CHAPTER FOUR

The Science of Decline

> Few problems are less recognized, but more important than, the accelerating disappearance of the earth's biological resources. In pushing other species to extinction, humanity is busy sawing off the limb on which it is perched.
>
> —Paul R. Ehrlich

Though he lacked the quantitative tools available to today's scientists, Edward Howe Forbush recognized the threat that free-ranging cats posed to birdlife. Forbush was born in Massachusetts in 1858 and grew up in Quincy, West Roxbury, and Worcester. He was a passionate all-around naturalist and accomplished ornithologist from a very young age. Eastern Massachusetts was still heavily wooded in the mid-nineteenth century, and as a young child Forbush immersed himself in the outdoors. At the age of fourteen he taught himself taxidermy and by sixteen had been appointed the curator of the Worcester Natural History Society's ornithology collection. He was founder of the Massachusetts Audubon Society and first president of the Northeastern Bird Banding Association (later known as the Association of Field Ornithologists). He eventually became the Massachusetts state ornithologist. Forbush is perhaps best known for *The Birds of Massachusetts*. It took him four years to complete the three volumes; they were finally finished

in 1929, the year of his death. To this day, *The Birds of Massachusetts* is considered an extremely valuable reference on the birds of New England.

Forbush was a keen observer, and one of his responsibilities as an ornithologist was to document threats to birds. In 1916 he wrote a 112-page monograph entitled *The Domestic Cat: Bird Killer, Mouser and Destroyer of Wildlife; Means of Utilizing and Controlling It.* In his prefatory notes, Forbush provides some insight into his motivations for penning this monograph.

> Questions regarding the value or inutility of the domestic cat, and problems connected with limiting its more or less unwelcome outdoor activities, are causing much dissension. The discussion has reached an acute stage. Medical men, game protectors and bird lovers call on legislators to enact restrictive laws. Then ardent cat lovers rouse themselves for combat. In the excitement of partisanship many loose and ill-considered statements are made. Some recently published assertions for and against the cat, freely bandied about, have absolutely no foundation in fact. The author of this bulletin has been misquoted so much by partisans on both sides of the controversy that in writing a series of papers on the natural enemies of birds it has seemed best, in justice to the cat and its friends and foes, as well as to himself, to gather and publish obtainable facts regarding the economic position of the creature and the means for its control.[1]

At the time, most cities and towns in the Northeast were overrun with cats. To demonstrate the problem, Forbush collected statistics on the number of cats humanely destroyed by the Animal Rescue League of Boston and the Society for the Prevention of Cruelty to Animals based in New York. Over a ten-year period in Boston, 210,000 cats were destroyed, and in one notable day 269 cats and kittens were euthanized. In New York, the annual average of cats killed over ten years had been 16,400. But in 1911, the New York SPCA had killed over 300,000 cats. In both locations, the cats euthanized were largely animals taken from homes, rather than

strays from the streets, so these numbers did not necessarily reflect the number of cats in the environment. Forbush saw an enormous problem unfolding. In another passage, he states the following:

> The widespread dissemination of cats in the woods and in the open or farming country, and the destruction of birds by them, is a much more important matter than most people suspect, and is not to be lightly put aside, as it has an important bearing on the welfare of the human race.[2]

Forbush likely knew little about the previous five mass extinctions on earth and certainly did not understand that he was in the midst of a sixth. But his observation is prescient.

What Forbush understood was that cats were spreading across New England like a veritable plague, and they were preying on enormous numbers of small birds and mammals. Forbush would also write about the diseases cats spread, especially rabies (see chapter 5). But the majority of his monograph focused on the direct impacts cats have on the environment, particularly their predation on birds. He conducted a survey all around New England and collected a series of anecdotal observations, and then used this information to estimate larger-scale impacts in a simple model. Some of the comments from people he queried include:

> I am skeptical when anyone says "my cat never catches birds," I have seen an active mother cat in one season devour the contents of almost every robin's nest in an orchard, even when tar, chicken wire and other preventatives were placed on the trunks of the trees.

> Mr Graham Forgie asserts that his cat kills about three birds per day.

> A friend had a cat which she was very proud of because it was such a good hunter and that in October it had killed and brought in twelve birds in two days. Nearly all of these birds were myrtle warblers.

> Mr. Charles Crawford Gorst of Boston says that a friend told him that his cat had 14 birds laid out for its young for breakfast.[3]

Forbush liked to include quotes and anecdotes in his work—they go on and on, and each tells the same story. Forbush wanted to come up with an estimate of the numbers of birds killed per year by cats in the state of Massachusetts. He synthesized the information from all correspondents and estimated that each cat kills ten birds a year. He also estimated that on average there were two cats per farm. Based on this he estimated that in 1916, cats killed about 700,000 birds in the state of Massachusetts. Forbush considered this an underestimate, although some detractors found the number excessive. A colleague of Forbush, Dr. George Field, came up with an independent calculation. Field estimated that there was at least one stray cat for every 100 acres in Massachusetts, and that on average each cat kills one bird every ten days. This formula yielded an annual bird mortality estimate of 2 million for the state. Scientists from New York and Illinois did their own math using their best available data and came up with estimates of annual bird mortality due to cats at 3.5 million and 2,508,530, respectively. Forbush concludes his 1916 monograph: "The cat, an introduced animal, is not needed here outside of buildings. It has disturbed the biological balance and has become a destructive force among native birds and mammals."[4]

The year Forbush published his monograph on cats was a particularly transformational time for bird conservation. It was less than a decade after the back-to-back terms (1901–9) of Theodore Roosevelt. A powerful U.S. president, Roosevelt had a passion and dedication for understanding and conserving species along with their habitats. Much like Forbush, he was a lifelong naturalist with an insatiable curiosity for the outdoors. Roosevelt was quite knowledgeable about large mammals and was an advanced amateur ornithologist, keenly aware of issues surrounding bird conservation.

