The River Torne International Watershed

TRIWA II Work Report

Fish communities of 15 lakes in River Torne basin: aspects of lake typology and ecological status

Samuli Sairanen
Martti Rask
Finnish Game and Fisheries Research Institute

Stefan Stridsman
Kerstin Holmgren
Swedish Board of Fisheries

2007

Contents

1. Introduction

The River Torne watershed is an international River Basin District according to the EU Water Framework Directive (WFD). The WFD requires cross-border cooperation in areas where waters are common for many countries such as River Torne area. One of the objectives of WFD is to achieve good ecological status for all surface waters by 2015. The assessment of ecological status in rivers and lakes is based on chemical and biological factors (phytoplankton, macrophytes, benthic macroinvertebrates and fish) according to the WFD.

The aim of TRIWA I project (The River Torne International Watershed) was to develop a harmonised Finnish-Swedish typology for lakes and rivers in the River Torne watershed. Another aim was to establish reference conditions for the most common water types of the River Torne watershed. Both above-mentioned aims were achieved in TRIWA I project (Elfvendahl et al. 2006). Developed harmonised typology and reference conditions for lakes were based on water chemistry, phytoplankton and benthic macroinvertebrates, but fish fauna was not included because of the lack of resources.

This work is a part of TRIWA II project, in which one aim is to complement the reference conditions with some new biological elements: periphyton (in rivers) and fish (in lakes). Another important aim is to evaluate the usefulness of chosen biological factors for evaluating the ecological status of the aquatic environment in the North.

The aim of this work was to test the developed harmonised preliminary and revised TRIWA lake typologies using fish community data from the reference lakes. Another aim was to evaluate the ecological status of the lakes using both Finnish and Swedish typologies and ecological quality ratios (EQR's). Aim was also to make comparisons between the preliminary and revised TRIWA typologies and national evaluations of ecological status of the reference lakes. Final aim was to evaluate the usefulness of fish community data for evaluating the ecological status of the aquatic environment in the North.

2. Survey lakes and typology

2.1 Finnish and Swedish typologies

The Finnish typology for lakes has a total of 12 lake types. Lakes are divided into different types by mean depth, lake area and water colour. Typology contains three size-classes (<5 km^2, 5-40 km^2 and >40 km^2) and three colour-classes (<30 mg Pt/l, 30-90 mg Pt/l and >90 mg Pt/l). Lakes are considered shallow if the mean depth is below three meters. Also lakes that have short retention time, are naturally nutrient rich or are located in the highland areas of Lapland are separate lake types.

The main difference in Swedish typology compared to Finnish typology is the ecoregion approach. The Swedish typology has a total of seven ecoregions and 16 lake types in each of them (Naturvårdsverket 2006). Lakes are divided into different types by maximum depth, lake area, water colour and alkalinity. Typology contains two depth-classes (<5 m and >5 m), two size-classes (<10 km^2 and >10 km^2), two colour-classes (<50 mg Pt/l, and >50 mg Pt/l) and two alkalinity-classes (<1,0 mekv alk and >1,0 mekv alk). This results in 48 possible lake types for the River Torne area.

2.2 Preliminary TRIWA typology

The preliminary harmonised TRIWA typology for lakes has a total of 13 lake types. Lakes are divided into different types by ecoregion, lake area and water colour. Preliminary typology contains three groups for ecoregion (mountain, inland and coastal lakes), three size-classes (0,5-2 km^2, 2-10 km^2 and >10 km^2) and two colour-classes (<60 mg Pt/l and >60 mg Pt/l). The lakes that included in the fish community survey were mainly the same as in TRIWA I project where the water chemistry, phytoplankton and benthic macroinvertebrates of the selected lakes were studied excluding mountain lakes (type 1). The requirements for potential reference lakes were limited anthropogenic impact, good water quality and moderately easy accessibility by car. According to the preliminary harmonised TRIWA typology the selected lakes represent 3 lake types from the coastal and inland regions (Table 1). The lake types were small clear-water inland lakes (type 2), small brown-water inland lakes (type 3) and small brown-water coastal lakes (type 9). Lake Nuuksujärvi was not included in the typologies because there were no water chemistry data available.

2.3 Revised TRIWA typology

The results of the earlier survey (Elfvendahl et al. 2006) showed that biological elements did not support the ecoregion based grouping of the preliminary harmonised typology. This led to the revised harmonised typology where inland and coastal lake types were combined to southern lowland lake types. The revised harmonised typology for lakes has a total of 7 lake types. Revised typology contains two groups for ecoregion (northern highland and southern lowland lakes), three size-classes (0,5-2 km^2, 2-10 km^2 and >10 km^2) and two colour-classes (<60 mg Pt/l and >60 mg Pt/l). According to the revised harmonised TRIWA typology the selected lakes represent 2 lake types from the southern lowland region (Table 2). The lake types were small clear-water lowland lakes (type 2) and small brown-water lowland lakes (type 3).

Table 1. Characteristics of the surveyed lakes by preliminary TRIWA lake types. Water quality parameters represent the seasonal means of surface water from 2004.

LAKE	ALTITUDE (m.a.s.l)	AREA (ha)	MAX DEPTH (m)	pH	COLOUR (mg Pt/l)	P-tot (µg/l)	N-tot (µg/l)
Type 2							
Isolompolo (Fi)	233	54,4	2,0	6,95	50	12	284
Keimiöjärvi (Fi)	333	60,8	7,8	6,97	38	14	232
Olosjärvi (Fi)	242	191,8	13,7	6,98	42	13	298
Suolajärvi (Swe)	316	70,6	8,0	7,18	20	17	314
Valkeajärvi (Swe)	315	62,0	11,0	7,22	13	6	255
Type 3							
Kitkiöjärvi (Swe)	255	156,3	15,0	6,72	67	13	278
Nivunkijärvi (Fi)	298	144,2	2,0	6,90	63	14	338
Nulusjärvi (Fi)	231	81,6	2,0	6,95	77	16	350
Oustajärvi (Fi)	235	53,0	2,0	6,66	105	15	380
Pääjärvi (Swe)	189	92,0	3,9	6,89	67	33	638
Type 9							
Liehittäjäjärvi (Swe)	132	107,6	6,3	6,74	101	16	370
Merijärvi (Fi)	85	113,8	5,8	6,91	115	21	472
Pirttijärvi (Swe)	141	142,4	6,2	6,73	133	24	514
Puolamajärvi (Fi)	91	164,2	8,8	7,11	44	11	282

Table 2. Characteristics of the surveyed lakes by revised TRIWA lake types. Water quality parameters represent the seasonal means of surface water from 2004.

LAKE	ALTITUDE (m.a.s.l)	AREA (ha)	MAX DEPTH (m)	pH	COLOUR (mg Pt/l)	P-tot (µg/l)	N-tot (µg/l)
Type 2							
Isolompolo (Fi)	233	54,4	2,0	6,95	50	12	284
Keimiöjärvi (Fi)	333	60,8	7,8	6,97	38	14	232
Olosjärvi (Fi)	242	191,8	13,7	6,98	42	13	298
Puolamajärvi (Fi)	91	164,2	8,8	7,11	44	11	282
Suolajärvi (Swe)	316	70,6	8,0	7,18	20	17	314
Valkeajärvi (Swe)	315	62,0	11,0	7,22	13	6	255
Type 3							
Kitkiöjärvi (Swe)	255	156,3	15,0	6,72	67	13	278
Liehittäjäjärvi (Swe)	132	107,6	6,3	6,74	101	16	370
Merijärvi (Fi)	85	113,8	5,8	6,91	115	21	472
Nivunkijärvi (Fi)	298	144,2	2,0	6,90	63	14	338
Nulusjärvi (Fi)	231	81,6	2,0	6,95	77	16	350
Oustajärvi (Fi)	235	53,0	2,0	6,66	105	15	380
Pirttijärvi (Swe)	141	142,4	6,2	6,73	133	24	514
Pääjärvi (Swe)	189	92,0	3,9	6,89	67	33	638

3. Material and methods

3.1 Sampling and analysis

Test fishing

The test fishing of the small clear-water (type 2) and brown-water (type 3) lowland lakes was carried out separately in Finland and Sweden. In Finland the fishing was carried out by the Finnish Game and Fisheries Research Institute from august to September 2006. In Sweden the fishing was carried out by the Swedish Board of Fisheries in august 2005 and 2006. NORDIC multimesh survey nets 1,5 x 30 m (Appelberg et al. 1995) were used in the test fishing. NORDIC nets consist of 12 panels (2,5 m each) having mesh sizes 5, 6.25, 8, 10, 12.5, 15.5, 19.5, 24, 29, 35, 43 and 55 mm (Fig. 1). Test fishing was carried out using a stratified random sampling method (Kurkilahti 1999). The survey lakes were divided into depth zones from which the net sites were chosen randomly. Main differences between the national test fishing methods were different boundaries of the depth zones and the use of pelagic nets in Finland. In Finland the lakes were divided into two depth zones, which were 0-3 m and 3-10 m. In the shallowest zone only benthic nets were used whereas in a depth zone 3-10 m pelagic nets were also used. In Sweden the lakes were divided into three depth zones (0-3 m, 3-6 m and >6 m) and only benthic nets were used. In Finland the sampling effort ranged from 12 to 24 net nights and in Sweden from 16 to 24 net nights according to lake area and depth (Table 3 and 4). The nets were set in the evening and they were hauled in the next morning. Every lake in Finland was sampled twice on two non-consecutive dates, when possible, whereas lakes in Sweden were sampled once.

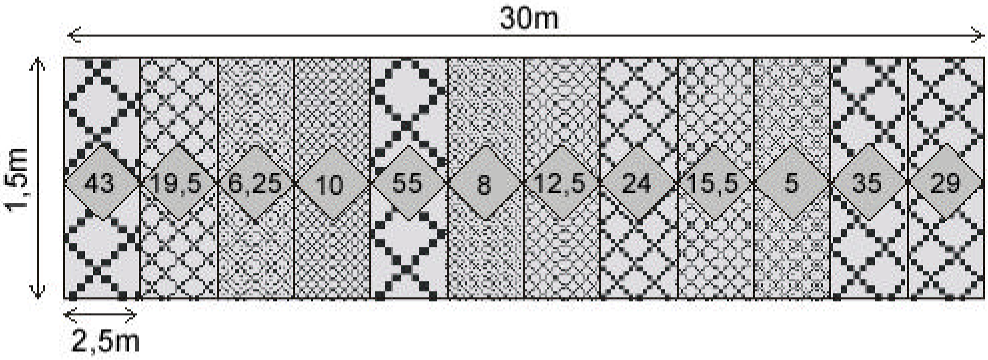


Fig. 1. The construction of the NORDIC multimesh survey net.

Table 3. Survey lakes in Finland 2006 and fishing effort/depth zone according to area and depth.

LAKE	AREA (ha)	MAX DEPTH (m)	NUMBER OF NET NIGHTS/DEPTH ZONE			
			0-3 m	3-10 m		
			Benthic	Pelagic	Benthic	Total
Isolompolo	54,4	2	12	-	-	12
Keimiöjärvi	60,8	7,8	8	4	4	16
Merijärvi	113,8	5,8	8	6	6	20
Nivunkijärvi	144,2	2	16	-	-	16
Nulusjärvi	81,6	2	12	-	-	12
Olosjärvi	191,8	13,7	8	8	8	24
Oustajärvi	53,0	2	12	-	-	12
Puolamajärvi	164,2	8,8	8	8	8	24

Table 4. Survey lakes in Sweden 2005 and 2006, and fishing effort/depth zone according to area and depth.

LAKE	AREA (ha)	MAX DEPTH (m)	NUMBER OF NET NIGHTS/DEPTH ZONE 0-3 m Benthic	3-6 m Benthic	>6 m Benthic	Total
Kitkiöjärvi	156,3	15	8	8	8	24
Liehittäjäjärvi	107,6	6,3	12	10	2	24
Nuuksujärvi	114	8	8	8	-	16
Pirttijärvi	142,4	6,2	20	4	-	24
Pääjärvi	92	3,9	13	3	-	16
Suolajärvi	70,6	8	8	8	8	24
Valkeajärvi	62	11	8	9	7	24

The catch of each net was handled separately and by mesh size. Each catch was sorted by species and then counted and weighed. Total catches, catches of species groups and catches of each fish species were calculated as catch per unit effort (CPUE, g/net and CPUE, number/net). For size distributions, the total length of every fish was measured at 1 cm accuracy. In Finland also the total number and weight of potentially piscivorous perch (*Perca fluviatilis*) (>15 cm) was calculated separately for predatory fishes proportion.

Age determination

Age determinations of perch were made from opercular bones (topmost bone of the gill cover) using stereomicroscope. The age determinations were made at least from 50 individuals per each lake. The radius of opercula and the distance of each annual ring from the stem of opercula was measured. Back calculation of perch growth was done according to formula of Monastyrsky (Bagenal & Tesch 1978): $L_i = (S_i/S)^b L$, where L_i = length at age i, S_i = distance of annual ring from the stem of opercula at age i, S = radius of opercula, L = total length and b = constant. Constant b value of 0,88 (Raitaniemi et al. 1988) was used. Age determinations were also carried out separately in Finland and Sweden, which caused some problems. There seemed to occur a systematic error in the age determinations of perch from Lake Liehittäjänjärvi, Lake Pirttijärvi and Lake Pääjärvi. The first annual ring was apparently not found and that was taken into account in the results. Age determination and back calculation of growth of whitefish (*Coregonus lavaretus*) from Lake Valkeajärvi (n = 52) were made from scales.

Comparison of typologies

The comparisons between the lake types were done using same fish community variables as in evaluation of ecological status. They were total CPUE's, Simpson's diversity indexes, biomass proportion of cyprinids in the catch, perch/cyprinids biomass ratio, mean weight of fishes, the biomass proportion of potentially predatory percids, number of species and number of sensitive species. Only benthic nets were noticed in calculations. Only cyprinid species that benefit from eutrophication were included in cyprinids proportion variable. These were roach (*Rutilus rutilus*), bleak (*Alburnus alburnus*) and bream (*Abramis brama*). The sensitive species, that indicate conditions of the hypolimnion, benthic quality and conditions of the littoral zone (mainly stony shores), were vendace (*Coregonus albula*), whitefish, brown trout (*Salmo trutta*), burbot (*Lota lota*), bullhead (*Cottus gobio*) and minnow (*Phoxinus phoxinus*). Means and standard deviations were calculated for each variable separately by lake type. Lake Nuuksujärvi was not included in the typologies because there were no water chemistry data available.

Evaluating the ecological status

Ecological quality ratio (EQR) describes the similarity or difference of biological quality elements from reference conditions. Ecological quality ratio can be measured for a single variable or index that constitutes from several variables. The EQR is calculated by dividing the observed value with reference value. The status class can be considered high if the observed value is equal to the reference value.

The ecological status of the reference lakes was evaluated using national ecological quality ratios, which constitutes from several variables. The Finnish EQR4 (Tammi et al. 2006) is based on variables that are sensitive to eutrophication. They were total CPUE's (g/net and number/net), the biomass proportion of cyprinids and indicator species. If no cyprinid fishes were present in a lake then cyprinids proportion variable was not used. Both benthic and pelagic nets were noticed in calculations but EQR values were also calculated separately for benthic nets. First the reference lakes were divided into different lake types according to Finnish national typology. Then the EQR values for each variable from every lake were calculated by dividing the observed values with type specific reference values. EQR values were transformed to the scale 0-1 by multiplying EQR values with a constant. Finally the EQR values of each variable were combined to EQR4 by calculating average from their EQR's. In Finnish EQR4 the class boundaries between the ecological classes are set to equal distances (Table 5).

The Swedish EQR8 (Holmgren et al. 2007) is based on eight different variables. They were the number of species, Simpson's diversity indexes for both number and biomass, total CPUE's (g/net and number/net), mean weight of fishes, the biomass proportion of potentially predatory percids and perch/cyprinids biomass ratio. If no cyprinid fishes were present in a lake then perch/cyprinids biomass ratio variable was not used. Likewise if perch was not present in a lake then predatory percids variable was not used. Only benthic nets were noticed in calculations. The lake-specific reference value for each variable was calculated using equations including one to four environmental factors (altitude, lake area, maximum depth, annual mean in air temperature, and/or location below or above the highest coast line after deglaciation). Intercepts and regression coefficients in the equations were revealed by using data from 116 non-limed lakes with low values in acidity (pH > 6), nutrients (total phosphorous < 20 µg/l) and land use (agriculture < 25 % and built-up area < 1 % of the catchment). The residuals for each variable from every lake were calculated by subtracting reference value from observed value. Next the Z-values were calculated by dividing residuals with variable specific standard deviations (SD). Then the Z-values were transformed to P-values by scaling Z-values to scale 0-1. Finally the P-values of each variable were combined to EQR8 by calculating the average of P-values. The EQR8 class boundaries between the ecological classes are also presented in table 5.

Table 5. The boundaries of ecological status classes according to national EQR's.

EQR4	Status class	EQR8
1,0-0,8	High	1,0-0,72
0,8-0,6	Good	0,72-0,46
0,6-0,4	Moderate	0,46-0,30
0,4-0,2	Poor	0,30-0,15
<0,2	Bad	<0,15

3.2 Statistical methods

The differences in the most important fish community variables between the preliminary lake types (2,3 and 9) were tested with one-way Analysis of Variance (ANOVA). In the case of statistically significant difference ($p < 0.05$) the pair-wise differences were tested using Tukey's test. The differences in fish community variables between the revised lake types (2 and 3) were tested using T-test. In the case of few fish community variables their dependence on the environmental factors was tested using stepwise regression model. All statistical analyses were carried out using the SYSTAT v10.2 software.

4. Fish community structure in the surveyed lakes

4.1 Total CPUE's

The total CPUE's in biomass varied between 751 to 5824 g/net in the surveyed lakes (Fig. 2). Respectively, the total CPUE's in numbers varied between 18 to 236 ind./net. In both cases the highest catches were caught from Lake Nuuksujärvi whereas the lowest biomass catch were caught from Lake Nivunkijärvi and the lowest number catch from Lake Valkeajärvi respectively. There was also a positive correlation between the total CPUE's and lake productivity (Fig. 3). The total CPUE's in biomass and numbers seemed to increase along the total phosphorus gradient. However, that was mainly due to high CPUE's in Lake Nuuksujärvi, which also had the highest total phosphorus concentration. On the other hand in lakes Isolompolo and Keimiöjärvi especially the total CPUE's in biomass were quite high in respect to their low total phosphorus concentration and apparently low trophic status.

