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Fish community changes in the cooler of the Ignalina Nuclear Power Plant

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The study focuses on the changes of fish community and population parameters (abundance, biomass, growth rate) in Lake Drūkšiai as the cooler of the Ignalina Nuclear Power Plant. Results of investigations before launching the INPP and in different stages of its exploitation as well as the impact on ecological processes of the ecosystem of the cooler, including biological productivity, are generalised. Ichthyological investigations in different aquatic areas of the lake in 2005–2007 revealed rather significant changes in fish species diversity and community structure as a result of changes in its thermal regime and intensive anthropogenic eutrophication. The tendencies of changes in fish diversity and community structure are revealed. Fish growth rates in different aquatic areas of the lake are estimated. Roach and perch populations served as an example to demonstrate higher growth rates in the "warm water" zone of the lake as compared with the "cold water" zone. As regards fishery, Lake Drūkšiai continues to be a high-productivity water body with intensive angling, but insufficient commercial fishing. In 2007, fish stocks in the lake averaged 671.78 t and the commercial fish catching limit was ca. 67.180 t, or 18.5 kg/ha. Our investigations show that fish stocks in Lake Drūkšiai have decreased by 9% compared with the results of earlier investigations.

Key words: Lake Drūkšiai – cooler of the Ignalina Nuclear Power Plant, fish community, population parameters and their changes

INTRODUCTION

Since the year 1984, Drūkšiai, the largest lake of Lithuania, has been used for cooling the energy blocks of the Ignalina Nuclear Power Plant (INPP). Subject to the loading of the power plant, 80–160 m^3/s of water is used for cooling the energy blocks and then, warmed up to 8–10 °C above the norm, discharged back into the lake. This undoubtedly affects the hydrothermal and hydrodynamic regime of the lake (Šarauskienė, 2002). Warm water discharged from thermal and nuclear power plants induces different changes in the ecosystems of coolers: water temperature increases due to additional amounts of heat, formation of thermogradients, changes in hydrodynamic regime, increased evaporation from water surface, etc. All these factors affect the ecological processes, including biological productivity, of the ecosystem of the cooler. The thermal regime, its change, stratification and effects on biota of Lake Drūkšiai were the subject of investigation for E. Žukaitė, A. Astrauskas, J. Virbickas, L. Račiūnas, B. Pernaravičiūtė, E. Bernotas and other researchers of the Institute of Ecology (Šarauskienė, 2002).

Before launching the INPP, Lake Drūkšiai had been a low-productivity mesotrophic water body with oligotrophic traits. During the first several years of exploitation of the power plant (1984–1988) the trophical status of the lake did not materially change. Later, in 1994–1997, as a result of continuous contamination with household wastewater and storm sewer water of the Visaginas town as well as effluent from the INPP grounds and the chemical water treatment facility, the average concentration of total phosphorus in the lake increased 2.4-fold compared with the concentration before launching the INPP, and the concentration of phosphate phosphorus increased as much as 9-fold (Salickaitė-Bunikienė et al., 1997). Throughout the period of exploitation of the INPP, Lake Drūkšiai has retained medium mineralization (Salickaitė-Bunikienė et al., 1997). Changes in the biomass of phytoplankton have acquired an indefinite character both within and between seasons; however, the tendency for its annual integral primary productivity to increase was considerably obvious and in 1996 reached the dimensions characteristic of a eutrophic water body (Mažeikaitė et al., 1997). When summarizing investigations of different authors, J. Virbickas has stated that temperature increase up to 34–37 °C inhibited the development of all groups of algae (Вирбицкас, 1988). The biomass of zoobenthos (without Dreissena) in the littoral of the lake increased ca. 235-fold compared with the period before exploitation of the INPP (Račiūnas, 1991). In recent years, the lake has been massively inhabited by mollusc *Dreissena polymorpha* Pallas, first recorded in 1978 and constituting 5.62 thousand t in 1989 (Račiūnas, 1991).