He kept a list of birds spotted on and around the White House property and collected and prepared many bird and mammal specimens (281 birds and 361 mammals, which now reside in the Smithsonian's National Museum of Natural History). His father, Theodore "Thee" Roosevelt Sr., whom he adored, was an ardent philanthropist and one of the founders of the American Museum of Natural History in New York. During his presidency, Roosevelt used his "bully pulpit" to protect close to 230 million acres of land by establishing 150 national forests, the first fifty-one federal bird reservations, five national parks, and the first four national game preserves.

Roosevelt knew of the extinctions of species such as the Great Auk and the Labrador Duck in the mid-1800s, and he had seen firsthand the demise of the American Bison, the Passenger Pigeon, and the Carolina Parakeet (and the eventual extinctions of the latter two in 1914 and 1918, respectively). Roosevelt's close friend Frank Chapman, considered a dean of American ornithology, made Roosevelt keenly aware of the massacres of waterbirds (herons, egrets, ibises) occurring in Florida and surrounding southern states, mostly for the purpose of gathering feathers to adorn women's hats. Populations of many species had declined to dangerously low numbers. Historian Douglas Brinkley, in his Roosevelt biography, *Wilderness Warrior: Theodore Roosevelt and the Crusade for America*, tried to capture his subject's feelings on the issue: "Certain bird species—herons, terns and ibises, for example—mesmerized Roosevelt. As president he insisted that killing one of these Florida exotics was a federal crime."[5]

The Roosevelt presidency put wildlife conservation on the map in the United States at a make-or-break moment in our conservation history. Roosevelt's close friendships with the likes of George Bird Grinnell, John Muir, and Gifford Pinchot (his eventual choice for the first chief of the U.S. Forest Service, 1905–10) profoundly influenced his outlook. In 1909, at the end of Roosevelt's second term, the North American Conservation Conference was held in Washington, and, at Roosevelt's urging, representatives from Canada, Newfoundland, and Mexico were present; Roosevelt likely understood the implications of the decline of the migratory bird

species the nations all shared. By the end of the conference, a permanent conservation commission that contained members from each country had been established. This would eventually lead to a formal agreement between the United States and the United Kingdom (acting on behalf of Canada) to protect migratory birds. Signed on August 16, 1916, it was called the Migratory Bird Treaty. Two years later, in 1918, the U.S. Congress implemented the Migratory Bird Treaty Act (MBTA) to carry out the treaty's imperatives.

The MBTA provides that it is unlawful to "pursue, hunt, take, capture, kill, attempt to take, capture or kill, possess, offer for sale, sell, offer to purchase, purchase, deliver for shipment, ship, cause to be shipped, deliver for transportation, transport, cause to be transported, carry, or cause to be carried by any means whatever, receive for shipment, transportation or carriage, or export, at any time, or in any manner, any migratory bird, included in the terms of this Convention for the protection of migratory birds or any part, nest, or egg of any such bird." The MBTA today protects 800 species of birds and is probably the most important piece of legislation in the history of bird protection. That said, although it has worked to save several species of waterbirds from overhunting for feathers and food, it has not yet worked as a legal instrument to protect birds from cats (we will revisit this in chapter 6). This likely would have infuriated Forbush, who could see that cats were hunting and impacting many smaller and less charismatic species of birds (and mammals) than the humans hunting herons and egrets and that these species also needed federal protection.

Today, many species of waterbirds are flourishing. Herons, egrets, waterfowl, and numerous other groups have clearly benefited from the MBTA, from several other key pieces of legislation (e.g., the North American Wetland Conservation Act), and from the work of influential groups representing the interests of waterfowl hunters, such as Ducks Unlimited. But while the MBTA has worked for some species, it does not appear to have worked for all—especially nongame species. A recent analysis of bird population trends by a large assemblage of government, academic, and nonprofit groups, published in *The State of the Birds 2014*,

suggests that populations of species considered to be indicators of wetland health have increased by 37 percent since 1968. Populations of indicator bird species from grassland habitats, however, have declined by over 40 percent, and some individual species, including McCown's Longspur and Sprague's Pipit, have declined by over 75 percent since 1968. Indicator bird species from eastern forests have declined on average by upwards of 32 percent, and some individual species, such as the Cerulean Warbler and Eastern Whip-poor-will, have declined by over 75 percent. Even species once thought to be common, such as the Rusty Blackbird, Common Nighthawk, and Chimney Swift, are disappearing before our very eyes. And shorebirds, seabirds, and all the endemic bird species of Hawaii are declining precipitously. Overall, in excess of one-third of the bird species (233 species) in North America have declined significantly since around 1970.

After forty-five years of bird population decline, it seems obvious that our currently available legal instruments are failing. More distressing is the fact that these declines are happening all over the globe, in similar patterns—wherever monitoring schemes have been in place, they are recording fewer and fewer birds year after year. In the United Kingdom, for example, woodland and farmland birds and seabirds, both migratory and resident, are all exhibiting declines similar to those reported in the United States. Roosevelt, were he alive today, likely would declare such bird declines, at home and abroad, a crime against humanity.

