

**Exhibit Dates: September 2011 – March 2012**

## **Chernobyl, 25 Years Later: Biological Legacy of a Nuclear Meltdown**

This exhibit highlights research conducted by a team of scientists from Texas Tech University at Chernobyl, Ukraine, the site of a 1986 nuclear meltdown. The primary goal of the TTU research in Chernobyl is to achieve an understanding of the biological consequences of chronic exposure to radiation in the environment.

Texas Tech's Chernobyl research team is co-directed by Dr. Robert Baker, Horn Professor of Biological Sciences and Director of the Natural Science Research Laboratory (NSRL) of the Museum, and Dr. Ron Chesser, Professor of Biological Sciences and Director of the Center for Environmental Radiation Studies. Other members of the research team include Dr. Brenda Rodgers, Assistant Professor of Biological Sciences, and Dr. Carl Phillips, Professor of Biological Sciences.

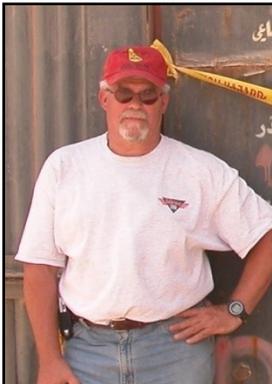
Dr. Baker has conducted 20+ research trips to Chernobyl since 1994, the most recent being in August of 2011 to collect additional mammal specimens from the radioactive zone. In total, the TTU research team has conducted more than 70 trips to Chernobyl to conduct biological research, to assist in the building of an International Radioecology Laboratory in Ukraine, and to assist in the coordination of an international coalition between the governments of Iraq and Ukraine.



Dr. Robert J. Baker



Dr. Ronald Chesser



Dr. Carleton J. Phillips



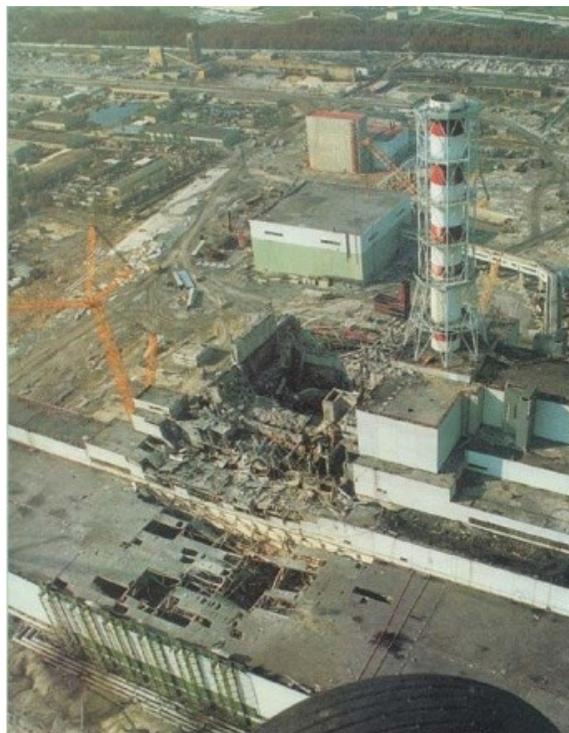
Dr. Brenda Rodgers

## The Chernobyl Meltdown, 1986

The Chernobyl Nuclear Power Plant is located approximately 15 km (9.3 miles) northwest of the village of Chernobyl and 3 km (1.9 miles) southeast of the city of Pripjat, in what is now the independent nation of Ukraine (a former Republic of the Soviet Union). On April 26<sup>th</sup>, 1986, Reactor 4 of this complex went out of control during a test, leading to two explosions and a fire. Over the next 10 days, 100-200 million Curies of radiation was released into the atmosphere. The Chernobyl meltdown is the worst nuclear power plant accident in history.

Due to the prevailing winds and storm patterns, radioactive material was scattered over much of the northern hemisphere, particularly the western USSR and Europe. The amounts dispersed in many areas were minimal and posed no significant threat to humans or the environment. However, nearly 150,000 sq. km (58,000 sq. miles) in Ukraine, Russia, and Belarus were contaminated in an irregular dispersal pattern that included areas of particularly high radiation fallout as well as relatively “clean” areas.

Generally, the most radioactive sites are within a 10 km (6.2 mile) radius of the plant. Within weeks after the accident, a zone of 30 km (18.6 mile) radius from the plant, known as the Exclusion Zone, was completely evacuated. As more data documenting the spread of the radiation became available, the Exclusion Zone was modified and extended, and additional evacuations were ordered. Estimates of the number of people relocated as a result of the mandatory evacuations vary greatly, but the total probably exceeds 200,000. Today, 4,300 sq. km (1,660 sq. miles) encompassing more than 100 villages and towns in Ukraine, Russia, and Belarus, remain abandoned of human habitation.



