Radiocesium concentrations in wild reindeer at Dovrefjell, Norway.

Radiocesium-konsentrasjoner hos villrein på Dovrefjell, Norge.

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Abstract: Seasonal radiocesium concentrations varied about 6 times in wild reindeer following the Chernobyl accident, from 8 KBq/kg in August to 46 KBq/kg in March. These results agree with the predictions of earlier models. The within-season coefficient of variation was 52–62%. Between one half and 3/4 of this variation was explained by altitudinal and geographical factors, i.e. a 5-fold increase in concentrations from the westernmost to the easternmost locations across the watershed at Dovrefjell, and a 6-fold increase in concentrations from feeding locations in the subalpine to the high alpine zone in autumn. The positive correlation with altitude was reversed in winter for animals foraging in the subalpine coniferous zone on arboreal lichens.

Rangifer, 7(2): 42–45

Skogland, T. 1987. Radiocesium-konsentrasjoner hos villrein på Dovrefjell, Norge.

Sammendrag: Konsentrasjonene av radiocesium hos villrein gjennom sesongene som fulgte Tsjernobyl-ulykken varierte meget, fra 8 KBq/kg i august til 46 KBq/kg i mars. Disse resultater samsvarer med hva som kunne forutsies i tidlige modeller. Variasjonskoeffisienten innen sesong var 52–62%. Mellom halvdelen og tre fjerdedeler av variasjonen kunne forklares fra høydemessige og geografiske faktorer, d.v.s. en 5-foldig økning i konsentrasjonen fra den vestligste til de østligste lokaliseringer over vannskillet på Dovrefjell og en 6-foldig økning i konsentrasjonene fra beitelokaliseringer fra den subalpine til den høyalpine sone om høsten. Den positive korrelasjon med høyden ble snudd om vinteren for dyr som beitet på skjegglav i den subalpine barskogsone.

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Introduction

Radiocesium concentrations have been monitored in wild reindeer following the Chernobyl accident from June 1986 until the present time in a study area at Dovrefjell (Fig. 1). The area encompasses the reindeer management units of Snøhetta to the west and Knutshø, Rondane north, mid and south, and Sølenkletten areas to the east. There is little exchange of animals between the units. The Snøhetta and Knutshø units are located on both sides of the east–west watershed.

Meteorological observations indicated that most fall-out had occurred on the east side of the watershed (NOU 1986, Skogland 1986).

Measurements of uptake of radiocesium in lichens (*Cetraria* and *Cladonia* spp. which are the major reindeer winter diet plants, depending on availability, Gaare and Skogland 1975, Skogland 1984) indicate an approximate 4.5-fold increase in levels from the low to the high alpine zone (Gaare 1986). Within-site variation in uptake in lichens is also very large (Gaare 1986, this volume). In this report I analyze the seasonal, geographical and altitudinal variation of radiocesium concentrations in adult (>1yr.) wild reindeer from the Dovrefjell study area. The results are based on samples of fresh upper hind leg muscle tissues taken from animals shot in the field in various parts of the study area. All mea-

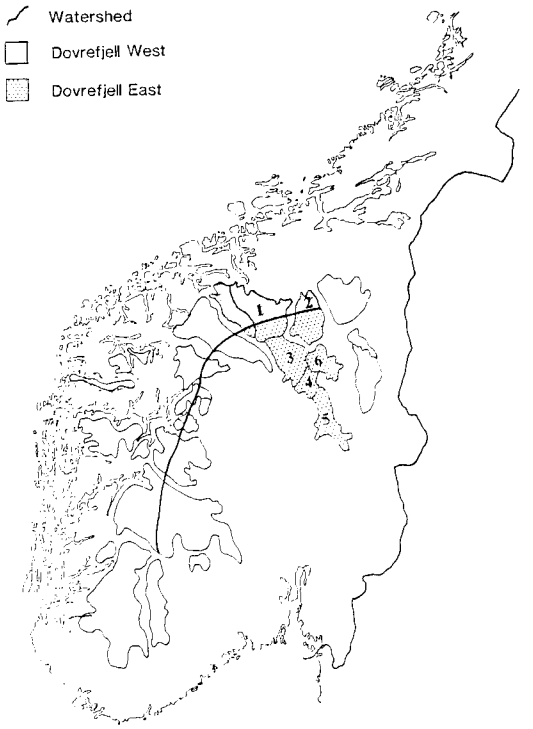

Figure 1. The geographical location of the study area at Dovrefjell in southern Norway (shaded parts). The line drawn along the coastal mountain range indicates the watershed. Each reindeer management unit within the shaded study area is marked by a number: 1 Snøhetta, 2 Knutshø, 3 Rondane north, 4 Rondane mid, 5 Rondane south, and 6 Sølenkletten. The other wild reindeer managements units in southern Norway are also shown on the map.

