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Incorporating the current sixth great mass extinction theme into evolution education, science education, and environmental education research and standards

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Abstract

Humanity is currently in the midst of a self-induced great mass extinction of plant and animal life that is having and will have profound effects on the future biological evolution of Earth's species if environmental sustainability is not reached. A thorough review of existing evolution education, science education, and environmental education research and existing evolution education, science education, and environmental education standards reveal that this newly emerging and crucially important theme has yet to be incorporated into these two areas which strongly influence future curriculum development and implementation. This manuscript presents: a brief overview of the five past great mass extinctions; a brief overview of past and present human activities associated with the current sixth great mass extinction; a brief overview of present and future rates of species extinctions and their influence on biological evolution; and a brief appeal to begin to incorporate the current sixth great mass extinction theme into evolution education, science education, and environmental education research and standards.

Keywords: Anthropogenic, Biodiversity, Biological evolution, Education, Research, Sixth great mass extinction, Standards, Sustainability

Background

Humanity is currently in the midst of a self-induced great mass extinction of plant and animal life (e.g., Jackson 2008; Wake and Vredenburg 2008; Zalasiewicz *et al*. 2010) that is having and will have profound effects on the future biological evolution of Earth's species (Wagler 2011a) if environmental sustainability is not reached (e.g., World Wide Fund for Nature WWF 2012; Pimm and Raven 2000). A thorough review of existing evolution education, science education and environmental education research (e.g., ERIC; ProQuest; EBSCO) and existing evolution education, science education, and environmental education standards (e.g., North American Association for Environmental Education NAAEE 2012; National Research Council NRC 1996; National Research Council NRC 2011) reveal that this newly emerging and crucially important theme has yet to be incorporated into these two areas which strongly influence future curriculum development and implementation. This manuscript presents a brief overview of the five past great mass extinctions; a brief overview of past and present human activities associated with the current sixth great mass extinction; a brief overview of present and future rates of species extinctions and their influence on biological evolution; and a brief appeal to begin to incorporate the current sixth great mass extinction theme into evolution education, science education, and environmental education research and standards.

A brief overview of the five past great mass extinctions

Earth is approximately 4.5 billion years old (Dalrymple 2001). During Earth's history there have been five past great mass extinctions (Erwin 2001; Jablonski 1995) (Table 1). During all of these past great mass extinctions, there was 'a profound loss of biodiversity during a relatively short period' (Wake and Vredenburg 2008, 11466). The first past great mass extinction occurred

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Table 1 Earth's five past great mass extinctions

Great mass extinction	Number	Date extinction occurred	Cause of extinction	Loss of life
Ordovician-Silurian extinction	1st	Approximately 439 million years ago	Fluctuations in sea level; extensive glaciations; global warming	'Approximately 25% of the families and nearly 60% of the genera of marine organisms were lost.
Late Devonian extinction	2nd	Approximately 364 million years ago	Global cooling after bolide impacts may have been responsible	'22% of marine families and 57% of marine genera, including nearly all jawless fishes, disappeared.'
Permian-Triassic extinction	3rd	Approximately 251 million years ago	Causes are debated. The leading candidate is flood volcanism. This led to profound climate change. The volcanism may have been initiated by a bolide impact	'95% of all species (marine as well as terrestrial) were lost, including 53% of marine families, 84% of marine genera, and 70% of land plants, insects, and vertebrates.'
End Triassic extinction	4th	Approximately 199 to 214 million years ago	'Opening of the Atlantic Ocean by seafloor spreading related to massive lava floods that caused significant global warming.'	'Marine organisms were most strongly affected (22% of marine families and 53% of marine genera were lost), but terrestrial organisms also experienced much extinction.'
Cretaceous-Tertiary extinction	5th	Approximately 65 million years ago	Causes are debated. Possible causes include a giant asteroid impact in the Gulf of Mexico and climatic changes resulting from volcanic floods in India	'16% of families, 47% of genera of marine organisms, and 18% of vertebrate families were lost.'

Notes: (1) The first and second great mass extinctions 'may not qualify because new analyses show that the magnitude of the extinctions in these events was not significantly higher than in several other events' (Wake and Vredenburg 2008, 11466). See Alroy (2008) for the specific details associated with this research. (2) The direct quotes are from (Wake and Vredenburg 2008, 11466). Wake and Vredenburg's original sources were Erwin (2001) and Jablonski (1995). (3) This figure has been modified and reproduced with permission from Wagler 2011b.

approximately 439 million years ago while the fifth took place approximately 65 million years ago (Erwin 2001; Jablonski 1995). 'The fifth great mass extinction is the most well-known to the general public because it involved the extinction of the non-avian dinosaurs (Wake and Vredenburg 2008) and the survival of the only existing living group of dinosaurs, the birds' (Wagler 2012, 49). The Permian-Triassic extinction was Earth's most destructive past great mass extinction in which 95% of all species went extinct (Erwin 2001; Jablonski 1995). With all five past great mass extinctions the biological evolution of existing species was profoundly affected. Recovery was slow (i.e., several million years) and was facilitated by the evolution of new species instead of the re-expansion of the surviving species (Myers *et al*. 2000; Veron 2008).

