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# Three galleries of the Anthropocene

**Libby Robin,[1] Dag Avango,[2] Luke Keogh,[3] Nina Möllers,[3] Bernd Scherer[4] and Helmuth Trischler[3]**

**Abstract**

This paper considers three 'galleries' that explore the Anthropocene in cultural ways, and the implications of the Anthropocene idea for cultural institutions and heritage. The first gallery is the 2014–2016 exhibition *Welcome to the Anthropocene: The Earth in Our Hands*, [*Willkommen im Anthropozän: Unsere Verantwortung für die Zukunft der Erde*] at the Deutsches Museum in Munich. The second 'gallery' of Anthropocene Posters sponsored by the Art Museum, Haus der Kulturen der Welt (HKW), placed the Anthropocene in a 'museum without walls' in the streets of Berlin in 2013. The third 'gallery of the Anthropocene', was not a museum, but rather a landscape gallery (or 'spectacle') of in situ industrial heritage in Svalbard. Pyramiden, a town established to mine coal well north of the Arctic Circle in the early 20th century, has been recently transformed as an attraction for climate change science and heritage tourism. Here the hybridized local landscape creates a snapshot of the Anthropocene, bringing together industrial coal-mining heritage buildings, polar tourism and science forged in the geopolitics of the changing Arctic environment.

**Keywords**

Anthropocene, community participation, Deutsches Museum, environmental crisis, environmental humanities, global change science, Haus der Kulturen der Welt, museum exhibitions, Pyramiden, Rachel Carson Center

As global warming and climate change begin to affect different local communities in very different ways, museums become places for personal reflection on the future of the planet. The public is thirsty for clear information and nuanced discussions on environmental change at both local and global scales, but there are few opportunities for serious conversations about these issues that are inclusive of diverse audiences, and people of all ages. Museums focus on the material world: objects, artworks and historical collections. Such materiality can be helpful in environmental

[1]National Museum of Australia, Australia
[2]Royal Institute of Technology, Sweden
[3]Deutsches Museum, Germany
[4]Haus der Kulturen der Welt, Germany

**Corresponding author:**
Libby Robin, National Museum of Australia, GPO Box 1901, Canberra, Australian Capital Territory 2601, Australia.
Email: libby.robin@anu.edu.au

discussions, which are often abstract and filled with modelling that is beyond the mathematical literacy of the general public. Objects reach beyond the limitations of words, speaking directly to people without the limitations of language (Bennett, 2001, 2010).

This paper explores three real and very different 'galleries' of the Anthropocene. It considers how the material display of objects can foster conversations about living in times of rapid environmental change. Global knowledge is most commonly either narrowly scientific or packaged simplistically by the 'fast and furious' commercial media (Christensen, 2013). In museums, there is a space to sponsor a 'third way'. The exhibition is an example of *slow media*, a forum for thoughtful reflection. By analogy with the slow food movement, the slow medium of a museum gallery offers room to explore the complexities of a rapidly changing world on a personal scale. The very pace of a museum visit and the process of engaging with physical objects and artwork is itself helpful for enabling participation and discussion about the factors driving accelerating change in the 21st century, a time where change has become so widespread that a new geological epoch, the Anthropocene, has been proposed (Crutzen, 2002; Crutzen and Stoermer, 2000). Time spent with well-chosen displays, perhaps enhanced by casual companionship with other visitors in that gallery space, can give individuals and communities the chance to respond to a spectacle where they can 'reshape media content as they personalize it for their own use' (Ekström et al., 2011: 1).

The big narrative of the Anthropocene is that human activities are shaping the way the planet works. While it was atmospheric chemists who proposed the new geological epoch of the Anthropocene in 2000, the concept held immediate appeal for global change scientists more broadly: oceanographers, glaciologists, environmental physicists, soil scientists and geologists were all discovering patterns of unprecedented change in their respective long-term data sets (Zalasiewicz et al., 2008, 2011). The *metaphor* of the Anthropocene (Larson, 2011) has also proved attractive to artists and humanists, who are exploring the implication of geological 'deep time' changes on how people respond emotionally to our changing Earth (Autin and Holbrook, 2012). The concept gained sufficient traction by 2014 to justify the creation of this new interdisciplinary journal, *The Anthropocene Review* (Oldfield et al., 2014). The journal showcases much truly interdisciplinary scholarship and scholarly debate about how to conceptualize the Anthropocene, as well as offering commentary on what should be its starting point and critiques of the profound moral issues raised by imagining humanity as a singular geological driving force (Malm and Hornborg, 2014).

The concept of humans 'changing the face of the Earth', to use a phrase from the famous Princeton conference of 1955 (Thomas, 1956), has a longer history than the Anthropocene (Warde, 2013: 98–100). There are debates about when the Anthropocene began: was it the agricultural revolution (Kaplan et al., 2011), the industrial revolution (Crutzen, 2002), the atomic bomb (Masco, 2010) or even the Stone Age (Doughty, 2013) that triggered the human signature in the planet's system? Whichever origin story they prefer, most proponents agree that there has been an acceleration of change from the 1950s onwards, the 'Great Acceleration', called by some the 'second stage' of the Anthropocene (Robin, 2013; Steffen et al., 2011). The 1950s may even become the 'first stage' for the stratigraphers, as they need to identify material change in the lithosphere to mark and adopt formally a new stratigraphic epoch (Zalasiewicz and Williams, 2013). Such change is provided by the nuclear signatures in soils and sediments from the 1950s (Masco, 2010). Museums are also concerned with the material world: they have collections and galleries that explore the meaning of objects. This chapter explores some possibilities for using a museum context to help understand the Anthropocene. A museum gallery offers audiences concrete ways to think about this concept, which is abstract in both space and time. In each of the galleries documented here, the Anthropocene idea has moved beyond stratigraphy and natural science, and expands the humanities to engage with the moral and ethical context of global dynamic change.

We first consider the 2014–2016 exhibition *Welcome to the Anthropocene: The Earth in Our Hands* [Willkommen im Anthropozän: Unsere Verantwortung für die Zukunft der Erde] hosted by the Deutsches Museum in Munich, a traditional science and technology museum. Our second 'gallery', is the outreach Anthropocene poster project of the Art Museum, Haus der Kulturen der Welt (HKW) in the streets of Berlin, as a 'museum without walls' (Friman, 2006; Malraux, 1965; Meades, 2012). The third 'gallery of the Anthropocene', was a whole landscape spectacle (Ekström et al., 2011), of in situ industrial heritage in Svalbard. Pyramiden, a town established to mine coal well north of the Arctic Circle, has been transformed as an attraction for climate change science and heritage tourism. Here the hybridized local landscape creates a snapshot of the Anthropocene, bringing together industrial coal-mining heritage buildings, polar tourism and science forged in the geopolitics of the changing Arctic environment.

## The Anthropocene at the Deutsches Museum, Munich

### *Background*

Why is it that the Deutsches Museum in Munich has become the home for the first large-scale special exhibition solely dedicated to the Anthropocene in the world? Of primary importance, it can draw on the objects and collections of the world's largest Science and Technology museum. It also has the expertise and networks of the Rachel Carson Center for Environment and Society (RCC), an international research center in Munich supported since 2009 by the German Ministry for Education and Research (Keogh and Möllers, in press). The RCC is dedicated to furthering research and discussion in the field of international environmental studies and to strengthen the role of the humanities and cultural institutions in current discussions about environmental policy. Alongside its academic activities and a strong international fellowship program, the Center's mission includes an obligation to public outreach. Working in partnership with the Deutsches Museum has proved a powerful way for research to influence big, diverse public audiences (Mauch and Trischler, 2013: 6).

The Deutsches Museum was founded to promote the principles of science and engineering in the early 20th century. German engineers sought social acknowledgment for their creativity and innovation, reinforcing their role in steering and planning a new modern society. Led by advocate, electrical engineer Oskar von Miller, professional engineers sought a space where technological achievements and inventions could be presented as cultural and artistic masterworks. The prominent engineer Rudolph Diesel and many other influential supporters swung in behind the idea of a museum that communicated the importance of engineering achievements to the general public, and asserted their cultural value to the nation (Füssl, 2010: xv). In 1925, the Deutsches Museum finally opened permanent galleries on 'Museum Island' (formerly known as 'Coal Island') in the Iser River in central Munich. The museum's initial focus was on 'masterpieces', galleries assembled as progressive histories of scientific and technological development. Rows of objects were arrayed, starting with older, simpler versions and, often supported by gifts from industry, ending with the newest and most 'advanced' technology. The successive lines of objects in the exhibitions reinforced a message about the linear advancement of technology, the progressive view typical of engineering at that time. The museum drew on traditional basic sciences and applied technologies from physics, geology, astronomy and chemistry to energy and mining technologies. Its industry support drove exhibitions of transportation and household appliances. Neither the environment nor the social context of the new technologies was included in such exhibits. Nature was not a subject of inquiry or display.

Over the century, the scope of the Deutsches Museum has broadened to include a range of exhibitions and collections including those that engage with environmental issues and other aspects of technology in society. In 1992, the year of the United Nations conference on the Environment at Rio, the Deutsches Museum opened a gallery *Environment* [*Umwelt*]. Following the museum's original mission to trace 'development', the new notion of 'sustainable development' (Brundtland, 1987) inspired a gallery that took in very different ideas, including population growth, fossil-fuel use, the hole in the ozone layer, recycling, and water and air pollution. In general, this exhibition relied not so much on the objects of the collections, but on models, texts and images for its storylines; one installation, however, displayed tools used for scientific environmental analysis, including an ozone-measuring cell and a soil moisture sensor. Overall, the environment was framed as a story of decline with technical innovations offering alternative pathways towards a more sustainable future.

Each of the themes in *Environment* was presented through images, text and media installations which focused on causation as a premise. The message was that through harnessing technology humans have caused problems but that new technologies might offer solutions to these issues. By making *causation* the focus, instruments used to analyse and measure the environment could became its objects. The exhibition was otherwise carried by images and text, which was reworked in 1998 and moved to a different place within the museum, but the basic storyline reflected the museum's approach to the environment, and *Environment* still stands at the time of writing. The gallery has helped to raise awareness of environmental problems arising from technological advancements, but it did not attempt an integrated view of nature and culture.

Triggered by scientific findings and public discussion on climate change resulting particularly from the IPCC reports, the Deutsches Museum presented a special exhibition on *Climate: The Experiment with the Planet Earth* in 2002. This dealt mostly with the scientific background on climate change. Subthemes included worldwide networks for measuring and gathering data, meteorology, historical technological ideas for influencing climate and natural catastrophes resulting from climate change. The exhibition also included a historical review of human reactions to climate variability in the past and present. The underlying idea that nature and technology could no longer be viewed separately, but needed to regarded as interdependent was very poignantly expressed in the catalog:

> Weather and climate, one might think, are not suitable topics for a museum of technology, as they concern nature. […] Nature and culture, however, may no longer to be neatly separated from each other which is why the prominent symbol of technological culture, the steam engine, is chosen as the opening of this climate exhibition in the museum of technology. (Hauser, 2002: 9 trs.)

## *The philosopy of 'Welcome to the Anthropocene'*

Focusing on climate as a global and interdisciplinary topic had historically been the Deutsches Museum's first step towards a more integrative view on environment, and it was this thinking that created the opportunity for the new Anthropocene exhibition in 2014. In this 'age of humans' we must think, reflect and discuss; as curators we cannot just exhibit, we must create platforms of discussion.

Climate change, more than any other issue before it, has brought into sharp focus the ability of the human species to influence planetary systems as a whole, but this is only one of many anthropogenic changes affecting the Earth's systems in the twenty-first century. As well as the carbon cycle, humans are significantly altering the nitrogen, phosphorous and sulphur cycles, changing sediment movement and water vapor flow from land to atmosphere (through land-cover change).

There has been a Great Acceleration of global changes since around 1950 (Steffen et al., 2011: 742). For example, population, wealth and human consumption and usage of things (ranging widely from paper to water) have all risen exponentially in this period. Financial and business institutions have become 'globalized' (and this phenomenon has been measured using the proxy of the expanding number of McDonald's restaurants). People are moving ever faster around the world with growing international tourism. Some say that humanity is driving the sixth major extinction event in Earth's history (Barnosky et al., 2011).

Humanities scholars have cautioned that an overarching concept such as Anthropocene, with its scientific basis, lacks cultural diversity and might even reinforce regimes of power and capital that have brought us to this point (Clark, 2011; Malm and Hornborg, 2014; Wilke, 2013). Cultural diversity provides an important 'creative friction' in a globalized world, something which museums are well-positioned to support (Tsing, 2005: x; Witcomb, 2009). A critical approach to the 'we' that is presented in a museum is essential: might a species-level understanding of humanity downplay the challenges of environmental justice, where the fossil-fuel-prints of the few drive adverse changes for the many (Nixon, 2011)? Finding a material representation for unequal consumption patterns and the distribution of resources and wealth is by no means easy, but is critical to any museum display on this subject (Davis, 2002; Gordillo, 2011).

Accepting that humans have fundamentally altered the way natural systems work and have shaped global climate change, closes the bifurcation between the natural and the cultural: in the Anthropocene natural and cultural systems are interdependent. We now have integrated systems that embrace cultural and biophysical dimensions, and we need scholars who can work with our hybridized Earth. As chemists Will Steffen and Paul Crutzen and historian John McNeill have noted: 'Humanity is, in one way or another, becoming a self-conscious, active agent in the operation of its own life support system' (Steffen et al., 2007: 619). This new period also reshapes our understanding of humanity, as postcolonial theorist and historian Dipesh Chakrabarty notes: 'To call human beings geological agents is to scale up our imagination of the human' (Chakrabarty, 2009: 206).

Drawing on insights from a wide range of scholarly disciplines, the members of the Deutsches Museum exhibition team decided to use the concept of an 'usworld' (translated from the German *Unswelt*) advocated by the geologist Reinhold Leinfelder (Leinfelder, 2012, 2013; Leinfelder et al., 2012: 12–17). Such a notion of 'us' makes it difficult to separate nature and culture, and forces thinking with a hybrid nature-culture world. An *usworld* challenges how we know ourselves. Although as a species we have become a geological force, as individuals we are pro-active actors on this stage. The Anthropocene is not just about irreversible environmental changes, it is also a historical phenomenon. Anthropocene-changes have accelerated over a period that showcases many of the great innovations and thinking about human freedom. An usworld approach blends nature, culture, technology and society into single hybridized perspective, an Anthropocene imaginary, that is compatible both with the original mission of the Deutsches Museum and with the expectations of its 21st century visitors.

As literary theorist Sabine Wilke has written, the humanities: 'concern themselves with the study of intellectual creation and the critique of dominant narratives, myths, and ideologies, and the critical engagement with fundamental questions of meaning, value, responsibility, and purpose in a period of escalating crisis' (Wilke, 2013: 67–74). For Wilke, a critical Anthropocene approach must engage with frameworks and insights from postcolonial theory and environmental justice and continuously expose the ideological underpinnings of a developing Anthropocene narrative. The geological time depth of the Anthropocene can provoke new scales for imagining the material conditions of human life: it brings Big History (Christian, 2011) to this history museum. In their recent book *Making the Geologic Now*, Elizabeth Ellsworth and Jamie Kruse explore the notion that the geologic has become a condition of contemporary life with a group of artists and scholars. Their approach is not so much a direct critique but rather to discuss and unpack the 'geological turn' and human responses to it. They 'direct sensory, linguistic, and imaginative attention toward the material vitality of the Earth itself' (Ellsworth and Kruse, 2013: 25). Their primary focus, inspired by the work of Jane Bennett, is materiality – shifting us away from pictorial images and views of landscape toward the Earth's surface itself: 'Making a geologic turn, we create an opportunity to recalibrate infrastructures, communities, and imaginations to a new scale – the scale of deep time, force, and materiality'. Ellsworth and Kruse continue: 'we are not simply "surrounded" by the geologic. We do not simply observe it as a landscape or panorama. We inhabit the geologic' (Ellsworth and Kruse, 2013: 25).

If we inhabit the geologic (Szerszynski, 2012), then an exhibition or gallery of the Anthropocene might aspire to place people in their own strata?

## *Practicalities*

In this section we discuss the conception and goals of *Welcome to the Anthropocene: The Earth in Our Hands* [*Willkommen im Anthropozän: Unsere Verantwortung für die Zukunft der Erde*], which opened to the public on 5 December 2014. The exhibition's main goal is to inform visitors about the Anthropocene as a current concept that considers humanity as a driver of physical change on Earth. It shows the effects of humanity as a biological and geological actor and the extent of these changes. By translating the concept into a three-dimensional space, the exhibition offers the general audience a unique opportunity to *experience* the Anthropocene and learn about the current state of scientific knowledge and debate. It does not conceptualize the Anthropocene as a narrative of decline, but rather as a complex and often ambivalent story of destruction, re-shaping and feedback loops between these processes. Nature and culture are taken together as an integrated and hybrid system. This thread is explored throughout the exhibition, for example, through as an installation about invasive species and in an experiential section that sets out to disrupt preconceived ideas of 'nature'.

The curators instigated an internal survey to find out what their audience already knew about the Anthropocene, and to get a sense of how to 'pitch' the text-based panels. They drew on the views of over 100 patrons in a two month period in late 2012 (Bäuerlein and Förg, 2012). While 80% of those interviewed supported the idea that the museum should engage with 'controversial topics', an even greater number (86%) had not previously heard of the Anthropocene. Many were interested in the environment, and saw the impacts of industry as bad for the environment: almost half of the patrons said that industry could not solve environmental problems.

In the light of this survey, the curators 'pitched' the Anthropocene as a holistic, systemic, and reflective concept, enabling the inclusion of a range of global-scale environmental problems. *Welcome to the Anthropocene* was created in an open-ended format that enabled visitors to engage actively with it, including responding with solutions. The idea of the Anthropocene itself introduces and brands the exhibition, and also frames the responses of the visitors.

The exhibition covers 1450 $m^2$ (c. 15,600 square feet) and is structured in three parts. The first section provides a comprehensive introduction into the Anthropocene both as a geological hypothesis and new conceptual framework. The introduction includes a range of technological objects that highlight the eras of industrialization (from the late 1800s, building on Paul Crutzen's narrative of the origins of the Anthropocene) and the Great Acceleration from the 1950s. The second part of the exhibition consists of six thematic areas that present selected phenomena of the

**Figure 1.** Plan for field of paper daisies, *Welcome to the Anthropocene* 2014. Design: Klaus Hollenbeck Architekten.

Anthropocene, looking particularly at systemic connections, global and local interdependencies, and temporal dimensions. The themes covered are urbanization, mobility, nutrition, evolution, human–machine interaction and ‘nature’. Given the challenges of nature-culture hybrid in the Anthropocene, ‘nature’ is a significant area that has been understood differently before the Anthropocene era (van Mensvoort and Grievink, 2011). Connecting these themes is a geological layer of materiality that embeds visitors in the *strata* of their creation. This draws on the theoretical ideas of Ellsworth and Kruse (2013). The third and final part of the exhibition discusses the future in the Anthropocene. It looks at past visions of the future, emphasizing their transformative potential while simultaneously highlighting their fragility and ambivalence. It then discusses possible scenarios of the future for people to consider in a more relaxing space; the final installation invites people to listen to possible scenarios and to plant their own possible scenario in an evolving field of paper daisies (Figure 1). Thus each individual visitor has the opportunity to offer a personal reflection on their aspirations for the Anthropocene.

As an epoch, the Anthropocene encompasses the entire globe throughout Earth history. As a new epoch and a philosophical framework, it weaves connections between a very large number of phenomena, many previously unconnected. The challenge for a museum is to define, research, shape and represent the Anthropocene epoch even as it unfolds. While exhibitions are always selective representations of specific interpretations of our world, the uncertainty that surrounds the Anthropocene challenges traditional perceptions of museums as authorities and mediators of knowledge, and demands space for raising questions and reflecting on uncertainty. Museums of science and technology, such as the Deutsches Museum, can no longer represent themselves as mere purveyors of authentic knowledge, even where visitor research suggests that a large part of the public continues to expect to receive authoritative information from museum exhibitions. *Welcome to the Anthropocene* created a space – literally and figuratively – for free thinking, discussion and imagining a new concept, drawing on abstract and academic ideas and creating ways for the public to participate.

Traditional museum objects were not easy to incorporate into such an exhibition. When it came to pinpointing the stories and finding an ‘Anthropocene moment’ (or even origin story), it became messy. In the end, the curators elected to live with the complex messiness and concentrate rather on the networks, systems of interconnections and chaos. Since the world in the Anthropocene is no longer ordered, the exhibition explores the navigation of chaos. In translating the Anthropocene into a three-dimensional gallery, the exhibition explores the systems of the Anthropocene and their interrelationships and feedbacks. An exhibition space affords visitors multi-perspective and nonlinear opportunities: they make their own paths, touring where they want to, forming their own experiences, and coming up with different interpretations. Part of the idea of the landscape of paper flowers folded by individuals was to capture the diversity of visitor experience.


**Figure 2.** Comic image of the Twittering Machine, an automated singing bird made by Blaise Bontemps in Paris around 1875. Artist: Marcus Gruber.

The conceptual approach of reflexivity and engagement with the public also manifests in the curators' idea to integrate the museum's permanent galleries into the Anthropocene exhibition by way of a graphic novel, *Auf dem Weg ins Anthropozän – ein Crashkurs.* [*Anthropocene Milestones: Illustrating the Path to the Age of Humans*] (Hamann et al., 2014). A international class of design students at the Berlin-based University of Fine Arts has used a carefully chosen set of objects ranging from mining to nanotechnology, from textile industry to remote sensing, to visualize stories that narrated the past, present, and the future of the Anthropocene (Figure 2). The students' visual trace of object-based stories also represented humanity's own trace in the geological strata of planet Earth. Moreover, the students' views on the Anthropocene complement and challenge those of the curators: the graphics further blur boundaries between nature and culture, sciences and humanities, technology and arts.

## The Anthropocene Project of the Haus der Kulturen der Welt

### *Background and philosophy*

The Haus der Kulturen der Welt (HKW) stands in the heart of Berlin, surrounded by the Federal Chancellery, parliament buildings, and office of the Federal President. It is a place for art and cultural productions in a globalized world. HKW develops new forms of knowledge production at the intersection of art and academic research. In positing new subjects, it seeks to open new perspectives on, and points of access to, an increasingly interconnected and interactive world. The Anthropocene idea was an attractive challenge, sympathetic with the central mission of HKW: but as an art museum the concept needed to get beyond a definition based on physical science or technology. HKW has developed a major set of Anthropocene projects to speak to the discourse of daily life and society. The idea of the Anthropocene had low recognition in Berlin at the time the project was launched in 2013, as HKW established using a survey similar to the one undertaken by the Deutsches Museum with similar results (Bäuerlein and Förg, 2012). Nevertheless, HKW sought to make it accessible and relevant for a general audience, and to elicit participatory responses.

The gallery of Anthropocene Posters, which we focus on here, was complemented by two other initiatives: an exhibition in the museum in spring 2013, the *Whole Earth Project* and a major educational intervention, the Anthropocene curriculum (in progress as we write).


**Figure 3.** Is the Anthropocene beautiful?
*Source*: HKW.

The *Whole Earth Project* used the Californian 1960s idea of the *Whole Earth Catalog* (Brand, 1968–1971) this art exhibition that explored three key iconic images in global thinking – the mushroom cloud of atomic energy, the 'blue marble' view of Earth and the Marshall McLuhan media metaphor of 'the global village' (McLuhan and Fiore, 1968). The exhibition showed how, in California in the 1960s and 1970s, a technological-economic force arose that stormed Western thinking. On the one side was a hippie movement, inspired by romantic and Far Eastern holistic teachings, that was protesting America's involvement in the Vietnam War. On the other was its avowed adversary, the military-technological complex, including the atom bomb and the view of the Earth from the NASA space voyages. The idea that 1960s 'people power' was just as global in its reach and influence as the technological achievements of the era was a way to highlight the personal response to the complexity of life in the Anthropocene now, the planetary inheritance of these years (Turner, 2013). The Whole Earth 'moment' was not about any particular political stance, but rather about a new vision of the fragile and lonely planet, the only one that has a biosphere to support life (Robin, 1997: 149–151). The exhibition received excellent reviews (Baumgärtel, 2013; Häntzschel, 2013; Quack, 2013).

Much of the effort in the HKW Anthropocene project has been directed towards education. The focus of the *Anthropocene Campus* initiative is a nine-day intensive course for 100 international doctoral and post-doctoral scholars (14–22 November 2014). Materials for this course are available online, and will become the backbone for a multifaceted, multi-author text book developed through the event with the participants as co-authors. Encouraging positive participation rather than despair about the Anthropocene moment is an important mission in all these initiatives. The humanities and arts bring different tools and styles from traditional natural sciences, which can stimulate curiosity and invite different people to engage with the concept.

