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Ecosystem-based translation of health research: expanding frameworks for environmental health

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Increasing concern for the consequences of global ecological change (GEC) has seen sustainable ecological development emerge as a human health priority.[1,2] Policy frameworks are in place to protect the health-nurturing properties of the natural environment and to limit the health harms of development. Landmark events such as the Ottawa Charter (1986), United Nation's (UN) Conference on Environment and Development (1992), the Convention of Biodiversity (1992), UN Framework Convention on Climate Change (1992), the Millennium Development Goals (2000), the Millennium Ecosystem Assessment (2005), and now the UN Sustainable Development Goals (SDG) 2015–2030 have had significant impact on domestic policy, including within Australia. There are concurrent calls for biodiversity conservation to be mainstreamed (e.g. Australia's Biodiversity Conservation Strategy 2010–2030) and for strategic consideration of the World Health Organization's Health in All Policies (2013), in addition to SDG and carbon emission reduction goals that exist and provide frameworks within which such aspirations may be met.

Despite this, policy and translation to limit GEC and associated health risks is variable and translation-ready research is scarce, including in Australia. This is due in part to prevailing political, economic and academic paradigms. However, the health research community can assist to reduce barriers to translation by improving the usability of research within existing frameworks and policies. Health in its broadest sense[3] is not only transdisciplinary but regulated, in Australia, by diverse government departments such as those responsible for environment and energy, planning, agriculture, family and community services, and employment. This list is neither exhaustive nor the same in all states. Coordinated multiagency collaboration is ultimately required to address GEC and achieve SDG and related health goals. Nurturing common language and metrics can assist this process, as can identifying linkages and available tools, as we present here.

For some elements of GEC (e.g. climate change; pollution; stress on finite agricultural land, water and non-renewable resources) some direct health impacts are, or can be, forecast, measured, monitored and potentially regulated. Though these elements present significant challenges, we have been effective in the past in addressing novel threats. Australia's effective reduction of the use of stratospheric ozone-depleting chemicals is a precedent for success in mitigating a direct and urgent health risk, here involving coordinated effort across government and industry.[4] Likewise, Australia has demonstrated global leadership to control tobacco use, with highly successful and creative translation of the science (considered novel 70 years ago) linking smoking to disease.[5] New, insufficiently quantified environmental health risks continuously require attention (coal seam gas extraction bi-products[6] and glyphosate herbicide[7] are current examples). System perspectives that identify relationships between such 'proximal' health risks and those more 'distal', such as eroding ecological (and social) capital are essential if we are to develop primordial preventative strategies (i.e. that inhibit the emergence of risk factors) for broader and long-term health outcomes.

For other elements of GEC – including the most acute component, the escalating global crisis of biodiversity loss – the majority of harmful impacts to human health are indirect. For a health researcher and potentially the translator of such research, the multi-scalar, dynamic and complex nature of biodiversity (the variety of life forms at genetic, species and ecosystem levels) complicates its consideration as a 'variable' determining specific health outcomes. Indeed, this complexity has maintained a heated debate, particularly regarding emerging infectious diseases (EIDs).[8-10] Evidence is also accumulating of adverse human health impacts from biodiversity loss for immunological, nutritional, psychological and developmental function, and other non-communicable diseases in addition to its impact on the health of ecosystems.[11]

Life-supporting consequences of healthy ecosystems, such as clean air, water, soil, disaster risk reduction and climate regulation, are widely acknowledged as ecosystem services, i.e. benefits to humans from ecosystems[12] and are monitored and protected through state Environment Protection Agencies and the Federal Department of Environment and Energy. Parks Victoria has provided international leadership to promote nature-based approaches to reduce non-communicable disease risks and improve psychological and developmental function through the 'Healthy Parks Healthy People' program.[13] Australia has not made similar progress for endemic – predominantly vector-borne and wildlife-hosted – infectious diseases. However, robust research effort continues to elucidate detailed and nuanced ecologies of these diseases. As an example, temporal associations with historic and contemporary periods of rapid native vegetation and land-use change (a key driver of biodiversity loss) can be demonstrated for the emergence of many such diseases in Australia.[14]

