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oppdragsmelding

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John Atle Kålås
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NATURENS TÅLEGRENSER
Miljøverndepartementet
Fagrapport 41

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NORSK INSTITUTT FOR NATURFORSKNING

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Abstract

Kålås, J.A., Ringsby, T.H. & Lierhagen, S. 1993. Metals and radiocesium in wild animals from the Sør-Varanger area, North Norway. - NINA Oppdragsmelding 212: 1-26.

This paper reports the concentrations of metals (Al, As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se and/or Zn) in kidney and/or liver samples, and radiocesium (^{137}Cs) in muscle or 'whole body' samples from common shrews, grey-sided voles, hares, capercaillie and/or willow ptarmigan from the Sør-Varanger area. Comparisons are drawn with reference data from further west in Finnmark and/or other parts of Norway and, for some metals, with data from areas close to the smelters on the Russian side of the border. The highest concentrations of, respectively, Cd, Zn and Pb were found in adult willow ptarmigan, Hg and Al in adult hares, Cr and Ni in livers from grey-sided voles, and Cu and Se in common shrew livers. As and Co concentrations were below our detection limits (As: 0.3 mg kg^{-1} dry weight, Co: 0.6 mg kg^{-1} dry weight, and 3 times higher for the common shrew samples) in all the samples. Compared with available reference data from Norway, the relatively highest levels were found for Cu and Ni in adult willow ptarmigan and hares, and Hg in adult hares. High Cu values were found at both Jarfjord and Pasvik. Concentrations exceeding 0.5 mg kg^{-1} Ni were found in the Jarfjord sub-area and, as regards willow ptarmigan, in the sub-area north of Varangerfjord (Nord-Varanger). Liver samples from grey-sided voles from the Sør-Varanger area also showed relatively high Ni concentrations, and Cr concentrations also seem to be increasing. However, for Ni and Cr no reference data are available for this species. Large differences in the concentrations of metals in animals from different locations may have natural causes (e.g. concentrations of metals in the soils, differences in diets, and so on), or be caused by the activity of man (e.g. pollution). On the basis of this study, it is difficult to draw a direct link between high metal concentrations in kidneys and/or livers and airborne pollution from the Russian smelters for other elements than Ni, Cu, Cr and probably to some extent Pb. The rather slight increase in Pb in willow ptarmigan in the area may, however, be explained by local air pollution. Also relatively high concentrations of Hg were found in adult hares, but regional differences within Sør-Varanger indicate there is no relationship to the Russian smelters. All the ^{137}Cs measurements were lower than the concentrations found on Dovrefjell, central Norway, in the years immediately following the Chernobyl reactor accident. No samples showed concentrations of the analysed metals in excess of the limits where negative effects on animals can be measured.

Key words: Metals, radiocesium, hare, grey-sided vole, common shrew, capercaillie, willow ptarmigan, Sør-Varanger.

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Referat

Kålås, J.A., Ringsby, T.H. & Lierhagen, S. 1993. Metaller og radiocesium i viltlevende dyr fra Sør-Varanger, Nord-Norge. - NINA Oppdragsmelding 212: 1-26.

Denne undersøkelsen er en del av en mere omfattende kartlegging av omfanget av lufttransporterte forurensinger i norske områder nær de russiske nikkel smelteverkene på Kola-halvøya. Arbeidet er initsiert av Ekspertgruppen for Studier av Effekter i Terrestre Økosystem under den felles Norsk-Russiske kommisjonen for Miljøsamarbeid. Denne undersøkelsen er i all hovedsak finansiert av Direktoratet for naturforvaltning. En rekke lokale personer og institusjoner har deltatt i innsamlingen av prøver (se foreword). Vi takker alle disse for et verdifullt samarbeide. Vi har kartlagt forekomster av metaller (Al, As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se, og/eller Zn) i lever og/eller nyre fra spissmus, gråsidemus, hare, storfugl og lirype fra Sør-Varanger området. Det inngår også målinger av forekomstene av radioaktivt cesium (137Cs) i muskel fra hare og lirype og "hele dyr" for gråsidemus fra dette området. Resultatene er sammenholdt mot prøver fra referanseområder fra vestligere deler av Finnmark og/eller med tilgjengelig informasjon fra andre deler av Norge. For enkelte av metallene er det også gjort sammenligninger med prøver fra russiske områder svært nær nikkel-smelteverkene. For Cd, Zn og Pb ble de høyest konsentrasjonene funnet i voksne liryper, mens Al og Hg konsentrasjonene var høyest i voksne harer, Cr og Ni var høyest i gråsidemus og mest Cu og Se ble funnet i spissmusene. For As og Co fant vi ingen verdier over våre deteksjonsgrenser (As: 0,3 mg kg-1, Co 0,6 mg kg-1 tørrvekt). Sammenlignet med tilgjengelige bakgrunnsdata fra Norge ble de relativt høyeste metallnivåene funnet for Cu og Ni i lirype og hare, og for Hg i hare. Høye Cu konsentrasjoner ble funnet både i Jarfjord og i Pasvik områdene. For Ni ble verdier over 0.5 mg kg-1 funnet i Jarfjordområdet og for lirype også på en lokalitet på nordsida av Varangerfjorden (Nord-Varanger). Leverprøver fra gråsidemus viser også høyest Ni verdier nærmest smelteverkene og for disse prøvene ser det også ut til å være forhøyede Cr verdier. Det foreligger imidlertid ikke bakgrunnsmateriale fra andre deler av landet for forekomster av disse metallene hos denne arten. Det kan være store forskjeller mellom dyr fra forskjellige områder når det gjelder forekomster av metaller i lever og nyre. Dette kan ha naturlige årsaker (forskjeller i metallforekomster i berggrunn/jordsmonn, forskjeller i diett osv.), eller det kan skyldes menneskelig aktivitet (eks. luftforurensing). I denne undersøkelsen dokumenterer vi forhøyede konsentrasjoner av Ni, Cu og Cr som etter all sansynlighet kan tilskrives luftforurensing fra de russiske nikkel-smeltevrkene. Pb verdiene synes også å være noe forhøyede i deler av Sør-Varanger området. Mønsteret i Pb forkomstene indikerer imidlertid at dette delvis skyldes lokal luftforurensing. De lokale forskjellene i forekomstene av Hg i Sør-Varanger indikerer at også de relativt høye Hg konsentrasjonene har andre årsaker enn forurensing fra Russland. Alle målte 137Cs konsentrasjonene ligger på bakgrunnsnivå og var lave sammenlignet med nivåer funnet på Dovrefjell de første åra etter Chernobyl reaktor ulykken. Alle målte metallkonsentrasjoner ligger betydelig under de grenser der negative effekter på fugler og dyr kan ventes, og de grenser som er satt for næringsmiddel for mennesker. Mere informasjon om vilt i kosthold kan fåes hos den lokale næringsmiddelkontrollen.

Emneord: Metaller, radiocesium, hare, gråsidemus, spissmus, storfugl, lirype, Sør-Varanger.

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Preface

This study is part of the research initiated by a group of experts set up by the Joint Norwegian-Russian Commission on Environmental Cooperation to study the effects of pollution on the terrestrial ecosystem. One of the main objectives was to study the environmental impacts of the Russian nickel smelters close to the Norwegian border. The study was mainly financed by the Directorate for Nature Management, but some additional support was given by the Environmental Office of the County Governor of Finnmark.

We are grateful to G. Henriksen and E. Lund from the Environmental Office of the County Governor of Finnmark, S.E. Nordhus from the Kirkenes Regional Office of the Directorate for State Forests and Land, and G. Gulbrandsen from the Norwegian Association of Hunters and Anglers, Finnmark Region, for organising the collection of animals, and all the local hunters who helped to collect samples of game species. We also wish to thank Steinar Wikan and the border guards (GSV), Korpfjell and Elvenes, for collecting the small mammals. The Zoological Museum at the University of Bergen kindly carried out species identification of all the small mammals as well as extracting and measuring liver samples from the common shrews. The skins and/or bones of the common shrews are preserved there. We are also indebted to E. Gaare, E. Løbersli, I. Myklebust, T. Nygård and E. Steinnes for valuable discussions and comments on the manuscript, and to Richard Binns for improving the English.

Trondheim March 1993

John Atle Kålås

Contents

1 Introduction

This study is part of the research initiated by a group of experts set up by the Joint Norwegian-Russian Commission on Environmental Cooperation to study the effect of pollution on the terrestrial ecosystem. One of the main objectives was to study the environmental impacts of the Russian nickel smelters. This report gives data on the metal load in livers and kidneys of wild animals living in the part of Norway most strongly affected by airborne pollution from the Russian smelters (Sivertsen et al. 1992).

Several studies have shown that elevated levels of heavy metals in birds and mammals may be lethal or give sub-lethal effects such as reduced growth, anaemia, kidney lesions and testicular damage as well as behavioural effects (see Eisler 1985, 1987, 1988a, 1988b, Pedersen & Nybø 1989, Nybø 1991, McBee & Bickham 1991, Scheuhammer 1991). Increased availability of metals to plants, and through them to herbivorous birds and animals, may be caused by either direct addition of metals to ecosystems from human activity or increased availability of heavy metals due to increased soil acidity (Løbersli 1991, Scheuhammer 1991).

The Sør-Varanger area in Finnmark, North Norway is affected by airborne pollution from the nickel smelters on the Kola peninsula (Sivertsen et al. 1992). This report presents data about the concentrations of metals (As, Al, Cd, Co, Cr, Cu, Hg, Ni, Pb, Se and Zn) in kidneys and/or livers from capercaillie (*Tetrao urogallus*), willow ptarmigan (*Lagopus lagopus*), hares (*Lepus timidus*), common shrews (*Sorex araneus*) and grey-sided voles (*Clethrionomus rufocanus*) from the Sør-Varanger area. The results are compared with reference data from western Finnmark and information on metal concentrations in animals from other parts of Norway (Kålås & Lierhagen 1992, Kålås et al. 1992a, 2b). For some metals, comparison has also been possible with areas close to the large nickel smelters on the Russian side of the border (Glazov et al. 1992). Concentrations of radiocesium (^{137}Cs) in willow ptarmigan, hares and grey-sided voles are also presented.

2 Methods

2.1 Study areas

Sør-Varanger
Samples of birds and hares from the Sør-Varanger area have come from 6 sub-areas (**Figure 1**). Jarfjord (north of the smelters) and Svanvik (west of the smelters) are the sub-areas expected to be most affected by air pollution (Aamlid 1992). Less pollution can be expected in the northern part of Pasvik (N-Pasvik), southern part of Pasvik (S-Pasvik), Neiden and Nord-Varanger sub-areas (Aamlid 1992, Sivertsen et al. 1992). Small mammals were collected from three locations (Korpfjell, Elvenes and Svanvik) (**Figure 1**); those from Korpfjell and Svanvik can be expected to register the highest pollution levels.

Reference areas
Reference data for willow ptarmigan were collected from Stilla (Alta), Tamsøy (Porsanger) and Øvre Anarjokka (Kautokeino), and for hares from Hasvik (Hasvik) (**Figure 1**). Concentrations of metals in these two species were also compared with samples from other parts of Norway (Kålås & Lierhagen 1992, Kålås et al. 1992a). Reference data for common shrews were collected from Karasjok (Karasjok) and Kongsfjord (Berlevåg). In the case of grey-sided voles, data for seven of the metals could be compared with similar data on bank voles (*Clethrionomys glareolus*) from other parts of Norway (Kålås et al. 1992b).

