Hahn et al. 2006, Fabricius et al. 2007). Nevertheless, the emphasis on participatory research processes is not the norm in resilience thinking; in fact, interventions need not be participatory, or participation might be reduced to stakeholder consultation. This contrasts with the position upheld more or less uniformly by EAH, which maintains that a participatory research process will ultimately lead not only to better research outcomes, but will also challenge the underlying expert-community power dynamics. Yet, designing meaningful multistakeholder participatory research remains a challenge in any field (Parkes et al. 2003, Viswanathan et al. 2004), and in most cases, distinct levels of participation have been identified that go from "contractual participation" to "collaboration participation" (Biggs 1989, Mertens et al. 2005).

Social and Gender Equity

Ecosystem approaches to health seek to understand the drivers of health disparities, that is, why there are heterogeneous health outcomes within a social–ecological system. The notion of "health inequity" refers "to differences which are unnecessary and avoidable but, in addition, are also considered unfair and unjust" (Whitehead 1992:5). Health inequities occur across ethnicity, race, socioeconomic status, educational levels, geographic location, or gender (Forget and Lebel 2001). As gender is a transversal reality in any social context, EAH scholars tend to subsume health inequities under the category "social and gender equity."

Examples of the impact of gender on health promotion abound. Saint-Charles et al. (2012) compared the gendered nature of information diffusion and uptake in practices that promote health in rural Costa Rica (Rioux-Pelletier et al. 2009) and the Brazilian Amazon (Mertens et al. 2012). In some Costa Rican communities,

where women tended to be more isolated and have less access to information on pesticides, they found that women were less likely to adopt protective measures and also they were less likely to transmit information on best-use practices for pesticides. By contrast, in the communities in the Brazilian Amazon where women tended to be opinion leaders regarding health issues, women were key in the adoption of dietary practices that reduced mercury exposure from fish consumption. Similarly, with regard to the "Soils, Food, and Healthy Communities" project in Malawi that aimed at implementing alternative cropping strategies to combat food insecurity, Kerr et al. (2012) report that the integration of gender equity into the project design led to positive effects on health and livelihoods through the empowerment of women who traditionally were afforded less decision-making power.

Framing research questions and methods through the lens of gender and social equity can assist in unpacking the power relationships that constitute an important, yet underlying, causal basis for persistent health and environmental disparities. Equity issues arise when there is a rigid structuring of power relationships that leaves little room for transformation and change, thus creating a power imbalance (Dakubo 2011). In resilience terms, gender and social inequity is similar to rigidity traps that emerge from highly connected systems with strong feedbacks and that result in self-reinforcing behavior that cannot be easily changed (Carpenter and Brock 2008, Gunderson et al. 2010). Whereas rigidity traps are an active focus in resilience (see Enfors 2013), questions of power and equity have been largely sidelined (exceptions are Peterson (2000), Armitage (2008)). A greater recognition of equity and gender issues could be of interest to the resilience community given that planned actions and management strategies that recognize these issues can be more effective, while failing to integrate equity considerations can reinforce preexisting power dynamics within communities (Mertens et al. 2005, Saint-Charles et al. 2012) and may beget inadequate policies or faulty public services (Doyal 2000).

Tools and methodologies for dealing with gender and social equity considerations are still scant in most fields, but there are promising advances in EAH and in development (Charron 2012). For instance, EAH researchers have developed tools to tackle the multifaceted nature of water governance and health that include equity considerations (Parkes and Horwitz 2009, Parkes et al. 2010); others have used a social network approach to analyze equity of participation among social groups (Mertens et al. 2005).

Knowledge to Action

Enhancing the health of people and the integrity of ecosystems relies on creating and mobilizing knowledge to guide implementation. A first step is creating a bridge between what we know, that is our knowledge and understanding of the system, and what we do, that is the actions, policies, and practices that we ultimately implement (Charron 2012). Although this knowledge-to-action may seem an obvious necessity for tackling wicked problems, the reality is that much of the knowledge generated from research does not make it past the papers in which it is published (Lavis et al. 2002). The standard practice of knowledge synthesis and dissemination through academic venues is by itself insufficient for addressing complex, real-world problems (Graham et al. 2006, Graham and Tetroe 2007, Straus et al. 2009). Notice that knowledge-to-action is a research outcome that implies acting to implement change, whereas participatory research is an approach to gaining insights but not necessarily acting upon them.

