



# How Does Human Activity Affect Species Extinctions?

God's Word clearly articulates His expectation that we should be faithful stewards of His creation (Genesis 2:15; Exodus 23:5, 10-12; Leviticus 25:2-7, 23, 24; Numbers 22:23-33; Deuteronomy 25:4; Matthew 12:11). Thus, we should become broadly informed on issues that affect life on our planet and proactively accept our responsibility to safeguard the wellbeing of our cohabitants—the extraordinarily diverse microbes, plants, and animals that God created and repeatedly pronounced as “good” (Genesis 1).

Today, many scientists believe we are confronted with one of the planet's greatest extinction events of all time, which has produced an ecological meltdown and biodiversity crisis. Unfortunately, many issues relating to this dire situation have become highly politicized, creating polarization. Whereas some Christians seem unconcerned that God says He will hold us accountable for the way we manage

*“The ecological crisis is rooted in humankind's greed and refusal to practice good and faithful stewardship within the divine boundaries of creation.”<sup>1</sup>*

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the resources He provided with the original creation, others insist we should join the largely secular movement to preserve that which remains of that creation.

To gain a better perspective on the relationship between human activities and species extinctions, we will first summarize the history of human-caused extinctions. We will then describe three key lines of evidence that humans have caused many extinctions, a problem that continues to gain alarming momentum. Within this context, we will explore the primary anthropogenic (human-related) causes of species extinctions and biodiversity loss. In the conclusion, we will revisit the Christian perspective on species extinctions and urge a greater role in ameliorating the destruction of God's creation.

## History of the Modern Extinction Crisis

Extinctions have featured prominently in Earth history, as

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evidenced by abundant fossil remains from various catastrophic events. Today, however, many scientists believe the planet is in the midst of a major extinction crisis driven largely by human activities.<sup>2</sup> Three distinct waves of human-caused extinction have been identified.<sup>3</sup>

- The first wave occurred long ago when humans moved to previously uninhabited areas, causing animals that had never before encountered humans to quickly succumb to overhunting. On Earth's major continents, humans butchered the “megafauna” (large mammals), including the mammoths (genus *Mammuthus*), mastodons (*Mammut*), and bison (*Bison*) of North America.<sup>4</sup> However, island ecosystems were the most severely afflicted. As the Polynesians spread across the Pacific Islands, as many as 2,000 species of birds vanished.<sup>5</sup> On Madagascar, at least eight species of flightless elephant birds (family Aepyornithidae), two species of Malagasy hippopotamus (*Hippopotamus*), up to 17 species of giant lemurs (primates of suborder Strepsirrhini), the giant fossa (*Cryptoprocta spelea*, a large, cat-like carnivore), and several additional mammals were exterminated.<sup>6</sup> On other Indian Ocean islands, several species of giant tortoise (family Testudinidae)<sup>7</sup> and 14 species of birds,<sup>8</sup> including the dodo (*Raphus cucullatus*, a flightless pigeon), vanished shortly after the arrival of humans. After the Maori settled New Zealand, at least 34 landbird species disappeared, among them some of the largest modern birds, including 11 species of flightless moas (family Dinornithidae), the Haast's eagle (*Harpagornis moorei*), and two species of adzebills (genus *Aptornis*).<sup>9</sup> These extinctions, corroborated largely by sub-fossil faunal remains coexisting with human artifacts, are sobering.

- The second wave of exterminations coincided with European conquests in many parts of the planet (500 to 40 years ago). Modern approaches to agriculture devastated natural ecosystems by converting broad swaths of land to a few favored food crops. More-efficient food production and advances in technology, fueled by new sources of energy, produced a population explosion. Relying on superior weaponry and modes of transportation, Europeans quickly colonized and subjugated much of the planet, spreading the ecological damage to new areas.

- The third wave, resulting from overpopulation and globalization in the past 40 years, has greatly accelerated the loss of biodiversity. Globalization has especially intensified the homogenization of biodiversity due to the transport of non-native (alien) species to new places, and the spread of disease. Compared to the first wave, the second and third waves have exacted a taxonomi-

cally broader and much more devastating toll on biodiversity, and have forever altered the planet. According to the 2011 International Union for Conservation of Nature (IUCN) Red List of Threatened Species, 32 percent of extant plants, 12 percent of fishes, 27 percent of amphibians (a very disconcerting figure), 15 percent of reptiles (many species have yet to be assessed), 6 percent of birds, and 14 percent of mammals are listed as either endangered or critically endangered—at extreme risk of extinction.<sup>10</sup> Many more are listed as vulnerable to extinction.

