JYVÄSKYLÄN YLIOPISTON BIO- JA YMPÄRISTÖTIETEIDEN LAITOKSEN TIEDONANTOJA
PROCEEDINGS OF THE DEPARTMENT OF BIOLOGICAL AND ENVIRONMENTAL SCIENCE, UNIVERSITY OF JYVÄSKYLÄ

1/2023

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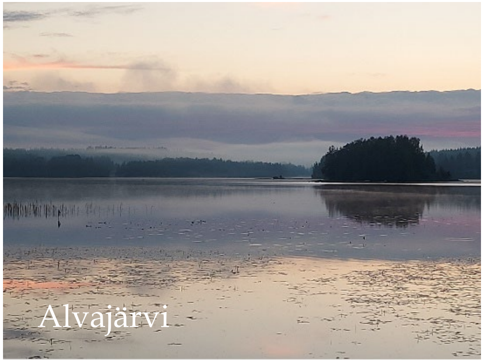
Roach and perch stocks recovered rapidly from 3-year removal fishing: long-term multi-mesh gill net monitoring in small humic lakes



UNIVERSITY OF JYVÄSKYLÄ

Jyväskylän yliopiston bio- ja ympäristötieteiden laitoksen tiedonantoja /
Proceedings of the Department of Biological and Environmental Science,
University of Jyväskylä

Toimittaja / Editor: Timo J. Marjomäki

Co-funded by
the European Union

Kansikuva / Cover photo: Juha Karjalainen, Juhani Pirhonen, Timo J. Marjomäki

ISBN 978-951-39-9539-3 (PDF)
ISSN 2669-8986
Julkaisun pysyvä osoite / Permanent address to this publication:
http://urn.fi/URN:ISBN:978-951-39-9539-3

Jyväskylä 2023

ABSTRACT

Karjalainen, Juha, Keskinen, Tapio, Ruokonen, Timo J. & Marjomäki, Timo J.
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Jyväskylä: University of Jyväskylä, 2023, 41 p. + 8 appendices.
Proceedings of the department of biological and environmental science, University of Jyväskylä 1/2023
ISSN 2669–8986
ISBN 978-951-39-9539-3 (PDF)

Knowledge about the fish abundance and community composition is important in fisheries management, assessment of the exploitation potential, ecological state of lake ecosystems and impact of intensive fishing in lake restoration. In small, shallow lakes with no commercial fishing, estimating the fish stocks is challenging. Catch data are usually not collected, and direct counting of fish, e.g. by echo sounding is imprecise. Standardized test gill net fishing is widely used in Europe in assessment of ecological status in water management work. In this study, the changes in the fish communities of four central Finnish lakes (Jyväs-, Tuomio-, Alva- and Patajärvi) were monitored for more than 20 years by test gill net fishing. Fishing was done with standard multi-mesh gill nets, and the catches were sampled for age and growth determinations. In 2004–2006, a biomanipulation campaign with fyke nets was carried out in Jyväsjärvi, enabling the estimation of the roach and perch population size using cohort analysis. In every lake, the dominant species in the gill net catches were roach and perch. The average share of perch was the highest in the brownish Patajärvi and roach in Tuomio- and Alvajärvi. The share of perch increased in Tuomio-, Alva- and Patajärvi during the monitoring period. In total, 16 species were caught from the four lakes. The gill net catch per unit effort (CPUE) was regularly the highest in Tuomiojärvi, where net fishing is prohibited. The three-year intensive fyke net fishing catch of Jyväsjärvi was 104 tons (308 kg ha^{-1}), mostly bream, roach and perch. Intensive fishing targeted 2-year-old and older fish, and based on the cohort analysis, the roach and perch abundance decreased to less than 10 % of the original. The share of old and large perch and roach decreased. The gill net CPUE of perch and roach varied strongly between-years in all lakes. In Jyväsjärvi, the gill net CPUE of roach decreased during the intensive fishing period, but not statistically significantly. With the abundant year-classes hatching during that period, the roach and perch populations quickly recovered after the intensive fishing ended, and the gill net CPUE of the roach returned to the pre-intensive fishing level. With the applied gill net fishing effort, the CPUE provided an index of the abundance of fish stocks and the proportions of the most abundant species. The selectivity of the fyke nets and gillnet made it difficult to use uncorrected CPUE as a comparable index of abundance, fyke nets targeting older age groups.

Keywords: fish biomass; fisheries; management; perch; roach; size distribution; test gill net fishing; unit catch.

TIIVISTELMÄ

Karjalainen, Juha, Keskinen, Tapio, Ruokonen, Timo J. & Marjomäki, Timo J.
Särki- ja ahvenkannat toipuivat nopeasti kolmen vuoden tehokalastusjakson jälkeen: koeverkkokalastus pienten humusjärvien pitkäaikaisseurannassa
Jyväskylä: Jyväskylän yliopisto, 2023, 41 s. ja 8 liitettä.
Jyväskylän yliopiston bio- ja ympäristötieteiden laitoksen tiedonantoja 1/2023
ISSN 2669–8986
ISBN 978-951-39-9539-3 (PDF)

Kalatiheyden, -biomassan ja -yhteisön koostumuksen tunteminen on tärkeää kalastuksen ohjauksessa, kalataloudellisen hyödyntämispotentiaalin arvioinnissa, järviekosysteemien ekologisen tilan määrityksessä sekä hoitokalastuksen vaikutuksien arvioinnissa. Pienissä, matalissa järvissä, joissa ei harjoiteta laajamittaista kaupallista kalastusta, kalakantojen arvioiminen on haasteellista. Saalistietoja ei yleensä kerätä, ja kalatiheyden suora mittaus esim. kaikuluotaimella on epätarkkaa ja epätäsmällistä. Standardoitua koeverkkokalastusta käytetään laajasti Euroopassa ekologisen tilan arviointiin vesien hoitotyössä. Tässä tutkimuksessa seurattiin yli 20 vuoden ajan koeverkkokalastuksin neljän keskisuomalaisen järven (Jyväs-, Tuomio-, Alva- ja Patajärvi) kalayhteisöjen muutoksia. Koeverkkokalastukset tehtiin usean solmuvälin tutkimusverkoilla keräten samalla saaliista näytteitä ikä- ja kasvumäärityksiin. Vuosina 2004–2006 Jyväsjärvellä toteutettiin rysäpyyntinä hoitokalastus, mikä mahdollisti särki- ja ahvenpopulaation koon arvioinnin kohorttianalyysillä. Kaikilla tutkimusjärvillä verkkosaaliin valtalajeja olivat särki ja ahven. Keskimääräinen ahvenen osuus oli suurin ruskeavetisessä Patajärvessä ja särjen Tuomio- ja Alvajärvessä. Ahvenen osuus kasvoi Tuomio-, Alva- ja Patajärvellä seurantajakson aikana. Kaikkiaan saaliiksi neljältä järveltä saatiin 16 kalalajia. Yksikkösaalis oli säännöllisesti korkein Tuomiojärvellä, jossa verkkokalastus on kiellettyä. Jyväsjärven kolmen vuoden hoitokalastuksen saalis oli 104 tonnia (308 kg ha^{-1}). Eniten saaliissa oli lahnaa, särkeä ja ahventa. Hoitokalastus kohdentui 2-vuotiaisiin ja vanhempiin kaloihin, ja särjen ja ahvenen populaatiot pienenivät kohorttianalyysin perusteella alle 10 %:iin alkuperäisestä. Vanhojen ja suurten ahventen ja särkien osuus väheni. Ahvenen ja särjen koeverkkoyksikkösaaliin vuosien välinen vaihtelu oli kaikilla järvillä suurta. Jyväsjärvellä särjen verkkoyksikkösaalis pieneni rysähoitokalastusjakson aikana, mutta ei tilastollisesti merkitsevästi. Jaksolla syntyneiden runsaiden vuosiluokkien myötä särki- ja ahvenkannat toipuivat nopeasti hoitokalastuksen päätyttyä ja särjen verkkoyksikkösaalis palautui tehopyyntiä edeltävälle tasolle. Toteutetulla pyyntiponnistuksella verkkoyksikkösaalis antoi indeksin kalakantojen runsaudesta ja runsaslukuisimpien lajien lajisuhteista. Koeverkon ja rysän valikoivuus hankaloitti korjaamattomien yksikkösaaliiden käyttöä kalakannan indeksinä. Rysäkalastus kohdistui vanhempiin ikäryhmiin.

Hakusanat: ahven; hoitokalastus; kalabiomassa; kalasto; koeverkkokalastus; kokojakauma; särki; yksikkösaalis.

CONTENTS

1 INTRODUCTION

Science-based information about freshwater fish communities and population abundance is an essential part of many environmental monitoring programmes (Radinger *et al*. 2019). The fish communities in lakes and rivers produce versatile ecosystem services, sensitively reflect multifactorial environmental stressors and are an essential component of biodiversity. Naturally, the monitoring of fish stocks is required in the assessment and governance of recreational and commercial fishing in order to avoid over-exploitation of the most desirable species. Monitoring approaches and methods vary depending on the questions asked (Radinger *et al*. 2019), but in general, lake fish monitoring usually requires catch per unit effort (CPUE) data from recreational and/or commercial fishing and standardised test fishing organized by managers or researchers. Test fishing with multi-mesh gill nets, fyke nets, seines, trawls, and electrofishing provides information on the species and size composition of the fish community, although the catches of different gear always provide information on only a certain part of the fish community (Olin *et al*. 2009, Jurvelius *et al*. 2011, Rask *et al*. 2020).

Biomanipulation of fish communities has been used to improve the water quality of eutrophicated lakes (Carpenter *et al*. 1985, Mehner *et al*. 2002). Typically, in biomanipulation projects, the main objective is to extensively reduce the abundance of planktivorous fish populations (often especially cyprinids) to create a top-down cascading effect via zooplankton predation to phytoplankton. The results of biomanipulation have been variable and often temporary (Drenner and Hambright 1999, Mehner *et al*. 2002). Short-term changes in fish populations and water quality usually have been seen if the mass removal has been effective enough, 70–90 % removal of the stocks of cyprinids. However, in many cases fish populations can compensate for temporary intensive fishing by increasing their growth, reproduction and survival after the fishing period (Mehner *et al*. 2002). The long-term 22-year mass removal of cyprinids in Lake Tuusulanjärvi, Southern Finland, did not cause long-term changes in fish abundance and species relations (Rask *et al*., 2020). The total catch of mainly bream (*Abramis brama*), white bream (*Blicca bjoerkna*) and roach (*Rutilus rutilus*) varied between 30 and 180 kg ha^{-1}, 22-year total catch being 1616 kg ha^{-1} in Tuusulanjärvi.

The fish community of four boreal lakes in Central Finland have been monitored for more than 20 years and this report summarizes the main results of the monitoring programme. All study lakes, Jyväsjärvi, Tuomiojärvi, Alvajärvi, and Patajärvi, are located in the municipality of Jyväskylä. Their catchment areas have been subject to intensive anthropogenic land use. Jyväsjärvi has been in poor condition in the 1960s and 1970s due to municipal and industrial wastewater but has since recovered thanks to a prominent reduction in external loading and human-assisted hypolimnetic oxygenation (Salonen *et al.* 2005, Kuha *et al*. 2016). In the biomanipulation project in Jyväsjärvi in 2004–2006, intensive fishing of cyprinids and perch was practiced with fyke nets. Recreational fishing with angling, trolling and lure fishing is allowed in all study lakes. In Jyväsjärvi, Alvajärvi and Patajärvi, gill net fishing is allowed for commercial and recreational fishers. Gill net fishing is prohibited in Tuomiojärvi. Fishing in Jyväsjärvi is currently mainly recreational gill netting and trolling targeting pikeperch, in addition to winter and summer angling. Fishing in Alvajärvi and Patajärvi is mainly recreational. The impact of recreational fishing focusing on roach and perch is negligible in the study lakes.

The aim of this study is to monitor the changes in the abundance and composition of the fish community in the lakes and to analyze how multi-mesh gill net test fishing reflects these changes. In Jyväsjärvi, Pope's (1972) cohort analysis was applied, on the basis of fyke net catches obtained in biomanipulation, to estimate the abundance and biomass of roach (*Rutilus rutilus*) and perch (*Perca fluviatilis*) populations, the two dominant species in all lakes. In particular, it was investigated how the catch per unit effort of multi-mesh gill net fishing corresponded to large changes in population density and biomass in Jyväsjärvi.

2 MATERIAL AND METHODS

2.1 Study lakes

The fish communities of lakes Jyväsjärvi, Tuomiojärvi and Alvajärvi were monitored in the years 2001–2021 and Patajärvi 2001–2015. Tuomiojärvi and Alvajärvi are located in the catchment area of the River Tourujoki, which flows into Jyväsjärvi (Fig. 1). Lake Patajärvi is located in the Lake Muuratjärvi catchment. All lakes are mesotrophic (Table 1). In Finnish lake typology (Anon. 2013), they belong to category 2, small humic lakes, with the exception of Patajärvi, which belongs to category 6, humus-rich lakes. These two categories of lakes make up 22.5 % of all lakes in Finland (9 % of the lake surface area).

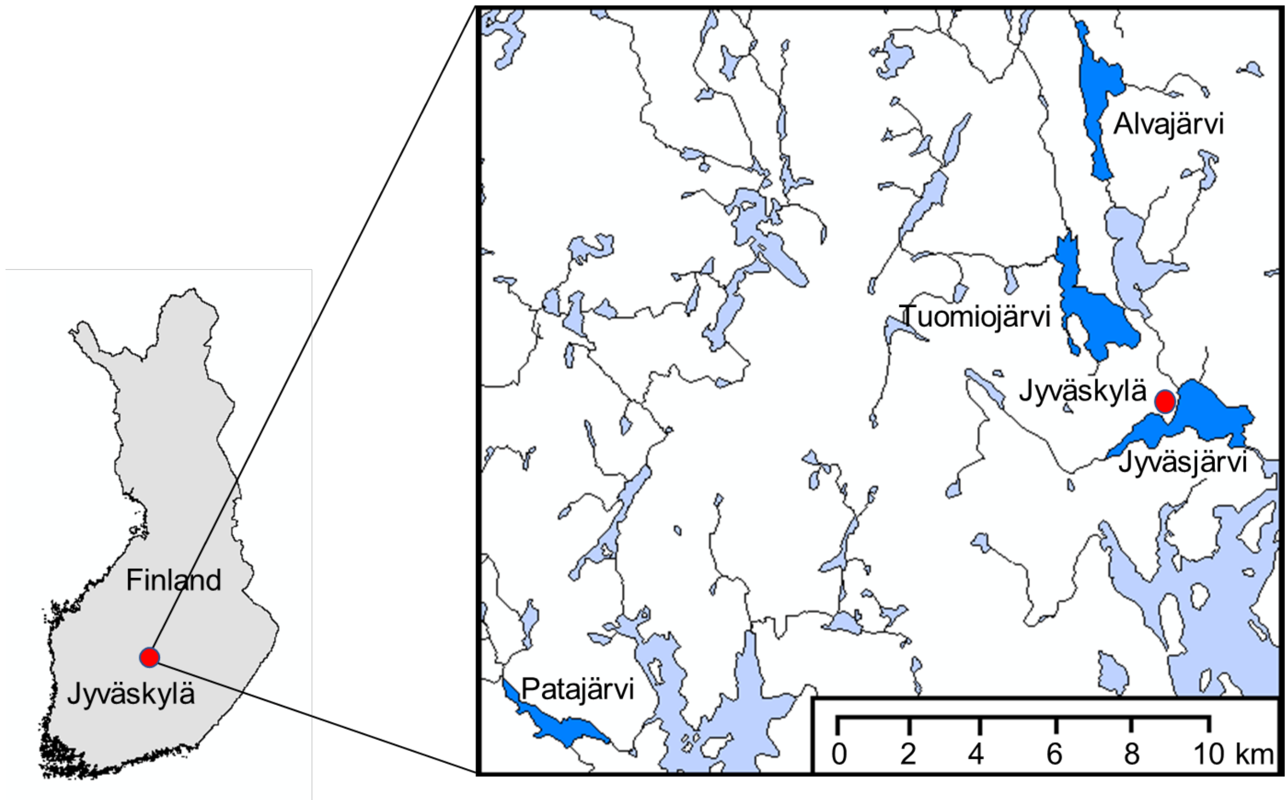

FIGURE 1 Location of the study lakes in Central Finland.

TABLE 1 Characteristics of the study lakes Jyväsjärvi, Tuomiojärvi, Alvajärvi and Patajärvi. The mean (min–max) phosphorous and nitrogen concentrations and colour in epilimnion in July–August in 2001–2018 are represented. Data from SYKE's databases (https://www.syke.fi/fi-FI/Avoin_tieto/Ymparistotietojarjestelmat).

	Jyväsjärvi	Tuomiojärvi	Alvajärvi	Patajärvi
Location N	62°14' 16”	62°15' 45”	62°18' 58”	62°09' 23”
E	25°46' 55”	25°43' 08”	25°43' 04”	25°26' 56”
Area (km^2)	3.37	2.98	2.09	1.28
Maximum depth (m)	26	13	17	18
Mean depth (m)	7	4	4	6
Total phosphorus (µg l^{-1})	27 (16–41)	17 (12–21)	31 (24–41)	18 (15–23)
Total nitrogen (µg l^{-1})	646 (460–900)	431 (380–500)	628 (470–950)	544 (470–630)
Colour (Pt mg l^{-1})	60 (40–80)	43 (35–50)	84 (70–100)	97 (80–130)

2.2 Gill net test fishing

The fish communities of the four study lakes have been monitored by gill net test fishing annually from 2001 to 2013 and every other year thereafter until 2021, except in Patajärvi, where the last test fishing was carried out in 2015. Spatially, fishing was carried out using stratified random sampling based on depth strata (Fig. 2, Table 2). Lakes were divided into 50x50 meters squares, and the nets in each stratum were placed in randomly selected squares. The orientation of each of the littoral nets (parallel or perpendicular to the shoreline) was also randomized. The total fishing effort was 12–30 gill net days per lake per year. Test fishing was mainly carried out in August (Appendix 1). The nets were set before noon and lifted the next morning (soak time 20–24 h).

In 2001–2009, YK-type multi-mesh nets (30 m × 1.5 m, 9 panels with mesh sizes 10, 12, 15, 20, 25, 30, 35, 45 and 55 mm from knot to knot) were used, and in 2010–2021 Nordic multi-mesh survey nets (30 m × 1.5 m, 12 panels with mesh sizes 5, 6.25, 8, 10, 12.5, 15.5, 19.5, 24, 29, 35, 43 ja 55 mm from knot to knot, European Standard EN 14757:2005). To ensure the comparability of data throughout the study period, catches were intercalibrated between the net-types used: 5, 6.25 and 8 mm mesh size catches from Nordic nets were excluded, as these mesh sizes do not exist in YK-type gillnets. Furthermore, since the areas of the panel areas differ between the net types used, the catches of the ≥ 10 mm panels of the Nordic-nets were adjusted to match the area of a YK-net panel (5 m^2) by multiplying them by a factor of 1.333 (Voutilainen and Huuskonen 2006). The abundance index, catch per unit effort (CPUE), was measured for each species as wet mass (g net^{-1} day^{-1}) and number (individuals net^{-1} day^{-1}). Unless otherwise noted in the text, all CPUE-estimates are expressed as a stratum volume (Table 2) -weighted average of the stratum-specific averages.

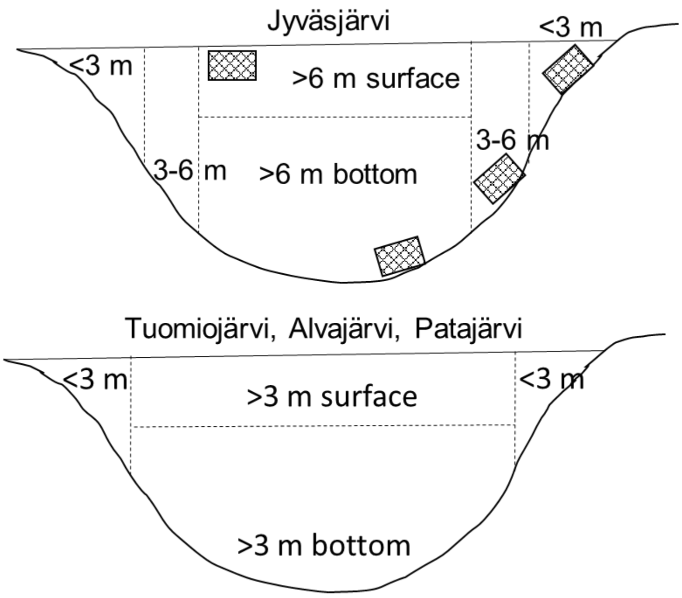

FIGURE 2 Gill net test fishing strata in Jyväsjärvi, Tuomiojärvi, Alvajärvi and Patajärvi. Only Jyväsjärvi had an intermediate sublittoral stratum of 3–6 m.

