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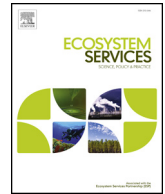
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Ecosystem services for human health in Oceania

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1. Introduction

The state of ecosystems and the health and well-being of people that depend on them are fundamentally linked. However, these links are often obscured – geographically, as globalised trade separates production of goods and ecosystem services from consumers; across time, as physical and mental impacts accumulate across lifespans; and through the complexity of competing socio-economic and cultural influences. Pervasive societal dualisms like nature-culture, and even social-ecological, fragment thinking and decision-making. Definitions differ across sectors. Health encapsulates well-being in the World Health Organization's holistic, landmark 1948 definition of health. A broader, health-inclusive well-being is articulated as the output of the Millennium Ecosystem Assessment (MEA), and its ecosystem service framework (Millennium Ecosystem Assessment, 2005).

There has recently been a renewed awareness within the health metasector of natural systems as health 'settings'. Continued improvement in many global health indicators has occurred alongside substantial detriments to global ecology, but gains in the former are slowing (McMichael and Butler, 2011). Ecological determinants have re-entered the health lexicon (Hancock et al., 2015). This has extended to the earth-system or planetary scale as 'Planetary Health', bringing a professional emphasis to ancestral claims like "to damage the Earth is to damage the self" (Whitmee et al., 2015; Prescott and Logan, 2019). The Sustainable Development Goals (SDGs) represent opportunity to recognise ecosystem-health and wellbeing linkages, but these risk remaining sectoralised (Nilsson et al., 2018). Indeed, 'Health' is identified as a separate SDG (3) even though efforts to 'ensure healthy lives and promote wellbeing for all at all ages' depend on most other SDGs and vice versa (for example, McFarlane et al., in press).

Within the health community, collaborations such as One Health,

EcoHealth, and most recently Planetary Health have championed co-ordination of research and services, traditional knowledge, earth-system science, sustainability and equity, for health of humans, animals and ecosystems. There is increasing convergence of ideas (for further explanation see Buse et al., 2018). However, this has rarely translated into formal assessment of health within ecosystem services management (with exceptions, e.g. Horwitz and Finlayson, 2011; Reis et al., 2015; Chiabai et al., 2018; Jenkins et al., 2018; McFarlane et al., 2018) but all have links with the MEA (Corvalan et al., 2005).

Emerging efforts within the health sector to embrace natural systems as essential health 'settings' (Horwitz and Parkes, 2016) and the aspirations of the SDGs for cross-integration creates incentive to re-frame physical, mental and sociocultural health outcomes, including within ecosystem services frameworks (Wood et al., 2018). Importantly, use of ecosystem service frameworks provides the opportunity to make explicit where trade-offs between SDG 3 (Health) and other SDGs are being made.

This paper revisits ecosystem services–health linkages with specific emphasis on the Oceania region (defined biogeographically, see Maynard et al., in this issue), particularly the small island developing states (SIDS) where health challenges are greatest (World Health Organisation, 2018). In doing so it aims to increase cross-sectoral dialogue and to engage health within ecosystem services frameworks and planning in the region.

2. Ecosystem–health links in Oceania

The health and wellbeing of populations within the culturally and biologically diverse region of Oceania is heterogeneous. Human health in the developed nations of Australia and New Zealand is characterised by high life expectancy (with notable exceptions for Indigenous

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populations) and non-communicable diseases such as cardiovascular disease, cancer and diabetes. Together with mental health problems, these are now dominant causes of morbidity and mortality (Australian Institute of Health and Welfare, 2018; Ministry of Health, 2018). Elsewhere in the region population health is characterised not only by the ‘double burden of disease’ – that is, both traditional scourges of infectious diseases, and what are now the highest rates of non-communicable disease in the world – but increasingly by the ‘triple burden of disease’ (World Health Organisation, 2018). The latter term recognises the exacerbation of infectious and non-communicable diseases by climate change, now experienced in this region.

The Pacific is one of the most natural disaster-prone regions on earth. Between 1976 and 2015, SIDS in the region experienced 191 occurrences of storms, floods and drought (noting this data does not specifically include earthquakes, volcanic eruptions and tsunamis, also experienced) which resulted in 1140 deaths, close to 6.8 million affected persons, and over US\$ 3.4 billion in damages (World Health Organisation, 2018). The disproportionately high vulnerability of SIDS relates not only to event frequency and severity but to their geography, often low elevation, small number of people, limited resources and poor national coping mechanisms (Hanna and McIver, 2014; McIver et al., 2016). Resilience to natural disasters is improved by good response systems (early warning systems) and infrastructure (World Health Organisation, 2018) but also through environmental management. For example, coastal mangrove forests and reefs can buffer the impact of storms and terrestrial vegetation can slow landslides (Jenkins and Jupiter, 2015).