### Contemporary Evidence of Human Impacts on Extinctions

Additional evidence demonstrates the dramatic impact humans presently exert on biodiversity:

- First, analyses of species-area relationships show that extinction is strongly area-related. As a general rule, a 50 percent reduction in habitat will result in a 10 percent loss of species, and a 90 percent reduction in habitat will result in a 50 percent loss of species<sup>11</sup>; however, depending on taxonomic group, scale, and nature of land conversion, species loss can be lower or much higher.<sup>12</sup> Human conversion of natural habitats has been substantial. We will discuss this in the next section.
- Second, analyses of documented extinctions reveal that biodiversity losses are rapidly accelerating. Estimates vary regarding the current rate of species extinctions, but generally range between 5,000 and 100,000



**An artist's conception of the dodo, a flightless bird that became extinct less than a century after Europeans discovered it in the late 1500s.**

species per year, with as many as half of all bird and mammal species projected to disappear within 200 to 300 years.<sup>13</sup> These rates, derived by a variety of methods, are considered to be 10 to 10,000 times greater than natural rates of extinction.<sup>14</sup>

- Third, humans are currently using approximately 24 percent of the Earth's net primary productivity (NPP),<sup>15</sup> a measure of the net amount of carbon assimilated in a given period by vegetation. Some regions experience substantially higher human-appropriated net primary productivity (HANPP). Considering future human population growth, advancing technology, and proposed substitution of biomass for fossil fuel use, the increasing proportion of HANPP—largely benefiting a single species—will leave an increasingly smaller portion of NPP (trophic energy) available to other species.<sup>16</sup> Several studies have shown that HANPP is inversely related to biodiversity,<sup>17</sup> supporting the hypothesis that energy availability in ecosystems is a determinant of species diversity.

Clearly, the evidence for humans causing species extinctions is undeniable.



## Anthropogenic Causes of Species Extinctions

So how do humans currently contribute to species extinctions? We do so in six major ways and through synergistic combinations of these ways.

- **Habitat Destruction, Degradation, and Fragmentation.** Humans damage the habitats of other species primarily by clearing land for agriculture and by grazing of domestic animals.

Other destructive activities include logging, mining, burning, preventing natural fires, damming or diverting rivers and streams, draining wetlands, and eliminating keystone species like tortoises (family Testudinidae), beavers (*Castor*), and prairie dogs (*Cynomys*), whose activities create habitats for other species. These activities, combined with urbanization and the construction of roads and powerline corridors connecting urban areas, have severely degraded and fragmented habitats, disrupting the natural movements of many species and promoting the loss of local species populations.

Nearly a quarter (22 percent) of the land on our globe has been substantially converted to human-dominated uses.<sup>18</sup> Habitat loss has been most extensive in tropical and temperate forests, temperate grasslands, and tropical savannas, with up to 49 percent of some major biomes completely converted to human use.<sup>19</sup> By contrast, tundra and boreal forest biomes remain almost entirely intact (<2.5 percent lost).<sup>20</sup> Analyses based on species-area curves portray a shocking toll of deforestation on biodiversity, with estimates of 0.1–0.3 percent of tropical forest species—a whopping 14,000–40,000 species—disappearing annually.<sup>21</sup> The effects of habitat fragmentation can be nearly as devastating as habitat loss, disrupting the dispersal of individuals between growing and diminishing populations (metapopulations), and potentially resulting in extinction cascades.<sup>22</sup> Even as forests continue to dwindle, deforestation may still be accelerating.<sup>23</sup>

Today, the livestock industry sector is by far the single largest anthropogenic user of land, accounting for 70 percent of all agricultural property.<sup>24</sup> Livestock production is a key driver of many destructive ecosystem changes, including deforestation, conversion of forests and woodlands to grassland, desertification, and soil compaction and erosion with subsequent sedimentation of water courses, wetlands, and coastal areas.<sup>25</sup> Animal production also facilitates the establishment and spread of invasive plants and animals, as well as zoonotic diseases that humans contract through their contact with animals.<sup>26</sup>

**I**ntroduced species sometimes hybridize with rare native species, resulting in genetic homogenization or “genetic pollution”—the replacement of good genes with bad genes—and even extinction.

- **Introduction of Non-native (Alien) Species.** Recent globalization has facilitated the spread of introduced species. Approximately 50,000 non-native species of microbes, plants, and animals thrive in the United States, and an estimated 500,000 have invaded other nations of the world.<sup>27</sup> Most microbe and invertebrate introductions have been accidental, whereas most plant and vertebrate introductions have been intentional.<sup>28</sup> An estimated 10 to 20 percent of suc-

cessfully introduced species become invasive pests, disrupting natural ecosystems.<sup>29</sup> As a major driver of extinctions, alien species have caused up to 40 percent of species extinctions in the U.S.<sup>30</sup> and up to 80 percent in other regions of the world.<sup>31</sup> One of the most devastating invasion-induced extinction events known resulted from the introduction of the predatory Nile perch (*Lates nilotica*) into Lake Victoria (East Africa), which caused the loss of between 200 and 400 endemic cichlid fish species and several other native fishes.<sup>32</sup>