The ichthyofauna of Lake Drūkšiai is rich and interesting; however, in the course of recent decades it has suffered rather great changes due to the changed ecological conditions and introduction of new species. Since old times fish has been an important source of living for inhabitants round the lake; therefore, considerable data have been compiled on fish diversity in this water body. According to the data of different sources, 23–26 fish species were recorded in the lake in the second half of the last century. Before the beginning of the construction of the INPP (1950–1975), the fish community of Lake Drūkšiai had been dominated by stenothermal fish species: lake smelt *Osmerus eperlanus* (L.) and vendace *Coregonus albula* (L.), the biomas of which accounted for ca. 40% of the total fish biomass of the lake (Astrauskas, 1986; Вирбицкас и др., 1993). Such species were numerously accompanied by the roach, perch, bream and pike. Lake Drūkšiai was also inhabited by alien species introduced from the neighbouring lakes through small streams, namely the Peipsi whitefish *Coregonus lavaretus maraenoides* (Poljakow), common carp *Cyprinus carpio* L. and later the pikeperch *Sander lucioperca* (L.) and sun bass *Leucaspius delineatus* (Heck.), which became widespread all over Lithuania. It is also interesting to note that then the lake was home for rarer species – European weels *Silurus glanis* L. and gudgeon *Gobio gobio* (L.). The littoral zone where rivers take their rise was even inhabited by typical river fishes: bullhead *Cottus gobio* L., dace *Leuciscus leuciscus* (L.) and ide *Leuciscus idus* (L.). The high fish diversity, including the occurrence of stenothermal species, evidenced highly favourable ecological conditions for this group of fish. The biomass of lake smelts started to decrease already in the period of construction of the power plant in 1976–1983, when considerable amounts of biogenes and toxicants found way from land to water and large zones with the lack of oxygen formed in the near-bottom strata of deepwater areas (Вирбицкас, Шевцова, 1986). Particularly drastic decreases in the biomass of stenothermal fish were observed in the first years of exploitation of the INPP (1984–1986): the total biomass decreased 8-fold, of lake smelts 2.7-fold, and of vendaces even 58.8-fold (Вирбицкас, 1988a). In the meanwhile, the total biomass of eurythermal fish species went up by ca. 35%, although the total biomass of ichtyocenosis increased by mere 2.5%. After launching the second reactor unit (1987–1988), the total biomass of fish increased by 14.2% compared to 1976–1983 (Вирбицкас и др., 1993).

No significant fluctuations in the biomass of most fish species were recorded in 1994–1999. The ichthyomass of the lake was mainly composed of the populations of ten fish species: roach *Rutilus rutilus* (L.), perch *Perca fluviatilis* L., silver bream *Blicca bjoerkna* (L.), bream *Abramis brama* (L.), bleak *Alburnus alburnus* (L.), rudd *Scardinius erythrophthalmus* (L.), gudgeon *Gymnocephalus cernuua* (L.), pike *Esox lucius* L. and tench *Tinca tinca* (L.). In total, 18 fish species have been registered in the lake during the investigation period.

Investigations into the change of reproductive indices of fish were carried out in Lake Drūkšiai in the first years of exploitation of the INPP (Вирбицкас, 1988; Вирбицкас и др., 1993). However, subsequent investigations in the cooler focused merely on changes in fish numbers and biomass in the pelagial of the lake (Астраускас, 1988; Astrauskas, Jovaiša, 1994; Astrauskas et al., 1995; Astrauskas et al., 1997; Bernotas et al., 1997; Astrauskas et al., 1998); therefore, they could not give a complete view of qualitative and quantitative changes in the fish community. Investigations into the structure and growth rates of different age groups of the vendace of Lake Drūkšiai after the INPP had been put into exploitation (Pernaravičiūtė, 1999) showed that their growth rates changed significantly as a result of change of ecological conditions in the lake.

Throughout the period of exploitation of the power plant, the biomass of eurythermal fish increased on average 2.5-fold and the biomass of stenothermal fish decreased 6–7-fold. In general, the lake is characterized by a rather high productivity of ichthyofauna. The lake is fit for both commercial fishing and intensive angling.

