Acta Zoologica Lituanica. 2000. Volumen 10. Numerus 4
ISSN 1392-1657

INFLUENCE OF PHYSICAL WATER PARAMETERS ON THE GROWTH AND ABUNDANCE OF VENDACE AND SMELT UNDER NATURAL AND THERMOGRADIENT CONDITIONS

Birutė PERNARAVIČIŪTĖ, Gražina BALKUVIENĖ

Institute of Ecology, Akademijos 2, 2600 Vilnius, Lithuania

Abstract. In the article, influence of some water parameters on the distribution and growth rate of the stenothermic cold-water fish species vendace (*Coregonus albula* L.) and smelt (*Osmerus eperlanus* L.) is discussed. The volume of cold-water mass as well as water trophic stage are of a great importance to the functioning of populations of these species under natural conditions. Under thermogradient conditions, changes in the populations are being resulted in by chemical and thermal water pollution. Ichthyological research of many years has shown the volume of the thermal cold-water zone in a lake as well as water trophic stage therein, which is exhibited by change in parameters of water colour and transparency, to be essential to growth rate and age structure variations in smelt and vendace.
Key words: water temperature, transparency, colour, oxygen, fish growth

INTRODUCTION

The stenothermic cold-water fish species vendace (*Coregonus albula* L.) and smelt (*Osmerus eperlanus* L.) belong to Salmoniformes. Vendace is an individual of Coregoninae and smelt – of Osmeridae.

Vendace are wide spread in northern and central European waterbodies. In Lithuania, vendace are being found in 75 lakes, their area totalling 30,000 ha of which 23% belong to Lakes Drūkšiai and Dusia. Vendace are abundant in Lakes Dringis, Baluošas, Baltieji Lakajai, Asveja, Tauragnas, Alaušas, Didžiulis, as well as other large, deep, cold-water lakes. It is a typical planktophagous short-living fish. It grows rather rapidly to reach its maturity at the age of 1^{+}-2^{+}. Vendace spawn in autumn, water temperature dropped to 4-5°C.

According to statistic data on commercial fishing for 1950-1983, vendace were fished for in 58 Lithuanian lakes. Based on data of the Ministry of Environment vendace made 6.1% of the total amount of the fish caught during 1974-1985 (Bružinskienė, Virbickas, 1988) and 15.9% of that during 1996-1999.

Vendace are fished for mostly in oligomesotrophic, mesotrophic, thermo-deep and medium-deep lakes where large volumes of cold-water mass with the water temperatures physiologically optimal to vendace ($t \leq 15$°C) are being observed during the period of summer thermal stagnation and where water colour is not above XIV according to Forel-Ulle scale (Virbickas, 1987).

The distribution area of smelt (*Osmerus eperlanus* L.) is similar to that of vendace: smelt are found in middle and east European waterbodies. In Lithuania, the following smelt species are found: migratory smelt (*Osmerus eperlanus* L.), living in the Baltic Sea and spawning in the lower reaches of the Nemunas River, and resident smelt (*O. eperlanus m. relicta*), observed in the freshwater Curonian Lagoon (*O. eperlanus m. spirinchus*) and lakes (*O. eperlanus m. relicta*). To resident smelt, optimal water temperature is 12°C and water colour – ≤XVI (by Secchi) (Virbickas, 1987). Accordingly, they, like vendace, inhabit only large, deep and cold lakes. In Lithuania, they reside in approximately 50 lakes. In 1974-1985, smelt made 0.8% of the total lakes catch and in 1996-1999 – 0.5% of it (data of the Ministry of Environment).

MATERIAL AND METHODS

Material was obtained during 1994-1999 from six natural lakes of different depth and the cooling reservoir of Ignalina Nuclear Power Plant, Lake Drūkšiai.

Biological analysis of the fish was made and the fish were aged using widespread methods (Pravdin, 1966; Tchugunova, 1952). Fish lengths were measured using Smitt's scheme, *longitudo caudalis* (l_c), *longitudo totalis* (L).

Water temperature in the lakes was taken during the

period of summer thermal stagnation with deep-water and electronic thermometers. On thermal research, water transparency (T_m) was estimated with Secchi disc and colour ($C_{No.}$) with Forel-Ulle scale.
The thermal zones t ≤ 15, 10, and 8°C were determined using graphs of water temperature distribution according to depth. Thereafter mean thickness (m) of vertical water levels in corresponding thermal zones in the lakes was estimated. Afterwards water volume (V) of a corresponding thermal zone was estimated in relative (%) values using tables of lake areas and volumes. In the article, the volumes of cold-water masses for the lakes investigated by E. Žukaitė and parameters of water colour and transparency (Žukaitė, 1990, 1991) are used.