TABLE 2 The proportional water volumes of test fishing strata and the number of nets in each stratum per fishing day in Jyväsjärvi, Tuomiojärvi, Alvajärvi and Patajärvi. There were 4 strata in Jyväsjärvi and only 3 in Tuomiojärvi, Alvajärvi and Patajärvi (cf., Fig. 2): in these lakes the boundary between the pelagic bottom and surface layers was 3 m, while in Jyväsjärvi it was 6 m.

Stratum	Jyväsjärvi	Tuomiojärvi	Alvajärvi	Patajärvi
< 3 m littoral zone	0.081	0.275	0.239	0.11
3–6 m sublittoral zone	0.264	-	-	-
Bottom layer	0.328	0.338	0.458	0.700
Surface layer	0.327	0.387	0.239	0.190
Gill nets stratum^{-1} day^{-1}	7–12	4–5	4–5	4–5

2.3 Biomanipulation in Jyväsjärvi

In the biomanipulation period 2004–2006, intensive fyke net fishing by commercial fishers targeted potentially planktivorous cyprinids and small perch. The fishing season started every year immediately after the ice-out in late April–early May and continued for 1.5–2 months. The mass of the total catch was recorded on each fishing day and the species composition was estimated from random catch samples (approx. 30 kg per sample) taken once a week.

In 2004, intensive fishing was carried out from 3 May to 2 July. From 8 to 21 fyke nets were used daily by 3 fishers and the nets were emptied on 48 days, a total of 661 fyke net catches during the fishing season. In 2005, intensive fishing was carried out from 27 April to 14 June. Three fishers were fishing with 8–20 fyke nets per day. The nets were emptied on 38 days, totalling 533 fyke net catches. In 2006, one fisher fished with 12 fyke nets from 6 May to 13 June. The fyke nets were emptied 420 times on 35 days. The catch per unit effort was calculated as the number and wet mass of each species per fyke net day (24 h).

2.4 Cohort analysis of roach and perch

Abundances of 2 years old and older roach and perch during the biomanipulation period, May 2004 – July 2006, were estimated using cohort analysis (Pope 1972), a simplified approximation of Virtual Population Analysis (Gulland 1965).

Recorded total daily (d) fyke net catch mass for both species (s) was first converted to individuals (C). These were then divided into catches of different cohorts (c) ($C_{s,c,d}$). This was done on the basis of estimates of mean mass and age distribution obtained from the catch samples. Age distributions were estimated based on the length distribution of the catch samples and the age–length key. One key was used throughout the annual fishing season, as fish growth was low during the season.

The abundance of each cohort ($N_{s,d,c}$) was estimated by Pope's (1972) formula:

$$N_{s,c,d} = N_{s,c,d+1}\, e^{-M_s} + C_{s,c,d}\, e^{-\beta M_s},$$

where M_s = instantaneous other (natural + other fishing) mortality for the species s. The most likely estimate of M was considered to be 0.5 yr^{-1} for both species, 0.00137 d^{-1}. For simplicity, a constant value was used for every cohort at different ages. The parameter that schedules the effect of fishing, β, was set to 0.5. However, it has practically no effect on population size estimation when using the Pope's method on daily basis.

Terminal (= end of fyke net biomanipulation fishing season in 2006) fishing mortality ($F_{s,T}$) was estimated by

$$F_{s,T} = f_T\, q_{s,T},$$

where f_T = terminal fishing effort (fyke net days) during the terminal period, the last 7 days of fishing and q_s = estimate of terminal catchability (proportion of cohort caught with one fyke net per day). Perch q_s was estimated based on the removal method (Leslie & Davis 1939, Braaten's 1969 modification) in the second half of the fishing season, May 16-June 13, 2006, after the spawning season. Catches of perch aged at least two years were combined. A q_s estimate of 0.0047 per fyke net day was considered an overestimate because fish are likely not moving in the lake fast enough to compensate for the daily decrease in fish density at fyke net sites. A value of 0.003 was considered the most probable value for perch $q_{s,T}$. For roach, q could not be estimated using the removal method, as no clear relationship between CPUE and cumulative catch was observed. The most likely value was a slightly lower value compared to perch, 0,002.

The terminal $N_{s,c,T}$ at the beginning of the last fishing week was then estimated using Baranov's (1918) catch equation

$$N_{s,c,T} = C_{s,c,T} (M_s * 7/365 + F_{s,T}) / (F_{s,T} * (1\text{-}\exp(M_s * 7/365 + F_{s,T})),$$

where $C_{s,c,T}$ = fyke nets catch of cohort c of species s during the terminal fishing period = the last 7 days. The Pope's equation was used from that backwards in time.

The impact of uncertainty in M_s and $q_{s,T}$ on $N_{s,d,c}$ estimates was assessed using *@RISK* (Palisade). Daily $N_{s,d,c}$ estimates were recalculated 10 000 times with random constant values of M_s and $q_{s,T}$ drawn from triangular density function distributions (minimum, most likely, maximum) with parameters describing our expert judgement of the uncertainty in their values. The statistical distribution of the 10 000 values of $N_{s,d,c}$ was then used to indicate uncertainty about cohort abundances.

The most likely M_s value of roach, including both natural mortality and mortality cause by fishing other than the intensive fishing, was set to 0.5 a^{-1} and its minimum to 0.25 and maximum to 1.0 based on Peltonen & Horppila (1992), Horppila & Peltonen (1994), Sairanen (2006). Similar values were used for perch, based on Nyberg (1976), Thorpe (1977), Rask & Arvola (1985), Heibo *et al*. (2005), Sairanen (2006), Kokkonen *et al*. (2019).

The values that were the considered the minimum, most probable and maximum for $q_{s,T}$ of roach were 0.0005, 0.002 and 0.005 per fyke net day, respectively. The corresponding values for perch were 0.001, 0.003 and 0.007 per fyke net day.

2.5 Comparison between gill net CPUEs and fish biomass estimates

The CPUE of multi-mesh gill nets (g net^{-1} day^{-1}) and cohort analysis-based estimates of total biomass (kg ha^{-1}) of roach and perch in Jyväsjärvi were compared during the period of intensive fishing in 2004–2006. In this comparison, both estimates included only fish older than 2 years: for gill net catches, only roach larger than 9 cm and perch larger than 11 cm were included in the analysis. Multi-mesh gill net fishing was carried out in August 2003, 2004, and 2005, while fish biomass estimates represented the beginning of the fyke net fishing season in the following spring 2004, 2005 and 2006. Additional data were collected from the literature (Karjalainen *et al*. 1999, Ruuhijärvi *et al*. 2017) to the analysis of the association between roach CPUE from multi-mesh gill net fishing and biomass of roach in lakes.

3 RESULTS AND DISCUSSION

3.1 Catches of intensive fyke net fishing in Jyväsjärvi

During the Jyväsjärvi biomanipulation project in 2004–2006, the total catch of intensive fyke net fishing was 104 tonnes (308 kg ha^{-1}), of which bream 41 tonnes, roach 24 tonnes, and perch 27 tonnes (Table 3). The catch of roach varied between 18 and 28 kg ha^{-1} and perch between 15 and 45 kg ha^{-1} in different years. The bream catch varied from 21 to 68 kg ha^{-1}.

TABLE 3 Fyke net catches in Jyväsjärvi in 2004–2006. "Other" consists of silver bream (B*licca bjoerkn*a), rudd (*Scardinius erythropthalmus*), pikeperch (*Sander lucioperca*), European whitefish (*Coregonus lavaret*us), burbot (*Lota l*ota) and European bullhead (*Cottus gobio*).

Species	2004	2005	2006	Total		
	tonnes	tonnes	tonnes	tonnes	kg ha^{-1}	%
Roach	9.4	8.5	6.1	23.9	71	23
Perch	15.2	5.1	6.9	27.2	81	26
Bream	22.8	10.7	7.2	40.7	121	39
Bleak	0.5	1.3	0.6	7.8	23	7
Ruffe	0.2	0.3	0.4	0.9	3	3
Smelt	0.0	< 0.1	0.6	0.6	2	1
Other	1.6	0.5	0.5	2.6	8	1
Total	55.0	26.4	22.3	103.7	308	

Jeppesen and Sammalkorpi (2002) developed an equation based on the phosphorus concentration of water in Finnish and Scandinavian lakes to estimate how much fish biomass should be removed from per year, so that removal would have a favorable effect on water quality or the fish community. Estimated with this equation, the annual catch requirement of Jyväsjärvi is about 90 kg ha^{-1}. The annual catch from Jyväsjärvi in the first year of intensive fishing period was more than 150 kg ha^{-1}, and over three years averaged about 100 kg ha^{-1} a^{-1}. This removal caused a clear decrease in fish populations. In the extensive fish removal projects in Finland, in the first fishing years, the largest catches have been 130 to 150 kg ha^{-1} a^{-1} in some lakes of the same lake type and nutrient level as Jyväsjärvi (Ruokonen et al. 2019). Annual catch from 30 to 80 kg ha^{-1} has been a typical catch in the early years of the projects. Nevertheless, catches per hectare vary greatly depending on fishing effort, fish community structure and other factors.

Especially in 2005 and 2006, the fyke net roach CPUE in mass decreased significantly during the intensive fishing season (Fig. 3). Perch CPUE decreased during the fishing seasons in 2004 and 2006, but not in 2005 (Fig. 3). The peak CPUE for both species during the first 10 days in 2004 and 2006 is due the spawning season, when mature fish accumulate in the littoral zone. The daily CPUEs of roach, perch, bream, and bleak are presented in Appendix 2.

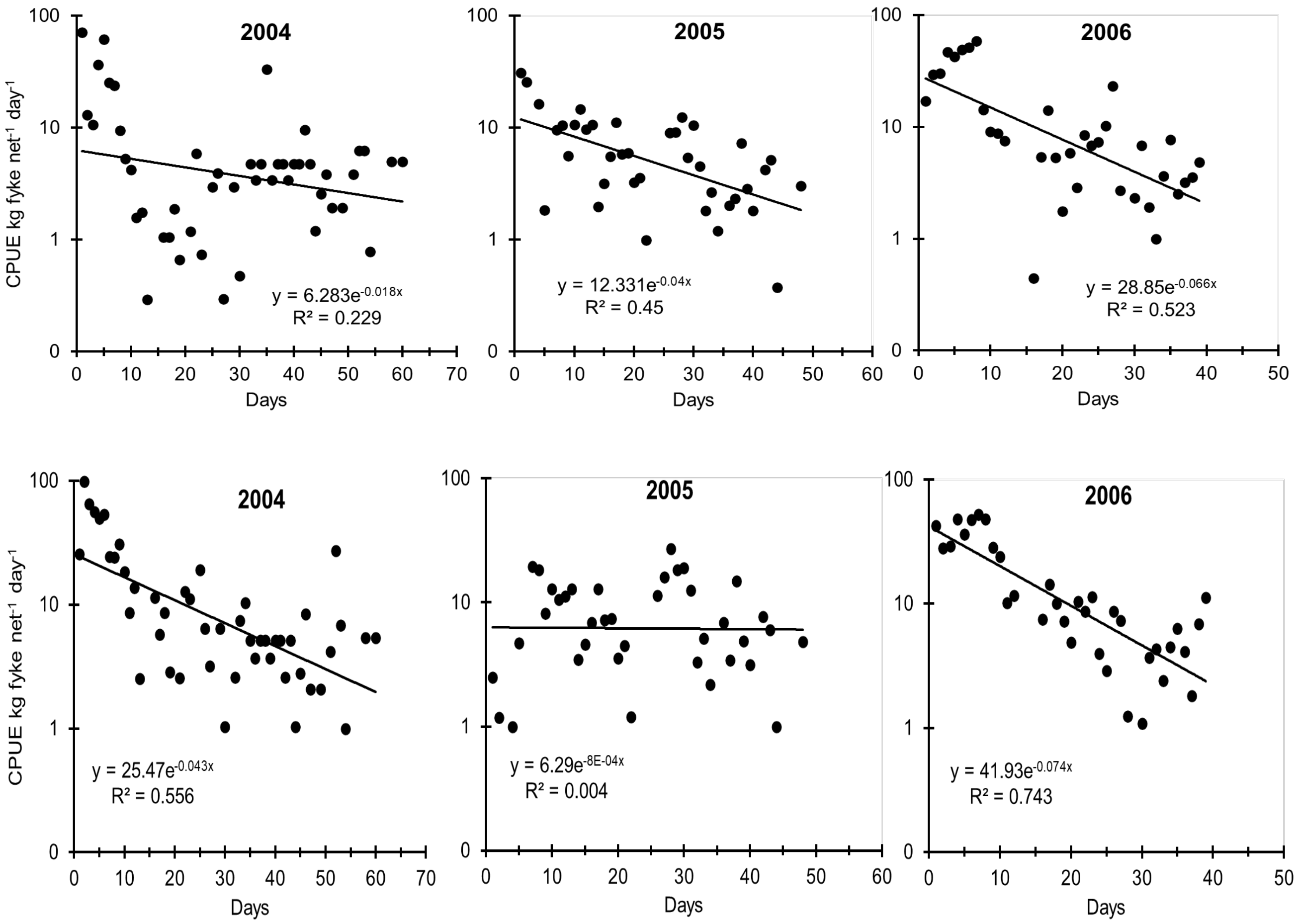

FIGURE 3 Catch per unit effort in mass (CPUE, kg fyke net^{-1} day^{-1}) of roach (upper panels) and perch (lower panels) in Jyväsjärvi during the intensive fishing period 2004–2006. The days on the x-axis start from the beginning of fishing. Note the logarithmic scale on the y-axis.

3.2 Species composition of gill net test fishing catches

Perch and roach were the most numerous fish species in the multi-mesh gill net catches in all lakes, and pikeperch and pike were the most abundant predatory species (Fig. 4 and 5). In Jyväsjärvi, Tuomiojärvi, Alvajärvi and Patajärvi, 14, 12, 11 and 12 fish species were caught, respectively. Altogether, the species were perch (*Perca fluviatilis*), pikeperch, ruffe (*Gymnocephalus cernua*), roach (*Rutilus rutilus*), bream (*Abramis brama*), silver bream (*Blicca bjoerkna*), rudd, bleak (*Alburnus alburnus*), crucian carp (*Carassius carassius*), ide (*Leuciscus idus*), pike (*Esox lucius*), burbot (*Lota lota*), smelt (*Osmerus eperlanus*), whitefish (*Coregonus lavaretus*) and vendace (*Coregonus albula*). Stocked rainbow trout (*Oncorhynchus mykiss*) were caught in Tuomiojärvi occasionally. In Jyväsjärvi, the relative proportions (%) of dominant species, roach and perch, were 24 % (SD = 7) and 61 % (SD = 12) in number, and 34 % (SD = 6) and 42 % (SD = 11) in mass, respectively. In Tuomiojärvi, the relative proportion of roach in number varied from 27 % to 68 % and increased during the study period (correlation between year and CPUE%, Spearman $R_s = 0.681$, $p = 0.003$), while the proportion of perch in number decreased (max = 68 %, min = 27 %, $R_s = -0.618$, $p = 0.008$), but increased in mass (min = 18 %, max n = 51 %, $R_s = 0.696$, $p = 0.002$). Similarly, in Alvajärvi, the relative proportion of roach in number increased during the study period (min = 16 %, max n = 76 %, Spearman $R_s = 0.620$, $p = 0.008$), while the proportion of perch in mass increased (min = 16 %, max n = 47 %, $R_s = 0.605$, $p = 0.010$). In the most humic Patajärvi, which has the smallest littoral area, the proportion of perch increased bot in number (Spearman $R_s = 0.591$, $p = 0.026$) and in mass (Spearman $R_s = 0.662$, $p = 0.010$) during the study period, and the mean CPUE% of perch was greater, 53 % (SD = 16) in number and 51 % (SD = 15) in mass, than in any other lake. In Jyväsjärvi, the CPUE% of roach or perch was not significantly correlated with the sampling year.

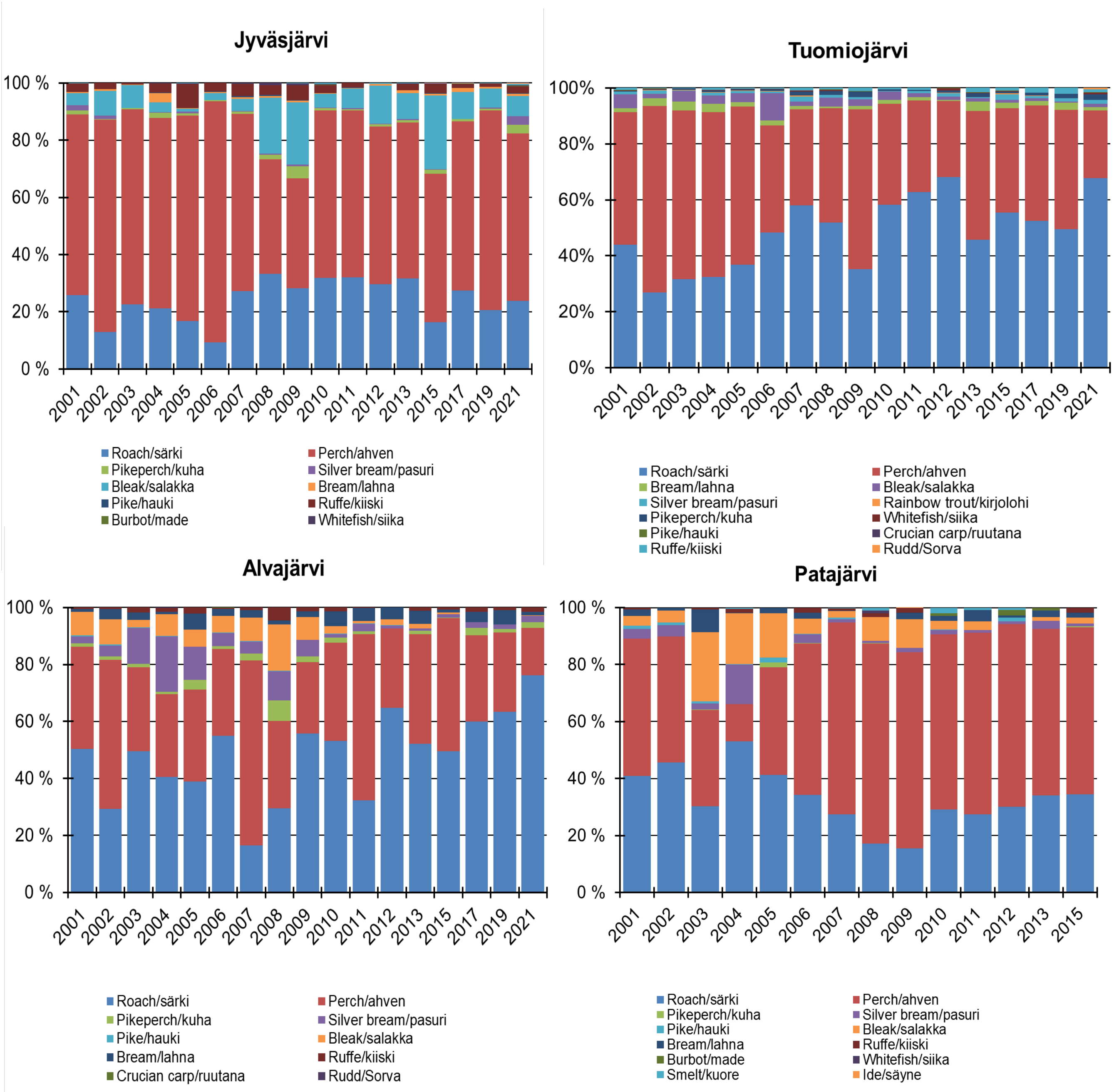

FIGURE 4 Species composition of test fishing gill net catches (proportions of number of individuals) in 2001–2021 in Jyväsjärvi, Tuomiojärvi, Alvajärvi and in 2001–2015 in Patajärvi.

