

^{137}Cs in small forest lakes of Finland after the Chernobyl accident

R. Saxén, M. Rask, J. Ruuhijärvi, P.J. Vuorinen, A. Rantavaara, U. Koskelainen

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Ritva Saxén, Aino Rantavaara and Ulla Koskelainen
STUK – Radiation and Nuclear Safety Authority,
Laippatie 4, P.O. Box 14, FI-00881 Helsinki, FINLAND

Martti Rask and Jukka Ruuhijärvi
RKTL – Finnish Game and Fisheries Research Institute
Evo Game and Fisheries Research
Rahtijärventie 291, FI-16970 Evo, Finland

Pekka J. Vuorinen
RKTL – Finnish Game and Fisheries Research Institute (Helsinki)
Viikinkaari 4, P.O. Box 2, FI-00791 Helsinki, Finland

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STUK – Radiation and Nuclear Safety Authority

P.O.Box 14, FI-00881 Helsinki, Finland

Tel. +358 9 759 881

Fax +358 9 759 88500

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Abstract

A joint monitoring study between the Radiation and Nuclear Safety Authority (STUK) and the Finnish Game and Fisheries Research Institute (FGFRI) on the radioactivity of forest lakes in Evo, Southern Finland, was started in summer 1987. Besides fish, lake water and other biota, such as zooplankton, larvae of various insects and aquatic plants, were analysed from these lakes. Soil samples from the lake catchments were also analysed in 1988–1989. In 1992, samples of bottom sediment were analysed from one lake for ¹³⁷Cs. In addition, fish from the Finnish Acidification Research Project of FGFRI from several small forest lakes in 1986–1989 were analysed for ¹³⁷Cs. The results obtained in the joint study of STUK and FGFRI are gathered in this report.

The highest activity concentrations of ¹³⁷Cs in fish were about 30 000 Bq/kg (w.w.) in 1987 in pike from Lake Iso Valkjärvi, which is a clear-water seepage lake having no natural inlet or outlet. Variation in the activity concentrations of ¹³⁷Cs in fishes in small forest lakes in the area receiving the highest deposition in Finland has remained large since the Chernobyl deposition. Interspecific differences in ¹³⁷Cs levels of fish were consistent with their trophic position in the food webs. Ten-fold interlake differences in ¹³⁷Cs contents of lake water were noted within the same municipality in 1987.

In the bottom sediment of Lake Iso Valkjärvi, 95% of ¹³⁷Cs was present in the uppermost 10 cm and about 70% in the uppermost 3 cm in 1992. The total amount of ¹³⁷Cs detected in the sediment profile was only a quarter of the average deposition in the municipality of Lammi measured by Arvela et al. (1990). Average values for ¹³⁷Cs in soil in the catchments of five lakes as Becquerels per unit area were clearly higher than the average value for the deposited ¹³⁷Cs in the municipality of Lammi determined by Arvela et al. (1990).

An aquatic plant, the yellow iris, was the most effective ¹³⁷Cs accumulator of all the organisms studied, having a bioconcentration factor of 115 000 on a dry weight basis. Some other plants and fish were also efficient accumulators of ¹³⁷Cs.

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Avainsanat: ¹³⁷Cs, kala, metsäjärvi, vesieliö

Tiivistelmä

Vuonna 1987 Säteilyturvakeskus (STUK) aloitti yhteistyössä Riista- ja kalatalouden tutkimuslaitoksen (RKTL) kanssa seurantaohjelman, joka koski Tshernobylin onnettomuudesta peräisin olevan radioaktiivisen cesiumin esiintymistä ja pitkäaikaisvaihteluita pienissä metsäjärvissä. Joitakin kalanäytteitä otettiin jo vuonna 1986. Kalanäytteiden lisäksi muutamista Evon järvistä analysoitiin järvivesinäytteitä sekä muita kalojen ravintoverkon eliöitä, kuten eläinplanktonia, erilaisten hyönteisten toukkia ja monenlaisia vesikasveja. Lisäksi vuosina 1988 ja 1989 analysoitiin maanäytteitä järvienvallama-alueilta laskeuman tarkemmaksi määrittämiseksi. Vuonna 1992 selvitettiin myös ¹³⁷Cs:n jakautuminen yhden järven pohjasedimenttiin. Evon järvien lisäksi STUK analysoi kalanäytteiden ¹³⁷Cs-pitoisuudet RKTL:n järvien happamoitumista koskevaan hankkeeseen (HAPRO) kuuluneista pienistä metsäjärvistä eri puolilla Suomea. Tähän raporttiin on koottu STUK:n ja RKTL:n yhteishankkeessa saadut tulokset.

Korkeimmat kaloissa havaitut ¹³⁷Cs:n aktiivisuuspitoisuudet olivat noin 30 000 Bq/kg tuorepainoa kohti vuonna 1987. Niitä esiintyi Iso Valkjärvessä, mikä on niukkaravinteinen, lievästi happamoitunut laskujoeton järvi. Järvien välinen vaihtelu kalojen ¹³⁷Cs-pitoisuuksissa oli ja on edelleen suuri. Kalalajien välinen ¹³⁷Cs-pitoisuuksien vaihtelu seuraa niiden ravinnonottotavan mukaista asemaa ravintoketjussa. Järvivesien ¹³⁷Cs-pitoisuuksissa havaittiin vuonna 1987 kymmenkertaisia eroja saman kunnan alueen pienissä järvissä.

Vuonna 1992 Iso Valkjärven sedimentissä havaittu ¹³⁷Cs:n kokonaismäärä oli vain neljännes ulkoisen säteilyn mittausten perusteella määritetystä Lammin kunnan keskimääräisestä ¹³⁷Cs-laskeumasta. Yli 95 % pohjasedimentissä havaitusta ¹³⁷Cs:sta oli sedimentin ylimmässä 10 cm:ssä ja liki 70 % ylimmässä 3 cm:ssä. Järvien valuma-alueilta määritetyt ¹³⁷Cs-pitoisuudet pintalaskuun (Bq/m²) sen sijaan olivat selvästi korkeampia kuin edellä mainittu keskimääräinen kunnan ¹³⁷Cs-laskeuma.

Verrattaessa analysoituja vesieliöitä keskenään, havaittiin, että kurjenmiekka keräsi eniten ¹³⁷Cs:ä eli sen biokonsentraatiokerroin oli suurin. Myös jotkut muut vesikasvit sekä kalat olivat tehokkaita ¹³⁷Cs:n kerääjiä.

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1 Introduction

The deposition of ^{137}Cs following the Chernobyl accident was unevenly distributed in Finland (Fig. 1) (Arvela et al. 1990). Radiocaesium reached lakes via direct deposition and later with runoff waters from the lake catchments. After entering lakes, ^{137}Cs transferred into food chains and raised the activity concentrations of fish and other biota. The increase was large in those lakes located in areas with the highest deposition.

A joint monitoring study between the Radiation and Nuclear Safety Authority (STUK) and the Finnish Game and Fisheries Research Institute (FGFRI) on the radioactivity of forest lakes in Evo, Southern Finland, was started in 1987, one year after the Chernobyl accident. However, some fish samples were already taken in 1986. The role of Evo Game and Fisheries Research in the project was sampling and that of STUK was sample analysis. The sampled lakes were in most cases small forest lakes, which are not very important in terms of freshwater fishing in Finland, but their significance is emphasized due to their large number ($> 53\,000$ lakes of $1\text{ ha} - 1\text{ km}^2$). Furthermore, these lakes often have conditions resulting in a high transfer of ^{137}Cs into fishes.

The activity concentrations of radiocaesium were followed after the Chernobyl accident during 1987–1991, 1995, 2001 and 2006 in several lakes in the municipality of Lammi, in one lake in Nokia and in Kuru, and in two lakes in Hyvinkää. Besides fish, lake water samples were also analysed from these lakes. In 1992, samples of bottom sediment and other biota were also analysed from one lake for ^{137}Cs . The amounts of radiocaesium deposited in these municipalities differed significantly from each other. The lakes also differed in hydrological characteristics. In addition, fish were sampled from several small forest lakes for ^{137}Cs analysis by the Finnish Game and Fisheries Research Institute in 1986–1989, during the test fishing carried out in the Finnish Acidification Research Project (HAPRO, Tuunainen et al. 1991). For comparison, some larger lakes were also sampled for fish during the first few years following the Chernobyl deposition.

The purpose of this study was to examine the long-term changes in the activity concentrations of ^{137}Cs in water and in fishes of the sampled lakes and to identify possible differences between lake types and fish species. Two of the lakes included in this study had also been sampled during the nuclear weapons testing period in the 1960s. This provided an opportunity to compare the transfer of ^{137}Cs originating from the Chernobyl deposition with that from nuclear weapons testing. The purpose was also to compare various aquatic organisms as accumulators of ^{137}Cs .

2 Material and methods

2.1 Sampled lakes

The most frequently sampled lakes included in the study were from the municipalities of Lammi (Lakes Halsjärvi, Iso Valkjärvi, Kuohijärvi, Mekkojärvi, Pääjärvi, Savijärvi, Rahtijärvi, Valkea Kotinen, Valkea Mustajärvi and Vähä Valkjärvi), Nokia (Lake Alinenjärvi), Kuru (Lake Honkajärvi) and Hyvinkää (Lakes Kytjärvi and Suolijärvi) (Fig. 1).

Most of the lakes studied were small forest lakes with a surface area of a few hectares. For comparison, the larger lakes Kuohijärvi and Pääjärvi in Lammi were sampled for fish during a few years after the Chernobyl deposition. Lakes Kytjärvi and Suolijärvi in Hyvinkää are also larger than 1 km² in area.

The location of the lakes in Lammi is illustrated in Figure 2. Characteristics of the most frequently sampled lakes are presented in Table I. Several other lakes, besides those mentioned above, were sampled for fish mainly in 1986 in central parts of the country. The municipalities, together with the number of lakes sampled in each municipality, are provided in Figure 3.

Most of the lakes of this study were located in the area of relatively high ¹³⁷Cs deposition. In October 1986 the average deposition of ¹³⁷Cs in the municipalities of Lammi, Nokia and Kuru was 46.50, 47.76 and 41.04 kBq/m², respectively (Arvela et al. 1990). By contrast, the deposition in Hyvinkää was rather low, being 9.26 kBq/m² on average in 1986. In the five-level classification of municipalities according to the deposition of ¹³⁷Cs, Lammi and Nokia belong to class 5, Nokia and Kuru to class 4 and Hyvinkää to class 2 (cf. Fig. 1). The less frequently sampled lakes were mainly in areas categorised as deposition class 5 or 4, while only a few were in classes 2 and 3 and one in class 1.

2.2 Water sampling, sample treatment and analysis

Most of the small lakes in Lammi were sampled for lake water. Water samples were taken 3 times per year during 1987–1991. In 1995, 2001 and 2006, water samples were taken once a year in Lakes Savijärvi, Rahtijärvi, Valkea Mustajärvi and Iso Valkjärvi. From Lakes Halsjärvi, Vähä Valkjärvi and Mekkojärvi, water was sampled only in 1995 after the three-times-per-year sampling in 1987–1991. In Lake Iso Valkjärvi, water samples were also taken annually from 1992–1994. The total number of water samples included in this study amounted to 175.