Results and discussion

1. Vendace and smelt growth peculiarities under natural conditions

Ichthyological research into Lithuanian lakes has shown vendace to reach their maturity at the age of 1^+-2^+. Among the caught vendace the individuals which l_c ranged 15-24 cm, Q – 50-100 g and age – 2^+-3^+ prevailed. Borderline age of the vendace was 4^+-6^+, rarely 7^+. Lake Asveja (Dubingiai) made an exception where a fish aged 11^+ with l_c = 27.5 cm and Q = 300 g was caught in 1963. That was the only lake where that old vendace was found (Orlova, Sinevičius, 1967; Sinevičius, 1972). Vendace growth in Lake Asveja is being greatly influenced by some factors determining water quality. It is a thermo-deep (Δt ~ 0.3°C) lake and its water trophic stage is mesotrophic (T_m ~ 6.0 m, $C_{No.}$ ~ VIII-IX) (based on data for 1962-1964). In the lake, volume of the thermal zone t ≤ 15°C, making 63.5% V, is very favourable for vendace in summer time. The narrow and long form of Lake Asveja prevents strong winds, thus mixing of the water mass is weak resulting in decreased oxygen concentrations in deep water layers. As a result of this, oxygen deficit (1.07 mg/l) was found at a depth of 13.5 m (Hydrobiological research into Lithuanian lakes, 1975).
Growth parameters for resident smelt, like for vendace, varied with different cold-water lakes. In Lithuanian lakes, smelt l_c fluctuated on average from 3.5 to 17.4 cm and Q from 0.2 to 50.3 g. In catches of spawning smelt, 1^+-2^+-aged 6.0-6.5-cm-long individuals predominated as a rule. Water temperature most favourable for their spawning was 5-6°C. Growth rate in resident smelt compared with that in migrating smelt from the Baltic Sea was rather low: 0^+: l_c on average ranged 4.3-7.9 cm, Q – 0.5-2.6 g; 1^+: 8.0-10.5 cm, 2.7-7.4 g; 2^+: 10.5-12.6 cm, 8.3-13.5 g; 3^+: 12.0-13.2 cm, 13.0-18.7 g; 4^+: 15 cm, 27.5 g; 5^+: 17.4 cm, 45.4 g; 6^+: 19.0 cm, 65.1 g (Mištautaitė, 1972). The largest individuals were caught in Lakes Asveja and Didžiulis where especially favourable conditions for the functioning of the populations were observed: in Lake Asveja, the thermal cold-water zone t ≤ 10°C made 52.8% V, and in Lake Didžiulis – 54.6% V. In these waterbodies, smelt reach their maturity aged 2^+.
In scientific literature, vendace is divided into large and small. It is a relative division, however, as growth rate and age of vendace are subject to environmental parameters.
Over the study period, l_c of vendace caught in natural lakes was in the range 11.2-31.5 cm, Q – 10.5-406 g, age – 0^+-7^+ (Table 1). In Lakes Tauragnas, Ūkojas, Baluošas, and Akmena, larger vendace were caught compared with Lakes Dusia and Plateliai. The insignificant fluctuation of parameters of mean length and mass observed in age groups in different years of the research had likely been conditioned by a variety of meteorological conditions in different calendar years as well as errors of calculation resulted in by different numbers of the analysed fish in the samples.
High parameters regarding vendace growth were estimated in Lithuania's deepest lake, **Lake Tauragnas**. It is a very thermo-deep lake (Δt = 2.0°C) with large volume of cold-water zones t ≤ 15°C (65.1% V), t ≤ 10°C (52.3% V). Its water optical parameters (T_m ~ 5.6 m, $C_{No.}$ ~ IX) are typical of oligomesotrophic lakes. Over the period of summer thermal stagnation oxygen deficit (~2 mg/l) was observed in Lake Tauragnas deep-water layers. Based on literary data, large vendace resided therein in 1958. The length of the largest individual caught l_c = 26 cm, Q = 225 g, and age – 5^+. Vendace growth rate was high: 1^+: l_c = 15.1 cm, Q = 22.5 g; 3^+: 24.5 cm, 159 g; 5^+: 25.0 cm, 183 g (Bagdžius, 1961). Large individuals have been caught in Lake Tauragnas over the recent years, too. The length of the largest vendace caught L = 31.0 cm, l_c = 29.0 cm, Q = 230g, age – 6^+. In the catches, 3^+-4^+ fish prevail (95.8% of the vendace caught). Older vendace (5^+, 6^+) are few (1.7%). They reach their sexual maturity at the age of 2^+. Vendace growth rate is still high: 1^+: l_c = 16.0 cm, Q = 45 g; 2^+: 20.0-22.1 cm, 61.0-112.2 g, etc. (Table 1).
Smelt growth rate in Lake Tauragnas was medium: 1^+: l_c = 8.8 cm, Q = 38.0 g; 2^+: 11.6 cm, 8.9 g. Ageing 6^+ the fish were up to 20.5 cm and 64.0 g. They reached their maturity aged 1^+. A mature Lake Tauragnas smelt was 9-10 cm long (Mištautaitė, 1973). Smelt body mass in the catches over the recent years has been in the range 12-36 g and mean mass 27.9 g.