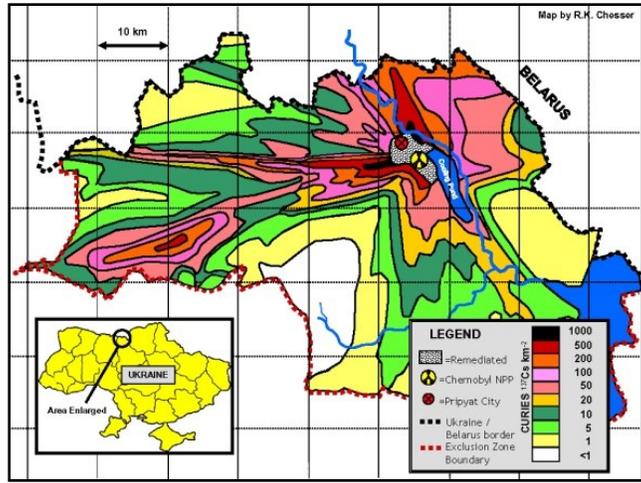
*View of Reactor 4 following the explosion and fire.*



*Location of Chernobyl Nuclear Power Plant in northern Ukraine, near the border of Belarus. Also labeled are the cities of Chernobyl and Pripjat. The white dashed circle shows the original 30 km-radius Exclusion Zone. The yellow line delineates the current Exclusion Zone. Within the Exclusion Zone there are highly radioactive areas, as well as areas with little or no radiation.*



*Immediately following the explosions and fire at Chernobyl, the radiation was dispersed primarily westward due to the prevailing wind patterns. The following day, the winds shifted northward and dispersed radiation over Glyboke Lake and into neighboring Belarus.*



*This figure illustrates the dispersion of  $^{137}\text{Cs}$  in the regions around Chernobyl. Black and red areas indicate the areas of highest radiation fallout. The isotope  $^{137}\text{Cs}$  is used as the model for the distribution of radiation in the environment, because it is the most long-lived of the 100+ radioactive elements that were released from the Chernobyl reactor. Most of the radioactive elements released were short-lived and decayed rapidly, and thus less than 3% of the initial radioactivity in the area remains today. Because of their long half-lives, however,  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  are still present in the environment and will persist for many more decades.*

When construction of the Chernobyl Nuclear Power Plant began in 1970, the Soviets envisioned that it would be a primary source of electricity for the western USSR. Even after the 1986 meltdown and explosion of Reactor 4, the Chernobyl power plant remained active for many years. However, the entire complex was eventually decommissioned in 2000.

After the meltdown of Reactor 4, a cement and lead structure called a sarcophagus was hastily built over the remains of the reactor to contain the nuclear materials and to protect the contents from the weather and the environment. The sarcophagus was poorly constructed, however, and is now crumbling and beyond repair. A new steel containment structure is currently under construction to completely encase the original sarcophagus, and is due to be completed in 2014.

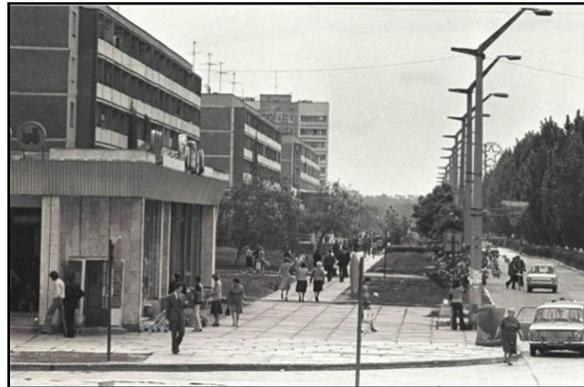


*The dark gray structure is the sarcophagus over the remains of Reactor 4.*

## The Human Element

The city of Pripjat, located just 3 km (1.8 miles) from the plant, had been constructed beginning in 1970 specifically to house the workers of the Chernobyl Nuclear Power Plant. It was considered at the time to be the most modern, advanced city in the Soviet Union. After the accident, the entire population of nearly 50,000 people was evacuated. The residents were told at the time to take only essential items with them, as they would be “returning to their homes in a few days.” Today, the decaying city is a stark testament to the human element of the Chernobyl disaster.

Below are a series of “before” and “after” images of the once young and vibrant city of Pripjat, which is slowly being reclaimed by nature.



Additional photos of the abandoned and decaying homes, schools, parks, and churches within the Exclusion Zone.



Although the 30 km Exclusion Zone remains officially closed to resettlement, approximately 1,000 people returned to their homes in Chernobyl and other villages within the zone in the years after the accident. These “self-settlers”, most of whom are elderly, have been unofficially allowed to inhabit the area. The population has now dwindled to a few hundred. They raise their own food and drink from their wells. By living within the 30 km zone, they are exposed to higher than normal levels of background radiation. The general consensus among these settlers is that they do not fear the potential long-term effects of the radiation, as they are already near the ends of their lives. One elderly woman was quoted as saying “I survived the siege of Leningrad. This Chernobyl is no big deal. It is just a little thing.”



*Typical rural Ukrainians who have returned to live within the Exclusion Zone.*



*Garden at one of the settler's homesteads.*

## **Environmental Impact**

From an environmental standpoint, the Chernobyl disaster has provided a virtual laboratory for scientists to study the effects of multi-generational radiation exposure on plants, animals, and ecosystems. The results of these studies have been varied, sometimes surprising, and often contradictory. They all point, however, to a continued need to investigate the environmental impacts of such events.

