This mutant pig fetus was collected near Chernobyl in 1988.

# HALF-LIFE

**TWENTY-FIVE YEARS AFTER THE CHERNOBYL MELTDOWN, A SCIENTIFIC DEBATE RAGES. IS THE AREA AROUND THE REACTOR A DEATH TRAP FULL OF MUTANTS OR A NEW EDEN FOR THREATENED SPECIES?**

**BY ADAM HIGGINBOTHAM**

PHOTOGRAPHS BY GUILLAUME HERBAUT

Today, wolves, lynx, and elk roam the area around the reactor.

# The pine trees framing the entrance to the forest appear to be normal. Unremarkable. But the crackling dosimeter says otherwise.

On this freezing February afternoon, about 2 miles from the concrete sarcophagus that now entombs the number four reactor at the Chernobyl nuclear power plant, Gennadi Milinevsky, a physicist from a university in Kiev, walks along a path carpeted with pine needles and patches of recent snow. The size of a transistor radio, the dosimeter emits a sharp click when it detects a radioactive particle. Milinevsky waves the instrument: Its digital readout indicates levels of radiation 120 times higher than normal. As he walks, the staccato popping gets faster as the levels climb to 250 times higher than normal. "It's not good," he says. He ventures toward a wide clearing littered with the trunks of dead trees. Milinevsky suggests stopping the tour here. On the far side of the clearing, he knows, the dosimeter will begin to make a sound no one wants to hear: a terrifying snowstorm of screeching white noise, indicating highly toxic levels of gamma radiation some 1,000 times above normal.

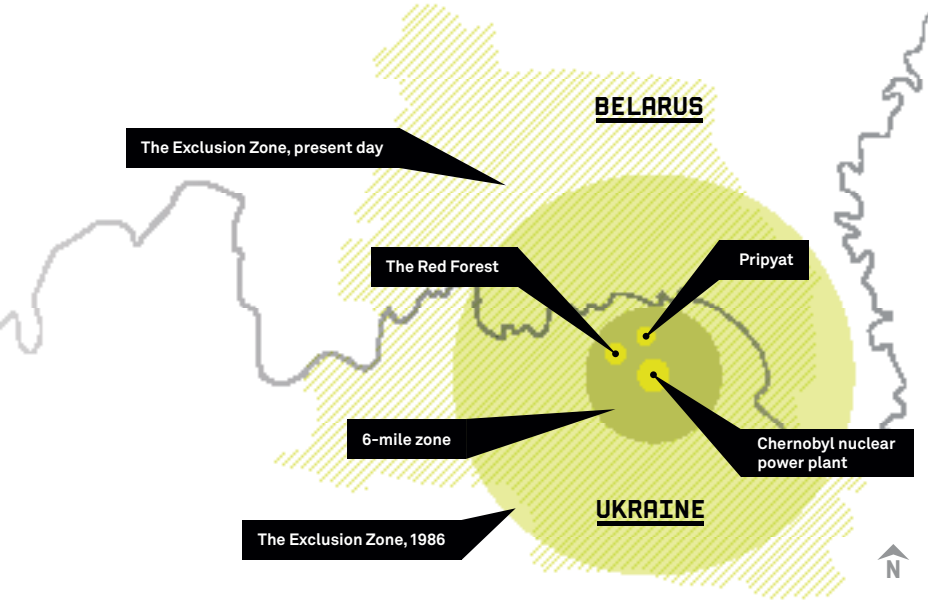
This is the poisoned heart of the Red Forest, nearly 4,000 acres of pine trees that were blanketed with radioactive isotopes of strontium, cesium, plutonium, and microscopic pieces of uranium that roiled from the blazing core of reactor number four over 10 days in April and May of 1986. The pines died in a matter of days, the russet needles marking the windblown path of the most deadly radioactivity to escape the burning reactor. Twenty-five years later, it remains one of the most contaminated ecosystems on earth.