## *The Anthropocene Posters*

HKW and the Deutsches Museum both expended considerable effort on encouraging public response, rather than 'telling' the viewer what they should see. The two institutions collaborated in some parts of their respective Anthropocene projects. Both were concerned to build a


**Figure 4.** Is the Anthropocene just?
*Source*: HKW.

new hybridity between science, technology, and the arts. The HKW gallery, however looked rather different from *Welcome to the Anthropocene*. Its gallery of *Anthropocene Posters* ran on the principle of inclusive reflexivity and sought to overcome the anomie and sense of alienation in busy public areas through presenting its gallery to the streets of Berlin.

If the Anthropocene thesis is an heuristic means of achieving a new understanding of thought and action in an interconnected world, then the aesthetic chosen is important. Some people see spatially or holistically, others read the captions or cues, then look at images or objects separately. The idea of text-as-art, as practiced by conceptual artist Barbara Kruger in the USA, for example, has appeal to a wide range of viewers. Kruger uses strongly textual art to disrupt social norms and stir moral responses (Miller, 2012; Smith, 1991). The *Anthropocene Posters* gallery sought those strong responses to text, but added masks, beautiful composite faces, to the questions that reinforced the hybridity of nature and culture in the concept of the Anthropocene. The mask is beautiful and it is also challenging: it is a space for arresting questions in the everyday world of the streets. The aesthetic is the combination of the text, the image and the context of ordinary life.

Thus in this 'gallery', situated in public urban space, the human being stands front and center of the intervention (Lassiwe, 2012). Who is this *anthropos*? We think we know ourselves, but perhaps we are someone else? Passing observers encountered three masks, each bearing a question. Three seemingly simple, yet fundamental questions speak to the big idea of the Anthropocene, a world formed by people, a world where culture and nature are entwined.

(1) *Is the Anthropocene beautiful?* (Figure 3). HKW is an art museum and it explores experience as aesthetics. How does the new nature inscribe itself into our bodies? How do we experience a world whose urban centers no longer know true darkness? How do we experience a world whose creatures and things are increasingly produced either chemically or biogenetically? Conceptually, the point is that the things humans create are never purely objects that stand opposite us as *Welt* ('world'), but always also possess subjective aspects which, in turn, relate back to humanity. That is, people and things are situated in a constant state of interaction, co-constructing each other (Bennett, 2010).


**Figure 5.** Is the Anthropocene human?
*Source*: HKW.

(2) *Is the Anthropocene just?* (Figure 4). Although the human species has produced the nature that is the subject of the Anthropocene, the specific, concrete actions have been, and are, carried out by individuals, groups, companies, and societies. The moral implications and responsibility are often set aside if the Anthropocene is only defined by natural sciences. Most often the instigators of the action are not the ones who grapple with the impacts of the action. For a long time, the main instigators, the people who benefited most from the spoils of the industrial revolution and the fossil-fuel economy lived in the West. Those bearing the brunt of these actions were geographically dispersed around the world, and economically more likely to come from the Global South. As industrial activities and increasing fossil-fuel use expand in the non-West, the relationship has become more opaque. In any case, the sociopolitical process of exchange affects people and institutions at the local, regional, and global level all over the world.

(3) *Is the Anthropocene human?* (Figure 5). Humans are simultaneously beings of nature and culture. No longer can either sphere be regarded as a discrete area unto itself. Things from the world of objects, whether found or self-produced, repeatedly gain importance, become part of culture, then lose significance again and become 're-naturalized'. Continual cycling takes place. Since the 17th century, the division between the two spheres, the dualism of nature and culture, has seemingly driven development. The realm of nature has been conceptualized as an inert resource to service human needs. The nature that was produced through economic and cultural processes – the polluted air, the gyre of plastic in the Pacific ocean – did not register in the cultural self-conception of man. They were neither nature nor culture. They fell through a black hole in conceptualizing. Now, through the Anthropocene thesis, the full significance of these new natures is brought to human consciousness: is there culture without nature? Is the new stuff human?, asks the poster.

## The Anthropocene in situ: Pyramiden, industrial heritage and the new tourism of climate change

In the third 'gallery of the Anthropocene', we consider another place beyond museum walls, the in situ industrial heritage of Pyramiden, a coal-mining town in the Arctic Circle, refashioned for climate change science and polar tourism. Human design and global environmental changes here have made a whole landscape a 'spectacle' of the Anthropocene (Ekström et al., 2011). This is a museum without walls, a landscape-scale gallery that provokes thought about the Anthropocene at the extremes of the inhabited world.

## Historical background

In the high latitudes of the Arctic, 1°C of global warming makes for greater and faster changes than at temperate latitudes. The 'polar effect' has fuelled a climate change tourism, with people anxious to see glaciers 'before they melt' and extreme environments remote from people, yet disproportionately affected by their activities. The Ilulissat Glacier in Greenland, for example, has become an iconic place for visiting American politicians, a place that signifies 'climate change' as surely as an image of a polar bear on a sea-ice floe. The USA and other states of the Arctic council wish to mitigate the consequences of climate change in the Arctic, protect the environment and support climate science. At the same time, however, they want to protect their traditional interests in resources and sovereignty there (Norwegian Ministry of Foreign Affairs, 2011; Norwegian Ministry of Justice, 2009; Putin, 2013). At Svalbard, Russian and Norwegian actors combine these seemingly contradicting policy goals, by transforming coal mines into industrial heritage sites. Could an Arctic coal mine such as Pyramiden become a touchstone place for climate change tourists as Ilulissat is?

Norwegian and Russian companies started coal-mining at Svalbard (also called Spitsbergen) in the early 20th century. At this time the energy extraction boom drove international debate about the legal status of Svalbard itself. The archipelago had been recognized as an international space – an unoccupied 'no-man's land' – until it emerged as potentially profitable. Promised wealth from coal increased interest (particularly among northern states) in staking a nationalist claim for influence in this windy, cold and remote territory. Norway first demanded sovereignty, but was opposed by Sweden and Russia because of their respective economic and political interests. The coal mines became part of this conflict, not just because of the resources, but also because these nations could use their existing mines as 'effective occupation', a precursor to claiming sovereignty (Avango, 2005; Avango et al., 2010; Berg, 1995).

Pyramiden became a material representation of intersecting interests and future visions. It was established initially by a Swedish company, which built a few huts there in 1910. The original plan was to create a mining town to supply coal to the Swedish steel industry. The company also developed a nationalist interest in strengthening Sweden's influence in negotiations on the legal status of Spitsbergen, particularly in blocking Norway's claim to sovereignty. In the end, the mining town was not built and in 1920, Norway was granted sovereignty over Svalbard (the Norwegian name for the place) through a treaty. In the following years, the world economy slumped, and the depression forced most companies to leave Svalbard, including the Swedish group that had started Pyramiden. The huts were abandoned (Avango, 2005).

In the years that followed, the situation changed and energy extraction became a nationalist project. From the late 1920s, state-supported companies from Norway and the Soviet Union began to mine coal at Svalbard. The Norwegians wanted to maintain their case for sovereignty by effective occupation, and the Norwegian economy could use the energy. The Soviet Union was first and foremost in it because the rapidly industrializing Murmansk region needed coal. However, the strategic importance of this part of the Arctic was also a key factor (Avango et al., 2014).

Norway and the Soviet Union each operated several mining towns on Svalbard at this time. One of these was Pyramiden, which the Soviet Union bought from its Swedish owners in 1927. Starting in the mid-1930s, the Soviet company Trust Arktikugol developed an elaborate mining settlement there, which soon became the most splendid on Svalbard. The new owners brought their settlement housing and services of a remarkably high standard, along with elegant and ambitious architectural designs. There was nothing on a comparable scale among Norwegian mining settlements in Svalbard until the 1980s. The 1930s settlement at Pyramiden was more than a stake in the geopolitical discourse: it was a signal of strong Soviet intentions for Svalbard (Norwegian Commissioner of Mines, unpublished reports, 1934–1966).

When the Soviet Union fell, the new Russian government had a different vision, which excluded Pyramiden. With the emphasis elsewhere, Trust Arktikugol closed down the town in 1998. Over the following years, the settlement infrastructure slowly deteriorated, becoming a victim of melt-water rivers and looters (Eggestad et al., n.d.; Umbreit, 2006).

At the same time, an increasing number of Norwegians came to question the Svalbard coal-mining industry, because the mines were unprofitable and hard to rationalize with Norway's own policy for protecting the environment at Svalbard or its international status as a leader in environmental thinking (Brundtland, 1987; Naess, 1973). In 2001, the Norwegian government passed a new environmental law, which limited the possibilities for mining in Svalbard. By this time the last Russian mine operating in Svalbard, Barentsburg, was running out of coal. The Trust Arktikugol began to cast around for alternative uses for its settlements at Svalbard. The company envisioned two main options: first, to open another coal-mining town where it might be profitable to mine coal, and second, to re-purpose the existing mining towns. Any plan for a new coal venture would contravene the new Norwegian environmental regulations and so it was abandoned (Åtland and Pedersen, 2008). Instead the Russians moved to their second option, to re-develop their coal-mining settlements into hubs for Arctic tourism, conservation and science.

The Russian state restarted its activities at Pyramiden around 2010. In cooperation with the governor of Svalbard, The Trust Arktikugol carefully renovated parts of the settlement and in the spring of 2013, it reopened the hotel. The company sought to re-create Pyramiden as a tourist attraction and a base for international Arctic climate science, promoting it as an industrial heritage site with a unique Soviet character (Sergey Tzikoleuko, technical director of Trust Arktikugol (Moscow office) and Peter Goroshinskiy, head land surveyor of the Trust Arktikugol at Barentsburg, personal communication, 2013) To use Pyramiden as a platform for science stations provided grounds to compete with the Norwegian hub for Arctic climate science at the former mining settlement Ny Ålesund, an important anchoring point for Norway's sovereignty at Svalbard.

Pyramiden's facelift also opened a window of opportunity to the Norwegian authorities. During the Cold War years, the Norwegian governors of Svalbard, as far as possible, had refrained from intervening in Russian activities on Svalbard, in order to maintain peaceful relations with their neighbor. After the end of the Cold War, Norway asserted its legal authority, requiring the Trust Arktikugol to abide by Norwegian laws in Svalbard (Jörgensen, 2010). Norwegian regulations, which required companies to make area plans for their settlements and to protect buildings and material remains that are older than 1946 as 'cultural heritage', became an important dimension of diplomatic relations.

The Norwegian governor responded to Russia's new concept for Pyramiden by calling on the Trust Arktikugol to make an area plan. The company contracted a Norwegian firm for the purpose, while the governor enrolled heritage professionals to identify structures that should be protected as heritage. Based on the consultants' report from November 2013, the governor declared parts of Pyramiden as 'cultural heritage'. This effectively turned these identified parts of the Soviet town into an industrial heritage site protected under Norwegian law (Avango and Solnes, 2013; Sandodden, 2013).

**Figure 6.** Central Pyramiden, showing Soviet architecture.
*Source*: Dag Avango.

Pyramiden is a gallery of international industrial heritage (Soviet style) evocative of the former era of Arctic extraction, a fossil-fuel landscape refashioned to serve new futures in the Arctic, including tourism (Figure 6). Re-using the settlement suits both Norwegian and Russian Arctic policy makers. The interested parties can both see how this place enables them to continue to control resource use, to maintain influence or sovereignty and to protect the environment. Supporting science, particularly climate science, in this far northerly place is itself a sustainable development for both nations.

By defining Pyramiden as an industrial heritage site, and a site for climate change science and polar tourism, both Norway and Russia can showcase their global environmental and cultural credentials, while keeping a close eye on a region that is increasingly strategically important as the climate warms and the Arctic sea ice melts . Visitors coming to this spectacle can see the hybridity of the worlds of nature and culture, of energy landscapes and their post-fossil-fuel uses (Figure 7). They stay in a comfortably refurbished Soviet hotel, refashioned after the Cold War to suit the needs of climate change scientists.

## Reflections: The implications of the Anthropocene for cultural institutions

The Anthropocene poses a challenge to humanity and to planet Earth. It is also a challenge for the museum world to engage with this on a human scale and within the space of a gallery, even one beyond a museum building. All these galleries in different ways acknowledge the new perspective on the relationship between nature and culture brought by the Anthropocene. Traditional (and often cherished) museum frameworks that compartmentalize knowledge into disciplines, cultures and periods of time are no longer useful. Nonetheless, because they are collecting institutions, museums are in a position to connect the deep past through the Anthropocene present to the deep future through objects and collections.

The original idea of a museum was that it was a house for collections. The nature of collections have changed over time, and so has the idea of the 'house'. In the rapidly changing times of the Anthropocene world, the museum gallery is taking new forms. We see gardens that are set out like museum cabinets, and built museums that include indoor forests (Robin, 2007). Communities demand spaces that work for their traditional needs, leading to different sorts of museums, and sometimes to significant new sorts of spaces within them, for example, the living Marae (meeting house) in Te Papa, the National Museum of New Zealand in Wellington, used for museum, community and religious purposes.

**Figure 7.** Aerial view Pyramiden, Svalbard.
*Source*: Dag Avango.

Museums that seek to explore big abstract ideas such as the Anthropocene find themselves pushing the edges of the classic museum form, which is a gallery or room that places objects and visitors in conversation with each other. *Welcome to the Anthropocene* at the Deutsches Museum is the most traditional of the three galleries discussed. A Science and Technology Museum is also the most appropriate *museum form* to house discussions of the unintended and far reaching consequences of the industrial revolution (Robin et al., 2013). The Art Museum, Haus der Kulteren der Welt, has taken the Anthropocene to the community beyond its museum walls, using text-as-art in the streets of Berlin. Both of the German gallery forms strive to inform the public, to offer viable and accessible representations of big ideas in ways that encourage public participation in the Anthropocene.

The third 'gallery' takes the idea of the museum form itself to another level again: Pyramiden is a global museum of a local place, a place where ideas of change, of fossil fuels in the environment and where international debates have focused on the local and specific circumstances, yet they also resound with issues affecting other polar places and regions (including in Antarctica). Pyramiden is only accidentally a 'gallery of the Anthropocene', and its hybrid nature/culture is historical rather than artful. In Pyramiden, the actors have all come from somewhere else and re-made the place according to different nationalist visions. Now it is a place where new visitors and scientists come to explore ideas about climate change at the far northern edge of the inhabitable world.

These are not the only places holding conversations about global environmental change, but the Europeans perhaps provide stronger support to cultural institutions to intervene in public and global policy issues. For museum and heritage professionals the three galleries taken together showcase very different ways for how a museum might 'house' Big Ideas. For those already engaged with the Anthropocene concept, the examples demonstrate how the cultural sector might further enliven public discussions about the future of the planet.

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# Prelude to the Anthropocene: Two new North American Land Mammal Ages (NALMAs)

**Anthony D Barnosky,[1,2,3] Michael Holmes,[1,2,3] Renske Kirchholtes,[1,2] Emily Lindsey,[1,2] Kaitlin C Maguire,[4] Ashley W Poust,[1,2] M Allison Stegner,[1,2,3] Jun Sunseri,[1] Brian Swartz,[1,5] Jillian Swift,[1] Natalia A Villavicencio[1,2] and Guinevere OU Wogan[1,3]**

**Abstract**
Human impacts have left and are leaving distinctive imprints in the geological record. Here we show that in North America, the human-caused changes evident in the mammalian fossil record since c. 14,000 years ago are as pronounced as earlier faunal changes that subdivide Cenozoic epochs into the North American Land Mammal Ages (NALMAs). Accordingly, we define two new North American Land Mammal Ages, the Santarosean and the Saintagustinean, which subdivide Holocene time and complete a biochronologic system that has proven extremely useful in dating terrestrial deposits and in revealing major features of faunal change through the past 66 million years. The new NALMAs highlight human-induced changes to the Earth system, and inform the debate on whether or not defining an Anthropocene epoch is justified, and if so, when it began.

**Keywords**
Anthropocene, biochronology, Holocene, land mammal ages, mammals, paleontology

## Introduction

'Anthropocene' is an informal term now widely used to identify the time in Earth history that begins when *Homo sapiens* become a geological-scale force for planetary change (Crutzen, 2002; Steffen et al., 2011b; Zalasiewicz et al., 2012). Discussions are underway about whether to

[1]University of California-Berkeley, USA
[2]University of California Museum of Paleontology, USA
[3]University of California Museum of Vertebrate Zoology, USA
[4]University of California-Merced, USA
[5]Stanford University MAHB, USA

**Corresponding author:**
Anthony D Barnosky, Department of Integrative Biology, University of California, 1005 Valley Life Sciences Building, #3140, Berkeley, CA 94720, USA.
Email: barnosky@berkeley.edu

formally recognize the Anthropocene as a new geological epoch and where to place its beginning, but the debates are still unresolved (Crutzen and Steffen, 2003; Steffen et al., 2007, 2011a, 2011b; Waters et al., 2013). Many proponents of the Anthropocene suggest that it began either around the year AD 1800, coinciding with intensification of the Industrial Revolution and attendant changes to the Earth system, or else around 1950 when many geochemical, physical and biotic signals of human population growth and globalization accelerated and became evident worldwide (Crutzen and Steffen, 2003; Steffen et al., 2011a, 2011b; Zalasiewicz et al., 2012).

However, pronounced pre-18th century human influences on the global ecosystem also are evident in geological, archaeological and paleontological records. Geochemical signals arguably indicate human influence on the atmosphere as early as 8000 years ago (Ruddiman, 2003) (see also Crucifix et al., 2005, for arguments in opposition to this idea), and a large body of archaeological evidence documents humans as an integral part of the Earth system since their first appearance about 160,000 years ago. Such considerations have led some to recognize the 'Paleoanthropocene': the time from the first human impacts many millennia ago to the first widespread influence of industrialized society (Foley et al., 2014).

Among the pre-industrial anthropogenic impacts are step-wise changes in mammalian faunas around the world, characterized by the introduction and often extinction of species that accompanied human dispersal. On the global scale such events are diachronous, spanning hundreds of thousands of years. They correspond with dispersal of *Homo sapiens* out of Africa, to Eurasia and Australia, and finally to the Americas (Barnosky and Lindsey, 2010; Barnosky et al., 2004; Koch and Barnosky, 2006; Martin and Steadman, 1999; Martin and Wright, 1967; Wroe and Field, 2006). Within each continent and on islands, the human immigrations and their impacts on the non-human mammal species appear geologically rapid, resulting in pronounced faunal changes within as little as two millennia (Goebel et al., 2008; Koch and Barnosky, 2006; Meltzer, 2009; Waters and Stafford, 2007) and even within a century or so on some islands (Burney et al., 2001; Martin and Steadman, 1999; Steadman, 2006). Here we present evidence that these anthropogenically driven step-wise changes apparent in the fossil record of mammals provide a useful way to highlight some major human alterations to the Earth system that preceded industrialized Anthropocene times, while at the same time completing a formal biochronologic system that has proven valuable in subdividing geological time.

For pre-Holocene time, paleofaunal changes have been used to define biochronologic units known as land mammal ages. Land mammal ages subdivide geological epochs by recognizing distinctive assemblages of mammal species, each of which characterize a certain span of geological time (Figure 1). This is possible because at irregularly spaced intervals through the Cenozoic, the mammal fauna of a given place demonstrates marked species- and genus-level turnover caused by evolution, immigration and sometimes extinction (Woodburne, 2004b, 2006). These turnover events are rapid with respect to the relative coherency of species assemblages that persist from one turnover event to the next. Each coherent assemblage represents one land mammal age, and the relatively rapid turnover events result in recognizable boundaries that separate ages. Land mammal ages were first formalized in North America (Wood et al., 1941) and now are recognized to be 'one of the most useful ways with which to discuss the timing of geohistorical events' within a given geographic region (Woodburne, 2006). Subsequent to their definition in North America, land mammal ages were codified for South America (Flynn and Swisher, 1995), Asia (Wang et al., 2013) and Australia (Megirian et al., 2010). A method of subdividing time based on distinctive mammal faunas (the MN zones) also is widely used in Europe (Lindsay, 1997). As originally proposed, the North American Land Mammal Ages (NALMAs) subdivided the Paleoocene through Pliocene epochs (Wood et al., 1941). Later, two NALMAs were defined to subdivide the

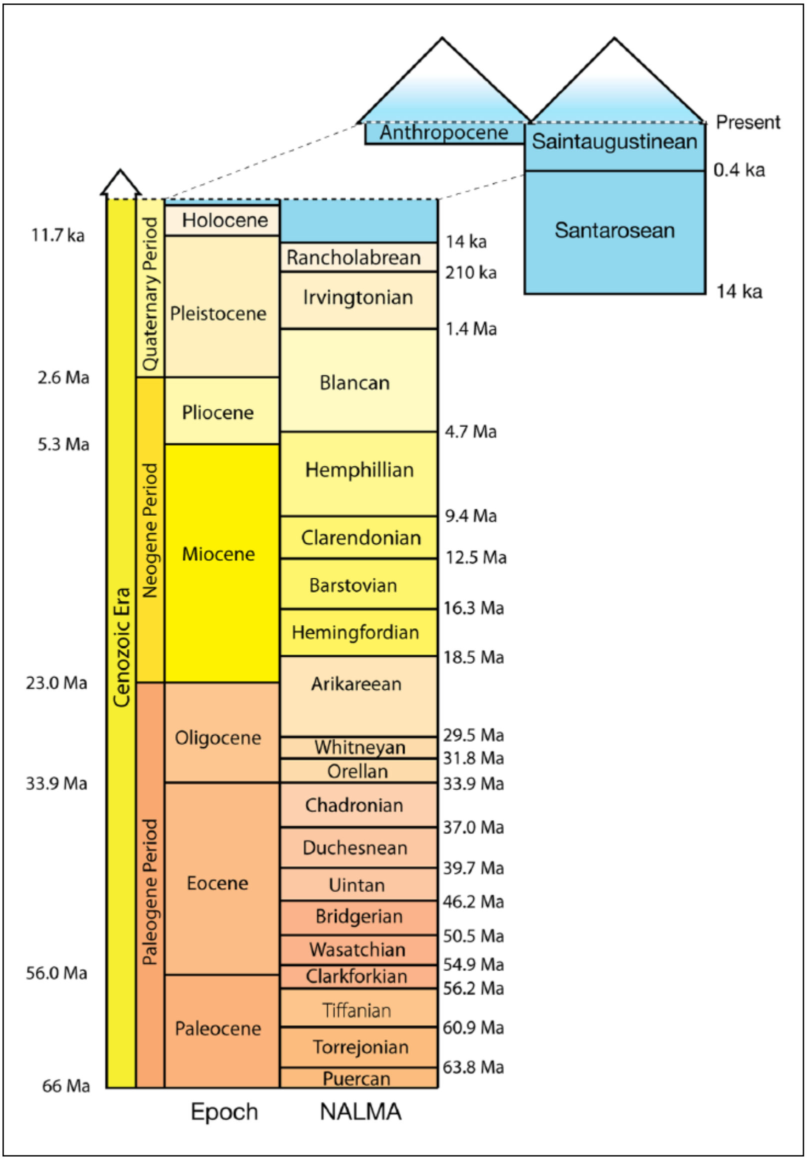


**Figure 1.** The North American Land Mammal Ages (NALMAs) and their correlation with the Cenozoic geologic timescale. The new NALMAs defined here are indicated in blue. ka = thousand years ago, Ma = million years ago.

Pleistocene (Savage, 1951), but the land mammal biochronology has, until now, excluded the Holocene (Figure 1).

Here, we complete this highly useful biochronologic scheme by defining two Holocene NALMAs, which serves two purposes. First, the new NALMAs enhance stratigraphic and temporal correlation in Holocene deposits that lack direct radiocarbon or other age determinations. Second, pertinent to the Anthropocene debate, recognizing Holocene NALMAs highlights the important, step-wise episodes of human-induced ecological change that are otherwise hidden by the larger-scale Pleistocene–Holocene–Anthropocene trichotomy. Following standard practice of restricting land mammal age definitions to a given continent, the new land mammal ages apply only to North America. However, defining land mammal ages based on anthropogenically induced faunal changes, as we do for North America, is applicable worldwide (although temporal boundaries, characteristic taxa and names would by necessity differ for each continent).

The new NALMAs proposed here are the Santarosean, which begins with the first entry of humans into North America south of 55°N latitude, widely thought to have occurred between 14,000 and 15,000 years ago, and the younger Saintaugustinean, which begins with the introduction of domesticated megafauna north of 25°N latitude about 400 years ago. The beginning of the younger age (Saintaugustinean) defines the termination of the preceding NALMA (Santarosean).

