

Chapter 18

The Third Wave

Island birds are especially vulnerable to extinction because they inhabit small areas, have small population sizes or both. On the continents, there are far greater areas to inhabit, and huge population sizes are more common. Continents generally have longer and more diverse geological histories than oceanic islands. With more time, area, climatic changes, topographic variation, and habitat diversity, the continental biota evolves with a different dynamic than do most island biotas. So, continents are home to far greater numbers of species and they are more strongly buffered against extinction.

Around 90% of the bird species that became extinct in the Holocene were endemic to islands¹. Many others remain threatened or endangered today. A 1994 survey reported roughly 250 endangered bird species; over half are island endemics. But the proportion of endangered and threatened island birds is gradually diminishing, because most vulnerable island birds are already extinct and the number of endangered continental species is rising rapidly. Stanley Temple of the University of Wisconsin has observed that today the locus of bird extinction is shifting. “Although the majority of the world’s endangered species still come from islands, it is clear that the process of extinction has been shifted geographically from relatively low-diversity island avifaunas to species-rich continental areas and habitats that support the world’s greatest variety of bird life. As the numbers of endangered and extinct birds from these areas continue to expand, there will be an unprecedented reduction in the diversity of birds on earth.”² This third pulse of Quaternary dinosaur extinction may ultimately prove the most severe of all.

North America

In the last 200 years, North America has lost more bird species than any other comparable landmass³. There are three major sources of reduced survivorship, all familiar from our tour through of some of the world’s islands: introduced species, human overkill, and habitat destruction. Each is exacerbated by human population growth. James Greenway, of the American Museum of Natural History, studied the geography of extinction and its symmetry with human population growth in New England. Europeans arrived in about 1600, when the eastern half of the continent was heavily forested (fig. 18.01). Most was cleared by humans in the early years of westward expansion. Long before Europeans arrived, the forests had already been altered by American Indians, who frequently burned the undergrowth. But European tools and agricultural practices

induced heavy deforestation. The original forest highlands were dominated by hickory, oak and chestnut trees. Lower hills and valleys supported maple and beech forests. Natural fires were also a regular part of these forests, creating many clearings among the trees. These forests have now been decimated. In their place stands secondary growth and agricultural land, vastly altering the original environment.

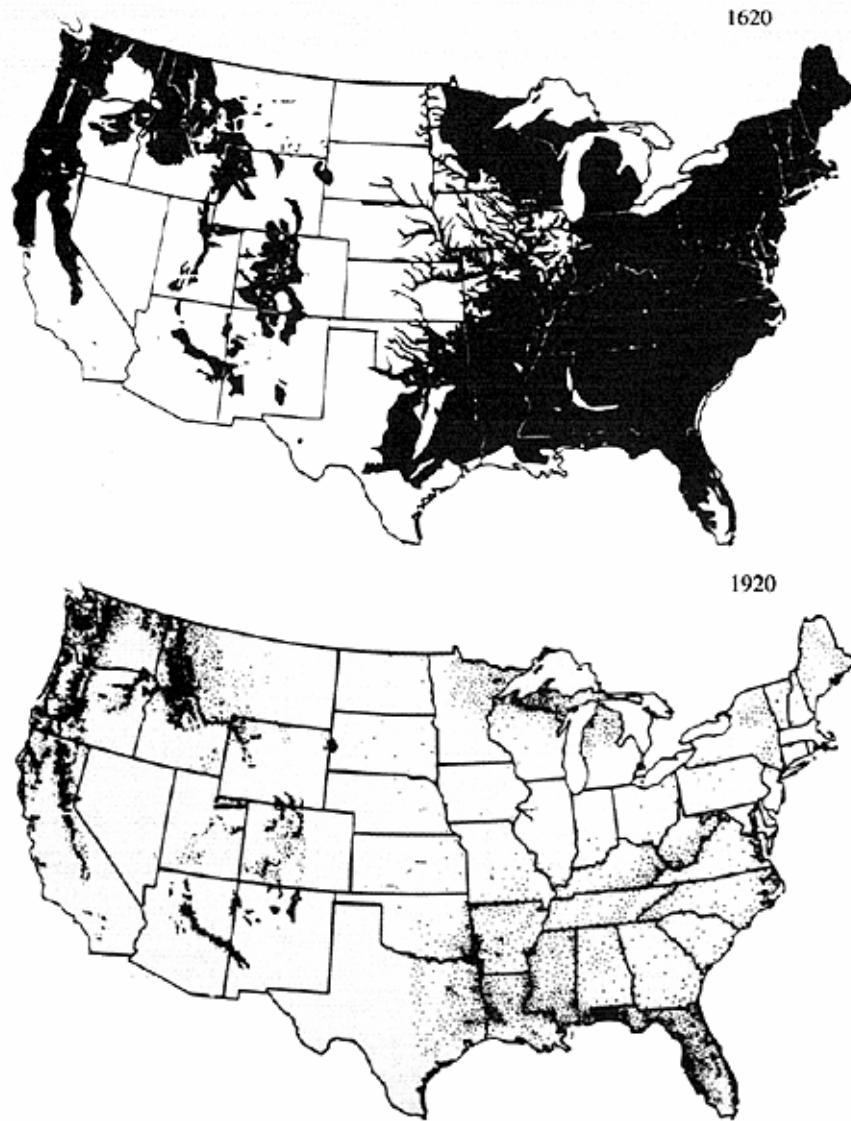


Figure 18.01 When European settlement of North America began in earnest in the early 17th century, forests stretched over half the continental US. By the early 20th century, only a sparse patchwork of forests remained. (From A. P. Dobson 1996. Conservation and biodiversity. Scientific American Library, New York.)

