Climate change and its consequences for cultural and language endangerment

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1. Introduction

Endangerment is a concern in many disciplines, as it foreshadows loss of biological, cultural, or linguistic diversity. The causes of endangerment are many and, in this age of globalization, it is tempting to ascribe similar forces as playing a role in endangerment (and ultimately extinction) across varied disciplines and areas of human experience.

In ecology, it is generally accepted that major threats to plants, birds, mammals, and other life forms include land use conversion (urbanization, natural resource extraction, agriculture, etc.), invasive species, and climate change. Although some will argue that there are no documented examples of any species going extinct as a direct consequence of any of these forces (but see Watson 2016), it is widely accepted that risk levels today are significantly higher than in past millennia, with current rates of extinction being about 1000 times the estimated long-term background rate (Pimm et al. 2014). This current human-mediated loss of biological diversity is referred to by many as the "sixth mass extinction" (Leakey and Lewin 1995, Barnosky et al. 2011, Kolbert 2014, Ceballos et al. 2015), the other five mass extinctions having occurred over geological time as the result of one natural catastrophe or another.

Human cultures developed in an intimate association with the rich biological diversity of their natural surroundings; some would say "co-evolved" with nature (Harmon 1996). Plants and animals are central to the identity and integrity of most cultures. Taro (*Colocasia esculenta*), for instance, is not only a staple food crop in much of the Pacific, but is central to the creation story in Vanua Lava and in other Pacific cultures (Caillon and Degeorges 2007). So, too, is the white pine tree (*Pinus strobus*) in the northeastern United States, which some Native American nations refer to as the "Tree of Peace" (Schroeder 1992, Lobo et al. 2010). The loss or endangerment of any such cultural keystone species (*sensu* Garibaldi and Turner 2004) would result in the associated peoples forever losing something of their identity, culture, and ultimately language. Thus, as biological diversity is eroded, so too is the rich cultural and linguistic fabric of our species, suggesting a direct correspondence between biological and language endangerment.

However, the processes leading to endangerment in the natural world are not necessarily the proximal ones leading to endangerment of human cultures and languages. One recent and widely cited study suggests that extinction risks for languages exceed those for birds and mammals. Here, Sutherland (2003) used International Union for the Conservation of Nature (IUCN) criteria to determine that approximately 12% of birds, 25% of mammals, and 27% of languages of the world are of conservation concern (namely, the critically endangered, endangered, or vulnerable categories of IUCN); however, other studies (e.g., assessments by UNESCO) estimate an extinction risk for languages as high at 50%. Although similar factors help explain the broad diversity of biodiversity and languages globally (Sutherland 2003), those factors explaining extinction risk for birds and mammals (high altitude, high human densities, and insularity) do not necessarily apply to endangered languages.

Given that climate change can alter the integrity of biological and ecological systems, is it possible that that such an anthropogenic force can also directly or indirectly impact linguistic and cultural diversity? This question has not been explored to any great extent despite the fact that many studies and essays on cultural and linguistic diversity cite climate change as an operative factor. The correlation (though not necessarily causation) between biological and linguistic diversity is supported by the linguistics literature (e.g., Harmon 1996, Nettle and

Romaine 2000) and by more recent ecological studies (e.g., Loh and Harmon 2005, Gorenflo et al. 2012, Amano et al. 2014). Gorenflo et al. (2012), for instance, draw inferences regarding these biological and cultural relationships using mapping and statistical methods and suggest that this concordance is attributable in part to the "ecology" of human societies (including competition, or lack of, for resources), roles of human movements and dispersal in (and to) some areas of the world and not others, and topographic barriers. In an earlier comprehensive and ecologically based review, Harmon (1996) notes that of the 25 countries with the greatest number of endemic vertebrate species, 16 are also among the top 25 in endemic languages. This rate of 64% is true also for plants. Thus, Harmon suggests that there has been some co-evolution of cultural groups with their locally adapted biota. This is a reasonable hypothesis, as communities and peoples through time have differentially used and selected for or against plants and other resources in their habitat.

Amano et al. (2014) go a step further and consider a number of factors such as latitude, altitude, topographic diversity, rainfall, and socioeconomic drivers such as GDP and other markers of globalization, along with "risk components" (adapting those commonly used in ecology) such as geographic range size, speaker population size, and speaker population growth rate (which can be positive or negative). What they find are hotspots of threatened languages in areas marked by high rainfall, high topographic diversity, and rapidly increasing human populations. Such areas, not surprisingly, are concentrated in the tropics, subtropics, Himalayas, northern Australia, eastern Eurasia, northern Russia and Scandinavia, and northwest North America.