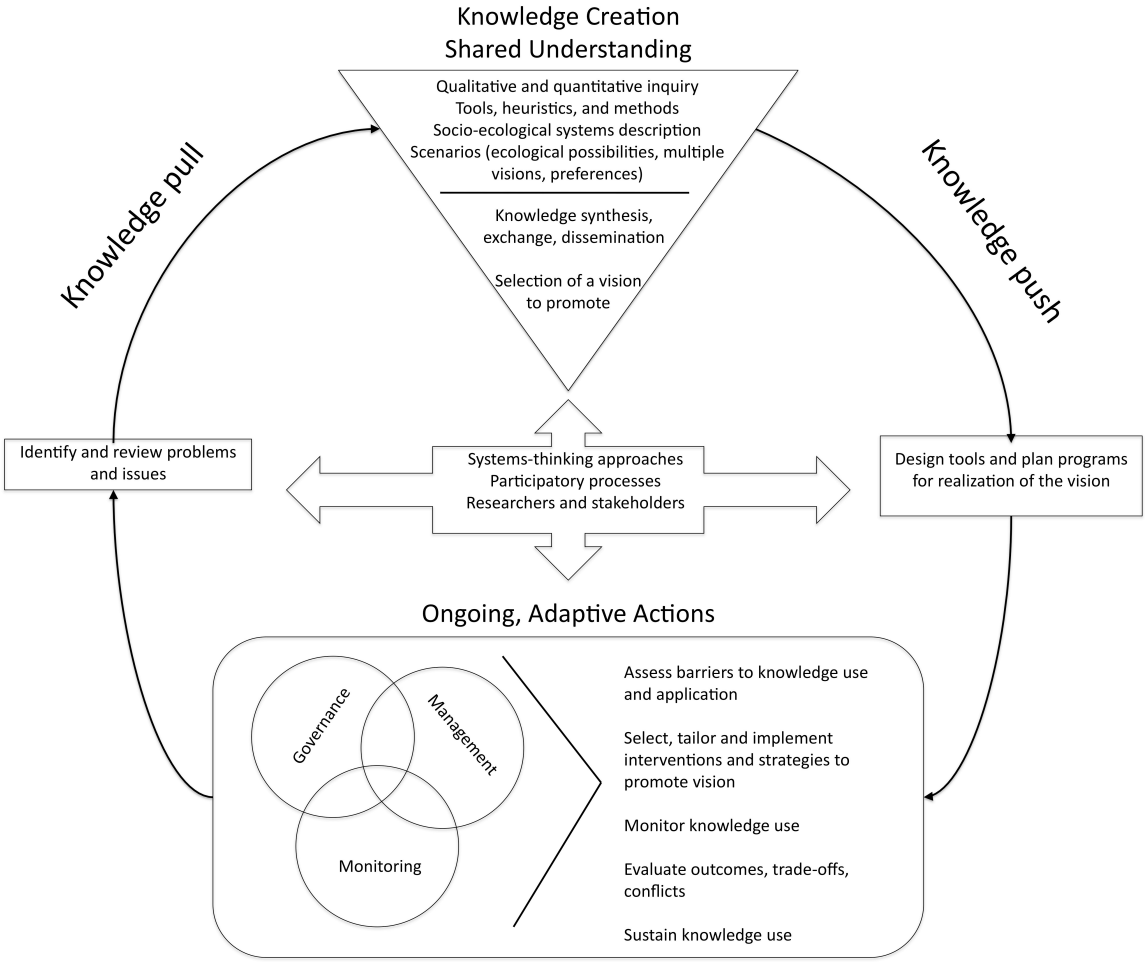
Moving from theory to praxis and translating knowledge into appropriate strategies for intervention can be paramount in improving health and ecosystems in the context of sustainable development (Boischio et al. 2009). There are examples of research-based evidence successfully leading to action, for instance, research to promote alternative crop-management practices brought about a shift in local agricultural practices that reduced pesticide use in Ecuador (Orozco and Cole 2012). In Nepal, community-led research initiatives have changed hygiene and sanitation practices and transformed contaminated riverbanks to gardens as a measure against tapeworm infections (Joshi et al. 2012). External factors such as financial constraints, sociopolitical contexts, or the experience and quality of decision makers can limit implementation (Elliott and Popay 2000). For example, in Nicaragua and Costa Rica, where there is a wealth of research evidence linking the use of agrochemicals to negative health impacts, trade agreements often interfere to undermine health regulations (Rosenthal 2005).