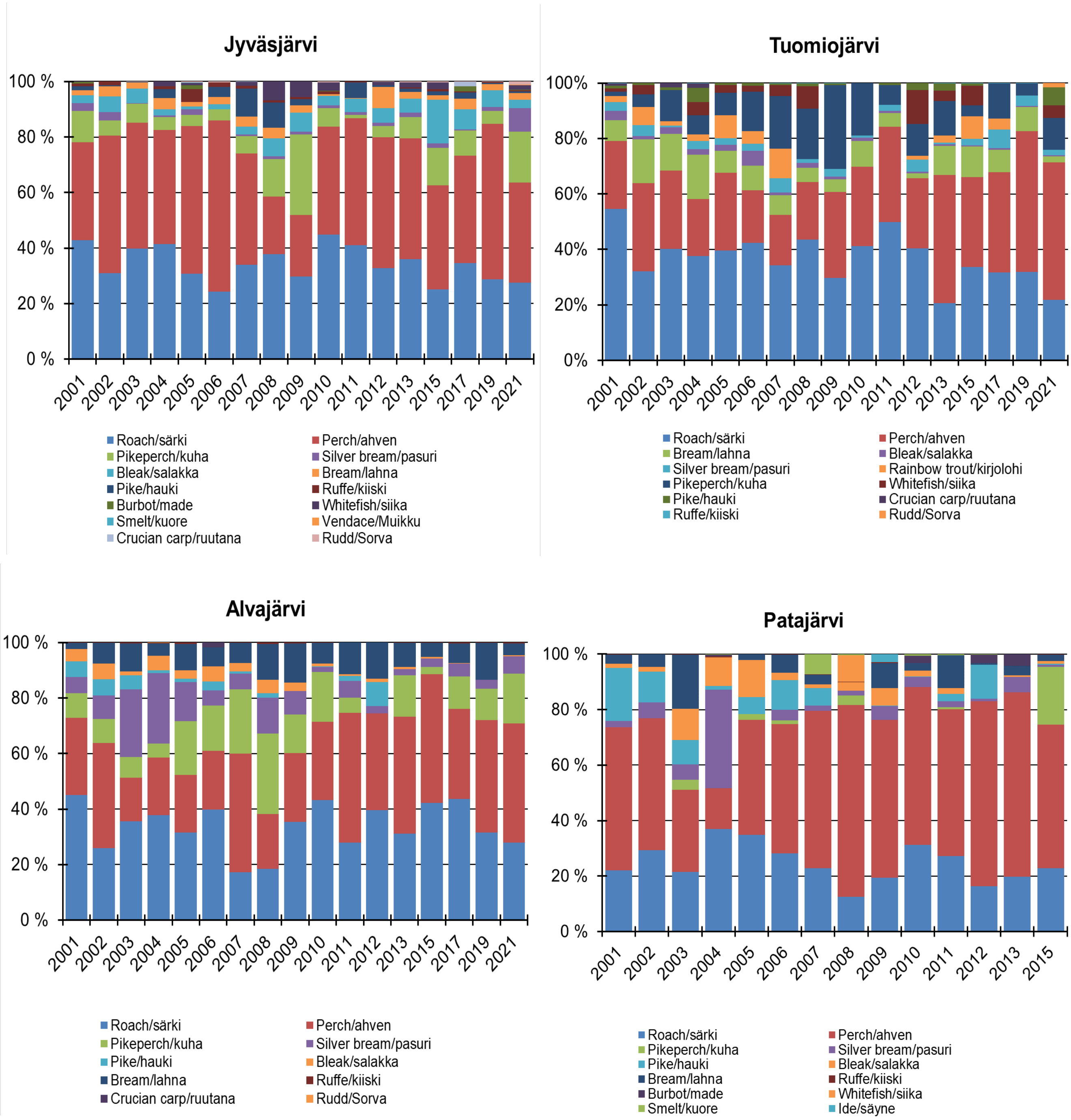

FIGURE 5 Species composition of test fishing gill net catches (proportion of catch mass) in 2001–2021 in Jyväsjärvi, Tuomiojärvi, Alvajärvi and in 2001–2015 in Patajärvi.

3.3 Catch per unit effort of dominant species in gill net fishing

In 2001–2021, the mean roach CPUE in mass (g net^{-1} day^{-1}) in gill net test fishing was 701, 1305 and 637 in Jyväsjärvi, Tuomiojärvi and Alvajärvi, respectively (Fig. 6, Appendix 3–6), and that in 2001–2015 in Patajärvi 162 g net^{-1} day^{-1}. The mean perch CPUE (g net^{-1} day^{-1}) was 832, 1088 and 651 in Jyväsjärvi, Tuomiojärvi and Alvajärvi, respectively, and 344 in Patajärvi in 2001–2015 (Fig. 6). The CPUEs of other species are presented in Appendix 3–6.

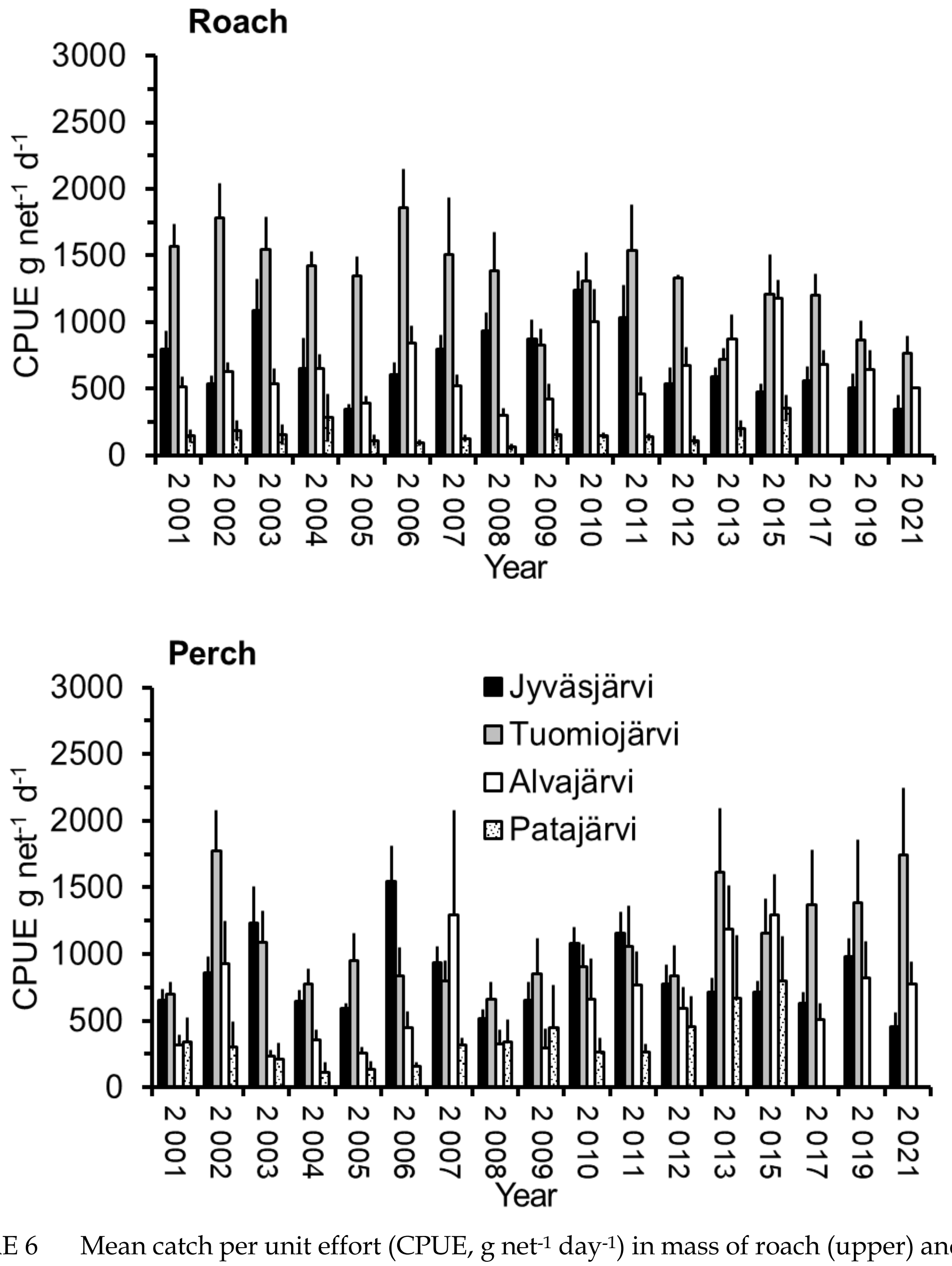

FIGURE 6 Mean catch per unit effort (CPUE, g net^{-1} day^{-1}) in mass of roach (upper) and perch (lower) with multi-mesh gill nets (YK-net intercalibrated) in Jyväsjärvi, Tuomiojärvi, Alvajärvi in 2001–2021 and in Patajärvi in 2001–2015. Vertical lines represent standard errors.

In 2001–2021, the mean gill net roach CPUE in number (individuals net^{-1} day^{-1}) was 17, 58 and 30 in Jyväsjärvi, Tuomiojärvi and Alvajärvi, respectively (Fig. 7, Appendix 3–6) and 10 in in Patajärvi in 2001–2015. The mean perch CPUE (individuals net^{-1} day^{-1}) was 45, 56 and 23 in Jyväsjärvi, Tuomiojärvi and Alvajärvi, respectively, and 15 in Patajärvi in 2001–2015 (Fig. 7). The CPUEs of other species are presented in Appendix 3–6.

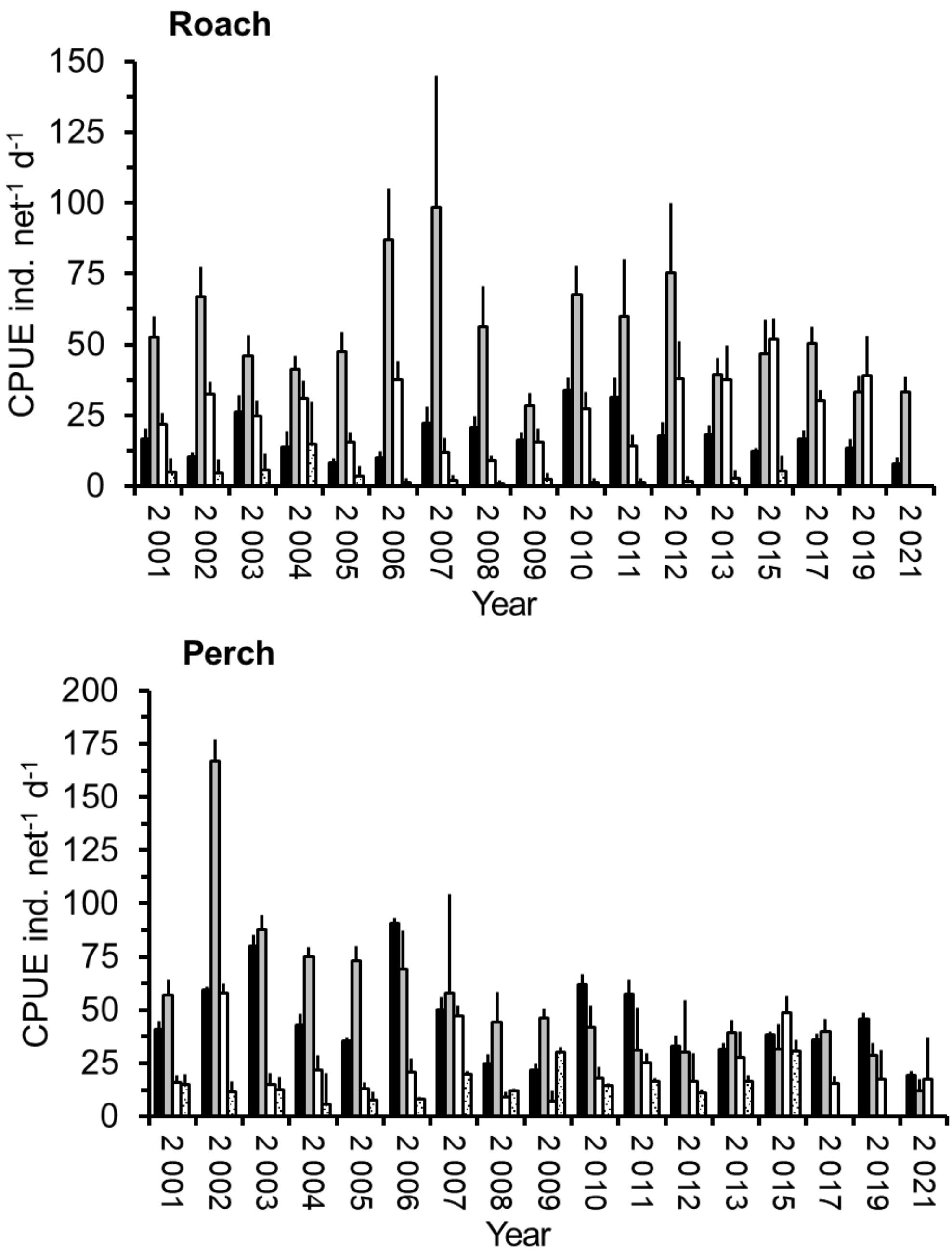

FIGURE 7 Mean catch per unit effort in number (CPUE, individuals net^{-1} day^{-1}) of roach (upper) and perch (lower) with multi-mesh gill nets (YK-net intercalibrated) in Jyväsjärvi, Tuomiojärvi and Alvajärvi in 2001–2021 and in Patajärvi in 2001–2015. Vertical lines represent the standard errors.

In Tuomiojärvi, Alvajärvi and Patajärvi, perch CPUE in mass had a significant positive correlation with the sampling year during the study period (Spearman correlation between year and CPUE in mass, Spearman $R_s = 0.475$, $p = 0.054$, $R_s = 0.490$, $p = 0.046$ and $R_s = 0.582$, $p = 0.029$, respectively). In Tuomiojärvi, perch CPUE in number of had a significant negative correlation with the sampling year ($R_s = -0.902$, $p < 0.001$), while CPUE in mass in Alvajärvi correlated negatively with the sampling year (($R_s = -0.801$, $p < 0.001$). In Alvajärvi, a positive correlation was observed between roach CPUE in number and the sampling year and in number ($R_s = 0.502$, $p = 0.040$) but not in mass CPUE ($R_s = 0.279$, $p = 0.277$). In Jyväsjärvi, there was no significant correlation between sampling year and CPUE in number or mass of perch and roach ($p > 0.05$).

The mean mass (CPUE in mass divided by CPUE in number, Fig. 8) of roach in gill net catches had a decreasing trend in Jyväsjärvi (linear regression, slope = -1.20, p = 0.033) and Tuomiojärvi (linear regression, slope = -0.77, p = 0.036). In Alvajärvi, the mean mass was highest in the middle of the study period and there was no significant trend (linear regression, slope = 0.28, p = 0.58). In Patajärvi, the mean mass of roach in test fishing increased from 2001 to 2015 (linear regression, slope = 0.72, p = 0.001, Fig. 8).

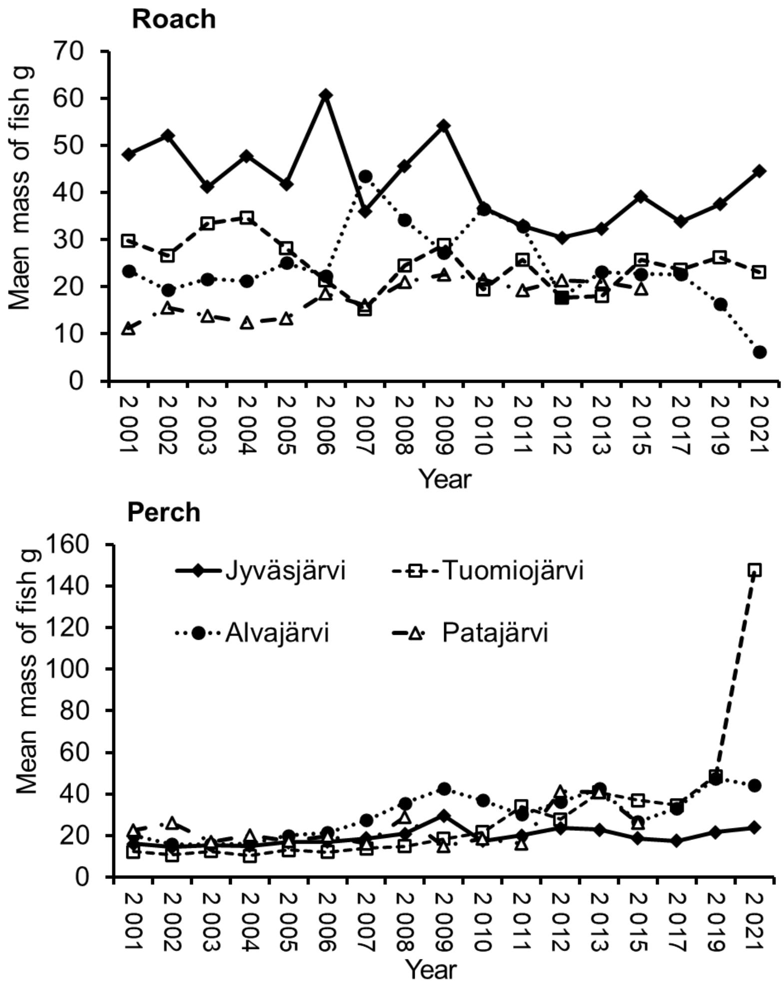

FIGURE 8 Mean wet mass (CPUE in mass divided by CPUE in number of individuals) of roach (upper) and perch (lower) caught with multi-mesh gill nets (YK-calibrated) in Jyväsjärvi, Tuomiojärvi, Alvajärvi in 2001–2021 and in Patajärvi in 2001–2015.

The mean mass of perch increased especially in Tuomiojärvi (linear regression, slope = 2.25, $p < 0.001$), but also in Jyväsjärvi (linear regression, slope = 0.57, $p = 0.025$) and Alvajärvi (linear regression, slope = 1.68, $p = 0.002$). A non-significant linear trend was observed in Patajärvi (linear regression, slope = 0.85, $p = 0.13$).

TABLE 3 Mean catch per unit effort of roach and perch in mass (CPUE g net^{-1} day^{-1}) in multi-mesh gillnet fishing in Jyväsjärvi, Tuomiojärvi, Alvajärvi and Patajärvi before the intensive fishing period with fyke nets in Jyväsjärvi (2001–2003), during (2004–2006) and after (2007–2021), in Patajärvi in (2007–2015). SE = standard error of mean.

Species	Lake	Before		During		After	
		Mean	SE	Mean	SE	Mean	SE
Roach	Jyväsjärvi	807.0	158.0	534.4	95.6	718.3	83.6
	Tuomiojärvi	1632.4	76.7	1541.3	158.8	1150.6	91.5
	Alvajärvi	560.3	34.9	628.0	131.9	660.2	79.8
	Patajärvi	161.8	12.3	162.6	59.6	160.9	30.6
Perch	Jyväsjärvi	916.7	169.0	927.7	307.1	783.3	68.5
	Tuomiojärvi	1186.6	314.8	852.0	50.8	1126.1	107.9
	Alvajärvi	492.8	217.4	353.9	54.5	774.5	106.9
	Patajärvi	284.5	37.7	133.9	12.5	444.8	69.2
Pikeperch	Jyväsjärvi	164.3	36.2	71.9	15.2	224.4	68.4
	Tuomiojärvi	242.7	113.0	384.4	116.1	455.6	73.9
	Alvajärvi	141.5	34.9	222.8	75.4	308.4	59.7
	Patajärvi	26.2	-	5.6	1.1	114.1	103.8
Bleak	Jyväsjärvi	99.2	26.6	30.9	10.3	124.1	21.9
	Tuomiojärvi	86.5	8.6	126.2	51.2	25.4	4.3
	Alvajärvi	69.9	35.1	80.9	22.3	28.0	9.5
	Patajärvi	33.8	23.4	43.6	20.0	15.7	5.9
Bream	Jyväsjärvi	50.3	8.5	49.5	15.1	55.7	11.1
	Tuomiojärvi	534.1	191.9	422.2	97.3	226.4	35.3
	Alvajärvi	119.0	48.0	112.9	20.3	183.6	17.5
	Patajärvi	63.8	38.2	9.8	6.0	34.1	9.2
Silver bream	Jyväsjärvi	37.2	15.4	10.7	5.6	30.2	7.9
	Tuomiojärvi	108.5	56.7	102.0	11.9	191.84	23.1
	Alvajärvi	214.5	87.6	242.4	99.8	97.5	16.1
	Patajärvi	30.3	7.7	141.7	129.2	20.0	6.5
Ruffe	Jyväsjärvi	15.2	6.0	36.0	10.7	14.3	2.7
	Tuomiojärvi	2.4	1.4	3.3	0.5	3.9	0.5
	Alvajärvi	3.5	0.8	4.6	1.5	4.6	0.9
	Patajärvi	1.2	0.3	1.9	1.0	2.4	0.5
Pike	Jyväsjärvi	13.5	5.9	46.5	25.5	70.5	26.7
	Tuomiojärvi	35.2	3.8	85.2	55.5	66.7	24.6
	Alvajärvi	94.3	23.8	33.1	17.8	46.9	17.2
	Patajärvi	85.3	19.7	21.9	7.5	23.6	13.1

TABLE 4 Mean catch per unit effort in number (CPUE individuals net^{-1} day^{-1}) in multi-mesh gillnet fishing in Jyväsjärvi, Tuomiojärvi, Alvajärvi and Patajärvi before the intensive fyke net fishing period in Jyväsjärvi (2001–2003), during the period (2004–2006) and after (2007–2021, but in Patajärvi in 2007–2015). SE = standard error of the mean.