## Defining NALMAs

The North American Land Mammal Ages were first proposed (Wood et al., 1941) 'to recognize discrete intervals of time based on the evolution of fossil mammals' (Woodburne, 2004a); thus, the definition of a land mammal age is based solely on the mammal fauna as represented in the fossil record. As originally defined, the NALMAs were 'only loosely tied to a stratigraphic framework' (Woodburne, 2004a); this, and other nuances of the method by which NALMAs were first constructed (Woodburne, 2004b, 2006), means that, strictly speaking, they are biochronologic units. That is, NALMAs are 'intervals of *time* [emphasis added] as represented by fossils', rather than biostratigraphic units, which are empirical entities (physically, you can touch them) 'based on stratigraphic disposition of fossils' (Woodburne, 2004a). In this respect, NALMAs are similar to geochronologic units, the difference being that NALMAs were originally defined explicitly as time units that could be recognized from the evolutionary progression of mammal lineages, without specification of biostratigraphic zones first. That methodology differs from the normal procedure that a stratigrapher would have used, which is to first designate biostratigraphic zones, then use the time span of the biostratigraphic zone to recognize a material chronostratigraphic unit, the time span of which would be designated the geochronologic unit.

The definition of biochronologic units versus geochronologic ones may well reflect the prevailing interests of vertebrate paleontologists in understanding evolutionary relationships during the 1930s and 1940s, rather than emphasizing geological relationships, though of course, the two are in fact intimately intertwined – the initial NALMAs were defined in the midst of the Modern Evolutionary Synthesis. A decade later, the NALMAs that cover the last half of the Pleistocene (the older Irvingtonian and younger Rancholabrean; Figure 1) were defined (Savage, 1951). By that time, vertebrate paleontologists were explicitly grappling with how land mammal ages aligned with biostratrigraphic units and, indeed, whether or not they were even biochronologic units (Savage, 1951).

It was later pointed out (Woodburne, 2004a, 2006), however, given that recognizing the evolutionary progression of fossil mammals relied on determining their distribution through strata, the land mammal ages were essentially grounded in biostratigraphic assemblage zones, although such zones were not specified. Subsequent work more rigorously characterized some of the NALMAs and portions thereof as formal biostratigraphic units by applying strict stratigraphic methodology (Woodburne, 2004a).

Current practice is still to regard land mammal ages as biochronologic units, although now first-appearance data are considered the best way to assign beginning and end points to the time intervals (Woodburne, 2004b, 2006). Thus, ideally, the beginning of each land mammal age is defined by the first appearance of a single mammal taxon – either an immigrant or a newly evolved species – and the end of an age is defined at the beginning of the superjacent one. This approach is analogous to how biostratigraphic interval zones are defined; the difference being, with biostratigraphic interval zones, the defining taxa demarcate a physical entity, and with biochronologic units, the defining taxa demarcate the time that subsequent taxa first appeared. In defining a land mammal age, it is also customary to specify which taxa first appear within it (in addition to the boundary-defining taxon), which taxa go extinct and which genera or species are common in fossil deposits of that age.

It is important to recognize that, in the absence of independent dating to assign a numerical age to their boundaries, NALMAs indicate only the relative order of time slices, that is, which times were younger and which were older. Determining how old a given NALMA is – that is, when it begins and ends in terms of years before present – is a separate process from actually defining the NALMA, and relies on associating the fossils that document earliest records of the defining taxon with materials that can provide a numerical age-determination. The numerical dating is typically provided by radioisotopic techniques such as K-Ar, Ar-Ar, or magnetostratigraphy for older NALMAs, or U-series or radiocarbon dating for youngest NALMAs. Because the definition of the NALMA is decoupled from dating it, the numerical age of a NALMA can change without affecting its definition. Typically, such changes occur because new specimens of defining taxa are discovered and/or are associated with better numerical dates. In theory, it would be possible to fix boundaries at key localities and/or at agreed-upon dates (the 'golden spike' approach of designating a Global Boundary Stratotype Section and Point and/or Global Standard Stratigraphic Age), but such efforts have not yet been undertaken.

By convention (Savage, 1951; Wood et al., 1941; Woodburne, 2004a, 2004b, 2006), the name of a NALMA is derived from a geographic location that contains a particularly good example of a fossil assemblage characteristic of the age (notably, this is seldom the site that contains the first appearance of the defining taxon). See Woodburne (2006) for additional considerations and requirements, to which we adhere in defining the NALMAs presented here.

## Santarosean North American Land Mammal Age

The name Santarosean is derived from Santa Rosa Island, California, where the Arlington Springs site has yielded some of the oldest directly dated human bones in North America (Erlandson et al., 2011; Goebel et al., 2008; Johnson et al., 2002; Waters and Stafford, 2007), domestic dogs *Canis lupus familiaris* (Rick et al., 2008) and taxa that last appear in this NALMA (*Mammuthus* and *Peromyscus nesodytes*) (Agenbroad, 2001; Rick et al., 2005, 2008). Santa Rosa Island was less separated from the mainland and contiguous with the adjacent Channel Islands when its earliest known humans arrived, because sea level was lower. As sea level rose, human occupation continued as the islands became disconnected from each other; the complex of archaeological sites on both Santa Rosa and the other Channel Islands records one of the most continuous sequences of human habitation from some 13,000 years ago into the latest Holocene. The archaeological evidence also is associated with fossils of terrestrial mammals, marine mammals and invertebrates (Erlandson et al., 2011; Rick et al., 2005), an association critical to correlating the newly defined NALMA to other biostratigraphic, geochronologic and archaeological timescales. This wealth of relevant data from the region makes Santa Rosa Island an ideal name-bearer for the newly defined land mammal age. Other sites (notably Anzick and Paisley Caves, see below), while candidates based on early occurrence of humans, exhibit a less rich suite and/or less continuous published record of associated taxa.

The beginning of the Santarosaean NALMA is set at the earliest appearance of *Homo sapiens* in North America south of 55°N (Table 1). We follow standard practice for defining NALMAs by specifying a latitudinal boundary (Bell et al., 2004). Domestic dogs, *C. lupus familiaris*, also appear in North America first during the Santarosean (Morey and Wiant, 1992; Rick et al., 2008) (Table 1).

The beginning of the Santarosaean – immigration of *Homo sapiens* into central North America – is well documented by many sites that contain unequivocal evidence of human presence associated with radiocarbon dates ranging from about 14.9 to 10.2 thousand years ago (Figure 2). (Throughout this paper radiocarbon dates are expressed in calendar years before present as calibrated using the Oxcal IntCal 13 curve.) The oldest well-substantiated dates on a human bone come from two sites. From one of them, the Anzick site in western Montana (Figure 2), an infant skeleton yielded an AMS $^{14}C$ date of 12,722–12,590 cal. yr BP (Rasmussen et al., 2014). The second date comes from Arlington Springs, which is located on Santa Rosa Island, California, the name-bearer for the new NALMA. Arlington Springs produced several human femur fragments (presumably from the same femur) that yielded dates ranging from 8982–8426 cal. yr BP (Johnson et al., 2002; Waters and Stafford, 2007) to 13,014–12,709 cal. yr BP (Erlandson et al., 2011; Goebel et al., 2008; Johnson et al., 2002). The oldest age-range is thought to be the most reliable because the bone fragment that yielded that date (13,014–12,709 cal. yr BP) was better preserved than other dated parts of the femur, and the femur was associated with a well preserved rodent jaw that produced a concordant date (Johnson et al., 2002) (and see Table 2).

The age determination for nearly all other early-human sites in North America relies on dating materials associated with archaeological evidence. Typically the dates are on charcoal, non-human bone, or wood that is found in stratigraphic proximity to human-made artifacts. Many of these dates cluster between about 12.6 and 13.0 thousand years old, and several are associated with Clovis artifacts (as is the Anzick infant), suggesting that the Clovis culture was widespread during an interval that lasted up to 400 years (Gilbert et al., 2008; Goebel et al., 2008; Meltzer, 2009; Waters and Stafford, 2007). The oldest dates that are widely accepted for human presence in central North America come from coprolites – purported to be human because they yield human as well as wolf ancient-DNA (Gilbert et al., 2008) – that were excavated from Paisley Caves, Oregon. These dates would place humans in Oregon by 14.1 thousand years ago, and possibly as early as 14.9 thousand years ago. Given that humans were certainly widespread in central North America by about 12.6 thousand years ago, and that Paisley Caves and other sites (Gilbert et al., 2008; Goebel et al., 2008; Meltzer, 2009) suggest pre-Clovis presence by at least 14,000 years ago, we provisionally set the beginning of the Santarosean at 14,000 years before present, recognizing that with more discoveries and dates, its inception may well be shown to be a few hundred years (or perhaps even more) older.

Extinctions of mammals within the Santarosean NALMA include many genera of megafauna and a few small-bodied mammal species. The megafaunal extinctions of at least 17 radiocarbon-dated genera occur between the time humans first entered central North America and approximately 10,000 years ago (Barnosky et al., 2004; Grayson, 2007; Koch and Barnosky, 2006) (Table 1). Therefore it is possible to recognize an early and a late phase for the Santarosaean; the early phase is characterized by the co-occurrence of *Homo sapiens* with now-extinct megafauna of the genera *Arctodus* (short-faced bear), *Bootherium* (Harlan's musk ox), *Camelops* (camel), *Castoroides* (giant beaver), *Cervalces* (stag moose), *Equus* (native North American horse), *Euceratherium* (shrub ox), *Paramylodon* (ground sloth; earlier taxonomies consider this *Glossotherium*), *Mammut* (mastodon), *Mammuthus* (mammoth), *Megalonyx* (Jefferson's ground sloth), *Mylohyus* (Long-nosed peccary), *Nothrotheriops* (Shasta ground sloth), *Palaeolama* (stout-legged llama), *Platygonus*

**Table 1.** Newly defined North American Land Mammal Ages (NALMAs). The taxa listed under 'Common mammal taxa' are not exhaustive; only some very common representative genera are listed. In general, see Tables 2–5 for details and references.

| | NALMA | | |
|---|---|---|---|
| | Santarosean | | Saintaugustinean |
| | Early | Late | |
| **Start date** | 14 kya | 10 kya | AD 1540 |
| **Defining taxa** | *Homo sapiens* | *Homo sapiens* | *Equus caballus* |
| **First appearances** | *Homo sapiens* | *Canis familiaris* | *Bos taurus, Capra hircus, Felis catus, Mus musculus, Myocastor coypus, Oryctolagus cuniculus, Ovis aries, Rattus norvegicus, Rattus rattus, Sus scrofa* |
| **Common mammal taxa** | Extinct megafauna such as *Camelops, Equus, Mammuthus, Mammut*, giant ground sloths, etc. Extant taxa such as *Lepus, Microtus, Neotoma, Odocoileus, Sylvilagus* | Extinct megafauna absent. Many extant native North American taxa such as: *Canis, Castor, Cervus, Homo, Lepus, Microtus, Neotoma, Peromyscus, Odocoileus, Spermophilus, Sylvilagus*, etc. | Same as for Late Santarosean |
| **Last appearances** | **Arctodus, *Bootherium, Bretzia, *Camelops, §Capromeryx, *Castoroides, *Cervalces, *Equus, §Eremotherium, ¶Euceratherium, §Glyptotherium, §Hemiauchenia, *Mammut, *Mammuthus, §Megalonyx, §Miracinonyx, *Mylohyus, §Navahoceras, Neochoerus, *Nothrotheriops, Oreamnos harringtoni, *Palaeolama, §Pampatherium, *Panthera, *Paramylodon, *Platygonus, Saiga, *Smilodon, §Stockoceros, *Symbos, *Tapirus, §Tetrameryx, Torontoceros, §Tremarctos* | *Ochotona whartoni, Peromyscus nesodytes* | *Canis rufus, Dipodomys gravipes, Geomys pinetis goffi, Microtus ochrogaster ludovicaianus, Monachus tropicalis, Mustela nigripes, Neotoma anthoni, Neotoma bunkeri, Neotoma martinensis, Neovison macrodon, Peromyscus pembertoni, Peromyscus polionotus decoloratus, Peromyscus alticolus alticolus, Puma yagouroundi, Sigmodon arizonae arizonae, Sigmodon fulviventer goldmani, Sorex ornatus juncencis* |

*Notes*: For last appearances in the early Santarosean:
*Indicates genera for which robust radiocarbon dates indicate last records between 14 and 10 kya.
§Indicates genera for which radiocarbon dates have a reasonable probability of being older than 14,000 years, that is, the 95.4% probability range for calibrated dates extends beyond, or the entire range is older than, 14,000 years.
¶Indicates genera that have produced calibrated dates for which the 95.4% probability range extends younger than 10,000 years.
Genera without symbols do not have well-substantiated published radiocarbon dates.

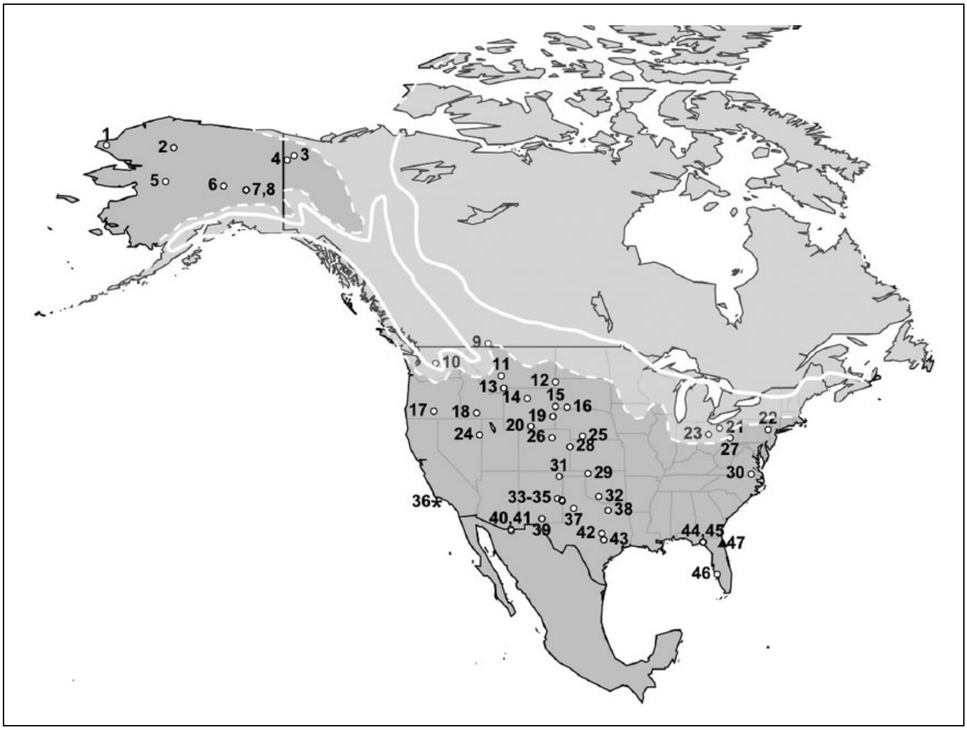


**Figure 2.** Map of North America showing localities relevant to the establishment of the new NALMAs. White dots indicate sites that document human presence between 14.9 to 10.2 thousand years ago. The * indicates Arlington Springs on Santa Rosa Island, namesake locality for the Santarosean NALMA; the **Δ** indicates Saint Augustine, Florida, namesake locality for the Saintaugustinean NALMA. Lighter gray indicates area covered by glacial ice at the height of the last glacial (dotted white line), and at about 14,000 years ago when the Santarosean commenced (solid white lines). 1: Tuluaq, AK; 2: Mesa, AK; 3: Old Crow, Canada; 4: Bluefish Caves, Canada; 5: Nogahabara, AK; 6: Nenana, AK; 7: Swan point, AK; 8: Broken Mammoth, AK; 9: Wally's Beach, Canada; 10: East Wenatchee, WA; 11: Indian Creek, MT; 12: Mill Iron MT; 13: Anzick, MT; 14: Colby, WY; 15: Sheaman WY; 16: Lange-Ferguson, SD; 17: Paisley Caves, OR; 18: Buhl, ID; 19: Hell Gap WY; 20: Union Pacific, WY; 21: Paleo Crossing, OH; 22: Shawnee-Minisink, PA; 23: Sheriden Cave, OH; 24: Bonneville Estates, NV; 25: La Sena and Lovewell, NE; 26: Dent, CO; 27: Meadowcroft, PA; 28: Kanorado, KS; 29: Jake Bluff, OK; 30: Cactus Hill, VA; 31: Folsom, NM; 32: Domebo, OK; 33: Clovis, NM; 34: Blackwater Draw, NM; 35: Arch Lake, NM; 36: Arlington Springs, CA; 37: Lubbock Lake, TX; 38: Aubrey TX; 39: Pendejo Cave, NM; 40: Murray Springs, AZ; 41: Lehner, AZ; 42: Gault, TX; 43: Wilson-Leonard, TX; 44: Sloth Hole, FL; 45: Page-Ladson, FL; 46: Warm Mineral Springs, FL; 47: Saint Augustine, FL.

(flat-headed peccary), *Smilodon* (saber-tooth cat), and *Tapirus* (tapir). Of those, all but *Bootherium, Mylohyus, Nothrotheriops, Cervalces* and *Casteroides* have been reported to be associated with evidence of humans in archaeological sites, though the strength of association in some cases is uncertain (Boulanger and Lyman, 2014; Grayson and Meltzer, 2002, 2003). Other megafauna taxa listed in Table 1 either have youngest radiocarbon dates that are older than 14,000 years, or have not produced dates. It is unknown whether those taxa were present when the first humans entered North America; more radiocarbon dates are needed to determine this. The available radiocarbon dates indicate that the early phase of the Santarosean spans from at least 14,000 (and probably

**Table 2.** Radiocarbon dates pertinent to establishing earliest human presence at Arlington Springs, Santa Rosa Island.

| Material dated/stratigraphic context | $C^{14}$ age | Plus/minus | IntCal 13 calibration | Source |
|---|---|---|---|---|
| Femur fragment (A) CAMS-13055 | 7830 | 110 | 8982–8426 | (Johnson et al., 2002) |
| Femur fragment (A) CAMS-16814 | 9180 | 70 | 10,520–10,225 | (Johnson et al., 2002) |
| Femur fragment (B) CAMS-16810 | 10,960 | 80 | 13,014–12,709 | (Johnson et al., 2002) |
| Charcoal from same stratum as human bone (CAMS-13036) | 10,090 | 70 | 11,989–11,345 | (Johnson et al., 2002) |
| *Peromyscus nesodytes* mandible from soil matrix around human femora (CAMS-17125) | 11,490 | 70 | 13,468–13,181 | (Johnson et al., 2002) |
| Soil layer above human bone | not reported | not reported | ~12,900 (?) | (Johnson et al., 2007) |
| Upstream alluvial deposits thought to correlate with human bone-bearing layer | 10,860 | 70 | 12,917–12,666 | (Johnson et al., 2007) |
| Charcoal from organic earth in contact with human bone (L-568-A) | 10,400 | 2000 | 19,780–7843 | (Orr, 1960, 1962a, 1962b) |
| Charcoal from 1 foot away (L-650) | 10,000 | 200 | 12,250–11,079 | (Olson and Broecker, 1961; Orr, 1962a, 1962b) |
| Long bone fragment (UCLA-1899) | 10,080 | 810 | 13,650–9551 | (Berger and Protsch, 1989) |
| Charcoal from stratum beneath that in which human bone was found (UCLA-748) | 11,300 | 160 | 13,452–12,814 | (Berger and Libby, 1966) |

*Notes*: Johnson et al. (2002) reviewed the radiocarbon dates that have been cited for establishing earliest human presence at Arlington Springs and reported those listed in the first five rows of this table. Dates obtained in the 1960s and 1980s are less reliable than those obtained in the Johnson et al. (2002) study because of improvements in analytical technique; in addition, the dates obtained in the 1960s and 1980s are from materials associated with human occupation, rather than from human bones (an exception might be UCLA-1899, though the taxon is not specified). Johnson et al. (2002) considered CAMS-16814 and CAMS-16810 to be the most reliable dates because they were on XAD-decalcified collagen. The differences in age, even though the samples come from the same femur, are due to differential preservation in different parts of the bone. The most ancient date on the femur (CAMS-17125) is concordant with one obtained from an even better preserved *Peromyscus* mandible (CAMS-17125) that was found in the same sediment block as the dated femur fragments. Meltzer (2009) noted that the human individual that was dated may have fed on marine organisms, which can skew a radiocarbon age; however, the agreement between the dates on human bones and the surrounding charcoal and *Peromyscus* bones suggests this source of error may not be significantly influencing the dates.

somewhat older, as noted above) to approximately 10,000 years ago (recognizing that additional radiocarbon dating efforts may well adjust the numerical age of this boundary). The late phase of the Santarosean is characterized by the occurrence of *Homo sapiens* but the absence of the extinct megafauna genera noted above. The late phase and the entire Santarosean NALMA terminates with the first appearance of domesticated megafauna in mid-latitude North America, which marks the beginning of the following NALMA, the Saintaugustinean.

**Table 3.** Summary of faunal information from 16th-century Saint Augustine. The table lists taxa represented by mammal bones found at archaeological sites. This information is based on excavations at six different sites: Lorenzo Joseph De Leon (SA 23-1), Lester's Gallery (SA 29-2), Episcopal Church (SA 31-1), Ximenez-Fatio (SA 34-2), Public Library site (SA 34-3) and Francisco Ponce de Leon (SA 36-4). (Reitz and Scarry, 1985).

| Taxa | Lorenzo Jose De Leon | Lester's Gallery | Episcopal Church | Ximenez-Fatio | Public Library site | Francisco Ponce de Leon |
|---|---|---|---|---|---|---|
| *Bos taurus* | x | x | x | x | x | x |
| *Canis familiaris* | x | | | | | |
| Capra/Ovis | x | | | | | |
| *Didelphis virginiana* | x | | x | | | |
| *Felis dometicus* | x | | x | x | | x |
| *Odocoileus virginianus* | x | x | x | x | | x |
| *Procyon lotor* | x | | x | x | | x |
| *Rattus rattus* | x | | x | | x | |
| *Scalopus aquaticus* | | | | x | | |
| *Sciurus* spp. | x | | | | | x |
| *Sigmodon hispidus* | x | | x | | | |
| *Sus scrofa* | x | x | x | x | x | x |
| *Sylvilagus* spp | x | x | x | | x | x |

*Notes*: Pedro Menendez de Aviles founded Saint Augustine in 1565. The ship that departed from Spain, which he commanded, was noted to have: 'One hundred horses and mares, two hundred calves, four hundred swine, four hundred sheep and some goats, and all the other cattle and livestock that shall seem proper to you' (Solís de Merás, 1923). Horse bones are rare in these archaeological sites because they were not typically used for food. The only horse remains are horse hairs from the Francisco Ponce de Leon site (SA 36-4) reported in (Deagan, 1978). Deagan (1978), citing Eugene Lyon, also mentions the presence of horsehair sieves in a 16th-century household inventory. The most abundant domestic animals found in the archaeological assemblages were pigs. Sheep and goats were introduced when St. Augustine was founded, but their establishment was not successful because of environmental conditions and they are not common in archaeological faunal assemblages at this time (Reitz and Scarry, 1985). Sixteenth-century affiliation of the materials has been made based on two criteria: 'Deposits had to originate at or below the earliest occupation level at the site' and were associated with ceramics that predated 1600 (Deagan, 1978).

## Saintaugustinean North American Land Mammal Age

The beginning of the Saintaugustinean NALMA is defined by the first immigration of domesticated horses, *Equus caballus*, north of Mexico (25°N latitude). Other first appearances in the Saintaugustinean include *Bos primigenius* (domesticated cow), *Capra hircus* (domesticated goat), *Ovis aries* (domesticated sheep), *Sus scrofa* (domesticated pig), *Rattus norvegicus* (Norway rat), *Mus musculus* (house mouse) and *Felis catus* (domesticated cats) (Table 1) (Arnade, 1961; Crosby, 2003). The namesake for the NALMA is Saint Augustine, Florida, where Spanish colonizers established a settlement in 1565 that continues to be occupied today (Deagan, 1978), and from which archaeological and historical records document most of the taxa noted above (Reitz, 1992) (Tables 3, 4). Characteristic taxa include the suite of species that are still extant today (Kays and Wilson, 2002). Extinctions during the Saintaugustinean include *Neotoma anthoni* (Anthony's wood rat), *Neotoma bunkeri* (Bunker's wood rat), *Neotoma martinensis* (San Martín Island wood rat), *Neovison macrodon* (sea mink) and *Peromyscus pembertoni* (Pemberton's deer mouse), among others (IUCN, 2014) (Tables 1, 5).

