State of fish populations in small forest lakes in the Norwegian, Finnish and Russian area

A sub - report of the Interreg project '*Development and implementation of an integrated environmental monitoring and assessment system in the joint Finnish, Norwegian and Russian border area*' (2003 - 2006).

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2006

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1. Introduction

In 2005, small lakes were also studied within the program “Environmental monitoring in border area”. All the water bodies located mainly between Finland and Russia have been studied (Table 1, Fig. 1). The methods used in fish sampling, morphological, pathological and heavy metal analyses were similar those applied in the Paz watercourse. In small lakes, fish studies were carried out jointly with Lapland Regional Environment Centre (Rovaniemi) and Institute of North Industrial Ecology Problems, Kola Science Centre (INEP, Apatity) in August, 2005.

Table 1: Lake localities sampled during the project period in 2005.

Locality	Lat.	Long.	Country	Approx. distancefrom smelters
Mellalompola	69°19.794´	28°54.703´	F	75 km
Suovaselkajarvi	68°57.176´	28°27.514´	F	100 km
Kantojarvi	68°59.745´	28°39.937´	F	95 km
Aittojarvi	69°25.575´	28°57.482´	F	70 km
Kivijarvi	67°58.638´	24°19.438´	F	250 km
Kochejaur[1]	68°35.853´	28°40.250´	R	120 km
Virtuovoshjavr	68°45.894´	28°47.548´	R	100 km
Shuonijarvi	69°15.692´	30°05.363´	R	20

[1] Investigations in the Kochejaur Lake have been conducted also in August 2002.

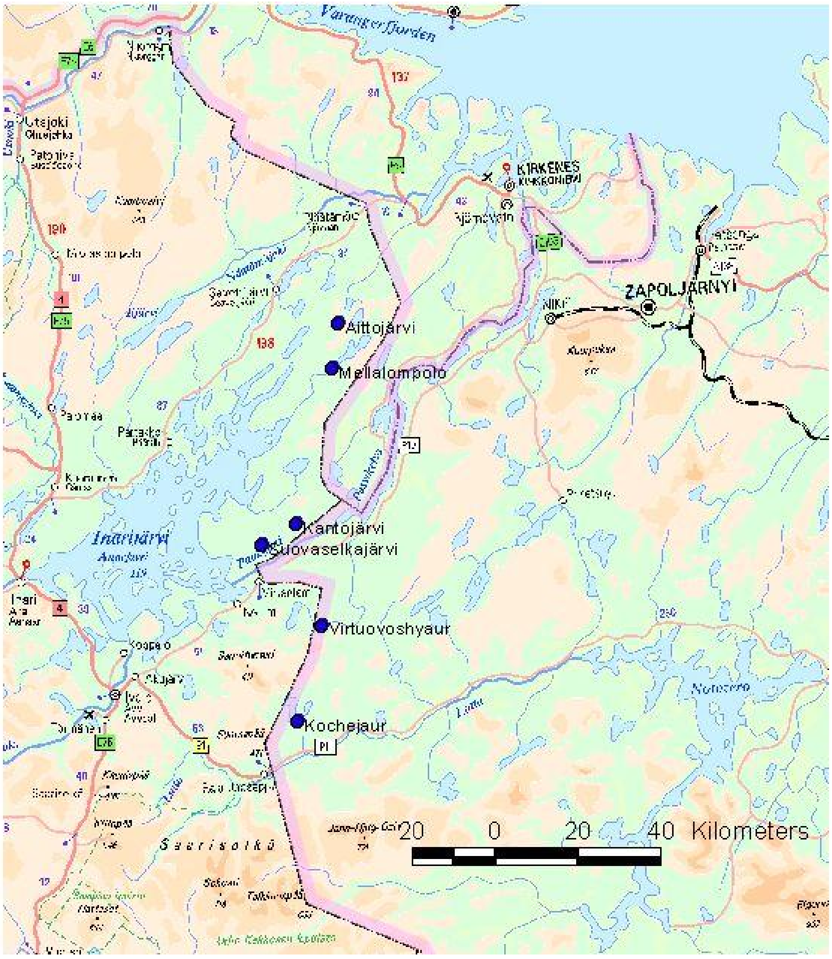


Figure 1. Lakes sampled during the project period in 2005.

2. Study area

As for its landscape type, the investigated area can be classified as a combination of flat dips of lake - glacial plains and denudation and denudation - tectonic massifs with broken overburden mantle with the elevations up to 200 m. The relief was formed in the ice age. Most territory is a lake - forested area with waterlogged parts and hills (absolute elevations of 120 - 450 m). Elevations of ridges and hills are 10 - 60m, achieving sometimes 180m. Hill crests are flat and, on the whole, smoothed. Hill slopes' gradient is as low as 5–15°. Most river valleys are wide, having flat waterlogged slopes. The area under study composed of sand and sandy soil, rubble and gravel, being over 6m in thickness. Mountain tops and slopes are composed of rubble - sandy and stony soil. Some river valleys are composed of sand - gravel and rubble soil. These lakes are of a glacial origin, 0.36 - 8.5 km^2 in area, 133 - 267m in elevation, 2.7 - 12.5m in the average depth. (Catalogue of lakes…, 1962).

3. Methods

The state of small lakes of forest zone (Aittijarvi, Kantojarvi, Suovaselkajarvi, Mellalompola, Stuorajarvi, Kochejaur, Virtuovoshjavr and Shuonijavr) was studied within the program “Environmental monitoring in border area” in 2005 in Russia, Norway and Finland.

Fish collection._Sampling was carried out with the aid of a standard set of bottom nets from nylon monophylamenth with a length of 25 m and height of 1.5 m with the following mesh sizes; 16, 20,31,36,40 mm, thread diameter – 0.15 mm for the nets with small meshes and 0.17 mm for the nets with large meshes. Such nets allowed catching fish of all ages with a length of 8 - 10 cm and more. The nets were employed in the littoral zone one by one perpendicular to the coast and in the profundal zone - ten and more nets in one order.

Weight, length and age determination. The caught fish was for a short period of time subjected to ichthyologic treatment, i.e. description of basic indices of fish bodies. The weight of fish was measured to the nearest 1 g, and internals organs - to the nearest 0.1 g. Fish were measured for total length, Smith length (AC) and production length (AD) (to the nearest 1.0 mm). Measurements were effected using ichthyologic rule.

Macro - diagnostics. The clinical and pathologo - anatomical signs were based on visual fish examination during the fist hour after collection. The fish were at various stages of disease ranging from initially insignificant pathological changes in organs up to the serious damages to the entire organism (Moiseenko, 2001). Alterations of exterior, colour, condition and form of internal organs were documented. The percentagt of sick fish in the each local polluted zone was calculated. Dissection was carried out to record the stage of maturation, fattiness, stomach filling. The pathologo - morphologic and pathologo - anatomical analyses under field conditions were executed through standard methods, described earlier (Arshanitsa, Lesnikov, 1987; Kashulin, 1999). Pathologic deviations of internals were estimateв according to four - ball scale, where 0 testifies to absence of apparent pathologies. External observations, including body shape and appearance, depigmentation of skull, gill structure and colour, presence of external parasites (located on the gill ore outer body), and gross morphological superficial alterations, were then recorded.

The age of fish was determined according to scale (whitefish and salmonid families); operculum (perch) and cleitrum (pike). A binocular MBC - 10 was employed for age determination with magnification ×5 and ×20.

Tissue sampling. Tissue were removed from each fish the following order: gill, liver, spleen, kidney. After removal, the gonads, liver were weighed (to nearest 0.1g). All tissues for histopathology were fixed in Bouin solution. Two sections of gill (first and second right - side gill arches), middle and caudal thirds of kidney were collected. Livers were apportioned for biochemical and histopathological analysis. Paraffin blocks were sectioned at 5 - 7 µm, mounted on glass slides, and then stained with haematoxylin & eosin. All tissue sections were screened and subjected to detailed histopathological analysis. Sections were prepared according to standard methods (Ham and Corwack, 1979).

For heavy metal analysis of fish organs and tissues 10 - 15 samples of the same size were taken from each site. Liver, kidney, gill, muscles tissue and skeleton (spine) samples were taken.

Sampling was carried out with the aid of stainless steel scalpel and knife. Sampling of tissues and organs (weight 3 - 10 g) were taken into plastic sachet and were frozen for further heavy metal analysis in laboratory environment. Dissection of fish and were carried out with knife, scissors and scalpel made of stainless steel. The samples of organs were dried to constant weight at a drying chamber at 105^{o} C. After that the samples were subjected to wet ashing in nitric acid solution with further filtration. The determination of heavy - metal contamination was fulfilled through flame atomic absorption spectrophotometry using Perkin - Elmer 5000, AANALIST800 and AAS30. The concentrations of heavy metals in fish are expected as $\mu g \cdot g^{-1}$ dry weight of tissue, and for Ca, Mg, K, Na as $mg \cdot g^{-1}$ dry weight.

The catches included whitefish, perch, pike, burbot, trout, grayling and burbot. Arctic salmon was rare in the catches.

Tissue for histopathological analysis were removed from each fish the following order: gill, liver, spleen, kidney. After removal, the gonads, liver were weighed (to nearest 0.1g). All tissues for histopathology were fixed in Bouin solution. Two sections of gill (first and second right - side gill arches), middle and caudal thirds of kidney were collected. Livers were apportioned for biochemical and histopathological analysis. Paraffin blocks were sectioned at 5 - 7 µm, mounted on glass slides, and then stained with haematoxylin & eosin. All tissue sections were screened and subjected to detailed histopathological analysis. Sections were prepared according to standard methods (Ham and Corwack, 1979).

4. Results

4.1. Fish community composition

There were nine fish species recorded in the lakes studied (Table 2). Only sparsely rakered whitefish was recorded in the lakes mentioned above. Whitefish was the dominant fish species in all the lakes except for Suovaselkajarvi and Shuonijarvi Lakes where perch and trout species prevailed, respectively (Fig. 2). Due to lakes shallowness almost all the species studied were sampled in different area of water.

4.2. Fish population ecology

a) Size and age distribution

The SR whitefish population of small lakes is composed of large - sized fish in comparison with that of the Paz watercourse. On the average, fish species are from 18.2cm to 35.5cm long in Virtuovoshjavr and Suovaselkajarvi Lakes, respectively (Fig. 3). Fish species of over 30cm long are rarely found in Kantojarvi, Aittojarvi and Virtuovoshjavr Lakes. The perch population is differently distributed in size, being on the average from 19.5cm to 25.9cm long in Kantojarvi and Kochejaur Lakes, respectively. The largest one's are caught in Kochejaur and Virtuovoshjavr Lakes (Fig. 3). Trout and char, the most numerous in catches from Shuonijarvi Lake, were, on the average, of 24.5 cm and 24.3 cm long, respectively.

Table 2: List of fish species present in the studied lakes (Me – Mellalompola; Su – Suovaselkajarvi; Ka – Kantojarvi; Ai – Aittojarvi; Ki – Kivijarvi; Ko – Kochejaur; Vi – Virtuovoshjavr; Sh – Shuonijarvi).

Fish species	Me	Su	Ka	Ai	Ki	Ko	Vi	Sh
Trout (*Salmo trutta*)	X					X		X
Arctic char (*Salvelinus alpinus*)	X							X
SR whitefish (*Coregonus lavaretus*)	X	X	X	X	X	X	X	
Grayling (*Thymallus thymallus*)	X			X				
Pike (*Esox lucius*)	X	X	X	X		X	X	
Perch (*Perca fluviatilis*)		X	X	X	X	X	X	X
Burbot (*Lota lota*)								X
9 - sp. stickleback (*Pungitius pungitius*)	X	X	X	X	X	X	X	X
Minnow (*Phoxinus phoxinus*)	X	X	X	X	X	X	X	X

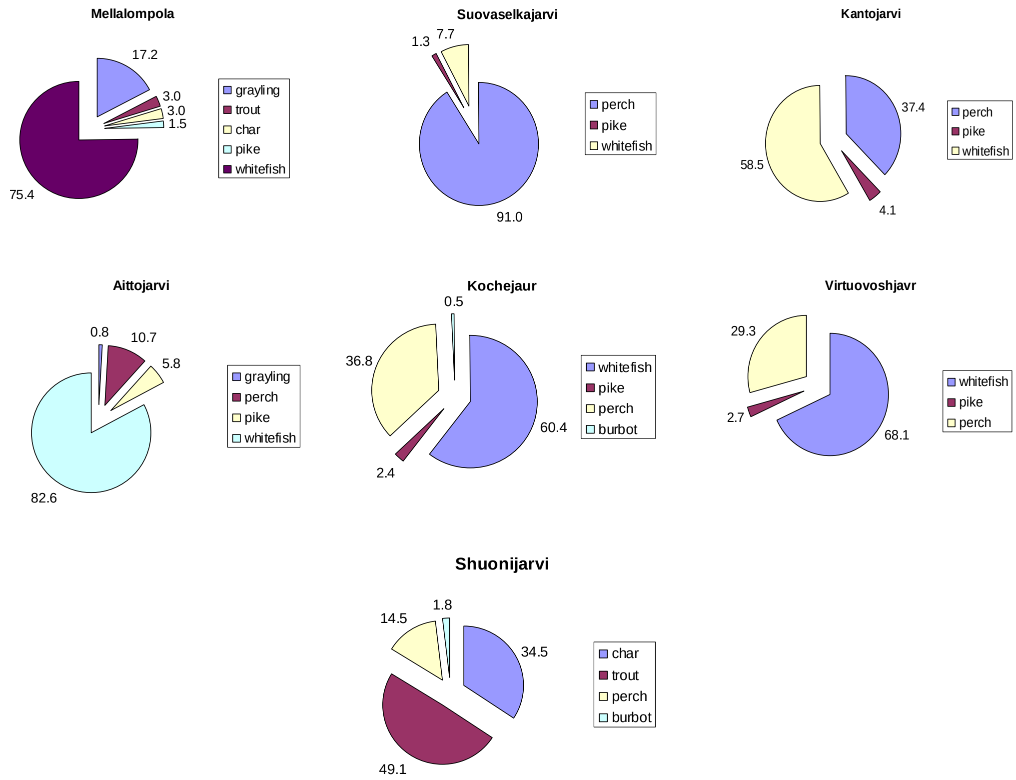


Fig. 2: Fish community composition in catches of the small lakes in 2005.

Whitefish of maximum age was recorded in Kochejaur Lake. There were two specimens of 11 and 12 years. The age limits of other whitefish populations ranged from 4 (Suovaselkajarvi L.)

to 9 years (Virtuovoshjavr L.) (Fig. 4). There were only 4 age classes of SR whitefish in Suovaselkajarvi Lake. Fish scale is clearly indicative of the growth rate being high. Whitefish is likely to release from fish farms.The maximum age of single perch was 14 and 15 years in Virtuovoshjavr Lake and 13 years in Kochejaur Lake. The trout and char of the Lake Shuonijarvi were more abundant at age 3 years and not exceed 5 years for both species.

b) Sexual maturation

The minimum size of first maturation was 16.5 cm in Virtuovoshjavr and the maximum – 33.5 cm in Kantojarvi. Single SR whitefish from small lakes come to maturate quite early, at age of 1 - 2 years. Besides, 1+ year old fish from Suovaselkajarvi Lake had mature gonads of 110g in weight and of 21.0cm in length, respectively. This may also result from its being kept in artificial conditions. Matured char and trout of 2 years in age were found in Shuonijarvi Lake. The matured fish percent in age classes was the same (Fig. 4). The percent of whitefish going to spawn was between 60 % (Aittojarvi) and 75 % (Suovaselkajarvi and Kantojarvi).

The decrease in age, size and maturity range of fish populations in the polluted water areas is a criterion of poor water quality. What featured the whitefish populations studied was a small number of age groups, rejuvenation of populations, maturation in early age and high rate of fish missing the spawning.

4.3. Heavy metal contamination in fish

The most abundant species in the water bodies under study were sparsely rakered whitefish, perch and pike. In water bodies: Shuonijarvi (Pechenga area), Otervatn and Andre Guoikalubb (Jarfjord), trout and arctic char were studied for heavy metal contamination.

Due to the fact that copper and nickel are the main pollutants produced by copper - nickel production, it was these elements that were comparatively analyzed for metal accumulation in fish of the studied water bodies. Besides, mercury was singled out for identification of differences in toxic matter accumulation in fish organs and tissues.

It was established that, on the whole, metals have been irregularly accumulated in fish organs and tissues. These elements tend to accumulate in so - called target organs. Copper, for example, tends to accumulate in fish liver. The highest Ni concentrations were recorded in kidney and skeleton of whitefish and perch, and in gills and skeleton of pike. Higher mercury accumulation in muscles was recorded in perch and pike. Higher mercury concentrations have been recorded in whitefish liver and kidney. Nevertheless, with high toxic level of mercury in mind, and taking into account a high role of the studied species in nutrient budget, the muscle tissue was selected for comparison of mercury accumulation levels in fish.

1.Whitefish

Copper. The Cu concentrations in whitefish liver varied within wide limits in the catch. The difference between the maximum and minimum limiting values was significant in whitefish from Kivijarvi, Suovaselkajarvi and Virtuovoshjavr Lakes, accounting for 4.93 – 120.27, 7.98 – 74.68 and 11.00 – 96.52 $\mu g/g^{-1}$ dry wt, respectively. Besides, the level of copper accumulation in whitefish liver sampled from these lakes was also high. Mean Cu concentrations over 30 $\mu g/g^{-1}$ dry wt were found in fish from the lakes 50 - 70km away from the Pechenganickel smelter (Aittojarvi, Kivijarvi, Suovaselkajarvi) and the highest Cu concentrations, above 40 $\mu g/g^{-1}$ dry wt, were recorded in whitefish from a far away lake (Virtuovoshjavr) (Fig. 5).