MATERIALS AND METHODS

Study area

Physical and geographical survey of Lake Drūkšiai. Drūkšiai is the largest lake of Lithuania. It is situated in north-eastern Lithuania, an area with the greatest abundance of lakes by the frontier with Latvia and Belarus. The area of the lake is 4900 ha, the greatest depth is 33.3 m, average depth is 7.5 m, the volume of water masses of the lake is 370223.5×10^3 m^3. Deepwater areas constitute a small part of the lake; e. g., areas with the depth from 24 m to the bottom occupy 50 ha, or merely 1% of the total area and 0.4% of the total volume (Жукайте, 1986). The prevailing depth of the lake is up to 12 m. Areas with the depth up to 12 m occupy 4062 ha, or 83% of the total area and 88% of the total volume. The littoral is wide and occupies ca. 1200 ha, or 25% of the total area of the lake. As per data of 1973, the area of the lake is 44.8 km^2. Up to 1953, the water level of Lake Drūkšiai was natural, but after construction of a hydropower plant on the Prorva River (Belarus) and later (in 1983) of the Ignalina Nuclear Power Plant, the water level went up by one meter. Since 1984, the water of Lake Drūkšiai has been used for cooling the reactor units of the nuclear power plant. The amount of water used for cooling is 9 times the water volume of the lake (367.6 million m^2). The water discharged from the cooling system is warmer than the natural water temperature of the lake; therefore, currently a great part of the aquatic area is ice-free in winter. Warm water greatly affects the flora and fauna of Lake Drūkšiai as well as the overall development of the lake. The first reactor unit of the INPP started operating at the end of 1983. In 1985–1987, the power output of the INPP was 1300–1500 MW. In 1987, the second reactor unit was launched and the power output of the plant increased up to 2500 MW. With one energy block operating, ca. 80 m^3/s of water was taken from the lake to condense the exhaust steam and after warming by 9–12 °C discharged back to the lake. The distribution of temperature fields of surface water depends on the amount of heat discharged to the lake and meteorological conditions (air temperature, wind direction and strength). In calm weather, the trail of heat is dragging horizontally from the mouth of the warm water discharge canal up to the periphery of the lake. Surface water temperature is gradually and rapidly decreasing from the mouth of the warm water discharge canal towards the lake. A warm stream moving along the water surface is 2.5–3 m thick. A considerable linear temperature stratification, preventing water masses from mixing, can be observed in the warm water discharge zone all year round; e. g., in summer at the depth of 3 m we can observe a relatively low water temperature and a rather homogeneous thermal field, including the zone near the warm water discharge canal.

Between the strongly warmed-up surface strata and considerably colder strata below, there forms a temperature "leap" layer characterised by great thermogradients near the warm water discharge canal. Vertical temperature gradients sometimes exceed 10 °C/m in spring and early summer. Along the direction of the warm stream, these gradients decrease together with the decreasing surface water temperature. In the deepest places of the lake where the effect of warm water is insignificant, the distribution of water temperatures is close to natural with the gradient of 1–2 °C/m.

In winter, the surface water temperature is ca. 12 °C in the warm water discharge zone. The area of the ice-free zone depends on the amount of heat discharged to the lake and on air conditions. With one energy block operating in February 1985–1987, the ice-free area ranged from 7 to 12 km^2, whereas, e. g., in 1988 when two energy blocks were functioning, it reached 17 km^2 (Жукайте, 1992). Based on temperature surveys performed since 1984, the aquatic area of Lake Drūkšiai can be divided into seven zones (Gailiušis et al., 1997). After the closure of the first energy block in 2004, the thermal loading of the lake decreased.