Domesticated *Equus caballus* is designated the defining taxon because of its widespread occurrence in the paleontological and archaeological record, and because it is morphologically

**Table 4.** Summary of faunal information from 17th-century Saint Augustine. The table lists taxa represented by mammal bones found at archaeological sites. This information is based on excavations at two different sites: Ximenez-Fatio (SA 34-2), Public Library site (SA 34-3) and Francisco Ponce de Leon (SA 36-4) (Reitz, 1992). The two sites excavated here are the same sites studied for the 16th-century under the same name.

| Taxa | Ximenez-Fatio | Francisco Ponce de Leon |
|---|---|---|
| *Bos taurus* | x | x |
| Caprine, Sheep/Goat | x | |
| *Equus caballus* | | x |
| *Odocoileus virginianus* | | x |
| *Procyon lotor* | x | |
| *Rattus* | x | |
| *Scalopus aquaticus* | x | |
| *Sciurus niger* | x | |
| *Sus scrofa* | x | x |
| *Sylvilagus palustris* | x | |
| *Sylvilagus* spp. | x | x |
| *Urocyon cinereoargenteus* | | x |

*Notes*: By the 17th century cattle ranches were established at St. Augustine and surrounding areas (Arnade, 1961). Reitz (1992) mentioned that horses and caprines were raised in the town or in nearby areas, but to a limited extent. Horses were a mark of status and their remains would be rare in midden deposits (Bushnell, 1981). *Ovis aries* and *Capra hircus*: Sheep and goats are difficult to identify from each other from their bone remains and usually are listed just as Caprine.

distinguishable from native North American Pleistocene horses (e.g. those that went extinct in the early Santarosaean) through characteristics of the mandible, cranium and in some cases tooth wear associated with biting a bit (Figure 3). The introduction of domestic *Equus caballus* into the Americas is well documented through historical records that date the beginning of the Saintaugustinean NALMA fairly precisely. By 1494, Spanish explorers had off-loaded horses onto islands in the Caribbean (Johnson, 1943), and by 1519, 16 horses had been ridden to the present site of Mexico City (Robinson, 2004). In 1539, the DeSoto expedition took 223 horses from Florida to Mississippi, and in 1540 the Coronado expedition, with their horses and other domesticated stock, penetrated into northern Mexico, Arizona and New Mexico (Chard, 1940; Haines, 1938; McKnight, 1959; Winship et al., 1896). This is the earliest documented introduction of domesticated horses that established a lasting breeding stock north of 25°N latitude; the horses, sheep and other domesticated animals the European explorers and colonizers introduced became incorporated into the lives of various Native American inhabitants. We therefore regard 1540 as the beginning of the Saintaugustinean NALMA. Lasting populations of horses, sheep, goats and pigs were established in Saint Augustine, Florida, when it was settled in 1565 (Arnade, 1961; Deagan, 1978; Reitz, 1992) (Tables 3, 4), by which time domesticated horses were well established in northern Mexico and southwestern USA.

## Implications of recognizing new NALMAs

Previously, the sequence of NALMAs ended with the Rancholabrean, which has generally been regarded as the time when the North American mammal fauna took on a modern aspect as indicated by the common occurrence of extant species (Bell et al., 2004; Savage, 1951). However, for about 95% of the Rancholabrean as previously defined, the fauna contained at least 60 extinct

**Table 5.** Species extinctions and extirpations in the Saintaugustinean. Data from IUCN Red List of Threatened Species (IUCN, 2014).

| Taxon | Date of extinction or extirpation | Global extinction species | Global extinction subspecies | Extirpated between 55° and 25° N latitude | Comment |
|---|---|---|---|---|---|
| *Canis rufus* | 1980 | Y | | | Re-introduced to North Carolina after going extinct in the wild |
| *Dipodomys gravipes* | 1986 | Y (possibly) | | | Listed as CR possibly extinct not seen since 1986 despite surveys |
| *Geomys pinetis goffi* | ? | | Y | | |
| *Microtus ochrogaster ludovicianus* | ? | | | Y | |
| *Monachus tropicalis* | 1952 | Y | | | |
| *Mustela nigripes* | 1987 | | | Y | Extinct in the wild 1987 – current pops are all re-introduced |
| *Neotoma anthonyi* | ? | Y | | | No sightings since at least 2000 |
| *Neotoma bunkeri* | ? | Y | | | No sightings since at least 2000 |
| *Neotoma martinensis* | ? | Y | | | No sightings since at least 2000 |
| *Neovison macrodon* | 1894 | Y | | | |
| *Peromyscus alticolus alticolus* | 1930 | | Y | | |
| *Peromyscus polionotus decoloratus* | ? | | Y | | |
| *Peromyscus pembertoni* | 1931 | Y | | | |
| *Puma yagouroundi* | ? | | | Y | |
| *Sigmodon arizonae arizonae* | ? | | Y | | |
| *Sigmodon fulviventer goldmani* | ? | | Y | | |
| *Sorex ornatus juncencis* | ? | | Y | | |

megafauna species – most of them likely playing important roles in structuring regional and local ecosystems, as inferred from the ecological effects of extant large mammals (Estes et al., 2011; Owen-Smith, 1987) – and the species most characteristic of mammal faunas of modern aspect, *Homo sapiens*, was absent. Therefore, formally recognizing the Santarosean and Saintaugustinean also gives the Rancholabrean coherency, by characterizing it as the last mammal faunas in North America that were not anthropogenically modified, rather than lumping the human-impacted faunas (Alroy, 2001; Koch and Barnosky, 2006) of the last temporal sliver of the Rancholabrean in with the pre-human faunas that comprise the vast majority of that NALMA. In addition, with definition of the more recent NALMAs discussed in this paper, the endpoint of the Rancholabrean becomes tightly placed at the immigration of a single taxon (*Homo sapiens*) into central North America, a procedure that conforms with the method used to define endpoints of all other NALMAs.

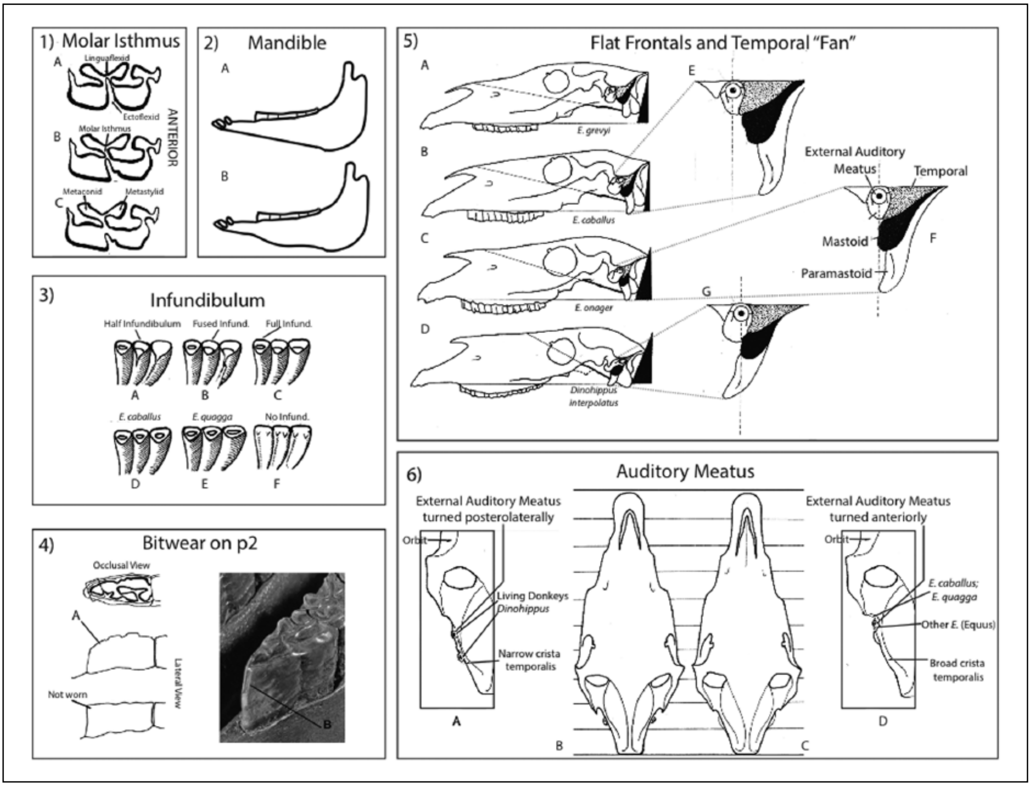


**Figure 3.** Morphological characters used to distinguish *Equus caballus* from Pleistocene Equus; drawings from Bennett (1980) and Brown and Anthony (1998). 1: A molar isthmus is present on the m3 in middle wear (A, B) and ectoflexids do not pass through it fully (C). 2: The mandible is relatively flat along the ventral borders of the horizontal rami (A) as opposed to dorsoventrally convex rami, with the deepest part of the jaw located ventral to the middle of the cheek tooth row as seen in Pleistocene *Equus* (B). 3: Full infundibulum in all lower incisors (D) and i3 is not elongate as seen in *E. quagga* (E). 4: Bitwear: p2 beveling – pitted and worn wear on the anterior 1/3 portion of the occlusal surface (see Brown and Anthony, 1998 and Anthony et al., 2006 for how to measure beveling); p2 anterior (nonocclusal) wear pattern (B), image from Scott et al. (2010). 5: Flat frontals across the dorsal surface (B) as opposed to frontal doming (A); Low basicranial flexion and small occipital angle (B) as opposed to high basicranial flexion and a large occipital angle (C, D); mastoid, paramastoid and temporal 'fan' is opened and mastoid has broad visible contact with the crista temporalis (E) as opposed to a closed 'fan' (G). 6: External auditory meatus turned anteriorly and close behind the glenoid (E) as opposed to angled posteriorally (A) as seen in living donkeys and *Dinohippus* or positioned posteriorally as seen in all other *E.* (Equus) (D); paramastoid processes and the mastoid portion of the temporal bone can be clearly observed in dorsal view lateral to the crista temporalis even though the crista temporalis is broadened (C). This differs from the external auditory meatus being visible in dorsal view due to narrow crista temporalis (B).

Until now, the Rancholabrean has had a diachronous and somewhat amorphous endpoint defined generally as at the extinction of the Pleistocene megafauna (Bell et al., 2004), which as presently known may span several thousand years in North America (Grayson, 2007; Grayson and Meltzer, 2003; Koch and Barnosky, 2006), although as noted above, the majority of well-dated last records of genera cluster between 14,000 and 10,000 years ago.

The two NALMAs we define here also underscore three step-wise changes in mammal faunas of North America that occurred since c. 14,000 years ago, each of which reflects increasing anthropogenic influence in ecological structuring. The first is at the inception of the Santarosean, when a new megafaunal species – *Homo sapiens* – immigrated into the North American ecosystem, influencing the ecological network in major ways as a large predator and omnivore (Alroy, 2001; Barnosky, 2008). The second major modification is the transition from the early to the late Santarosean, marked by the extinction of at least 17 megafaunal species. Most recent work attributes at least some of these extinctions to human influence, although the intensity of the event was probably also exacerbated by climate change (Brook and Barnosky, 2012; Koch and Barnosky, 2006). After this, human population sizes continued to grow, as humans became the primary megafaunal species on the continent. The beginning of the Saintaugustinean heralds the onset of yet another significant faunal event, with the addition of several new megafaunal species – this time large animals bred to serve human needs.

While we focus on North America in this study, an increasingly well documented paleontological and archaeological record worldwide indicates that this three-step progression is characteristic of how mammal faunas have evolved on all continents, although the timing of human arrival, megafaunal extinction, rising importance of domesticated megafauna and species involved differ in each case. These last three steps in development of the existing mammal fauna are equal in magnitude and character to pre-anthropogenic faunal changes, which form the basis for clearly demarcating successive episodes of Cenozoic time and subdividing geological epochs. Therefore, our results also bear on the ongoing debate regarding whether humans have introduced a geological and paleontological legacy to the extent that designation of an Anthropocene epoch is warranted. First, at least in the paleontological record of North American mammals, an anthropogenic legacy is already evident, which suggests that the even more intense human impacts since onset of the Industrial Revolution will trigger yet another step-wise change; indeed, historic extinctions of mammals in North America (Table 5) and increased extinction risks worldwide indicate those impacts already are underway (Schipper et al., 2008). Second, the past step-wise changes in the mammal paleontological record highlight that the Anthropocene as presently conceived (Steffen et al., 2011a; Waters et al., 2013; Zalasiewicz et al., 2012) had an important prelude: anthropogenically induced changes to the Earth system began long before human impacts intensified over the past two centuries (Foley et al., 2014). We suggest that recognizing this prelude is essential to inform discussions about whether the Anthropocene merits designation as a geological epoch, when the Anthropocene actually began (whether or not it attains formal epoch status), and how the biosphere has evolved as a result of human activities on Earth.

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*Perspectives and controversies*

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# Map stories can provide dynamic visualizations of the Anthropocene to broaden factually based public understanding

**Andrew Zolnai**

**Abstract**

Provision of broadly accessible and spatially referenced visualizations of the nature and rate of change in the Anthropocene is an essential tool in communicating to policy makers and to the wider public, who generally have little or no contact with academic publications and often rely on media-based information, to form and guide opinion. Three examples are used to demonstrate the use of geo-referenced data and GIS-based map compilations to provide accurate and widely accessible visual portrayals of historical processes. The first example shows the spread of Neolithic agriculture from Mesopotamia west and north across Europe over several millennia. The second plots the history of the drainage of the Fens (wetlands) in eastern England from the early seventeenth century onward. A third example illustrates one way in which releasing data in the public domain can lead to the enhancement of public data holdings. A concluding discussion outlines ways in which the methodology illustrated may be applied to processes key to understanding the Anthropocene.

**Keywords**

Anthropocene processes, data-based visualization, geographic information systems (GIS), map stories, public understanding

## Introduction

Many non-specialists, who have an interest in current environmental change and its likely future consequences, gain their insights and form their opinions on the basis of what appears in the media or is available via the internet. Both sources of information can be readily manipulated by those with a vested interest in promoting a particular point of view. It follows that the quality of information that is beyond specialist, peer-reviewed literature and is openly available, should be

Wipro Ltd, UK

**Corresponding author:**
Andrew Zolnai, 27 Beach Road, Wipro UK Ltd, Cottenham, Cambridge CB24 8RG, UK.
Email: aizolnai@gmail.com

authoritative, readily understandable and transparent with regard to sources and their validity. One of the aims of a transdisciplinary journal concerned with the Anthropocene must be to widen the access to factually based reconstructions of key processes in ways that demonstrate their nature, rate and spatially differentiated impacts. The present contribution to the journal's 'Perspectives' theme is presented with this aim in mind. Two linked and complementary goals are involved – the portrayal of the results derived from specialist research in ways that make them understandable for a non-specialized audience, and the development of modes of information diffusion that essentially democratize the understanding gained. This article illustrates a methodology, familiar to a growing number of environmental scientists, which has the potential to achieve both these goals. The examples used are contrasted in terms of the processes, timescales and impacts involved. They serve to illustrate the scope of the approach used and its applicability to a wide range of changes, processes and impacts key to understanding the role of human activities in the Earth system in the past, at present and in the future. A third example illustrates the positive role that the technology now available can play in augmenting and enhancing existing government agency data holdings.

## *The nature of the technology*

Twenty-five years ago, Ray Price (1989) noted that 'human activities now involve an annual flux of earth materials equal to that of plate tectonics'. While he did not comment on when that influence started, he also stated that 'new technologies for digital data bases and for digital geoscience maps and sections offer exciting new prospects for better integration and analysis of geoscience data, even on a global scale'. The technology now available makes this readily achievable.

First there is the huge volume of ongoing research and publication in fields ranging across the humanities, social and environmental sciences. Some of the results appear in peer-reviewed journals, others in current affairs media. Many are illustrated by figures and maps that use geographic boundaries, basic cultural features such as rivers, roads and cities, and relevant administrative boundaries such as countries, states or counties, depending on location. A recent trend has emerged to put many such studies in broader and more fully articulated spatial and social contexts. This stems partly from the increasingly interdisciplinary nature of many studies. As location is often the common underpinning, it makes sense to use maps as the common platform upon which to post all the information. The next section will show how the use of spatially referenced data spanning a wide range of social or environmental information can tease out relationships that were obscured when it was tabulated without its geographic context. Martin Lewis (*Geocurrents* 2014) a geohistorian at Stanford University took pains to illustrate his research in maps, and to popularize it via his blog. His work includes examples where his ability to embed spatially referenced results in a fuller context allows him to correct reports and resultant misconceptions popularized in the press – for example Lewis (2012) rectifies recent research throwing new light on the sensitive topic of Indo-European racial and linguistic origins.

A great deal of research data is in the public domain, and is available online barring publication, copyright and media barriers. Recently, governments have also been releasing their geographic data into the public domain (Ordnance Survey, 2010), so that the geographic reference information is widely available to the public; and where that is neither complete nor available, 'crowd sourcing' by soliciting contributions especially from an online community has started to fill in the gaps (British Library, 2014). Hardware and software to personally publish this information has also become more affordable if not free. Personal computers can now handle data of virtually any size; the web allows data users to access and distribute the same.

The current scope of digital mapping allows the precise location of data and offers the means to illustrate spatial, temporal and attribute relationships. Last but not least, there is an increasing library of free data available on the web that allows the posting of geo-referenced data against relevant backdrops that set the context for the data.

One of the main ways to process and display these maps today is through the use of 'geographic information systems' (GIS) that are designed to capture, store, manipulate, analyse, manage and present all types of geographical data. Their use in scientific literature has increased rapidly in recent years, often in combination with 'DEMs' (digital elevation models or 3D representation of a terrain's surface) and other Remote Sensing products such as satellite imagery, air photos and 'LiDAR' (a detection system which works on the principle of radar, but uses light from a laser). Some sense of the scope and breadth of applications can be gained from examples such as Yang (2009), Wilson et al. (2004), Nettley et al. (2013) and the many products of ESRI (www.esri.com). Most examples deal with contemporary trends and their future implications for vulnerability and management, though there are rarer examples documenting past changes (Salzer and Bunn, 2012/2013).

A second vital tool is 'web mapping service' (WMS), a standard protocol to serve over the Internet geo-referenced map images that are generated by a map server using data from a GIS. The first thrust of this paper is that (a) GIS offers new ways to combine, analyse and display the maps and data, and (b) WMS offer new ways to publish the same data, not only for widespread public access but also in a way that engages experts, stakeholders and the public alike. The second thrust of this paper is that both GIS and WMS greatly enhance the scope for an informed public debate on the key issues that Anthropocene studies will raise.

Two contrasted examples are used below to illustrate the power of this approach. In terms of time frames, they are drawn from the Neolithic and the pre-/post-Industrial Revolution period. They are used to show how GIS and WMS in combination can help make processes, changes and problems in the Anthropocene visually accessible, whilst maintaining the integrity of the historical data, thus underpinning broader understanding and rational discourse. A third example shows how making public the data used in such studies helps government custodianship and transparency of the critical underpinning of the studies.

## *The spread of Neolithic agriculture*

Although many researchers accept the original Crutzen and Stoermer (2000) definition of the Anthropocene, linking it to industrial development from around AD 1800 onwards, several authors, focusing on the gradual transformation of the Earth's surface through the development of agriculture, with the consequent impacts on atmospheric greenhouse gas concentrations, see the Anthropocene as beginning much earlier (Ruddiman, 2013). Key to their view of the Anthropocene is the spread of Neolithic agriculture from Mesopotamia west and north across Europe, a process spanning over 5 millennia.

Through detailed and intricate spatial interpolation, Pinhasi et al. (2005) discussed how early agriculture spread in the Neolithic (11,000–4500 BC) from Mesopotamia though the Middle East and Southern Europe to Northwest Europe. Whether 'indigenous and animated by imitation (cultural diffusion) or else […] driven by an influx of dispersing populations (demic diffusion)' (the authors suggest the latter), it pinpoints an early onset of 'the relationship between humans and their environment' through farming (Oldfield et al., 2013) – in other words a deep and lasting effect on the environment as opposed to, say, hunter-gatherers with less impact (Lee, 2005).

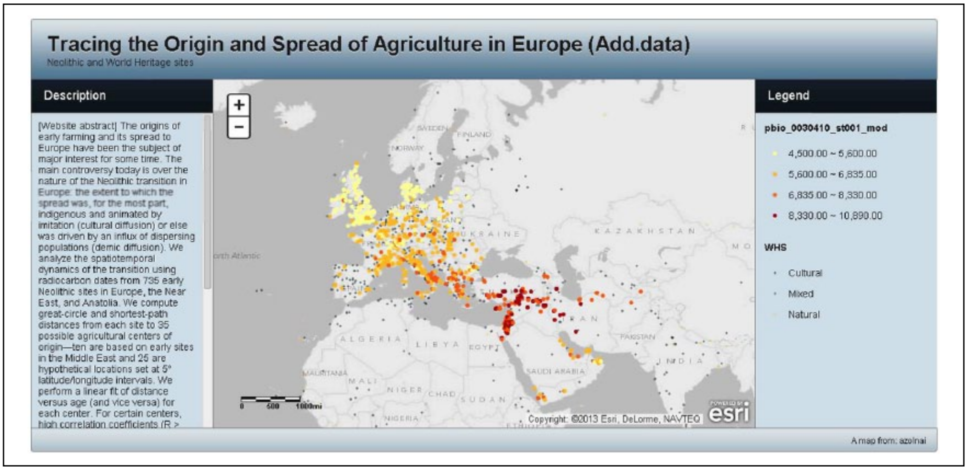


**Figure 1.** Data posted directly on the internet (Zolnai, 2012) from sources discussed in the text: this map story has the abstract at left, the map at centre and the legend at right. It is a synoptic view putting all information in the line of sight along with its geographical context. Panning left and right or zooming in and out helps orient the reader and facilitate a better grasp of the details.

But how are such intricate details effectively conveyed to others who do not have the background to grasp their significance, whilst maintaining geo-historical accuracy and promoting rational debate? The data themselves are in the public domain (Pinhasi et al., 2005), but accompanying maps are only accessible as images that do not lend themselves to further investigation. New tools are, however, at hand in the form of software that allows posting spreadsheet data on the internet. As long as there is a location attribute to pinpoint data on a map, these can then be transformed into 'map stories' that can communicate the meaning and significance in a form more readily engaging the attention of a non-specialist audience daunted by the original academic sources. Among the many options available, ESRI ArcGIS Online helps post maps directly on the internet (Figure 1).

## *The drainage of the English Fens*

One of the most distinctive landscapes of lowland Britain is that of the Fens, lying along the eastern edge of southern England. Geologically, they comprise areas of low-lying marine silt fringed landwards by extensive areas of peat. In their present form they are a man-made landscape resulting from extensive draining from the early seventeenth century onwards. The history of the drainage of the Fens as they evolved from medieval swamplands to drained fenlands before and after the English Civil War was documented by H C Darby (1969). Together with a companion book on the medieval fenlands, Darby's two books contain 25 and 35 map figures in 200 and 310 pages, respectively.

The recent release of Ordnance Survey (2010) OpenData has made it possible to post Darby's data from the figures in his two books. Parishes are the geographic units that have remained constant since the Middle Ages. OpenData now provides free infrastructure data such as counties and parishes, roads and rivers, etc. in digital map format. It is therefore easy to derive a local subset for the counties of East Anglia. As parishes were the constant geographic unit since Domesday, attributes were simply added to those map files and augmented with Darby's classifications. Data and details (Zolnai, 2011) are available on an Academic data share website and on ArcGIS Online.

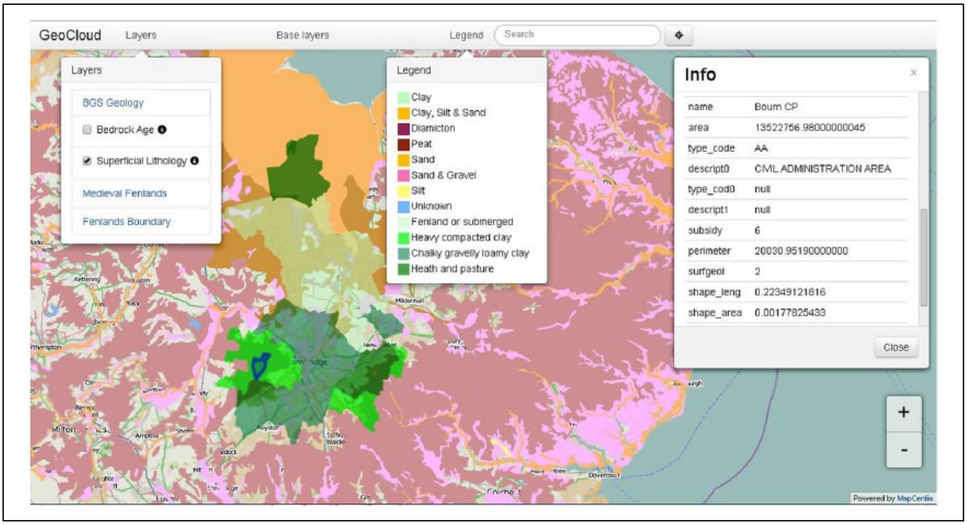


**Figure 2.** Data posted via web servers by publishing Amazon web service (Zolnai, 2011): when data become so comprehensive in their size and extent that a file service (Figure 1) is no longer enough, then a web mapping service will host as many layers as needed for the relevant context. Complete attributes and full attribution required by many data sources allow greater flexibility and full transparency so important to data journalism. Here the polygons from Darby's land polygons for ~AD 1800, are set against the British Geology Survey web services of the same area in the current era.