After arriving at the laboratory, water samples were acidified, a caesium carrier was added and the samples were concentrated by evaporation to dryness. The residues were analysed for gamma-emitting radionuclides using either pure

or lithium-drifted germanium detectors with relative efficiencies between 38% and 100% (Sinkko, 1981; Klemola and Leppänen, 1997).

2.3 Fish samples, sample treatment and analysis

The total number of fish samples collected during this project from 1986–2006 was 1 077. Most of the samples were taken from small lakes in Lammi, as shown in Table II, which gives the numbers of samples according to the lake and year. In addition to the above-mentioned lakes, small lakes from several municipalities in central parts of Finland, mainly sampled in 1986, are included as ‘other lakes’ in Table II.

The fish species sampled were those typical of each lake. The most common species were perch (*Perca fluviatilis*) and pike (*Esox lucius*), which were analysed from each of the lakes. Samples of whitefish (*Coregonus lavaretus*), roach (*Rutilus rutilus*), burbot (*Lota lota*), bream (*Abramis brama*), pikeperch (*Sander lucioperca*), bleak (*Alburnus alburnus*) and vendace (*Coregonus albula*) were also analysed from some lakes. Fish samples were taken once or twice a year.

Each fish sample consisted of several pooled specimens (3–158), especially if the fish were small in size. In the case of large fish, one sample consisted of one to three specimens. Samples of perch comprising numerous specimens were divided into three size groups: < 15 cm, 15–20 cm and > 20 cm. After arriving at the laboratory, the lengths of the fish (the smallest and the largest) and number of specimens in the sample were determined.

The fish were gutted as normally in the kitchen. Larger fish were filleted and the fillets were analysed for gamma-emitting radionuclides. Heads and entrails were removed from the small fish and the edible parts of the fish were then analysed for gamma-emitting radionuclides. The samples were analysed either as fresh or, most commonly, as dried for gamma-emitting radionuclides using either pure germanium or lithium-drifted germanium detectors with relative efficiencies between 38% and 100%. The measurements were performed in cylindrical geometries of either 560 ml or 30 ml (Sinkko 1981, Klemola and Leppänen 1997).

2.4 Other biota

Samples of zooplankton, *Asellus aquaticus*, insect larvae and aquatic plants were also taken, mainly from Lake Iso Valkjärvi in 1992, but also from some other lakes in 1987, the total number of the samples being about 70. The samples were dried and analysed for gamma-emitting radionuclides with semiconductor detectors in the cylindrical geometry of 30 ml.

2.5 Bottom sediment

A profile of 30 cm of bottom sediment was taken from Lake Iso Valkjärvi in 1992 with a Limnos sampler. The profile was cut into slices of 2 cm, and the five top centimetres into slices of 0.5 cm. The slices were dried and analysed for gamma-emitting radionuclides.

2.6 Soil

Soil samples were taken from the catchments of the lakes in Lammi in 1988 and 1989 to determine the local deposition more precisely than the municipal average (Arvela et al., 1990). The soil samples were taken with a spade, without mixing the soil layers, from a fixed surface area. The soil samples were dried and analysed for gamma-emitting radionuclides. Besides soil samples, a mobile measuring system (equipment located in a car) was used to measure external radiation in the vicinities of the lakes in Lammi to map the local variations in deposited ^{137}Cs .

3 Results and discussion

3.1 ^{137}Cs in lake water

Two caesium isotopes, ^{134}Cs and ^{137}Cs , were detected in all the samples until the 2000s. The amount of ^{134}Cs was about half that of ^{137}Cs in April–May 1986 and it entirely originated from the Chernobyl deposition. By comparison, a small proportion of ^{137}Cs (approximately 20%, estimated on the basis of the values for Lake Päijänne in early May 1986) originated from atmospheric nuclear weapons tests. In the 2000s, even the highest activity concentrations of ^{134}Cs were below 0.002 Bq/l.

^{137}Cs contents of water were highest in Lake Iso Valkjärvi, being 4.6 Bq/l in early June 1987. The next highest contents were recorded in Lakes Vähä Valkjärvi and Valkea Mustajärvi. The lowest contents of ^{137}Cs in the lakes of Lammi in summer 1987 were observed in Lake Halsjärvi, being 0.5 Bq/l (Fig. 4). Ten-fold interlake differences in ^{137}Cs contents were noted, even within the same municipality. The uneven distribution of deposited ^{137}Cs resulted in differences between samples from different municipalities and even within one municipality.

In addition, several environmental factors may cause differences in the transfer of radionuclides through the aquatic pathway, especially during the long term after deposition. The transfer of ^{137}Cs into fish is a complicated dynamic process that is associated with the type of fish, the quality of the lake water, the water residence time and flow rate, sedimentation processes and the amount of suspended solids in the water (Sundbom et al. 2003, Håkanson et al. 1992, Rowan and Rasmussen 1995, Saxén and Ilus 2008, Smith et al. 2000).

In most lakes a short-term decrease in ^{137}Cs concentrations in water rapidly took place after the Chernobyl deposition. For instance, in Lake Päijänne the half-life of ^{137}Cs was 50 days during 1986, but thereafter the decrease was slower (Saxén 2004). In the lakes of this study, the situation during the first year after the deposition is unknown, because water sampling only started in 1987.

3.2 ^{137}Cs in fish

^{137}Cs contents of fish were highest in Lake Iso Valkjärvi, Lammi. The highest activity concentrations of ^{137}Cs were about 30 000 Bq/kg (w.w.) in pike from Lake Iso Valkjärvi and 25 000 Bq/kg (w.w.) in perch from Lake Alinenjärvi in 1987. Temporal changes in the activity concentrations of ^{137}Cs in perch from various lakes are illustrated in Figure 5.

The long water residence time (3–4 years) of Lake Iso Valkjärvi is one reason for the highest activity concentrations of ^{137}Cs being recorded in the

fish and water of this lake. Possibly also for the same reason, ^{137}Cs in fish also remained clearly higher for a longer time than in the other study lake. Some of the lakes studied were not only oligotrophic but also acidified, such as Lake Iso Valkjärvi, which intensifies the transfer of ^{137}Cs into fish (Saxén and Ilus 2008).

Various fish species from Lake Kytäjärvi had already been analysed for ^{137}Cs in 1964 as a follow-up to the atmospheric nuclear weapons tests. This was the year of maximum fallout from these tests, and the activity concentrations of ^{137}Cs in perch, pike, burbot and roach were 43, 28, 31 and 14 Bq/kg w.w., respectively (Kolehmainen et al. 1966). In the first three years following the Chernobyl deposition, the variation in the activity concentrations of ^{137}Cs in fishes was slightly higher than in 1965, ranging from 22 to 110 Bq/kg, but thereafter it remained at the level of 1964 or even lower. In Lake Suolijärvi the activity concentrations of ^{137}Cs in 1965 were clearly higher than in Lake Kytäjärvi, varying from 66 to 140 Bq/kg (w.w.) (Kolehmainen et al. 1966). The highest post-Chernobyl values in 1988 were from 190 to 440 Bq/kg (w.w.) in perch and pike. A clear difference in the level of ^{137}Cs between these two lakes was detected after the Chernobyl deposition, as was also found during the nuclear weapons testing period in the 1960s. This was because the transfer of ^{137}Cs into fishes is more effective in oligotrophic lakes (Lake Suolijärvi is classified as dysoligotrophic) than in eutrophic lakes (Lake Kytäjärvi is classified as dyseutrophic). Oligotrophic lakes are ion-poor and because caesium behaves physiologically like potassium, it is readily accumulated in fish.

In 1986 the main factor causing variation in the activity concentrations of ^{137}Cs in fish was local differences in the amounts of deposited ^{137}Cs within the same area. In later years, the role of environmental factors affecting the transfer of ^{137}Cs in the lake and its catchment and the uptake of ^{137}Cs by fish became more pronounced. The largest lakes of this study were Lakes Kuohijärvi and Pääjärvi. A large difference in the activity concentrations of fish between these lakes was recorded (Fig. 6). In lake Pääjärvi, all samples had less than 1 000 Bq/kg (w.w.) ^{137}Cs , while in lake Kuohijärvi the highest activity concentration in pike in 1988 was close to 7 000 Bq/kg (w.w.) (Fig. 6). This was, however, lower than the highest values in some smaller-sized lakes in the same area.

In lake Alinenjärvi small and medium sized perch and small pike had higher activity concentrations of ^{137}Cs in 1987–1988 opposite to later years (Fig. 7).

Variation in the activity concentrations of ^{137}Cs in fishes in small forest lakes in the area receiving the highest deposition in Finland (class 5 in Fig. 1) was large in 1987 (Fig. 8) and has remained large since the Chernobyl deposition (Saxén 2007). The results for various samples taken from less frequently sampled lakes are summarised in Appendix 1.

Interspecific differences in the level of ^{137}Cs and in the year of the peak occurrence were also relatively clear (Figs. 9–10). The highest contents of ^{137}Cs were observed in pike and perch and were clearly lower in roach, whitefish and burbot (Fig. 9). The peak value for pike was somewhat higher than that for perch, which in turn was about twice as high as that in whitefish. The annual average value for roach was about one half of the respective value in whitefish. At its highest, the variation in pike was 3.5 times greater, that of perch 2.5 times greater and that of whitefish about 2 times greater than the annual average (Fig. 10). Interspecific differences in ^{137}Cs levels of fish were consistent with their trophic position in the food webs.

3.3 Bioconcentration factors for fish

Bioconcentration factors ($\text{CF} = \text{Bq/kg in fish} / \text{Bq/kg in water}$) describe the fate of ^{137}Cs in a lake. This factor is often used in models used to predict ^{137}Cs levels in fish (Rowan and Rasmussen 1994). Variation in the ratios is large, as shown in the Figure 11, which illustrates annual averages of CF together with variation in some lakes. The long-term average bioconcentration factors, in turn, were obtained from the slopes of the lines describing activity concentrations of ^{137}Cs in fish versus those in water of the same lake during the whole study period. The long-term values determined with the method mentioned above differ somewhat from those calculated from the annual values (Table III). For fish, bioconcentration factors were on average about 5000 on a fresh weight basis (Table III), with large inter-lake and intra-lake variation.

3.4 ^{137}Cs in sediment of Lake Iso Valkjärvi in 1992

In 1992, ^{137}Cs was vertically distributed in the bottom sediment of Lake Iso Valkjärvi such that > 95% of ^{137}Cs was present in the uppermost 10 cm and 68% in the uppermost 3 cm (Fig. 12). The total amount of ^{137}Cs detected in the sediment profile, 9 300 Bq/m², was only a quarter of the average deposition in the municipality of Lammi measured by Arvela et al. (1990). Consequently, a significant proportion of the deposited ^{137}Cs remained in the lake water and biota, because this lake has no significant input or output rivers.