Greenway estimated that 431 million acres of original forest were cleared; only about nineteen million acres remain. Another measure of this loss involves population density. In 1754, there were twenty-four acres of forest per person in Massachusetts. About 1790, as settlers began to move west toward the Appalachians, large tracts of forest were burned to augment agricultural areas. As populations grew, the forests shrank. In 1776 there were seventeen acres per person, in 1800 eleven acres, by 1830 only eight acres, and by 1850 only four. By 1850, virtually all the original forest was gone in Massachusetts. Within a few decades virtually all the US east of the Mississippi had been cleared. Several bird species abundant in 1850 are now extinct, and a growing number are threatened or endangered.

American universities had established excellent traditions in natural history by the beginning of the 19th century. For more than 200 years the eastern US has been studied by skilled natural historians, observing and writing about birds. One of the greatest was a prolific writer, a meticulous illustrator, and the world's foremost authority on the living species of North American dinosaurs--John James Audubon. Several species that he observed and painted in the wild, at a time when they suffered no obvious threat, have since become extinct. In these cases, the trail of clues leading scientists to the cause of their extinction is preserved on paper rather than stone. The testimony of Audubon and the subsequent generations of wildlife biologists he helped inspire vividly document the extinction of species on a continental scale.

Martha

Next to *Archaeopteryx* and the Dodo, the Passenger Pigeon (*Ectopistes migratorius*) is probably the world's most famous extinct bird. At the beginning of the 19th century, it was quite possibly the most abundant bird in North America, if not on Earth (fig. 18.02). So, it is hard to understand how it could be that the last wild specimen was shot in the early fall of 1899, and by then the species was all but extinct^{4,5}.

Audubon prefaced his description of the Passenger Pigeon with the words "The multitudes of Wild Pigeons in our woods are astonishing. Indeed, after having viewed them so often, and under so many circumstances, I even now feel inclined to pause, and assure myself that what I am going to relate is fact.... In the autumn of 1813, I left my house at Henderson, on the banks of the Ohio, on my way to Louisville. In passing over the Barrens a few miles beyond Hardensburgh, I observed the Pigeons flying from north-east to south-west, in greater numbers than I thought I had ever seen them before, and feeling an inclination to count the flocks that might pass within the reach of my eye in one hour, I dismounted,

seated myself on an eminence, and began to mark with my pencil, making a dot for every flock that passed. In a short time finding the task which I had undertaken impracticable, as the birds poured in countless multitudes, I rose, and counting the dots then put down, found that 163 had been made in twenty-one minutes. I traveled on, and still met more the farther I proceeded. The air was literally filled with Pigeons; the light of noon-day was obscured as by an eclipse, the dung fell in spots, not unlike melting flakes of snow; and the continued buzz of wings had a tendency to lull my senses to repose.”⁶

In 1810, Alexander Wilson, a preeminent ornithologist of the time, observed a huge flock in Kentucky, estimating that it contained 2.2 billion individuals⁷. A later ornithologist reported in 1871 on a breeding colony in Wisconsin, estimating at least 136 million birds were present in an area covering 850 square miles⁸. The roosts of these great flocks could also cover several square miles, and trees often collapsed under the sheer weight of roosting pigeons.



Figure 18.02 In the early 19th century, the Passenger Pigeon congregated in flocks of millions of birds. (From *The Illustrated Sporting and Dramatic News*, July 3, 1875).

Given that the bird is now extinct, it is hard to believe that such accounts were true, regardless of their sources. But a close relative of the Passenger Pigeon also migrates in great flocks and breeds in immense colonies containing millions of birds. The Eared Dove (*Zenaida auriculata*) lives in northeastern Brazil and central Argentina, forming spectacular, wide-ranging flocks that confirm the estimates for the Passenger Pigeon⁹. It is a close analog to the Passenger Pigeon in many key evolutionary strategies that may have been responsible for the extinction of its cousin. American hunters and professional bird trappers are commonly indicted as primary suspects in the loss of the Passenger Pigeon. But from studying the Eared Dove and historic accounts of the Passenger Pigeon, it is evident that habitat alteration was a significant, if not predominant, factor in its extinction.