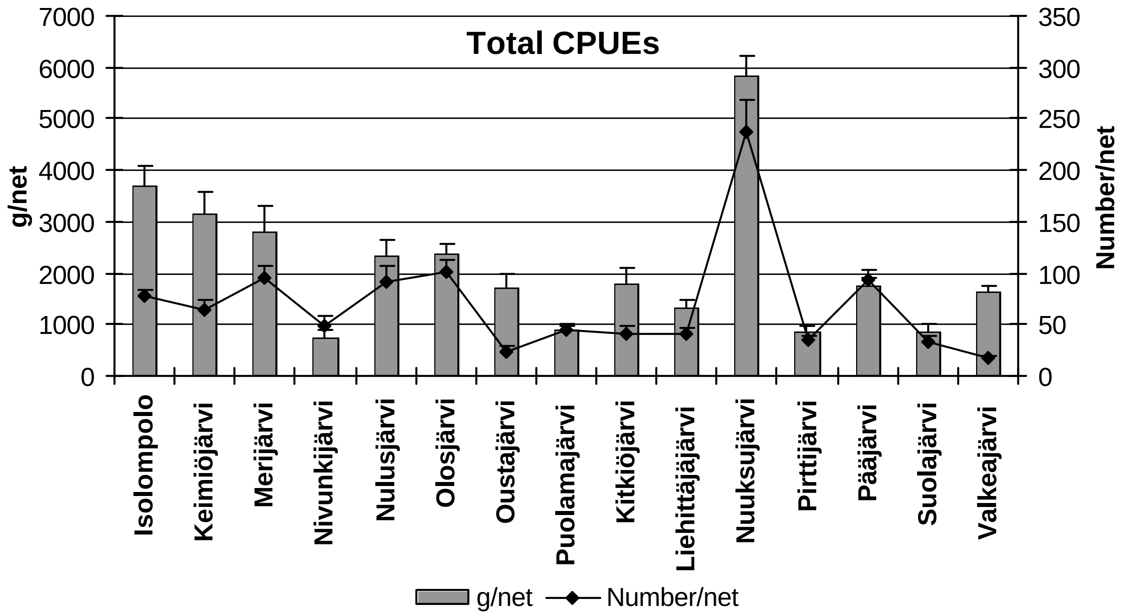


Fig. 2. The total CPUE's in surveyed lakes 2005-2006 and standard errors (s.e).

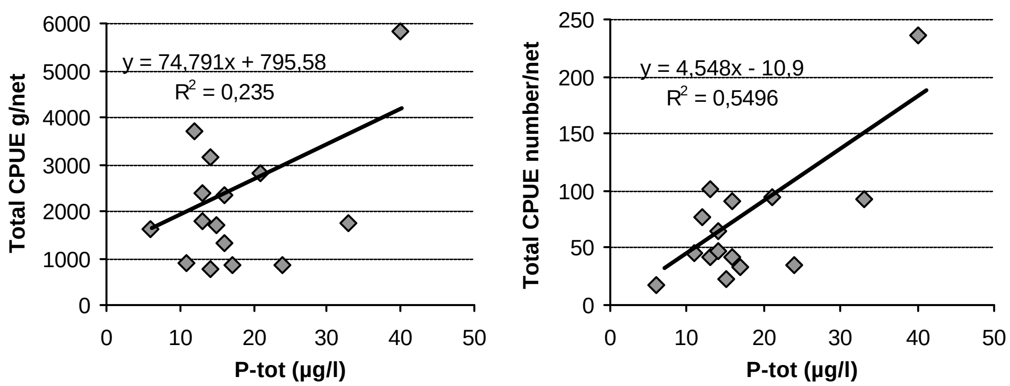


Fig. 3. Correlations between the total CPUE's and lake productivity of the surveyed lakes.

4.2 CPUE's of fish species

Based on test fishing results the species number varied between 1 and 8 in the surveyed lakes (Table 6 and 7). Perch was the most common fish species in the surveyed lakes missing only from Lake Valkeajärvi. Pike (*Esox lucius*) and roach were both present in 11 lakes and ruffe (*Gymnocephalus cernuus*) was present in 8 lakes. Other fish species were not as common as those above-mentioned. According to CPUE's perch and roach were the dominant fish species in biomass catch and number catch. Only clear exception was Lake Valkeajärvi where whitefish was the dominant fish species. The test fishing results are not totally comparable because the national test fishing practices differed from each other. In the case of lakes Keimiöjärvi, Merijärvi, Olosjärvi and Puolamajärvi the total CPUE's would have been generally higher if pelagic nets were not used (Table 8). But because the variation of CPUE's is large the significance of such differences remained minor. Also the biomass proportion of cyprinids in the catches would remain 2 to 5 percent units smaller if only benthic nets were noticed. In the case of lakes Merijärvi and Olosjärvi the CPUE's of pelagic species such as vendace and bleak would remain 25 to 92 % smaller if pelagic nets were not used. However, the influence of using pelagic nets to overall results remained quite small because the proportion of vendace and bleak in the total catches were initially small.

Table 6. The CPUE's (g/net) according to fish species in surveyed lakes 2005-2006.

	CPUE (g/net) OF FISH SPECIES														
LAKE	PERCH	RUFFE	PIKE	VENDACE	WHITEFISH	TROUT	BURBOT	BULLHEAD	MINNOW	DACE	IDE	ROACH	BLEAK	BREAM	**TOTAL**
Isolompolo	1482,7	2,6	614,3		59,5				0,1			1529,9	15,5		3704,6
Keimiöjärvi	3132,6					17,9	2,7								3153,2
Merijärvi	1546,0	3,8	213,5									301,2	18,0	736,7	2819,1
Nivunkijärvi	750,9														750,9
Nulusjärvi	545,0	6,9	33,2	4,5	5,0					161,2		1480,4	84,4		2320,6
Olosjärvi	746,6	2,4	118,8	10,5	5,8				0,3			1386,0	92,0		2362,3
Oustajärvi	1621,3		74,3												1695,6
Puolamajärvi	268,4	13,8			19,7							595,9			897,8
Kitkiöjärvi	1358,3		60,1	14,2								370,9			1803,5
Liehittäjäjärvi	865,7	2,7	137,1									316,1			1321,6
Nuuksujärvi	2172,9		409,0									3242,0			5823,9
Pirttijärvi	553,7	6,7	68,6									205,8	34,1		868,9
Pääjärvi	575,6		84,4									1093,6			1753,6
Suolajärvi	428,3	87,6	62,5		178,1						11,2	73,4			841,0
Valkeajärvi					1562,6		37,9	0,7	35,5						1636,7

Table 7. The CPUE's (number/net) according to fish species in surveyed lakes 2005-2006.

	CPUE (number/net) OF FISH SPECIES														
LAKE	PERCH	RUFFE	PIKE	VENDACE	WHITEFISH	TROUT	BURBOT	BULLHEAD	MINNOW	DACE	IDE	ROACH	BLEAK	BREAM	**TOTAL**
Isolompolo	11,1	0,3	0,7		0,3				0,1			63,3	1,4		77,2
Keimiöjärvi	64,3					0,1	0,1								64,5
Merijärvi	72,6	1,3	0,1									15,0	0,9	5,2	94,9
Nivunkijärvi	48,1														48,1
Nulusjärvi	31,4	2,2	0,1	0,4	0,1					2,8		43,2	10,6		90,8
Olosjärvi	12,7	0,5	0,1	1,5	0,2				0,3			73,7	12,2		101,2
Oustajärvi	22,1		0,3												22,4
Puolamajärvi	11,9	1,2			0,0							32,5			45,7
Kitkiöjärvi	26,8		0,1	1,3								13,0			41,2
Liehittäjäjärvi	29,8	1,0	0,3									10,2			41,3
Nuuksujärvi	106,2		0,4									129,7			236,3
Pirttijärvi	19,2	1,8	0,1									11,3	1,8		34,2
Pääjärvi	22,9		0,1									70,6			93,5
Suolajärvi	18,8	11,3	0,0		0,8						0,1	1,8			32,9
Valkeajärvi					8,8		0,5	0,1	8,3						17,6

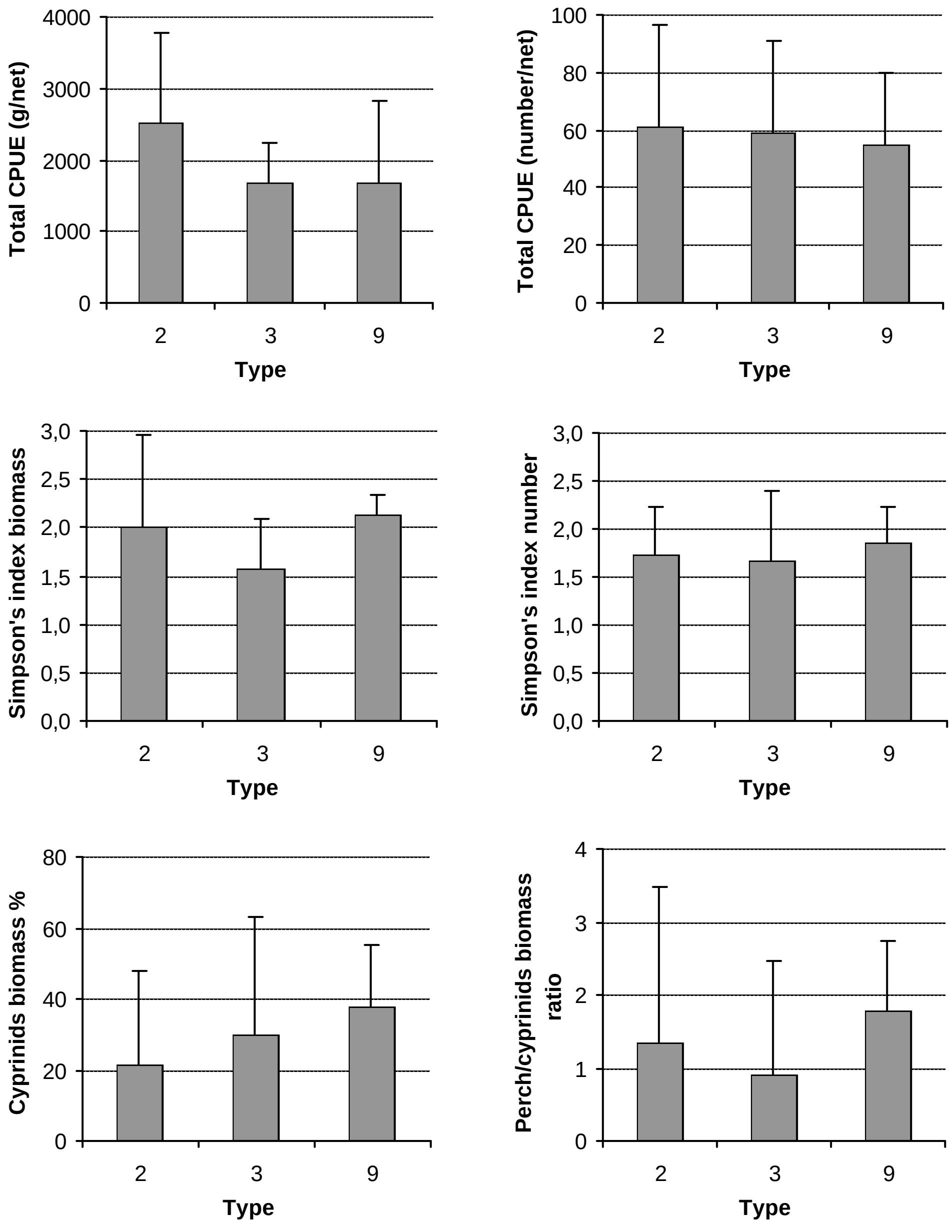
Table 8. Influence of using pelagic nets to most important fish community variables.

Lake	**Total CPUE (g/net)**	**Total CPUE (number/net)**	**Mean weight (g)**	**Cyprinids biomass %**	**Number of species**	**Number of sensitive species**
Keimiöjärvi						
all nets	3153,2	64,5	48,9	-	3	2
benthic nets	3690,1	75,5	48,9	-	3	2
Merijärvi						
all nets	2819,1	94,9	29,7	37,5	6	-
benthic nets	3385,9	90,4	37,4	35,6	6	-
Olosjärvi						
all nets	2362,3	101,2	23,4	62,6	8	3
benthic nets	2675,4	103,1	25,9	57,7	8	3
Puolamajärvi						
all nets	897,8	45,7	19,7	66,4	4	1
benthic nets	1094,3	53,1	20,6	63,1	3	0

5. Comparison of TRIWA typologies using fish community variables

5.1 Testing the preliminary TRIWA typology

Comparison of the preliminary lake types 2, 3 and 9 was done with compiled data using the most important fish community variables. Total CPUE's in biomass were higher in the small clear-water inland lakes (type 2) than in the small brown-water inland (type 3) and coastal lakes (type 9) (Fig. 4). Also the mean weight of fishes in the catch and the number of species was highest in the type 2 lakes, whereas the biomass proportion of cyprinids was highest in the small brown-water coastal lakes. However, the observed differences were not statistically significant due to high variation within the lake types. The only fish community variable that expressed clear between-type differences was the number of sensitive species. The number of sensitive species was highest in the type 2 lakes, which differed statistically from the other lake types.



CONTINUE

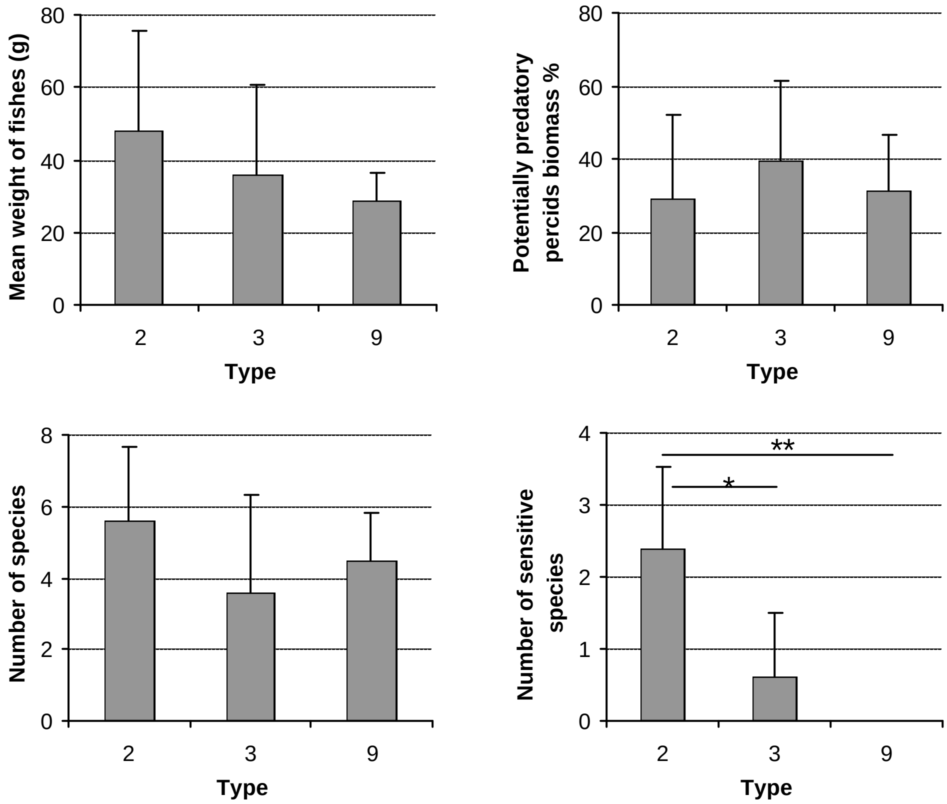
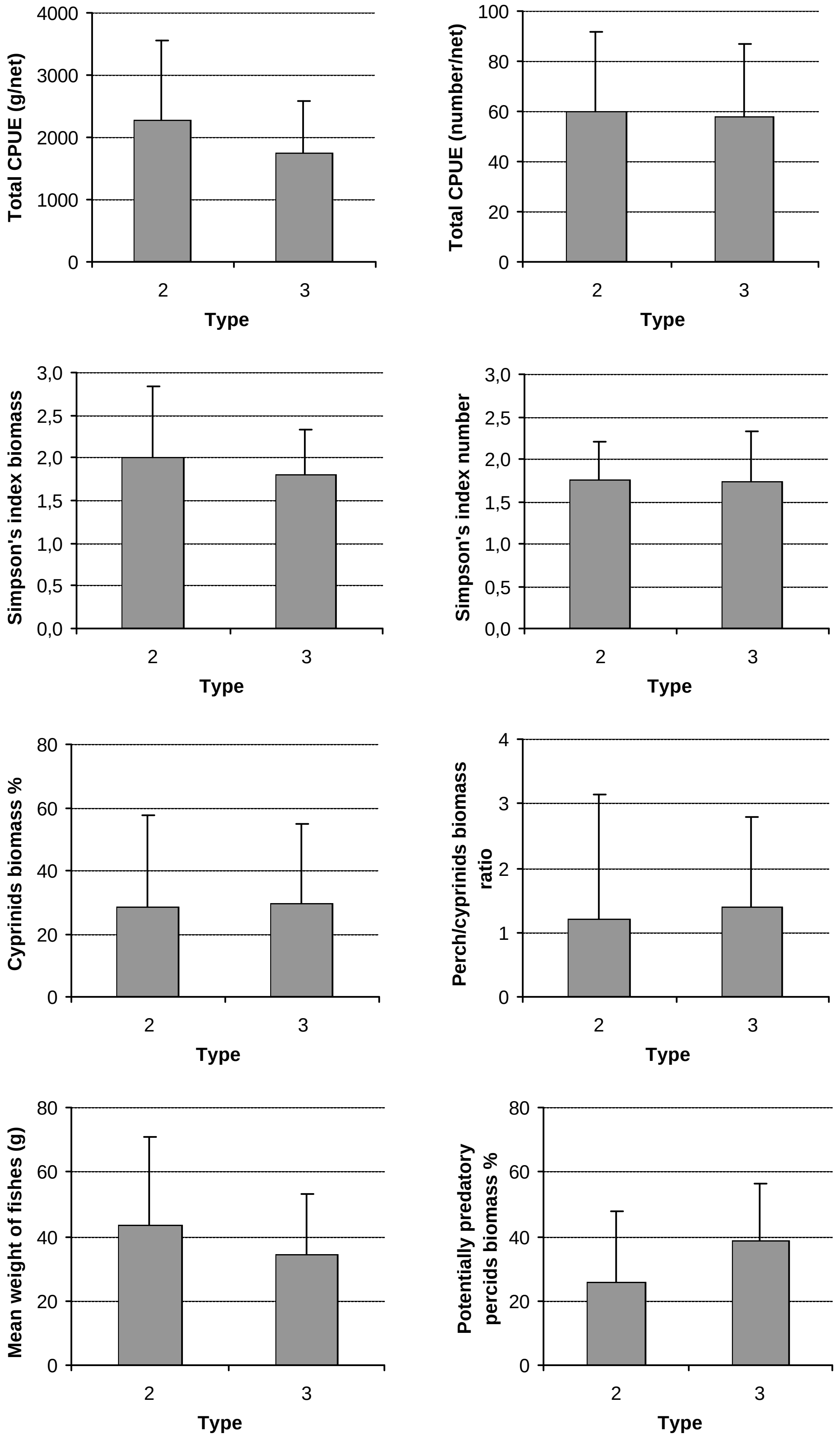


Fig. 4. The means and standard deviations (SD) of the most important fish community variables of the surveyed preliminary lake types. Statistically significant differences between the types are marked with lines and asterisks (ANOVA, * = $p<0.05$, ** = $p<0.01$), type 2: n = 5, type 3: n= 5, type 9: n = 4.