Table 1. Vendace (*Coregonus albula* L.) growth in Lithuanian lakes of different thermal regime

Lake	Date	Age, year							
		$0^+(1)$	$1^+(2)$	$2^+(3)$	$3^+(4)$	$4^+(5)$	$5^+(6)$	$6^+(7)$	$7^+(8)$
Tauragnas	1995	-	16.0	20.0	22.1	23.7	-	-	
			45	84	121.7	145			
	1996	-	-	19.5	22.7	24.3	-	-	
				61	132	151			
	1997	-	-	22.1	24.0	26.7	29	-	
				115.2	149.4	182	230		
Ūkojas	1998	-	-	23.8	26.4	29.5	35.7	-	
				122	201	302	438		
Baluošas	1997	-	15.6	19.6	22.4	23.7	25.0	-	
			32	76	115	143	157		
	1999	-	-	16.8	-	-	25.5	27.5	31.5
				50.7			166	25.8	406
Akmena	1999	-	18.4	19.4	22.6	23.5	25.2	-	-
			55.3	66.6	104.8	115	141.2		
Dusia	1994	-	13.3	18.8	20.3	21.6	-	-	-
			20.4	55.8	66.8	73.2			
	1996	-	16.7	17.8	21.6	-	24	-	-
			45.8	55.7	75.8		129		
	1997	-	-	18.8	20.1	-	-	-	-
				64.6	83.7				
Plateliai	1995	11.5	12.8	16	-	-	-	-	-
		15	20	42					
	1996	12.8	14.2	17.4	19.5	-	-	-	-
		15	20	41	59				
	1997	13.5	14.8	16.5	-	-	-	-	-
		20	29.7	36					
	1999	11.2	15.0	16.6	-	-	-	-	-
		10.5	27	37.6					
Drūkšiai	1965-76	-	17.5	18.0	19.6	20.8	22.5	-	-
			52.5	65	80.1	97	140		
	1986	-	18.4	19.2	20.3	-	-	-	-
			82.5	93.2	114				
	1991	11.9	14.6	17.7	19	-	-	-	-
		16	28	53	69				
	1992	12.8	16.8	17.7	19.5	-	-	-	-
		17	47	55.2	72.9				
	1993	11.3	17.0	18.7	19.9	-	-	-	-
		14	49	67	81				
	1996	10.2	15.4	16.6	18.9	-	-	-	-
		8.9	32.7	40.9	61.0				

l_c – fish length, cm; Q – fish mass, g

Based on the above data it could be stated that in Lake Tauragnas, which features large volume of cold-water zones (t ≤ 15°C – 65.1%, including t ≤ 10°C – 52.3%, and t ≤ 8°C – 46.0% V), stable conditions favourable for the cold-water fish species vendace and smelt and also for the cold-water hydrobionts that make a good and accessible nutrition base for these fish species have formed (Grigelis, Balkuvienė et al., 1982; Grigelis, Nainaitė, 1981).

In the thermo-deep **Lake Ūkojas**, the thermal zone t ≤ 15°C made 52.7%, including t ≤ 10°C – 39.4% and t ≤ 8°C – 32.5% V. Optical parameters of water (T_m ~

4.7 m, $C_{No.}$ ~ X) were typical of oligomesotrophic lakes (Žukaitė, 1991). In near-bottom water layers, high concentrations of fused oxygen (2-7 mg/l) and low concentrations of biogenic substances were observed (Grigelis, Balkuvienė et al., 1982). A hydrochemical and thermal regime in the lake made conditions favourable for cold-water hydrobionts to live in and for the life and growth of the stenobiontic cold-water fish vendace and smelt.

In the lake, vendace l_c ranged 21.8-35.7 cm, Q – 108-438 g, and age – 2^+-5^+. Fish growth rate was high: 2^+ fish l_c = 23.8 cm, Q = 122 g. The length of the largest individual caught L = 38.5 cm, l_c = 35.7 cm, Q = 438 g (Table 1).

The smelt l_c in the catch fluctuated between 12.1 and 16.7 cm, Q – 12-28 g, age – 2^+-4^+. Fish growth rate was high: 2^+: l_c = 13.7 cm, Q = 14 g; 3^+: 14.8 cm and 20 g; 4^+: 15.5 cm and 23 g.

Lake Baluošas is attached to the group of thermo-deep lakes. The zone optimal for vendace t ≤ 15°C made 44%, while t ≤ 10°C and t ≤ 8°C – 28.4% and 19.1% V, respectively. T_m ~ 4.5 m, $C_{No.}$ ~ XII-XIII. Oxygen concentration in the near-bottom water layers <2 mg/l (Grigelis, Balkuvienė, 1982).