2.2 Materials

About 300 birds and mammals were collected from the Sør-Varanger area. Of these, 138 were selected to analyse for metal concentrations and 81 for radiocesium concentrations (**Table 1**). Of the willow ptarmigan, it was mainly adults (> 1.2 years) that were selected for metal analysis. The age of young willow ptarmigan varied between 3 and 5 months. In the case of hares and capercaillie, both adults (hares: > 1 year; capercaillie: > 1.2 years) and young (hares: 2-7 months; capercaillie: 3-4 months) were included. Only sexually mature grey-sided voles were analysed (body weight 29-38 g wet weight (WW), approximate age 1-4 months). Both immature and mature common shrews were analysed (body weight 6.5-11.5 g (WW), approximate age 0.5-4 months). The willow ptarmigan samples were evenly distri-

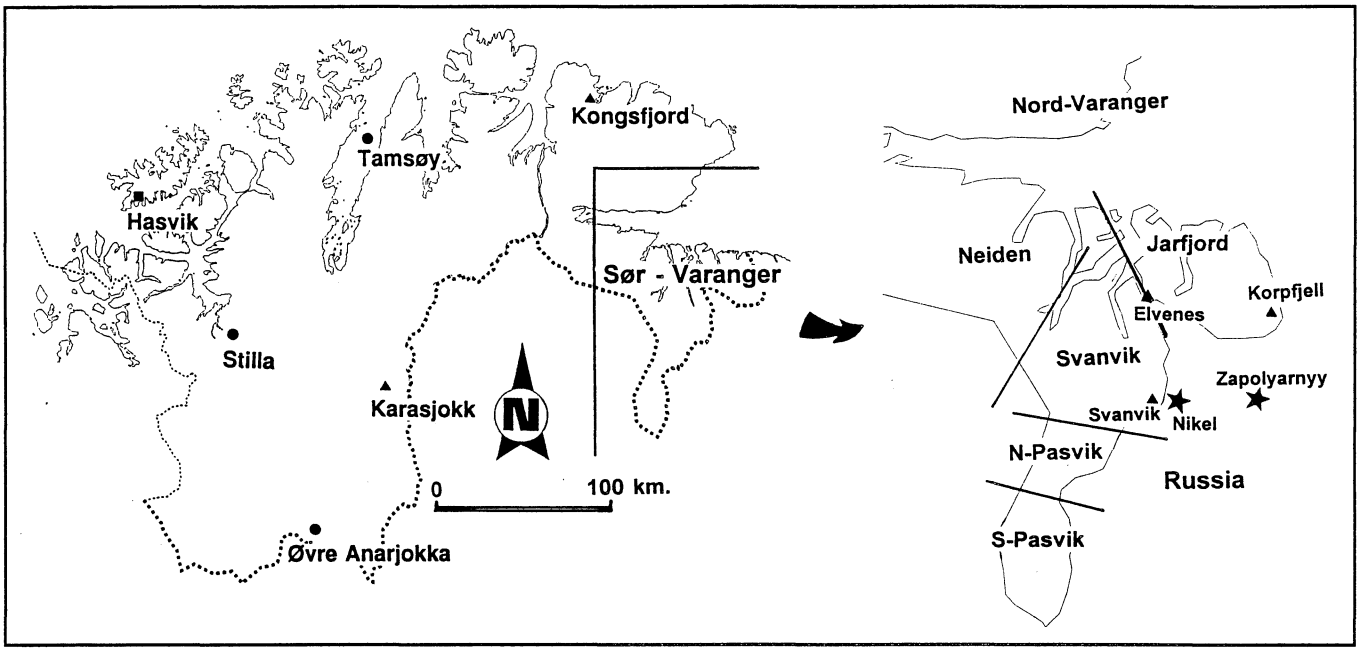

Figure 1. The areas studied in Sør-Varanger (at right divided in sub-regions), and reference areas elsewhere in Finnmark for willow ptarmigan (dots), hares (squares) and common shrews (triangles). Stars show the closest Russian smelters. - Undersøkelsesområdet i Sør-Varanger (til høgre oppdelt i regioner) og referanseområder i Finnmark, lirype (sirkel), hare (firkant), spissmus (triangel). Stjernene viser de nærmeste russiske smelteverkene.

Table 1. Animals collected from the Sør-Varanger area and the reference areas in Finnmark, and analysed for metal concentrations and ^{137}Cs, respectively. - Dyr samlet i Sør-Varanger området og i referanseområder i Finnmark og analysert for forekomster for henholdsvis metaller og radiocesium (^{137}Cs).

	Metals		Radiocesium	
Species	Sør-Varanger No. indiv.	Reference areas No. indiv.	Sør-Varanger No. indiv.	Reference areas No. indiv.
Willow ptarmigan				
Juveniles	14	-	-	-
Adults	40	9	20	6
Capercaillie				
Juvenile	9	-	-	-
Adults	5	-	-	-
Hare				
Juvenile	17	3	11	1
Adults	10	2	9	2
Grey-side vole				
Adults	18	-	18	-
Common shrew	25	6	-	-

buted through Sør-Varanger (**Figure 2A**). The capercaillie samples came from the southern part of the area and the hare samples mainly from the northern part (**Figure 2B** & **2C**). Samples of adult willow ptarmigan (n = 5) and adult hares (n = 3) from Nord-Varanger are also included (**Figure 1**).

All birds and most hares were collected by local hunters during September - November 1991; seven hares were collected during November 1992 - January 1993. Before the hunting season started, all the hunters were instructed on how to handle and store the animals. Collection of game in Sør-Varanger was organised by the Directorate for State Forests and Land (Kirkenes Region). All small mammals were trapped in mouse traps. Shrews were trapped in the Svanvik sub-area in July 1990 (n = 2), September - October 1991 (n = 6) and September 1992 (n = 6). Shrews were collected at Korpfjell (n = 5) and Elvenes (n = 6) in September 1992, Kongsfjord in September 1990 (n = 2) and September 1991 (n = 2) and Karasjok in October 1991 (n = 2). All the grey-sided voles were trapped in September 1992. Animals were frozen (-20 °C) as soon as possible after being killed (max. 12 hrs for small mammals and 24 hrs for most samples of the game species). Details are given in **Appendix 1**.

2.3 Laboratory procedures

Only titanium tools were used when dissecting the birds and animals in the laboratory. Because of the small size of livers and kidneys, the same digestion procedure was used for all elements. The standard amount of tissue used to analyse for metal concentrations was 1.2-1.5 g (WW) of kidney and 1.0-1.2 g (WW) of liver. For willow ptarmigan this amounted to a whole kidney. In the case of capercaillie and hares a sample was taken across the middle of the kidney. Liver tissue was obtained by taking a sample across the liver. Because of the small size of common shrew livers, smaller samples (0.25-0.35 g WW) had to suffice.

Breast muscles from willow ptarmigan and leg muscles from hares were used to analyse for radiocesium. 'Whole body' samples were used in the case of grey-sided voles, but the liver was removed for metal analysis and the stomach and gut were removed to exclude variations caused by variations in the content of these organs. About 20 g (WW) were used for the radiocesium analysis.

2.4 Analytical methods

Metals. The kidney and liver samples were dried for about 17 hrs in a Christ LDC-1 freeze dryer. The final pressure and theoretical temperature for the freeze drying were 0.04 mbar and -50 °C, respectively. In the case of liver, the dry weights (DW) as a percentage of the wet weights (WW) were: common shrews 31.8 % (SD = 1.2, n = 17), grey-sided voles 27.4 % (SD = 1.4, n = 18), hares 27.1 % (SD = 2.7, n = 32), willow ptarmigan 31.9 % (SD = 2.1, n = 64), capercaillie 28.2 % (SD = 1.5, n = 14). Corresponding dry weight proportions for kidney were: hares 23.2 % (SD = 1.8, n = 32), willow ptarmigan 24.7 % (SD = 1.5, n = 55), capercaillie 23.8 % (SD = 1.3, n = 14).

Each sample (standard 0.3-0.4 g DW) was digested in 4.5 ml Scan pure concentrated (14.4 M) nitric acid (HNO_3) in a microwave oven (Milestone MLS 1200). The common shrew liver samples weighed 0.1-0.15 g DW. The elements were determined by atomic absorption spectroscopy (AAS) (Perkin Elmer Model 1100B). A graphite furnace (HGA 700) with an automatic sampler (AS 70) was used for Al, As, Cr, Pb and Se, and a hydride system (FIAS 200) with an automatic sampler (AS 90) for Hg. The othyer elements (Cd, Co, Cu, Ni and Zn) were analysed by flame AAS. All values are given as mg kg^{-1} DW. This procedure resulted in the following standard detection limits (all values as mg kg-1 DW, the numbers in brackets show the value used in the statistical analysis when a sample had a concentration below the detection limits): As = 0.3 (0.2), Al = 0.3 (0.2), Cd = 0.01, Co = 0.6 (0.4), Cr = 0.15 (0.1), Cu = 0.5, Hg = 0.015 (0.01), Ni = 0.5 (0.3), Pb = 0.2 (0.15), Se = 0.4 (0.3) and Zn = 0.5. The small size of common shrew livers required the detection limits for these samples to be 3 times higher than those given above.

No samples showed concentrations of As and Co in excess of the detection limits, and a large proportion of samples from common shrews contained concentrations below the detection limits for some other elements, too: Al 52 % of the samples, Cr 80 %, Hg 52 %, Ni 100 % and Pb 87 %. Lower concentrations than the detection limits were also found for some elements in other species (liver: Al 22 %, Cr 67 %, Hg 14 %, Ni 87 % and Pb 31 % (mainly for grey-sided voles), kidney: Al 15 %, Ni 84 % and Pb 19 %).