Methods

Investigations were carried out in 2005–2007 in three sites of Lake Drūkšiai: in the "warm water" zone of the lake by the mouth of the warm water discharge canal (site 1), in the "cold water" zone of the lake by the Tilžės Bay (site 2), and special coldwater and other fish research was done in the profundal zone of the lake by the cooling water intake canal (site 3). Investigations were carried out twice per year – in June and October. Special research into the distribution of the spined loach *Cobitis taenia* L. was performed in the littoral zone of the lake in 2006. Spined loaches were caught together with other near-coast fishes using a 10 m long 8–4 mm mesh fry dragnet. Research was done in eight different sites in "warm" and "cold" zones of the lake, with an average 100 m^2 fishing area in each site. The sites are presented in Fig. 1. Species composition and abundance of fish were investigated using vendace bottom multi-mesh gill nets and selective nets of different mesh size, where one section was 5 m in length, 3 m in height and mesh size range was 17–22–25–30–40–50–60 mm (Thoresson, 1993). Each site was furnished with four

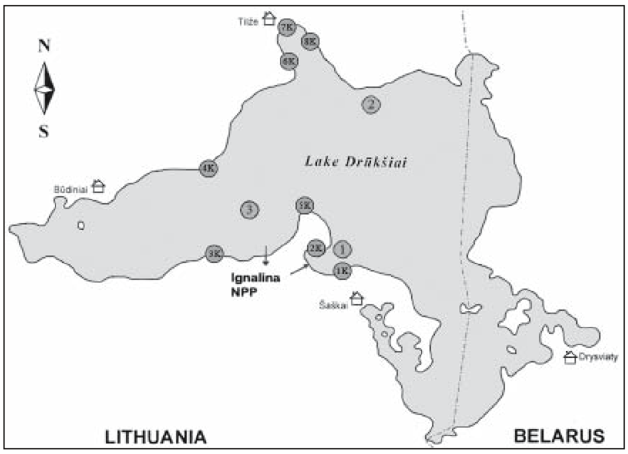

Fig. 1. Location of research sites in Lake Drūkšiai: 1–3 – permanent fish monitoring sites; 1 K – 8 K – *Cobitis taenia L.* monitoring sites

selective nets with the aggregate length 120–160 m. All catches were recalculated as per 30-m-length net (CPUE, catch per unit effort). In addition, there were used 40–70 mm mesh nets and vendace 18–20 mm mesh nets. Vendace nets were used only in the profundal zone of the lake by the intake (site 3).

The general ichthyological analysis of caught fish was based on the generally acknowledged methods (Правдин, 1966; Thoresson, 1993). The theoretical number (N) and biomass (B) of fish in the community were recalculated for an area unit (unit/ha and kg/ha) (Methods for fish stock control and record in the Lithuanian lakes and water reservoirs, 1996):

$$N = \frac{n}{p\,k}, \quad B = \frac{Q}{p\,k},$$

where n is the total number of caught fish, Q is the total mass of caught fish, p is the fishing area, k is the catchability coefficient (part of the fish community caught, the coefficient is subject to abiotic variables of the water body). In 2007, Lake Drūkšiai was subject to the catchability coefficient of 0.1.

Age was identified according to fish scales (Правдин, 1966; Thoresson, 1993). When characterising the status of roach and perch populations, growth rates were assessed based on the species growth rate groups established for Lithuanian lakes (Grigelis, 1975).