Based on the literary data (Skorupskas, 1979), 10.0-26.5-cm-long vendace were found during 1966-1970 in Lake Baluošas catches. They demonstrated high growth rate: 2^+ fish l_c = 18.3 cm, Q = 56.9 g. The largest vendace caught l_c = 26.5 cm, Q = 210 g, age – 7^+.

On researching Lake Baluošas in 1997 and 1999 vendace were caught which l_c ranged 14.8-32.0 cm, Q – 28-416 g, and age – 1^+-7^+. Their growth rate was just as high: 2^+ fish l_c ranged 16.8-19.6 cm, Q – 50.7-76 g. There were some large individuals in the catches, their L ranging 34-35 cm, l_c – 31-32 cm, Q – 396-419 g, age – 7^+.

Comparatively large smelt were found in the lake: their L in the range 15.5-17 cm, l_c – 13.5-16 cm, Q – 16-32 g.

Near-bottom water layer temperature at the deepest point of Lake Akmena was 7.4°C in summer and 2.2°C in winter, Δt – 5.2°C. It was a thermo-medium-deep lake. Its thermal zone t ≤ 15°C made 48%, including t ≤ 10°C with 28.8%, and t ≤ 8°C with just 0.3% V.

In August 1999, l_c of the vendace caught was 17.5-27 cm, Q – 45-172 g, age – 1^+-5^+. Compared to Lakes Ūkojas and Tauragnas, growth rate was lower and almost equalled that in Lake Baluošas vendace: 2^+ vendace l_c = 19.4 cm, Q = 66.6 g. Growth rate was higher at the age of 1^+-3^+, and then declined. The age of the largest individual caught was 5^+, L = 30 cm, l_c = 27 cm, Q = 172 g.

Lake Plateliai featuring relatively small cold-water zones t ≤ 15°C and t ≤ 10°C making 29.3 and 26.6% V, respectively, and better water trophic stage (T_m ~ 6 m, $C_{No.}$ ~ XII) was distinguished for small vendace reaching their maturity at the age of 1^+. Their life duration was only 3^+. At the age of 2^+, Lake Plateliai vendace l_c = 16.0-17.4 cm and Q = 36-42 g.

Ichthyological research carried out in the most vendace-productive **Lake Dusia** over 1961-1973 showed the vendace growth evolution to change with changing environmental factors (water temperature, oxygen regime, zooplankton biomass, etc.). At the age of 1^+, vendace l_c changed on average 13.7 (1967) to 19.2 cm (1971), and Q – 27.1 to 72.1 g, while at the age of 2^+ – 19.1 to 20.8 cm and 63.4 to 94 g. An early warm spring was estimated to induce while hot summer to reduce vendace growth. The lowest growth rate was observed during the outstandingly hot summer 1967, while the highest – in 1971 when due to an early and warm spring zooplankton biomass significantly increased. At that time vendace growth rate in Lake Dusia was higher than in any other Lithuanian lake (Sinevičius, 1975). Despite Lake Dusia being attached to thermo-medium-deep lakes (Δt ~ 7.5°C), its thermal zone t ≤ 15°C made 43.2% V. The thermal zone t ≤ 10°C was absent in the lake due to the strong dynamic mixing of water mass reaching very deep water layers. T_m ~ 6 m, $C_{No.}$ ~ IX-X. Because of intense water mass and oxygen mixing O_2 = 7.4 mg/l Lake Dusia was very favourable for hydrobionts.

The research of 1994-1996 has shown Lake Dusia vendace growth rate to equal their low growth in 1967: 1^+: l_c ranged 13.3-16.7 cm, Q – 20.4-45.8 g; 2^+: 17.8-19.0 cm, 55.7-64.6 g. In Lake Dusia, vendace reach their maturity aged 1^+. The caught smelt l_c was in the range 7.0-16.0 cm, Q – 1-27 g, age – 0^+-4^+. At the age of 0^+ smelt l_c = 7.9 cm, Q = 1.0 g; 1^+: 11.3 cm, 47 g; 2^+: 12.6 cm, 12.4 g; 3^+: 16 cm, 25 g. In the lake, smelt reached their maturity at the age of 1^+.

2. Vendace and smelt growth peculiarities under thermogradient conditions

In oligomesotrophic, mesotrophic, and eutrophic lakes, the regressive successions of fish communities resulted in by changing environmental factors are best indicated by change in dominating species and species elimination, variation in vendace and smelt abundance being among them.

Thermal and chemical water pollution, the impact of which varies depending on the power of Ignalina Nuclear Power Plant (INPP), has been one of the main factors determining changes in populations of the stenothermic cold-water planktophagous smelt and vendace in Lake Drūkšiai.

The research into the age structure and growth rate in

Lake Drūkšiai vendace carried out after the launch of the INPP demonstrated a great change in vendace growth rate under changing ecological conditions in the lake. The following periods could be distinguished in the vendace growth dynamics: before the INPP launch (until 1984) – a base state period; after the INPP launch (1984-1989) – a period of thermogradient conditions formation; 1990-1995 – a stabilization period; 1996-1997 – a period of decreased water quality.