The Passenger Pigeon could fly at sustained speeds approaching 60 miles per hour, rapidly covering long distances. Its migrations represented great foraging expeditions. As Audubon described: “These are entirely owing to the necessity of procuring food, and are not performed with the view of escaping the severity of a northern latitude, or of seeking a southern one for the purpose of breeding. They consequently do not take place at any fixed period or season of the year. Indeed, it sometimes happens that a continuance of a sufficient supply of food in one district will keep these birds absent from another for years.”¹⁰

As they entered new areas to feed, the birds were massacred and trapped with deadly efficiency as they roosted at night and bred. Audubon described one site 40 miles long and three miles wide, where Pigeons roosted along the Green River in Kentucky, detailing the slaughter that was planned and executed.

“Many people were involved, one traveling over 200 miles and driving 300 hogs to be fattened on the pigeons that were slaughtered. “Here and there, the people employed in plucking and salting what had already been procured, were seen in the midst of large piles of these birds. The dung lay several inches deep, covering the whole extent of the roosting-place. Many trees two feet in diameter, I observed, were broken off at no great distance from the ground; and the branches of many of the largest and tallest had given way, as if the forest had been swept away by a tornado. Every thing proved to me that the number of birds resorting to this part of the forest must be immense beyond conception. As the period of their arrival approached, their foes anxiously prepared to receive them. Some were furnished with iron-pots containing sulfur, others with torches of pine-knots, many with poles, and the rest with guns....Suddenly there burst forth a general cry of “Here they come!” The noise which they made, though yet distant, reminded

me of a hard gale at sea, passing through the rigging of a close-reefed vessel. As the birds arrived and passed over me, I felt a current of air that surprised me. Thousands were soon knocked down by the pole men. The birds continued to pour in. The fires were lighted, and a magnificent, as well wonderful and almost terrifying, sight presented itself. The Pigeons, arriving by thousands, alighted everywhere, one above another, until solid masses were formed on the branches all round. Here and there the perches gave way under the weight with a crash, and, falling to the ground, destroyed hundreds of the birds beneath, forcing down the dense groups with which every stick was loaded. It was a scene of uproar and confusion. I found it quite useless to speak, or even to shout to those who were nearest to me. Even the reports of the guns were seldom heard, and I was made aware of the firing only by seeing the shooters reloading.”¹¹

Professional netters trapped birds by the thousand. By the time the laws banning the practice took effect it was too late. From one nesting colony, two railroad cars per day filled with pigeons could be sent to eastern markets. Audubon visited New York in March of 1830 and found that pigeons “were so abundant in the markets, that piles of them met the eye in every direction.” At the famous Wisconsin colony of 1871, 1.2 million birds were taken by 600 professional pigeon netters in one nesting. Reportedly, “hundreds” of sport hunters and professional trappers followed the birds across wide regions, taking a large toll as they went¹². With such vivid testimony it might appear that the bird's extinction rests squarely on *Homo sapiens*.

But astonishingly, the number of birds killed by people may have amounted to only a few percent of these flocks¹³. The Eared Dove, whose populations range between 1 million and 10 million birds, have suffered similar losses without significant long-term declines in population levels. In northern Argentina, an Eared Dove population estimated at 3 million is considered a pest, and attempts to extirpate it have included poisoned baits and year-round trapping. About 420,000 birds were exterminated in one application of poison, but no long-term effects were observed. So many birds breed several times each year that the species withstood the attacks by doubling or quadrupling their numbers every season.

Several key life-history characteristics of the Passenger Pigeon appear to have been responsible for their extinction¹⁴. The Passenger Pigeon may have descended from pigeons of the Great Plains, evolving into the hardwood forests and exploiting its profuse food supply. Whatever its history, the endemic Passenger Pigeon never spread beyond to the eastern hardwood forests. The limiting factor was food. Its main staple was mast--the

fruits of hardwood trees, particularly Beech trees. Beech mast is far more enriched in protein and carbohydrates than acorns and chestnuts, but the pigeons fed on these also. They foraged for accumulations of these fruits on the ground beneath the trees. The distribution of mast-producing trees naturally limited the pigeon's upper range to the southern part of Canada, and to the eastern half of North America.

Mast production is irregularly timed and distributed across eastern forests. Mast trees tend to have abundant crops every two to five years, but no regular cycle exists, except that the mast-producing trees of several species often synchronize their irregular production. Consequently, all the trees over widespread areas would produce in great abundance at the same time. Some biologists have argued that this satiates seed predators, like squirrels and jays, as well as pigeons, while leaving some seeds to produce new trees. Whatever the reason, forests present a patchwork of resources in any given season, with some regions producing abundant mast supplies and others not. During "migration," the Eared Dove wanders widely but loosely follows a linear course as it scours broad areas of the forest for food.

The Passenger Pigeon migrated in the same pattern. Its great flocks were well suited for discovering and exploiting the patches of high mast production. They would respond to sightings of other birds on the ground that might have discovered a mast cache. Hunters, accordingly, set out 'stool pigeons', luring dozens or hundreds of birds into a trap. Covering vast areas, the pigeons scoured the ground for mast. The availability of food was critical for their breeding. Both the length of their breeding season and their Spring nesting episodes were correlated with the supply of mast. Population levels were probably also determined by mast supply, as they are in the Eared Dove. Their gregariousness and the size of their congregations greatly facilitated the discovery of food.