The Chernobyl Exclusion Zone now encompasses more than 1,600 square miles of northern Ukraine and southern Belarus, a ragged swatch of forests, marshes, lakes, and rivers. Cordoned off by a fence and armed guards soon after the accident, the perimeter was first drawn up according to airborne surveys of gamma radiation contamination conducted in the days after the explosions, and it has since been expanded more than once. The current zone extends up to 60 miles from the power plant, the main entrance on the Ukraine side blocked by a paramilitary checkpoint equipped with radiation screening tools. Deeper within the region, a 6-mile zone designates the most heavily contaminated areas around the plant.

In the months after the accident, Soviet authorities undertook drastic measures to deal with the catastrophe. Almost 1,000 acres of the Red Forest had perished, and nearly 4 square miles of topsoil around the sarcophagus was scraped away and buried as radioactive waste. Of the 250 settlements and villages in the zone that were evacuated, the most radioactive were bulldozed in their entirety and interred. Contaminated livestock were slaughtered, and abandoned pet dogs were shot by teams of local hunters. By the time the process of liquidation was finished, the land surrounding the reactor had been transformed into a sterile moonscape, a nightmarish post-nuclear wasteland flattened by machinery and sprayed with chemicals designed to trap radioactive particles close to the ground.

Since then, nature has slowly crept in. Once an area of heavy industry and collectivized agriculture, the zone is now nearly indistinguishable from the surrounding countryside. The forest has reclaimed long-abandoned villages and farmland; roads and buildings are being swallowed up by thickets of trees and shrubs. The natural process of radioactive decay has already removed some toxic particles from the environment. Those isotopes with short half-lives have already disappeared. Some longer-lived isotopes gradually leached into the soil and have been dispersed by wind, birds, and insects.

About a decade ago, the animal sightings began. Naturalists started to report signs of an apparently remarkable recovery in the ecology of the quarantined territory. They photographed the tracks of a brown bear and saw wolves and boar roaming the streets of the abandoned town of Pripyat. In 2002, a young eagle owl—one of only 100 thought to be living in all of Ukraine




The current Exclusion Zone is roughly 1,600 square miles of land contaminated with some degree of radiation. The Ukrainian government will open safer areas for tourism this year, most likely lower-radiation locations outside the 6-mile zone that surrounds reactor number four. Travel tip: Don't picnic in the center of that dark-green circle.

at the time—was seen dozing on an abandoned excavator near the sarcophagus. The following year, an endangered white-tailed eagle was captured and radio-tagged within 3 miles of the plant. By early 2005, a herd of 21 rare Przewalski's horses that had escaped from captivity in the quarantined area six years earlier had bred successfully and expanded to 64. It seemed the disaster that had banished industry, agriculture, pesticides, cars, and hunting from Chernobyl had inadvertently created a sprawling wildlife park.

A 2006 report by the Chernobyl Forum—an international panel of 100 experts assembled by the UN, the World Health Organization, and the International Atomic Energy Agency—lent scientific weight to the evolving notion that the Exclusion Zone was turning into a haven for wildlife. The report, based on environmental, socioeconomic, and human health research, explained that levels of radioactivity in the zone had declined several-hundred-fold and took an optimistic view of the disaster's aftermath, both for human beings and animals. While there was no denying that some central areas of the zone, including the Red Forest, remained acutely contaminated and potentially lethal, the authors stated that no adverse effects of low-level radiation had been reported in plants or animals in much of the area around the reactor. Rather, the size and diversity of the animal population had actually expanded in the absence of people. "The Exclusion Zone," the authors concluded, "has paradoxically become a unique sanctuary for biodiversity."

It was an amazing story—sinister wasteland transforms into blooming, post-nuclear Eden—and it became the subject of documentaries on Animal Planet and the BBC and a central theme of the book *Wormwood Forest: A Natural History of Chernobyl*. It was also used by Gaia theorist James Lovelock to argue that we could save the rain forests from the ravages of man by burying nuclear waste in them. This idea, of nature healing itself even in the face of the grievous wounds mankind can inflict, is as appealing as it is counterintuitive.

