The Sixth Great Mass Extinction

by Ron Wagler

Five past great mass extinctions have occurred during Earth’s history. Humanity is currently in the midst of a sixth, human-induced great mass extinction of plant and animal life (e.g., Álroy 2008; Jackson 2008; Lewis 2006; McDaniel and Borton 2002; Rockström et al. 2009; Rohr et al. 2008; Steffen, Crutzen, and McNeill 2007; Thomas et al. 2004; Wake and Vredenburg 2008; Zalasiewicz et al. 2010). This article explains the first five great mass extinctions, the current great mass extinction, and the human activities and rates of species extinction associated with the current extinction. The sixth great mass extinction can be used to teach students about environmental change and its impacts and extinction. The topics and resources discussed here can also be aligned to all seven of the crosscutting concepts in A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC 2011, 4-1–4-2), which include examples such as cause and effect: mechanism and
Earth’s past great mass extinctions

The Earth is over 4.5 billion years old (Dalrymple 2001), and during the planet’s history, five past great mass extinctions have occurred (Erwin 2001; Jablonski 1995). During all of these past great mass extinctions, there was an enormous loss of life in a short time (see Figure 1). The first great mass extinction occurred approximately 439 million years ago; 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. The most destructive past great mass extinction was the Permian–Triassic extinction, in which 95% of Earth’s species went extinct (Erwin 2001; Jablonski 1995)

Human activities associated with the current great mass extinction

There is an ever-increasing scientific voice stating that humanity has entered a sixth great mass extinction (e.g., Alroy 2008; Jackson 2008; Lewis 2006; McDan-

<table>
<thead>
<tr>
<th>Name</th>
<th>Number</th>
<th>Date of extinction</th>
<th>Cause of extinction</th>
<th>Loss of life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordovician–Silurian extinction</td>
<td>1st*</td>
<td>~439 million years ago</td>
<td>Fluctuations in sea level; extensive glaciations; global warming</td>
<td>“Approximately 25% of the families and nearly 60% of the genera of marine organisms were lost.”</td>
</tr>
<tr>
<td>Late Devonian extinction</td>
<td>2nd*</td>
<td>~364 million years ago</td>
<td>Global cooling after bolide (large exploding meteor) impacts may have been responsible.</td>
<td>“22% of marine families and 57% of marine genera, including nearly all jawless fishes, disappeared.”</td>
</tr>
<tr>
<td>Permian–Triassic extinction</td>
<td>3rd</td>
<td>~251 million years ago</td>
<td>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.</td>
<td>“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.”</td>
</tr>
<tr>
<td>End Triassic extinction</td>
<td>4th</td>
<td>~199–214 million years ago</td>
<td>“Opening of the Atlantic Ocean by seafloor spreading related to massive lava floods that caused significant global warming.”</td>
<td>“Marine organisms were most strongly affected (22% of marine families and 53% of marine genera were lost), but terrestrial organisms also experienced much extinction.”</td>
</tr>
<tr>
<td>Cretaceous–Tertiary extinction</td>
<td>5th</td>
<td>~65 million years ago</td>
<td>Causes are debated. Possible causes include a giant asteroid impact in the Gulf of Mexico and climatic changes resulting from volcanic floods in India.</td>
<td>“16% of families, 47% of genera of marine organisms, and 18% of vertebrate families were lost.”</td>
</tr>
</tbody>
</table>

Notes: The direct quotes are from Wake and Vredenburg (2008, p. 11466). Wake and Vredenburg’s original sources were Erwin (2001) and Jablonski (1995). This figure has been modified and reproduced with permission from Wagler 2011.

“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, p. 11466). See Alroy (2008) for the specific details associated with this research.
iel and Borton 2002; Rockström et al. 2009; Rohr et al. 2008; Steffen, Crutzen, and McNeill 2007; Thomas et al. 2004; Wake and Vredenburg 2008; Zalasiewicz et al. 2010). Unlike the past five great mass extinctions, “human activities are associated directly or indirectly with nearly every aspect of the current extinction spasm” (Wake and Vredenburg 2008, p. 11472). These human activities have taken many forms, with the most devastating and far-reaching anthropogenic direct drivers affecting global biodiversity being (1) the spread of invasive species and genes; (2) overexploitation of species; (3) habitat modification, fragmentation, and destruction; (4) pollution; and (5) climate change (MEA 2005; WWF 2010) (see Figure 2 for more human activities).