The British Geological Survey (2014) also released its bedrock and superficial geology data as files and as web services. These were readily combined with the above on a web map combining Mapcentia GeoCloud2 and Amazon Web Services (Figure 2), together with the all-important metadata posted right in the table of contents: 'Boundary Lines' from the Ordnance Survey must be attributed as part of the government's fair-use policy, and the metadata allow the viewer to explore and evaluate the origin and validity of the attribute data.

The 1794–1813 agricultural land cover was derived by assigning a land cover class per Parish from Darby's *The Draining of the Fens*. This land cover and the 1641 Lay Subsidy classes correlate quite well: this supports Darby's conclusion that the economic regime did not vary much after the Middle Ages. The 1877 and current superficial geology also correlate well (Figure 3), but subtle differences can be seen: silt and peat have similar extents, as do clay in the north, central and south-eastern Cambridgeshire, however the clay belt running SW–NE at centre appears to have shrunk significantly from the 1800 to the present, presumably as a result of the effects of cultivation where it forms only a thin layer overlying peat.

While it has been argued that the Industrial Revolution marks the onset of the Anthropocene, this study illustrates one way in which, at a regional level, significant human effects on the environment as the drainage of the Fens, started in pre-Industrial Revolution seventeenth-century East Anglia. It parallels some of the indications of early industry noted by Fischer-Kowalski et al. (2014).

## *Illustrating one benefit of placing data in the public domain*

The East Anglia Fenlands data set has had a varied history. It started as an aid to the Fens Historic Environment Project (Akeroyd et al., 2010) to do geo-historic research to help plan environmental

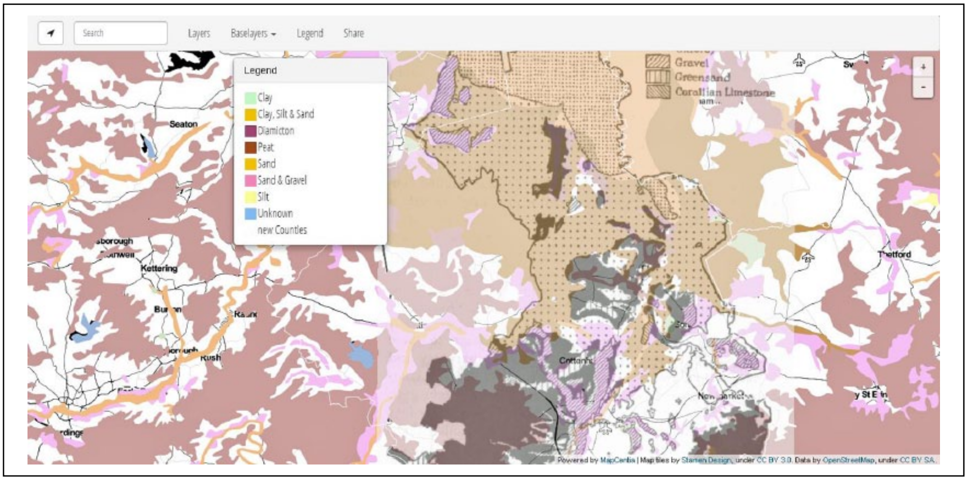


**Figure 3.** Cambridgeshire land cover history in 1877 and today (Zolnai, 2014): web services post geo-referenced maps (rubber-sheeted to the corresponding Parish boundaries), and show the greater details of the surficial geology as it evolves from 1877 to today, viz. peat areas are stable but clay areas have shrunk as pasture areas increase.

conservation and tourism in East Anglia. It survives as the Great Fen Action Plan (Great Fen Team, 2010), jointly supported by the UK government and Wildlife Trust. The maps were created in 2011 (Zolnai, 2011), when funding was cut and the project stalled. Whilst it amounted to a not-insignificant amount of volunteer work from the author, the free software (www.qgis.org) initially used allowed the GIS part to proceed without funding. All data were then posted on an academic share site (www.sharegeo.ac.uk) as industry-standard shape files under a Creative Commons license. Finally they were posted online as described in the previous paragraph using tools on Amazon Web Services on a 'freemium' model (initial use is free, then usage fees increment as pay-as-you-go, and generally remain nominal – most anti-virus software is free, for example, but a modest annual fee adds automatic upgrades and technical support).

The 1SpatialCloud has an online validation service[1] (Zolnai, 2013) the author helped test by running validation checks on: (a) attribute data that had been hand-entered by the author in the GIS, and (b) UK Ordnance Survey Parrish polygons to which attribute data were added. The manual data entry showed no errors, but the Ordnance Survey data did – communications with them showed that the errors found (submetric) fell below their quality control threshold (metres), but they invited the author to upload the corrected data for inclusion in the next government data repository upload in 2012 – the corrected Boundary Line vector data were downloaded and re-tested in 2013, and the number of errors dropped from 25 to 1 in 1900 polygons (Zolnai, 2013).

This is a success story of 'volunteered geographic information' (Goodchild, 2007) helping improve government data repositories. It illustrates how, in making data freely accessible, governments can foster cooperation through public input. Volunteer geography thus fosters public engagement in the process of government data custodianship in this simple example.

## *Summary and potential application to the Anthropocene*

These examples shown above illustrate a variety of ways in which the Anthropocene can be explained to and explored by the widest possible audience. In the first example, multiple data sets from a variety of sources have been combined; in the second case, material from a single major source has been compiled and combined with related, open access, geo-referenced data. The final section illustrates one way in which data quality can be enhanced by placing data in the public domain and making it widely accessible. They show that:

- Research published with geographic coordinates can be posted directly on web services and made into engaging web stories.
- Published figures can be added to administrative boundary data freely available from certain governments and combined into 'geo-history' maps.
- Freely available government data services can be used directly to display phenomena at the present day or from the recent past.

The methodology used here is in effect very simple:

- Harvest relevant material from specialist publications already available.
- Ensure that the metadata includes:
  - the detailed attribute information produced by research specialists in their own fields,
  - the exact geographic locations either from the data itself, or added to authoritative geographic data.
- Post the data on maps and/or on the internet for the broadest possible reach.

Some of the opportunities ripe for exploitation include the presentation of spatially disaggregated time series of the dramatic trends highlighted by Steffen et al. (2004) and taken as markers for the Great Acceleration. This could also reinforce the key point made by Malm and Hornberg (2013) in their counter to the view that Anthropocene is not, in terms of its human drivers, a global phenomenon. Similar treatment could be used to present integrated time series data on many of the contemporary issues such as resource depletion, energy use and environmental, including marine ecosystem damage.

This will ensure that the most authoritative data are published in a manner that is both fully transparent and as widely accessible as possible. Like all other presentation formats, map stories are open to distortion and manipulation. Complete transparency and full documentation of all metadata are therefore essential in order to allow critical evaluation of sources, questions of biased selectivity and misrepresentation.

The thrust of this 'perspectives' contribution is that publishing authoritative data in a readily accessible and engaging manner benefits both general public and researcher. Researchers see the chances of data corruption and misinterpretation reduced, and the public sees their understanding and trust increased; both sides can thus foster real debate based on accessible, authenticated data, thereby promoting 'data democracy': that may well become the single best way, alongside the initiatives illustrated by Barnosky et al. (2014a, 2014b) both to influence policy makers, and to inform the public at large.

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## Note

1. 'Online spatial validation' is a process whereby GIS vector data are uploaded to a web service, where some rules are drawn up, and the data passed through algorithms that measure how well they meet the

prescribed rule criteria. A simple rule for polygons and polylines is that all segments join up to form a closed polygon or continuous line – tolerances can be set for how far apart segments can be and still be joined – vectors are usually scanned or digitized to varying specs, say for electrical wires inside buildings (centimetres), drainage pipes along roadsides (tens of centimetres) or cross-country transmission lines (metres).

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# Human rights and the environment in the Anthropocene

**Louis J Kotzé[1,2,3]**

## Abstract

Human rights are considered ethical demands that operate at an elevated juridical level. They have become popular legal constructs that contribute to the traditional instrumentalist and the more esoteric functions of law. While there is often considerable criticism leveled against human rights, as creatures of law and as legal mechanisms possessing unique characteristics, they are also uniquely situated and able to perform a singular mediating role in the human–environment interface. The recent mushrooming of rights to a healthy environment, environmental-related procedural rights and other substantive political and socio-economic rights bearing on environmental interests, is testimony to their increasing popularity. Yet, despite their prevalence in the environmental regulatory domain, the arrival of the Anthropocene is possibly set to require a complete rethink of the way in which we use human rights to mediate the human–environment interface. This is because the Anthropocene presents an urgent call for dramatic regulatory interventions of a kind hitherto unseen. Accepting the continuing prevalence of human rights as part of the environmental regulatory domain, this article argues that there is every reason to believe that their traditional role, nature, objectives and construction should change because of the Anthropocene. The article carries this argument by discussing the Anthropocene and its features that might influence conceptions of human rights and the environment as they are currently embedded in the social institutions of environmental law and governance. The argument then uses climate change as a useful explanatory context to identify and to understand the different types of rights issues that might arise in the Anthropocene. The next part of the discussion then takes stock of human rights in the environmental context by evaluating the way in which they currently mediate the human–environment interface. The article concludes with suggestions founding a re-imagination of the relationship between human rights and the environment in the Anthropocene.

## Keywords

Anthropocene, anthropocentrism, climate change, Earth Charter, ecocentrism, environmental governance, environmental law, equity, justice, rights, sustainability

[1]North-West University, South Africa
[2]University of Lincoln, UK
[3]Global Network for the Study of Human Rights and the Environment

**Corresponding author:**
Louis J Kotzé, North-West University, 11 Hoffman Street, Faculty of Law, Potchefstroom 2521, South Africa.
Email: louis.kotze@nwu.ac.za

## Introduction

Scientists have recently estimated that the Earth is moving from the Holocene into the Anthropocene epoch (Zalasiewicz et al., 2008). It signifies a period in geological time where humans are considered to be dominant forces equaling the great forces of nature that catapulted the Earth into earlier geological epochs. If recent scientific predications are to be believed, the ecological, and as a result the socio-legal, political and economic problems that arise in the Anthropocene will steadily become more severe, unpredictable, complex and of a magnitude hitherto unseen (Steffen et al., 2011).

As a result, society will probably have to revisit and interrogate the myriad socio-legal institutions that it uses to regulate or mediate the human–environment interface (otherwise understood as the relationship between humans and the environment). Environmental law and governance are examples of institutions that society would typically use in this respect, where law plays an important role in the regulation of the effects of human behavior on the environment and facilitating adaptation to changing environmental conditions.[1] Allot generally describes the social functions of law (admittedly rather idealistically)[2] as being three-fold: '(1) Law carries the structures and systems of society through time. (2) Law inserts the common interest of society into the behavior of society-members. (3) Law establishes possible futures for society, in accordance with society's theories, values and purposes' (Allot, 2000: 69). In terms of this description, law is the architecture of society; it ensures that society protects its common interests and realizes its goals by influencing behavior; and based on its temporally forward-looking view, law acts now to make possible a certain kind of world and society for the present and for the future. As part of the general law and governance paradigm, while human rights contribute to the three social functions of law identified by Allot, they also fulfill a much more esoteric function than the traditional instrumentalist function of 'normal' law.[3] This is so because human rights are ethical demands instead of legal commands or putative legal claims, providing a juridical expression of the underlying ethics of a society. This is a consideration which is illustrated by the fact that the implementation of human rights often goes well beyond legislative enactment and enforcement (Amartya, 2004: 315, 319). Human rights, when they lay claim to a value or good, that claim or value is automatically raised to an elevated juridical level (usually to the constitutional level), thus affording greater protection, but simultaneously also a greater justificatory basis to claim entitlements (Kotzé, 2012a: 199). In this sense human rights are 'high-level public order values or goods at the apex of public policy' (Weston and Bollier, 2013: 116).

Human rights have played, and continue to play, an important role in mediating the human–environment and the human–human interface in the environmental context. They do so by: fostering stronger environmental laws; providing a safety net that closes gaps in environmental laws; providing non-derogable minimum standards for environmental governance; improving implementation and enforcement of environmental laws; promoting environmental justice; increasing public involvement; fostering government and private-sector accountability; improving environmental education; and providing a more just interplay between socio-economic demands on the one hand and environmental demands on the other (Boyd, 2012: 233–252). As a counterpoint to these positive attributes, human rights in the environmental context, and specifically environmental rights, have been criticized for being vague (or 'troublingly indeterminate operationally', Weston and Bollier, 2013: 117–118), absolute, redundant and undemocratic; for being non-justiciable, which means they are incapable of being settled by law or by the action of a court; for being too anthropocentric due to their promotion of economic and social freedoms, too culturally imperialist, too focused on individuals as a result of their grounding in liberal individualism and for being disingenuous by creating false hope (Boyd, 2012: 33–44).

In similar vein, while this article does not critically consider the coherence, cogency and legitimacy of human rights, it is worth briefly pointing to some criticisms leveled against human rights generally which are relevant in the environmental context. For example, human rights are often negatively perceived to be couched in a masculinist ontology because they are based on the male as the basis for their normativity; because of their predominant Western characteristics, human rights sometimes exclude indigenous non-Western cultures and concerns, thereby compromising and limiting the model of universal nature and experiences that human rights seek to espouse; the promotion and protection of human dignity through material wellbeing is seen as the core of human rights, which is mostly achieved through increased economic security and, hence, increased consumption activities (Petersen, 1990); due to a lack of competitive market forces that press states for compliance, supra-national human rights instruments are mostly ineffective (Hathaway, 2002: 1935–1937); because the origin of human rights also have religious roots, they are used in a perverse way to justify unjustifiable encroachments on the rights and interests of others (Shestack, 1998: 205–206); related to the foregoing, human rights provide the justificatory basis for complete human mastery over the world that lies outside the human being, also by creating entitlements instead of duties and responsibilities as well; and human rights are individualistic, thus countering efforts that seek to foster greater harmonious interdependence (Gearty, 2010: 7–8).

Yet, despite these valid criticisms, it seems as if the popularity of human rights in the environmental context is increasing. It is, for example, estimated that approximately 147 countries have entrenched environment-related rights in their national constitutions to date with a recent empirical study showing that on balance, rights, despite their many shortcomings, observably improve the overall environmental governance effort (Boyd, 2012: 245–251). If this number is anything to go by, one could reasonably assume that human rights will continue to remain essential constructs in the global environmental regulatory domain. To this end, Hajjar Leib (2011: 1–2) estimates that: '[T]he human rights system offers sophisticated legal and extra-legal mechanisms necessary to tackle both the severe impact of human activities on the environment and the human rights implications of ecological degradation'.

On balance, as creatures of law and as legal mechanisms possessing unique characteristics enabling them to perform a singular mediating role in the human–environment interface, human rights will remain an important part of the larger environmental law and governance effort. If we accept the continuing prevalence of human rights, is there any reason to believe that their traditional role, nature, objectives and construction should change because of the Anthropocene? I believe that there is.

## The purpose and structure of this article

Some might suggest that the current ecological crisis has made human beings more resourceful. They may also argue that nature itself is resourceful and capable of being increasingly resilient which suggests that the Anthropocene epoch is not all bad, except that it raises the stakes in terms of the political battles that need to be fought and mediated upon. Taking a more critical view in line with the majority of commentators on the Anthropocene, this article, however, suggests that the Anthropocene brings starkly to the fore the possibility of a human-induced mass extinction on Earth, the potential for the loss of resilience and functional integrity of the Earth and its systems, and a host of uncertainties that go to the core of human existence in an anthropogenically altered and human-dominated Earth System (Wagler, 2011; Woodwell, 2002). As a result, one could reasonably expect that there would be a renewed focus on the role of law more generally and, more specifically, human rights in the Anthropocene. Accordingly, the central question that this article poses is: to what extent will the Anthropocene conceptually affect our vision of the mediating role of human rights in the environmental context and our vision of the relationship between human rights and the environment?

The enquiry commences with a brief description of its focus. It then proceeds to a discussion of the meaning and nature of the Anthropocene by specifically focusing on those features of the Anthropocene that might influence conceptions of human rights and the environment as they are currently embedded in the social institutions of environmental law and governance. The argument then uses climate change as a useful explanatory context briefly to identify and to understand the different types of rights issues that might arise in the Anthropocene. The next part of the discussion then takes stock of human rights in the environmental context by evaluating the way in which they currently mediate the human–environment interface – a discussion which will show that business-as-usual approaches to human rights and the environment are probably inadequate to accommodate the myriad socio-political and ecological challenges that arise in the Anthropocene. The article concludes with suggestions founding a re-imagination of the relationship between human rights and the environment in the Anthropocene.

Where necessary, I draw on the South African legal framework and its environmental right for illustrative practical examples, and for the sake of global relevance, also on the Earth Charter. The Earth Charter seeks to provide an ethical framework for sustainable interaction between humans and non-human living entities in a more just and peaceful world. It is a civil society ethical framework that has been widely endorsed by communities, business, governments and non-governmental organizations (Bosselmann and Engel, 2010). In this sense, I use the Earth Charter where possible as a moral soft law framework upon which to build the case for an understanding of ‘rights’ which are appropriate for the Anthropocene.

## Focus

There are various different ways to describe the manifestation of rights in the environmental context. While there may be other classifications, some use ‘environmental rights’ and ‘environmental human rights’, while others prefer ‘human rights and the environment’ (Hajjar Leib, 2011: 3). While there is little agreement on the conceptual difference between these terms, it is generally accepted that ‘environmental rights’ relate to the (mostly substantive) right to a clean and healthy environment that is not harmful to health and wellbeing. ‘Environmental human rights’ is a somewhat broader category of reference that could include all human rights that have a bearing on the environment, including procedural and substantive rights (e.g. the rights to human dignity, life, administrative justice, access to information and access to justice).[4] ‘Human rights and the environment’ is the broadest category of the three because it situates human rights and the environment as two separate yet distinctly interrelated issues. I find the latter categorization to be the most appropriate for the purpose of this article because the focus on ‘human rights and the environment’ allows for a decidedly holistic consideration of the relationship between *all* human rights (be they procedural or substantive, ecocentric or anthropocentric) and the environment.

As well, in accordance with the all-encompassing idea of the Earth System, I connote a broad meaning to the term ‘environment’. Rockström et al. (2009: 23) define Earth System as:

> … the integrated biophysical and socioeconomic processes and interactions (cycles) among the atmosphere, hydrosphere, cryosphere, biosphere, geosphere, and anthroposphere (human enterprise) in both spatial – from local to global – and temporal scales, which determine the environmental state of the planet within its current position in the universe.

Expressed thus, all Earth System processes are characterized by non-linear feedbacks and complex, unpredictable interactions that range between the living biosphere as well as physical and chemical processes (Kosoy et al., 2012). For regulatory purposes in the context of the legal domain, I understand the 'environment' to include in its broadest sense: living nature including people, micro-organisms, plant and animal life; the man-made environment; land, water and air; and the complex physical, chemical, aesthetic and cultural properties and processes that are part of the entire Earth System.

## Exploring the Anthropocene

The term 'Anthropocene' was recently coined by Paul J Crutzen and Eugene F Stoermer unofficially to denote a new epoch in the geological timescale (Crutzen and Stoermer, 2000). As the Editorial to the first issue of this journal explains, the Anthropocene unofficially signifies a new human-induced geological epoch which expresses the geological significance of anthropogenic change (Oldfield et al., 2014). The Anthropocene suggests that the Earth is rapidly moving into a critically unstable state with Earth systems gradually becoming less predictable, non-stationary and less harmonious as a result of the global human environmental imprint. In doing so, the Anthropocene raises a seemingly straightforward practical question with more complicated and far-reaching moral implications: in this time of aggressive global change, how and to what extent are humans able to respond adequately to this unequal balance in the human–environment and human–human relationship through their socio-legal institutions, including human rights?

As a concept, the Anthropocene removes much of the hitherto prevailing uncertainty that it is people that are responsible for global ecological demise. It therefore re-emphasizes the vagaries of anthropocentrism, which is understood in the present context to be 'the attitude that presents the human species as the centre of the world, enjoying hegemony over other beings and functioning as masters of a nature which exists to serve its needs' (Domanska, 2010: 118). To be sure, anthropocentrism is seen to be the 'philosophical driving force behind ecological crises' (Hajjar Leib, 2011: 27). By denoting human beings as a force of nature or a geological agent (as opposed to their being at the mercy of forces of nature), the Anthropocene makes humans the principal determinants or ecological agents of the environment (Chakrabarty, 2009). This insistence could have profound moral implications for society, especially insofar as people will now have to question their centrality in the human–environment relationship precisely because it is this very centrality which has led to the transition from the 'forgiving' Holocene to the supposedly apocalyptic Anthropocene. Humans will also therefore have to question the prevailing dominance of anthropocentrism and the potential and reformative possibilities that other environmental ethics such as ecocentrism may hold. (As the counterpoint of anthropocentrism, ecocentrism emphasizes the intrinsic value of nature and the central tenet of the concept lies in 'removing humanity from the center of the universe and replacing it with nature' (Hajjar Leib, 2011: 28.)) Most importantly though, humans will have to start taking seriously a new position of responsibility they hold as a result of the Anthropocene; a responsibility that extends not only to themselves and their own survival, but also to the natural living, but non-human, world.

The Anthropocene also sets the background for a new regulatory paradigm to the extent that it provides for a new kind of understanding about environmental degradation and environmental harm, which it expresses through the idea of 'planetary boundaries'. There is a realization that we are crossing those planetary boundaries that represent the dynamic biophysical 'space' of the Earth System within which humanity has to date evolved and thrived. These planetary boundaries 'respect Earth's "rules of the game" or, as it were, define the "planetary playing field" for the human enterprise' (Rockström et al., 2009: 5). So, instead of viewing environmental degradation as localized and media- or issue-specific incidents that have little cumulative impacts which could easily be controlled through localized responses, the argument that we are now pressing against planetary boundaries seeks to refocus our attention on the non-negotiable planetary preconditions that humanity needs to respect in order to avoid the risk of calamitous global environmental change.

To avoid reaching critical tipping points in the Earth System that might lead to rapid and irreversible change, regulatory efforts in the Anthropocene should strive to ensure survival and continuation of life on Earth (Biermann et al., 2012). These efforts must be accomplished through a range of preventive, mitigation and adaptation strategies in society's economic, political, cultural, religious, broader social and legal structures. While the Anthropocene will conceptually in all likelihood exert tremendous strain on society's existing normative systems, it nevertheless presents an urgent call for dramatic regulatory interventions of a kind hitherto unseen if we are to avoid crossing these tipping points. A significant component of this regulatory response will have to be legal because it is through law, among other social institutions, and its myriad constructs such as rights, that society determines and guarantees limits and allocates responsibilities (Philippopoulos-Mihalopoulos, 2014).

## Human rights and the Anthropocene: The example of climate change

If we accept that human rights as a part of the broader legal paradigm must be employed in regulatory interventions for the Anthropocene, what are the different types of environment-related human rights issues that could arise in the context of the Anthropocene? The answer lies, at least partly, in the revealing phenomenon of climate change because climate change is a clear expression of a global human-induced ecological disaster in the Anthropocene.

Climate change has become a substantial scholarly concern mostly because of the need to understand the science behind it; the ineffectiveness of law, governance and human rights in their attempts to sufficiently respond to climate mitigation and adaptation; its global nature, impact and reach; and its intergenerational or temporal dimensions (e.g. Arnold, 2011). The following issues all popularly permeate the climate governance–human rights discourse and they are exemplary of the types of rights issues that might also arise in the Anthropocene: intergenerational justice and the intergenerational application of rights; the procedural rights of non-state parties and their rights to representation and participation in the climate negotiation process; the rights of states (especially low island states); the responsibilities and liabilities of states and multinational corporations for climate change; the rights of ecological or climate refugees; possible infringements of the fundamental rights to property, life, human dignity and equality as a result of climate-induced ecological degradation; the rights to property, development and poverty alleviation, especially of least developed communities; the protection of minorities and indigenous peoples; rights that protect and provide basic socio-economic entitlements such as access to water; issues of equity and justice as exemplified by the North–South divide within and between states; and the possible rights of the environment itself, including species that are becoming extinct due to climate-induced habitat loss (Knox, 2009; Limon, 2009; Spier, 2012). The example of climate change suggests that rights issues in the Anthropocene will probably revolve around, among others: the ability of rights to protect the environment; the inter- and intra-generational application of rights and their ability to ensure equity; the extent to which rights could achieve environmental justice; procedural rights related to good governance; the limits that rights impose on development vis-à-vis the environment; and the range of public- and private-sector duties to protect, respect, promote and fulfill rights-based obligations.

Unsurprisingly perhaps, these issues do not differ much from those that permeate the prevailing human rights and environment discourse, thus suggesting that the arrival of the Anthropocene will not herald an introduction of any new issues into the environment and human rights paradigm. But while the issues will remain the same, as I indicate below, the urgency to address these issues, the extent to which they should be addressed, and our approaches to human rights in the environmental context, must manifestly change as a result of the Anthropocene.