But a pair of scientists are now calling these claims into serious question. According to US-based evolutionary biologist Timothy Mousseau, there is scant evidence to back up the idea of Chernobyl as a radioactive Wild Kingdom. "People say these things—they're simply anecdotes," Mousseau says. "It's totally irrational." Nonetheless, last December, the Ministry of Emergencies—the Ukrainian agency responsible for overseeing the Exclusion Zone—announced that it would formally open the zone to mass tourism in 2011. In January, meanwhile, the country's parliament approved a multibillion-dollar plan to build two new Russian-designed nuclear reactors in western Ukraine, some of the first to be started there since the collapse of the Soviet Union.

The post-earthquake explosions at Japan's Fukushima Daiichi nuclear power plant in March have reminded the world of the potentially disastrous impact of nuclear accidents. The immediate effects of that crisis are still being determined. Meanwhile, the ecological repercussions of radiation exposure in the Exclusion Zone are now the subject of an increasingly bitter and polarized scientific dispute. On one side, there are Ukrainian and US scientists who argue that plants and animals throughout the zone are shrugging off the effects of long-term exposure to low levels of radioactivity and are thriving in a fecund wilderness. And on the other is the view represented by Mousseau and his colleague, a Danish biologist named Anders Møller, whose work supports a far more sobering hypothesis: The results of chronic exposure to low-level radiation are little understood and potentially catastrophic. Their evidence suggests that the zone is not an enchanted forest but a radioactive roach motel: Animals go in, but they don't always come out.

**WHAT WAS THE EFFECT OF THESE RADIOACTIVE CONTAMINANTS? COULD THERE BE AN EVOLUTIONARY RESPONSE THAT WOULD ALLOW ANIMALS TO COPE WITH THIS STRESS?**

**At 57, Møller is** soft-spoken and diffident; his narrow face is weather-beaten, and gray hair recedes from his temples in waves. Back in 1990, when the Soviet Union was collapsing, Møller was an assistant professor at Uppsala University in Sweden. He won a