A brief overview of past and present human activities associated with the current sixth great mass extinction

Humanity has entered a sixth great mass extinction driven by our excessive activities (e.g., Alroy 2008; Jackson 2008; Lewis 2006; McDaniel and Borton 2002; Rockström *et al*. 2009; Rohr *et al*. 2008; Steffen *et al*. 2007; Thomas *et al*. 2004; Wake and Vredenburg 2008; Zalasiewicz *et al*. 2010). These activities have taken many forms but the most devastating anthropogenic direct drivers affecting global biodiversity are: (1) habitat modification, fragmentation, and destruction; (2) pollution; (3) climate change; (4) overexploitation of species; and (5) the spread of invasive species and genes (Millennium Ecosystem Assessment MEA 2005; World Wide Fund for Nature WWF 2012).

The simple reality is we have become, through our sheer numbers and consumption rates, the greatest destructive force to our ecosystems and the organisms that live in them. For the first time in human history, there are too many of us taking too much from the very ecosystems that sustain us. The number of humans on Earth at any one time has grown astronomically over the last 260 years. 'Two thousand years ago, there were 300 *million* people on Earth. One thousand years ago, there were 310 million people on Earth, and 260 years ago, there were 790 million people on Earth (all values are approximate; United Nations 1999). In the last 260 years, the human population has increased by 6.2 *billion* people. Currently, there are 7 billion people on Earth, and the human population is projected to be 9.3 billion by 2050 (all values are approximate; United Nations 2011a; US Census Bureau 2010)' (Wagler 2012, 50).

Just as the number of humans on the planet (at any one time) has grown astronomically so has the staggering amount of natural resources we remove and consume from global ecosystems. We now use more than half of all available fresh water (Crutzen 2002) and between one-third and one-half of all land on Earth (Lewis 2006). We move more soil, rock, and sediment than all natural processes combined and have built reservoirs that hold from three to six times as much water as in natural rivers (Lewis 2006). We release into the atmosphere, from the burning of fossil fuel and biomass, more nitric oxide and sulfur dioxide than all natural sources combined and use more nitrogen fertilizer than is fixed in all natural terrestrial ecosystems (Crutzen 2002).

Humans have destroyed approximately 75% of temperate forests, Mediterranean forests, and temperate grasslands and have replaced them with cultivated land (Millennium Ecosystem Assessment MEA 2005). Human fishing removes more than 25% of the primary production in upwelling ocean regions, more than 35% of the primary production in the temperate continental shelf (Crutzen 2002), and 65% of global river discharge (and the aquatic habitat supported by this water) is under moderate to high threat from human influence (Vörösmarty *et al.* 2010).

Through our burning of fossil fuels we have elevated atmospheric CO_2 concentrations to their highest levels in 15 million years, driving global warming, rising sea levels, and climate change (Tripati *et al.* 2009). For example, from 1990 to 2008, global fossil fuel emissions increased 41% and from 2000 to 2008, global fossil fuel emissions increased 29%. The increase from 2000 to 2008 occurred 'in conjunction with increased contributions from emerging economies, from the production and international trade of goods and services, and from the use of coal as a fuel source' (Le Quéré *et al.* 2009, 1). 'Based on global human consumption rates, humanity exceeded Earth's biocapacity in the mid to late 1980s (World Wide Fund for Nature WWF 2008). Humanity's demand on Earth's living resources now exceeds the planet's regenerative capacity by about 30 percent' (Wagler 2012, 50). This percentage is increasing and 'as a consequence, ecosystems are being run down and waste is accumulating in the air, land and water' (World Wide Fund for Nature WWF 2008, 2).

A brief overview of present and future rates of species extinctions and their influence on biological evolution

Earth's evolutionary biodiversity has been greatly impacted by our collective activities. Over the past 300 years, we have increased global species extinction rates 100 to 1,000 times Earth's historical geological background rate (Pimm *et al.* 1995; Rockström *et al.* 2009). 'Modeled future extinction rates are projected to be 10,000 times Earth's historical geological background rate (Millennium Ecosystem Assessment MEA 2005)' (Wagler 2012, 51). Twelve percent of birds, 23% of mammals, 32% of amphibians, 52% of cycads (a group of evergreen palm-like plants), and 25% of conifers are threatened with extinction (Millennium Ecosystem Assessment MEA 2005). These percentages are only known because these taxonomic groups are the only ones that have been comprehensively evaluated by science (Millennium Ecosystem Assessment MEA 2005, 35). All other taxonomic groups have not currently been evaluated but scientists believe similar trends are occurring.