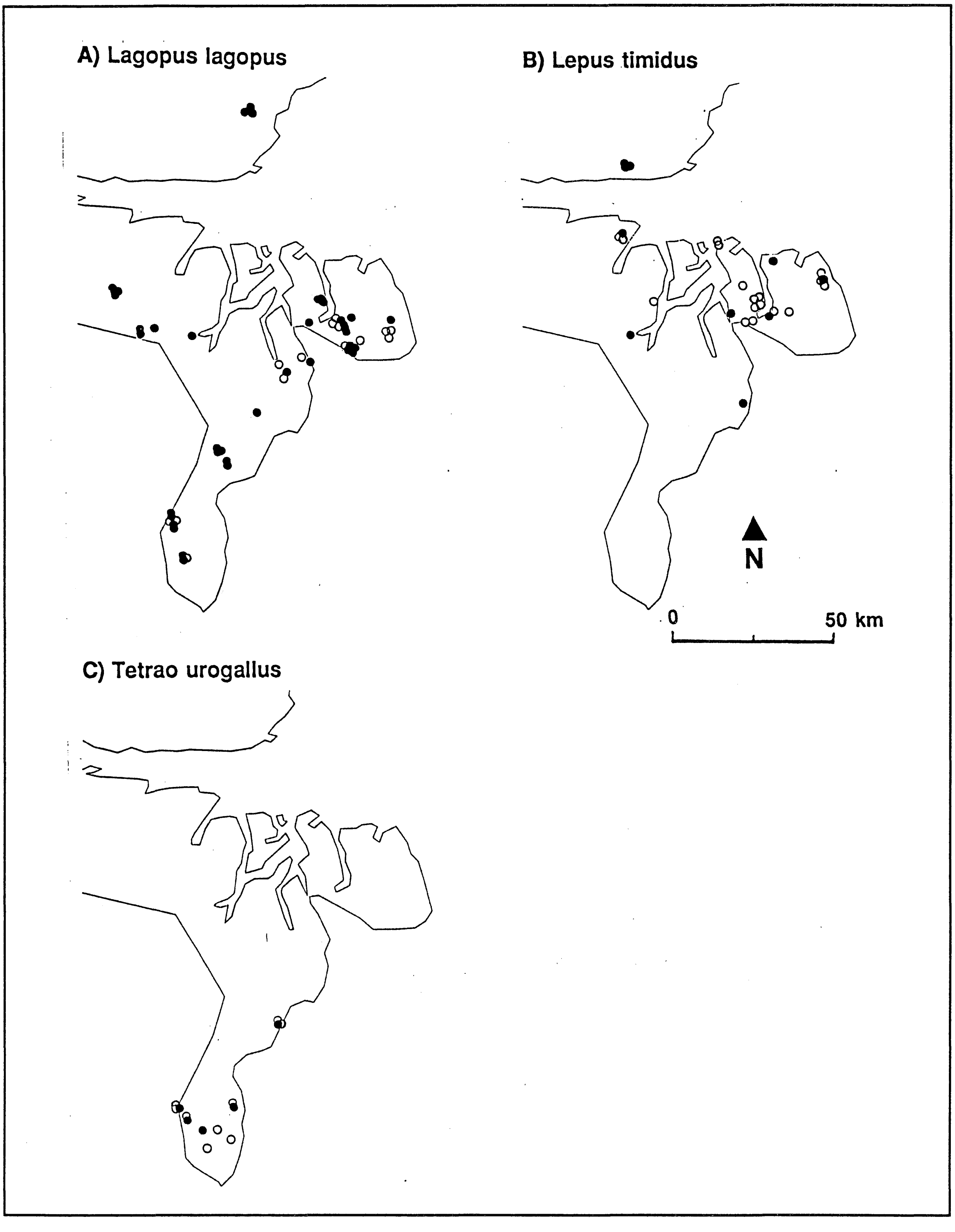

Figure 2. Location of samples from A) willow ptarmigan, B) hares, and C) capercaillie. Filled circles - adult animals, open circles - animals in their first year. - Fordeling av innsamlede prøver A) lirype, B) hare, C) storfugl. Fylte sirkler - voksne individer, åpne sirkler - unge individer.

Because of the low concentrations of Al in the tissues analysed, the results may be affected by Al contamination during sampling and laboratory procedures. Efforts were made to reduce such contamination. Blind samples indicate that Al contamination is restricted to < 5 % of the samples. To prevent such contamination influencing our conclusions, all Al measurements in excess of 10 mg kg^{-1} (3 % of all Al analysis) have been excluded. Pb contamination may also occur through the use of lead cartridges when some of the game was obtained. All Pb measurements in excess of 10 mg kg^{-1} (4 % of all Pb analysis) have therefore been excluded.

The accuracy of the analytical procedures was checked against the National Bureau of Standards (NBS) for bovine liver 1577A ((Al), Cd, Cu, Hg, Pb, Se, Zn), dogfish liver DOLT-1 (As, Cd, Cr, Cu, Hg, Pb, Se, Zn) and dogfish muscle DOLM-1 (As, Cd, Cu, Cr, Hg, Ni, Pb, Se, Zn). The accuracy of the analytical procedures seems good for most metals (**Table 2**). However, only about 50 and 70 % of the concentrations given for Cr in the two dogfish standards could be detected. For Cr similar detection rate was found in the study of metals in large mammals in the Sør-Varanger area (Sivertsen et al. 1991). For Ni we were not able to detect levels above our detection limit (0.5 mg $^{-1}$) for the Dogfish muscle standart (certified values 0.9-1.5 mg kg^{-1}) indicating that our digestion procedures were not abel to extract all Ni present in the tissue samples.

Radiocesium. The muscle and 'whole body' samples were cut into small pieces and dried for about 48 hrs at 60 °C. About 6 g (DW) were used for the radiocesium analysis. The dry weights (DW) of muscle as percentages of the wet weights (WW) were 22.7 % (SD = 1.2, n = 9) for hares and 26.6 % (SD = 0.9, n = 15) for willow ptarmigan, and for 'whole body' (grey-sided voles) they were 29.4 % (SD = 1.5, n = 18). All radiocesium values are given as ^{137}Cs Bq kg^{-1} DW.

Radiocesium was quantified by integral counts (460-932 KeV counting windows) using an LKB Wallace: CompuGamma 1282 3"x3" NaI detector (active volume = 15.7 cm^2) connected to an LKB Wallace 1224 computer. ^{137}Cs was measured against a standard analysed with a HPE - detector at the Isotop laboratory at the University of Trondheim. Næumann & Gaare (1991) give a fuller description of the analytical procedures. The ptarmigan and hare samples were counted for 3 hrs and the grey-sided vole samples for 10 hrs, resulting in a detection limit of 50 Bq kg^{-1} DW. No samples were below this limit.

Table 2. International reference standards (National Bureau of Standards) analysed. Values are given as mg kg^{-1}. - Analyserte referansestandarder for kontroll av analysekvalitet. Alle verdier gitt som mg kg^{-1}.

	Certified value Sertifisert verdi			Present work Denne studien		
Standard/Element	x	min	max	x	s.d	n
Bovine liver (1577A)						
Aluminium (Al)	0.8*			0.78	0.14	10
Cadmium (Cd)	0.44	0.38	0.50	0.45	0.11	25
Copper (Cu)	158	151	165	162	15.4	61
Mercury (Hg)	0.004	0.002	0.006	0.004	0.002	5
Lead (Pb)	0.14	0.12	0.16	0.14	0.06	43
Selenium (Se)	0.71	0.64	0.78	0.77	0.04	5
Zink (Zn)	123	115	131	133	10.3	61
Dogfish-liver (DOLT-1)						
Arsenic (As)	10.1	8.7	11.5	6.92	0.51	9
Cadmium (Cd)	4.18	3.9	4.46	3.99	0.23	7
Copper (Cu)	20.8	19.6	22.0	18.0	1.49	7
Cromium (Cr)	0.40	0.33	0.47	0.30	0.02	4
Mercury (Hg)	0.225	0.188	0.262	0.236	0.019	7
Lead (Pb)	1.36	1.07	1.65	1.12	0.22	7
Selenium (Se)	7.34	6.88	7.76	6.58	0.25	6
Zink (Zn)	92.5	90.2	94.8	82	4.4	6
Dogfish-muscle (DOLM-1)						
Arsenic (As)	17.5	15.6	19.8	17.4	3.5	8
Cadmium (Cd)	0.086	0.074	0.098	0.098	0.01	4
Copper (Cu)	5.22	4.89	5.55	5.8	0.27	6
Cromium (Cr)	3.6	3.2	4.0	1.7	0.27	8
Mercury (Hg)	0.79	0.71	0.07	0.67	0.02	8
Lead (Pb)	0.40	0.28	0.52	0.39	0.12	10
Selenium (Se)	1.62	1.50	1.74	1.43	0.28	4
Zink (Zn)	21.3	20.3	22.3	20.5	1.5	6

* - The standard material is not certified for Al. The indicated value is the approximate consentration given by Veterinærinstuttet, Oslo (0,77) and the University of Umeå (0,84) (see Sivertsen 1991). - Standarden ikke sertifisert for Al. Oppgitt verdi er nivå funnet av Veterinærinstituttet (0,77) og Universitetet i Umeå (0,84) (se Sivertsen 1991).

3 Results and discussion

3.1 Metals

The highest concentrations of Cd and Pb were detected in livers from adult willow ptarmigan and the highest Zn concentrations were in willow ptarmigan and hare kidneys. The highest concentrations of Al and Hg were found in adult hare livers and kidneys, respectively. The Cr and Ni concentrations were highest in grey-sided vole livers, and Cu and Se concentrations were highest in common shrew samples (**Table 3**). All measurements of As and Co were below the respective detection limits.

When the two grouse species from the Pasvik sub-areas were compared, kidney samples showed that concentrations of most metals were significantly higher in adult willow ptarmigan (n = 11) than in adult capercaillie (n = 5) (**Table 4**) (Cd: $p < 0.002$, U = 1.0; Cu: $p < 0.09$, U = 12.5; Zn: $p < 0.001$, U = 1.0) (Mann-Whitney U-test). The highest values of Hg were found in capercaillie ($p < 0.02$, U = 5.5).

Samples of both young and adult capercaillie, hares, common shrews and some willow ptarmigan were analysed. For most metals, the highest values were found in adults. In the case of liver samples, these differences were significant for Cd ($p < 0.003$) in capercaillie, Al ($p = 0.046$), Cd ($p < 0.0001$), Cu ($p = 0.014$) and Hg ($p < 0.012$) in hares from Sør-Varanger, and Cd ($p < 0.0001$) and Pb ($p=0.05$) in willow ptarmigan from Jarfjord and Svanvik (all tested by the Kruskal-Wallis test, corrected for ties). Common shrew samples showed a significant relationship between body weight (representing age) and Cd in the liver (r = 0.55, n = 31, p = 0.001).

The concentrations of some metals (Al, Cd, Cu, Hg, Ni, Pb and Zn) in the kidneys of willow ptarmigan, capercaillie and hares were also determined, revealing that Cd, Cu, Hg, Ni and Zn had the highest concentrations in kidneys compared with livers; no distinct differences in Al and Pb could be detected. Three of the metals showed significant relationships between concentrations in livers and kidneys (e.g. the willow ptarmigan sample from Sør-Varanger (n = 40): Al: r = 0.36, p = 0.02; Cd: r = 0.72, $p < 0.0001$; Hg: r = 0.53, p = 0.0006), whereas no significant relationship was found for the other four metals for this sample (Cu: r = 0.25, p = 0.11; Zn: r = 0.28, p = 0.09; Pb: r = 0.02, p = 0.89). Moreover, most samples showed the same relationship between the concentrations of Cd, Cu and Zn in kidneys as was convincingly demonstrated by Elinder & Piscator (1978) and Myklebust (1992) (e.g. the adult willow ptarmigan kidney sample from Sør-Varanger (n = 40): Cd-Cu: r = 0.63, $p < 0.0001$; Cd-Zn: r = 0.86, $p < 0.0001$; Cu-Zn: r = 0.78, $p < 0.0001$, the grey-sided vole sample (n = 18): Cd-Cu: r = 0.46, p = 0.05, Cd-Zn: r = 0.41, p = 0.09, Cu-Zn: r = 0.91, $p < 0.0001$, and the common shrew sample from Sør-Varanger (n = 31): Cd-Cu: r = 0.14, p = 0.46, Cd-Zn: r = 0.25, p = 0.16, Cu-Zn: r = 0.55, p = 0.001).

Aluminium

The highest Al concentrations were found in hare livers (**Table 3**), but the levels were not particularly high compared with samples from other parts of Norway (Kålås & Lierhagen 1992). None of the species studied showed significant differences between the sub-areas in Sør-Varanger, or between the Sør-Varanger sample and reference areas (**Table 5**).

Arsenic

The As concentrations in livers never exceeded the detection limits of our analytical procedures (0.9 mg kg^{-1} for the common shrew, and 0.3 mg kg^{-1} for other species). As concentrations in birds and mammals are usually very low (Nyholm 1986). The study carried out by Sivertsen et al. (1991) on metals in livers of reindeer, elk and sheep in Sør-Varanger revealed that only the reindeer sample from Jarfjord had a higher concentration than 0.07 mg kg^{-1} WW (approximately 0.3 mg kg^{-1} DW). Although our study was inappropriate for detecting low-level pollution of As, it at least shows that extensive As pollution of wildlife does not exist in the Sør-Varanger area.

