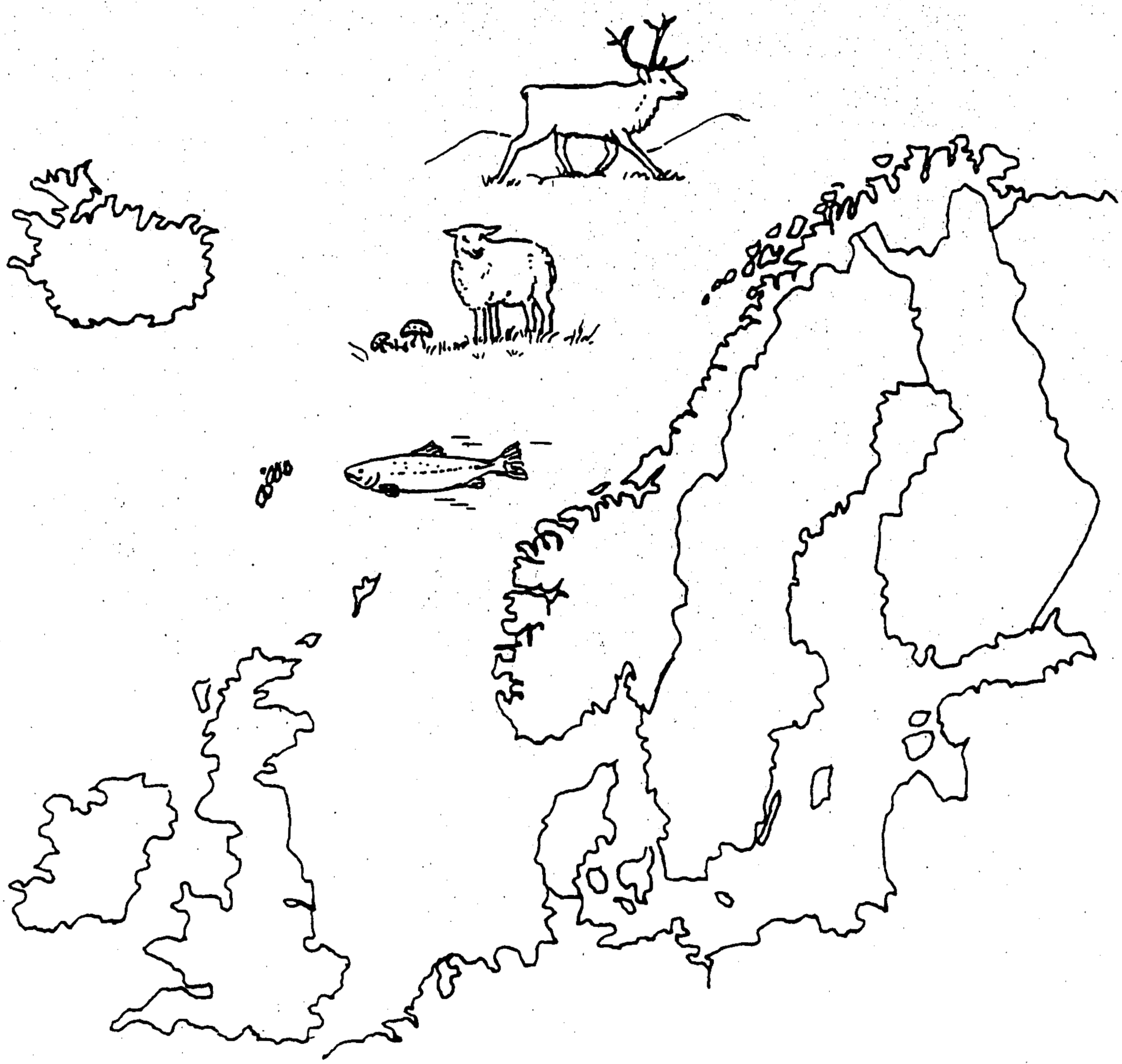
TECHNICAL REPORT EKO-2.2

Transfer of radiocesium via mushroom to roe deer and man

TR-EKO-2(1995)2



NORDISK KJERNESIKKERHETSFORSKNING

INTRODUCTION

The EKO-2 project, "Long ecological half-lives in semi-natural systems", consists of three subprojects; sheep grazing on uncultivated pasture, mushroom and freshwater fish. The main aim is to identify the contribution from semi-natural systems, by determining ecological half-lives for specific foodstuffs from these areas, and thus determine dose to man.

By producing models that can decrease the uncertainties in dose calculations, it is possible to quickly develop a picture of possible consequences in a fallout situation, and implement appropriate countermeasures. Foodstuffs from semi-natural areas (such as uncultivated pastures) accounts for a considerable portion of the dose to man.

Transfer of radiocesium via mushroom to roe deer and man.
Very little data for consumption of food products from the forest system has been available. Preliminary studies show, that in Sweden up to 25 GBq of radiocesium yearly are transferred to man via mushroom. A questionnaire has been worked out, in order to map the average consumption in a representative group of the population in Sweden, Denmark and Finland. Focus has been put on amounts and species of mushrooms. The questionnaire will later be connected to radiocesium levels in mushrooms, and the development over time (halflife) for different species.

Mushroom also plays an important role in the uptake of radiocesium by vegetation at higher levels, and is probably the cause for radiocesium being easily available for a long time. Most animals show strongly increasing levels of radiocesium when mushrooms are available in August-September, and roe deer is one of the largest consumers of mushroom. Up to 20-30% of the paunch content is mushroom in this period. Samples of roe deer meat and roe deer paunch has been collected, in order to estimate the role of intak eof mushroom.

This technical report consists of the results from the forest project during the last year (1995).