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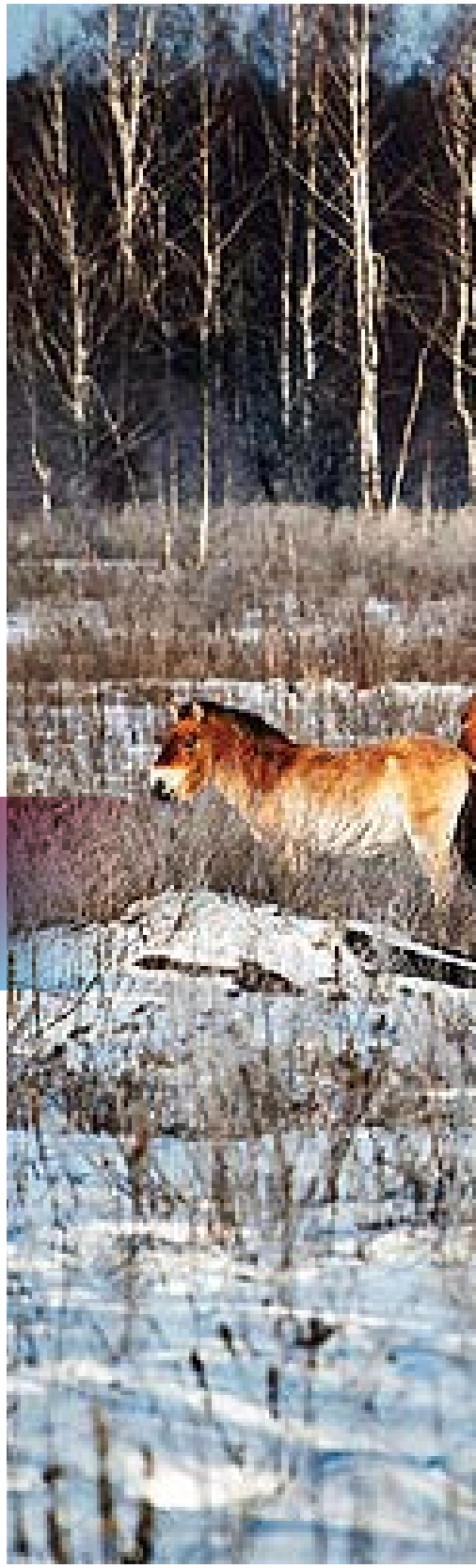
modest $600 grant as part of an initiative to send scientists to the newly independent countries of Eastern Europe, and he spent the money on a plane ticket to Kiev in May 1991. With the assistance of a student affiliated with the Ukrainian National Academy of Sciences, he gathered data on the effects of Chernobyl contamination on Ukrainian barn swallows. For 10 days, the student drove Møller from place to place in his parents' Lada, catching birds in the barns of collective farms. At night, they slept in a tent. Almost all information gathered about the effects of the disaster by Ukrainian scientists remained secret, and Møller could not afford a dosimeter. So at the beginning of the trip, while Møller sat outside the Academy of Sciences in the Lada, the student broke into the office where the radiation contamination maps of northern Ukraine were held and copied the numbers into a notebook. The resulting paper, published in 1993, showed significant abnormalities in the birds captured in radioactive areas. It was Møller's first published work on the ecological impact of Chernobyl, and 20 years later he still remembers how quiet it was when he awoke every morning in the tent. "That was when I first noticed there were very few animals in the contaminated areas," he recalls.

Mousseau, Møller's research partner, is a 52-year-old professor of biology at the University of South Carolina who first visited the Exclusion Zone in 1999 as part of a USC exchange program with Ukrainians in the Chernobyl area. He began collaborating with Møller the following year. One of the first projects they started together—a survey of previously published literature on Chernobyl's post-accident flora and fauna—revealed remarkably little research into the population effects of the low-level doses of radiation. Much of the work done by Western scientists concentrated on mapping the distribution of radioactive isotopes, or radionuclides. Of the research done by Russians and Ukrainians in the area, much of it had been classified as secret and never revealed. What had been published was rarely available electronically, and hard copies proved all but impossible to find, having been destroyed or lost in the chaos that enveloped Eastern European science when Soviet funding finally ran out. "You could not physically locate the journals," Mousseau says. "They were just gone." What little they could find had never been translated into English.

In 2000, the pair set out to answer some fundamental questions about the ways animals responded to life in the zone: What was the effect of these radioactive contaminants? Could there be an evolutionary response that would allow animals to cope with this stress? They chose to examine Møller's species specialty, the barn swallow, which makes an ideal experimental subject because the birds nest in buildings, they're easy to catch, and their eggs and chicks are readily accessible. They also return to the same nesting areas year after year, so it's possible to track the fate of individuals and populations over time.

Armed with permits to enter the zone, radiation dosimeters, and nearly invisible mesh "mist" nets commonly used by ornithologists, Møller and Mousseau caught birds nesting within the same habitat in areas with both high and low levels of contamination and assessed them for evidence of mutations. They found a strong correlation between highly contaminated areas and physical changes that ranged from partial albinism (white patches in feathers) to malformed tails. In uncontaminated areas, they noted, these physical changes occur much less frequently. They published their results in the journal *Evolution* in 2001 and have returned to the zone at least once a year ever since.

