

Radioactivity in wild reindeer populations in Norway

Levels of radioactive caesium increased rapidly in wild reindeer from areas contaminated from the fallout from the Chernobyl accident in the winter of 1987 and 1988. This was primarily due to radioactive contamination in lichen, which the animals grazed on during wintertime. During the period from 1986 to mid-1990s, there was a rapid decline in levels of caesium-137. From the late 1990s to the mid-2000s, the decline slowed substantially. During the last 10-15 years a minimal long-term decline has been observed. This period is dominated by year-to-year variations, possibly caused by the presence of mushrooms in the region.



Wild reindeer. Photo: Martin Blom

Radioactive contamination in Norwegian nature

Radioactive contamination in Norwegian nature mainly originates from the atmospheric nuclear tests in the 1950s and 1960s and the Chernobyl accident in 1986. The Chernobyl accident is the main source of radioactive contamination in Norway and resulted in elevated levels of radioactivity in the mountainous regions in central parts of Norway. The radioactive fallout from the

Chernobyl accident consisted of several different radioactive nuclides such as iodine-131, caesium-134, caesiums-137 and strontium-90. Many of the radionuclides in the fallout had short half-lives and have disappeared due to radioactive decay. Caesium-137 has a long half-life (30.2y) and is still present in the Norwegian environment.

Uptake in food chain

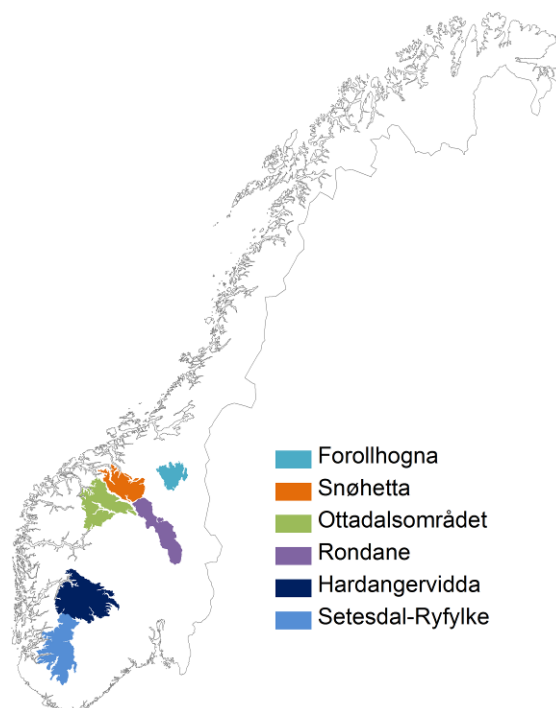
The radioactive nuclide caesium-137 is taken up by organisms because it is chemically similar to the necessary nutrient potassium. In biological systems, caesium behaves similarly to potassium. Therefore, the body absorbs the radioactive isotope caesium-137, which is transported around the body together with potassium. Radioactive isotopes of caesium will, therefore, be able to emit radiation to muscles and other tissues.

Radioactive caesium is transferred in food chains. Levels of radioactive contamination in various species of fish, birds and animals are largely determined by the food choices of the species.

Monitoring of wild reindeer populations

The habitats of several wild reindeer populations in Norway were severely affected by the radioactive fallout from the Chernobyl accident. Since 1986, annual collection of meat samples from wild reindeer has been carried out in the northern part of Rondane. In 2001, sampling was expanded to include the wild reindeer areas of Setesdal–Ryfylkeheiene, Hardangervidda, Nord-Ottadalen, Snøhetta, and Nord-Rondane. Since 2006, the collection has also included the Forollhogna wild reindeer area (Map 1).

The Norwegian Institute for Nature Research (NINA) carried out monitoring of wild reindeer from Rondane in the period 1986–2001. In autumn 2001, Norwegian Program for Monitoring of Radioactive Contamination in Terrestrial and Freshwater system was established. The program is funded by the Ministry of Climate and Environment and coordinated by the Norwegian Radiation and Nuclear Safety Authority (DSA). Since 2002, monitoring of radioactivity in wild reindeer has been carried out in collaboration with NINA and DSA.



Map 1. Wild reindeer areas where muscle samples of wild reindeer are collected annually for caesium-137 analysis.

Radioactive caesium in wild reindeer

After the Chernobyl accident, levels of radioactive caesium increased rapidly in wild reindeer from the contaminated areas in the winter of 1987 and 1988. In the Rondane reindeer population, median values during wintertime were up to 13 500 Bq/kg wet weight in reindeer meat with maximum values up to 25 000 Bq/kg wet weight.