RESULTS AND DISCUSSION

During ichthyological research in different aquatic areas of Lake Drūkšiai in 2005–2007, 14 fish species were recorded: catches in the "cold water" zone were composed of ca. 8–12 fish species, in the "warm water" zone of 6–10 species, and in the near-shore zone of 7 species. The list of ichthyofauna was composed of typical, lymnophylic and most frequent dwellers of such type lakes: vendace, pike, roach, bream, silver bream, tench, bleak, rudd, crucian carp *Carassius carassius* (L.), carp *Cyprinus carpio* L., spined loach, burbot *Lota lota* (L.), ruffe and perch. The results of our research showed that species diversity significantly decreased in Lake Drūkšiai – from 23–26 fish species before exploitation of the INPP down to 14 species registered to date. Among coldwater fish, lake smelts are no longer caught; therefore, we can make an assumption that this species disappeared from the lake. Drūkšiai is no longer home for the catfish and some earlier introduced species such as whitefish and pikeperch. The littoral zone no longer holds the above-mentioned river fish species – bullhead, dace, ide, nor gudgeon, which were still registered not long ago (Bernotas, 2001). The distribution and abundance of the introduced warm-water species such as German carp *Carassius auratus gibelio* (Bloch) and common carp increased. As to more interesting species, our investigations resulted in several catches of spined loach in the near-shore zone. As per data obtained from anglers, the "warm water" zone of the lake inhabits two more introduced warm-water species – grass carp *Ctenopharyngodon idella* (Valenc.) and silver carp *Hypophthalmichthys molitrix* (Valenc.); however, during experimental research these species have not been caught and we can state that their populations are not abundant.

Currently, the lake inhabits two fish species from the list of protected species of the EU Habitat Directive: spined loach, which is a rather frequent species dwelling exclusively in the shallow part of the lake, and vendace which, contrary to the spine loach, is holding in the deepwater zone of the lake and is a pelagic – coldwater fish. Because of the worsening ecological conditions, their numbers have considerably decreased. Spine loaches as other near-shore fishes were caught using a fry drag-net in eight different research sites in "warm" and "cold" zones of the lake (Table 1). They were caught in only three research sites with the frequency of occurrence of 37.5%. In the "cold water" zone, adult spined loaches were caught in the northernmost bay of the lake, in two sites. The density of spined loaches was 2.4–3.3 unit/100 m^2, biomass 11.9–13.2 g/100 m^2. In the "warm water" zone, only spined loach fry was caught in one site, but their density was very high (even 600 unit/100 m^2) and biomass was 300 g/100 m^2. In the "warm water" zone (in the sites where spined loaches were caught), they accounted for 2–4.2% of the total near-shore community by numbers and 0.7–1.6% by biomass.

Considerable changes may be observed on the level of fish community structure as a result of thermal regime changes and the impact of intensive anthropogenic eutrophiication. The generalised data from the last three years about the structure of fish community according to density (N, %) and biomass (B, %) per CPUE (30 m length net) in Lake Drūkšiai are presented in Fig. 2. The fish community was basically composed of three eurythermal species: silver bream (32.9%), perch (30.1%) and roach (21.7%). During the recent period, the abundance of silver breams significantly increased, whereas that of roaches and breams decreased. The greatest changes occurred in the populations of stenothermal fish species. As already mentioned, lake smelts are not caught at all, whereas vendaces account for ca. 3% of the total abundance of fish. By biomass, the lake is dominated by the roach (38.7%), followed by several species with insignificant differences in biomass: perch (15.7%), bream (14.0%), tench (12.1%) and silver bream (9.5%). Changes in the structure of fish community started with the beginning of exploitation of the INPP, which could be corroborated by literature data (Astrauskas, 1993). Some authors (Вирбицкас, Шевцова, 1986) state that some eurythermal fish species, which had earlier been very scanty, namely silver bream, rudd and tench, have been observed to show significant biomass increases in the lake. As per statistical data of commercial fishing, the biomass of each of the above species accounted for no more than 0.3% of the total ichthyomass of the lake before exploitation of the power plant. After launching the power plant, the abundance and biomass of euryttermal species started considerably increasing. Bernotas (2001) carried out investigations in the lake in 1995–2000 and documented rather significant biomass changes of such species: the biomass of the silver bream made already ca. 10% (16.1 kg/ha), that of the rudd 3% (4.6 kg/ha), and that of the tench 1% (1.6 kg/ha) of the total biomass of fish in Lake Drūkšiai.