5.2 Testing the revised TRIWA typology

Comparison of the revised lake types 2 and 3 was done with compiled data using same variables as in the case of preliminary lake types. Total CPUE's in biomass were higher in the small clear-water lakes (type 2) than in the small brown-water lakes (type 3) (Fig. 5). Also the mean weight of fishes in the catch and the number of species was higher in the small clear-water lakes than in the small brown-water lakes. The biomass proportion of potentially predatory percids was higher in the small brown-water lakes. However, the observed differences were not statistically significant due to high variation within the lake types. No differences between the lake types were found in the total CPUE's in number, Simpson's indexes, biomass proportion of cyprinids or perch/cyprinids biomass ratio. The only fish community variable that expressed clear between-type differences was the number of sensitive species as in the case of preliminary lake types. The number of sensitive species was higher in the small clear-water lakes than in the small brown-water lakes and the difference was statistically significant.


Total CPUE (g/net)
4000
3000
2000
1000
0
2
3
Type
Total CPUE (number/net)
100
80
60
40
20
0
2
3
Type
Simpson's index biomass
3,0
2,5
2,0
1,5
1,0
0,5
0,0
2
3
Type
Simpson's index number
3,0
2,5
2,0
1,5
1,0
0,5
0,0
2
3
Type
Cyprinids biomass %
80
60
40
20
0
2
3
Type
Perch/cyprinids biomass ratio
4
3
2
1
0
2
3
Type
Mean weight of fishes (g)
80
60
40
20
0
2
3
Type
Potentially predatory percids biomass %
80
60
40
20
0
2
3
Type

CONTINUE

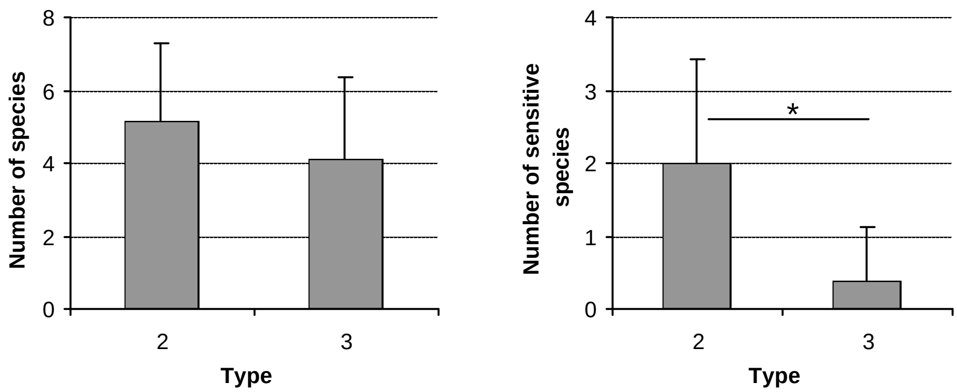


Fig. 5. The means and standard deviations (SD) of the most important fish community variables of the surveyed revised lake types. Statistically significant differences between the types are marked with lines and asterisks (T-test, * = p<0.05), type 2: n = 6, type 3: n = 8.

5.3 Comparison of preliminary and revised TRIWA typologies

The testing results of preliminary and revised TRIWA typologies were quite similar. No statistically significant differences between lake types were found in total CPUE's, Simpson's indexes, biomass proportions, mean weight or number of species. In both typologies the number of sensitive species was the only fish community variable that expressed clear between-type differences.

No clear differences in preliminary typology were found between inland and coastal region lakes fish communities. In that sense the fish fauna results support the earlier results (Elfvendahl et al. 2006) of the other biological factors (benthic macroinvertebrates and phytoplankton). The observed differences in the number of sensitive species were depending on water colour. Ecoregion did not affect the number of sensitive species. Therefore revised typology where the lake types of inland and costal regions are combined seems justified. On the other hand, the number of sensitive species was also dependent on lake productivity, altitude and maximum depth (Fig. 6). Water colour, lake productivity, altitude and maximum depth together explained 63 % of the variation in the number of sensitive species (r^2 = 0.629, p = 0.044), but most of the variation was explained by water colour and lake productivity (r^2 = 0.606, p = 0.006). The small clear-water lakes (type 2) were on the average more oligotrophic, deeper and were situated higher above the see level than small brown-water lakes. These lake characteristics explain the number of sensitive species perhaps better than just water colour.

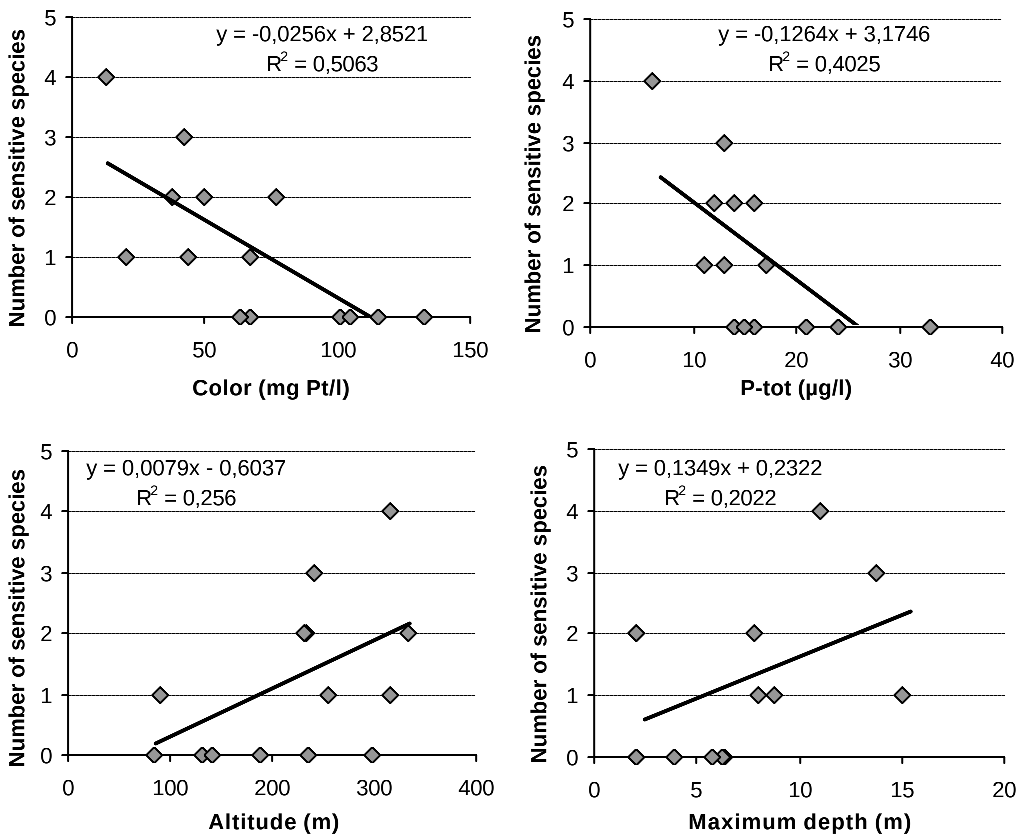


Fig. 6. Correlations between the number of sensitive species and water colour, lake productivity, altitude and depth of the surveyed lakes.

6. Fish community based ecological status of the survey lakes

6.1 Finnish EQR4

According to Finnish EQR4 the fish community based ecological status of the surveyed lakes was generally good or high (Fig. 7). The ecological status was moderate only in Lake Merijärvi and Lake Nivunkijärvi where the EQR4 values were lower than 0,6, which is the borderline between good and moderate conditions. In the case of Lake Merijärvi that was due to high total CPUE's (g/net and number/net) (Table 9). In the case of Lake Nivunkijärvi that was due to lack of indicator species. According to Finnish EQR4 the ecological status of lakes Puolamajärvi, Liehittäjäjärvi, Pirttijärvi and Suolajärvi was high. If only benthic nets were noticed the ecological status of lake Olosjärvi would change from good to high and lake Puolamajärvi from high to good. In the case of Lake Valkeajärvi the too high biomass catch of whitefish lead only to good overall ecological status. But according to Olin M. (personal comment) Lake Valkeajärvi should also be considered in the highest class. Thus the fish community based EQR4 results suggest that almost all the surveyed lakes are representing reference conditions, except lakes Merijärvi and Nivunkijärvi.

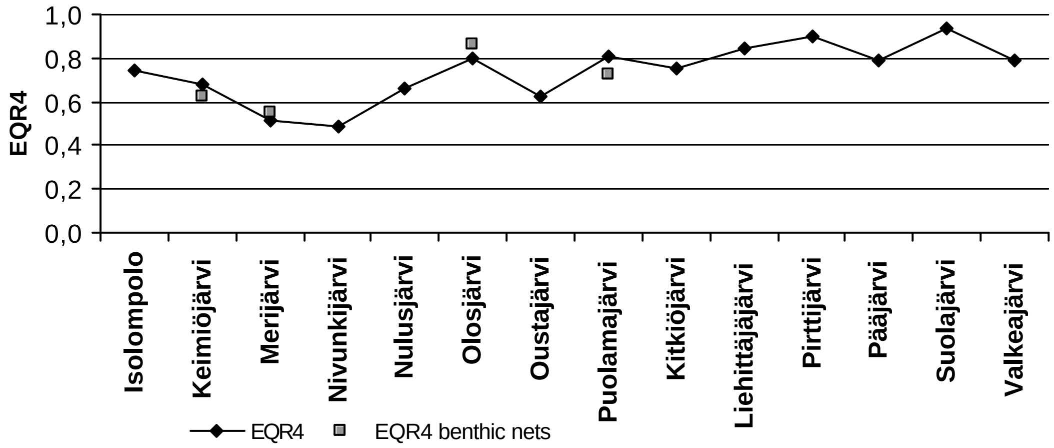


Fig. 7. The Finnish EQR4 values of the surveyed lakes. The borderline between good and moderate ecological status is 0,6.

Table 9. Ecological status of surveyed lakes according to Finnish EQR4.

Lake	Status class				
	CPUE biomass	CPUE number	Cyprinids % biomass	Indicator species	EQR4
Isolompolo	Bad	High	High	High	Good
Keimiöjärvi	Poor	High		Good	Good
Merijärvi	Poor	Poor	High	Moderate	Moderate
Nivunkijärvi	Good	Good		Bad	Moderate
Nulusjärvi	Good	Good	Moderate	High	Good
Olosjärvi	Good	Good	High	High	Good
Oustajärvi	Good	Good		Good	Good
Puolamajärvi	High	High	Moderate	High	High
Kitkiöjärvi	Moderate	High	High	Good	Good
Liehittäjäjärvi	High	High	High	Good	High
Pirttijärvi	High	High	High	Good	High
Pääjärvi	High	Good	High	Good	Good
Suolajärvi	High	High	High	High	High
Valkeajärvi	Moderate	High		High	High

6.2 Swedish EQR8

According to Swedish EQR8 the fish community based ecological status of the surveyed lakes was generally moderate or poor (Fig. 8). The ecological status was good only in Lake Oustajärvi, Lake Pirttijärvi and Lake Valkeajärvi where the EQR8 values were higher than 0,46, which is the borderline between good and moderate conditions. In the cases of Lake Isolompolo and Lake Nivunkijärvi the ecological status was evaluated even bad (Table 10). In both cases the values of each variable lead to status classes bad or poor. The fish community based EQR8 results suggest that almost all the surveyed lakes are not representing reference conditions, except lakes Oustajärvi, Pirttijärvi and Valkeajärvi.

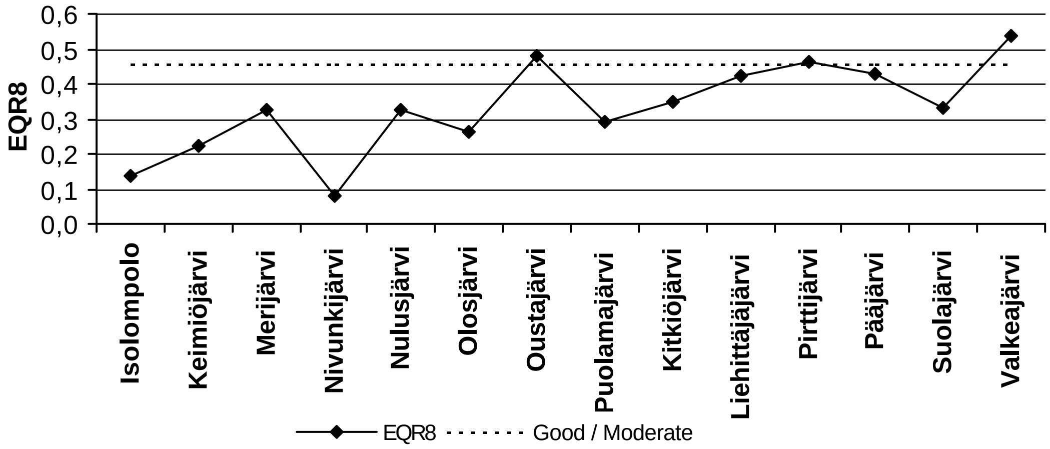


Fig. 8. The Swedish EQR8 values of the surveyed lakes. The borderline between good and moderate ecological status is 0,46.

Table 10. Ecological status of surveyed lakes according to Swedish EQR8.

Lake	Status class							
	Number of species	Simpson's index number	Simpson's index biomass	CPUE biomass	CPUE number	Mean weight	Potentially predatory percids	Perch/ cyprinids ratio	EQR8
Isolompolo	Bad	Poor	Bad	Bad	Bad	Poor	Poor	Bad	Bad
Keimiöjärvi	High	Bad	Moderate	Bad	Bad	Poor	Bad		Poor
Merijärvi	Good	Bad	Good	Bad	Bad	Good	Good	Bad	Moderate
Nivunkijärvi	Bad	Bad	Poor	Bad	Bad	Bad	Bad		Bad
Nulusjärvi	Bad	Poor	Good	High	Bad	Bad	High	Bad	Moderate
Olosjärvi	Bad	Moderate	Good	Bad	Bad	Bad	High	Bad	Poor
Oustajärvi	Good	Bad	Moderate	High	Good	High	Bad		Good
Puolamajärvi	Bad	Moderate	High	Good	Bad	Bad	Moderate	Bad	Poor
Kitkiöjärvi	High	Good	High	Poor	Bad	Poor	Bad	Bad	Moderate
Liehittäjäjärvi	Moderate	Poor	High	High	Poor	Poor	Moderate	Poor	Moderate
Pirttijärvi	High	High	High	Poor	Moderate	Bad	Poor	Poor	Good
Pääjärvi	Good	Poor	High	High	Bad	Bad	High	Bad	Moderate
Suolajärvi	Bad	High	Bad	Good	Bad	Bad	High	Bad	Moderate
Valkeajärvi	Good	High	Moderate	Poor	Poor	High			Good

6.3 Comparison of national EQR's

The results from two different national EQR methods were almost opposite. According to Finnish EQR4 results the ecological status of the surveyed lakes was generally good and the lakes are representing reference conditions (Table 11). Whereas, according to Swedish EQR8 results the situation was quite opposite. In that sense the fish community based Finnish EQR4 results support the earlier results (Elfvendahl et al. 2006) of the other biological factors (benthic macroinvertebrates and phytoplankton) and water chemistry. Because according to earlier results the survey lakes are representing reference conditions. The Finnish EQR4 values were also calculated separately for benthic nets, but the influence to overall results remained minor. The ecological status class of the lakes Keimiöjärvi and Merijärvi remained similar. Whereas, the ecological status class of lake Olosjärvi would change from good to high and lake Puolamajärvi from high to good. Generally the ecological status of each lake was according to Finnish EQR4 1 to 2 classes higher than according to Swedish EQR8. But for example in the case of Lake Isolompolo the fish community based ecological status was good according to EQR4, whereas according to EQR8 the ecological status was bad. Also in the case of Lake Puolamajärvi the results were quite opposite. Only in the case of lakes Merijärvi and Oustajärvi the results were similar. According to both methods the ecological status in Swedish lakes was generally higher than in Finnish lakes. The Finnish EQR4 is simple and seems to give easier higher status classes than Swedish EQR8, which seems to be more conservative method. A previous study also indicated that EQR8 might work less well for lakes in northern Sweden (Holmgren 2007). For example the northernmost national reference lakes had higher NPUE and proportion of piscivorous percids than expected from lake-specific reference values. A similar pattern was found for NPUE of all lakes in the present study, and for proportion of piscivorous percids in six lakes. It might be also noted that no lakes from the Torne River catchment were included in the calibration data set used for defining lake-specific reference values. Perhaps both methods should be developed before using in practice, because the results are now too far from each other.

Table 11. Ecological status of surveyed lakes according to national EQR's.

