Preventing Loss of Animal Species Under Human-Caused Climate Change

Patrick Gonzalez

The tropical cloud forest of Monteverde, Costa Rica, offered a final home for the golden toad (sapo dorado; *Incilius periglenes*). A private protected area, the Reserva Biológica Bosque Nuboso Monteverde, conserved its last remaining habitat. The mists of the cloud forest kept the skin of the golden toad moist—essential for the survival of amphibians. Scientific research (Pounds et al. 1999; Pounds et al. 2006) shows that human-caused climate change lifted the cloud deck at Monteverde, increasing aridity and the susceptibility of amphibians to chytrid fungal disease, killing golden toads. Sadly, the golden toad was last seen in 1989, leading the International Union for Conservation of Nature, in 2004, to declare the species extinct (IUCN 2004).

The tropical island of Bramble Cay (Maizab Kaur), a Torres Strait island of Australia, offered a final home for the Bramble Cay melomys rodent (*Melomys rubicola*). The island is uninhabited, covers just two to four hectares of land, depending on tides, and reaches a maximum elevation of just three meters above sea level (Waller et al. 2017). Published scientific research (Slangen et al. 2016; Frederikse et al. 2020; IPCC 2021; NASA 2024) shows that human-caused climate change raised sea level 21 centimeters from 1900 to 2023, from meltwater of glaciers running from land into the oceans and the expansion of seawater when it warms. The closest tidal gauge to Bramble Cay recorded a 17-centimeter rise in sea level from 1990 to 2014 and storm surges up to 115 centimeters (Waller et al. 2017). Sea level rise and storm surges have caused episodes in which salt water completely washed over the island, killing vegetation essential as a food source for melomys and possibly carrying the little animals out to sea to drown. Sadly, the Bramble Cay melomys was last seen in 2009 and intensive surveys from 2011 to 2014 found none (Waller et al. 2017), leading the Government of Australia, in 2019, to declare the species extinct (Australia Threatened Species Scientific Committee 2019).

The Intergovernmental Panel on Climate Change (IPCC 2022a) has assessed published scientific evidence on detection and attribution of biodiversity changes and concluded that anthropogenic climate change caused the extinctions of these two animal

▲ Left: Golden toad (sapo dorado; *Incilius periglenes*), extinct since 1989, due to anthropogenic climate change. US FISH AND WILDLIFE SERVICE
Right: Reserva Biológica Bosque Nuboso Monteverde, Costa Rica, its final habitat. CENTRO CIENTÍFICO TROPICAL

species. So far, they are the only detected species extinctions attributed to climate change.

The total number of plant and animal species on Earth is not precisely known and may fundamentally be unknowable. One analysis generally accepted by scientists (Mora et al. 2011) estimates the total as 8.7 ± 1.3 million species, included all described and those not yet described, 90% of the total belonging to the animal kingdom. Taxonomists have identified and described 2.2 million species (IUCN 2023; Catalogue of Life 2024), with approximately 150,000 of these species reported as extinct (Catalogue of Life 2024). Due to the sheer number of species on Earth and the large fraction not yet described, it is possible that climate change has caused other extinctions.

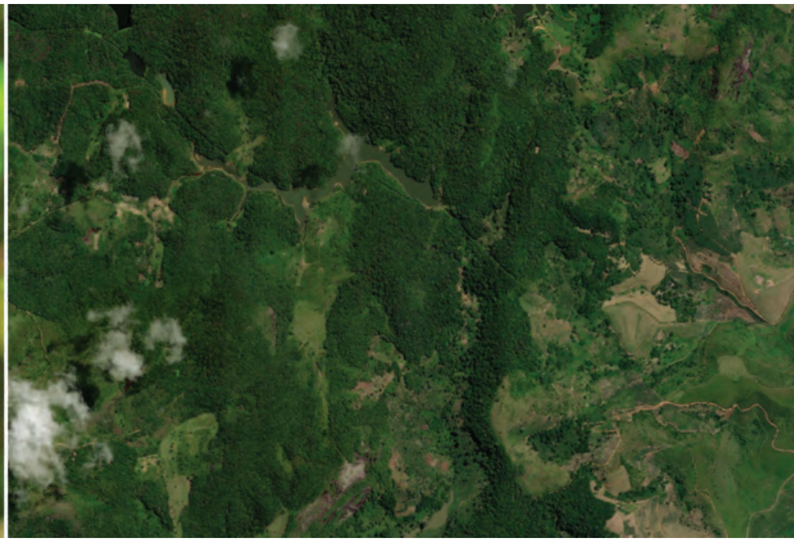
Habitat destruction, overexploitation, hunting, environmental pollution, and other non-climate change human factors have caused more species extinctions than climate change (IUCN 2023). Urbanization, agricultural expansion, deforestation, and other human land changes have reduced the global area of natural ecosystems by one-third to one-half, destroying habitat for plants and animals (Foley et al. 2005; Hooke et al. 2012; Venter et al. 2016; Simmonds et al. 2023).

