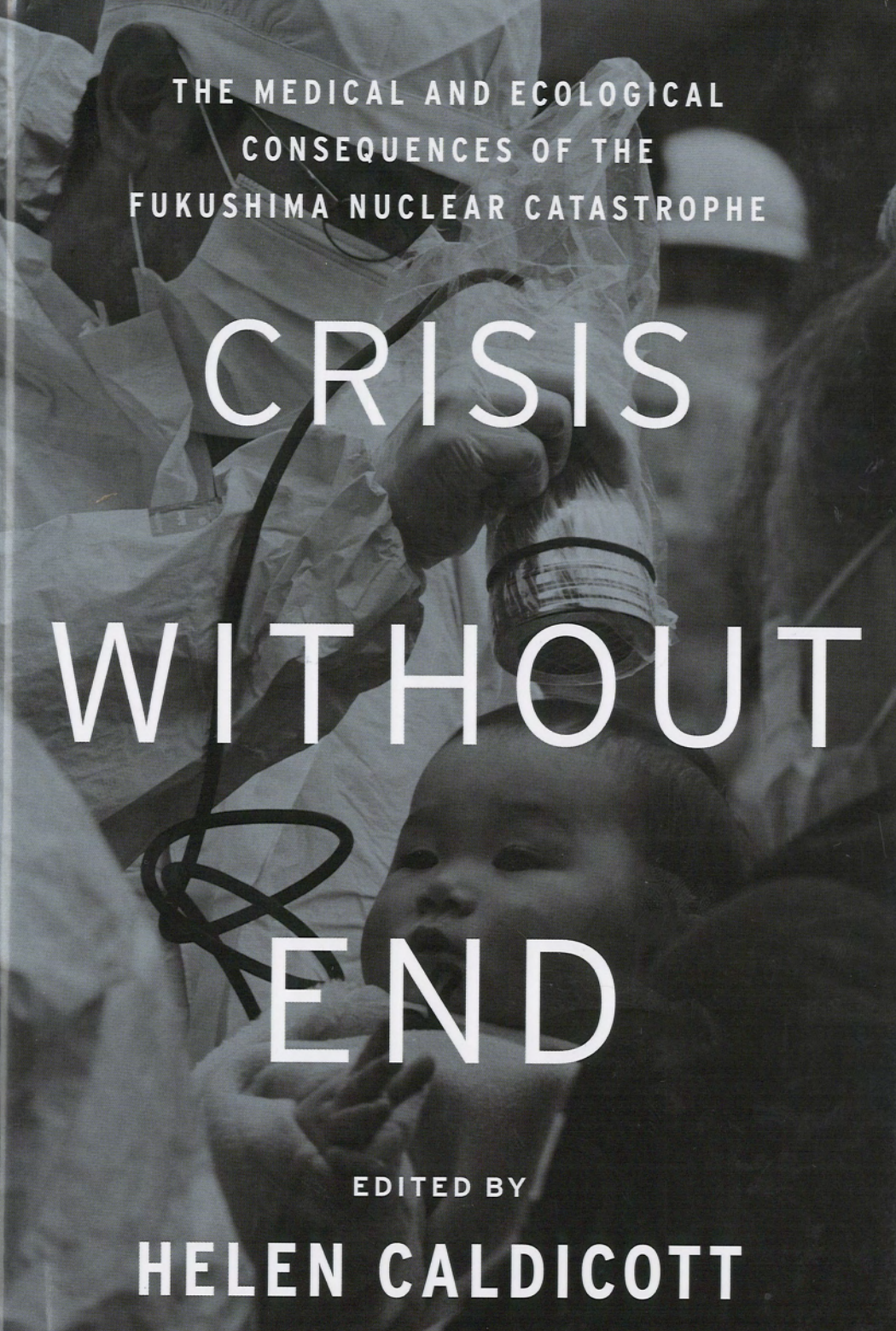

THE MEDICAL AND ECOLOGICAL CONSEQUENCES OF THE FUKUSHIMA NUCLEAR CATASTROPHE

# CRISIS WITHOUT END

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**HELEN CALDICOTT**

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# The Biological Consequences of Chornobyl and Fukushima

Timothy Mousseau

A number of years ago, prior to March 11, 2011, my colleagues and I worked on the impact of radioactive contaminants in Chornobyl. Our interest was driven by evolutionary ecology and genetics, not radioecology, nor nuclear medicine, nor antinuclear activism. At first, we worked primarily with birds because they were easy to catch, identify, and count. Not discouraged by the fence around Chornobyl, birds entered the most contaminated areas of the site, and tracking them has allowed us to study the long-term health impact of these contaminants.