You do not have to be a Nobel laureate or a president (or, as in the case of Roosevelt, both) to realize that species decline in number prior to going extinct. The fact that we are seeing such sharp declines in so many bird species likely means that other animal and plant species that we are not even monitoring are declining as well. Population declines can turn into extinctions quickly; a species that takes many tens of thousands of years to evolve can be gone in fifty years or much less (as in the case of the Stephen's Island Wren). Declining populations eventually reach a minimum

size below which mates have difficulty finding each other, and even if they do, cannot produce enough young to sufficiently sustain or increase the population. Furthermore, if they do successfully reproduce, remaining individuals are often inbred and thus have severely reduced genetic diversity. Harmful mutations in offspring occur at higher frequencies, and the species is less likely to survive future environmental pressures (e.g., habitat loss or a new disease) should they arise. The Greater Prairie Chicken, Whooping Crane, Hawaiian Crow, and Florida Panther are all species (or subspecies) that have gone through population bottlenecks (small population sizes) and are experiencing reduced reproductive success and displaying higher rates of abnormalities. Although these species persist today, it is unclear how much longer they will remain on the planet.

One of our greatest challenges in the twenty-first century will be reversing the declines and potential extinctions of so many species. Part of the issue for bird extinctions lies in the fact that it is impossible to know where and how every bird dies—we do not have the equivalent of an airplane black box affixed to every individual. Sometimes the problem is clear, and this certainly was the case for a few waterbird species in the early 1900s—individuals were being overharvested (shot and killed) in tremendous numbers. People could see that big and charismatic animals like the Great Egret were disappearing. Cause and effect were relatively obvious, and there was little need for more information to spur action. The problem was less clear with the mid-twentieth-century disappearance of Peregrine Falcons, Brown Pelicans, and Bald Eagles, but once populations had dropped to precipitous levels, action was taken. The pesticide DDT was determined to be the cause, steps were taken (albeit slowly) to curb its usage, and the populations bounced back. In both cases, the problem was a single factor that once eliminated allowed species to rebound. Nature is resilient given the chance; once a threat is removed, populations often recover.

We do know human activities are largely responsible for the declines of bird species. Habitat loss, climate change, pesticides, collisions with large structures—as well as predation by cats—all cause mortality and play a role in driving species declines to varying degrees. We know that the impacts of some of these threats

(a.k.a. mortality factors) are often indirect and not immediate. For example, habitat destruction and climate changes might impact reproductive success in a later season. We know as well that these threats can interact, that a given species can be impacted by more than one threat, and that impacts of multiple threats can accumulate. Take, for example, a New Hampshire–breeding population of the Ovenbird (*Seiurus aurocapilla*), a small songbird from the warbler family. Its annual cycle extends from those breeding grounds in New Hampshire, where it resides from May to July, to wintering grounds in Cuba and the Dominican Republic, where it lives from October to April. Birds from that population can die at any time while on the breeding or wintering grounds, or during their roughly month-long migrations to and from these areas. It is difficult to identify with any precision the relative impact of a mortality factor, such as the free-ranging cat, to all birds that make these journeys over such large spatial areas and wide expanses of time—and most bird species (>75 percent) in North America migrate! We count birds and detect population declines while birds are on their breeding grounds, yet the mortality can occur at any time of the year. The causation mystery is complicated by the fact that when a small- to medium-size bird (say, a sparrow) dies in the wild, it often vanishes within hours. If it is killed by a predator, mortality is swift, and the prey is usually consumed rapidly. A pile of feathers is all that is left. Few people see the death of an animal in nature.

The fact that cats kill small animals like birds and mammals is by itself not groundbreaking news (fig. 4.1). The challenging issue, and the bar that has been set as to whether we tolerate outdoor cats on the landscape, has been to determine whether cats impact not just individuals of a given species but the broader populations within which individuals exist. Natural populations fluctuate in size from year to year and must maintain a certain number of individuals to remain stable over the long term. How do we assess the magnitude of cats' effect on naturally fluctuating wildlife populations? This requires understanding whether mortality from cat predation is "compensatory"—meaning these deaths substitute for deaths that would have occurred from other causes like disease or

starvation—or "additive," meaning deaths that add to the tally of those caused by other factors. Some argue that we should not be concerned about the mortality imposed by cats because it is compensatory: the animals killed by cats are from a "doomed surplus" that would have died anyway. However, if increased mortality due to cats is additive, stable populations would start to decline, and already declining populations would spiral downward even faster.

Demonstrating whether a given mortality event is compensatory or additive over a large area, such as a country or even a state, is very challenging; it is simply impossible to track all mortality events and assign causation to each incident within a population. Tracking mortality within migratory bird populations poses an additional complication: In most cases we do not know where breeding birds from a particular area go to spend the winter, nor where wintering birds go to breed in the summer. When a northbound migratory bird like an Ovenbird rests and refuels within a patch of woods in Cape May, New Jersey, in the spring, only to get killed by a cat, we do not know the breeding population to which that bird was going or the winter population from which it came. This obscures our understanding of impacts on population processes of these populations. But there are ways to assess the degree to which cats may impact important population processes, including vital rates like survival and reproduction at local scales that can illuminate population declines at larger scales.

There are an estimated 8.1 million domestic cats in the United Kingdom today, a particularly high density of cats for a land area the size of Alabama. Most of these cats are owned. The English are by and large a nature-loving people; more than 1 million people claim membership to the Royal Society for the Protection of Birds (RSPB), the British equivalent of the National Audubon Society. Yet the English are inclined to let their cats roam outdoors, and even the RSPB has an article posted on its website stating that free-ranging cats are not causing a problem and that their impacts represent compensatory mortality.