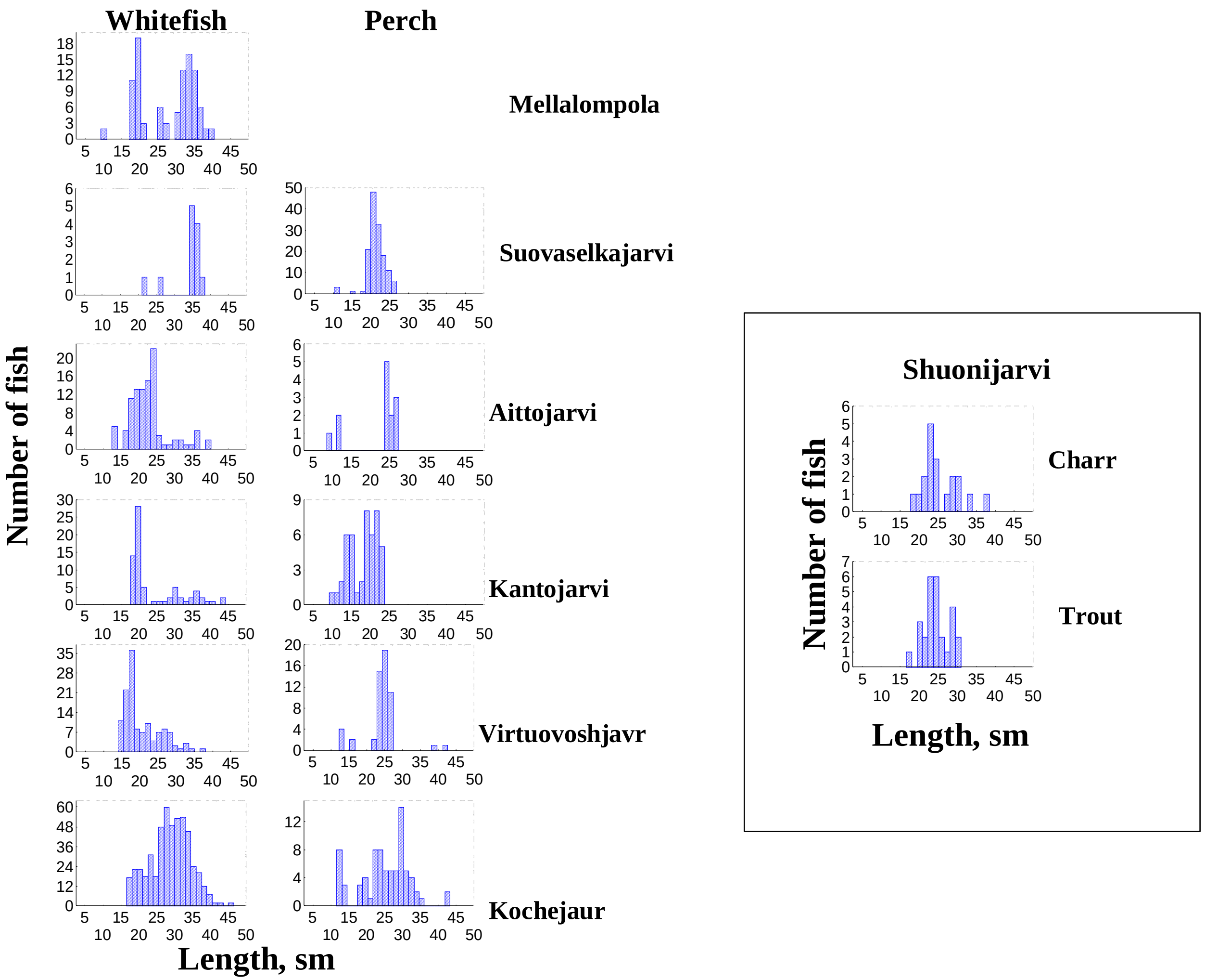


Fig. 3: Size distribution of SR whitefish, perch, char and trout in the studied lakes.

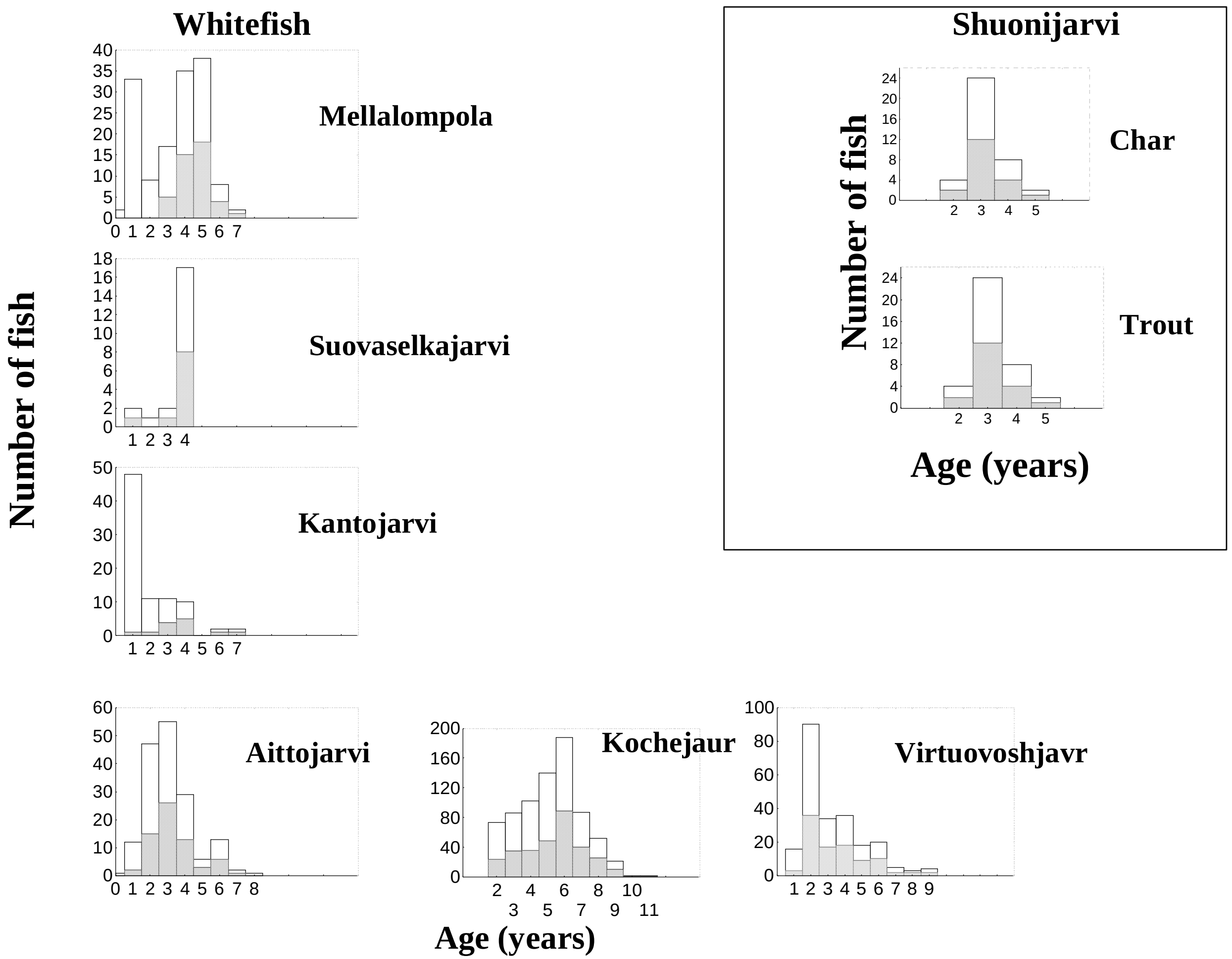


Fig. 4: Age composition of SR whitefish, char and trout in the studied lakes. Shaded bars represent sexually mature fish

Nickel. The highest Ni concentrations have been also recorded in whitefish kidney from Virtuovoshjavr Lake (Fig. 5). Similar concentrations were observed in whitefish from Aittojarvi Lake (over 6 μg/g $^{-1}$ dry wt). In other water bodies, mean Ni concentrations in kidney varied from 1.44 (Suovaselkajarvi) to 4.37 μg/g $^{-1}$ dry wt (Mellalompola).

Mercury. The highest mean concentrations of mercury in muscle of whitefish were recorded in Kantojarvi (1.20 μg/g $^{-1}$ dry wt) and Suovaselkajarvi (1.02 μg/g $^{-1}$ dry wt) lakes. Mercury concentration in whitefish from other water bodies was half as many as that mentioned above, though even minimum mercury concentrations in tissue of whitefish were above 0.3 μg/g $^{-1}$ dry wt (Fig. 5). It is apparent that mercury concentrations in fish depend not only on the industrial production processes high mercury concentrations were recorded in fish tissue from small forest lakes located far away from large operations and densely populated areas.

2. Perch

Copper. The same highest copper concentrations, recorded in whitefish, have been also found in liver of perch from Virtuovoshjavr Lake, being as high as11.96 μg/g $^{-1}$ dry wt. The corresponding values of perch from Kochejaur Lake were 10.97 μg/g $^{-1}$ dry wt but copper concentrations in liver of perch varied in a greater range. (Appendix, Table 5). Minimum mercury concentrations were found in perch from Aittojarvi Lake (Fig. 5). It should be noted that the maximum levels of copper accumulation in liver of perch from Virtuovoshjavr Lake were 3.5 times lower as compared to that of whitefish.

Nickel. Perch dominated over whitefish in nickel contamination of kidney. The highest Ni concentrations in kidney were also found in perch from Virtuovoshjavr Lake, accounting for 5.37 μg/g $^{-1}$ dry wt. At the same time, mean nickel concentrations in Kochejaur Lake located not far away (16 km to the south), were minimum against that in other forest lakes (2.74 μg/g $^{-1}$ dry wt) (Fig. 5). Widely varied Ni concentrations were recorded in perch from Kantojarvi Lake (from 0.91 to 10.30 μg/g $^{-1}$ dry wt).

Mercury. High mercury concentrations were recorded in muscles of perch from Kochejaur Lake. But in other water bodies mercury concentration exceeds 0.7 μg/g $^{-1}$ dry wt (Fig. 5). Perch is apparently more sensitive to mercury accumulation in muscle tissue than whitefish, the latter having higher mercury concentrations in liver and kidney (Appendix, Table 1 - 10).

3. Pike

Copper. Pikes from Mellalompola and Suovaselkajarvi Lakes had high standard error values of the copper concentrations in liver. This can be due to a small catch (Fig. 5). At the same time, copper accumulation in some individuals was substantially higher than that in other pikes from the same catch. The maximum Cu concentration in pike from Aittojarvi Lake accounted for 44.35 μg/g $^{-1}$ dry wt. The minimum mean copper concentration (about 8 - 9 μg/g $^{-1}$ dry wt) has been recorded in liver of pike from Kivijarvi and Virtuovoshjavr Lakes (Appendix, Table 10). Cu values in pikes from other water bodies varied between 18 - 25 μg/g $^{-1}$ dry wt.

Nickel. The highest Ni concentrations (up to 6.41 μg/g $^{-1}$ dry wt) and mean concentrations in liver of pike were recorded in Virtuovoshjavr Lake, which is similar to that recorded in the species above. Minimum Ni accumulation values in liver of pike were recorded in Kivijarvi Lake (0.70 μg/g $^{-1}$ dry wt.). The mercury concentration in pike from other water bodies ranged from 1.01 - 2.26 μg/g $^{-1}$ dry wt (Fig. 5). The Ni concentration in kidney of pike were, on the whole, lower compared to that recorded in whitefish and perch, with the highest concentrations in pike were recorded in gills and skeleton (Appendix, Tables 1, 3, 4, 5, 6, 9, 10).

Mercury. Mercury concentration in muscle of pike, a predatory fish, exceeded that recorded in tissue of whitefish and perch. Even minimum mercury concentration in muscle of pike exceeded 0.8 µg/g $^{-1}$ dry wt (Appendix, Tables 1, 3, 4, 5, 6, 9, 10). The highest mean mercury concentration has been recorded in tissue of pike from Aittojarvi and Kantojarvi Lakes, being as high as 2.14 and 2.89 µg/g $^{-1}$ dry wt., respectively.

It is noteworthy that in spite of higher mercury concentration recorded in muscle of pike against that of whitefish, the mercury concentration in kidney of whitefish was comparable and even exceeded that in muscle of pike. There was a decreasing distribution in Cu concentration in organs and tissues of the three fish species as follows: liver>kidney>gills>skeleton>muscle. The highest Ni concentrations were recorded in skeleton and kidney of all the species studied. The minimum Ni and Cu concentrations were typical of muscle tissue of all the species. The minimum mercury concentrations were observed in gills and skeleton of whitefish, perch and pike (Appendix, Table 1 - 10).

Trout and char of small lakes

More numerous data on heavy metals content in rare fish species such as trout and char were obtained in 2005. Studies were made in water bodies located at different distance from the Pechenganekel smelter .

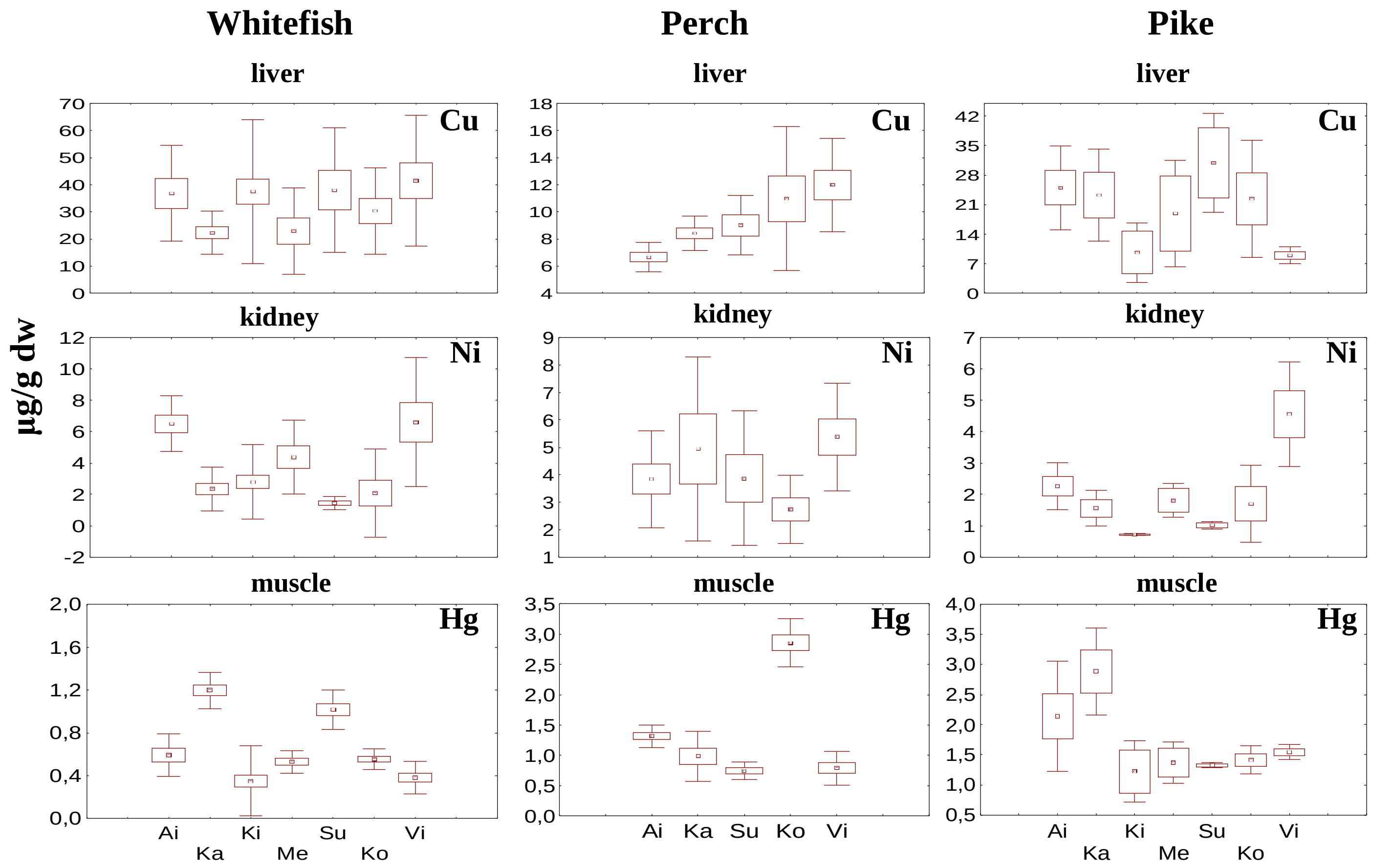
1. Trout

Copper. The highest copper concentration was recorded in liver of trout from Otervatn and Andre Guoikallub Lakes (Fig. 5). Furthermore, copper concentration in trout from Otervatn Lake varied greatly from 133.07 to 928.57 µg/g dry wt. The minimum copper content was recorded in liver of trout from Mellalompola Lake (33.48 µg/g dry wt), the average concentration not exceeding 67.52 µg/g dry wt. The average copper concentration recorded in trout from the reference Stuorajavri Lake is lower than that recorded in trout from other lakes (132.78 µg/g dry wt). It is should be noted that trout liver is capable of accumulating the highest copper content as compared to both other fish organs and other fish species studied.