We have studied biodiversity at Chornobyl since 2000 and Fukushima since 2011. Most organisms that we have examined showed significantly increased rates of genetic damage in direct proportion to the level of exposure to radioactive contaminants. Many organisms showed increased rates of deformities, developmental abnormalities, eye cataracts, and even tumors and cancers. Reduced fertility rates were also common. We found that about 40 percent of male birds in

the more contaminated parts of Chornobyl are completely sterile, with no sperm or only a few dead sperm. Many of the birds have reduced life spans. As a consequence, many of these populations are small and have reduced growth rates. Some of these species have actually died out in the most contaminated areas. Individuals of species that are surviving well now may accumulate mutations that will be passed on to the next generation. Some of these individuals live long enough to migrate out of the area, carrying these mutations and their potential effects to populations that have never been exposed to radiation.

Understanding the effects of radioactivity in the environment is not easy. All of us are different. Some of this is the result of genetic mutations that, even if they are expressed (most are not), probably do not influence our survival or ability to reproduce. The natural world is a complicated heterogeneous place. Every point in space and time is slightly different, for instance, with respect to the amount of sunlight it receives, the temperature, the plants and animals that are there, the birds that might fly by. In order to ascertain the effect of radioactivity or radioactive contaminants on an individual, a population, or a species, this variability must be factored into the equation. We have accomplished this by employing a massively replicated biotic inventory design, which involves counting every last organism in hundreds of places in both Chornobyl and Fukushima repeatedly through time.

At Fukushima, as of July 2012, we had made 700 biotic inventories. At Chornobyl, we stopped at 896. We measured



the number of birds, the species of birds, the number of spiders, and so forth. We measured many of the environmental variables that might be relevant in determining the presence or absence of a given group of organisms—the meteorology, the hydrology, the species of plants, the presence of water. We set up about half a kilometer of mist nets to catch thousands of birds to obtain blood and feather samples for analysis of their DNA and their overall health. We measured radiation levels, too, first using a very simple measure of radiation levels—the Geiger counter. We then calculated the partial effects of radioactive contaminants on populations while statistically controlling for the many other environmental factors that can influence abundance and diversity. Such an approach had not ever been previously taken by any team of scientists.

We also made use of a radionuclide identifier system to identify the source of radiation in any given area, and we have developed miniature dosimeters using TLDs—tiny crystal chips that capture radiation. By placing a TLD on a bird, releasing the bird, and then recapturing the bird, we can verify how much radiation it is exposed to and accurately estimate the external dose to an individual. We have also measured internal radiation dose by taking birds, putting them in a lead enclosure in the field, and measuring the amount of radioactive material inside their bodies to estimate internal dose. As a result, we have discovered a good relationship between our simple Geiger counter measures of background radiation in a certain location and how much radiation organisms

in that same location are experiencing both externally and internally.

There have been, in recent years, a number of reports that the Chornobyl zone is a thriving Eden for wildlife. The origin of this story can be found in a statement released by the Chornobyl Forum of the International Atomic Energy Agency (IAEA) a few years ago, which suggested that the many plant and animal populations had grown and the biome of the Chornobyl exclusion zone had considerably improved because of an absence of humans inside the zone. These statements implied little or no direct effects of radiation on the plants and animals of the region. This report also suggested that much of the human morbidity was a result of stress and other environmental factors unrelated to radiation exposure. But at the time this report was written, there were no rigorous studies of plant and animal biodiversity and abundance in the Chornobyl zone. The absence of data was used to support the argument that radiation effects were largely absent or at least irrelevant for the health of the populations. Much of our recent research into Chornobyl and Fukushima has been inspired by this report. Our goal has been to provide the scientific evidence needed to address these questions thoroughly. As evolutionary biologists, and not antinuclear activists, we had no prior expectations or any interest in any specific outcome.