TONE
08.12.95

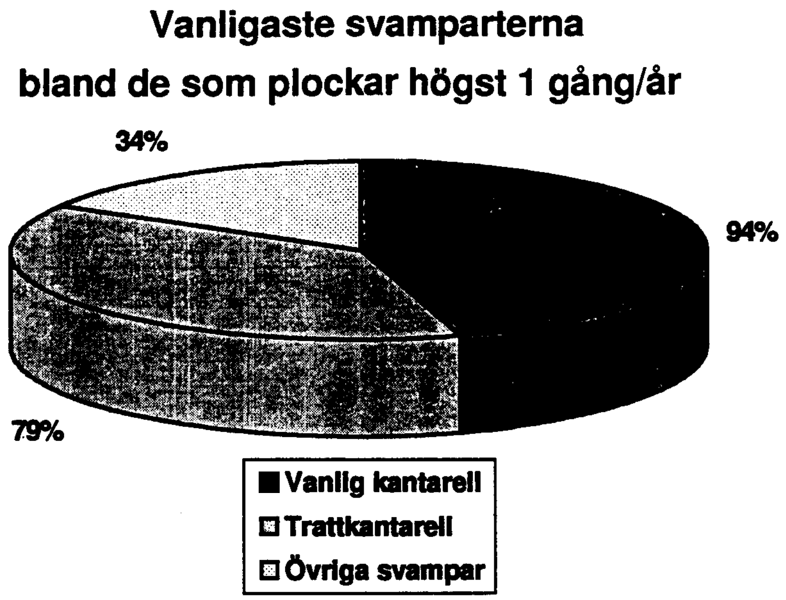
EKO-2 årsrapport, Karl J. Johanson

1. Enkät om svenskarnas svampplockningvanor.

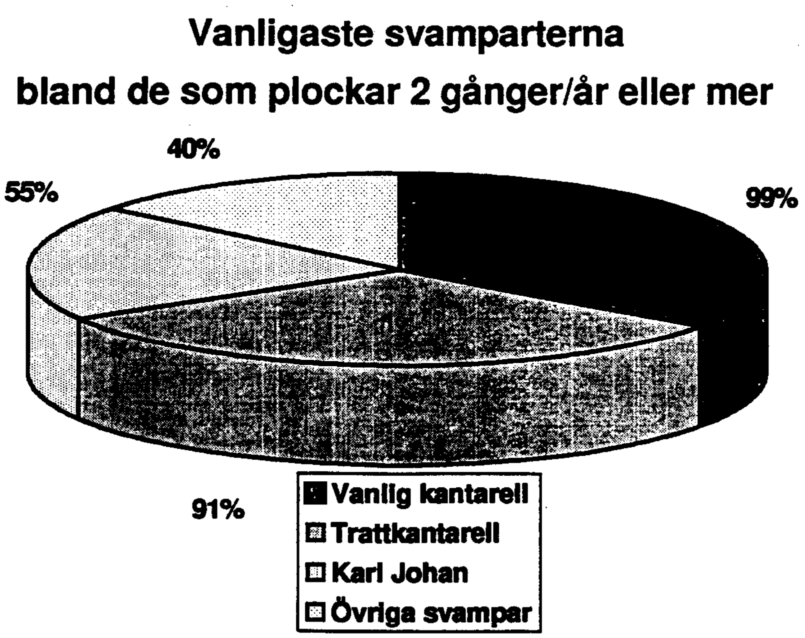
Under sommaren 1995 skickades ett frågeformulär (Bilaga 1) ut till 1000 hushåll i Avesta kommun i Dalarna. Kommunen ligger i centrala delarna av Sverige, har ett lågt ^{137}Cs nedfall från Tjernobyl och inom kommunen finns en blandning av tätort och landsbygd som är relativt representativ för Sverige. Vi fick svar från 516 hushåll som var villiga att besvara ytterligare ett frågeformulär (Bilaga 2) där de i mera detalj fick besvara hur stora mängder svamp och vilka arter de plockade 1995 jämfört med normalår. Svaren från denna enkät kommer fortfarande in varför vi nu redovisar en delrapportering av redan inkomna svar.

Av de 516 som besvarade första enkäten var det 148 (29 %) som inte plockade svamp, 68 (13 %) som plockade svamp högst en gång per år och 300 (58 %) som plockade svamp 2 gånger eller flera per år. De svamparter som den senare gruppen plockade var kantarell där 99 % av de som plockade svamp uppgav att kantarellen fanns med i deras svampkorgar, 91% plockade trattkantarell, 55 % plockade Karl Johan och 40 % plockade även övriga svampar främst murklor och och soppar (Figur 2). Även bland de som bara plockade svamp en gång per år dominerade kantarell och trattkantarell (Figur 1). Bland de som plockade svamp mera än två gånger kan två grupper urskiljas; 1. de som plockade framförallt kantarell och trattkantarell och 2. de som plockade ett stort antal arter. Resultat visar också att de flesta under 1995 plockade betydligt mindre mängd svamp än under "normala" år. Skillnaden är ofta omkring 50 %. Relativt många som normalår plockade svamp hade under 1995 inte plockat svamp. Mängden svamp som plockats under 1995 har varierat från några enstaka svampar till 25 liter. Med god svamptillgång kan denna siffra gå upp till 65 liter.

De slutsatser som vi hittills kan göra är att kantarell och trattkantarell är de svamparter som plockas mest i Sverige. För att uppskatta överföringen av ^{137}Cs till människa kommer man troligen sanningen relativt nära med en förenklad modell där vi antar att 50 % kantarell och 50 % trattkantarell återspeglar artsammansättningen. Enligt Hultman (1983) plockas det i Sverige 3 kg färskvikt svamp per person eller 0.24 kg torrvikt.. Om man förutsätter 50/50 fördelning mellan kantarell och trattkantarell dvs 0.12 kg torrvikt per person och TF_g (Bq per kg svamp dv/ Bq per m^2) för de två arterna till 0.39 och 0.94 Bq per kg svamp torrvikt/ Bq per m^2 (Johanson opublicerade resultat) erhålls en uppskattat kollektivt överföring av 468 Bq av ^{137}Cs via kantarell och 1,128 Bq via trattkantarell till medelsvensson i Sverige, totalt



Figur 1. Procentuella fördelningen i valet av svamparter mellan hushåll som plockar svamp 1 gång per år.

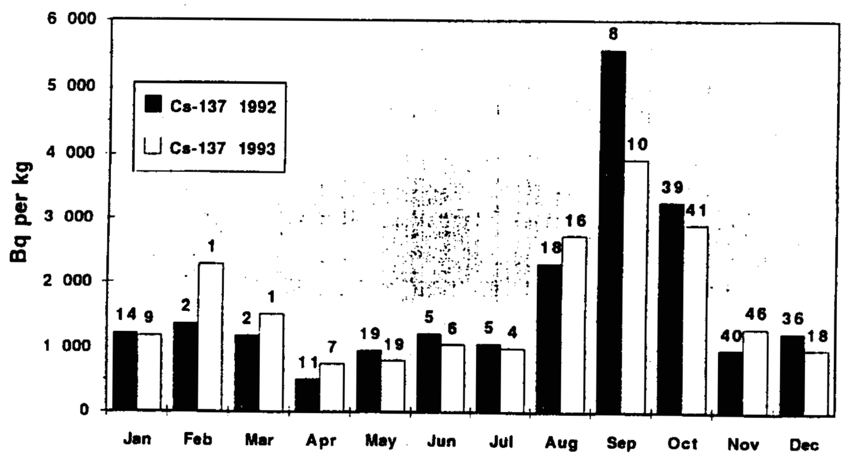


Figur 2. Procentuella fördelningen i valet av olika svamparter mellan hushåll som plockar svamp flera än 2 gånger per år.

1,596 Bq . Detta innebär en årlig överföring av 12.8 GBq via svamp till Sveriges befolkningen, vilket motsvarar en dosåttagande av 166 manSv förutsatta att ICRPs dose conversion factors (ICRP 1991) är riktiga. Man kan alltid diskutera hur nära sanningen denna siffra är, men kvar står det faktum att överföring av ^{137}Cs via svamp troligen kommer att vara den viktigaste överföringsvägen i Sverige. Som jämförelse kan nämnas att transfer via älg motsvara en årlig dosåtagande av ca 30 manSv (Johanson and Bergström 1994) och via bär ungefär lika mycket (Johanson and Kardell 1995) . Detta innebär alltså att även om beräkningarna för svamp skulle innebära en överskattning av ^{137}Cs transfer med 100 % är ändå detta bidrag det viktigaste och uppgår till ungefär lika mycket som härrör från andra vägar från skogsekosystemet.

2. Rådjur och svamp

Rådjur är de stora svampkonsumenterna i skogsekosystemet. Våra vomanalyser visar att under perioden augusti till oktober kan svampinnehållet i vommarna av rådjur i medeltal vara ca 20 till 30 % (Bergström & Johanson, manuskript 1995). En beräkning av ^{137}Cs intaget hos rådjur under svampsäsongen stiger med mellan 300 och 700 % och innebär att ^{137}Cs halten i rådjur stiger kraftigt (Figur 3, Johanson 1995). Detta innebär att ^{137}Cs intaget via svamp blir den helt dominerande bidraget under svampsäsongen. Ovanstående beräkningar baseras på att medelhalten av ^{137}Cs i de svampar som rådjuren äter är lika med medelhalten i alla svampar som vi har insamlat under ett år. Det är dock inte visat att rådjuren äter alla svampar vi beräknat medelvärde på eftersom artsammansättningen av de svampar som rådjuren äter inte är känd.