They have gathered a rising mountain of data and published dozens of papers, all suggesting that the chronic low-level radioactivity of the zone and the hot particles that find their way into the soil and food in the area cause long-term damage to the organisms that live there. In barn swallows, they found deformed beaks and eyes, tumors,



**A GROUP OF PRZEWALSKI'S HORSES THAT HAD ESCAPED FROM CAPTIVITY INTO THE QUARANTINED AREA WERE THRIVING. IT SEEMED THE DISASTER HAD CREATED A SPRAWLING WILDLIFE PARK.**

damaged toes, and asymmetrical tails. (All of these changes, of course, can make the birds less successful at catching food, migrating, and breeding.) They also found high rates of dead or deformed sperm in birds nesting in the most contaminated areas, further demonstrating the reproductive cost of living in the zone. When they examined a wider sample of bird species, and then invertebrates and spiders, they found similar results: "a very strong signal of contamination effects on abundance and biodiversity," Mousseau says. In other words, populations declined as radioactivity increased. The evidence of the damage caused by the contamination was alarming: Gathering their results on abnormalities in barn swallows for a *Biology Letters* paper that same year, they described the external examination of 7,700 individual birds, declaring it "the most extensive data set on abnormalities in animals ever recorded."

Most startlingly, in 2005, Møller and Mousseau did a chemical analysis of the feathers of swallows captured in Ukraine and Denmark to identify where each bird had spent its winter migration. They compared the results with those from specimens caught in Ukraine before 1986, found in the collection of the National Museum of Natural History in Kiev, and noticed a distinct pattern. Barn swallows were now coming into the zone for the summer from a greater number of locations than before the accident. This suggested that the population of birds living in contaminated areas around Chernobyl was not sustaining itself without outside help: The area was a sink. Given the low survival and fertility rates, the population could only be propped up by constant immigration. And what is true for swallows might also be true for the other species whose presence in the zone, drawn in by the absence of humans, has seemed so remarkable.

Yet, despite the apparently overwhelming weight of their data, Møller and Mousseau's work has been dismissed by some experienced Chernobyl researchers. One of their fiercest critics also happens to be one of their former Exclusion Zone assistants: Sergey Gaschak, a Ukrainian biologist who has spent his professional life tracking and studying the fauna of the zone. Gaschak not only disputes Møller and Mousseau's published results, he also questions their methodology, motives, and integrity—and regrets that his name is published alongside theirs in various journals. "I'm very sorry that I met them," says Gaschak, whose scientific conclusions paint a far different picture.

**ANDERS MØLLER'S RESEARCH SUGGESTS THAT RADIATION CONTAMINATION IN THE AREA AROUND CHERNOBYL IS HAVING A DIRE EFFECT ON ANIMAL POPULATIONS.**

**The battered SUV** crawls down an overgrown track in the Exclusion Zone, branches scraping the hood. Outside, the cesium-137 contamination, according to the radiation atlas, is at near maximum for the zone. Sergey Gaschak abruptly breaks off a discussion of his research to jab a finger out the window. "Ooh!" he points across the muddy river to a khaki strip of land. "Elks!" Less than 100 yards away, a pair of massive brown beasts with white legs, dappled coats, and erect ears regard the SUV with calm curiosity. Suddenly they break away, melting quickly into the birch forest behind them. "When they run, it almost looks like they're swimming," Gaschak says. "Such soft movement. Amazing."

Forty-eight years old, balding, and sharp-featured, Gaschak has spent more than two decades working in the zone—almost certainly longer than any other scientist. The elk, he believes, are just part of the evidence that much of the Chernobyl Exclusion Zone is indeed a safe refuge for Ukrainian wildlife; elsewhere, he points out the tracks of lynx and raccoon dogs on the surface of a frozen pond, along with dam-building works that indicate a beaver colony. Outside the most contaminated stretches of the zone, he says, large mammal populations have now reached the density he would expect on unpolluted land where hunting was banned.