Peter Churcher and John Lawton knew the challenges of demonstrating whether a particular source of mortality is additive versus compensatory—so they set up a study explicitly focused on this problem in a small town—the Bedfordshire village of Felmersham, about sixty miles due north of London. Their study tracked seventy domestic cats and all prey items each cat brought back to their homes over the entire year of 1981. In total, cats brought back 1,090 prey items: 535 mammals, 297 birds, and 258 unidentified animals. House Sparrows (*Passer domesticus*)—a native resident species in England and Europe—made up 16 percent of all kills. Churcher and Lawton also estimated the population of House Sparrows over the same area where they were tracking cats. This allowed them to gauge the specific impact of cats on the population of House Sparrows in the area where the two overlapped. They estimated that cat kills made up a minimum of 30 percent, and possibly as much as 50 percent, of the annual mortality for this bird. These figures led them to conclude that cats were imposing significant predation on House Sparrows and implied that they likely were "additive" to the natural levels of mortality. House Sparrows declined by over 60 percent in England from 1994 to 2004, and although recent experimental evidence suggests that nestling food limitation was the major limiting factor, it is not too much of an intellectual stretch given Churcher and Lawton's findings to see that predation by cats is also a significant contributing factor.

Understanding the mortality impacts of cats does not always require putting the research into the framework of additive versus compensatory mortality. A study by Kevin Crooks and Michael Soule in 1999 provides another clear illustration of how domestic cats drive declines and local extinctions of songbird populations. Their study took place in the native coastal sage-scrub habitats of southern California, where land has been fragmented severely by varying degrees of development. This habitat fragmentation has resulted in the elimination of the Coyote (*Canis latrans*) in some habitat patches, while the species' populations have remained relatively intact in others. This patchiness allowed the researchers to test an idea known as the "mesopredator release hypothesis." The

hypothesis predicts that the absence of a large predator (Coyotes) results in the release or population growth of mesopredators, such midsize predatory animals as Raccoons, opossums, and cats. Because midsize predators prey more commonly on songbirds, the hypothesis also predicts a decline and even local extinction of birds and other small prey items. As predicted, where Coyotes were absent, numbers of cats and Raccoons went up, and bird abundance and diversity declined. Similarly, where Coyotes were present and abundant, mesopredators were absent, and bird diversity and abundance was high. In other words, Coyote and cat abundances were better predictors of bird abundance and diversity than other habitat-related factors. Crooks and Soule also demonstrated that Coyotes eat cats when they are present in the habitat fragments. Cat remains showed up in 21 percent of all Coyote scat samples. A more recent independent confirmation of how much Coyotes like to eat cats comes from North Carolina–based zoologist Roland Kays and colleagues. Using camera traps operated by citizen scientists within thirty-two protected forested areas in six states along the East Coast, they found that when Coyotes were present, cats were absent; and when Coyotes were absent, cats were present.

Perhaps even more noteworthy in the Crooks and Soule study is their demonstration of how predation by cats, because they are subsidized predators, can be so much more significant compared to natural predation levels. They estimated that residents with houses bordering forest fragments each owned on average 1.7 cats. Seventy-seven percent of these owners let their cats outdoors, and 84 percent of these cats brought back kills. The researchers went on to calculate that for each moderately sized land fragment (50 acres), there were approximately thirty-four bird-killing cats. By comparison, natural predators (Raccoon, skunks, Coyote) in each fragment would typically be present in no more than one or two pairs. How can a fragment support so many cats—and even when its birds are eliminated, further lowering food availability for predators? It is simple—the cats are not killing for food. Owned cats (and colony cats) are subsidized predators—their persistence is not determined by the food they gather; they are already fed at home

with a can of tuna-flavored Friskies Buffet. This subsidization allows free-ranging cats to persist at levels far above natural predator densities and the carrying capacity of a particular habitat. As a result, their impact can be far greater than that of any natural predator. There is no shortage of studies documenting the rates of predation at local and regional scales of cats on a diversity of bird and mammal species, including California Quail, California Thrasher, Gray Catbird, Northern Mockingbird, Black Redstart, Wood Mouse, and harvest mice.

Sometimes even the mere presence of a predator can impact prey species. Colin Bonnington and colleagues, of the Department of Animal and Plant Sciences at the University of Sheffield, England, for example, had a hunch that the presence of a cat near a bird nest could have indirect, sublethal effects on individuals and populations. They knew from previous research that predators influence prey populations simply by altering prey behavior—such effects are exceedingly common across many predator-prey systems. Such sublethal effects can reduce population size by changing the habitats an animal might use and also by reducing parental care at a nest—both of which impact reproductive success. Bonnington and colleagues tested the latter idea in a suburban area of Sheffield during the breeding season of 2010 and 2011. They found blackbird nests and placed a taxidermy mount of a cat, a squirrel, or a rabbit within about six feet of the nest. The mounts were left in place for only fifteen minutes; once they were removed the researchers measured the rates at which the adults attended to the nest, either to commence incubation or to feed nestlings. The results were clear. In response to the cat mount, adults made significantly more alarm calls and reduced their provisioning rates by up to one-third, compared to the adults reacting to the rabbit and squirrel mounts. In addition, because the adults reduced their nest attentiveness, significantly more nestlings were eaten by predators after exposure to the stuffed cat compared to exposure to the stuffed rabbit or squirrel. Changing the predation rates at nests can be a major contributing factor to whether a population grows or declines.