3.5 ^{137}Cs in soil in the catchments of lakes in Lammi

In 1988, the total amounts of ^{137}Cs in soil varied over a wide range, from 48 000 Bq/m² to 148 000 Bq/m², being lowest in the catchment of Lake Vähä Valkjärvi and highest in the catchment of Lake Mekkojärvi (Fig. 13). Most of the ^{137}Cs

(76–98%) was found in the three uppermost centimetres of the soil at all the sampling points. In the catchments of Lakes Valkea Mustajärvi, Vähä Valkjärvi, Iso Valkjärvi, Savijärvi and Rahtijärvi, 90–95% of ^{137}Cs was found to be in the uppermost 3 cm. The effect of the type of catchment area is seen as similarities in the vertical distribution patterns at various stations (Fig. 14). Vertical distributions in the catchments of Lakes Savijärvi and Rahtijärvi are similar. These catchments are comprised of mixed deciduous forest on morainic soil. Distributions in the catchments of Lakes Iso Valkjärvi and Valkea-Mustajärvi also resemble each other, and both have catchments consisting of pine moorland on glacial-fluvial sandy soil. In these catchments, most ^{137}Cs (> 80%) was found in the uppermost 1.5 cm in 1988. The catchment of Lake Mekkojärvi consists of wet swamp having equally high ^{137}Cs activities per unit area in the uppermost 3 cm (Fig. 14). The total amounts of ^{137}Cs in soil clearly declined in the catchments of Lakes Valkea Mustajärvi and Iso Valkjärvi, Lammi, while the ^{137}Cs content of soil close to Lakes Rahtijärvi and Savijärvi was almost the same in 1989 as in 1988. Average values for ^{137}Cs in soil in the catchments of five lakes varied in 1989 from 60 to 90 kBq/m², and variation based on two to five parallel profiles was quite reasonable (Fig. 13). All the values for ^{137}Cs in soil as Becquerels per unit area were clearly higher than the average value for the deposited ^{137}Cs in the municipality of Lammi determined by Arvela et al. (1990).

3.6 Comparison of various organisms as indicators of ^{137}Cs

Samples of zooplankton, *Asellus aquaticus*, larvae of various species, tadpoles, water mites and aquatic plants were taken mainly from Lake Iso Valkjärvi in 1992, but also in 1987 and from some other lakes in Lammi (Tables IV–VIII). Bioconcentration factors were also calculated for all these organisms (Tables IX–XIII).

Comparison of various organisms as accumulators of ^{137}Cs is mainly based on results for biota from lake IsoValkjärvi in 1992, the year when many species were sampled and analysed. Comparison with the results from the other lakes is difficult because of the different sampling times.

An aquatic plant, the yellow iris, was the most effective ^{137}C accumulator of all the organisms studied, having a bioconcentration factor (CF) of 115 000 on a dry weight basis (Table XIII). Some other plants were also efficient accumulators of ^{137}Cs , while sphagnum and bottom mosses had the lowest bioconcentration factors (Table XIII). CFs for larvae of the mayfly and dragonfly (about 11 000–24 000 on a dry weight basis) were almost as high as for some plants (Tables XII & XIV). The water slater *Asellus aquaticus* took up somewhat less ^{137}Cs than the fly larvae but more than zooplankton. Tadpoles and water

mites as well as bottom mosses were similar indicators of ^{137}Cs to zooplankton (Tables IX–XIII). Ilus et al. (2006) also found a plant, *Equisetum fluviatile*, to be the most efficient accumulator of ^{137}Cs among the organisms included in their study. Bioconcentration factors for fish are also among the highest values among aquatic biota (Fig. 11, Table III), as also stated in the study by Saxén and Ilus, 2008.

4 Conclusions

The transfer of radiocaesium to fish following deposition is a complicated process and depends on many factors. An oligotrophic status connected with a low potassium content and low lake water pH intensifies the uptake of ^{137}Cs by fish. A low sedimentation rate in a lake and bogs in the drainage area cause the ^{137}Cs levels in the water to remain higher and thus more available to the food web and fish. Combinations of water and drainage area characteristics are numerous and no two lakes are the same. Many of the lakes studied here represent conditions of maximum transfer and uptake of ^{137}Cs by fish. The results also demonstrate that since the Chernobyl deposition, variation in the activity concentrations of ^{137}Cs in fish from forest lakes has remained high in the area that received the highest deposition in Finland. Regarding various organisms as accumulators of ^{137}Cs , an aquatic plant, yellow iris, was the most effective of all the organisms studied. Bioconcentration factors for some other plants and fish were also among the highest values among the aquatic biota studied.

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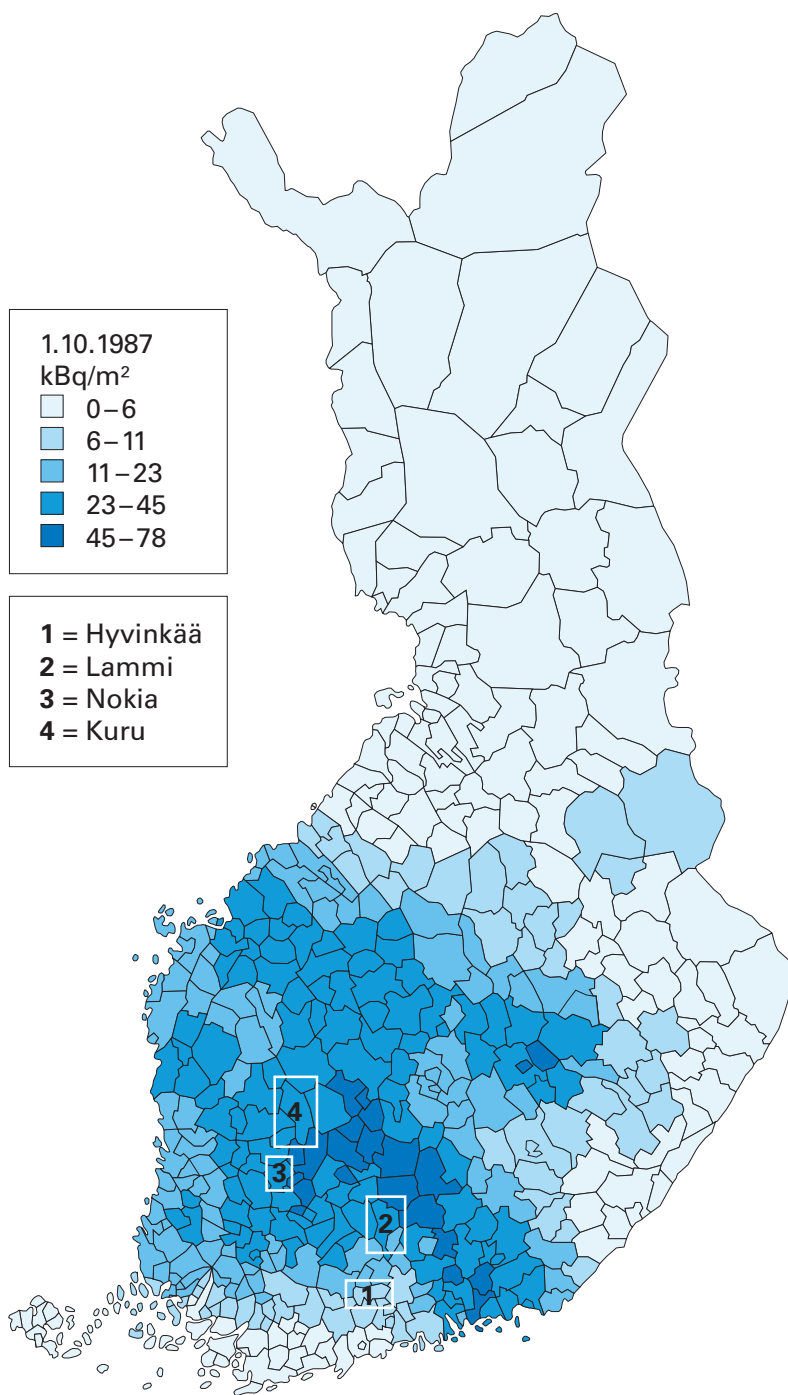


Fig. 1. Distribution of ¹³⁷Cs deposition in Finland and division of the country into five areas on the basis of the average municipal deposition (Arvela et al. 1990).

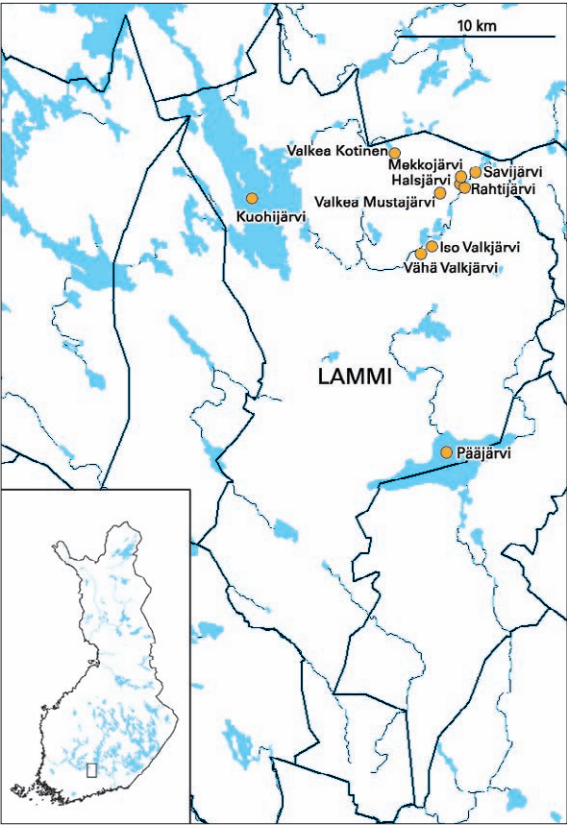


Fig. 2. Location of the lakes included in the study from the municipality of Lammi.

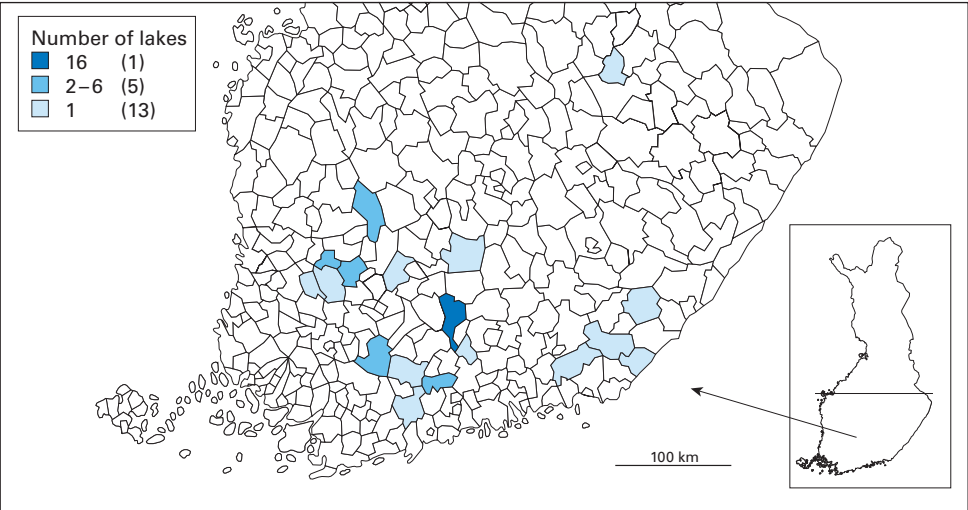


Fig. 3. The municipalities in which the sampled lakes are located. The number of sampled lakes is indicated with a colour code.