Cadmium

Kidneys from adult willow ptarmigan showed the highest concentrations of Cd (**Table 4**) and significant differences were found between the sub-areas in Sør-Varanger and when Sør-Varanger was compared with the reference areas in Finmark (**Table 5**). However, liver concentrations were not particularly high compared with samples from elsewhere in Norway (Kålås & Lierhagen 1992). Data from other parts of Norway indicate that Cd levels in willow ptarmigan are considerably affected by the proportion of willow shrubs (*Salix* spp.) in the winter diet of the birds (Myklebust 1992). Willow shrubs may have very high natural concentrations of Cd (Kålås et al. 1991, Myklebust 1992), and willow ptarmigan and hares selectively feed on willow

Table 3. Sample sizes and mean concentrations of metals (mg kg^{-1}) in liver samples from animals collected i Sør-Varanger area and reference areas in Finnmark county. Where < 25 % of the analyses of a metal were above the detection limit for that metal only those samples showing concentrations above that limit (D), and the total sample size (N) are given, as D/N. < - idicates that every value in this sub-sample is below the detection limit. - Anall prøver (sample) og gjennomsnittlige konsentrasjoner av metaller (mg kg^{-1}) i lever fra dyr innsamlet i Sør-Varanger og referanseområder i Finnmark. Dersom under 25 % av analysene var over deteksjonsgrensen for et metall, er antall prøver over denne grensen (D) og totalt antall prøver analysert (N) vist i tabellen som D/N. < - viser at alle verdiene innen dette området var under deteksjonsgrensen. juv - ung, ad - voksen.

Sample	Sample juv	Sample ad	Al juv	Al ad	Cd juv	Cd ad	Cr juv	Cr ad	Cu juv	Cu ad	Hg juv	Hg ad	Ni juv D/W	Ni ad D/W	Pb juv	Pb ad	Se juv	Se ad	Zn juv	Zn ad
Willow ptarmigan																				
Sør-Varanger																				
Jarfjord	8	14	0.50	0.90	1.0	6.8	0.27	0.10	12.7	13.4	0.042	0.034	0/8	0/14	1.23	0.65	0.71	0.80	97	92
Svanvik	3	3	0.69	1.22	3.6	7.3	0.30	0.13	10.7	12.6	0.035	0.036	1/3	0/3	1.28	1.08	0.73	0.75	72	78
N-Varanger		5		0.44		6.2		0.07		12.5		0.029		0/5		1.26		0.85		84
Neiden		7		0.69		3.9		0.18		10.7		0.026		0/7		1.01		0.56		72
N-Pasvik		5		0.62		7.0		0.11		10.8		0.036		0/5		0.46		0.50		71
S-Pasvik	3	6	1.10	0.47	1.0	9.8	0.14	0.23	12.2	12.1	0.051	0.042	0/3	0/6	0.53	0.57	0.69	0.75	71	85
Reference areas																				
Porsanger		3		0.33		6.0		<0.1		12.2		0.017		0/3		1.94		0.45		99
Øvre Anarjokka		2		1.51		8.1		<0.1		13.8		0.039		0/2		0.44		0.47		88
Alta		4		0.24		4.1		<0.1		13.9		0.054		0/4		0.92		0.59		94
Capercaillie																				
Sør-Varanger																				
N-Pasvik	2	1	0.81	<0.3	1.5	6.3	0/2	0/1	10.4	10.4	0.020	<.015	0/2	0/1	<0.2	0.29	0.77	0.74	76	145
S-Pasvik	7	4	1.09	1.22	1.7	4.1	0/7	0/4	10.6	9.7	0.041	0.019	0/7	0/4	0.25	0.18	0.86	0.80	76	70
Hare																				
Sør-Varanger																				
Jarfjord	14	4	1.77	4.37	0.57	1.9	2/14	0/4	14.3	13.5	0.028	0.101	1/14	0/4	0.54	1.18	0.85	1.69	96	107
Svanvik		1				4.1		0/1		13.0		0.596		0/1		<0.2		1.16		109
N-Varanger		3		4.40		4.6		0/3		10.9		0.069		0/3		1.13		0.99		99
Neiden	3	2	6.15	4.63	0.37	1.3	0/3	0/2	13.9	9.6	0.063	0.105	2/3	1/2	0.34	0.32	1.55	1.85	95	77
Reference area																				
Hasvik	3	2	2.33	4.45	0.33	0.61	0/3	0/2	17.9	14.9	0.017	0.024	0/3	0/2	0.24	1.64	0.85	0.58	113	97
Grey-side vole																				
Korpfjell		6		1.19		1.67		0.21		13.8		0.027		0.70		1/5		1.68		86
Svanvik		6		0.70		1.14		0.19		12.8		0.081		0.72		1/6		1.67		82
Elvenes		6		0.76		0.57		0.17		13.2		0.157		0.49		1/6		1.77		84
Common shrew																				
Korpfjell		5		0/4		1.76		1/5		23.3		3/5		0/5		3/5		4.58		75
Svanvik		14		3/14		3.70		3/14		22.6		2/14		0/14		0/14		3.89		74
Elvenes		6		1/5		1.97		0/5		23.2		1/6		0/6		1/6		3.57		72
Reference areas																				
Karasjokk		2		1/2		2.50		1/2		21.2		2/2		0/2		0/2		4.51		67
Kongsfjord		4		2/4		1.85		1/4		19.8		1/4		0/4		0/4		5.90		67

Table 4. Sample sizes and mean concentrations of metals (mg kg^{-1}) in kidney samples from animals collected i Sør-Varanger area and reference areas in Finnmark county. Where < 25 % of the analyses of a metal were above the detection limit for that metal only those samples showing concentrations above that limit (D), and the total sample size (N) are given, as D/N. < - idicates that every value in this sub-sample is below the detection limit. - Anall prøver (sample) og gjennomsnittlige konsentrasjoner av metaller (mg kg^{-1}) i nyre fra dyr innsamlet i Sør-Varanger og referanseområder i Finnmark. Dersom under 25 % av analysene var over deteksjonsgrensen for et metall, er antall prøver over denne grensen (D) og totalt antall prøver analysert (N) vist i tabellen som D/N. < - viser at alle verdiene innen dette området var under deteksjonsgrensen. juv - ung, ad - voksen.

	Sample		Al		Cd		Cu		Hg		Ni		Pb		Zn	
Sample	juv	ad	juv	ad	juv	ad	juv	ad	juv	ad	juv	ad	juv	ad	juv	ad
Willow ptarmigan																
Sør-Varanger																
Jarfjord		14		2.74		111		18.1		0.103		6/14		1.20		122
Svanvik		3		1.19		104		21.5		0.091		0/3		1.07		127
N-Varanger		5		1.71		74		15.8		0.079		2/5		0.88		114
Neiden		7		0.74		53		15.7		0.089		0/8		0.58		106
N-Pasvik		5		2.69		114		18.1		0.095		0/5		0.47		132
S-Pasvik		6		0.92		121		19.1		0.097		0/6		0.58		124
Reference areas																
Porsanger		3		0.90		68		13.7		0.041		0/3		0.15		105
Øvre Anarjokka		2		6.09		66		15.2		0.115		0/2		0.42		109
Alta		4		0.82		24		15.5		0.087		0/4		1.05		103
Capercaillie																
Sør-Varanger																
N-Pasvik	2	1	1.85	1.12	5.2	29	13.8	17.8	0.096	0.103	0/2	0/1	0.28	0.61	83	89
S-Pasvik	7	4	3.77	1.19	4.8	31	14.6	15.3	0.220	0.230	0/7	0/4	0.25	0.54	87	93
Hare																
Sør-Varanger																
Jarfjord	14	4	1.01	1.74	4.5	32	15.9	16.4	0.224	0.538	5/14	2/4	0.75	0.61	101	109
Svanvik		1		0.96		102		19.2		0.641		0/1		<0.2		130
N-Varanger		3		0.83		103		15.6		0.377		0/3		0.43		130
Neiden	3	2	2.62	0.74	2.5	47	16.8	18.8	0.323	0.734	0/3	0/2	0.28	0.20	94	132
Reference area																
Hasvik	3	2	1.53	1.27	2.5	16	16.5	18.9	0.073	0.145	0/3	0/2	0.24	0.52	105	111

Table 5. Kruskal - Wallis tests (corrected for ties) for differences between sub-areas of the Sør-Varanger area, and between the Sør-Varanger samples and reference samples from Finnmark for adult willow ptarmigan, young hare, grey-side vole and common shrew samples. χ^2 - Chi-square value (Yates corrected), p - shows probability. Where > 40 % of the analysis of a metal were above the detection limit for that metal, differences were tested by comparing the number of samples above the limit with the number of samples below it by using a Chi-square test. - Statistiske tester for forskjeller mellom områder innen Sør-Varanger og mellom Sør-Varanger og referanseområdene i Finnmark. χ^2 - Chi-kvadrat, p - sansynlighet.

	Al		Cd		Cr		Cu		Hg		Ni		Pb		Se		Zn	
Sample	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p	χ^2	p
Willow ptarmigan, adults																		
Liver:																		
Within Sør-Varanger	4.53	0.48	7.42	0.19	12.50	0.029	7.81	0.17	4.25	0.51			6.14	0.29	11.60	0.04	8.39	0.14
Sør-Varanger-Reference	2.75	0.10	1.04	0.31	5.09	0.024	2.13	0.14	0.66	0.42			0.01	0.92	5.96	0.015	7.86	0.005
Kidney:																		
Within Sør-Varanger	8.51	0.13	11.68	0.04			11.58	0.04	1.96	0.85	11.52	0.04	6.23	0.28			8.28	0.14
Sør-Varanger-Reference	0.08	0.78	8.43	0.004			7.94	0.005	0.72	0.40			0.71	0.40			5.94	0.015
Common shrew																		
Liver:																		
Within Sør-Varanger	1.70	0.43	3.67	0.16	1.27	0.53	0.26	0.88	4.25	0.12			9.85	0.007	3.46	0.18	1.56	0.46
Sør-Varanger-Reference	2.48	0.12	0.20	0.65	0.12	0.73	7.48	0.005	3.89	0.05			1.86	0.17	6.41	0.01	4.41	0.04
Grey-side vole																		
Liver:																		
Within Sør-Varanger	2.90	0.24	3.82	0.14	0.01	0.47	0.69	0.71	8.22	0.016	2.27	0.32	0.03	0.99	0.56	0.76	0.97	0.62

shrubs in winter where these are available (Norris et al. 1979, Karlsen 1983). Hence, in both willow ptarmigan and hares it is very difficult to detect any extra load of Cd caused by pollution. In agreement with the food preference hypothesis, adult capercaillie from Pasvik, which mainly feed on pine needles, show significantly lower concentrations of Cd in kidney than adult willow ptarmigan from the same district ($p < 0.002$, $U = 1.0$) (Mann-Whitney U-test) (**Table 4**). Both the grey-sided vole and common shrew samples showed normal Cd levels (Nyholm 1986, Kålås et al. 1992b), as did the common shrews collected close to the Russian smelters (Glazov et al. 1992).

Cobalt

The Co concentrations in livers never exceeded the detection limits of our analytical procedures (1.5 mg kg^{-1} for common shrews and 0.5 mg kg^{-1} for other species). Co concentrations in birds and mammals are usually below these levels (Nyholm 1986). The study carried out by Sivertsen (1991) on metals in livers of reindeer, elk and sheep in Sør-Varanger revealed that only the reindeer sample from Jarfjord had a higher concentration than 0.2 mg kg^{-1} WW (approixmately 0.8 mg kg^{-1} DW). The analytical method used is unable to detect low-level pollution of Co. Glazov et al. (1992) found only two common shrew samples from very close to the Russian smelters that had higher Co concentrations than 0.6 mg kg^{-1} DW. The present study, however, at least indicates that there is no extensive Co pollution in the Sør-Varanger area.