In the last several decades, 20% of Earth's coral reefs have been destroyed and another 20% degraded (Millennium Ecosystem Assessment MEA 2005). 'Only 44,838 of Earth's 1,642,189 described species have been assessed in terms of conservation status by the International Union for Conservation of Nature (IUCN) Red List. Over one third (i.e., 16,928 species) of the 44,838 species on the IUCN Red List are threatened with extinction (International Union for Conservation of Nature Red List IUCN 2009)' (Wagler 2012, 51). Further news of concern comes from the (World Wide Fund for Nature WWF 2008), which measures some of Earth's biodiversity. Based on the trends of 1,686 species of mammal, bird, reptile, amphibian, and fish living in nearly 5,000 populations, a 30% decline in biodiversity has been observed from 1970 to 2005 (World Wide Fund for Nature WWF 2008).

Lastly, the most disheartening information comes from the tropics, where approximately two-thirds of all organisms live, primarily in tropical humid forests (Pimm and Raven 2000). Currently, over half of our tropical humid forests have been destroyed and countless unknown species lost. At the present deforestation rate, it is estimated the tropical humid forests that remain and the discovered and undiscovered species they contain will be destroyed by 2060, causing unprecedented consequences for our species and putting an end to these species' long evolutionary histories. When considering the ever-increasing trajectory of humanities anthropogenic activities, there is a high probability that major evolutionary radiations have been and will be lost in the near future (Millennium Ecosystem Assessment MEA 2005) if environmental sustainability is not reached.

A brief appeal to begin to incorporate the current sixth great mass extinction

Because the current sixth great mass extinction incorporates all five of the direct drivers affecting global biodiversity (i.e., (1) habitat modification, fragmentation, and destruction; (2) pollution; (3) climate change; (4) overexploitation of species; and (5) the spread of invasive species and genes (Millennium Ecosystem Assessment MEA 2005; World Wide Fund for Nature WWF 2012)) the theme allows for the most encompassing way to educate people about the impact of global anthropogenic activities on the well-being and biological evolution of Earth's species (Wagler 2011a). Unfortunately, this theme is absent from existing evolution education, science education and environmental education research, existing evolution education, science education and environmental education standards, and only extremely minimal examples exist in current curriculum (i.e., Wagler 2011a; Wagler 2011b; Wagler 2012). If the educational efforts of the evolution education, science education, and environmental education community are to be a relevant force assisting in bringing humanity back into global sustainability during the 21st century, it is essential that researchers and those that develop standards begin to incorporate the current sixth great mass extinction theme into their work.

Educational research that is conducted and standards that are developed that incorporate the current sixth great mass extinction theme should also be framed with the following concepts.

1. Educational emphasis should be placed on ways humanity can equitably and ethically begin to non-coercively modify our current behaviors to reduce the two overarching factors causing the current sixth great mass extinction: (1) the current size of the human population; and (2) the current natural resource consumption rate of the human population (e.g., World Wide Fund for Nature WWF 2012).
2. This knowledge should be augmented with an educational awareness that, as a general trend, the greatest human population growth is occurring in the least developed countries (United Nations 2011b) and the highest-per-capita human natural resource consumption rate is occurring in the most developed countries (e.g., World Wide Fund for Nature WWF 2012).
3. Educational emphasis should be placed on ways the international community can ethically reduce global inequality by assist in lifting over 1 billion of the poorest humans on Earth out of absolute poverty (i.e., living on less than US $1.25 per day (World Bank 2012) (People and the Planet PP 2012).

Research is needed to identify educational interventions that have the capacity to lead humanity to future global sustainability. These research finds must be central to the development of future standards that guide the establishment of effective curriculum and educational interventions. These research-based standards have the potential to influence schools, districts, state and federal departments and agencies, national education groups and many other education entities in adopting and implementing effective sustainability curriculum and educational interventions. These efforts will educate, thereby influencing humans to change their behaviors to decrease the level of global anthropogenic activity that is causing the current great mass extinction. By educating others about these complex issues, humanity can potentially modify our current behaviors and reach a point of future sustainability avoiding an anthropogenic environmental disaster of global proportions.

Competing interests
The author declares that he has no competing interests.

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