Tropical Mata Atlântica (Atlantic Forest) in Pernambuco, Brazil, provided the last home for the Alagoas foliage-gleaner bird (*Philydor novaesi*). The private Reserva Particular do Patrimônio Natural Frei Caneca protected the last Alagoas foliage-gleaners. The bird required intact tropical mixed evergreen-deciduous forest with a thick understory, located on upper elevations of hills (Barnett et al. 2005), but clearing of Mata Atlântica for agriculture and timber have reduced the biome to 11–26% of its estimated pre-European settlement extent (Ribeiro et al. 2009; Rezende et al. 2018). Sadly, the Alagoas foliage-gleaner was last seen on September 13, 2011 (Lees et al. 2014; Pereira et al. 2014), leading the International Union for Conservation of Nature, in 2018, to declare the species extinct (IUCN 2018).

Analyses of paleoecological and contemporary biodiversity measures indicate that habitat destruction, overexploitation of plants, and hunting of animals have caused the extinction of one-tenth of plant and animal species globally in the past 12,000 years, 1,000 times natural background rates (De Vos et al. 2015; Butchart et al. 2018; Pimm and Raven 2019; Parmesan et al. 2022). This demonstrates that, historically, conventional threats have exerted a more severe influence on biodiversity than climate change.

Extirpation is the disappearance of a population of a species from a distinct geographic area. From 1849 to 2012, human-caused climate change, more than other human factors, caused extirpations in more than 400 plant and animal species, (Wiens 2016; Roman-

Left: Bramble Cay melomys rodent (*Melomys rubicola*), extinct since 2009, due to anthropogenic climate change. QUEENSLAND ENVIRONMENTAL PROTECTION AGENCY
Right: Bramble Cay (Maizab Kaur), Torres Strait, Australia, its final habitat. QUEENSLAND ENVIRONMENTAL PROTECTION AGENCY

Left: Alagoas foliage-gleaner bird (*Philydor novaesi*), extinct since 2011, due to deforestation. CIRO ALBANO
Right: Reserva Particular do Patrimônio Natural Frei Caneca (middle), its final habitat, and agricultural land (right), Pernambuco, Brazil. APPLE, INC.

Palacios and Wiens 2020). From 1908 to 2016, climate change reduced bird species richness 40% in the Mojave Desert, including sites in Joshua Tree National Park, Death Valley National Park, and Mojave National Preserve, from increased aridity and physiological heat stress (Iknayan and Beissinger 2018; Riddell et al. 2019). Climate change caused extirpations of American pika (*Ochotona princeps*), a small mammal of cool upper-elevation talus slopes, from ten sites in the Great Basin, Nevada, and in Oregon, by 2008 (Beever et al. 2011). From 1901 to 2014, climate change reduced bumble bee species richness and abundance up to one-third across North America and Europe (Soroye et al. 2020; Janousek et al. 2023).

If we do not cut carbon pollution from cars, power plants, and deforestation, projected climate change could drive many animal and plant species extinct in the future. Under a scenario of high greenhouse gas emissions, climate change of 4°C above pre-industrial levels could cause extinction of 13% of animal and plant species (range 3–25%), more than destruction of habitat and hunting caused in the past 12,000 years (Urban 2015; Parmesan et al. 2022; Wiens and Zelinka 2024).

The US Endangered Species Act lists 32 species as threatened specifically due to climate change (US Fish and Wildlife Service 2024; US National Marine Fisheries Service 2024). These include Canada lynx (*Lynx canadensis*), corals (20 species), eastern black rail (*Laterallus jamaicensis*), emperor penguin (*Aptenodytes forsteri*), Gunnison sagegrouse (*Centrocercus minimus*), ʻiʻiwi bird (*Drepanis coccinea*), meltwater lednian stonefly (*Lednia tumana*), polar bear (*Ursus maritimus*), ringed seal (*Phoca hispida*), rufa red knot (*Calidris canutus rufa*), western glacier stonefly (*Zapada glacier*), and whitebark pine (*Pinus albicaulis*).