Global homogenization of biodiversity (i.e., biomonotony) through introductions is reducing the distinctive biotas of many regions and disrupting fragile ecosystems. Introduced species tend to be ecological generalists that either outcompete, prey upon, parasitize, hybridize with, or spread diseases to native species, which tend to be ecological specialists with a limited geographical distribution.<sup>33</sup> Introduced species sometimes hybridize with rare native species, resulting in genetic homogenization or “genetic pollution”—the replacement of good genes with bad genes—and even extinction.<sup>34</sup> Invasive species also affect biodiversity by disrupting ecosystem dynamics, including nutrient enrichment,<sup>35</sup> water balance,<sup>36</sup> and fire regimes.<sup>37</sup> Many introduced species are synanthropic—adapted to human-dominated environments—where they become superior competitors.<sup>38</sup>

Island ecosystems are especially vulnerable to alien-species introductions because they host relatively few species, which are less capable of competing with and defending themselves against introduced species from continents. Nearly half of all known plant and animal extinctions since 1600 have occurred on islands.<sup>39</sup> Invasive predators such as cats (*Felis catus*) and rats (*Rattus* spp.) have become established on more than 80 percent of the world’s islands.<sup>40</sup> Fortunately, invasive mammal eradications from islands<sup>41</sup> and population reintroductions of endangered species<sup>42</sup> have helped to stem the losses.

Apart from the toll on biodiversity, alien species also cripple





human economies. In the United States alone, invasive species cost in excess of U.S.\$138 billion annually for damage and control costs.<sup>43</sup> Notorious examples include the zebra mussel (*Dreissena polymorpha*), a mollusk that has clogged freshwater ecosystems throughout much of the U.S.,<sup>44</sup> and the kudzu (*Pueraria lobata*), a plant that has overgrown large swaths of the eastern U.S.<sup>45</sup>

• **Overexploitation of Biotic Resources.** In the past, humans relied on hunting, fishing, trapping, and gathering to serve their fundamental needs. Although some societies recognized the importance of a sustainable harvest, history informs us that others failed at this, causing their demise when they overexploited vital resources.<sup>46</sup>

We have already noted the devastating consequences of overhunting for many of the larger terrestrial vertebrates, but other organisms and ecosystems have also suffered because of human activity. Aquatic and marine ecosystems have long been exploited for a diverse range of taxa, but large fish have suffered especially from intensified and highly efficient fishing techniques, resulting in the widespread decline and collapse of major fish stocks. It is estimated that only 10 percent of the global biomass of large predatory fish remains.<sup>47</sup> Forests have also suffered from heavy timber and charcoal harvests, causing endangerment or extinction not just of many plants, but also animals that depend on them.<sup>48</sup> In any ecosystem, the loss of a single species, especially species organisms that have a major impact on the populations of other species (e.g., predators and pollinators), can profoundly disrupt ecosystems, which threatens additional species with extinction.<sup>49</sup> In one compelling case, persecution and subsequent decline of the dingo (*Canis lupus dingo*), the top terrestrial predator in Australia, allowed smaller predators to overwhelm marsupial prey, triggering a massive extinction (18 mammalian species) over much of the continent.<sup>50</sup> Today, humans exploit other species for reasons that go far beyond fundamental needs. Trade in plants, animals, and plant and animal derivatives represents a multi-billion-dollar industry due to the growing demand for trophies, novelty food and clothing, decorative items, pets, and traditional medicine, including aphrodisiacs.<sup>51</sup> This trade, much of it illegal, not only puts tremendous pressure on biodiversity through over-collection,<sup>52</sup> but also exposes nations to the risk of introduced pathogens<sup>53</sup> and invasive species.<sup>54</sup>



**Coauthor William Hayes with a Magnificent Frigatebird.**

• **Pollution.** Pollution comes in many forms. It results from any addition to air (including light and noise), water, land, or food that threatens the activities, health, or survival of living organisms. Whether localized (e.g., garbage) or global (e.g., acid rain, greenhouse gases), pollutants substantially alter or poison the habitats of sensitive species, leach away nutrients, disrupt the physiology and natural behaviors of organisms, and even kill these organisms directly. Aquatic and marine ecosystems are particularly vulnerable, as they are subject to spills, pathogens, thermal pollution from industries and power plants, and especially runoff containing leached toxins from terrestrial ecosystems, resulting in oxygen depletion (from eutrophication) and toxic substance accumulation (bioaccumulation).<sup>55</sup> Every acre of farmland and mile of road, as well as our home and school backyards, represent sources of pollutants that injure other species. Many toxins notoriously bioaccumulate in tissues (e.g., DDT, PCB), becoming increasingly concentrated and toxic in higher-level animals.<sup>56</sup> Two additional forms of pollution, light<sup>57</sup> and noise,<sup>58</sup> can negatively affect foraging and anti-predator behaviors, reproductive success, population density, community structure, and ecosystem function in ways that we have only just begun to understand.

