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Biological and cultural diversity in the context of botanic garden conservation strategies

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ABSTRACT

Impacts of global climate change, habitat loss, and other environmental changes on the world's biota and peoples continue to increase, especially on islands and in high elevation areas. Just as floristic diversity is affected by environmental change, so too are cultural and linguistic diversity. Of the approximately 7000 extant languages in the world, fully 50% are considered to be at risk of extinction, which is considerably higher than most estimates of extinction risks to plants and animals. To maintain the integrity of plant life, it is not enough for botanic gardens to consider solely the effects of environmental change on plants within the context of major conservation strategies such as the Global Strategy for Plant Conservation and the Convention on Biological Diversity. Rather, botanic gardens should actively engage in understanding and communicating the broader impacts of environmental change to biological and cultural diversity.

1. Introduction

Historically, botanic gardens have focused primarily on attractive displays of horticultural collections, plant exploration and collecting, and plant taxonomy (Crane et al., 2009). The social relevance and appeal of gardens to the public has been largely one of recreation and aesthetics and, until the mid-20th Century, many botanic gardens and arboreta offered little else to public users and visitors.

In response to well documented threats to the world's biological diversity, many botanic gardens now consider conservation as a key element of their programmes and mission, as do most major botanic garden professional associations such as American Public Gardens Association, International Association of Botanic Gardens, not to mention the conservation-focused Botanic Gardens Conservation International. Botanic gardens exert greater social and scientific relevance than ever (Alberch, 1993; Heywood, 2011) by making major contributions to informal science education, plant genetic conservation (Maunder et al., 2001a), and to studies of climate change (Miller-Rushing et al., 2006), invasive plants, and other environmental issues.

These environmental issues are unquestionably affecting ecological systems and threatening the health of plant populations globally. The erosion of biological diversity may well lead to loss of the world's cultural and linguistic diversity (Maffi, 2001; Nabhan et al., 2002; Millennium Ecosystem Assessment, 2005; Moseley, 2010; Loh and Harmon, 2014). Threats to both biological and cultural diversity are linked, and conservation of plants for their own sake (as critical as that is) is not sufficient. Conservation programmes, to be truly effective and meaningful, must also consider the biocultural benefits that can be achieved. Botanic gardens engaged in conservation have a unique and substantial opportunity to include cultural revitalization and awareness as a component of a larger conservation effort and messaging (Dunn, 2008, 2012).

In fact, significant historical environmental changes (including in climate) have resulted in collapse of cultures. One prominent historic example is that of Angkor (Buckley et al., 2010; Day et al., 2012; Lawson and Oak, 2014; Penny, 2014). Based on tree ring analyses, sedimentation types and rates, and other data from the 14th and 15th centuries, it seems clear that decades-long drought, intense monsoons, and other factors resulted in a number of cascading impacts leading to the eventual downfall of the Khmer culture (Buckley et al., 2010). By the end of the 15th century, Angkor had collapsed (Penny, 2014).

In what is now the southwest United States, similar outcomes have been described. Here, the Anasazi suffered at least two

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devastating droughts between the mid-12th and the late 13th centuries, which reduced winter and summer precipitation to such a degree that maize production largely failed (Benson et al., 2007b). By 1300 CE, the Anasazi and Fremont cultures had collapsed and any residual populations either migrated or "withered" (Benson et al., 2007a).

The historical relationships between climate change, environmental change, and social transformation (and eventual loss of cultural and linguistic diversity) are complex, with factors operating on different temporal, spatial, socioeconomic, political, and other scales. This is equally true today, which makes learning from the past in the context of current issues both possible and necessary.

2. Global plant conservation

Public engagement in issues such as plant conservation and biodiversity is an important means for gardens to claim social relevance (Maunder et al., 2001b; BGCI, 2010; Royal Botanic GardensKew, 2016). It is well known that a large proportion of plants (Royal Botanic GardensKew, 2016) and animals are at risk of extinction, with the magnitude of risk varying by region of the world (Myers et al., 2000; Thomas et al., 2004). Thomas et al. (2004), for example, estimate that up to 30% of all species will face serious extinction risks by 2050.

As threats to plants escalate, other organisms within their ecological setting are also of conservation concern. Recognition of the broader threats to entire ecological systems has led to the identification of "biodiversity hotspots" (Myers et al., 2000; Mittermeier et al., 2011); namely, regions of the world that face particularly grave threats to ecosystems and ecosystem integrity. Recognition of such hotspots (many of which occur in the tropics, island systems, and Mediterranean) has been useful in shaping global conservation priorities and strategies.