## Taking stock of human rights and the environment

What are the prevailing characteristics or traditional traits of human rights and human rights–environment discourse that could negatively impact on the utility of human rights in the Anthropocene? First, the human rights and environment discourse is mostly mono-disciplinary. To date, human rights have mostly been the exclusive domain of law, philosophy, politics and other social sciences, and there remains (perhaps deliberately) a deep divide between the 'social world' of philosophy, anthropology, sociology, politics, law and economics on the one hand, and the 'material world' of engineering and natural science on the other (Uhrqvist and Lövbrand, 2009). The inevitable result is that the potential utility of human rights, both as scholarly legal constructs and as practical legal tools to mediate the human–environment interface is significantly diluted for the sake of a reality where science will in all probability have to play an increasingly dominant role in broader institutional regulatory efforts.

Second, tensions between ecocentrism and anthropocentrism continue to pervade the human rights–environment arena (Feris, 2008). An anthropocentric formulation of environment-related rights stems from the core foundation of human rights, i.e. human rights are concerned with the human and with the rights flowing from being human. As Gearty (2010: 7–8) explains:

> … the [anthropocentric] discussion is invariably about the self-fulfilment of the individual, his or her ability to set goals for leading a full life and then being free to go on to achieve those targets. The debate is about what are the necessary building blocks of such a successful life; it is not about what that life can or ought to do to make the world around it a better place, even for others to live in, much less simply for the planet's sake.

Such a formulation thus sees the environment as a life-sustaining good or entitlement to be added to all other material conditions of human welfare including housing, food and healthcare. Anthropocentric-oriented rights are utilitarian and they focus on the socio-economic context thus seeking to ground, improve access to and expand human claims to resources with a view to ensuring economic development in its widest sense (Bosselmann, 2005). An ecocentric formulation of environment-related rights instead sees the environment as a condition to life, thus placing limitations on individual freedoms. Stopping short of giving rights to the environment (with minor exceptions as indicated below), ecocentric rights accordingly are more inclined towards limitations of human entitlements to resources. They recognize the intrinsic and not the functional value of the environment, while simultaneously seeking to preserve ecological integrity (Bosselmann, 2005). Mostly, human rights in the environmental context have a decidedly anthropocentric focus where rights emphasize the utility of the environment and ecosystem goods and services for the benefit of human health and wellbeing (Boyd, 2012: 40–41). For example, South Africa's environmental right provides that 'everyone has the right to an environment that is not harmful to their health or well-being' (section 24 of the *Constitution of the Republic of South Africa*, 1996). There are very few exceptions to this more general trend. Two exceptions, however, are Ecuador and Bolivia's constitutional experiments incorporating a more ecocentric objective into human rights by granting the environment a 'right to exist, persist, maintain and regenerate its vital cycles, structure, functions and its processes in evolution' (article 71 of the Constitution of Ecuador). This right-formulation is the first of its kind at the constitutional level and it is exemplary of one of the possible (but likely unpopular, due to its limitations on growth), manifestations that an ecocentric right might take.[5]

While ecological formulations of human rights could admittedly be criticized for many reasons, they do provide an opportunity to restrict socio-economic (developmental) activities that obstruct natural cycles, structures, functions and processes, while promoting ecological resilience (Gibson-Graham and Roelvink, 2009). Yet, human rights in the environmental context continue to be anthropocentric and the ecocentric formulation of rights continue to be resisted by human rights formulations in the environment context, and more specifically, by the powers with vested interests in keeping rights anthropocentric. Clearly in some instances, such as the South African environmental right, the 'environmental' right bears more on socio-economic developmental claims that are disguised as ecological safeguards because rights formulated in this way almost always justify socio-economic development at the expense of ecological concerns. The result is that today, there remains little doubt that anthropocentric human rights have simply not been adequate in confronting the political economy and power structures of industrial capitalism. Herein lies the fundamental conundrum humanity finds itself in: given prevailing political realities, increased demand for limited resources, and the prevailing global consumer-driven culture coupled with continuously increasing population growth, how can society ever shift to an ecocentric approach? A radically different human culture is probably needed (including values, laws, institutions and so forth), but we can only make incremental changes through these and the results will not always be immediately apparent. It would be naïve to imagine that laws and human rights alone could affect the necessary changes to an ecologically sensitive and respectful society. The possible role for law and human rights in this respect is a much more nuanced (and realistically limited) one which asks the question: to what extent could a more ecocentric formulation of human rights contribute to a changed human culture that shows greater respect for Earth and its systems?

Third, related to the previous point, human rights in the environmental context are often used disingenuously in the sustainable development paradigm to advance socio-economic development at the cost of ecological concerns. This is because the orthodox three-tiered (social–economic–environment) and 'development versus conservation' approach of sustainable development continues to dominate efforts to mediate the human–environment interface. These trite sustainability constructs also remain the most generally accepted framework in which to cast environmental law, governance and rights. The South African environmental right again provides a useful example in this respect, because it affords people a right 'to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that … secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development' (section 24 of the *Constitution of the Republic of South Africa*, 1996). In other words, the environmental right recognizes the need for development that is ecologically sustainable, but only insofar as ecological concerns do not inhibit justifiable socio-economic development. Through this weak form of sustainability, the environmental right could be used to advance socio-economic developmental interests while ecological interests remain at the periphery of concern.

Fourth, to date there is neither a universally applicable hard law instrument in the form of a global treaty, for example, that explicitly provides for a substantive environmental right (Turner, 2014), nor has such a right been accepted into the corpus of customary international law.[6] It is only regionally that treaties explicitly provide for environmental rights, which are all anthropocentic.

These include the *American Convention on Human Rights*, 1969 with its *San Salvador Protocol* of 1988 that states: '[e]veryone shall have the right to live in a healthy environment and to have access to basic public services' (article 11(1)); and article 3(2) of the *Asian Human Rights Charter*, 1998 providing for the right to a 'clean and healthy environment'. The *Arab Charter on Human Rights*, 2004 also includes a right to a healthy environment as part of the right to an adequate standard of living that ensures wellbeing and a decent life (article 38), and article 24 of the African Union's (AU) *African (Banjul) Charter on Human and Peoples' Rights* (African Charter) states: '[a]ll peoples shall have the right to a general satisfactory environment, favorable to their development'. The latter Charter is considered the first international law instrument to explicitly recognize a substantive environmental right (Du Plessis, 2011). The only potential candidate for a procedural rights-based approach to environmental matters is the United Nations Economic Commission for Europe (UNECE) *Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters* (Aarhus Convention), 1998 that provides in article 1 for the right 'to live in an environment adequate to his or her health and well-being' and for a whole range of procedural rights to protect and enforce the former.[7] Despite these regional arrangements, the operation of human rights continues to be seriously restricted by state borders and sovereignty, which results in fragmented protection of individual interests in specific countries and/or regions rather than a more holistic and universalistic approach. Rights are also 'localized' because they mostly apply to the present generation. In other words, rights, generally speaking, do not function globally in a temporal sense, any more than they do in a geographical sense. This situation clearly means that rights are unlikely to be able, on their present construction, to respond to the interconnected nature of the myriad intertwined and temporally linked concerns that the Anthropocene raises.

Fifth, the fragmented approach of current rights-based orderings is contrary to the interconnected conception of the Earth and its systems and it is not conducive to accommodating the degree of interconnectedness that the Earth System and Earth System governance (as the most likely global governance candidate in the Anthropocene) demands. Biermann et al. (2010: 202) define Earth System governance as:

> … the interrelated and increasingly integrated system of formal and informal rules, rule-making systems and actor-networks at all levels of human society … that are set up to steer societies towards preventing, mitigating and adapting to global and local environmental change and, in particular, earth system transformation, within the normative context of sustainable development.

Thus described, Earth System governance is clearly meant to be a holistic and integrated response to the complex problems in the Anthropocene and is set to become the new global environmental governance paradigm in the Anthropocene age (Kotzé, 2012b). Human rights will conceivably also (have to) play a role in Earth System governance, but they can only do so if they become more compatible with this integrated approach to Earth System governance's holistic premise. While separate issues such as biodiversity conservation and water pollution will remain important, like environmental law, human rights will have to take a broader view and 'must adjust to accommodate broader notions of [the] environment' (Godden and Peel, 2010: 6), in a global sense embracing geographical, temporal and environment-issue dimensions characterizing the total-field relations implicated in the Anthropocene. To again use South Africa as an example: in environment-related rights adjudication, the courts continue to view socio-economic and environment-related rights in isolation. As I have pointed out elsewhere (Kotzé, 2010), in its interpretation of the right of access to water in the *Constitution of the Republic of South Africa*, 1996, the Constitutional Court in the, now infamous, case of *Mazibuko and Others v City of Johannesburg and Others* (CCT 39/09

[2009] ZACC 28) chose to divorce socio-economic entitlements that the right of access to water guarantees, from the very much interrelated environmental entitlements and protection that the environmental right offers.[8] It probably did so because it mistakenly failed to see the crucial role that water plays in broader environmental (which automatically also implies socio-economic) concerns (Kotzé and Bates, 2012). This is a classic example of the institutionally driven disconnect between the brown (socio-economic) and green (ecological) agendas. The brown agenda prioritizes pervasive challenges related to improving human wellbeing without harming the environment, especially in developing country contexts. Yet, the fear of over-emphasizing the green agenda must not be over-stressed. Ideally the intricate, and often conflicting, interconnection between brown and green issues should be recognized and responded to in a non-hierarchical and integrated way that best mediates potential dichotomies arising from seemingly opposing interests (Grant et al., 2013).

## Considerations for a new vision of human rights and the environment in the Anthropocene

In view of the foregoing considerations, our approach to human rights and the environment, or at least some aspects thereof, will have to be overhauled in response to the challenges of the Anthropocene. While the issues that the human rights–environment relationship raises in the Anthropocene will remain similar to those we are struggling with today, it is our approaches to addressing these issues and the depth and span of these approaches that will probably have to change. What are some of the considerations (there may be many others) that could affect the way we will have to re-imagine the relationship between human rights and the environment in the Anthropocene epoch?

### *'Humanizing' the Anthropocene*

In addition to their orthodox and more specific functions, human rights have the distinct potential to 'humanize' the Anthropocene. They could do it in the same way that they have been 'humanizing' climate change by providing a human perspective to ecological disasters. For Limon (2009: 450–451):

> … a human rights perspective or 'human rights lens' helps shift the focus of international debate on climate change more directly onto individuals and the effects of climate change on their lives. This, in turn, has important potential consequences for how climate change is perceived. One of the key failings of climate change diplomacy over the past two decades is that the phenomenon has been viewed as a scientific projection … It is far harder for world governments to remain ambivalent in the face of human suffering, especially when that suffering is on a global scale and is man-made, than is the case with physical phenomena such as melting icecaps or bleaching coral. Humanizing climate change thus creates an ethical imperative to act that can with time translate into legal obligations.

Or, as Gearty (2010: 21) explains, 'an insistence on attention to human rights has the effect of forcing all decision-makers to look outside their own circle, to see the human as well as the global consequences of their actions'. I would suggest that human rights have a similar 'humanizing' role to play in the Anthropocene because they have the ability to transcend the pure scientific domain in which we usually understand Earth System changes. In this way, human rights could bring the ecological crises of the Anthropocene closer to human understanding, as it were, by providing a human perspective on anthropogenic change and its ecological consequences. This could be accomplished, for example, at a scientific level through deeper cross-pollination between Earth System sciences and the social science of human rights; and at a policy and governance level through drafting of laws and human rights that actually consider and which are sensitive to Earth System evidence and predictions, and which aim to set limits on human behavior according to scientifically determined boundaries in the Earth System.

Of course this does not mean that human rights should promote an anthropocentric focus at the cost of a more ecocentric one (see the discussion below). Human rights in the Anthropocene should rather be seen to have an extended remit or vision – namely – to address ecological and socio-economic concerns that arise in the Anthropocene more effectively because they are translated into 'human' terms by admitting the inevitability of the human perspective that insists on the non-privileged participation of humans in the Earth System (De Lucia, 2013). In this way human rights could be used to ignite different forms of state responsiveness – and normative responsiveness more generally – being deployed instead of 'normal' environmental law and governance mechanisms, in order to address more broadly some of the ecological, socio-economic, legal and political crises in the Anthropocene. Human rights could therefore acquire a broader utility and function and should be applied as such to mediate more comprehensively the human–environment interface. More importantly, as Limon suggests above, human rights could be used to create the ethical imperatives that could later be translated into legal obligations creating specific duties and corresponding entitlements in order to address the ecological and socio-economic vagaries of the Anthropocene. However, for human rights adequately to carry the human face of the Anthropocene, they will have to be both interrogated and reimagined from a broader multidisciplinary framework, and moved beyond the current limits of black letter law and legal positivization to respond to a richer and more complex set of imperatives and concerns. Humanizing the Anthropocene through human rights should thus also seek to enable a greater degree of inter-disciplinary research concerning the meanings and manifestations of human rights. While the term 'Anthropocene' was coined by a chemist and a marine scientist, the challenge will now be how to translate this geological phenomenon and its treatment in the natural sciences to the social sciences, focusing on the place and role of people in the environment, and the social institutions through which people mediate the human–environment interface.

Indeed, the very distinction between the social and material world in the human rights and environment context might have to fall away in the Anthropocene if the collective scientific responses to human rights challenges arising in the Anthropocene epoch are to be comprehensively approached and applied to the Earth System idea in any meaningful way. The complexity and indivisibility of the holistically conceived Anthropocene, the centrality of the human and human (social) processes in this phenomenon, and the global interconnectivity between anthropogenic ecological impacts and the effects of these impacts on humans and the Earth and its systems, demand a far more diverse and integrated view and a multidisciplinary scientific approach that should focus on the relationship between, for example, the legal and the ecological, and the ecological-legal and the socio-political-economical. In fact, 'it is this interconnectivity and the unprecedented scale of the human transformation of the Earth system that calls for a new paradigm in the way science seeks to understand global environmental problems and to provide solutions' (Leemans et al., 2009: 4–5). The same can confidently be said of human rights-based approaches; the Anthropocene demands the search for a new paradigm.

## *From anthropocentrism to ecocentrism*

In the Anthropocene, 'any attempt to explain or predict the behavior of large biophysical systems can no longer succeed without addressing human actions as a central concern' (Kotchen and Young, 2007: 149). As suggested above, humans are central to the idea of the Anthropocene in many ways. First and most generally, humans stand at the conceptual core of the Anthropocene – as its etymological roots indicate: the term 'Anthropocene' derives from the Greek 'anthro' and 'cene' which mean 'human' and 'new' respectively (Slaughter, 2012: 119). Second, and more specifically, the Anthropocene implies the idea that humans are the principal instigators of global environmental change and that humans are responsible for the Earth moving out of its former geological epoch, the Holocene. A third reason for the centrality of humans to the Anthropocene is the idea that humans are intrinsically coupled with, and that they form a part of, Earth and its biophysical systems: it is clear that human and biophysical systems are coupled where human actions affect biophysical systems, biophysical forces affect human wellbeing, and humans respond variously to these forces (Kotchen and Young, 2007). This does not, however, mean that humans are – or should be – the central concern in the Earth System. They remain only a part of this system which 'behaves as a single, self-regulating system comprised of physical, chemical, biological *and human components*' (International Geosphere-Biosphere Programme, 2001).[9] In other words, while the Anthropocene identifies humans as being the central cause of the crises in the Anthropocene, it does not mean that humans are the central concern for Anthropocene normativity, for responses to its crises, or primary beneficiaries of any regulatory and/or normative interventions. Ecological concerns should carry equal weight despite (or perhaps as a counter measure to) the fact that some of the most prominent international environmental soft law instruments, among others, worryingly state that '[H]uman beings are at the centre of concerns for sustainable development' (Rio Declaration on Environment and Development, 1992, Principle 1).

It has been suggested that the Anthropocene is confronting head-on the dominant place of humanity in the natural world as expressed by widely endorsed international environmental law instruments (Steffen et al., 2011: 862). Neoliberal hegemony is deeply entrenched in the world's regulatory regimes with the majority of legal orders structurally committed to furthering neoliberal anthropocentric objectives, assumptions and closures which continue to threaten the living order (Grear, 2013).[10] Neoclassical, neoliberal, welfare economic thinking and rationale choice theories are manifestly grounded in anthropocentrism, which blatantly ignores intra- and intergenerational equity. Some even argue that consumerism, as an expression of this type of economic thinking, is 'sanctioning ecocide through its ignorance of natural limits' (Slaughter, 2012: 122). Moreover, the liberal notion of human rights that is grounded in Modernity, itself pits humans as masters of nature and entitled recipients against a defenseless environment (Bosselmann, 2004). To be sure, human rights, with their anthropocentric focus and liberal ideas of individual freedom and human dignity, are partly to be blamed for the current ecological overreach. Such closures provide a haunting analogue to the way in which human rights in the environmental context are also imprisoned by the prevailing illogic of anthropocentrism.

A new ethic is evidently required in the Anthropocene. What would this ethic be? I would suggest that the answer, perhaps unsurprisingly and rather uninspiringly, lies in ecocentrism. Lövbrand et al. (2009: 12) propose that ecocentrism may very well gain renewed attention in the Anthropocene: '[D]escriptions of the world as an intrinsically dynamic, interconnected web of relations in which there are no dividing lines between the living and non-living, or the human and non-human … resonate well with the Anthropocene imagery'. At the heart of the ecocentric ethic lies the realization that the future of life on Earth depends squarely on safeguarding ecological integrity,[11] which would, among others, require a deliberate effort to shift the parochial orthodox human focus that human rights have held since Modernity, to a more inclusive ecological one which does not only include responsibility for the self, but also for all other non-human entities: '[i]n the light of the fact that no species can survive without respecting its ecological conditions, an anthropocentric perception of human freedom [as expressed by human rights in this instance] appears as an absurdity. It is the saw to cut the branch we are sitting on' (Bosselmann, 2004: 63). The move towards an ecocentric ethic could be facilitated by means of human rights but only if these rights themselves are constructed in such a way as to underline their amenability to the promotion of ecocentric characteristics and values. In other words, to become more ecologically responsible as well, human rights will have to redefine the individual freedom they seek to provide and protect, even if this might also mean that human rights could loose their individual character and become something else entirely; something more grounded in communal and group conceptions of rights that extend well beyond individual freedom.

In contemplating the reasons for environmental law's ineffectiveness, Richardson proposes that: '[I]n theory, environmental law can be a means of serving both our own-self-interest, such as by safeguarding drinkable water or breathable air, as well as extending enlightened protection to other creatures, such as conserving endangered species or advancing animal welfare' (Richardson, 2001). Extrapolated to human rights, this argument could be equally true. As with environmental law more generally, human rights could therefore provide the ethical means for 'enlightened protection' which should shift its human-dominated focus to a more balanced ecocentric-anthropocentric vision. So, instead of its manifestly anthropocentric formulation that states:

Everyone has the right:

(a) to an environment that is not harmful to their health or wellbeing; and
(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that:

(i) prevent pollution and ecological degradation;
(ii) promote conservation; and
(iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

the South African environmental right could assume a more ecocentric orientation which could include something along the following lines:

Everyone has the right:

(a) to an environment that is not harmful to their health or wellbeing; and
(b) to have the environment protected, for the benefit of present and future generations and for the benefit of sustaining ecological integrity, through reasonable legislative and other measures that:

(i) prevent pollution and ecological degradation;
(ii) promote conservation; and
(iii) secure ecologically sustainable development.

Such a formulation resonates particularly well with the alternative ecological formulation of the relationship between humans and the environment as expressed by Principle I of the Earth Charter which provides for 'respect and care for the community of life'. It is an example of the necessary paradigm shift that seeks to ensure a holistic and more collective consideration of the welfare of both humans and other living non-human entities (Bosselmann, 2004).

Another possibility is a ‘human right to commons- and rights-based ecological governance’, that has been taken up in the recently proposed Universal Covenant Affirming a Human Right to Commons- and Rights-Based Governance of Earth’s Natural Wealth and Resources. This right provides a system: ‘for using and protecting all the creations of nature and related societal institutions that we inherit jointly and freely, hold in trust for future generations, and manage democratically in keeping with human rights principles grounded in respect for nature as well as human beings, including the right of all people to participate in the governance of wealth and resources important to their basic needs and culture’ (article 1(1) Commons Law Project, 2013; Weston and Bollier, 2013).

A far more extreme ecological reformulation of human rights, in the *Universal Declaration of Rights of Mother Earth*, 2011, has recently been proposed by the Bolivian government to the United Nations. The Declaration recognizes that the Earth is a living entity and as a result ‘Mother Earth’ could lay claim to the full range of fundamental rights normally attributed to humans including, among others: the right to life and to exist; the right to be respected; the right to regenerate its bio-capacity and to continue its vital cycles and processes free from human disruptions; the right to maintain its identity and integrity as a distinct, self-regulating and interrelated being; the right to water as a source of life; the right to clean air; the right to integral health; the right to be free from contamination, pollution and toxic or radioactive waste; the right to not have its genetic structure modified or disrupted in a manner that threatens it integrity or vital and healthy functioning; and the right to full and prompt restoration.[12] Considering the legal fraternity’s continued resistance to afford trees standing (to paraphrase Stone (1972)), and the prevailing strong political resistance to such a drastic change to the foundations of law which collectively work to undermine the legitimacy of the proposed Declaration, it is understandably likely that this proposal will not gain any credence soon. Yet, the fact that the debate has been initiated in the global political arena suggests that it could make it less difficult in future to negotiate for human rights that are more ecocentric and collective in their orientation.

In sum, an ecological reorientation of rights evinces the potential that human rights could have to refocus attention away from serving human needs exclusively, to an approach that instead seeks to ensure care for human wellbeing, while simultaneously respecting the limits of Earth’s life-supporting systems and the ecological integrity of other species. At the very least it is one, among other attempts, to give ‘ethico-juridical significance to the material situations of countless human beings, non-human animals and living ecosystems placed in unprecedented danger by the irresponsible pursuit of profit and by its associated ecological legacies’ (Grear, 2013: 111).

### *Sustainable development, human rights and the environment*

The anthropocentrism versus ecocentrism debate also relates to the sustainable development paradigm, which is popularly used as a conceptual framework for environmental law and rights. I would suggest that the Anthropocene requires a new vision of sustainable development, which is required to reform current visions of human rights in the environmental context and simultaneously to achieve a dramatic shift from the orthodox existing conceptions of sustainable development through which humans justify and rationalize their environmental claims.[13] Why is this so? Like modern environmental law, human rights are ‘increasingly blinded by ideological palliatives such as ‘sustainable development’ that help us rationalize our continuing encroachments upon the planet’ (Richardson, 2001). For example, the South African environmental right constitutionalizes sustainable development through entrenchment thereof and it seeks to ensure ecologically sustainable development, only then to dilute this obligation by inserting the ‘justifiability criteria’ referred to above. In other words, ecological sustainable development should be secured, but only to the extent that it is justified in the socio-economic development and needs context. In this way sustainable development, as a constitutional ideal, is used as a constitutionally mandated rationalization, justification even, for discarding ecological concerns in favor of socio-economic ones.

What is also clear is that the greatest fallacy of weak sustainable development in general, and more specifically in the Anthropocene paradigm, is its disingenuousness and its complacent promise of sufficient resources in a time of global ecological upheaval. In even starker retrospective terms: '[sustainable development] has failed to meaningfully change the human behavior that created the Anthropocene' (Craig and Benson, 2013: 843). To be sure, sustainable development has been used as the ethical justification for the legal creation of deeply embedded anthropocentric human demands on dwindling resources. This is evident in, for example, the *United Nations Declaration on the Right to Development*, 1986, which explicitly acknowledges that: 'the human person is the central subject of the development process and … development policy should therefore make the human being the main participant and beneficiary of development'.[14]

As well, sustainable development as a political concept remains fundamentally disconnected from the scientific realities of the Anthropocene, presupposing as it does, that humans have the ability to determine what the minimum requirements are that would be necessary to maintain ecological integrity, and ultimately to control, through their laws and other regulatory interventions, the Earth System (Craig and Benson, 2013: 847). This is all but impossible in the Anthropocene, which is characterized by multi-scalarity, complexity, non-stationarity and other variables which lie beyond human control. The Anthropocene neither allows developmental issues simplistically to be characterized as being 'economic', 'social' and/or 'environmental' (the 2002 World Summit on Sustainable Development approach); nor does it tolerate decisions with a potential ecological impact to be made based on the impoverished 'environment versus development' rhetoric (the 1992 United Nations Conference on Environment and Development approach) (Robinson, 2012). These orthodox weak approaches can only remain tenable if they are sensitive to the complexities of the Anthropcene and if they are recast in 'stronger' ecological language which explicitly discards the 'environment versus development' distinction or the traditional three-pillar distinction assumed by the current discourse.