As Gaschak and Igor Chizhevsky, a researcher at the Chernobyl Ecocenter, trundle through the zone in the hope of catching sight of more elk, moose, or the white-tailed eagle, Gaschak explains that he began working with Møller and Mousseau eight years ago. The pair's findings over the course of that period are the result of a biased and unscientific agenda, he says in halting but scientifically proficient English. They're interested only in suggesting that all radiation is damaging, "to see certain conclusions and ignore everything which will prevent them." Gaschak says some of the data he gathered on Møller and Mousseau's behalf does not support their published findings. "I know Chernobyl Zone," he says. "I worked here

many years. I can't believe their results."

Gaschak first arrived in the zone just a few months after the accident, in July 1986. A recent graduate of Kharkov's university with a degree in biology, he was recruited by the military to be a liquidator, aiding in the post-disaster cleanup. He lived for 55 days in a camp just outside the perimeter of the zone, regularly spending 12 hours a day decontaminating vehicles close to the remains of reactor number four. He had little notion of the risks he was taking. "I knew nothing about radiation," he says, "or almost nothing."

At university, he had studied wildlife, specializing in bird behavior, capturing and banding thousands of birds every year. So on his days off he roamed through the zone and into the edges of the Red Forest, where he spotted species he had never seen before. "For me, it was very interesting to see a new region, new nature, a new set of plants and animals." He thought that the pine trees in the forest looked sickly. "I did not know they were dead."

Four years later, he returned to begin work as a technician at an experimental farm near Pripyat. There, he helped monitor cattle found roaming over the contaminated land soon after the accident—three cows and a bull, which the scientists named Alpha, Beta, Gamma, and Uranium. He has worked in the zone ever since. It was at the farm that he first saw surprising evidence that radiation was not having the damaging long-term effect on animals that he had expected. Alpha, Beta, and Gamma had initially been rendered infertile by the acute doses of radiation but later recovered. The first post-Chernobyl calf was born at the farm around 1989. And when the experimental herd was expanded to 30 or more, it included some animals raised on uncontaminated land outside the zone. Gaschak and the team examined the blood of the two groups of animals, expecting to find some evidence of differing levels of radiation exposure; they found none. "We could not explain it," he says. In 1992, he switched from the study of agricultural animals to wildlife and for the first time started traveling widely throughout the zone, hunting wild boar and deer for specimens. Eventually, he conducted the first census of birds living in Pripyat, publishing his results in *Vestnik Zoologii*, a journal of Ukraine's National Academy of Sciences. Despite the area being only a little more than a mile from the reactor and very heavily contaminated in places, Gaschak says, "there are high populations of birds there." In 2006, in his capacity as the deputy director for science of the Chernobyl Center's International Radioecological Laboratory, he coauthored a survey of vertebrates living in the zone. The researchers found 66 species of mammals, 11 of reptiles, and 249 of birds.

But Gaschak has not been able to publish as much as he would like, as over the years funding for Chernobyl research has slowly dwindled along with waning international interest and the sinking Ukrainian economy. With grants for his own work hard to come by, Gaschak has been forced to contract out his radiological expertise to the Ukrainian nuclear industry and become a hired hand on the increasingly rare occasions when foreign scientists need data collected in the zone. "Over the last 10 years," he says, "I have to sell myself to other researchers." As a result, he has been credited as coauthor on many papers published in Western journals.

His relationship with Mousseau began in 2003, when they won a US grant to study the contamination of birds living in the zone; they published a paper together a few years later. Gaschak also helped Møller and Mousseau install the 232 nest boxes in some of the most highly radioactive areas of the zone, in the Red Forest, and helped gather the resulting data on the great tits and flycatchers found there. When he saw the paper Møller and Mousseau planned to publish, he was shocked. "There were several principal conclusions which did not derive from my data," he says. "They ignored, distorted my data." The published paper correlated high levels of radiation and low levels of occupation of the nest boxes, suggesting that the birds avoided breeding in highly contaminated areas. But Gaschak says that the experiment was never designed with this hypothesis in mind and therefore used no suitable reference sites to control for the variation in habitat—an absence in the Red Forest of the mature pines favored by flycatchers for nesting, for example—that might just as readily explain the unoccupied boxes. The

