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■ *Research Paper*

Ecosystem Approaches to Health and Well-Being: Navigating Complexity, Promoting Health in Social–Ecological Systems

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Ecosystem Approaches to Health (also known as 'ecohealth') link population or community health and well-being with the environment and sustainable development. The approach is based on the understanding that health outcomes emerge from interrelationships within social–ecological systems. The ecohealth approach rests on principles of transdisciplinarity, participation, gender and social equity, systems thinking, sustainability, and research-to-action. This paper introduces the emerging field of ecohealth as an approach rooted in systems thinking. The approach will be illustrated with three case studies; an application to interrelated crises of poverty, environmental degradation, and zoonotic disease along the Bishnumati River in Kathmandu, Nepal; improvement of community well-being in a low-income informal settlement in Chennai, India; and an ongoing project with the Credit Valley Conservation Authority in Southern Ontario, Canada that is oriented to identifying and communicating relationships among ecosystem services and human health so as to demonstrate the importance of watershed management. These projects are typical of the Anthropocene, in which human systems impact the natural systems upon which they depend. Copyright © 2016 John Wiley & Sons, Ltd.

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INTRODUCTION[1]

The Ecosystem Approach to Human Health (also known as the 'ecohealth' approach) links population or community health and well-being

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[1] This paper is based on my keynote address at the ISSS in 2015.

with the environment and sustainable development. The approach is based on the understanding that health outcomes emerge from interrelationships within coupled human and natural (social–ecological) systems. It is a framework to study and manage relationships between human beings and the environment in pursuit of co-benefits, improving both ecosystem health and human well-being. The ecohealth approach is intended to be applied in situations of complexity where traditional 'normal science' approaches tend to fail—situations of irreducible uncertainty, multiple completing interests, interacting relationships, problems that are their own causes, and more. Such situations are also known as *wicked*, *turbulent*, *ill-structured*, *fuzzy*, *soft*, *messy*, or *real-world* problems (Rittle, 1972; Checkland, 1976; Trist, 1980; Mason and Mitroff, 1981; Morley, 1986; Bardwell, 1991; Ludwig, 2001).

The approach was pioneered in the 1990s by the International Development Research Centre (IDRC)—an agency of the Canadian Federal government (Forget and Lebel, 2001; Lebel, 2003) and by associated researchers and stakeholders. IDRC is still influential in this emerging field, but ecohealth has since expanded to involve communities of practice around the world. It has been incorporated as one of the fields of interest for the International Association for Ecology and Health (and its journal EcoHealth) and has been adopted as an operating framework by several development and civil society organizations such as Veterinarians without Borders and the Network for Ecosystem Sustainability & Health. Given its origins at IDRC, it has been applied mostly in development contexts in the Global South.

The ecohealth approach is based on six principles (Charron, 2012): systems thinking, including an appreciation of the complexity of real-life problematic situations; knowledge-to-action as this is an explicitly applied approach; transdisciplinarity defined as an approach that integrates stakeholder knowledge in substantial and meaningful ways (not only a variety of relevant areas of professional and academic expertise); participation which is an extension of transdisciplinarity (with implications for empowerment of stakeholders); concern with gender and social equity; and orientation to intervention for social and environmental sustainability.

Ecohealth is a promising approach, but it is not well known outside of a relatively small group of researchers and practitioners. It is the objective of this paper to introduce the ecosystem approach to human health to the broader systems thinking community as an approach grounded in systems thinking. After first discussing what is meant by 'health' and 'ecosystem approach' in ecosystem approaches to health, I will illustrate the approach with a review of three ecohealth projects.

These projects were selected for several reasons: (i) the author's familiarity and/or involvement with the projects; (ii) they demonstrate application of the ecohealth approach to problematic situations involving complex coupled human and natural systems; and (iii) they demonstrate problems associated with the Anthropocene in which the scale of human impact on natural systems undermines their ability to support human systems—which are also characteristic of situations of complexity.

WHAT IS HEALTH?

> "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 1948)"

The WHO definition above is from the *Preamble to the Constitution of the World Health Organization* as adopted by the International Health Conference in New York in 1946. It is still the most cited definition of health. It is a holistic definition that stands in contrast to traditional medical and epidemiological practice which responds to 'end of pipe' complaints and which is dominated by linear causal models.

This broad definition of health leads to a more complex, inter-related and non-linear understanding than conventional linear thinking. For example, in the health promotion field, there are hundreds of ecological models of health such as

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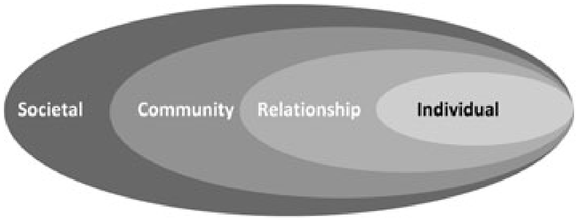

Figure 1 The social–ecological model (after Centers for Disease Control and Prevention, 2007)

the one in Figure 1. Each is oriented to a particular health issue, such as colorectal cancer (Nuss *et al*., 2012) childhood obesity (Ohri-Vachaspati *et al*., 2015), and violence prevention (Terry, 2014). Each of these identifies risk factors at different hierarchical levels, implying that conditions of health can exist not only at the level of the individual but also at each of the other levels. It also suggests (as systems thinkers will recognize) that health at any particular level is related to health at levels of wider systems and subsystems.