Before the INPP exploitation, vendace growth parameters in Lake Drūkšiai were very similar to the mean vendace growth parameters in Lake Dusia in 1967. In 1967, for example, Lake Dusia 3^+ vendace l_c = 20.2 cm and Q = 74.7 g (Sinevičius, 1977), and Lake Drūkšiai ones – 19.6 cm and 80.1 g, respectively (Orlova, Sinevičius, 1967). The borderline age of Lake Drūkšiai vendace was 5^+ at that time. Their growth rate differed from that in the rapidly growing Lake Tauragnas vendace (Bagdžius, 1961) but surpassed the one in Lake Plateliai (3^+: 14.5-15.5 cm, 35-45 g in 1956 (Bagdžius, 1959)) (Table 2).

In the initial stage of the research in 1984-1986, significant increase in vendace growth was observed. Despite the fact that the thermal zone t ≤ 15°C decreased from 8.5% V in the base state to 6.8% V in 1986, the thermal cold-water zone t ≤ 10°C increased for 0.4% V. T_m also increased for 0.4 m, as well as oxygen concentration at the deepest point in the west of the lake (≥30 m deep) from 1.15 mg/l in the base state to 1.98 mg/l in 1986 (Bunikis, Salickaitė, 1992). Water colour $C_{No.}$ changed from XI in the base state to XII in 1986.

Under increased water temperature in Lake Drūkšiai, the vegetation period became longer and the nutrition base of vendace improved. The research into vendace growth in 1986 showed that under those conditions 1^+ vendace l_c increased from 17.5 cm in the base state to 18.4 cm in 1986, and Q – from 52.5 g to 82.5 g, respectively; 2^+: 18.0-19.2 cm, 65-93.2 g; 3^+: 19.6-20.3 cm, 80.1-114 g. However, no 4^+ years old individuals were caught in 1986 (Table 1).

Under the increased warm-water zone t ≥ 15°C since 1991 and diminished cold-water thermal zones and under declined water optical parameters, vendace growth rate became higher equalling that in the base state. It should be mentioned that fluctuations in 0^+ vendace linear growth rates synchronically reflected the volume of the thermal cold-water zone ≤15°C, while the increased oxygen concentrations in the near-bottom water layer did not have significant influence on their growth rates (Table 3).

Disappearance of the thermal zone t ≤ 8°C, marked decrease of water transparency (from 5 m in the base state to 2.8 m in summer 1997), changes in water colour from X-XI in 1976 to XIII in 1994-1996 (in 1997 it was impossible to estimate water colour ac-

Table 2. Growth dynamics for four years old (3^+) vendace in Lithuanian lakes

	Drūkšiai		Dusia		Plateliai		Tauragnas	
Year	1965	1996	1967	1996	1956	1996	1991	1996
l_c	19.6	18.9	20.2	21.6	14.5-15.5	19.5	23.5	22.7
Q	80.1	61.0	74.7	75.8	35-45	59.0	140.0	132.0
t ≤ 15°C	8.5 (1976-83)	3.5	43.2		27.5	65.1	64.0	
T_m	5.0 (1976-83)	3.6	6.8		5.7		5.6	
$C_{No.}$	X-XI (1976-83)	XIII	IX-X		XI		IX-X	

l_c – fish length, cm; Q – fish mass, g; t ≤ 15°C – thermal zone, %; T_m – water transparency, m; $C_{No.}$ – water colour (No.)

Table 3. Change in linear growth of one-year-old (0^+) vendace in Lake Drūkšiai in 1991-1996

Year	1991	1992	1993	1996
l_c	11.9	12.8	11.3	10.2
t ≤ 15°C	6.3	8.0	5.8	3.5
$C_{No.}$	XII	XII-XIII	XIII	XIII
O_2	2.52	2.04	5.55	2.62

Note: l_c – fish length, cm; Q – fish mass, g; V – water volume, (10^6 m^3); $C_{No.}$ – water colour (No.); O_2 – oxygen concentration at a depth of 30 m, mg/l (O_2 – based on Salickaitė and Bunikienė's data)

cording to Forel-Ulle scale because of intense water bloom) resulted in deteriorated water quality in Lake Drūkšiai. Interaction of thermal, chemical and meteorological determiners conditioned lower growth rates in vendace (Table 3).

Ichthyological research of many years showed the mean body mass of 0^+ vendace to be also directly dependent on the volume of the thermal cold-water zone $t \leq 15°C$ and lake water trophic stage in a correspondent year. Growth of individuals of older age groups, on the other hand, did not demonstrate that kind of dependence, as their growth depended not only on lake water quality parameters in a correspondent year, but also on their changes in earlier calendar years. For instance, 3^+ fish growth was determined by changed living conditions in the lake during their growth evolution in 1990-1993. It was also estimated that the dependence between vendace growth, water transparency, and oxygen concentration was weak. Only under significant decrease in Lake Drūkšiai water transparency and under oxygen deficit in the deeper water layers of the lake the impact of parameters determining water quality on decreased vendace growth was observed (Table 4).

