Supplementary material: tables and figures

S. TABLE 1. Correlation between the time series from different study areas for the water level in spring (hm_{y}, on white background) and water level in autumn ($h_{Nov15\ y-1}$, on gray background). Pearson correlation coefficients (r), risk levels (p) according to the one-tailed hypothesis (H1: positive correlation) and the number of observations (n). Statistically significant correlation coefficients are in **bold.**

		S. Konnevesi	Puula	Tehinselkä	Ruotsalainen
S. Konnevesi	r		**0.801**	**0.855**	**0.685**
	p		< 0.001	< 0.001	0.002
	n		23	23	15
Puula	r	**0.619**		**0.728**	**0.507**
	p	< 0.001		< 0.001	0.027
	n	23		23	15
Tehinselkä	r	**0.872**	**0.650**		**0.661**
	p	< 0.001	< 0.001		0.004
	n	23	23		15
Ruotsalainen	r	**0.821**	**0.772**	**0.644**	
	p	< 0.001	< 0.001	0.005	
	n	15	15	15	

S. TABLE 2. Correlation between the time series from different study areas for inter-annual variation in wintertime water level changes (Δh). Pearson correlation coefficients (r), risk levels (p) according to the one-tailed hypothesis (H1: positive correlation), and number of observations (n). Statistically significant correlation coefficients are in **bold.**

		S. Konnevesi	Puula	Tehinselkä
Puula	r	**0.835**		
	p	< 0.001		
	n	23		
Tehinselkä	r	**0.821**	**0.628**	
	p	< 0.001	< 0.001	
	n	23	23	
Ruotsalainen	r	**0.753**	**0.607**	**0.777**
	p	< 0.001	0.008	< 0.001
	n	15	15	15

S. TABLE 3. Sampling dates by study area from 2000 to 2022.

Year	Tehinselkä	Ruotsalainen	Southern Konnevesi	Puula
2000	2.−4. May		15.−16. May	10.−12. May
2001	2.−4. May		14.−15. May	9.−11. May
2002	2.−4. May		13.−16. May	8.−10. May
2003	15.−16. May		19.−20. May	20.−23. May
2004	3.−5. May		17.−19. May	11.−13. May
2005	2.−4. May		16.−17. May	11.−13. May
2006	11.−12. May		23.−26. May	29.−31. May
2007	23.−25. April		9.−10. May	2.−4. May
2008	7.–8. May	5.–6. May	14.−15. May	12.−13. May
2009	6.–7. May	4.–5. May	11.−12. May	18.−20. May
2010	6.–7. May	3.–5. May	20.−21. May	17.−19. May
2011	5.–6. May	2.–4. May	10.−12. May	16.−18. May
2012	10.–11. May	8.–9. May	23.−25. May	21.−22. May
2013	13.–14. May	6.–8. May	13.−15. May	20.−22. May
2014	24.–25. April	22.–23. April	28.−29. April	28.−29. April
2015	22.–24. April	20.–21. April	4.−5. May	6.−7. May
2016	25.–28. April	27.–28. April	3.−4. May	10.−12. May
2017	3.–4. May	2.–4. May	22.−26. May	17.−18. May
2018	9.–11. May	14.–16. May	16.−18. May	21.−23. May
2019	29. April–1. May	2.–6. May	9.−13. May	6.−8. May
2020	28.–30. April	27.–30. April	4.−7. May	11.−13. May
2021	3.–5. May	27.–29. April	10.−12. May	10.−12. May
2022	18.–20. May	16.–18. May	16.−20. May	23.−25. May

S. TABLE 4. Whitefish larval sampling scheme in the littoral and pelagic zones of the study lakes. Samples were collected in 4 strata in the littoral zone and one pelagic stratum in two vertical sampling depths. In the sublittoral zone there were differences in depth limits: $^{1)}$ Ruotsalainen $^{2)}$ Tehinselkä $^{3)}$ Southern Konnevesi $^{4)}$ Puula. In the strata with bottom depth > 2 m, the lower limit of whitefish distribution was assumed to be 2 m from the surface.

Site	Bottom depth stratum, m	Sampling depth, m	Number of samples (n)	Methods
Littoral	0-0.5	0-0.5	4	tube net, wading
Littoral	0.5–1	0–0.3	1	bongo net, boat
Littoral	1–2	0–0.3, 0–0.6	2	bongo net, boat
Littoral	2-4 $^{1)}$, 2–6 $^{2)}$ 2–7 $^{3)}$,2–10 $^{4)}$	0–0.3, 0–0.6 $^{1,2,3,4)}$	2	bongo net, boat
Pelagic	> 4 $^{1)}$, > 6 $^{2)}$ > 7 $^{3)}$, > 10 $^{4)}$	0–0.3, 0–0.6 $^{1,2,3,4)}$ 0–0.6, 0.7–1.3 $^{3)}$	2	bongo net, boat

S. TABLE 5. The water volume of sampling strata in the study lakes. For all strata with a bottom depth ≥ 2 m, the volume of the 0–2 m layer for the surface was included in the stratum volume.