Species	Lake	Before		During		After	
		Mean	SE	Mean	SE	Mean	SE
Roach	Jyväsjärvi	17.7	4.7	10.6	1.6	19.1	2.3
	Tuomiojärvi	55.3	6.2	58.6	14.4	53.6	6.4
	Alvajärvi	26.5	3.2	27.9	6.6	32.3	6.3
	Patajärvi	12.0	0.5	12.1	5.4	8.0	1.6
Perch	Jyväsjärvi	59.9	11.3	56.3	17.4	38.2	4.3
	Tuomiojärvi	103.8	32.7	72.3	1.7	36.6	3.6
	Alvajärvi	29.5	14.3	18.5	2.9	22.7	4.2
	Patajärvi	13.1	1.1	7.1	0.7	18.8	2.7
Pikeperch	Jyväsjärvi	0.5	0.2	0.7	0.2	0.8	0.2
	Tuomiojärvi	0.7	0.2	0.8	0.2	1.1	0.2
	Alvajärvi	0.8	0.3	0.9	0.2	1.1	0.2
	Patajärvi	0.1	-	0.2	0.2	0.1	0.1
Bleak	Jyväsjärvi	6.3	1.9	1.7	0.6	7.7	1.5
	Tuomiojärvi	5.2	0.6	8.5	4.5	1.6	0.3
	Alvajärvi	0.8	0.3	0.9	0.2	1.1	0.2
	Patajärvi	3.7	2.7	3.9	2.0	1.3	0.5
Bream	Jyväsjärvi	0.4	0.1	0.8	0.7	0.4	0.1
	Tuomiojärvi	4.3	1.5	3.0	0.6	1.4	0.2
	Alvajärvi	1.9	1.1	1.4	0.5	1.9	0.3
	Patajärvi	1.3	0.8	0.3	0.1	0.6	0.2
Silver bream	Jyväsjärvi	0.8	0.3	0.1	0.1	0.3	0.1
	Tuomiojärvi	1.5	0.8	1.1	0.1	1.1	0.3
	Alvajärvi	3.9	1.5	7.6	3.7	1.5	0.3
	Patajärvi	1.0	0.1	3.2	2.8	0.4	0.1
Ruffe	Jyväsjärvi	1.4	0.4	3.1	0.6	1.9	0.3
	Tuomiojärvi	0.5	0.3	0.6	0.1	1.0	0.1
	Alvajärvi	0.6	0.2	0.8	0.3	0.8	0.1
	Patajärvi	0.2	< 0.1	0.4	0.2	0.5	0.2
Pike	Jyväsjärvi	< 0.1	< 0.1	0.1	0.1	0.1	< 0.1
	Tuomiojärvi	0.1	< 0.1	0.1	< 0.1	0.1	< 0.1
	Alvajärvi	0.2	0.1	0.1	< 0.1	0.1	< 0.1
	Patajärvi	0.3	< 0.1	0.1	0.1	0.1	< 0.1

In 2001–2003, before the intensive fishing period, the mean CPUE ± SE of roach was 18 ± 5 ind. (807 ± 158 g), during the intensive fishing period in 2004–2006 it was 11 ± 2 (534 ± 96 g) and after the intensive fishing period in 2007–2021 19 ± 2 ind. (718 ± 84 g) (Table 3 and 4). The lowest roach CPUE in number (8 ind. net^{-1} day^{-1}) and mass (345 g net^{-1} day^{-1}) was detected in 2005, after 2 years of intensive fyke net fishing. Thus, the mean CPUE of roach during the intensive fishing period was lower than before and after. However, due to high general variability in multi-mesh gill net CPUE there was no statistically significant difference in roach CPUE in number or in mass between the periods before, during and after (ANOVA, $p = 0.418$ in mass and $p = 0.166$ in number). Also, in the control lakes Tuomiojärvi, Alvajärvi and Patajärvi, roach CPUE did not differ between the three periods (ANOVA $p > 0.05$, Table 3 and 4).

In Jyväsjärvi, during the intensive fishing period 2004–2006, the fyke net catch of bream was the highest of all species every year (Table 3), but the CPUE of bream in multi-mesh gill net fishing was at the same level as the CPUE before and after the intensive fishing period (Fig. 9, Table 3 and 4). Bream CPUE was the highest in Tuomiojärvi, where gill net fishing is completely prohibited.

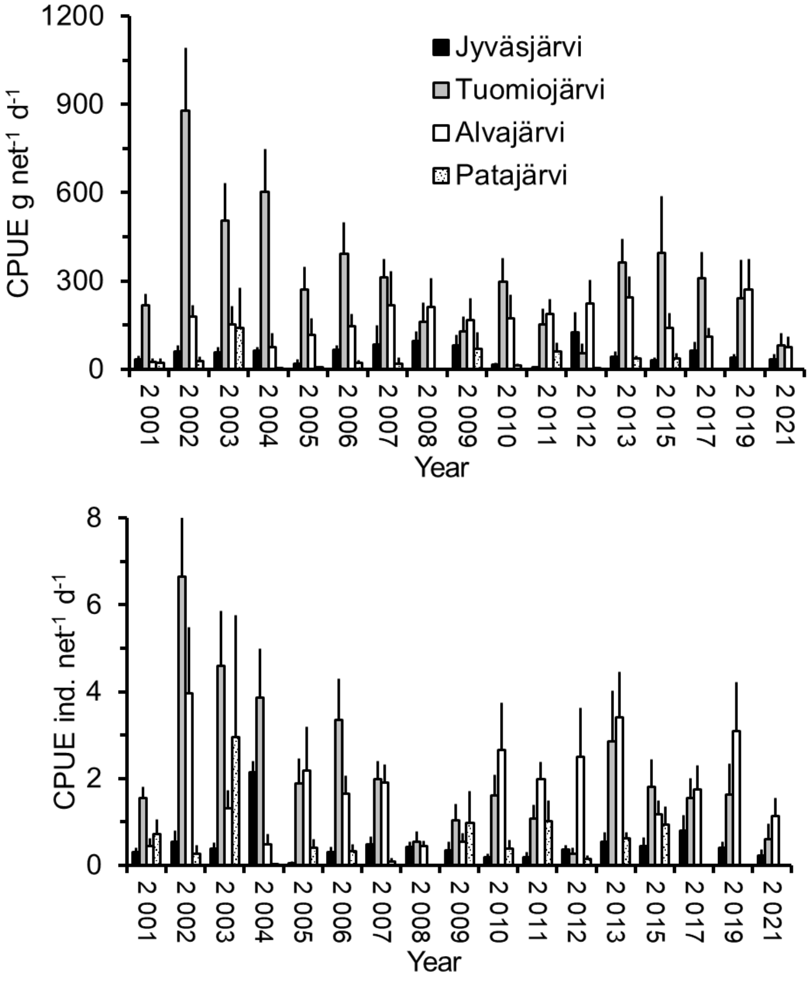

FIGURE 9 Mean catch per unit effort of bream in mass (CPUE g net^{-1} day^{-1}, upper panel) and in number (individuals net^{-1} day^{-1}, lower panel) in Jyväsjärvi, Tuomiojärvi and Alvajärvi in 2001–2021 and in Patajärvi in 2001–2015. Vertical lines represent standard errors.

The mean mass of bream in the multi-mesh gill net catch varied considerably during the monitoring period (Fig. 10).

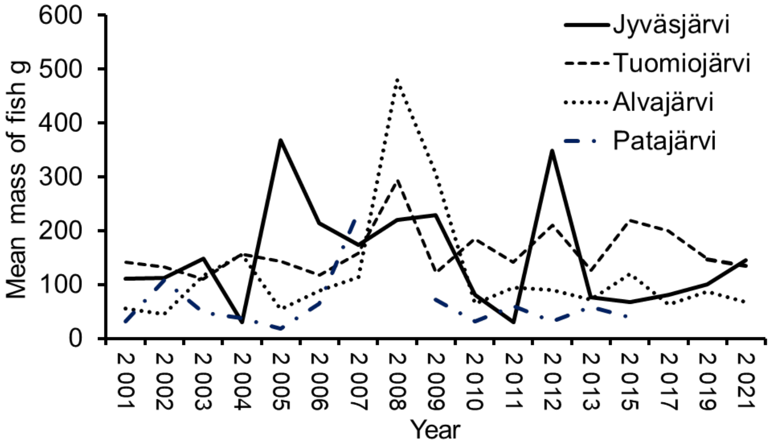

FIGURE 10 Mean mass (g) of bream in multi-mesh gill net fishing in Jyväsjärvi, Tuomiojärvi and Alvajärvi in 2001–2021 and in Patajärvi in 2001–2015.

In multi-mesh gill net fishing, the mean CPUE in numbers in the study lakes was generally low for many species (Table 4): < 1 individual per gill net day for pikeperch and pike, < 5 individuals for bream, silver bream and ruffe and < 10 individuals for bleak. Only roach and perch had a mean CPUE > 20 individuals. Only these eight species were caught with the multi-mesh nets every year. For most species, the number of fish caught was low and the coefficient of variation (CV) of CPUE and thus the inter-annual variation of CPUE was high (Fig. 11).

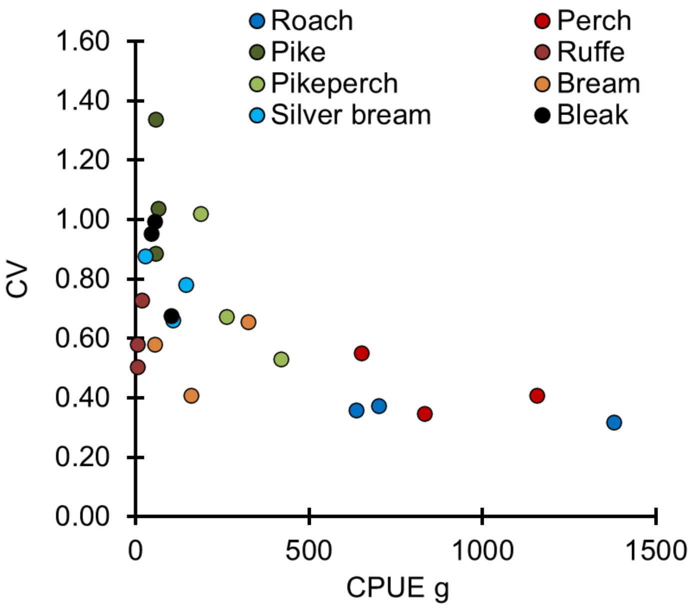

FIGURE 11 Coefficient of variation (CV) of multi-mesh gill net fishing CPUE (g net^{-1} day^{-1}) in relation to the mean CPUE in Jyväsjärvi, Tuomiojärvi and Alvajärvi in the years 2001–2021.

In this study, strata volume (Table 2) weighting was applied when calculating the gill net test fishing mean CPUEs. Instead, strata area weighting is used in CPUE estimates of, e.g. the widely used survey method EN 14757 (Water quality. Sampling of fish with multi-mesh gillnets). Four volume strata were used in Jyväsjärvi, while in other lakes with different morphometry only three strata (Fig. 2). In 2015, the littoral stratum had the highest fish densities in Jyväsjärvi and Tuomiojärvi and in the surface stratum in Alvajärvi and Patajärvi (Fig. 12). In Tuomiojärvi, the total CPUEs were almost identical with and without stratum volume weighting (without volume weighting = the mean of the stratum-specific mean CPUEs) while in Jyväsjärvi the volume weighted mean CPUEs were slightly lower (Fig. 13). In Patajärvi, the bottom stratum has a large proportion of lake volume (i.e. small littoral and large > 3 m area).

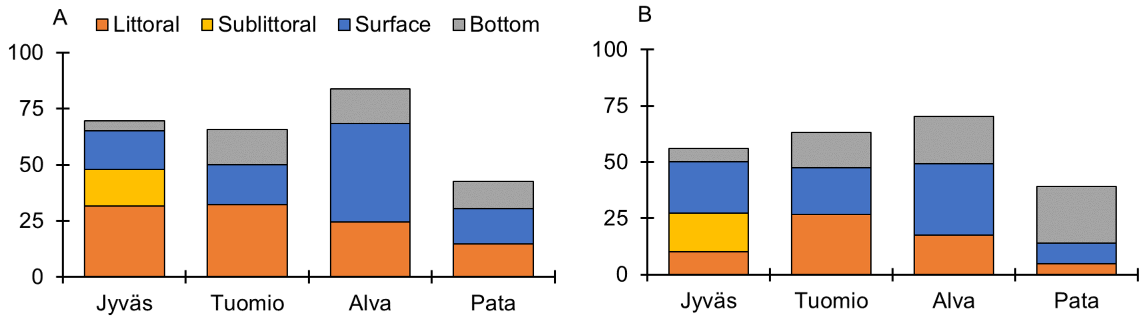

FIGURE 12 Mean CPUE in number of all species (individuals net^{-1} day^{-1}) in the different sampling strata of multi-mesh gill net fishing in Jyväsjärvi, Tuomiojärvi, Alvajärvi and Patajärvi in 2015. A) without strata volume weighting and B) with strata volume weighting.

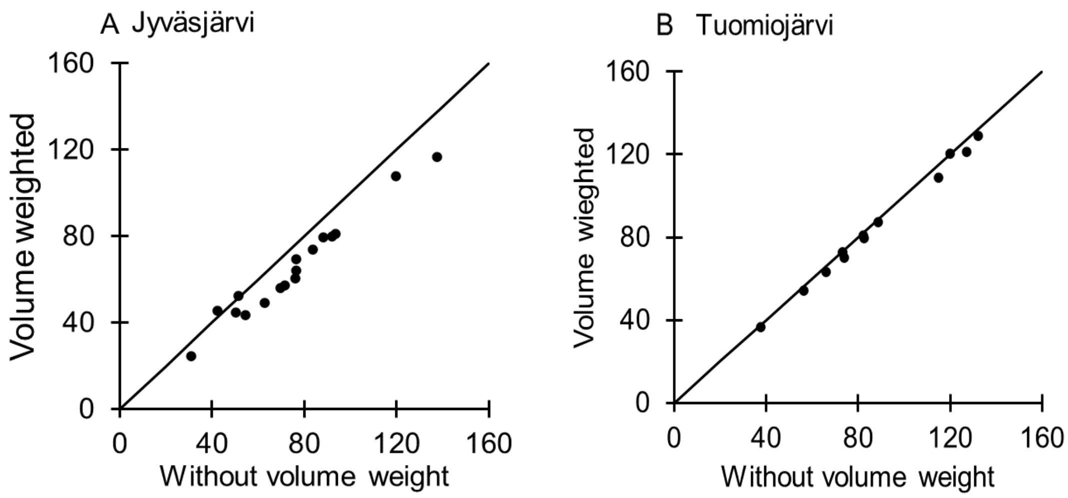

FIGURE 13 Annual mean CPUE of all species (black circles, individuals net^{-1}day^{-1}) of multi-mesh gill net fishing calculated with and without stratum volume weighting in A) Jyväsjärvi and B) Tuomiojärvi in 2001-2021. Black solid line indicates 1:1 ratio between variables.

CPUEs in different strata varied between years both in Jyväsjärvi and Tuomiojärvi, and especially in Tuomiojärvi, where the catches were occasionally high also in the bottom stratum (Fig. 14).

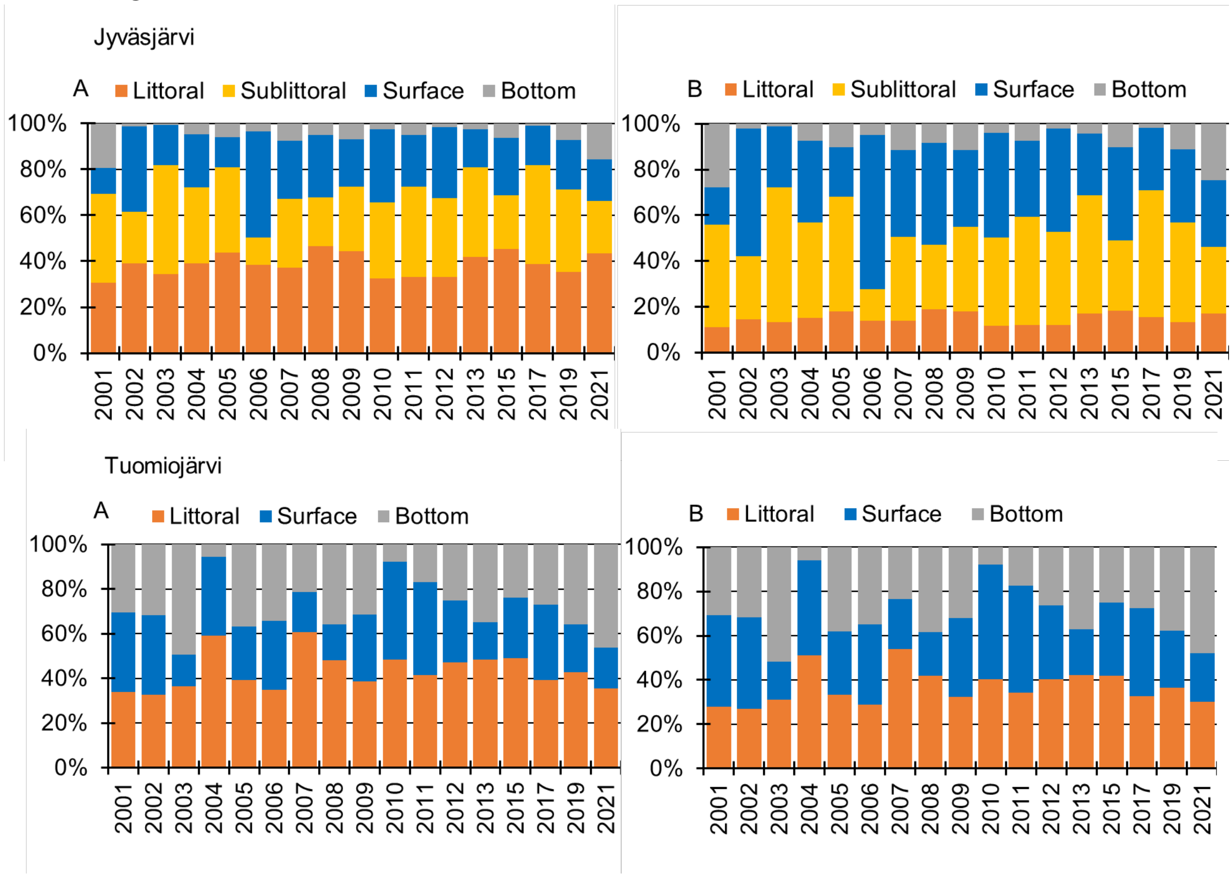

FIGURE 14 Proportional CPUE in number of all species of multi-mesh gill net fishing in the different sampling strata in Jyväsjärvi, Tuomiojärvi, Alvajärvi and Patajärvi in 2015. A) without strata volume weighting and B) with strata volume weighting.

3.4 CPUE of multi-mesh gill nets vs. CPUE in Finnish WFD lakes

Standard Nordic multimesh gill nets are used in the monitoring of several Finnish lakes in the assessment of the status of lakes related to EU Water Framework Directive (WFD). The WFD survey method is generally similar to the method used in this study, so the WDF data are reasonably comparable to those obtained in this study. Data from 23 WFD survey lakes (Lake type-specific data were obtained from Finnish Environment Institute) with the lake type and nutrient status similar to our study lakes were used as a reference (Fig. 15).

The average CPUE in mass of roach in WFD survey lakes was 547 g net^{-1} day^{-1}, with a wide range from 62 g to 1268 g (Fig. 15). Perch CPUE ranged from 113 g to 1200 g, with average of 495 net^{-1} day^{-1}. The CPUEs found in this study were mainly within the range in WFD lakes, but Tuomiojärvi typically had higher roach and perch CPUE (Fig. 15).