Some species of plants and animals are less sensitive to radiation than others. For example, all of the Scotch pine trees in the affected area west of the reactor (400 hectares) died from the initial fallout, and this area soon became known as the Red Forest due to the red-brown color of the dead pine trees. However, birch trees and aspen trees are more radioresistant and survived the initial fallout, and have continued to grow and spread throughout the region.

After the explosion, some of the most radioactive areas were *remediated* – the contaminated soil was turned under. Remediated areas give off approximately 5 millirems of radiation an hour. Areas that are not remediated give off up to 1000 millirems (1 rem) per hour. The highest dose for humans over a year should not exceed 100 millirems.



*Red Forest near Chernobyl Nuclear Power Plant.*



*Pine seedlings were planted in the Red Forest as biological indicators after the accident. They did not survive. Today, 25 years after the accident, the amount of radiation in the environment has been greatly reduced by decay, and pine trees are finally beginning to grow in unremediated areas.*



*Surviving birch trees in the Exclusion Zone. The remains of dead pine trees can be seen on the ground.*

When Texas Tech's research team first visited the region in 1994, they were shocked at both the impact of the disaster on human life and culture, as evidenced by the evacuation and subsequent decay of Pripyat and other towns and villages, but also by the natural beauty and lushness of the landscapes. Although most of the exclusion zone remained highly contaminated with radioactivity, it was far from the "nuclear desert" predicted by the media immediately after the Chernobyl incident.

While it is documented that some plants and animals were killed by acute, high-level doses of radiation in the first days after the accident, no species was wiped out completely. Because the areas of acute radiation exposure were relatively small, and were interspersed with areas of lower radiation exposure, the affected areas were quickly repopulated with surviving animals from the neighboring low-dose and clean areas.

In fact, the beauty and biodiversity of the region are striking. Abundant grasses, wildflowers, mosses, trees, and other plants thrive at the site, and all of the native mammals from the area occur, even in the most contaminated regions. Only the persistent clicking of a Geiger Counter reveals the presence of the radioactive contamination in the environment.



*Wildflowers flourishing in the yard of an abandoned home.*



*Water lily on Glyboke Lake, adjacent to the Chernobyl facility.*



*Bee on a wildflower.*



*Swans on Glyboke Lake.*

## **Texas Tech's Chernobyl Project**

The primary goal of Texas Tech's Chernobyl research team has been to determine the genetic consequences of radiation exposure to wildlife in the region.

From 1994 to 2011, Dr. Baker and his colleagues have visited the site multiple times to collect small mammal specimens, primarily field mice and voles, from the contaminated areas as well as from "control" regions with little or no radioactive contamination. They have been evaluating the radiation loads and genetic consequences to the rodents over time (now 50+ generations since the accident).



*Ron Chesser and Robert Baker setting traps in the Exclusion Zone.*



*Ukrainian researcher Sergey Gaschak and TTU graduate student Heather Meeks gather traps after a night of collecting small mammals in a research area.*



*Collection sites for comparative studies of small mammals from highly contaminated areas inside the Exclusion Zone (Red Forest and Glyboke Lake) and uncontaminated areas outside the Exclusion Zone (Oranoe, Chista, and Nedanchichy).*



*Checking the radiation level of a trap site with a Geiger Counter.*

Tyvec suits and respirators were advised to protect researchers and visitors in the most highly-radioactive zones, particularly in the first years after the incident. Over time, radioactivity levels in the region around the Chernobyl complex have declined to such a degree, however, that such precautions generally are not required, particularly for short-term exposures as experienced by researchers and other visitors. In fact, the Chernobyl area was recently opened for guided public tours.

When they first began their studies, Dr. Baker and his colleagues expected that they might find gross mutations in the DNA of the animals they captured, perhaps morphological changes, or possibly that some species had been extirpated. Their results, however, have been surprising, as they have documented essentially no genetic, chromosomal, morphological, reproductive, or longevity changes in the small mammals that they have examined.

In a living organism, the radioactive isotope  $^{137}\text{Cesium}$  is mistaken for potassium and is absorbed into muscle tissues; similarly,  $^{90}\text{Strontium}$  mimics calcium and is built into bone material. Thus, these elements recycle through the environment inside animals. Despite the incredibly high doses of radiation present in the bones and muscles of the captured animals at Chernobyl, particularly the bank voles, it appears insufficient to cause a great degree of genetic change. These results have been documented through a series of experiments.

Experiment 1 - Compared rodents from the Exclusion zone with those from uncontaminated areas for radiation load and obvious physical effects.

Result – Rodents from the contaminated areas were carrying extremely high radiation loads in their bones and muscles. However, there were no observed physical anomalies, and females were carrying normal embryos.

Experiment 2 – Examined the chromosomes of rodents from the contaminated zone.

Result – No chromosomal damage was evident. This raised the question, Was there an adaptive change in the rodents from the contaminated zone, after nearly 20 generations of exposure, that allowed them to tolerate the radiation?