The results of the monitoring of 2007 revealed differences in the abundance and biomass of fish in different sites of Lake Drūkšiai. In the "warm water" zone, fish abundance in summer and autumn was higher than in the "cold water" zone and reached 61.4 individuals per CPUE, whereas in the "cold water" zone the abundance averaged mere 25.1 individuals. As regards biomass per CPUE, the situation was opposite, i. e. 59.963 kg in the "cold water" zone versus 15.011 kg in the "warm water" zone (Tables 2, 4). Both the "cold" and "warm" zones were dominated by roach, perch and silver bream by numbers, whereas according to the

Table 1. **Density (N, %) of the spined loach and other fish species in the near-shore zone of Lake Drūkšiai in 2006**

Site	"Warm water" zone		"Cold water" zone					
	1	2	3	4	5	6	7	8
Silver bream					95.6			
Perch	100.0	1.1	61.8	97.4		100.0	82.1	95.8
Roach		6.6	2.9	2.6			11.9	
Bream			35.3		0.1		0.7	
Rudd		4.4					3.3	
Spined loach		87.9					2.0	4.2
Bleak					4.2			

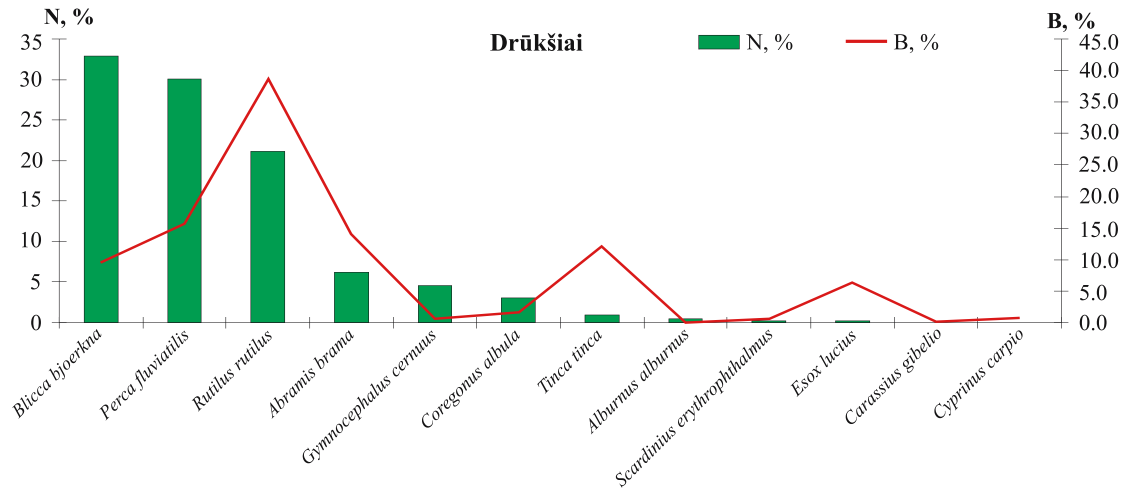

Fig. 2. Fish community structure by density (N, %) and biomass (B, %) per CPUE (30 m length net) in Lake Drūkšiai in 2005–2007

Table 2. **Fish species composition, abundance (n), biomass (kg) and catches per CPUE (30 m length net) in the "cold water" zone of Lake Drūkšiai in 2007**

Fish species	Abundance (n)			Biomass (kg)		
	Total	CPUE	%	Total	CPUE	%
Vendace	22	1.4	5.6	0.912	0.059	1.7
Pike	2	0.08	0.31	3.79	0.203	5.9
Roach	141	7.0	27.9	28.767	1.686	49.0
Bream	23	1.3	5.2	8.104	0.457	13.3
Silver bream	69	3.8	15.1	1.654	0.093	2.7
Bleak	3	0.16	0.64	0.008	0.0005	0.01
Tench	10	0.51	2.1	9.835	0.526	15.3
Rudd	2	0.08	0.31	0.345	0.018	0.5
Perch	159	9.4	37.4	6.29	0.382	11.1
Ruffe	23	1.4	5.6	0.258	0.015	0.4
Total	327	25.13	100	59.963	3.439	100

Table 3. **Fish species composition, abundance (n), biomass (kg) and catches per CPUE (30 m length net) in the "cold water" zone of Lake Drūkšiai (profundal zone before the INPP intake) in 2007**