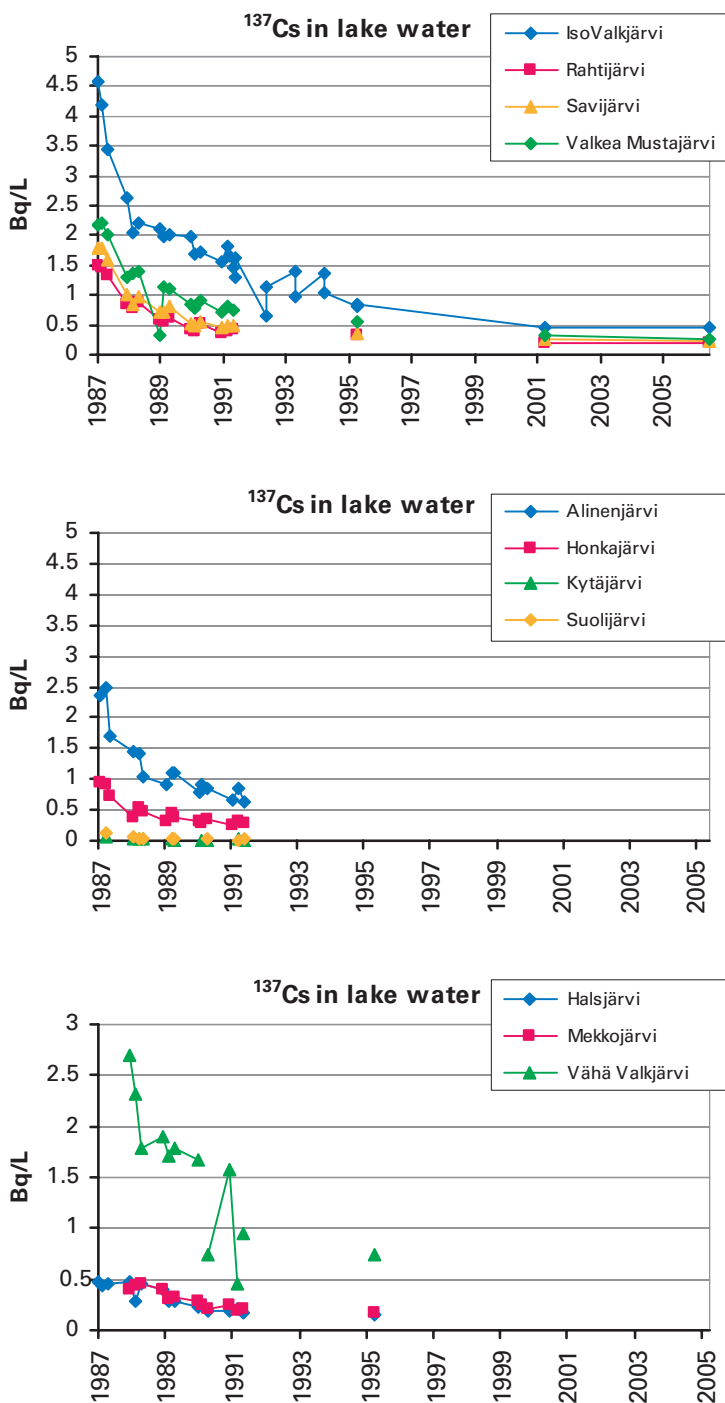


Fig. 4. Activity concentrations of ^{137}Cs with variation (Bq/L) in lake water samples since 1987.

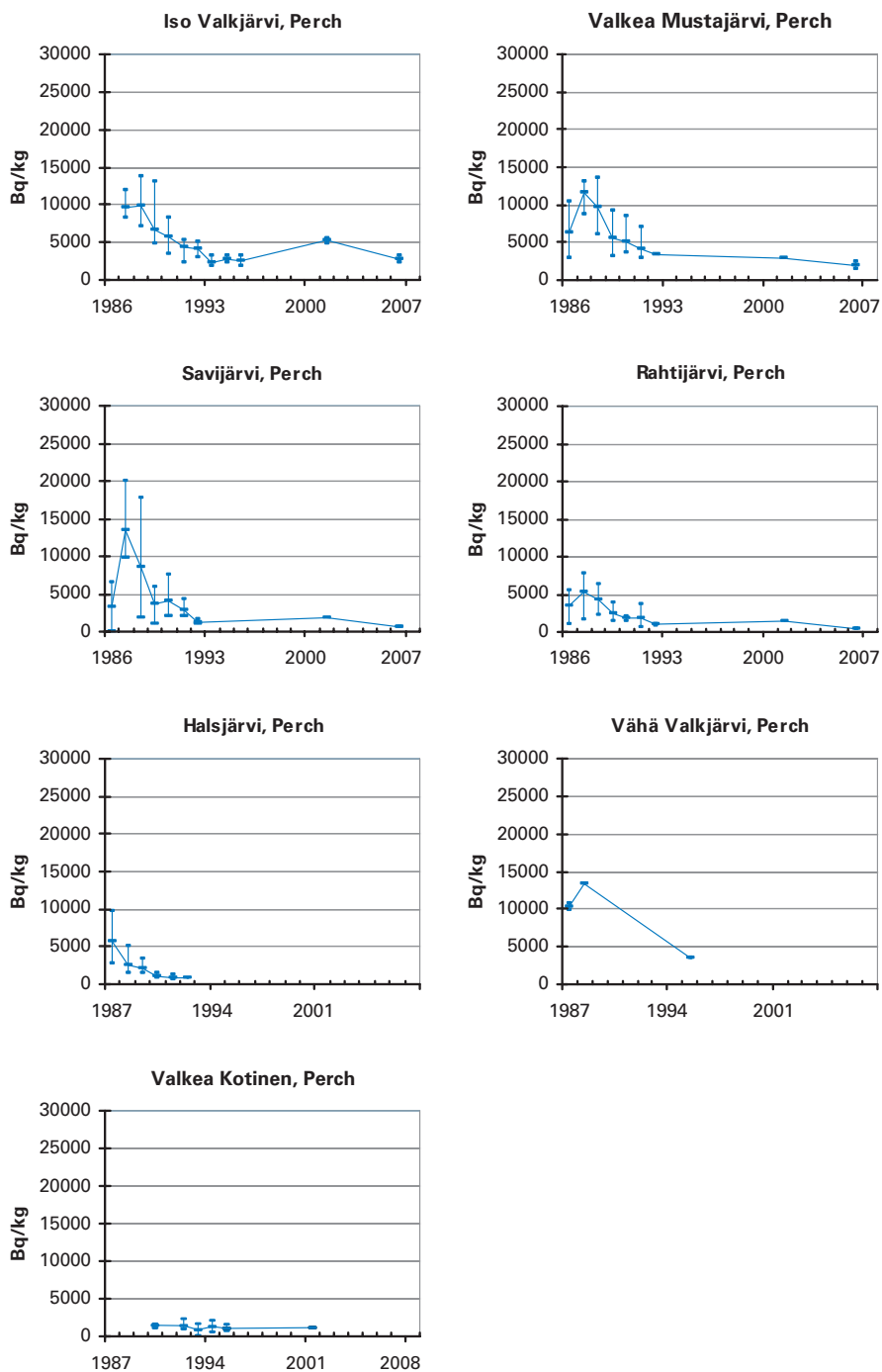


Fig. 5a. Annual averages of ^{137}Cs with variation range (Bq/kg w.w.) in perch sampled in 1987–2006 from lakes in Lammi.

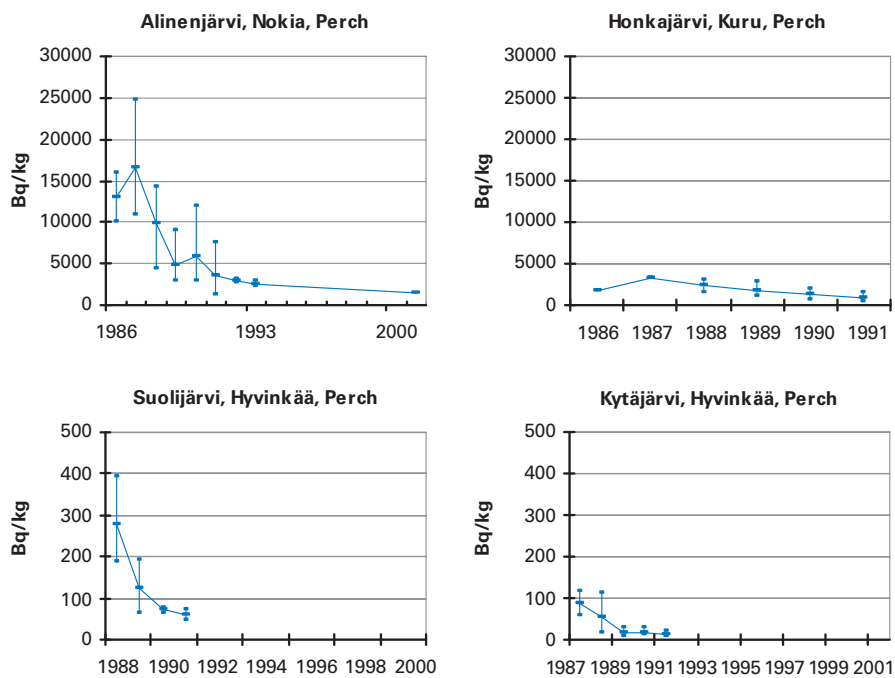


Fig. 5b. Annual averages of ^{137}Cs with variation range (Bq/kg w.w.) in perch sampled in 1987–2006 from lakes in Nokia, Kuru and Hyvinkää.