Figur 1. Beliggenheten av undersøkelsesområdet på Dovrefjell i Sør-Norge (skyggede partier). Den tykke linjen langs fjellkjeden angir vannskillet. Hvert villreinområde er markert med nummer: 1 Snøhetta, 2 Knutshø, 3 Rondane nord, 4 Rondane mellom, 5 Rondane sør og 6 Sølenkletten. De andre villreinområdene i Sør-Norge er også vist på kartet.

surements are the sum of Cs-134 and Cs-137 activities done according to standard procedures (Njåstad 1987).

Results and discussion

Seasonal variation

Seasonal variation in radiocesium concentrations in reindeer foraging from contaminated pastures has long been known (Hvinden 1961), and seasonal variation in *Rangifer* has been monitored for a long period (Hanson 1982). Models to explain seasonal variation have been developed (e.g. Holleman and Luick 1971). Their model predicts a 3–7-fold increase from a seasonal low value in August to a seasonal high in mid to late winter (Holleman and Luick 1971, White *et al.* 1986), while empirical data from Hanson (1982) show a 5–10-fold seasonal difference. Figure 2 shows the seasonal radiocesium concentration in wild reindeer from Dovrefjell east of the watershed. The seasonally lowest level of 8 KBq/kg in August increased to the highest seasonal level of 46 KBq/kg in late winter. The coefficient of variation (CV) of seasonal samples was very high. In September 1986 it was 52.6% at Dovrefjell (n=30, Fig. 2) and 62.5% (n=31) at Sølenkletten. The sample CV was 61.6% in winter (range 19–98 KBq/kg, n=29, Fig. 2).

Altitudinal variation

At Sølenkletten muscle radiocesium concentrations were significantly correlated with the altitudinal location where the animals had been collected (Fig 3, $r=0.76$, $p<0.001$, $df=31$). This reduced the CV from 62.5 to 23.7%. The regression predicts a 6-fold increase in radiocesium concentration in reindeer by an altitudinal increase in foraging location from the subalpine to high alpine zone. The sample CV from samples of animals shot in the mid-to high-alpine zone (1250–1500 m altitude) in winter was 32.4%. The CV in samples of animals shot in

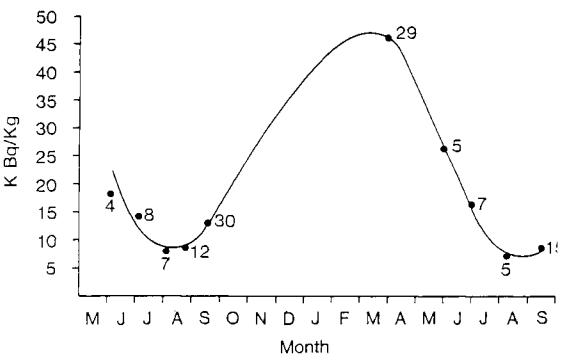

Figure 2. Seasonal radiocesium concentrations in wild reindeer east of the watershed at Dovrefjell. The number of sampled animals is shown on the graph.

Figur 2. Variasjonen i konsentrasjonen av radiocesium hos villrein øst for vannskillet på Dovrefjell. Antall undersøkte rein er vist på figuren.

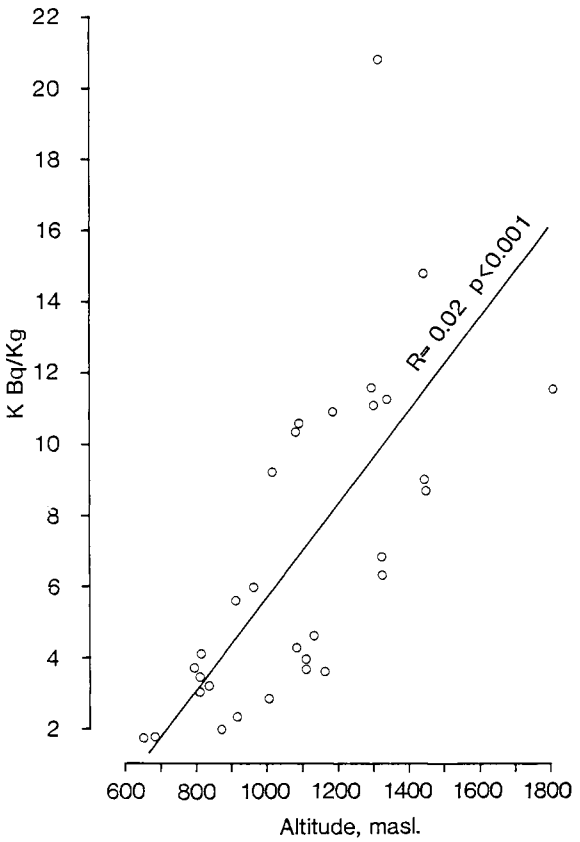

Figure 3. Radiocesium concentrations in wild reindeer from the Sølenkletten area during Aug./Sept. in relation to the altitudinal location where the animals were collected.