Figur 3. ^{137}Cs aktivitetskoncentration muskel från rådjur under olika månader av året.

Avsikten var att under 1995 undersöka detta genom att bestämma de svamparter som återfinns i rådjursvommar. På grund av att 1995 var ett mycket dåligt svampår kunde vi inte genomföra detta - det skulle dessutom inte ha blivit en bra beskrivning av rådjurens val av olika svamparter eftersom många arter inte fanns att tillgå i skogen. ^{137}Cs halterna i rådjur var under perioden augusti och september 1995 mycket lägre än under normala år. Under oktober gick dock halterna upp något och i vårt försöksområde uppträdde ett antal rådjur med halter överstigande 5,000 Bq per kg. Inom Gävle kommun som ligger något längre norrut gick ^{137}Cs halterna i rådjur upp under andra veckan i september. En intressant observation är att halterna i älgar (ca 150) i vårt försöksområde i år var i medeltal 440 Bq per kg. Under 1994 var medeltalet 680 och under perioden 1986 tom 1993, 750 Bq per kg. Vi kan alltså konstatera att 1995 var ett speciellt år eftersom det aldrig har varit så låga halter både när det gäller rådjur och älg sedan 1986 och reduktionen jämfört med förväntat normalvärde är ca 40 %. Man kan på grundval av detta göra vissa reflektioner. Normalt finner man i älgvommar 1 - 2 % svamp under svampsäsongen, vilket om älgarna har ett sådant intag under en lång period höjer halterna i älgarna med ca 20 %. Värdena från 1995 tyder på intaget av svamp skulle vara större än 1 - 2 % - troligen upp mot 4 %. I annat fall är det svårt att förklara årets låga halter i älg. Det har inte skett någon nedgång i ^{137}Cs halterna i älgens övriga födoväxter under 1995.

3. Ekologiskt halveringstid i svamp.

Insamling av svamp har även i år utförts på de tre 20 x 20 meters ytor som vi använt från 1990 och framåt. Svamptillgången har dock varit liten, men några arter har ingått i årets insamling. Resultaten är ännu inte bearbetade.

4. Referenser

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TACK FÖR ER MEDVERKAN!

Skicka tillbaka enkäten i det bifogade, frankerade kuvertet. Vi är givetvis tacksamma om Ni fyller i och skickar tillbaka enkäten så fort som möjligt, ...men hellre sent än aldrig.

Vi är tacksamma för alla svar vi får!

Ni som kan ses som aktiva svampplockare kommer till hösten, under svampsäsongen, att få ytterligare en enkät från oss angående hur mycket ni plockar av varje svampart. Det vore därför bra om Ni reflekterar lite över hur mycket Ni egentligen plockar av de olika arterna när Ni är ute i svampskogen i höst.

Har Ni några frågor är Ni välkomna att ringa oss.

Susanna Johansson 018-67 28 88
eller 25 14 42

eller

Karl-Johan Johanson 018-67 12 90

SVERIGES LANTBRUKSUNIVERSITET
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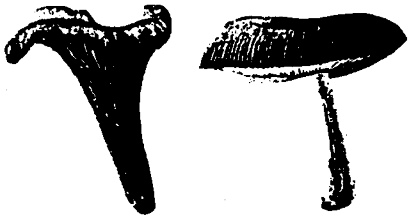
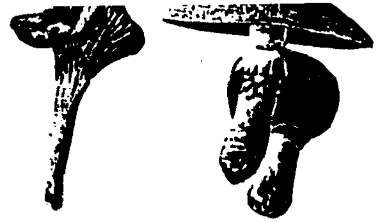


HEJ!



Detta är en enkät angående Era svampplockningsvanor.

Vi på institutionen för radioekologi, vid Sveriges lantbruksuniversitet, behöver information om svenska folkets svampplockningsvanor. Vi hoppas nu att Ni vill hjälpa oss genom att svara på denna enkät.

Ni har blivit slumpmässigt utvald att delta i denna undersökning. Ert svar kommer att behandlas konfidentiellt och användas för att få en bild av de genomsnittliga svampplockningsvanorna.

Institutionen för radioekologi är en av många institutioner vid Sveriges lantbruksuniversitet. Vi sysslar med att studera radioaktiva ämnens transport från natur till människa. I och med Tjernobylolyckan har detta varit ett aktuellt forskningsområde. Vi studerar bla radiocesiums transport från skogen till människan. En viktig väg är via våra svampar.

Vi vill genom denna enkät få reda på hur många som plockar svamp överhuvudtaget och vad de plockar för arter. Alla svar är värdefulla för oss, även från Er som inte plockar någon svamp alls.

Vi hoppas på Er hjälp!

Frågorna besvaras för hela hushållets räkning, dvs alla familjemedlemmar.

1. Hur många personer ingår i Ert hushåll?

1 ❑ 2 ❑ 3-4 ❑ 5 eller fler ❑

2. Ålder?

Vuxna personernas ålder: ....
Ev barns ålder: ....

3. Brukar Ni plocka svamp?

JA ❑
NEJ ❑

4. Om JA, ungefär hur ofta är Ni ute och plockar svamp?

högst 1 gång/år ❑
2-3 gånger/år ❑
mer än 3 gånger/år ❑

5. Vilka svamparter plockar Ni?

❑ Vanlig kantarell

❑ Trattkantarell

❑ Karl-Johan

❑ Champinjoner

❑ Riskor

❑ Sandsopp

❑ Övriga soppar

❑ Rynkad tofsskivling

Andra, nämligen: ....

Prosjekt 11531: EKO-2, Sopp-Rådyr-Menneske på Ytterøya (NT fylke)

Mål

Kartlegge nivået av ^{137}Cs i sopp og rådyrkjøtt på Ytterøya i Trondheimsfjorden.

Området

Ytterøya ligger på 63 45' N og 11 O i Trondheimsfjorden. Den er fra 1964 del av Levanger kommune i Nord-Trøndelag fylke. Landskapet er for det meste flatt med skogåser i vest. Det høgste punktet er Sandsetheia, 211 m oh. Øya er 28 km^2, er 15 km lang med lengderetning NO-SV. Det er ca 50% dyrket mark, 25% produktiv skog og resten er lågbonitets skog og litt myr. Jordsmonnet er ofte rikt, tidligere har det vært en kalkgruve på øya. Nedbøren er 750 mm årlig, og klimaet er, lokalt sett, mildt med snødekket mark bare i korte perioder. Ytterøya er det område som har flest soltimer i året i Midt-Norge. Dette og den låge nedbøren henger samen med at området ligger i regnskykke av Fosenfjellene i vest.

Sopplukking er ikke særlig utbredt, men det felles årlig ca 250 rådyr på øya i jakttiden fra 16.8 til 23.12.

Tsjernobylnedfall er kartlagt fra helikopter av NGU (Norges geologiske undersøkelser). Jordbruksområdene viser fra 0-100 pulser/s, skog og høgdedragene 250-300 pulser/s. Kalibrering til Bq/m^2 er ikke forsvarlig gjennomført for dette området, men 300 pulser/s antas å svare til omtrent 5-20 kBq/m^2. Det vil si at nedfallet var middels til noe under det.

