Benefits of biodiversity to human health and well-being

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THE NATIONAL PARK SYSTEM hosts some of the most diverse resources found anywhere on the planet. Parks host more variety in plant and animal organisms than almost any other land use (Flynn et al. 2009). Parks also curate our nation's cultural diversity, including landscapes, values, aesthetics, stories and belief systems, science, and knowledge. This variation among plants and animals, including cultural variation in humans, is called biodiversity (WHO 2014). Biodiversity is profoundly important to the health and sustainability of all species, including our own, regardless of where we live, work, or play. Biodiversity gives resilience—from the microbes that contribute to the formation of the human biome to the genes that help us adapt to stress in the environment—supports all forms of livelihoods, may help regulate disease, and is necessary for physical, mental, and spiritual health and social well-being.

Biodiversity can be explored in a number of emerging movements and schools of thought that are changing how we value and care for nature. Edward O. Wilson defined the term "biophilia," in his 1984 book of the same title, as the natural and instinctive bond humans have to other living things. Biophilia means that human affiliations with other life are deeply rooted in our biology and necessary for our well-being. An increasing amount of science supports this theory, and several very successful and prominent science and social movements have developed based on this science. The One Health movement promotes interdisciplinary approaches recognizing the interconnectedness of human, animal, and environmental health, and has been embraced by the veterinary, medical, and scientific communities as a way to promote and protect the health of all species and the environment on which all depend. The Healthy Parks Healthy People movement was initiated by Parks Victoria, Australia, in 2000, and has subsequently been institutionalized by the National Park Service to protect and promote the sum total of cultural and natural resources entrusted to our care (including park environments, park facilities, and programs) collectively, as health resources. In 2012 the U.S. National Park Service sponsored a Healthy Parks Healthy People motion that was adopted by the International Union for Conservation of Nature (IUCN) and its members, including government and nongovernmental organizations and scientists, to "protect the Earth's two most important assets—nature and people" and "to promote the benefits of enhancing healthy ecosystems and human health and well-being synergistically." As stated in the "Revisiting Leopold" report, this interconnectedness between human well-being and nature could have significant management and stewardship implications for parks, and there is need to examine and promote this science as an additional avenue to benefit parks and biodiversity (NPSAB 2012). This report was created following a request from NPS Director Jarvis and is intended to act as a guide for natural resource goals, policy, and action within the National Park Service.

Human dependence on biodiversity extends beyond the food we eat, the air we breathe, and the water we drink (fig. 1). This dependence has been classified into four main services—provisioning, regulating, cultural, and supporting—and each is essential to human health (Millennium Ecosystem Assessment 2005). In this article we examine four ways in which biodiversity benefits human health and include examples of how parks contribute to this emerging science and understanding.

Figure 1 (facing page). Exposure to biodiversity in nature has multiple benefits to both mental and physical health at any age.

Provisioning services

Humans depend upon biodiversity for survival, such as for the foods we eat, medicines we use to stay healthy, and materials we wear or use to build our homes. These services are the tangible products or items that we and other species consume for survival. Although this may be less obvious to the average American who purchases supermarket food from a select few grain and livestock species, a large variety of organisms maintain human consumption needs. Historically, this variety was much greater, but even today, wildlife serves as an important protein and iron source for much of the developing world, and botanical products serve as the base for both modern and traditional medicines. For example, 118 of the 150 most commonly used drugs are based on natural sources (ESA 1997).

Natural resources are not typically harvested from national parks for consumptive purposes aside from selected grazing and hunting provisions; however, park vegetation provides oxygen and removes and stores tremendous amounts of carbon dioxide, and snowmelt from national parks provides a significant source of municipal water to many major cities. The Tuolumne River system in Yosemite National Park provides water to more than 2.5 million people in the San Francisco Bay area.

Regulating services

Our dependence upon biodiversity, however, goes far beyond simple consumption of resources. Biodiversity influences how disease occurs in an individual or population, how the local climate is able to support life, and how resilient an area will be against flooding or a catastrophic storm. Regulating services are the processes that renew resources and ensure

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a functional, habitable environment. These include the well-known ecosystem services of cleaning air and water, as well as the less well-understood services of climate modification, immune and brain function modulation (from symbiotic bacteria, the human "microbiome"), and modulation of infectious disease. Many regulating services are currently being studied for their benefits to human health, and science continues to identify new ways in which humans depend on other organisms to modulate our internal and external environment.