Between one-third and one-half of all land on Earth is now used by humans. We have built water reservoirs that can hold six times as much water as is in all of Earth’s natural rivers. We also now move more rock, sediment, and soil than all natural processes combined (Lewis 2006). Through our increased burning of fossil fuels we have elevated atmospheric CO₂ concentrations to their highest levels in 15 million years, driving climate change, rising sea levels, and global warming (Tripati, Roberts, and Eagle 2009). From 1990 to 2008, global fossil fuel emissions increased 41%; from 2000 to 2008, emissions increased 29%. The latter increase 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, p. 1).

As the amount of natural resources people consume goes up, the number of people on Earth, at any one time, has also grown astronomically over the past 200 to 300 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 2011; U.S. Census Bureau 2011). Based on global human consumption rates, humanity exceeded Earth’s biocapacity in the mid- to late 1980s (WWF 2008). Humanity’s demand on Earth’s living resources now exceeds the planet’s regenerative capacity by about 30 percent. “This global overshoot is growing and, as
a consequence, ecosystems are being run down and waste is accumulating in the air, land and water” (WWF 2008, p. 2). Humanity as a whole has become, through sheer numbers and consumption rates, the dominant force destroying Earth.

**Current and future rates of species extinction**

Global biodiversity has been greatly affected by our collective activities. It is estimated there are 5 to 30 million living species on Earth (Dirzo and Raven 2003; MEA 2005). Humans have accelerated, over the past 200 to 300 years, 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 (MEA 2005).

Currently 12% of birds, 23% of mammals, 32% of amphibians, 52% of cycads (a group of evergreen palm-like plants), and 23% of conifers are threatened with extinction (MEA 2005). These percentages are known because these five taxonomic groups, out of all the major taxonomic groups on Earth, are the only ones that have been comprehensively evaluated by scientists (MEA 2005, p.35). In the last several decades, 20% of Earth’s coral reefs have been degraded and another 20% destroyed (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 (IUCN 2009). Further disheartening news comes from the Living Planet Index (WWF 2008), which measures the Earth’s biodiversity. Based on the trends of nearly 5,000 populations of 1,686 species of mammal, bird, reptile, amphibian, and fish, a 30% decline in biodiversity has been observed from 1970 to 2005 (WWF 2008).

Finally, the worst news comes from the tropics, where approximately two-thirds of all organisms live, mainly in tropical humid forests (Pimm and Raven 2000). At present, over half of Earth’s tropical humid forests have been destroyed and countless undiscovered species lost. At the current deforestation rate, it is estimated the remaining tropical humid forests and the species they contain (discovered and undiscovered) will be destroyed by 2060, causing unprecedented consequences for humanity.

**Characteristics of the sixth great mass extinction curriculum theme**

The degree to which humans have affected Earth has been made obvious by science, yet there is little discussion of these human activities in most middle school science classrooms. There is a need, at this level, to begin to integrate aspects of the current sixth mass extinction into existing curricula. The sixth great mass extinction is a newly emerging scientific theme that has great potential in the middle school science classroom. Because the sixth great mass extinction has components that address abiotic, biotic, and societal factors; it can be integrated into life science class, physical science class, and non-science classes such as social studies and art (NRC 1996, 2009, 2011). The theme also lends itself for use in scientific inquiry activities in both the indoor and outdoor classroom (NRC 1996, 2009, 2011). The theme is relevant to students since, on some level, the sixth mass extinction has the potential to affect the quality of their lives, the quality of life of people they know, and life on Earth (NRC 1996, 2009, 2011).

The sixth great mass extinction theme can also be aligned to A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC 2011), which lays out seven crosscutting concepts (NRC 2011, p. 4-1-4-2) that bridge science and engineering disciplines and “help provide students with an organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world” (p. 4-1). For example, one of the seven crosscutting concepts in the Framework is “Stability and Change” (NRC 2011, p. 4-11-4-13), where it is stated, “For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of the system are critical elements of study” (p. 4-2). The current great mass extinction provides an excellent theme for repeatedly reinforcing this crosscutting concept because human activities (via human-built systems) have radically destabilized and changed the biosphere’s natural systems over the past 200 to 300 years.

