Cultural heritage and climate adaptation. A cultural evolutionary perspective for the Anthropocene

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Abstract *Terms such as resilience, vulnerability and adaptation are heterogeneously defined in the contemporary climate change adaptation literature and, hence, remain difficult to operationalise. In this paper, we offer a cultural evolutionary perspective, where these terms are mapped onto the terminology of triple-inheritance theory, which clarifies how risks arise through the complex interplay of social and ecological feedbacks. Studies of past risk, vulnerability and resilience are often conducted within a historical ecological framework. As both ecological (synchronic) and evolutionary (diachronic) understandings of human culture ultimately derive from the same source of inspiration – Darwinian evolutionary theory – they are, we argue, readily integrated. We take steps towards such an integration, which not only offers a unified theoretical and conceptual framework for studies of past and present vulnerability and resilience, but also provides explicit mechanisms for how issues of future vulnerability and resilience can be approached.*

Keywords historical ecology; adaptation; vulnerability; resilience; niche construction; extended evolutionary synthesis

Introduction

Humanity is now living through a period of rapid and serious global change that is riddled with vulnerabilities and systemic risks, encapsulated by the notion of the Anthropocene (e.g. Bauer and Ellis, 2018, Malhi, 2017, Finney and Edwards, 2016, Braje, 2016, Boggs, 2016). The debate about the reality or otherwise, the precise definition and time of onset of the Anthropocene is intense; we here follow Ruddiman (2018) in using the term as an informal yet evocative and productive heuristic notion that leads our attention to the important relations between humans and the environment. In 1992, a "Warning to Humanity" was issued by 1,700 scientists about the growing intensity of threats our species must face in the coming century due to ecological consequences of our activities on the world stage (https://www.ucsusa.org/about/1992-world-scientists.html#.Wsdcbsi-lMY). In 2017, this was followed by an update signed by more than 16,000 scientists affirming the state of emergency as it continues to intensify twenty-five years later (Ripple et al., 2017). Just as *Homo sapiens* is accumulating an extinction debt in relation to many other species (Kuussaari et al., 2009), we are likely to also accumulate a sustainability debt in relation to ourselves where past decisions weigh in on present and future opportunities for sustainable lives and livelihoods. At the heart of this convergence of crises is a meshwork of feedbacks between human social systems and their numerous relationships with the environments they depend upon.

In this paper, we apply the integrative framework of cultural evolution to conduct a root cause analysis on ecological vulnerability in order to clarify the use of concepts like adaptation and risk assessment in the practical settings of policy implementation and program development. This is done in conjunction with historical developmental insights drawn from the field of archaeology to demonstrate how communities in the past adapted (or failed to adapt) to changing environments in the manner of 'history as quasi-controlled experiments' (Diamond and Robinson, 2010, Nelson et al., 2016). While we are fully cognizant that a great deal of care is needed when attempting to offer *concrete* solutions to the quandaries of the Anthropocene (cf. Lane, 2015) from disciplines such as history and archaeology (Cooper and Sheets, 2012, Guttmann-Bond, 2010), we nonetheless suggest that placing human-environment interactions in historical and specifically in cultural evolutionary perspective offers a great deal of eminently practical insight, which can be translated into policy (cf. Kaufman et al., 2018, Jackson et al., 2018, Adamson et al., 2018, Djindjian, 2011, Rockman, 2012, d'Alpoim Guedes et al., 2016). At the core of our argument are two points: firstly, that evolutionary science offers greater rigour and clarity about the meaning of adaptation than is typically developed in practitioner contexts where policies are cultivated for 'climate adaptation' of cities, nations, regions, and the planet. Secondly, the multiple feedbacks between genetic, cultural and ecological inheritance systems – what is known as triple-inheritance or niche construction theory (Fig. 1; Odling-Smee et al., 2013, Odling-Smee, 2006, Odling-Smee et al., 2003) – are sensitively attuned to the assessments of vulnerability and risk management for dealing with anthropogenic climate change in the coming decades. In connecting the Anthropocene with the niche construction model, our thinking is inspired by and converges with the arguments of Erle Ellis and colleagues (Ellis et al., 2018, Ellis et al., 2016, Ellis, 2015) and dovetails with the discussion of long-term human socio-ecological engineering by Fox et al. (2017). Complementing these papers, we here focus in on cultural evolutionary processes and the terminology used to frame and understand them.