The SIDS are extensively vulnerable to climate change (McMichael et al., 2003; McIver et al., 2016). Direct health impacts include injuries from increased frequency and intensity of extreme weather events including cyclones, heatwaves and droughts. Indirect impacts such as altered distributions of arthropod vectors, intermediate hosts and pathogens, and increased incidence of water- and food-borne diseases and mental health problems are also increasingly recognised (McMichael et al., 2003; World Health Organisation, 2018). For example, potentially fatal Ciguatera poisoning, the result of consuming coral reef fish contaminated by toxins from dinoflagellates and Cyanobacteria, is particularly prevalent in Oceania (Skinner et al., 2011). Elevated sea surface temperatures associated with global warming, and physical damage to reefs are believed to be rapidly shifting its extent and range (Bambrick, 2018).

The importance of biodiversity and contact with natural environments for mental, spiritual, cultural, as well as physical health is now well recognised (Romanelli et al., 2015). Reduction and redistributions of species due to climate change, population and development pressures are likely to drive changes in these dimensions of health, as well as the supply of traditional food and livelihoods (Bell et al., 2013). Action to reduce modifiable stresses on biodiversity, and ecosystem services such as addressing pollution, illegal- and over-harvesting, is already a strategy utilised at local and regional levels (Jupiter et al., 2014). Research and policy to acknowledge specific biodiversity-health relationships in SIDS is required.

One of the most critical short- and long-term threat to the health and wellbeing of Pacific Island people is freshwater quality and quantity, already stressed through population growth, catchment degradation (including land use and soil erosion for surface waters, and contamination of groundwater by agricultural pollutants, heavy metals, microbial pollution) and by salt water intrusion from rising seas levels. Low-lying atolls such as Tokelau, Tuvalu, and Kiribati have among the lowest potential water availability (McIver et al., 2016). Management of ecosystem processes to protect and boost the provision of safe, clean and adequate freshwater within island ecosystems will have many benefits.

Drought and water shortages can lead to increased transmission of pathogens, exacerbated by high temperatures (Singh et al., 2001). Common pathogens that exhibit this relationship include bacteria such

as *Salmonella enterica* subsp. *enterica* (typhoid) and soil transmitted helminths which are widespread in many parts of Oceania. These are best prevented through good hygiene and sanitation. For example, many SIDS have experienced increasing rates of typhoid in the last decade associated with unimproved sanitation facilities with transmission by drinking contaminated surface water and consumption of unwashed produce (Prasad et al., 2018). Better management of environmental conditions in water catchments and improved sanitation could reduce incidence and recurrence of typhoid fever (Jenkins et al., 2016).

Recent reports also confirm the emergence and outbreaks of leptospirosis in the SIDS (Lau et al., 2016). *Leptospira* are excreted in the urine of infected animals (particularly rodents). Disease is associated with poverty, poor living conditions, and flooding as it extends contact with contaminated water and soil (Perez et al., 2011; Lau et al., 2016; Guernier et al., 2018). Management of rodents and catchments, by being attentive to regulatory services (prevention of excess rodent populations, maintenance of hydrological controls and riparian filtration capacities) will therefore be important interventions to reduce prevalence.

Emergence of zoonotic and vector-borne infectious disease associated with intense periods of native vegetation clearing have been described for Australia (McFarlane et al., 2013) but there has been little progress in realising ecosystem-based interventions (McFarlane et al., 2018). Within the SIDS, most zoonotic infectious diseases are transmitted by mosquitoes and have been introduced or moved between islands by travellers (Roth et al., 2014; Weinstein et al., 2018). Rates of infections from vector-borne viruses Zika, Chikungunya and Dengue are on the increase in New Zealand, Australia (Queensland) and the Pacific Islands particularly Fiji, French Polynesia and New Caledonia (Roth et al., 2014). Malaria may soon be eliminated from some SIDS (Wangdi and Clements, 2018).

Mosquito control as an ecosystem service is largely dependent on the ecological niche of the vector. Many are highly adapted to humans and their dwellings (i.e. synanthropic) including important vectors *Aedes aegypti*, *Aedes albopictus* and *Aedes polynesiensis*. The latter is an endemic species also capable of breeding in natural water bodies. For predominantly synanthropic species, removing water holding containers around urban infrastructure is most effective for reducing reproduction. While not in Oceania, recent work (de Jesús Crespo et al., 2018) has shown that dengue occurrence was lower in neighbourhoods with higher wetland cover even after controlling for population density and other socio-economic aspects, suggesting that regulating ecosystem services may be important.