As settlers moved westward, old forests were completely cleared, transforming large areas into agricultural lands, especially where beech trees had lived in fertile bottom lands. Huge volumes of wood were also cut for fuel. The amount cut for fuelwood alone probably exceeded today's overall timber harvest. Deforestation accelerated in the 1870's with the invention of portable steam sawmills, and by the end of the 19th century most old tracts of original forest disappeared. Secondary growth that has been allowed to come back between the agricultural regions consists mostly of sprouts that rarely grow to maturity, because it's ready to cut for lumber in half the time it takes for the trees to grow into large-scale mast producers. The brushy understory that this type of forest fosters is difficult for the pigeons to move through as they look for mast. Domestic hogs competed with Passenger Pigeons for the mast that was produced by the trees that had not been cut.

The decline of the forests coincided with the decline in the great breeding colonies. Evidently, their social organization was critical for locating food, because isolated pairs and small groups that survived into the 1890's eventually disappeared. Scattered sightings were not uncommon in the first few years of the 20th century¹⁵.



Figure 18.03 Martha, the last Passenger Pigeon. (From E. Fuller 1987. *Extinct Birds*. Viking/Rainbird, London).

In a way, Audubon predicted this fate. “Persons unacquainted with these birds might naturally conclude that [human predation] would soon put an end to the species. But I have satisfied myself, by long observations, that nothing but the gradual diminution of our forests can accomplish their decrease, as they not unfrequently quadruple their numbers yearly, and always at least double it.”¹⁶

The last known individual of this species was named Martha (fig. 18.03) by keepers in the Cincinnati Zoological Gardens, where Martha passed her last years. In late 1914, in the ornithological journal *The Auk*, an anonymous editor published this obituary:

“*Ectopistes migratorius*, once one of the most notable species in the North American avifauna became extinct on September 1, by the death of the last surviving specimen, a female, which had lived for twenty-nine years in the aviary of the Cincinnati Zoölogical Garden. It is rarely possible to state the exact date of the extinction of a species as the process is usually a gradual one, but in view of the fruitless efforts extending over the past ten years to find evidence of the existence of wild Passenger Pigeons we may safely consider the passing of this last captive specimen as the extinction of the species.”¹⁷

Too Adaptable?

The extinct Carolina Parakeet (*Conuropsis carolinensis*) suffered a similar fate, its last members dying in the same zoo only 4 years later (fig. 18.04). But its extinction was different. It was present in great abundance when Europeans arrived in North America, ranging from the Gulf of Mexico to the Great Lakes, and from the Mississippi River east to Florida. It had an orange face, a yellow head and neck, with green body plumage. It lived in non-migratory flocks, nesting in holes of mature trees in old deciduous forests. They sometimes assembled sizable rookeries in huge hollows. Repotredly, they had a fondness for seeds of elm, maple, cypress, pine, and beech, as well as thistles and cocklebur¹⁸.

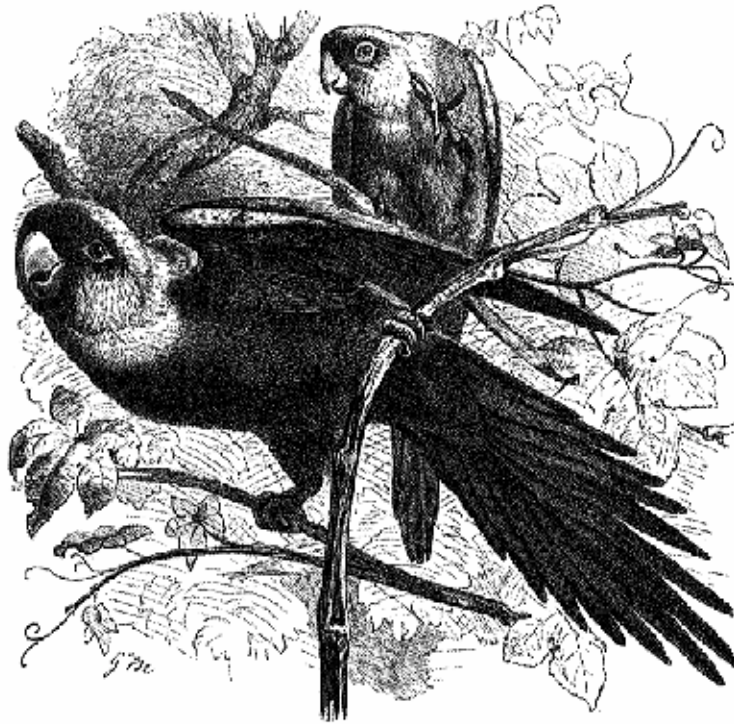


Figure 18.04 The Carolina Parakeet. (From E. Fuller 1987. *Extinct Birds*. Viking/Rainbird, London).