Figure 1. *The niche construction framework that in addition to genetic inheritance mechanisms includes both cultural inheritance – ideas, norms, tools – and ecological inheritance – the built environment as well as long-lasting aspects of the humanly modified environment. All three inheritance domains are linked by complex feedbacks, which can be aligned resulting in adaptive/sustainable dynamics or out of alignment to different degrees resulting in unsustainable disequilibrium or maladaptation dynamics – the sustainability debt accumulated by previous generations but paid in the present. Redrawn from Odling-Smee (2007).*

Central to this argument are the notions of 'adaptation', 'vulnerability' and 'resilience', which are widely used in the contemporary climate change literature, yet notoriously heterogeneous in their meaning (Lorenz, 2013, Hufschmidt, 2011, Vogel et al., 2007, Smit and Wandel, 2006, Adger, 2006). The canonical Intergovernmental Panel on Climate Change (2014: 118) defines adaption as follows:

The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

This perspective foregrounds contemporary conditions and their projections into the future. In evolutionary theory, however, adaptation is defined precisely as the result of a diachronic, historical or evolutionary process that matches a given organism or population to its environment or, occasionally, a process in which organisms modify environments to better suit their selective requirements (Odling-Smee et al., 2003, Lewontin, 1978). Also in terms of material culture, which is the particular focus of an archaeological perspective, the term adaptation should likewise be reserved for changes in a particular trait that demonstrably take place over time and are due to selection (O'Brien and Holland, 1990, O'Brien and Holland, 1992). Not discriminating sharply between resilience and adaptation is analytically problematic, however, as resilience references flexibility, adaptability and future events, whilst adaptation is the end-result of a process and thus references the past. In fact, there are several other distinct classifications for a given feature or behaviour (Laland and Brown, 2002), but all require information about the trait's history. Failure to distinguish between true adaptations and their alternatives prevent, we argue, an understanding of the causes and consequences of any particular socio-ecological, behavioural constellations. Furthermore, the strength of applying a cultural evolutionary framework to understanding climate change adaptation rests in the pressing task of pre-empting future climate changes and their effects. Evolutionary theory offers a coherent framework for not only hindcasting previous cultural evolution, but also for forecasting such trajectories – and so for engineering future resilience in an evidence-based manner (cf. McLaughlin, 2012, Fox et al., 2017).

This essay is an attempt at exploring this analogy in more depth. In addition to providing a unified framework for understanding past and present societal change under environmental pressures, this evolutionary approach also offers insights into how we may be able to shape future resilience. The archaeological record does not offer easy templates for adaptation. Archaeology and, more broadly, all historical disciplines do, however, offer a suite of powerful narratives of past adaptations and their limits. Narratives are already called for in the contemporary climate change adaptation debate (Pancost, 2017, Nielsen, 2013, Carter and van Eck, 2014); the reason why they are such a powerful tool is that humans are evolved to relate to narratives and to extract salient and actionable information from them (e.g. Sugiyama and Sugiyama, 2009).

In summary, what we are proposing here is that a cultural evolutionary framework informed by archaeological approaches can offer the following benefits:

- The perspective functions at a time-scale which is sufficiently long to encompass all of the bio-social mechanisms and feedbacks relevant to understanding human-climate interactions.
- It provides an integrated theoretical perspective capable of conceptualizing the above dynamics, that can be used both to hindcast and forecast cultural-environmental trajectories.
- As will be shown below, it demonstrates how an integrated evolutionary perspective can help clarify terminological confusion in both theoretical and policy arenas—especially in relation to concepts such as adaptive management, vulnerability and resilience.

- All of which suggests that an understanding of cultural heritage, and landscape learning in particular (discussed below and in Rockman, 2009a) can provide a catalogue of past adaptations that might be culturally recycled in the present or future.