In the Hawaiian Islands (included in the Polynesia/Micronesia hotspot; Myers et al., 2000), 90% of the ca. 1200 native flowering plant taxa are endemic, with more than 30% listed by the US Fish & Wildlife Service as threatened or endangered. Given continued threats from land use change, urban development, invasive species, climate change, and sea level rise, the threats of extinction are likely to increase. Because of the high extinction risks to plants and the high endemism in these islands, the efforts of many conservation organizations and government programmes are needed to meet the extinction challenge. To avoid redundancy of effort, many organizations focus on some specific aspect of the larger conservation imperative. Lyon Arboretum in Honolulu, Hawai'i, for example, specializes in *ex-situ* conservation using micropropagation, or tissue culture. Of the 400 threatened or endangered Hawaiian plant taxa, more than 200 are now in tissue culture, five of which are extinct in the wild.

Climate change presents additional challenges for the natural world, botanic garden management, and home gardening. Studies at the Royal Botanic Gardens, Kew (UK) and the Arnold Arboretum (Harvard University, USA) clearly demonstrate the changing phenology of plants during the past century. At RBG Kew, for example, many spring flowering plants now bloom 1–3 weeks earlier than 20–30 years ago (Bell, 2007; Royal Botanic GardensKew, 2008). Such phenological data are readily obtained from plant collections and curatorial records at other botanic gardens and herbaria (e.g., Miller-Rushing et al., 2006; Primack and Miller-Rushing, 2009). Thus, the critical importance of botanic garden resources, data, and scientific programmes to better understanding global environmental issues cannot be overstated. Yet, few botanic gardens and botanic gardens associations have developed clear strategies to adapt to climate change. Notable exceptions include Botanic Gardens Conservation International (BGCI, 2010; 2016), Australian botanic gardens (Council of Heads of Australian Botanic Gardens, 2008), and the Royal Horticultural Society (Webster et al., 2017).

3. Loss of cultures and languages

Concerns about the present and future loss of plant species are considerable. By some estimates, the world could be losing 25–50 plant taxa per year, or about 100 times the background rate of one extinction per million species per year (Pimm et al., 2014). Sutherland (2003) documented threats to birds, mammals, and languages using the IUCN-based threat categories of critical, endangered, and vulnerable (IUCN, 2001) and estimated that 12% of birds and 24% of mammals worldwide are at risk.

Largely missing from the discussion is the potential impact of changes in plant diversity, ecosystem integrity, and ecosystem services on human cultural diversity. Human cultures are influenced and shaped by the natural environment (and vice versa); thus, environmental degradation can (to which the historical examples described earlier attest) lead to social disruption and the loss of cultural integrity and identity (Millennium Ecosystem Assessment, 2005).

The impacts of environmental and land use change (e.g., invasive species, over-harvesting of natural resources, agricultural and urban development) on natural systems and biological diversity are well documented, with current and future effects of climate change being potentially among the most severe (Thomas et al., 2004; Pimm et al., 2006; Coreau et al., 2009; Sommer et al., 2010). In the most vulnerable parts of the world (e.g., Pacific Island nations and high elevation areas), impacts of environmental changes such as sea level rise threaten to erode biological diversity and thereby cultural and linguistic diversity as a result, in part, of communities being forced to migrate to new and unfamiliar areas (Shearer, 2011; Dunn, in press). The recognition of linkages among biological, cultural, and linguistic diversity had led to the increasingly broad use of the term "biocultural diversity" and attempts to restore or sustain such links *in situ* as "biocultural conservation" (for more in-depth treatment of these concepts, see Maffi, 2001, 2002; Nabhan et al., 2002; Loh and Harmon, 2005, 2014).

The effects of climate and environmental changes on biological diversity are not linear. In fact, there is generally a "lag" effect (Ray et al., 2016; Watson, 2016) much as there is with the effects of increasing atmospheric CO_2 on temperature. Thus, despite warnings about the role of climate change in species extinctions, it is only recently that a case has been documented; namely, the extinction of the Bramble Cay melomys (*Melomys rubicola*) in Australia (Gynther et al., 2016; Watson, 2016). The ultimate impacts of climate change (manifest via species rarity and extinctions, agricultural failure (REFS), sea level rise and loss of coastline habitat, among others) will undoubtedly lead to reduced cultural and linguistic diversity (Watson, 2000; Crate, 2011; Nakashima et al., 2012; Wang et al., 2014) following some lag effect.