Scientists have learned a great deal about the regulating services of biodiversity by studying the human health impacts of ecosystem alteration and degradation (Myers et al. 2013). Human-made dams and irrigation projects have been linked to increases in vector-borne diseases such as malaria, leishmaniasis, and schistosomiasis (see Myers et al. 2013 for review). Deforestation and human encroachment into wildlife habitat have been associated with the emergence of several zoonotic diseases, including HIV and ebola (Hahn et al. 2000; Ostfeld 2009). Direct correlations between increased incidence of several infectious diseases, including Lyme, Chagas', West Nile virus, and hantavirus, and decreasing mammalian or avian species diversity also demonstrate the protective, regulating service of biodiversity (see Ostfeld and Keesing 2012 for review).

The biodiversity in parks serves many of these regulating services, whether it be flood mitigation from parks with swamps and floodplains, disease-regulating services of predators and other wildlife species that reside in parks, or clean air and water. Park research also is leading the way to learning more about the regulating services of biodiversity: a study from Channel Islands National Park suggests that an increase in species richness, in particular predators, can decrease the prevalence of hantavirus in deer mouse populations and thereby decrease human disease risk (Orrock et al. 2011).

Climate change is expected to increase the importance of regulating ecosystem services (Nelson et al. 2013). Wetlands, marshes, and riparian areas mitigate floods, filter water, and can mitigate damage from natural disasters such as hurricanes, which are predicted to occur with increasing intensity and frequency as global temperature rises. Many vector-borne diseases are already increasing in prevalence and expanding their geographic range because of climate change, and wildfires are becoming more frequent and more severe (Nelson et al. 2013). Regulating ecosystem services are increasingly important means to adapt to and dampen negative effects of climate change.

Cultural services

Our dependence on biodiversity also includes cultural services that promote health for individuals, communities, and society. Cultural services include inspiration, education, recreation, aesthetics, traditional knowledge, and opportunities for scientific discovery and are derived from interaction with or exposure to biodiversity (Millennium Ecosystem Assessment 2005). Cultural services deliver health-promoting benefits of biodiversity and sustain the relationship of people with nature that is necessary to support life (Frumkin 2001; Abraham et al. 2010).

Nature experience has been found to have a positive impact on physiological and psychological health. Research has shown that contact with nature improves cognitive function and relieves stress (Gladwell et al. 2013). Further, nature experience has been associated with higher levels of physical activity, lower levels of mortality and chronic disease, improved self-esteem, and improved immune function (Gladwell et al. 2013; Nieuwenhuijsen et al. 2014; Karjalainen et al. 2010; Maller et al. 2006; Barton and Pretty 2010; Pretty et al. 2005; Thompson Coon et al. 2011). People living in biodiverse natural areas are less prone to allergies and other chronic inflammatory diseases than people living in landscapes of lawns and concrete (Hanski et al. 2012).

The incidence of depression and anxiety, as well as asthma/COPD, diabetes, and coronary heart disease, has been found to be significantly reduced for people living with more green space (10% or more than the average) within a 1 km (0.6 mi) radius (Maas et al. 2009).

Participation in outdoor recreation provides a range of potential benefits. These include health improvement from physical activity, spiritual well-being, an increase in self-esteem, mental restoration, and an appreciation for the natural environment (Buchner and Gobster 2007; Frumkin 2001; Hartig 1993; Hoener et al. 2010; McCurdy et al. 2010; Kaplan and Kaplan 1989; Kaczynski and Henderson 2007; Leahy et al. 2009). There is also evidence indicating that exercise conducted in outdoor settings or green space may be of more value to mental health, physical performance, and motivation to maintain exercise adherence than exercise conducted in other settings (Logan and Selhub 2012).