Fish species	Abundance (n)			Biomass (kg)		
	Total	CPUE	%	Total	CPUE	%
Vendace	15	1.6	19.0	0.568	0.060	9.7
Pike	1	0.1	1.2	2.230	0.239	38.6
Silver bream	1	0.1	1.2	0.034	0.004	0.6
Perch	54	5.8	69.0	2.876	0.308	49.7
Ruffe	8	0.8	9.5	0.074	0.008	1.3
Total	79	8.4	100	5.782	0.619	100

Table 4. **Fish species composition, abundance (n), biomass (kg) and catches per CPUE (30 m length net) in the "warm water" zone of Lake Drūkšiai in 2007**

Fish species	Abundance (n)			Biomass (kg)		
	Total	CPUE	%	Total	CPUE	%
Roach	93	12.7	20.7	3.424	0.467	22.1
Bream	28	3.8	6.2	0.924	0.126	6.0
Silver bream	221	30.1	49.0	6.066	0.827	39.2
Rudd	1	0.1	0.2	0.054	0.07	3.3
Perch	89	12.1	19.7	4.349	0.593	28.1
Ruffe	19	2.6	4.2	0.194	0.026	1.2
Total	451	61.4	100	15.011	2.109	100

biomass per CPUE, the "cold water" zone was largely dominated by roach (1.686 kg or 49%) and the "warm water" zone by three species: silver bream, perch and roach (0.827–0.467 kg or 39.2–22.1%). In summer, tench and bream populations also constituted a considerable part of the total biomass of the "cold water" zone (15.2% and 24.3%, respectively). In the deepwater (profundal) part of the lake (before the cooling water intake for the INPP), fish diversity was lower compared with other parts. The community was largely dominated by the roach (69%), with rather significant numbers of vendace (19%) and (in the near-bottom strata) ruffe (9.5%; Table 3).

A comparison of data from many years (1993–2007) showed that in Lake Drūkšiai fish abundance decreased to 30.1 ind. and biomass to 2.4 kg per CPUE (Fig. 3, 4). Compared with the results from other Lithuanian lakes, the biological resources of fish of Drūkšiai remain considerably high.