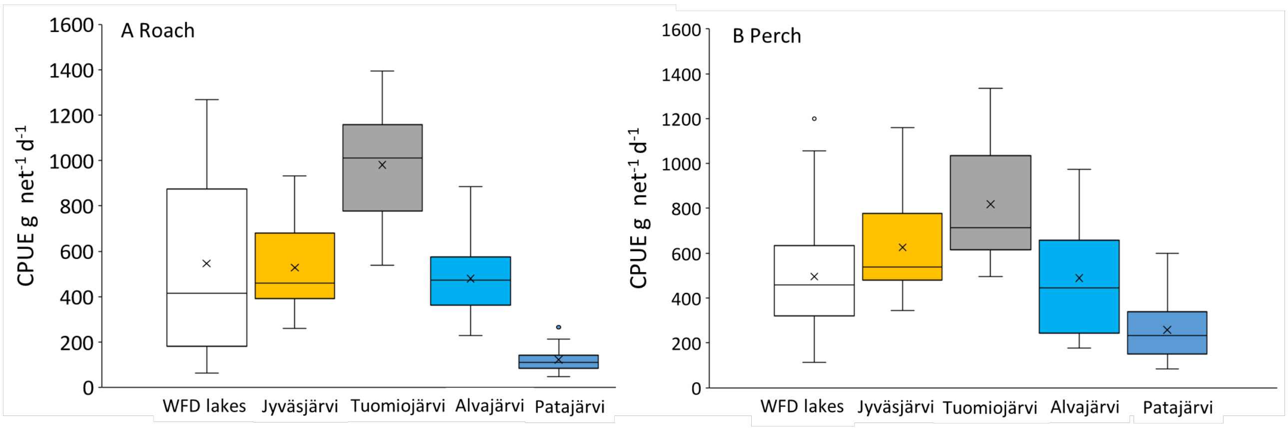

FIGURE 15. Catch per unit effort (CPUE, g net^{-1} day^{-1}) in mass of A) roach and B) perch with standard multi-mesh gill nets in selected Finnish Water Framework Directive assessment lakes (n = 23) in 2001–2021, in Jyväsjärvi, Tuomiojärvi, Alvajärvi in 2001–2021, and in Patajärvi in 2001–2015. × = average.

3.5 Size distribution of roach and perch in fyke net and gill net catches

In 2004 and 2005, both fyke net and multi-mesh gill net catches of roach included fish of several age groups, but in 2006 the catches were dominated by small 1- and 2-year-old fish (Fig. 16). Similarly, the perch catches were dominated by small 1- and 2-year-old fish in 2005 and 2006. Note that fyke nets were used in May–June and multi-mesh gill nets in late summer, when the fish were slightly larger than in early summer. The smallest mesh size in the multi-mesh gill nets used in 2004–2006 was 10 mm, and no fish smaller than 7–8 cm were caught. Overall, 1-year-old fish were only partially recruited into the catches of both fyke net and multi-meshed gill nets.

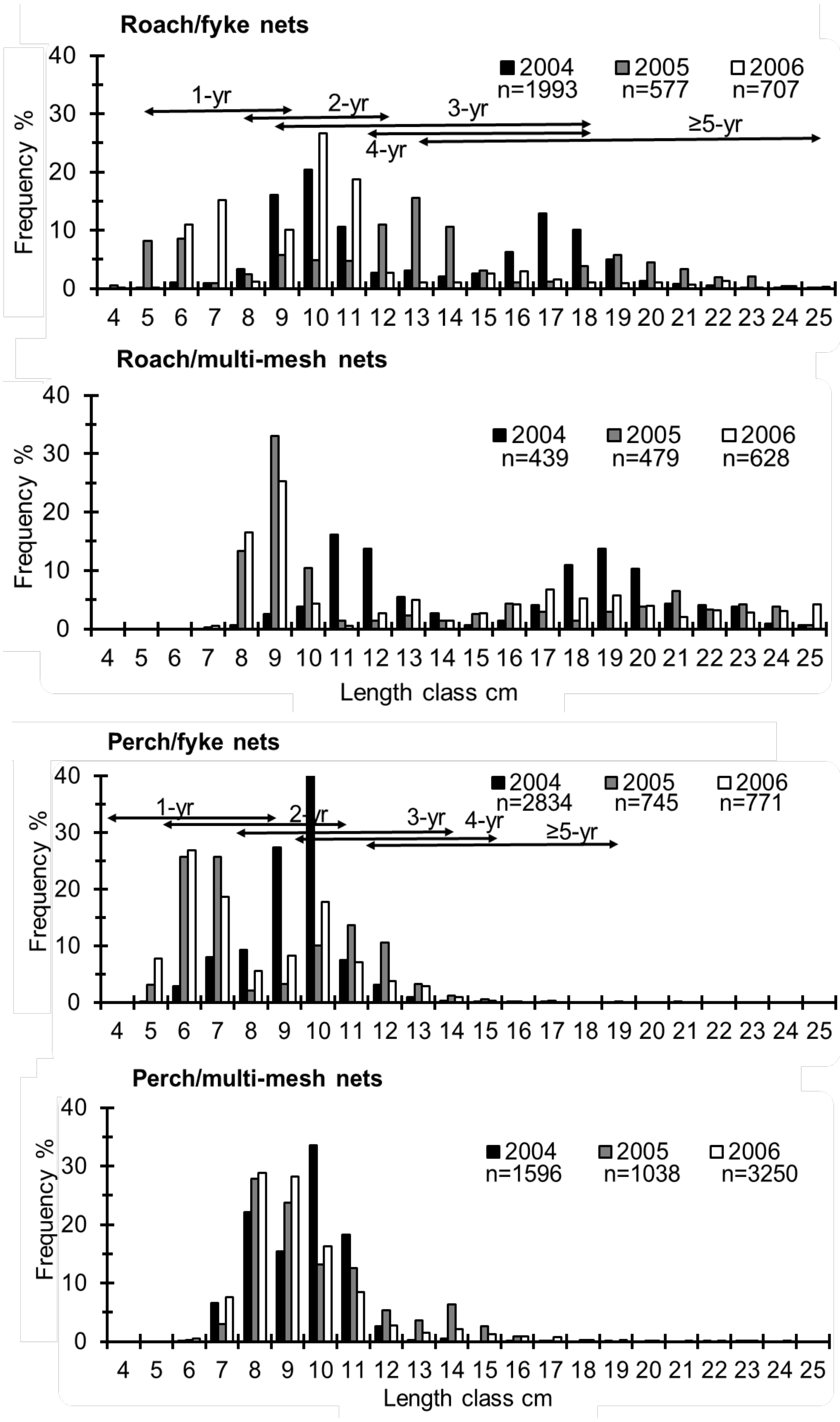

FIGURE 16 Length distribution of roach (two upper panels) and perch (two lower panels) in fyke net and multi-mesh gill net catches in 2004–2006. The length classes are 3 = 3–3.9 cm, 4 = 4–4.9 cm etc. total length and the horizontal lines show the age of fish in different length classes 1-yr = 1 year old fish, 2-yr = 2 years old fish etc.. No strata volume weighting.

In Jyväsjärvi, before the intensive fishing period (2001–2003), the proportion of small < 11 cm roach was low in the catch of multi-mesh gill nets in 2001 and 2002, but larger in 2003, when the strong year-class 2002 dominated (Fig. 17). Intensive fyke net fishing in the spring of 2004–2006 effectively reduced the number of large roach in the population, and in August 2005 and 2006, small roach made up the majority of the multi-mesh gill net catches. The proportion of > 10 cm individuals in the gill net catches was 97, 53 and 58 % in 2004, 2005 and 2006, respectively, while in the years before and after the intensive fishing period the mean proportion of > 10 cm fish was 87 % (range 52 %–97 %). Shortly after the cessation of intensive fyke net fishing, the number of larger and older roach began to increase again in the population (Fig. 17, the lowest panel). In Tuomiojärvi and Alvajärvi, the proportion of roach > 10 cm was on average 78 % (range 40 %–96 %) and 80 % (range 54 %–95 %) (Appendix 7 and 8).

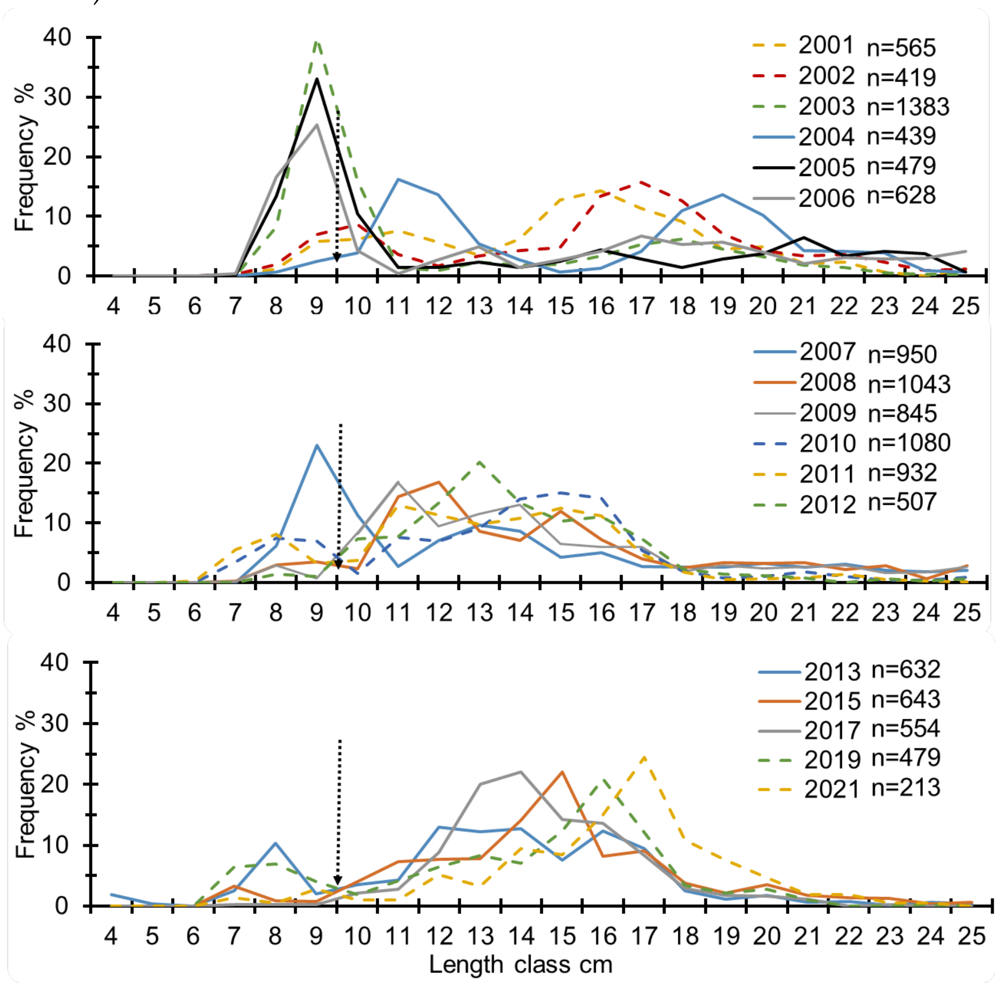

FIGURE 17 Length distribution (%, number of fish) of roach in multi-mesh gill net catches in 2001–2021 in Jyväsjärvi. In the years 2001–2009, YK-nets (mesh size 10–55 mm) and in 2010–2021 Nordic nets (5–55 mm). The length classes are 4 = 4–4.9 cm, 5 = 5–5.9 cm etc. total length. The vertical dotted lines indicate the limit of the usability of fish in commercial fish products, such as canned fish (10–20 cm) or fish paste (> 15 cm) (Suomi 2018). No strata volume weighting.

The summer of 2002 was warm, and the perch also produced an abundant year-class in Jyväsjärvi (Fig. 18), which prevailed in catches even in 2004, when intensive fishing began. Fyke net fishing targeted small perch quite inefficiently: 1-year-old fish were only partially recruited into the fyke net catches. The number of large perch has increased in recent years in Jyväsjärvi, but especially in Tuomiojärvi (Appendix 7) and Alvajärvi (Appendix 8). In Jyväsjärvi, Tuomiojärvi and Alvajärvi, the share of perch over 10 cm in total multi-mesh net catch was 58 % (range 33–78 %), 30 % (10–52 %) and 44 % (18–75 %), respectively.

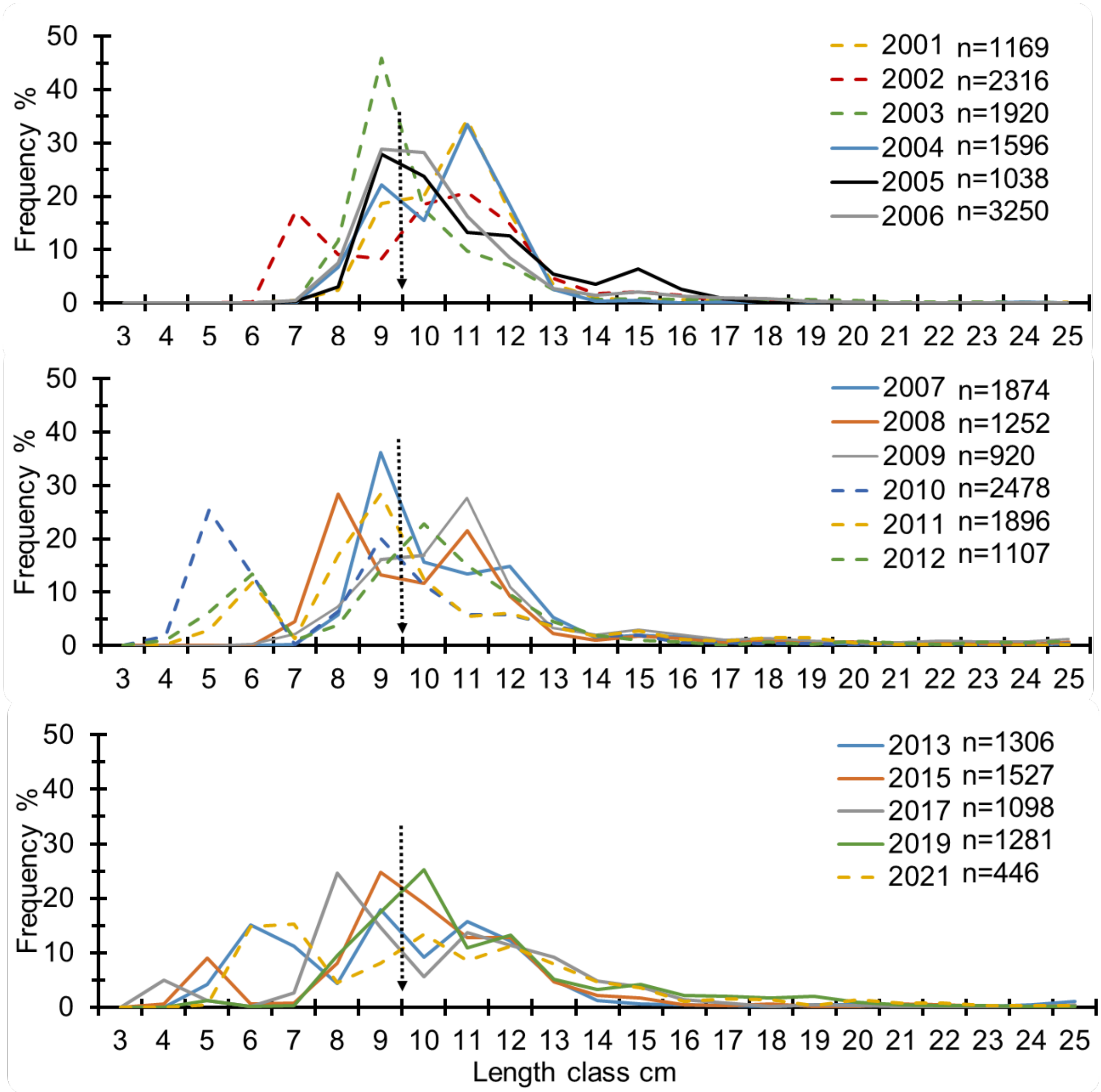

FIGURE 18 Length distribution (%, number of fish) of perch in multi-mesh gill net catches in 2001–2021 in Jyväsjärvi. Years 2001–2009 YK-nets (10–55 mm) and 2010–2021 Nordic nets (5–55 mm). the length classes are 3 = 3–3.9 cm, 4 = 4–4.9 cm etc. total length. The vertical dotted line indicates the limit of the usability of fish in commercial fish products such as canned fish (10–15 cm), fish paste (15-25 cm) or fillet (> 15 cm). No strata volume weighting.

3.6 Abundance of roach and perch in Jyväsjärvi

In Jyväsjärvi, the cohort analysis estimate of the total number of roach (≥ 2 years old) at the beginning of the intensive fishing period in 2004 was 0.9 million individuals (80 % likelihood interval 0.8–1.1 million) (Fig. 19), about 3000 indiv. ha^{-1}. The roach population consisted of more than 10 year-classes. At the end of the fishing season 2006, the abundance of the roach population (≥ 2 years old) was only 0.11 million individuals (80 % likelihood interval 0.06–0.16 million), about 300 indiv. ha^{-1}, and about 75 % of the fish were 2 years old.

The estimate of roach biomass at the beginning of the fishing season 2004 was 26 tons (77 kg ha^{-1}) (Fig. 19). After the fishing season 2006, the biomass was less than 2 tons (6 kg ha^{-1}) mainly consisting of 4 age groups.

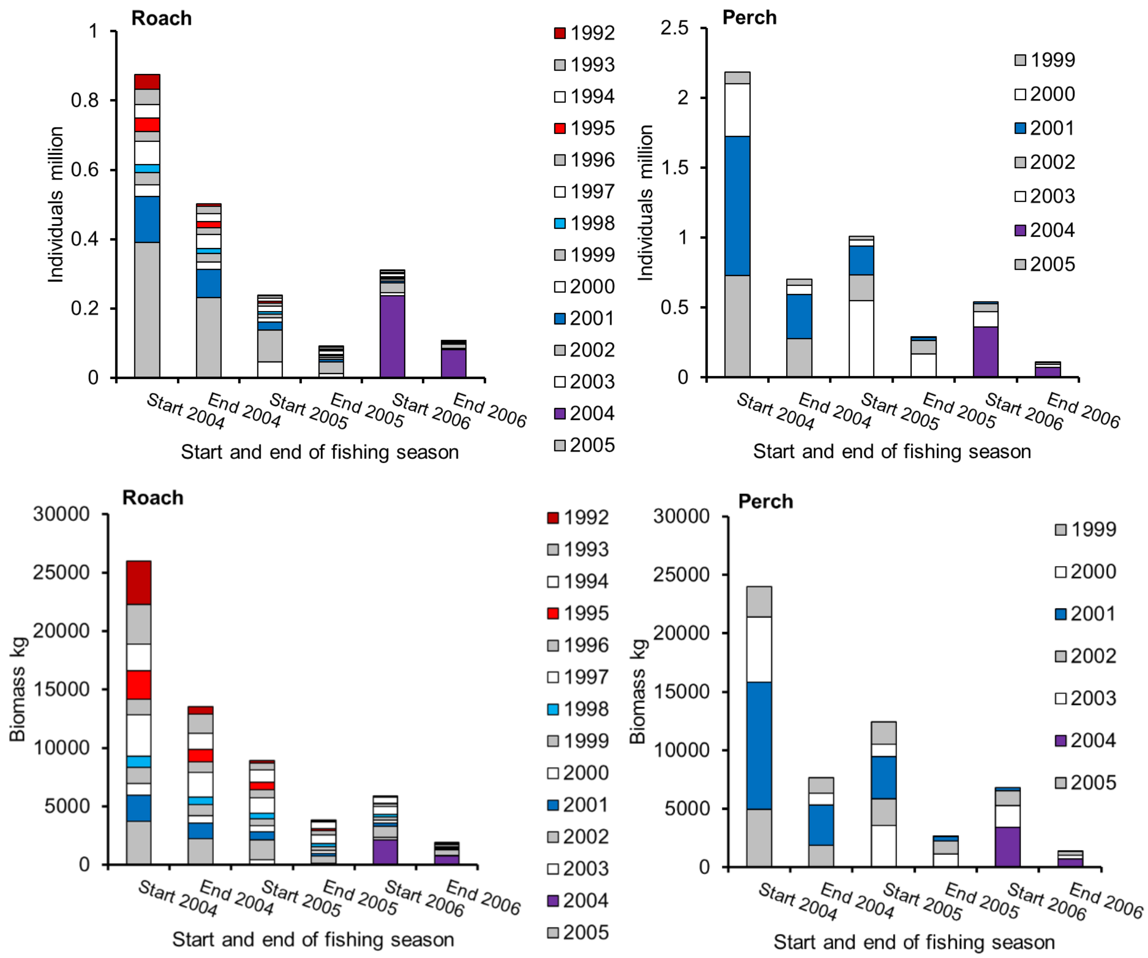

FIGURE 19 The number (individuals, upper panels) and biomass (kg, lower panels) of roach (left) and perch (right) by year-class in Jyväsjärvi in 2004–2006 as assessed by cohort analysis.