It is clear there are many ways, including both through direct mortality at local scales and indirect sublethal impacts, that cats

can influence the behavior of prey and populations of birds and mammals. Understanding the impacts of cats at large scales—specifically, how they might be contributing to population declines of widespread species—is challenging, as we have discussed. But the local-scale impacts—which, after all, add up to large-scale impacts—send a clear message: cats impact bird and mammal populations. That being said, can we estimate the amount of mortality that cats impose at even larger scales, say across the United States?

Once again we need to turn to statistical modeling, and a first step is to physically count the number of dead birds brought home by a cat (if not already consumed). Such tallies can provide important insights into the relative severity of predation by cats. At least fifty-five independent, peer-reviewed studies have quantified the rates at which species such as amphibians, reptiles, birds, and mammals are killed by owned and unowned free-ranging cats. After excluding studies with unusually high mortality estimates, small sample sizes of cats (< 10), those with experimental manipulations of any kind, or those involving questionnaires asking people to recall predation events, Scott Loss, Tom Will, and Peter Marra found seventeen studies of owned cats allowed to roam outside in which the animals brought in a minimum of 1.14, and a maximum of 33.18, birds per cat per year. Forbush was not that far off when he estimated that owned cats in Massachusetts brought in about ten birds per year each. Nineteen published studies of the number of prey killed by unowned cats found that these animals returned between 30.0 and 47.6 birds per cat per year. Rates of mammal kills per cat per year were found to be much higher, with estimates between 8.7 and 21.8 mammals for owned cats and between 177.3 and 299.5 per unowned cat per year.

These numbers are almost certainly underestimates, as cats do not bring back everything they kill. Two studies confirm that they hold back some of their quarry. Roland Kays and Amielle DeWan, in 2004, put radio collars on eleven owned cats around the Albany, New York, area and asked their owners to keep all the prey their cats brought home so positive identifications could be made (fig. 4.2). They also did intensive observations of the cats in the field to quantify actual kills. Cats brought home about 1.7 prey items

per month but actually killed 5.5 prey animals each month—more than a threefold difference. About ten years later another study, this one led by graduate student Kerrie Anne Loyd at the University of Georgia, looked at the same problem but with a new twist—she employed the use of "Kitty Cams." These are small video cameras suspended around the neck and just below the chin of a cat for up to ten days. Cat owners removed the cameras at the end of each day to download data and recharge the Kitty Cam battery. Loyd collected data from fifty-five cats over a one-year period. The video footage showed that 44 percent of the cats (roughly twenty-two animals) hunted wildlife, and that these cats brought home less than 25 percent of what they actually killed. The implication of both studies is that prey-return data underestimate actual kill rates by owned cats by a significant amount.

If you can estimate the number of animals killed by cats over some time frame, and you know the number of cats that hunt (as Forbush did in 1916 in Massachusetts and as Temple did in 1986 in Wisconsin), you can estimate the total number of animals killed by cats at the scale of interest. In 1991 a conservationist and ornithologist named Rich Stallcup attempted such a tally. Stallcup was a legendary birder and all-around naturalist from Oakland, California. He cofounded the renowned Point Reyes Bird Observatory in 1965 (PRBO, now Point Blue Conservation Science) and was famous for his uncanny ability to bring nature to humans. Over his career, Stallcup wrote several books and seventy-five articles for his "Focus" column in the *Quarterly Journal of the Point Reyes Bird Observatory*. One such column, published in 1991 on the heels of the Temple estimate for Wisconsin, generated great attention. Entitled "Cats: A Heavy Toll on Songbirds. A Reversible Catastrophe," it was one of the first (albeit completely back of the envelope) estimates for the bird mortality caused by owned cats across the contiguous United States. Stallcup described how songbirds on every continent are in steep decline and for many reasons—global warming, habitat loss, but also *cats*. His point was clear: the cat take across the United States was massive, and compared to so many of the other threats facing birds, the cat problem was reversible.

Stallcup did some simple calculations to develop his model. First he needed to estimate the number of owned cats that were allowed outside. He used an estimate from the *San Francisco Chronicle* (March 3, 1990) that put the number of domestic house cats allowed outside at 55 million. Stallcup viewed this as a conservative estimate but reduced this number by 20 percent, assuming that at least that many cats were not let outside or were too old or slow to catch wildlife. This gave him a final estimate of 44 million owned cats that were allowed outside and able to hunt. He then estimated the kill rate of the 44 million cats. He wanted to be "very conservative," so he estimated that only one out of ten cats kills one bird a day resulting in 4.4 million birds per day, or easily over 1 billion birds killed by cats per year across the United States. One could argue that Stallcup's numbers were underestimates for multiple reasons—including the fact that he did not include feral or free-ranging, unowned cats in his population estimates. In his words:

> Add to this the plague of feral cats. How many? No one knows, but they occur everywhere in temperate North America (except deserts and high mountains), and in some places are abundant. . . . Along the California coast it is common to see 10 to 15 during a day's outing (and these are nocturnal animals). Certainly, there are many million, country-wide. What do they eat? Wildlife. Nothing but wildlife.[6]