Chromium

Only low concentrations of Cr were found in the liver samples analysed (**Table 3**). The highest ones were found in willow ptarmigan and grey-sided voles. Significantly higher concentrations were found in willow ptarmigan from the Sør-Varanger area compared with those from reference areas (**Table 5**). Glazov et al. (1992) found 0.6 mg kg^{-1} DW of Cr in common shrew livers close to the smelters (up to 5-6 km) and 0.1 mg kg^{-1} 20 km south of the smelters. Cr concentrations in excess of 0.3 mg kg^{-1} were found in only 4 of the 25 samples of common shrews from the Sør-Varanger area analysed. The analyses of NBS reference standards indicate that we were unable to detect all the Cr present in the samples by using HNO_3 digestion. Hence, the Cr concentrations in the samples from Sør-Varanger are probably somewhat higher (50-80 %) than are given here.

Copper

As regards liver samples, the highest concentrations of Cu were found in common shrews (**Table 3**) and these were significantly higher in Sør-Varanger than in the reference areas (**Table 5**). However, compared with results from other studies, the concentrations do not seem particularly high, either for common shrews (Hunter et al. 1981, 1982) or voles (Hunter et al. 1981, Kålås et al. 1992b). In the case of common shrew livers, considerably higher Cu-concentrations have been found close to the Russian smelters (Glazov et al. 1992). Liver samples from grouse and hares showed no tendency for increased Cu concentrations compared with samples from other parts of Norway (Kålås & Lierhagen 1992). The kidneys are known to accumulate Cu to a greater extent than the livers (Myklebust 1992) and kidney samples from grouse and hares showed high Cu concentrations. Compared with other parts of Norway (Kålås et al. 1992a), the Cu values found in adult willow ptarmigan and adult hares in Sør-Varanger were among the highest observed (**Table 4**). As regards willow ptarmigan, significant variations are found from one sub-area to another in Sør-Varanger (**Table 5**), the highest figures being recorded along the Russian border (Jarfjord, Svanvik and both Pasvik sub-areas). Our results are in accordance with increased concentrations of Cu found in some of the most important food plants for these species in these sub-areas (Aamlid 1992).

Mercury

Relatively low concentrations of Hg were found in both kidney and liver samples (**Tables 3** and **4**). The highest ones were in adult hare kidneys. The concentrations in the Jarfjord, Svanvik and Neiden sub-areas are higher than in any of the other twenty locations in Norway where Hg data are available (Kålås et al. 1992a). The reference values from Hasvik are also much lower than the Sør-Varanger samples. Even though sample sizes are low, this indicates increased Hg levels in the area. Adult willow ptarmigan kidneys, however, have only low concentrations of Hg, and no significant differences were found between the sub-areas in Sør-Varanger (**Table 5**). Compared with Hg levels in fish-eating mammals, insectivorous birds and raptors (Holt 1969, Nordheim et al. 1984), the concentrations found in hares in Sør-Varanger are still very low, in keeping with their low position in the food chain.

Nickel

In grouse and hares, kidneys were the type of sample most frequently containing higher Ni concentrations than the detection limit. Higher Ni values than 0.5 mg kg^{-1} (DW) were found in 15 of the 67 samples. Eight of these were from willow ptarmigan and seven from hares. Six of the willow ptarmigan were from the Jarfjord sub-area and two from Nord-Varanger (**Table 4**), resulting in significant differences from one part of the Sør-Varanger area to another (**Table 5**). All the high hare samples were from Jarfjord. No detectable concentrations were found in any of the other sub-areas or the reference areas. The highest values in liver samples were found in grey-sided voles (**Table 3**), the highest average concentrations of these being from the two locations closest to the Russian nickel smelters. These data support other studies showing elevated levels of Ni in the areas closest to the Russian smelters (Aamlid 1992, Sivertsen et al. 1992). The willow ptarmigan data also indicate that the south-eastern part of Nord-Varanger is affected by Ni pollution. The grey-sided vole samples showed a significant negative relationship between Ni concentration in the liver and the total body weight of the animal (r = 0.61, n = 18, p = 0.008) (**Figure 3**). No examples of higher concentrations of Ni than the

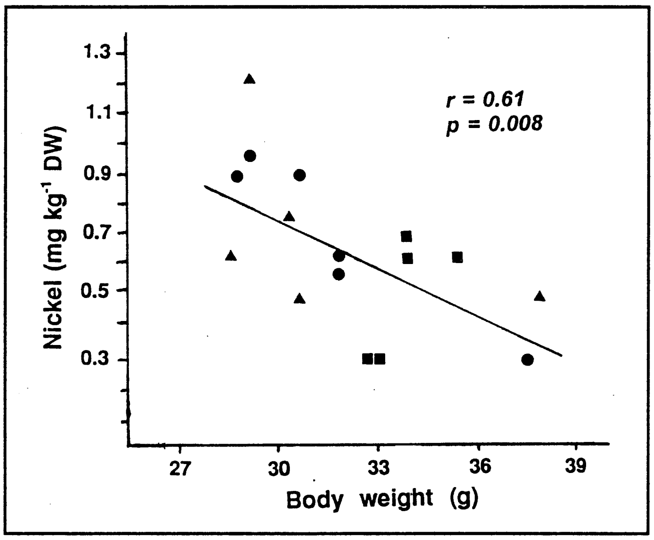

Figure 3. Relationship between the weight of grey-sided voles and the Ni concentration in liver for animals sampled at Svanvik (dots), Korpfjell (triangles) and Elvenes (squares) in Sør-Varanger (y = -0.051x + 2.30, r = 0.61, n = 18, p = 0.008). - Sammenhengen mellom kroppsvekt og nikel-innhold i lever for gråsidemus innsamlet ved Svanvik (sirkel), Korpfjell (triangel) og Elvenes (firkant) i Sør-Varanger.

detection limit (1.5 mg kg^{-1}) were found in common shrew livers. Such high values have only been measured very close to the Russian smelters (Glazov et al. 1992). The analyses of NBS reference standards indicate that we were unable to detect all the Ni present in the tissue samples. Hence, the Ni concentrations in the samples from Sør-Varanger are probably somewhat higher than are given here. However, Ni seems to be only sparsely absorbed from the gastrointestinal tract, and for mammals excretion in the urine is nearly complete in a few days after an the intake (Amadur et al. 1986). Hence, no strong Ni-accumulation can be expected by dietary intake of Ni.

Lead

The highest lead concentrations were found in the willow ptarmigan livers from the northern parts of Sør-Varanger (**Table 4**). Even though the values found in Jarfjord and Svanvik and Nord-Varanger are higher than those in most locations studied in central and northern Norway, they are only about 1/4 of the highest levels measured in southernmost Norway (Kålås & Lierhagen 1992). Low Pb concentrations were found in both grey-sided vole and common shrew livers. Measurements of 3.7 mg kg^{-1} Pb in common shrew livers reported by Glazov et al. (1992) from close to the smelters indicate relatively high Pb contamination in these areas. However, Pb concentrations in excess of 0.6 mg kg^{-1} were only found in 4 of the 25 common shrew livers from Sør-Varanger.

Selenium

The highest Se concentrations were found in common shrew livers, and thereafter in grey-sided voles and hares (**Table 3**). Because willow ptarmigan samples showed only small variations within the individual sub-areas, there were significant differences between the various Sør-Varanger sub-areas and between Sør-Varanger and reference areas (**Table 5**). All values were, however, well within the range found for locations in southern Norway (Fimreite et al. 1990).

Zinc

The highest concentrations of Zn were found in kidneys from willow ptarmigan and hares (**Table 4**). Differences from one sub-area to another were significant for several of the samples (**Table 5**). The average values for the various sub-areas, for both livers and kidneys, were well within the range found elsewhere in Norway (Kålås & Lierhagen 1992, Kålås et al. 1992a, 1992b). Relative to the concentrations in common shrew livers in Sør-Varanger, extremely high Zn concentrations (328 mg kg^{-1}) have been found closer to the Russian smelters (Glazov et al. 1992).

3.2 Radiocesium ^{137}Cs

All samples counted for ^{137}Cs in this study were low compared with concentrations found in willow ptarmigan (Pedersen & Nybø 1992) and small mammals (Steen & Skogland 1992) on Dovrefjell, central Norway, during the years immediately after the Chernobyl reactor accident (Table 6). Some small differences from one sub-area to another could, however, be recognised. No significant differences could be found between age classes in hares (Kruskal-Wallis test, corrected for ties: χ^2 = 0.013, df 1,18, p = 0.91). These samples were therefore pooled in **Table 6**. In the Sør-Varanger samples, no significant differences was found between hares and willow ptarmigan (Kruskal-Wallis test, corrected for ties: χ^2 = 1.177, df 1,53, p = 0.28). There were significant differences between willow ptarmigan from different sub-areas in Sør-Varanger, the highest values being in the two Pasvik sub-areas (Kruskal-Wallis test, corrected for ties: χ^2 = 11.42, df 4,51, p = 0.022), and the Sør-Varanger sample had significantly higher concentrations of radiocesium (mean = 171 ± 38 (SD) Bq kg^{-1}) than the reference samples (mean = 136 ± 8 (SD) Bq kg^{-1}) (Kruskal-Wallis test, corrected for ties: χ^2 = 8.07, df 1,39, p = 0.005). The lowest concentrations were counted in the grey-sided vole samples. These cannot, however, be compared with the other species because 'whole body' samples were used. A significant difference was found for grey-sided voles between the three sampling sites in Sør-Varanger, the lowest values being at Svanvik (Kruskal-Wallis test, corrected for ties: χ^2 = 8.48, df 2,16, p = 0.014).

Table 6. Radiocesium (^{137}Cs) given as Bq mg^{-1} DW, in breast muscle from willow ptarmigan, leg muscle from hares and 'whole body' samles from grey-side vole from Sør-Varanger and reference areas in Finnmark. - Radiocesium (^{137}Cs) gitt som Bq mg^{-1} DW, i brystmuskel fra lirype, lårmuskel fra hare og 'hele' gråsidemus fra Sør-Varanger og referanseområder i Finnmark.

Location	Grey-side vole			Hare			Willow ptarmigan		
	mean	SD	n	mean	SD	n	mean	SD	n
Sør-Varanger area:									
Jarfjord				177	75	11	161	20	14
Korpfjell	104	54	6						
Elvenes	94	17	6						
Svanvik	70	7	6	440		1	166	42	3
N-Varanger				161	61	3			
N-Pasvik							185	45	5
S-Pasvik							215	41	6
Neiden				220	73	5	143	25	7
Reference areas in Finnmark:									
Porsanger									
Øvre Anarjokka							138	15	2
Alta							135	6	4
Hasvik				160	54	2			

3.3 Concluding remarks

Compared with available reference data this study shows increased levels of Cr, Cu, Hg, Ni and partly also Pb in Sør-Varanger for at least one of the species included in this study. Reference data on Al, Cd, Cu, Hg, Pb and Zn in livers from willow ptarmigan, hares and voles from other parts of Norway (Kålås & Lierhagen 1992, Kålås et al. 1992b) show the relatively highest concentrations for Cu and Hg in hares. For kidney samples, available data from willow ptarmigan and hares (Kålås et al. 1992a) show that the relatively highest values of metals in adult animals were for Cu in willow ptarmigan and hares, and Hg in hares. High Cu concentrations were found in willow ptarmigan in both Jarfjord and Pasvik. No nationwide rereference data are available for Cr, Ni and Se, but those from Finnmark show increased concentrations of Ni in kidneys from willow ptarmigan and hares from Sør-Varanger and Cr in livers from the willow ptarmigan samples from Sør-Varanger. Concentrations of Ni in excess of 0.5 mg kg^{-1} were found in willow ptarmigan and hares from the Jarfjord area and in willow ptarmigan from the north side of Varangerfjord (Nord-Varanger). The liver sample from grey-sided voles from the Sør-Varanger area also showed relatively high Ni and Cr concentrations. However, no reference data for this species are available for these metals.