But their voracious appetites made them a pest. As the original forests were cut and burned, they turned to domestic seeds and fruits like a plague of locust. Audubon recorded that whole flocks would descend on grain fields covering them “so entirely that they presented to the eye the same effect as if a brilliantly coloured carpet had been thrown over them.” They destroyed entire orchards in a “wanton and mischievous manner,” a characterization in keeping with the large brains and intelligence of parrots generally. The demise of the Carolina Parakeet was hastened by its gregariousness. Instead of flying away, the flock would often hover over birds wounded by hunters, facilitating the flock's extermination in a single afternoon.

During 90 years of westward human expansion, the range of the Carolina Parakeet retreated rapidly toward the Mississippi. In their wake, frontier colonists left a broad swath of deforested lands barren of the parakeet's natural food. The last sightings of this bird generally coincide with the first wave of human population growth and the establishment of permanent settlements. The final sightings¹⁹ in Ohio were in 1832, in Indiana 1856, in Kentucky in 1878, in the central Mississippi drainage in 1857, from the upper Missouri River in 1881, from Florida in 1904, from Missouri in 1905, from Louisiana in 1910, and from Kansas in 1912. Through human extermination and habitat destruction, the range of the Carolina Parakeet shrank to the size of one cage in the Cincinnati Zoo.

The California Condor

The California Condor (fig. 18.05) teeters close to extinction, due not so much to habitat destruction as direct human persecution. It is a giant member of the vulture family, which today consists of seven species ranging across the Western Hemisphere. The Andean Condor is the largest flying bird, but its northern cousin is only slightly smaller. Both have wingspans approaching nine feet. Their feet leave footprints in soft substrate that are seven inches across. Condors are the undisputed soaring champions of the land, as the albatross is over the water. Effortlessly riding thermals, they soar widely over the California scrub, searching for dead or dying animals, even along roadways and around dumps. Their hunting network is widespread, because the birds watch each other from great distances. If one goes down after food, others in the air know it right away. No record exists of a California Condor attacking a living animal. They are generally solitary but are also seen in pairs. It is not known whether they pair for life, but the same pair has been observed to return to the same nest season after season for many years. They survive in captivity for three decades. All members of the family are now protected, but the California bird remains critically endangered.

In the Pleistocene, the California Condor ranged over much of North America. Even in prehistoric times these birds extended east into Florida and have been found in caves and other sites in Texas, New Mexico, Arizona and Utah. Between 1500 and 3000 years ago the Condor nested in Texas and probably other southwestern states²⁰. But the arrival of American settlers in the West led to a steady restriction of its range. By the 1800's, it disappeared from all but the western margin of its former range. During the 19th century, condors still soared majestically over the ground from British Columbia to Baja California. The last sighting of a condor in Mexico occurred about 1930. Since 1937, the condor has been confined to California, where its populations continue to diminish (fig. 18.06).



Figure 18.05 The California Condor (From J. Terres, 1991. The Audubon Society Encyclopedia of North American Birds. Wing Books, New York).

The decline of condor populations is related to the colonization of the west. Many condors were shot, possibly constituting the major source of mortality in these slowly reproducing birds. Individuals also died from eating poisoned carcasses of bears and coyotes that were targeted in massive ‘varmint’ campaigns in California during the 19th century. Strychnine and lead poisoning, more than habitat decline, have both been cited as the source of condor mortality. By 1980, only about 23 birds remained in the wild, along with about two dozen captive birds in American zoos²¹. In 1987, the last of the wild birds were captured. They reproduced with some success and the numbers have rebounded to the point that by July 1994, the captive population had risen to 89. Birds are now being returned to the wild with some success in California. Six birds were also released in 1996 onto the Colorado Plateau of Arizona and southern Utah, to establish a second wild population. As of this writing, there are 17 condors in the wild and 104 in captivity.