Despite Stallcup's rough estimate, from the early 1990s, the birding establishment endorsed a much lower number. In ornithological textbooks (such as the most recent edition of *Ornithology* by Frank Gill) and field guides (including those published by famed birder and artist David Sibley) the number listed was hundreds of millions (up to 500 million) of birds killed by cats every year. It was as if even ornithologists refused to believe the number could be so high, even though the math was straightforward and simple. Interestingly, even at just 500 million birds killed by cats each year, cat-caused mortality was considered to be the second-highest cause of bird mortality, after window strikes—collisions with glass

windows on buildings and houses—which were thought to kill 1 billion birds per year. Because it had not really been done before, a U.S.–wide estimate, developed from the most solid peer-reviewed science available, was needed to better understand the magnitude of cat impacts. By 2013, hundreds of papers had been published to support the development of this more exacting analysis. Such an estimate also needed to incorporate uncertainty (a minimum and a maximum kill rate) for the number of birds killed by free-ranging cats every year; remember, there is uncertainty involved even in estimating something as simple as how much it costs to drive the length of the state of California.

A simple modeling exercise was precisely what Scott Loss, Tom Will, and Peter Marra did with their groundbreaking study in 2013. The estimate they developed for cat-caused animal mortality was part of a larger effort to develop better estimates for each of several direct but unintended human-caused mortality factors for birds in the contiguous United States. These included collisions with buildings (primarily windows), communication towers, wind turbines, and vehicles; electrocutions at power lines; and predation by cats. Existing figures were in need of checking and updating; and in the case of cats, a first systematic estimate was needed. For mortality due to free-ranging cats, Loss et al. first performed an exhaustive review of the existing scientific literature for studies that included cat-caused mortality on amphibians, reptiles, birds, and mammals to come up with the best numbers to plug into their model. They looked at hundreds of studies but included in their review only those from temperate mainland or large island areas (New Zealand and the United Kingdom), with a sample size of at least ten cats and at least one month of sampling. To reduce bias, studies were excluded from the final analysis if they, for example, reported unusually high estimates of mortality, or if the cats wore bells or bibs that may have reduced predation rates.

The final model for estimating total annual mortality was a little more complicated than previous versions (e.g., Stan Temple's) but still straightforward. The researchers first estimated the annual mortality from owned cats with this formula:

Annual mortality from owned cats (mp) =
npc × pod × pph × ppr × cor

- *npc* is the number of owned cats in the contiguous United States
- *pod* is the proportion of owned cats allowed to have outdoor access
- *pph* is the proportion of outdoor owned cats that hunt wildlife
- *ppr* is the annual predation rate by outdoor-hunting owned cats
- *cor* is a correction factor to account for the fact that owned cats do not return all prey to owners (remember that cats give their owners only a portion of what they kill)

Then, they estimated the annual mortality from unowned cats:

Annual mortality from unowned cats (mf) =
nfc × pfh × fpr

- *nfc* is the number of unowned cats (or free-ranging cats) in the contiguous United States
- *pfh* is the proportion of unowned cats that hunt wildlife
- *fpr* is the annual predation rate by hunting unowned cats

The total annual mortality is the combined annual mortality estimate from owned and unowned cats:

Total annual mortality from all cats = mp + mf

Let's consider how Loss et al. came up with the numbers for each of the figures in the model in a little more detail. First, how many cats are there in the United States?

Fortunately, at least two estimates for the number of owned cats in the United States had been developed since Stallcup gleaned his information from the *Chronicle*. Two independent nationwide pet-owner surveys estimated the number as 86.4 million and 81.7

million cats, respectively. The mean estimate of 84 million owned cats is almost twice as high as Stallcup (or at least the *Chronicle*) had reported just twenty years earlier. Next: how many of these cats were allowed outside, and how many then hunted? Based on eight different studies, between 40 percent and 70 percent of owned cats were allowed outside; three additional studies suggested that between 50 percent and 80 percent of these animals actually hunted. Seventeen peer-reviewed studies were used to estimate the bird return rates per owned cat per year. An additional twenty-six studies were used to estimate mortality rates on amphibians, reptiles, and mammals. A correction factor (between 1.2 and 3.3) was then included in the model to account for the fact that cats do not always bring their kills home. Calculating the model estimates for unowned cats was a bit more complicated.

Actual estimates of the number of outdoor unowned cats just do not exist, for several reasons. First, cats are not easy to detect and count. They are quiet, stealthy, and intentionally avoid notice—all evolved behaviors consistent across all cat species. The other problem is that people who maintain colonies of cats do not report their whereabouts and do not keep records of their numbers—despite calling them "managed colonies." Rough estimates do exist and include between 20 and 120 million unowned outdoor cats, with 60 to 100 million cats the most frequently cited range. Because of this uncertainty, Loss et al. used a minimum and maximum of 30 million and 80 million unowned cats—a very conservative number. Studies of unowned cats typically report that 100 percent are hunters, so this parameter was set between 80 percent and 100 percent. Finally, from a total of forty-five peer-reviewed studies conducted in temperate regions, Loss et al. estimated that each individual unowned cat annually kills 1.9 to 4.7 amphibians, 4.2 to 12.4 reptiles, 30.0 to 47.6 birds, and 177.3 to 299.5 mammals per year. Given this component data, coming up with the final estimates for the magnitude of the impacts of free-ranging cats was now as simple as pushing a button.