A unified framework for cultural evolution including climate change adaptation

The idea that evolutionary theory provides a unified and unifying framework for understanding human behaviour and culture is not new. For instance, Mesoudi et al. (2006) offer a detailed discussion and classification of how various branches of the social and human historical sciences correspond to counterpart disciplines in biology, all which 'only make sense in the light of evolution' (Dobzhansky, 1973: 125; Fig. 2). Mesoudi and O'Brien (2009) further expand on this specifically with regards to archaeology, a discipline that is vital for understanding the pathways taken in the past by different communities and cultures towards sustainable (adaptive) or unsustainable (maladaptive) constellations (Rockman, 2012).

The framework presented by Mesoudi and colleagues is, however, incomplete with regard to more applied aspects of evolutionary studies. The fields of conservation and landscape management are increasingly addressed from an evolutionary point of view, where the robust establishment and understanding of baseline conditions and the trajectories of community composition over time provide vital insights for subsequent interventions (e.g. Svenning et al., 2016). In Figure 2, the right-hand equivalent of conservation biology – or at least some part of it – could be defined as 'applied cultural evolutionary studies' aimed at reducing vulnerability and strengthening resilience through evidence-based and historically informed interventions. In biological conservation studies, the fossil record informs studies of evolutionary history; in cultural evolution, the 'fossil' record of cultural evolution – archaeology – informs understandings of how particular societies have changed under varying social and natural selective pressures.

Figure 2. *Unified framework for cultural evolution that maps the structures of biology to analogues in the social sciences. Just like conservation biology draws on insights from all fields on the left-hand side, applied cultural evolutionary studies draw on insights from all fields on the right-hand side. In this paper, we focus on the contribution of evolutionary archaeology in particular. From Mesoudi et al. (2006).*

The temporally dynamic interaction of individual and collective behaviours with the changing contexts of cultural and natural pressures is critical in this regard. A trait or behaviour that is adaptive one day may not be so the next – and the faster the cultural or bio-physical context changes, the more likely it is that a given trait be in disequilibrium vis-à-vis the (socio-ecological) environment and hence not be adaptive (cf. Table 1). The same holds true of future adaptations to anticipated climate (or other) pressures. Unless these are known with confidence, any behavioural changes can simply not be known to be adaptive.

A concrete example of these bio-social feedbacks is explored in depth in Riede (2017), comparing the path-dependent cultural evolution of Late Pleistocene Final Palaeolithic communities in northern Europe after the eruption of the Laacher See Volcano (Germany) around 13,000 cal BP, compared with the more geographically dispersed Upper Magdalenian culture. The active debate among archaeologists studying material artefacts before and after this geologically-induced disruption has accumulated rich datasets and narrative analyses for the emergence of adaptations between those people who were isolated by the mid-range impacts of the volcano as distinct from those people further south and east who maintained larger trade networks. When viewed through the integrative perspective of cultural evolution, a comparative analysis like this can be catalogued to map the inheritance of social structures, technological capabilities, and other aspects of the cultures involved as a process of selecting adaptations in altered environments (Riede et al., 2017). Other case studies relating to other kinds of climate risks and other societal forms from around the world – Kaufman et al. (2018) and Jackson et al. (2018) provide useful examples – can be used in similar ways. Such a catalogue may then be used for guiding policy discussions in current landscapes where major environmental changes are occurring today.

Conceptual analysis of adaptation, vulnerability, and resilience

We have already alluded to one key difference between the conceptual use of 'adaptation' in climate policy and its precise expression in biology, namely that the former is about anticipating future risks and the latter has to do with prior selective fitness in ancestral environments. The interdisciplinary nature of sustainability challenges requires that conceptual clarity be carefully developed when communicating about ideas that have diverse usage between fields. A further reason to unpack the different ideas involved is that specific advances in the field of cultural evolution research can be brought to bear on the assessments of vulnerability and risk due to socio-ecological change that are distinctive for human communities. There are several concepts related to adaptation in the biological sciences that can be modified and extended to the cultural realm. Of particular importance is the increasing hierarchical complexity of feedback loops that arise when, ecological, genetic and cultural inheritance systems are combined in a unified framework.