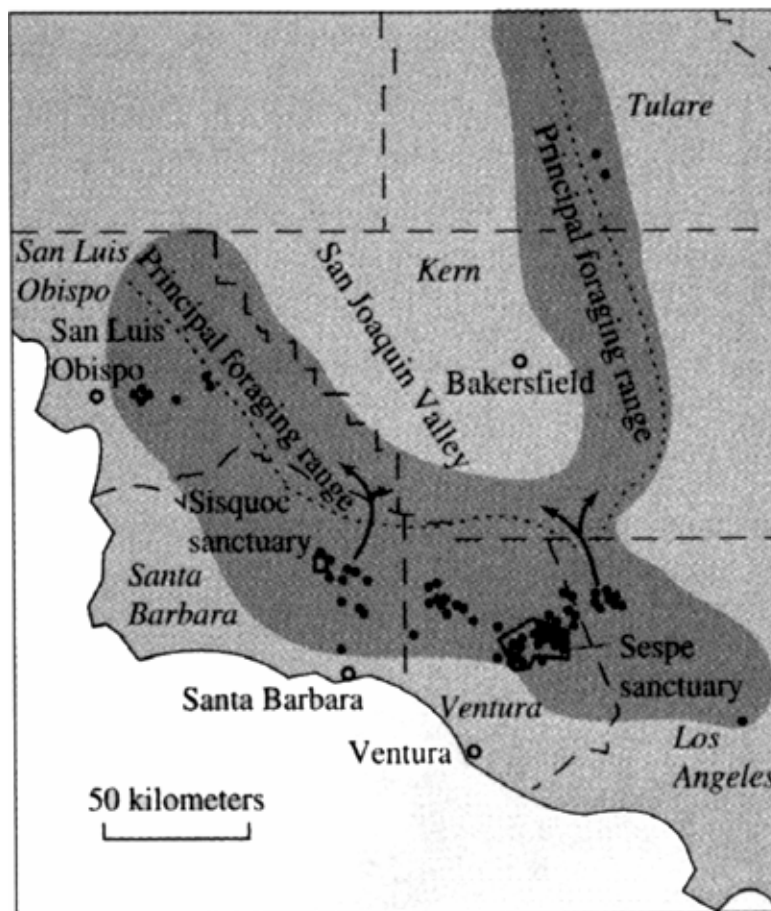


Figure 18.06 Range of the California Condor, since 1937. (From A. P. Dobson 1996. Conservation and biodiversity. Scientific American Library, New York.)

Geography of the Continental Threat

Today across North America there are 50 threatened bird species²². Habitat disruption has catalyzed complex consequences that are beginning to catch up with North American birds. In the United States numerous endangered bird species are threatened either directly or indirectly by disruption of woodlands and adjacent wetlands. Bachman's Warbler, Kirtland's Warbler, the Golden-cheeked Warbler, the Black-capped Vireo, the Red-cockaded Woodpecker, the Spotted Owl, and the Whooping Crane are among thirteen critical species, twelve endangered species, and twenty-one vulnerable species. In some cases the threatened habitat is in the tropics, where the birds breed. In others the threat is related to competition from introduced species or species that thrive in the disrupted habitat. Environmental toxicity also drives the decline, most strongly affecting birds at the top of the food chain.

Birds on other continents face the same problems, but far more species are at risk. The threat is most severe in the tropical forests of South America, central Africa, and southeastern Asia because this is where avian diversity is greatest. Until recently, these regions were spared the effects of European technology on forested lands. But technology and foreign agricultural practices struck with a vengeance more recently.

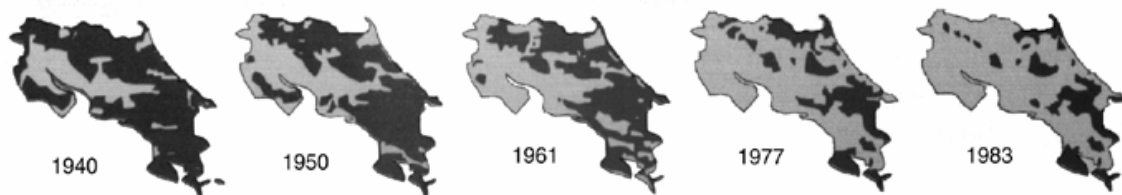


Figure 18.07 In the few short years between 1940 and 1983, Costa Rica was heavily deforested. (From A. P. Dobson 1996. *Conservation and biodiversity*. Scientific American Library, New York.)

Throughout tropical forests, human populations are growing very rapidly. Many inhabitants are impoverished, and providing fire for warmth and cooking represents a strong incentive to cut trees (fig. 18.07). Wood is cheap compared to kerosene or bottled gas. By 1980, developing countries used wood and other 'non-commercial' sources for 90% of all energy consumed. In many countries deforestation has yielded desertification-expansion of deserts into previously forested regions. Globally in 1987-89, just over half the wood produced annually was used for fuel and charcoal. In Africa during this period, 89 percent of cut wood was burned for these purposes and in Asia 74 percent. In Europe, however, only 15% of the wood cut went to fuel. European populations are now

comparatively static, while in tropical countries populations are growing at rates exceeding the 2% per year global average^{23, 24}.

An insidious cycle commences with tropical deforestation. Forested uplands are cleared for new agricultural lands or fuel. Excess runoff from rain, which had been prevented by the forest's biota, triggers rapid soil erosion. Any remaining soil is soon leached of its nutrients by the farming practices. Having lost its agricultural value, it is abandoned, and another tract is burned. Down river, in developing countries without adequate flood control systems, flooding and crop destruction ensues from the increased upland runoff. And as the population grows, more of the land is bound in this chain of poverty. As forests are cleared, some of the carbon combined in the wood is released to the atmosphere as carbon dioxide. As E. O. Wilson writes "The net loss of tropical forest cover world-wide during 1850-1980 contributed between 90 and 120 billion metric tons of carbon dioxide to the earth's atmosphere, not far below the 165 billion metric tons emanating from the burning of coal, oil, and gas."²⁵