Pushing a button, or buttons, is exactly what happened. No one had ever tried to rigorously quantify, through a synthesis of the best available data, the number of animals killed by cats across the

United States. The numbers were substantially higher than anyone expected, especially given that previous estimates for birds had been in the hundreds of millions (except for Stallcup's), and there had been no estimates for other animals. The final mortality numbers showed that cats killed between 1.3 and 4 billion (median 2.4 billion) birds per year, with unowned cats causing the majority of the mortality (69 percent). Many of these birds were likely juveniles, but no details of species or age and sex were available. The final estimates for mammal mortality were also alarming; 6.3 to 22.3 billion (median 12.3 billion) mammals were killed every year by outdoor cats. Annual mortality for amphibians and reptiles was in the hundreds of millions—95 to 299 million amphibians and 258 to 822 million reptiles. Even the minimum estimates, which are highly conservative, were cause for double takes.

As shockingly high as the numbers are, the analysis is sound; the article announcing the results was reviewed by some of America's most accomplished scientists. It is interesting to note that the study dovetailed closely with a similar analysis of direct anthropogenic mortality of birds conducted in Canada, also in 2013. Across Canada, where there are fewer cats than in the United States, the animals were implicated in the deaths of 204 million birds per year (a median estimate). As in the United States, this makes cats the most significant source of direct anthropogenic bird mortality.

Do these estimates allow us to say with certainty that cat mortality at continental scales is additive or compensatory for bird populations? No, they do not. For the reasons described earlier, these estimates cannot definitively answer that question because information is, and will continue to be, incomplete at these scales—and also because we do not have reliable estimates for the population sizes of most bird species in the United States. For small mammals, reptiles, and amphibians, estimates of population size do not even exist. What the estimates do provide is insight into the magnitude of the mortality. And when combined with the many local studies that illustrate impacts on population processes (as we have described above) at smaller scales, they raise a serious concern about the ecological impacts of free-ranging cats.

The Loss, Will, and Marra paper appeared in the international science journal *Nature Communications* on January 29, 2013. That same day, a Tuesday, *The New York Times* picked up the story. Running under the headline "That Cuddly Kitty Is Deadlier Than You Think," the piece, by science reporter Natalie Angier (which included a photo of a domestic cat clutching a rabbit in its jaws) ignited a firestorm. The science and the various interpretations of the science emerged from the obscurity of the cat and ornithology communities and landed squarely in pop culture. Angier's piece was the most e-mailed and most commented-upon piece that week on the *Times*'s website. It was more popular than stories on the war in Afghanistan, the world economy, and human poverty. Within twenty-four hours, more than 300 other international media outlets (including NPR, *USA Today*, the BBC, and the CBC) picked up the story, and approximately 600 million unique viewers on websites read the report that estimated that kill rates by cats are three to four times higher than mortality figures previously bandied about. The Loss et al. paper positioned the domestic cat as one of the single greatest human-linked and direct threats to wildlife in the United States, and emphasized that more birds and mammals die at the mouths of cats than from wind turbines, automobile strikes, pesticides and poisons, collisions with skyscrapers and windows, and other so-called direct anthropogenic causes combined.

The *Nature Communications* paper struck a chord. Cat lovers and bird lovers—already at odds—finally had a public spotlight for debate. The battle lines were bright and clear. Some were in favor of leash laws for cats, euthanasia of strays, and the elimination of cat colonies and trap-neuter-return (TNR) programs (in which unowned cats are caught, vaccinated, spayed or neutered, and released into the wild again). Others were in favor of leaving any and all cats free to be, kill, and cuddle. A brief survey of the 1,691 comments the *New York Times* received on its website over three days illustrates the polarizing topic:

Simply keep cats inside. Indoor cats are healthier, less prone to disease, fleas and mites, and are much more sociable. Particularly in the suburbs and rural areas, mice, voles, moles, snakes, amphibians and birds must be protected from cat predation. These native creatures are valuable pollinators and seed dispersers for native plants as well as food for native predators . . .

I have maintained a feral colony for 15 years in Austin TX. There were close to 30-40 cats in the colony when I started and moved in the home near their territory. I fed them, made sure they had access to water, trapped, neutered and released every member, fixed every kitten and found homes for them if the queens were not spayed in time. Some cats came, some cats went. After 15 years, there are now only 3 left (sad face). The oldest is 9 years old and there were 2 recent additions. The old one is friendly now to me and will stay on as an outdoor kitty. The 2 new ones are friendly and will be fixed, vaccinated and rehomed soon. While I don't see many dead birds, I do find dead rodents and snakes (mostly coral and rattler). Trap, neuter, release does work over time and WHAT would you rather have near your home? DISEASE CARRYING MICE AND RATS, POISONOUS SNAKES, or a few feral cats that leave you alone?

I'm surprised by all of these cat friendly comments. I love cats and have two who stay entirely indoors, and as far as I can tell don't really want to go outside. There are many species of native birds that are endangered, partially due to predation by cats, a non-native species. Cats should not be allowed outside, period. It is irresponsible, and will eventually result in the extinction of more native species. In my opinion, feral cats should be humanely killed. I love cats, but I love birds too, and can't stand to see my neighbors' cats roaming my neighborhood, looking for their next kills.

Here in Florida we encourage our cat to roam and capture rats and mice. We encourage our cat (Rusty) to ignore cat

> haters who keep their cats in cages or trapped in a house with nothing but a sand box and a scratching post. I read your piece to him and he appears not the least put out and commented that cats that can't hunt are like people who prefer canned food over fresh.[7]

A majority of ecologists, ornithologists, and millions of bird aficionados see outdoor cats, whether owned or unowned, as killing machines. Many biologists are convinced that predation by this invasive species is indeed contributing to the catastrophic downward spiral of many bird and mammal populations. The tens of thousands of well-meaning people who nurture unowned cats, and the millions of domestic-cat owners who let their cats outdoors, all value these animals as sentient beings. They view them as part of the landscape, as much an element of the natural order as trees and clouds. Some in the cat advocacy world say, "We are a nation of animal lovers. We are not a nation of cat people or bird people." Yet there is a conflict between cat advocates and bird advocates—a war, quite literally to the death in the animals' case, whether or not the cat lovers or bird lovers will admit it.