**Middle school science curriculum topics associated with the sixth great mass extinction**

The current great mass extinction provides an abundance of education opportunities for middle school science teachers and their students. The five major
Major anthropogenic direct driver of biodiversity loss: Habitat modification, fragmentation, and destruction
Relevant science curriculum topics:
- Deforestation rates and locations
- Effect on invertebrate (e.g., coral, insect, crustacean, and arachnid) biodiversity because of habitat modification, fragmentation, and destruction
- Examples of habitat modification, fragmentation, and destruction (e.g., Madagascar and North American tall grass prairie)
- The association between human population dynamics (e.g., population growth, population density, factors that affect and regulate population growth) and habitat modification, fragmentation, and destruction
- Impact on global carrying capacity because of habitat modification, fragmentation, and destruction
- Impact on trophic levels, food chains, food webs, and energy flow within ecosystems because of habitat modification, fragmentation, and destruction
- Past and current species extinctions associated with habitat modification, fragmentation, and destruction
- Physical alteration of waterways and the impact on habitat
- Role of habitat modification, fragmentation, and destruction in species extinction
- The impact of habitat modification, fragmentation, and destruction on erosion and sedimentation rates

Major anthropogenic direct driver of biodiversity loss: Overexploitation of species
Relevant science curriculum topics:
- Examples of overexploitation of species (e.g., American bison and Galapagos tortoise)
- Overexploitation of species impact on endemic species, endangered species, and threatened species
- How the goal of environmental sustainability is affected by overexploitation of species
- Effect on vertebrate (e.g., fish, amphibian, reptile, bird, and mammal) biodiversity because of overexploitation of species
- The association between human population dynamics (e.g., population growth, population density, factors that affect and regulate population growth) and overexploitation of species
- Examples of species extinctions because of overexploitation of species
- Overexploitation of species and the impact on predator-prey cycles
- Overexploitation of species impact on trophic levels, food chains, food webs, and energy flow within ecosystems
- Overexploitation of tropical humid forests and other forests
- Past and present species extinctions associated with overexploitation of species

Major anthropogenic direct driver of biodiversity loss: The spread of invasive species and genes
Relevant science curriculum topics:
- Effect of global warming (e.g., increased range of invasive species)
- Examples of invasive species (e.g., Guam [brown tree snake] and Australia [cane toad])
- Impact of invasive species on endemic species, endangered species, and threatened species
- Impact of invasive species on species evolution (e.g., natural selection and coevolution)
- Invasive species’ impact on predator-prey cycles
- Invasive species’ impact on trophic levels, food chains, food webs, and energy flow within ecosystems
- How environmental sustainability is affected by the spread of invasive species and genes
- Invasive species’ role in species extinction
- The influence of invasive species and genes on biodiversity, biocapacity, species richness, genetic diversity, and ecosystem diversity

Major anthropogenic direct driver of biodiversity loss: Pollution
Relevant science curriculum topics:
- Acid rain
- Air pollutants (e.g., carbon monoxide, nitrogen dioxide, sulfur dioxide, lead, PM_{2.5}, and PM_{10})
Bioaccumulation and biomagnifications of chemicals (e.g., mercury and PCBs) in food chains
- Chlorofluorocarbon and stratosphere ozone depletion (i.e., the ozone “hole”)
- The association between per capita human ecological/carbon footprint and pollution
- The association between human population dynamics (e.g., population growth, population density, factors that affect and regulate population growth) and pollution
- Soil pollutants (e.g., hydrocarbons, heavy metals, herbicides, and pesticides)
- Pollution’s impact on human health
- Pollution’s impact on trophic levels, food chains, food webs, and energy flow within ecosystems
- Water pollutants (e.g., volatile organic compounds and fertilizers)

Major anthropogenic direct driver of biodiversity loss: Climate change

Relevant science curriculum topics:
- Effects of global warming
- The association between per capita human ecological/carbon footprint and climate change
- Deforestation’s role in climate change
- Greenhouse gases’ (e.g., carbon dioxide, methane, surface ozone, and nitrous oxide) role in climate change
- The relationship between atmospheric carbon dioxide and ocean acidification
- Climate change’s effect on plant biodiversity
- Climate change’s impact on trophic levels, food chains, food webs, and energy flow within ecosystems
- Increased desertification as a result of climate change
- Natural cycles’ (e.g., water’s) alteration because of climate change
- The role of climate change in species extinction

Note: Figure 3 has been modified and reproduced with permission from Wagler 2011.

global anthropogenic direct drivers of biodiversity loss associated with the sixth great mass extinction are an excellent framework for presenting the complexity and challenges humanity is facing. Figure 3 presents these direct drivers and examples that can be integrated into existing science-curriculum topics. Topics can be combined to integrate across middle school physical and life sciences and across the five direct drivers of biodiversity loss. For all of the direct drivers, the scale of human impact can be addressed at the local, national, or global level.