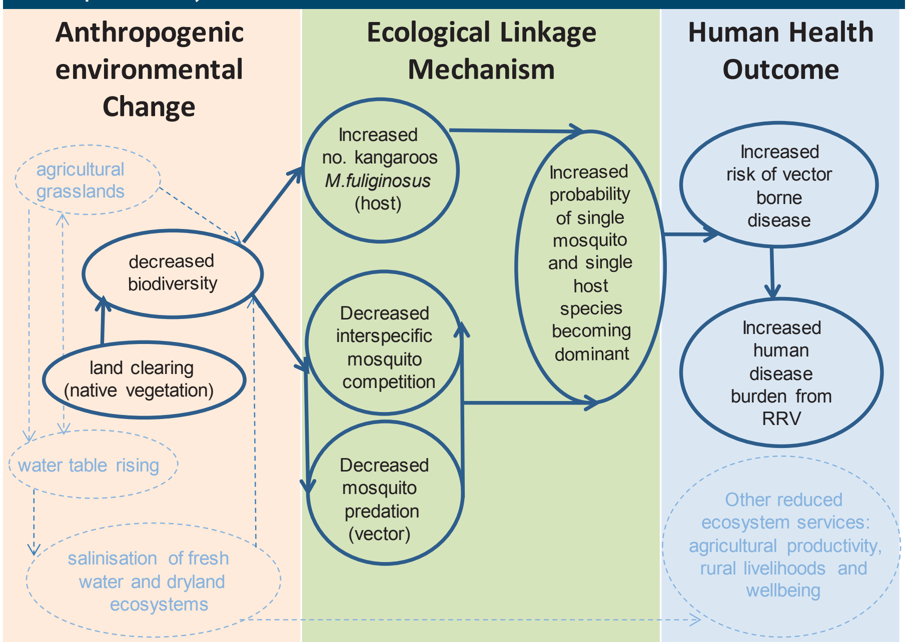
Opportunities to pilot nature-based primordial interventions that synergise with broader ecosystem service protection concerns can be identified for many zoonotic and vector-borne diseases in Australia.

For example, in Western Australia, agriculture-driven deforestation has led to a rise in the water table, resulting in dryland salinity. Mosquito vectors of Ross River Virus (RRV) have increased in abundance in this more saline environment and in response to altered predator and competitor compositions.[15] Kangaroos, important reservoir hosts for RRV, are also attracted to and thrive in these inhabited agro-ecosystems. Improving dryland salinity could potentially not only lower the abundance of vectors for RRV but also generate important soil, catchment and agricultural co-benefits.[16] The key relationships and responsibilities for such an intervention are displayed in Figure 1.

In another example, increased shedding of Hendra virus, a high-fatality disease of horses and humans, transmitted from flying foxes, occurs during winter months in south-eastern Queensland and northern New South Wales, when flying foxes experience nutritional stress.[17] Critical winter feeding resources for flying foxes are not only underrepresented in reserves but are diminishing.[18] Remnant stands of winter-flowering eucalypts could be protected and restored through existing conservation mechanisms, thus potentially reducing Hendra virus transmission.[19] This could provide a starting point for adaptive management and research. Additional benefits to ecological connectivity of this biodiverse but rapidly developing region would also occur.

A significant barrier to many potential ecosystem-based interventions arises from conflict with commercial interests. Costs to health and environment, transferred or 'externalised' by developers to local government and ratepayers, are rarely accounted for in development applications. For example, in 2015, the largest recorded RRV outbreak in 20 years occurred, with 6,121 confirmed cases, centred on coastal South East Queensland.[20] This was driven by seasonal conditions that favoured mosquito reproduction, especially via high tides and rainfall-driven, prolonged flooding of marshland and mangrove forest adjacent to residential areas. Residents of reclaimed coastal wetlands and adjacent areas had to minimise time spent outdoors and conscientiously apply insecticides; many who could not avoid infections suffered fatigue and polyarthritis for six months or more with prolonged absences from workplaces. Some costs can be estimated. Brisbane City Council spends $3.5 million a year on insecticidal spraying of the city's salt marshes to protect a population of 1.2 million[21] and the cost to the health system has been estimated as $1,070 for each case of RRV,[22] beyond the personal and productivity costs described above. Lost or altered ecosystem services of coastal fishery, primary production and coastal protection by mangrove forests and livelihood revenue from tourism are not currently captured. As a consequence, estimates of health costs are incomplete and cannot be assessed against the value of real estate in this area.

Figure 1: Ecological linkages between biodiversity loss, enhanced Ross River Virus (RRV) transmission and human health impacts in salinity-affected Western Australia.



Salinity is high priority issue for Aust. Dept. Environment and Dept. Agriculture, via National Landcare Program

Research is required to establish the attributable risk of salinity driven RRV vector enhancement and to monitor response to landscape restoration.

Ross River Virus (RRV) is a nationally notifiable disease. Vector control is a municipal responsibility

As human populations further disrupt ecosystems, thus escalating the risk of disease incidence, reactive responses will become economically, socially – and even politically – unacceptable. As an example, in the near future, residents and authorities of zoonotic infectious disease 'hot spots' such as rapidly populating South East Queensland may demand alternatives to cumulative primary interventions. Already these include minimising potential contamination of equine feed and water with bat secretions, and the obligatory use of personal protective equipment (PPE) to care for sick horses, even if vaccinated, to limit risk of Hendra virus disease. The use of PPE and/or rabies vaccination is also recommended to those who handle dead and moribund bats potentially infected with Australian Bat Lyssavirus. Bat deaths can occur on an immense scale (hundreds of thousands) following heat waves.[23] Avoiding outside activity in extended areas and seasons of high RRV risk and increased municipal mosquito spraying might also be required.