The emotional and cognitive dimension involved in the experience of nature is another area of scientific investigation that demonstrates the restorative value of nature and its importance to people's well-being. The presence of water, trees, and grass has been found to help people to relax and renew, and to reduce aggression (Kuo and Sullivan 2001). The restorative benefits of urban green spaces and their soundscapes were identified in one study as the top three reasons for visiting an urban park in Amsterdam, Netherlands: "to relax," "to listen and observe nature," and "to escape from the city" (Chiesura 2004). People with a strong sense of connection to nature report more happiness than those who are less connected. A high degree of nature relatedness is also associated with more environmentally protective behavior (Nisbet 2013; Zelenski and Nisbet 2014). The beneficial physiological effects of nature experience are also being discovered. A variety of studies have shown that spending time walking or contemplating in a forest setting is associated with lower cortisol (a stress hormone), lower blood pressure and pulse rate, and increased heart rate variability (Li et al. 2008; Logan and Selhub 2012). Visits to forest settings have been shown to improve immune responses and the production of anti-cancer proteins (Li and Kawada 2011). Individuals exposed to nature experience decreased recovery times post-illness or -operation and a decreased need for analgesia compared with those with no nature exposure (Depledge et al. 2011).

Access to nature is also closely linked to individual and community health. Evidence is mounting that proximity to parks and other green spaces has benefits for health and health-related behavior, especially of urban residents, and aids in reducing health disparities among populations (Richardson and Parker 2011; Wells and Evans 2003). Communities with more green spaces report a higher sense of connectivity, increased cohesion, and lower crime rates (reviewed in Largo-Wight 2011). Conversely, environmental degradation is associated with poor mental health, including depression and a loss of sense of place (Speldewinde et al. 2009). Residents of greener areas experience greater mental health than those who live in or relocate to areas with less green space (Alcock et al. 2014). This effect was reversible if individuals moved again to areas with more green space.

Supporting services

Supporting services are the ways in which biodiversity provides the building blocks for life. Supporting services are necessary for all other ecosystem services to exist. These include primary production (i.e., photosynthesis and chemosynthesis) of new organic matter, cycling of nutrients necessary for life, and pollination. Without this constant creative process, life would quickly grind to a halt. Primary productivity is a key determinant of biodiversity (Rosenzweig 1995), meaning that plants and animals alike are dependent upon this supporting service for survival. Humans may be the best example of this, as humans are estimated to use or co-opt 40% of all net primary productivity (Vitousek et al. 1986).

Conclusions

Biodiversity is important and should be conserved for its values and benefits to human health and well-being. Increased understanding of these health benefits may improve public support for conservation. As land use change and other anthropogenic disturbances to ecosystems impact biodiversity, we continue to learn more about how much humans depend upon the natural world and biodiversity for their well-being. Fortunately, the National Park Service is well positioned to raise understanding and appreciation of the values and benefits of biodiversity to protect and preserve our two most vital resources: nature and people.

Literature cited

Abraham, A., K. Sommerhalder, and T. Abel. 2010. Landscape and well-being: A scoping study on the health-promoting impact of outdoor environments. International Journal of Public Health 55:59–69. doi:10.1007/s00038-009-0069-z.

Alcock, I., M. P. White, B. W. Wheeler, L. E. Fleming, and M. H. Depledge. 2014. Longitudinal effects on mental health of moving to greener and less green urban areas. Environmental Science and Technology. ePub ahead of print, available at http://pubs.acs.org/doi/abs/10.1021/es403688w.

Barton, J., and J. Pretty. 2010. What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. Environmental Science and Technology 44(10):3947–3955. doi:10.1021/es903183r.

Buchner, D. M., and P. H. Gobster. 2007. Promoting active visits to parks: Models and strategies for transdisciplinary collaboration. Journal of Physical Activity and Health 4(Supplement 1):S36–S49.

Chiesura, A. 2004. The role of urban parks for the sustainable city. Landscape and Urban Planning 68:129–138.

Depledge, M. H., R. J. Stone, and W. J. Bird. 2011. Can natural and virtual environments be used to promote improved human health and well-being? Environmental Science and Technology 45(11):4660–4665. doi:10.1021/es103907m.

Ecological Society of America (ESA). 1997. Ecosystem services: Benefits supplied to human societies by natural ecosystems. Issues in Ecology 2:1–17.