Nickel. The character of nickel accumulation in kidney of trout was similar to copper accumulation in liver. The nickel concentration level in kidney of trout from Jarfjord area was 2.5 times as much on the average as that of trout from the reference area (Stuorajavri Lake) and 3.7 times as much as that in trout from Mellalompola Lake in which the nickel content in kidney of trout was minimum (Fig. 6). The nickel accumulation level in trout kidney was commensurable to that in kidneys of other fish species from the lakes studied.

Mercury. The highest mercury concentration in fish tissue was marked in trout from Mellalompola Lake and the metal content exceeded 0.9 µg/g dry wt in all the fish analyzed. The range of mercury content in fish tissue between minimal and maximal concentration in trout were the most significant in the lake Shuonijarvi (from 0.20 to 1.63 µg/g dry wt).

The lowest mercury concentration has been recorded in tissue of trout in lakes of the Jarfjord area (Fig. 6). However, the highest mercury concentration in this fish species was recorded in kidney and liver (Appendix, Tables 2, 7).



Ai – Aittojarvi; Ka – Kantojarvi; Ki – Kivijarvi; Me – Mellalompola; Su – Suovaselkajarvi;
Ko – Kochejaur; Vi - Virtuovoshjavr

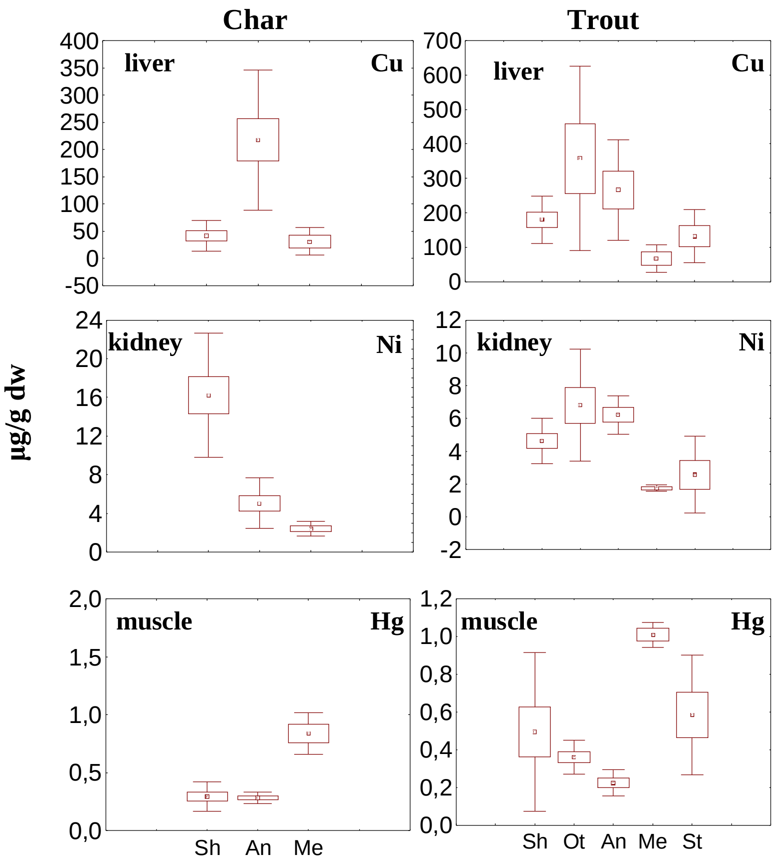
Fig. 5: Concentrations of Cu (liver), Ni (kidney) and Hg (muscle) in fish from the small lakes

2. Char

Copper. The distribution of copper, nickel and mercury in char organism was characterized by maximum concentration of these metals in all three lakes that inhabited by char. The copper concentration in liver of char from Andre Guoikallub was the highest, exceeding 200 µg/g dry wt (Fig. 6). The minimum copper concentration here was 97.29 and the maximum - 442.79 µg/g dry wt. Copper is similarly distributed in trout and char liver but the capability of trout to accumulate metal in this organ is probably higher.

Nickel. The maximum average nickel concentration was recorded in kidney of char from Shuonijarvi Lake (16.21 µg/g dry wt). The minimum nickel concentration in chars from Mellalompola Lake was eight times less, not exceeding 2.42 µg/g dry wt (Fig 6). The difference between nickel concentration in kidney of trout and char in the lakes studied was insignificant.

Mercury. As for trout, the highest mercury concentration was recorded in tissue of char from Mellalompola Lake (to 1.06 µg/g dry wt) (Fig. 6). This peculiarity was mentioned for other fish species from small lakes. At the same time, the highest mercury concentration was recorded in char kidney and liver.



Sh - Shuonijarvi; An – Andre Guoikallub; Me – Mellalompola; Ot – Otervatn; St – Stuorajavri

Fig. 6: Concentrations of Cu (liver), Ni (kidney) and Hg (muscle) in fish from the small lakes

On the whole, the analyses of heavy metal content in organs and tissues of trout and char showed high concentration of copper in liver and nickel in kidneys in fish from Otervatn and

Andre Guoikallub Lakes. However, the capability of kidney of char from Shuonijarvi lake to accumulate nickel was even higher. The main tendency is the highest accumulation of mercury in fish tissue from small forest lakes.

4.4. Pathological effects

The pathological change in fish from small lakes has been shown in detail in report of Paz watercourse and presented in Appendix (fig. 1 - 10).

The studies of fish population in Kochejaur lake were carried out in the early 1990s (Kashulin, 1994, 1999), in 2002 and 2005. In the early 1990s, most fish from this lake had disorders in gills, liver and kidney. For instance in 1991 - 1992 the number of liver pathologies increased, resulting in the change of color and mosaic structure (83 - 100 %). About 23 % of fish had gonads pathologies in the form of strangulated and twisted gonads (male) and gelatiniforme, poor pigmentation of berries (female) and gonads asymmetry. The frequency of liver diseases sharply increased from 1991 (8 %), in 1992, having attacked a third of fish (Kashulin et al., 1999). The frequency of main pathologies has become equal in the last decade. Nevertheless, most pathologic change in whitefish from this lake strikes liver and kidney, vitally important organs (Fig. 7). The findings of recent investigations of whitefish testify an increased pathology occurrence in liver, kidney and gonads as compared to the data of 2002. At present, the number of fish with pathologic transformation of gills is still unchanged (40 %). Thus, whitefish tends to deteriorate in state, negative changes affecting the most vital organs, including the reproductive system. In 2005, an androgyne fish was caught.

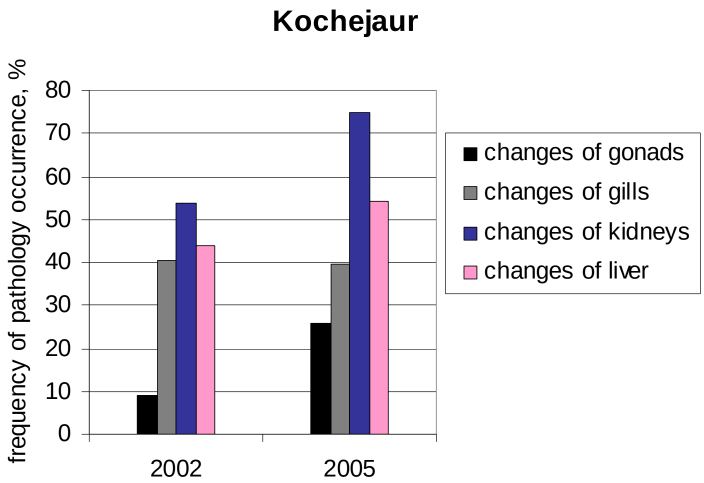


Fig. 7: Pathologic changes of inner organs of whitefish in the lake Kuetsjarvi in 2002 and 2005.

It should be noted that of all the forest lakes studied, Kochejaur and Virtuovoshjavr Lakes are the most distant from the sources of air borne industrial pollution. At the same time, the number of fish with disorders in kidney, liver and gills inhabiting these lakes is the greatest (Fig.8). Nevertheless, the degree of the change can be characterized as initial. The most common pathology of inner organs of whitefish inhabiting forest lakes of Finland (Aittojarvi, Kantojarvi, Mellalompola and Suovaselkkajarvi Lakes) are: pale coloring, mosaicism and an elongated liver (up to 83 % - Suovaselkkajarvi Lake) and kidney pathologies (up to 78 % - Aittojarvi Lake) (Fig. 8).

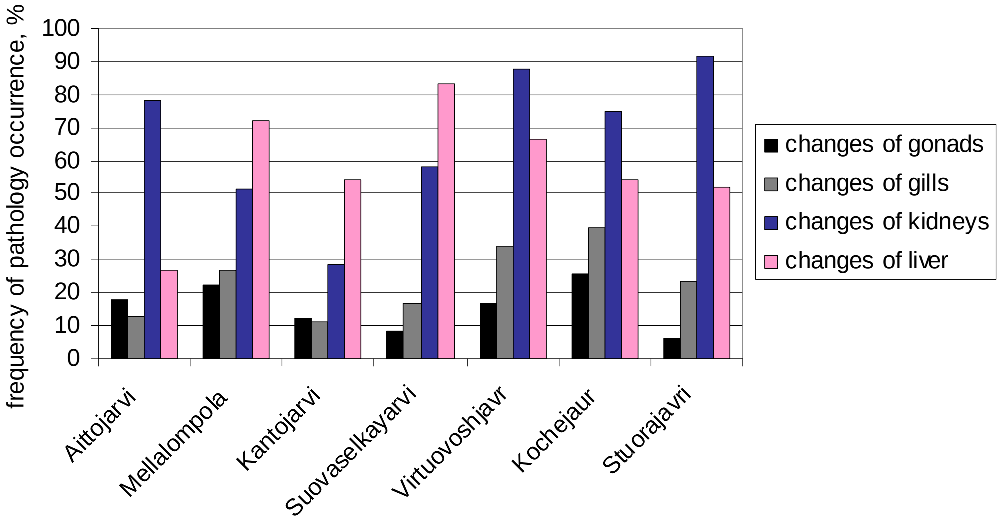


Fig. 8: Pathologic changes of inner organs of whitefish in the small forest lakes in 2005.

Pike was also small in number in catches from small forest lakes. The most common disorder observed in pike from these lakes was slight greenish color of muscular tissue and mouth and liver pathologies in some species. No visual pathology has been observed only in pikes (two samples) from Mellalompola Lake.

Histopathological indices

Gills. Numerous secondary gill lamellae are lined up along both sides of gill filament. The gill lamella surface is covered with simple squamous epithelial cells and many capillaries separated by pillar cells run parallel along the surface. The pillar cells are differentiated from the endothelial cells of capillaries. There are mucous cells on some parts of the secondary gill lamella and its basal epithelium. Chloride cells are seen on the basement of the secondary gill lamella that rarely registered in freshwater fishes (An atlas, 1982). Normal structure of gill filaments is shown in Appendix, Fig. 1.

Fusions of secondary lamellaes were also detected in Aittojarvi Lake and Stuorajavri Lake (the reference lake). Clavate - globate lamellaes were also recorded in individual fish in Mellalompola Lake (Appendix, Fig. 2). Haemorrhages between secondary lamellaes were found in fish sampled in Kantojavri Lake and Mellalompola Lake (Appendix, Fig. 3).

Liver. Normal liver structure is shown in Appendix, Fig. 4. Foci of necrobiosis and sclerotic alterations around vesicular walls were observed in fish sampled in Kantojarvi Lake and Mellalompola Lake (Appendix, Fig. 5). Circulatory disturbances, such as stasis vessel and erythrocytes breakdown within liver blood vessels were also found (Appendix, Fig. 6, 7).

Kidney. Normal kidney structure was found in fish species sampled in Suovaselkajarvy Lake(Appendix, Fig. 8). Only one whitefish has local deposition of haemosiderin, necrosis of stroma and non - specific acute inflammations. Haemorrhage, foci of necrosis of interstitial hematopoetic tissues, destruction of tubular and glomerulus epithelium were found in fish sampled in Kantojarvi Lake (Appendix, Fig. 9). In this study, histopatholgical alterations of three primary target organs, the gill, liver and kidney, were also examined. In all the locations studied, fish has proliferative, degenerative, structural and inflammatory alteration of a different degree (Appendix, Fig. 10).

In Kantojarvi and Suovaselkajarvi Lakes no progressive change (proliferation) was found. But some peculiar change in gills, liver and kidney of fish from small lakes was found in fish from the contaminated area.

5. Discussion

Population characteristics

The studies of fish communities in the period of 2002 - 2005 in Finland, Norway and Russia showed that the ichtyofauna of the studied water bodies included eight fish species from freshwater - arctic (whitefish, trout, arctic char, burbot), boreal - piedmont (grayling) and boreal –flat (pike, perch) fauna complexes (Nikolskiy, 1980). A representative of panto - caspian complex, nine - spined stickleback appeared to be in stomach of predatory fish and also was noticed visually (Nikolskiy, 1980).

The most widespread species were whitefish, perch and pike, found in 14 out of 15 investigated water bodies. The whitefish of forest zone (Aittojatvi, Kantojatvi, Suovaselkajarvi, Mellalompola, Kochejaur, and Virtuoshjavr) were represented only by sparsely rakered form. Both sparsely rakered and densely rakered forms are present in the lake Inari, the Paz watercourse and the background area (Stuorajarvi). The vendace, which was introduced in the lake Inari, at present is distributed in the whole Paz river system. Whitefish was chosen as the main subject of inquiry for the study of pollution of ecosystems by mining and smelting industry.

Whitefish. In 2005 higher average values of weight and length had the densely rakered whitefish of the Suovaselkajarvi Lake (Fig. 9).

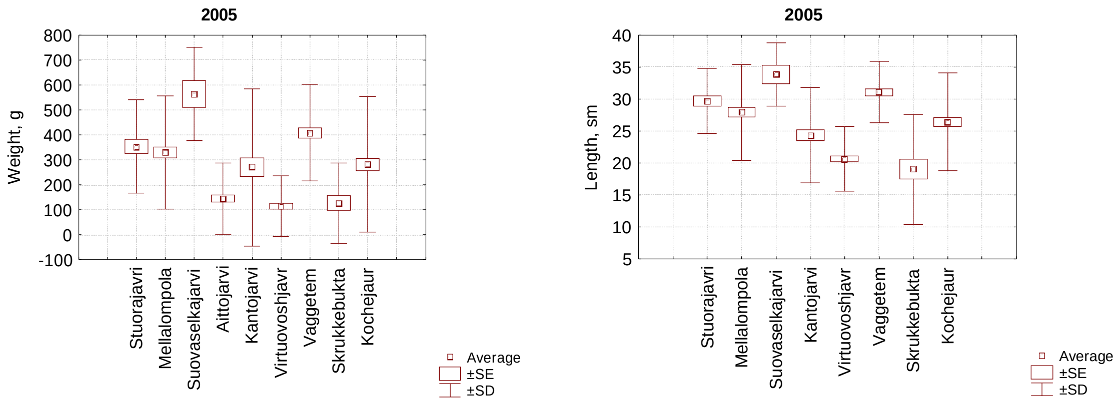


Fig. 9: Comparative size and weight characteristics of sparsely rakered whitefish in 2004 and 2005.

This may caused due to growing at fish farms. Whitefish in Stuorajarvi and Mellalompola Lakes and in Vaggetem reservoir also was of great size and weigh (Fig. 9).

In small forest lakes of Finland and in the border area of Russia, where only SR whitefish was recorded in 2005, the maximum age of fish varied from 4+ (Suovaselkajarvi Lake) to 11+ (Kochejaur Lake).

It is typical for whitefish to reach its maturity at age 4+ - 7+ (Reshetnikov, 1980). But in the course of prolonged pollution of water bodies, fish show a drop in maturation age, joining the spawning shoals. The whitefish reproduction in the studied areas is very peculiar. In some lakes and reservoirs, whitefish reach maturity at extremely early age of 0+ - 1+ with the following minimum sizes: 6 - 14g in weight and 8.9 - 12.1 cm in length (Kuetsjarvi Lake, Bjornevatn, Skrukkebukta, Inari Lake). The early maturation is now peculiar to following water bodies: at age 0+ in Bjornevatn reservoir and in Skrukkebukta - at age of 1+. In Inari Lake, in some cases, both forms of whitefish at age 1+ were ready to spawn. Whitefish from the reference area (Stuorajarvi Lake) reach maturity at age 4+. At the same time, the age of first spawning, whitefish, inhabiting the water bodies remote from the sources of industrial pollution, were recorded at age of 2+ (Kochejaur, Virtuovoshjavr).

Due to the fact that the spawning period of whitefish is quite prolonged and falls on autumn - winter period and the studies are carried out in July - September, it is difficult to judge about the number of whitefish participating spawning or missing spawning. Nevertheless, the share of fish in the studied populations of SR whitefish, presumably ready to spawn, varied substantially. The highest rate of mature portion of population was peculiar to forest lakes (from 66 % - Aittojatvi, Kochejaur to 75 % - Suovaselkajarvi). The data on the Paz watercourse varied from 16.7 (Rajakoski) to 66.1 % (Kuetsjarvi) for SR whitefish.

Trout and arctic char. The largest size and weight values of trout were recorded in reference Lake. The lowest values for weight and length were characteristic of trout from Shuonijarvi Lake. The size and weight characteristics of trout from catches in 2005 are indicative of the role of the distance between lakes and smelters and of the pollution level (the nearer the lake to smelter, the smaller and shorter the fish is) (Fig. 10).