Experiment 3 – To address that question, wild rodents from uncontaminated regions were transplanted into the contaminated region (in enclosures) and later examined for chromosomal or genetic damage.

Result – No effect from the radiation was evident in the transplanted mice.

Experiment 4 – The enclosure experiment was repeated with “Big Blue” transgenic mice (special lab-raised mice that carry a gene that glows “blue” if it undergoes a mutation) and with radiosensitive mice to look for evidence of chromosomal breakage or changes in genes.

Result – Genetic effects on the Big Blue and transgenic mice were subtle, with no effects on longevity or reproduction.

Experiment 5 – Compared the genetic diversity of bank vole populations from contaminated and uncontaminated regions.

Result – Genetic diversity in bank vole populations was widely variable in both the contaminated and uncontaminated regions and appeared to be a function of natural geographic variation. There was no evidence of increased mutation rates in the radioactive group.



*This vole (Microtus) is fitted with a dosimeter collar, a device that measures radioactivity. The animals are captured, collared, released, and recaptured several days later. The dosimeters are retrieved from the animals, and the amount of radiation that the mice had been exposed to can be read from the dosimeters.*



*Bank vole*

Research has revealed that the Bank Vole (*Myodes [Clethrionomys] glareolus*) picks up the most radioactivity of any small mammal (has the highest radioactive body burden). Thus, it was expected that if any mammal would show signs of mutation or genetic disruption, the bank vole would be the one. Nonetheless, the research team has been unable to document negative biological affects in the voles living in even the most radioactive regions. They are the most common rodent in the region and appear healthy in all respects.

In addition to their genetic research, the Texas Tech team has documented many ecological observations from the Chernobyl zone. When the Texas Tech team began their research in 1994 (8 years after the accident), the Red Forest area had become a grassland habitat, and grassland species of mammals were commonly found. Over the years, as the trees and other plants in the Red Forest experienced ecological succession (progressive change through time), the mammalian fauna experienced succession as well. Species associated with forests have become common and dominant. Thus, the species present in the area has been as expected based on local ecology. If there is an effect of the presence of radiation on the ecosystem, other than removal of humans, it is not obvious from a gross perspective.



*Bird nest at the edge of the Red Forest.*



*This Forest Dormouse (*Dryomes nitedula*) was caught in an area that approaches 1 rad per hour.*



*These specimens are from the Radioactive Collection of the NSRL. The Radioactive Collection contains more than 2,500 specimens from the Chernobyl region. In addition to the preserved skins and skeletons, more than 10,000 tissue samples of the specimens (such as muscle, heart, liver, kidney) are permanently archived in the NSRL's Genetic Resources Collection. These tissue samples allow additional genetic studies to be conducted for years to come.*

## Creation of a Natural Reserve

Because most of the human population has been removed from the area, there is essentially no hunting pressure or agricultural impact on the wild animal population in the Exclusion Zone. This absence of human habitation has led to an increase in numbers of native wild animals. Many species are more abundant within the Exclusion Zone, despite high levels of radiation, than they are in areas outside the Exclusion Zone that have little or no radioactivity but do have typical farming and ranching practices. In published articles, the Texas Tech team has compared the Exclusion Zone to a wildlife preserve, and in fact both Belarus and Ukraine have designated Exclusion Zone areas as natural reserves.

Native species such as gray wolves, wild boar, moose, beavers, and roe deer are booming in the area, and rare species such as lynx and brown bear have even been observed. Endangered Przewalski's horses were introduced and have multiplied to become the largest wild population of the species outside Mongolia.



*Moose (Alces alces)*



*Wild Boar (Sus scrofa)*



*Grey Wolves (Canis lupus)*



*Przewalski's Horse (Equus ferus)*

## Conflicts and Controversy

During the 25 years since the Chernobyl incident, there have been hundreds of scientific studies conducted and papers published on the environmental and biological impacts of the event. These papers have been authored by a multitude of scientists from around the world, and surprisingly reflect a confounding complexity of opinions and conclusions about the biological significance of the Chernobyl accident.

Some researchers have concluded that chronic exposure to Chernobyl radiation is having a devastating effect on the flora and fauna, whereas other research results, including that of the Texas Tech researchers, have shown limited or no negative biological effects. Admittedly, conflicts in the interpretation of research results and their significance to society are common in science. Further, some science is flawed by poor experimental designs, personal bias, or other factors that can lead to questionable or conflicting results.

Additional research, including detailed, long-term studies on genetic load, population genetics, demography, mutation rate, life expectancy, fertility, fitness, radioresistance, etc., are needed to understand if wildlife populations exposed to chronic radiation differ from unexposed populations. Further, the Texas Tech research team emphasizes that their research results on the small mammals and ecology of the region do not imply a low risk to human health from radiation exposure. The issues raised concerning latent and long-term effects must be resolved before the total significance of this disaster to native wildlife, and to humans, can be understood.