Flynn, D. F. B., M. Gogol-Prokurat, T. Nogeire, N. Molinari, B. Trautman Richers, B. B. Lin, N. Simpson, M. M. Mayfield, and F. DeClerck. 2009. Loss of functional diversity under land use intensification across multiple taxa. Ecology Letters 12(1):22–33. doi:10.1111/j.1461-0248.2008.01255.x.

Frumkin, H. 2001. Beyond toxicity: Human health and the natural environment. American Journal of Preventive Medicine 20(3):234–240.

Gladwell, V. F., D. K. Brown, C. Wood, et al. 2013. The great outdoors: How a green exercise environment can benefit all. Extreme Physiology and Medicine 2(3). doi:10.1186/2046-7648-2-3.

Hahn B. H., G. M. Shaw, K. M. De Cock, and P. M. Sharp. 2000. AIDS as a zoonosis: Scientific and public health implications. Science 287(5453):607–614.

Hanski, I., L. von Hertzen, N. Fyhrquist, et al. 2012. Environmental biodiversity, human microbiota, and allergy are interrelated. Proceedings of the National Academy of Sciences. doi:10.1073/pnas.1205624109.

Hartig T. 1993. Nature experience in transactional perspective. Landscape and Urban Planning 25:17–36.

Hoehner, C. M., R. C. Brownson, D. Allen, et al. 2010. Parks promoting physical activity: Synthesis of findings from interventions in seven national parks. Journal of Physical Activity and Health 7(Supplement 1):S67–S81.

Kaczynski, A. T., and K. A. Henderson. 2007. Environmental correlates of physical activity: A review of evidence about parks and recreation. Leisure Sciences 29:315–354. doi:10.1080/01490400701394865.

Kaplan R., and S. Kaplan. 1989. The experience of nature: A psychological perspective. Cambridge University Press, Cambridge, UK.

Karjalainen, E., T. Sarjala, and H. Raitio. 2010. Promoting human health through forests: Overview and major challenges. Environmental Health and Preventive Medicine 15:1–8. doi:10.1007/s12199-008-0069-2.

Kuo, F. E., and W. C. Sullivan. 2001. Aggression and violence in the inner city: Impact of environment via mental fatigue. Environment and Behavior 33(4):543–571.

Largo-Wight, E. 2011. Cultivating healthy places and communities: Evidenced-based nature contact recommendations. International Journal of Environmental Health Research 21(1):41–61.

Leahy, J., M. Shugrue, J. Daigle, and H. Daniel. 2009. Local and visitor physical activity through media messages: A specialized benefits-based management application at Acadia National Park. Journal of Park and Recreation Administration 27(3):59–77.

Li, Q., and T. Kawada. 2011. Effect of forest environments on human natural killer (NK) activity. International Journal of Immunopathology and Pharmacology 24(1)(Supplement 1):39S–44S.

Li, Q., M. Kobayashi, and T. Kawada. 2008. Relationships between percentage of forest coverage and standardized mortality ratios (SMR) of cancers in all prefectures in Japan. The Open Public Health Journal 1:1–7.

Logan, A. C., and E. M. Selhub. 2012. Vis Medicatrix naturae: Does nature "minister to the mind"? BioPsychoSocial Medicine 6:11. doi:10.1186/1751-0759-6-11. Available at http://www.bpsmedicine.com/content/6/1/11.

Maas J., R. A. Verheij, S. de Vries, et al. 2009. Morbidity is related to a green environment. Journal of Epidemiology and Community Health 63:967–973. doi:10.1136/jech.2008.079038.

Maller, C., M. Townsend, A. Pryor, et al. 2006. Healthy nature healthy people: "Contact with nature" as an upstream health promotion intervention for populations. Health Promotion International 21(1):45–54. doi:10.1093/heapro/dai032.

McCurdy, L. E., K. E. Winterbottom, S. S. Mehta, and J. R. Roberts. 2010. Using nature and outdoor activity to improve children's health. Current Problems in Pediatric and Adolescent Health Care 40(5):102–117. doi:10.1016/j.cppeds.2010.02.003.

Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: Biodiversity synthesis. World Resources Institute, Washington, D.C. Accessed 25 April 2014 at http://www.millenniumassessment.org/documents/document.354.aspx.pdf.