**BUT SERGEY GASCHAK BELIEVES THAT THE DATA LEADING TO SUCH GLOOMY CONCLUSIONS HAS BEEN DISTORTED.**

data Gaschak had collected did show that the birds were deeply affected by high levels of radiation in their habitat and food—morphological changes in their bodies and internal organs and a higher rate of mortality in eggs and chicks. But it provided nothing to support the notion that they avoided highly contaminated areas, he says. He submitted his objections to Møller and then asked that his name be removed from the paper. Møller refused, explaining that Gaschak's contribution to the fieldwork was such that he should be credited, whether he liked it or not. Gaschak hasn't spoken to him since. "He didn't want his name put on a paper that showed negative effects of radiation," Møller says. "I was sincerely disappointed. I've never in my life experienced anything like this before." But Møller and Mousseau stand by their results. "We have displayed the data in the paper and we still have the files," Møller says. "There's no discrepancy."

Gaschak says his own data from the survey isn't comprehensive enough to publish a counterpoint. "Theoretically, I could," he says. "But I don't have real reference data. I can only suggest some conclusions—not enough to show something contrary to Møller."

Gaschak isn't the first former colleague to call Møller's research into question. In 2003, the Danish Committees on Scientific Dishonesty ruled that he had fabricated data in a 1998 paper on oak leaf asymmetry. (He and his coauthor had already issued a retraction in 2001, citing flawed measurements and analysis.) Based on that ruling, in 2005 the University of Copenhagen's Zoological Museum declined to renew his bird-banding permit, making it nearly impossible for him to continue his barn swallow studies in his native country. Ultimately, the French National Center for Scientific Research was unable to find any evidence that Møller committed deliberate fraud. He now works as research director at the Laboratory of Ecology, Systematics, and Evolution at the University of Paris-Sud and attributes the whole thing to personal animosity.

But the incident continues to provide ammunition for critics of his Chernobyl work. These include Ron Chesser and Robert Baker, professors of biology at Texas Tech University who have also worked with Gaschak in the zone—where they, too, have described wildlife "thriving." But although Baker and Chesser have conducted numerous studies in the zone and are among Møller and Mousseau's most high-profile critics, they have published less on their findings there, and very few of their papers afford direct comparison to Møller and Mousseau's findings with barn swallows and other species. Their most

spectacular paper on Chernobyl, a study of genetic mutations in rodents that made the cover of *Nature* in 1996, was retracted a year later because of data discrepancies. Their often publicized statements about booming wildlife in the zone are drawn not from a scientific journal but from a 2006 *American Scientist* magazine article.

"I've never seen any data related to any kind of census, any kind of quantitative assessment of numbers," Mousseau says. (Indeed, Gaschak's assertions about the population density of large mammals in the zone are based on observational estimates.) This year, Møller and Mousseau hope to finally gather enough data to conclusively establish the density and abundance of mammal populations in the zone, returning with a team to conduct a widespread census. In the meantime, they have continued to produce attention-grabbing research on avian life. At the beginning of February, the online journal *PLoS ONE* published their latest paper, showing that birds they captured within the zone had brains 5 percent smaller than those they found outside it. "Microcephaly," Møller says. "A common condition in humans in Ukraine in these contaminated areas."

Which raises a key point: If the entire debate about the ecosystem of Chernobyl were simply about the fate of barn swallows or wild boar, the conflict might be easily dismissed as arcane bickering between biologists. But the stakes are much higher, because the animal studies may shed real light on the effects of long-term radiation exposure on humans. Post-Chernobyl, obtaining statistically significant epidemiological data on cancer was complicated by Soviet-era secrecy and disinformation and by the scattering of the hundreds of thousands of workers who participated in the cleanup and then returned to their homes across the Soviet Union.