Special emphasis can be placed on how we can begin to slow the amount of global environmental degradation humans are causing. This issue can be explored by asking students to research the two main factors causing global environmental degradation: (1) the current size of the human population and (2) the current natural-resource consumption rate of the human population. As a general trend, the greatest human population growth is currently occurring in less developed countries, and the highest-per-capita human natural resource consumption rate is occurring in more developed countries. Make your students aware that a person in a more developed country, such as the United States, consumes (on a per-capita basis) a great deal more natural resources than a person in a less developed country. Therefore, a person in a more developed country causes much more environmental degradation, either directly or indirectly, than a person in a less developed country. I accomplish this by having students calculate their ecological footprint at the Global Footprint Network website (see Resources). As a class, we then choose the characteristics of an individual living in poverty in a developing country (the least consumptive choices on the ecological footprint calculator). Through this, students grasp the concept that they (as individuals living in a developed country) are consuming much more natural resources than a person in a developing country, and therefore they are causing (indirectly or directly) more environmental degradation.

Lastly, discuss with your students ways humanity can equitably and ethically begin to reduce both of these overarching factors by changing current behaviors.

Resources for exploring the topics presented

Many free, online resources are available to assist you and your students in exploring the topics presented (see
THE SIXTH GREAT MASS EXTINCTION

Resources). These resources include, but are not limited to, interactive websites with student activities and interactive websites for teacher-guided, student-generated, question-based investigations; scientific information or scientific reports for teacher-guided, student-generated, question-based investigations; scientific studies for incorporation into teacher-guided class discussions; and middle school science pedagogy techniques.

Using the topics and exploring the resources will provide you with many opportunities to integrate this content into your existing curriculum. It will also provide you and your students with an abundance of opportunities to learn about the sixth great mass extinction and many of the anthropogenic activities associated with it. For example, two of the online resources available in the Resources section are Google Earth and the U.S. Environmental Protection Agency’s MyEnvironment; most of the topics presented in Figure 3 can be explored with Google Earth (http://earth.google.com) and numerous Google Earth interactive environmental activities (www.earthblog.com). MyEnvironment (www.epa.gov/myenvironment) allows users to pinpoint any location in the U.S. (via satellite map) and assess the air, water, and land quality. Furthermore, it shows what toxic releases (i.e., pollution) the Environmental Protection Agency is allowing in your area or throughout the U.S. This will allow you to address the topics in Figure 3 associated with the direct driver of pollution. MyEnvironment will also allow you to do a multitude of other activities linked to the environment that can facilitate investigations about the topics presented in Figure 3.

Conclusion

Earth sustains us and makes our existence possible. For the first time in human history, there are too many of us taking too much from Earth. This is causing organisms to go extinct and poisons to accumulate in our air, water, and land. Letting students explore and find solutions to these problems has the potential to begin to slow these effects. I would propose, in our ever-changing world, that this is an essential skill we all need.

References


**Resources**

**General**

Google Earth—http://earth.google.com

Interactive websites with student activities or interactive websites for teacher-guided, student-generated, question-based investigations


Google Earth Blog: Source for interactive environmental activities—www.gearthblog.com

The Habitable Planet: A wealth of information and interactive activities about Earth—www.learner.org/courses/envsci/unit

TOXMAP: Find out which toxins are being released near you and their health effects—http://toxmap.nlm.nih.gov

U.S. Environmental Protection Agency: Superfund: Learn about superfund sites and where they exist—www.epa.gov/superfund

U.S. Environmental Protection Agency’s MyEnvironment: Explore environmental issues anywhere in the U.S.—www.epa.gov/myenvironment

Worldometers: Find statistics about current human population and environmental degradation—www.worldometers.info

**Scientific information or scientific reports for teacher-guided, student-generated, question-based investigations**

IUCN 2009

The IUCN Red List of Threatened Species: View the conservation status of Earth’s species by searching a species name or by conservation status category—www.iucnredlist.org


**Scientific studies for incorporation into teacher-guided discussions**

Alroy 2008; Erwin 2001; Jackson 2008; Rohr et al. 2008; U.S. Census Bureau 2011; Wake and Vredenburg 2008; Zalasiewicz et al. 2010

**Middle school science pedagogy techniques**


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