Major climate change threats for individual species include loss of snow and ice essential as platforms for mammals to hunt (Canada lynx, polar bear), coral bleaching and ocean acidification (20 coral species), loss of habitat free of avian malaria (ʻiʻiwi bird), inundation of coastal habitat by sea level rise (rufa red knot), and increased wildfire, mountain pine beetle infestations, and biome shifts (whitebark pine). US national parks protect many of the listed threatened species, including Canada lynx in North Cascades National Park, rufa red knot in Cape Cod National Seashore, western glacier stonefly in Glacier National Park, and whitebark pine in Yosemite National Park.

In a miracle of nature, the eastern population of monarch butterflies (*Danaus plexippus*) migrates each year up to 3,000 km from midwestern Canada and the US down to México for the winter. Individual butterflies fly the entire journey south. The return migration occurs in stages by succeeding generations.

Monarch butterfly (*Danaus plexippus*), Berkeley, California, USA. PATRICK GONZALEZ

Monarchs face threats at both ends of the migration: in Canada and the US, neonicotinoid insecticides kill butterflies and glyphosate herbicides kill milkweed, their required food plant; in México, deforestation destroys oyamel fir (*Abies religiosa*) forest, their required vegetation. Along the way, climate change adds threats of heat and aridity above the thermal tolerance of the species. Climate change under high emissions could cause heat-induced mortality of 60–80% of eastern monarchs in Canada and the US; cutting emissions to meet the Paris Agreement goal could limit heat-induced mortality to 0–40% (Zylstra et al. 2021; Zylstra et al. 2022). Climate change also increases risks of heat and aridity-induced mortality of butterflies across the western US, including the western population of monarch butterflies that migrates between the interior West and the California coast (Crossley et al. 2021; Forister et al. 2021; Crossley et al. 2022). Climate change also increases risks to eastern monarchs of upslope shifts and contraction of oyamel fir forests in México (Brower et al. 2009; Sáenz-Romero et al. 2012; Gomez-Pineda et al. 2020; Sáenz-Romero et al. 2020). Cutting carbon pollution to limit future heating would reduce risks to butterflies (Sáenz-Romero et al. 2012; Crossley et al. 2021).

Improving resilience of species and ecosystems to climate change starts with reducing the conventional threats of habitat destruction, overexploitation, hunting, and environmental pollution. This is the primary biodiversity benefit of national parks and other protected areas, which globally protect an average of 10% more plant and animal species than non-protected areas (Gray et al. 2016; Cazalis et al. 2020; Brodie et al. 2023; Langhammer et al. 2024). National parks accomplish this by protecting ecosystems from agricultural expansion, timber harvesting, oil and methane gas drilling, and hunting. For monarch butterflies, eliminating the use of insecticides and herbicides and protecting and restoring milkweed in Canada and the US are critical actions to save the species (Thogmartin et al. 2017; Lukens et al. 2020). In México, protection and natural regeneration of oyamel fir would conserve essential habitat (Guzmán-Aguilar et al. 2020).

To improve resilience of species and ecosystems under climate change, conservation of potential refugia offers a key natural resource management approach. Climate change refugia are areas for which geographic location, topography, and other local factors cause climate to remain more stable and hospitable to plants and animals (Gonzalez et al. 2010; Morelli et al. 2016; Stralberg et al. 2020; Xu et al. 2022; Saunders et al. 2023). In Joshua Tree National Park, published scientific research (Sweet et al. 2019) has identify potential refugia for Joshua trees (*Yucca brevifolia*) and park staff prioritize these for protection from fires, which are not natural in the area, and removal of invasive plants (Barrows et al. 2020; Parmesan et al. 2022). In Mount Rainier and North Cascades National Parks, spatial analyses (Johnston et al. 2012) have identified potential refugia for the hoary marmot (*Marmota caligata*) and other high-elevation mammals.

The forward-thinking actions that I encourage in this edition of *Climate Change Solutions* are energy conservation and energy efficiency for homes and other buildings. Energy conservation aims to eliminate the needless waste of energy. Energy efficiency solutions accomplish a task in a way that uses less energy to perform the same function. These common-sense measures cut the carbon pollution that causes climate change and save money.