In the first years following the Chernobyl accident, levels of radioactive caesium in reindeer were strongly linked to radioactivity in lichen. Lichen is the primary food source for wild reindeer in winter, when other food is scarce. This led to especially high levels of radioactive caesium in reindeer during winter following the 1986 fallout.

Contaminated lichen and seasonal variations

Moss and lichens do not have soil-bound roots and therefore absorb nutrients directly through the surface. This makes them particularly vulnerable to air pollution. They can live for many years without withering and can therefore maintain radioactivity levels from a direct fallout for a long time. New

moss and lichen that grow, however, will be less contaminated.

After the radioactive fallout, levels up to 68 000 Bq/kg dry weight were measured in lichen. High levels of radioactive caesium in lichen, resulted in much higher levels in wild reindeer in winter compared to autumn. (Figure 1). These high winter levels decreased quickly. Today the contaminated lichen has mostly been grazed down, and the previously large seasonal variations have almost disappeared.

Reindeer's main food sources

Except during wintertime, a reindeer's main food sources are different types of plants and mushrooms. The level in plants declines more slowly, as they continue to take up radioactive caesium from the soil. Many species of mushrooms have a very high ability to absorb radioactive caesium from the soil. Mushrooms lack chlorophyll, and do not have the ability to carry out photosynthesis. Many mushroom species, therefore, live in close association with plant roots. They provide the plant with water and minerals and receive sugar (made via photosynthesis) in return. Many mushroom species can, therefore, effectively absorb radioactive caesium from soil via the same mechanisms as potassium. As a result, mushroom fruit bodies can contain 10–100 times as much radioactive caesium as plants. When reindeer consume mushrooms, a clear increase in caesium-137 levels in muscle tissue can be seen.

Differences between populations

The wild reindeer populations in the northern part of Rondane and Snøhetta have the highest concentrations of caesium-137 during the monitoring period (Figure 2). They have high peak values in the early 2000s and often exceed mean values of 1000 Bq/kg wet weight with occasionally elevated values of 2000–3000 Bq/kg wet weight. Both areas have large within-population variability in addition to large between year variations. Monitoring results from the last 10 years show a very slow decline in radioactivity in reindeer populations.

Populations in Reinheimen-Breheimen and Forollhogna show moderate levels of caesium-137. These populations show a clear longtime decline even though some annual fluctuations are observed. Over the last decade, contamination levels have generally stabilized at low to moderate concentrations of caesium-137.

Populations from Hardangervidda and Setesdal-Ryfylkeheiene have relatively low concentrations of caesium-137 although some variability between years has been observed.

Ecological half-life in Rondane population

Long-term monitoring of caesium-137 in wild reindeer from Rondane shows that radioactivity levels in meat decreased with an ecological half-life of approximately 4 years for the period 1986–1996. (Ecological half-life is the time it takes for a given radionuclide in the ecosystem to be reduced by half). For the period 1996–2004, the half-life is approximately 31 years which is the same as the physical half-life of caesium-137. The measurements from the last 10-year period show that the decline is now very slow, but that there are quite large variations from year to year. The same pattern is found in semi-domestic reindeer in contaminated areas.

Over time, concentrations of caesium-137 in lichen have been greatly reduced, but levels in the reindeer's main food sources for the rest of the year—plants and fungi—decline more slowly, as they continue to absorb radioactive substances from the soil.

Conclusion

After the Chernobyl accident, levels of radioactive caesium increased rapidly in wild reindeer from the contaminated areas in the winter of 1987 and 1988. This was primarily due to radioactive contamination in lichen, which the animals grazed on during wintertime. During the period from 1986 to mid 1990s, there was a rapid decline in levels of caesium-137 in the Rondane population. During the late 1990s–mid 2000s, the decline slowed substantially and differences between populations

became more apparent. During the last 10–15 years, a minimal long-term decline has been observed. The latest period is dominated by year-to-year variations maybe caused by the presence of mushrooms in the region.

There is generally no health risk associated with eating wild reindeer meat. Specific dietary recommendations exist for people who consume large amounts of wild reindeer, domestic reindeer,

other game species, freshwater fish, mushrooms, and berries harvested from contaminated areas. These recommendations advise that annual intake of radioactive caesium should not exceed 80,000 becquerels (Bq) per year.

Even though 40 years have passed since the Chernobyl accident, radioactive caesium is still present in the Norwegian environment, circulating in the terrestrial ecosystem.