But these ecological models rarely acknowledge the complex social–ecological context within which they are constructed. I believe this to be a mistake. Ecosystems underpin all of our social and economic systems and feed back into them as well. This is demonstrated by a large body of work in the environment and health field that addresses a wide range of environmental determinants of health such as water quality and diarrhea (Levy *et al*., 2012), schistosomiasis (Stensgaard *et al*., 2013), exposure to pesticides (Rauh and Margolis, 2016), indoor air quality and respiratory health (Hulin *et al*., 2012), malaria (Bevilacqua *et al*., 2015), dengue (Fazidah A. Siregar *et al*., 2015), helminth-related diseases such as tapeworms and filariasis (Gazzinelli *et al*., 2012), and zoonoses such as leptospirosis (Mwachui *et al*., 2015) and avian influenza (Waltner-Toews, 2007).

Most work addressing such environmental determinants of health is driven by responses to specific adverse health outcomes, leading to public health prevention strategies to address their occurrence. Researchers, public health practitioners, and environmental managers, however, are beginning to understand the role of ecosystems in health *promotion*. For example, a recent study of 30 000 residents of Toronto found that having 10 more trees in a city block improves (self-reported) health in ways comparable to being seven years younger (Kardan *et al*., 2015). There are many such relationships; Table 1 presents some that are related to the density of green space in cities.

Such environment and health relationships are often multiple, diffuse, and interacting, and they are embedded in complex coupled human and natural systems. Science rooted in linear approaches tends to fall short in such situations. Even though the evidence of such relationships is strengthening, we need better ways of informing intervention in situations of complexity and uncertainty.

Table 1 Density of green space has been found to be significantly associated with several health outcomes (Source: Table 8 in Zupancic et al., 2015)

Health benefit	Related study
Lower stress levels and a greater resilience to stressful life events	Nielsen and Hansen, 2007; van den Berg *et al*., 2010
Healthy weights	Bell *et al*., 2008; Lachowycz and Jones, 2011; Norman *et al*., 2010; West *et al*., 2012
Reduced morbidity	Maas *et al*., 2009
Reduced risk of cardiovascular disease	Maas *et al*., 2009; Mitchell and Popham, 2008
Lower risk of heat-related stress and morbidity	Harlan *et al*., 2013
Healthy blood pressure	Hartig *et al*., 2003
Improved cardio-metabolic health (reduced risk of diabetes, heart disease, or stroke)	Paquet *et al*., 2013
Healthy pregnancy and births	Dadvand *et al*., 2012; Donovan *et al*., 2011; Kihal-Talantikite *et al*., 2013; Laurent *et al*., 2013

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AN ECOSYSTEM APPROACH

Ecosystem approaches—such as ecohealth—draw upon systems thinking and complexity science to address such situations. Formulations of ecosystem approaches most commonly employed in ecohealth are the Adaptive Ecosystem Approach (AEA) (Kay *et al*., 1999; Bunch, 2001; Waltner-Toews *et al*., 2008) and the Adaptive Methodology for Ecosystem Sustainability and Health (AMESH) (Waltner-Toews, 2004; Waltner-Toews *et al*., 2004). That the ecosystem approach is a systems approach is explicit, having been informed and operationalized by methods such as Soft Systems Methodology and Viable Systems Analysis (Bunch, 2003; Waltner-Toews and Kay, 2005; Bunch *et al*., 2008).

A schematic representing the AEA is presented in Figure 2. It outlines an iterative approach that draws upon systems thinking and is operated by collaborative processes to understand relevant systems of interest, both regarding physical and ecological aspects, as well as social, cultural, and political characteristics of the situation. Conceiving of social–ecological systems as self-organizing, holarctic and open (SOHO) systems, this approach involves a system study leading to the identification of sets of possibilities that, in Soft Systems jargon, are systemically desirable and culturally feasible. These could be full-blown

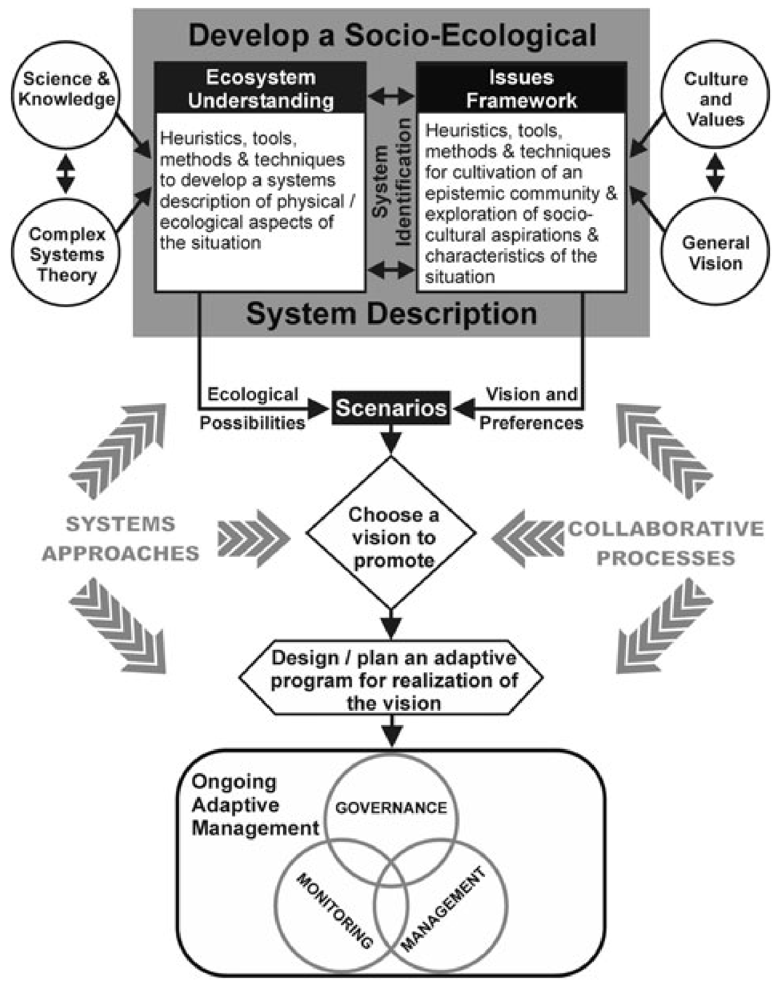

Figure 2 The adaptive ecosystem approach (Bunch, 2001 after Kay et al., 1999)

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scenarios or individual interventions. An intervention is chosen, implemented, and subsumed in an ongoing cycle of adaptive management.