Myers, S. S., L. Gaffkin, C. D. Golden, R. S. Ostfeld, K. H. Redford, T. H. Ricketts, W. R. Turner, and S. A. Osofsky. 2013. Human health impacts of ecosystem alteration. Proceedings of the National Academy of Sciences 110(47):18753–18760.

National Park System Advisory Board Science Committee (NPSAB). 2012. Revisiting Leopold: Resource stewardship in the national parks. Accessed 5 May 2014 at http://www.nps.gov/resources/upload/Revisiting-Leopold-Accessible-2-13.pdf.

Nelson, E. J., P. Kareiva, M. Ruckelshaus, et al. 2013. Climate change's impact on key ecosystem services and the human well-being they support in the United States. Frontiers in Ecology and the Environment 11(9):483–493. doi:10.1890/120312.

Nieuwenhuijsen, M. J., K. Hanneke, C. Gidlow, et al. 2014. Positive health effects of the natural outdoor environment in typical

populations in different regions in Europe (PHENOTYPE): A study programme protocol. BMJ Open 4:e004951. doi:10.1136/bmjopen-2014-004951. Accessed 25 April 2014 at http://www.staffs.ac.uk/schools/sciences/geography/links/IESR/themes_bioDiv.shtml.

Nisbet, E. K. 2013. The NR-6: A new brief measure of nature relatedness. Frontiers in Psychology 4:813. doi:10.3389/fpsyg.2013.00813.

Orrock J. L., B. F. Allan, and C. A. Drost. 2011. Biogeographic and ecological regulation of disease: Prevalence of Sin Nombre virus in island mice is related to island area, precipitation, and predator richness. The American Naturalist 177(5):691–697.

Ostfeld, R. S. 2009. Biodiversity loss and the rise of zoonotic pathogens. Clinical Microbiology and Infection 15(1):40–43. doi:10.1111/j.1469-0691.2008.02691.x.

Ostfeld, R. S., and F. Keesing. 2012. Effects of host diversity on infectious disease. Annual Review of Ecology, Evolution, and Systematics 43:157–182. doi:10.1146/annurev-ecolsys-102710-145022.

Pretty J., J. Peacock, M. Sellens, and M. Griffin. 2005. The mental and physical health outcomes of green exercise. International Journal of Environmental Health Research 15(5):319–337. doi:10.1080/09603120500155963.

Richardson, D., and M. Parker. 2011. A rapid review of the evidence base in relation to physical activity and green space and health. Report. HM Partnerships, Liverpool, UK. 28 pp. Available at http://www.hmpartnerships.co.uk/wp-content/uploads/2011/10/Physical-Activity-Green-Space-and-Health-FINAL-DRAFT.pdf.

Rosenzweig, M. L. 1995. Species diversity in space and time. Cambridge University Press, Cambridge, UK.

Speldewinde, P. C., A. Cook, P. Davies, and P. Weinstein. 2009. A relationship between environmental degradation and mental health in rural Western Australia. Health Place 15(3):865–872.

Thompson Coon, J., K. Boddy, K. Stein, R. Whear, J. Barton, and M. H. Depledge. 2011. Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review. Environmental Science and Technology 45(5):1761–1772. doi:10.1021/es102947t.

United Nations Global Compact and the International Union for the Conservation of Nature (IUCN). 2012. A framework for corporate action on biodiversity and ecosystem services. Available at http://www.unglobalcompact.org/docs/issues_doc/Environment/BES_Framework.pdf.

Vitousek, P. M., P. R. Ehrlich, A. H. Ehrlich, and P. A. Matson. 1986. Human appropriation of the products of photosynthesis. Bioscience 36(6):368–373.

Wells, N. M., and G. W. Evans. 2003. Nearby nature: A buffer of life stress among rural children. Environment and Behavior 35(3):311–330. doi:10.1177/0013916503251445.

Wilson, Edward O. 1984. Biophilia. Harvard University Press, Cambridge, Massachusetts, USA.

World Health Organization (WHO). 2014. Biodiversity. Accessed 25 April 2014 at http://www.who.int/globalchange/ecosystems/biodiversity/en/.

Zelenski, J. M., and E. K. Nisbet. 2014. Happiness and feeling connected: The distinct role of nature relatedness. Environment and Behavior 46(1):3–23. doi:10.1177/0013916512451901.

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