In addition, Amano et al. (2014) identify areas that have suffered few documented language extinctions, yet support a disproportionately large number of threatened languages.

Such areas (northwest Australia, New Guinea, desert regions of Africa and the Middle East, Brazil, among others) are thusly considered to be at a high threat level for future language extinctions. What they have in common is being marked by higher economic growth and greater seasonality and therefore would benefit from concerted efforts to mitigate risks and minimize threat levels to both biological and linguistic diversity.

In many areas of the world, languages have already gone extinct and are currently dominated by large-range widely spoken languages. This echoes the situation with biological diversity, where some regions of the world are incredibly diverse and with significant extinction risks (Cape Floristic Region, for example), while others have considerably lower extinction risks (much of western Europe) not because the flora is particularly resilient, but because the ecological systems have been drastically altered and simplified by historic and current human activities (see Thomas et al. 2004).

It is one thing to search for underlying patterns, but another matter entirely to discern similar processes and unifying explanations for concordance in extinctions or extinction risk in ecological vs. language systems. However, it is essential to have an understanding of the dynamic relationship between biological and cultural/linguistic diversity (Gadgil et al. 1993, Pretty et al. 2009) if we are to have some success in mitigating impacts as natural and cultural systems unravel, and as the sixth extinction leads us into what we might call “the seventh extinction,” namely of the world’s languages and cultures.

2. Cultures, Languages, and Environmental Change

There are many reasons why languages, and some more than others, are endangered. Here, the emphasis will be on constructing an ecological paradigm based on environmental changes in the near present, while also drawing on examples from history that might inform us today. Linguistic diversity will be used as a proxy for human cultural diversity. This might not sit well with some, but as Harmon (1996) notes, languages are the building blocks of cultural diversity. To which it might be added, so too are species the building blocks of biological diversity.

For a more complete view of the impacts of environmental (and, principally climatic) change on cultures and languages, it is useful to begin with a historical perspective.

2.1 Climate change in human cultural history

Environments, cultures, and languages change. Historically, cultures around the world have had to cope with, adapt to, or disappear in response to environmental changes (particularly to rapid ones) and natural disasters. The disappearance of a culture is of particular concern, as it signals the rapid extinction of its language and its traditional ecological knowledge (Nabhan et al. 2002, Maffi 2005). More gradual environmental changes can lead people to migrate and assimilate, resulting in a slow motion loss of cultural and language integrity and diversity.

One prominent historic example of the demise of a culture in response to environmental and climatic change 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 forensic 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, including a reduced water supply, a compromised water delivery infrastructure, and reduced agricultural production. Extended severe droughts, interspersed with extreme monsoon rainfalls apparently were too much for Angkor systems and culture to manage (Penny 2014) and contributed to the eventual downfall of the Khmer culture (Buckley et al. 2010). By the end of the 15th century, Angkor had collapsed, with the elite class (and some other privileged individuals) moving to what is current-day Phnom Penh (Penny 2014). What this meant for the Khmer culture, cultural practices, or language is unclear, but it is likely that cultural blending and some erosion of Khmer culture was one outcome.

A broader view shows that water management was key to maintenance of political power in many historic cultures and states and to distribution of settlements across landscapes. Between the 9th and 16th centuries, regions as disparate as mainland Southeast Asia, Sri Lanka, and the Maya lowlands were highly susceptible to extreme variations in weather and to climatic shifts (Lucero et al. 2015). In each culture (centered respectively in Angkor in SE Asia, Anuradhapura in Sri Lanka, and Tikal in the Maya lowlands), water was managed and distributed via intricately linked systems. Water was also considered a component of the "cosmological landscape" central to each culture's origin stories. As environmental conditions changed, owing in part to climatic shifts, infrastructure failed, with cultural integrity eroding as conditions forced migration and assimilation.