Note that this is a framework or an approach, rather than a recipe. Every situation is different, and so the specific methods, tools, and techniques are not prescribed.

Similarly, AMESH describes a learning cycle that involves exploration and analysis of the situation and its context, identification of relevant stakeholders and their perspectives, systems analysis and synthesis (both quantitative and qualitative) and collaborative learning and action through the identification of interventions, implementation, monitoring, and evaluation (Figure 3). More than AEA, AMESH highlights both the health and well-being dimensions and foregrounds the participatory and transdisciplinary aspects of the approach.

CYSTIC HYDATIDOSIS IN KATHMANDU

The first of three demonstrations of ecosystem approaches to health that I present in this paper was initiated in the early 1990s as a collaborative

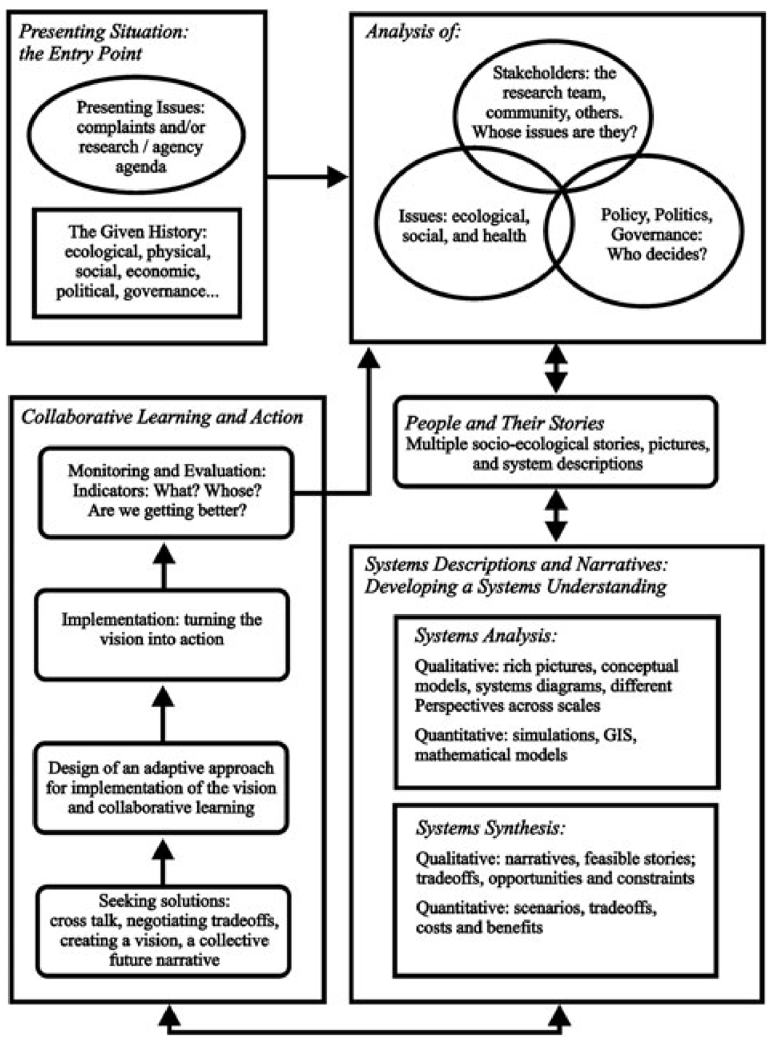

Figure 3 The adaptive methodology for ecosystem sustainability and health (Waltner-Toews, 2004; Waltner-Toews et al., 2004). ©NESH, with permission

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project among researchers at the National Zoonoses and Food Hygiene Research Centre (Nepal), the University of Guelph (Canada), the Center for Disease Control (USA), and Salford University (UK). The leaders on the project were Dr. Joshi (Nepal) and Dr. Waltner-Toews (Canada).

The point of entry for the project was a concern for Cystic echinococcosis in several Kathmandu neighbourhoods. This disease in people, which occurs worldwide, is caused by a two-host parasite, *Echinococcus granulosis*. The definitive hosts are canids such as dogs, foxes, and wolves, in which the parasite lives as an intestinal tapeworm and causes no discernable health problems. The eggs are shed in the feces and are ingested by intermediate hosts, which are usually ruminants such as sheep and cattle. In these hosts, the parasites pass into the bloodstream and grow into tumour-like cysts in various parts of the body, including the lungs, diaphragm, and, occasionally, the brain. When the animal is killed, if the cyst is eaten by the definitive host, the life cycle is completed. People who accidentally ingest the eggs also develop cysts, but unless they are eaten by dogs, remain 'dead-end' hosts. In wards 19 and 20 of Kathmandu, where animals were being slaughtered along the banks of the Bishnumati River, local veterinarians noted hydatid cysts in buffaloes being slaughtered. They also noted a substantial rate of cystic hydatidosis in area hospitals, and significant death rates in people from whom surgeons were attempting to remove the cysts. This situation along the banks of the Bishnumati River in 1991 is described by Waltner-Toews *et al*. (2003, p. 23):

> "In the early dawn, by a series of small fires, water buffaloes are pithed and slaughtered beside a trickle of muck that was once the Bishnumati River. Vultures wait in the branches of a few nearby trees. Below them, between the groups of men eviscerating the carcasses, dogs and pigs forage, and people bathe, defecate, and come to fetch their household water."