Sutherland (2003) further attempted to fit IUCN criteria to the world's languages and concluded that at least 25% of languages are at risk. Most linguists who document endangered languages put this number considerably higher. The United Nations Educational, Scientific and Cultural Organization (UNESCO) estimates that of the *ca.* 6900 extant languages, 50% are endangered (Moseley, 2010). The definition of "endangered" varies by author, just as it does in the biological realm. For languages, the seminal work of Krauss (1992, 2007) suggests that as many as 95% of the world's languages fall in a broad category of "endangered" along his "safe" to "extinct" continuum (Lee and Van Way, in press). This is a striking number however "endangered" is defined. The Index of Linguistic

Diversity (ILD; Harmon and Loh, 2010) suggests that the world's language diversity declined 20% from 1970 to 2005. Indigenous languages have suffered greatest losses, falling more than 60% in the Americas, 30% in the Pacific, and 20% in Africa (Harmon and Loh, 2010).

Although there is no broadly accepted "background extinction rate" for languages, the current rate of language loss is extreme and has increased significantly in recent times, with nearly two-thirds of all language extinctions occurring in the past 60 years (Campbell and Rehg, in press). This leads to an estimate of one language going extinct approximately every 3 months, or about 4.3 per year (Campbell and Okura, in press). Linguists now identify and map "language extinction hotspots" (e.g., National Geographic Society's Enduring Voices Project: NGS, 2013). Human cultural diversity is at greater risk than biological diversity. Loss of cultures and languages results in lost knowledge of the plant world, uses of plants, and traditional ecological knowledge, not to mention loss of a significant part of our humanity.

Plant and cultural/language diversity are linked in significant ways. For example, many Pacific cultures rely on taro (*Colocasia esculenta* (L.) Schott) for food and for spiritual purposes, with some believing that their ancestry derives directly from taro. Taro is, indeed, at risk from a number of diseases, including taro leaf blight (*Phytophthora colocasiae*) which is common in many parts of the Pacific (Trujillo et al., 2002). More devastating is the Alomae-Bobone virus complex which destroyed nearly 90 percent of the taro crop in the Solomon Islands in the 1990s (Milldrum, 2016).

Of equal, if not greater, concern are the significant and lethal effects of at least two diseases on ʻōhiʻa (*Metrosideros polymorpha*), an important forest tree in the Pacific whose flowers are widely used in making lei. This tree is endemic to Hawaiʻi and comprises about 80% of Hawaiʻi's native forest. Now, stands of *M. polymorpha* in Hawaii are being decimated by myrtle rust (*Puccinia psidii*; syn: *Uredo rangelii*) and more recently by another fungal pest (*Ceratocystis fimbriata*) causing what is known as Rapid ʻŌhiʻa Death (ROD) (Loope, 2016). ROD is spreading throughout the Pacific and, as of September 2016, has destroyed more than 20,000 ha of *M. polymorpha* forest on the Big Island of Hawaiʻi alone (Loope, 2016).

These examples suggest a biological and cultural crisis. If taro, ʻōhiʻa, or any other culturally significant plant becomes locally extinct, so too will elements of that people's cultural integrity and identity. Taro is so central to some cultures that, for instance, the Vanua Lavans (Bank Islands, Vanuatu) state, "we do not grow taro to live, we live to grow taro" (Caillon and Degeorges, 2007). As botanic gardens (and other plant conservation organizations) develop and implement meaningful conservation strategies, they have a unique opportunity to participate in cultural and linguistic conservation.

Risks to culture and language from environmental degradation are not restricted to the Pacific nor to islands (Millennium Ecosystem Assessment, 2005; Romaine and Gorenflo, 2017). However, as anthropogenic factors (climate change, sea level rise, land conversion) strengthen, threats to various "cultural keystone species" (Garibaldi and Turner, 2004) will likely increase.

Because biological diversity and cultural diversity are linked, conservation of "biocultural diversity" (Maffi, 2001, 2005; Loh and Harmon, 2005, 2014) should be a key element of any restoration and recovery strategy (Nabhan et al., 2002; Dunn, 2008). Awareness of this link between erosion of biological and cultural integrity has led to the suggestion of hotspots and indices of biocultural diversity (Loh and Harmon, 2005, 2014). It is not surprising that hotspots of biological and biocultural diversity overlap considerably, and is a useful reminder of the interdependence of natural and human diversity (Hamilton et al., 2017).