## Documented Results from Texas Tech's Chernobyl Research

1. Observations by the TTU team do not indicate a reduced abundance of wildlife, but rather, a greater number of individuals than is present in non-radioactive sites beyond the 30 km zone. Large mammals, such as moose, roe deer, Russian wild boars, wolves, European badgers, and raccoon dogs, are common in the most radioactive regions. In fact, the team has compared Glyboke Lake and the Red Forest to a wildlife preserve, where the fauna is protected. Normal farming and agricultural practices and other human impacts appear to be more detrimental to wildlife than the world's worst nuclear power plant disaster.

Chesser, R. K., and R. J. Baker. 1996. Life Continues at Chernobyl. *La Recherche* 286:30-31 (*in French*).

Baker, R. J. and R. K. Chesser. 2000. The Chornobyl Nuclear Disaster and Subsequent Creation of a Wildlife Preserve. *Environmental Toxicology and Chemistry* 19:1231-1232.

Chesser, R.K., and R.J. Baker. 2006. Growing up with Chernobyl. *American Scientist* 94:542-549.

2. All of the species of rodents and shrews that would naturally occur in the Red Forest region before the Chernobyl accident, are still present in the Red Forest, even in the most radioactive regions.

Baker, R.J., M.J. Hamilton, R.A. Van Den Bussche, L.E. Wiggins, D.W. Sugg, M.H. Smith, M.D.

Lomakin, S.P. Gaschak, E.G. Bundova, G.A. Rudenskaya, and R.K. Chesser. 1996. Small mammals from the most radioactive sites near the Chernobyl nuclear power plant. *Journal of Mammalogy* 77:155-170.

3. The body-burden of radioactive Cesium and Strontium is highly variable across different species as well as different individuals of the same species, although each species has a characteristic body-burden.

Chesser, R. K., D.W. Sugg, A. J. DeWoody, C.H. Jagoe, M.H. Smith, M.D. Lomakin, R.A. Van Den Bussche, C.E. Dallas, K. Holloman, F.W. Whicker, S.P. Gaschak, I.V. Chizhevsky, V.V. Lyabik, E.G. Buntova and R.J. Baker. 2000. Concentrations and Dose Rate Estimates of <sup>134</sup>, <sup>137</sup>Cesium and <sup>90</sup>Strontium in Small Mammals at Chernobyl, Ukraine. *Environmental Toxicology and Chemistry* 19:305-312.

4. Bank voles (*Myodes*) have the greatest body-burden of radionuclides of any small mammal in the region.

Chesser, R. K., D.W. Sugg, A. J. DeWoody, C.H. Jagoe, M.H. Smith, M.D. Lomakin, R.A. Van Den Bussche, C.E. Dallas, K. Holloman, F.W. Whicker, S.P. Gaschak, I.V. Chizhevsky, V.V. Lyabik, E.G. Buntova and R.J. Baker. 2000. Concentrations and Dose Rate Estimates of <sup>134</sup>, <sup>137</sup>Cesium and <sup>90</sup>Strontium in Small Mammals at Chernobyl, Ukraine. *Environmental Toxicology and Chemistry* 19:305-312.

Baker, R.J., A.M. Bickham, M. Bondarkov, S. P. Gaschak, C.W. Matson, B.E. Rodgers, J.K. Wickliffe and R. K. Chesser. 2001. Consequences of polluted environments on population structure: The bank vole (*Clethrionomys glareolus*) at Chernobyl. *Ecotoxicology* 10:211-216.

5. Bank voles complete all of their normal life-cycle characteristics while living in the Red Forest.

Matson, C. W., B. E. Rodgers, R. K. Chesser and R. J. Baker. 2000. Genetic diversity of *Clethrionomys glareolus* populations from highly contaminated sites in the Chernobyl region. *Environmental Toxicology and Chemistry* 19:2130-2135.

Baker, R.J., A.M. Bickham, M. Bondarkov, S. P. Gaschak, C.W. Matson, B.E. Rodgers, J.K. Wickliffe and R. K. Chesser. 2001. Consequences of polluted environments on population structure: The bank vole (*Clethrionomys glareolus*) at Chernobyl. *Ecotoxicology* 10:211-216.

6. Hundreds of necropsies of rodent specimens living in the Red Forest have failed to reveal a single cancerous-appearing growth.

Bondarkov, M.D., S.P. Gaschak, Yu.A. Ivanov, A.M. Maksimenko, A.N. Ryabushkin, V.A. Zheltonozhsky, L.V. Sadovnikov, R. K. Chesser, and R.J. Baker. 2003. Parameters of radiation situation on the territory of the Red Forest site in the Chernobyl exclusion zone as impact factors for wild non-human species. Pp. 196-199 In: Contributed Papers of International Conference on the Protection of the Environment from the Effects of Ionizing Radiation. 6-10 October 2003, Stockholm, Sweden. IAEA-CN-109/100.

7. None of the TTU research supports the hypothesis that rodents living in the most radioactive regions are less fit than individuals living in “clean” regions.

Rodgers, B. E., J. K. Wickliffe, C. J. Phillips, R. K. Chesser, and R. J. Baker. 2001. Experimental exposure of naïve bank voles, *Clethrionomys glareolus*, to the Chernobyl, Ukraine, environment: A test of radioresistance. *Environmental Toxicology and Chemistry* 20:1936-1941.