Initially, the research team undertook traditional epidemiological studies to address the disease. This included household questionnaires on dog-care practices, clinical examinations, screening of blood sera, and reviews of clinical cases in the area. A variety of public health communication strategies were tried to change behaviours that supported the transmission cycle of the tapeworm (Neudoerffer *et al*., 2005). Interventions proposed included killing stray dogs, strict dog control measures for owned dogs, modernization, and securing slaughtering in large facilities. However, after some years of intensive work, there was no improvement in the situation. The program had run up against embedded cast norms and cultural practices with respect to dogs and slaughtering. For example, small-scale open-air butchers did not want to become slaughterhouse workers, and dogs were seen as 'community police.' The traditional 'normal science' approach failed when faced with a situation of complexity. The team decided to take another tack. As relayed by Neudoerffer *et al*. (2005, p. 4 [online]) "while human health remained the ultimate goal, we had decided that this could best be achieved by improving the health of the eco-social system within which that health was one outcome (i.e., taking an ecosystem approach to health)."

This ecosystem approach to the problem widened the focus from a single zoonotic relationship to a wider social–ecological system. The process became much more participatory, identifying and empowering various stakeholder groups such as butchers and street sweepers. They then better understood the human social part of the situation that was coupled to the biophysical system. And because the process became participatory, local stakeholders took ownership of the interventions, making them both more appropriate and more sustainable.

As part of this work researchers and local assistants undertook an extensive process of household questionnaires, interviews and focus groups that produced narratives for a wide range of stakeholders. These were translated to influence diagrams, having to do with stakeholder concerns and stakeholder actions, for each stakeholder. These were then integrated to form a more holistic picture as synthesis diagrams (see Neudoerffer *et al*., 2005).

By the turn of the millennium, the 18 stakeholder groups that participated in the investigation were able to identify, implement, and successfully

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maintain interventions (Joshi *et al.*, 2012). These included a biogas plant to compost organic waste, the transformation of the riverbank to community gardens, removal of livestock from the river bank, and improved and community-maintained sanitation facilities. Importantly, even though the project expanded beyond the original zoonotic point of entry, the echinococcus transmission cycle was, in the end, broken by these multiple and interacting interventions on the landscape. For example, in Figure 4 you can track peer pressure from multiple community groups through to the removal of livestock from the river, which is one of several contributing factors to break the cycle.

Based on this work, and several other projects in Africa and Latin America, the researchers developed a general methodology which they called AMESH, which was then tested on several other sites.

ENVIRONMENT AND HEALTH IN A CHENNAI SLUM

The second case is a project in which I collaborated with colleagues at York University (David Morley and Beth Franklin) and the University of Madras (T. Vasantha Kumaran and V. Madha Suresh) as well as several Indian NGOs. We worked with two 'worst case scenario' communities in Chennai in southern India. One of these was partially destroyed on 26 December 2004 by a Tsunami, and the population relocated to relief and rehabilitation camps, and finally to tenement structures (Bunch *et al.*, 2005). We worked with the other, known as Anju Kudisai (or Anjukudusai) ('five huts' in Tamil), from 2004 to 2009.