Lake	Status class	
	EQR4	EQR8
Isolompolo	Good	Bad
Keimiöjärvi	Good	Poor
Merijärvi	Moderate	Moderate
Nivunkijärvi	Moderate	Bad
Nulusjärvi	Good	Moderate
Olosjärvi	Good	Poor
Oustajärvi	Good	Good
Puolamajärvi	High	Poor
Kitkiöjärvi	Good	Moderate
Liehittäjäjärvi	High	Moderate
Pirttijärvi	High	Good
Pääjärvi	Good	Moderate
Suolajärvi	High	Moderate
Valkeajärvi	High	Good

7. Lake specified results

Isolompolo (type 2)

The total CPUE's of Lake Isolompolo were 3705 g/net and 77 ind./net (Table 12). Based on test fishing results there occurs at least seven different fish species in Lake Isolompolo. According to CPUE's the most important species in biomass catch were roach (1530 g/net), perch (1483 g/net) and pike (614 g/net). The most abundant species in number catch were roach (63 ind./net) and perch (11 ind./net). The proportion of other fish species in the catch was minor. The biomass proportion of cyprinid fishes (roach and bleak) in the catch was 42 % and percid fishes (perch and ruffe) 40 % respectively. In case of number catch cyprinid fishes were dominant with 65 % proportion of the catch. The biomass proportion of predatory fishes (perch >15 cm and pike) in the catch (55 %) can be considered very high.

Table 12. Total catches, CPUE's and percentages according to fish species in Lake Isolompolo 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	17792	1482,7	40,0	133	11,1	14,4
Ruffe	31	2,6	0,1	4	0,3	0,4
Pike	7372	614,3	16,6	8	0,7	0,9
Whitefish	714	59,5	1,6	3	0,3	0,3
Minnow	1	0,1	0,0	1	0,1	0,1
Roach	18359	1529,9	41,3	760	63,3	82,1
Bleak	186	15,5	0,4	17	1,4	1,8
Total	44455	3704,6	100,0	926	77,2	100,0
Percids	17823	1485,3	40,1	137	11,4	14,8
Cyprinids	18545	1545,4	41,7	777	64,8	83,9
Perch >15 cm	17190	1432,5	38,7	109	9,1	11,8
Predatory fishes	24562	2046,8	55,3	117	9,8	12,6

Perch in Lake Isolompolo were quite large, because most of the individuals in the catch were 13-24 cm in length (Fig. 9). Especially there was plenty of large over 20 cm in length individuals in the catch. Roach were quite small in Lake Isolompolo, because most of the individuals in the catch were 7-11 cm in length.

Perch in Lake Isolompolo were on an average 5,7 cm in length after the first growth season at age 1 and 17,3 cm in length at age 5 respectively (Fig. 10). The growth of perch in Lake Isolompolo is moderately fast, because perch exceeds 20 cm length on an average during the seventh growth season. The largest perch (40 cm, 1106 g) in the catch was measured 16 years old. According to age determinations the year-class 2004 was totally missing from test fishing catch.

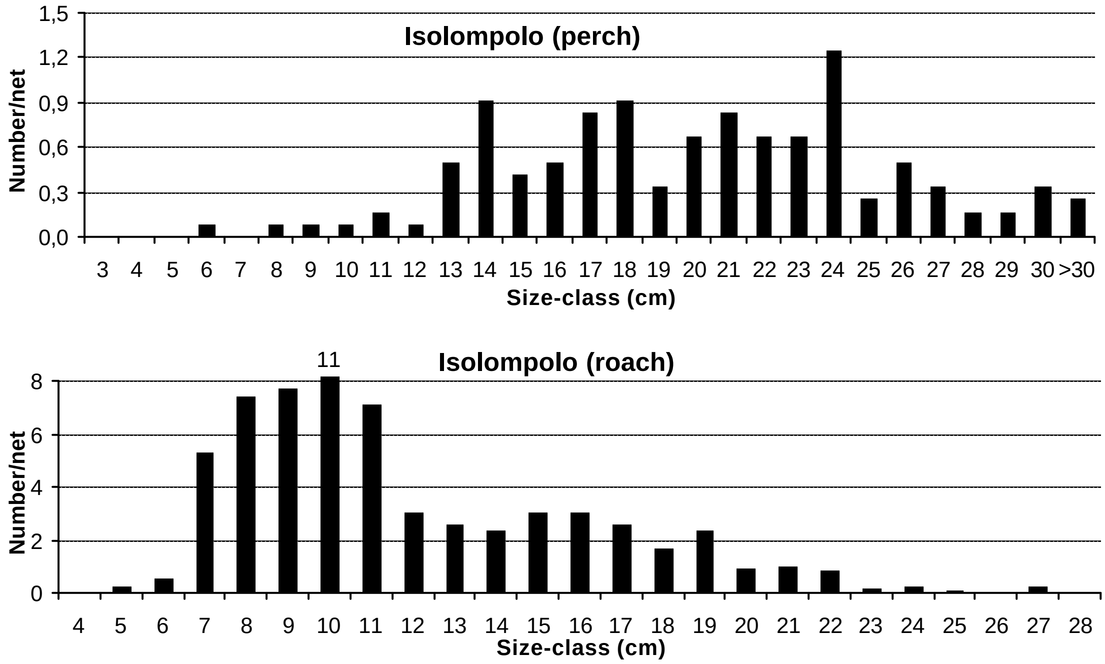


Fig. 9. Size distributions of perch and roach in test fishing catch from Lake Isolompolo 2006.

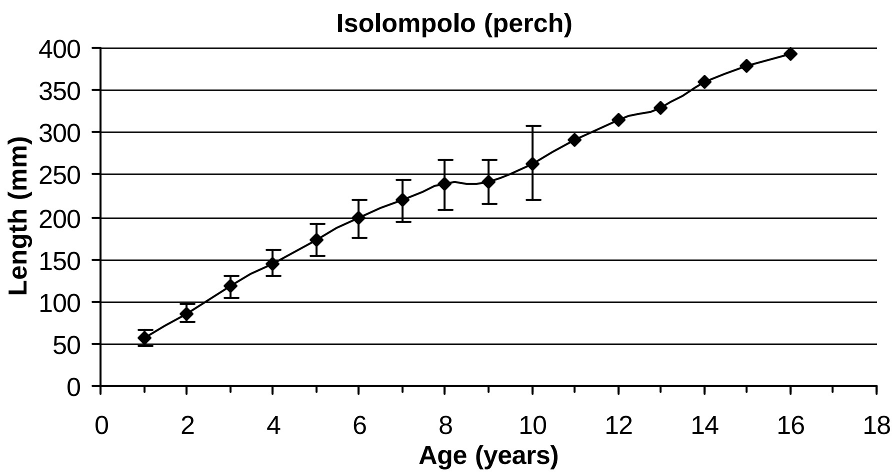


Fig. 10. Back calculated average lengths of perch at age in Lake Isolompolo 2006 and standard deviations (SD), n = 86.

Keimiöjärvi (type 2)

The total CPUE's of Lake Keimiöjärvi were 3153 g/net and 65 ind./net (Table 13). Based on test fishing results there occurs at least three different fish species in Lake Keimiöjärvi. Test fishing group also made visual observation of minnow shoal on the littoral zone. According to CPUE's the most important species in biomass catch was perch (3133 g/net). The most abundant species in number catch was also perch (64 ind./net). The proportion of other fish species in the catch was very small consisting of only two trout and one burbot. The biomass proportion of predatory fishes (perch >15 cm, trout and burbot) in the catch (81 %) can be considered extremely high.

Two dominate size-classes clearly separate from the size distribution of perch (Fig. 11). 12-13 cm in length individuals, which according to age determinations belong to the year-class 2003 (3+-age group), were dominant. Another dominat size-class were 16-17 cm in length individuals, that mainly belong to the year-class 2002 (4+-age group). According to age determinations year-classes 2004 and 2005 seemed to instead remain very week.

Table 13. Total catches, CPUE's and percentages according to fish species in Lake Keimiöjärvi 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	50122	3132,6	99,3	1029	64,3	99,7
Trout	286	17,9	0,6	2	0,1	0,2
Burbot	43	2,7	0,1	1	0,1	0,1
Total	50451	3153,2	100,0	1032	64,5	100,0
Percids	50122	3132,6	99,3	1029	64,3	99,7
Perch >15 cm	40374	2523,4	80,0	606	37,9	58,7
Predatory fishes	40703	2543,9	80,7	609	38,1	59,0

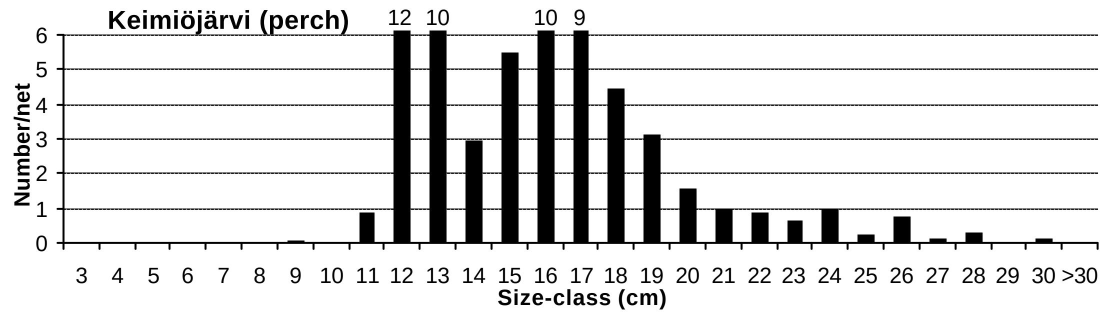


Fig. 11. Size distribution of perch in test fishing catch from Lake Keimiöjärvi 2006.

Perch in Lake Keimiöjärvi were on an average 6,0 cm in length after the first growth season at age 1 and 18,3 cm in length at age 5 respectively (Fig. 12). The growth of perch in Lake Keimiöjärvi is moderately fast, because perch exceeds 20 cm length on an average during the sixth growth season. The growth of perch is also quite constant during the first eight growth seasons.

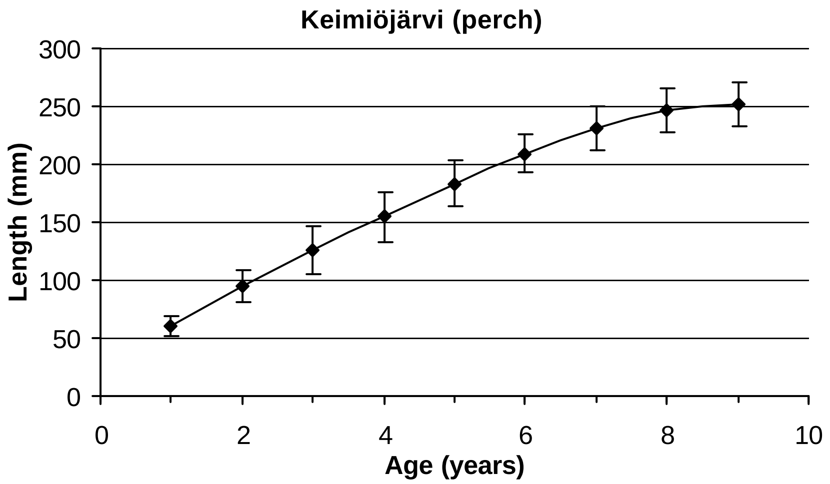


Fig. 12. Back calculated average lengths of perch at age in Lake Keimiöjärvi 2006 and standard deviations (SD), n = 87.

Olosjärvi (type 2)

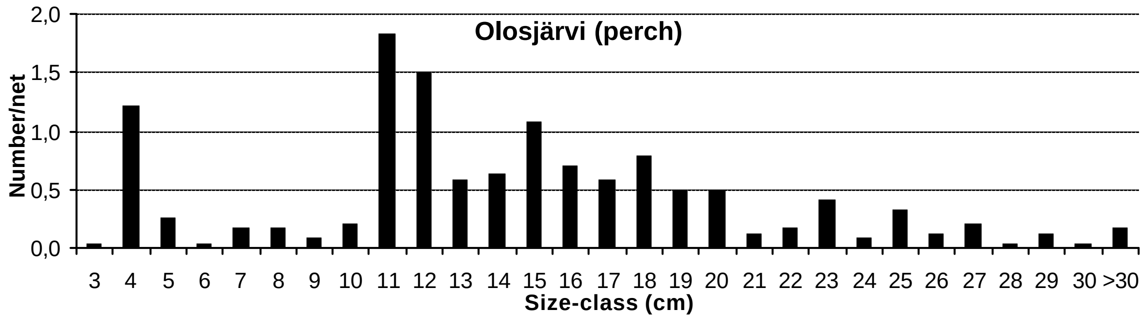
The total CPUE's of Lake Olosjärvi were 2362 g/net and 101 ind./net (Table 14). Based on test fishing results there occurs at least eight different fish species in Lake Olosjärvi. According to

CPUE's the most important species in biomass catch were roach (1386 g/net) and perch (747 g/net). The most abundant species in number catch were roach (74 ind./net), perch (13 ind./net) and bleak (12 ind./net). The proportion of other fish species in the catch was minor. Cyprinid fishes (roach and bleak) were dominant with 63 % proportion of the biomass catch whereas proportion of percid fishes (perch and ruffe) remained 32 %. In case of number catch cyprinid fishes were overwhelming dominant with 85 % proportion of the catch. The biomass proportion of predatory fishes (perch >15 cm and pike) in the catch (32 %) can be considered moderate.

Table 14. Total catches, CPUE's and percentages according to fish species in Lake Olosjärvi 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	17919	746,6	31,6	305	12,7	12,6
Ruffe	58	2,4	0,1	13	0,5	0,5
Pike	2850	118,8	5,0	3	0,1	0,1
Vendace	252	10,5	0,4	37	1,5	1,5
Whitefish	138	5,8	0,2	4	0,2	0,2
Minnow	7	0,3	0,0	6	0,3	0,2
Roach	33263	1386,0	58,7	1768	73,7	72,8
Bleak	2207	92,0	3,9	292	12,2	12,0
Total	56694	2362,3	100,0	2428	101,2	100,0
Percids	17977	749,0	31,7	318	13,3	13,1
Cyprinids	35470	1477,9	62,6	2060	85,8	84,8
Perch >15 cm	15361	640,0	27,1	144	6,0	5,9
Predatory fishes	18211	758,8	32,1	147	6,1	6,1

The dominant size-class of perch in Lake Olosjärvi was individuals of 11-12 cm in length, that according to age determinations mainly belong to the year-class 2003 (3+-age group) (Fig. 13). Past summer 2006 juveniles (0+-age group) also separate from the size distribution at point of 4 cm in length fishes. Perch year-classes 2004 and 2005 seemed to remain very week. Roach were quite small in Lake Olosjärvi, because most of the individuals in the catch were 6-11 cm in length.



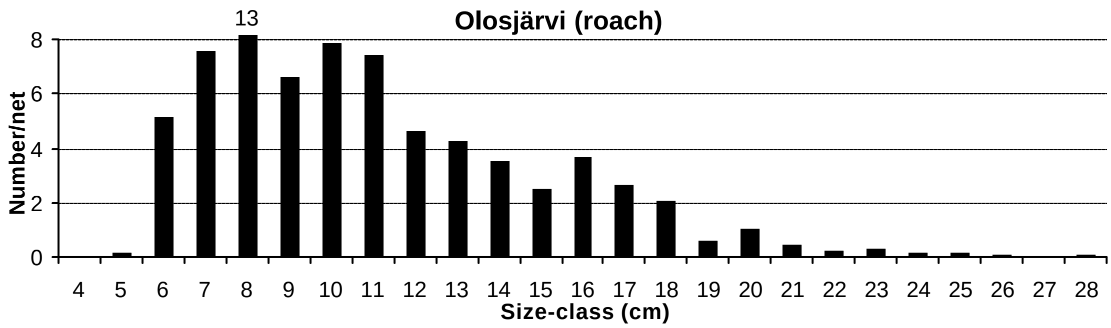


Fig. 13. Size distributions of perch and roach in test fishing catch from Lake Olosjärvi 2006.

Perch in Lake Olosjärvi were on an average 5,6 cm in length after the first growth season at age 1 and 17,9 cm in length at age 5 respectively (Fig. 14). The growth of perch in Lake Olosjärvi is also moderately fast, because perch exceeds 20 cm length on an average during the sixth growth season. The growth of perch is also quite constant during the first six growth seasons.

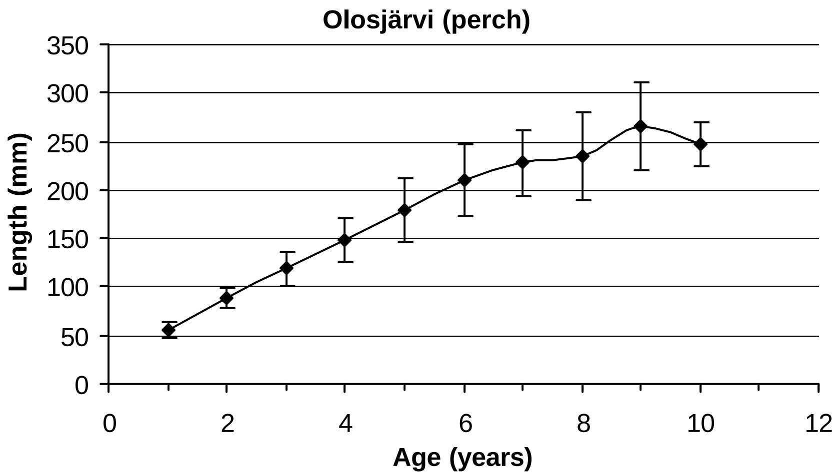


Fig. 14. Back calculated average lengths of perch at age in Lake Olosjärvi 2006 and standard deviations (SD), n = 96.

Puolamajärvi (type 2)

The total CPUE's of Lake Puolamajärvi were 898 g/net and 46 ind./net (Table 15). Based on test fishing results there occurs at least four different fish species in Lake Puolamajärvi. According to CPUE's the most important species in biomass catch were roach (596 g/net) and perch (268 g/net). Also the most abundant species in number catch were roach (33 ind./net) and perch (12 ind./net). The proportion of other fish species (ruffe and whitefish) in the catch was minor. Cyprinid fishes (roach) were dominant with 66 % proportion of the biomass catch whereas proportion of percid fishes (perch and ruffe) remained 30 %. In case of number catch cyprinid fishes were overwhelming dominant with 71 % proportion of the catch. The biomass proportion of predatory fishes (perch >15 cm) in the catch (10 %) can be considered low.