We begin with a brief overview of what adaptation is understood to be for biological organisms using a combination of population approaches, optimality modelling, and comparative methods (see also Olson and Arroyos-Santos, 2015 for a more extensive treatment). A biological adaptation can be thought of as the outcome of Darwinian evolution where some change in the environment alters the fitness criteria for reproductive success. Since there is always some amount of variation in physical or behavioural traits for members of a population, this change in fitness criteria increases the prevalence of these traits in future generations. The collection of physical or behavioural traits for an organism that get expressed through the complex interplay of genetic and developmental biology are called phenotype – and it is the phenotype that embodies whatever adaptations might accumulate in the population through time.

Extend this to cultural adaptation, which can be thought of as the equivalent process for social, behavioural, or technological traits for biological species that have cultural capabilities or for ‘replicator’ systems in culture like business models or scripted practices that may also evolve according to Darwinian mechanisms. An example of a ‘replicator’ system is the modular design, transport, and construction of Sears Roebuck houses from their mail-in catalogue that enabled users to reproduce the same cultural artefacts in a programmed manner (Wimsatt and Griesemer, 2007). Here, it is the cultural traits that vary among members of the population and increase or decrease in prevalence in changing environments. The fitness criteria involved in cultural adaptation may (and often do) include biological components but are considered to be cultural because it is the selection of social or material cultural traits like behaviours, practices, beliefs, or tools that are considered in this kind of evolutionary change.

This process of cultural adaptation can be seen in the scenario explored in Waring et al. (2015) for the management of fisheries in Fiji. Their analysis makes use of cultural multi-level selection theory to track adaptations in models of governance, ownership, and harvesting practices during the rise of chiefdoms, in a subsequent period of British colonial rule, and as part of the later transition to globalization across larger trade networks. All three inheritance systems are in play –biological, cultural and socio-ecological – with the selection of cultural traits arising from the existence of prior knowledge during each period of change most strongly expressed in the socio-ecological niches for this timescale. The institutional level of response to policy alterations has bidirectional influence with the structures of both households and cooperative fishing practices that are at scales similar to what can be evaluated in the archaeological record for other island communities from the past.

At the heart of gene-culture coevolution and niche construction is the cultivation of social and ecological niches that alter the selection environment for both biological and cultural adaptations. The spread of biological adaptations conducive to cultural traits (such as those for language and tool use) will increase the fitness for members of the population that are capable of developing them. At the same time, the spread of cultural adaptations will alter the fitness criteria for biological adaptations and alter the evolution of phenotypes for the organisms themselves (Sterelny, 2007, Laland et al., 2001, Laland et al., 2000). Finally, modifications of the physical environment with lasting effects are inherited by subsequent generations, often with positive selective outcomes, but at times also with negative ones – in the form of an accumulated sustainability dept. Examples of this interplay between genetic, cultural and ecological inheritance include lactose tolerance in agricultural systems with animal husbandry, growth of cortical brain volume in social environments that selected for various aspects of language, and reduction in the length of intestines in the digestive system after adoption of cooking practices by early hominids (e.g. O'Brien and Laland, 2012, Laland, 2008, Smith, 2007, Sterelny, 2007, Wrangham and Carmody, 2010). Indeed, much of human behaviour, cultural production and relations to the environments can profitably be understood in a biocultural perspective (see Carroll et al., 2017 for a recent review).

Let us begin to clarify how adaptation can be understood in historical terms to make clear how such a biocultural evolutionary perspective may be important for the management of vulnerability and risk in human communities today. Table 1 captures the main features of distinction for how to think about adaptations in the present and the past. There are two major points to emphasize here. The first is that temporality matters. The functional roles that an adaptation might perform are defined with respect to environmental conditions that may be changing. As the Darwinian selection process takes place, the fitness criteria that lead to advantageous spreading across a population will depend on what is happening in the environment at that time. One outcome of this temporal dimension is that adaptations that performed well in the past may become less beneficial or even detrimental in the future.