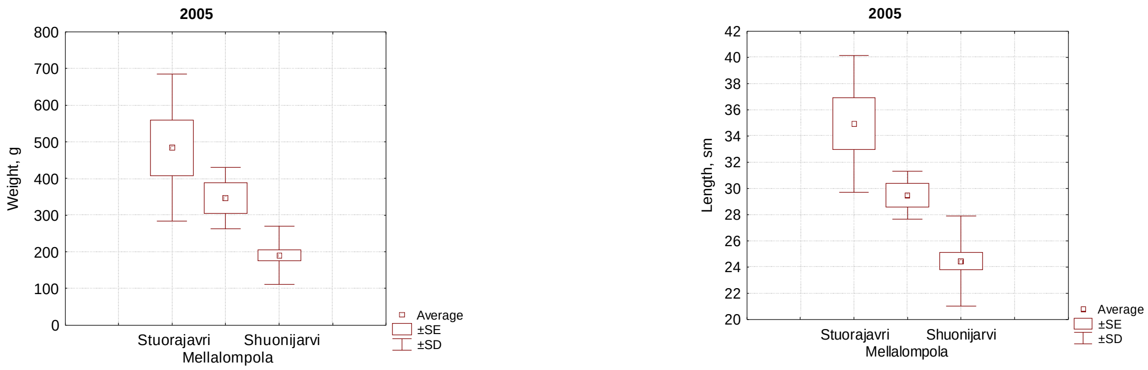


Fig. 10: Comparative size and weight characteristics of trout in 2005.

The arctic char was most widespread in Shuonijarvi Lake. Sometimes it was found in Inari and Mellalompola Lakes. On the whole, its weight varied from 64g to 875 g (average - 258 g) and length - from 17.7cm to 40.0 cm (average - 27.3 cm).

Pike. The maximum sizes were registered in 2005 in the lake Aittojarvi. The pike from the lake Stuorajarvi (reference region) had small average sizes (Fig. 11).

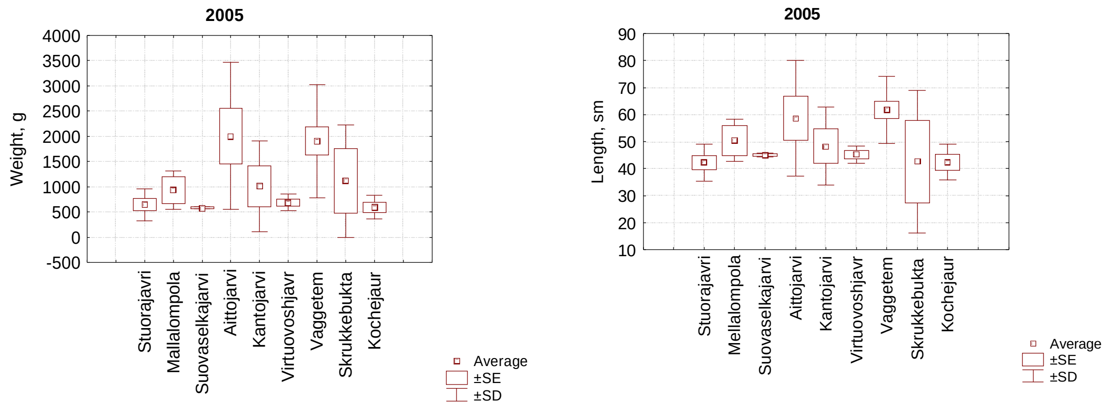


Fig. 11: Comparative size and weight characteristics of pike in 2005.

Perch. This species from the Kochejaur and Virtuovoshjavr Lakes are of a greater average size in compare to other places studied including the Paz watercourse (Fig. 12). Perches from Stuorajarvi Lake had intermediate position of length and weight between other water bodies.

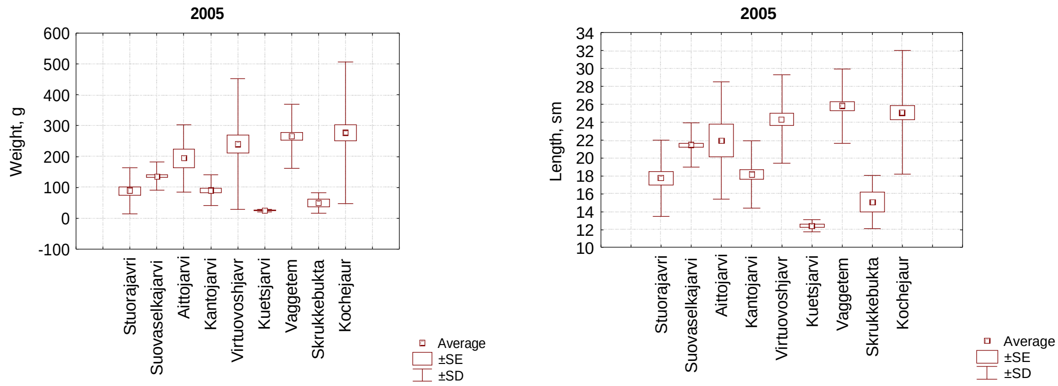


Fig. 12: Comparative size and weight characteristics of perch in 2005.

Grayling. According to our research data, grayling was most widespread in Mellalompola Lake. In other water bodies, it was caught in some cases.

Burbot. The greatest catches of burbot were in the Paz watercourse. In forest lakes burbot was caught in some cases.

Some population parameters in the water bodies located at various distances from the sources of industrial pollution have been carried out to reveal the change found in fish populations. The degree and character of change may be due to natural variability of basic biological characteristics of fish and also can testify to negative consequences of anthropogenic processes.

The organisms exposed to different levels of pollution may have different survival strategies for each species to maintain their existence in the current situation (Peakall, 1995). The responses of organisms providing their existence in polluted environment can be used as biomarkers. The change in the main characteristics and features of the population is under the influence of the environment. The change can be regarded as an adaptation of the population to newly formed environment otherwise there is no way for it to exist (Koshelev, 1983). As a system is exposed to the influence of some stressor, the modes of the population response are similar. In this connection, the grown - up population response may be similar to that caused by other stressors (Kashulin et al., 1999).

Several kinds of fish response to heavy industrial pollution are distinguished (Munkittrick and Dixon, 1989). Two types of response are characteristic of fish from large water bodies of the Kola Peninsula which are heavily polluted by industry (Moiseenko, 2002);
1) switch to a shorter reproduction cycle and rejuvenation of shoal as a response to a considerable decrease in the number of individuals ;
2) decrease in growth rate with increased fattiness, delay in maturation and missing of spawning.

Difference in size and weight characteristics of both forms of whitefish and other fish species throughout the study period in various regions of the Paz watercourse may be caused by high migration rate. The openness of the water area and widespread whitefish distribution in the Paz watercourse are obvious reasons for the size, weight and age range peculiarities among the species recorded.
A decrease in age, size and maturity range with fish populations in the polluted water areas is the criterion of poor water quality. There are the peculiarities characteristic of whitefish

population studied such as small number of age groups, rejuvenation of population, maturation in early age and high rate of fish missing the spawning.

Heavy metals content in whitefish

The most prolonged studies of heavy metal contamination of organs and tissues have been carried out of whitefish – *Coregonus lavaretus L.* The sparsely rakered whitefish has been selected to study copper and nickel contaminations, the main pollutants in various water bodies.

Copper. The findings of studies carried out in 2002 in the water bodies of the Paz River and in Kochejaur Lake (Fig. 13), revealed the highest copper concentrations in liver of whitefish in the Rajakoski reservoir, which can be explained by extremely high values of metal content in individual fish. These values varied greatly - from 13.42 to 129.77 µkg/g dry wt. On the whole, mean Cu concentrations in liver of whitefish varied within the following limits: 15 - 33 µkg/g dry wt.

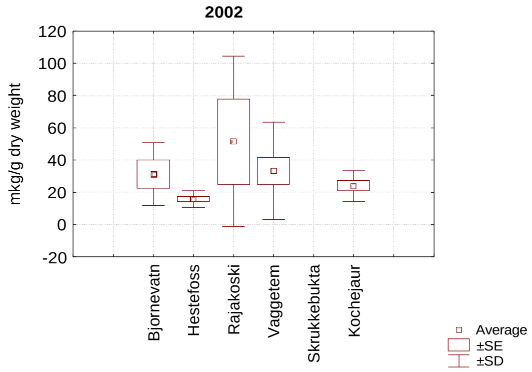


Fig. 13: Cu concentrations in liver of sparsely rakered whitefish in the investigated water bodies in 2002.

The comparison of similar indices of polytypic water bodies located at a different distance from the Pechenganickel smelter, made in 2005 showed that the copper content in liver of whitefish sampled in Kuetsjarvi Lake decreased. This could be due to a small catch because the catch was dominated by small - sized fish. Mean concentrations of copper in whitefish liver from heavily polluted water body (Kuetsjarvi) were comparable to those characteristic of whitefish from small forest lakes, exceeding it some cases. The copper contamination of liver was minimum in fish from the lake taken as the reference one (Fig. 14).

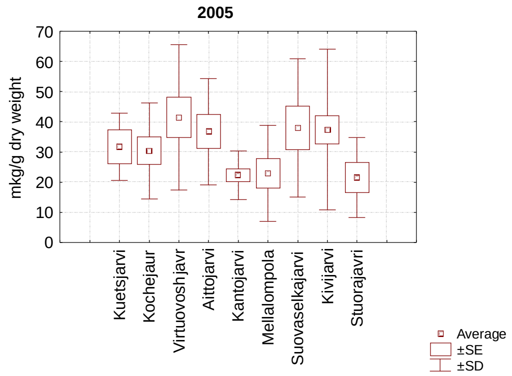


Fig. 14: Cu concentrations in liver of sparsely rakered whitefish in the investigated water bodies in 2005.

Nickel. The accumulation of Ni in kidney of SR whitefish (2002) depended on the distance of the water body from the pollution source. Thus, the highest Ni concentration was observed in the Bjornevatn area and the minimum - in the Rajakoski area and in Kochejaur Lake (Fig. 15).

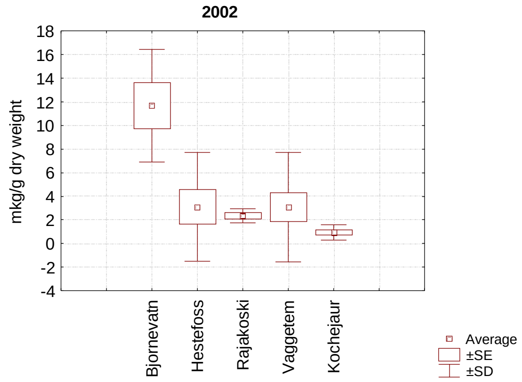


Fig. 15: Ni concentrations in kidney of sparsely rakered whitefish in the investigated water bodies in 2002.

The comparison of Ni accumulation in kidney of whitefish from Kuetsjarvi Lake and other water bodies studied in 2005, indicated higher concentration, with average value being of 22.72 μkg/g dry wt (Fig. 16). The mean Ni concentration in whitefish from small forest lakes (Virtuovoshjavr and Aittojarvi) was as high as 6.50 - 6.60 μkg/g dry wt. In other water bodies, including the reference area (Stuorajavri Lake), the Ni concentration was below 5 μkg/g dry wt.

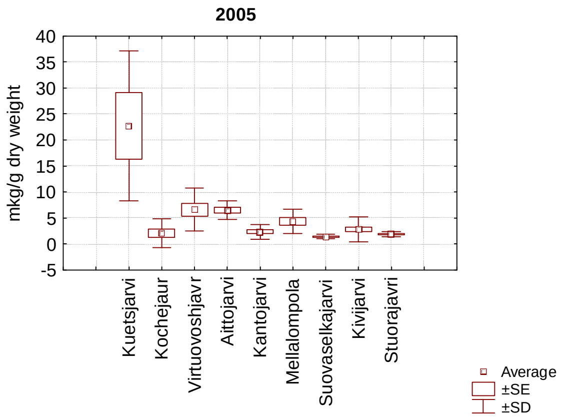


Fig. 16: Ni concentrations in kidney of sparsely rakered whitefish in the investigated water bodies in 2005.

Fish pathology

The pathologic change of whitefish from the lakes under study has been analyzed to show that the disorders in liver and kidney were in general common. It should be noted that the frequency of liver and kidney pathologies tend to increase throughout the whole period of study.

In the water bodies located both in the vicinity and at a large distance from the source of air borne industrial pollution, fish pathologies were regular episodes. It is obvious that the intensity and nature of fish pathology in the water bodies exposed to different levels of air borne industrial load acquire similar character. In the water bodies of the reference area (Stuorajavri) and in small forest lakes (Kochejaur, Virtuovoshjavr, Aittojarvi, Kantojarvi, Mellalompola and Suovaselkajarvi) organ violations were a regular case, like in water bodies located in the vicinity of the sources of pollution (Fig.65).There was a dependence of pathology occurrence in liver and kidney and in gonads and gills of whitefish from the studied lakes (Fig.17).

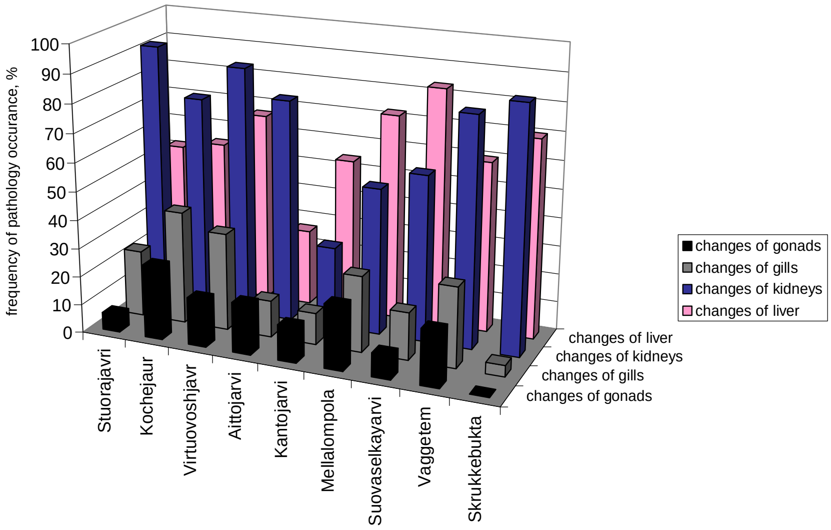


Fig. 17: Pathologic changes of inner organs of whitefish in the studied lakes in 2005.

The most frequently found disorders in whitefish were connective - tissue expansions, which may testify to an increase in Ni load in the water bodies, which provoked the development of this particular type of pathologies. Besides, at present, no dependence of gills and squama pathology characteristic of whitefish is found from the load level and remoteness of the water body from the source of pollution. The fact can be explained by nutrition peculiarities of fish. The heavy metal content in bottom fish and organisms is higher, as a rule. The benthos nutrition type of whitefish determines a higher level of heavy metal contamination of fish bodies. Thus, an increase in metal concentration due to food affects liver and kidney, in particular. Besides, small forest lakes are predisposed to anthropogenic acidification and subsequent increase in secondary pollution. This may act as an additional factor inducing pathological processes in fish organs and tissues.

At the background of a regular increase according to approach to the source of pollution, the intensity and frequency of pathology in predatory fish (pike) and in whitefish were characterized by the initial pathology stages occurrence in water bodies remote from the sources of pollution.

6. Conclusions and recommendations

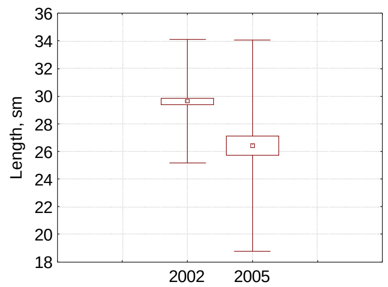
It is desirable to include small forest lakes studied earlier into monitoring programs. In 2005, there were seven lakes studied in Finnish (Aittijarvi, Mellalompola, Kantojarvi and Suovaselkajarvi lakes) and Russian (Kochejaur, Virtuovoshjavr and Shuonijarvi) areas. The decision was made to select less number of waterbodies to be studied in future monitoring programs. There were defined some troubles with lake selection. For instance, no whitefish inhabit Shuonijarvi Lake.. Whitefish population in two lakes in Finnish area (Suovaselkajarvi and Kantojarvi) is not numerous, being kept, presumably, artificially. So, there are two lakes more adequate for monitoring studies such as: two Finnish lakes – Aittojarvi and Mellalompola and two Russian lakes – Kochejaur and Virtuovoshjavr.

The studies of forest lake fish population (that of whitefish, particularly) to be carried out in the border area between Finland and Russia are of great importance. The most actual problem faced researchers intending to study these kinds of water bodies, is heterogeneous natural conditions of the watershed characteristics, location relative to pollution sources and troubles with correlation definition between the level and gradient of anthropogenic load (as registered to Paz watercourse).

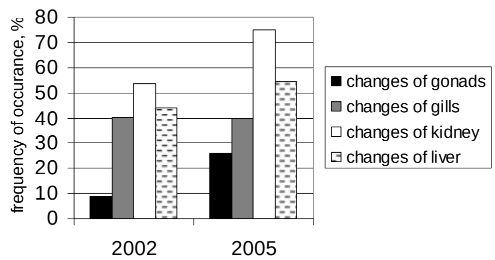
The lakes above are the most available for continuation of future monitoring programs because they meet following requirements:
1) lake locations are favorable to control the smelter activity in the south direction under anthropogenic load gradient;
2) two lakes in the Russian area (Kochejaur and Virtuovoshjavr) are located in the restricted border area where the level of any human activity is minimized. Mellalompola and Aittojarvi Lakes (Finnish side) are remoted too, inhabiting wild fish population;
3) the results of previous studies in Kochejaur and Virtuovoshjavr lakes are available;
4) water bodies are fish - populated (mainly, by whitefish *Coregonus lavaretus* and predatory fish species – perch, pike and trout).