Rodgers, B.E., R. K. Chesser, J. K. Wickliffe, C. J. Phillips and R. J. Baker. 2001. Sub-chronic exposure of BALB and C57BL strains of *Mus musculus* to the radioactive environment of the Chernobyl exclusion zone. *Environmental Toxicology and Chemistry* 20:2830-2835.

8. Micronuclei resulting from chromosomal breaks in the production of red blood cells are elevated in the Red Forest. The implications of this are poorly understood.

Rodgers, B. E., J. K. Wickliffe, C. J. Phillips, R. K. Chesser, and R. J. Baker. 2001. Experimental exposure of naïve bank voles, *Clethrionomys glareolus*, to the Chernobyl, Ukraine, environment: A test of radioresistance. *Environmental Toxicology and Chemistry* 20:1936-1941.

Rodgers, B.E., R. K. Chesser, J. K. Wickliffe, C. J. Phillips and R. J. Baker. 2001. Sub-chronic exposure of BALB and C57BL strains of *Mus musculus* to the radioactive environment of the Chernobyl exclusion zone. *Environmental Toxicology and Chemistry* 20:2830-2835)

9. The radiation plumes produced by Chernobyl during the first 10 days were re-constructed and potential doses estimated (primarily the work of Dr. Ron Chesser).

Chesser, R.K., and B.E. Rodgers. 2008. Near-field particle dynamics and empirical fallout patterns in Chernobyl's Western and Northern Plumes. *Atmospheric Environment* 42:5124-5139.

Chesser, R. K., M. Bondarkov, R. J. Baker, J. K. Wickliffe, and B. E. Rodgers. 2004. Reconstruction of radioactive plume characteristics along Chernobyl's Western Trace. *Journal of Environmental Radioactivity* 71:147-157.

10. Chronic exposure creates a different biological consequence when compared to acute doses.

Rodgers, B.E., R. K. Chesser, J. K. Wickliffe, C. J. Phillips and R. J. Baker. 2001. Sub-chronic exposure of BALB and C57BL strains of *Mus musculus* to the radioactive environment of the Chernobyl exclusion zone. *Environmental Toxicology and Chemistry* 20:2830-2835.

11. It is extremely difficult to get funding for sustained research documenting the biological consequences of living in the environment created by the Chernobyl disaster.

Chesser, R.K. and R.J. Baker. 2006. Growing up with Chernobyl. *American Scientist* 94:542-549.

## Future Work and Unanswered Questions

Although it is clear that plant and animal life has survived, and even flourished, in the radioactive areas around the Chernobyl plant, the long-term consequences of living there remains unanswered. The Texas Tech Chernobyl research team is continuing to investigate these potential long-term effects, utilizing advanced methods such as genome sequencing.

One experimental design that has been proposed is to bring Bank Voles from the region, which have been living in the radioactive environment for more than 50 generations, into the laboratory and perform inbreeding studies. Bank Voles readily adapt to the laboratory and their biology permits inbreeding crosses to easily be performed. Inbreeding studies would document if new semi-lethal mutations have built up in the populations. Such a study would be a 3- or 4-year effort, and would cost over \$1.5 million. The TTU team has applied to granting agencies for research funding to conduct these experiments.

The recent earthquake and subsequent tsunami in Japan, which resulted in the release of radiation into the environment from the Fukushima Daiichi nuclear power plant, documented that society still has tremendous fears, and limited understanding, of the effects of radiation exposure on the environment as well as human life. Following the events in Japan, the Texas Tech team was contacted by numerous news agencies regarding their Chernobyl research and its implications for the environment in Japan. The TTU Chernobyl research team is hopeful that an opportunity to conduct similar biological and environmental studies in Japan may become available in the near future.

## Scientific Publications Resulting from Texas Tech's Chernobyl Research

### Submitted

Howell, E. K., S. P. Gaschak, K. D. W. Griffith, and B. E. Rodgers. 2011. Low-dose radiation is protective *in utero*. Submitted to *Reproductive Toxicology*.

### 2011

Baker, R.J. and J.K. Wickliffe. 2011. Wildlife and Chernobyl: The scientific evidence for minimal impacts. *Bulletin of the Atomic Scientist*. 14 April 2011. Web Edition.

Howell, E. K., S. P. Gaschak, K. D. W. Griffith, and B. E. Rodgers. 2011. The effects of chronic low-dose irradiation on tolerance to chemotherapeutic agents. *Environmental Toxicology & Chemistry* 30(3):640-649.

Wickliffe, J.K., and R.J. Baker. 2011. Clarification and explanation of experimental design and mechanistic dose-response effects for significant radioecological impacts. *Biology Letters Online*. ISSN: 1744-957X

## 2009

Meeks, H. N., R. K. Chesser, B. E. Rodgers, S. P. Gaschak, and R. J. Baker. 2009. Understanding the genetic consequences of environmental toxicant exposure: Chernobyl as a model system. *Environmental Toxicology and Chemistry* 28(9):1982-1994.

