Amphibian and Reptile Conservation 6(1):1-24.

POINT OF VIEW

Can humans share spaceship earth?

Eric R. Pianka

Section of Integrative Biology C0930, University of Texas at Austin, Austin, Texas, USA

***Abstract.*—Earth was a pretty durable spaceship, but we have managed to trash its life support systems, the atmosphere, and the oceans. Humans have also destroyed vast areas of habitats and fragmented many others. We have modified the atmosphere and in doing so have increased the greenhouse effect, which has changed the climate to produce ever increasing maximum temperatures. Increased temperatures threaten some lizard species in highly biodiverse tropical and subtropical regions. Many lizards are also threatened by habitat loss and over-harvesting. Although lizards are ectotherms and might therefore be expected to be resilient to global warming, evidence strongly suggests that many species could be threatened by warming. Some, such as fossorial or nocturnal species or those in cold temperate regions, may be little affected by climate warming but many others such as thermoconformer species in tropical forests and live bearers appear to be particularly vulnerable. The 2011 IUCN Red List of Threatened Species lists 12 lizard species as extinct and another 462 species as Critically Endangered, Endangered, or Vulnerable. Together, these constitute at least 8.4%, probably more, of all described lizard species. The highly biodiverse lizard fauna of Madagascar is especially threatened mostly due to habitat loss from extensive deforestation by humans. Three of the IUCN listed species are monitor lizards. Most varanids are top predators, generally have large territories, and have low population densities, which make them particularly vulnerable to habitat loss, habitat fragmentation, and over-harvesting. All monitor lizards are listed by CITES as Endangered, and five species are officially listed as "threatened with extinction." Others, including the sister taxon to varanids, the Earless monitor *Lanthanotus* from Borneo, and several island endemic *Varanus* species from biodiversity hot spots in SE Asia should be added to these lists. The future survival of all lizards including varanids will depend on our ability to manage the global environment. Sustainable management will require controlling the runaway population growth of humans, as well as major changes in our use of resources. To maintain lizard biodiversity, anthropogenic climate change and habitat destruction must be addressed.**

Key words. Biodiversity, climate change, conservation biology, deforestation, extinction, global warming, *Lanthanotus*, lizards, Madagascar, Milankovitch cycles, overpopulation, threatened species, *Varanus*, wildlife management

Citation: Pianka ER. 2012. Can humans share spaceship earth? *Amphibian and Reptile Conservation* 6(1):1-24(e49).

Introduction

Amphibian and Reptile Conservation invited me to write an essay for this special issue on the conservation biology of monitor lizards. As I began to write, I quickly realized that I wanted to address the much larger issue of the enormous impact we humans have had on the entire planet (our one and only "spaceship" Boulding 1966) as well as on all of our fellow Earthlings. Although the subjects of anthropogenic climate change and habitat loss are far too broad to be fully addressed here, I offer a synopsis and attempt to illustrate selected global-scale issues with examples drawn from lizards, monitors where possible.

I ask readers to indulge me and permit some opinions and editorializing.

The incomplete fossil record shows that lizards first appeared 150 million years ago—since then many clades have appeared and some have gone extinct (Evans 2003). The oldest varanoid fossils date from about 90 million years ago (mya) but the clade is older than that (Molnar 2004). Throughout this long evolutionary history, lizards have survived many extreme climate changes. The planet has undergone numerous ice ages as well as some extremely warm episodes. However, the exploding human population combined with increased energy use per person has resulted in ongoing increases in global temperatures. Will lizards be able to survive?

Correspondence. *Email: erp@austin.utexas.edu*

Anthropogenic extinction events

Hundreds of species, especially megafauna, in many different taxa went extinct during the transition from the Pleistocene to the present day. Possible causes of this "Quaternary extinction event" (Koch and Barnosky 2006, http://en.wikipedia.org/wiki/Quaternary_extinction_event) include climate change and overkill by human hunters as people migrated to many previously uninhabited regions in the New World and Australia during the late Pleistocene and Holocene. Humans first reached Australia about 50,000 years ago but did not get to the Americas until about 13,000 + years ago. Massive extinctions followed soon thereafter on both continents, strongly suggesting that anthropogenic activities were involved. Fossil records show that Pleistocene extinctions following human invasions were extensive and among others included many large mammals, such as mammoths, mastodons, chalicotheres, gomphotheres, pampatheres, glyptodonts, many ungulates, saber-toothed cats, cave lions, cave bears, diprotodons, several marsupial carnivores, lemurs, as well as various apes including other humans. Some birds that perished include giant South American Adzebills and huge Australian emu-like Dromornithids.

A more recent wave of extinctions followed human colonization of many islands, including the Caribbean and Galápagos Archipelagos, Indian Ocean islands, Hawaii, New Caledonia and other Pacific islands, Madagascar, islands of the Mediterranean, and New Zealand. Many flightless island birds, including Dodos and Moas, went extinct (Steadman 2006), as did other island endemics such as land tortoises. Of course, little evidence is available for how people might have affected smaller species such as most lizards, but at least one gigantic Australian monitor lizard is known to have gone extinct during the Pleistocene following human colonization. A potentially greater anthropogenic extinction event is currently underway.

History of global warming

Together, the atmosphere and the oceans control climate. Ocean currents act as conveyor belts moving heat away from the equator. Changes in ocean currents due to tectonic events like the rise of the Panamanian isthmus 3-5 mya, or the ongoing constriction of the Indonesian through flow by the northward movement of the Australian plate have had drastic impacts on past climates and are likely to do so again in the future. However, we now face a dramatic and rapid anthropogenic change in global climate—humans have broken the life support systems of spaceship Earth. When coupled with massive habitat loss and fragmentation due to human overpopulation, all denizens of planet Earth are potentially imperiled.

With the advent of human agriculture and city states about 10,000 years ago, humans began large scale deforestation. Human activities, primarily deforestation, began to alter atmospheric carbon dioxide and methane levels many centuries ago, long before the industrial revolution (Ruddiman 2003, 2005). Oxygen isotopes in air samples from ice cores from the Antarctic and Greenland dating back for more than 400,000 years have allowed inference of temperature changes over most of the last half a million years. Four prolonged ice ages are evident. These changes are caused largely by periodic fluctuations in Earth's orbit and the inclination of its axis known as the Milankovitch cycles. Four spikes in temperature were spaced approximately every 100,000 + years. Earth is presently in a warm interglacial phase, and through burning of fossil fuels, deforestation, and loss of soil and peat carbon, CO_2 levels have increased to well above any that have occurred over the last 400,000 years. The last thermal spike has been prolonged for considerably longer than the three preceding ones. Earth should be entering a colder glacial period but has stayed warm for roughly the last 10,000 years ("the long summer" Fagan 2004). An ice age seems overdue (Ruddiman 2003).

This extended warm period corresponds to the invention of agriculture and the resulting surge in human population and, based on current evidence, is almost certainly due to anthropogenic activities, especially deforestation and burning of fossil fuels. The rate of global warming is accelerating because long frozen reserves of methane are now being released into the atmosphere (in terms of the greenhouse effect, each molecule of methane is equivalent to 25 molecules of carbon dioxide). When a molecule of methane burns, it gives off heat and is oxidized into two molecules of water and one of carbon dioxide, both of which are powerful greenhouse gases. Long frozen fossil methane is being released from rapidly thawing permafrost and from the deep oceans at an ever accelerating rate. As temperatures rise, more methane bubbles up to the surface, further raising temperatures in an ever-increasing positive feedback loop. A tipping point has probably already been reached at which climate cannot return to pre-industrial conditions. Eventually, of course, the Milankovitch cycles will generate another ice age, but that could be many millennia from now.

Human activities, especially the enhanced greenhouse effect, but also including burning of fossil fuels and even the waste heat produced by nuclear reactors, have added greatly to our already overheated spaceship. Glaciers are melting, and sea levels have risen by a foot since 1900 and are rising by over three mm per year (Kemp et al. 2009). The high specific heat of water has helped to moderate this increased heat load to some extent, resulting in the world's oceans warming by nearly a full degree

Celsius over the past half century. The oceans also absorb carbon dioxide, forming carbonic acid, which leads to acidification and the bleaching of coral reefs.

Despite frequent outcries that global warming is some sort of hoax, the vast majority of experts are convinced that it is a real and enduring threat. If current trends continue, the planet will be at least 1-2 °C warmer by 2050 (IPPC 2007, NOAA 2012). Moreover, the rate of climate change seems to be ever increasing and appears to be irreversible.

Until the advent of agriculture, humans were hunter gatherers—many fewer of us existed. Food supplies lead population—populations tend to increase to the level that foods will allow. Agriculture has been called "the worst mistake in the history of the human race" (Diamond 1987) because it allowed us to increase in population density to unsustainable levels, ultimately leading to the present day overpopulation crisis (Catton 1982). We could never have reached seven billion without fossil fuels. Just as supplies of bird and bat guano began to be exhausted, the Haber-Bosch process rescued agriculture by using methane to fix atmospheric nitrogen and produce virtually unlimited amounts of ammonium nitrate (Smil 2001, http://en.wikipedia.org/wiki/Haber_process), which is an explosive as well as a fertilizer. Without this technological "advance," neither Germany nor Japan could ever have gone to war—moreover, humans would have been limited by food supplies at much lower population densities. Basically, humans exploited these one-time fossil energy reserves to demolish many of Earth's natural ecosystems and turn them into arable land and crops to feed increasing numbers of people. We turned the tall grass prairies of North America into fields of corn and wheat and replaced bison herds with cattle, ultimately into masses of humanity. Of course, without agriculture and fossil fuels, we could never have built cities, let alone developed our civilization and human knowledge. However, in many ways our cities are little more than giant but fragile feed lots supporting unsustainably dense aggregations of people. Without a steady inflow of food, water, and power and a continual outflow of garbage and sewage, cities will collapse. We missed our chance to live in a sustainable world.