But one of the few certainties to emerge from research into low-level radiation since 1986 is that different species react to chronic exposure in different ways. Pine trees cope less well than birch. Migrant barn swallows are apparently very radiosensitive, resident birds less so. Winter wheat seeds taken from the Exclusion Zone in the days after the disaster and since germinated in uncontaminated soil have produced thousands of different mutant strains, and every new generation remains genetically unstable, even 25 years after the accident. Yet a 2009 study of soybeans grown near the reactor seemed to show that the plants change at a molecular level to protect themselves against radiation. No one can be certain where human beings might fall on this continuum of DNA damage and long-term adaptation. "That's what we want to know," Møller says. "Are we more like barn swallows or soybeans in terms of radiation-induced mutation?"

Finding the answer to this question may take decades or even centuries. The genetic effects of chronic radiation exposure on each species studied so far have often been subtle and varied and only conclusively shown after many generations. The potential genetic changes in human beings—only now producing their third generation, as the children of the liquidators themselves raise families—may take hundreds of years to fully unravel. Meanwhile, the Ukrainian government, seemingly satisfied with the anecdotal evidence of the zone-based research team, is pushing ahead with its plan to open the zone to tourism. Sergey Gaschak fears that future plans will include repopulating the Exclusion Zone at the earliest opportunity.

**THE ANIMAL SIGHTINGS BEGAN 10 YEARS AGO. NATURALISTS PHOTOGRAPHED THE TRACKS OF A BROWN BEAR AND SAW WOLVES AND BOAR ROAMING THE STREETS OF ABANDONED TOWNS.**

The repopulation of the zone is something that neither he nor Møller and Mousseau wish to see: Gaschak because he wants the zone to become a permanent wildlife reserve where elk and lynx can live beyond the reach of Ukraine's enthusiastic hunters; Møller and Mousseau because they fear for the long-term health of a human population exposed to mutagens that remain in the environment. While iodine-131 decayed long ago and the strontium and cesium are slowly becoming less potentially lethal, the hot particles of plutonium-241 scattered across the landscape are actually decaying into an even more toxic isotope, americium-241. A more powerful emitter of alpha radiation than plutonium, americium is also more soluble and can easily find its way into the food chain. Americium-241, in turn, decays into neptunium-237, another energetic alpha emitter that has a half-life of more than 2 million years. As of yet, the long-term effect of americium-241 on animals remains largely unknown.

In the meantime, Møller and Mousseau's *PLoS* paper on bird brain sizes has come to the attention of the Ukrainian government. Chizhevsky assisted Møller and Mousseau with their data collection. As Gaschak plays tour guide on the radioactive safari, Chizhevsky's phone rings. News of the paper has reached the Ministry of Emergencies, and the minister is not happy. Who gave these scientists permission to catch birds in the zone? he wants to know. And why is a researcher employed by the Ukrainian government credited on this paper? Angry questions are passed down the chain of command. At the end of it, Chizhevsky is summoned to explain himself before his boss.

After Chizhevsky hangs up, he and Gaschak discuss the paper. Chizhevsky says he never saw a draft of it before it was published. Gaschak notes that accurately measuring the heads of birds is potentially problematic. "You can measure the same animal 10 times, and 10 times you can get a different result," he says. "If I give this bird to Igor, he measures: new results." Chizhevsky also maintains that 5 percent is simply not statistically significant. "Strange result," he shrugs.

Later that afternoon, Chizhevsky returns from the meeting with his superiors to report that he has mollified them about his part in the paper but suggests that access to the region may become more difficult for Møller and Mousseau; their definitive mammal study might not be completed. "They'll get more attention from Ministry for what they're doing," Chizhevsky says. "Next time, they will have some problems in the Exclusion Zone, I think."

It's time to leave. Chizhevsky pulls the car out to the long, empty road that leads through one last radiation checkpoint and, beyond it, to the outside world.