Similarly, there may be phenotypic traits that were not selected upon in the past meaning they were not previously an adaptation. Yet due to the complex interplays between various traits it is possible for features that served no functional role to become integrated with other features that arise during the formation of an adaptation. These are called 'spandrels' and they are important for practitioners because care is needed to avoid the problem of misplaced causality where a story is told about prior evolutionary change that is not what actually occurred (Gould and Lewontin, 1979). It is interesting to note in this context, that the original analogy famously used by Gould and Lewontin to illustrate the idea of functionally neutral traits in biology came from the cultural domain. Many features of the built environment or details of social and behavioural norms are probably functionally neutral but often seen as somehow adaptive.

Also, there can be new adaptations that make use of the functionality of past adaptations to create novel abilities—which go by the name of 'exaptations' (Gould and Vrba, 1982). Feathers are now considered to be exaptations because they originally evolved in flightless animals to help with temperature regulation and were later selected for flight abilities in descendent species. Again, exaptations are argued to be at least as common in the cultural as they are in the biological domain (Gould, 1991, Larson et al., 2013).

A classic example of a spandrel is the chin on our faces. There is no historic evidence that chins by themselves served any functional role in the way our bodies worked in the past. But as selection pressures gave rise to adaptations in the jaw, mouth and face, they merely pulled along the areas in between as part of a seamless process of functional integration. The chin was not selected for yet was itself changed as a by-product of developments for other adaptations. By the same token, however, the notion of exaptation is also important in the argument that past behaviours that are not currently seen to hold adaptive value may become relevant under changing circumstances in the future, an argument at the core of historical ecology (Barthel et al., 2013a, Barthel et al., 2013b, Costanza et al., 2007).

Implicitly and with regard to disaster risk reduction, this is also what the foundational American disaster sociologist Gilbert White (1974) argued when he suggested that optimally resilient communities adopt behaviours and disaster responses that have both, in his terms, ‘pre-industrial’ and ‘industrial’ components (Table 2). Framed in our terminology, White argues that we carefully investigate human behaviours past and present for traits that may be exaptive and hence become adaptive under projected future conditions. While humans cannot predict the future (Mesoudi, 2008), sophisticated methods for deriving qualified projections of future physical selective regimes – for instance, of global climate – have been developed. Conversely, however, similarly qualified projections of future social selective regimes remain rare (Oreskes and Conway, 2014).

The second point to emphasize is that hierarchical feedbacks of gene-culture-environment coevolution create very complex developmental processes where increases in cultural fitness may have temporal mismatches with biological fitness, and where ecological inheritance can lead to the accumulation of a considerable sustainability debt across generations. An example from the economics of human societies illustrates this point: consider what it means to create a successful business in a cultural system where money is used that has the features of being debt-based and compound-interest-bearing. In this situation, money is created by issuing loans that must be paid back with additional interest. The interest calculations are based on the current principle amount (initial loan plus total interest accrued), thus making the debt service conform to the mathematical pattern of exponential growth. In a monetary system that behaves this way, the successful business is one whose business model (how money is earned) is able to scale in an exponential manner.

Here, we have a cultural setting where the fitness criteria for success in business requires exponential growth. Yet, any student of biology or physics will promptly note that living systems – including cultural systems (Tainter, 2006) – cannot grow exponentially without eventually levelling off to a fixed maximum size or moving into a stage of overshoot-and-collapse. The process of cultural selection drives the economy to ‘grow exponentially or die' while the biological selection process requires the organism to 'grow to maturity and stabilize.' This creates a mismatch between cultural adaptations in the market system and other aspects of these cultural systems as well as biological adaptations in the organization of human communities at the population level. As long as the cultural system selects for exponential growth, the economy will follow a trajectory toward territorial expansion and eventual overshoot-and-collapse. It is here that the importance of having clarity about the temporal and gene-culture feedback components of adaptations if we are to build up scientifically rigorous measures for vulnerability, resilience and risk in human communities. Evolutionary economics provides novel ways forward here (Waring et al., 2017, see also Kareiva and Fuller, 2016).