We propose a knowledge-to-action process in Fig. 3 as a way to conceptualize the bridge between what we know and what we do based on Waltner-Toews and Kay (2005) and Graham et al. (2006), which might be useful for ecohealth and resilience scholars alike. Figure 3 represents an iterative research cycle combining systems thinking and participatory approaches, where researchers, communities, leaders, and policy makers are key actors. End users and knowledge creators engage in an open dialog on goals, means, and ends during this process (Parry et al. 2009). Knowledge is created through mixed-methods inquiry that combines innovative tools and heuristics. Scenarios that integrate different ecological and health possibilities are explored to provide a narrative description of a future system. Knowledge moves through a funnel, distilling to become more useful for adaptive management actions and better tailored to the specific problem. Based on a common vision for the future that emerges from scenario planning, knowledge feeds into ongoing governance actions, management, and monitoring.

AGENDA FOR FUTURE RESEARCH AND PRACTICE

Given the wealth of experience that practitioners and scholars of EAH and resilience thinking have, there are many areas of fruitful interaction between the two fields that merit further consideration. We suggest that health is a good point of departure. Health is a useful tool for awareness building and governance as it is easily knowable, intuitive, and able to cut across diverse groups (Rapport et al. 2009). As such, it holds the potential to join diverse communities and bring well-being to the forefront of political debates. Discussions on health can also help policy makers and the public to move away from reductionist thinking to consider the system as a whole (Lackey 2001, Rapport and Mergler 2004). Experience shows that individuals and communities can quickly organize and mobilize to address an issue when health is a direct and immediate concern; for example, when vital resources such as water are at risk of being contaminated. Accordingly, an explicit link between health and well-being outcomes and social–ecological system management can give new framings to wicked

Fig. 3. A knowledge-to-action process for EAH, adapted from Graham (2006) and Waltner-Toews and Kay (2005). Drivers of the cycle may be initiated when: (1) a problem is identified, and there is a need for new knowledge to address the issue (knowledge pull); (2) new knowledge is deemed useful for management, and researchers wish to inform leaders or decision makers (knowledge push); (3) a mutual push–pull situation. Participatory research designs are vital in that they enable the coconstruction of knowledge, promote awareness and capacity building among the actors involved, and foster the adoption of research evidence in ways that respect cultural values and social norms. Systems thinking approaches help navigate uncertain and complex situations and integrate social and ecological considerations.



problems, lead to scientific innovation, and to socially relevant research and intervention.

There are ample opportunities for further integration of concepts, particularly around the following research foci: Firstly, the collective expertise of ecohealth researchers could offer important contributions to our understanding of health–ecosystem interactions within the ecosystem services framework. Ecosystem services are the direct and indirect benefits that humans derive from ecosystems that contribute to their well-being; these include provisioning (e.g., timber, fish, fiber), regulating (e.g., climate regulation, erosion control), cultural (e.g., recreational use, spiritual fulfillment), and supporting (e.g., nutrient cycling) services (cf., Costanza et al. 1997, MA 2005). The bulk of work in ecosystem services focuses on provisioning services, with less attention being paid to the contribution of other types of services; specifically, the contribution of regulating and cultural services remains understudied (Raudsepp-Hearne et al. 2010, Chan et al. 2012). Ecohealth could be of great help in addressing this gap, given that many studies examine how environmental change, especially the degradation of regulating services and cultural benefits, produces harm or disease. This is reflected in many of the case studies cited in this article, e.g., mercury contamination tied to soil erosion, ciguatera blooms tied to the contamination of coral reefs, etc. Within the resilience literature, the need to focus on how change in ecosystem services affects the well-being of the most vulnerable has also been identified (Carpenter et al. 2009). Participatory methodologies for assessing ecosystem services have the potential to bring perspectives from marginalized groups and

communities, but they remain relatively unexplored within ecosystem service research (exceptions are Pereira et al. 2005, Berbés-Blázquez 2012). Given the centrality of equity and participation in ecohealth research and its focus on vulnerable and impoverished populations, there is much to be learned from a closer integration of these two approaches.