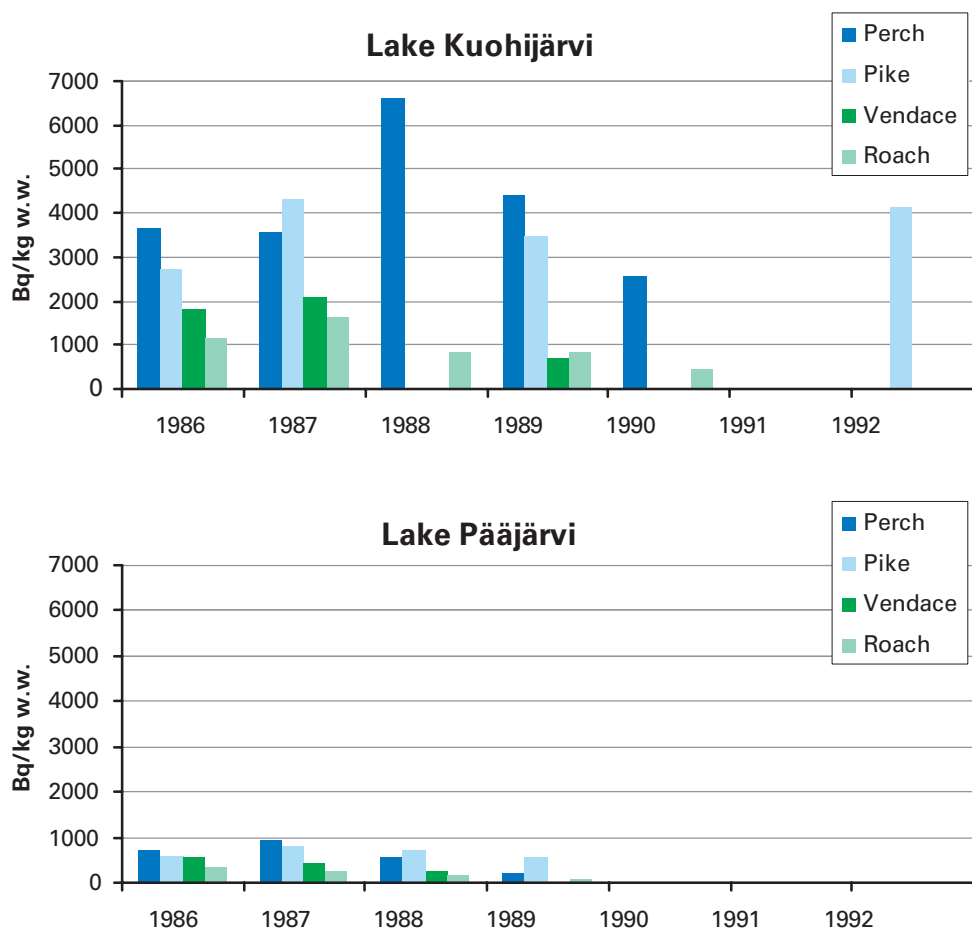


Fig. 6. Activity concentrations of ¹³⁷Cs (Bq/kg w.w.) in various fish species sampled from Lakes Kuohijärvi and Pääjärvi, the largest lakes in this study. Their surface areas are 35 km² (Kuohijärvi) and 13.4 km² (Pääjärvi). For the location of the lakes, see Fig. 2.

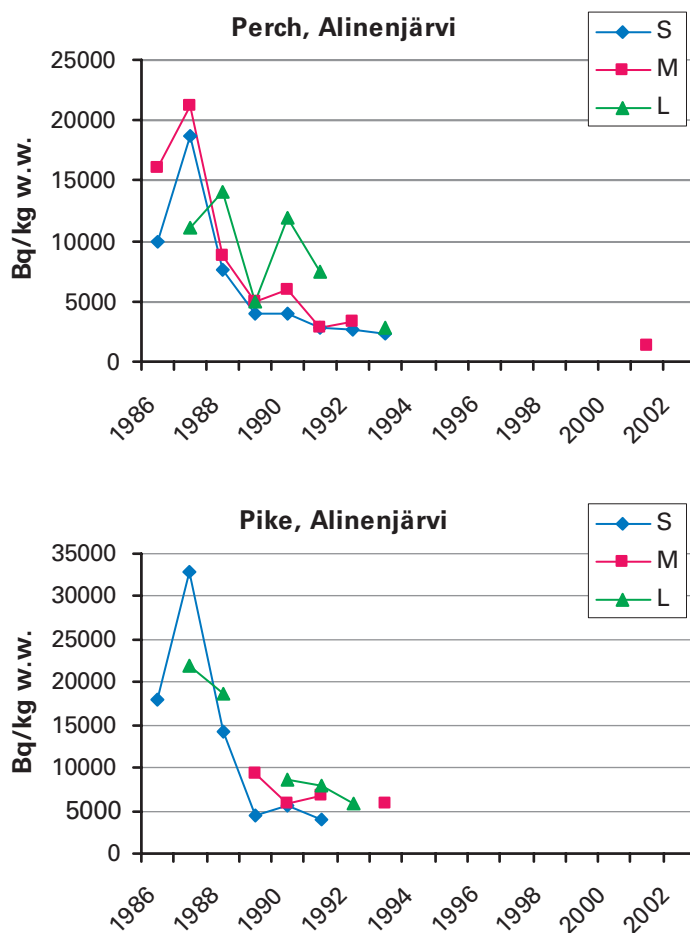


Fig. 7. Activity concentrations of ^{137}Cs (Bq/kg w.w.) in perch and pike of various sizes (s = small, m = medium, L = large) sampled in 1986–1993 from Lake Alinenjärvi.

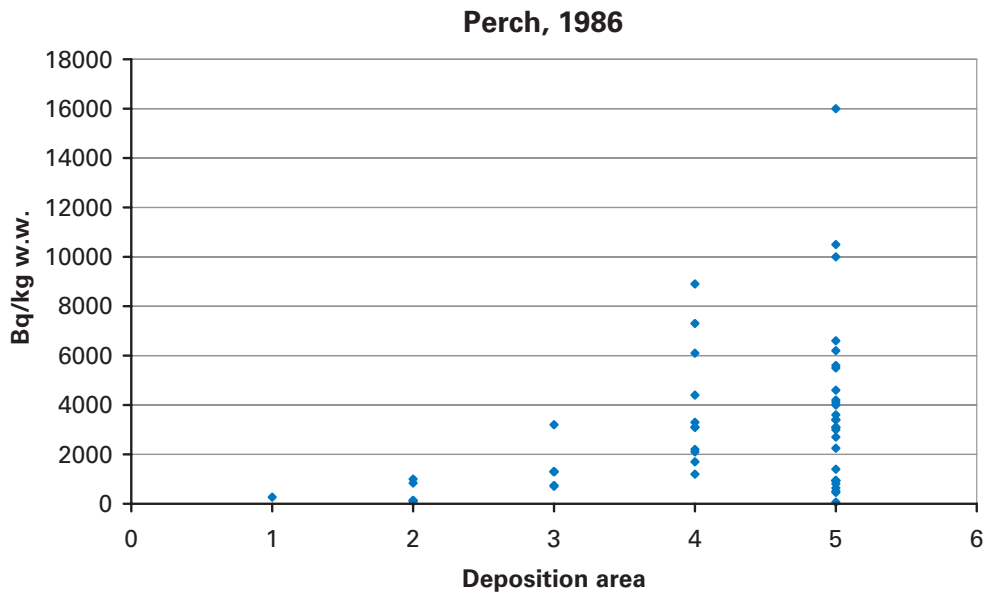


Fig. 8. Activity concentrations of ^{137}Cs in perch (Bq/kg w.w.) sampled from various deposition areas in 1986. The total number of samples included in the data is 51. For deposition areas, see Fig. 1.

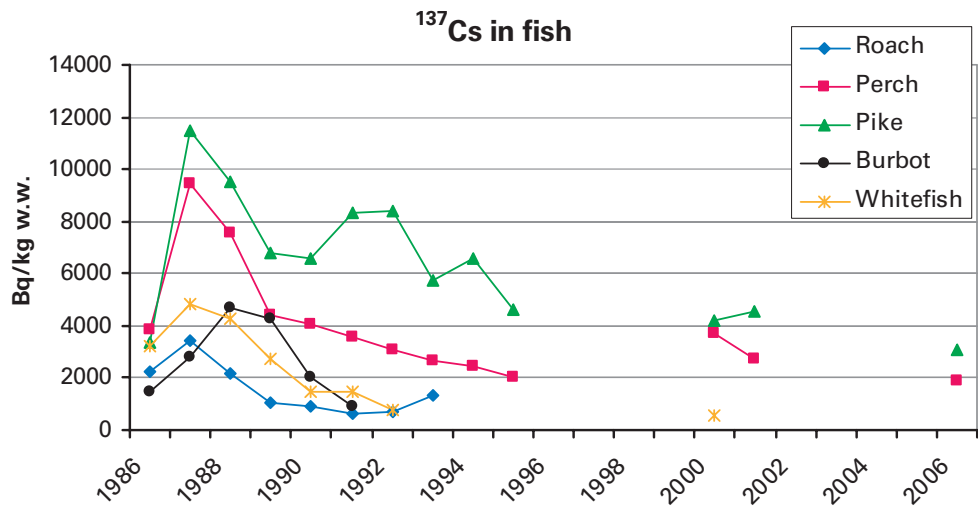


Fig. 9. Annual average activity concentrations of ^{137}Cs in five fish species (Bq/kg w.w.) sampled from small forest lakes in the area having ^{137}Cs deposition between 45–78 kBq/m² in 1986 (deposition areas in Fig. 1).

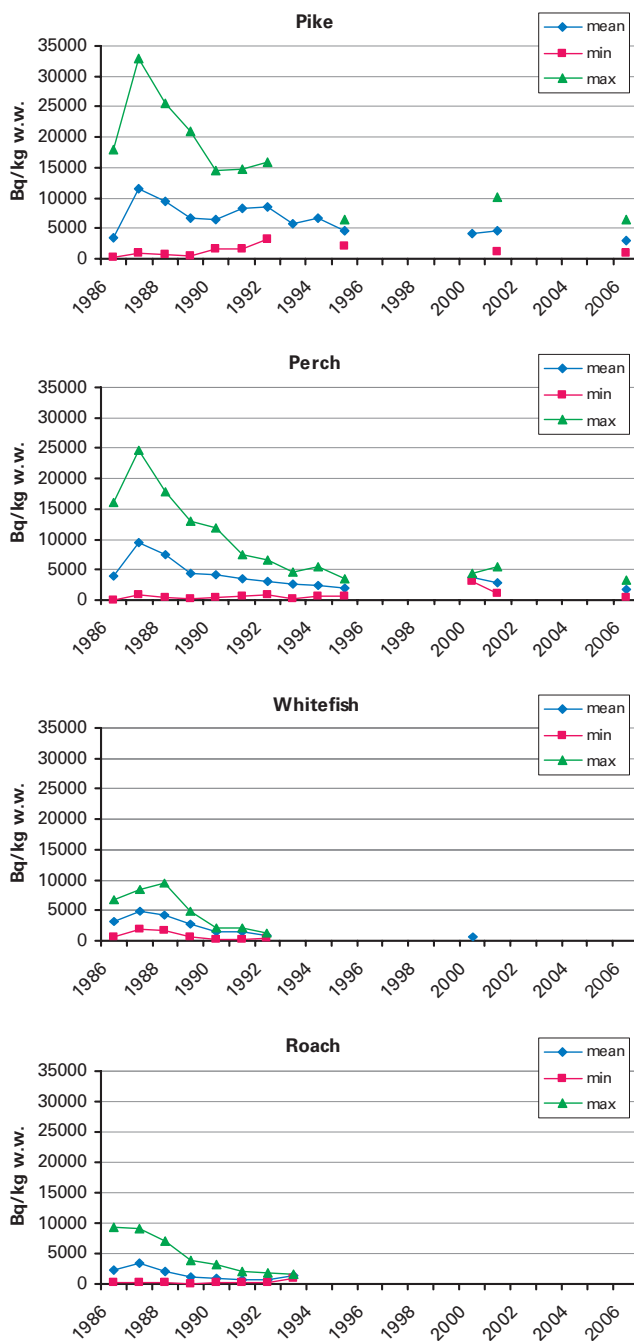


Fig. 10. Annual averages and minimum and maximum values of ^{137}Cs in perch, pike, white fish and roach (Bq/kg w.w.) sampled since 1986 from small forest lakes in deposition area 5. For deposition areas, see Fig. 1.