Året 1995 og tanker om videreføring

Med de økonomiske begrensninger som følger av at NINA er en privat stiftelse er det lagt opp et noe mindre ambisiøst opplegg. Vi samler ved hjelp av jegerne som jakter rådyr på øya, prøver av kjøtt fra skutte dyr. Vomprøver og faecesprøver tas i den utstreking jegerne er villige til det. Innsamling av faeces fra bakken gjennom sesongen er arbeidsintensivt og må begrenses. For 1995 har vi til nå fått 45 kjøttprøver og 10 vom og faecesprøver. Vi har begrunnet forventning om at det ved sesongens slutt vil være ialt 60 kjøttprøver, 20 vomprøver og 20 faecesprøver. Prøvene vil bli analysert på nyåret når jakten er over.

Det er tatt kontakt med Nyttevekstforeningen i Trøndelag. Fra medlemmer som har plukket sopp på Ytterøya vil det både for 1995 og 1996 bli analysert prøver av de mest aktuelle soppslag: *Cantarellus (to spp), Boletus edulis, Rozites caperata, Lactarius spp.* Gjennom denne foreningen og også Utmarkslaget søkes det etter lokale sopplukkere. 1995 var et ujevnt soppår, med svakt i august til bra i september og tildels i oktober. Kommer det varme perioder kan det stadig komme ny sopp.

Vi regner med større oppslutning fra jegere og folk lokalt når møter om årets resultater er holdt og dessuten er publisert i lokalpressen. Vi ser derfor fram mot ett godt datasett i 1996.

1994 og 1995 er det for andre formål samlet inn underkjever av elg fra ulike kommuner i landet. Dette er ledd i rullerende overvåkning og stadig nye kommuner kommer med. Det planlegges oppfølging i årene som kommer. Etter avtale vil målinger at radiocesiuminnholdet i kjøttprøver fra disse kjevene bli inkludert i datarapporten fra den prosjektdelen NINA har ansvar for.

Trondheim 23.11.95

Eldar Gaare

Aino Rantavaara
STUK, Finland

24. November 1995

SURVEY ON CONSUMPTION OF MUSHROOMS AND OTHER WILD PRODUCTS

1 Introduction

The use of some food products from semi-natural environment for human food has essentially decreased in the course of the last decades. At the same time, the nutritronal value of food of wild origin is emphasized and campaigns for increasing their use are carried out. The food from forest and freshwater ecosystems has earlier been a necessity but is nowadays more a byproduct from different free-time outdoor activities. There are regional differences in this respect. Variation is expected to relate to industrial structure and availability of forests. Cultural differences between the five Nordic countries are obvious. Species used for food and cooking traditions vary in neighbouring northern countries. The eastern European tradition prevails in Finland but seems not to be known in Scandinavia. Common intake parameters applied in all nordic countries would certainly mislead those who plan advice for consumers in a fallout situation.

Transfer of radiocaesium to different food products from seminatural environment have been studied intensively since 1986. Uptake mechanisms are investigated to clarify the exceptionally great contents of radiocaesium in mushrooms. The range of radiocaesium contents found in edible mushrooms in Northern Europe is tens of thousands of becquerels per kilogram fresh weight. Among the species of lowest contents is Boletus edulis, and the highest contents have been found in the Lactarius and Russula species. Contents in edible fraction of mushrooms vary also by cooking methods, depending on, e. g. parboiling or soaking before the actual cooking.

Estimation of the exposure to internal radiation via mushrooms and other wild products includes several sources of variation, which are related both with radiocaesium contents and consumption rates. The household surveys and food consumption studies carried out from nutrition point of view do not generally give enough information for purposes of radiation protection. When radiation doses from intake of wild products are assessed, the complexity of the issue should be considered, and the use of simplified assumptions avoided.

The goal of the survey is to estimate the per capita consumption of mushrooms for the whole population and to identify the group of maximum consumers in the Nordic countries. The species of mushrooms representing different radiocaesium uptake and different dynamics will be considered. National picking models by species of mushrooms, by population subgroup and by geographical areas will be derived from the survey data. Consumption of mushrooms will be compared with use of other wild products by the subjects interviewed, in order to identify possible critical groups. Picking and use of mushrooms for human food are the main object of the survey, as they are assumed to add variation to dietary radiocaesium more than other foodstuffs of wild origin. In all, the results will improve the reliability of internal dose estimates.

The dynamics of radiocaesium in the seminatural environment refers to long-term contamination and almost constant recycling of radiocaesium in the uppermost organic layers of forest soils. This means that the relative contribution from forest products to the dietary radiocaesium will increase in the course of time when radiocaesium contents in most other types of foodstuffs show a declining trend.

There are several methots for analysis of consumption of foodstuffs. In case of wild products, which are not mainly distributed via food market, e.g. food balance sheets (one of the few internationally comparable consumtion data, published by most countries), do not tell the truth. Only a small fraction of products consumed are included in statistics of commercial food distribution.

Household surveys based on book-keeping of foodstuffs bought by households have in some cases been complemented with information on foods produced or provided for own use outside the food market. They are seldom planned to give information on species of food types, which should be known in radiological assessements if contamination dynamics of different species differ.

2 Methods

2.1 Questionnaire

Sweden

Quite simple yes/no answers were asked for in the first Swedish run carried out in 1995. So were the pickers of mushrooms found in the population sample. The second questionnaire was addressed to the persons who had told they are pickers of mushrooms. The second survey with a new, more accurate questionnaire is going on.

Norway

Due to the assumed very low consumption of wild mushrooms in Norway, no survey has been planned. Instead, members of a few households in the region of roedeer reseach will be interviewed. The general picture of use of mushrooms will be described after contacts with relevant organizations.

Denmark

Consumed amounts of mushrooms by species will be asked in the Danish questionnaire. In addition to this, consumption of wild berries and fish will be asked. The survey will be carried out at the end of 1995.

Finland

Consumtion of mushrooms by species, wild bernies and fresh water fish will be asked in the Finnish survey, which will be carried out in winter 1995-96. In addition, some background information related to the use of wild products will be asked, as ages of household members and professional or other relation with wild ecosystems. It is known that intensity of picking wild berries and mushrooms varies with geographical region, and picking for sale is important for economy of many households in eastern and nothern regions. Commercial picking will be distinguished from picking for own use.

Iceland

The general pattern of using mushrooms for human food will be described in co-operation with radioecologists involved in the current NKS- (Nordic Nuclear Safety) programme.

2.2. Population sample

In Sweden one municipality in southern part of the country was chosen as a research area. From the address register one thousand individuals were included in the first sample. The survey will continue using a more exact questionnaire addressed to them who use mushrooms according to the first survey. For other countries the region will be defined considering the goals of the survey. More than one geographical region are needed in Finland.

Rather small fraction of Nordic population is expected to use mushrooms as a main dish regularly and often (several times a month or week). To get reliable estimates for the size and consumption rates for maximum consumers, an additional survey will be carried out among relevant subgroups of population, if the first population sample does not reveal a critical group.

3 Use of the survey results

The national models for use of mushrooms (and eventually other wild produce) give an opportunity to estimate short and long term estimates for dietary radiocaesium received via these products. The ecological halflives are under study in EKO-2 project and will be combined with information from consumption rate survey.

Radioecological characteristics of ^{137}Cs in Danish Rozites caperatus.

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ABSTRACT

Samples of Rozites caperatus from Denmark and Greenland were analyzed for radiocesium. A total of 13 greenlandic and 56 Danish samples were included. The main objective was to determine the effective halflife of ^{137}Cs in an important representative of the ectomycorrhizal basidiomycetes. Other purposes was: To investigate the suitability of Rozites caperatus as a bioindicator of radiocesium in soil, to measure observed ratios fruitbody/soil and to determine whether any differences in uptake of radiocesium caused by differences between the temperate region, represented by Denmark, and the arctic region, represented by Greenland, could be detected.