In other parts of the world, such as in what is now the southwest United States, similar instances can be described. The Anasazi suffered at least two devastating droughts between the mid-12th century and the late 13th century which reduced winter and summer precipitation to such a degree that maize production largely failed (Benson et al. 2007b). During the first drought, it is hypothesized that most of the great houses in the central San Juan basin were abandoned. During the second, the Four Corners region was vacated. Although Benson et al. (2007b) are of the view that climate change was a primary "push factor" in the reduction and migration of Anasazi populations, they do acknowledge that there is room for discussion on the magnitude of such effects and note that by 1300 CE the Anasazi and Fremont cultures had collapsed, and that residual populations either migrated or "withered" (Benson et al. 2007a).

A similar situation occurred in the Neo-Assyrian Empire during the 9th – 7th centuries BCE. This powerful and dominant culture and state controlled much of the Near East, yet collapsed dramatically in the 7th century BCE. Traditional explanations have invoked military conflicts with Babylonian and Median forces as causing the collapse. However, two other factors cannot be ruled out: a major increase of the Assyrian population that was not sustainable once drought conditions occurred and an episode of severe drought in the Near East during the mid-7th century BCE (Schneider and Adalı 2014). Once again, we see the intersection of demographic, political, and climatic factors.

Lawson and Oak (2014) use modeling and sensitivity analysis to suggest that, more broadly, political instability and cultural demise can result from other forces causing social and political unrest, with climate change often being a proximal, rather than ultimate, cause of collapse. The relationship between climate change and social transformation (and eventual loss of cultural and linguistic diversity) is obviously a complex and multi-dimensional one, 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.

2.2 Climate change and contemporary civil conflict

The effects of climate change on cultural integrity and survival (and thus on cultural memory and language) can lead to civil unrest and political instability. However, considerable controversy has arisen in the literature regarding cause and effect between current civil conflicts and climate change. Much of this debate centers on the work of Hsiang and colleagues (e.g., Hsiang et al. 2011) who postulate that civil conflicts from 1950-2004 are, indeed, linked to climate change, and are twice as likely during El Niño (hotter and drier) than during La Niña (cooler and wetter) years. They attribute ENSO (El Niño/Southern Oscillation) as being a significant factor in 21% of all civil conflicts since 1950. Although the specific mechanisms linking climate (and climate change) to conflict are vague and elusive, ENSO does influence several weather anomalies and climatological factors (temperatures, precipitation, humidity, soil moisture) which, in turn, negatively affect agrarian and non-agrarian livelihoods and economies (Hsiang et al. 2011), cumulatively leading to unrest. Furthermore, ENSO can affect natural disasters (tropical cyclones, for instance) which might have been a factor in some of the historic scenarios.

Hsiang and colleagues take things further when they claim “consistent support” for a causal relationship between climate change and civil conflict. The historical associations described above are based largely on inference and cannot be tested statistically. However, Hsiang and Burke (2014) conducted a meta-analysis of a large body of literature and claim that (1) there is a consistency in the association across spatial scales, (2) the risk of conflict increases with increasing temperature in temperate and warm regions of the world, (3) violent transitions are generally associated with hot and dry periods, and (4) “annual conflict risk” doubles in the tropics when the global climate shifts from a La Niña to an El Niño pattern. Although some of these associations are self-evident, the conclusion that global climate change, not just local changes or variations, has a measurable impact on stability and conflict globally is a bold one.

Because associations and statistical probabilities do not necessarily prove causality, the work of Hsiang and colleagues has received some withering critiques, most notably from Buhaug et al. (2014) who reanalyzed what they believe to be a more appropriate subset of studies in the meta-analysis of Hsiang et al. (2014) and arrive at a more constrained conclusion; namely, that of all the conflict types tested in the models of Hsiang et al. (2014), only conflicts between "organized non-state actors" and "state military forces" should be included in such a meta-analysis. Thus, Buhaug et al. (2014) eliminated all other conflict types (revolts, demonstrations, etc.) from their reanalysis. From this much reduced data set, they conclude that there is no identifiable broad relationship between climate variability and civil conflicts. However, it is worth noting that another study (O'Loughlin et al. 2014) suggests that higher temperatures do, in fact, heighten the level of conflict and that extremely dry and hot conditions elevate the prevalence of rioting and protesting, two of the conflict types discarded by Buhaug et al. (2014) in their critique.

What is not considered in much of this literature is that one kind of conflict can evolve or escalate into another, as is well-known in human history and has been documented in the recent Syrian uprising (de Châtel 2014). Thus, categorizing conflicts simply as one type or another limits our ability to make links between, and responses to, the dynamic phenomena of climate change and civil conflict.