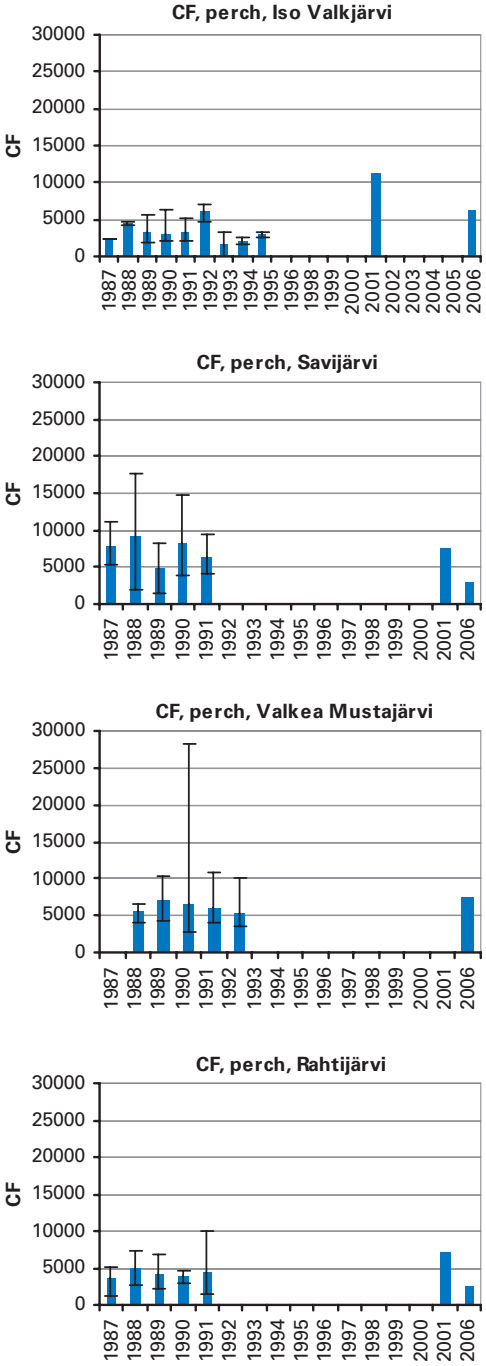


Fig. 11. Annual averages of bioconcentration factors (CF) with variation ranges for perch in four lakes of Lammi in 1987–2006.

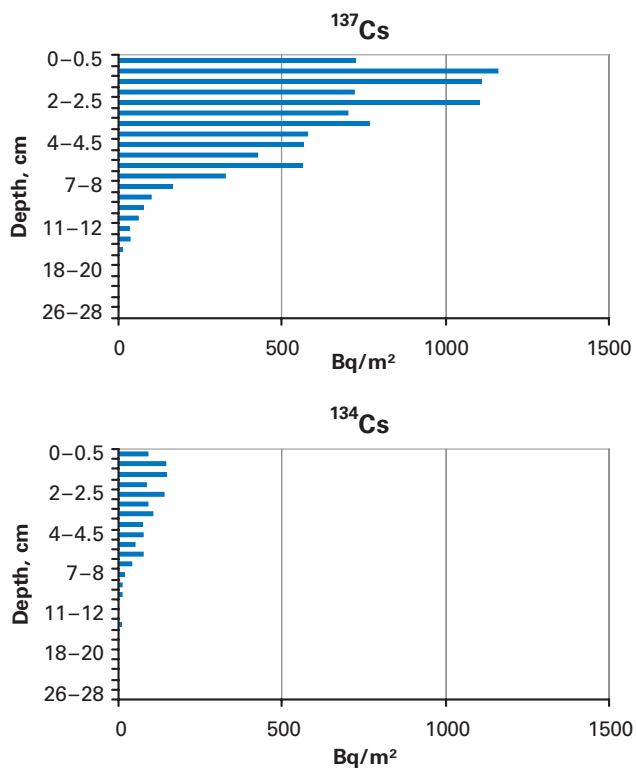


Fig. 12. Vertical distribution of ^{137}Cs and ^{134}Cs in the bottom sediment of Lake Iso Valkjärvi, Lammi, in 1992.

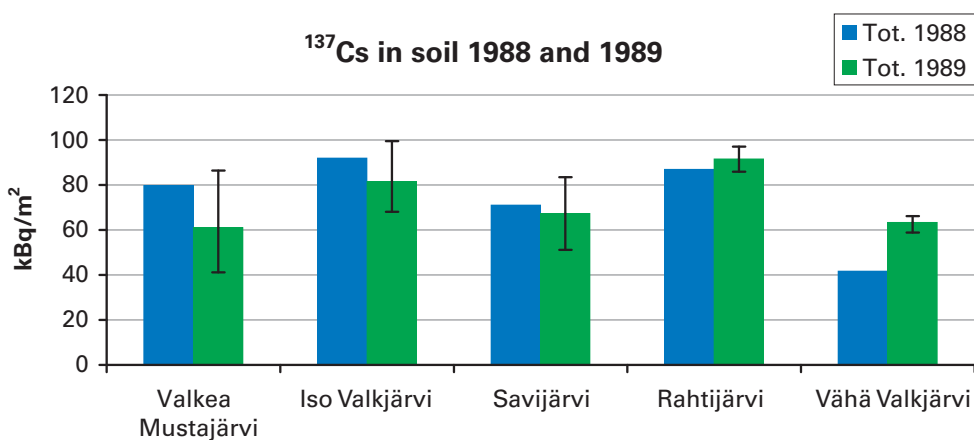


Fig. 13. Average amounts of ^{137}Cs in soil in the catchments of the study lakes (kBq/m²). Two to five parallel profiles from each catchment were analysed to the depth of 16–25 cm, but in Lake Valkea Mustajärvi to the depth of 10–15 cm.

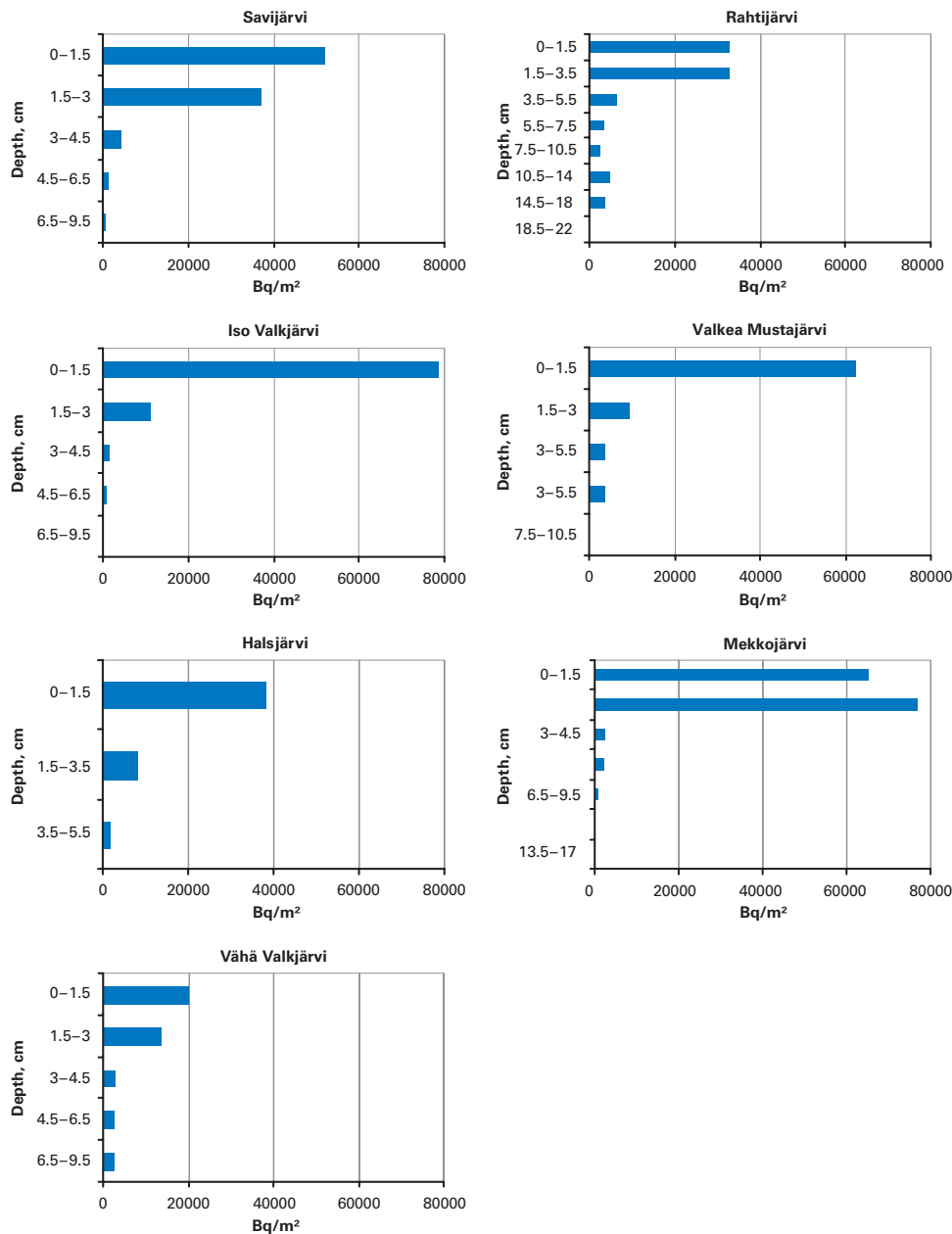


Fig. 14. Vertical distribution of ^{137}Cs in soil in the catchments of various lakes in Lammi in 1988.

Table I. Characteristics of some of the studied lakes.

Lake	Area km ²	Mean depth m	pH	Conductivity mS/m ^b	K mg/l	P µg/l	N µg/l	Water res. time, y	Colour mgPt/l	Ca+Mg mg/l
Halsjärvi	0.05	3	6.0 ^a	3.9 ^a	0.78 ^a	19 ^a	413 ^a	1 ^a	177 (111–303) ^a	5.83 ^a
IsoValkjärvi	0.04	3	4.8 ^a 5.3 ^b	1.3 ^a 1.3 ^b	0.34 ^a 0.473 ^b	18 ^a 17 ^b	401 ^a 505 ^b	3–4 ^a 3.3 ^b	60 (45–92) ^a 55 ^b	1.19 ^a
Rahtijärvi	0.13	6	6.1 ^a 6.2 ^b	3.4 ^a 3.9 ^b	0.73 ^a 0.775 ^b	23 ^a 29 ^b	539 ^a 575 ^b	1 ^a <1 ^b	186 (148–253) ^a 180 ^b	5.03 ^a
Savijärvi	0.27	6	6.1 ^b	3.6 ^b	0.713 ^b	28 ^b	566 ^b	<1 ^b	185 ^b	
Valkea Mustajärvi	0.14	4	6.3 ^a 6.3 ^b	2.2 ^a 2.3 ^b	0.54 ^a 0.653 ^b	9 ^a 11 ^b	346 ^a 472 ^b	>4 ^a >3 ^b	29 (18–44) ^a 30 ^b	2.86 ^a
Mekkojärvi	0.003		5.4 ^a	3.6 ^a	0.76 ^a	32 ^a	621 ^a	<1 ^a	371 (292–488) ^a	5.53 ^a
Vähä Valkjärvi	0.02		4.4 ^a	2.0 ^a	0.15 ^a	8 ^a	220 ^a	3–4 ^a	2 (0–9) ^a	0.79 ^a

^a Values taken from Penttilä et al. (1993).^b Values are averages of 1987–1991 and are taken from Rask and Metsälä 1991.**Table II.** Number of fish samples taken from various lakes during 1986–2006. One sample usually consisted of several pooled fish specimens. Perch and pike were the most common sampled species.