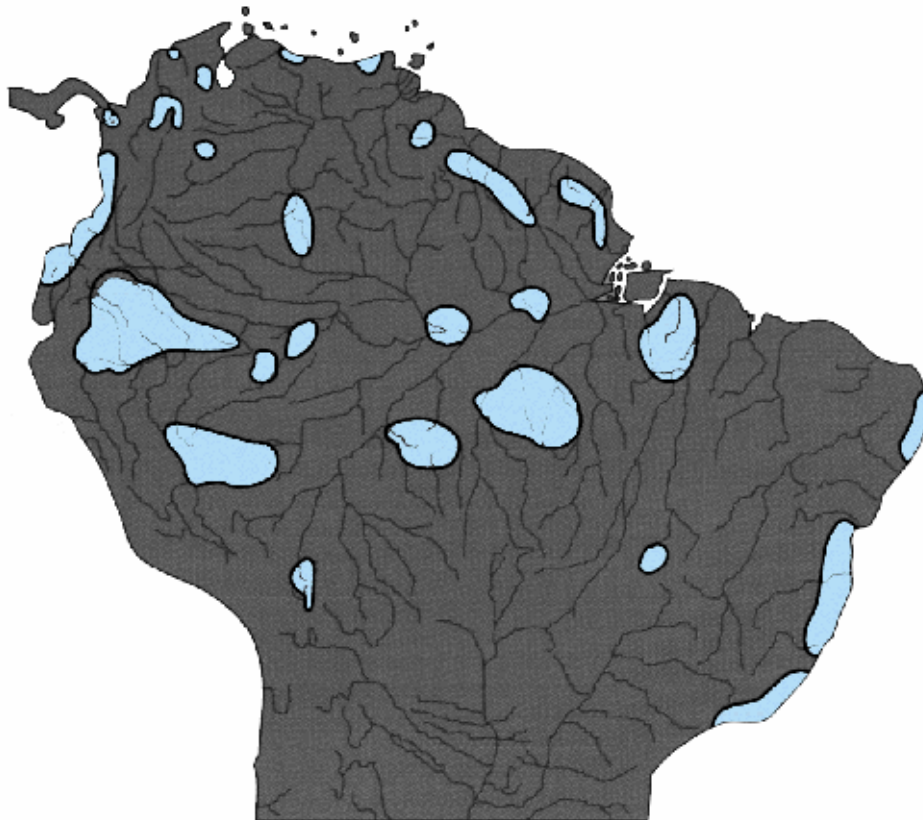


Figure 18.08 The colored areas of tropical South America have especially high numbers of endemic species. (From A. P. Dobson 1996. Conservation and biodiversity. Scientific American Library, New York.)

Joel Cohen estimates that developing countries converted 1.45 million kilometers (145 million hectares) of forest to farmland between 1973 and 1988. During this time, human populations increased by 1.2 billion people. This translates to deforestation of 0.12 hectare per person--a rectangle 50 meters by 24 meters or one quarter of an American football field. If each additional person requires 0.12 hectare of land, each additional billion people require 1.2 million square kilometers of additional land, which would otherwise host wildlife²⁶. Wilson observed the irony, that if nineteenth-century technology had been born midst tropical rain forests instead of temperate-zone oaks and pines, there would be very little biodiversity left to save.