Human populations have grown exponentially over the past century, doubling each generation. Our economic system, based on runaway greed and the principle of a chain letter—growth, growth, and more growth, is fundamentally flawed. Ponzi schemes like this only work briefly, until the cost of recruiting resources needed to sustain them exceeds the value they represent. We are far overextended in terms of local resource bases already, and approaching limits in things transported from afar, such as quality timber, larger fishes and some minerals. As transport costs rise, bulky and heavy items (such as metal ores) will become regionally scarce, until eventually transport becomes a limiting factor. The prevalent attitude that no limits exist in a finite world is obviously insane, but somehow it has become politically incorrect even to allude to overpopulation. Not wanting to face reality, people are locked in denial that such a problem could even exist. And yet, population pressures clearly underlie and drive almost all of the many challenges we face, from energy and food shortages to political unrest and climate change. Some are convinced that technology will come to our rescue, but so far it has only led us farther out on thin ice.

Many think that the solution to the energy crisis is access to more energy, but that will only exacerbate the planet's heat load and accelerate the rate of global warming.

Why lizards?

When I was about six years old in the mid-1940s, our family drove east from our hometown, in far northern California, across the U.S. to visit our paternal grandparents. Somewhere along Route 66, we stopped at a roadside park for a picnic lunch. There I saw my first lizard, a gorgeous, green, sleek, long-tailed arboreal creature (later I determined that this must have been an *Anolis carolinensis*) climbing around in some vines. We did our utmost to catch that lizard, but all we were able to get was its tail. I stood there, looking up at the sassy tailless lizard, wishing intensely that I was holding it instead of just its tail.

About a year later back in California, I caught my first garter snake, which I tried to keep as a pet. Alas, it soon escaped. Then in the third grade, I discovered that the classroom next door had a captive baby alligator. I was transfixed by that alligator and stood by its aquarium for hours on end, reveling in its every move. As a little boy, I was obviously destined to become a biologist, long before I had any inkling about what science was. Years later, in graduate school, I discovered the rich layers of the biological cake (Figure 1), and eventually I went on to earn a Ph.D., and, later, my D.Sc. as an ecologist.

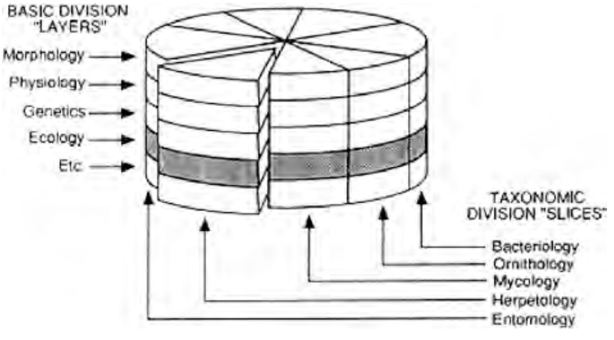


Figure 1. Biological "cake" showing the intersection of taxon-based sciences (slices) and concept-based sciences (layers)—neither is complete without the other. Rather than specialize on just one taxonomic unit, ecologists study the interactions between organisms and their environments across all taxa.

People sometimes ask me why I study lizards. Or worse, some say "what good are lizards?" to which I respond with "what good are YOU?" Those who would think, let alone ask, such a narrow-minded question seem to me to be hopelessly anthropocentric. Lizards are spectacular and beautiful fellow Earthlings that deserve our full respect and care. They were here long before us and deserve to exist on this spaceship, too.

When my co-author Laurie Vitt and I received the advance copy of our coffee-table book "Lizards: Windows to the Evolution of Diversity," we sat side-by-side thumbing through its pages. Laurie said "if there's a copy of this 50 years from now, people will be looking at these photos and saying 'were these things really here?'" For us, and for many others, a world without lizards would not be a world worth living on. That said, let us explore future prospects for all lizards including monitors. Gibbons et al. (2000) reviewed the global decline of all reptiles, comparing it to the loss of amphibians, especially frogs. They identified many threats, including habitat loss and degradation, introduced invasive species, pollution, disease, unsustainable land use, and of course global climate change.

Minimum Viable Populations and Extinction Vortices

Conservation biologists have formulated concepts of "minimum viable population size" and "extinction vortices." Together, these can capture an endangered species and inexorably drive its population to extinction (Gilpin and Soulé 1986; Pianka 2006; Traill et al. 2007), as follows. Habitat destruction, degradation, and fragmentation lead to reduced population density or even rarity, at which stage a species' survival becomes precarious. Small populations lose genetic variation, which limits their ability to adapt to changing environments. They also experience elevated demographic stochasticity, which can lead to extinction by a random walk process if deaths exceed births. When exposed to added insults of climate change, pollution, disease, and competition and predation by invasive species, a threatened target species can become doomed to extinction.

Because they are aquatic and long-lived, pollution and disease are important threats to crocodilians and turtles, but these two agents are less likely to impact most lizards. However, studies of pollutant contamination of aquatic African nile monitors living near abandoned chemical stockpiles in West Africa showed that pesticide and heavy metal contamination levels in tissues differ between the sexes, but are not high enough to have noticeable detrimental effects (Ciliberti et al. 2011, 2012). Nevertheless, Campbell and Campbell (2005) suggest that lizards could be useful as sentinel species to detect and monitor low levels of pollution through bioaccumulation.

For many lizard species, habitat loss and climate change are the two major factors that have had strong negative impacts and both will almost certainly continue to increase well into the foreseeable future.

Habitat destruction and species loss: Modern day fossils

When I first began studying desert lizards just half a century ago, North American deserts were largely unfenced and pristine. Permits were not required to conduct field research, and lizards were very abundant at a dozen study areas I worked from southern Idaho to Sonora. I have since returned to several of these former study sites only to find that they no longer support any lizards: one is now part of the city of Mojave, California, another at Twentynine Palms has been developed, and a third outside Casa Grande, Arizona, is now a trailer park. Two sites in northern Mexico have succumbed to agriculture (Google Earth). Specimens collected a mere 50 years ago, safely ensconced in major museums, now represent fossil records of what was once there before humans usurped the habitat (Pianka 1994). Human populations have more than doubled during the past half century—we already use over half of the planet's land surface and more than half of its freshwater. Our voracious appetite for land and other resources continually encroaches on the habitats of all our fellow Earthlings, including lizards.

Many people embrace the anthropocentric attitude that Earth and all its resources exist solely for human benefit and consumption. Organized religions teach mastery of nature and by setting people above all else, they have led to many of the worst ecological abuses. For example, the Bible says "be fruitful, and multiply, and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth" (Genesis I, 28), but it also says "and replenish the earth." Our numbers have increased vastly, and we have overfished the world's oceans and decimated many birds, but we have not abided by the latter command. Instead we have raped and pillaged the planet for anything and everything it can offer. Millions of other denizens of spaceship Earth evolved here just as we did and are integral functional components of natural ecosystems. All life on Earth requires space to live—other organisms have as much right to exist on this planet as people do. We need to embrace bioethics and we must learn to share.

Climate change

At present, because of the effects of elevated levels of greenhouse gasses, Earth cannot even dissipate the incident solar radiation it receives from the Sun fast enough to stay in thermal balance (Hansen et al. 2005). Climate change includes not only temperature but also has dra-