Such 'primary prevention' strategies as above have the potential to undermine ecosystem health. Spraying with organochlorines, introducing Gambesia spp. to predate larvae and filling in wetlands has had profound and negative impacts on wetland ecologies in the past. Current approaches with mosquito-specific larvicides and physical modifications are less damaging to other aquatic life. However, biodiverse wetlands (e.g. with high diversity of macrophytes, macroinvertebrates, and higher vertebrates), in contrast to polluted, nutrient-rich waterbodies, host abundant predators and competitors of mosquito larvae and have the potential to limit mosquito proliferation and RRV risk.[24] Addressing such ecological imbalances will not eliminate disease risk but illustrates mutual ('co-') benefits to improving human and ecosystem health.

Primordial prevention strategies that address disease risks within the broader management of ecosystem services essential for population health (e.g. clean air, water, etc.) or emerging as protective (e.g. of immunological, mental and cardiovascular health) may also generate co-benefits. Improved respiratory health and improved fitness are well-publicised co-benefits of carbon emission reduction strategies that restrict urban vehicle use.[25] We advocate a similar exploration, and costing, of co-benefits of good environmental management and human health. Trade-offs are inevitable, but an approach that takes account of, and seeks to prevent the consequences of, the currently externalised costs of development to the ecosystem, biodiversity and health, has the potential to identify clusters of solutions and avoid cascades of new problems. Past interventions that controlled rodent- and vector-borne diseases by introducing predatory invasive species, using non-specific pesticides and destroying ecosystems provide valuable warnings of previous simplistic 'primordial' approaches.

More complex approaches require multisector collaboration and environmental planning that recognises the parameters of ecosystem size, distribution, condition, connectivity that influence ecosystem health and ecosystem service benefits. Existing instruments such as the South East Queensland Ecosystem Services framework[26] could be revisited to develop an additional layer of planning with environmental health promotion and disease risk reduction considerations. Through such a process, trade-offs and co-benefits would become apparent and necessitate further examination.

The inherent value of ecosystems has shifted broadly from a narrative of moral responsibility to that of life support.[27] It is common for conservation strategies to promote their significance to health and wellbeing (e.g. Australia's Strategy for Nature [Draft] 2018–2030). This is not based on detailed or systematic appreciation of how integrated ecological function drives specific disease relationships or underpins human health, but it signals a readiness to engage with such research.

To progress, research undertaken to answer these questions must be amenable to translation by existing agencies and through common tools and metrics. For example, Health Impact Assessments, an adjunct to Environmental Impact Assessments, can, in some settings, maximise consideration of integrated human health impacts of policies, programs and developments.[28,29] Assessing or addressing risk comprehensively may be complicated by political and industry interests, but a growing number of international best practice approaches provide guidance.[30] Indeed, integrative approaches to managing human health impacts, sustainable development and competing ecosystem service delivery have also been developed,[31,32] likewise research and translation design that accommodates the complexity and uncertainty in a changing global environment.[31]

In addition to appropriate methodology, engaging and collaborating broadly with stakeholders and agencies is central. Only a minority of natural areas are protected within the Australian National Reserve System, or with legal protection under the *Environment Protection and Biodiversity Conservation Act* (1999) or other relevant state laws. The majority of land lies within private – including Aboriginal and Torres Strait Islander – ownership. Thus, behaviour change through ecological health literacy and cross-cultural learning, as well as zoning and management, represent potential applications of research.

The high capacity of science and health infrastructure in countries such as Australia has contributed to the relatively low public health impact of many environmental health hazards, including our endemic, wildlife-origin zoonotic diseases. However, understanding how these and other health risks may be reduced within an ecosystem service framework will be increasingly valuable as climate change and pressures on natural environments intensify. Benefits could transcend national boundaries, especially if regional epicentres of ecological, political and social disintegration widen, creating milieux for potential pandemics. We are in a gainful position to progress research and translation of research into policy using the frameworks already available in Australia. This will be strengthened by promoting common language and metrics across disciplines and agencies, including costing that includes externalities and co-benefits, and by supporting research into ecological linkage mechanisms and the broader ecosystem service 'settings' of health risks. Existing tools inclusive of stakeholder inputs can address ecosystem service trade-offs. These can be used to identify or trial primordial preventative 'eco-social' strategies. Aggregated, these have the potential to address GEC as health risk. We advocate concerted effort to refine these approaches and to promote a sense of urgency in their implementation.

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