Lake	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2000	2001	2006
Alinenjärvi	6	16	10	15	12	4	5					1	
Halsjärvi	1	11	14	11	13	8	3						
Honkajärvi	2	3	9	3	13	7							
Iso Valkjärvi		8	16	20	28	55	44	11	24	8		9	9
Kuohijärvi	13	8	6	9	6		1						
Kytäjärvi	3	7	16	10	7	14							
Mekkojärvi		2	2										
Pääjärvi	9	2	7	7									
Rahtijärvi	21	19	22	17	15	19	7					4	4
Savijärvi	17	18	19	15	15	14	6					4	4
Suolijärvi	1	2	11	9	4	7							
Valkea Kotinen					7		13	3	16	1		1	
Valkea Mustajärvi	5	9	14	21	28	26	9				4	2	5
Vähä Valkjärvi		3	1							2			
Other lakes	65	8			3			6					

Table III. Lake-specific, long-term bioconcentration factors (CF) (Bq/kg w.w. in fish/Bq/kg in water) of ^{137}Cs for perch in five lakes, determined with two methods.

Lake	CF (a) average	CF (a) min	CF (a) max	CF (b)	R ²
Iso Valkjärvi	3770	1330	12300	1710	0.510
Valkea Mustajärvi	6110	2680	28200	5460	0.940
Savijärvi	7330	1500	17800	8620	0.596
Rahtijärvi	4200	1210	9960	3780	0.583
Alinenjärvi				6850	0.630

(a) Arithmetic mean with min and max, calculated for the whole study period

(b) Determined from the slope of the lines, with R², values for the whole study period**Table IV.** Activity concentrations of ^{134}Cs and ^{137}Cs in the water slater, *Asellus aquaticus*, (Bq/kg d.w.) from various lakes.

Lake	Sampling date	Number	^{137}Cs Bq/kg d.w.	^{134}Cs Bq/kg d.w.
Iso Valkjärvi	9.6.1987	110	17400	7300
Iso Valkjärvi	22.7.1987	150		
Iso Valkjärvi	30.10.1987	230	17900	6600
Iso Valkjärvi	2.6.1992		8200	870
Savijärvi	15.6.1987	100	9700	4000
Savijärvi	3.8.1987	67		
Savijärvi	5.11.1987	80	6000	2300
Rahtijärvi	16.6.1987	78	6400	2400
Rahtijärvi	30.7.1987	170	4500	1700
Rahtijärvi	5.11.1987	100	5300	2000
Halsjärvi	11.6.1987	110	9200	3100
Halsjärvi	30.7.1987	150		
Halsjärvi	26.10.1987	250	4800	1500
Valkea Mustajärvi	15.6.1987	110	13400	5600
Valkea Mustajärvi	4.8.1987	250	14400	5200
Valkea Mustajärvi	19.10.1987	390	9600	3600
Mekkojärvi	11.6.1987	130	3900	1700
Mekkojärvi	29.7.1987	370	4800	1300
Mekkojärvi	16.10.1987	130	2500	970
Vähä Valkjärvi	9.6.1987	155	19300	8200
Vähä Valkjärvi	28.7.1987	110	13800	5600
Vähä Valkjärvi	8.10.1987	110	31000	11800

Table V. Activity concentrations of ^{137}Cs and ^{134}Cs in zooplankton (Bq/kg d.w.).

Lake	Sampling date	^{137}Cs , Bq/ kg d.w.	^{134}Cs , Bq/ kg d.w.
Iso Valkjärvi	9.6.1987	11100	4600
Iso Valkjärvi	28.7.1987	19500	5500
Iso Valkjärvi	30.10.1987	22200	7800
Iso Valkjärvi	19.10.1988	3400	850
Iso Valkjärvi	10.11.1989	2500	490
Iso Valkjärvi	5.11.1990	3900	540
Iso Valkjärvi	2.12.1991	8300	850
Iso Valkjärvi ^a	25.5.1992	5400	430
Iso Valkjärvi	9.6.1992	5800	550
Iso Valkjärvi	11.6.1992	5700	570
Iso Valkjärvi	26.6.1992	5900	470
Iso Valkjärvi	26.6.1992	6000	520
Iso Valkjärvi	6.7.1992	6500	550
Iso Valkjärvi	22.7.1992	5800	490
Valkea Mustajärvi	11.6.1987	1000	370
Valkea Mustajärvi	4.8.1987	11600	4700
Valkea Mustajärvi	19.10.1987	7700	3000
Valkea Mustajärvi	25.8.1988	2500	690
Valkea Mustajärvi	9.11.1989	1500	290
Valkea Mustajärvi	5.11.1990	4700	650
Halsjärvi	11.6.1987	3300	710
Halsjärvi	25.8.1988	1500	450
Rahtijärvi ^b	16.6.1987	4600	580
Rahtijärvi ^c	16.6.1987	6900	2000
Rahtijärvi	20.10.1988	15300	4300
Rahtijärvi	6.11.1990	4500	530
Savijärvi ^b	15.6.1987	1300	520
Savijärvi ^c	15.6.1987	2400	1100
Savijärvi ^b	30.7.1987	1600	430
Savijärvi	5.10.1988	5500	1500
Savijärvi	6.11.1990	3000	590
Vähä Valkjärvi	28.7.1987	12600	3600
Vähä Valkjärvi	8.10.1987	8800	3500
Vähä Valkjärvi	25.8.1988	7500	210
Vähä Valkjärvi	10.11.1989	2300	530
Mekkojärvi	10.6.1987	1500	680
Mekkojärvi	29.7.1987	500	260
Mekkojärvi	16.10.1987	890	330
Mekkojärvi	20.10.1988	2100	570

^a copepods^b littoral samples^c pelagial samples

Table VI. Activity concentrations of ^{137}Cs and ^{134}Cs in the larvae of various organisms (Bq/kg d.w.).

Lake	Species	Date	^{137}Cs Bq/kg d.w.	^{134}Cs Bq/kg d.w.
Iso Valkjärvi	<i>Ephemeroptera, mayfly</i>	30.5.1992	15400	1400
Iso Valkjärvi	<i>Odonata, dragonfly</i>	22.6.1992	7300	620
Iso Valkjärvi	<i>Chironomidae, chironomids</i>	22.6.1992	2200	220
Iso Valkjärvi	<i>Trichoptera, caddisfly</i>	22.6.1992	4800	400
Mekkojärvi	<i>Chaoborus, phantom midge</i>	20.10.1988	230	120
Vähä Valkjärvi	<i>Trichoptera, caddisfly</i>	25.8.1988	4300	1100

Table VII. Activity concentrations of ^{137}Cs and ^{134}Cs in tadpoles and water mites (Bq/kg d.w.) from Lake Iso Valkjärvi in 1992.

Species	^{137}Cs Bq/kg d.w.	^{134}Cs Bq/kg d.w.	^{40}K Bq/kg d.w.
Tadpole	6390	590	840
<i>Hydracarina, water mites</i>	5680	510	1200

Table VIII. Activity concentrations of ^{137}Cs and ^{134}Cs in aquatic plants (Bq/kg d.w.) from Lake Iso Valkjärvi in 1992.

Species	Latin name	^{137}Cs , Bq/kg d.w.	^{134}Cs , Bq/kg d.w.
Sedge (Sara)	<i>Carex spp. (L.)</i>	42200	4000
Bog-bean (Raate)	<i>Menyanthes trifoliata</i>	20700	1900
Marsh cinquefoil (Kurjenjalka)	<i>Potentilla palustris</i>	52000	4800
Sphagnum moss (Rahkasammal)	<i>Sphagnum spp.</i>	15000	1300
Yellow iris (Kurjenmiekka)	<i>Iris pseudacorus</i>	75200	6500
Yellow water-lily (Ulpukka)	<i>Nuphar lutea</i>	47700	4100
Bottom moss (Pohjasammal)	<i>Bryophyta</i>	5100	440

Table IX. Bioconcentration factors (CF = Bq/kg in organism / Bq/kg in water) of ^{137}Cs for zooplankton on a dry weight and wet weight basis. In the calculation of the CF on a wet weight basis, an empirically determined ratio of dry to wet weight of 0.019 was used.

Lake	Date	CF (d.w.)	CF (w.w.)
Iso Valkjärvi	25.5.1992	8300	160
Iso Valkjärvi	9.6.1992	8900	170
Iso Valkjärvi	11.6.1992	8600	160
Iso Valkjärvi	26.6.1992	9100	170
Iso Valkjärvi	26.6.1992	9200	180
Iso Valkjärvi	6.7.1992	9900	190
Iso Valkjärvi	22.7.1992	8900	170
Valkea Mustajärvi	11.6.1987	470	9
Valkea Mustajärvi	4.8.1987	5200	100
Valkea Mustajärvi	19.10.1987	3800	73
Valkea Mustajärvi	25.8.1988	1800	35
Valkea Mustajärvi	9.11.1989	1400	26
Valkea Mustajärvi	5.11.1990	5300	100
Halsjärvi	11.6.1987	7000	130
Halsjärvi	25.8.1988	5100	100
Rahtijärvi a	16.6.1987	3100	58
Rahtijärvi b	16.6.1987	4600	87
Rahtijärvi	20.10.1988	17300	330
Rahtijärvi	6.11.1990	8700	160
Savijärvi a	15.6.1987	700	13
Savijärvi b	15.6.1987	1300	25
Savijärvi a	30.7.1987	910	17
Savijärvi	5.10.1988	5800	110
Savijärvi	6.11.1990	5500	110
Vähä Valkjärvi	25.8.1988	3300	61
Vähä Valkjärvi	10.11.1989	1300	24
Mekkojärvi	20.10.1988	4500	86

Table X. Bioconcentration factors (CF = Bq/kg in organism (d.w.) / Bq/kg in water) of ^{137}Cs for larvae of various organisms on a dry weight basis.

Lake	Species	Year	CF (d.w.)
Iso Valkjärvi	<i>Ephemeroptera</i> , mayfly	1992	23500
Iso Valkjärvi	<i>Odonata</i> , dragonfly	1992	11200
Iso Valkjärvi	<i>Chironomidae</i> , chironomids	1992	3300
Iso Valkjärvi	<i>Trichoptera</i> , caddisfly	1992	7400
Mekkojärvi	<i>Chaoborus</i> , phantom midge	1988	500
Vähä Valkjärvi	<i>Trichoptera</i> , caddisfly	1988	1800

Table XI. Bioconcentration factors (CF = Bq/kg in organism (d.w.)/Bq/kg in water) of ¹³⁷Cs for *Asellus aquaticus* on a dry weight basis.