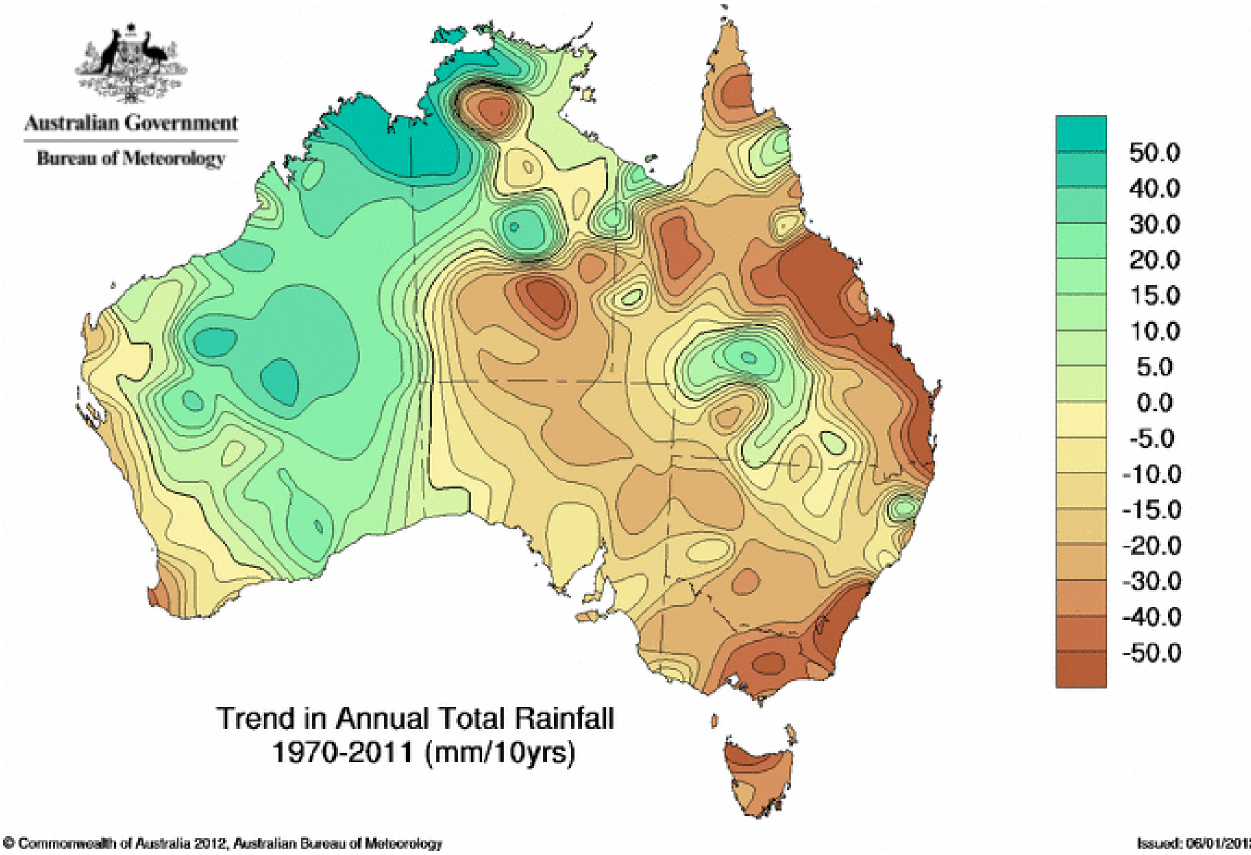


Figure 2. Trends in annual total rainfall in Australia over the past four decades (*Reprinted with permission from the Australian Bureau of Meteorology*).

matic effects on the amount and periodicity of precipitation, producing both droughts and floods locally. The atmosphere and oceans are commons (Hardin 1968) that must be shared by all, but sadly they have been much abused.

Because of the vastness and isolation of the Australian deserts, I used to think that Australian desert lizards, including varanids, would be able to persist long after humans had gone extinct (Pianka 1986), but I am no longer so sanguine. Global climate change is having a massive impact upon the Australian continent. A map from the Australian Meteorological Bureau (Figure 2) shows long-term trends in rainfall over the past four decades. The eastern 2/3rds of the continent has become much drier, whereas rainfall has increased dramatically in the westernmost top end and interior of Western Australia.

Historically, interior Western Australia had a low and stochastic annual rainfall of about 150-250 mm and might thus be particularly vulnerable to the 20-30% per decade increase in precipitation. After being away from my long-term study site for only five years, I drove right past it because the vegetation has changed so much I didn't even recognize it. Shrubs are encroaching and spinifex is declining. These floral changes are having an impact on the fauna, including insects and other arthropods, and abundances and diversity of their predators, birds and lizards, have declined.

Lizard thermal biology and behavior

Lizards are often described as "cold blooded," however, this loose term is a confusing misnomer—many lizards maintain active body temperatures as high as mammals and nearly as high as those of birds. Whereas birds and mammals are endotherms that generate body heat metabolically to maintain their thermal optima, lizards are ectotherms that rely mainly on the external environment to regulate their body temperature via behavioral adjustments. Nocturnal lizards including most geckos are passive thermoconformers, maintaining body temperatures close to external ambient temperatures when active at night. In contrast, many diurnal lizards are heliotherms that regulate their body temperature behaviorally by choosing to be active during times when environmental temperatures are most favorable and by selecting appropriate microhabitats such as basking sites. During early morning hours, when environmental temperatures are cold, these lizards bask in warmer sunnier spots and achieve body temperatures well above ambient conditions. As the day progresses and temperatures climb, they then exploit a narrow thermal window during which they can move around freely, foraging, and mating along with other daily activities (Figure 3). Later in the day, as air and substrate temperatures rise above thermal optima, they select cooler microhabitats such as shady areas or avoid high temperatures altogether by becoming inactive and going underground. Even within geographically widespread species, populations from colder high latitude regions compensate for cooler temperatures by being active at slightly lower body temperatures and by activity later in the day when ambient temperatures are higher (Pianka 1970).

Consequently, diurnal lizards living in cold temperate regions should be able to accommodate to climate warming by becoming active earlier on a daily and seasonal basis (Kearney et al. 2009). However, many shade-seeking tropical forest lizards are remarkably sensitive to high temperatures and have few behavioral ways of escaping from higher ambient air temperatures (Huey et al. 2009; Huey and Tewksbury 2009). Such thermoconformer species are exceptionally vulnerable to extinction because even modest elevations of forest temperatures may induce heat stress. Higher air temperatures in the shade of their forest microhabitats may lead to their decline and possible extinction. Moreover, not only will warmer forest temperatures depress the physiological performance of shade-dwelling forest species during summer, but it may also enable warm-adapted, open-habitat competitors and predators to invade tropical forests and replace these shade species through increased competition and predation (Huey et al. 2009).

Climate change imperils lizards in other ways as well (Huey, Losos, and Moritz 2010; Sinervo et al. 2010). Sinervo et al. (2010) documented extinctions in 24 out of 200 populations of 48 species of *Sceloporus* lizards in Mexico. They suggested that when hours of restriction in thermal refuges exceed four hours, the resulting shortened thermally acceptable periods for activity of female lizards in spring were probably responsible because females could not acquire resources adequate for reproduction. Figure 3 shows how the already narrow thermal window for activity is further shortened by global warming. Live bearing species at low latitudes and elevations are particularly prone to extinction, presumably because embryonic development is compromised by higher maternal body temperatures. Sinervo et al. (2010) modeled possible global extinction trends and suggested that, if current warming trends continue, 58% of Mexican *Sceloporus* species and 20% of the world's lizard species could go extinct by 2080. For varanids, they estimate local extinction levels by 2080 of 17.8% and a species extinction level of 16.2%. Using similar climate niche models, Araujo et al. (2006) suggested that many European reptiles could benefit from global warming by expanding their geographic ranges. However, because such modeling efforts do not include consideration of many critical biotic niche dimensions, particularly habitats, microhabitats, and foods, they may not be very reliable predictors. More sophisticated studies of this sort are badly needed.

Threatened lizards

A recent review of the conservation status of reptiles found that 21% of the world's lizard species are threatened (Böhm et al. 2012). The IUCN (International Union for the Conservation of Nature) Red List of Threatened Species, based on just over half of the known lizard species, lists 12 species as already extinct, 75 species as Critically Endangered, 173 others as Endangered, and 214 more as Vulnerable (IUCN 2011). These four lists sum to 462 species (an underestimate, as a couple thousand other species were not included), representing nearly 8.4% of the 5,634 named lizard species (Reptile Database 2012). The actual percentage of threatened species would presumably be higher if all lizard species

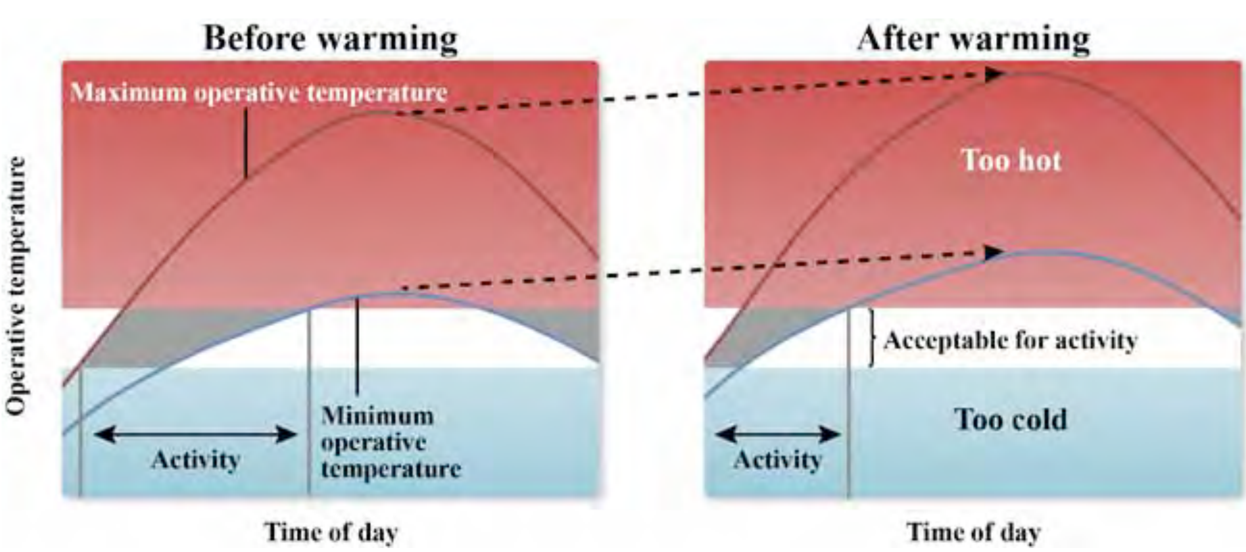


Figure 3. Global warming will shorten activity times for lizards, thus reducing energy gains from feeding below minimum levels needed for reproduction, potentially leading to failed reproduction and extinction (*Reprinted in modified form with permission from Huey et al. 2010, Science 328:833*).