Being large and long - living inhabitants in freshwater ecosystems, fish can exhibit all kinds of effect produced on water bodies for a long period. That is why the representatives of fish communities can exactly serve as indicators of the ecosystem status. It is necessary to take into account the following indices of ichthyofauna: population characteristics: pathological change by a histo - pathological analysis as well as heavy metals accumulation level in fish.

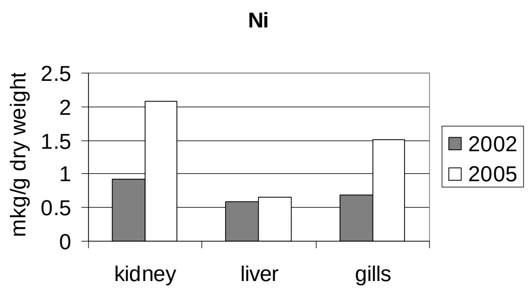
Earlier studies of whitefish population in Kochejaur Lake, remote from industrial plants, have shown a decrease in size - and - weight characteristics, shift of population mass parts to younger age classes, pathology occurrence frequency and increase in heavy metals accumulation level in fish organisms during the last three years (Fig. 18).



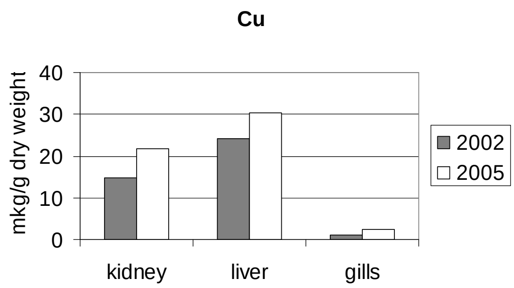
length changes



pathology



Ni concentration in organism in 2002 and 2005



Cu concentration in organism in 2002 and 2005

Fig. 18: Whitefish indices recorded for Kochejaur Lake (2002 and 2005)

Recent fish whitefish population studies carried out in small forest lakes in the border area in 2005 show quite similar tendencies both in organisms and population level. There were marked small number of age classes, early maturation of fishes; high level of fish pathology (of similar character recorded in fish from intensive polluted lakes). The levels of heavy metals accumulation in fish organs in small lakes now commensurable to these parameters in fish from Vaggetem and Skrukkebukta (Paz watercourse). At the same time, the results obtained during a one - year studies can not be unambiguously interpreted as the consequences of smelters activity or of other sources of pollution. So further examination of fish populations (particularly, that of whitefish) in these lakes should be continued in order to get a reliable assessment of change recorded and the control the following parameters:

- heavy metals accumulation levels in fish;
- pathological change of fish (frequency and intensity);
- characteristics of population constituent (size - and - weight, age and sex particularities, processes of regeneration).

Population. Sampling will be carried out based on a standard set of bottom nets from nylon monophylamenth, 25m long and 1.5m high, with the mesh size - 16, 20,31,36,40 mm, thread diameter – 0.15mm for nets with small mesh size, and 0.17mm - for nets with large mesh size. The nets will allow fish of all ages and of 8 - 10cm and more long to be caught.. The nets will be employed in the littoral zone one by one, perpendicular to the coast and in the profundal zone - ten and more nets in one line. For fish population structure to be analyzed, it is necessary to catch approximately one hundred of whitefish species from each lake. As for the predatory fish species is concerned, the number should be about 50 species. This part of study will cover the basic characteristics description of fish (length and age, size and age distribution, age determination, analyses of fattiness, nutrition, spawn and reproduction).

Pathology._ For this kind of analyses, fish species should be fresh (fresh caught). The clinical and pathological - and - anatomical signs should be based on visual fish examination during the fist hour after collection. The fish at various stages of disease range from initially insignificant pathological changes in organs up to the serious damages of the entire organism. Alteration of exterior, colour, condition and form of internal organs should be documented. Dissection is to be carried out to record the stage of maturation, fattiness, stomach filling. The pathological - and - morphologic and pathological - and - anatomical analyses under are made in situ by conditional methods. Pathological deviations of internals are to be estimated according to a four - ball scale, where 0 testifies to the absence of apparent pathologies. External observations, including those of body shape and appearance, skull depigmentationl, gill structure and colour, presence of external parasites (located on the gill or on a surface of fish body), and gross morphological superficial alteration, are to be recorded. In case of discrepant conditions, histology of some tissues is to be analyzed.

Heavy metals._In general, 10 - 15 individuals are necessary to be tested for heavy metals (HM) content in fish organs and tissues. Regular - sized fishes (whitefish and predatory – pike, perch, trout) should be taken. Standard analyses include five constituents of fish organism to HM content's determination: gills, liver, kidney, skeleton (spinal column) and muscle (tissue). After the samples have been transported in a frozen state to laboratory, they should be analyzed by atomic - absorption methods.

7. Acknowledgements

Funding for the work within the program "Environmental monitoring in border area" in 2002 - 2005 in Russia, Norway and Finland was provided by the Environmental department of Finnmark County government, Ministry of Environment of Finland, Lapland Regional Environment Centre, and in collaboration with Norwegian College of Fishery Science of University of Tromsö. The authors thank all the participants of the study for their support especially for: Markku Örn, Ilona Grekelä, Vladimir A. Dauvalter Viktor V. Snegov, Dmitry B. Denisow, Neonila P. Voevodina, Ingrida A. Terentjeva, Galina S. Platonenkova, Aleksey A. Pariaz.

We are looking forward to future cooperation.

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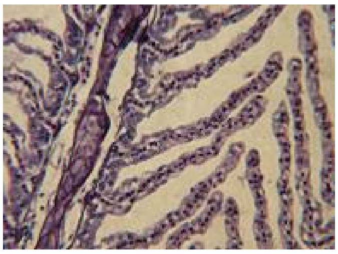
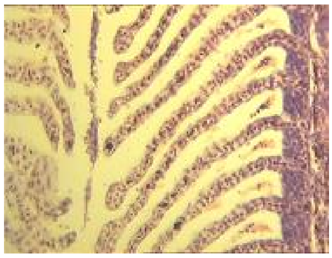
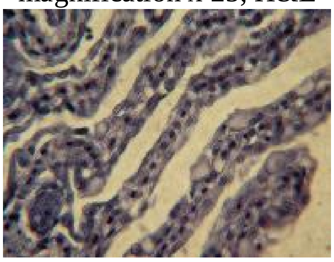
Appendix



Aittojarvi Lake,
magnification x 25, H&E



Kantojarvi Lake,
magnification x 25, H&E

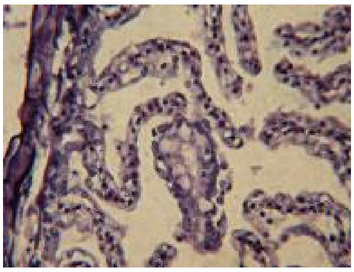


Mellalompola Lake,
magnification x 40, H&E

Stuorajavri Lake,
magnification x10, H&E

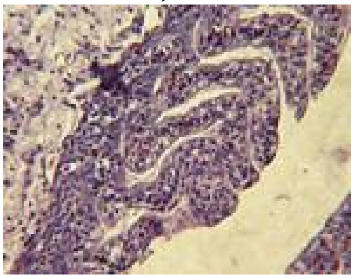
Appendix fig. 1: Normal structure of the whitefish gill.

adjacent lamellae and filaments extensively fused, Stuorajavri L, magnification x25, H&E

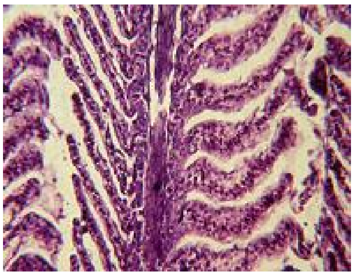


swellen secondary gill lamellae Aittojarvi Lake, magnification x40, H&E

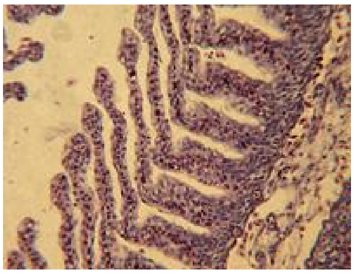
fusion of secondary lamellaes, Stuorajavri Lake, magnification x 10, H&E



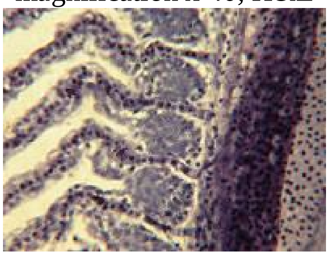
hyperplasia of gill epitelium hasresulted in fusion of lamellae. Note that epitelium has proliferated beyond tips of lamellae. Aittojarvi Lake, magnification x 40, H&E



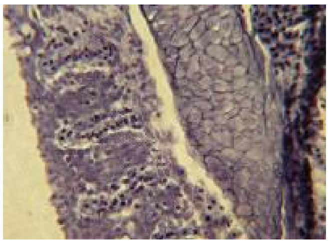
hyperplasia of gill epithelium, thickened abnormal lamellaes, Kantojarvi Lake, magnification x25, H&E



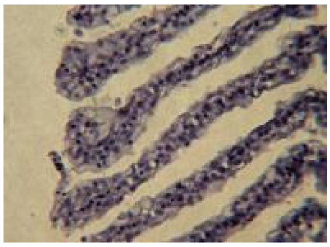
hyperplasia of gill epithelium, Aittojarvi Lake magnification x25, H&E



hyperplasia of gill epithelium, Mellalompola Lake, magnification x 40, H&E

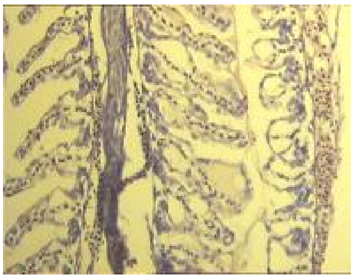


severe hyperplasia of gill epithelium, Mellalompola Lake, magnification x 40, H&E

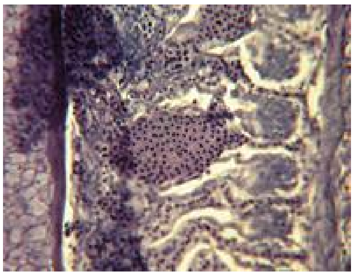


clavate - globate lamellae, Mellalompola Lake, magnification x40, H&E

Appendix fig. 2: Progressive alterations in the whitefish gill.

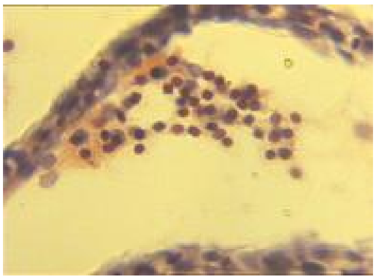


edematous secondary lamellae, Kantojarvi Lake, magnification x 25, H&E



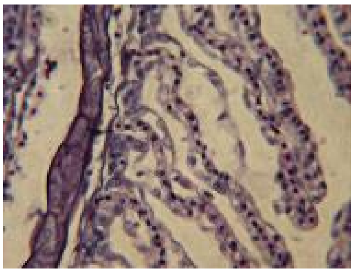
Some lamellae were distended by rounded masses of blood cells, Mellalompola Lake magnification x 40, H&E

Haemorrhage between secondary lamellae, Kantojavri Lake, magnification x 40, H&E



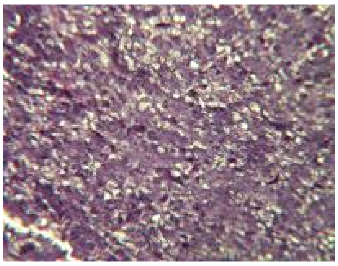
Increasing secretion mucus and desquamation gill epithelium, Kantojarvi Lake, magnification x 25, H&E

swollen, edematous lamellae, Aittojarvi Lake, magnification x 25, H&E

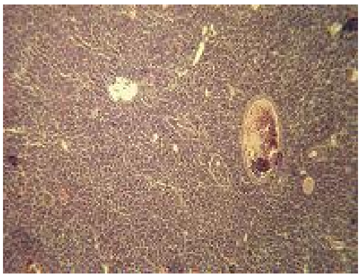


swollen, edematous lamellae, Aittojarvi Lake, magnification x 40, H&E

Appendix fig. 3: Circulatory and inflammatory altered blood flow in the gills of whitefish.

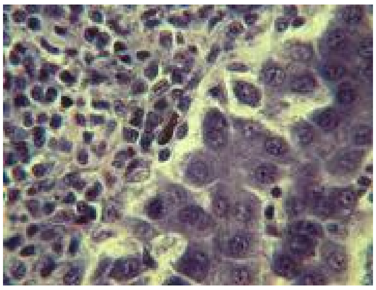


char, Shuonijarvi Lake, magnification x 40, H&E

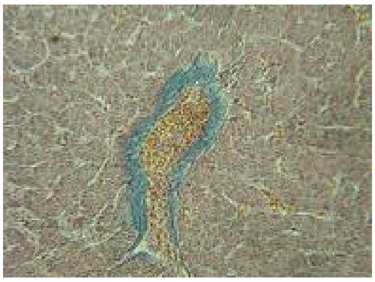


whitefish, Aittojarvi Lake magnification x 10, H&E

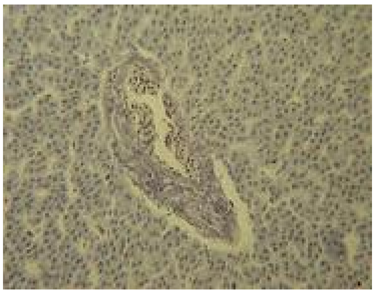
Appendix fig. 4: Normal structure of the liver.



Showing the border area oh the granuloma (more smaller) and normal hepatocytes, magnification x 100, H&E

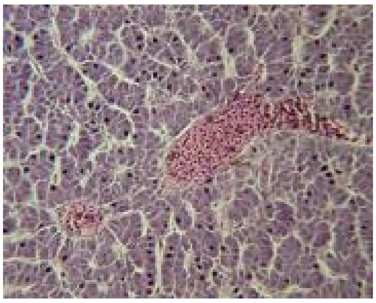


Section of liver of whitefish, showing fibrosis thickening of wall of blood vessel, Rajakoski location, magnification x 40, azokarmin

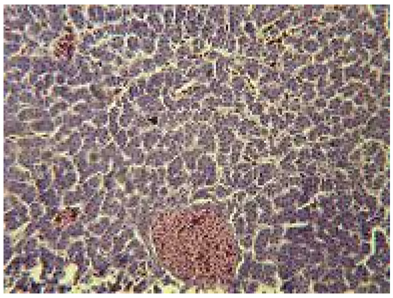


showing fibrosis thickening of wall of blood vessel, Kantojarvi Lake, magnification x 40, H&E

Appendix fig. 5: Proliferative alterations of whitefish liver.

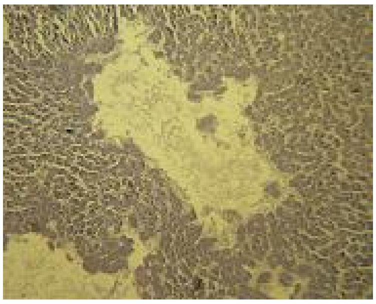


showing stas vessel and pyknotic nuclei in the hepatocytes, Stuorajavry Lake, magnification x 40, H&E.

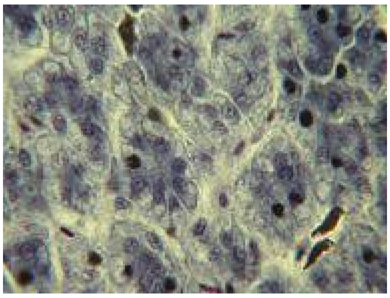


showing stas vessel and breakdown of erythrocytes within blood vessel Kantojarvi Lake, magnification x 40, H&E.

Appendix fig. 6: Circulatory disturbances (altered blood flow) of liver of whitefish.



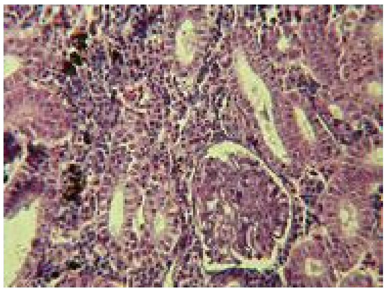
section of liver of whitefish, showing extensive foci of necrosis of the parenhima Kantojarvi Lake, magnification x 10, H&E



some nucleus small and picnotic, vacuoles are presence within the hepatocytes, Kantojarvi Lake, magnification x 100, H&E

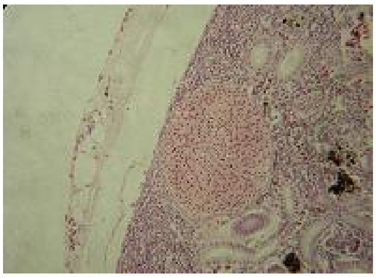
Appendix fig. 7: Degenerative and structural alterations of whitefish liver.

Char, Shounijarvy Lake, magnification x25 H&E.

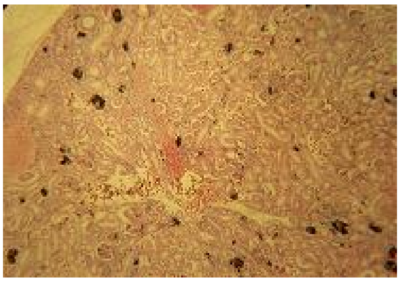


whitefish, Kantojarvi Lake, magnification x25 H&E..