Compared with the base state, the borderline age in Lake Drūkšiai vendace declined from 5^+ to 3^+ under the impact of the INPP.

In the experimental catches, under the impact of the INPP vendace l_c varied from 10.2 to 20.3 cm, and Q from 8.9 to 114 g (Table 1). In the base state, individuals of six age groups (0^+ to 5^+) were found, their l_c being up to 22.5 cm, Q = 140 g, age – up to 5^+, and in 1996 individuals of four age groups (0^+ to 3^+) were observed, the oldest vendace being as young as 2^+.

After the launch of the INPP, Lake Drūkšiai smelt were investigated in winter 1985 (January 23-30). The caught smelt l_c ranged 6-11 cm, Q – 1.4-6-8 g, age – 0^+-2^+. In a catch of 2,627 individuals, 7-9-cm-long 1^+ fish weighing 2.8 g prevailed, making 93% of the caught smelt. Small individuals, up to 6-cm long and 1.4 g of weight, made 3.8%, while large – 3.2%, their l_c being 10-11 cm, and Q – up to 6.8 g.

It was established that in summer 1984 the thermal zone $t \leq 10°C$ in Lake Drūkšiai made as much as 2.6% V, T_m increased up to 7.0 m, and $C_{No.}$ remained similar to that in the base state, i.e. XI. In addition, at the deepest points in the lake no oxygen deficit was observed. That water quality experienced during the first years of the INPP exploitation was favourable for a normal functioning of smelt.

The comparison of the smelt growth rate in Lake Drūkšiai in 1985 with the mean smelt growth rate in other 11 Lithuanian lakes in 1963-1970 (Mištautaitė, 1972) revealed growth parameters for young-of-the-year smelt to be almost similar. Growth rate in older smelt was lower in Lake Drūkšiai (Table 5).

Table 4. Body mass growth dynamics in different age groups of vendace in Lake Drūkšiai

Fish age	1965-76	1986	1991	1992	1993	1996	1997
0^+	-	-	16	17	14	8.9	-
2^+	65	93.2	53	55.2	67	40.9	-
3^+	80.1	114	69	72.9	81	61	-
Thermal zone	1976-1983						
$t \leq 15°C$ (V%)	8.5	6.8	6.3	8.0	5.8	3.5	8.4
$C_{No.}$	X-XI	XII	XII	XII-XIII	XIII	XIII	not established
T_m	4.7	5.4	4.7	4.8	5.0	3.6	2.0
O_2	1.15	1.98	2.52	2.04	5.55	2.62	0.86

Note: $C_{No.}$ – water colour (No.); T_m – water transparency, m; O_2 – oxygen concentration (station 2) at a depth of 30 m, mg/l (O_2 – based on Salickaitė and Bunikienė's data)

Table 5. Smelt growth in Lake Drūkšiai and other Lithuanian lakes

Lake	Date	Age (years)		
		0^+	1^+	2^+
Drūkšiai	1985	6.6/1.6	8.1/3.2	9.8/5.5
Other lakes of Lithuania	1963-1970	6.1/1.6	9.3/5.1	11.6/10.9

Note: l_c/Q: l_c – fish length, cm; Q – fish mass, g

In 1950-1970, smelt in the commercial Lake Drūkšiai catches made up to 50% of ichthyomass, however already at the time the INPP was under construction the decreased population abundance was observed (1979-1983).

After the second INPP energy block was launched in 1988 and water temperature increased on average for 2-3°C, the thermal zone t ≤ 10°C has disappeared, and the thermal zone t ≤ 15°C significantly diminished to make just 4.3% V (in the base state t ≤ 15°C made 8.5% V). T_m has also dropped from 7.0 m in 1984 to 5.4 m in 1987. Water colour has become XII. Despite lake oxygen regime being favourable (0_2 ~ 5.4 mg/l), due to good lake aeration the smelt population began suddenly diminishing because of increased water temperature.

Conclusions

Research into growth rate in some stenothermic cold-water fish in Lithuanian lakes in the context of changing water parameters (temperature, transparency, oxygen) show the functioning of vendace and smelt populations to be directly dependent on the volume of cold-water (t ≤ 10-15°C) mass and the water trophic stage of a lake during the vegetation period. The best growth parameters for vendace and smelt were established to be in thermo-deep lakes with the thermal zone t ≤ 15°C making 60% of the total water mass volume in the lake (V), water transparency (T_m) being ≥5 m, colour ($C_{No.}$) being ≤X according to Forel-Ulle scale. Thermo-medium-deep lakes with the thermal zone t ≤ 10°C making ≤20% and the thermal zone t ≤ 15°C making ≤30% V, T_m being ≤5m, and $C_{No.}$ being ≥X demonstrate lower vendace and smelt growth rates.