Table 1. Critically Endangered lizards by families, genus, number of species, and localities.

Family	Genus	No. species	Localities
Agamidae	*Cophotis*	1	Sri Lanka
Agamidae	*Phrynocephalus*	2	Turkmenistan; Armenia; Azerbaijan; Turkey
Anguidae	*Abronia*	1	El Salvador, Honduras
Anguidae	*Celestus*	2	Hispaniola (Haiti and Dominican Republic)
Anguidae	*Diploglossus*	1	Montserrat
Carphodactylidae	*Phyllurus*	1	Queensland, Australia
Chamaeleonidae	*Brookesia*	1	Madagascar
Chamaeleonidae	*Calumma*	2	Madagascar
Chamaeleonidae	*Furcifer*	1	Madagascar
Diplodactylidae	*Eurydactyloides*	1	New Caledonia
Gekkonidae	*Cnemaspis*	1	Western Ghats, India
Gekkonidae	*Dierogekko*	6	New Caledonia
Gekkonidae	*Hemidactylus*	1	Socotra Island, Yemen
Gekkonidae	*Lygodactylus*	1	Madagascar
Gekkonidae	*Manoatoa*	1	Madagascar
Gekkonidae	*Oedodera*	1	New Caledonia
Gekkonidae	*Paroedura*	1	Madagascar
Gekkonidae	*Phelsuma*	3	Madagascar
Iguanidae	*Brachylophus*	1	Fiji
Iguanidae	*Cyclura*	5	Bahamas; Jamaica, Cayman Islands, Virgin Islands, Dominican Republic
Iguanidae	*Ctenosaura*	2	Oaxaca, Mexico, Honduras
Lacertidae	*Acanthodactylus*	4	Israel, Turkey, Tunisia, Algeria
Lacertidae	*Darevskia*	1	Georgia; Turkey
Lacertidae	*Eremias*	1	Armenia, Azerbaijan, Iran and Turkey
Lacertidae	*Gallotia*	4	Canary Islands, Spain
Lacertidae	*Iberolacerta*	1	Sierra de Francia, Salamanca, Spain
Lacertidae	*Philochortus*	1	Egypt; Libya
Lacertidae	*Podarcis*	1	Vulcano Island, Italy
Phrynosomatidae	*Sceloporus*	1	Peña Blanca, Queretaro, Mexico.
Polychrotidae	*Anolis*	2	Cuba; Culebra, Puerto Rico
Pygopodidae	*Aprasia*	1	Victoria, Australia
Scincidae	*Afroablepharus*	1	Annobon Island, Equatorial Guinea
Scincidae	*Brachymeles*	1	Cebu Island, Philippines
Scincidae	*Chalcides*	1	Morocco
Scincidae	*Emoia*	1	Christmas Island
Scincidae	*Geoscincus*	1	New Caledonia
Scincidae	*Lerista*	1	Queensland, Australia
Scincidae	*Lioscincus*	1	New Caledonia
Scincidae	*Marmorosphax*	2	New Caledonia
Scincidae	*Nannoscincus*	3	New Caledonia.
Scincidae	*Paracontias*	3	Madagascar
Scincidae	*Plestiodon*	1	Bermuda
Scincidae	*Pseudoacontias*	1	Madagascar
Sphaeroddactylidae	*Gonatodes*	1	Saint Vincent and the Grenadines
Sphaeroddactylidae	*Sphaerodactylus*	1	Haiti
Teiidae	*Ameiva*	2	Saint Croix; Cochabamba, Bolivia
Tropiduridae	*Stenocercus*	1	Provincia Bolivar, Ecuador

were included. Island species are particularly prone to extinction due to invasive species increasing competition or predation, almost total vegetation clearance, or to over-harvesting.

Two of the extinct species were teiids (*Ameiva*) from the islands of Guadeloupe and Martinique. Two others were tropidurids in the genus *Leiocephalus* (one known only from Martinique has not been seen since the 1830s and the other was last seen around 1900). The Navassa rhinoceros iguana, *Cyclura onchiopsis*, once found only on Navassa Island off Puerto Rico, has not been seen since the middle of the 19th century. The New Zealand endemic diplodactyline gecko, *Hoplodactylus delcourti*, also went extinct in the mid 19th Century. Last recorded in 1840, the Giant galliwasp, an anguid, *Celestus occiduus*, from Jamaica, was probably driven extinct by introduced mongoose predators. The skink, *Leiolopisma mauritiana*, known only from Mauritius, went extinct around 1600 also due to introduction of predators. The Cape Verde giant skink, *Macroscincus coctei*, died out early in the 20th century due to hunting pressures and prolonged drought on its island habitats. The Giant day gecko, *Phelsuma gigas*, known only from Rodrigues, Mauritius, disappeared around the end of the 19th century. The Tonga ground skink, *Tachygyia microlepis*, is thought to have gone extinct in 1994. *Tetradactylus eastwoodae*, a small limb-reduced gerrhosaurid known only from two specimens collected at the type locality Limpopo, South Africa, has not been seen since it was originally described in 1913 and seems to have succumbed to its habitat being transformed into pine plantations.

One of the places where lizards have been hardest hit is the large island of Madagascar. Deforestation there has been extensive. Some 220 + species occur there, and almost half of these (105 species in 21 genera belonging to four families) are classified by the IUCN as either Critically Endangered (14 species), Endangered (42 species), or Vulnerable (49 species). In Madagascar nature reserves, 21% of lizards have gone extinct (Sinervo et al. 2010). Madagascar allows massive exports of its charismatic and highly sought after lizards, and its geckos (*Phelsuma* and *Uroplatus*) and chameleons (*Brookesia*, *Calumma*, and *Furcifer*) are especially marketable in the herpetoculture trade.

The IUCN Red List of Threatened Species includes 75 lizard species in 47 genera from 15 families classified as "Critically Endangered" (Table 1).

Ten species of habitat-specialized arboreal anguids in the genus *Abronia* from montane cloud forests that have been extensively deforested by humans for agriculture and cattle ranching in Mexico and central America are on the IUCN Red List of Threatened Species. One species *Abronia montecristoi* listed as "Critically Endangered" has not been seen in El Salvador for half a Century (Campbell and Frost 1993) but may still occur on a couple of isolated mountains in Copan Honduras (J. R.

Figure 4. A prime candidate for imminent extinction, the very rare Guatemalan *Abronia frosti*. *Photo courtesy of Jonathan Campbell.*

Figure 5. The rare Earless monitor lizard, *Lanthanotus borneensis*, from Borneo. *Photo by Alain Compost.*

McCranie, pers. comm.). Six Mexican *Abronia* species are Endangered, and three are Vulnerable. Three highly Vulnerable Guatemalan species are *A. frosti*, *A. meledona*, and *A. campbelli* (J. A. Campbell, pers. comm.). Because of their small population sizes and limited geographic ranges in areas heavily overpopulated with humans, many *Abronia* are essentially "dead man walking" species that will go extinct during our lifetimes (Campbell and Frost 1993; J. A. Campbell, pers. comm.). Sadly, some species of *Abronia* likely went extinct in southern Guatemala and adjacent El Salvador due to habitat destruction even before they were officially described by biologists (Campbell and Frost 1993). Rare and endangered species of *Abronia* are also threatened by illegal collection for the pet trade.

Eight species of *Sceloporus* are on the IUCN Red List: one is Critically Endangered (*S. exsul*, Mexico), three are Endangered, and four are Vulnerable. The Dunes sagebrush lizard, *S. arenicolus*, is endemic to small areas of sandy habitats, occurring in localized populations chiefly on the Mescalero Sands in southeastern New Mexico and the Monahan Sandhills in adjacent Texas. Large-scale habitat destruction and activities associated with oil and gas extraction constitute the major threat to the continued existence of *S. arenicolus*. Widespread use of herbicide for control of Shinnery oak is causing significant reductions in Sand dune lizard populations due to development of unsuitable grassland habitat. Increased habitat fragmentation results in increased probability of extinction of individual populations. Other activities, including off road vehicle use, livestock grazing, and fire may also contribute to habitat destruction (L. A. Fitzgerald, pers. comm.).

The region with the highest density of threatened species is Southeast Asia, a recognized hot spot of biodiversity. Sister to monitor lizards, the Earless monitor *Lanthanotus*, known only from Sarawak on Borneo, is a threatened species: this elusive rare lizard may also occur in West Kalimantan, also on Borneo (Iskandar and Erdelen 2006). Only about 100 *Lanthanotus* have ever been collected and virtually nothing is known about the natural history or biology of this living fossil (Pianka 2004a). *Lanthanotus* is not listed by either the IUCN or CITES but it should be considered potentially threatened.