Using a cohort analysis, Horppila and Peltonen (1994) estimated that the biomass of $\geq$ 2-year-old roach in Lake Vesijärvi was about 130 kg ha^{-1} before intensive fishing began there. Compared to Jyväsjärvi, the higher biomass density may be partially due to the higher trophic state of Vesijärvi before intensive fishing.

The fyke net fishing mortality and catchability estimates for roach were considerably higher in the second (2005) and third year (2006) compared to the first year (2004) (Table 5).

TABLE 5 Length of the intensive fyke net fishing period, fyke net fishing effort (f) and estimates of instantaneous total (Z), other (M) and fyke net fishing mortality during the fishing period and the average fyke net catchability (q = F / f) based on the most likely considered values of constant annual M and terminal catchability.

Year	Period	f	Roach				Perch			
	d	fyke net d	Z	M	F	q (%)	Z	M	F	q (%)
2004	60	1018	0.56	0.08	0.47	0.05	1.13	0.08	1.05	0.10
2005	47	738	1.49	0.06	1.42	0.19	1.27	0.06	1.20	0.16
2006	32	468	1.06	0.04	1.02	0.22	1.59	0.04	1.54	0.33

Based on the cohort analysis, the estimate of the perch population ($\geq$ 2 years old) at the beginning of the fishing season in 2004 was about 2.2 million individuals (80 % likelihood interval 2.1–2.6) (Fig. 19), about 7000 ind. ha^{-1}. During the three-years of intensive fyke net fishing, the age structure of the population changed considerably. The perch population ($\geq$ 2 years old) initially consisted mostly of age groups 2–4, the proportion of 2-year-old fish being about 1/3. At the end of the fishing season in 2006, the population was dominated by 2-year-old fish, accounting about 2/3. The total number of perch ($\geq$ 2 years old) was 0.1 million individuals (80 % likelihood interval 0.07–1.5), about 300 ind. ha^{-1}.

At the beginning of the 2004 fishing season, the biomass estimate of the perch population was 24 tons (71 kg ha^{-1}). Biomass decreased every year during fishing season and was partially replaced by the growth of existing individuals and the recruitment of a new year-class. At the end of fishing season in 2006, the population biomass was slightly over 1 ton (4 kg ha^{-1}). Perch fyke net fishing mortality and catchability estimates were considerably higher in the second (2005) and especially third year (2006) compared to the first year (2004) (Table 5).

Jeppesen & Sammalkorpi (2002) developed an equation to roughly estimate the biomass (kg ha^{-1}) of fish populations based on phosphorus concentration in cyprinid dominated mainly shallow Danish lakes. When the equation is applied to Jyväsjärvi, the biomass of all fish is estimated to be about 70 kg ha^{-1}. Based on the cohort analysis, the estimate of the total amount of only perch and roach before intensive fishing was much higher, about 150 kg ha^{-1}. In addition, the total catch of all species in the first year of intensive fishing in 2004 was over 150 kg ha^{-1}. Thus, the fish biomass of Jyväsjärvi before intensive fishing was much higher than expected from the phosphorus content of the lake.

The uncertainty of population estimates based on cohort analysis (and more generally VPA) is affected by uncertainty in the level of other mortality and terminal fishing mortality. The effect of terminal fishing mortality is relatively greatest at the end of the calculation period and is diluted when counting backwards in time. The relative impact of other mortality (M) depends on its proportion of total mortality (Z). In Jyväsjärvi, the fyke net fishing mortality estimate for both perch and roach was clearly higher than the most likely value of other mortality (0.5 yr^{-1}), which is a prerequisite for the successful application of the method.

According to the above population estimates, intensive fyke net fishing considerably decreased the number and biomass of both perch and roach and caused changes in their age structure. When the intensive fishing ended in 2006, the biomass ($\geq$ 2 years old) of both perch and roach was less than 10 % of the initial value in spring 2004 and the population of both species consisted mainly of young age groups. Such changes in fish populations are expected to occur as a result of increased mortality and have often been observed after intensive fish removals in various biomanipulation projects (Peltonen & Horppila 1992).

3.7 CPUE of multi-mesh gill nets vs. population biomass estimates

The CPUE of multi-mesh gill nets (g net^{-1} day^{-1}) and cohort analysis estimates of the total biomass (kg ha^{-1}) of roach and perch in Jyväsjärvi were compared in the intensive fishing period 2004–2006 (Fig. 20). Both estimates decreased from 2004 to 2006. The association between CPUE and total biomass estimates of roach was further investigated using available data from two other lakes, Lake Tuusulanjärvi (Ruuhijärvi *et al.* 2017) and Lake Pohjanlampi (Karjalainen *et al.* 1999). Nonlinear regression (power function) of combined CPUE and biomass data for roach from the three lakes (Fig. 21) was statistically significant ($R^2 = 0.574$, $F = 13.5$, $p = 0.004$).

The CPUE of multi-mesh gill net fishing carried out using standardized methods seems to be a useful rough index for estimating roach biomass and potential catch in small and medium-sized lakes in Finland. Multi-mesh net fishing CPUE and size distribution of target species are useful preliminary information for planning roach exploitation for commercial fishing in lakes where no other stock monitoring data are available. This is the situation in almost all Finnish lakes. Suomi (2018) stated, based on interviews with fish processing enterprises, that the minimum size limit of the usability of fish in commercial fish products is > 10 cm: Canned fish 10–15 cm, fish paste 15-25 cm and fillet > 15 cm. The size distribution information of multi-mesh gill nets and fyke nets was rather uniform in these size classes.

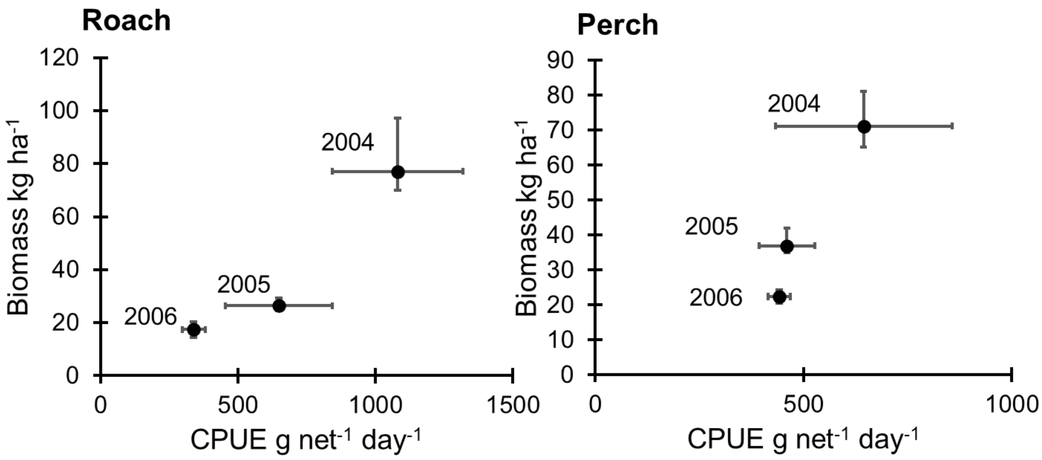

FIGURE 20 CPUE in mass of multi-mesh gill nets vs. biomass estimate based on cohort analysis of ≥ 2 years old roach (left) and perch (right) in Jyväsjärvi in 2004–2006. Horizontal lines represent standard error of gill net CPUE and vertical lines represent 80 % likelihood interval of biomass. Both estimates include only > 2 years old fish: roach longer than 9 cm and perch longer than 11 cm in gill net catches in August 2003, 2004 and 2005. The corresponding fish biomass estimates were taken from the beginning of the fyke net fishing season in the spring of 2004, 2005 and 2006.

In Jyväsjärvi, the relationship between the perch gill net CPUE and the biomass estimate remained unclear according to our three-year data. Olin et al. (2015) stated that if the factors affecting the catchability of perch in multi-mesh gill nets are taken into account, the multi-mesh gill net CPUE using standard methods can be used as a rough index of perch density in small forest lakes. Our perch data are too sparse to confirm this suggestion, and when the standard errors of estimates are taken into account, CPUE values for > 9 cm perch at even the highest and lowest stock phases (2004 vs. 2006 in Fig. 16) were not significantly different in Lake Jyväsjärvi. For other fishes, the number of fish caught with multi-mesh gill nets was low and the inter-annual variation of CPUE was high (Fig. 11), which makes the assessment of stock biomass highly uncertain. According to Prchalova et al. (2008) and Marjomäki *et al.* (2015), gill net sampling overestimates perch abundance compared to cyprinids.

The catchability of fish with multi-mesh gill nets is affected by many factors, such as fish species, sex ratio, water colour content, anoxic hypolimnion and temperature. In addition, gill net catchability has been shown to be strongly inversely related to fish density due to the catch accumulating in the net during fishing (Olin *et al.* 2004, Marjomäki *et al.* 2015). The assumed convex relationship, power function exponent > 1 (however, not significantly so in Fig. 21), between gill net CPUE and biomass estimate based on cohort analysis (Fig. 21) is consistent with this phenomenon. For long soak times, such as in this study about 20 h, the gill net CPUE is by no means a directly proportional index of fish density. Thus, at the beginning of the study period, before intensive fishing reduced fish density quite considerably, gill net CPUE must have underestimated fish biomass. Due to this, the decrease in fish density was also underestimated. The considerable collapse of the perch and roach populations due to fishing is also supported by the CPUE data of the fyke nets (Table 2). Catch data estimates based on cohort analysis were only available for the years 2004–2006. After that, multi-mesh gill net fishing was the only method of monitoring fish stocks in Jyväsjärvi.

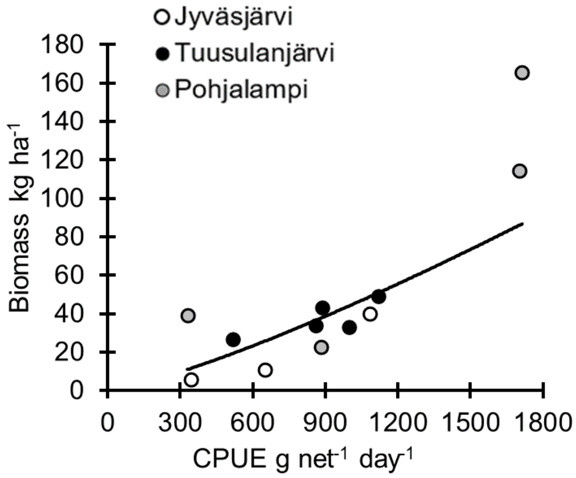

FIGURE 21 The power function ($y = 0.0076\ x^{1.25}$, $R^2 = 0.77$) fitted to the data of CPUE of multi-mesh gill nets and the biomass estimate based on cohort analysis of roach in Jyväsjärvi, Tuusulanjärvi (Ruuhijärvi *et al*. 2017) and Pohjalampi (Karjalainen *et al*. 1999).

It is also worth noting that Jyväsjärvi is not a closed system, but is connected to Lake Päijänne and the fish migrate between lakes (Lilja *et al*. 2003, Syväranta *et al*. 2008). However, intensive fishing was carried out only in Jyväsjärvi, while fishing for the studied species in Päijänne was negligible. Thus, the migration of fish between Jyväsjärvi and Päijänne can cause uncertainty in the comparison between the CPUE of the multi-mesh gill net in August and the CPUE of the fyke net in spring. Overall, a comprehensive analysis of larger datasets of multi-mesh gill nets against independent biomass or density estimates from diverse lakes is needed to improve the applicability of multi-mesh net fishing for fish stock monitoring.

3.8 Conclusions

In Lake Jyväsjärvi in 2004–2006, intensive fyke net fishing yielded annually 6.1–9.4 tons of roach and 5.1–15.2 tons of perch with, i.e., 18–28 kg ha^{-1} and 20–45 kg ha^{-1}, respectively. The annual catch of roach was 2–4 times the maximum ecologically sustainable yield estimate by Ruokonen *et al*. (2019) for small- and medium-sized lakes in southern and central Finland. The annual perch catch exceeded the maximum sustainable yield estimates by Ruokonen *et al*. (2019) 4–10-fold. The effect of the temporarily increased mortality caused by intensive fishing on the roach and perch populations of Jyväsjärvi was similar to the effect of the massive mortality caused by a winter kill due to hypoxia in Lake Äimäjärvi (Ruuhijärvi *et al*. 2010): reduction of populations induced an increase in reproduction success and growth as compensatory effects. As a result, the populations recovered within a few years to the level before intensive fishing. Rapid increases in fish density and biomass after 2–3-year fish removal for biomanipulation have been attributed to increased reproduction efficiency, increased recruitment and/or increased growth rate of fish in many biomanipulated lakes (Hansson *et al*. 1998, Karjalainen *et al*. 1999, Olin *et al*. 2006, Rask *et al*. 2020).

In fyke net catches of Jyväsjärvi, 63–79 % of roach individuals and 33–52 % of perch were longer than 10 cm (2-year-old or older), the ultimate minimum size limit for commercial fish processing. Thus, only 3–5 % of the roach and 28–38 % of the perch biomass, in the fyke net catches consisted of these small-sized fish that cannot be efficiently utilized by current fish processing methods. Similarly, the multi-mesh gill net fishing showed that majority of the roach (> 75 %) catch was > 10 cm in all our study lakes indicating high potential for exploitation of these inland fish resources in Finland. The intensive annual fyke net fishing yielded almost 6 000 kg and 4 000 kg of > 10 cm roach and perch for 3 years, respectively. However, this resource is spatially rather fragmented and in all, small humic and humus-rich lakes make up < 10 % of the surface area of Finnish lakes. a potential harvest strategy for such a resource based on small separate populations is pulse fishing (Carvalho et al. 2019) i.e., rotation of intensive fishing periods and closure periods.

Standardized multi-mesh gill net fishing has been regularly used to determine the composition of fish communities and ecological status in Finnish lakes (Rask *et al*. 2010). The CPUE of multi-mesh gill net fishing appears a usable rough index to estimate roach and perch biomass and potential catch levels in small and medium-sized Finnish lakes. Interestingly, the highest fish abundance among our study lakes was in Tuomiojärvi which is a recreational fishing area and where gill net fishing is prohibited. Our data also showed how different fish abundance can be between very similar lakes. There was *ca*. 8-fold difference on average in roach abundance and *ca*. 3-fold difference in perch abundance between Tuomiojärvi and Patajärvi. This difference in fish abundance can be even higher because we used the soak time of 20–24-hour and in higher fish density the CPUEs of roach and perch were lowered due to the saturation of nets (Marjomäki *et al*. 2015).

In Finnish lakes, information on roach and perch populations and their productivity is very scarce and is mainly based on temporary intensive fishing projects for biomanipulation and management of water quality. Multi-mesh gill net fishing CPUE and size distribution of target species are useful preliminary information for planning roach and perch exploitation for commercial fishing in lakes where no other stock monitoring data are available. However, our data showed that even in a lake the annual variation in multi-mesh gill net CPUE is high. This is due to the changes in population size and the age structure of fish year by year but also random errors affecting the catchability (condition during fishing, variation between fishing locations in each year). Furthermore, gill nets underestimate the proportion of small (< 10 cm) fish in size distribution and some pelagic species such as smelt or vendace are almost missing in the multi-mesh gill net catch although it can be the most abundant species in the trawl catch (Olin *et al*. 2009). Gill net fishing can only produce supporting information for fisheries management and comprehensive fish community studies need the application of multiple methods (Rask *et al*. 2020).

Biomanipulation by intensive fishing aims to change the planktonic food web in a target lake and often also aims to change the species composition of the fish community by increasing the proportion of predator fish and improving the value of the fish community for the fishery. During the 3-year intensive fishing in Jyväsjärvi, the ecosystem changes were rather minor, although some altered energy flow pathways were observed (Syväranta et al. 2011). Fish removal was followed by abundant year classes. The increase in the number of young fish subsequently increased the utilization of pelagic resources. This was reflected as a decrease in relative energy contribution from littoral sources indicating increased trophic diversity and occupied niche area. However, only minor changes were observed in the trophic positions of fish or planktonic food web (Syväranta et al. 2011). One reason for the minor effects was that the springtime fyke fishing was mainly targeting ≥ 2-year-old fish and young fish that had not yet been recruited to the fishing had a high potential to grow and compensate for the effects of harvesting of the older fish. From fyke net catches and multi-mesh gill net fishing we mainly got information about ≥ 2-year-old fish and the abundance of younger fish remained

Despite the limitations of our monitoring methods, multi-mesh gill net fishing brought out interesting trends in the proportional abundance of the dominant fish species, roach and perch, in our study lakes. In all three lakes where the intensive fish removal was not carried out, the proportion of perch biomass increased towards the end of the study period. In the future, it will be interesting to examine the connection of this change to the wide-ranging changes taking place in our environment, such as the browning of waters and the effects of climate change.

ACKNOWLEDGEMENTS

During this 21-year follow-up study, Jonna Kuha, Antti Kytölä, Mikko Mäkinen, Olli Nousiainen, Rosanna Sjövik, Tuula Väänänen and numerous students have participated in the project's fieldwork, fish sample preparation, age determination and data storage, all of whom we would like to thank for their invaluable work and commitment. This research has been partly financed in the years 2001–2006 by the European Regional Development Fund and in the years 2017–2022 by the European Sea and Fisheries Fund (TUKALA, Research and fishermen's partnership program) both supported also by Ministry of Agriculture and Forestry Finland. Monitoring work has been done also in part of the European long-term ecological network and Finnish long-term ecosystem and socio-ecological research network.

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Appendix 1. Test fishing by multi-mesh gill nets: fishing dates and epilimnion temperatures (T, C°) in Jyväsjärvi, Tuomiojärvi, Alvajärvi and Patajärvi. YK = multi-mesh nets (mesh size 10–55 mm knot to knot) and N = NORDIC multi-mesh survey nets (5–55 mm).

	Net type	Jyväsjärvi		Tuomiojärvi		Alvajärvi		Patajärvi	
Year	YK/N	Date	T	Date	T	Date	T	Date	T
2001	YK	13.–15.8.	18.3	23.–24.8.	18.7	28.–29.8.	18.1	5.–6.9.	15.2
2002	YK	13.–15.8.	22.3	21.–22.8.	21.0	26.–27.8.	21.4	27.–29.8.	19.7
2003	YK	11.–14.8.	18.5	18.–19.8.	19.1	25.–26.8.	16.2	28.–29.8.	13.9
2004	YK	3.–6.8.	21.4	10.–11.8.	21.5	23.–24.8.	21.1	26.–27.8.	19.8
2005	YK	9.–12.8.	18.7	16.–17.8.	18.3	22.–23.8.	18.7	25.–26.8.	15.5
2006	YK	7.–10.8.	22.1	24.–25.8.	21.4	15.–16.8.	22.1	21.–22.8.	20.2
2007	YK	7.–9.8.	20.0	23.–24.8.	20.5	13.–14.8.	20.0	15.–16.8.	21.9
2008	YK	4.–7.8.	17.8	11.–12.8.	16.6	13.–14.8.	17.8	18.–19.8.	16.3
2009	YK	17.–21.8.	17.3	10.–11.8.	21.3	24.–25.8.	17.3	26.–27.8.	16.5
2010	N	2.–6.8.	22.4	9.–10.8.	23.5	11.–12.8.	22.4	16.–17.8.	21.7
2011	N	8.–11.8.	20.2	15.–16.8.	19.0	17.–18.8.	20.2	2.–4.8.	21.9
2012	N	6.–21.8.	20.4	9.–10.8.	18.4	13.–14.8.	20.4	15.–16.8.	18.6
2013	N	13.–15.8.	19.9	6.–7.8.	21.1	8.–9.8.	19.9	20.–21.8.	17.2
2015	N	10.–13.8.	15.5	3.–4.8.	18.6	5.–6.8.	15.5	17.–18.8.	18.7
2017	N	7.–10.8.	18.2	16.–17.8.	18.7	14.–15.8.	18.8		
2019	N	12.–15.8.	17.9	19.–21.8.	17.6	22.–23.8.	17.8		
2021	N	2.–6.8.	14.3	15.–16.9.	11.4	30.–31.8.	15.4		
		6–7.9.							

Appendix 2 Catch per unit effort (CPUE kg fyke net day^{-1}) of intensive fyke net fishing in 2004–2006 in Jyväsjärvi.