Lake	Year	CF (d.w.)
Iso Valkjärvi	9.6.1987	3800
Iso Valkjärvi	30.10.1987	5200
Iso Valkjärvi	2.6.1992	12600
Savijärvi	15.6.1987	5400
Savijärvi	3.8.1987	
Savijärvi	5.11.1987	3800
Rahtijärvi	16.6.1987	4300
Rahtijärvi	30.7.1987	3100
Rahtijärvi	5.11.1987	4000
Halsjärvi	11.6.1987	19500
Halsjärvi	30.7.1987	
Halsjärvi	26.10.1987	10700
Valkea Mustajärvi	15.6.1987	6100
Valkea Mustajärvi	4.8.1987	6500
Valkea Mustajärvi	19.10.1987	4800
Mekkojärvi	11.6.1987	10000
Mekkojärvi	29.7.1987	11200
Mekkojärvi	16.10.1987	5500
Vähä Valkjärvi	9.6.1987	7100
Vähä Valkjärvi	28.7.1987	6000
Vähä Valkjärvi	8.10.1987	17300

Table XII. Bioconcentration factors (CF = Bq/kg in organism (d.w.)/Bq/kg in water) of ¹³⁷Cs for tadpoles and water mites on a dry weight basis from Lake Iso Valkjärvi in 1992.

Species	CF (d.w.)
Tadpole	9800
<i>Hydracarina</i> , water mites	8700

Table XIII. Bioconcentration factors (CF = Bq/kg in organism (d.w.)/Bq/kg in water) of ¹³⁷Cs for aquatic plants from Lake Iso Valkjärvi in 1992.

Species	Latin name	CF (d.w.)
Sedge (Sara)	<i>Carex spp.(L.)</i>	64500
Bog-bean (Raate)	<i>Menyanthes trifoliata</i>	31700
Marsh cinquefoil (Kurjenjalka)	<i>Potentilla palustris</i>	79500
Sphagnum moss (Rahkasammal)	<i>Sphagnum spp.</i>	23000
Yellow iris (Kurjenmiekkä)	<i>Iris pseudacorus</i>	115000
Yellow water-lily (Ulpukka)	<i>Nuphar lutea</i>	72900
Bottom moss (pohjasammal)	<i>Bryophyta</i>	7800

APPENDIX 1.

Activity concentrations of ^{137}Cs and ^{134}Cs for various fish species sampled in 1986–1995 from lakes that are not included in the main text.

Lake	Municipality	Species	Sampling date	min size cm	max size cm	^{137}Cs Bq/kg w.w.	^{134}Cs Bq/kg w.w.	Deposition class
Suurlampi	Taipalsaari	Perch	11.7.1986	16	20	270	110	1
Suurlampi	Taipalsaari	Roach	11.7.1986	24	30	280	110	1
Moksijärvi	Vihti	Perch	17.7.1986	12	20	840	430	2
Moksijärvi	Vihti	Roach	13.7.1986	17	20	230	120	2
Salmisenjärvi	Ylämaa	Perch	10.7.1986	10	18	1000	550	2
Salmisenjärvi	Ylämaa	Roach	10.7.1986	20	25	1400	780	2
Siilinjärvi	Siilinjärvi	Perch	1.7.1986	7	7	140	68	2
Siilinjärvi	Siilinjärvi	Perch	2.7.1986	11	16	83	44	2
Siilinjärvi	Siilinjärvi	Perch	2.7.1986	6	7	130	56	2
Siilinjärvi	Siilinjärvi	Pike	1.7.1986	44	44	40	14	2
Siilinjärvi	Siilinjärvi	Roach	1.7.1986	11	19	51	26	2
Siilinjärvi	Siilinjärvi	Roach	2.7.1986	3.5	5	40	29	2
Iso Melkutin	Loppi	Perch	24.7.1986	9	13	1300	670	3
Iso Melkutin	Loppi	Roach	24.7.1986	17	25	650	330	3
Kaitajärvi	Tammela	Perch	22.7.1986	25	25	740	270	3
Kaitajärvi	Tammela	Perch	22.7.1986	14	20	710	330	3
Riihijärvi	Luumäki	Perch	9.7.1986	15	18	1300	620	3
Riihijärvi	Luumäki	Perch	9.7.1986	19	25	1300	690	3
Riihijärvi	Luumäki	Pike	9.7.1986	35	35	430	190	3
Riihijärvi	Luumäki	Pike	9.7.1986	29	29	750	340	3
Salmijärvi	Tammela	Perch	25.7.1986	10	18	3200	1700	3
Vähä Melkutin	Tammela	Pike	23.7.1986	33	33	530	230	3
Vähä Melkutin	Tammela	Roach	23.7.1986	17	23	490	260	3
Ahmausjärvi	Mouhijärvi	Perch	11.6.1987	17	17	2800	1200	4
Aurajärvi	Äetsä	Perch	7.8.1986	12	19	7300	3700	4
Aurajärvi	Äetsä	Perch	7.8.1986			8900	4400	4
Hirvijärvi	Anjalankoski	Perch	8.7.1986	10	17	3100	1900	4
Hirvijärvi	Anjalankoski	Whitefish	8.7.1986	33	33	990	530	4
Hirvijärvi	Anjalankoski	Roach	4.7.1986	18	25	1400	840	4
Iso Koukero	Kuru	Perch	26.6.1986	9	19	3300	1800	4
Iso Suksijärvi	Mouhijärvi	Perch	6.8.1986	20	22	1200	670	4
Iso Suksijärvi	Mouhijärvi	Perch	6.8.1986	18	20	2100	1100	4
Iso Suksijärvi	Mouhijärvi	Perch	6.8.1986	10	10	2200	1100	4
Iso Suksijärvi	Mouhijärvi	Roach	6.8.1986	17	23	1600	810	4
Sorvijärvi	Vammala	Perch	8.8.1986	10	13	4400	2300	4
Sorvijärvi	Vammala	Perch	8.8.1986	13	19	6100	3400	4
Sorvijärvi	Vammala	Perch	11.6.1987	7	14	7000	2900	4
Sorvijärvi	Vammala	Pike	11.6.1987	49	49	4500	1900	4
Sorvijärvi	Vammala	Roach	8.8.1986	33	35	1700	920	4
Sorvijärvi	Vammala	Roach	11.6.1987	35	35	2300	950	4
Valkeajärvi	Kuru	Perch	24.6.1986	9	20	3100	1700	4
Valkjärvi	Kärkölä	Bream	17.7.1986	31	31	21	14	4

Activity concentrations of ^{137}Cs and ^{134}Cs for various fish species sampled in 1986–1995 from lakes that are not included in the main text. (Continued)

Lake	Municipality	Species	Sampling date	min size cm	max size cm	^{137}Cs Bq/kg w.w.	^{134}Cs Bq/kg w.w.	Deposition class
Vanajavesi	Kalvola	Smelt	11.5.1987	8	13	480	200	4
Vanajavesi	Kalvola	Smelt	11.5.1987	9	13	510	200	4
Vanajavesi	Kalvola	Roach	11.5.1987	19	24	590	240	4
Vanajavesi	Kalvola	Roach	11.5.1987	14	18	570	250	4
Haukilampi	Lammi	Pike	3.10.1986	50	50	340	140	5
Haviseva	Kangasala	Perch	15.7.1986	23	23	2300	1100	5
Haviseva	Kangasala	Perch	15.7.1986	12	19	1400	1600	5
Haviseva	Kangasala	Perch	15.7.1986	9	11	6200	3300	5
Haviseva	Kangasala	Pike	15.7.1986	52	52	2300	1200	5
Haviseva	Kangasala	Roach	15.7.1986	19	23	2500	1300	5
Heinijärvi	Nokia	Perch	5.8.1993	17	20	2600	130	5
Heinijärvi	Nokia	Perch	5.8.1993	21	23	2500	140	5
Iso Mustajärvi	Lammi	Perch	20.11.1986	10	17	3400	1600	5
Iso Mustajärvi	Lammi	Pike	20.11.1986	42	45	3800	1800	5
Iso Mustajärvi	Lammi	Whitefish	2.7.1986			770	420	5
Iso Mustajärvi	Lammi	Whitefish	20.11.1986	22	30	2400	1100	5
Iso Mustajärvi	Lammi	Whitefish	20.11.1986	19	27	3300	1500	5
Iso Mustajärvi	Lammi	Roach	15.7.1986			1500	830	5
Iso Mustajärvi	Lammi	Roach	20.11.1986	13	20	2800	1300	5
Iso Mustajärvi	Lammi	Roach	20.11.1986	19	22	3200	1500	5
Iso Ruuhijärvi	Lammi	Perch	15.7.1986	13	20	3600	1800	5
Iso Ruuhijärvi	Lammi	Perch	24.7.1986	9	20	4000	2100	5
Iso Ruuhijärvi	Lammi	Perch	29.7.1986	9	16	4100	2200	5
Iso Ruuhijärvi	Lammi	Pike	15.7.1986	20	40	2600	1400	5
Iso Ruuhijärvi	Lammi	Pike	18.7.1986	47	47	570	270	5
Iso Ruuhijärvi	Lammi	Whitefish	5.8.1986	30	30	1700	830	5
Iso Ruuhijärvi	Lammi	Whitefish	6.8.1986	22	34	2200	1200	5
Iso Ruuhijärvi	Lammi	Roach	29.7.1986	12	18	2700	1300	5
Järvenjärvi	Nokia	Perch	8.6.1990	17	19	450	67	5
Järvenjärvi	Nokia	Perch	8.6.1990	25	25	530	73	5
Järvenjärvi	Nokia	Asp	8.6.1990	26	29	340	56	5
Mekkojärvi	Lammi	Pike	10.6.1987	45	45	5100	2200	5
Mekkojärvi	Lammi	Pike	28.7.1987	43	43	6000	2400	5
Mekkojärvi	Lammi	Pike	25.5.1988	37	37	5200	1600	5
Mekkojärvi	Lammi	Pike	21.10.1988	44	44	4400	1200	5
Onkimajärvi	Lammi	Pike	4.8.1989	52	52	2200	420	5
Porrasjärvi	Nokia	Perch	4.8.1993	17	20	4600	260	5
Ruokejärvi	Nokia	Perch	5.8.1993	15	16	1600	91	5
Ruokejärvi	Nokia	Perch	5.8.1993	14	14	1800	110	5
Syrjänalunen	Lammi	Roach	28.8.1986	15	24	1600	840	5
Valkjärvi	Lammi	Whitefish	1.8.1986	29	34	4600	2400	5
Valkjärvi	Lammi	Whitefish	15.8.1986	36	37	6600	3400	5
Vuorijärvi	Kuhmoinen	Pike	29.8.1986	44	58	5700	2900	5
Vuorijärvi	Kuhmoinen	Whitefish	28.8.1986	40	44	4700	2400	5
Ylinenjärvi	Nokia	Perch	3.8.1993	23	25	3900	220	5

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Laippatie 4, 00880 Helsinki
Puh. (09) 759 881, fax (09) 759 88 500
www.stuk.fi

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