Monitor lizards

Of all the lizard families, monitor lizards (Varanidae) are among the most endangered. Monitor lizards have long been greatly admired by their many aficionados. According to Mertens (1942), Werner (1904) called them the "proudest, best-proportioned, mightiest and most intelligent" of lizards. Monitors appear curious, can count, have memories, have shown map knowledge, and plan ahead (Sweet and Pianka 2003). They have greater aerobic capacity, metabolic scope, and stamina than other lizards. Because of their size, some large monitors can retain body heat in their nocturnal retreats allowing them to emerge the next morning with body temperatures well above ambient air temperatures. Their mass thus confers a sort of "inertial homeothermy" on them (McNab and Auffenberg 1976).

Many monitors are top predators that live in a wide variety of habitats, ranging from mangrove swamps to dense forests to savannas to arid deserts. Some species are aquatic, some semi-aquatic, others terrestrial, while still others are saxicolous or semi-arboreal or truly arboreal. The varanid lizard body plan is thus versatile and has been exceedingly successful as it has been around since the late Cretaceous, 80-90 million years ago, but now, many are threatened due to human activities.

Varanus are morphologically conservative, but vary widely in size, ranging from the diminutive Australian pygmy monitor *Varanus brevicauda* (about 17-20 cm in total length and 8-20 g in mass, Pianka et al. 2004) to the largest living varanid, the Indonesian Komodo dragons (*Varanus komodoensis*), which attain lengths of three m and weights of 150 kg. During the Pleistocene, pygmy elephants are thought to have been their major prey (Auffenberg 1981). Luckily for varanophiles, when these small elephants went extinct, Komodo dragons were able to survive by switching to smaller prey. However, these big lizards are themselves dwarfed by the largest known terrestrial lizard, a closely-related gigantic varanid, *Megalania prisca*, originally placed in the genus *Varanus*. *Megalania* is a Pleistocene fossil (19,000-26,000 years BP) from Australia, estimated to have reached six m in total length and to have weighed as much as 600 kg (Hecht 1975; Auffenberg 1981).

These spectacular creatures must have been as formidable as modern-day saltwater crocodiles. The major prey of these gigantic monitor lizards is thought to have been large diprotodont marsupials (rhinoceros-sized beasts, now extinct, that were relatives of wombats and koalas). Being contemporary with aboriginal humans in Australia, *Megalania* very likely ate *Homo sapiens* as well. Its teeth were over two cm long, curved, with the rear edge serrated for cutting and tearing the skin and flesh of its prey as these powerful predators pulled back on their bite. Many other species of *Varanus* also possess such teeth. *Varanus komodoensis* routinely kill deer and pigs (recently introduced by humans) in this way—one Komodo monitor actually eviscerated a water buffalo (Auffenberg 1981). *Varanus komodoensis* and *Megalania prisca* are/were ecological equivalents of large saber-toothed cats (Akersten 1985; Auffenberg 1981).

Endangered varanids

Many of Earth's 70-odd described species of monitor lizards (Varanidae) are potentially Endangered. Five varanid species, *Varanus komodoensis*, *V. bengalensis*, *V. flavescens*, *V. griseus*, and *V. nebulosus*, are officially listed under the CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) on their Appendix I protected list (http://www.cites.org/eng/resources/trade.shtml), which means these species are classified as Threatened with extinction. Komodo dragons are considered Vulnerable by the International Union for the Conservation of Nature and Natural Resources (IUCN 2011). Only a few thousand *Varanus komodoensis* now exist in the wild, and these populations are restricted to the Indonesian island of Flores and a few nearby smaller offshore islands. Komodos were first successfully bred in captivity at the Smithsonian National Zoo in Washington, D.C. in 1992, and they have since been bred in several other major zoos. Juveniles have been sold to many other zoos around the world where these giant lizards have become centerpieces of reptile exhibits. Funds from these sales were earmarked to sponsor studies of Komodo dragons in the wild. Resulting studies have documented low population sizes and reduced genetic variation and suggest that genetic bottlenecks have occurred (Ciofi 2002; Ciofi et al. 2002). These data on population genetics should be useful in conservation efforts.

All other species of monitor lizards are classified by CITES under Appendix II, loosely defined as "species that are not necessarily threatened with immediate extinction, but may become so unless trade in such species is subject to strict regulation to avoid utilization incompatible with survival of the species in the wild." The IUCN lists two of the three Philippine frugivorous species, *V. mabitang* and *V. olivaceus*, as Endangered and Vulnerable, respectively (IUCN 2011). The third, recently described *V. bitatawa*, should also be considered Endangered (Welton et al. 2010). All three of these Philippine species have restricted geographic ranges and live in areas with high densities of humans, and should be added to the CITES Appendix I list. In 1997, the European Union wisely imposed import restrictions from Indonesia of live animals and their products for four species of monitor lizards, *V. dumerilii*, *V. jobiensis*, *V. beccarri*, and *V. salvadorii* (Engler and Parry-Jones 2007). Island endemic species, such as the handsome Yellow monitor *V. melinus* (also known as the Quince monitor) from SE Asia are much sought after and bring high prices in the herpetoculture trade—*V. melinus* has been proposed to be added to CITES Appendix I. However, it may be premature to declare *V. melinus* as Threatened because it occupies an area on Mangole and Taliabu as large as Long Island and this species thrives in coconut plantations and second growth—a similar argument can be made for *V. beccarri* from the large, impenetrable and uninhabited Aru Islands (S. S. Sweet, pers. comm.).

Hunting pressures on some species of varanids for the skin trade are extremely high with estimates of over two million being killed annually (De Buffrenil and Hemery 2007; Jenkins and Broad 1994; Pernetta 2009). Huge numbers of African *V. niloticus* are captured inhumanely using baited treble hooks. Shine et al. (1996, 1998) claim that populations of some monitor lizards, especially Asian *V. salvator*, may be able to withstand such intensive pressure by virtue of their ecological flexibility and high reproductive rate. However, because these high harvesting rates target pre-reproductive and early reproductive animals, they may well prove to be unsustainable over the long term (De Buffrenil and Hemery 2007).

According to Pernetta (2009), based on a review of CITES records over the 30-year period from 1975 and 2005, over 1.3 million live varanids representing some 42 species were harvested worldwide during these three decades. Over one million (90.6% of the total) of these belong to just three heavily exploited species: *V. exanthematicus*, *V. niloticus*, and *V. salvator*. Over a million live specimens of these three species were exported from Benin, Ghana, and Togo, mostly to the USA. According to CITES records, proportions of lizards reported as wild caught have fallen since 1996-98, as putatively "ranched and farmed" animals have risen to 50% (*V. exanthematicus*) and 75% (*V. niloticus*) of the total harvest taken in 2005. As of 2005, all *V. salvator* were still being reported as wild caught. For all remaining varanid species, numbers reported as "ranched and farmed" or captive bred have increased steadily since 1998, totaling over 50% by 2005.

Commercial trade in live monitor lizards of other species is dwarfed by the vast numbers killed for their skins over the decade from 1995 to 2005, about 20 million lizards were brutally killed for their skins. During the same decade, annual numbers of live lizards traded fluctuated around 80,000 to 90,000 and peaked with of over 120,000 in 2002. Almost 100,000 live monitors of 39 other much less abundant smaller species were exported from Indonesia, Malaysia, Philippines, Tanzania, and Thailand. Legal exports from Thailand and the Philippines were stopped in 1992 and 1994, respectively. However, uncommon endemic species are still being exported from Indonesia and Malaysia. Smuggling and illegal trade continues along with legal exportation (Christy 2008; Pernetta 2009; Schlaepfer et al. 2005; Yuwono 1998).

Africa, Asia, and Australia compared

Almost half of the 70 known species of monitor lizards are found in Australia, whereas species richness is considerably lower in Africa and mainland Asia. Varanid diversity is also high in tropical SE Asia, where many island endemics occur. African and mainland Asian monitors are large and include terrestrial and aquatic species. Small size has evolved independently twice: Once in a clade of monitor lizards from the humid tropics of SE Asia east of Wallace's Line and again in Australia, which hosts its own large clade of pygmy monitors in the subgenus *Odatria* (Pianka 2004b).

Because human population densities are much higher in Africa and Asia than in Australia, African, and Asian monitor lizards face greater threats from humans than do those in Australia. Among the monitor species most heavily exploited for the skin trade, two are African (the terrestrial *V. exanthematicus* and aquatic *V. niloticus*) while

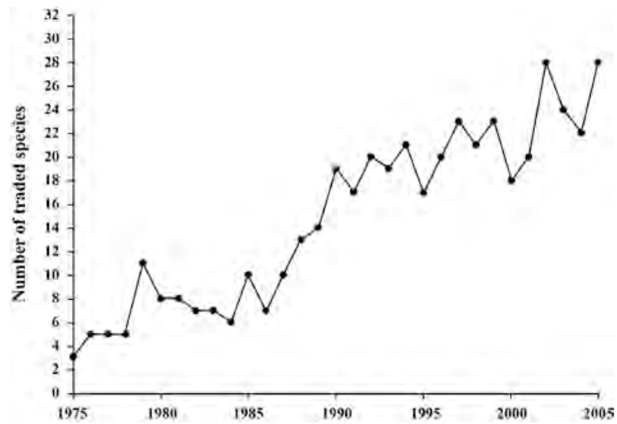


Figure 6. Number of species of living varanids traded over the 30 year period from 1975 to 2005, based on CITES data (from Pernetta 2009).

the third most exploited species is the widespread aquatic SE Asian species *V. salvator*. Populations of three other terrestrial Asian species (*V. bengalensis*, *V. flavescens*, and *V. nebulosus*) have been decimated and all three are listed as Endangered on the CITES Appendix I list. Habitat destruction in semiarid African and Asian habitats has been extensive. Desertification has claimed much of the Sahara and is spreading southwards in the Sahel.