Whether climate change is the ultimate or a proximate factor in some civil uprisings, climate *is* changing and significant impacts to agriculture and agricultural livelihoods are occurring. For instance, in an assessment of crop yields since the 1990s in Europe, Moore and Lobell (2015) show a significant correlation between warming trends during the growing season and reduced continent-wide yields of wheat and barley, with greatest impact being in the Mediterranean region.

Similar results have been observed in other areas of the Middle East, particularly the Fertile Crescent and Syria. Prior to the recent Syrian uprising of 2011, the region had experienced one of the most severe droughts on record (Kelley et al. 2015). The suggestion is that drought, driven by climate change (and likely also by over-grazing; de Châtel 2014), had a catalytic effect that led to political unrest. With nearly 4.5 million people internally displaced and another 1.5 million refugees who left the region entirely (de Châtel 2014, Kelley et al. 2015), it is reasonable to consider the consequences for the integrity and sustainability of cultures (and thus of languages) in the face of such complex and long-term environmental disruption.

3. Climate Change and Contemporary Biocultural Diversity

When considering present-day forces at play in language endangerment, many studies have considered risks from diseases, large-scale deforestation, extraction of natural resources, urbanization, and globalization (e.g., Harmon 1996, Austin and Sallabank 2011, Amano et al. 2014). Some, such as Mufwene (2004), are of the view that too much emphasis has been placed on globalization, arguing that the vitality of some languages (as with biological species) depends on the ecology of their existence and that languages change and evolve. Languages, as Mufwene (2004) notes, have been dying for a long time. The rate today is higher; however, because globalization is complex and does not affect the entire world uniformly, it is difficult to assign particular language losses to a complex phenomenon. Mufwene (2004) does concede that globalization could have some impact at local scales, especially on indigenous languages in former settlement colonies.

It can be argued, however, that one major result of globalization is climate change and that climate change *does* affect the entire world in one way or another. The question is: can we draw a direct link between climate change (a global phenomenon) and language endangerment (often a local or regional one)? In exploring this question further, we would do well to consider the concept of an "ethnosphere" (Davis 2009) which is just as important to the survival of the planet as the biosphere, as it is a biocultural framework for all life on earth. Thus, habitat destruction (as a consequence of climate change or any other process) can result in the erosion of cultural diversity and thereby to language loss. Just as an old-growth forest is a complex, vibrant, rich, diverse system, so too each language can be considered an "old-growth forest of the mind" or a "watershed of thought" (Davis 2009).

The link between biological and cultural diversity has been described adequately and clearly by many authors, as has the necessity to explicitly link biological and cultural concerns in conservation planning and priorities (Davis 2009, Nabhan et al. 2002, Loh and Harmon 2005, Maffi 2005, Gorenflo et al. 2012, Hong 2013). Language stabilization and revitalization efforts require, in part, documenting Davis' (2009) ethnosphere; namely, the lexicon of a culture or community (Native American tribes, in the case of Nabhan et al. 2002, for example), which includes the names of plants, animals, and their habitats, as well as recording ecological information that will be of value in ecological restoration and biocultural conservation.

Climate change brings changes in temperatures, precipitation, disease, and the ability of non-native species to expand their range and to disrupt ecological systems. Thus, any disruption to the biological diversity of an area or region, caused by climate change, has significant implications for the stability of the local indigenous communities and thus for language vitality. Although many studies making this point have been conducted in the tropics and subtropics, this link is equally relevant in the Arctic (Lopez 2001, Kassam 2009, Shearer 2011, Ray et al. 2016) where climate change is not only melting the permafrost landscape, but threatens to melt away cultures, languages, and livelihoods.

Figueroa (2011) and others have observed that contemporary indigenous and local communities are among the first to experience the direct and adverse consequences of climate change, yet they contribute the least to global greenhouse gas emissions. Although some will argue rightly that languages, cultures, and natural systems change over time, it is one thing when cultural and ecological disruption and loss are self-initiated; it is another entirely when they are "other-initiated" (Figueroa 2011). In any case, as Figueroa puts it, "where goes the environment, so goes the culture."

Direct causative links from climate change, to ecological change, and to cultural threats are inferential; however, they are compelling and supported by examples of major disruptions (particularly on island systems and in the tropics) to indigenous livelihoods, tipping the balance between humans and nature (Hong 2013) and, as stated earlier, resulting in civil conflict and unrest, migration, and a new class of displaced persons; namely, climate change refugees (López-Carr and Marter-Kenyon 2015). Unfortunately, the climate-ecology-language links are largely overlooked and deserves considerably more attention (Austin and Sallabank 2011).