Table 15. Total catches, CPUE's and percentages according to fish species in Lake Puolamajärvi 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	6442	268,4	29,9	286	11,9	26,1
Ruffe	332	13,8	1,5	29	1,2	2,6
Whitefish	472	19,7	2,2	1	0,0	0,1
Roach	14302	595,9	66,4	780	32,5	71,2
Total	21548	897,8	100,0	1096	45,7	100,0
Percids	6774	282,3	31,4	315	13,1	28,7
Cyprinids	14302	595,9	66,4	780	32,5	71,2
Perch >15 cm	2100	87,5	9,7	42	1,8	3,8
Predatory fishes	2100	87,5	9,7	42	1,8	3,8

The dominant size-class of perch in Lake Puolamajärvi was individuals of 12-13 cm in length (Fig. 15). Past summer 2006 juveniles (0+-age group) also separate from the size distribution at point of 5-6 cm in length fishes. Only a few large over 20 cm perch were caught. According to age determinations perch year-classes 2004 and 2005 seemed to remain quite week. Roach were also quite small in Lake Puolamajärvi, because most of the individuals in the catch were 9-13 cm in length.

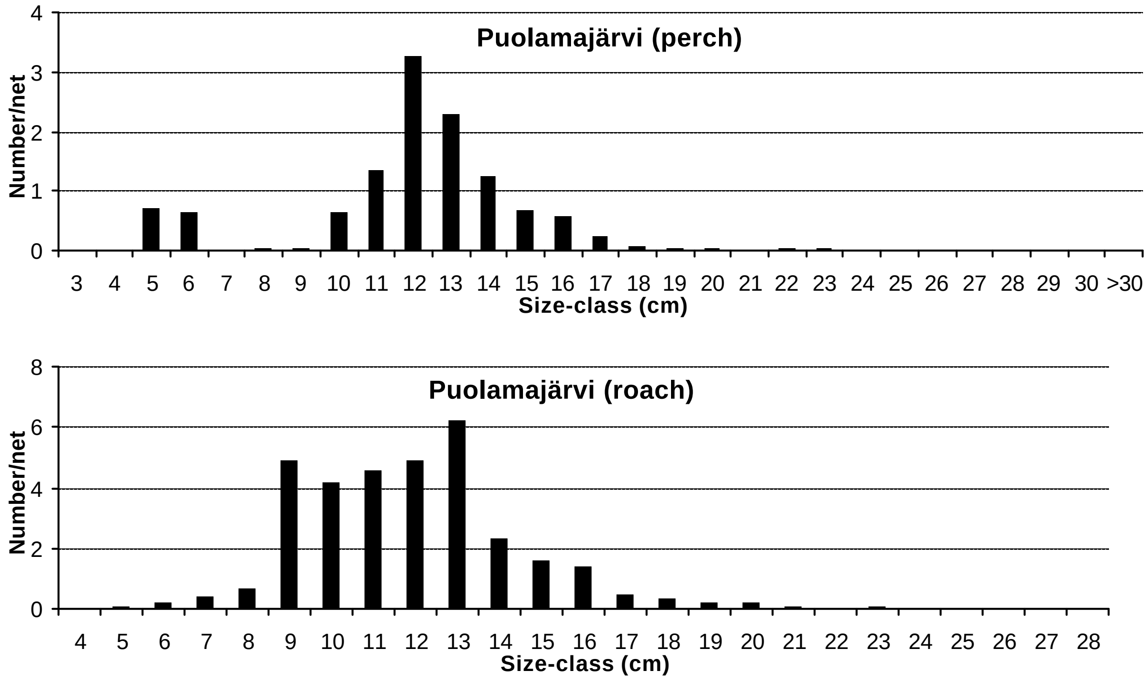


Fig. 15. Size distributions of perch and roach in test fishing catch from Lake Puolamajärvi 2006.

Perch in Lake Puolamajärvi were on an average 6,2 cm in length after the first growth season at age 1 and 15,0 cm in length at age 5 respectively (Fig. 16). The growth of perch in Lake Puolamajärvi is quite slow, because perch exceeds 20 cm length on an average during the ninth growth season. The largest perch (23,4 cm, 152 g) in the catch was measured 10 years old.

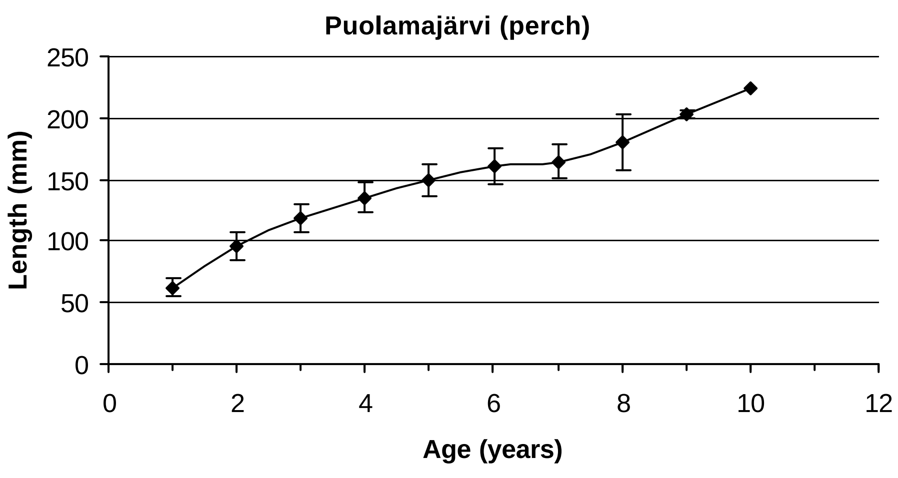


Fig. 16. Back calculated average lengths of perch at age in Lake Puolamajärvi 2006 and standard deviations (SD), n = 56.

Suolajärvi (type 2)

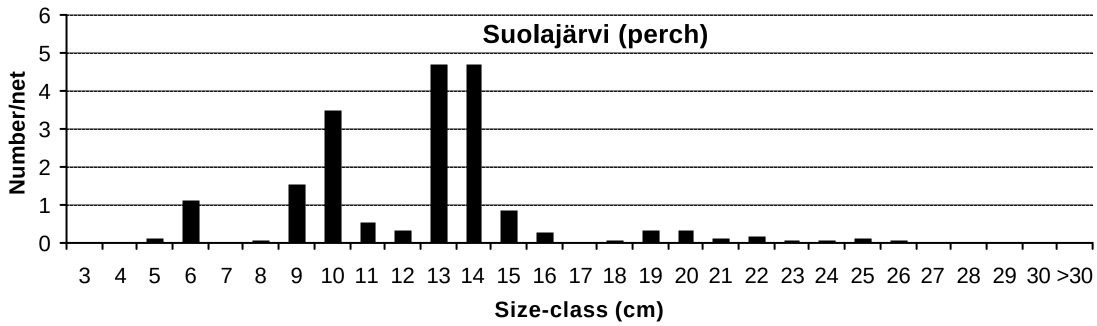
The total CPUE's of Lake Suolajärvi were 841 g/net and 33 ind./net (Table 16). Based on test fishing results there occurs at least six different fish species in Lake Suolajärvi. According to

CPUE's the most important species in biomass catch were perch (428 g/net) and whitefish (178 g/net). The most abundant species in number catch were perch (19 ind./net) and ruffe (11 ind./net). The proportion of other fish species in the catch was minor. Percid fishes (perch and ruffe) were dominant with 61 % proportion of the biomass catch and even 92 % proportion of the number catch.

Table 16. Total catches, CPUE's and percentages according to fish species in Lake Suolajärvi 2005.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	10278	428,3	50,9	452	18,8	57,2
Ruffe	2102	87,6	10,4	272	11,3	34,4
Pike	1500	62,5	7,4	1	0,0	0,1
Whitefish	4275	178,1	21,2	19	0,8	2,4
Ide	269	11,2	1,3	2	0,1	0,3
Roach	1761	73,4	8,7	44	1,8	5,6
Total	20185	841,0	100,0	790	32,9	100,0
Percids	12380	515,8	61,3	724	30,2	91,6
Cyprinids	1761	73,4	8,7	44	1,8	5,6

Three different year-class clearly separate from size distribution of perch in Lake Suolajärvi 2005 (Fig. 17). Summer 2005 juveniles (0+-age group) separate from size distribution at point of 5-6 cm in length fishes. According to age determinations year-class 2004 (1+-age group) separate at point of 9-10 cm in length fishes and year-class 2003 (2+-age group) at point of 13-14 cm in length fishes. The dominant size-class of roach in Lake Suolajärvi was individuals of 14-15 cm in length.



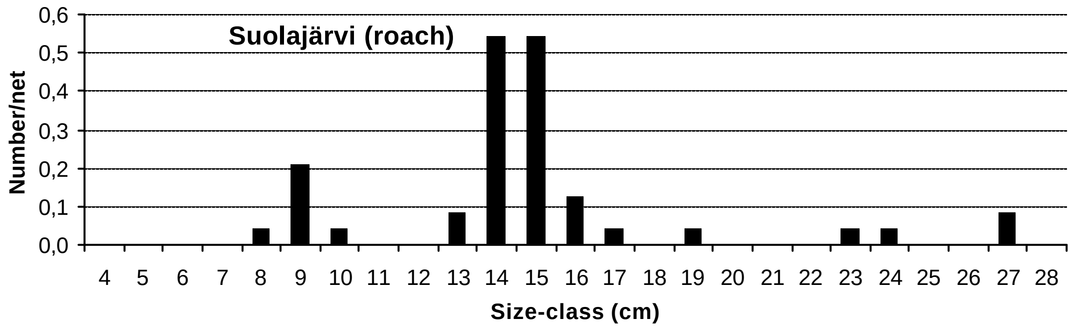


Fig. 17. Size distributions of perch and roach in test fishing catch from Lake Suolajärvi 2005.

Perch in Lake Suolajärvi were on an average 8,0 cm in length after the first growth season at age 1 and 18,8 cm in length at age 5 respectively (Fig. 18). The growth of perch is quite fast in Lake Suolajärvi, because perch exceeds 20 cm length on an average during the sixth growth season. The growth of perch is also quite constant.

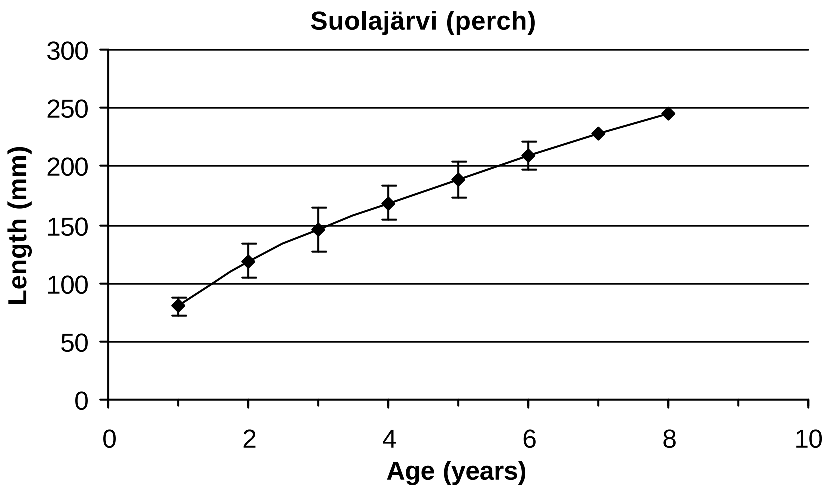


Fig. 18. Back calculated average lengths of perch at age in Lake Suolajärvi 2005 and standard deviations (SD), n = 50.

Valkeajärvi (type 2)

The total CPUE's of Lake Valkeajärvi were 1637 g/net and 18 ind./net (Table 17). Based on test fishing results there occurs at least four different fish species in Lake Valkeajärvi. According to CPUE's the dominant fish species in biomass catch was whitefish (1563 g/net). Instead the most abundant species in number catch were whitefish (9 ind./net) and minnow (8 ind./net). The proportion of other fish species in the catch was minor.

Table 17. Total catches, CPUE's and percentages according to fish species in Lake Valkeajärvi 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Whitefish	37502	1562,6	95,5	211	8,8	49,9
Burbot	911	37,9	2,3	11	0,5	2,6
Bullhead	18	0,7	0,0	3	0,1	0,7
Minnow	851	35,5	2,2	198	8,3	46,8
Total	39281	1636,7	100,0	423	17,6	100,0

The dominant size-class of whitefish in Lake Valkeajärvi was individuals of 29-32 cm in length (Fig. 19). Also two different year-class clearly separate from size distribution. According to age determinations past summer 2006 juveniles (0+-age group) separate at point of 13-15 cm in length fishes and year-class 2005 (1+-age group) at point of 21-23 cm in length fishes.

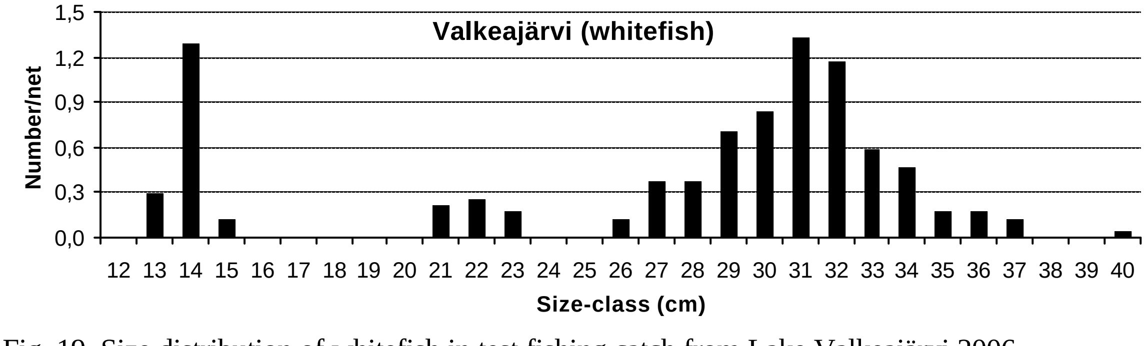


Fig. 19. Size distribution of whitefish in test fishing catch from Lake Valkeajärvi 2006.

Whitefish in Lake Valkeajärvi were on an average 12,9 cm in length after the first growth season at age 1 and 31,5 cm in length at age 5 respectively (Fig. 20). During the first four growth seasons the growth of whitefish in Lake Valkeajärvi is moderately fast. However the growth slows down after the individuals have exceeded 30 cm length.

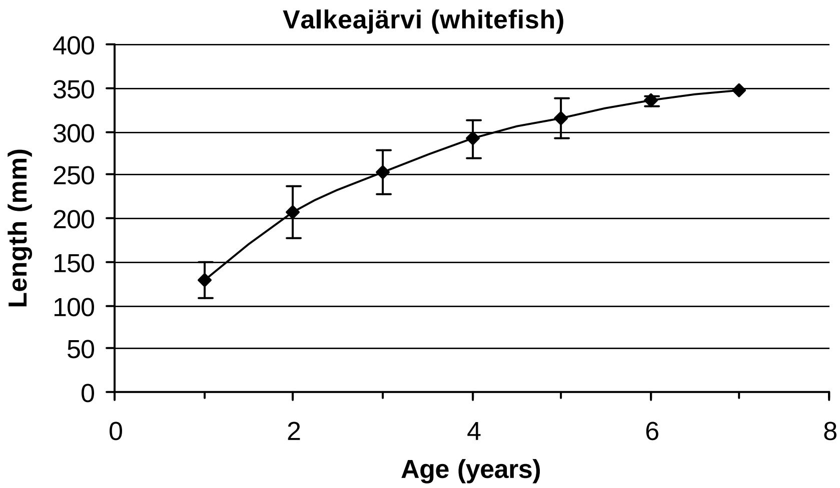


Fig. 20. Back calculated average lengths of whitefish at age in Lake Valkeajärvi 2006 and standard deviations (SD), n = 52.

Kitkiöjärvi (type 3)

The total CPUE's of Lake Kitkiöjärvi were 1804 g/net and 41 ind./net (Table 18). Based on test fishing results there occurs at least four different fish species in Lake Kitkiöjärvi. According to CPUE's the most important species in biomass catch were perch (1358 g/net) and roach (371 g/net). The most abundant species in number catch were also perch (27 ind./net) and roach (13 ind./net). The proportion of other fish species in the catch was minor. Percid fishes (perch) were dominant with 75 % proportion of the biomass catch and 65 % proportion of the number catch.

Table 18. Total catches, CPUE's and percentages according to fish species in Lake Kitkiöjärvi 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	32599	1358,3	75,3	643	26,8	65,0
Pike	1443	60,1	3,3	3	0,1	0,3
Vendace	342	14,2	0,8	30	1,3	3,0
Roach	8901	370,9	20,6	313	13,0	31,6
Total	43285	1803,5	100,0	989	41,2	100,0
Percids	32599	1358,3	75,3	643	26,8	65,0
Cyprinids	8901	370,9	20,6	313	13,0	31,6

The dominant size-class of perch in Lake Kitkiöjärvi was individuals of 11 cm in length (Fig. 21). Past summer 2006 juveniles (0+-age group) also separate from the size distribution at point of 4-6 cm in length fishes. The dominant size-class of roach in Lake Kitkiöjärvi was individuals of 9-11 cm in length.

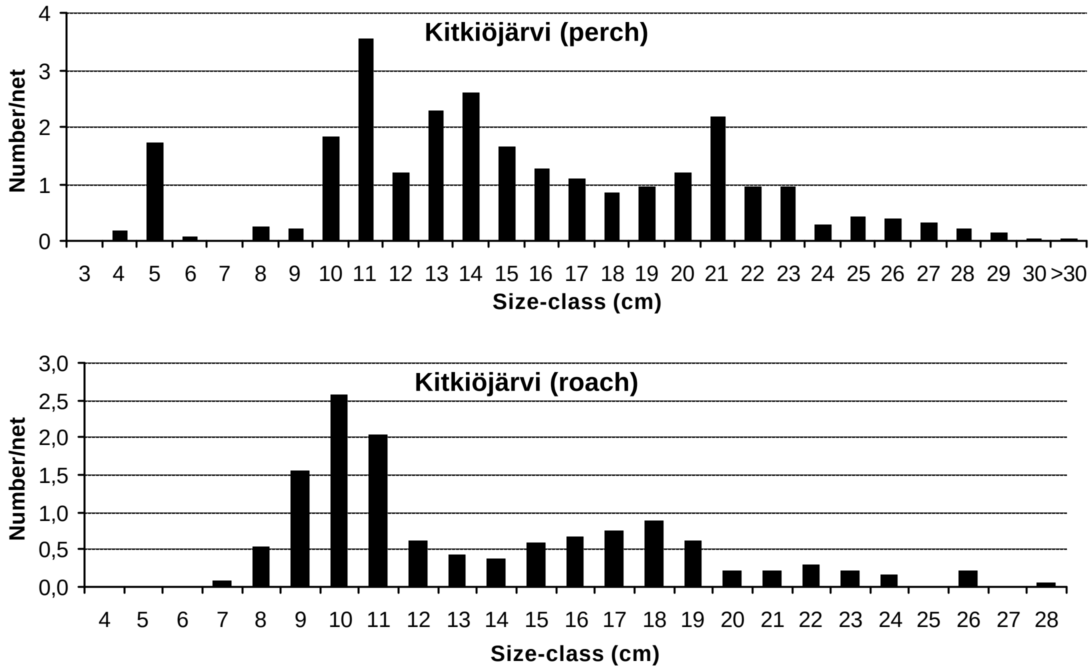


Fig. 21. Size distributions of perch and roach in test fishing catch from Lake Kitkiöjärvi 2006.