In contrast, much of the landscape in Australia remains comparatively semi-pristine. Although native aboriginals do hunt monitor lizards for food, most Australian monitors cannot be considered threatened. Australia has never permitted legal exports of its fauna, except among zoos. The large clade of pygmy monitors (subgenus *Odatria*) includes many charismatic species much sought after by herpetoculturists. Some of these, including *V. acanthurus*, *V. gilleni*, *V. glauerti*, *V. pilbarensis*, *V. storri*, and *V. tristis* have leaked out of Australia illegally and are now being bred in captivity and are available for sale. Several larger Australian monitors, including *V. gouldii flavirufus*, *V. mertensi*, and *V. varius* are also bred in captivity and available for sale. Captive breeding programs reduce demand for wild caught lizards, hence promoting conservation. However, an animal in a cage is out of context and can never substitute for a wild one living in its natural habitat where it evolved, to which it is adapted, and where it makes profound ecological sense (Pianka 2006). Unfortunately, captive animals in zoos will never replace those living in the wild because habitat destruction is typically irreversible, so re-introduction of captives back into natural habitats is unlikely.

Cane toads and varanids

South American cane toads, *Bufo marinus*, were introduced as a biological control agent into sugar cane fields in Queensland in 1935 (Ujvari and Madsen 2009). These toads are toxic, even as eggs or tiny tadpoles (Shine

Figure 7. The arboreal Australian pygmy monitor *Varanus gilleni*. *Photo by Eric R. Pianka.*

2012). Cane toads have become an Australian ecocatastrophe, recently expanding their range northwards and westwards, where they have reached Arnhem Land and the Kimberley during the last decade (Urban et al. 2007). Many invertebrates, some marsupials, crows, raptors, freshwater crocodiles, turtles, snakes, and lizards, including at least eight species of monitor lizards (*Varanus acanthurus*, *V. glauerti*, *V. glebopalma*, *V. gouldii*, *V. mitchelli*, *V. mertensi*, *V. panoptes*, and *V. semiremex*) that eat Cane toads have been negatively affected (Doody et al. 2006, 2007, 2009; Shine 2012; Ujvari and Madsen 2009). An effort has been made to breed the Mangrove monitor *V. semiremex* in captivity for release back into the wild (S. Irwin, pers. comm.). Monitors have been found dead with Cane toads in their mouths and/or stomachs. Limited anecdotal evidence suggests that some monitors have adapted to Cane toads either by refusing to eat them or not eating their toxic parts.

Shine (2010) reviewed the impact of Cane toads on Australia's native fauna, including monitor lizard populations. Varanid populations declined in Cape York following the arrival of Cane toads (Burnett 1997). Over a 6-7 year period before and after toad invasion, large declines in population densities of three species of monitors, *Varanus panoptes* (83-96%), *V. mertensi* (87-93%), and *V. mitchelli* (71-97%) were reported by Doody et al. (2009). Following toad arrival in the Darwin area, occupancy of water holes by *V. mertensi* fell from 95% to 14% over an 18-month period (Griffiths and McKay 2007). In Kakadu National Park, radio-tracked *V. panoptes* suffered 50-70% mortality due to toad invasion (Holland 2004). In a second radio-tracking study on the Adelaide River floodplain, at least 90% of adult male *V. panoptes* were killed by toad ingestion (Ujvari and Madsen 2009). Evidence is overwhelming that invasion of Cane toads has had serious impacts on many Australian varanid populations.

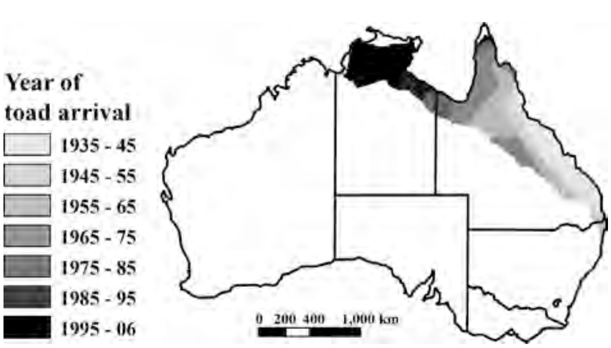


Figure 8. Spread of cane toads across Australia.

Invasive species of lizards (and snakes)

An unfortunate flip side to threatened and endangered species exists: Some lizard species have invaded habitats where they do not belong, sometimes with adverse effects on native species.

Being tropical, Florida is particularly prone to invasions and hosts a long list of introduced exotics, most by way of the pet trade (Krysko et al. 2011). At least eight species of *Anolis* (*A. chlorocyanus*, *A. cristatellus*, *A. cybotes*, *A. distichus*, *A. equestris*, *A. garmani*, *A. porcatus*, and *A. sagrei*) have been introduced in southern Florida, where *A. sagrei* appears to be displacing the more arboreal native *A. carolinensis*. Both species coexist in other areas with greater vegetation structure. Basilisks and iguanas, both *Ctenosaura* and *Iguana*, have also invaded. The Curly tail lizard, *Leiocephalus carinatus*, native to the Bahamas, was introduced to Florida in the 1940s to combat sugar cane pests. The Hispaniolan curly tail *L. schreibersii* has invaded more recently. Texas horned lizards (*Phrynosoma cornutum*) have long had well-established populations in Florida—ironically, these lizards have gone extinct over large parts of their original geographic range in Texas. Three exotic species of agamids (*Agama agama*, *Calotes versicolor*, and *Leiolepis belliana*) and three teiids (*Ameiva ameiva*, *Aspidocelis sexlineatus*, and *Cnemidophorus lemniscatus*) have populations in Florida. Mediterranean geckos (*Hemidactylus turcicus*) have been introduced into many southern states, including Florida, Louisiana, and Texas. Four other species of *Hemidactylus* (*H. frenatus*, *H. garnoti*, *H. mabouia*, and *H. platyurus*) are also found in south Florida and the Florida Keys. The gecko, *Sphaerodactylus elegans*, has established itself in the Florida Keys. The large Asian tokay gecko, *Gekko gecko*, and Madagascar day geckos *Phelsuma grandis*, also have established populations in Florida. Several of these Florida invasive lizard species (*Anolis sagrei*, *Phrynosoma cornutum*, *Hemidactylus turcicus*, and *H. garnoti*) have also managed to establish themselves in South Carolina and Georgia.

Even one varanid species has successfully invaded southwestern Florida. The large African aquatic monitor *V. niloticus* has been introduced into the wild around the Cape Coral region, where a feral breeding population has become established. These voracious predators are preying on many native North American species, including waterbirds, Burrowing owls (*Athene cunicularia*), eggs of sea turtles, and other native wildlife (Enge et al. 2004). Efforts to eradicate this invasive monitor population have failed and *V. niloticus* appear to be expanding their geographic range in Florida. Snakes, of course, are merely one (albeit rather successful) clade of legless lizards. Three species of large constrictors have now established breeding populations in Florida. These include Boa constrictors and two species of pythons, the largest being Burmese pythons (*Python molurus*) (http://www.wired.com/wiredscience/2009/10/giant-snakes/).

Four species of Old World lacertids have established themselves in the New World. Populations of the European wall lizard *Podarcis muralis* thrive in Garden City, Long Island, New York, and in Cincinnati, Ohio. *Podarcis muralis* and the green lacertid (*Lacerta viridis*) have been introduced in the United Kingdom. *Lacerta viridis* has been introduced in Kansas. The Italian wall lizard *Podarcis sicula* was also introduced to Long Island, New York, about 1966-67. *Lacerta melisellensis fiumana* was first reported from Philadephia in 1931 and was still extant in 1959.

Three exotic lizards have been introduced on the island of Mauritius, the Asian agamid, *Calotes versicolor*, the Madagascar panther chameleon, *Furcifer pardalis*, and the Madagascar day gecko, *Phelsuma grandis*.

Jackson's chameleons (*Chamaeleo jacksonii*), natives of Kenya and Tanzania, were released in the Hawaiian Islands in 1972 and have spread to several islands where they are now well established. They give birth to living young and feed largely on native insects and snails, at least one of which is itself endangered. Males sport three rhinoceros like horns on their snouts and can reach total lengths of nearly 25 cm about half of which consists of a strongly prehensile tail. Many people like these attractive chameleons, which are exported from Hawaii to the mainland USA where they are sold as pets. More recently, the much larger (up to two feet long) Veiled chameleon (*Chamaeleo calyptratus*), native to Yemen and Saudi Arabia, has been illegally introduced to Hawaii. Veiled chameleons lay very large clutches of eggs and are primarily insectivorous but they also feed on leaves, flowers, and buds, as well as an occasional bird or small mammal. Concerned about these invasive chameleons, Hawaiian officials have attempted to restrict movements of chameleons between islands.