3.1 Marking Time and Ecological Calendars

Other impacts on local and indigenous communities are more subtle or less directly observable. For example, indigenous communities across the world use environmental and others cues to determine when and where to plant, harvest, hunt, among other essential activities (Kassam et al. 2011, Singh et al. 2011, Ens et al. 2015). Often, the cue is phenological, such as leaf or flower emergence serving as an indication for timing of a particular activity. One result of climate change is the ever-earlier flowering phenology of many plants. The shadbush (*Amelanchier* spp., also known as serviceberry), for instance, is a small tree of the northern temperate regions of North America and is named such because when it flowers, shad (a fish) are plentiful, as they are spawning in the rivers (Newman 2012). Consequently, earlier flowering of shadbush will no longer be synchronized to the running and spawning of shad and will lose its cultural significance and value.

In a thorough study of a local community in India, Singh et al. (2011) observed the effects of climate change on the biocultural context of the Adi tribal peoples of Arunachal Pradesh in the Himalayas. The rich biocultural knowledge of the Adi was documented via interviews, in-depth observations of biocultural practices, workshops with residents, surveys, and other methodologies. As evidenced by the results obtained, residents are well aware of climate change and its impacts on their traditional lifestyle and resources. Plant diversity has been drastically altered, with many wild plants used for medicines and foods either dwindling markedly or no longer available. One formerly common plant (*Aconitum spicatum*), used as an arrow poison in hunting, is now uncommon. And the microbial diversity also seems to be shifting, as the fermentation of certain beverages important to the Adi culture is increasingly difficult. The Adi also use flowering of bamboo as a bio-meteorological cue to predict drought and to warn of increased populations of rats.

A further example, more directly related to ecological calendars, is the altered flowering phenology of the "dekang" tree (*Gymnocladus burmanicus*) which is significant for two reasons. First, the tree usually produces pods during the Solung festival. Now, the flowering and fruiting are earlier. Second, the production of pods during the Solung festival is an indication that it is time to hunt. As a result, climate change has disrupted the link between a cultural festival and hunting for food.

In Australia, too, ecological calendars (or "indigenous seasonal calendars") are used by indigenous groups (Leonard et al., 2013, Ens et al. 2015). And in Estonia, an ecological calendar based on 52 phenological events has been developed (Ahas et al. 2000). Continued climate change could result in the loss of important cultural traditions and agricultural practices and thus of livelihoods and cultural integrity.

High elevation areas, with their shorter growing season, narrowly available water supplies (from ice and snow packs), and other aspects of the cultural environment make them particularly vulnerable to climate change. In the Pamir Mountains of Afghanistan and Tajikistan, the Pamiri employ a fascinating ecological calendar which uses the human body to mark both time and specific ecological and pastoral and hunting events (Kassam et al. 2011). Unlike the Gregorian calendar, the calendar of the human body is not fixed relative to the solar year. Rather, counting time and events using cues and parts of the human body is initiated based on observations and analyses in each community. Many ecological calendars use phases of the moon, along with other bio-meteorological phenomena, as signals for planting, hunting, harvesting, among other activities. The Pamiri calendar of the body, however, focuses on the sun and is used to mark the timing of agricultural activities and certain parts of the year are counted with reference to human anatomical features.

Although a full explanation of this body calendar is complex, Kassam et al. (2011) provide a very lucid account. In short, most such calendars begin counting the passage of significant events at the sole of the foot, proceeding upward to include the ankle, shin, knee, thigh, and penis before reaching the heart. The heart is associated with the vernal equinox and the Pamiri celebration of a new year. Ultimately, this counting will reach the head. This signals a time of quiescence before the calendar proceeds back down the body to the foot, pausing again at the heart for an autumnal festival. Interestingly, this repetition and reversal suggests a sense of time as an annual oscillation, similar to seasonal bird migrations, renewed activity and then hibernation of animals, key phenological events in plants, and rhythms of the human body itself. With climate change, the various events in the environment lose their synchronicity.