## 2008

Chesser, R. K., and B. E. Rodgers. 2008. Near-field radioactive particle dynamics and empirical fallout patterns in Chernobyl's western and northern plumes. *Atmospheric Environment* 42:5124-5139.

Rodgers, B. E., and K. M. Holmes. 2008. Radio-adaptive response to environmental exposures at Chernobyl. *Dose Response* 6(2):209-221.

## 2007

Chesser, R. K., and R. J. Baker. 2007. Lessons of Chernobyl. *Scientific American Brazil* (in Portuguese) 6:78-85.

Hoofer, S. R., S. Gaschak, Y. Dunina-Barkovskaya, J. Makluk, H. N. Meeks, J. K. Wickliffe, and R. J. Baker. 2007. New information for systematics, taxonomy, and phylogeography of the rodent genus *Apodemus* (*Sylvaemus*) in Ukraine. *Journal of Mammalogy* 88:330-342.

Meeks, H. N., J. K. Wickliffe, S. R. Hoofer, R. K. Chesser, B. E. Rodgers, and R. J. Baker. 2007. Mitochondrial control region variation in bank voles (*Clethrionomys glareolus*) is not related to Chernobyl radiation exposure. *Environmental Toxicology and Chemistry* 26: 361-369.

## 2006

Baker, R. J. 2006. Review of: *Wormwood Forest: a Natural History of Chornobyl* by Mary Mycio. Joseph Henry Press, Washington, D.C. *Bulletin of the Atomic Scientist* Jan/Feb 2006:59-61.

Chesser, R. K. 2006. The 20-year legacy of Chernobyl. *Congressional Record*. [Testimony before a U.S. Congressional Hearing]. 20 pp, 27 April 27 2006.

Chesser, R. K., and R. J. Baker. 2006. Growing up with Chernobyl. *American Scientist* 94(6):542-549.

Wickliffe, J. K., Y. V. Dunina-Barkovskaya, S. P. Gaschak, B. E. Rodgers, R. K. Chesser, M. Bondarkov, and R. J. Baker. 2006. Variation in the mitochondrial DNA control region haplotypes in populations of the bank vole, *Clethrionomys glareolus*, living in the Chernobyl environment, Ukraine. *Environmental Toxicology and Chemistry* 25:503-508.

## 2005

Bickham, A., and R. K. Chesser. 2005. *Chernobyl*. Pp. 533-534 in: *Encyclopedia of Toxicology*, 2nd Ed., Elsevier.

Bondarkov, M. D., S. P. Gaschak, J. A. Goryanaya, A. M. Maximenko, R. K. Chesser, and R. J. Baker. 2005. Radionuclides accumulation and dose burden in small mammals in Chernobyl zone. Pp. 237-241 in: *Contributed Papers of International Conference on the Protection of the Environment from the Effects of Ionizing Radiation*. 6-10 October 2003, Stockholm, Sweden. IAEA-CN-109/100.

#### 2004

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## The Chernobyl Project as an Educational Opportunity

Texas Tech's Chernobyl research has involved more than a dozen Texas Tech graduate and undergraduate students and postdoctoral fellows, so far. Shown is a list of these individuals and their current positions in the academic and scientific communities. The study of the natural laboratory created by the Chernobyl disaster has been a fertile educational experience for Texas Tech students and has been valuable to Texas Tech's image as an educational and research institution.

### Post-doctoral associates:

Dr. Ron Van Den Bussche. 1995-1996. Ph.D., Texas Tech University. Present Position: Professor and Associate Dean of Arts and Sciences, Oklahoma State University.

Dr. Caleb Phillips. 2010-2012. Ph.D., Purdue University. Present Position: Postdoctoral Teaching Fellow, Texas Tech University.

### Ph.D. students:

Dr. James Andrew DeWoody. 1997. Dissertation Title: Molecular Evolution in *Microtus* from Chernobyl, Ukraine. Present Position: Professor, Dept. of Forestry & Natural Resources, Purdue University.

Dr. Kateryna Dmytrivna Makova. 1999. Dissertation Title: Microsatellite Evolution in Mice (*Apodemus*): Origin of Alleles, Multiple Paternity, and Mutation Rate at Chernobyl. Present position: Associate Professor, Biology Department, Penn State University.

Dr. Anton Nekrutenko. 1999. Dissertation Title: Development of Species and Genome Specific Genetic Markers by Representational Difference Analysis: Application in Systematic and Evolutionary Research. Present position: Associate Professor, Biochemistry and Molecular Biology Department, Penn State University.

Dr. Brenda E. Rodgers. 2000. Dissertation Title: Cytogenetic Effects of Exposure to Chornobyl Radiation. Present position: Assistant Professor, Department of Biological Sciences, Texas Tech University.

Dr. Jeffrey K. Wickliffe. 2002. Dissertation Title: Molecular Genetic Consequences of Exposure to Ionizing Radiation: Studies at Chornobyl. Present position: Assistant Professor, Tulane University, New Orleans, Louisiana.

Dr. Heather N. Meeks. 2009. Dissertation Title: The Biological Effects of Ionizing Radiation Exposure. Present Position: Defense Threat Reduction Agency, Department of Defense, Fort Belvoir, Virginia.