• **Spread of Diseases.** Global commerce and travel have spread exotic diseases to many parts of the world. Introduced pathogens, often referred to as “pathogen pollution,” have contributed to unprecedented levels of emerging infectious diseases (EIDs). Most EIDs exist within a host-parasite continuum among interacting wildlife, domestic animal, and human populations.<sup>59</sup>

In addition to threatening human health directly, many EIDs can also devastate biodiversity. Disease in some cases has been a leading factor of local, regional, and global extinctions. Notable examples of global extinction include numerous Hawaiian birds, the thylacine (*Thylacinus cynocephalus*, a large marsupial carnivore often called the Tasmanian tiger), a Polynesian tree snail (*Partula turgida*), the Christmas Island rat (*Rattus macleari*), and the sharp-snouted day frog (*Taudactylus acutirostris*).<sup>60</sup> Many additional species have been forced to the brink of extinction by introduced disease.<sup>61</sup>

• **Climate Change and Anthropogenic Global Warming.** Climate change has many causes. Natural causes arise from inherent variation in solar output, the Earth’s orbital characteristics, volcanic activity, atmospheric carbon dioxide concentrations, and



oceanic currents. However, many scientists today believe that humans have contributed significantly to the current warming trend, a hypothesis referred to as anthropogenic global warming (AGW). The combustion of vast amounts of fossil fuels, combined with the removal of nearly half the world's vegetation, has significantly elevated greenhouse gases in the atmosphere, including carbon dioxide, methane, and nitrogen oxides, since the beginning of the Industrial Revolution.<sup>62</sup> While evidence for the current global warming trend is compelling, the link between human activities and global warming, despite intense study, remains controversial and highly politicized.<sup>63</sup>

If global warming trends continue, the long-term impacts on biodiversity and species extinctions could be catastrophic, with estimates of resulting species extinctions ranging from three percent to 78 percent.<sup>64</sup> The physical consequences of global warming include the melting of polar ice caps and glaciers, resulting in rising sea levels that could profoundly affect ecosystem processes. The biological consequences of global warming include shifts in distribution, abundance, morphology, seasonal timing of behavior, and changes in disturbance regimes. If temperatures continue to rise, many species, such as those living on mountaintops and on islands, will be unable to disperse to cooler areas, and thus be doomed to extinction.

Regardless of whether AGW truly exists, humans have significantly elevated greenhouse gases in the atmosphere. Carbon dioxide (CO<sub>2</sub>), in particular, has increased by about 38 percent from pre-industrial conditions.<sup>65</sup> High levels of CO<sub>2</sub> are slowly increasing the acidity of oceans. Acidification affects the availability and solubility of mineral compounds, such as calcite and aragonite, which corals, mollusks, and echinoderms require to build their skeletons. The major reef builders, scleractinian corals and coralline red algae, respond to acidification by reduced growth rates, reduced abundance, and increased post-mortem dissolution.<sup>66</sup> Some mollusks and echinoderms also suffer decreased reproduction at lower pH.<sup>67</sup> If ocean acidification continues, marine extinctions and loss of ecosystem services to humans will be inevitable.<sup>68</sup>

## Conclusions

The evidence for accelerating species extinctions is highly compelling, and the influence of humans on extinctions can be readily identified.

Unfortunately, many people reject the notion that humans have profoundly altered the Earth's ecosystems, and refuse to take responsibility for caring for God's creation. Ironically, the intense focus on AGW by climate scientists has desensitized many skeptics toward other equally or more compelling anthropogenic factors that irrefutably contribute to species extinctions and the unfolding ecological crisis. Environmental scientists have probably hurt their own cause by pushing AGW so forcefully, and Christians committed to an environmental

ethic might do well to de-emphasize the importance of AGW. We must not forget that humans do in fact exacerbate the extinction problem in numerous ways, including habitat degradation, introductions of alien species, excessive pollution, over-exploitation, and the spread of disease.

Even though some Christians appear to have forgotten that God cares deeply about biodiversity, many others believe it is God's will for us to embrace environmental stewardship, and want to help improve the situation. After all, God provides for the needs of all creatures, not just humans (e.g., Job 38:19-41; Psalm 36:6, 104:27, 28, 147:9; Jonah 4:11; Matthew 6:26). Should we be any less benevolent? How can we be indifferent toward the loss of species that God, after creating them, declared to be "very good" (Genesis 1:31)?

Devoted stewards of God's creation will seek ways in which humans can live more harmoniously with the multitude of other life forms. They should also become more involved in efforts to save what remains of the creation. ✍

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