All samples counted for ^{137}Cs in this study gave lower concentrations. Five to ten times higher concentrations were found on Dovrefjell, central Norway, in the years immediately after the Chernobyl reactor accident.

Large differences in the concentrations of metals in animals from different locations may have natural causes (e.g. concentrations of metals in the soils, differences in diets, and so on), or be caused by man (e.g. pollution). On the basis of this, it is difficult to document a direct link between high metal concentrations in kidneys and livers in wild animals and birds, and airborne pollution. However, when comparing metal concentrations found in the wild animals in this study to the information on precipitation quality (Sivertsen et al. 1992), concentrations in soil and potential food plants in the Sør-Varanger area, we conclude that the increased concentrations of Cu, Cr and Ni is caused by airborne pollution from the Russian smelters. The rather slight increase in Pb in willow ptarmigan in the area may, however, also be explained by local air pollution. Relatively high concentrations of Hg were also found in adult hares, but differences within Sør-Varanger indicate that these concentrations are unrelated to the Russian smelters. Our analytical procedures were inappropriate for detecting low-level pollution of As and Co. Our analyses shows, however, that there were no extensive As or Co pollution of wildlife in the Sør-Varanger area.

None of the samples showed that concentrations of any of the metals studied exceeded the limits where negative effects on animals can be expected. No measurements exceeded the limits recommended for human consumption. Further information on the use of game can be obtained at the local offices of the Departement of Food Control.

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Appendix 1. Metals in A) *Lepus timidus*, B) *Tetrao urogallus* and C) *Lagopus lagopus*. LOC - locality (1-Jarfjord, 2-Svanvik, 3-North-Varanger, 4-Neiden, 5-N-Pasvik, 6-S-Pasvik, 10-Porsanger, 11-Øvre-Anarjokka, 12-Alta, 15-Hasvik), JNR - journalnumber, DATE - date, YE - year, FRE - time between death and freezing (h), S - sex (1-male, 2-female), A - age (1-juvenile, 2-adult), WEI - weight (g), AL/AS/CD/CO/CU/CR/HG/NI/PB/SE/ZN - concentrations of the respective metals in liver, given as mg kg^{-1} dry-weight, NAL/NCD/NCU/NHG/ NNI/NPB/NZN - concentrations of the respective metals in kidney, given as mg kg^{-1} dry-weight, < - value below the actual detection limit, . - no valid value. - Metaller i A) hare, B) storfugl og C) lirype. Følgende koder gjelder: LOC - lokalitet (1-Jarfjord, 2-Svanvik, 3-Nord-Varanger, 4-Neiden, 5-N-Pasvik, 6-S-Pasvik, 10-Porsanger, 11-Øvre-Anarjokka, 12-Alta, 15-Hasvik), JNR -journal-nummer, DATE - dato, YE - årstall, FRE - tid fra felling til nedfrysing (timer), S - kjønn (1-hann, 2-hunn), A - alder (1-ung, 2-voksen), WEI - vekt (g), AL/AS/CD/CO/CU/CR/HG/NI/PB/SE/ZN - konsentrasjoner av de respektive metallene i lever, gitt som mg kg^{-1} tørr-vekt, NAL/NCD/NCU/NHG/NNI/NPB/NZN - konsentrasjoner av de respektive metallene i nyre, gitt som mg kg^{-1} tørr-vekt, < - verdi under deteksjonsgrensen, . - ingen godkjent måling.

A) *Lepus timidus*:

LOC	JNR	DATE YE	FRE	S	A	WEI	AL	AS	CD	CO	CU	CR	HG	NI	PB	SE	ZN	NAL	NCD	NCU	NHG	NNI	NPB	NZN
1	21301	24/10-91	.	2	1	2817	.59	<0.3	.54	<0.5	14.8	<.15	.018	<.50	<.20	.79	102	.57	3.0	15.9	.266	.96	.42	136
1	21303	23/ 9-91	12	.	2	3078	4.37	<0.3	1.10	<0.5	12.2	<.15	.050	<.50	<.20	.53	101	2.07	20	19.2	.453	<.50	<.20	114
1	21304	23/ 9-91	12	1	1	2644	.77	<0.3	.33	<0.5	13.1	<.15	<.015	<.50	<.20	<.40	97	2.05	.5	17.2	.144	<.50	<.20	97
1	21305	23/ 9-91	12	2	1	3316	7.63	<0.3	.33	<0.5	14.0	<.15	<.015	<.50	.27	<.40	86	.75	.7	16.7	.135	<.50	<.20	95
1	21306	26/10-91	2	1	1	2532	1.08	<0.3	.37	<0.5	13.3	<.15	.041	<.50	.26	.61	96	2.47	1.7	18.4	.233	<.50	.28	103
1	21318	12/11-91	7	2	1	2800	1.15	<0.3	.50	<0.5	15.3	<.15	.031	<.50	.60	1.40	109	.70	4.1	15.4	.161	<.50	.84	108
1	21319	12/11-91	7	1	1	2296	.93	<0.3	.74	<0.5	18.2	<.15	.057	<.50	.35	<.40	125	1.43	5.3	17.9	.637	<.50	.76	143
1	21326	27/10-91	44	1	2	3141	.	<0.3	3.38	<0.5	12.3	<.15	.255	<.50	.48	2.87	118	3.21	43	15.2	1.21	<.50	.37	106
1	21327	20/ 9-91	12	2	1	2733	.79	<0.3	.11	<0.5	8.10	<.15	.019	.68	<.20	<.40	69	1.22	1.1	21.1	.143	<.50	<.20	102
1	21329	25/ 9-91	12	1	2	3416	.	<0.3	2.22	<0.5	14.6	<.15	.041	<.50	3.25	2.48	113	1.03	35	16.4	.228	.97	.43	113
1	21330	25/10-91	1	2	1	3319	3.61	<0.3	.95	<0.5	15.4	<.15	.017	<.50	1.05	2.06	113	.44	9.2	17.0	.179	<.50	.34	106
1	21335	8/ 1-93	.	1	2	3909	.	<0.3	1.08	<0.5	14.9	<.15	.060	<.50	.85	.89	97	.64	30	14.8	.264	1.1	1.48	101
1	21336	8/ 1-93	.	2	1	3840	.	<0.3	.84	<0.5	17.1	<.15	.045	<.50	.85	1.37	94	.95	8.9	13.4	.194	1.2	1.82	94
1	21337	8/ 1-93	.	2	1	3297	1.73	<0.3	1.06	<0.5	14.7	<.15	.020	<.50	.71	.79	94	.77	8.2	15.5	.144	.71	1.42	83
1	21338	8/ 1-93	.	1	1	3084	1.20	<0.3	.71	<0.5	12.1	.54	.034	<.50	.78	1.05	95	.37	6.3	13.4	.345	<.50	1.60	106
1	21339	8/ 1-93	.	2	1	2337	.87	<0.3	.41	<0.5	17.6	.16	.023	<.50	.50	.94	99	.56	3.1	14.8	.154	.77	1.14	92
1	21340	11/ 1-92	.	2	1	3860	1.28	<0.3	.61	<0.5	15.6	<.15	.041	<.50	.54	1.35	106	<.30	3.6	13.5	.288	.63	.85	79
1	21341	15/11-92	.	.	1	3488	1.35	<0.3	.52	<0.5	11.1	.41	.027	<.50	1.25	.38	71	1.74	7.3	12.5	.113	<.50	.58	82
2	21320	5/11-91	10	2	2	3043	.	<0.3	4.11	<0.5	13.0	<.15	.596	<.50	.20	1.16	109	.96	102	19.2	.641	<.50	<.20	130
3	20302	26/10-91	33	.	2	3401	5.69	<0.3	4.98	<0.5	8.52	<.15	.017	<.50	2.30	.80	91	1.65	96	14.8	.176	<.50	.81	130
3	20303	17/10-91	2	1	2	3428	2.99	<0.3	5.98	<0.5	12.3	<.15	.167	<.50	.65	1.47	117	<.30	98	16.4	.829	<.50	.34	136
3	20306	28/10-91	.	2	2	4092	4.52	<0.3	2.87	<0.5	11.9	<.15	.024	<.50	.44	.70	89	.65	112	15.7	.125	<.50	<.20	124
4	21302	12/10-91	4	.	1	2954	8.55	<0.3	.68	<0.5	13.1	<.15	.140	<.50	.53	2.60	100	2.41	4.5	14.9	.636	<.50	.35	84
4	21317	25/10-91	6	1	1	2535	4.50	<0.3	.11	<0.5	14.7	<.15	.024	1.20	<.20	1.15	94	3.78	1.9	18.7	.212	<.50	<.20	99
4	21321	26/10-91	21	2	1	2696	5.40	<0.3	.34	<0.5	13.8	<.15	.025	1.16	.35	.90	90	1.68	1.2	16.9	.122	<.50	.33	98
4	21322	25/10-91	7	1	2	3185	7.51	<0.3	1.51	<0.5	8.21	<.15	.041	.65	.49	1.92	73	1.13	69	14.4	.797	<.50	.25	127
4	21328	26/10-91	23	1	2	3087	1.76	<0.3	1.00	<0.5	11.0	<.15	.170	<.50	.20	1.78	81	.36	23	23.1	.670	<.50	<.20	137
15	21307	16/10-91	51	1	1	3805	2.35	<0.3	.43	<0.5	16.0	<.15	.030	<.50	.43	1.59	100	2.09	1.9	13.1	.095	<.50	.42	83
15	21312	16/10-91	51	2	1	2594	3.86	<0.3	.43	<0.5	18.3	<.15	<.015	1.25	<.20	.48	115	1.10	4.5	22.1	.065	<.50	<.20	141
15	21313	16/10-91	51	1	1	2665	.79	<0.3	.14	<0.5	19.3	<.15	<.015	<.50	<.20	.47	124	1.39	1.1	14.3	.059	<.50	<.20	92
15	21315	16/10-91	51	2	2	3498	5.28	<0.3	.48	<0.5	12.2	<.15	.028	<.50	2.91	.61	83	1.37	17	17.4	.111	<.50	.79	105
15	21316	16/10-91	51	2	2	3940	3.62	<0.3	.74	<0.5	17.7	<.15	.019	<.50	.37	.55	111	1.16	16	20.3	.178	<.50	.24	117

B) *Tetrao urogallus*:

LOC	JNR	DATE YE	FRE	S	A	WEI	AL	AS	CD	CO	CU	CR	HG	NI	PB	SE	ZN	NAL	NCD	NCU	NHG	NNI	NPB	NZN
5	20403	24/ 9-91	21	1	1	.	1.42	<0.3	1.17	<0.5	9.63	<.15	.030	<.50	<.20	.65	70	3.10	3.3	15.1	.069	<.50	.27	91
5	20416	24/ 9-91	21	2	1	.	<.30	<0.3	1.87	<0.5	11.2	<.15	<.015	<.50	<.20	.88	82	.60	7.1	12.4	.122	<.50	.30	75
5	20418	24/ 9-91	21	2	2	.	<.30	<0.3	6.30	<0.5	10.4	<.15	<.015	<.50	.29	.74	145	1.12	29	17.8	.103	<.50	.61	89
6	20402	21/ 9-91	27	2	1	.	1.09	<0.3	.93	<0.5	10.1	<.15	.022	<.50	<.20	.81	66	5.98	3.3	15.0	.086	<.50	.	90
6	20405	30/ 9-91	17	1	1	.	1.26	<0.3	1.86	<0.5	11.4	<.15	.038	<.50	<.20	.98	76	1.63	4.2	17.4	.151	<.50	<.20	98
6	20406	29/ 9-91	9	1	1	.	1.82	<0.3	1.71	<0.5	11.8	<.15	.093	<.50	.68	.94	85	5.78	3.9	14.0	.209	<.50	<.20	81
6	20407	18/ 9-91	.	1	1	.	.48	<0.3	1.40	<0.5	10.6	<.15	<.015	<.50	<.20	<.40	73	1.80	2.7	12.3	.081	<.50	.60	80
6	20408	18/ 9-91	16	2	2	.	<.30	<0.3	3.60	<0.5	10.5	<.15	.020	<.50	<.20	.55	77	<.30	13	13.3	.176	<.50	<.20	84
6	20410	28/ 9-91	31	2	1	.	1.17	<0.3	1.56	<0.5	10.3	<.15	.018	<.50	.29	.99	74	5.28	3.2	13.0	.091	<.50	.23	84
6	20411	12/10-91	24	2	2	.	2.37	<0.3	6.52	<0.5	11.1	<.15	.034	<.50	<.20	1.00	75	.86	36	16.9	.410	<.50	.27	101
6	20412	12/10-91	24	2	2	.	2.11	<0.3	3.96	<0.5	10.1	<.15	<.015	<.50	.25	.90	70	2.93	51	17.1	.153	<.50	.84	108
6	20414	30/ 9-91	18	2	1	.	.68	<0.3	1.86	<0.5	10.2	<.15	.044	<.50	.21	.93	76	2.41	6.5	14.2	.310	<.50	<.20	81
6	20415	30/ 9-91	18	2	1	.	1.13	<0.3	2.31	<0.5	9.93	<.15	.065	<.50	<.20	1.08	81	3.50	9.8	16.6	.611	<.50	.24	96
6	20417	30/ 9-91	19	2	2	.	<.30	<0.3	2.42	<0.5	7.17	<.15	<.015	<.50	<.20	.74	56	.75	21	13.8	.179	<.50	.90	78

C) *Lagopus lagopus*:

LOC	JNR	DATE YE	FRE	S	A	WEI	AL	AS	CD	CO	CU	CR	HG	NI	PB	SE	ZN	NAL	NCD	NCU	NHG	NNI	NPB	NZN
1	20126	20/ 9-90	.	2	2	612	3.87	<0.3	7.60	<0.5	13.5	<.15	<.015	<.50	<.20	1.12	95	8.26	115	19.5	.082	.82	.90	120
1	20127	1/10-90	.	1	2	558	.62	<0.3	6.89	<0.5	13.5	<.15	<.015	<.50	.48	.60	83	<.30	69	21.7	.073	1.8	1.84	119
1	20128	20/ 9-90	.	1	2	519	.80	<0.3	2.77	<0.5	11.4	<.15	.023	<.50	1.18	.64	78	4.97	25	15.8	.064	1.4	.99	106
1	20138	21/ 9-91	5	1	1	579	1.09	<0.3	.56	<0.5	12.1	.36	.030	<.50	.	.67	156	.	.	.	.	.	.	.
1	20158	17/10-91	4	1	2	686	.30	<0.3	13.0	<0.5	10.7	<.15	.050	<.50	1.25	.95	70	.42	256	25.1	.122	<.50	1.14	154
1	20164	22/ 9-91	32	1	2	703	.95	<0.3	4.50	<0.5	9.82	<.15	<.015	<.50	.31	<.40	64	5.12	63	15.3	.060	<.50	.	102
1	20165	22/ 9-91	33	1	2	651	<.30	<0.3	2.52	<0.5	13.7	<.15	.021	<.50	.	.86	76	.61	51	15.8	.061	<.50	4.05	107
1	20173	24/10-91	.	2	1	504	<.30	<0.3	.70	<0.5	8.50	.36	.023	<.50	1.93	.68	57	.	.	.	.	.	.	.
1	20175	12/ 9-91	24	2	2	555	.61	<0.3	6.80	<0.5	14.2	<.15	.030	<.50	.63	1.30	83	7.28	77	16.2	.078	2.3	.71	116
1	20176	12/ 9-91	24	1	1	612	.78	<0.3	1.84	<0.5	16.1	.42	.021	<.50	.86	.85	91	.	.	.	.	.	.	.
1	20181	25/10-91	3	1	1	667	<.30	<0.3	.69	<0.5	11.7	.15	<.015	<.50	.68	.58	70	.	.	.	.	.	.	.
1	20182	25/10-91	3	1	1	673	<.30	<0.3	.73	<0.5	11.0	<.15	.024	<.50	.98	1.00	77	.	.	.	.	.	.	.
1	20183	17/10-91	24	1	2	666	<.30	<0.3	12.9	<0.5	12.7	.22	.024	<.50	1.03	.69	83	.68	237	22.2	.136	<.50	.56	164
1	20184	17/10-91	24	1	2	687	.93	<0.3	3.88	<0.5	14.1	<.15	.036	<.50	.36	.59	80	.88	52	15.8	.078	<.50	.38	103
1	20185	17/10-91	24	1	2	581	.94	<0.3	12.1	<0.5	14.5	.16	.032	<.50	1.37	.92	82	2.40	126	17.3	.090	<.50	.45	122
1	20186	23/10-91	7	2	2	517	.99	<0.3	32.3	<0.5	19.1	<.15	.054	<.50	<.20	1.10	205	3.08	290	20.9	.078	<.50	1.81	176
1	20187	23/10-91	7	2	1	537	.57	<0.3	1.66	<0.5	13.7	.16	.031	<.50	1.74	.73	89	.	.	.	.	.	.	.
1	20189	17/10-91	.	1	2	632	.84	<0.3	11.5	<0.5	13.3	<.15	.040	<.50	<.20	.59	86	2.77	127	15.7	.108	.68	.61	118
1	20191	17/10-91	.	2	1	573	.	<0.3	.76	<0.5	15.8	.	.037	<.50	1.20	.	126	.	.	.	.	.	.	.
1	20193	17/10-91	.	2	2	533	.40	<0.3	3.26	<0.5	11.2	<.15	.048	<.50	.81	.56	68	.39	96	18.2	.099	<.50	.34	117
1	21141	11/ 1-91	5	1	2	606	1.11	<0.3	20.7	<0.5	15.9	.26	.023	<.50	.56	1.59	98	1.33	72	19.0	.	1.3	2.76	141
1	21142	15/ 9-90	.	1	1	497	.49	<0.3	1.16	<0.5	12.8	.	.158	<.50	.	1.19	110	.	.	.	.	.	.	.
2	20136	22/ 9-91	8	1	2	659	.63	<0.3	4.57	<0.5	11.7	.21	.023	<.50	.75	.49	65	<.30	119	21.2	.081	<.50	1.98	137
2	20137	22/ 9-91	7	1	1	618	1.68	<0.3	.52	<0.5	12.4	.28	<.015	<.50	1.00	.88	75	.	.	.	.	.	.	.
2	20147	27/10-91	.	1	2	639	.39	<0.3	10.6	<0.5	12.8	<.15	.035	<.50	.68	.91	81	1.86	108	23.8	.098	<.50	.87	129
2	20155	27/10-91	.	1	1	694	<.30	<0.3	1.44	<0.5	10.3	.35	.019	<.50	.	.66	62	.	.	.	.	.	.	.
2	20172	19/ 5-91	.	2	1	534	<.30	<0.3	8.86	<0.5	9.50	.26	.076	<.50	1.56	.66	78	.	.	.	.	.	.	.
2	20190	20/10-91	23	1	2	565	2.64	<0.3	6.91	<0.5	13.3	<.15	.050	<.50	1.81	.85	88	1.52	83	19.5	.093	<.50	.35	117
3	21111	12/10-91	1	1	2	.	.35	<0.3	9.49	<0.5	13.5	<.15	.032	<.50	1.47	.81	84	.89	87	16.0	.074	<.50	1.14	110
3	21112	26/ 9-91	24	2	2	.	.72	<0.3	9.23	<0.5	15.0	<.15	.034	<.50	1.85	.98	89	2.51	94	16.5	.077	<.50	1.70	120
3	21113	12/10-91	1	1	2	.	<.30	<0.3	4.93	<0.5	10.8	<.15	.024	<.50	.51	.93	86	1.20	37	13.9	.093	.70	.44	100
3	21114	26/ 9-91	2	1	2	.	.59	<0.3	3.12	<0.5	10.0	<.15	.020	<.50	.57	.53	75	1.79	93	17.2	.055	<.50	.31	131
3	21115	26/ 9-91	3	2	2	.	.36	<0.3	4.05	<0.5	13.3	<.15	.035	<.50	1.90	1.01	87	2.16	55	15.4	.095	.72	.81	108
4	20132	25/ 9-91	24	1	2	618	.51	<0.3	4.13	<0.5	11.8	.23	.022	<.50	.	<.40	72	.	72	14.1	.069	<.50	1.04	107