Cultural heritage as adaptations for future resilience

In the last section we explored how adaptations in cultural inheritance systems may have temporal mismatch with adaptations in biological and ecological inheritance systems. It was also noted that care must be taken to avoid misattribution of causation with just-so stories about past adaptations that were actually by-products involving different selection mechanisms operating on another adaptation. One framework developed in archaeology that helps clarify this interplay is landscape learning, which explores how human groups gather and share environmental information from the perspective of colonization (Rockman, 2009a).

Landscape learning involves the gathering of environmental knowledge about locational coordinates and physical characteristics of natural resources, limitational cycles and constraints of the local environment and social combination of locational and limitational knowledge that informs ongoing practices communicated among group members. Said another way, it is about how a particular group of people figure out 'how we live here' in a recently colonized landscape. When viewed through an evolutionary lens, this social learning process can be understood as the accumulation of ecological knowledge of and cultural adaptations to the new environment through variation, selection and retention of cultural adaptations. The accumulation of such knowledge and its transformation into sometimes sustainable and sometimes mismatched behaviours can be seen in many examples in the archaeological and historical records (Riede and Pedersen, 2018, Krasinski, 2018, Rockman, 2009b, Rohland, 2017, Nelson et al., 2016).

Colonization processes – in other words, locational changes – are not the only instances in which potential mismatches between individual or community and the environment occur. Climate and environment change also can bring about mismatches in the absence of locational changes (Svenning and Sandel, 2013). So, any situation where either there is migration due to environmental disruption (e.g. climate refugees) or alteration of local environments where people remain in place but the context has fundamentally changed will require some form of adaptation. But in both cases, there is also a likelihood that past adaptations have become mismatches. Climate refugees carry with them cultural adaptations from different landscapes than they move into and indigenous people discover that 'how they live' needs to change as they adapt to new landscape conditions.

A powerful example of this can be found in the forced migration to village life for the people of Ethiopia (Scott, 1999) where local knowledge among farmers about several crop varieties that were successful in one location did not easily transfer during relocation: when to plant, how deeply to sow, how to prepare the soil and how to tend and harvest are peculiar to each plot of land. This knowledge is stored collectively in the oral archive of techniques, seed varieties and ecological information that no longer applies as the farmer is moved to vastly different settings.

The growing body of research on cultural heritage offers a way to catalogue, analyse and translate those cultural adaptations which have been well-suited to each kind of landscape in the past so that they might be applied as evidence-based adaptations for increased resilience (or reduced vulnerability) in their altered landscapes of the present or emerging future. It is in this way that cultural evolution generates insights about what is and is not adaptive; and such insights are directly applicable to issues of climate change adaptation in the world today.

Conclusion: a manifesto for a cultural evolutionary approach to risk, resilience and vulnerability

Research in historical ecology has long pointed towards the past as a key to fully understanding our current climatic and environmental predicaments (Armstrong et al., 2017, Crumley et al., 2015, Barthel et al., 2013a, Barthel et al., 2013b, Szabó, 2010, Balée, 1998, Whitehead, 1998, Crumley, 1993, Swetnam et al., 1999, Foster et al., 2016).

However, as recently pointed out by Fitzhugh et al. (2018) and as argued in this paper, this focus on ecology – the synchronic – must be supplemented by a robust understanding of biocultural evolution – the diachronic. Along with Fitzhugh et al. (2018), we argue that a cultural evolutionary approach is ideally suited for clarifying the terminological confusion surrounding terms such as resilience and vulnerability and for integrating synchronic and diachronic perspectives. This resonates with likeminded arguments from conservation biology (Laland and Boogert, 2010, Boogert et al., 2006) and from sociology (McLaughlin, 2012) that similarly point towards the need to evaluate adaptions in light of their selective histories, but also point towards our ability to, in principle, construct our own niches (Odling-Smee et al., 2003) and hence to engineer the adaptive *cultural* landscapes that to a large extent determine the costs and benefits of our actions. In this way, we may mitigate or alleviate any sustainability debts. Evolutionary approaches have much to offer to our understanding of sustainability (Brooks et al., 2018).