In Lake Drūkšiai, the cooling basin of the INPP, vendace population growth under thermogradient conditions was established to be dependent on the change in the volume of the thermal zone t ≤ 15°C. After the first energy block of the INPP was launched, during the period of summer thermal stagnation in 1984-1986 under the almost unchanged thermal zone t ≤ 15°C, changed $C_{No.}$, T_m and O_2, the prolonged vegetation period, significant increase in vendace growth was observed. After the launch of the second energy block of the INPP and under the increased thermal zone t ≥ 15°C and the decreased thermal zones t ≤ 15, 10°C, under deteriorating optical parameters of lake water, decreased growth of vendace was estimated, while smelt was not found at all. Under the regulated power of the INPP and stabilized regime of Lake Drūkšiai, vendace age has diminished on average from 5^+ to 3^+ to compare with the base state. Due to increased water temperature in the deep water layers and deteriorated water quality the smelt population in the lake has become almost extinct.

References

Astrauskas A., Bernotas E., Jovaiša R. 1995. Žuvų rūšinės ir matmeninės sudėties, gausumo ir erdvinio pasiskirstymo ypatumai. *'Drūkšių ežero poveikis gamtai ir visuomenei'.* Vilnius. 175-190. [Peculiarities of species and dimensional composition, abundance and spatial distribution of fish. *'Impact of Lake Drūkšiai on nature and society'*]. Vilnius, 175-190.

[Astrauskas A. 1986] Астраускас А. 1986. Пространственно-временное распределение пелагических рыб оз. Друкшяй. *Теплоэнергетика и окружающая среда*. Вильнюс, 5: 110-112. [Distribution of deep-sea fish in Lake Drūkšiai with respect to space and time. *Thermal power generation and environment*]. Vilnius, 5: 110-112.

[Bagdžius B. 1959] Багджюс Б.К. 1959. Материалы по рыбохозяйственному исследованию группы озер Северо-западной части Литвы. *Lietuvos TSR Mokslų akademijos darbai.* Serija B 1 (17): 161-174. [Material on fishery research in a group of lakes of the northwestern part of Lithuania. *Works of the Academy of Sc. of the Lithuanian SSR. Series B* 1] (17): 161-174.

[Bagdžius B. 1961] Багджюс Б.К. 1961. Рыбы и перспективы рыбохозяйственного освоения некоторых озер Литвы. *Автореферат дис. канд. биол. наук*. Вильнюс, 28. [Fishes and fishery prospects in some Lithuanian lakes. *Summary of doctoral dissertation*]. Vilnius, 28.

Bružinskienė A., Virbickas J. 1988. Verslinė ir mėgėjiška žvejyba. Vilnius. [Commercial and amateur fishing]. Vilnius.

[Bunikis A., Salickaitė L. 1993] Буникис А., Салицкайте Л. 1993. Гидрохимический режим. *Терлоэнергетика и окружающая среда* 10 (4.2): 10-19. Вильнюс. [Hydrochemical regime. *Thermal power generation and environment*] 10 (4.2): 10-19. Vilnius.

Grigelis A., Nainaitė O. ir kt. 1981. Vandens bestuburiai. *Lietuvos TSR Nacionalinis parkas*. Vilnius, Mokslas, 73-78. [Aquatic invertebrates. *National park of the Lithuanian SSR*]. Vilnius, Mokslas, 73-78.

[Grigelis A., Balkuvienė G. et al. 1982] Григялис А.И., Балкувене Г.Ф. и др. 1982. Биологическая продуктивность озер национального парка Литовской ССР. 1. Гидробиологическая характеристика. *Тр. АН ЛитССР. Сер. В* 3 (79): 54-64. [Biological productiveness in the lakes of the National Park of the Lithuanian SSR. 1. Hydrobiological characteristics.

Works of the Academy of Sc. of the Lithuanian SSR. Series B 3] (79): 54-64.

[Mištautaitė V. 1972] Миштаутайте В.Т. 1972. Морфология и экология корюшки – *Osmerus eperlanus* (L.) водоемов Литвы. *Автореферат дис. канд. биол. наук.* Вильнюс, 24. [Morphology and ecology of smelt – *Osmerus eperlanus* (L.) in Lithuanian waterbodies. *Summary of doctoral dissertation*]. Vilnius, 24.

[Mištautaitė V. 1973] Миштаутайте В.Т. 1973. Морфоэкологическая изменчивость корюшки водоемов Литвы. 2. Темр. роста и время наступления половой зрелости. *Тр. АН ЛитССР. Сер. В* 3 (63): 55-67. [Morpho-ecological variability in smelt in Lithuanian waterbodies. Growth rate and age of sexual maturity. *Works of the Academy of Sc. of the Lithuanian SSR. Series B*] 3 (63): 55-67.