4	20133	25/ 9-91	24	2	2	538	<.30	<0.3	1.55	<0.5	9.08	<.15	.024	<.50	2.05	.68	58	<.30	21	12.0	.059	<.50	.44	89
4	20135	10/10-91	26	1	2	655	<.30	<0.3	6.09	<0.5	12.9	<.15	.027	<.50	.79	.56	86	<.30	90	17.8	.113	<.50	.53	129
4	20141	29/ 9-91	8	1	2	650	.50	<0.3	3.73	<0.5	12.6	.44	.016	<.50	2.22	.56	72	1.43	57	20.2	.065	<.50	.81	120
4	20142	29/ 9-91	4	1	2	625	.88	<0.3	2.45	<0.5	4.17	.15	<.015	<.50	.29	.55	66	<.30	30	13.3	.042	<.50	.20	88
4	20143	29/ 9-91	4	1	2	557	.	.	.	.	.	.	.	.	.	.	.	2.34	43	15.9	.057	<.50	.51	102
4	21102	20/ 9-91	48	1	2	539	.36	<0.3	4.64	<0.5	13.3	<.15	.057	<.50	.42	.76	76	.61	52	16.2	.152	<.50	.	105
4	21103	20/ 9-91	48	1	2	675	2.21	<0.3	4.86	<0.5	11.3	<.15	.027	<.50	.27	.54	73	<.30	54	16.2	.154	<.50	.61	112
5	20195	7/10-91	3	1	2	666	.71	<0.3	9.77	<0.5	10.4	<.15	.028	<.50	.30	<.40	72	1.37	170	22.5	.095	<.50	.52	160
5	20196	7/10-91	5	2	2	644	.36	<0.3	5.56	<0.5	9.21	.15	.026	<.50	<.20	.52	64	2.32	125	18.5	.054	<.50	.24	137
5	20197	17/10-91	20	1	2	662	.35	<0.3	3.27	<0.5	9.65	<.15	.057	<.50	.43	.49	63	2.46	88	15.5	.084	<.50	.29	115
5	20199	17/10-91	19	1	2	692	<.30	<0.3	12.1	<0.5	12.4	<.15	.021	<.50	.57	.43	79	6.87	106	17.0	.067	<.50	.81	116
5	21101	17/10-91	21	2	2	602	1.49	<0.3	4.05	<0.5	12.2	.22	.050	<.50	.87	.77	79	.43	80	17.1	.176	<.50	.	134
6	20148	27/10-91	22	2	2	581	.52	<0.3	3.70	<0.5	7.17	1.20	.029	<.50	.39	.54	60	<.30	49	17.6	.078	<.50	.28	111
6	20149	27/10-91	20	1	2	668	.38	<0.3	10.0	<0.5	14.6	.15	.055	<.50	1.08	.65	96	.43	124	17.4	.124	<.50	.84	133
6	20166	28/ 9-91	6	1	1	671	<.30	<0.3	.68	<0.5	12.7	<.15	.044	<.50	.46	.68	73	.	.	.	.	.	.	.
6	20167	29/ 9-91	.	1	1	646	1.78	<0.3	.51	<0.5	11.8	.26	.021	<.50	.86	<.40	64	.	.	.	.	.	.	.
6	20168	29/ 9-91	.	1	2	679	<.30	<0.3	12.9	<0.5	15.5	<.15	.057	<.50	.25	.80	142	.93	121	19.7	.078	<.50	1.68	142
6	20169	29/ 9-91	.	1	1	642	1.32	<0.3	1.77	<0.5	12.2	<.15	.087	<.50	.27	1.10	75	.	.	.	.	.	.	.
6	20170	29/ 9-91	.	2	2	555	<.30	<0.3	14.3	<0.5	11.7	<.15	.066	<.50	.37	1.12	68	.84	142	17.3	.134	<.50	.56	114
6	20174	27/10-91	.	2	2	540	.68	<0.3	8.86	<0.5	11.5	<.15	.028	<.50	.76	.76	70	2.26	90	16.3	.058	<.50	.38	101
6	20180	27/10-91	3	1	2	678	.85	<0.3	9.05	<0.5	12.2	.15	.018	<.50	.56	.62	74	.86	197	26.3	.108	<.50	.39	145
10	21117	24/ 9-91	.	1	2	574	<.30	<0.3	2.87	<0.5	11.8	<.15	.020	<.50	.36	.76	68	1.76	71	14.7	.046	<.50	<.20	112
10	21118	24/ 9-91	.	1	2	695	.58	<0.3	7.95	<0.5	12.8	<.15	.022	<.50	<.20	<.40	124	<.30	86	14.2	.057	<.50	<.20	107
10	21119	24/ 9-91	.	1	2	620	<.30	<0.3	7.15	<0.5	12.0	<.15	<.015	<.50	5.32	<.40	106	.73	46	12.3	.019	<.50	.	96
11	21105	11/ 9-91	.	1	2	551	2.25	<0.3	7.39	<0.5	14.0	.15	.046	<.50	.52	.48	85	9.43	68	14.2	.117	<.50	.45	105
11	21106	10/ 9-91	.	1	2	632	.76	<0.3	8.86	<0.5	13.7	<.15	.032	<.50	.36	.46	91	2.75	64	16.2	.113	<.50	.39	112
12	21125	22/10-91	8	1	2	677	<.30	<0.3	3.68	<0.5	12.8	<.15	.051	<.50	.94	.49	94	.70	37	15.5	.092	<.50	.44	110
12	21127	2/11-91	6	2	2	555	.34	<0.3	3.33	<0.5	15.6	<.15	.051	<.50	1.22	.63	104	<.30	11	12.2	.050	<.50	1.05	79
12	21132	2/11-91	4	2	2	479	<.30	<0.3	3.86	<0.5	14.2	<.15	.065	<.50	.51	.77	87	1.89	22	15.9	.120	<.50	1.83	104
12	21133	2/11-91	6	1	2	623	<.30	<0.3	5.63	<0.5	13.3	<.15	.050	<.50	.99	.47	90	.50	23	18.2	.086	<.50	.88	119

Appendix 2. Metals in A) *Sorex araneus* and B) *Clethrionomus rufocanus*. LOC - locality (1-Korpfjell, 2-Elvenes, 3-Svanvik, 5-Karasjokk, 6-Kongsfjord), S - sex (1-male, 2-female), WEI - weight (g), DATE - date given as 'day month', YE - year, AL/AS/CD/CO/ CU/CR/HG/NI/PB/SE/ZN - concentrations of the respective metals in liver, given as mg kg^{-1} dry-weight, < - value below the actual detection limit, . - no valid value. - Metaller i A) spissmus og B) klatremus. Følgende koder gjelder: LOC - lokalitet (1-Korpfjell, 2-Elvenes, 3-Svanvik, 5-Karasjokk, 6-Kongsfjord), S - kjønn (1-hann, 2-hunn), WEI - vekt (g), DATE - dato gitt som 'dag måned', YE - årstall, AL/AS/CD/CO/ CU/CR/HG/NI/PB/SE/ZN - konsentrasjoner av de respektive metallene i lever, gitt som mg kg^{-1} tørr-vekt, < - verdi under deteksjons-grensen, . - ingen godkjent måling.

A) *Sorex araneus*:

LOC	S	WEI	DATE	YE	AL	AS	CD	CO	CR	CU	HG	NI	PB	SE	ZN
1	2	6.8	15 9	92	<0.9	<0.9	4.50	<1.5	<.45	26.8	.072	<1.5	<.45	3.80	106
1	2	7.8	17 9	92	<0.9	<0.9	1.09	<1.5	.55	21.7	.030	<1.5	.72	3.69	69
1	1	7.5	19 9	92	<0.9	<0.9	.70	<1.5	<.45	21.9	.051	<1.5	.81	4.19	63
1	2	7.1	22 9	92	<0.9	<0.9	.48	<1.5	<.45	23.8	.111	<1.5	<.45	4.67	72
1	1	8.0	22 9	92	<0.9	<0.9	2.01	<1.5	<.45	22.1	.044	<1.5	.71	6.53	66
2	1	7.2	16 9	92	<0.9	<0.9	1.11	<1.5	<.45	21.9	.030	<1.5	<.45	3.65	70
2	1	9.6	18 9	92	.91	<0.9	2.46	<1.5	<.45	23.1	.030	<1.5	<.45	3.36	74
2	1	9.2	18 9	92	.	<0.9	2.03	<1.5	.	23.2	.030	<1.5	.89	3.39	70
2	1	6.7	20 9	92	<0.9	<0.9	2.68	<1.5	<.45	23.9	.030	<1.5	<.45	3.86	81
2	2	8.1	22 9	92	<0.9	<0.9	1.84	<1.5	<.45	22.0	.043	<1.5	<.45	3.12	69
2	2	8.8	22 9	92	<0.9	<0.9	1.69	<1.5	<.45	24.9	.050	<1.5	<.45	4.06	69
3	2	8.6	20 10	91	1.1	<0.9	3.66	<1.5	<.45	23.9	.030	<1.5	<.45	3.66	75
3	1	8.9	20 10	91	<0.9	<0.9	1.80	<1.5	.68	21.4	.030	<1.5	<.45	3.02	72
3	2	11.3	20 10	91	<0.9	<0.9	11.8	<1.5	<.45	21.7	.044	<1.5	<.45	3.80	72
3	1	7.4	2 7	90	2.6	<0.9	1.41	<1.5	.61	19.7	.030	<1.5	<.45	4.39	76
3	1	6.7	2 7	90	<0.9	<0.9	1.48	<1.5	.61	25.1	.030	<1.5	<.45	5.94	84
3	2	6.5	14 10	91	<0.9	<0.9	3.51	<1.5	<.45	17.8	.030	<1.5	<.45	3.71	68
3	1	6.7	14 10	91	<0.9	<0.9	4.50	<1.5	<.45	22.5	.030	<1.5	<.45	3.83	90
3	2	7.0	14 10	91	1.4	<0.9	1.47	<1.5	<.45	24.0	.086	<1.5	<.45	5.28	74
3	1	9.8	20 9	92	<0.9	<0.9	4.09	<1.5	<.45	23.5	.030	<1.5	<.45	5.84	68
3	1	6.5	20 9	92	<0.9	<0.9	.90	<1.5	<.45	22.1	.030	<1.5	<.45	2.74	74
3	1	8.0	20 9	92	<0.9	<0.9	2.26	<1.5	<.45	20.6	.030	<1.5	<.45	2.19	64
3	1	7.2	20 9	92	<0.9	<0.9	2.65	<1.5	<.45	26.3	.062	<1.5	<.45	3.68	71
3	1	9.1	20 9	92	<0.9	<0.9	6.94	<1.5	<.45	24.2	.030	<1.5	<.45	3.27	72
3	1	9.0	20 9	92	<0.9	<0.9	5.26	<1.5	<.45	23.1	.041	<1.5	<.45	3.14	79
5	2	7.5	11 10	91	1.6	<0.9	3.47	<1.5	<.45	22.1	.055	<1.5	<.45	.	71
5	1	6.8	11 10	91	<0.9	<0.9	1.52	<1.5	1.20	20.2	.068	<1.5	<.45	4.51	62
6	2	8.2	20 9	90	1.4	<0.9	1.66	<1.5	<.45	20.2	.053	<1.5	<.45	4.52	65
6	1	7.6	20 9	90	1.4	<0.9	1.54	<1.5	<.45	19.1	.030	<1.5	<.45	5.35	69
6	2	9.5	17 9	91	<0.9	<0.9	1.86	<1.5	<.45	20.0	.041	<1.5	<.45	4.72	64
6	1	7.8	17 9	91	<0.9	<0.9	2.34	<1.5	<.45	19.9	.043	<1.5	<.45	9.00	70

b) *Clethrionomus rufocanus*:

LOC	S	WEI	DATE	YE	AL	AS	CD	CO	CR	CU	HG	NI	PB	SE	ZN
1	2	29.1	14 9	92	1.5	<0.3	.76	<0.5	.20	13.2	.025	1.2	<.15	1.69	78
1	2	37.8	15 9	92	1.6	<0.3	1.01	<0.5	.18	10.8	.079	.50	.20	1.61	64
1	2	30.5	22 9	92	.35	<0.3	.89	<0.5	.16	13.2	.015	.50	<.15	1.79	83
1	2	30.4	13 9	92	.92	<0.3	.48	<0.5	.27	13.3	.023	.81	<.15	1.66	81
1	2	28.5	15 9	92	.	<0.3	3.02	<0.5	.21	17.6	.010	.66	<.15	1.65	122
1	2	37.8	13 9	92	1.6	<0.3	3.86	<0.5	.22	14.4	.010	.50	.	1.70	85
2	2	34.0	16 9	92	<0.3	<0.3	.19	<0.5	<.15	12.0	.205	.72	<.15	1.55	71
2	1	32.8	17 9	92	.63	<0.3	.71	<0.5	<.15	12.6	.050	<.5	.20	1.57	88
2	2	33.9	17 9	92	2.0	<0.3	.43	<0.5	.22	14.1	.301	.68	<.15	2.00	84
2	1	33.1	17 9	92	.69	<0.3	.56	<0.5	.18	12.8	.039	<.5	<.15	1.99	81
2	2	33.0	17 9	92	<0.3	<0.3	.91	<0.5	.21	13.5	.144	<.5	<.15	1.88	89
2	2	35.4	16 9	92	.85	<0.3	.60	<0.5	.22	14.3	.201	.62	<.15	1.64	91
3	2	29.2	20 9	92	.58	<0.3	.94	<0.5	.17	13.5	.067	.98	<.15	1.59	88
3	2	30.6	20 9	92	.76	<0.3	.39	<0.5	.17	12.9	.052	.88	<.15	1.59	87
3	2	31.7	20 9	92	.55	<0.3	2.28	<0.5	.16	13.3	.159	.60	<.15	1.70	80
3	2	31.9	20 9	92	.71	<0.3	.65	<0.5	.24	13.4	.022	.65	<.15	1.86	84
3	2	28.9	20 9	92	.88	<0.3	.54	<0.5	.	12.0	.088	.89	<.15	1.60	73
3	2	37.6	20 9	92	.72	<0.3	2.06	<0.5	.	11.5	.096	<.5	.40	1.66	78

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Oversikt over utgitte rapporter

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