An effective halflife ranging between 1.8 and 2.8 years with a mean of 2.3 years was determined for Chernobyl derived ^{137}Cs. The corresponding ecological halflife was 2.5 years. For fallout derived ^{137}Cs no reliable effective or ecological halflives could be calculated, but an effective halflife close to the

physical is most probable.

For Chernobyl derived ^{137}Cs a significant relation between fruitbody concentration and deposition to ground was determined. It was indicated that presence/absence of tree crown cover was an important factor for the radiocesium concentration in Rozites caperatus in Tisvilde i.e. the radiocesium concentration was the lowest in fruitbodies growing below trees and highest in those growing under little openings betweeen trees. The Observed Ratios of Chernobyl and fallout derived ^{137}Cs was highest for Chernobyl cesium until 1994, where they became equal.

Differences in uptake of ^{137}Cs in Rozites caperatus between arctic and temperate specimens of Rozites caperatus are discussed. This part of the material was too sparse to draw any significant conclusions.

INTRODUCTION

Rozites caperatus ((L.:Fr.) P. Karst.) is among the mushroom species with the highest uptake of radiocesium from soil. This is confirmed in a great number of investigations from all over Europe e.g. Mascanzoni (1987), Haselwandter et al. (1988), Bakken & Olsen (1990). Until today higher radiocesium concentrations, in Danish material, have only been measured in Hygrophorus hypothejus ((Fr.:Fr) Fr.) (Strandberg in prep.) and in one species of Cortinarius, Strandberg (1992). Most international, if not all, investigations have been concentrated on comparative studies of a larger number of mushroom species. Few authors have dealt with the time perspective. Elstner et al. (1987) and (1989) presents results from Germany from 1986 and 1987. Haselwandter (1978) and Haselwandter et al. (1988) compared the uptake of radiocesium in 7 species before (1974) and after the Chernobyl accident in 1986. It was found that the pattern of uptake was the same in both years and that it was species related. Heinrich (1992) found that radiocesium uptake in mushrooms generally was in the order symbiotic forest mushrooms > saprophytic forest mushrooms > meadow land mushrooms. In Norwegian mushrooms Olsen (1994) suggest a biological halflife of Chernobyl derived ^{137}Cs close to the physical, because no constant decrease was observed. However other observations from Norway reported by Gulden and Amundsen (1994) showed a decrease in some species, but an increase in others. Some species neither, decreased nor increased during the period e.g. Rozites caperatus.

In common to all investigations cited are that they have no exact assessments of timedependent changes, such as determinations of ecological or effective halflife of radiocesium in any species of mushrooms. It might be so that the lack of a clear decrease has lead some authors to conclude that the effective halflife is equal to the physical. As fungi are among the products from natural ecosystems with a high potential for transfer of radiocesium to man, effective halflives for radiocesium in fungi are valuable to know. The present study is presents an assessment of the effective halflife of Chernobyl derived ^{137}Cs in one mushroom species, Rozites caperatus.

The use of mushrooms as bioindicators presents both advantages (Giovani et al. 1990 and Mietelski et al. 1994) and disadvantages compared to lichen and moss species. The main difference is that mushrooms monitors a combination of parameters such as availability, deposition and depth penetration, while mosses and lichens simply gives an indication of the deposition pattern. The performance of lichen and moss as bioindicators of radiocesium as well as other airborne contaminants has been assessed in several investigations e.g. Mattson & Lidén (1975), Guillitte et al. (1990), Crête et al. (1992) and Sloof & Wolterbeck (1992).

To elucidate differences between mycelias growing under arctic and temperate conditions some arctic material is included in the investigation. The ecological halflife might be longer in the arctic because of the general trend towards a slower rate of the biogeochemical processes with increasing northern latitude.

MATERIAL & METHODS

Samples

The material consists of 69 samples of Rozites caperatus obtained from the Botanical Museum of Copenhagen, private persons and own collections of Rozites caperatus and soil samples from Tisvilde Hegn in North Zealand (table 1). Of the 69 samples of fruitbodies, 13 are from Greenland and 56 from Denmark.

Site description

Tisvilde Hegn (56°03'N 12°06'E) is a near shore forest on sandy ground. The sampling site is an area with Scots pine (Pinus silvestris) on old deposits of shifting sand. The podsolic soil is mainly sand covered by an approximately 5 cm thick organic layer. Mosses, such as Pleurozium schreberi, Scleropodium purum and Hylocomium splendens, dominates the forest floor. Local importance have lichens (especially Cladina sp.), herbs and dwarfbushes e.g. Linnaea borealis, Fragaria vesca, Empetrum nigrum and Vaccinium vitis-idaea. The clay content of the soil is low, between 0 and 2 % and pH varies between 4 and 5.

Sampling and treatment

Fruitbodies of Rozites caperatus was sampled from distinct mycelias in Tisvilde Hegn. The limitation of mycelias of Rozites caperatus is most often easy (Strandberg & Rald, 1995), because they grow in well defined small groups.

Mushroom samples were cleaned from soil and litter and the base was cut off. They were brought to the laboratory where the mass was determined. Finally they were dried at 50°C for 48 hours and ground, before the dry weight mass was determined. Samples from other parts of Denmark and Greenland received from the Botanical Museum of Copenhagen and private persons were treated similarly.

Soil samples were collected with a 5 cm diameter cylindrical stainless steel core. The upper 5 cm of soil including moss and litter was sampled for determination of deposition to ground.

Soil was sampled in the autumn of 1993 from mycelia 1 - 8, from the mycelias 9 - 14 sampling took place in the autumn and winter of 1994 - 95. Mushroom samples was dried at 50°C and ground before counting. Soil samples was dried at 100°C and after determination of the mass they were finally incinerated at 450°C before analysis for radiocesium. Tables in Campbell (1979) were used for determination of significance levels of correlation coefficients (r).

Counting

Samples were measured for ^{134}Cs and ^{137}Cs using a Ge(Li) detector. Both 604 and 795 keV spectral lines were used for determination of ^{134}Cs, hereby a weighted mean of the ^{134}Cs determination was obtained. Standards for determination of isotopes of cesium were made from watery solutions of cesium chloride. The correction for variation in density between samples was made according to Lippert (1983).

Samples and standards were measured in 200 ml cylindrical plastic containers for a maximum of 24 hours. Smaller samples obtained from the Botanical Museum of Copenhagen were measured in small volume cylinders (max. 2.05 ml) in a hollow Ge(Li) crystal. The statistical counting error on measurement of ^{134}Cs varied between 1 and 10 %. Results were decay corrected to date of sampling. Location and year of individual samples are presented in table 1.

^{134}Cs results are not presented, but they were used for the calculation of the Chernobyl derived proportion of ^{137}Cs in soil and fruitbodies. This calculation was carried out using a ratio of ^{134}Cs to ^{137}Cs of 0.54 (Aarkrog et al. 1988) on the 26th of aprile 1986.

RESULTS & DISCUSSION

In table 2 results on total deposition to soil (upper 5 cm) and concentration in fruitbodies from the 14 known mycelias of Rozites caperatus in Tisvilde Hegn are presented. In the table it is also indicated whether the mycelias is covered by the forest canopy or is free. In 1991 all Chernobyl derived radiocesium in Tisvilde Hegn was present in the OAh horizon and vegetation this layer makes up the upper 5 cm of the profile (Strandberg 1994). Results concerning the retrospective analysis of radiocesium concentrations in Rozites caperatus from Greenland and Denmark are presented in table 3.