When we started working with the Anju Kudisai community in 2004, it was a small

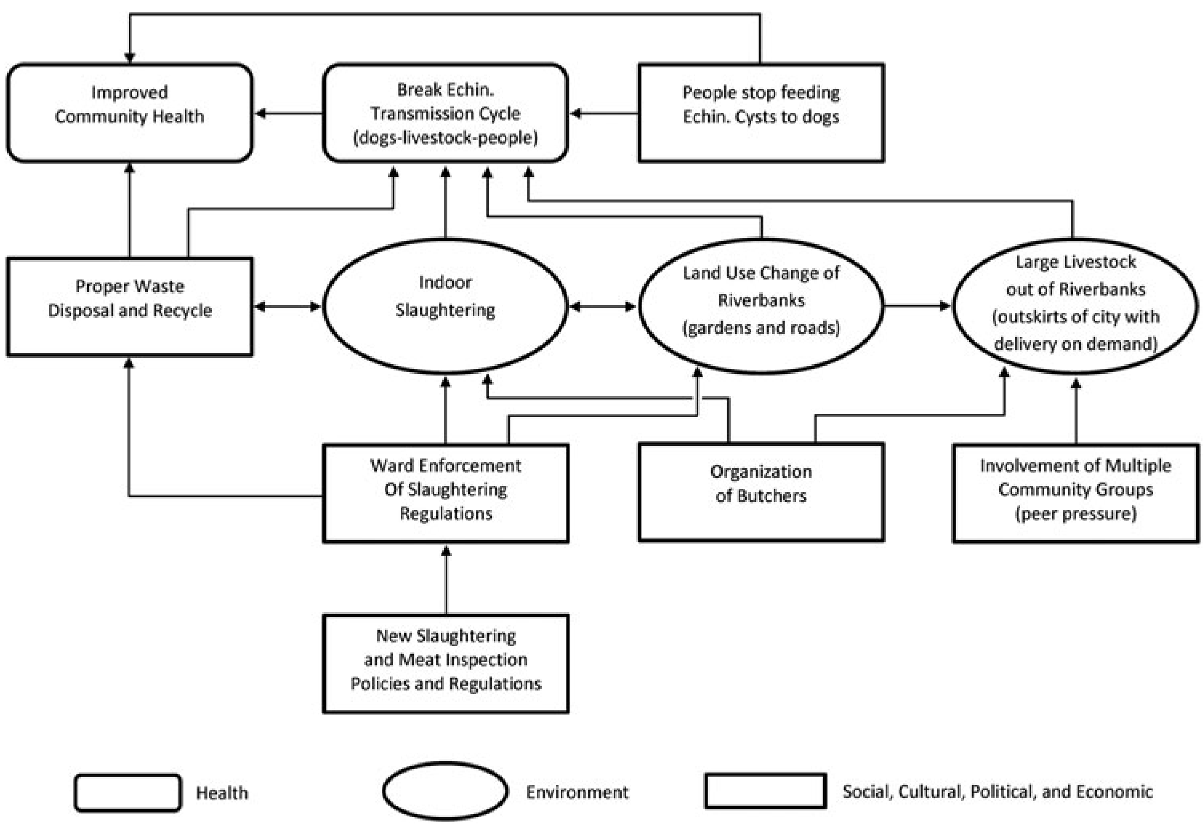

Figure 4 Social and ecological outcome pathway for breaking the cycle of echinococcosis transmission in Wards 19 and 20, Kathmandu, Nepal (Redrawn from Joshi et al. (2012))

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inner-city squatter settlement of 256 households. Located on land between a road and a polluted river, the community lacked access to basic urban services such as toilets, protected water supply, electricity, and solid waste collection. The community was characterized by high rates of illiteracy, recurring outbreaks of cholera and other disease, unemployment, high rates of drug and alcohol abuse and other manifestations of intense urban poverty. My colleague Vasantha Kumaran described the situation as follows (Kumaran *et al*., 2012, pp. 103–104):

> "[Anju Kudisai] inhabitants are daily wage workers who work in the fish market. Women are mostly maid servants in the local middle class households…Hygiene levels are very low and the [one room] homes (they cannot be considered residences) are used for all purposes, from cooking, washing, eating to sleeping. With minimal vents, it is a haven for breeding pathogens and viruses. Garbage is dumped right next to the Cooum [River] and clogs the drains. There is always an unpleasant odour in the air and it is also a natural habitat for worms and insects. Mosquitoes are a menace. At the beginning of the project, people were reluctant, indifferent and arrogant. Outsiders were … unwelcome."

There are hundreds of such communities in Chennai. Often, however, these communities will be associated with one or more service NGO's or religious organizations, or will be 'adopted' by a school or other organization (Thillai and Narayanan, 2015). Drawing upon resources and building capacity with such organizations, over time, such informal squatter settlements evolve, often becoming indistinguishable from regular low-income neighbourhoods. Unlike many other so-called 'slums', Anju Kudisai in the early 2000s was hostile to collaboration with outside organizations, and seemed to be stuck in a resilient and maladaptive domain of behaviour that resisted even incremental improvement.

To address this problematic situation, we adopted the AEA and operated it in a Participatory Action Research mode. AEA is explicit about drawing upon systems thinking and complexity science to understand self-organizing, holarchic and open (SOHO) systems (Kay *et al*., 1999; Bunch, 2003; Waltner-Toews and Kay, 2005). Accordingly, a key concept we used to guide understanding and management of the situation was that of attractors (from Chaos Theory) or regimes (from Resilience Theory). This is also related to concepts such as resilience and self-organization and describes a domain of behaviour of a complex system in which the system maintains its organization and can resist external pressures … up to a point. At some point it may evolve, or be pushed, across a tipping point (in lay language), also variously referred to in Chaos Theory, Catastrophe Theory, and Resilience Theory as a 'bifurcation', 'threshold,' 'regime shift,' 'phase transition', or 'flip'.

If the Anju Kudisai situation involved a complex, resilient, mal-adaptive system, then it stood to reason that there was an attractor that described the domain of behaviour of the system. Also, perhaps there were potential alternative attractors that were more desirable, and that would also be resilient. We wanted to find a way to manage the situation through a regime shift.

The Project Team worked with community partners and stakeholders in a participatory action research mode. At first, this took the form of a system study, attempting to map and understand the system, and progressed into visioning, and intervention. Activities initially included transect walks, photovoice narratives, socio-economic surveys, community mapping, key informant interviews, small group meetings, larger community meetings, and more. This work allowed us to characterize the current resilient domain of behaviour or 'regime' of the Anju Kudisai situation, and informed interventions that targeted desirable alternative regimes. Regimes were identified in terms of relationships internal to the slum, between the community and their wider system, and between the community and their environmental context.

The initial regime, for example, was characterized internally by isolation and lack of trust, a dependency relationship to outside agencies and organizations, and a physical environment that acted as a waste dump and presented health risks such as vectors for, and exposure to, enteric pathogens, cholera, typhoid, dengue, chikungunya,

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Figure 5 A photograph of a community map of Anju Kudisai, Chennai, India. The photographs were taken by men, women, and children during modified transect walks through the community that incorporated photovoice techniques. Community members took pictures of places and situations in their community that they perceived as important, and then explained their rationale to project team members. These explanations are the photo captions (in Tamil). ©NESH, with permission

malaria and tuberculosis. Many of these relationships contributed to the resilience of the system. For example, it is well known that the illegality of the existence of such communities, that is, lack of tenure, dissuades residents from making investments in their homes and community (Durand-Lasserve and Royston, 2002).

So the team built rapport with the community, while employing a number of techniques common to participatory development. Figure 5 shows a community map that was developed as part of this process. It is illustrated with photographs taken by men, women and children in the community and captioned in Tamil. They were produced on modified transect walks combined with photovoice techniques to draw out places of concern to different groups of community members. This map was used in community meetings to orient discussion to relationships in the community that could be targeted to undermine the current regime (and make it less resilient) and to generate discussion about a future vision—a more desirable domain of behaviour. It also served to bring youth into the discussion. They were more likely to be literate, and they explained the captions to their elders.