Furthermore, the use of the body calendar has declined over the decades owing to various attempts to integrate the Pamiri into the dominant society. As a result of social and environmental forces, the Pamiri's ability to anticipate the rhythms of the seasons is compromised. Among environmental changes noted by the Pamiri (and which threaten their cultural integrity, livelihood, and pastoral lifestyle) are increased intensity of spring rainfall, poor quality of certain fruits, and reduced quality of fodder. Furthermore, they have observed that sowing and harvesting are each 15-30 days earlier than 10 years prior. Thus, recalibrating the Pamiri calendar of the body (or any other indigenous calendar) is important for developing anticipatory capacity among villagers and reducing the stress associated with climate change (Kassam et al. 2011).

Climate change is having an immediate and measurable impact on the ability of indigenous communities to adapt to climate change and, with the increasing loss of cultural knowledge (such as use of ecological calendars) and pressure to assimilate, the loss of culture, tradition, stories, and language are clearly threatened. Although climate change is threatening to disrupt culturally significant bio-temporal indicators of landscape response, the resurrection and recalibration of ecological calendars is one possible mitigation strategy.

3.2 The Special Case of Island Cultures

It is widely acknowledged that the effects of climate change will impact island populations more than those on other land masses (Austin and Sallabank 2011, Ens et al. 2015, Tershy et al. 2015). With their high proportion of coastal area and with, for the most part, fewer places of higher ground to which to migrate, island communities are particularly vulnerable because climate change will result in warmer air and sea surface temperatures, sea level rise (also a result of ice melt in other parts of the world), altered rainfall patterns and intensity, and more intense storms. In fact, the increased sea surface temperature in the Pacific Ocean currently exceeds the global mean temperature rise (Lazrus 2012). Cumulatively, these changes will affect the sustainability and availability of natural and cultural resources. Marine food sources and habitats (e.g., coral reefs) might be reduced owing to warmer near shore waters.

It is true that cultures are dynamic and that some communities will attempt to adapt (IPCC 2007, Salick and Byg 2007, Salick and Ross 2009, IPCCA 2011). In fact, adaptation is one of the greatest assets and attributes of cultural knowledge and traditional ecological knowledge (TEK) as they provide the necessary cultural memory, based on multiple generations of experience and wisdom, to respond effectively to an array of environmental and social perturbations (McMillen et al. 2014). In the face of climate change, a significant erosion of biocultural diversity (with language being one element) globally is not a foregone conclusion. Yet, such erosion is highly likely and, in places, is already occurring. These risks and realities must be addressed and mitigated. Furthermore, perception of "risk" might itself be a cultural construct to which we need to be sensitive. A number of recent reports provide some valuable guidance and toolkits for climate change adaptation in island and other contexts (IPCC 2007, Salick and Byg 2007, IPCCA 2011).

Addressing the particular concerns of island communities in the full biocultural context is complex and daunting (McMillen et al. 2014). Various entities, from sub-national NGOs, to government entities at all levels, to major international NGOs (e.g., IUCN) are taking this situation seriously. The IUCN, for instance, has multiple research programs and capacity building programs, and policy initiatives focused on island systems. The UN, with its program on Small Island Developing States (SIDS), is also committed to a better understanding of the full impact of climate change on vulnerable island systems and cultures.

4. Migration

In the historical examples cited earlier (Angkor, Anasazi), climate change was a natural phenomenon (climate rebounding following the Little Ice Age), whereas the disruption of many vulnerable cultures today is in response to anthropogenic process not of their own doing. With contemporary climate change, cultures are being disrupted if not outright shattered. This has led to increasing calls for the international community to respond directly and swiftly to migration (Myers 2002) as a matter of environmental justice (Figueroa 2011, Pourhashemi et al. 2012), a topic directly relevant to the stability and survival of cultural diversity.

One possible response by local and indigenous communities (island cultures or other) to the impacts of climate change is migration, either within the country or across borders. With migration comes a host of issues (Lazrus 2012) for which few answers are available. For instance, if residents of Kiribati, Tuvalu, or other island systems are forced (by circumstances beyond their control) to migrate elsewhere, to where will they move? What are the political and economic consequences and who will accept the financial burden? Migration is a major concern (Myers 2002, López-Carr and Marter-Kenyon 2015) with implications for cultural and language integrity.