Secondly, social network analysis, SNA, is an active focus of new research for scholars of ecohealth (e.g., Mertens et al. 2005, 2008, 2012; Saint-Charles et al. 2012) and resilience thinking (e.g., Bodin et al. 2006, Bodin and Crona 2009, Ernstson et al. 2010, Rathwell and Peterson 2012), representing another area of possible engagement. From the SNA perspective, the relationships and the patterns created by ties in a social network are key to understanding social life (Marin and Wellman 2011). Generally, SNA has been applied in resilience research to investigate the structural characteristics of community and stakeholders' networks that concede adaptive management of natural resource (Bodin and Crona 2009). Many works within the resilience literature also analyze network connections across institutional or governance levels, likely influenced by the concept of panarchy (e.g., Ernstson et al. 2010, Rathwell and Peterson 2012). In ecohealth, SNA has been used as a tool to map community networks, emphasizing the role that interpersonal relationships uphold in participation, leadership, and the diffusion of healthier behaviors (Maillé and Saint-Charles 2012, Mertens et al. 2005, 2008, 2012, Saint-Charles et al. 2012). Given that SNA in resilience has focused on vertical connectivity whereas ecohealth has tended to emphasize horizontal connectivity, we believe that each can contribute its unique expertise to the enhancement of social–ecological systems.

Thirdly, health is a highly dynamic and complex problem to which the application of resilience heuristics can add new understandings. As we have broadly illustrated above, health insights may be gained through framing a situation in terms of scale interactions, regime shifts, and thresholds. Within this perspective, exploring the positive and negative feedbacks between components of a system can pinpoint the key relationships that sustain a given state, such as one with high disease incidence, or that can push the system into a more desirable configuration, such as one where wellness is favored. This would also involve noting threshold levels and conditions that might be crossed and give rise to nonlinear responses, which might result in a regime shift.

Fourthly, many EAH scholars work to reflect critically on how values frame research and discourse. Becoming aware of and examining the normative values that underlie research and practice are of importance to ecohealth and resilience alike. Within the resilience literature, normative issues are sometimes engaged in a critical and reflexive way, for example, by questioning "resilience of what to what,"; but "for whom" and to "what ends" are less clearly considered in practice (Cote and Nightingale 2012). In very general terms, resilience thinking tends to overlook power dynamics and cultural aspects such as norms and beliefs that underlie normative questions, including self-reflexive inquiry like who benefits from research and how. This oversight is not systematic and is changing within resilience (Peterson 2000, Armitage 2008); however, some ecohealth references from a critical or cultural studies perspective could serve as a bridge to deeper explorations (Dakubo 2011). However, ecohealth has an explicit commitment to explore how normative values guide research, including safeguarding equal opportunities and promoting environmental and social justice, which are cornerstones of healthy societies (Maillé and Saint-Charles 2012).

CONCLUSIONS

Briefly, our departure point in this paper was that human health is both a driver and a result of social, economic, and environmental circumstances, as defined in ecohealth. We also took note that despite a well-established interest in human and community well-being, health itself remains an underexamined topic within resilience research. Hence, we carried out a theoretical exploration that considered the possibilities of bringing together EAH, as practiced predominantly by the communities of practice in ecosystem approaches to health (CoPEHs), and resilience thinking, as practiced by the Resilience Alliance. To guide our reflection we focused on seven themes relevant to the holistic examination of issues related to social–ecological systems and that are developed to different extents in each field. These were: scale interactions, regime shifts, adaptive environmental management, social learning, social and gender equity, participation, and knowledge to action. There is a high degree of complementarity between the two approaches. With health and well-being as central and unifying issues, there are critical areas of research and practice that could benefit from a tighter cooperation between the ecohealth and resilience communities centered around filling gaps in the ecosystem service framework, expanding the scope of social network analysis, developing system heuristics for health and pushing the normative dimension of resilience.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/6264

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