The Chornobyl exclusion zone is a heterogeneous place. There are vast areas that are free of radioactive contamination. Some of the cleanest areas have less background radiation than Central Park in New York. The background



radiation in Central Park is about 0.1 microsievert per hour. In the cleanest parts of the Chornobyl zone, it is about 0.05. The notion that the Chornobyl zone was a new Eden galvanized us to count all the animals there, including the beautiful, endangered Przewalski's horses, which were introduced into the Chornobyl zone following the disaster.

In terms of birds, once we had statistically controlled for other environmental factors, we found that there were only about a third as many birds as there should have been in the highly radioactive areas and only half as many species. Some of the numbers were so low that the populations could not be sustained. Because we noticed that it was difficult to find some insects, we decided to count them, too. One of the most notable discoveries was the near-absence of bees in the most contaminated areas. There were also fewer spiders, fewer grasshoppers, fewer dragonflies, and fewer butterflies (butterflies appear to be hypersensitive to these contaminants, which is consistent with reports in Japan of mutant butterflies post-Fukushima). The same results were found with mammals—from small rodents to deer.

The Ukrainian government has been trying to capitalize on the tourists who want to see the reactor and the wildlife. Unfortunately, there is rarely any wildlife to see, and so they have set up a small zoo in Chornobyl so that tourists, and journalists, can take pictures of wolves and wild boar.

At Fukushima, we compiled three hundred biotic inventories in July 2011 and an additional four hundred inventories in July 2012. We have been working with barn swallows and

barn swallow nests, and the overall results have been the same: significantly reduced numbers of individuals in the more contaminated areas. There were fourteen species of birds with which we could perform direct comparisons between Chornobyl and Fukushima, and the relationship between radiation and abundance was found to be about twice as strong in Fukushima in the first year after the disaster as it was in Chornobyl more than twenty years after the disaster. This implies that there is a lack of resistance or an increased radiosensitivity in the Japanese birds. Perhaps some Chornobyl birds have evolved some degree of resistance, or at least the species that are susceptible have significantly declined throughout the exclusion zone over the last twenty-six years. In Chornobyl, every taxonomic group that we examined showed declines in the more contaminated areas, while in Fukushima, only birds, butterflies, and cicadas showed a significant signal of decline. Curiously, the number of spiders actually rose in the more contaminated areas of Fukushima in 2011, perhaps due to reduced numbers of predators (e.g., birds). Based on our extensive surveys of animals in Chornobyl and Fukushima, abundance and diversity in clean areas of the zone may appear to be normal (although this has not been tested), but in areas of significant contamination, many organisms show sufficient declines in abundance to have impacts on overall biodiversity. This refutes the implied positive impacts suggested by the IAEA's Chornobyl Forum reports.

In Chornobyl, we have captured and measured more than two thousand birds over the past few years. We have detected



unusual abnormalities among the birds: strange color patterns; patches of white feathers; tumors on beaks, on wings, or around the eye; strange growths on feet or on their rear ends; missing patches of skin; and cataracts in their eyes. Such abnormalities have rarely been reported anywhere else. Chornobyl birds have smaller brains, too. Neurological development was clearly impacted as a consequence of the contamination. Smaller brains mean reduced cognitive function, and the birds are less likely to survive. It remains to be seen what the long-term prospects for wildlife in Fukushima will be. It is still too early to tell, although recent studies on butterflies by Japanese scientists are consistent with our findings for Chornobyl.

It does not take a genius to make the observations we made at Chornobyl and Fukushima, but the problem is that nobody has looked, or if they have looked, they have not followed through by compiling, analyzing, and publishing the data properly in peer-reviewed scientific reports. Unfortunately, there is no funding in this area. Scientists, like plumbers, must be paid for their efforts. My conclusion is that the governments and regulatory bodies associated with nuclear accidents do not want to know the answers to the fundamental questions related to the impact of radiation on wildlife, and by extension, human beings.