Individual and community responses to these environmental changes, should they become irreversible and threatening to livelihoods, include migration either within the local region or to completely new areas, the latter being one of the few options for island inhabitants. Locally, the threat to cultural and language integrity is potentially minimal. In the case of long-distance migration to unfamiliar areas, the results could be culturally devastating. At present, many islands and island systems in the Pacific (Republic of Kiribati, Marshall Islands, Tuvalu, among others) are facing imminent threats (López-Carr and Marter-Kenyon 2015). Kiribati is an archipelago of 32 flat coral atolls, none of which is more than 3m above sea level. It is does not take much of a sea level rise, particularly if compounded by strong storms, to cause large areas to be completely and permanently under water. Consequently, Kiribati and other island states are negotiating, with mixed results, with other nations for repatriation. With migration, and likely assimilation, will come loss of TEK, language, and national identity (Lazrus 2012, Tershy et al. 2015).

By 1995, an estimated 25 million people globally were sufficiently affected by climatic and other changes to be considered informally as "environmental refugees" (Myers 2002, Pourhashemi et al. 2012). That number could increase to as many as 250 million by 2050 (Pourhashemi et al. 2012) and not all are island communities. As described earlier, the climate-driven unrest in Syria and elsewhere is also forcing significant human migration.

Formal refugee status is generally applied only to individuals who flee for religious, racial, or political reasons. Current conventions (e.g., the Geneva Refugee Convention of 1951) do not apply to those migrating in response to environmental pressures not of their own making (Myers 2002, Pourhashemi et al. 2012).

Lazrus (2012) has referred to migration as a "failure to adapt." In reality, many of the changes to which local and indigenous communities must adapt are occurring too quickly for adaptation (other than migration and its attendant cultural and language implications) to be realistic. Adaptation is a concept that applies more to evolution and natural selection, typically over long time-scales in response to gradual changes.

5. Natural and "Artificial" Selection

There will be those who suggest that change happens. It happens in nature, in cultures, and with languages. That is undeniable. And they may further say that the changes we are seeing now in the biocultural realm are part of this natural and cultural evolution. However, there are two major distinctions to be made. First, the rate of change in evolution is generally slow, although there is the notion advanced by some evolutionary biologists that long periods of relative stasis, or equilibrium, are punctuated by short rapid bursts of evolutionary change (Gould and Eldredge 1977). A similar hypothesis has been proposed for some language groups (Atkinson et al. 2008). Nonetheless, over the long term, relative gradualism is surely one feature of natural, cultural, and language evolution.

When new, anthropogenic, forces are involved, the rate of change is hastened. However, natural and cultural systems generally cannot adapt readily to rapid changes. This leads to loss of diversity (biological, cultural, linguistic) at an unprecedented rate (see Pimm et al. 2014 for a thorough review of biological extinction rates). In this context, the statement by Lazrus (2012) that migration is a "failure to adapt" is imprecise. It is not possible to adapt.

Second, evolution by natural selection requires some level of genetic diversity on which to operate. If that genetic diversity is diminished owing to anthropogenic or other factors, the possibilities for future change and diversification are reduced. This is not meant to suggest that we artificially prop up diversity of all kinds. But, it does mean that the long-term viability of natural and cultural systems, and their co-evolution, should not be artificially constricted by human activities. Historic (non-anthropogenic) climate changes have been gradual allowing for linguistic diversification (Honkola et al. 2013), whereas current rates of change are so swift that linguistic diversity is being eroded. It is important that as much diversity as possible be maintained today so that future diversity, in whatever direction "evolution" takes us, is assured.

6. Are You Stressed Yet?

Imagine being an individual in a local or indigenous community faced with the consequences of a new climate reality. For most of us in the developed world, there are options aplenty, including outright denial. For the rest of the world, for those cultures whose survival is intimately tied to the landscape (e.g., the Pamiri referenced earlier), changes beyond their control must be immensely stressful. At a molecular level, it has been shown in western developed societies that psychosocial stress leads to chromosomal telomere shortening, which in turn is associated with accelerated human aging.

In an important study, Zahran et al. (2015) demonstrate (apparently for the first time) the relationship between stress and telomere shortening in a poor indigenous population; specifically, the Sahariya in central India. The Sahariya have been living for centuries in their ancestral homes in a central India landscape that was recently set aside as a conservation reserve (Kuno-Palpur Wildlife Sanctuary). It was the idea of the Indian government to reintroduce Asiatic lions to the reserve. Implementation of this plan in the mid-1990s had two immediate and related consequences. First, lions and humans in the same area are not a good result; thus, the villagers had to be moved. Second, it reinforced the largely erroneous notion that restoration and conservation of protected areas and of human-cultural conservation are mutually exclusive.