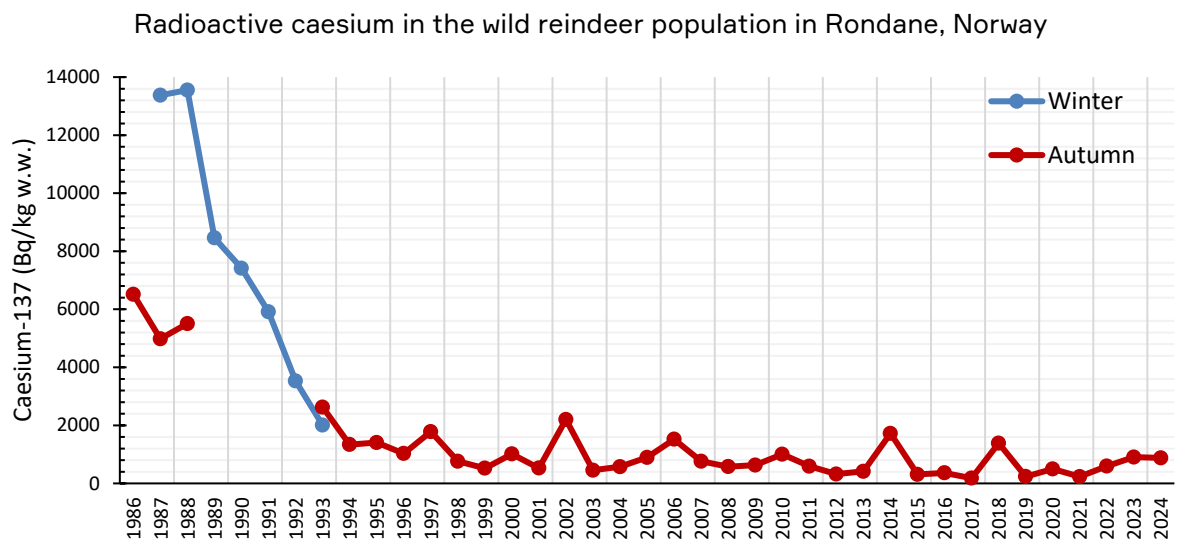


Figure 1. Concentration (median values) of caesium-137 (Bq/kg wet weight) in Rondane wild reindeer population during the period 1986–2024. The figure shows the differences between winter and autumn values and the variations between years caused mainly by mushrooms.

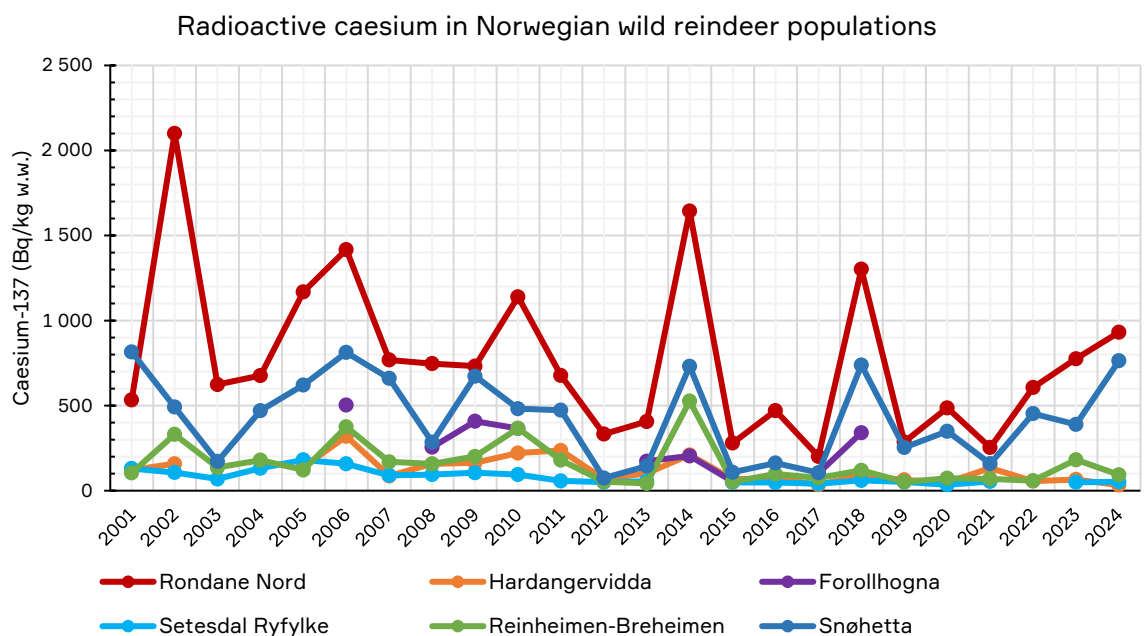


Figure 2. Concentration (mean values) of caesium-137 (Bq/kg wet weight) in selected wild reindeer population in Norway during the period 2001–2024