Figur 3. Konsentrasjonen av radiocesium hos villrein fra Sølenkletten gjennom august/september i forhold til dyrenes høydelokalisering.

the sub- to low-alpine zone (600–1200 m altitude) was 61%. Radiocesium concentrations were higher in samples from animals that had been feeding on arboreal lichens, compared to those that had been feeding on the mid-high-alpine barren-ground lichens dug from craters in the snow. The ground was partly snowcowered during the Chernobyl fall-out period, while arboreal lichens were completely snowfree. This could explain some of the variation. Unpublished measurements indicate that arboreal lichens had higher radiocesium concentration than ground lichens at low altitude. Hence the positive correlation between altitude and radiocesium concentrations in reindeer feeding on a mixed vascular-lichen autumn diet can be virtually reversed in winter if the animals move to the subalpine coniferous forest at lower altitudes and start to feed on arboreal lichens.

Geographical variation

If we disregard seasonal variation it was evident that both altitude and geographical location contribute to variation in radiocesium concentration in reindeer at Dovrefjell. Samples from animals harvested west of the watershed had consistently lower concentrations (Skogland 1986). A sample of harvested reindeer from the whole region collected during the regular hunting season (Au. 25 – Sept. 15) was divided into subsamples representing each of the 8 counties in which hunting was licensed. The mean radiocesium concentration from reindeer shot in each county was significantly correlated with the mean geographical distance of each county's reindeer hunting area from the watershed (Fig. 4). The comparison has been made using only material from animals shot above tree line in the low-high-alpine zone within each

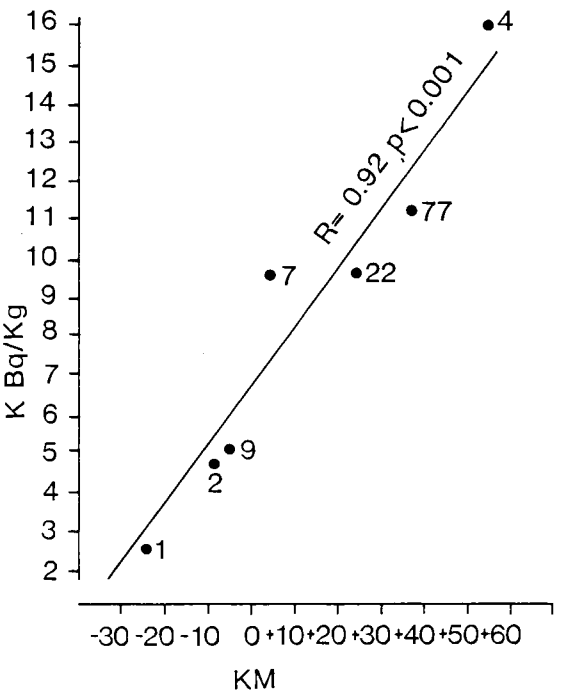

Figure 4. Mean radiocesium concentrations in wild reindeer from separate counties within wild reindeer management units located along a west-east gradient across the watershed at Dovrefjell. Aerial distance is measured in km from the watershed.

Figur 4. Gjennomsnittlig konsentrasjon av radiocesium fra forskjellige kommuner innen villreinområder beliggende langs en vest-øst gradient over vannskillet på Dovrefjell. Distanse i luftlinje fra vannskillet er angitt i km.

county. For animals sampled during the autumn season on alpine range, the regression model predicts that by moving eastwards an average increase of 1.4 KBq/kg muscle/10 km can be expected. Although reindeer move about during foraging, the short biological half time of radiocesium in reindeer feeding on green forage during summer (5–8 days, Holleman and Luick 1971) results in rapid turnover of ingested radiocesium. The rapid adjustments to the mean concentration within each selected foraging location, as found in this study, is probably a result of the short biological half time of radiocesium, although some of the variation is probably also due to the radiocesium body pool retention times.

Much of the within season variation in the fall-out pattern following the Chernobyl accident, reflected in tissue concentrations of radiocesium in wild reindeer at Dovrefjell, can be explained by geographical altitudinal factors. Seasonal variation in radiocesium concentrations follows pattern explained by changing seasonal food habits. The ratio of radiocesium per kg fresh reindeer muscle to lichen radiocesium concentration in lichen dry weight, sampled at approximately the same altitude, was 0.6 (Skogland 1987). This is similar to ratios found in *Rangifer* and lichens before the Chernobyl accident (see White et al. 1986). The low summer values found in this study are explained by the much lower concentrations of radiocesium in those vascular plants which comprise the summer diet of wild reindeer (Gaare and Skogland 1975, Skogland 1984, Bretten 1987).

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