The vision that emerged was characterized by the development of trust and social capital beyond family and immediate neighbours, and the emergence of a community-based organization that engages women, men, and youth. Externally, it involved the capacity to access and direct

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external resources in the pursuit of livelihood alternatives and improved health and well-being. The environmental context was envisioned to be improved by both infrastructure investments and changes in attitude and behaviour.

Thinking about the envisioned attractor begged the questions; 'Will such a state self-organize and maintain itself?' 'Will it be resilient?' Our understanding of complexity led us to think so. Successes leading to improved health and well-being should set up a positive feedback, reinforcing the successful behaviour. An example from Anju Kudisai was the development of community capacity to cross scales with the wider system. By the end of the first year of the project, a women's group had formed in the community. An issue of concern to them was the children's habit of open air defecation. The children did not want to use public facilities on the roadside because they were afraid to go into the dark and smelly boxes. One morning one of our field staff came to the community and, to his surprise, found 30 women waiting for him. They took him in tow and walked to the local ward councillor's office, where they petitioned for a children's toilet; an open design that the children would use. The councillor supported the petition, arranged funding, and mobilized the public works

Figure 6 A member of the women's group in Anju Kudisai, Chennai, India choosing a location for the first bathing hut. The location was previously used to dispose of trash and for open air defecation. ©NESH, with permission

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department. Within the year, they had the toilet. Emboldened by their success the women next worked towards bathing rooms where they could wash themselves and their children without worrying about trying to keep all their belongings and supplies dry inside of their one room huts. By 2009, there were five shared bathing huts in the community (Figure 6).

It was an uneven road, however. There were dozens of initiatives: community cleanups, gardens, livelihood training, self-help groups, tree planting, health camps, hygiene programs, and more. For every one that had some success, at least two failed. The envisioned regime was not achieved, but the situation did evolve. It evolved to a different place: one in which women and youth have separate community groups, but men are not involved, where community leaders have emerged, but where community organizing for a children's tuition centre has been stymied by a local industrialist, where physical improvements have been made such as improved drainage, women's bathing rooms, lighting, and solid waste collection but where growth of huts in the slum has worsened crowding. Most importantly, there is the possibility that the slum can continue to evolve. It is no longer stuck in its mal-adaptive trap.

ECOSYSTEM SERVICES AND WELL-BEING BENEFITS IN SOUTHERN ONTARIO

For the final case, I will move from the Indian subcontinent to Canada—the Credit River Watershed to the west of Toronto. This project is ongoing (2013–2018) and is supported by sub-grants from a partnership project funded by the Social Sciences and Humanities Research Council of Canada (SSHRC) called the *Water, Economics, Policy and Governance Network*, the Metcalf Foundation, and by contributions from our partner, the Credit Valley Conservation Authority (CVC).

The Credit River Watershed is located in a highly populated region of Canada with a wide range of landscapes and ecosystems. Most of its ~1 000 000 residents are concentrated in the lower half of the watershed in the Cities of Mississauga and Brampton—part of the Toronto urban agglomeration. The other half of the watershed's approximately 1000 km^2 area is rural agricultural land and protected area (the Niagara Escarpment, the Oak Ridges Moraine, and the Toronto Green Belt). The watershed is under pressure from rapid urbanization and climate change. It is 21% forested, although this is highly fragmented, having only 3% core forest (CVC, 2013).

CVC partners understood that their watershed management and conservation work impacted human health and well-being. They wanted to demonstrate this to watershed residents and to other governance organizations. However, they did not have the in-house capacity, nor the resources, to explain and track human health outcomes. In this sense, they are typical. In a recent survey of five watershed management organizations (including two other southern Ontario Conservation Authorities), we found that while these entities recognized that their work intervened in ecosystem structure and functioning that produced goods and services leading to a wide range of human well-being benefits, they had little capacity to demonstrate these final benefits, and they operated in separate 'silos' with respect to organizations with public health expertise (Morrison *et al*., 2012). This partitioning of attention and jurisdiction is typical of the normal reductionist science and traditional mechanistic management approaches that are deeply embedded in our society and governance structures (Bavington, 2002; Berkes, 2003; Chapman, 2004; Innes and Booher, 2010). To remedy this situation, our collaborative project adopted an ecohealth approach that focused on the coupling on human and natural systems in the Credit River watershed.

In the first phase of the project, the goal was to identify relationships between watershed ecosystems and human health/well-being, and to communicate these with watershed residents, managers, and policy makers. The current phase of the project focuses on scenario planning to inform conservation actions that target both ecosystem health and human well-being outcomes.

Once again, we work with the understanding that ecosystem health and human health are emergent properties of interconnected and

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co-evolving human and natural systems. To provide a conceptual framework for this project, we adopted the Millennium Ecosystem Assessment's characterization of linkages between ecosystem services and domains of health and well-being (see Corvalan *et al*., 2005). Ecosystem services are ‘the benefits people obtain from ecosystems’ (Millennium Ecosystem Assessment, 2005). The relationships among supporting, provisioning, regulating, and cultural ecosystem services and the human well-being dimensions of security, basic materials for a good life, physical health, good social relations, and freedom of choice and action can be more or less direct, intense, and amenable (or vulnerable) to mediation by human action or influence.