In addition, mosquito transmitted lymphatic filariasis is a leading cause of disability in SIDS. Mass drug administration (MDA) has effectively reduced lymphatic filariasis prevalence, but mosquito vector biology can complicate MDA strategy so combined or multiple approaches to vector control, potentially including ecosystem management, are required (Brelsfoard et al., 2008).

High rates of obesity and associated non-communicable diseases such as diabetes mellitus are major health problems across Oceania. These are complex problems and require integrative and culturally appropriate strategies that address diet and activity (Hardin et al., 2018). The SIDS are currently facing a nutrition transition, from one traditionally dominated by low fat diets, complex carbohydrates, fresh fish and meat and leafy greens, to diets based on refined starch, oils, processed meats and sugar sweetened foods (Farrell et al., 2019). Such modern diets are a major contributor to non-communicable diseases in the region (Charlton et al., 2016). Production of traditional foods, cultural landscapes and the two-way benefits of ‘caring for country’ are accompanied by the co-benefit of physical activity.

Beyond exercise, further physical and psycho-social benefits of nature exposure and connectedness have been dominant recent themes of biodiversity–health research. This includes health impacts of gut and integument microbial diversity, itself continuous with the broader environment (Brito et al., 2016). Nature exposure is of particular

Table 1
Cultural ecosystem services, contributions of biodiversity, and their health outcomes (adapted from Horwitz et al. (40)).

Cultural ES	Summary of the biodiversity contributions to interlinkages	Summary of health outcomes (not always positive outcomes)
<i>Cultural diversity</i>	Reciprocal relationship between cultural diversity and biological diversity in the diversity of life, at whatever levels of richness. Linguistic diversity is related to both; Indigenous languages are intimately related to place.	The recognition of cultural diversity has demonstrable health benefits for cultures (often minorities) that have suffered from domination and oppression, often characterised by the replacement of Indigenous languages with colonial ones. Breaking cultural links with biological diversity might have poorer health outcomes for the same reasons.
<i>Spiritual and religious values</i>	Sacred elements of the biota and living systems; worship of biota; kindness and gratitude toward biota	Contribution to spiritual well-being; sense of wholeness and being 'at one', everywhere and forever (connecting the present with the past and the future).
<i>Knowledge systems (traditional and formal)</i>	Knowledge of pharmaceuticals Knowledge of food products Knowledge contributing to rituals, socialising processes.	When and where to use biological materials for alleviating poor health or disease. When and where to use biological materials for better diet and nutrition
<i>Educational values</i>	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.	Alleviation of psychosocial stress related disorders. Learned capacities to avoid environmental hazards and physical injury or death
<i>Inspiration</i>	Ecosystems in general, and elements of biodiversity in particular, provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising	Contributing to well-being in a myriad of ways; human lives can be made more comfortable and secure, and problems solved practically by mimicking.
<i>Bequest, intrinsic and existence values</i>	The existence of biodiversity itself.	Innate contributions. Bequest giving provides individuals with a sense of personal worth and having 'made a difference' to other life, and to next generations.
<i>Aesthetic values</i>	People find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations	Linked to stress relief, ecotherapy
<i>Social relations</i>	Ecosystems influence the types of social relations that are established in particular cultures.	Sharing ecosystem experiences, like land and water rehabilitation/restoration, and resource sharing networks, are important for maintaining sense of place and providing psychosocial benefits.
<i>Sense of place</i>	Many people value the "sense of place" that is associated with recognized features of their environment, including elements of the biota (rare, common, iconic, endemic) and aspects of the ecosystem.	Psychosocial disorders associated with the loss of, or inability to derive, solace connected to the present state of one's home environment.
<i>Cultural heritage values</i>	Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.	Protection of heritage values will enhance cultural recognition, if done without the continuation of any domination or oppression that might have occurred in the past and promote the continuation of cultural practices where they have health-related outcomes.
<i>Recreation and ecotourism</i>	People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area. Also, recreation relating to animals or plants, caring for pets or gardens or parks and reserves.	Physical exercise, fitness and the myriad contributions this makes to physical and mental health. Alleviation of psychosocial disorders.

relevance to urban populations where exposure to green and blue spaces provide opportunity to redress health impacts of living in a highly modified and biologically simplified environment (Aerts et al., 2018). It has also been of interest to protected area managers such as Parks Victoria's Healthy Parks Healthy People and New Zealand's Department of Conservation (Blaschke, 2013; Townsend et al., 2015). Despite the need for more specific quantification of the biodiversity required, duration of exposure and magnitude and duration of effects on human health and well-being, these relationships are readily incorporated into discussions of health services from ecosystems (Sandifer et al., 2015).