The foregoing means that development can only be acceptable if it is ecologically justifiable, which means that weak sustainable development, as a moral framework or ethic for sustainably mediating the human–environment interface, is not credible any longer in the Anthropocene. In this way, the right to development (and other rights that sanction or enable development such as property rights) can only exist and be enforced if they are grounded in and adhere to the dictates of what would be ecologically justifiable in the biosphere as a whole. Similar to the limitation clauses that operate in some Bills of Rights,[15] ecological justifiability could place legal restrictions on and limit the right to development and property rights, or for that matter any rights claim that places undue demands on the biosphere. Or, in the words of the Earth Charter, limitations could be justified based on the consideration that: 'the freedom of action of each generation is qualified by the needs of future generations' (Principle I(4)(a)).[16] Thus, if development disproportionately benefits one generation at the expense of another (future) generation, it would be unjustifiable, and could then be legally limited. And where ecological processes are disrupted by development (in its broadest sense), it could be justifiable to restrict the right to development, because in the Anthropocene 'the liberal economic assumptions of ever-growing material accumulations for autonomous consumers – the logic of consequence-less consumption – are no longer tenable' (Dalby, 2007: 159).

Is a world without sustainable development a plausible proposition? I would suggest that it is when viewed through the lens of the Anthropocene and when it is placed against the purpose of rights. One of the functions of rights in the environmental context is that they should provide entitlements to people and provide the moral authority to claim certain benefits; benefits that mostly arise from human interaction with the ecosystem, its goods and services. In the Anthropocene, however, 'the degrees of freedom for sustainable human exploitation of planet Earth are severely restrained' (Rockström and Karlberg, 2010: 257). These restraints will similarly have to be imposed on rights to ecological goods and services and this could mean that traditional rights to environmental resources might have to be recast in a more limited anthropocentric, but expanded ecological language, so as to lessen the anthropogenic impact of increased global entitlements and demands. Recasting human rights in this way will have to happen through a paradigm of strong sustainability that seeks to reconnect humans with the environment, as it were.

## *Rights, equity and justice*

For Robin and Steffen (2007: 1712), there are two certainties in the Anthropocene: 'Earth is singular and beset by anthropogenic change; [and] these changes are unevenly distributed both physically (changes more extreme at the poles) and ethically (environmental injustice)'. Environmental injustice and discrimination and other related issues of intra- and intergenerational equity are thus clearly central to the Anthropocene. While the emphasis remains on traditional manifestations of inequity such as the North–South divide, unequal access to resources, inequalities in the distribution of environmental benefits and a disproportionate spread of historic, present and future state liabilities and burdens, the Anthropocene will necessitate a re-thinking of resource allocation, access and distribution in a much more profound manner. The need to do so arises from the realization that inequality often drives both excess consumption and population growth, which cumulatively pushes against Earth System limits, or planetary boundaries (Kosoy et al., 2012). Inequality also exacerbates conflict, and halters any meaningful progression towards cooperative solutions for strong sustainability. There is after all little motivation for impoverished sectors of society to consume even less than they already do, when rich societies are not willing to significantly compromise as well for the common good through a willingness to more equitably distribute environmental benefits and proportionally absorb environmental impacts. As Kosoy et al. (2012: 76) state: '[m]oving towards equity will make urgently needed collaborative efforts possible, including negotiations, treaties, multilateral governance approaches, aid for sustainable development, cooperation in green economy projects and infrastructure, and diversion of funds away from conflict toward needed changes'. How could human rights contribute to facilitating such a reorientation for equality and justice in the Anthropocene? As liberal, Modernist creations, human rights work to promote the freedom of *homo oeconomicus* (a view that is firmly embedded in neoclassical neoliberal economics). However, with the restrictions on freedom that a more enlightened ecocentric formulation of rights could bring about, the possibility arises to imagine a type of freedom of what Bosselmann (2004) terms, an 'enlightened *homo ecologicus universalis*'. This is a being that is much more connected with the environment, who seeks out solidarity instead of competition, and whose freedom is conditional on the foregoing. Individuals thus become planetary citizens; an idea which the Earth Charter espouses in its preamble as follows:

> To move forward we must recognize that … we are one human family and one Earth community with a common destiny. We must join together to bring forth a sustainable global society founded on respect for nature, universal human rights, economic justice, and a culture of peace. Towards this end, it is imperative that we, the peoples of Earth, declare our responsibility to one another, to the greater community of life, and to future generations.

As well, the focus in the Anthropocene should move from issue-specific 'problems' of environmental inequality, discrimination and injustice, such as those now manifesting in the climate change context (including sea level rise and climate refugees) to more overarching questions of ecological interdependence between humans on the one hand, and 'the other', between humans, the Earth and its systems and the manner in which humans benefit from and put pressure on Earth and its systems. Questions of intra- and intergenerational equity in the Anthropocene will thus have to transcend its silo-based and human-centered focus to include issues of equity as far as the Earth and Earth Systems are concerned. Such a holistic and integrated shift will require conceptions of intra- and intergenerational equity and justice to move from the anthropocentric to the ecocentric ethic. It will likewise require a re-imagination of justice in the Anthropocene, where conceptions of justice will have to shift the exclusive focus from humans to the entire Earth System, including the achievement of justice for non-living entities (Lorimer, 2011). A conception of environmental justice in the Anthropocene might therefore very well entail a consideration of ecological resources as benefactors or claimants and not only as resources that humans, as traditional claimants, see themselves as being entitled to. In this way, 'ecological justice' could be more conceptually suitable than 'environmental justice', because it helpfully shifts the focus from a human-centered approach to an ecological one in which ecological equilibrium, now and in future, would be the fulcrum not only for the realization of the human rights of access to resources and resource allocation, but also for the extent to which these resources are available to provide access and equitable allocation in substantive terms. For example, Armesto et al. (2010) have a different vision for land use and human claims to land use in the Anthropocene. They postulate that all future land policy decisions should incorporate social values and ecological considerations in equal measure: '[N]ew land development policies should define socially acceptable targets considering non-instrumentalist values, different cultural relationships between people and the land, the intrinsic link between local cultures and biological diversity, the protection of local economies, and ethical concerns about the social and environmental consequences of [a] free-market economy' (Armesto et al., 2010: 157–158).

Another pertinent equity issue in the Anthropocene raises questions with respect to equity in efforts to adapt to a changing Earth in the Anthropocene; it focuses on the ethics of adaptation. While the annihilation of life as we know it during the Athropocene is a distinct possibility, it is also likely that humans will adapt and be able to create livable environments through sheer ingenuity. For example, Hodson and Marvin (2010: 299) suggest in an article on ecological urbanism in the Anthropocene that humans might create 'ecologically secure premium enclaves' that are reminiscent of the apocalyptic visions of futuristic science fiction movies. These secure and utter exclusive enclaves will transcend conventional notions of ecological constraint by creating ecological security though technological advancement and producing their own food, energy and other life-supporting systems, goods and services, reusing wastes as resources and reducing reliance on external infrastructures. The ecological security of these enclaves would, however, not only depend on factors such as energy efficiency, recycling and reuse, but also on the extent to which limited resources could be provided to a limited population that must deliberately be kept as small, and therefore as exclusive, as possible. This would necessarily entail restricted access as current manifestations of these enclaves, such as 'eco-blocks', 'urban gated communities' or 'ecologically secure gated communities', already suggest. While these enclaves might provide protection and nourishment for a privileged (rich) few, vast numbers of (poor) people might not be fortunate enough to find protection in these ereas. As Hodson and Marvin (2010: 310–311) state:

> Our concern then is that eco-cities represent one particular response to the problems of climate change, resource constraint and energy security in a period of particular ecological emergency and economic crisis.

> As such we should see them as the purest attempt to create neo-liberalised environmental security, not at the scale of the whole city or even the planet, but a more bounded divisible security in order to try to guarantee ecological security for elites.

Neoliberalized environmental security thus raises issues of discrimination, equity and justice. This future scenario of secure ecological enclaves is not too far removed from current reality as it exemplifies what is happening today in cities the world over where rich inhabitants are safely ensconced in protected, privileged areas while poor masses have to survive on the bare minimum. And the gap between rich and poor is growing in most countries as reflected by rising income disparity. Scientific predictions, however, are more or less in agreement that anthropogenic ecological disasters will increase in frequency and severity, and it is therefore likely that the intra- and intergenerational divide between rich and poor people will only deepen as ecological disasters and food and energy scarcity in the Anthropocene intensify. Moreover, deliberate attempts to increase neoliberalized environmental security by the few who are able to do so, will probably increase exponentially, at a dire cost to the remainder of the world population. While human rights are fighting an uphill battle today in dealing with environmental injustice, discrimination and inequality, this situation is likely to become worse as the rich–poor divide, and the circumstances causing the divide, exacerbate. Herein lies a profound challenge to human rights in the Anthropocene: namely how to effectively address inter- and intergenerational justice on such a large scale. What would arguably be required, among others, is for human rights not to be hijacked to serve any neoliberal environmental security agenda, but instead to serve the broader Earth community to ensure equality and justice as far as the proportional and equal spread of environmental costs and benefits among everyone on Earth, is concerned.

### *Rights, social human interiors and external structural change*

In exploring the potential of human, cultural and institutional innovations to react to the realities of the Anthropocene, Slaughter (2012: 122) argues that ‘the most profound and potentially influentially shaping responses to the global predicament originate … in … social and human interiors’. Because of their deep moral foundations, human rights could be considered to be external legal means to transmit innate and internal human entitlements ‘to the outside’, as it were. Human rights are legal constructs and law is an external or objective deposit of human experience (Nagan and Otvos, 2009). Human rights then, as part of the human interior, could play a profound role to achieve some form of external change. The changes that these internally rooted external means (rights) should bring about must be more than incremental; they will have to exude some transformative force that would also lead to structural changes. In the words of Biermann et al. (2012: 1306):

> … incremental change – the main approach since the 1972 Stockholm Conference on the Human Environment – is no longer sufficient to bring about societal change at the level and with the speed needed to mitigate and adapt to Earth system transformation. Structural change in global governance is needed, both inside and outside the UN system and involving both public and private actors.

While human rights and the rights-based approach to environmental governance have been part of the post-1972 global legal and governance constellation (including at local, national, regional and international levels), they have only marginally contributed to the minimal incremental changes that have occurred (Weston and Bollier, 2013). Some strides have been made in addressing procedural and substantive issues, such as in the case of rights to participation and access to justice, as well as the right to a clean environment, but the structural impact of rights is questionable in the larger scheme of things. Mostly, human rights have proved insufficient to achieve the types of structural changes that are necessary to meaningfully address the myriad socio-political, legal and ecological challenges in the Anthropocene.

For human rights to contribute to more fundamental structural changes, the world arguably requires a paradigm shift in world politics, law and governance similar to the human rights revolution that occurred in 1945 with the creation of the United Nations structures and the adoption of the *Universal Declaration of Human Rights* in 1948. What would be needed is an 'environmental moment' in history with an impact equaling that of the Second World War, the 11 September 2001 terror attacks in the USA, or the recent global financial collapse, which have changed the way we perceive and seek to regulate human rights issues, security issues and global financial issues respectively.[17] The social, economic and legal changes to our socio-legal, economic and political structures that occurred following these events (even though some might argue these to be mere cosmetic modifications), suggest that changes to the socio-legal, political and economic architecture of humanity are possible, but only if events are perceived by humans as being sufficiently threatening to our safety, wellbeing, quality of life and indeed to human life itself.[18] If this were to happen, the establishment of a more powerful United Nations environment organization to replace the less-than-influential United Nations Environment Programme (UNEP) could be made more palatable to world leaders by justifying its creation from a human rights-based perspective. While the need for thoroughgoing global structural reform is by no means a novel proposal, with many propagating the idea of a World Environment Organization,[19] the idea that it should be based and justified by invoking the morality of human rights is a refreshing perspective which resonates well with similar calls for the establishment of, for example, a United Nations Climate Change Security Council (Ng, 2010).

Could imminent catastrophic ecological disasters herald an 'environmental moment' that will achieve the deep structural changes that are necessary to survive in the Anthropocene? While some already argue that climate change has the potential to threaten peace and security in the way that other major catastrophes have done (Ng, 2010), the great majority of scientific evidence points to the inevitability of ecological crises and to the potential for socio-economic collapse in the Anthropocene. In this sense, the Anthropocene itself could be exemplary of an 'environmental moment'. Admittedly the threats of the Anthropocene are less immediate or sudden than, for example, a nuclear war – and accordingly, they have not yet been sufficient to affect the human conception of security and to achieve the deep structural changes that would be required. Anthropogenic ecological threats such as climate change are instead passive-aggressive because they are not vividly expressed and perceived as violence, nor are they (yet) fully products of inter- or intra-state political and ideological tensions (Ng, 2010). As Richardson (2001) states:

> Crises sometimes can trigger major structural reform … The problem is that most environmental problems and threats, such as climate change, are catastrophes in relative slow motion; although in geological time their emergence and impact can be exceptionally rapid, they remain perceptibly rather long-term for humankind.

The contribution of human rights to effecting structural changes in the environmental context will thus depend on perceptions and on the ability of human rights to contribute as moral and ethical justifications for wholesale structural reform of the global environmental law and governance architecture (as they did in the aftermath to the Second World War). It is, however, more likely that in the absence of a large-scale and sudden 'environmental moment', change would come from, what Weston and Bollier term, a 'Grotian Moment' that 'presents an unusual opening in our legal and political culture for [gradually] advancing new ideas for effective and just environmental protection' through, among others, civil resistance movements and new sorts of internet-based collaboration and governance, where human rights could play a central role (Weston and Bollier, 2013: 118–119).

## Conclusion

In the struggle for survival on Earth, the Anthropocene has thrown down the gauntlet. There is little doubt that the future of life on Earth will depend on how we are able to respond to the many challenges that the Anthropocene presents. To survive, humans ultimately have to stay within certain thresholds that are both morally derived and determined by bio-geophysical thresholds (Folke et al., 2011). While human rights are not too familiar with setting bio-geophysical thresholds, they can establish duties, entitlements, moral boundaries and governance obligations that could create the foundation of a legal normativity responsive to, and acting in tandem with, bio-geophysical thresholds in order to increase chances of survival in the Anthropocene. The allure of human rights lies, among other things, in their ability to transform society, the many socio-political, legal and economic institutions and the manner in which society interacts inter se and with the environment. This allure is likely to remain in times of increased uncertainty, because in the present uncertain time, humans tend to 'rely on background values to adopt rules of decision' (Krakoff, 2010). It is precisely these kinds of background values that are often incorporated into human rights. This, and the continued prevalence of human rights in the environmental context, suggests that rights will continue to play a decidedly important role in the Anthropocene.

Gibson-Graham and Roelvink (2009: 322) pessimistically propose that:

> … responding to the challenges of the Anthropocene … is about human beings being transformed by the world in which we find ourselves … it is about the earth's future being transformed through a living process of inter-being. But how do we put ourselves (and the Earth) in the way of such transformations? How do we get from an abstract ontological revisioning to a glimmer or a whiff of what to do on the ground? No answer arrives when we ponder this question – just a spacious silence and a slowing down.

I would suggest more optimistically that while human rights do not and cannot provide all the answers to the challenges of the Anthropocene, they do offer a familiar means to society to commence with an ontological revisioning that would allow for interventions through which to mediate more effectively the human–environment interface. This would, however, require some re-imagining of human rights themselves in the environmental context, and more specifically, in the new reality of the Anthropocene.

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## Notes

1. I understand environmental governance to be a normative institutional regulatory intervention and social construct that is predominantly based on law and that aims to influence how people interact with the environment (Kotzé, 2012b: Chapter 6).
2. There is justified criticism, from an ecological perspective, against this utopian view of law that portrays it as 'all good'. For example, Bosselmann (2004) points out that law, because it has its roots in Modernity, have no other comprehension of the environment than as resources that must be made available to satisfy human needs. This instrumentalized attitude of law only reinforces exploitative behavior and deepens ecological ignorance.
3. By 'instrumentalist' I mean to refer to the traditional prescriptive role of law as an instrument to direct human behavior through punishment and coercion.
4. Substantive rights are basic rights that provide for substantive claims such as the rights to life, the environment and human dignity. They typically set out a minimum threshold or standard which, if crossed, would open up various avenues for redress through the aid of procedural rights which are used to enforce substantive rights-based claims. Examples are the right to just administrative action; the right of access to information; and rights relating to access to courts and the enforcement of rights. The Aarhus Convention, 1998, discussed elsewhere in this article, is an example of a global instrument aimed at the advancement of procedural environment-related rights.
5. Other recent examples are the 2011 Ecuadorean Court decision protecting the Vilcabamba River (see Greene, 2011), and the recent recognition in New Zealand of the rights of the Whanganui River (2012) (see Postel, 2012).
6. At most, environmental entitlements are inferred indirectly from the provisions of other human-focused but environment-related treaties, such as the International Covenant on Economic, Social and Cultural Rights, articles 7(b), 10(3) and 12, 1966; the Convention on the Rights of the Child, article 24, 1989; and the International Labor Organization Convention Concerning Indigenous and Tribal Peoples in Independent Countries, articles 2, 6, 7 and 15, 1989 (Shelton, 2010: 266–267).
7. Despite its regional European focus though, this regional treaty is open to accession and ratification, also to non-European countries.
8. See respectively ss. 27 and 24 of the South African Constitution.
9. Emphasis added.
10. Grear (2013) uses 'closures' in this context to describe the way in which the world order is hegemonic, and through which it produces limits and a stifling sense of monolithic ideology that closes down the space for other modes of being and thinking by resisting such interventions or engagements with its dominant structures and modes of operation. Closures are those sites or ways of stifling the space for alternatives, crushing critiques, and shutting out alternative ways of proceeding.
11. Ecological integrity entails, among others, a 'recognition of and respect for the unalterable symbiotic relationship between humanity's future well-being and the integrity of those environmental processes that are requisite for sustaining the future" (Ayestaran, 2008: 154).
12. See article 2 of the Declaration and World People's Conference on Climate Change and the Rights of Mother Earth, 2011.
13. See, most recently, Craig and Benson (2013) and Robinson (2012).
14. See also the United Nations Declaration on the Right to Development, 1986, article 2, which expresses this right in similar terms.
15. See, for example, s 36 of the Constitution of the Republic of South Africa, 1996, which provides that: the rights in the Bill of Rights may be limited only in terms of law of general application to the extent that the limitation is reasonable and justifiable in an open and democratic society based on human dignity, equality and freedom, taking into account all relevant factors, including: the nature of the right; the importance of the purpose of the limitation; the nature and extent of the limitation; the relation between the limitation and its purpose; and less restrictive means to achieve the purpose.
16. See also Principle II(5)(e) that sets out the obligation to '[m]anage the use of renewable resources such as water, soil, forest products, and marine life in ways that do not exceed rates of regeneration and that protect the health of ecosystems'.

17. Some commentators even believe ‘climate change may be an issue as severe as war’ (Dryzek and Stevenson, 2011: 1865).
18. By this I do not mean to say that the current post-global financial crisis economy is ‘better’ or more suited to the challenges of the Anthropocene. The global economic model remains fundamentally embedded in the neoclassical paradigm that is manifestly blind to long-term sustainability prospects. This is due to its goals being stated in terms of full employment, relative price stability, economic growth and efficiency; all fundamentally anthropocentric in nature (Bosselmann et al., 2012).
19. See, among others, Biermann and Bauer (2005).

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# Is there an isotopic signature of the Anthropocene?

**Jonathan R Dean,[1] Melanie J Leng[1,2] and Anson W Mackay[3]**

**Abstract**

We consider whether the Anthropocene is recorded in the isotope geochemistry of the atmosphere, sediments, plants and ice cores, and the time frame during which any changes are recorded, presenting examples from the literature. Carbon and nitrogen isotope ratios have become more depleted since the 19th century, with the rate of change accelerating after ~AD 1950, linked to increased emissions from fossil fuel consumption and increased production of fertiliser. Lead isotope ratios demonstrate human pollution histories several millennia into the past, while sulphur isotopes can be used to trace the sources of acid rain. Radioisotopes have been detectable across the planet since the 1950s because of atmospheric nuclear bomb tests and can be used as a stratigraphic marker. We find there is isotopic evidence of widespread human impact on the global environment, but different isotopes have registered changes at different times and at different rates.

**Keywords**

Anthropocene, carbon, human impact, isotopes, lead, nitrogen, radioisotopes, Suess effect, sulphur

## Introduction

The Anthropocene, the term used informally to denote the current interval where humans have become a dominant force of global environmental change (Crutzen, 2002; Crutzen and Stoermer, 2000), is contentious. There is no doubt that humanity has left its mark on the planet. For example, humans now transport more soil and rock around the surface of the Earth than natural processes do (Wilkinson, 2005), $CO_2$ levels have risen dramatically to the highest levels seen in at least 800,000 years (Keeling et al., 2005; updated: http://scrippsco2.ucsd.edu/data/in_situ_co2/monthly_mlo.csv; Lüthi et al., 2008) and humanity is implicated in causing rates of species extinctions to increase well beyond background levels (Barnosky et al., 2011). Consequently, a working group of the

[1]British Geological Survey, UK
[2]University of Nottingham, UK
[3]University College London, UK

**Corresponding author:**
Jonathan R Dean, NERC Isotope Geosciences Facilities, British Geological Survey, Nottingham NG12 5GG, UK.
Email: jond@bgs.ac.uk

International Commission on Stratigraphy is set to present its preliminary findings in 2016 on whether the Anthropocene is distinctive and enduring enough to be defined as a new epoch and if so where the Holocene–Anthropocene boundary should be set (Foley et al., 2013; Gale and Hoare, 2012; Vince, 2011; Zalasiewicz et al., 2011). Ruddiman (2003, 2013) and Ruddiman et al. (2011, 2014) have argued the Anthropocene started in the early to mid Holocene, when they suggest land clearance and agriculture initiated changes in the composition of the atmosphere. Crutzen and Stoermer (2000), Crutzen (2002) and Steffen et al. (2011) have suggested a later date, in the late 18th or early 19th centuries, associated with the Industrial Revolution in Northern Europe. Alternatively, a 'Great Acceleration' in human impacts on the global environment has been suggested to have occurred ~AD 1950 (Steffen et al., 2007) and it has been proposed the Anthropocene could be defined as starting around this time (Zalasiewicz et al., 2014).

There is an urgent need to understand the impact humans have had on the global environment and when changes occurred. This review concentrates on wide-scale anthropogenic impact as recorded by isotope data from natural archives. Isotopes are different types of an element: they have the same number of protons but a different number of neutrons (e.g. Hoefs, 2009; Sharp, 2007). The ratio of one isotope of an element to another can vary through time depending on a host of environmental factors, meaning changes in isotope ratios can be used to reconstruct changes in, for example, climate, pollution and the composition of the atmosphere. In this review, we have selected the isotopes that previous studies have highlighted as important in tracking human impacts on the global environment. We show how isotopes record heavy metal contamination linked to technological innovations from Greek and Roman times onwards (lead isotopes), late-Holocene forest clearance and widespread fossil fuel burning since the onset of the Industrial Revolution (carbon isotopes), increased production and use of artificial fertilisers (nitrogen isotopes), acid rain (sulphur isotopes) and atmospheric nuclear weapons testing (caesium and plutonium isotopes). We consider how isotopes could contribute to the debate on where to set the Holocene–Anthropocene boundary.

Notation and standardisation of stable isotope data are summarised in Sharp (2007) and Hoefs (2009). $\delta^{13}C$ represents the ratio of $^{13}C/^{12}C$ and $\delta^{15}N$ the ratio of $^{15}N/^{14}N$ and are given in per mil (‰) relative to VPDB and AIR respectively. $\delta^{34}S$ represents the ratio of $^{34}S/^{32}S$ and is given in ‰ relative to VCDT. Lead isotopes are measured against a variety of standards as reviewed in Komárek et al. (2008). The abundance of $^{14}C$ ($\Delta^{14}C$) in a sample is given in ‰ relative to NIST oxalic acid activity corrected for decay (Stuiver and Polach, 1977). The abundance of radioisotopes such as $^{137}Cs$ and $^{239,240}Pu$ are measured in becquerel (Bq), with one Bq representing one decay per second (L'Annunziata, 2012).