In the first phase, the focus of our project was to bring together information about relationships between human well-being and ecosystem health and to create a way for the public, and environmental managers and planners, to learn about and use that information. We hope to build awareness among communities residing and working in the watershed in order to promote watershed health and human well-being. Our approach has been to identify indicators of such relationships that are relevant to the Credit River watershed, and then to develop a web-based geographic information system (web-GIS) to allow stakeholders to explore and understand those relationships.

As part of this work, we also needed to understand the perception of residents in the watershed with respect to the effect of the local environment on their well-being. This was accomplished by administering door-to-door household questionnaires in two urban neighbourhoods in the Credit River watershed. Residents were asked to evaluate their use and understanding of natural and green spaces and the benefits they receive when interacting with different kinds of green space and blue (water) space. This supplemented a larger watershed-scale survey commissioned by the Credit Valley Conservation Authority (Green Analytics, 2011). Results included a stronger understanding of the benefits of natural landscapes to human well-being by older respondents compared to younger generations; and the perception that places associated with water, such as streams and ponds, had a stronger effect on respondents' health compared to other green spaces (Belaskie *et al*., 2016).

We also engaged governance stakeholders at city planning departments, the regional municipality, conservation authorities, health departments, and environmental NGOs to assist us to identify and more fully to develop a short list of environment-health indicators for our project to implement. These were followed by key informant interviews with a larger group of similar stakeholders, whose interviews were recorded, transcribed, and are being subjected to content analysis. Ultimately, all of this information was used to develop an interactive on-line tool (the web-GIS, which can be accessed at http://cvc.juturna.ca).

The core of this tool is a web-distributed geographic information system, developed as free and open source software. The system is intended to connect to biophysical indicators identified through our earlier work, by allowing a user to select a health benefit from a menu. When this is done, information about the indicator and benefit are presented on the left information panel which can then lead the user to more detailed information and scientific studies. Also, data related to that indicator is loaded into the GIS map panel, and the user can explore that data at local, sub-watershed and watershed scales.

In the current phase of this work, such benefits will be tied to potential interventions (conservation actions) such as tree planting, trail building, wetland restoration, and more. To do this, we are developing the capability to undertake scenario planning based on the relationships and indicators we earlier identified. Scenario planning is ‘a systemic method for thinking creatively about possible complex and uncertain futures’ in which structured accounts of possible futures that consider external driving forces (such as urban development and climate change) as well as distinctly different management and policy interventions are explored (Peterson *et al*., 2003). In our application of scenario planning to the Credit River watershed, the web-GIS tool developed in Phase I of the project will serve as

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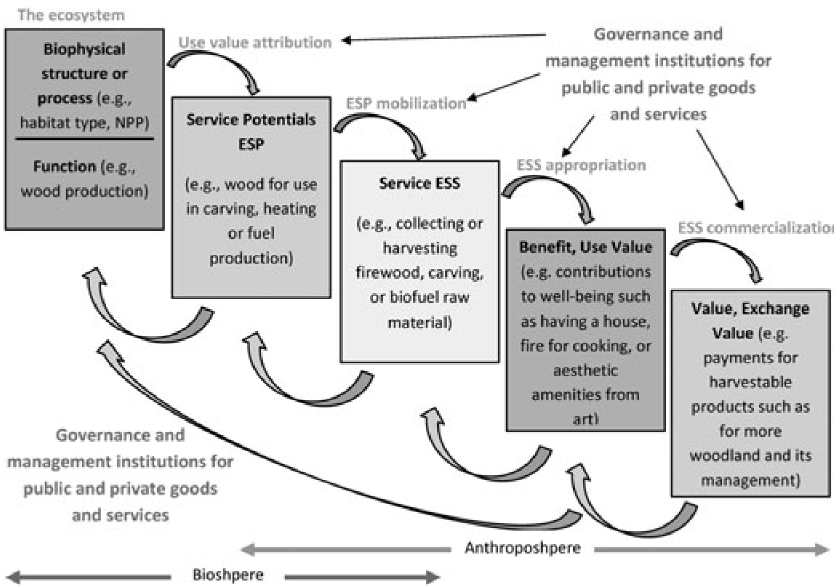

Figure 7 The cascade model of ecosystem services (modified from Verina Ingram et al. (2013) after Haines-Young and Potshin (2010) ©NESH, with permission). (NPP: Net Primary Production | ESP: EcoSystem Potentials | ESS: Eco-System Services)

a visual and analytic canvas in the development of scenario narratives.

Figure 7 is a version of the 'cascade model' of ecosystem services developed by Haines-Young and Potschin (2010) that we use to operationalize the relationships among ecosystems and human well-being for the purposes of developing scenarios. It demonstrates, in general, terms, how ecosystem structure and process contribute to human well-being (benefits derived from active use, passive use, and commercialization). It also nicely illustrates the coupling of human and natural spheres in a social-ecological system, both through this cascade and through feedback (e.g., pressures on the biophysical system and responses to mitigate pressures such as conservation actions). Table 2 demonstrates how this model can be used to map out the expected impacts of a conservation action on human health and well-being.

As a part of the scenario planning approach, we are developing a means to represent the overall contribution of ecosystem services to human well-being of various structural/landscape ecosystem components in different parts of the Credit River watershed. We will then engage watershed stakeholders in an exercise to value ecosystem services with respect to human health and well-being, and use these to develop scenarios representing a variety of conservation actions. Because the relevant services will be associated with quantitative values, the scenarios can then be used in support of decision making. Valuation of ecosystem services is increasingly seen as crucial to robust decision making in conservation planning and management (Atkinson *et al*., 2012). A large and growing literature points a variety of quantitative and qualitative, monetary and non-monetary approaches to valuation, including willingness to pay or willingness to accept (i.e., compensation), recreational demand, property values as proxy measures, and hedonic wage approaches (Freeman *et al*., 2014).