Perch in Lake Kitkiöjärvi were on an average 7,3 cm in length after the first growth season at age 1 and 17,2 cm in length at age 5 respectively (Fig. 22). The growth of perch in Lake Kitkiöjärvi is moderately fast, because perch exceeds 20 cm length on an average during the seventh growth season. The growth of perch is also quite constant during the first eight growth seasons.

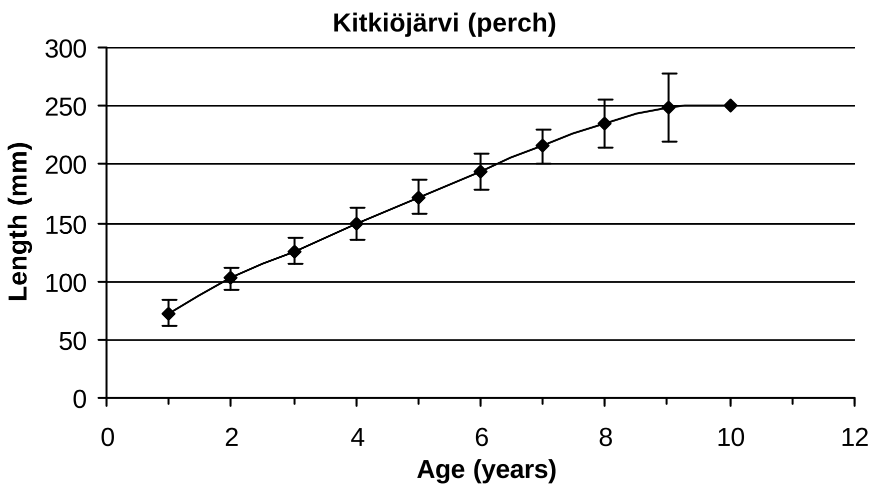


Fig. 22. Back calculated average lengths of perch at age in Lake Kitkiöjärvi 2006 and standard deviations (SD), n = 63.

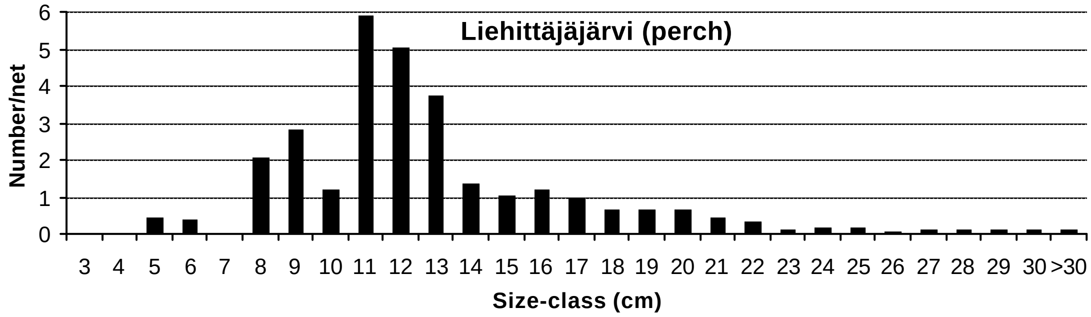
Liehittäjäjärvi (type 3)

The total CPUE’s of Lake Liehittäjäjärvi were 1322 g/net and 41 ind./net (Table 19). Based on test fishing results there occurs at least four different fish species in Lake Liehittäjäjärvi. According to CPUE’s the most important species in biomass catch were perch (866 g/net) and roach (316 g/net). The most abundant species in number catch were also perch (30 ind./net) and roach (10 ind./net). The proportion of other fish species in the catch was minor. Percid fishes (perch and ruffe) were dominant with 66 % proportion of the biomass catch and 75 % proportion of the number catch.

Table 19. Total catches, CPUE's and percentages according to fish species in Lake Liehittäjäjärvi 2005.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	20777	865,7	65,5	715	29,8	72,1
Ruffe	64	2,7	0,2	25	1,0	2,5
Pike	3291	137,1	10,4	7	0,3	0,7
Roach	7587	316,1	23,9	245	10,2	24,7
Total	31719	1321,6	100,0	992	41,3	100,0
Percids	20841	868,4	65,7	740	30,8	74,6
Cyprinids	7587	316,1	23,9	245	10,2	24,7

The dominant size-class of perch in Lake Liehittäjäjärvi was individuals of 11-13 cm in length (Fig. 23). Summer 2005 juveniles (0+-age group) also separate from the size distribution at point of 5-6 cm in length fishes. The dominant size-class of roach in Lake Liehittäjäjärvi was individuals of 13-17 cm in length.



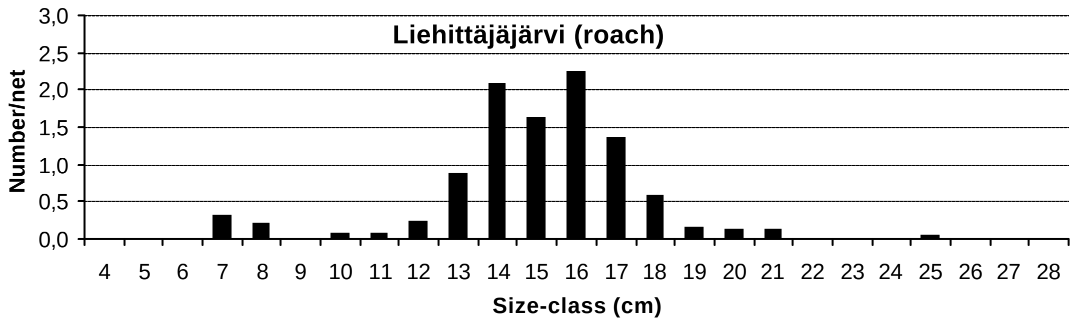


Fig. 23. Size distributions of perch and roach in test fishing catch from Lake Liehittäjäjärvi 2005.

Perch in Lake Liehittäjäjärvi were on an average 9,1 cm in length at age 2 and 17,0 cm in length at age 5 respectively (Fig. 24). The growth of perch in Lake Liehittäjäjärvi is moderate, because perch exceeds 20 cm length on an average during the seventh growth season. The growth of perch is also quite constant during the first six growth seasons.

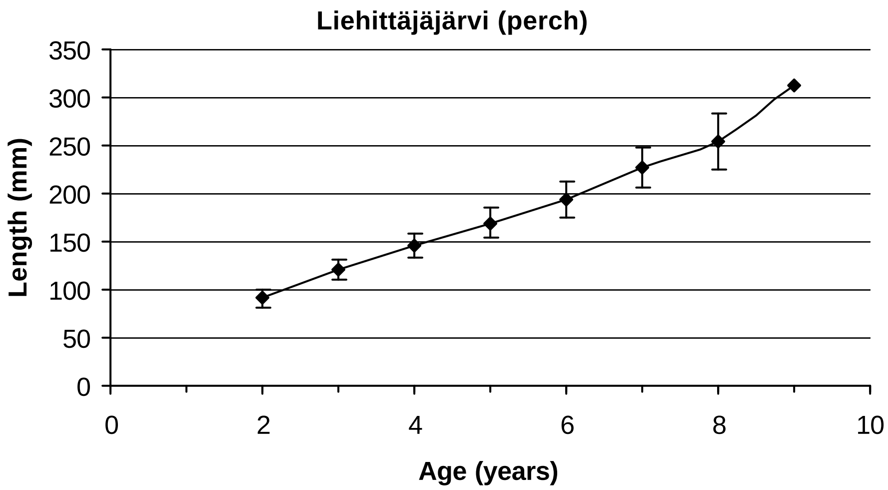


Fig. 24. Back calculated average lengths of perch at age in Lake Liehittäjäjärvi 2005 and standard deviations (SD), n = 49.

Merijärvi (type 3)

The total CPUE's of Lake Merijärvi were 2819 g/net and 95 ind./net (Table 20). Based on test fishing results there occurs at least six different fish species in Lake Merijärvi. According to CPUE's the most important species in biomass catch were perch (1546 g/net), bream (737 g/net) and roach (301 g/net). The most abundant species in number catch were perch (73 ind./net) and roach (15 ind./net). The proportion of other fish species in the catch was minor. The biomass proportion of percid fishes (perch and ruffe) in the catch was 55 % and cyprinid fishes 38 %. In case of number catch percid fishes were overwhelming dominant with 74 % proportion of the catch. The biomass proportion of predatory fishes (perch >15 cm and pike) in the catch (38 %) can be considered moderate.

Table 20. Total catches, CPUE's and percentages according to fish species in Lake Merijärvi 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	30919	1546,0	54,8	1451	72,6	76,4
Ruffe	75	3,8	0,1	26	1,3	1,4
Pike	4270	213,5	7,6	1	0,1	0,1
Roach	6024	301,2	10,7	299	15,0	15,8
Bleak	360	18,0	0,6	17	0,9	0,9
Bream	14734	736,7	26,1	104	5,2	5,5
Total	56382	2819,1	100,0	1898	94,9	100,0
Percids	30994	1549,7	55,0	1477	73,9	77,8
Cyprinids	21118	1055,9	37,5	420	21,0	22,1
Perch >15 cm	16846	842,3	29,9	99	5,0	5,2
Predatory fishes	21116	1055,8	37,5	100	5,0	5,3

The overwhelming dominant size-class of perch in Lake Merijärvi was individuals of 10-11 cm in length, that according to age determinations mainly belong to the year-class 2003 (3+-age group) (Fig. 25). Past summer 2006 juveniles (0+-age group) also separate from the size distribution at point of 6-7 cm in length fishes. According to age determinations the year-class 2004 was totally missing from test fishing catch and year-class 2005 seemed to remain moderately week. The dominant size-class of roach in Lake Merijärvi was individuals of 13 cm in length.

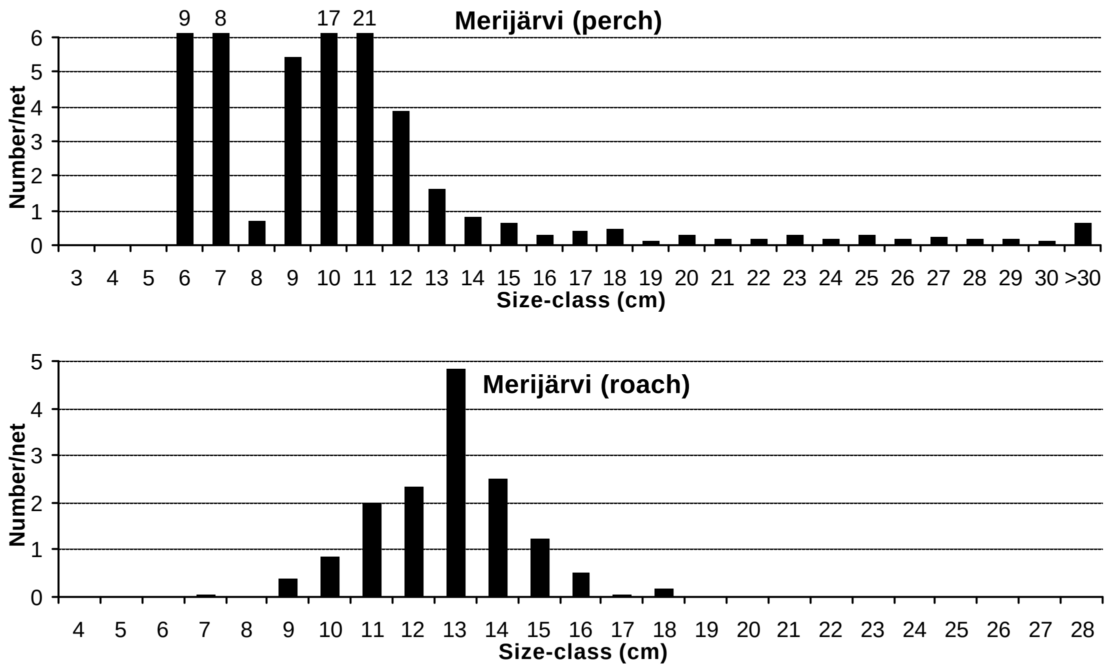


Fig. 25. Size distributions of perch and roach in test fishing catch from Lake Merijärvi 2006.

Perch in Lake Merijärvi were on an average 6,4 cm in length after the first growth season at age 1 and 12,4 cm in length at age 5 respectively (Fig. 26). The growth of perch in Lake Merijärvi is quite slow, because perch exceeds 20 cm length on an average during the ninth growth season. The largest perch (female, 37,2 cm, 696 g) in the catch was measured only 10 years old, whereas the oldest perch (male, 35,4 cm, 598 g) was measured 17 years old.

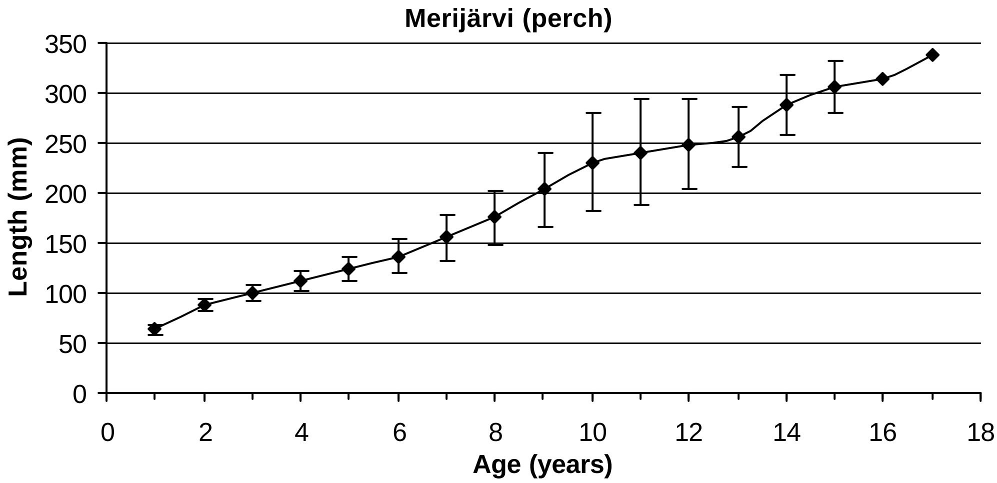


Fig. 26. Back calculated average lengths of perch at age in Lake Merijärvi 2006 and standard deviations (SD), n = 106.

Nivunkijärvi (type 3)

Based on test fishing results perch is the only fish species that occurs in Lake Nivunkijärvi. But according to test fishing group member the local fishermen get caught also vendace. CPUE's of perch were 751 g/net and 48 ind./net (Table 21). The biomass proportion of piscivorous perch (>15 cm) in the catch (57 %) can be considered quite high.

Table 21. Total catches, CPUE's and percentages according to fish species in Lake Nivunkijärvi 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	12014	750,9	100,0	769	48,1	100,0
Total	12014	750,9	100,0	769	48,1	100,0
Perch >15 cm	6813	425,8	56,7	87	5,4	11,3
Predatory fishes	6813	425,8	56,7	87	5,4	11,3

Four different year-class clearly separate from size distribution of perch in Lake Nivunkijärvi 2006, which is very exceptional in case of perch (Fig. 27). Past summer 2006 juveniles (0+-age group) separate from size distribution at point of 4-5 cm in length fishes. Year-class 2005 (1+-age group) separates at point of 7-9 cm in length individuals and year-class 2004 (2+-age group) at point of 11-13 cm in length individuals respectively. According to age determinations almost all 15-19 cm in length individuals belong to the year-class 2003 (3+-age group).

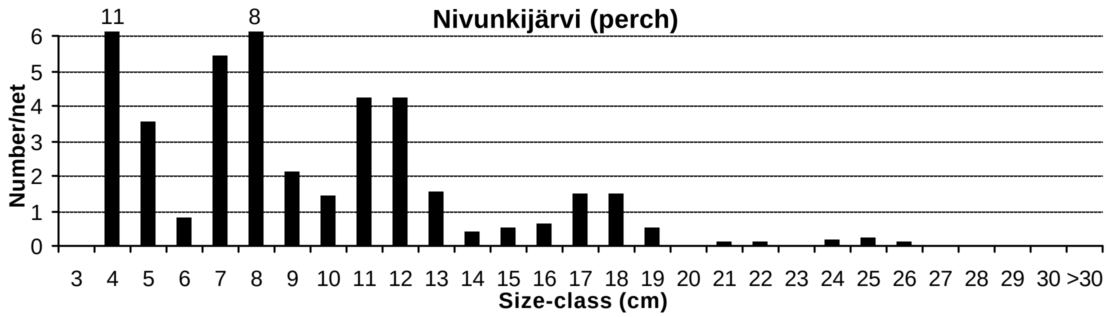


Fig. 27. Size distribution of perch in test fishing catch from Lake Nivunkijärvi 2006.

Perch in Lake Nivunkijärvi were on an average 5,4 cm in length after the first growth season at age 1 and 21,3 cm in length at age 5 respectively (Fig. 28). The growth of perch in Lake Nivunkijärvi is very fast, because perch exceeds 20 cm length on an average during the fifth growth season. Fastest growing individuals exceeded 20 cm length even during the fourth growth season, which can be considered exceptional fast growth in northern conditions. The oldest individuals that were caught belong to the year-class 2001 (5+-age group).