Natural environments also have profound cultural and spiritual importance to Indigenous and traditional landowners and their loss can be highly detrimental physically and mentally. Negative impacts on community stability and well-being can have long reaching effects, as experienced by forcibly displaced Indigenous groups, and may be anticipated as a future consequence of climate change (Bowles et al., 2014).

Health outcomes of cultural ecosystem services are summarised in Table 1. Cultural ecosystems services and their lifestyles and dietary consequences can protect from or result in disease. They also impact environmental management. For example, a festive harvest at a regular fish migration reveals place-based connections between oceans, rivers, land, culture, and economy, with consequences for diet and health and well-being (Jenkins et al., 2018). Similarly, the cultural and spiritual services derived from place by Indigenous Hawaiians, are also valued for their health benefits for people, and for ecosystems (Pascua et al., 2017).

Two examples of where an emergent attentiveness to ecosystem

services enhances ecosystem approaches to health follow.

3. Common platforms

Nations of the Pacific have been at the forefront globally of linking place and health. As early as 1995, the Yanuca Declaration created the notion of Healthy Islands – firmly placing health as an outcome of healthy environments. A 20-year review acknowledged that much needed to be done (see World Health Organization, 2015). Pacific leaders affirmed in the 2018 Pacific Islands Forum Leaders meeting in Nauru the 'Blue Pacific narrative' as a catalyst of collective action in Oceania in recognizing the intertwining of the human, animal and ecology nexus in adequately addressing emerging public health risks in the region. Additionally, other regional fora (principal among them the Oceania Planetary Health Forum in Nadi, Fiji, November 2018) have acknowledged the importance of One Health, Ecohealth and Planetary Health approaches to health security in Pacific Island countries. From them, an urgent need has been recognised for a consolidated platform for action that acknowledges the interdependency of the health of ecosystems, humans and other species. This consolidated platform will respond to the key regional health impacts by uniting and strengthening human, animal and environmental health, environmental management, natural resource management, and indigenous local knowledge. A common platform has the potential to provide capacity to develop policy, investment and action where co-benefits between health and environment are most likely, consistent with the Healthy Islands vision and calls for co-ordinated and integrated approaches to deliver the SDGs. An opportunity exists for the common platform to promote the use of ecosystem services that demonstrate co-benefits as the reportable

and accountability measures including SDG targets.

4. Watershed interventions for systems health (WISHFiji)

The WISHFiji project involves a research consortium between two Australian Universities, a Fijian University, The Fiji Ministry for Health, WHO, UNICEF, the Pacific Community and the Wildlife Conservation Society, established with funding from the Australian Department of Foreign Affairs and Trade and Bloomberg Philanthropies, to address three disease plagues within Fiji – leptospirosis, dengue and typhoid – as well as broader aspects of human well-being. It is a proof-of-concept project, focusing on the watershed, and its ecosystem services, as the functional setting (Jenkins et al., 2016) in which patterns of incidence and prevalence of diseases are identified, interventions planned and implemented, and the health sector organised to monitor, evaluate and respond. The project focuses on integrated “up-stream” solutions to prevent, detect and respond to water-related disease, as well as to mitigate degradation of downstream resources and ecosystems on which people rely for nutrition, livelihoods and cultural services. The health security of SIDS is inextricably linked to water safety and security, which are threatened by rapidly changing socio-ecological conditions. Traditional single-sector approaches are unable to address the challenges linked to water-related disease, which includes enteric and vector-borne diseases and is influenced by hygiene practices, sanitation, land use, ecosystem degradation, climate change, and their interactions. Health systems must evolve new and flexible ways of working with other sectors to improve primary prevention and responsiveness necessary for health security.

5. Conclusion

The challenge of integrating health across sectors to achieve SDGs creates an opportunity to incorporate ecosystems as a fundamental health setting. In countries such as SIDS in Oceania facing a ‘triple burden of disease’ with under-resourced health services there is even greater incentive to nurture ecosystem services and address synergies or trade-offs between narrow and broader health and well-being outcomes. There are many significant health issues in Oceania which may co-benefit or be directly serviced by ecosystems. We particularly note the importance of cultural ecosystem services and community and Indigenous perspectives in realising the contribution of ecosystem services to mental and socio-cultural health. Research such as the WISHFiji project and the development of a consolidated platform to provide exchange and dialogue, and the development of policy, investment and action that recognises ecosystem – health co-benefits, signals emergent support for ecosystem approaches to health. We strongly advocate the consideration of specific health outcomes within further ecosystem services research and planning in Oceania.

Declaration of Competing Interest

The authors declared that they have no conflicts of interest to this work. We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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