Depth zone (m)		Volume (m^3)			
		Tehinselkä	Ruotsalainen	S. Konnevesi	Puula
Littoral	0–0.5	462 715	117 298	1 245 544	803 356
Littoral	0.5–1	1 840 221	458 280	3 110 269	4 197 817
Littoral	1–2	8 894 101	1 869 631	7 044 600	17 029 931
Littoral	2–6	74 x 10^6			
	2–4		14 x 10^6		
	2–7			63 x 10^6	
	2–10				160 x 10^6
Pelagic	over 6	413 x 10^6			
Pelagic	over 4		74 x 10^6		
Pelagic	over 7			151 x 10^6	
Pelagic	over 10				200 x 10^6

S. TABLE 6. Significant mean differences in the ln(D + 1)-transformed larval density time series between the years. 2-ANOVA, multiple comparison: Tukey HSD. Mean difference and risk levels (p) according to the two-tailed hypothesis (H1: average larval densities are different) and 95 % confidence interval (CI).

Year	Year	Mean difference	p	CI
2022	2001	**-2.70**	0.021	-5.21– -0.21
2022	2002	**-2.57**	0.037	-5.08– -0.07
2022	2011	**-2.70**	0.008	-5.01– -0.37
2022	2015	**-2.71**	0.009	-4.99– -0.36
2022	2017	**-2.58**	0.014	-4.91– -0.26

S. TABLE 7. Parameter estimates, standard errors of the mean (s.e.), and significance (p) for linear (3a) and compensatory Ricker (5a) models fitted to the Päijänne Tehinselkä basin whitefish larval density–spawning stock data in 2000–2022. α = constant survival, β = compensatory density dependet mortality. One-tailed H1: α, β > 0.

Model	parameter	estimate	s.e.	p
Linear (3a)	α	2.23	0.66	0.001
Ricker (5a)	α	2.52	1.59	0.064
	β	0.02	0.10	0.415

S. TABLE 8. Parameter estimates, standard errors of the mean (s.e.) and significance (p) for linear (3b) model including environmental factors fitted to Päijänne Tehinselkä basin larval density-spawning population data 2000–2022. $\varphi 1$ = effect of wintertime water level change (Δh), $\varphi 1.1$ = effect of water level in autumn ($h_{Nov15y-1}$), $\varphi 1.2$ = effect of water level on spring (hm_y) and $\varphi 2$ = effect of vendace population, **year y**, age groups 1+ and older. One-tailed H1: α, β, $\varphi 1 > 0$, $\varphi 2 < 0$.

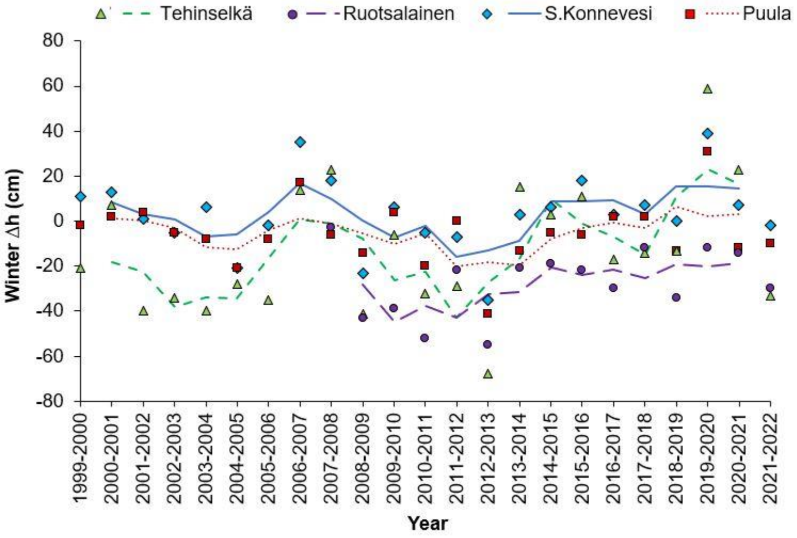
Model	parameter	estimate	s.e.	p
Linear (3b)	α	2.23	0.71	0.002
	φ_1	0.01	0.33	0.488
	φ_2	0.10	0.33	0.604
Linear (3b)	α	2.23	0.71	0.002
	$\varphi_{1.1}$	0.10	0.32	0.392
	φ_2	0.10	0.32	0.625
Linear (3b)	α	2.23	0.70	0.002
	$\varphi_{1.2}$	0.08	0.33	0.407
	φ_2	0.08	0.33	0.590

TABLE 9. Parameter estimates, standard errors of the mean (s.e.) and significance (p) for linear (3b) model including environmental factors fitted to Päijänne Tehinselkä basin larval density-spawning population data 2000–2022. φ1 = effect of wintertime water level change (Δh), φ1.1 = effect of water level in autumn ($h_{Nov15y-1}$), φ1.2 = effect of water level on spring (hm_y) and φ2 = effect of vendace population, **year y-1**, age groups 1+ and older. One-tailed H1: α, β, φ1, φ2 > 0.