Effective halflife of ^{137}Cs in distinct mycelias

The effective halflives of ^{137}Cs in the fruitbodies from those mycelias where sampling were carried out for three or more years showed an effective halflife of ^{137}Cs from Chernobyl ranging between 1.8 and 2.8 years (Fig 1 a-d). By normalizing to a date where fruitbodies were present at all involved mycelias (Fig 2) it was possible to improve the statistic of the calculation. Calculated in this way the resultant effective halflife of the Chernobyl derived ^{137}Cs gave the result of 2.3 years, which is equal to the mean of the individual calculations. $T_{1/2eco}$ was calculated from equation I.

$$\text{(I)}\quad T_{1/2eco}^{-1} = T_{1/2eff}^{-1} - T_{1/2phy}^{-1}$$

Results and statistical characteristics of the calculation of halflives are given in table 4.

Randa et al. (1990) observed an increase of the radiocesium content in Boletus badius from 1986 to 1988 from 14.8 in 1986 over 25.4 in 1987 to 38.3 kBq/kg D.W. in 1988. This increase is explained by the continued penetration of radiocesium to layers where it is available to Boletus badius.

Heinrich (1992) also observed an increase in most species from 1986 to 1989. In Norway Gulden & Amundsen (1994) reports results from Lierne on Rozites caperatus from 1989 to 1993. During this five year period no clear trend was observed, the material presented is apparently not from defined mycelias and very few replicates are included. However in species such as Suillus variegatus and Amanita fulva there may have been a decrease since 1990 and 1989 respectively. In other species the picture is more confused and in some cases an increase have taken place during the five year period e.g. in Cortinarius armillatus.

From own observations and those cited it is possible, though with some uncertainty, to predict a general picture of mushroom ^{137}Cs-contamination over time after an accident.

-An initial phase where some saprophytes are highly contaminated but the radiocesium concentration start to decrease after the first or second season after deposition because radiocesium penetrates the litter layer and consequently becomes unavailable to the superficial mycelia of most saprophytes. In this initial phase most symbiotic (ectomycorrhizal) fungi displays an increase as radiocesium availability is enhanced by penetration to the layers where most species in this group have their mycelia. This early phase lasts from a few years (say 2 - 5) up to several years, depending on the velocity of penetration, which again is a function of at least vegetation, soil and climate.

-The intermediate phase, where the levels in the symbiotic mushrooms seems to be more or less constant, but with variations in both directions because of differences in availability between seasons. The supply of radiocesium is more or less equal to the removal by decay and biogeochemical processes. Levels in saprophytes decrease because the penetration of radiocesium keeps on moving cesium away from the litter layer. The intermediate phase may last from a few to several years.

-Finally the terminating phase where radiocesium levels decreases as a result of the joint forces of biogeochemical processes and physical decay of radiocesium. This phase is characterized by the efficient halflife of radiocesium, which now can be derived from measurements of decreasing levels of radiocesium in fruitbodies. The efficient halflife will probably increase towards the physical halflife during the terminating phase because loss and supply due to biogeochemical processes becomes equal, hence it is only the physical decay that determines the rate of decrease. In the present study it is possible that this stage have been reached for fallout cesium from the early sixties. Thirty years therefore may consequently be the maximum time needed for ^{137}Cs to reach equilibrium. In other ecosystems and climates the time needed can be longer or shorter depending on the turnover rates.

Observed ratios of Chernobyl and fallout ^{137}Cs in Rozites caperatus

The observed ratio (OR, m^2/kg) fruitbody/soil as related to the deposition to the upper 5 cm of soil is shown in figure 3. The observed ratio expresses the ratio of the concentration of a given compound or element in a species, to the deposition of the same in the ground below the species. In this case ^{137}Cs from Chernobyl and A-weapon testing in the sixties is studied in Rozites caperatus and in the soil where the mycelia is situated. The OR may more or less describe an uptake from soil. According to Lieser & Steinkopff (1989) and Thiry et al. (1994) radiocesium cannot be fixed physico-chemically in the organic layer and humic acids could not be shown to have any marked effects on adsorption or fixation of Cs. Nevertheless has almost all experience shown that virtually all radiocesium deposition in natural ecosystems is located in the organic horizons (Fraiture 1992). According to Andolina and Guillitte (1990) the thickness of the humus layer and the organic content are the main parameters determining the retention of radiocesium in the upper soil layers. Thiry et al. (1994) states that humic acids and K has an indirect effect on the retention of Cs in the upper organic layers (OAh), by influencing the small amounts of mica particles to increase their cesium retention ability. In the case of mushroom fruitbodies the ^{137}Cs contamination may partly be due to uptake from soil, partly to a transfer from belowground to aboveground parts of the mycelia (the fruitbody). Maximum values of 56 % and 40 % of the total radiocesium deposition on acid forest soils were found to be present in the belowground fungal biomass (Brückmann & Wolters 1994, Guillitte et al. 1994).

Until 1994 the OR was higher for Chernobyl cesium than for fallout cesium. In 1994 The observed ratio was highest for fallout cesium in most cases. This may be because that Rozites caperatus takes up cesium from layers below 5 cm that are not included in the calculation of the observed ratio used in this context. In layers below 5 cm practically all ^{137}Cs is of fallout origin. The almost equal observed ratios of the two different derived cesium fractions indicate that the availability of Chernobyl derived cesium may have reached or be close to reach a balanced stage. Apparently such an equilibrium exists for fallout cesium from the sixties as indicated under the preceding heading. The observed ratio of Chernobyl derived cesium has shown a significant decrease from a value of 4 m^2/kg in 1991 to approximately 2 m^2/kg in 1994. No such decrease has taken place for fallout cesium, and the OR has been around 2.5 m^2/kg during the period. In 1994 the Chernobyl derived cesium is 8 years old, while most fallout cesium is more than thirty years old. If this span of years implies that the availability of radiocesium in temperate podsolic forest soil cease to decrease, apart from physical decay, it is an interesting characteristic of this type of ecosystem. If Chernobyl cesium behaves like fallout cesium we may predict that the decrease in availability to mushroom fruitbodies will slow down with time and somewhere in the span between 8 and 25 years after deposition will reach an efficient halflife almost equal to the physical.

Monitoring of radiocesium deposition using Rozites caperatus as an indicator species.

Monitoring of radiocesium using mushroom fruitbodies as indicator organisms has been used regionally in some cases. Fraiture et al. (1990) compared the ^{137}Cs concentration in fruitbodies of Boletus badius and Paxillus involoutus in Wallonie in Belgium. The same pattern of uptake was found in both species. The uptake was mainly influenced by wet deposition and soil type. Giovani et al. (1990) found that different ecological groups of mushrooms could be used as bioindicators of the radiocesium concentration in different soil depths. In other words mushrooms have some advantages as bioindicators, among which are their ability to concentrate radiocesium and thereby they facilitates measurement. The disadvantages are the heterogeneity of mushrooms as a group, the difficulties in knowing the mushrooms and maybe it is also possible that different strains of the same species have different properties as regards the ability to concentrate radiocesium.

The Danish samples seems to split into at least two groups. The samples from Tisvilde taken in the stand of scotch pine generally have a higher concentration of fallout radiocesium than those from the different beech forests. Most likely this difference is caused by differences in soil types between the two forest types i.e. the podsolation is more strongly developed in the pine forest.