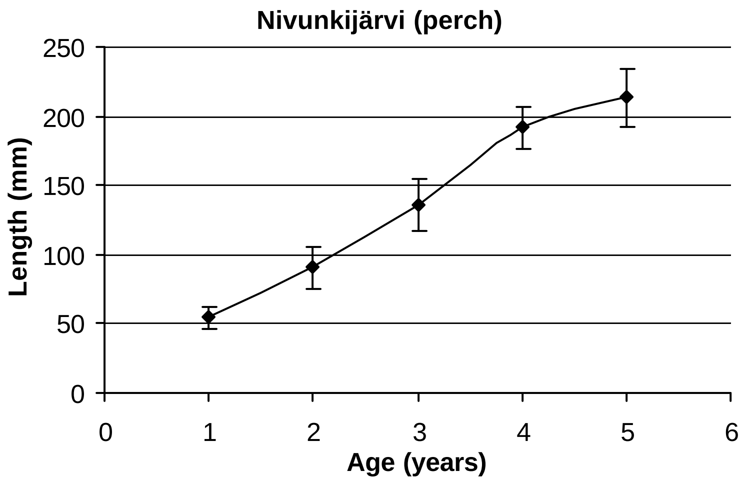


Fig. 28. Back calculated average lengths of perch at age in Lake Nivunkijärvi 2006 and standard deviations (SD), n = 99.

Nulusjärvi (type 3)

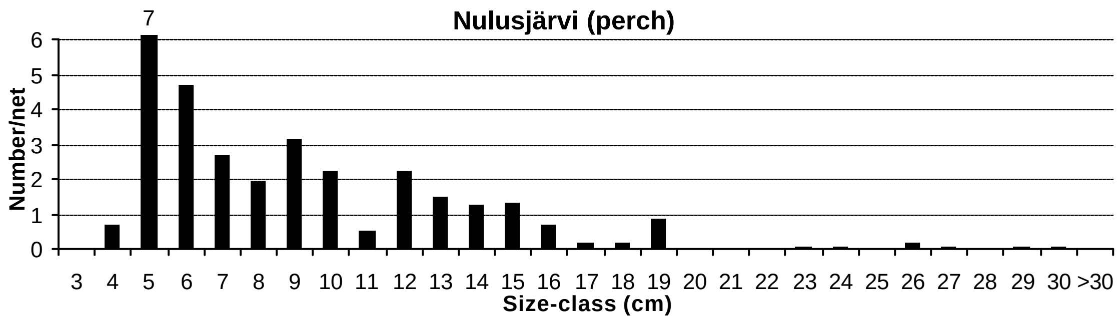
The total CPUE's of Lake Nulusjärvi were 2321 g/net and 91 ind./net (Table 22). Based on test fishing results there occurs at least eight different fish species in Lake Nulusjärvi. According to CPUE's the most important species in biomass catch were roach (1480 g/net) and perch (545 g/net). Whereas the most abundant species in number catch were roach (43 ind./net), perch (31 ind./net) and bleak (11 ind./net). The proportion of other fish species in the catch was minor. Cyprinid fishes (roach and bleak) dominate with 67 % proportion of the biomass catch, whereas proportion of percid fishes (perch and ruffe) remained 24 %. In case of number catch cyprinid fishes were dominant with 59 % proportion of the catch. The biomass proportion of predatory fishes (perch >15 cm and pike) in the catch (15 %) can be considered quite low.

Table 22. Total catches, CPUE's and percentages according to fish species in Lake Nulusjärvi 2006.

Fish species	**Total catch (g)**	**CPUE g/net**	**Biomass %**	**Total catch (number)**	**CPUE number/net**	**Number %**
Perch	6540	545,0	23,5	377	31,4	34,6
Ruffe	83	6,9	0,3	26	2,2	2,4
Pike	398	33,2	1,4	1	0,1	0,1
Vendace	54	4,5	0,2	5	0,4	0,5
Whitefish	60	5,0	0,2	1	0,1	0,1
Dace	1934	161,2	6,9	34	2,8	3,1
Roach	17765	1480,4	63,8	518	43,2	47,6
Bleak	1013	84,4	3,6	127	10,6	11,7
Total	27847	2320,6	100,0	1089	90,8	100,0
Percids	6623	551,9	23,8	403	33,6	37,0
Cyprinids	18778	1564,8	67,4	645	53,8	59,2
Perch >15 cm	3772	314,3	13,5	45	3,8	4,1
Predatory fishes	4170	347,5	15,0	46	3,8	4,2

The dominant size-class of perch in Lake Nulusjärvi was individuals of 5-6 cm in length, that according to age determinations belong to the year-classes 2006 (0+-age group) and 2005 (1+-age group) (Fig. 29). Only a few large over 20 cm perch were caught. The dominant size-class of roach in Lake Nulusjärvi was individuals of 10-11 cm in length.

Perch in Lake Nulusjärvi were on an average 5,2 cm in length after the first growth season at age 1 and 16,0 cm in length at age 5 respectively (Fig. 30). The growth of perch in Lake Nulusjärvi is moderate, because perch exceeds 20 cm length on an average during the seventh growth season. The growth of perch is also quite constant during the first nine growth seasons. The largest perch (30,1 cm, 364 g) in the catch was measured 9 years old.



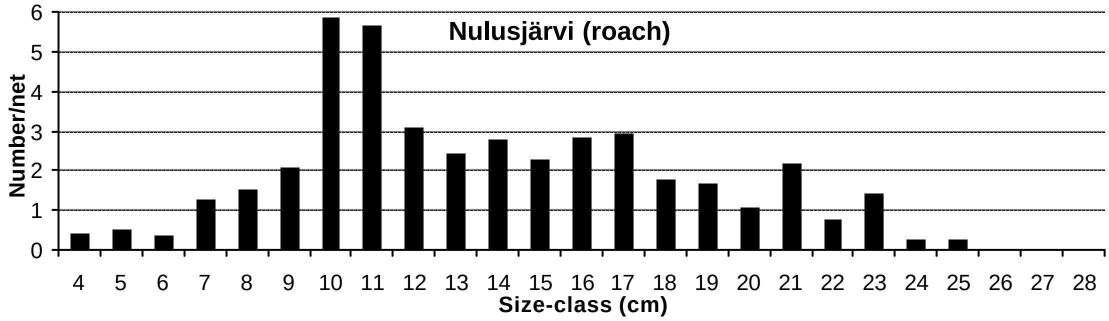


Fig. 29. Size distributions of perch and roach in test fishing catch from Lake Nulusjärvi 2006.

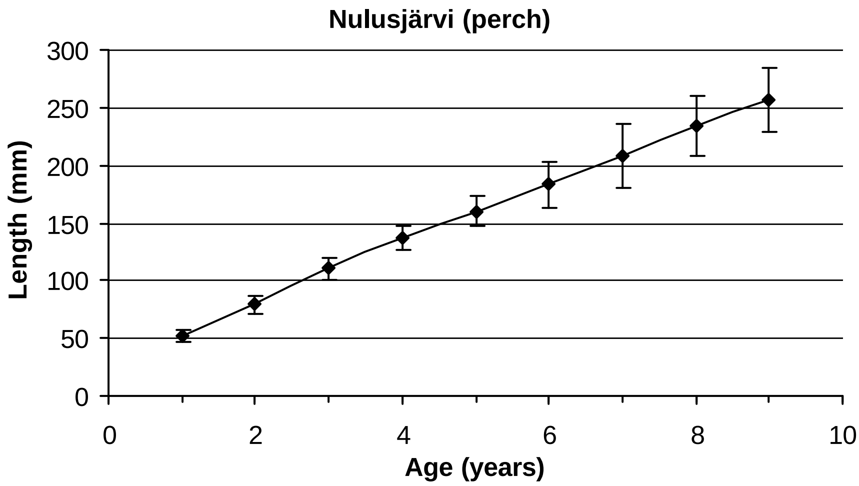


Fig. 30. Back calculated average lengths of perch at age in Lake Nulusjärvi 2006 and standard deviations (SD), n = 81.

Oustajärvi (type 3)

The total CPUE's of Lake Oustajärvi were 1696 g/net and 22 ind./net (Table 23). Based on test fishing results perch and pike are the only fish species that occur in Lake Oustajärvi. According to CPUE's perch is dominant species in both biomass catch (1621 g/net) and number catch (22 ind./net). The proportion of predatory fishes (perch >15 cm and pike) of the biomass catch was 85 % and number catch 41 % respectively. Even solely the biomass proportion of piscivorous perch (>15 cm) in the catch (81 %) can be considered exceptional high.

Table 23. Total catches, CPUE's and percentages according to fish species in Lake Oustajärvi 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	19455	1621,3	95,6	265	22,1	98,5
Pike	892	74,3	4,4	4	0,3	1,5
Total	20347	1695,6	100,0	269	22,4	100,0
Percids	19455	1621,3	95,6	265	22,1	98,5
Perch >15 cm	16462	1371,8	80,9	107	8,9	39,8
Predatory fishes	17354	1446,2	85,3	111	9,3	41,3

Three different year-class clearly separate from the size distribution of perch in Lake Oustajärvi 2006, which is very exceptional in case of perch (Fig. 31). Past summer 2006 juveniles (0+-age group) separate from size distribution at point of 5-6 cm in length fishes. Year-class 2005 (1+-age group) separates at point of 10-15 cm in length individuals. According to age determinations almost all 19-22 cm in length individuals belong to the year-class 2004 (2+-age group).

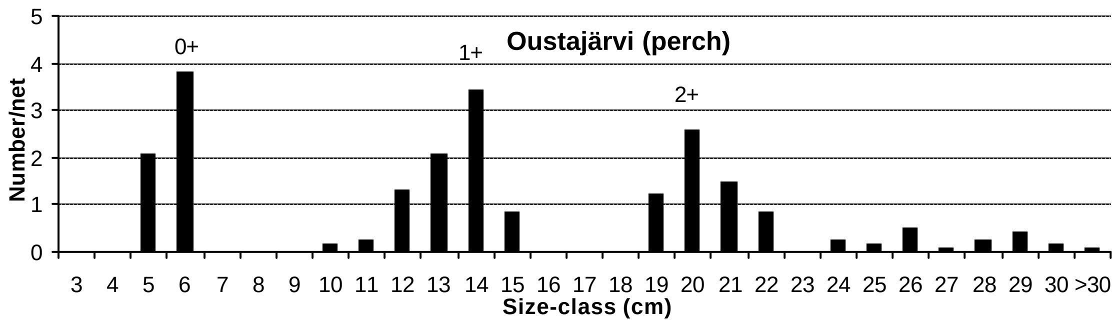


Fig. 31. Size distribution of perch in test fishing catch from Lake Oustajärvi 2006, 0+ = year-class 2006, 1+ = year-class 2005 and 2+ = year-class 2004.

Perch in Lake Oustajärvi were on an average 7,1 cm in length after the first growth season at age 1 and 21,0 cm in length at age 5 respectively (Fig. 32). The growth of perch in Lake Oustajärvi is very fast, because perch exceeds 20 cm length on an average during the fourth growth season. In case of year-class 2004 individuals exceeded 20 cm length during the third growth season (Fig. 31), which can be considered exceptional fast growth even in whole Finland scenario. The year-class 2003 was totally missing from test fishing catch, which may due to failure of reproduction or increased predation by older individuals of perch. Nevertheless, this has made enable the exceptional fast growth of perch. Because if we look at closer the growth of different year-classes, we can see that the growth rate of perch has increased after year 2003 especially in case of year-classes 2002 and 2004 (Fig. 33).

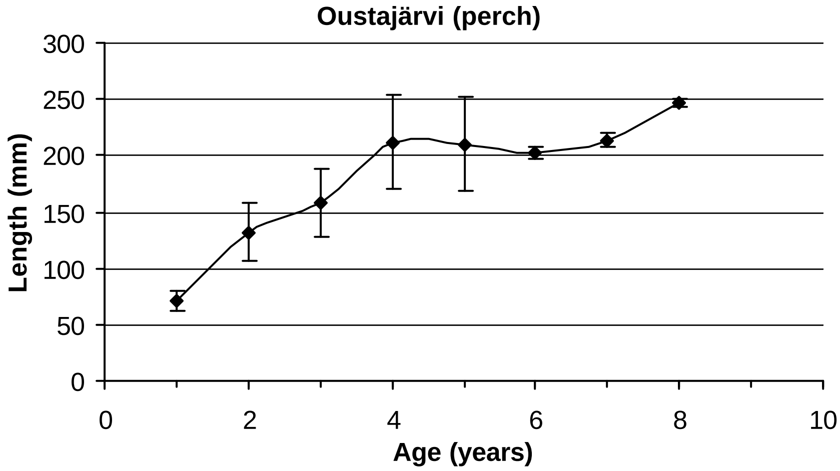


Fig. 32. Back calc ulated average lengths of perch at age in Lake Oustajärvi 2006 and standard deviations (SD), n = 83.

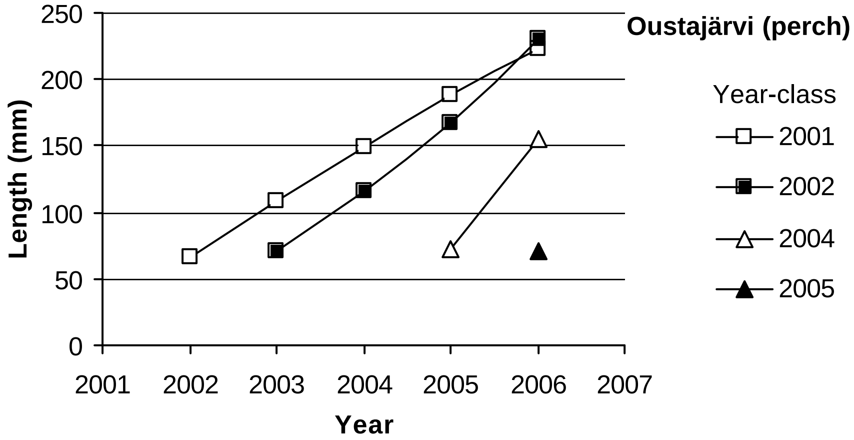


Fig. 33. Back calculated average lengths of perch at age for different year-classes in Lake Oustajärvi 2006.

Pirttijärvi (type 3)

The total CPUE's of Lake Pirttijärvi were 869 g/net and 34 ind./net (Table 24). Based on test fishing results there occurs at least five different fish species in Lake Pirttijärvi. According to CPUE's the most important species in biomass catch were perch (554 g/net) and roach (206 g/net). The most abundant species in number catch were also perch (19 ind./net) and roach (11 ind./net). The proportion of other fish species in the catch was minor. Percid fishes (perch and ruffe) dominate with 65 % proportion of the biomass catch, whereas proportion of cyprinid fishes (roach and bleak) remained 28 %. In case of number catch percid fishes were dominant with 61 % proportion of the catch.

Table 24. Total catches, CPUE's and percentages according to fish species in Lake Pirttijärvi 2005.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	13288	553,7	63,7	460	19,2	56,0
Ruffe	161	6,7	0,8	44	1,8	5,4
Pike	1647	68,6	7,9	2	0,1	0,2
Roach	4939	205,8	23,7	271	11,3	33,0
Bleak	818	34,1	3,9	44	1,8	5,4
Total	20853	868,9	100,0	821	34,2	100,0
Percids	13449	560,4	64,5	504	21,0	61,4
Cyprinids	5757	239,9	27,6	315	13,1	38,4

The dominant size-class of perch in Lake Pirttijärvi was summer 2005 juveniles that separate from size distribution at point of 5-6 cm in length individuals (Fig. 34). The dominant size-class of roach in Lake Pirttijärvi was individuals of 10-11 cm in length. Also 15-17 cm in length individuals were numerous in the catch.

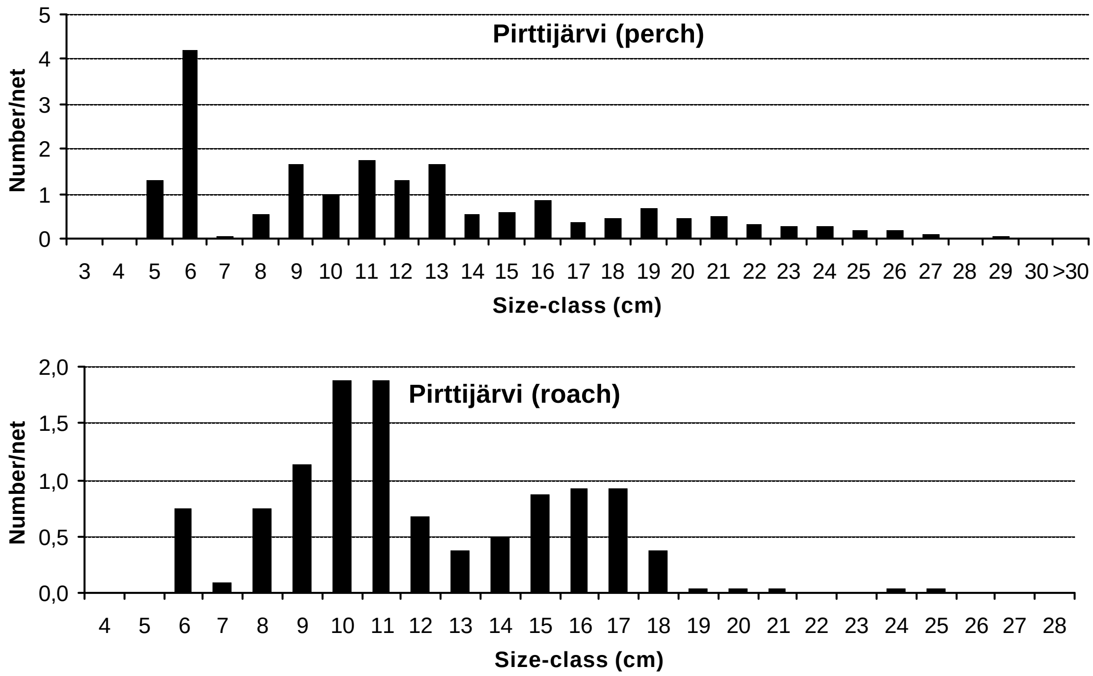


Fig. 34. Size distributions of perch and roach in test fishing catch from Lake Pirttijärvi 2005.

Perch in Lake Pirttijärvi were on an average 8,4 cm in length at age 2 and 18,0 cm in length at age 5 respectively (Fig. 35). The growth of perch in Lake Pirttijärvi is quite fast, because perch exceeds 20 cm length on an average during the sixth growth season. The growth of perch is also quite constant during the first eight growth seasons.