#### **Master's students:**

Dr. Cole Matson. 1999. Thesis Title: Characterization of the Mitochondrial DNA Control Region of *Clethrionomys*, and its Use as a Genotoxicological Marker. Present position: Executive Director, Center for the Environmental Implications of NanoTechnology (CEINT), Duke University.

Ms. Yelena Dunina-Barkovskaya. 2003. Thesis Title: Population genetics of rodents living in the Chornobyl environment based on mitochondrial and nuclear gene sequences. Present position: Biology teacher, Richland College, Dallas.

Mr. Adam Brown. 2006. Thesis Title: Effects of Low Dose Ionizing Radiation on Transcriptional Expression of DNA Repair and Reactive Oxygen Species Scavenging Genes: Studies at Chornobyl. Present position: PhD student, Greehey Children's Cancer Research Institute at the University of Texas Health Science Center at San Antonio.

Ms. Kristen M. Holmes. 2006. Thesis Title: Assessment of Radiation-induced Genotoxicity. Present position: Ph.D. student, M. D. Anderson Cancer Center, Houston.

Mr. Eric K. Howell. 2009. Thesis Title: Chemotherapeutic Challenge of the Chernobyl Rodent, *Apodemus flavicollis*. Present position: Ph.D. student, Texas Tech University.

#### **Undergraduate students:**

Mr. Erin Paul Reat. Highest degree, M.S., Purdue University. Present position: Quality Assurance Manager, Bexar County Criminal Investigative Laboratory, San Antonio.

Dr. Amanda J. Wright. Highest degree, Ph.D., Harvard University. Present position: Assistant Professor, Department of Biological Sciences, University of North Texas, Denton.

Dr. Lara E. Wiggins Johnson. Highest degree, M.D., Baylor Medical School. Present position: Pediatrician, University Medical Center, Lubbock.

Dr. Amy Bickham Baird. Highest degree, Ph.D., University of Texas at Austin. Present position: Assistant Professor of Biology, Department of Natural Sciences, University of Houston – Downtown.

## Outgrowths of the Chernobyl Project

Texas Tech's Chernobyl research project has led to at least three significant developments beyond its original scope:

1) The International Radioecology Laboratory (IRL) in Slavutych, Ukraine, was established in July 1998 as a result of an agreement signed by Ukraine and the United States. Dr. Ron Chesser was a lead coordinator in the design and building of the IRL (coordinating site selection, construction, hiring personnel, delivery of equipment, etc). The IRL is a regional base for conducting research in the areas of radioecology, radiobiology, dosimetry, and environmental protection. It ensures scientific and technical support and organization for carrying out research work within the Chernobyl Exclusion Zone.



*Guns Up!! A Chernobyl research team in Pripyat, Ukraine (from left to right: TTU graduate students Eric Howell and Ken Griffith, Dr. Ron Chesser, Dr. Brenda Rodgers, Dr. Carl Phillips, TTU graduate student Heather Meeks).*

2) The Center for Environmental Radiation Studies (CERS; website [cers.biol.ttu.edu](http://cers.biol.ttu.edu)) was established at Texas Tech University and is directed by Dr. Ron Chesser. The mission of the Center for Environmental Radiation Studies (CERS) is to promote research on the dispersion and biological/ecological effects of ionizing radiation, to advise government agencies on means to reduce risks to human health and environmental contamination, and to assess and predict the dispersion of radionuclides released by natural and man-made events.



*A Russian reactor southeast of Baghdad, one of 12 uranium enrichment plants the Center for Environmental Radiation Studies is helping to dismantle.*

3) In 2003, Dr. Carl Phillips received a William C. Foster Fellowship with the U.S. Department of State's Office of Proliferation Threat Reduction. The purpose of the office is to develop and implement programs that control the spread of technology or expertise that is required for making weapons of mass destruction. Dr. Phillips was assigned to work in Iraq, to re-train scientists who had previously worked in Saddam Hussein's weapons of mass destruction programs, with the goal of directing their expertise to civilian matters, such as water development, public health issues, and the rebuilding of industry. Phillips later served as interim special advisor to the Coalition Provisional Authority, the temporary government of Iraq. Dr. Phillips and Dr. Chesser are now using their experience at Chernobyl to assist and train the Iraqi government and scientists in the dismantling of decommissioned nuclear sites and the cleanup of radioactive debris, and in the building of a laboratory facility similar to the IRL in Ukraine. Recently, Dr. Rodgers began conducting research on the public health effects of radioactive contamination on people in the villages near the Iraqi nuclear facilities.



*Three Iraqi scientists training at the International Radioecology Laboratory in Slavutych, Ukraine, under the Train & Engage Program lead by TTU faculty members in 2008. The Train & Engage Program was an international effort—the United States, UK, Ukraine, and Iraq—created by TTU faculty members as part of the Nuclear Facilities Dismantlement Project in Iraq. The Iraqi participants in the project studied methods needed for public health assessment, analysis of radio-nuclide contamination, program and budget management, and project planning.*