Orlova A., Sinevičius P. 1967. Seliavos augimas kai kuriuose Lietuvos ežeruose. Nauji laimėjimai biologijoje ir biochemijoje. *LTSR jaunųjų mokslininkų – biologų ir biochemikų konferencija.* Vilnius, 261-265. [Growth of vendace in some Lithuanian lakes. New achievements in biology and biochemistry. *Conference of young scientists – biologists and biochemists of the LSSR*]. Vilnius, 261-265.

[Pravdin I. 1966] Правдин И.Ф. 1966. Руководство по изучению рыб. Москва. Пищепромиздат. [A guide to fish study]. Moscow.

[Sinevičius P. 1975] Синявичюс П.Ю. 1975. Биология и состояние запасов ряпушки оз. Дуся Литовской ССР. *Автореферат дис. канд. биол. наук*. Вильнюс, 24. [Biology and state of vendace resources in Lake Dusia in the Lithuanian SSR. *Summary of doctoral dissertation*]. Vilnius, 24.

[Sinevičius P. 1977] Синявичюс П.Ю. 1977. Ряпушки оз. Дуся. Гидробиологические исследования озер Дуся, Галстас, Шлавантас, Обялия. Вильнюс, 221. [Vendace in Lake Dusia. Hydrobiological research into Lakes Dusia, Galstas, Šlavantas, and Obelija]. Vilnius, 221.

[Skorupskas E. 1979] Скорупскас Э.Ф. 1979. Морфологическая, биологическая и промысловая характеристика ряпушки озер Алаушас, Балуошас и Вевис Литовской ССР. (2. Темпы линейного и весового роста и возрастной состав стад). *Тр. АН ЛитССР. Сер. В* 4 (88): 79-88. [Morphological, biological and commercial characteristics of vendace in Lakes Alaušas, Baluošas and Vievis in the Lithuanian SSR. (2. Rates of linear and weight growth and age structure in populations). *Works of the Academy of Sc. of the Lithuanian SSR. Series B*] 4 (88): 79-88.

[Tchugunova N. 1959] Чугунова Н.И. 1959. Руководство по изучению возраста и роста рыб. Москва. Издво АН СССР. [A guide to the study of age and growth of fish]. Moscow.

[Virbickas J., Žukaitė E. 1987] Вирбицкас Ю., Жукайте Э.О. 1987. Зависимости численности сиговых и корюшковых в ихтиоценозах от мощности низкотемпературных зон и уровней эвтрофирования. *Биологические ресурсы водоемов басс. Балтийского моря*. Вильнюс, 31-32. [Dependence of whitefish (Coregonidae) and smelt (Osmeridae) in ichthyocenoses on the volume of cold-water zones and eutrophication level. *Biological resources of waterbodies of the Baltic Sea basin*]. Vilnius, 31-32.

[Žukaitė E. 1990] Жукайте Э. 1990. Изменение прозрачности и цвета воды озер как показатель их эвтрофирования. *Ekologija* 1: 44-61. [Changes of water limpidity and colour as an index of the lakes eutrophication]. *Ekologija* 1: 44-61.

[Žukaitė E. 1991] Жукайте Э. 1991. Количественная оценка термического режима озер. *Ekologija* 2: 48-62. [Quantitative estimate of a thermal regime of lakes]. *Ekologija* 2: 48-62.

Fizikinių vandens kokybės rodiklių įtaka seliavos ir stintelės augimui ir gausumui natūraliose ir termogradientinėse sąlygose

B. Pernaravičiūtė, G. Balkuvienė

Santrauka

Straipsnyje aptariama kai kurių Lietuvos ežerų termikos, vandens skaidrumo, spalvos ir deguonies įtaka stenoterminių šaltamėgių žuvų rūšių – seliavos (*Coregonus albula* (L.) ir stintelės (*Osmerus eperlanus* (L.) – augimui. Panaudota daugiametė (1956-1996 m.) medžiaga. Nustatyta, kad minėtų žuvų rūšių funkcionavimui natūraliomis sąlygomis didelės reikšmės turi ežero šaltavandenių ($t \leq 10$, 15°C) masių tūriai bei vandens išsivystymo lygis. Termogradientinėse sąlygose (Drūkšių ežere – Ignalinos AE aušintuve) seliavų ir stintelių populiacijos augimas priklauso nuo terminės bei cheminės taršos masto. Dėl pakilusios Drūkšių ežero vandens temperatūros giluminiuose vandens sluoksniuose bei pablogėjusios vandens kokybės stintelės populiacija ežere beveik išnyko, o seliavų gyvenimo trukmė po AE paleidimo lyginant su bazine būkle vidutiniškai sumažėjo nuo 6 (5^+) iki 4 (3^+) metų.