In can be seen how the approach we have taken in the Credit River watershed project maps on to the AEA presented above. The first phase of the project was primarily oriented to the identification of a social–ecological system that is characterized by relationships among a watershed ecosystem and human health/well-being. The current phase is the development of alternative management scenarios. Scenario planning is

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Table 2 A matrix framework to describe the ecosystem services—human well-being cascade for a conservation action (use of permeable pavement, a type of low-impact development). This is based on work by Master in Environmental Studies research assistants Manorika Ranasinghe, Kemal Kepetanovic and Elizabeth Paudel. (R = regulating services; P = provisioning service; C = cultural service; S = supporting service)

Structural and/or landscape change				
Existing	Post intervention	Ecosystem function	Ecosystem service (R, P, C, S)	Final benefit
Use of impermeable surfaces such as asphalt and concrete in public and residential areas (ex: sidewalks, driveways, parking areas)	Increased % of permeable surface	Increased infiltration	R: Water regulation, Water purification Erosion regulation	Protection of people and property from floods and riverbank erosion
	Simulation of natural hydrological cycle	Reduced runoff volume and peak discharge rate		Protection of agricultural soils
		Increased groundwater recharge	R: Water regulation S: Water cycling	Secure resource access (clean water)
		Pollutant removal (large particles, oil, grease, TSS, metals, heavy metals, oil, grease, NOx, P, PO_4^{-3}, Ammonium)	R: Water purification and treatment Disease regulation	Protection of people from waterborne diseases
	Dark colour porous pavement (in PICP)	Reduces storm water temperature and its adverse effects on aquatic life	R: Thermal regulation/ Climate regulation C: Recreation	Recreation (through fishing in healthy waters) Nature appreciation
	Pervious concrete and aggregate bases with lesser SRI (Solar Radiation Index)	Absorbs less heat Reduces Urban Heat Island (UHI) effect	R: Thermal regulation/ Climate regulation	Comfort, lowered temperature Reduced heat stress
	Porosity and rubber/ polymer modifiers in PFC overlays	Absorbs noise Reduces noise pollution	R: Noise regulation	Comfortable noise level

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Table 3 A comparison of three projects based on the context for adopting the ecohealth approach, and the six ecohealth principles

Principles	Kathmandu	Chennai	Credit River Watershed
Context for adopting the ecohealth approach	Traditional epidemiological approach did not lead to change	Community resisted external actors and was not improving in an environment of top-down management	'Siloing' of environment and health hampered understanding and targeting health and well-being outcomes
System thinking	Researchers re-conceived the situation in terms of a social–ecological system	Approach based in understanding of domains of behaviour (attractors) and regime shifts	The project adopted a coupled human-natural systems approach informed by the ecosystem services cascade
Knowledge-to-action	Echinococcus transmission cycle was broken by systemic interventions on the landscape	Multiple interventions targeted and undermined relationships supporting the initial attractor and promoted an alternative desirable regime	Initial web-GIS tool communicated environment-health relationships. Current phase extends this to scenario planning for decision support
Transdisciplinarity	Engaged community stakeholder groups to develop understanding of the social–ecological system	PAR methods mobilized men, women, and children to develop understanding of key relationships	Governance and civil society actors were engaged in workshops to incorporate perspectives and knowledge about environment—health
Participation	18 stakeholder groups were engaged in a participatory approach. These took ownership of interventions in the system	Participatory approach developed capacity in community members to address environment—health relationships	Priorities for communicating environment—health relationships determined by stakeholders. Web-GIS tool designed to facilitate participation by watershed residents
Gender and social equity	Women and marginalized groups such as street sweepers were engaged and empowered as stakeholders	Women's and youth groups formed, empowering their voices, building capacity, and generating community leaders	Explicit juxtaposition of demographic and social data with environmental data is targeted at identifying situations of environmental and social justice in decision making
Sustainability	Environmental interventions on the landscape lead to a sustainable social–ecological system	Community has moved away from the initial mal-adaptive attractor, and is self-organizing around an alternative, more desirable attractor	Scenario planning will support decision-making for co-benefits—improving both ecosystem and human health

intended to support decision-making (the diamond in Figure 2), and the overall process is subsumed in ongoing governance, monitoring, and management processes of the Credit Valley Conservation Authority.

MOVING FORWARD WITH SYSTEMS THINKING AND ECOHEALTH

The projects presented in this paper demonstrate that the Ecosystem Approach to Health (ecohealth) is a systems-based approach to managing coupled human and natural systems to achieve co-benefits—improvements in human health and well-being as well as ecosystem health and environmental sustainability. Table 3 presents a comparison of each of the projects based on the context for adopting the approach, and the six ecohealth principles.

Ecohealth is a young and emerging field. As such, we need to continue to build the field, generate more cases, and fill the toolbox with methods and techniques that have been demonstrated to be useful in different kinds of situations. The projects in Kathmandu, Chennai, and the Credit River watershed are among a growing number of these cases.

We also need to strengthen the ability of ecohealth practitioners to think and act in terms of systems, and to include more people with training and experience in systems thinking on ecohealth project teams. Some practitioners of the ecohealth approach highlight the systems thinking dimensions of our work at venues such as the International Association for Ecology and Health's biannual EcoHealth conference, and organizations such as the Canadian Community of Practice in Ecosystem Approaches to Health incorporate modules on complexity and systems thinking in their training manual and field school. But this is not enough. Stronger ties with communities such as the International Society for the Systems Sciences are a real opportunity for ecohealth. Thus, this paper is intended not only to introduce the Ecosystem Approach to Health to the systems thinking community, but is also an invitation to systems thinkers to assist in the continued development of the approach.

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