4. Botanic gardens and biocultural programming

4.1. The global context

Acknowledging threats to both biological and cultural aspects of the world is explicit in important global strategies. Article 8(j) of the Convention on Biological Diversity (CBD, 1992) encourages all nations to "… respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities … for the conservation and sustainable use of biological diversity." As important a statement as this is, it places primacy on conserving biological heritage, rather than on cultural and human heritage (Dunn, 2008). Nonetheless, it does recognize a link between biological and cultural diversity.

More satisfying is Target 13 of the *Global Strategy for Plant Conservation* (GSPC; CBD, 2012) which states "Indigenous and local knowledge, innovations and practices associated with plant resources, [be] maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care." Here, plant life and cultures are considered equally. Thus, botanic gardens are key to reviving the human connection with the natural world (BGCI, 2010). As early as the 1980s, the French Nobel Laureate in Medicine, Francois Jacob (1982), noted, "in humans, natural diversity is further strengthened by cultural diversity."

A third international strategy (and another programme of the CBD) is the *Strategic Plan for Biodiversity 2011–2020* commonly referred to as the Aichi Targets (CBD, 2011; 2013). Here, three targets (Targets 13, 14, 18) relate directly to the importance of maintaining and safeguarding culturally valuable plants, ecosystem services that are relevant to indigenous and local communities, and traditional knowledge and practices.

Botanic gardens are taking an increasingly prominent role in global plant conservation (Maunder et al., 2001a,b; Miller et al., 2004; Crane et al., 2009; Blackmore et al., 2011; Wyse Jackson and Sharrock, 2011). Given that erosion of biological diversity is likely to lead to some erosion of cultural and linguistic diversity (Maffi, 2005; Lazrus, 2012; Loh and Harmon, 2014; Dunn, in press), botanic gardens with a strong conservation mission have an opportunity to play a critical part in biocultural conservation (Dunn, 2008) and to contribute to the implementation of GSPC and Aichi targets. This can take any number of forms, including (1) learning from indigenous peoples regarding traditional ecological knowledge, (2) learning local languages, (3) training indigenous peoples in conservation methods, (4) collaborating with indigenous and local communities on climate change adaptation strategies, and (5) adding biocultural information to interpretative signs in gardens and to education programmes.

4.2. Examples

Cornell Botanic Gardens (Cornell University, USA) has incorporated the concept of biocultural conservation into its new mission and vision statements and is leading an effort to establish a new Biocultural Gardens Network. This will facilitate bringing together staff, researchers, students, and others concerned about threats to biocultural diversity from the viewpoints of anthropology, ethnobotany, ethnoecology, ethics, law, linguistics, political science, and other disciplines. In addition, the Cornell Botanic Gardens is lending its ecological and horticultural expertise to a multi-disciplinary and multi-national climate change adaptation project with Native American communities in the USA and with indigenous and local communities in the Pamir Mountains of Central Asia (Friedlander, 2016). Furthermore, Cornell Botanic Gardens has recently signed a Memorandum of Agreement (MoA) with BGCI to develop an international training programme at Cornell University to train new and emerging global botanic garden leaders and to encourage greater focus on biocultural issues as they related to botanic garden conservation and education strategies.

The New York Botanical Garden includes explicit reference in its strategic plan to the link between biological and cultural diversity. The work of Dr. Michael Balick in Belize, Micronesia, and Melanesia (e.g., Lee et al., 2001; Balick, 2009) is a superb example for other gardens with strong research programmes to emulate. Similarly, Missouri Botanical Garden is developing new programmes to raise greater understanding of the importance of plants as natural resources and for their many cultural purposes (P. Wyse Jackson, pers. comm.). These initiatives will provide excellent support for achieving Targets 13 and 14 of the GSPC.

The Lyon Arboretum (University of Hawaiʻi) is developing a MoA with other institutions in the Pacific (University of Auckland, University of the South Pacific) and has signed a formal MoA with the Smithsonian Institution (National Museum of Natural History, USA) to facilitate exchange of information, faculty, and students. Such formal partnerships with allied organizations is an excellent way to deploy limited resources and to build meaningful inter-disciplinary, multi-institutional, and international projects and programmes.

Another programme of the Lyon Arboretum is Welina Mānoa (www.welinamanoa.org), a multi-institutional initiative for primary schools emphasizing Hawaiian culture and place-based and environmental education. Each partner (including Lyon, University of Hawaiʻi's School of Hawaiian Knowledge, and the Waikīkī Aquarium) provides a culture-rich series of learning experiences that are grounded in an intersection of Native Hawaiian knowledge and contemporary scientific knowledge of water, land, and ocean resources, as well as management and ecosystem and cultural sustainability.