Between 1998 and 2002, 24 Sahariya villages (about 8000 people total) were relocated to a degraded and deforested area 10km removed from their original and ancestral settlements. Others remained in a buffer zone, but had reduced access to the core of the reserve for natural and cultural resources. Furthermore, both sets of villagers were now some distance from one another and were socially isolated. Zahran et al. (2015) used various stress indicators to determine if individuals in the relocated village were suffering any more or less stress than those who remained in the buffer zone. These indicators included personal statements during interviews, ethnographic observations, physiological indicators (levels of salivary cortisol and α-amylase), and high-resolution measurements of chromosomal telomere length.

Indications, uniformly, were that the relocated villagers were experiencing significantly greater stress than their counterparts in the buffer. Most dramatically, the former had significantly shorter chromosomal telomeres. Because telomere length is tied to accelerated aging (and thus mortality), and mortality being one factor associated with language decline, it is worth further investigating the role of stress, as it relates to exogenous forces such as climate, on indigenous peoples and their cultural and linguistic survival.

7. Mitigation Strategies: Where There's Hope

Threats to indigenous and local communities from climate change seem clear and have the potential to lead to cultural and language extinction. Many organizations and individuals are actively developing strong mitigation strategies (e.g., IPCC 2007, Salick and Byg 2007, IPCCA 2011, Nakashima et al. 2012). The IPCC (2007) provides extensive analyses, along with specific recommended strategies, for various parts of the world, ranging from integration of indigenous knowledge into management plans (see also Vinyeta and Lynn 2013), better water management policies and infrastructure, and improved climate models to better forecast and plan for biological and cultural impacts. These are echoed by Salick and Byg (2007) who also call for more meaningful international climate commitments, further ethnoecological research, and more interdisciplinary efforts. The IPCCA (2011), in its "toolkit," provides a number of detailed case studies and tangible ways by which indigenous communities can be better adapted to deal with and to anticipate the impacts of climate change.

Summarizing all possible mitigation strategies would require a separate volume. Suffice it to say that some key approaches should include (1) land management policies that integrate the local biocultural needs into forest reserves (e.g., "community reserve forests," Singh et al. 2011), (2) integration of TEK and western science into comprehensive land management policies and practices and educational programs (Agrawal 1995, Kimmerer 2002, Alexander et al. 2011, Hill et al. 2012, Ens et al. 2015, Linnell et al. 2015), (3) new binding international conventions that explicitly address the climate change refugee crisis (Myers 2002, Pourhashemi et al. 2012), (4) greater interdisciplinary conservation programs, particularly acknowledging the role of anthropology (Crate 2011), (5) a more active role of botanic gardens (as well as other natural history organizations), taking advantage of their horticultural, botanic, and educational expertise and global reach (Dunn 2008, 2012), and (6) a greater engagement of religious groups and faith communities. With respect to the latter, it is worth noting that both the encyclical issued by Pope Francis 1 (Francis 1 2015) and the Islamic Declaration on Global Climate Change (IFEES Sciences 2015) make direct reference to the link between climate change and erosion of human cultural diversity.

With wider recognition of the links among environment, culture, and language, and an acknowledgement that the fabric of our human cultural diversity is unravelling at a faster rate than global biological diversity (thus the suggestion here of a seventh extinction), the imperative to engage with local and indigenous cultures in mitigating climate change and stemming the erosion of biological and linguistic diversity has never been greater. Our survival depends on it. Our future will thank us for it.

8. References

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Abstract

Climate change is arguably one of the most pressing issues facing humanity. The implications for natural ecological (terrestrial and marine) and agricultural systems are enormous. The diminishment and extinction of native species and increase in number and impact of invasive species are well documented. As natural systems are altered, the local communities and indigenous groups who have co-evolved with, and depend on, native plants and animals are challenged to maintain their integrity and livelihoods. Thus, the erosion of biological diversity can lead directly to the erosion of cultural and, thusly, linguistic diversity. Here the ramifications of climate change with respect to cultural and language endangerment, are examined, with particular emphasis on island systems, ecological calendars, civil conflict, and migration. Strong mitigation and adaptation strategies will be essential for cultural and language survival.

Keywords

biocultural, biodiversity, climate change, indigenous, island cultures, migration