The Brown tree snake (*Boiga irregularis*), a native of Australia, Indonesia, and Papua New Guinea, was accidentally introduced on the island of Guam in the 1950s with disastrous effects on native endemic lizard and bird species (Pimm 1987; United States Department of Defense 2008[1]).

Future prospects?

Maintenance of the existing diversity of varanids, as well as clade diversity of all other extant lizards, will depend increasingly on our ability to manage and share beleaguered spaceship Earth. Current and expanding levels of human populations are unsustainable and are direct and indirect causes of habitat loss. They also contribute to escalating rates of climate change. To address anthropogenic habitat loss and climate change, we will have to make major changes in our resource use.

Sadly, "wildlife management" is somewhat of a farce: Currently we are failing to adequately conserve species or habitats—we humans do not even have the will to limit our own population! Humans have now dramatically altered the ecology of over half of the land surface of this our one and only spaceship planet Earth. Conservation biology is a man-made emergency discipline rather like surgery is to physiology or war is in political science. Wild animals could and would flourish if people could manage to share the planet and leave them large enough undisturbed areas of habitat. However, even if we could somehow designate and maintain large nature reserves, the menace of irreversible global warming seems destined to take a heavy toll on all Earthlings. Hopefully, with new approaches and increased global efforts, lizards, including varanids, will be among the survivors of this current massive anthropogenic extinction event.

Acknowledgments.—I thank Craig Hassapakis for inviting me to write this essay. I am grateful to Robert Browne, Ray Huey, Mitchell Leslie, Sam Sweet, and Laurie Vitt, all of whom suggested many ways to improve this effort. Of course, all opinions expressed herein

[1]United States Department of Defense. 2008. Report to the Congress. Control of the Brown Tree Snake.

are my own and none of these people are responsible for any of them. Thanks to Jonathan Campbell for allowing us to use his photograph of *Abronia frosti*, Stephen Zozaya for allowing us to use his photograph of *Varanus glauerti*, and to Jeff Lemm who generously shared his outstanding photographs of varanids.

Literature cited

Araujo MB, Thuiller W, Pearson RG. 2006. Climate warming and the decline of amphibians and reptiles in Europe. *Journal of Biogeography* 33(10):1712-1728.

Auffenberg W. 1981. *The Behavioral Ecology of the Komodo Monitor*. University of Florida Press, Gainesville, Florida, USA.

Bayless MK, Adragna JA. 1999. The Banggai Island monitor: Notes on distribution, ecology, and diet of *Varanus melinus*. *Vivarium* 10:38-40.

Burnett S. 1997. Colonizing cane toads cause population declines in native predators: reliable anecdotal information and management implications. *Pacific Conservation Biology* 3(1):65-67.

Boulding KE. 1966. The economics of the coming spaceship Earth. In: *Environmental Quality in a Growing Economy*. Editor, Jarrett H. Resources for the Future/ Johns Hopkins University Press, Baltimore, Maryland, USA. 3-14.

Böhm M. et al. (217 co-authors). 2012. The conservation status of the world's reptiles. *Biological Conservation*. (In press).

Campbell JA, Frost DR. 1993. Anguid lizards of the genus *Abronia*: Revisionary notes, descriptions of four new species, a phylogenetic analysis, and key. *Bulletin of the American Museum of Natural History* 216:1-121.

Campbell KR, Campbell TS. 2005. The feasibility of using introduced lizards as indicators of environmental contamination. *Applied Herpetology* 2(2):149-159.

Catton WR. 1982. *Overshoot: The Ecological Basis of Revolutionary Change*. University of Illinois Press, Champaign, Illinois, USA.

Christy B. 2008. *The Lizard King: The True Crimes and Passions of the World's Greatest Reptile Smugglers*. Hachette Book Group, New York, New York, USA.

Ciliberti A, Berny P, Delignette-Muller ML, De Buffrenil V. 2011.The Nile monitor (*Varanus niloticus*; Squamata: Varanidae) as a sentinel species for lead and cadmium contamination in sub-Saharan wetlands. *Science of the Total Environment* 409(22):4735-4745.

Ciliberti A, Berny P, Vey A, De Buffrenil V. 2012. Assessing environmental contamination around obsolete pesticide stockpiles in West Africa: Using the Nile monitor (*Varanus niloticus*) as a sentinel species. *Environmental Toxicology and Chemistry* 31(2):387-394.

Ciofi C. 2002. Conservation genetics. In: *Komodo Dragons: Biology and Conservation*. Editors, Murphy JB, Ciofi C, De La Panouse C, Walsh T. Smithsonian Institute Press, Washington, DC, USA. 129-164.

Ciofi C, Smith BR, Hutchins M. 2002. Conservation: *In situ* and *ex situ* contributions. In: *Komodo Dragons: Biology and Conservation*. Editors, Murphy JB, Ciofi C, De La Panouse C, Walsh T. Smithsonian Institute Press, Washington, DC, USA. 211-230.

Cites. 2012. Convention on International Trade in Endangered Species of Wild Fauna and Flora. [Online]. Available: http://www.cites.org/eng/resources/trade.shtml [Accessed: 27 February 2012].

De Buffrenil V, Hemery G. 2007. Harvest of the Nile monitor, *Varanus niloticus*, in Sahelian Africa. Part 1: Impact of intensive harvest on local stocks. *Mertensiella* 16:181-194.

Diamond J. 1987. The worst mistake in the history of the human race. *Discover* magazine (May 1, 1987):64-66.

Doody JS, Green B, Sims R, Rhind D, West P, Steer D. 2006. Indirect impacts of invasive Cane toads (*Bufo marinus*) on nest predation in Pig-nosed turtles (*Carettochelys insulpta*). *Wildlife Research* 33(5):349-354.

Doody JS, Green B, Sims R, Rhind D. 2007. A preliminary assessment of the impacts of invasive cane toads (*Bufo marinus*) on three species of varanid lizards in Australia. *Mertensiella* 16:218-227.

Doody JS, Green B, Castellano C, Rhind D. 2009. Population-level declines in Australian predators caused by an invasive species. *Animal Conservation* 12(1):46-53.

Enge KM, Krysko KL, Hankins KR, Campbell TS, King FW. 2004. Status of the Nile Monitor (*Varanus niloticus*) in Southwestern Florida. *Southeastern Naturalist* 3(4):571-582.

Engler M, Parry-Jones R. 2007. *Opportunity or Threat: The Role of the European Union in Global Wildlife Trade*. TRAFFIC Europe, Brussels, Belgium.

Evans S. 2003. At the feet of the dinosaurs: The early history and radiation of lizards. *Biological Reviews* 78(4):513-551.

Fagan BM. 2004. *The Long Summer: How Climate Changed Civilization*. Basic Books, New York, New York, USA.

Gibbons JW, Scott DE, Ryan TJ, Buhlmann KA, Tuberville TD, Metts BS, Greene JL, Mills T, Leiden Y, Poppy S, Winne CT. 2000. The global decline of reptiles, déjà vu amphibians. *BioScience* 50(8):653-666.

Gilpen ME, Soulé ME. 1986. Minimum viable populations: Processes of species extinction. In: *Conservation Biology: The Science of Scarcity and Diversity*. Editor, Soulé ME. Sinauer, Sunderland, Massachusetts, USA. 19-34.

Griffiths AD, McKay JL. 2007. Cane toads reduce the abundance and site occupancy of freshwater goannas *Varanus mertensi*. *Wildlife Research* 34(8):609-615.

Hansen J, Nazarenko L, Ruedy R, Sato M, Willis J, Del Genio A, Koch D, Lacis A, LO K, Menon S, Novakov T, Perlwitz J, Russell G, Schmidt GA, Tausnev N. 2005. Earth's energy imbalance: Confirmation and implications. *Science* 308(5727):1431-1435.

Harden G. 1968. The tragedy of the commons. *Science* 162(3859):1243-1248.

Hecht M. 1975. The morphology and relationships of the largest known terrestrial lizard, *Megalania prisca* Owen, from the Pleistocene of Australia. *Proceedings of the Royal Society of Victoria* 87:239-250.

Holland DC. 2004. Interim report for study of impacts of cane toads, *Bufo marinus*, on two goanna species, *Varanus panoptes* and *Varanus gouldii*. Issues associated with the progressive entry into the Northern Territory of cane toads. Volume 1. Report No.1 October 2003. Legislative Assembly of the Northern Territory, Sessional Committee on Environment and Sustainable Development, Darwin, Australia.

Huey RB, Deutsch CA, Tewksbury JJ, Vitt LJ, Hertz PE, Alvarez Perez HJ, Garland T. 2009. Why tropical forest lizards are vulnerable to climate warming. *Proceedings of the Royal Society B* (Biological Sciences) 276(1664):1939-1949.

Huey RB, Tewksbury JJ. 2009. Commentary: Can behavior douse the fire of climate warming? *Proceedings of the National Academy of Sciences* 106(10):3647-3648.

Huey RB, Losos JB, Moritz C. 2010. Are lizards toast? *Science* 328(5980):832-833.

IPPC. 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Editors, Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL. Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA. [Online]. Available: http://www.ipcc.ch/publications_and_data/ar4/wg1/en/contents.html [Accessed: 26 February 2012].

Iskandar DT, Erdelen WR. 2006. Conservation of amphibians and reptiles in Indonesia: Issues and problems. *Amphibian and Reptile Conservation* 4(1):60-87.

IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. [Online]. Available: www.iucnredlist.org [Accessed: 28 February 2012].

Jenkins M, Broad S. 1994. *International Trade in Reptile Skins: A Review and Analysis of the Main Consumer Markets, 1983-1991*. Traffic International, Cambridge, United Kingdom.

Kearney M, ShinecR, Porter WP. 2009. The potential for behavioral thermoregulation to buffer "cold- blooded" animals against climate warming. *Proceedings of the National Academy of Sciences* 106(10):3835-3840.

Kemp AC, Horton BP, Culver SJ, Corbett DR, van de Plassche O, Gehrels WR, Douglas BC, Parnell AC. 2009. Timing and magnitude of recent accelerated sea-level rise (North Carolina, United States). *Geology* 37:1035-1038.

Kersten WA. 1985. Canine function in *Smilodon* (Mammalia: Felidae: Machairodontinae). *Natural History Museum of Los Angeles County, Contributions in Science* 356:1-22.

King DR, Pianka ER, Green B. 2002. Biology, ecology, and evolution. (Chapter 2). In: *Komodo Dragons: Biology and Conservation*. Editors, Murphy JB, Ciofi C, De La Panouse C, Walsh T. Smithsonian Institute Press, Washington, D.C., USA. 23-41.

Koch PI, Barnosky AD. 2006. Late quaternary extinctions: State of the debate. *Annual Review of Ecology and Systematics* 37(11):215-50.

Krysko KL, Burgess JP, Rochford MR, Gillette CR, Cueva D, Enge KM, Somma LA, Stabile JL, Smith DC, Wasilewski JA, Kieckhefer III GN, Granatosky MC, Nielsen SV. 2011. Verified non-indigenous amphibians and reptiles in Florida from 1863 through 2010: Outlining the invasion process and identifying invasion pathways and stages. *Zootaxa* 3028:1-64.

McNab BK, Auffenberg W. 1976. The effect of large body size on the temperature regulation of the Komodo dragon, *Varanus komodoensis*. *Comparative Biochemistry and Physiology, Part A: Physiology* 55(4):345-350.

Mertens R. 1942. Die Familie der Warane (Varanidae). *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft* 462, 466, 467:1-391.

Molnar RE. 2004 The long and honorable history of monitors and their kin. In: *Varanoid Lizards of the World*. Editors, Pianka ER, King DR. Indiana University Press, Bloomington, Indiana, USA. 10-67.

Murphy JB, Ciofi C, De La Panouse C, Walsh T (Editors). 2002. *Komodo Dragons: Biology and Conservation*. Smithsonian Institute Press, Washington, D.C., USA.

NOAA. 2012. National Oceanic and Atmospheric Administration, National Climatic Data Center. [Online]. Available: http://www.ncdc.noaa.gov/oa/climate/globalwarming.html [Accessed: 05 March 2012, 13:11:17 EST].

Pernetta AP. 2009. Monitoring the trade: Using the CITES database to examine the global trade in live monitor lizards (*Varanus* spp.). *Biawak* 3(2):37-45.

Pianka ER. 1970. Comparative autecology of the lizard *Cnemidophorus tigris* in different parts of its geographic range. *Ecology* 51:703-720.

Pianka ER. 1986. *Ecology and Natural History of Desert Lizards: Analyses of the Ecological Niche and Community Structure*. Princeton University Press, Princeton, New Jersey, USA.

Pianka ER. 1994. *The Lizard Man Speaks*. University of Texas Press, Austin, Texas, USA.

Pianka ER. 2004a. *Lanthanotus borneensis*. In: *Varanoid Lizards of the World*. Editors, Pianka ER, King DR. Indiana University Press, Bloomington, Indiana, USA. 535-538.

Pianka ER. 2004b. Evolution of body size and reproductive tactics. In: *Varanoid Lizards of the World*. Editors, Pianka ER, King DR. Indiana University Press, Bloomington, Indiana, USA. 549-555.

Pianka ER. 2006. The Vanishing Book of Life on Earth. [Online]. Available: http://www.zo.utexas.edu/courses/THOC/Vanishing-Book.html [Accessed: 28 February 2012].

Pianka ER, Vitt LJ. 2003. *Lizards: Windows to the Evolution of Diversity*. University of California Press, Berkeley, California, USA.

Pianka ER, King DR, King AR (Editors). 2004. *Varanoid Lizards of the World*. Indiana University Press, Bloomington, Indiana, USA.

Pimm SL. 1987. The snake that ate Guam. *Trends in Ecology and Evolution* 2(10):293-295.

Quaternary extinction event. [Online]. Available: http://en.wikipedia.org/wiki/Quaternary_extinction_event. [Accessed: 28 February 2012].

Reptile database. 2012. [Online]. Available: http://www.reptile-database.org/db-info/SpeciesStat.html [Accessed: 19 March 2012].

Ruddiman WF. 2003. The anthropogenic greenhouse era began thousands of years ago. *Climatic Change* 61(3):261-293.

Ruddiman WF. 2005. *Plows, Plagues, and Petroleum*. Princeton University Press, Princeton, New Jersey, USA.

Schlaepfer MA, Hoover C, Dodd Jr. KD. 2005. Challenges in evaluating the impact of the trade in amphibians and reptiles on wild populations. *Bioscience* 55(3):256-264.

Shine R. 2010. The ecological impact of invasive cane toads (*Bufo marinus*) in Australia. *Quarterly Review of Biology* 85(3):253-291.

Shine R, Harlow P, Ambariyanto, Boeadi, Mumpuni, Keogh JS. 1996. Monitoring monitors: A biological perspective on the commercial harvesting of Indonesian reptiles. *Mertensiella* 9:61-68.

Shine R, Ambariyanto, Harlow PS, Mumpuni. 1998. Ecological traits of commercially harvested water monitors, *Varanus salvator*, in northern Sumatra. *Wildlife Research* 25(4):437-447.

Sinervo B, et al. (with 25 co-authors). 2010. Erosion of lizard diversity by climate change and altered thermal niches. *Science* 328(5980):894-899.

Smil V. 2001. *Enriching the Earth: Fritz Haber, Carl Bosch and the Transformation of World Food Production*. The MIT Press, Cambridge, Massachusetts, USA.

Steadman DW. 2006. *Extinction and Biogeography of Tropical Pacific Birds*. The University of Chicago Press, Chicago, Illinois, USA.

Sweet SS, Pianka ER. 2003. The lizard kings. *Natural History* 112(9):40-45.

Sweet SS, Pianka ER. 2007. Monitors, mammals and Wallace's Line. Third multidisciplinary world conference on monitor lizards. Alexander Koenig Museum, Bonn, Germany. *Mertensiella* 16:79-99.

Traill LW, Bradshaw CJA, Brook BW. 2007. Minimum viable population size: A meta-analysis of 30 years of published estimates. *Biological Conservation* 139(2007):159-166.

Ujvari, B, Madsen T. 2009. Increased mortality of naïve varandid lizards after the invasion of non-native cane toads (*Bufo marinus*). *Herpetological Conservation and Biology* 4(2):248-251.

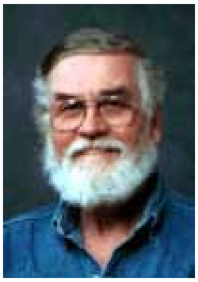
Urban M, Phillips BL, Skelly DK, Shiner R. 2007. The cane toad's (*Chaunus marinus*) increasing ability to invade Australia is revealed by a dynamically updated range model. *Proceedings of the Royal Society B* (Biological Sciences) 274(1616):1413-1419.

Welton LJ, Siler CD, Bennett D, Diesmos A, Duya MR, Dugay R, Rico ELB, VAN Weerd M, Brown, R. 2010. A spectacular new Philippine monitor lizard reveals a hidden biogeographic boundary and a novel flagship species for conservation. *Biology Letters* 6(5):654-658.

Werner E. 1904. Die Warane. *Blätter für Aquarien und Terrarienkunde* 5:84-87, 99-101.

Yuwono FB. 1998. The trade of live reptiles in Indonesia. In: *Conservation, Trade and Sustainable Use of Lizards and Snakes in Indonesia*. Editor, Erdelen W. *Mertensiella* 9:9-15.

Received: 05 March 2012
Accepted: 09 May 2012
Published: 08 August 2012



ERIC R. PIANKA earned a B.A. from Carleton College in 1960, a Ph.D. from the University of Washington in Seattle in 1965, and the D.Sc. degree on his collected works in 1990 from the University of Western Australia. He was a postdoctoral student with Robert H. MacArthur at Princeton University during 1966-68. He is currently the Denton A. Cooley Centennial Professor of Zoology at the University of Texas in Austin, where he has taught evolutionary ecology since 1968. Pianka has presented hundreds of invited lectures at most of the world's major academic institutions as well as several important plenary lectures. During his 45 year academic career, Eric Pianka sponsored 20 graduate students and published well over a hundred scientific papers, four of which became "Citation Classics," as well as dozens of invited articles, book chapters, and 18 books including an autobiography. His classic textbook *Evolutionary Ecology*, first published in 1974 went through seven editions, and has been translated into Greek, Japanese, Polish, Russian, and Spanish, and is now available as an eBook.