In Tisvilde the samples of Rozites seems to be divided into two groups, one with a higher concentration of radiocesium with mycelias situated in small clearings between forest crowns and another with a lower content of radiocesium growing beneath the tree canopies. This pattern is in accordance with observations by Fraiture et al. (1990) who found the following ranking of ^{137}Cs contaminated forest mushrooms after the situation of the fruitbodies in relation to the forest cover: In clearings or in clear cuttings < under the forest cover < under little openings in the forest cover or just at the forest skirt.

In Tisvilde in 1991 both Chernobyl and fallout radiocesium was mainly situated in the upper soil layers with only a minor fraction of 20 % and 3 % respectively remaining in the litter layer (Strandberg 1994). The correlation between the concentration in the fruitbodies of Rozites caperatus from the Tisvilde mycelias and the deposition to the upper 5 cm of soil was significant for Chernobyl derived ^{137}Cs (Fig. 4), this was not the case for fallout derived radiocesium.

Uptake of radiocesium in Rozites caperatus retrospectively

In figure 5 fallout ^{137}Cs concentrations in Rozites caperatus are compared retrospectively for Denmark and Greenland. The Danish material includes only samples from deciduous forests, i.e. collections from Tisvilde Hegn are omitted. The samples from the coniferous forest in Tisvilde have been presented in the sections above, and they have a higher concentration of fallout derived ^{137}Cs, than does the samples from Greenland and Denmark presented in figure 5.

Though one should be very careful to draw conclusions from an insufficient material, some trends in the material seems to be worthwhile to point out:

-No radiocesium was detected in the sample from 1946.

-No Chernobyl cesium was detected in the Greenlandic samples collected after 1986, this is due partly to the small samples, partly to the low deposition from Chernobyl in Greenland, especially in the continental parts where Rozites caperatus is most common.

-Uptake rates have not been measured from Greenland, but since the deposition from atmospheric A-weapon tests in southern Greenland was less than 2/3 of that in Denmark (Aarkrog 1994), there is some indication in the material that uptake ratios are somewhat higher in Greenland than in Danish deciduous forest.

-The Greenlandic material seems to show a maximum around 1983, while the Danish material apparently have been decreasing since the midsixties.

The fast ^{137}Cs concentration decrease in the Danish material seems to cease in 1975, this might indicate that equilibrium have been reached as this point, but it is just as likely to be due to natural variation. With the more slow biogeochemical processes in the arctic, it is to be expected that equilibrium will take place later after deposition in Greenland.

CONCLUSION

The effective halflife of Chernobyl derived ^{137}Cs in fruitbodies of Rozites caperatus was calculated to 2.3 years. The effective halflife for ^{137}Cs from fallout in the same fruitbodies could not be determined, but definitely it was longer and it is probably close to the physical halflife of 30 years.

Until 1993 Chernobyl Cs was taken up more readily than fallout cesium, but in 1994 there was no clear difference in rate of uptake from soil.

From the content of Chernobyl derived radiocesium in fruitbodies of Rozites caperatus it was possible to estimate the deposition per meter square in the upper 5 cm of soil at the sites where the fruitbodies were sampled.

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Table texts

Table 1.

Overview of Danish and Greenlandic samples of Rozites caperatus analyzed for radiocesium.

Table 2.

Concentration (Bq/kg d.w.) of Chernobyl and fallout derived ^{137}Cs in fruitbodies of Rozites caperatus from distinct mycelias in Tisvilde Hegn.

Table 3.

Fallout ^{137}Cs (Bq/kg d.w.) in Rozites caperatus in Denmark and Greenland retrospectively

Table 4.

Overview of halflives and underlying statistics

Tabel 1

Year	n	Biotop	Location	Longitude	Latitude
Greenland					
1946	1	Betula pubescens	Ivigtut	48°10'W	61°12'N
1973	1	Betula glandulosa	Paamiut	49°23'W	62°04'N
1979	1	Betula glandulosa	Paamiut	49°40'W	62°00'N
1981	1	Betula glandulosa	Paamiut	49°30'W	62°00'N
1983	1	Betula pubescens	Qinqua Valley	44°33'W	60°16'N
1987	1	Betula glandulosa	Paamiut	49°30'W	62°00'N
1987	2	Betula nana	Qorqut	50°54'W	64°16'N
1991	1	Betula pubescens	Qinqua Valley	44°33'W	60°16'N
1991	1	Betula pubescens	Grønnedal	48°08'W	61°19'N
1993	1	Betula glandulosa	Saputit Tasia	44°45'W	60°16'N
1993	2	Betula glandulosa	Paamiut	49°40'W	62°00'N
Denmark					
1967	1	Fagus sylvaticus	Silkeborg	09°36'E	56°07'N
1975	1	Fagus sylvaticus	Viborg	09°21'E	56°27'N
1982	1	Fagus sylvaticus	Århus	10°13'E	56°07'N
1982	1	Fagus sylvaticus	Addit Skov	09°35'E	56°03'N
1989	1	Quercus robur	Tinnet Krat	09°23'E	55°54'N
1991	3	Pinus silvestris	Tisvilde Hegn	12°06'E	56°03'N
1992	4	Pinus silvestris	Tisvilde Hegn	12°06'E	56°03'N
1992	1	Fagus sylvaticus	Nystrup plantage	08°30'E	57°00'N
1993	1	Picea abies	Tisvilde Hegn	12°05'E	56°03'N
1993	13	Pinus silvestris	Tisvilde Hegn	12°06'E	56°03'N
1994	1	Fagus sylvaticus	Grib Skov	12°21'E	56°01'N
1994	2	Picea abies	Tisvilde Hegn	12°05'E	56°03'N
1994	26	Pinus silvestris	Tisvilde Hegn	12°06'E	56°03'N

Table 2. Fallout and Chernobyl derived Cs-137 in fruitbodies of Rozites caperatus and in upper 5 cm of soil in Tisvilde Hegn. C = Chernobyl, F = Fallout. Results are Bq/kg D.W. for fungi and Bq/m square for soil
From mycelia 9 - 14 soil Fallout radiocesium is an approximation derived from what is in the upper 10 cm and the mean fallout deposition

	Mycel 1	Mycel 1	Mycel 2	Mycel 2	Mycel 3	Mycel 3	Mycel 4	Mycel 4	Mycel 5	Mycel 5	Mycel 6	Mycel 6	Mycel 7	Mycel 7
	C	F	C	F	C	F	C	F	C	F	C	F	C	F
	free		free		cover		cover		free		cover		cover	
Jord mean	1831		1953		1038		1106		2030		1385		1398	
03-Sep-91	9760	4425												
18-Sep-91	7960	4478	7641	5765										
22-Sep-92	5567	4166							6226	3855	4059	2320		
04-Oct-92	6571	3898												
03-Aug-93	5541	4358	3304	2996										
10-Aug-93	6025	3886	5075	3787	3630	1945							1965	2016
20-Aug-93	5601	3241									3421	1734		
30-Aug-93											3222	2657		
09-Sep-93											2469	1505		
16-Sep-93	2989	1414	2794	2613							4993	2026		
18-Sep-94	3343	5423	2850	2801			1373	2897			2326	3013		
19-Sep-94														
22-Sep-94	2904	4069					1287	2294			2227	2243	3554	3172
25-Sep-94	3237	4733	2396	2944							1841	2430		
03-Oct-94	3047	4765	2535	3508			2388	3015			1987	2832	4040	3541
03-Oct-94	4352	2009												
10-Oct-94														
12-Oct-94	6518	6206	3564	4460										