A very easy conservation practice is turning off lights, computers, other electronics when not in use. At night, reserve the use of outdoor lights for only when necessary to safely walk outside. Keeping outdoor lights off will also help to conserve the natural darkness of skies. This is a resource management goal in national parks, to reduce night-time disturbance of animal species and enhance visitor enjoyment of the stars. Another easy conservation practice is using natural light and ventilation from windows. This allows you to turn off lights, heating, or cooling. In cold weather, wearing warm clothes will allow you to turn down space heating. Heating water burns energy, so using cold water for washing clothes conserves energy. I routinely practice these lighting and other conservation actions at home and in the office and encourage everyone to adopt them. The practices are straightforward, don't require any new purchases, and benefit the environment. Residential and commercial buildings generated 31% of US greenhouse gas emissions in 2022, each sector accounting for half the total, for lighting, electronics, heating, cooling, and other uses (US EPA 2024).

For buildings, an effective conservation fix is weatherization, especially sealing air leaks around windows, doors, electrical outlets, and other areas, to cut off wasteful heating or cooling of the outdoors. The US Department of Energy *Energy Saver Guide* provides more sustainable features for homes and other buildings: https://www.energy.gov/sites/default/files/2022-08/energy-saver-guide-2022.pdf.

Energy efficiency actions involve the use of less energy-intense technology, either by substitution or updating. If you use an air conditioner, consider using fans instead. Alternatively, heat pumps are devices that cool and heat more efficiently than air conditioners and furnaces by transferring existing cool or warm air between the outdoors and indoor spaces, rather than generating new cool air or heat. Heat pump systems take many forms, adaptable to varied situations: https://www.energy.gov/energysaver/heat-pump-systems. For appliances of all types, the US Energy Star program (https://www.energystar.gov) provides a tested energy-efficiency certification label.

With the US Inflation Reduction Act of 2022, the administration of President Biden instituted many incentives for energy efficiency and renewable energy. This law provides the highest single US Government investment ever to cut greenhouse gas emissions and reduce climate change. For individuals, the Inflation Reduction Act funds the Energy Efficient Home Improvement Credit, a tax credit for weatherization, heat pumps, and other energy efficiency measures, and a Residential Clean Energy Credit for solar, wind, geothermal, and other home renewable energy systems. The US Environmental Protection Agency provides a guide to these credits: https://www.energystar.gov/about/federal-tax-credits.

Energy conservation and efficiency actions by individuals can combine to produce considerable energy and environmental savings. Consider the simple act of turning off unneeded lights. In the US, if each of 120 million households turned off the equivalent of one 100-Watt light bulb, the country would reduce its electric generation needs by 12 billion watts (gigawatts). A standard coal-fired power plant operates at 0.37 gigawatts (US EIA 2023). So, the total savings would be equivalent to 32 coal-fired plants. Turn off the switch, keep it off—if everyone does that, we can shut down 32 coal-fired plants. That's the power of individual action.

Energy conservation actions such as turning off unused lights, computers, other electronics save energy at no cost, instantly saving money. Energy efficiency improvements incur costs but less than the cost of electricity generation. Electricity saved in utility-funded energy efficiency programs in the US costs 1.8–3.0 cents per kilowatt-hour (¢/kWh) (Murphy and Frick 2023), compared to electricity generation costs of 5.2–16.6 ¢/kWh for coal, 3.9–10.1 ¢/kWh for methane gas, 2.4–9.0 ¢/kWh for solar, and 2.4–7.5 ¢/kWh for wind (Lazard 2023). Globally, in the building sector, electricity conservation and efficiency improvements produce more savings than costs (IPCC 2022b).

Recent results show that energy conservation, energy efficiency, renewable energy, and public transit solutions are working. California cut greenhouse gas emissions 17% from 2000 to 2021, even as population increased 16% and economic production increased 68% (California ARB 2023). Essentially, the state achieved this progress by increasing efficiency, reducing emissions per person 29% and emissions per dollar of economic product 51%. Likewise, the US cut greenhouse gas emissions 17% from 2005 to 2022, reducing emissions per person 25% and emissions per dollar of economic product 38% (US EPA 2024). Globally, average energy efficiency of economic product increased 20% from 2011 to 2020 (IEA 2023).

The IPCC (2022b) has found that, globally, energy conservation and efficiency improvements can potentially reduce greenhouse gas emissions from electricity generation 73% by 2050, equivalent to 2 billion tons of carbon per year, 14% of the amount needed to achieve net-zero emissions by 2050. This reduction is needed to meet the Paris Agreement goal of limiting the global temperature increase to 1.5-2°C above pre-Industrial levels, a limit that scientific research (IPCC 2023) indicates could avert the most drastic consequences of climate change. Energy conservation and efficiency offer meaningful actions to reduce climate change and help protect animal species and the national parks that provide them a home.

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