Date	Roach	Perch	Bream	Bleak	Date	Roach	Perch	Bream	Bleak	Date	Roach	Perch	Bream	Bleak
02.05.2004	70.6	25.5	127.6	23.8	27.04.2005	30.8	2.5	2.5	0.0	06.05.2006	17.1	42.7	102.5	0.0
03.05.2004	12.9	98.3	28.1	10.7	28.04.2005	25.4	1.2	38.0	4.7	07.05.2006	29.3	28.2	43.3	0.0
04.05.2004	10.6	65.1	162.8	1.3	30.04.2005	16.3	0.6	25.5	3.7	08.05.2006	30.1	29.2	28.3	1.7
05.05.2004	36.6	56.0	75.1	19.6	01.05.2005	1.8	4.7	18.9	2.4	09.05.2006	46.8	48.1	34.4	0.7
06.05.2004	61.6	49.7	62.9	19.5	03.05.2005	9.6	19.5	14.0	8.4	10.05.2006	42.3	36.3	36.3	0.3
07.05.2004	25.3	53.5	115.4	35.8	04.05.2005	10.4	18.3	31.1	10.4	11.05.2006	48.7	47.3	34.8	0.1
08.05.2004	23.7	24.5	85.7	15.9	05.05.2005	5.6	8.2	17.2	4.9	12.05.2006	51.0	52.5	37.5	0.7
09.05.2004	9.5	24.0	82.9	19.3	06.05.2005	10.6	12.9	15.4	7.7	13.05.2006	58.3	48.1	36.5	0.7
10.05.2004	5.3	30.8	88.8	16.5	07.05.2005	14.5	10.6	25.2	15.1	14.05.2006	14.2	28.3	19.8	0.3
11.05.2004	4.2	18.3	45.7	8.5	08.05.2005	9.6	11.3	38.0	8.5	15.05.2006	9.0	24.0	16.2	0.1
12.05.2004	1.6	8.6	29.6	2.8	09.05.2005	10.6	12.9	34.2	14.7	16.05.2006	8.8	10.2	6.4	0.0
13.05.2004	1.8	13.7	10.3	1.6	10.05.2005	2.0	3.5	6.8	0.2	17.05.2006	7.5	11.6	15.0	0.9
14.05.2004	0.3	2.5	5.7	5.3	11.05.2005	3.2	4.6	9.9	0.3	21.05.2006	0.4	7.4	31.9	2.1
17.05.2004	1.1	11.4	4.9	1.8	12.05.2005	5.5	6.9	10.0	0.3	22.05.2006	5.4	14.3	14.7	3.0
18.05.2004	1.1	5.7	4.9	2.8	13.05.2005	11.1	12.9	30.7	0.9	23.05.2006	14.0	10.0	14.0	0.6
19.05.2004	1.9	8.6	3.2	2.7	14.05.2005	5.8	7.2	10.8	0.0	24.05.2006	5.3	7.3	10.9	1.7
20.05.2004	0.7	2.9	6.0	5.6	15.05.2005	5.9	7.4	15.4	0.0	25.05.2006	1.8	4.9	10.5	0.1
22.05.2004	1.2	2.6	3.2	1.2	16.05.2005	3.2	3.5	5.3	0.0	26.05.2006	5.8	10.4	4.2	0.3
23.05.2004	5.9	12.8	6.4	1.5	17.05.2005	3.6	4.5	10.2	0.3	27.05.2006	2.9	8.7	4.0	0.6
24.05.2004	0.7	11.2	12.5	0.9	18.05.2005	1.0	1.2	35.3	3.5	28.05.2006	8.4	11.4	15.8	0.9
26.05.2004	2.9	19.1	6.0	1.1	22.05.2005	9.0	11.4	35.0	3.5	29.05.2006	6.8	4.0	4.8	7.1
27.05.2004	3.9	6.4	18.9	3.0	23.05.2005	9.1	15.9	32.7	4.2	30.05.2006	7.3	2.9	8.6	6.0
28.05.2004	0.3	3.2	31.9	11.9	24.05.2005	12.3	26.9	86.2	0.0	31.05.2006	10.2	8.6	11.4	0.0
30.05.2004	2.9	6.4	36.2	7.9	25.05.2005	5.4	18.4	38.6	0.0	01.06.2006	23.0	7.3	7.7	1.7
31.05.2004	0.5	1.0	51.7	2.4	26.05.2005	10.4	19.1	28.6	0.0	02.06.2006	2.7	1.2	5.4	2.0
02.06.2004	4.8	2.6	66.8	7.8	27.05.2005	4.5	12.5	29.2	0.0	04.06.2006	2.3	1.1	18.5	0.3
03.06.2004	3.4	7.4	43.0	4.8	28.05.2005	1.8	3.3	10.8	0.0	05.06.2006	6.8	3.7	7.3	0.1
04.06.2004	4.8	10.3	100.2	15.5	29.05.2005	2.7	5.1	22.5	0.0	06.06.2006	1.9	4.3	3.5	0.0
05.06.2004	33.3	5.2	66.3	7.8	30.05.2005	1.2	2.2	11.3	0.2	07.06.2006	1.0	2.4	1.5	0.7
06.06.2004	3.4	3.7	36.2	4.8	01.06.2005	2.0	6.9	18.9	0.4	08.06.2006	3.6	4.5	2.1	0.0
07.06.2004	4.8	5.2	58.4	7.8	02.06.2005	2.3	3.4	9.8	0.2	09.06.2006	7.7	6.3	3.8	6.8
08.06.2004	4.8	5.2	58.4	7.8	03.06.2005	7.3	14.8	16.1	0.4	10.06.2006	2.5	4.1	1.9	7.4
09.06.2004	3.4	3.7	25.8	4.8	04.06.2005	2.9	4.9	9.2	0.6	11.06.2006	3.2	1.8	1.2	4.6
10.06.2004	4.8	5.2	50.1	7.8	05.06.2005	1.8	3.2	11.8	0.0	12.06.2006	3.5	6.9	2.9	1.4
11.06.2004	4.8	5.2	8.3	7.8	07.06.2005	4.2	7.7	16.2	0.3	13.06.2006	4.8	11.2	1.2	0.3
12.06.2004	9.5	2.6	16.7	15.5	08.06.2005	5.2	6.0	11.8	0.2					
13.06.2004	4.8	5.2	8.3	7.8	09.06.2005	0.4	0.8	21.0	0.4					
14.06.2004	1.2	1.0	0.6	1.5	13.06.2005	3.0	4.8	5.1	0.1					
15.06.2004	2.6	2.8	0.3	3.9										
16.06.2004	3.8	8.3	0.2	3.9										
17.06.2004	1.9	2.1	0.4	7.8										
19.06.2004	1.9	2.1	0.4	23.3										
21.06.2004	3.8	4.2	0.8	15.5										
22.06.2004	6.3	27.1	7.5	12.6										
23.06.2004	6.3	6.8	6.8	6.3										
24.06.2004	0.8	0.8	1.4	12.6										
28.06.2004	5.0	5.4	0.4	20.2										
30.06.2004	5.0	5.4	0.4	20.2										

Appendix 3 Catch per unit effort (CPUE, the stratum volume-weighted average of stratum-specific averages) of multi-mesh gill net fishing (YK-net intercalibrated) in Jyväsjärvi from 2001 to 2021. Upper table represents mass of catch (g net^{-1} day^{-1}) and lower table gives number of fish in catch (individuals net^{-1} day^{-1}). SE is standard error of mean.

CPUE in mass

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2015	2017	2019	2021
Perch/ahven	657.10	859.22	1233.90	646.87	594.98	1541.14	934.38	517.13	650.16	1081.49	1153.05	777.16	716.38	715.26	630.84	983.88	456.63
SE	79.84	124.62	276.46	81.51	35.69	272.98	122.30	71.43	140.54	121.05	165.78	145.15	107.19	80.74	85.30	134.72	102.68
Roach/särki	797.68	538.02	1085.21	649.11	344.61	609.55	794.71	937.46	874.53	1241.68	1035.15	536.99	589.71	474.87	562.80	506.29	346.67
SE	134.93	58.89	236.59	234.53	41.73	88.80	107.92	134.32	142.17	142.20	241.32	119.69	68.97	60.31	102.35	109.39	107.79
Pike/hauki	25.20	9.65	5.77	50.95	0.22	88.34	235.20	226.26	61.11	0.09	141.68	11.15	19.48	29.13	34.76	9.07	7.72
SE		6.46	4.03	38.22	0.22	46.94	64.71	110.03	43.34	0.01	110.93	11.15	13.92	29.13	22.08	9.07	6.50
Ruffe/kiiski	19.93	22.39	3.25	15.35	51.58	40.96	22.23	20.11	23.94	28.79	9.50		7.26	14.02	6.81	6.39	3.97
SE		13.99	2.08	6.18	16.33	13.32	51.78	6.99	6.43	11.25	2.99		2.89	4.50	2.50	2.57	1.92
Pikeperch/kuha	211.76	93.24	187.77	70.10	46.37	98.88	149.73	339.91	852.08	187.09	31.32	66.13	125.16	255.53	147.31	81.03	233.38
SE	98.81	58.70	97.88	8.16	11.25	32.02	60.72	98.44	234.04	52.65	20.91	41.42	62.92	102.44	72.90	43.49	89.27
Smelt/kuore	0.58				0.61				0.67	2.12		1.24	0.36	0.66		0.64	0.75
SE					0.43				0.67	2.08		0.78	0.36	0.66		0.64	0.12
Bream/lahna	33.44	60.25	57.30	62.80	19.35	66.46	83.90	94.80	80.96	14.74	5.49	124.74	41.78	30.34	63.80	39.69	32.07
SE	12.25	19.55	17.46	12.91	13.63	15.74	64.12	34.01	35.59	6.75	4.05	69.82	17.48	10.39	27.97	12.35	18.29
Burbot/made	11.21				15.79					5.83					30.61		3.39
SE	11.21				15.79					5.83					33.06		3.85
Silver bream/pasuri	53.45	51.85	6.33	9.52	20.83	1.64	11.48	25.17	31.09	27.36	26.28	18.00	28.95	29.06	6.16	22.93	105.26
SE	12.14	17.92	3.11	6.03	10.29	1.17	51.95	9.26	22.60	16.54	14.38	14.73	16.67	15.25	3.42	8.94	57.15
Crucian carp/ruutana							3.70								25.23		
SE							51.89								25.23		
Bleak/salakka	52.90	99.66	145.00	35.44	11.38	46.02	68.21	158.24	199.74	92.67	119.25	86.86	79.94	299.45	117.37	106.20	37.77
SE	15.57	40.92	49.12	14.81	3.59	27.35	56.76	37.14	52.30	15.65	37.31	28.72	26.15	43.68	64.98	53.63	22.73
Whitefish/siika	1.20			28.37	9.35		33.77	168.65	164.21	85.76		20.24	29.06	44.52			19.91
SE	0.80			28.37	9.02		52.23	91.48	67.25	71.92		20.24	29.06	44.52			19.91
Rudd/sorva			2.19	0.11	4.65	9.43				6.67		0.74	4.99	6.75	2.94	1.37	13.79
SE			2.19	0.11	3.93	9.43				6.67		0.74	4.99	6.75	1.98	1.37	9.55
Vendace/muikku																	2.81
SE																	2.81
Total CPUE	1864.44	1734.27	2726.73	1568.62	1119.73	2502.41	2337.32	2487.73	2938.48	2774.30	2521.72	1643.26	1643.07	1899.59	1628.62	1757.48	1264.13
SE	220.65	204.02	560.76	285.52	49.15	360.52	81.17	348.94	418.94	231.17	336.26	257.84	206.10	211.34	239.90	195.56	299.35

CPUE in number

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2015	2017	2019	2021
Perch/ahven	40.72	59.29	79.75	42.77	35.45	90.80	50.34	24.83	22.02	61.94	57.34	32.91	31.48	38.52	36.01	45.52	19.16
SE	5.25	9.60	11.06	5.46	2.47	13.63	7.88	3.15	4.43	6.96	7.05	5.67	3.84	3.53	4.63	6.01	4.15
Roach/särki	16.57	10.33	26.31	13.59	8.25	10.03	22.06	20.52	16.16	33.79	31.44	17.64	18.24	12.11	16.63	13.48	7.79
SE	3.84	1.61	5.61	5.49	1.43	2.21	5.88	4.33	2.77	4.66	6.98	5.02	3.05	1.20	3.10	3.29	2.21
Pike/hauki	0.02	0.02	0.02	0.06	0.01	0.20	0.23	0.24	0.10	0.09	0.20	0.02	0.07	0.07	0.09	0.02	0.05
SE		0.01	0.01	0.04	0.01	0.09	0.14	0.10	0.07	0.01	0.11	0.02	0.06	0.07	0.06	0.02	0.04
Ruffe/kiiski	1.88	1.71	0.50	2.04	4.18	3.24	3.52	2.12	2.94	3.00	1.56		1.29	2.47	0.86	0.77	0.84
SE		1.06	0.32	0.83	1.15	0.93	1.14	0.83	0.91	1.13	0.52		0.48	0.66	0.28	0.28	0.40
Pikeperch/kuha	0.82	0.27	0.36	1.15	0.44	0.44	0.73	0.97	2.41	0.79	0.39	0.41	0.40	1.00	0.46	0.42	0.99
SE	0.36	0.17	0.16	0.67	0.28	0.16	0.21	0.27	0.56	0.20	0.16	0.24	0.16	0.21	0.18	0.18	0.34
Smelt/kuore	0.05				0.07				0.07	0.37		0.15	0.06	0.06		0.06	0.12
SE					0.05				0.07	0.36		0.09	0.06	0.06		0.06	0.75
Bream/lahna	0.30	0.54	0.39	2.14	0.05	0.31	0.48	0.43	0.35	0.18	0.19	0.36	0.54	0.45	0.79	0.40	0.22
SE	0.10	0.26	0.13	0.26	0.04	0.11	0.18	0.11	0.18	0.08	0.12	0.11	0.22	0.18	0.36	0.15	0.14
Burbot/made	0.05				0.04					0.07					0.06		0.04
SE	0.05				0.04					0.07					0.07		0.04
Silver bream/pasuri	1.23	0.91	0.13	0.14	0.25	0.02	0.14	0.23	0.30	0.27	0.24	0.20	0.30	0.28	0.09	0.25	0.99
SE	0.32	0.31	0.07	0.08	0.12	0.01	0.08	0.05	0.16	0.14	0.11	0.15	0.17	0.15	0.06	0.11	0.46
Crucian carp/ruutana							0.01								0.05		
SE							0.01								0.05		
Bleak/salakka	2.65	6.85	9.33	2.12	0.53	2.57	3.42	11.98	12.48	5.16	6.77	7.81	5.17	19.11	5.73	4.39	2.32
SE	0.67	3.16	3.37	0.78	0.16	1.56	1.40	3.35	3.32	0.82	1.88	2.15	1.77	2.71	3.02	2.31	1.32
Whitefish/siika	0.02			0.13	0.04		0.24	0.46	0.38	0.22		0.07	0.06	0.07			0.06
SE	0.01			0.13	0.04		0.09	0.22	0.16	0.15		0.07	0.06	0.07			0.06
Rudd/Sorva			0.02	0.01	0.02	0.02				0.02		0.01	0.01	0.04	0.05	0.01	0.06
SE			0.02	0.01	0.01	0.02				0.02		0.01	0.01	0.04	0.04	0.01	0.04
Vendace/muikku																	0.06
SE																	0.06
Total CPUE	64.30	79.91	116.79	64.15	49.32	107.64	81.17	61.78	57.21	105.91	98.12	59.59	57.63	74.19	60.82	65.32	32.71
SE	11.71	11.21	15.93	9.98	3.33	13.22	9.41	6.91	8.25	8.96	12.56	9.60	6.16	5.27	7.93	7.56	6.69

Appendix 4 Catch per unit effort (CPUE, the stratum volume-weighted average of stratum-specific averages) of multi-mesh gill net fishing (YK-net intercalibrated) in Tuomiojärvi from 2001 to 2021. Upper table represents mass of catch (g net^{-1} day^{-1}) and lower table gives number of fish in catch (individuals net^{-1} day^{-1}). SE is standard error of mean.

CPUE in mass

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2015	2017	2019	2021
Perch/ahven	697.95	1774.86	1087.13	774.51	947.63	833.92	800.61	660.93	853.63	905.52	1055.25	838.33	1614.40	1159.47	1370.49	1385.99	1742.54
SE	93.45	305.48	237.69	113.47	205.72	215.75	147.07	128.57	267.76	170.67	308.34	228.71	478.75	255.65	410.75	471.95	504.08
Roach/särki	1569.42	1785.02	1542.83	1425.47	1343.22	1855.36	1506.76	1387.33	824.05	1309.16	1540.17	1333.81	716.63	1205.92	1199.00	868.57	765.07
SE	165.91	255.02	243.36	106.58	149.90	289.93	425.20	286.92	128.14	209.99	339.91	18.94	89.65	300.65	160.79	142.01	132.92
Pike/hauki	28.22	35.84	41.35	195.93	23.25	36.50	23.44	36.71	18.39		20.18	85.54	91.62	32.12			225.20
SE	20.35	35.84	28.55	138.71	23.25	36.50	23.44	36.71	18.39		20.18	85.54	64.79	32.12			225.20
Ruffe/kiiski	5.00	2.17	0.17	4.24	2.34	3.46	7.38	3.26	4.69	1.94	2.16		3.99	3.40	4.79	4.71	2.73
SE	1.87	0.88	0.17	1.97	1.45	0.95	6.77	1.58	3.31	1.05	1.68		1.67	2.28	2.11	2.04	1.04
Pikeperch/kuha	41.96	253.14	433.03	258.58	278.14	616.35	833.45	571.87	833.91	599.99	219.80	381.03	434.29	139.56	479.33	116.42	401.99
SE	28.13	133.70	169.98	95.55	131.47	171.12	168.99	169.10	266.19	256.64	145.57	156.16	164.88	68.12	237.68	62.61	148.98
Rainbow trout/kirjolohi	63.14	367.73	58.66	92.58	280.23	200.78	470.26					45.04	89.35	294.14	150.17		
SE	63.14	207.26	41.71	63.47	144.23	157.01	162.09					40.29	89.35	156.13	150.17		
Bream/lahna	217.14	879.93	505.30	603.16	269.71	393.57	311.26	159.94	127.34	296.28	151.87	54.41	362.44	395.13	310.74	240.54	80.16
SE	38.99	211.53	127.96	145.89	78.81	105.37	62.07	66.99	52.80	80.86	54.84	33.06	80.32	192.78	87.60	130.65	42.07
Silver bream/pasuri	91.12	214.26	20.05	109.29	78.80	117.88	223.11	47.37	77.55	24.26	69.20	142.32	24.33	79.56	257.46	105.74	69.32
SE	27.17	42.73	13.49	39.93	45.87	35.00	68.54	19.56	32.18	14.96	32.57	91.57	18.58	25.68	118.50	66.59	39.38
Crucian carp/ruutana	22.30		57.53	64.09													
SE	22.30		57.53	64.09													
Bleak/salakka	96.59	69.50	93.49	76.20	73.94	228.58	38.38	56.45	27.14	38.10	25.83	22.52	16.87	17.36	19.96	7.75	8.60
SE	16.79	21.18	19.33	12.00	23.51	53.71	13.79	19.90	15.74	18.84	5.67	8.57	6.03	6.99	8.02	6.09	5.62
Whitefish/siika	37.29	192.88		177.51	91.73	102.51	178.40	257.97				400.87	128.55	255.02			163.06
SE	18.20	73.44		99.56	68.46	58.82	103.24	145.82				200.13	86.07	166.49			163.06
Rudd/sorva																	55.66
SE																	40.69
Total CPUE	2870.13	5575.33	3839.54	3781.56	3388.99	4388.91	4393.06	3181.83	2766.70	3175.25	3084.47	3303.86	3482.48	3581.66	3791.97	2729.71	3514.33
SE	274.01	255.02	666.20	376.90	437.93	638.21	802.10	487.39	80.84	372.48	665.76	539.89	675.59	534.49	694.92	595.97	492.74