The University Botanic Garden at Maseno University (Kenya) is actively engaged in collaborative research based on the knowledge of indigenous communities related to food, medical care, and sustainable use of forest products. In addition, the botanic garden works with local communities in environmental protection and biodiversity conservation with one result being greater awareness of biocultural approaches to management (J.C. Onyango, pers. comm.).

For gardens without international programmes, increasing awareness of threats to biocultural diversity can be incorporated readily into on-site educational offerings and special events. Many botanic gardens are located in regions with diverse cultures and ethnicities. The Queens Botanical Garden (New York City, USA), for instance, has a rich tapestry of events that encourage residents to express their cultural heritage within the context of a metropolitan botanic garden.

4.3. Interpreting plants in a biocultural context

It takes relatively little effort to include on interpretive signs reference to the cultural relevance and importance of various plants. Most botanic gardens provide some information on the evolutionary, taxonomic, and economic history of plants; however, the educational value of horticultural and other collections can be greatly enhanced by adding some reference to cultural uses and values.

As one example, the white pine (*Pinus strobus* L.) is an important forest tree in the northeastern United States. Early European settlers to North America in the 17th and 18th Centuries prized this pine for its straight tall trunks, making it widely used for masts of sailing vessels. This and other uses (particularly cabinet making and furniture) significantly reduced white pine numbers throughout its native range. As early as the mid-1920s, it was feared that it would become locally extinct in northern Illinois, USA (Pepoon, 1927). Although recovering in many areas, white pine is now threatened by a number of non-native insect and fungal pests.

What is not sufficiently appreciated is that white pine is of great cultural significance to Native American communities in parts of the eastern United States (Schroeder, 1992). Some refer to it as “the tree of peace” because if a tree were to be toppled (most commonly by high winds), the depression in the soil created by uprooting would be filled with the Native American community's weapons and buried. This cultural practice would anticipate the elimination of violence for the next generation.

The long evolutionary history of white pine, together with its relationship to other pines and its economic importance provides they type of interpretation that botanic gardens regularly employ to engage their visitors and the public. However, it takes very little effort to include, along with these other facts, reference to the biocultural importance of this, and other, plants.

By linking the need for plant conservation to a greater appreciation of cultural values and diversity, botanic gardens can provide more messages of “hope” for a public that is eager to know that conservation activities can be impactful and do relate directly to the broader human experience.

5. New gardens

For new gardens in the process of developing a conservation strategy, incorporating biological and cultural diversity is much simpler than for long-established gardens, and will immediately raise their profile on the global conservation stage. As a new arboretum is being planned for the west coast of South Korea (Dunn, 2012), a great opportunity exists to take a leading role in biocultural conservation and in implementing the resolution (M041) passed at the 2012 IUCN World Conservation Congress in Jeju, which explicitly addresses biological and cultural diversity in Korea and East Asia.

The Royal Botanic Garden of Jordan, which is nearing completion, interprets not only the rich botanical history and diversity of the country, but also its geologic and cultural history. Thus, the interdependence of biological and cultural conservation will be clear and explicit.

Finally, the Ethiopian Biodiversity Institute has been instrumental in establishing botanic gardens throughout the country. Thus far, three gardens are operational, with another seven being planned. A major focus is collaborating with local communities to keep alive the essential connections between indigenous knowledge and peoples (T. Awas, pers. comm.).

With these opportunities for botanic gardens come significant responsibilities. At a minimum, cultural sensitivity and full awareness of, and adherence to, international protocols, related to indigenous property rights (such as CITES, the Convention on International Trade in Endangered Species of Wild Fauna and Flora), respect for indigenous and traditional knowledge, and are paramount. Establishing partnerships with experienced organizations (NGOs, universities, museums, government agencies, professional associations and networks) will greatly enhance the likelihood of making a significant contribution to the long-term maintenance of the word's rich, but imperiled, biological and cultural diversity.

6. Conclusions

As botanic gardens and arboreta position themselves for the future, they should not lose sight of their core mission. As threats to biological diversity intensify globally, threats to cultural diversity also intensify. Thus, botanic gardens are now presented with an excellent opportunity to consider ways in which cultural diversity can be incorporated into their broader conservation programmes and strategies. Establishing partnerships with other organizations is one way for gardens to efficiently and effectively develop strong and meaningful initiatives. There is a dual imperative, biological and cultural, for all gardens engaged in plant conservation to consider innovative ways in which they can enhance and to increase awareness of cultural diversity as part of their conservation mission.

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