	Mycel 8	Mycel 8	Mycel 9	Mycel 9	Mycel 10	Mycel 10	Mycel 11	Mycel 11	Mycel 12	Mycel 12	Mycel 13	Mycel 13	Mycel 14	Mycel 14
	C	F	C	F	C	F	C	F	C	F	C	F	C	F
	free		cover		free		cover		cover		cover		free	
Jord mean	2023		1255		1467		904		904		907		828	
03-Sep-91														
18-Sep-91														
22-Sep-92														
04-Oct-92														
03-Aug-93														
10-Aug-93														
20-Aug-93														
30-Aug-93														
09-Sep-93														
16-Sep-93	6599	3416												
18-Sep-94	3685	4587												
19-Sep-94			1336	2028										
22-Sep-94	4277	5067												
25-Sep-94					2545	4284								
03-Oct-94							1891	2796	1946	2760	2066	2992	2834	5434
03-Oct-94														
10-Oct-94			1985	2777										
12-Oct-94														

TABEL 2

TABEL 3

	Denmark		Greenland		
Year	Jutland	Zealand	Paamiut	S.Greenland	Qorqut
1946				0	
1967	9213				
1973			3008		
1975	1071				
1979			3395		
1981			4288		
1982	594				
1982	1677				
1983				7482	
1987			5563		2958
1987					3833
1989	3097				
1991				1052	2996
1992	3318				
1993			2631	3524	
1993			2596		
1994		1383			

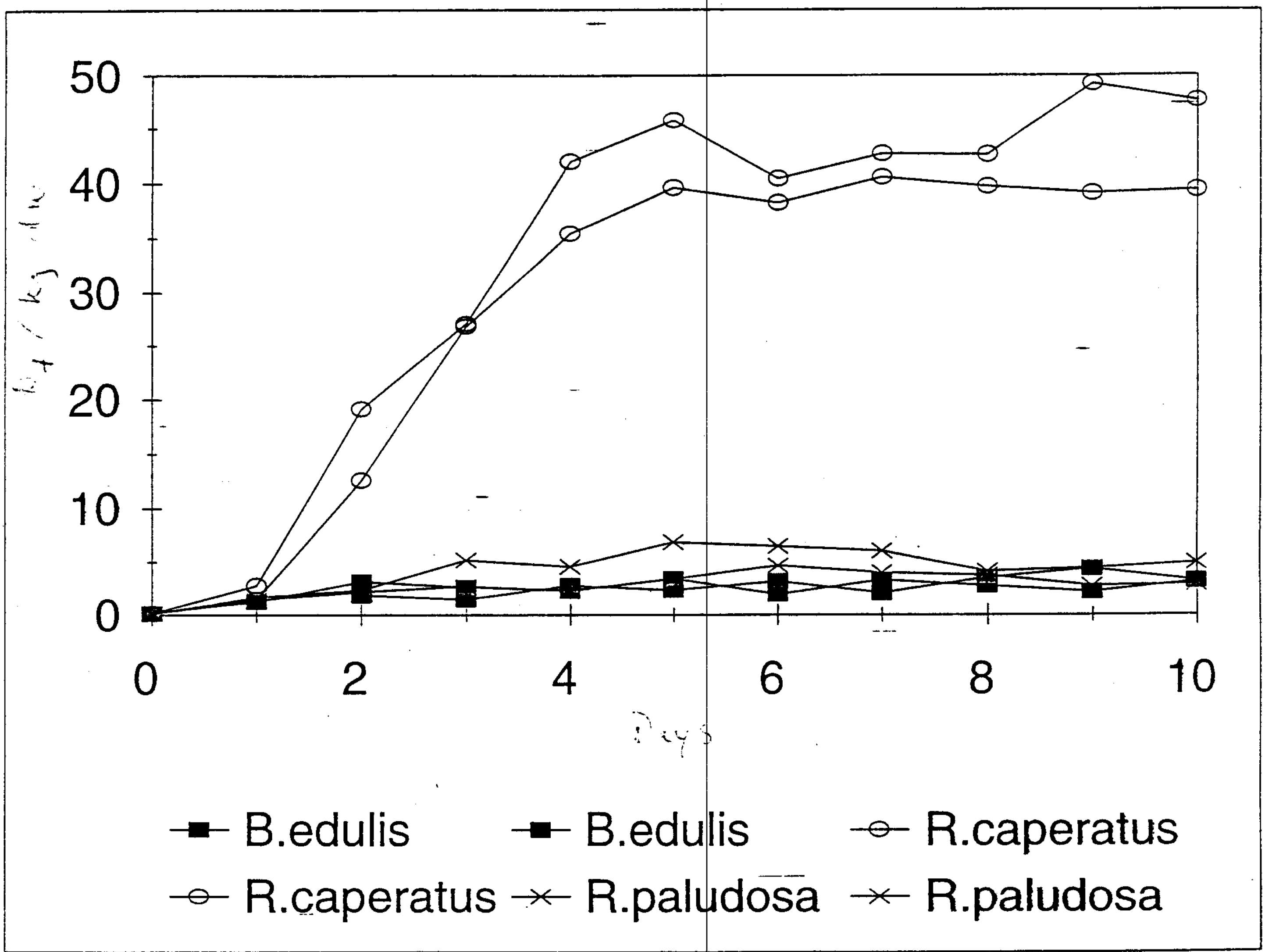
TABEL 4

Mycelia No	Cesium origin	r	v	α	$T_{1/2eff}$ years	$T_{1/2eco}$ years
1	C	0.772	12	1	2.5	2.7
	F	0.045	12	-		
	T	0.530	12	5	4.8	5.7
2	C	0.853	6	1	2.2	2.4
	F	0.564	6	-	4.9	5.9
	T	0.766	6	5	3.0	3.3
6	C	0.806	7	1	1.8	1.9
	F	0.449	7	-		
	T	0.542	7	-	4.9	5.9
5 & 8	C	0.847	2	-	2.8	3.1
	F	0.729	2	-		
	T	0.772	2	-	9.3	13.5
All normalised	C	0.799	33	0.1	2.3	2.5
	F	0.027	33	-		
	T	0.542	33	1	4.5	5.3

r = coefficient of correlation
v = Degrees of freedom
α = significance level

C = Chernobyl ^{137}Cs in upper 5 cm
F = Fallout ^{137}Cs in upper 5 cm
T = Total ^{137}Cs in upper 5 cm

Fig 1



50
40
30
20
10
0
0
2
4
6
8
10
Days
B.edulis
B.edulis
R.caperatus
R.caperatus
R.paludosa
R.paludosa

Figure Texts

Figure 1a-d.
Regressionlines and concentrations of ^{137}Cs in Rozites caperatus from 1991 - 1994 at distinct mycelias in Tisvilde Hegn. Upper graph = total ^{137}Cs, Middle graph = Chernobyl derived ^{137}Cs, Nethermost graph = ^{137}Cs from fallout.

Figure 2.
All values in figure 1 was normalised to 100 at the 18th of september 1994 where fruitbodies were present at al mycelias included and regression lines was drawn and halflife calculated.

Figure 3.
Observed Ratios of Chernobyl and fallout derived radiocesium in Rozites caperatus from mycelia 1 from 1991 to 1994.

Figure 4.
The relation between mean concentration of ^{137}Cs in fruitbodies of Rozites caperatus at mycelia 1 - 14 and soil concentration of ^{137}Cs in the upper 5 cm of soil at the site of the mycelias.

Figure 5.
Retrospective values of fallout derived ^{137}Cs in Rozites caperatus in Denmark and Greenland.