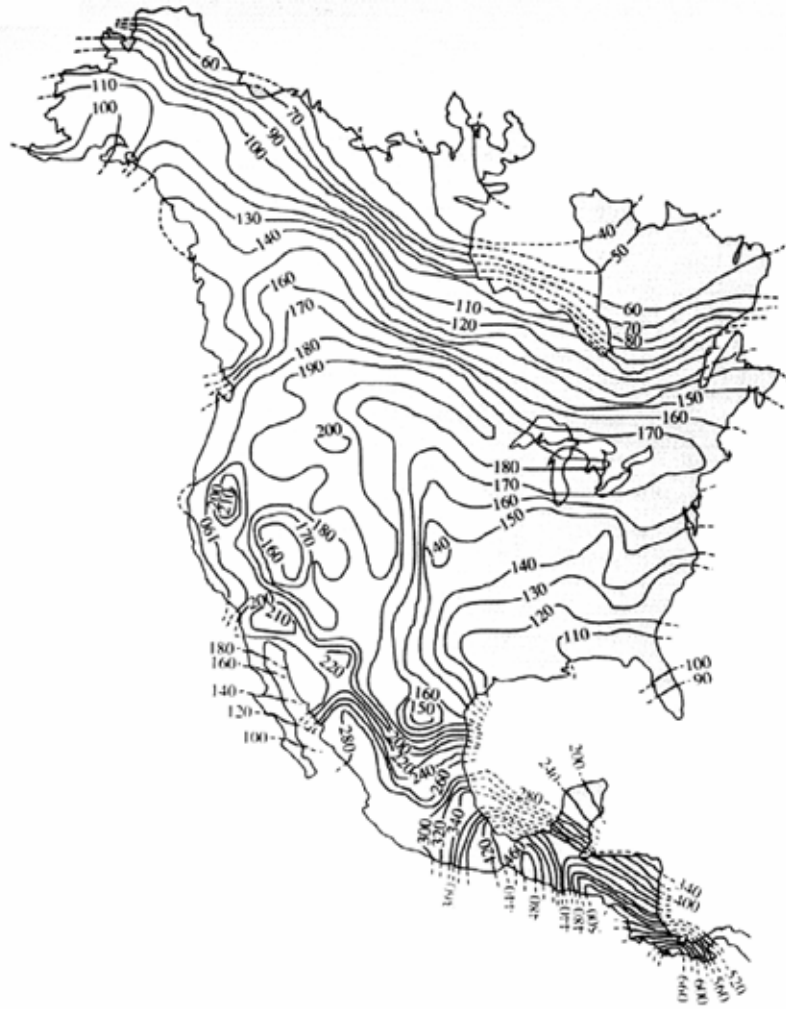


Figure 18.09 The contour lines on this map indicate the number of nesting bird species. Diversity rises by an order of magnitude moving from arctic regions toward the equator. (From A. P. Dobson 1996. Conservation and biodiversity. Scientific American Library, New York.)

In 1964, a series of reports on biodiversity, known as the Red Data Books, were compiled to identify and document endangered birds throughout the globe to prevent their

global extinction²⁷. The thresholds for determining whether a species is endangered or merely threatened reflect a range of criteria. If there has been a rapid decline in their population or if their range is small and becoming fragmented, they may be critically endangered. The overall size of their population, range, and other factors are also involved. Critically endangered species are those judged to have a 50-50 chance of going extinct in the next five years. Across the map of avian phylogeny species are threatened with extinction.

In the rapidly shrinking forests of South America, many different families of woodland birds have species that are threatened or endangered (fig. 18.08). Brazil ranks first today among New World countries in the number of endangered birds, with 16 critically endangered species, 31 endangered, and 56 vulnerable--a total of 103 threatened species. Columbia is fourth with 62 threatened species, Peru fifth with 60 threatened species, Ecuador seventh with 50 species, Argentina is twelfth with 40 threatened species, and most other countries host at least a few endangered species.

Through the loss of both wetlands and forest, many birds are threatened across southern Asia, Indochina, and over southeastern China. Human exploitation has also been a significant factor. China is second among continental countries in having 86 threatened species, India is third with 71 threatened species and most Old World continental countries are inhabited by threatened birds.

Evolution and Extinction

To Richard Owen, as to most pre-Darwinian scholars, species were static and incapable of change. Perhaps this is somewhat unfair, because there is evidence that Owen entertained the notion of limited transformation among species. Owen wrote of the *loss* of flight in the Dodo, for instance, admitting that its ancestors must have flown to Mauritius. But in the end, he rejected that two major groups within the Linnean classification, like reptiles and birds, could be related to one another as ancestor and descendant. When push came to shove, he rejected evolution as a general principle. Owen refused to accept that there could be small dinosaurs or that they could evolve feathers and flight, so he could never realize his mistake in claiming that Dinosauria is extinct.

If a meteorite struck Yucatan 65 million years ago, its effects on the indigenous dinosaurs were only short-lived (fig. 18.09). Central America is one of the centers of avian diversity today. Evidently, the evolution of today's great diversity of birds required great expanses of time, and we can now trace the history of Central American birds today back across the K-T boundary and deeply into time. The extinct Mesozoic dinosaurs,

moas, and other flightless birds that Owen described are all parts of this same major highway system on the vertebrate phylogenetic map. Owen's first encounter with an extinct dinosaur was with the Moa, and he unwittingly rediscovered the lineage when he named Dinosauria.

Richard Owen (fig. 18.10) was among the first to study extinct island birds, and he made them widely known within the scientific community. Although he recognized that some bird extinctions were caused by humans, he never suspected the full portent that scientists read into his discoveries today. Without understanding how species originate, that species evolve from other species and that time the diversity are linked, Owen never fully understood the meaning of the extinctions to which he was such an articulate witness. But in a way, he was also fortunate in his ignorance of the future for dinosaurs that we now contemplate.

With methods that offer greater testability for scientific hypotheses, the major features of vertebrate phylogeny have now been mapped out in general form. If current phylogenetic maps are correct, it appears that dinosaurs and our own primate lineage co-existed for a time span exceeding 70 million years. Both lineages survived whatever happened at the end of the Cretaceous. They further withstood the Pleistocene wave of extinction that surged across the globe. But following in its wake have come second and third waves, the second engulfing tropical islands and the third now moving across the continents. Both of the Holocene waves have cascaded from the tragic symmetry between human population growth and the loss of biological diversity. The third wave of extinction has yet to reach its crest, and it probably won't until after human population growth has peaked and begun to decline. By current estimates this is still a century away. So, in our museums and classrooms, we are training a next generation of scientists to test our view of living dinosaurs with discoveries of their own, and to confront the idea that the emergence of human agricultural and technological societies presents the greatest threat dinosaurs have ever faced.



Figure 18.10 Richard Owen and his grandson, who would grow up to become the Reverend Richard Owen, and write his grandfather's biography, taken ca. 1880. (From *The Life of Richard Owen*, by the Reverend Richard Owen, London, Kohn Murray, 1894.)

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