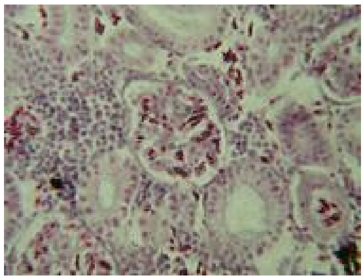
Appendix fig. 8: Normal structure of the kidney.



Venous stasis in the kidney of the whitefish, Kantojarvi Lake, magnification x 25, H&E

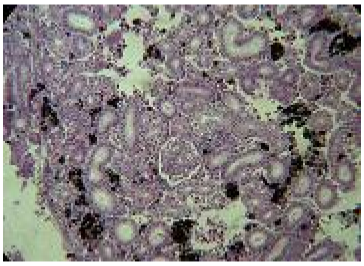


haemorrhage, destruction of the blood vessel, Kantojarvi Lake , magnification x10, H&E

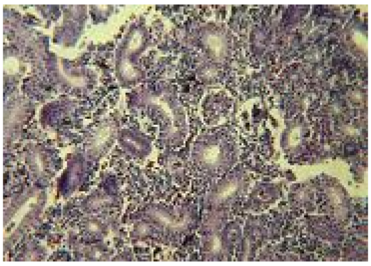


Increasing numerous erythrocytes in the glomerular capsule, Kantojarvi Lake, magnification x25, H&E

Appendix fig. 9: Circulatory disturbances in the kidney.



local foci of the deposition of haemosiderin and foci of ecrosis of hematopoetic tissues, Aittojarvi Lake, magnification x25, H&E



destruction of the glomerulus of the whitefish kidney, Kuetsjarvi Lake magnification x 25, H&E

picnosis of the renal tubules, Skrukkebukta, Paz River, magnification x100, H&E

Appendix fig. 10: Degenerative alterations in the whitefish kidneys in Aittojarvi Lake and in strongly polluted Kuetsjarvi Lake.

Appendix table 1: Concentrations of heavy metals in fish of the Lake Aittojarvi in 2005:

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
SR whitefish	muscle									
	Average	0.73	0.62	0.02	15	2.22	2.63	5.98	0.06	0.59
	Min	0.51	0.45	<0.01	11	1.06	1.15	0.58	<0.05	0.31
	Max	0.99	0.83	0.03	22	5.57	4.40	11.52	0.08	0.87
	St. dev.	0.18	0.11	0.01	3	1.30	1.14	3.99	0.01	0.20
	liver									
	Average	36.81	1.09	2.87	137	11.43	19.67	0.67	0.31	1.77
	Min	19.98	0.88	1.86	107	8.40	6.60	0.35	<0.05	1.25
	Max	75.30	1.31	4.65	164	14.61	50.49	1.19	0.89	2.67
	St. dev.	17.64	0.17	1.00	17	2.33	15.01	0.36	0.27	0.57
	kidney									
	Average	10.11	6.51	24.27	156	6.53	30.05	4.36	0.61	2.25
	Min	6.74	3.84	19.19	104	3.29	9.77	2.51	0.27	0.65
	Max	17.03	10.03	28.41	313	11.76	59.11	6.10	1.04	4.86
	St. dev.	3.16	1.78	2.83	63	2.80	16.99	1.26	0.30	1.19
	gills									
	Average	1.42	0.92	0.14	125	28.91	9.14	86.76	0.62	0.33
	Min	0.96	0.50	0.10	68	15.16	5.55	59.79	<0.05	0.14
	Max	2.08	1.43	0.20	357	54.64	13.57	124.57	1.34	0.60
	St. dev.	0.36	0.30	0.04	87	12.85	2.36	23.54	0.32	0.13
	skeleton									
	Average	1.16	5.05	0.01	95	48.64	12.85	267.51	0.39	0.08
	Min	0.87	4.52	<0.01	70	25.08	5.17	223.46	0.02	0.04
	Max	1.64	5.72	0.01	174	104.04	38.66	330.10	0.60	0.10
	St. dev.	0.26	0.39	0.002	31	23.46	9.50	33.95	0.18	0.02
Perch	muscle									
	Average	0.75	0.57	0.02	16	0.70	1.59	0.31	0.06	1.32
	Min	0.60	0.41	<0.01	14	0.57	1.14	0.23	<0.05	1.02
	Max	0.95	0.82	0.02	19	0.93	2.29	0.45	0.08	1.51
	St. dev.	0.11	0.14	0.01	2	0.10	0.41	0.08	0.01	0.18
	liver									
	Average	6.67	0.96	1.30	93	7.44	13.60	0.61	0.08	0.64
	Min	5.00	0.74	0.87	79	4.07	7.79	0.30	<0.05	0.43
	Max	7.95	1.28	2.36	103	12.09	24.53	1.34	0.15	0.85
	St. dev.	1.10	0.16	0.51	7	2.81	4.63	0.30	0.05	0.14
	kidney									
	Average	5.54	3.84	0.26	104	2.41	12.45	1.32	0.45	0.60
	Min	3.30	1.55	0.15	71	1.08	4.50	0.45	0.16	0.37
	Max	12.05	7.37	0.49	174	4.69	24.28	2.70	1.35	1.19
	St. dev.	2.68	1.77	0.11	31	1.26	6.43	0.71	0.35	0.24
	gills									
	Average	1.50	1.06	0.04	64	33.49	11.98	95.01	0.11	0.17
	Min	1.24	0.68	0.02	59	22.74	3.02	84.01	<0.05	0.12
	Max	1.81	1.89	0.05	68	45.01	40.85	108.11	0.15	0.24
	St. dev.	0.18	0.34	0.01	3	7.71	11.40	8.13	0.03	0.05
	skeleton									
	Average	1.03	4.19	0.01	53	39.90	5.83	186.89	0.10	0.08
	Min	0.84	3.59	<0.01	46	29.32	1.75	157.36	0.06	0.06
	Max	1.65	4.81	0.02	60	54.73	7.83	223.30	0.17	0.09
	St. dev.	0.23	0.36	0.003	5	8.50	1.62	22.74	0.03	0.01

Continuation (Table 1)

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
Pike	muscle									
	Average	0.80	0.51	0.02	19	0.68	1.35	1.76	<0.05	2.14
	Min	0.57	0.40	0.01	16	0.48	0.70	0.34		0.83
	Max	1.07	0.61	0.03	22	1.04	2.33	3.40	0.06	3.25
	St. dev.	0.19	0.10	0.01	3	0.19	0.81	1.11		0.92
	liver									
	Average	24.99	0.66	0.33	99	1.93	3.13	0.32	0.07	0.59
	Min	16.89	0.45	0.15	45	1.22	2.08	0.11	<0.05	0.28
	Max	44.35	0.95	0.61	174	2.70	6.73	0.50	0.07	0.96
	St. dev.	9.94	0.22	0.17	45	0.48	1.81	0.15	0.01	0.24
	kidney									
	Average	5.07	2.26	2.44	544	2.85	10.87	1.01	0.12	0.59
	Min	3.79	1.57	1.47	393	2.03	4.86	0.71	<0.05	0.17
	Max	6.54	3.35	3.53	643	3.76	17.57	1.23	0.22	1.12
	St. dev.	0.90	0.75	0.66	98	0.67	4.33	0.22	0.07	0.33
	gills									
	Average	1.19	0.95	0.11	465	15.69	1.89	128.92	<0.05	0.23
	Min	0.99	0.71	0.06	363	12.93	0.58	112.19		0.16
	Max	1.36	1.26	0.14	577	18.54	4.29	144.08		0.31
	St. dev.	0.13	0.19	0.03	81	2.37	1.32	12.77		0.07
	skeleton									
	Average	0.99	5.14	0.02	118	23.13	4.55	196.17	0.08	0.07
	Min	0.88	4.92	0.01	95	19.78	3.37	169.93	<0.05	0.06
	Max	1.05	5.48	0.02	136	29.35	5.73	217.86	0.12	0.11
	St. dev.	0.06	0.23	0.00	15	4.00	0.98	18.36	0.03	0.02

Appendix table 2: Concentrations of heavy metals in fish of the Lake Andre Guoikallub in 2005:

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
Char					muscle					
	Average	1.59	0.80	0.02	25	0.53	2.42	1.32	0.17	0.28
	Min	0.92	0.50	0.01	14	0.35	0.99	0.21	<0.05	0.23
	Max	3.16	1.10	0.04	39	0.66	8.43	3.44	0.35	0.41
	St. dev.	0.65	0.22	0.01	8	0.11	2.05	0.99	0.13	0.05
					liver					
	Average	217.62	1.52	3.05	176	7.17	31.18	1.20	0.10	0.30
	Min	97.29	1.05	2.21	125	5.83	11.86	0.74	0.05	0.21
	Max	442.79	2.43	4.15	220	10.12	57.08	1.79	0.17	0.39
	St. dev.	128.70	0.45	0.68	26	1.28	15.46	0.38	0.04	0.06
					kidney					
	Average	9.21	5.06	5.84	97	2.09	8.49	2.86	0.14	0.40
	Min	4.74	1.35	1.57	59	1.28	4.64	1.82	0.04	0.15
	Max	12.87	10.87	9.35	141	4.77	15.44	3.83	0.29	0.64
	St. dev.	2.86	2.62	2.23	20	1.03	3.43	0.58	0.07	0.14
					gills					
	Average	2.53	2.08	0.76	93	10.25	5.31	65.02	0.20	0.15
	Min	1.26	1.49	0.52	77	7.89	2.94	52.69	0.13	0.12
	Max	4.75	2.74	0.94	123	12.99	11.52	79.56	0.39	0.23
	St. dev.	0.94	0.42	0.13	11	1.88	2.34	9.33	0.07	0.03
Trout					muscle					
	Average	1.50	0.89	0.02	15	0.59	1.87	1.49	0.10	0.23
	Min	1.11	0.70	0.01	13	0.43	1.37	0.25	<0.05	0.16
	Max	1.85	1.15	0.02	18	0.74	2.88	2.88	0.18	0.38
	St. dev.	0.26	0.16	0.00	2	0.09	0.54	0.91	0.05	0.07
					liver					
	Average	266.57	1.64	2.55	178	4.66	9.89	1.48	0.15	0.24
	Min	105.66	1.08	1.72	151	2.68	7.44	0.87	<0.05	0.19
	Max	500.18	2.32	4.14	216	6.14	12.28	2.02	0.34	0.27
	St. dev.	145.24	0.59	0.86	27	1.23	2.02	0.43	0.13	0.03
					kidney					
	Average	5.80	6.23	3.86	184	2.01	14.30	5.25	0.20	0.33
	Min	4.47	4.82	2.77	149	1.58	6.92	2.86	0.10	0.21
	Max	6.95	8.16	5.79	223	2.93	32.85	8.14	0.37	0.48
	St. dev.	0.98	1.17	1.25	26	0.47	8.73	1.94	0.09	0.09
					gills					
	Average	1.28	2.45	0.76	300	8.32	3.84	78.84	0.18	0.09
	Min	0.68	1.99	0.55	210	6.41	2.86	56.13	0.09	0.05
	Max	1.85	2.85	0.94	390	9.44	7.19	104.06	0.39	0.17
	St. dev.	0.46	0.30	0.14	61	1.17	1.53	17.96	0.11	0.04

Appendix table 3: Concentrations of heavy metals in fish of the Lake Kantojarvi in 2005:

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
SR whitefish	muscle									
	Average	0.74	0.54	0.01	17	1.02	1.64	5.17	0.05	1.20
	Min	0.60	0.32	<0.01	15	0.58	0.85	0.56	<0.05	0.93
	Max	0.91	0.65	0.01	18	1.30	2.77	9.62	0.05	1.48
	St. dev.	0.10	0.12	0.00	1	0.22	0.72	2.38	0.00	0.17
	liver									
	Average	22.28	0.72	0.13	121	6.73	2.74	0.52	0.15	1.92
	Min	14.10	0.37	0.07	76	4.20	0.76	0.36	0.08	1.12
	Max	44.62	1.44	0.24	194	8.79	7.68	0.88	0.41	2.64
	St. dev.	8.01	0.32	0.05	34	1.07	2.29	0.14	0.10	0.48
	kidney									
	Average	7.24	2.34	1.54	172	2.60	4.27	1.69	0.10	1.92
	Min	2.39	0.97	0.18	94	1.48	2.36	1.22	<0.05	0.76
	Max	17.92	5.19	3.15	316	4.68	7.27	4.54	0.19	2.86
	St. dev.	4.30	1.39	0.91	63	0.89	1.28	0.90	0.04	0.54
	gills									
	Average	1.57	1.18	0.27	437	10.33	6.28	60.10	0.18	0.60
	Min	1.13	1.02	0.15	164	5.96	3.16	46.58	<0.05	0.42
	Max	1.96	1.60	0.50	744	13.38	19.82	77.53	0.49	0.77
	St. dev.	0.28	0.17	0.10	219	2.32	4.69	9.81	0.13	0.12
	skeleton									
	Average	1.09	4.81	<0.01	145	21.94	3.98	298.55	0.21	0.14
	Min	0.82	3.96		108	16.82	2.57	250.20	<0.05	0.08
	Max	1.48	5.79	0.01	191	30.08	6.03	327.65	0.73	0.19
	St. dev.	0.20	0.68		22	4.56	1.00	24.70	0.25	0.04
Perch	muscle									
	Average	0.71	0.59	0.01	18	0.96	4.04	0.85	0.05	0.98
	Min	0.54	0.41	<0.01	16	0.56	1.85	0.38	<0.05	0.56
	Max	0.99	0.73	0.02	29	1.45	8.35	2.26	0.05	1.58
	St. dev.	0.16	0.11	0.005	4	0.31	2.24	0.63	0.001	0.42
	liver									
	Average	8.43	1.00	0.84	103	8.23	16.73	0.76	0.27	0.46
	Min	6.17	0.45	0.44	85	5.71	10.07	0.43	0.06	0.34
	Max	10.34	2.48	1.15	110	12.89	23.75	1.32	0.92	0.62
	St. dev.	1.27	0.63	0.24	9	2.39	4.73	0.26	0.25	0.12
	kidney									
	Average	4.68	4.94	0.17	116	2.69	20.66	1.73	0.50	0.61
	Min	3.37	0.91	0.08	87	1.51	7.25	1.01	0.17	0.39
	Max	6.35	10.30	0.30	150	3.83	45.92	3.75	1.85	0.84
	St. dev.	1.16	3.36	0.06	21	0.85	14.08	0.90	0.50	0.13
	gills									
	Average	1.33	1.40	0.05	68	25.27	8.56	52.12	0.13	0.23
	Min	1.06	1.27	0.02	58	20.64	4.05	43.73	0.05	0.15
	Max	1.53	1.75	0.07	100	29.96	13.67	64.74	0.25	0.42
	St. dev.	0.14	0.14	0.01	12	3.10	3.01	6.65	0.06	0.08
	skeleton									
	Average	1.05	3.82	<0.01	77	43.43	5.95	122.56	0.18	0.07
	Min	0.84	3.01		64	32.13	3.28	99.89	0.05	0.05
	Max	1.30	5.47	0.01	98	50.07	8.81	159.02	0.50	0.11
	St. dev.	0.15	0.71		12	5.64	1.48	17.02	0.14	0.02

Continuation (Table 3)

		Cu	Ni	Cd	Zn	Mn	Al	Sr	Pb	Hg
Pike		muscle								
	Average	0.83	0.55	0.01	20	1.54	7.17	4.19	0.09	2.89
	Min	0.70	0.49	0.01	14	0.85	2.23	0.94	<0.05	2.40
	Max	0.99	0.63	0.01	29	2.39	11.48	7.23	0.13	3.96
	St. dev.	0.14	0.06	0.00	6	0.71	4.61	3.05	0.06	0.72
		liver								
	Average	23.29	0.47	0.11	137	4.28	10.60	0.68	0.23	0.95
	Min	13.40	0.28	0.07	97	2.38	2.08	0.39	0.09	0.86
	Max	33.17	0.83	0.14	189	7.18	25.58	1.31	0.39	1.10
	St. dev.	10.87	0.26	0.03	40	2.24	10.42	0.43	0.13	0.10
		kidney								
	Average	4.95	1.56	0.89	548	3.02	7.60	0.88	0.25	1.41
	Min	4.14	1.11	0.69	371	2.49	4.11	0.56	<0.05	0.78
	Max	5.76	2.37	1.23	742	3.56	14.05	1.07	0.40	2.23
	St. dev.	0.68	0.57	0.24	170	0.48	4.60	0.22	0.22	0.66
		gills								
	Average	1.74	3.13	0.09	352	20.54	12.62	116.51	0.13	0.34
	Min	1.57	2.47	0.07	289	18.94	10.78	100.86	0.07	0.25
	Max	1.95	3.44	0.10	446	23.08	14.06	139.58	0.18	0.46
	St. dev.	0.19	0.45	0.01	67	1.78	1.46	16.67	0.05	0.11
		skeleton								
	Average	0.77	6.06	0.01	115	30.50	4.36	155.86	0.08	0.09
	Min	0.68	5.47	<0.01	82	25.07	3.64	107.06	<0.05	0.07
	Max	0.82	6.91		140	35.00	5.00	190.53	0.10	0.11
	St. dev.	0.06	0.62		24	4.22	0.56	36.68	0.03	0.02

Appendix table 4: Concentrations of heavy metals in fish of the Lake Kivijarvi in 2005:

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
SR whitefish	muscle									
	Average	0.83	0.60	0.01	23	3.32	3.37	6.33	0.08	0.349
	Min	0.51	0.35	<0.01	14	0.70	1.36	0.33	<0.05	0.110
	Max	1.32	0.87	0.02	76	6.93	8.91	14.51	0.18	1.407
	St. dev.	0.22	0.12	0.004	11	1.54	1.55	3.78	0.04	0.328
	liver									
	Average	37.42	0.85	0.18	191	9.58	6.62	1.19	0.16	0.581
	Min	4.93	0.39	0.04	53	2.16	1.58	0.23	<0.05	0.213
	Max	120.27	1.45	0.40	329	17.05	18.59	6.94	0.41	1.149
	St. dev.	26.61	0.26	0.10	70	3.22	4.83	1.50	0.11	0.235
	kidney									
	Average	9.33	2.79	1.34	204	6.91	28.57	6.19	0.26	0.877
	Min	4.09	0.74	0.40	88	2.19	4.32	0.73	<0.05	0.381
	Max	25.30	12.65	3.63	484	19.17	69.60	27.83	0.90	1.644
	St. dev.	5.44	2.39	0.78	96	4.11	21.55	6.52	0.18	0.328
	gills									
	Average	1.93	1.04	0.04	292	26.07	13.82	55.28	0.17	0.116
	Min	1.34	0.39	0.02	79	16.77	2.79	38.03	<0.05	0.064
	Max	2.92	2.06	0.12	1493	37.71	123.68	99.11	1.26	0.250
	St. dev.	0.35	0.40	0.02	295	5.96	20.92	14.23	0.25	0.037
	skeleton									
	Average	1.03	3.36	<0.01	116	39.35	5.26	148.12	0.15	0.094
	Min	0.63	1.41		72	24.96	2.64	112.51	<0.05	0.047
	Max	2.04	4.44		216	62.60	8.98	185.15	0.36	0.207
	St. dev.	0.36	0.82		28	9.70	1.47	21.53	0.07	0.043
Pike	muscle									
	Average	1.10	0.82	0.01	23	1.12	3.01	0.54	0.08	1.223
	Min	0.99	0.67	0.01	20	1.08	1.93	0.49	0.06	0.862
	Max	1.22	0.97	0.01	25	1.17	4.08	0.58	0.10	1.585
	St. dev.	0.16	0.21	0.00	4	0.06	1.52	0.06	0.03	0.511
	liver									
	Average	9.62	0.45	0.04	81	3.17	3.10	0.29	<0.05	0.64
	Min	4.59	0.43	0.03	77	3.15	2.81	0.26		0.60
	Max	14.64	0.47	0.04	85	3.19	3.39	0.33	0.05	0.67
	St. dev.	7.11	0.03	0.01	6	0.03	0.42	0.05		0.05
	kidney									
	Average	4.23	0.72	0.30	88	3.01	5.17	1.19	<0.05	0.89
	Min	4.17	0.70	0.26	83	2.85	4.06	0.48		0.83
	Max	4.30	0.74	0.34	94	3.18	6.29	1.90		0.94
	St. dev.	0.10	0.02	0.06	8	0.24	1.58	1.01		0.07
	gills									
	Average	1.66	1.26	0.05	306	27.36	10.46	107.20	<0.05	0.20
	Min	1.56	1.22	0.04	244	26.17	7.41	99.60		0.18
	Max	1.76	1.31	0.07	367	28.54	13.51	114.80	0.06	0.22
	St. dev.	0.14	0.06	0.02	87	1.68	4.31	10.75		0.03
	skeleton									
	Average	1.09	4.71	<0.01	133	34.30	3.30	141.49	<0.05	0.15
	Min	1.08	4.68		131	33.57	3.28	136.52		0.14
	Max	1.10	4.75		135	35.03	3.33	146.46		0.17
	St. dev.	0.01	0.04		3	1.03	0.03	7.02		0.02

Appendix table 5: Concentrations of heavy metals in fish of the Lake Kochejaur in 2005:

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
SR whitefish	muscle									
	Average	0.79	1.10	<0.01	23	1.78	2.64	7.97	0.07	0.55
	Min	0.58	0.69		19	1.20	1.63	1.71	<0.05	0.40
	Max	0.98	1.61		31	2.70	4.22	16.18	0.11	0.71
	St. dev.	0.12	0.27		4	0.46	0.72	4.07	0.02	0.10
	liver									
	Average	30.39	0.66	0.25	452	7.27	5.22	1.34	0.17	0.89
	Min	13.05	0.22	0.06	180	4.08	1.51	0.59	0.08	0.30
	Max	59.68	1.09	0.65	1073	13.42	13.39	3.20	0.35	1.25
	St. dev.	15.95	0.25	0.16	269	2.62	3.03	0.91	0.07	0.30
	kidney									
	Average	21.65	2.08	2.82	80	4.39	21.63	3.85	0.35	1.11
	Min	10.17	0.75	1.62	58	2.40	7.85	1.44	0.10	0.66
	Max	40.40	10.87	5.10	107	6.95	44.19	12.76	0.85	1.38
	St. dev.	9.98	2.80	1.05	15	1.33	11.18	2.93	0.24	0.26
	gills									
	Average	2.46	1.51	0.04	234	19.42	21.02	80.09	0.23	0.20
	Min	1.19	1.07	0.01	160	7.22	8.61	51.72	<0.05	0.13
	Max	4.41	2.37	0.08	334	35.44	35.48	106.17	0.41	0.33
	St. dev.	0.79	0.40	0.02	47	7.31	8.63	15.02	0.09	0.06
	skeleton									
	Average	1.05	5.26	<0.01	152	37.46	7.52	258.14	0.21	0.09
	Min	0.82	3.74		128	18.48	4.08	205.08	0.11	0.06
	Max	1.30	8.33		182	67.42	9.75	322.56	0.37	0.13
	St. dev.	0.13	1.29		18	13.51	1.73	35.69	0.07	0.02
Perch	muscle									
	Average	0.91	0.90	<0.01	18	0.96	3.94	0.60	0.08	2.86
	Min	0.65	0.46		16	0.66	1.68	0.17	<0.05	2.35
	Max	1.30	1.72	0.02	21	1.40	9.01	2.50	0.11	3.42
	St. dev.	0.22	0.44		2	0.26	2.45	0.71	0.05	0.40
	liver									
	Average	10.97	0.93	0.48	104	4.98	9.95	0.52	0.11	1.65
	Min	5.92	0.34	0.23	83	2.92	2.96	0.26	<0.05	0.26
	Max	23.27	2.41	0.70	129	7.34	16.68	1.19	0.19	2.47
	St. dev.	5.30	0.57	0.17	15	1.37	4.77	0.28	0.05	0.66
	kidney									
	Average	4.18	2.74	0.11	97	1.58	12.35	0.97	0.43	1.01
	Min	3.22	1.17	0.08	77	0.91	5.13	0.25	0.05	0.60
	Max	5.95	4.31	0.16	131	2.07	23.79	2.27	1.13	1.55
	St. dev.	0.86	1.25	0.02	17	0.35	5.59	0.67	0.37	0.32
	gills									
	Average	2.27	2.21	<0.01	78	20.90	22.62	67.39	0.12	0.44
	Min	1.70	1.83		71	10.18	17.23	49.67	0.06	0.29
	Max	3.31	2.70		86	46.76	35.58	87.39	0.29	0.67
	St. dev.	0.44	0.34		6	12.17	6.20	11.85	0.07	0.14
	skeleton									
	Average	1.43	5.38	<0.01	73	29.06	4.42	131.98	0.09	0.23
	Min	0.87	3.96		61	14.80	3.07	106.14	0.06	0.15
	Max	3.83	7.98		87	49.43	5.83	158.24	0.17	0.36
	St. dev.	0.86	1.42		9	11.09	0.99	15.85	0.03	0.07

Continuation (Table 5)

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
Pike		muscle								
	Average	1.56	0.73	<0.01	20	1.47	6.82	2.53	0.20	1.41
	Min	0.82	0.55		15	0.97	5.26	0.67	<0.05	1.11
	Max	2.02	0.89	0.01	25	1.74	9.47	5.00	0.28	1.73
	St. dev.	0.52	0.14		4	0.34	1.83	1.77	0.07	0.23
		liver								
	Average	22.38	0.67	0.05	115	2.63	5.78	0.35	0.12	0.62
	Min	9.31	0.39	0.02	83	1.07	4.41	0.28	<0.05	0.48
	Max	38.21	0.86	0.07	147	3.94	7.70	0.48	0.14	1.01
	St. dev.	13.86	0.19	0.02	30	1.25	1.22	0.08	0.02	0.22
		kidney								
	Average	8.70	1.70	0.35	412	2.77	10.10	1.15	0.16	0.72
	Min	6.02	0.83	0.24	253	2.22	5.15	0.52	<0.05	0.43
	Max	11.89	3.81	0.47	550	3.07	16.68	3.00	0.24	0.90
	St. dev.	2.91	1.23	0.09	117	0.33	4.42	1.05	0.06	0.18
		gills								
	Average	1.97	3.50	0.01	333	15.85	18.97	95.53	0.23	0.25
	Min	1.75	2.66	<0.01	284	13.04	13.98	66.01	0.06	0.19
	Max	2.21	4.52	0.02	373	19.52	29.52	118.99	0.53	0.30
	St. dev.	0.21	0.75	0.01	41	2.42	6.09	21.04	0.20	0.04
		skeleton								
	Average	1.32	6.80	<0.01	141	30.46	3.75	155.19	0.16	0.11
	Min	1.01	5.63		126	24.01	2.61	132.74	0.13	0.09
	Max	1.54	8.87		149	41.82	4.81	187.56	0.18	0.13
	St. dev.	0.21	1.25		10	7.16	0.95	21.83	0.02	0.02

Appendix table 6: Concentrations of heavy metals in fish of the Lake Mellalompola in 2005:

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
SR whitefish	muscle									
	Average	0.72	0.65	0.02	15	0.88	3.19	2.61	0.13	0.53
	Min	0.55	0.41	0.01	11	0.63	1.05	1.09	<0.05	0.44
	Max	0.91	0.95	0.04	19	1.28	7.89	5.14	0.16	0.79
	St. dev.	0.12	0.15	0.01	2	0.26	2.29	1.43	0.03	0.11
	liver									
	Average	22.90	0.81	0.72	110	5.95	4.02	0.47	0.08	1.10
	Min	11.02	0.61	0.23	76	4.37	2.15	0.23	<0.05	0.80
	Max	68.32	1.17	1.33	145	7.48	6.72	0.73	0.17	1.55
	St. dev.	15.98	0.16	0.40	20	0.94	1.42	0.19	0.04	0.26
	kidney									
	Average	8.08	4.37	12.68	153	2.68	13.94	1.53	0.38	1.68
	Min	6.35	2.57	8.44	100	1.91	7.52	1.15	<0.05	1.07
	Max	13.44	10.56	23.71	229	3.38	20.37	1.85	0.68	2.45
	St. dev.	2.01	2.37	4.28	39	0.50	4.50	0.25	0.18	0.43
	gills									
	Average	1.32	1.11	0.46	354	9.47	10.25	56.05	0.11	0.21
	Min	0.84	0.78	0.25	77	6.21	2.10	43.22	<0.05	0.17
	Max	1.78	1.47	1.03	685	14.16	25.79	82.94	0.20	0.26
	St. dev.	0.31	0.19	0.22	201	2.64	7.67	10.77	0.05	0.03
	skeleton									
	Average	0.91	5.25	<0.01	177	18.92	7.97	263.19	0.23	0.10
	Min	0.66	4.41		81	11.43	3.32	210.58	0.15	0.08
	Max	1.24	7.07	0.01	265	34.23	24.34	367.39	0.31	0.15
	St. dev.	0.15	0.72		47	6.39	6.42	45.41	0.06	0.02
Char	muscle									
	Average	1.19	0.71	0.02	15	0.58	3.50	1.27	0.17	0.84
	Min	1.09	0.62	0.01	12	0.51	1.70	0.86	<0.05	0.59
	Max	1.33	0.82	0.03	18	0.73	7.05	1.77	0.52	1.06
	St. dev.	0.11	0.09	0.01	2	0.09	2.29	0.44	0.23	0.18
	liver									
	Average	31.00	1.12	0.73	115	5.96	5.85	0.32	0.11	1.29
	Min	9.79	0.67	0.39	100	4.55	3.03	0.21	<0.05	1.06
	Max	68.29	1.48	1.14	131	9.15	7.92	0.42	0.13	1.53
	St. dev.	25.18	0.34	0.27	15	1.82	2.01	0.08	0.01	0.23
	kidney									
	Average	6.66	2.42	14.09	110	2.31	12.57	0.86	0.34	2.04
	Min	5.55	1.58	5.76	103	1.99	7.69	0.70	0.10	1.61
	Max	7.25	3.38	20.33	117	2.92	20.95	1.17	0.72	2.52
	St. dev.	0.66	0.73	5.35	6	0.37	5.71	0.20	0.24	0.36
	gills									
	Average	1.93	1.30	0.32	78	16.57	23.38	77.00	0.23	0.41
	Min	1.43	1.16	0.18	65	14.34	4.62	67.22	<0.05	0.29
	Max	2.34	1.51	0.51	87	18.48	58.26	83.98	0.42	0.55
	St. dev.	0.37	0.13	0.14	10	1.54	21.69	6.88	0.17	0.12
	skeleton									
	Average	1.25	4.57	<0.01	65	14.00	8.40	134.80	0.22	0.16
	Min	1.01	3.93		51	12.16	4.25	115.88	0.13	0.12
	Max	1.94	5.43		79	16.81	14.47	146.22	0.35	0.19
	St. dev.	0.39	0.64		11	1.72	3.76	11.53	0.09	0.03

Continuation (Table 6)

		Cu	Ni	Cd	Zn	Mn	Al	Sr	Pb	Hg
Trout	muscle									
	Average	1.15	0.69	0.01	18	0.67	1.58	2.17	0.07	1.01
	Min	1.01	0.57	0.01	15	0.51	1.13	1.07	<0.05	0.93
	Max	1.31	0.96	0.02	21	0.86	2.47	3.71	0.07	1.08
	St. dev.	0.15	0.18	0.01	3	0.17	0.63	1.21	0.01	0.07
	liver									
	Average	67.52	0.71	0.48	99	3.74	2.77	0.59	<0.05	1.56
	Min	33.48	0.57	0.24	89	3.03	0.70	0.21		1.51
	Max	122.72	0.85	0.74	115	4.69	5.03	1.13		1.60
	St. dev.	39.29	0.12	0.22	13	0.73	1.82	0.40		0.05
	kidney									
	Average	6.29	1.76	2.04	170	3.05	7.36	0.95	0.13	2.36
	Min	5.76	1.59	1.73	151	2.68	6.04	0.39	0.07	2.21
	Max	7.27	2.04	2.80	198	3.50	8.87	1.51	0.20	2.55
	St. dev.	0.67	0.20	0.51	20	0.34	1.34	0.47	0.06	0.14
	gills									
	Average	1.86	1.14	0.69	392	14.49	10.54	95.70	<0.05	0.43
	Min	1.33	0.99	0.50	334	13.32	2.50	90.03		0.40
	Max	2.91	1.26	0.98	429	16.39	25.14	105.08	0.09	0.50
	St. dev.	0.72	0.14	0.22	40	1.46	10.05	6.90		0.05
	skeleton									
	Average	1.09	3.69	<0.01	226	16.95	5.39	210.02	0.24	0.17
	Min	0.95	3.25		178	14.52	4.00	184.84	0.09	0.15
	Max	1.34	4.40	0.01	265	21.31	8.20	242.32	0.35	0.19
	St. dev.	0.17	0.55		36	2.99	1.94	28.17	0.11	0.02
Pike	muscle									
	Average	0.68	0.57	0.01	18	2.57	1.61	6.46	<0.05	1.37
	Min	0.62	0.48	0.01	16	2.33	1.35	5.49		1.13
	Max	0.75	0.67	0.01	19	2.81	1.86	7.43		1.61
	St. dev.	0.10	0.14	0.00	2	0.34	0.37	1.37		0.34
	liver									
	Average	18.92	0.59	0.37	158	4.40	4.24	0.24	<0.05	0.48
	Min	9.99	0.41	0.12	72	4.25	1.51	0.23		0.42
	Max	27.85	0.77	0.61	244	4.56	6.96	0.25		0.53
	St. dev.	12.63	0.25	0.35	122	0.22	3.85	0.02		0.08
	kidney									
	Average	6.03	1.81	2.07	467	3.75	11.26	0.29	0.13	0.68
	Min	5.13	1.42	1.34	440	3.09	9.12	0.24	0.09	0.54
	Max	6.93	2.19	2.80	494	4.42	13.40	0.33	0.17	0.82
	St. dev.	1.27	0.54	1.04	39	0.94	3.03	0.07	0.05	0.19
	gills									
	Average	1.68	2.85	0.15	357	33.06	5.69	98.14		0.14
	Min	1.29	2.73	0.11	326	32.73	3.41	75.54	<0.05	0.09
	Max	2.07	2.96	0.20	388	33.39	7.97	120.73	0.15	0.19
	St. dev.	0.55	0.16	0.06	44	0.46	3.23	31.95		0.06
	skeleton									
	Average	1.04	7.29		141	51.08	7.35	160.00	0.21	0.07
	Min	1.02	6.36	<0.01	120	50.30	4.90	146.38	0.13	0.06
	Max	1.06	8.22	0.02	162	51.86	9.81	173.62	0.29	0.07
	St. dev.	0.03	1.31		30	1.10	3.47	19.27	0.11	0.005

Appendix table 7: Concentrations of heavy metals in fish of the Lake Otervatn in 2005:

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
Trout	muscle									
	Average	1.33	0.97	0.01	17	0.50	2.62	1.12	<0.05	0.36
	Min	1.04	0.55	0.01	13	0.33	0.45	0.44		0.25
	Max	2.06	2.52	0.02	25	1.03	8.93	2.72	0.06	0.53
	St. dev.	0.29	0.57	0.01	4	0.20	3.04	0.65		0.09
	liver									
	Average	357.82	3.59	1.23	220	4.02	9.75	2.26	0.15	0.37
	Min	133.07	1.97	0.51	50	2.62	1.46	0.74	<0.05	0.19
	Max	928.57	6.19	4.58	320	6.56	64.51	8.42	0.38	0.50
	St. dev.	267.79	1.51	1.24	76	1.22	19.35	2.22	0.15	0.10
	kidney									
	Average	9.99	6.80	1.17	406	1.40	7.65	3.31	0.27	0.40
	Min	4.04	3.18	0.06	228	1.07	2.21	1.96	0.13	0.22
	Max	20.91	15.21	3.00	704	1.98	35.56	5.78	0.95	0.57
	St. dev.	5.36	3.42	0.80	141	0.33	10.05	1.08	0.25	0.13
	gills									
	Average	1.45	1.77	0.22	237	5.31	5.93	87.13	0.22	0.07
	Min	1.01	1.25	0.06	114	3.17	2.41	69.42	0.13	0.03
	Max	1.96	2.52	0.56	357	7.76	17.35	103.48	0.45	0.18
	St. dev.	0.33	0.47	0.15	81	1.61	4.34	12.15	0.11	0.05

Appendix table 8: Concentrations of heavy metals in fish of the Lake Shuonijarvi in 2005:

		Cu	Ni	Cd	Zn	Mn	Al	Sr	Pb	Hg
Char	muscle									
	Average	1.03	1.58	0.01	19	0.86	2.54	2.12	0.07	0.30
	Min	0.83	0.81	0.01	14	0.40	1.27	0.70	<0.05	0.17
	Max	1.20	2.51	0.02	33	2.22	4.15	3.70	0.09	0.65
	St. dev.	0.13	0.65	0.01	5	0.60	0.83	0.93	0.02	0.13
	liver									
	Average	41.69	2.12	1.75	131	6.03	12.03	0.75	0.08	0.33
	Min	6.39	1.64	0.85	81	3.66	5.04	0.37	<0.05	0.22
	Max	98.29	3.48	2.38	190	11.34	17.94	1.40	0.11	0.62
	St. dev.	28.45	0.63	0.54	36	2.19	4.73	0.33	0.02	0.10
	kidney									
	Average	20.53	16.21	28.42	216	5.20	33.39	6.96	0.46	0.78
	Min	11.17	4.21	9.49	98	3.52	14.66	4.83	0.17	0.34
	Max	47.27	28.13	52.67	305	7.16	55.20	8.43	1.27	1.26
	St. dev.	12.80	6.42	13.17	60	1.23	12.25	0.97	0.29	0.27
	gills									
	Average	4.33	4.51	1.12	113	18.59	10.56	100.69	0.27	0.13
	Min	2.82	2.87	0.80	68	5.96	4.05	74.85	0.10	0.10
	Max	7.51	9.79	1.73	144	76.16	31.40	126.17	0.58	0.21
	St. dev.	1.35	2.01	0.28	21	22.19	7.67	14.38	0.15	0.03
	skeleton									
	Average	1.06	3.39	<0.01	67	19.08	7.53	116.81	0.18	0.09
	Min	0.40	2.35		20	4.47	3.98	38.20	0.04	0.02
	Max	1.53	5.25		104	61.80	10.50	157.04	0.37	0.48
	St. dev.	0.33	0.80		31	17.69	1.96	42.06	0.11	0.13
Trout	muscle									
	Average	1.04	0.73	0.01	20	0.68	1.79	1.11	0.13	0.49
	Min	0.56	0.56	<0.01	16	0.48	0.82	0.30	<0.05	0.20
	Max	1.41	1.01	0.01	30	1.05	3.95	2.28	0.19	1.63
	St. dev.	0.24	0.13	0.003	4	0.18	1.05	0.61	0.08	0.42
	liver									
	Average	180.20	1.28	0.55	109	4.15	4.24	0.73	0.08	0.59
	Min	92.12	0.92	0.26	89	3.22	2.18	0.44	<0.05	0.29
	Max	285.03	1.72	0.81	173	6.20	8.54	0.99	0.11	1.03
	St. dev.	68.81	0.26	0.16	24	0.86	2.18	0.22	0.03	0.21
	kidney									
	Average	7.56	4.63	2.16	255	3.16	9.73	3.58	0.14	0.67
	Min	3.92	2.56	1.45	178	1.66	3.20	1.62	<0.05	0.48
	Max	12.16	7.60	3.88	298	4.55	13.68	6.84	0.46	1.14
	St. dev.	2.14	1.39	0.83	37	0.98	3.56	1.45	0.15	0.21
	gills									
	Average	3.25	3.30	0.87	369	12.53	8.31	106.88	0.27	0.14
	Min	2.16	2.25	0.37	286	7.25	3.49	74.49	<0.05	0.09
	Max	5.03	5.47	1.56	535	18.54	30.17	140.60	0.68	0.19
	St. dev.	1.15	0.93	0.40	82	3.54	8.02	20.80	0.22	0.03
	skeleton									
	Average	1.23	3.61	<0.01	276	19.56	6.20	176.04	0.23	0.05
	Min	0.89	2.49		186	11.41	3.63	141.04	0.08	0.02
	Max	1.56	4.47		428	29.88	12.61	245.26	0.45	0.08
	St. dev.	0.23	0.60		70	5.25	2.85	28.51	0.11	0.02

Appendix table 9: Concentrations of heavy metals in fish of the Lake Suovaselkajarvi in 2005:

		Cu	Ni	Cd	Zn	Mn	Al	Sr	Pb	Hg
SR whitefish	muscle									
	Average	0.74	0.48	0.01	15	0.80	3.17	4.46	0.11	1.02
	Min	0.40	0.37	<0.01	10	0.62	1.45	0.71	<0.05	0.69
	Max	1.13	0.61	0.03	19	1.01	5.61	7.03	0.34	1.37
	St. dev.	0.20	0.08	0.01	3	0.13	1.47	1.96	0.09	0.19
	liver									
	Average	37.98	0.62	0.22	116	7.10	5.98	0.51	0.11	1.85
	Min	7.98	0.42	0.08	89	5.02	2.54	0.30	<0.05	0.72
	Max	74.68	0.80	0.41	178	9.70	10.11	0.91	0.18	3.32
	St. dev.	22.95	0.11	0.11	25	1.29	2.05	0.16	0.04	0.82
	kidney									
	Average	7.56	1.44	3.92	146	2.29	9.43	1.23	0.12	1.81
	Min	4.19	0.84	1.92	98	1.44	5.31	0.99	0.05	1.07
	Max	13.98	2.35	6.34	189	3.02	15.95	1.62	0.19	2.68
	St. dev.	2.49	0.42	1.53	29	0.48	3.24	0.21	0.06	0.53
	gills									
	Average	1.52	1.18	0.29	225	3.50	7.08	38.90	0.12	0.49
	Min	1.18	0.90	0.14	103	1.61	1.99	24.67	<0.05	0.33
	Max	1.83	1.76	0.45	341	5.01	18.94	50.70	0.24	0.61
	St. dev.	0.22	0.28	0.11	77	1.00	4.65	7.38	0.07	0.08
	skeleton									
	Average	0.83	4.78	<0.01	124	9.81	5.20	194.62	0.15	0.10
	Min	0.61	3.95		82	6.39	3.66	176.83	0.10	0.05
	Max	1.28	5.86		163	16.10	7.33	228.87	0.36	0.12
	St. dev.	0.21	0.62		25	3.20	1.34	14.67	0.07	0.02
Perch	muscle									
	Average	0.56	0.51	0.01	17	0.56	2.96	0.29	0.07	0.74
	Min	0.50	0.42	<0.01	15	0.44	1.30	0.16	<0.05	0.60
	Max	0.67	0.67	0.01	20	0.71	5.58	0.47	0.09	1.02
	St. dev.	0.06	0.10	0.00	2	0.10	1.38	0.12	0.02	0.14
	liver									
	Average	9.02	0.71	2.01	101	6.54	24.44	0.43	0.13	0.39
	Min	5.28	0.32	1.38	74	3.25	21.41	0.31	0.06	0.20
	Max	11.80	1.22	2.98	148	8.94	35.86	0.61	0.23	0.78
	St. dev.	2.19	0.32	0.48	23	2.19	4.87	0.11	0.05	0.19
	kidney									
	Average	4.53	3.87	0.39	111	1.77	51.25	1.19	0.34	0.35
	Min	3.62	1.75	0.30	88	1.14	18.41	0.74	0.06	0.19
	Max	6.78	9.42	0.63	121	2.26	165.08	2.26	0.72	0.57
	St. dev.	1.16	2.45	0.11	11	0.45	52.63	0.57	0.21	0.13
	gills									
	Average	1.55	2.09	0.05	68	15.02	11.36	53.23	0.35	0.16
	Min	1.26	1.66	0.03	60	11.24	7.11	43.78	0.14	0.12
	Max	1.88	2.77	0.05	95	25.19	20.13	67.81	0.54	0.25
	St. dev.	0.21	0.36	0.01	11	4.47	4.36	8.31	0.12	0.05
	skeleton									
	Average	0.86	4.16	0.02	60	24.86	5.24	117.14	0.21	0.06
	Min	0.61	3.59	<0.01	48	17.73	3.36	105.94	0.14	0.04
	Max	1.07	4.91	0.04	68	30.40	7.13	140.41	0.27	0.09
	St. dev.	0.15	0.37	0.01	6	4.63	1.22	10.31	0.05	0.02

Continuation (Table 9)

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
Pike	muscle									
	Average	0.77	0.50	0.01	14	1.02	4.43	2.35		1.32
	Min	0.71	0.42		13	0.64	2.84	0.82	<0.05	1.30
	Max	0.82	0.58		16	1.40	6.02	3.89	0.07	1.35
	St. dev.	0.08	0.11		2	0.53	2.25	2.17		0.04
	liver									
	Average	30.96	0.60	0.20	124	4.39	8.90	0.35	0.34	0.53
	Min	22.67	0.41	0.19	102	4.14	8.63	0.33	0.28	0.49
	Max	39.25	0.79	0.20	147	4.63	9.17	0.37	0.40	0.58
	St. dev.	11.72	0.27	0.00	32	0.35	0.38	0.03	0.08	0.07
	kidney									
	Average	5.18	1.01	0.89	478	3.14	6.88	0.55	0.08	0.82
	Min	5.18	0.93	0.80	455	3.10	6.21	0.53	0.07	0.71
	Max	5.19	1.09	0.99	501	3.17	7.54	0.56	0.09	0.92
	St. dev.	0.00	0.12	0.13	33	0.05	0.94	0.02	0.01	0.14
	gills									
	Average	1.89	2.50	0.19	421	11.87	10.37	68.59	0.12	0.25
	Min	1.78	2.11	0.18	409	11.42	8.53	60.41	0.10	0.24
	Max	1.99	2.88	0.20	432	12.32	12.20	76.76	0.15	0.26
	St. dev.	0.15	0.54	0.02	17	0.64	2.60	11.56	0.04	0.02
	skeleton									
	Average	1.13	6.28	<0.01	129	23.73	3.61	148.61	0.08	0.06
	Min	1.09	5.77		121	22.86	3.25	142.02	0.07	0.05
	Max	1.18	6.78		136	24.61	3.97	155.21	0.09	0.07
	St. dev.	0.07	0.72		11	1.24	0.51	9.32	0.02	0.02

Appendix table 10: Concentrations of heavy metals in fish of the Lake Virtuovoshjavr in 2005:

		Cu	**Ni**	**Cd**	**Zn**	**Mn**	**Al**	**Sr**	**Pb**	**Hg**
SR whitefish	muscle									
	Average	1.14	0.93	0.01	18	1.15	5.33	4.53	0.10	0.38
	Min	0.81	0.68	<0.01	13	0.68	3.06	1.62	<0.05	0.17
	Max	1.70	1.17	0.02	27	2.62	10.74	6.82	0.25	0.82
	St. dev.	0.31	0.12	0.00	4	0.52	1.95	1.67	0.08	0.15
	liver									
	Average	41.50	1.39	0.41	222	9.04	6.03	0.97	0.13	1.09
	Min	11.00	0.65	0.12	78	3.01	2.86	0.46	<0.05	0.48
	Max	96.52	6.14	0.90	320	17.17	11.18	1.74	0.30	1.98
	St. dev.	24.05	1.45	0.24	71	4.74	2.73	0.39	0.09	0.51
	kidney									
	Average	48.92	6.60	5.33	368	5.31	78.45	6.74	1.50	1.30
	Min	15.00	1.88	2.40	167	2.25	12.66	2.49	0.26	0.53
	Max	165.00	15.00	10.05	548	15.00	364.29	21.43	8.25	2.25
	St. dev.	41.53	4.12	2.28	115	3.71	98.12	5.66	2.18	0.53
	gills									
	Average	2.03	1.97	0.06	379	15.87	12.78	111.43	0.30	0.20
	Min	1.57	1.26	0.02	148	6.52	6.98	58.69	0.08	0.09
	Max	4.40	2.88	0.16	688	54.76	32.66	161.00	1.37	0.38
	St. dev.	0.78	0.50	0.04	161	13.42	6.86	31.28	0.33	0.08
	skeleton									
	Average	1.19	5.55	<0.01	199	19.52	8.88	286.35	0.28	0.07
	Min	0.87	3.71		145	11.72	3.00	218.74	0.11	0.05
	Max	1.79	7.27	0.01	305	41.99	23.32	351.56	0.73	0.13
	St. dev.	0.25	0.80		36	8.25	5.86	34.80	0.20	0.02
Perch	muscle									
	Average	0.69	0.64	0.01	19	0.82	1.83	0.67	<0.05	0.79
	Min	0.54	0.44	<0.01	17	0.58	1.24	0.27		0.32
	Max	1.14	0.83	0.02	25	1.09	2.64	1.31		1.13
	St. dev.	0.17	0.12	0.00	2	0.14	0.48	0.46		0.28
	liver									
	Average	11.99	1.39	1.45	128	7.46	25.13	0.79	0.07	0.62
	Min	8.94	0.90	0.51	104	4.81	14.74	0.47	0.05	0.30
	Max	20.53	1.92	2.09	213	14.76	34.72	1.22	0.13	1.05
	St. dev.	3.44	0.35	0.47	31	2.68	6.29	0.28	0.02	0.27
	kidney									
	Average	10.64	5.37	0.27	102	3.25	23.87	3.55	0.26	0.65
	Min	4.39	2.87	0.07	57	2.57	16.05	2.27	<0.05	0.32
	Max	16.72	8.60	0.75	126	5.00	33.01	5.00	0.81	1.29
	St. dev.	3.60	1.96	0.19	20	0.66	6.97	0.88	0.27	0.32
	gills									
	Average	1.42	3.10	0.01	71	18.65	10.59	112.87	0.09	0.11
	Min	1.06	2.28	<0.01	57	12.38	5.24	85.86	<0.05	0.06
	Max	1.76	4.57	0.03	86	30.40	19.17	143.60	0.15	0.27
	St. dev.	0.25	0.79	0.01	10	6.33	4.44	19.82	0.04	0.06
	skeleton									
	Average	1.11	4.66	0.02	61	24.08	3.59	220.91	0.12	0.06
	Min	0.86	3.69	<0.01	51	18.48	2.58	184.00	<0.05	0.03
	Max	1.37	5.15	0.03	71	34.83	4.38	272.83	0.27	0.12
	St. dev.	0.15	0.44	0.01	6	4.81	0.56	28.40	0.07	0.02

Continuation (Table 10)

		Cu	Ni	Cd	Zn	Mn	Al	Sr	Pb	Hg
Pike	muscle									
	Average	0.72	0.92	0.01	24	1.07	2.25	2.18	<0.05	1.55
	Min	0.64	0.56	<0.01	21	0.90	1.34	0.94		1.35
	Max	0.87	1.50	0.01	30	1.59	3.18	3.43		1.68
	St. dev.	0.09	0.40	0.001	4	0.29	0.75	1.12		0.12
	liver									
	Average	8.95	0.86	0.06	351	2.49	7.26	0.44	0.09	0.50
	Min	6.91	0.56	0.04	319	1.61	3.65	0.28	0.05	0.35
	Max	11.91	1.16	0.10	397	4.26	10.53	0.96	0.17	0.67
	St. dev.	1.97	0.29	0.02	34	1.04	3.41	0.29	0.05	0.15
	kidney									
	Average	12.11	4.56	0.49	778	8.55	14.16	4.40	0.28	0.70
	Min	9.76	2.62	0.24	564	5.65	11.07	1.60	0.08	0.36
	Max	18.59	6.41	0.83	1043	12.18	16.67	8.29	0.43	1.08
	St. dev.	3.69	1.67	0.22	207	2.79	2.01	2.83	0.14	0.29
	gills									
	Average	1.72	4.30	0.03	534	13.05	3.68	150.65	0.14	0.27
	Min	1.41	3.19	<0.01	477	12.03	3.49	121.26	<0.05	0.23
	Max	1.93	5.02	0.05	639	15.29	3.92	192.93	0.23	0.37
	St. dev.	0.20	0.76	0.02	64	1.36	0.19	30.22	0.13	0.06
	skeleton									
	Average	1.31	5.57	<0.01	184	22.45	3.06	225.13	0.10	0.10
	Min	1.02	4.96		159	17.83	2.56	200.74	<0.05	0.08
	Max	1.66	6.28		194	36.91	3.37	286.51	0.12	0.12
	St. dev.	0.25	0.63		14	8.11	0.34	35.47	0.03	0.02