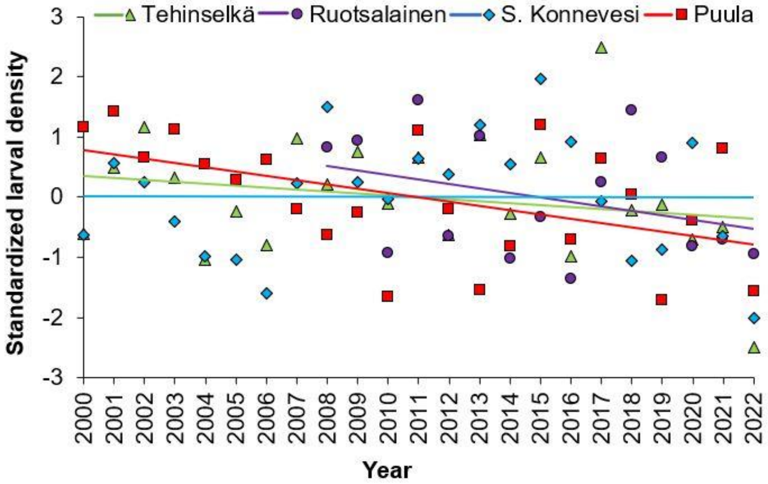
Model	parameter	estimate	s.e.	p
Linear (3b)	α	2.23	0.69	0.002
	φ_1	0.11	0.32	0.374
	φ_2	-0.29	0.32	0.810
Linear (3b)	α	2.23	0.69	0.002
	$\varphi_{1.1}$	0.02	0.32	0.472
	φ_2	-0.26	0.32	0.787
Linear (3b)	α	2.23	0.68	0.002
	$\varphi_{1.2}$	0.12	0.31	0.352
	φ_2	-0.28	0.31	0.805

S. TABLE 10. AICc analysis for different combinations of model 5b including the constant survival α, the compensatory density-dependent mortality β (Ricker 1954) and different non-correlated environmental factors fitted to Päijänne Tehinselkä basin larval density in year y. Data from the years 2000–2022. X = variable included in the model, Δh = wintertime water level change, $h_{Nov15\,y-1}$ = water level in Autumn y-1, hm_y = minimum water level in spring y, Ven y-1 = vendace population (ages 1+ and older) index in year y-1 and Ven y = vendace population (ages 1+ and older) index in year y, AICc = Akaike (1973) Information Criterion corrected for small sample sizes, ΔAICc = AICc – min(AICc), and w_i = Akaike weight, the probability that the model is the best among the whole set of considered models.

α	β	Δh	$h_{Nov15y-1}$	hm_y	Ven y-1	Ven y	AICc	ΔAICc	w_i
X							20.51	0.00	29.7 %
X	X						23.31	2.80	7.3 %
X		X					23.35	2.84	7.2 %
X			X				23.30	2.79	7.3 %
X				X			23.27	2.76	7.5 %
X					X		22.56	2.05	10.6 %
X						X	23.27	2.76	7.5 %
X	X	X					26.46	5.95	1.5 %
X	X		X				26.40	5.89	1.6 %
X	X			X			26.37	5.86	1.6 %
X	X				X		25.32	4.81	2.7 %
X	X					X	26.42	5.91	1.5 %
X		X			X		25.60	5.09	2.3 %
X			X		X		25.60	5.09	2.3 %
X				X	X		25.55	5.04	2.4 %
X		X				X	26.43	5.92	1.5 %
X			X			X	26.34	5.83	1.6 %
X				X		X	26.36	5.85	1.6 %
X	X	X			X		28.67	8.16	0.5 %
X	X		X		X		28.82	8.32	0.5 %
X	X			X	X		28.62	8.11	0.5 %
X	X	X				X	29.93	9.42	0.3 %
X	X		X			X	29.85	9.34	0.3 %
X	X			X		X	29.86	9.35	0.3 %



S. FIGURE 1. Water level change during winter, Δh (cm), and sliding mean (3 years) in regulated Tehinselkä and Ruotsalainen, unregulated Southern Konnevesi, and moderately regulated Puula. Negative Δh = a decrease in water level.



S. FIGURE 2. Time series of standardized ln(D + 1)-transformed whitefish larval density and corresponding linear trendlines in Päijänne Tehinselkä, Southern Konnevesi, and Puula in the years 2000–2022 and Ruotsalainen in the years 2008–2022. The linear trend was significant only in Puula ($p = 0.019$)(Table 2).