Placing humans and human culture within a co-evolutionary framework has become known as the extended evolutionary synthesis (EES; see http://extendedevolutionarysynthesis.com/ and Laland et al., 2015, Fuentes, 2016). This framework extends Darwinian evolutionary theory by accepting that a range of non-genetic inheritance mechanisms are at work in the world, some of which are cultural and ecological. History is critically important in understanding the trajectory and adaptive status of a given trait. At the same time the EES approach also opens up for modifying selective conditions. Niche construction theory is predicated on the insight that individuals can modify their own selective environments and hence provides a rationale for also acting on issues such as climate change and environmental degradation. And with selection also acting on multiple levels above the individual, this framework can be up-scaled to, for instance, households or communities (Wilson et al., 2014).

This should not, however, be understood as a call for large-scale environmental or social engineering. Instead, this stance suggests that even small actions at precisely the level of the individual, the household or the community can contribute significantly to future trajectories. Archaeology can here contribute not only by illuminating the evolutionary histories of particular traits, but also by producing evidence-based narratives of these trajectories at multiple spatial and temporal scales. Human are evolved to be attuned to narrative information (Sugiyama, 2008, Boyd, 2009, Carroll, 2017). This has been explored mostly in relation to fictional narratives, but non-fictional narratives about specifically climate change impacts can also be understood in this fashion (Helsing, 2018). In contrast to fictional or non-fictional narratives about *future* adaptations, archaeology offers evidence-based narratives of *past* adaptations. Whether through writing or through presenting these on site or in museums – all potential loci of future adaptations (Rees, 2017, Jackson et al., 2017, Hambrecht and Rockman, 2017) – the impact that such archaeological 'stories' of past adaptations and maladaptations can have in the present should not be underestimated.

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Table 1. *Mapping cultural evolutionary terms onto the terminology of disaster risk reduction (DRR) and climate change adaptation (CCA).*

Evolutionary classifications of traits/behaviours	**Description**	**Related DRR/CCA terms**
Adaptive behaviour/ adaptability	Adaptive behaviour is functional behaviour that increases reproductive fitness	Adaptive capacity
Adaptation	An adaptation is a character or trait favoured by natural selection for its effectiveness in a particular functional role	Pre-industrial coping mechanisms/traditional ecological knowledge; evolved resilience
Current adaptation	A current adaptation is an adaptation that has remained adaptive because of continuity in the selective environment	Evolved resilience
Past adaptation	A past adaptation is an adaptation that is no longer adaptive because of a change in the selective environment	Pre-industrial coping mechanisms/traditional ecological knowledge
Exaptation	An exaptation is a character that now enhances fitness but was not built by natural selection for its current role	Designed resilience
Dysfunctional by-product	A dysfunctional by-product is a character that neither enhances fitness nor was built by natural selection	Some spurious pre-industrial coping mechanisms
Evolutionary mismatch	A past adaptation that reduces fitness in the current selective environment due to changes in expression of functions from past adaptation	

Gene-culture mismatch	A cultural adaptation that involves trade off in fitness with respect to social and ecological factors.

Table 2. *Pre-industrial and industrial responses to natural hazards, following White (1974).*

Response types and characteristics		
	Pre-industrial	*Industrial*
Adjustment range	Wide	Restricted
Actors	Individuals, households, small groups	Authorities, authority-coordinated groups
Relation to nature	Harmonisation with	Technological control over
Capital investment	Low	High
Spatial variability in responses	High	Low
Response flexibility	High	Low
Loss perception	Perceived as inevitable	Losses may/should be reduced by government action, technology, science & development
Time-depth	Deep, where there is previous hazard knowledge, traditional responses are evolved	Shallow, industrial responses first emerge from mid-19th century onwards and often suppress or replace (especially in marginal and colonised areas) traditional responses

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