## Changes in the global carbon cycle

Human activity has altered the concentration and isotopic composition of the gases in the atmosphere. Rises in atmospheric methane ($CH_4$) and carbon dioxide ($CO_2$) are captured in gas bubbles in ice cores (e.g. MacFarling Meure et al., 2006; Rubino et al., 2013) ~5000 years ago and ~8000 years ago, respectively. Ruddiman (2003, 2013) and Ruddiman et al. (2011, 2014) have argued these increases were caused by humans, and this has led to the Early Anthropogenic Hypothesis, which argues anthropogenic effects on global climate began millennia ago and had it not been for human-induced greenhouse gas increases leading to global warming the climate would have cooled substantially during recent millennia. A key part of their argument involves using carbon isotopes to trace the origins of these increases in $CH_4$ and $CO_2$ to wetland expansion, linked to rice production, and to widespread forest clearance. $\delta^{13}C$ of atmospheric $CH_4$ ($\delta^{13}CH_4$) from ice core bubbles from the late Holocene have values ~−47‰ to −49‰ (Ferretti et al., 2005; Mischler et al., 2009). While some argue that these low values of $\delta^{13}CH_4$ could be explained by increased delivery of depleted (more negative) carbon from natural wetlands (e.g. Schmidt et al., 2004), Ruddiman et al. (2011) contend this would have been unlikely because of the drying in the late Holocene of northern monsoonal regions and the cooling of boreal regions, which would have reduced, not increased, $CH_4$ emissions of natural wetlands. Rather, they suggest that $\delta^{13}CH_4$ data could be explained by human emissions, with the observed mean of −48‰ satisfied by emissions from rice paddies (−63‰) and livestock (−60‰) and anthropogenic burning of grasses (−25‰). In terms of $CO_2$, Elsig et al. (2009) argue that the very small decrease in the $\delta^{13}C$ of atmospheric $CO_2$ ($\delta^{13}CO_2$) in the mid to late Holocene (before the Industrial Revolution), as atmospheric $CO_2$ concentrations were rising, would limit the net terrestrial contribution to atmospheric $CO_2$ during the last 7000 years to only ~5 ppm. Instead, there could have been large releases of $CO_2$ from the oceans (Broecker et al., 1999; Ridgwell et al., 2003). However, Ruddiman et al. (2011) argue that Elsig et al. (2009) underestimate carbon burial in boreal peat, and if burial in peat over the last 7000 years was greater than Elsig et al. (2009) calculated then it would require far greater anthropogenic emissions, via forest clearance, to balance the $\delta^{13}CO_2$ budget. The complexities of the carbon cycle mean the debate vis-à-vis the relative importance of human versus natural sources and sinks of carbon is complicated, and many researchers (e.g. Steffen et al., 2011) dismiss the plausibility of the Early Anthropogenic Hypothesis, but it is clear carbon isotopes are a key part of this debate.

As recorded in direct measurements from the atmosphere, in gas bubbles trapped in ice cores and in natural archives including tree rings (February and Stock, 1999; Stuiver and Quay, 1981), corals (Nozaki et al., 1978; Swart et al., 2010), foraminifera (Al-Rousan et al., 2004; Black et al., 2011) and marine molluscs (Butler et al., 2009), there has been a more substantial change in the $\delta^{13}CO_2$ of the atmosphere since the 19th century, with the trend to lower values through the 19th century accelerating after ~AD 1950 (Figure 1), at the time of increased fossil fuel consumption that followed the Second World War (Steffen et al., 2007). The changes in $\delta^{13}C$ are of a different magnitude and the absolute values are different in tree rings, corals, foraminifera and direct measurements of the atmosphere or of gas bubbles in ice. This is because as organisms use carbon during growth, they preferentially take up one isotope over another, causing a change in the $\delta^{13}C$ from the source, a process known as fractionation (e.g. Hoefs, 2009; Sharp, 2007). However, assuming this fractionation is constant through time, it is still possible to track changes in the composition of the atmosphere using tree rings, corals and foraminifera. The classic graph from Mauna Loa shows $\delta^{13}CO_2$ declining (−7.6‰ in 1980 to −8.3‰ in 2011) as $CO_2$ concentrations in the atmosphere have risen (316 ppm in 1959 to 396 ppm in 2013) (Figure 2) (Keeling et al., 2005; updated: http://scrippsco2.ucsd.edu/data/in_situ_co2/monthly_mlo.csv). There was also a decline in the amount of $^{14}C$ in atmospheric $CO_2$ ($\Delta^{14}CO_2$) in the first half of the 20th century (Levin et al., 2010; Stuiver and Quay, 1981), before the trend was interrupted in the 1950s and 1960s, followed by a decline again to the present day (Levin et al., 2013). These declines in $\delta^{13}CO_2$ and $\Delta^{14}CO_2$ (called the Suess Effect; Keeling, 1979; Suess, 1955) are linked to the burning of fossil fuels. Fossil fuels, such as the vast coal deposits of the Carboniferous period, are composed of the organic remains of organisms (mainly plants) that lived millions of years ago. Plants preferentially take up $^{12}C$ over $^{13}C$ so have low $\delta^{13}C$ (e.g. Farquhar et al., 1989), with most oil deposits having values of −32‰ to −21‰ and coal deposits −26‰ to −23‰ (Sharp, 2007). Consequently, $CO_2$ from fossil fuels contains on average 2% less $^{13}C$ per mole than atmospheric $CO_2$ (Keeling, 1979). Extraction and burning of these fossil fuel reserves releases this $^{12}C$-enriched carbon back into the atmosphere, leading to a decline in $\delta^{13}CO_2$. Old carbon from fossil fuels is also virtually free of $^{14}C$ (Keeling, 1979), since the time between being deposited in the fossil record and burning is many thousands of half-lives

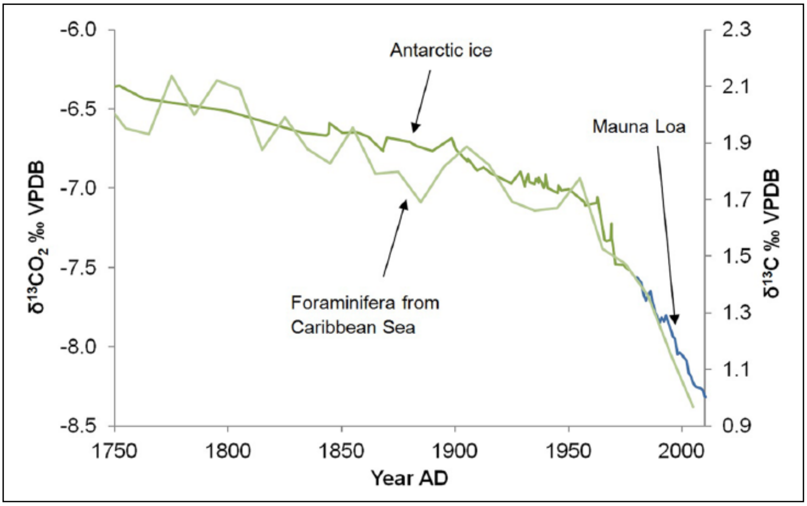


**Figure 1.** $\delta^{13}CO_2$ from Antarctic ice core record (Rubino et al., 2013), $\delta^{13}C$ record from foraminifera from the Caribbean Sea (Black et al., 2011) and $\delta^{13}CO_2$ from the Mauna Loa monitoring station (Keeling et al., 2005; updated: http://scrippsco2.ucsd.edu/data/in_situ_co2/monthly_mlo.csv). The former two records show a gradual depletion through the 19th century and an acceleration after ~AD 1950.

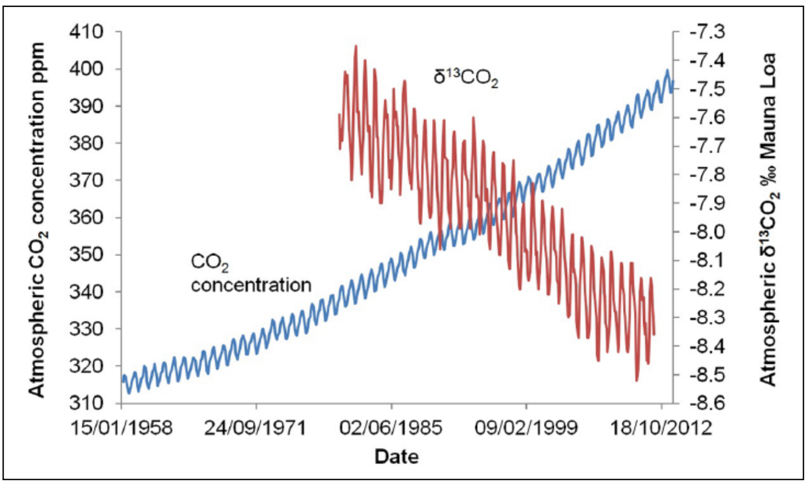


**Figure 2.** Monthly data from the Mauna Loa monitoring station (Keeling et al., 2005; updated: http://scrippsco2.ucsd.edu/data/in_situ_co2/monthly_mlo.csv) showing an increase in the concentration of $CO_2$ in the atmosphere from 1958 and a decline in $\delta^{13}CO_2$ from 1980 when monitoring of this began.

of $^{14}C$, so the release of this old carbon will lead to a decline in $\Delta^{14}CO_2$ in the atmosphere. $\delta^{13}C$ changes in the atmosphere have been vital in allowing the Intergovernmental Panel on Climate Change (IPCC) to conclude there is a 'very high confidence' that the dominant cause of the observed increase in $CO_2$ concentrations in the atmosphere since the 19th century has been the human burning of fossil fuels (IPCC, 2013).

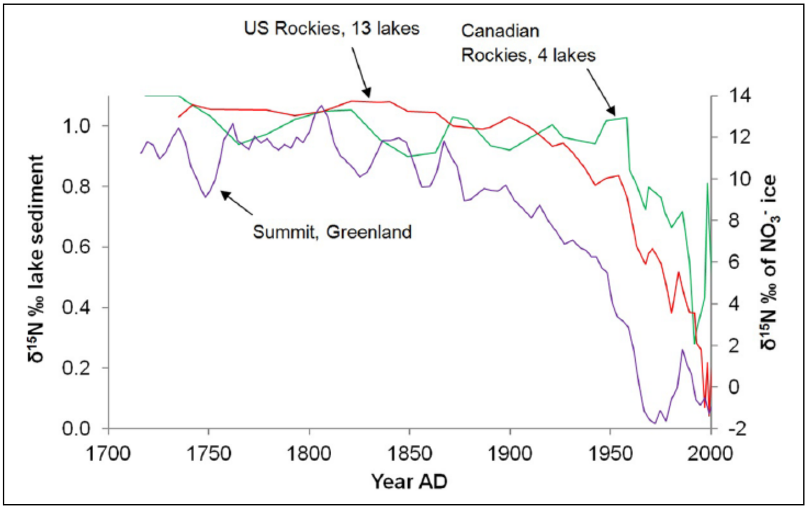


**Figure 3.** $\delta^{15}N$ from organic matter from lake sediments from the US and Canadian Rockies (three-point moving average) (Wolfe et al., 2013) and from nitrate in Greenland ice cores (Hastings et al., 2009). Depletion occurs after ~AD 1850, with an acceleration after ~AD 1950.

## Changes to the nitrogen cycle

There have also been changes in the global nitrogen cycle, with increases in the amount of reactive nitrogen (nitrogen compounds such as nitrogen oxides that support biological growth) in the atmosphere, thought to be mainly due to the burning of fossil fuels and the use of fertiliser in agriculture (Galloway et al., 2004; Jaegle et al., 2005). As with carbon isotopes and the carbon cycle, $\delta^{15}N$ can be used to track changes in the nitrogen cycle and identify the sources of the nitrogen released. Anthropogenic reactive nitrogen sources, especially fertilised soils (Park et al., 2012; Pérez et al., 2001), but also fossil fuel emissions (Felix et al., 2012), are generally thought to be depleted in $\delta^{15}N$ relative to natural sources (although they can have highly variable values and some have argued $\delta^{15}N$ from fossil fuel emissions is unlikely to be lower than that from natural sources; Sharp, 2007; Geng et al., 2014). In organic matter from remote lake sediments from across North America and the Arctic (Holmgren et al., 2010; Holtgrieve et al., 2011; Wolfe et al., 2013), and in nitrate ($NO_3$–) from ice cores from Greenland (Hastings et al., 2009), there have been declines in $\delta^{15}N$ from ~AD 1850 (Figure 3). (Again, note that as a result of fractionation, the values and magnitudes of change of $\delta^{15}N$ in lake organic matter and ice core $NO_3$– differ, but they both shown a decline at similar times.) $\delta^{15}N$ values in Greenland $NO_3$– declined from +10.6‰ in AD 1716 to +0.8‰ in AD 2005 (Hastings et al., 2009). The trend in $\delta^{15}N$ may be because of the increase in isotopically depleted nitrogen from anthropogenic sources (fossil fuel combustion and fertilisers) (Felix and Elliott, 2013; Hastings et al., 2009; Holtgrieve et al., 2011), although Geng et al. (2014) have argued that the decline may be due to an equilibrium shift in gas-particle partitioning of atmospheric $NO_3$– caused by increasing atmospheric acidity resulting from anthropogenic emissions of nitrogen and sulphur oxides.

As with $\delta^{13}C$, while there is a decline in $\delta^{15}N$ from the 19th century in many records, it is really after ~AD 1950 that the trend accelerates and becomes pronounced (Figure 3). The changes that have occurred in the last century in Sky Pond lake in the US Rockies, for example, are without

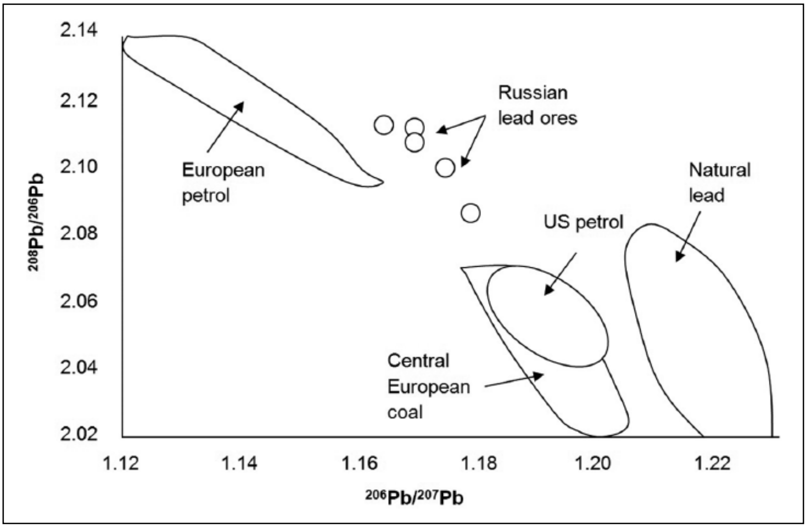


**Figure 4.** A $^{206}Pb/^{207}Pb$ versus $^{208}Pb/^{206}Pb$ plot showing the different isotopic compositions of selected lead sources. Modified from Komárek et al. (2008).

precedent in the 14,000 year record (Wolfe et al., 2013). Although, as we have demonstrated, the real drivers of the $\delta^{15}N$ trend are debated, it is probable that a combination of anthropogenic processes are causing this decline, so $\delta^{15}N$ is a useful tool in tracing human impacts on the global nitrogen cycle.

## Tracing pollution

As well as causing changes in the carbon and nitrogen cycles, human activity has caused pollution by remobilising certain elements. This can be traced using isotopes.

### *Lead isotopes*

For millennia, humans have been mining and smelting lead ores, which has released vast quantities of lead into the atmosphere, causing widespread airborne pollution (Adriano, 2001; Settle and Patterson, 1980). There is evidence for lead contamination in Greenland ice cores, carried there in the atmosphere as microparticles, for over 2000 years (e.g. Hong et al., 1994; Rosman et al., 1997). Since different lead ores have different lead isotope ratios, it is possible to pinpoint where the lead was being mined. Rosman et al. (1997) showed that between ~150 BC and AD 50, 70% of the lead seen in Greenland ice cores originated from southern Spain, and historical records show the Romans mined the area at this time. As well as different lead ores, lead isotope ratios can be used to distinguish between pollution from different industrial processes. Komárek et al. (2008), using $^{206}Pb/^{207}Pb$ versus $^{208}Pb/^{206}Pb$, were able to distinguish between lead emitted from vehicles in Europe and the USA, coal burning in central Europe and natural sources (Figure 4). More recently it has been shown that lead in Greenland ice is increasingly from Chinese sources (Bory et al., 2014).

Trends in lead isotope ratios (especially $^{206}Pb/^{207}Pb$) can also be used to track changes in pollution through time. For example, in Sweden, background $^{206}Pb/^{207}Pb$ is thought to be around 1.5, whereas atmospheric lead pollution derived from smelting, leaded petrol and burning of coal has a

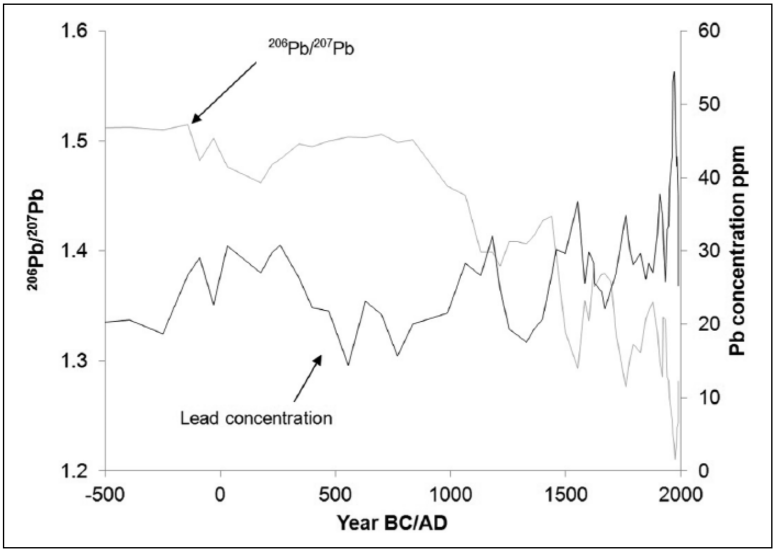


**Figure 5.** Trends in $^{206}Pb/^{207}Pb$ and lead concentrations from Lake Koltjärn in Sweden, with a depletion in the ratio taken to represent increased anthropogenic lead pollution (Renberg et al., 2002).

$^{206}Pb/^{207}Pb$ value of ~1.2 (Renberg et al., 2002). Lake sediments show there was a decline in the ratio in Roman times (to ~1.46), and then an increase to higher values in the Dark Ages ~AD 500–800 (~1.50) (Renberg et al., 2002). Minimum $^{206}Pb/^{207}Pb$ ratios (~1.22) were reached in the 1970s when leaded petrol consumption peaked (Figure 5). With the phasing out of leaded petrol in Europe there has been an increase in the ratio (currently ~1.28). The low $^{206}Pb/^{207}Pb$ in Roman times, related to lead mining, as seen in Greenland and Sweden, could be used to support the argument made by others (Certini and Scalenghe, 2011; Ellis et al., 2013; Ruddiman, 2003) using different proxies that substantial human impacts on the environment were occurring millennia before the Industrial Revolution.

## *Sulphur isotopes*

Sulphur isotope ratios can be used to track fossil fuel burning and to trace the sources of pollution because, as with lead isotopes, natural and anthropogenic sources often have different isotope ratios (e.g. Krouse et al., 1984; Lim et al., 2014). Sulphur released into the atmosphere has the potential to cause acid rain. Concerns over widespread ecosystem damage resulting from acid rain first gained prominence in Europe in the late 1950s. Tracing the sources of sulphur pollution is particularly important given sulphur compounds produced and released into the atmosphere in one country can travel across borders and cause acid rain in another (Metcalfe and Derwent, 2005). Yu et al. (2007) demonstrated how the $\delta^{34}S$ of sulphate in meteoric waters from Chuncheon in South Korea vary from +2.6 to +7.5‰, which is significantly different from the $\delta^{34}S$ of sulphate from locally combusted coal (−4.5 to −0.7‰). This was taken to suggest that sulphur implicated in acid rain in that region was not the result of local pollution. A decline in emissions over time from brown coal power stations in eastern Germany has been recorded in an increase in $\delta^{34}S$ of rain in Wroclaw in Poland, demonstrating the effectiveness of measures taken to reduce acid rain resulting from anthropogenic emissions (Jędrysek, 2000). Indeed, global sulphur emissions are showing an

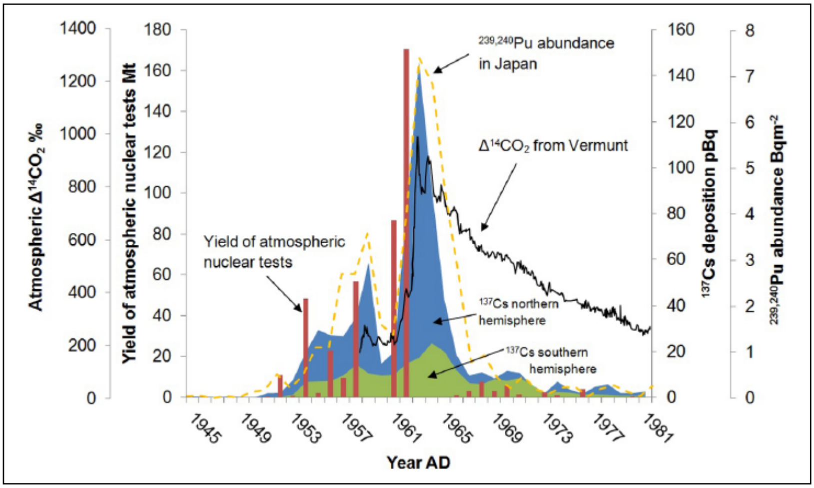


**Figure 6.** Yield of atmospheric nuclear tests per year shown by bars (UNSCEAR, 2000), $^{137}Cs$ deposition in Northern and Southern Hemispheres represented by areas (UNSCEAR, 2000), $^{239,240}Pu$ deposition in Japan shown by the dashed line (Hirose et al., 2000) and $\Delta^{14}CO_2$ measured at Vermunt, Austria shown by the solid line (Levin et al., 1985). The yield of atmospheric nuclear tests in the atmosphere peaked in 1962. $\Delta^{14}CO_2$ at Vermunt, $^{239,240}Pu$ in Japan and $^{137}Cs$ deposition in the Northern Hemisphere peaked in 1963 and $^{137}Cs$ in the Southern Hemisphere in 1964.

overall decline (Klimont et al., 2013). This demonstrates that some anthropogenic impacts on the environment, in this case acid rain linked to sulphur emissions as recorded by $\delta^{34}S$, have peaked, at least in some parts of the world.

## Radioisotopes

Some isotopes (e.g. $^{137}Cs$, $^{239}Pu$ and $^{240}Pu$) occur on Earth almost entirely because of their production and release into the atmosphere from nuclear reactors and especially atmospheric nuclear weapons testing. They provide a rather precise stratigraphic point in geological archives, with detectable levels first apparent ~AD 1952, and peak abundance ~AD 1963/1964 after a large number of atmospheric nuclear tests were carried out in AD 1962 before the Partial Nuclear Test Ban Treaty came into effect (Figure 6) (Hirose et al., 2000; United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2000). $^{14}C$ is produced naturally in the atmosphere through the interaction of neutrons with nitrogen atoms, but as discussed above the burning of fossil fuels had been leading to a decline in $\Delta^{14}CO_2$ in the atmosphere. This trend was interrupted as neutrons released by atmospheric nuclear tests increased the production of $^{14}C$ in the atmosphere, with a peak at a similar time to the peaks in $^{137}Cs$, $^{239}Pu$ and $^{240}Pu$ (Figure 6) (Graven et al., 2012; Levin and Kromer, 2004; Levin et al., 1985; Naegler and Levin, 2009), before a decline again to the present day, producing a time-dependent distribution pattern that is referred to as the 'bomb curve'. This is seen in archives such as tree rings (Hua et al., 2000) and corals (Roark et al., 2006).

## Conclusion

Changes in isotope geochemistry demonstrate that humans are having an impact on the global environment. Different isotopes have recorded different anthropogenic impacts, and changes have occurred at different times and different rates. $\delta^{13}C$ and $\Delta^{14}C$ show the input of fossil fuel-derived $CO_2$ into the atmosphere, $\delta^{15}N$ records reveal a change in the global nitrogen cycle, lead and sulphur isotopes are tracers of human pollution histories and radioisotopes record the point at which humans mastered nuclear weapons technology. Some of the isotopes that we use to demonstrate human impacts, especially carbon and nitrogen isotopes, could also be influenced in similar ways by natural processes. This complexity has led to the Early Anthropogenic Hypothesis debate. On the other hand, other isotopes, especially radioisotopes, but arguably also lead isotopes, show a clear human imprint: in the case of certain radioisotopes their occurrence is almost entirely due to human-induced nuclear reactions and in the case of lead isotopes the ratios are changed in ways unlikely to be due to natural processes.

As for whether isotopes can contribute to the debate on where to set the Holocene–Anthropocene boundary, we have shown there is a clear acceleration in the trend to lower $\delta^{13}C$ and $\delta^{15}N$ after ~AD 1950, at the time of the ‘Great Acceleration’ in human activities (Steffen et al., 2007), and a decade later there was a near synchronous, worldwide peak in radioisotopes related to atmospheric nuclear weapons testing that could be useful as a unique stratigraphic marker to define the boundary (Zalasiewicz et al., 2014). However, it has been argued that carbon isotopes show (smaller) changes in the global composition of the atmosphere hundreds to thousands of years before AD 1950 and other isotopes, such as lead, also show human impacts on the environment millennia ago. Therefore, while there *is* an isotopic signature of the Anthropocene, and isotope geochemistry can play a role in the decision of the International Commission on Stratigraphy regarding whether to define a new geological epoch, it is not clear from isotopes alone *where* to set the Holocene–Anthropocene boundary.

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