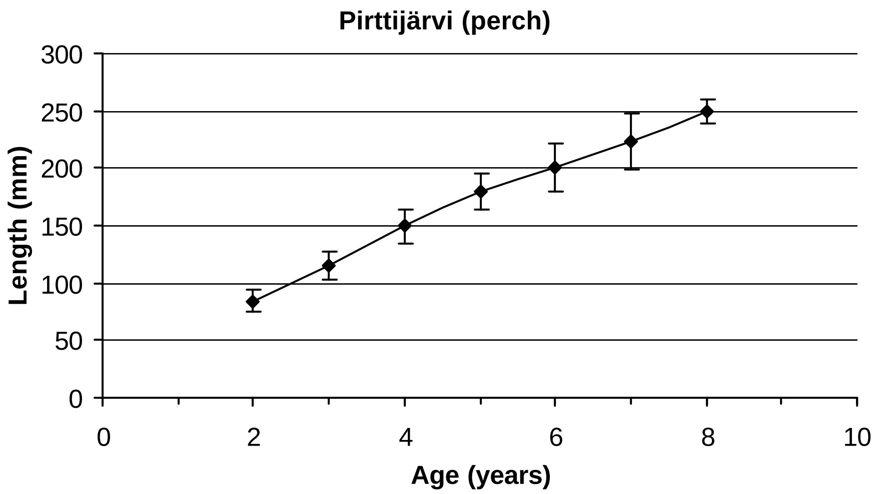


Fig. 35. Back calculated average lengths of perch at age in Lake Pirttijärvi 2005 and standard deviations (SD), n = 50.

Pääjärvi (type 3)

The total CPUE's of Lake Pääjärvi were 1754 g/net and 94 ind./net (Table 25). Based on test fishing results there occurs only three different fish species in Lake Pääjärvi. According to CPUE's the most important species in biomass catch were roach (1094 g/net) and perch (576 g/net). The most abundant species in number catch were also roach (71 ind./net) and perch (23 ind./net). The proportion of other fishes (only one pike) was minor. Cyprinid fishes (roach) were dominant with 62 % proportion of the biomass catch and 76 % proportion of the number catch.

Table 25. Total catches, CPUE's and percentages according to fish species in Lake Pääjärvi 2005.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	9210	575,6	32,8	366	22,9	24,5
Pike	1350	84,4	4,8	1	0,1	0,1
Roach	17497	1093,6	62,4	1129	70,6	75,5
Total	28057	1753,6	100,0	1496	93,5	100,0
Percids	9210	575,6	32,8	366	22,9	24,5
Cyprinids	17497	1093,6	62,4	1129	70,6	75,5

Two dominate year-class clearly separate from the size distribution of perch in Lake Pääjärvi 2005 (Fig. 36). Summer 2005 juveniles separate from the size distribution at point of 5-6 cm in length individuals. Another dominant year-class (probably 2003) separates at point of 10-12 cm in length individuals. The overwhelming dominant size-class of roach in Lake Pääjärvi was individuals of 7-8 cm in length. Also 13-17 cm in length individuals were numerous in the catch.

Perch in Lake Pääjärvi were on an average 8,6 cm in length at age 2 and 17,9 cm in length at age 5 respectively (Fig. 37). The growth of perch in Lake Pääjärvi is moderate, because perch exceeds 20 cm length on an average during the seventh growth season. The growth of perch is also quite constant during the first six growth seasons, but seems to slow down after the individuals have exceed 20 cm length.

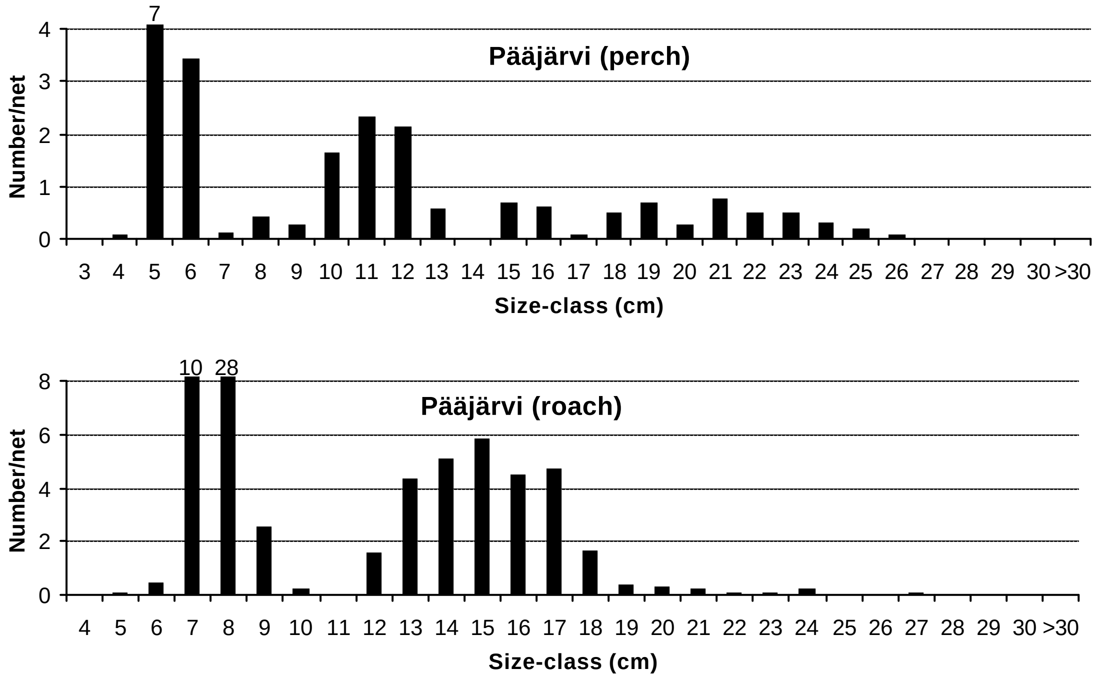


Fig. 36. Size distributions of perch and roach in test fishing catch from Lake Pääjärvi 2005.

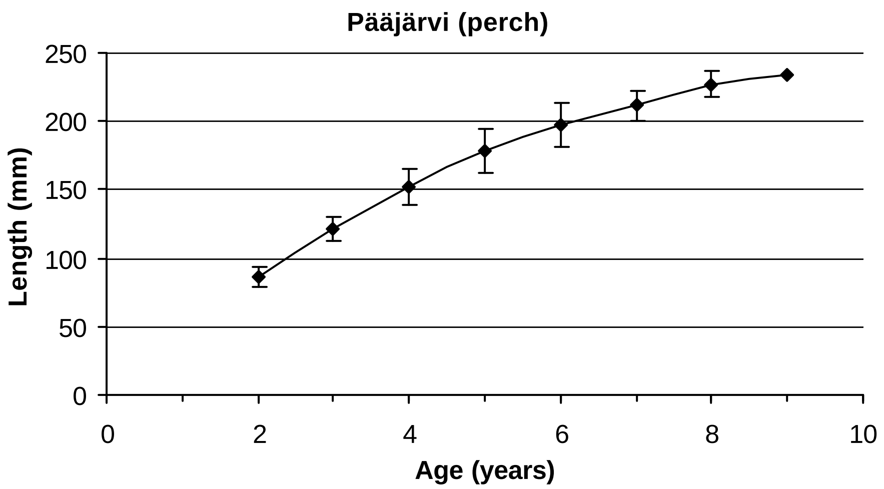


Fig. 37. Back calculated average lengths of perch at age in Lake Pääjärvi 2005 and standard deviations (SD), n = 50.

Nuuksujärvi

The total CPUE’s of Lake Nuuksujärvi were 5824 g/net and 236 ind./net (Table 26), which can be considered very high. Based on test fishing results there occurs only three different fish species in Lake Nuuksujärvi. According to CPUE’s the most important species in biomass catch were roach (3242 g/net) and perch (2173 g/net). The most abundant species in number catch were also roach (130 ind./net) and perch (106 ind./net). Cyprinid fishes (roach) were dominant with 56 % proportion of the biomass catch and 55 % proportion of the number catch.

Table 26. Total catches, CPUE's and percentages according to fish species in Lake Nuuksujärvi 2006.

Fish species	Total catch (g)	CPUE g/net	Biomass %	Total catch (number)	CPUE number/net	Number %
Perch	34766	2172,9	37,3	1699	106,2	44,9
Pike	6545	409,0	7,0	7	0,4	0,2
Roach	51872	3242,0	55,7	2075	129,7	54,9
Total	93182	5823,9	100,0	3781	236,3	100,0
Percids	34766	2172,9	37,3	1699	106,2	44,9
Cyprinids	51872	3242,0	55,7	2075	129,7	54,9

Three different year-class clearly separate from the size distribution of perch in Lake Nuuksujärvi 2006, which is very exceptional in case of perch (Fig. 38). According to age determinations past summer 2006 juveniles (0+-age group) separate from size distribution at point of 6-7 cm in length fishes. Year-class 2005 (1+-age group) separates at point of 10-12 cm in length individuals and year-class 2004 (2+-age group) at point of 15-17 cm in length individuals respectively. The overwhelming dominant size-class of roach in Lake Nuuksujärvi was individuals of 7-9 cm in length.

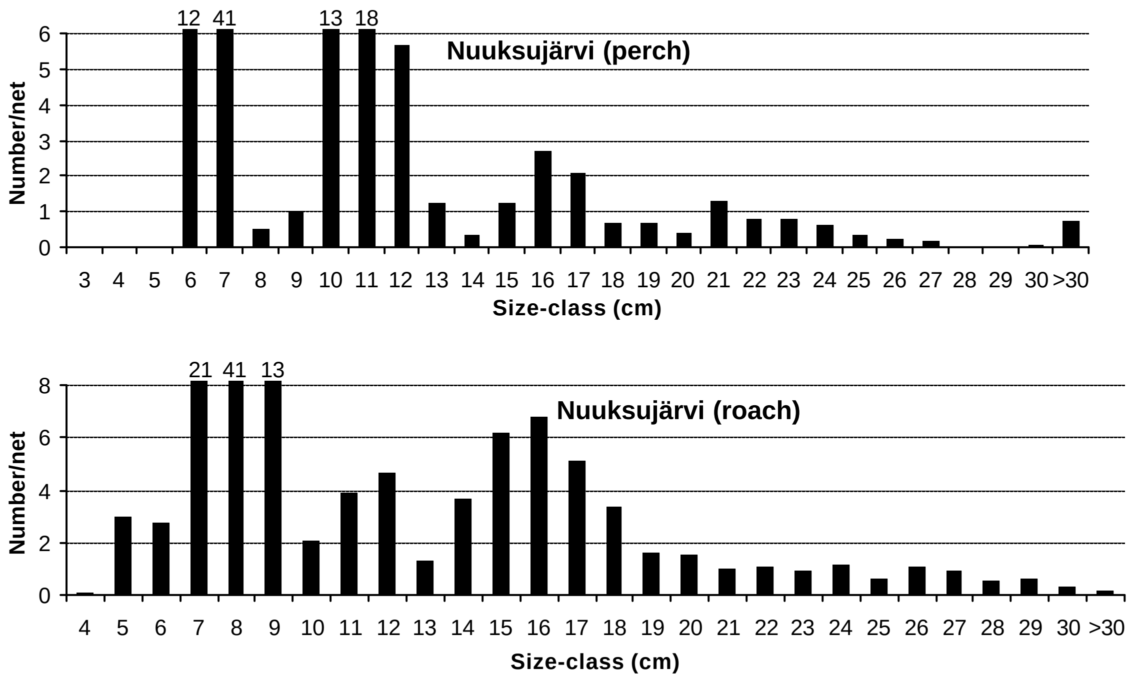


Fig. 38. Size distributions of perch and roach in test fishing catch from Lake Nuuksujärvi 2006.

Perch in Lake Nuuksujärvi were on an average 7,6 cm in length after the first growth season at age 1 and 21,0 cm in length at age 5 respectively (Fig. 39). The growth of perch in Lake Nuuksujärvi is very fast, because perch exceeds 20 cm length on an average during the fifth growth season. The growth of perch is also quite constant during the first seven growth seasons. The largest perch (36,0 cm) in the catch was measured 10 years old.

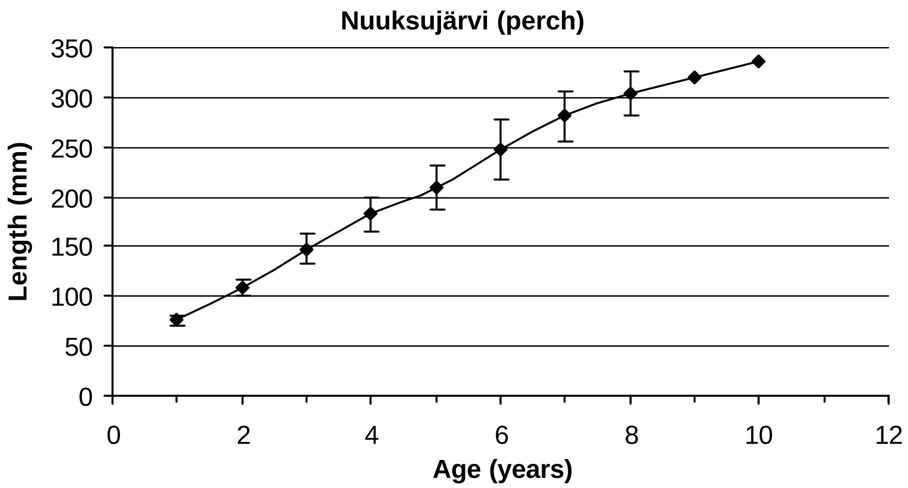


Fig. 39. Back calculated average lengths of perch at age in Lake Nuuksujärvi 2006 and standard deviations (SD), n = 62.

8. Conclusions and future perspectives

This work was one of the responses to TRIWA II goals to evaluate the suitability of selected aquatic biota, here fish assemblages in lakes, for assessing the environmental status of the Torne River system. The work was based on data gathered during this project and data gathered during the TRIWA I project.

In TRIWA I project, a preliminary lake typology was suggested including three main groups, mountain lakes, inland lakes and coastal lakes. Comparison of selected fish community parameters of humic coastal and humic inland lakes of this study indicated no significant differences. Therefore, the revised harmonised typology where the groups inland lakes and coastal lakes are combined, seems to be justified.

Comparison of lake types 2 (small clear water lakes) and 3 (small brown water lakes) in the revised system resulted in a significant difference only for the fish community parameter number of sensitive species. In case of the other variables the variation within the lake types was too high. Apparently the concentration of humic substances in the water is not the only factor affecting the number of sensitive species. Therefore attention should be paid also to other lake characteristics such as depth relations.

The limited number of lakes in this study (n=15) allows no meaningful comparison of Finnish and Swedish national typologies that may include a maximum of 12 and 48 lake types in the Torne River basin, respectively.

The ecological status of the lakes was assessed both with the Finnish EQR4 and the Swedish EQR8 procedure. According to the Finnish EQR4, 12 out of 14 lakes were classified to good or high status whereas according to the Swedish EQR8 only three of the lakes obtained the status good and even five lakes were classified to poor or bad status. The classification results from the Finnish protocol were closer to the ecological status obtained in TRIWA I project by using phytoplankton and benthic macroinvertebrates data. Keeping in mind that the TRIWA lakes were originally selected to meet and determine reference conditions, it seems that the Swedish EQR8 system resulted in too low values of ecological status of lakes.

The striking differences in the classification output between the Finnish EQR4 and the Swedish EQR8 system was discussed in an expert meeting in Trondheim, 4-6 June 2007. Several potential reasons for the different results were found. In the Swedish classification tool all variables are two-tailed and therefore sensitive also to low values of test fishing catches in order to detect the effects of acidification. In the Finnish method only the variables total biomass and number of individuals were two-tailed. There has been also essential differences in the reference lake material of the countries: the Swedish lake set consisted more of oligotrophic and acid sensitive highland lakes whereas the Finnish reference lake set was dominated by more productive lakes of lowland. As a result, the Finnish tool may be more reliable for classification of eutrophied lakes whereas the Swedish one may be better for acidified lakes.

The possibility to develop a common Nordic lake classification system was discussed preliminarily. The participants agreed that this would be a better alternative than continue with the intercalibration of two different systems. However, preparing a new tool demands both time and money, and, especially, more fish community data both from pristine reference lakes and from lake affected by human activities. In the meanwhile, using of the Finnish EQR4 is recommended for fish based classification of lakes in the international river basin district of River Torne.

References

Appelberg M., Berger H.M., Hesthagen T., Kleiven M., Kurkilahti M., Raitaniemi J. & Rask M. 1995. Development and intercalibration of methods in Nordic freshwater fish monitoring. Water, Air and Soil Pollution 85: 401-406.

Bagenal T.B. & Tesch F.W. 1978. Age and growth. In: Bagenal T.(ed.), Methods for assessment of fish production in fresh waters. Blackwell, Oxford. p. 101-136.

Elfvendahl S., Liljaniemi P. & Salonen N. 2006. The River Torne International Watershed — Common Finnish and Swedish typology, reference conditions and a suggested harmonised monitoring program. Länsstyrelsen i Norrbottens län, Luleå 2006:19, 86p.

Holmgren K. 2007. Fiskfaunans variation inom och mellan sjöar av olika karaktär. Fiskeriverket Informerar 2007:1, 44p. (in Swedish with English summary).

Holmgren K., Kinnerbäck A., Pakkasmaa S., Bergquist B. & Beier U. 2007. Bedömningsgrunder för fiskfaunans status i sjöar — utveckling och tillämpning av EQR8. Fiskeriverket Informerar 2007:3, 54p. (in Swedish with English summary).

Kurkilahti M. 1999. Nordic multimesh gillnet — robust gear for sampling fish populations. Academic dissertation, Department of Biology, University of Turku.

Naturvårdsverket. 2006. Naturvårdsverkets föreskrifter om kartläggning och analys av ytvatten enligt förordningen (2004:660) om förvaltning av kvaliteten på vattenmiljön. NFS 2006:1, 19p.

Raitaniemi J., Rask M. & Vuorinen P.J. 1988. The growth of perch, *Perca fluviatilis* L., in small Finnish lakes at different stages of acidification. Ann. Zool. Fennici 25: 209-219.

Tammi J., Rask M. & Olin M. 2006. Kalayhteisöt järvien ekologisen tilan arvioinnissa ja seurannassa. Alustavan luokittelujärjestelmän perusteet. Kala –ja riistaraportteja 383: 1-51. RKTL, Helsinki. (in Finnish).