Stepping back, what makes the impacts of cats especially troubling is that today every species that goes extinct or is declining in population size is doing so because of human activities. To a large degree, we control how quickly or slowly a species goes extinct. The problem is that the rate at which species are disappearing from the planet is far more rapid than what used to be considered a natural or background rate for species extinctions to occur. The background rate for species extinction is estimated by analyzing fossil records for millions of years prior to human existence (estimates are calculated as extinctions per million species-years, or E/MSY). Basically, the natural rate is estimated at roughly two extinctions per 1 million species-years. Put another way—there are two extinctions per 100 years per 10,000 species. This has led many scientists to conclude that this period of human existence, otherwise known

as the Age of the Anthropocene, is the sixth mass extinction in the history of life on earth.

Since life on earth began approximately 3.4 billion years ago, more than 5 billion species have emerged, evolving into a vast diversity of taxa from viruses to dinosaurs to cats. Most of these species, upwards of 99 percent of all that once lived on earth, have now gone extinct. The vast majority of these species extinctions occurred during five distinct and significant prehistoric events, recorded in the fossil record, which dates back 450 million years. The first of these major events began 447 million years ago, in the period of time known as the Ordovician, when all known life is believed to have occurred in the oceans. Then the climate began to change and continued to change over a 4-million-year period. It got cold, extremely cold, especially in the Southern Hemisphere, where rich coral reefs and associated species such as nautiloids, trilobites, and brachiopods became locked in ice, which caused the extinctions of these and eventually most other marine species. Large sheets of ice eventually blanketed the entire southern continent of Gondwana. (At this point in the earth's history, the land was separated into two large supercontinents—Gondwana in the south and Laurasia in the north.) As water became locked into ice, sea levels farther north declined, causing water chemistry to change. This further amplified the number of species extinctions in other parts of the globe. Eventually an estimated 75 percent of all species on earth went extinct in this period due to climate change; it would be the second-greatest mass extinction in earth's known history.

Four more mass species extinctions subsequently occurred: the Ordovician–Silurian extinction, the Permian–Triassic extinction (the largest), the Late Devonian extinction, and, the most recent, the Cretaceous–Paleogene extinction. The lattermost occurred just 66 million years ago. Each of these events had various causes, ranging from a gigantic asteroid striking the earth, a sudden release of methane gas from the ocean floor, climate change, or a combination of the above. These are all theories, of course, but most are based on strong lines of evidence. The mass extinctions themselves are not theories—they are fact. Another fairly certain

fact is that humans, had they existed, likely would have also gone extinct during any of these catastrophic events.

In the previous five mass extinctions, events like comets crashing into the earth and eruptions of methane gas from the ocean floor were out of the control of any living thing. Dinosaurs were minding their own business when, *BAM*—here's an asteroid! In this, the sixth mass extinction, human overpopulation and subsequent habitat destruction and climate change are clearly the primary drivers, but there are others—and the effects are cumulative and interacting. Human overpopulation, for example, results in overharvesting (fishing, hunting), various forms of pollution, and the spread and maintenance of invasive species. Cats are one invasive species in particular that, according to Felix Medina and his colleagues, has been implicated in at least 14 percent of global reptile, bird, and mammal extinctions on islands (discussed in chapter 2).

Cats are clearly having an impact and in that sense contributing to the sixth mass extinction. Are they the primary driver? No. But we cannot afford to focus solely on the main driver. We must tackle all the component parts and certainly the ones we have the power to control. If we were talking about the well-being of people instead of birds and were to focus only on solving the primary cause of human mortality, we would ignore all cancers, AIDS, drunk driving, and a host of other health and social maladies and instead focus all of our efforts on heart disease alone. This would hardly be acceptable.

We have known for many years that cats can cause extinctions and have significant impacts on birds and other small animals on islands and mainland areas. Countless studies have been conducted worldwide to document the impacts of cats at different scales. Collectively, the science is overwhelmingly conclusive that cats kill massive numbers of birds and other small animals and that these deaths impact population processes. Moreover, cats are known to have contributed to the declines of many island species and subspecies that have not gone completely extinct yet, from the Hawaiian Crow to the Socorro Mockingbird to the Lower Keys Rabbit (the list goes on and on). Many remain skeptical that cats are having a significant impact on wildlife, especially on a

continental level. They argue that we are not seeing actual species extinctions or even a demonstrable population decline that can be tied to cats. Although information is not complete for tying the population decline of a given species to cats at large scales, information describing cats' impacts on birds and other animals is clear and, when used in models, points to a need for action. The need for action is made more convincing by the critical point that extinctions are just one metric of global environmental health. When we lose a species to extinction, or an entire species declines, or local populations are wiped out, we are losing the important ecological functioning and critical ecosystem services that each of those populations provides. Collectively these extinctions and declines are all events that are contributing to the sixth mass extinction.

And if it is not bad enough that outside cats are accelerating the extinctions of many species of wild animals, they are also, evidence strongly suggests, as we will see in the next chapter, sickening—and in many cases killing—humans.