CPUE in number

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2015	2017	2019	2021
Perch/ahven	57.17	166.76	87.60	74.84	72.93	69.17	58.10	44.38	46.11	41.85	31.09	30.06	39.61	31.33	39.70	28.57	11.79
SE	9.14	23.28	19.63	10.87	14.37	17.34	8.68	8.14	13.78	7.30	6.70	8.26	7.86	7.39	9.92	7.30	2.57
Roach/särki	52.78	67.07	46.03	41.11	47.55	87.04	98.48	56.40	28.46	67.58	59.90	75.41	39.54	46.71	50.52	33.04	33.01
SE	7.23	10.64	7.13	4.81	6.89	17.91	46.40	14.06	4.32	10.19	20.09	18.93	5.77	12.01	5.89	5.86	5.83
Pike/hauki	0.09	0.07	0.14	0.12	0.03	0.03	0.05	0.07	0.07		0.07	0.15	0.18	0.07			0.09
SE	0.07	0.06	0.10	0.09	0.03	0.03	0.05	0.07	0.07		0.07	0.15	0.13	0.07			0.09
Ruffe/kiiski	0.91	0.50	0.03	0.78	0.42	0.59	1.63	0.61	0.95	0.51	0.58		1.35	0.82	1.54	1.41	0.51
SE	0.34	0.24	0.03	0.36	0.29	0.16	1.30	0.32	0.70	0.34	0.42		0.51	0.53	0.65	0.60	0.19
Pikeperch/kuha	0.20	0.91	0.84	0.75	0.60	1.17	2.59	1.56	1.70	0.86	0.31	0.97	1.05	0.45	1.07	1.03	1.00
SE	0.12	0.29	0.34	0.22	0.27	0.37	0.59	0.49	0.49	0.23	0.13	0.37	0.36	0.17	0.65	0.60	0.36
Rainbow trout/kirjolohi	0.06	0.25	0.09	0.13	0.27	0.21	0.45					0.11	0.09	0.25	0.09		
SE	0.06	0.15	0.07	0.08	0.15	0.17	0.14					0.10	0.09	0.14	0.09		
Bream/lahna	1.54	6.65	4.59	3.86	1.89	3.34	1.98	0.54	1.04	1.61	1.07	0.26	2.86	1.81	1.55	1.63	0.60
SE	0.27	2.14	1.26	1.14	0.56	0.96	0.42	0.24	0.37	0.47	0.32	0.13	1.16	0.63	0.45	0.72	0.36
Silver bream/pasuri	1.29	3.02	0.34	1.19	0.92	1.11	3.23	1.07	0.63	0.22	0.76	1.27	0.33	1.76	0.92	0.82	0.69
SE	0.35	0.43	0.20	0.50	0.62	0.31	1.28	0.43	0.26	0.15	0.28	0.63	0.23	0.46	0.33	0.48	0.28
Crucian carp/ruutana	0.03		0.07	0.04													
SE	0.03		0.07	0.04													
Bleak/salakka	5.96	4.02	5.66	3.91	4.17	17.48	2.56	3.54	1.82	3.47	1.46	1.48	1.08	0.73	0.89	0.32	0.51
SE	1.05	1.30	1.15	0.61	1.29	4.81	0.93	1.32	1.19	1.89	0.32	0.71	0.41	0.31	0.35	0.24	0.40
Whitefish/siika	0.20	0.46		0.28	0.17	0.21	0.38	0.47				0.82	0.18	0.27			0.27
SE	0.08	0.18		0.16	0.12	0.10	0.21	0.23				0.40	0.11	0.18			0.27
Rudd/sorva																	0.24
SE																	0.17
Total CPUE	120.24	249.70	145.40	127.00	128.95	180.34	169.45	108.66	80.77	116.10	95.25	110.54	86.27	84.19	96.28	66.83	48.70
SE	11.69	10.64	26.90	16.58	18.80	29.69	50.29	21.39	18.38	13.70	23.44	21.11	11.83	17.50	13.71	12.32	7.02

Appendix 5 Catch per unit effort (CPUE, the stratum volume-weighted average of stratum-specific averages) of multi-mesh gill net fishing (YK-net intercalibrated) in Alvajärvi from 2001 to 2021. Upper table represents mass of catch (g net^{-1} day^{-1}) and lower table gives number of fish in catch (individuals net^{-1} day^{-1}). SE is standard error of mean.

CPUE in mass

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2015	2017	2019	2021
Perch/ahven	317.78	925.06	235.60	357.03	257.98	446.71	1294.35	327.55	294.69	657.46	766.33	593.12	1183.02	1293.82	507.44	824.44	777.46
SE	75.47	319.61	46.01	75.82	43.96	122.62	785.49	103.81	143.19	309.22	252.73	155.71	329.49	305.18	120.93	271.20	163.65
Roach/särki	514.66	628.88	537.47	653.34	388.03	842.73	518.67	302.72	419.19	1003.98	458.38	677.79	870.81	1176.29	685.94	642.32	505.68
SE	77.95	67.65	115.06	102.32	60.58	128.96	88.42	47.48	120.13	244.96	135.05	137.94	188.69	142.98	99.55	148.20	5.43
Pike/hauki	65.53	141.52	75.94	16.70	13.98	68.61	22.55	25.96		7.09	31.40	147.67					
SE	24.99	55.74	53.72	16.16	13.98	33.95	22.55	16.23		7.09	31.40	147.67					
Ruffe/kiiski	1.89	4.74	3.89	6.15	6.05	1.47	3.04	10.30	3.46	2.56	0.34		5.33	4.29	6.25	2.65	7.87
SE	1.16	4.36	2.31	1.83	2.28	0.71	1.49	4.14	2.46	1.71	0.34		5.06	2.26	3.47	0.86	4.52
Pikeperch/kuha	100.80	211.01	112.67	85.38	237.39	345.52	699.85	477.90	167.17	417.02	89.40		421.16	70.54	184.20	232.18	324.86
SE	65.60	64.16	49.67	30.87	90.35	106.95	162.48	149.64	73.47	358.83	58.18		138.19	33.85	156.03	146.81	127.63
Bream/lahna	24.36	180.18	152.61	75.74	117.53	145.55	218.27	211.06	167.17	172.23	188.00	222.34	243.75	140.27	111.16	269.71	75.75
SE	11.60	36.69	63.10	46.35	56.49	43.03	113.64	98.35	73.47	80.72	49.45	80.61	71.57	49.71	29.22	103.82	34.81
Silver bream/pasuri	67.63	205.23	370.68	438.99	174.04	114.30	174.87	212.59	98.70	40.39	96.61	46.85	58.79	89.16	73.26	66.76	114.53
SE	22.52	60.56	247.09	116.20	79.46	35.56	41.77	44.01	40.86	29.55	65.53	31.63	30.65	65.85	29.22	29.88	39.33
Crucian carp/ruutana						35.21											
SE						23.44											
Bleak/salakka	50.43	138.02	21.12	91.74	38.13	112.97	93.81	80.08	37.81	23.83	8.55	20.65	22.12	13.86	1.42	0.00	5.44
SE	18.51	25.96	6.28	22.75	9.54	15.37	24.99	46.37	15.29	10.82	3.19	6.01	5.91	8.97	1.42		2.22
Rudd/sorva				0.72													
SE				0.72													
Total CPUE	1143.08	2434.64	1509.98	1725.78	1233.14	2113.08	3025.42	1648.17	1188.20	2324.56	1639.02	1708.42	2804.97	2788.22	1569.68	2038.04	1811.58
SE	214.43	452.75	365.88	241.45	242.91	334.14	778.91	461.49	307.41	641.59	454.16	295.86	678.94	402.46	337.24	555.04	273.07

CPUE in number

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2015	2017	2019	2021
Perch/ahven	15.68	58.04	14.80	21.97	12.83	20.80	47.04	9.22	6.93	17.77	25.34	16.38	27.77	48.66	15.33	17.33	17.63
SE	2.13	13.57	2.66	4.76	2.55	5.85	13.18	1.51	3.10	6.43	8.93	3.99	7.55	9.12	3.79	5.59	3.29
Roach/särki	21.97	32.60	24.84	30.79	15.45	37.62	11.91	8.85	15.39	27.45	13.99	38.06	37.64	51.69	30.30	39.17	80.33
SE	3.75	4.20	5.45	6.50	3.25	6.50	5.08	2.10	4.91	5.56	4.31	13.01	11.94	7.69	3.65	13.73	19.50
Pike/hauki	0.16	0.32	0.14	0.06	0.03	0.09	0.11	0.10		0.08	0.06	0.13					
SE	0.05	0.12	0.10	0.04	0.03	0.04	0.11	0.06		0.08	0.06	0.13					
Ruffe/kiiski	0.24	0.67	0.85	1.20	0.88	0.27	0.65	1.36	0.39	0.69	0.06		0.77	0.74	0.82	0.56	1.70
SE	0.14	0.61	0.54	0.35	0.33	0.12	0.34	0.52	0.24	0.48	0.06		0.62	0.36	0.46	0.19	0.83
Pikeperch/kuha	0.54	1.31	0.59	0.59	1.35	0.66	1.79	2.12	0.54	0.97	0.47		0.76	0.19	1.34	0.75	1.97
SE	0.29	0.29	0.24	0.25	0.39	0.29	0.71	0.73	0.20	0.78	0.29		0.24	0.08	1.22	0.34	0.98
Bream/lahna	0.43	3.95	1.31	0.49	2.18	1.65	1.91	0.44	0.54	2.67	1.98	2.49	3.42	1.17	1.75	3.10	1.13
SE	0.18	1.54	0.42	0.24	1.00	0.42	0.41	0.13	0.20	1.07	0.40	1.14	1.03	0.31	0.55	1.11	0.42
Silver bream/pasuri	1.04	4.26	6.38	14.84	4.58	3.28	2.97	3.06	1.63	0.56	1.09	0.53	0.58	1.17	0.95	0.99	2.42
SE	0.29	1.04	4.18	4.94	2.28	0.95	0.61	0.65	0.52	0.46	0.62	0.28	0.30	0.55	0.40	0.47	0.90
Crucian carp/ruutana						0.06											
SE						0.04											
Bleak/salakka	3.62	9.79	1.29	5.87	2.38	3.99	6.02	4.85	2.18	1.41	0.40	1.14	1.16	0.57	0.06	0.00	0.25
SE	1.42	1.83	0.39	1.91	0.57	1.15	1.62	3.16	0.87	0.78	0.16	0.33	0.34	0.35	0.06		0.12
Rudd/sorva				0.03													
SE				0.03													
Total CPUE	43.68	110.95	50.20	75.83	39.68	68.43	72.40	30.00	27.60	51.60	43.41	58.73	72.10	104.19	50.57	61.90	105.43
SE	6.46	15.95	10.13	15.87	5.66	11.08	13.92	9.30	7.93	10.90	13.62	14.24	16.26	13.41	7.33	17.20	7.54

Appendix 6 Catch per unit effort (CPUE, the stratum volume-weighted average of stratum-specific averages) of test gill net fishing (YK-net intercalibrated) in Patajärvi from 2001 to 2015. Upper table represents mass of catch (g net^{-1} day^{-1}) and lower table gives number of fish in catch (individuals net^{-1} day^{-1}). SE is standard error of mean.

CPUE in mass

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2015
Perch/ahven	340.83	299.67	212.88	112.27	133.87	155.52	317.22	340.63	450.91	263.57	264.74	452.18	671.42	797.93
SE	185.26	190.27	118.19	75.03	65.64	32.00	57.08	169.81	317.26	106.26	63.75	231.23	471.81	338.78
Roach/särki	144.87	185.68	155.00	281.47	112.35	94.12	127.93	46.27	153.89	144.86	136.31	110.30	200.75	351.95
SE	48.89	79.02	78.04	178.57	40.58	19.48	24.92	12.35	48.31	23.87	29.81	33.38	59.97	100.24
Pike/hauki	125.49	70.23	63.29	10.18	19.93	35.75	35.42		0.70	1.24	13.02	83.72		7.61
SE	125.49	58.75	38.07	10.18	12.88	35.75	35.42		0.70	1.24	13.02	74.73		7.61
Ruffe/kiiski	0.84		1.51	2.92		0.86	1.44	1.61	3.07					3.35
SE	0.73		1.26	2.70		0.65	1.44	1.49	2.91					2.03
Pikeperch/kuha			26.21		6.62	4.49		16.53			4.24			321.52
SE			26.21		3.33	4.49		16.53			4.24			321.52
Bream/lahna	22.26	28.93	140.14	1.04	7.04	21.30	19.49		70.25	12.25	59.78	4.23	35.97	36.62
SE	13.60	14.48	135.17	1.04	3.34	8.04	19.49		55.88	6.18	28.75	3.58	10.39	16.50
Burbot/made				4.40						12.17		20.75	41.80	
SE				4.40						12.17		13.20	41.80	
Silver bream/pasuri	15.11	35.94	39.74	270.88		12.53	10.53	8.30	39.25	16.12	10.57	5.95	57.30	12.14
SE	7.16	16.05	27.49	240.33		6.06	9.94	7.15	18.18	7.66	4.11	5.95	26.19	6.03
Whitefish/siika								46.62						
SE								46.62						
Bleak/salakka	50.43	138.02	21.12	91.74	38.13	9.30	7.38	14.92	50.62	9.93	10.57	20.65	4.71	13.86
SE	18.51	25.96	6.28	22.75	9.54	3.57	2.93	3.25	22.44	9.11	3.16	6.01	2.40	8.97
Smelt/Kuore				1.05				1.87		2.75	1.75	0.82		
SE				1.05				1.87		1.93	1.17	0.82		
Ide/säyne									23.43					
SE									23.43					
Total CPUE	699.84	758.47	659.88	775.94	317.94	333.88	519.40	476.74	792.12	462.89	500.98	698.60	1011.95	1544.98
SE	337.31	336.26	278.37	483.27	94.62	53.84	95.64	187.87	406.11	113.88	112.08	323.91	459.39	541.18

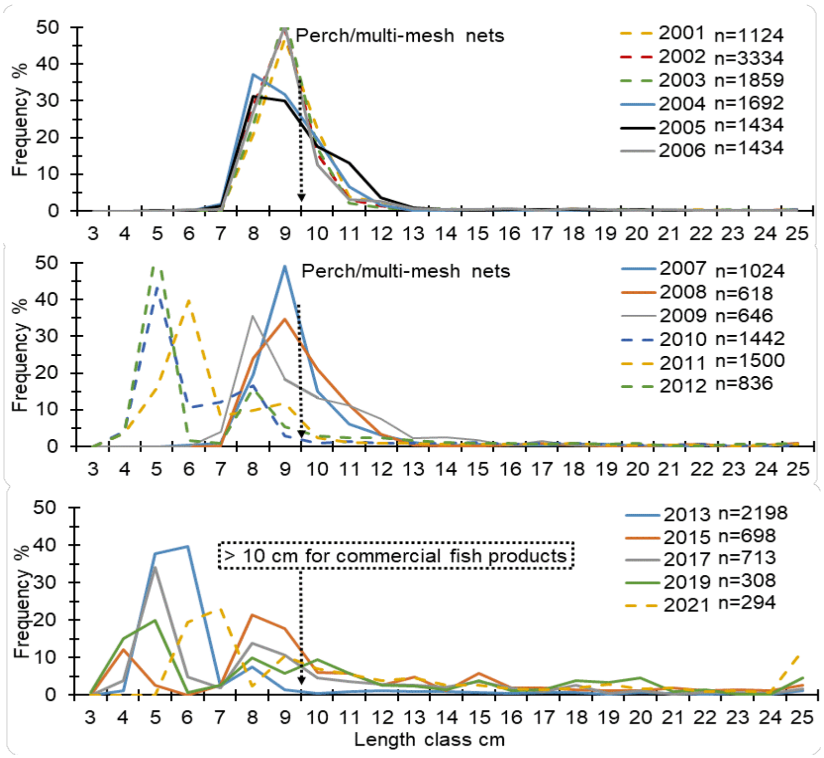
CPUE in number

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2015
Perch/ahven	15.13	11.53	12.60	5.59	7.77	7.87	19.61	11.83	30.13	14.22	16.40	10.99	16.50	30.56
SE	7.62	6.93	8.10	3.32	4.99	2.26	2.88	6.81	22.80	6.17	4.67	4.15	8.61	9.53
Roach/särki	12.87	11.93	11.22	22.78	8.49	5.09	7.95	2.91	6.83	6.75	7.06	5.15	9.57	17.97
SE	4.91	4.68	5.79	14.97	3.60	1.37	1.83	0.95	2.31	1.29	1.34	1.74	2.75	5.35
Pike/hauki	0.35	0.25	0.28	0.03	0.37	0.03	0.18		0.06	0.04	0.02	0.23		0.04
SE	0.35	0.18	0.19	0.03	0.20	0.03	0.18		0.06	0.04	0.02	0.17		0.04
Ruffe/kiiski	0.20		0.22	0.58		0.26	0.18	0.20	0.73					0.93
SE	0.18		0.18	0.53		0.19	0.18	0.18	0.70					0.54
Pikeperch/kuha			0.03		0.35	0.05		0.05			0.02			0.23
SE			0.03		0.20	0.05		0.05			0.02			0.23
Bream/lahna	0.71	0.27	2.95	0.03	0.40	0.33	0.08		0.98	0.38	1.01	0.14	0.61	0.93
SE	0.35	0.18	2.80	0.03	0.20	0.14	0.08		0.72	0.21	0.49	0.10	0.14	0.41
Burbot/made				0.03						0.23		0.31	0.31	
SE				0.03						0.23		0.20	0.31	
Silver bream/pasuri	1.04	1.06	0.79	5.96		0.43	0.30	0.13	0.67	0.36	0.24	0.15	0.75	0.42
SE	0.53	0.34	0.54	5.43		0.18	0.23	0.07	0.29	0.15	0.08	0.15	0.35	0.25
Whitefish/siika								0.18						
SE								0.18						
Bleak/salakka	1.10	1.08	9.06	7.72	3.20	0.79	0.66	1.41	4.40	0.70	0.76		0.41	1.05
SE	0.24	0.49	3.81	4.52	1.10	0.30	0.27	0.37	1.93	0.64	0.23		0.23	0.85
Smelt/Kuore				0.18			0.10	0.18		0.47	0.23	0.16		
SE				0.18			0.06	0.18		0.27	0.15	0.16		
Ide/säyne									0.06					
SE									0.06					
Total CPUE	31.40	26.12	37.14	42.88	20.58	14.84	29.05	16.87	43.84	23.15	25.73	17.11	28.15	52.13
SE	10.82	11.91	13.95	23.46	7.45	2.51	3.88	4.21	25.28	6.58	6.15	5.11	9.09	12.14

Appendix 7 Length distribution (%, number of fish) of roach and perch in multi-mesh gill net catches in 2001–2021 in Tuomiojärvi. Years 2001–2009 YK-nets (10–55 mm) and 2010–2021 Nordic nets (5–55 mm). Length classes are 3 = 3–3.9 cm, 4 = 4–4.9 cm etc. total length. Vertical dotted line indicates a limit for using fish in commercial fish products such as canned fish (10–15 cm), fish paste (15–25 cm) or fillet (> 15 cm). No strata volume weighting.

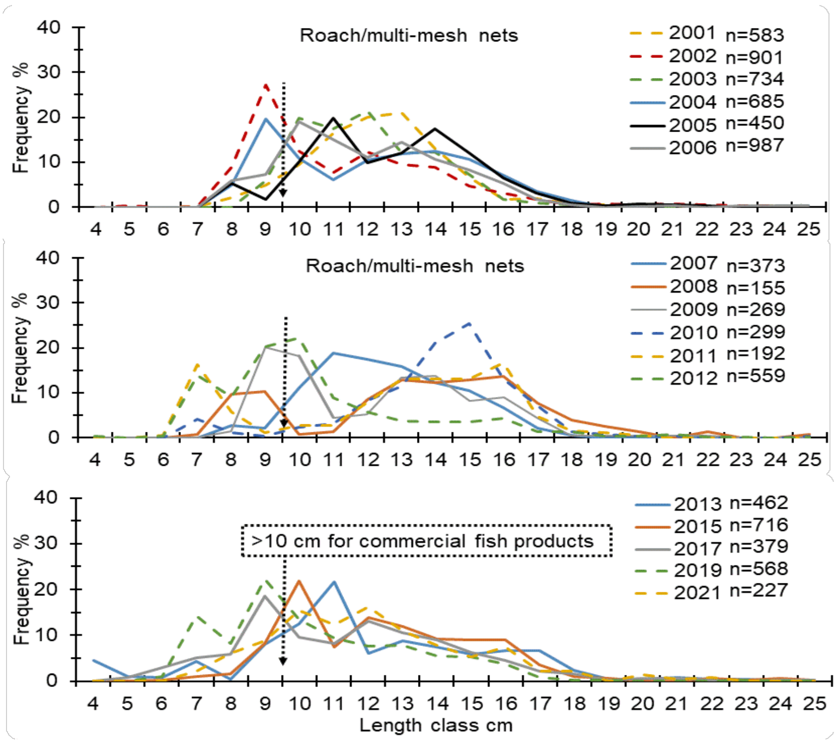
Roach

Perch



Appendix 8 Length distribution (%, number of fish) of roach and perch in multi-mesh gill net catches in 2001–2021 in Alvajärvi. Years 2001–2009 YK-nets (10–55 mm) and 2010–2021 Nordic nets (5–55 mm). Length classes are 3 = 3–3.9 cm, 4 = 4–4.9 cm etc. total length. Vertical dotted line indicates a limit for using fish in commercial fish products such as canned fish (10–15 cm), fish paste (15–25 cm) or fillet (> 15 cm). No strata volume weighting.

Roach



Perch