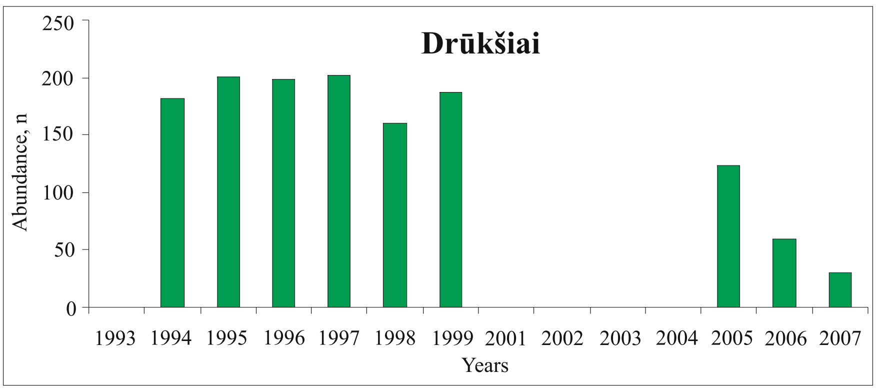

Fig. 3. Abundance dynamics of fish caught in Lake Drūkšiai per CPUE in 1993–2007

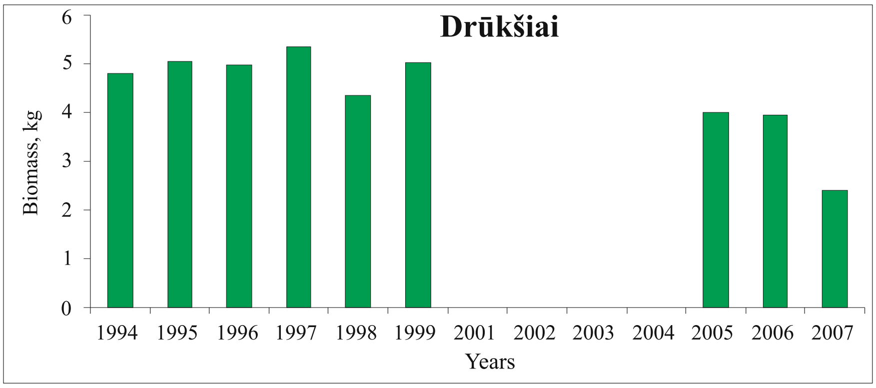

Fig. 4. Biomass (kg) dynamics of fish caught in Lake Drūkšiai per CPUE in 1993–2007

Annual fish stocks per unit of area (kg/ha) in Lake Drūkšiai were estimated applying a simplified method (Methods for fish stock control and record in the Lithuanian lakes and water reservoirs, 1996). In 2007, fish stocks of the lake averaged 671.78 t, whereas the commercial fish catching limit according to the data of investigation could reach ca. 67.180 t or 18.5 kg/ha (Table 5). The stocks of some low-value and rarer species were assessed from the actual data of experimental fishing; therefore, precise calculations cannot be made. In fact, the general productivity of these species might be higher. It concerns investigations into the productivity of populations of bleak, burbot, rudd and silver bream. Compared with the results of 1994–1999 (737.59 t; Bernotas, 2001), fish stocks have decreased by ca. 9%. The most remarkable decreases have been registered in the stocks of the perch (from 180.5 t to 94.86 t) and vendace (from 30.56t to 11.4 t). The biomass of other species decreased insignificantly. Tench stocks increased from 7.14 t to 93.85 t, and pike stocks increased from 7.81 t to 46.8 t. From the viewpoint of fishing, Lake Drūkšiai is a water body of high productivity, allowing intensive angling but insufficient commercial fishing. Statistical data show that in 1950–1973 commercial catches used to be 18.6 t (4.4 kg/ha) on average, and in 1974–1983 they increased up to 23.4 t (5.5 kg/ha) (Bružinskienė, Virbickas, 1988). Presently, commercial fishing is not actually pursued; e. g., catches in 2005–2007 averaged to mere 0.381 t (Data of the ministry of Agriculture of the Republic of Lithuania).

Fish growth rates in Lake Drūkšiai

Fish growth rates in Lake Drūkšiai changed after launching the INPP. During the first year of exploitation of the INPP, growth rates of all fish species, including coldwater stenothermal speices such as vendaces and lake smelts, increased, which was due to the rise in water temperature and widespread distribution of Dreissena molluscs (Вирбицкас, 1988). Later, with the launch of the second reactor unit (1987–1988) and increase of the thermal load of the lake, the growth rates of mesothermal and eurythermal fish species continued increasing, but those of stenothermal species started slowing down (Вирбицкас и др. 1993; Balkuvienė, Pernaravičiūtė, 1994). In subsequent years, even though the biomass of zoobenthos, in particular Dreissena, markedly increased and the abundance of metazooplankton recovered, the growth rates of mesothermal and eurythermal fishes also started to slow down (Balkuvienė, 1993; Balkuvienė, Pernaravičiūtė, 1994). The growth rates of many species in the "warm water" zone of the lake were faster than those in the "cold water" zone, which could be demonstrated by a comparison of roach and perch growth rates in two thermally different areas of the lake in 2005, i. e. the "cold water" zone where the thermal contamination of the INPP was minimal, and the "warm water" zone where the water temperature was 4–6 °C above the norm. The growth rates of both roaches and perches were considerably faster in the "warm water" zone as regards all middle-age groups. It is interesting to note that the greatest differences were found between five-year-old individuals (Fig. 5, 6). A comparison of growth data of 8-year-old (7+) roaches between 1994–1999 and 2005–2007 did not yield any differences. The average body mass of 8-year-old (7+) roaches ranged from 73.8 to 84.7 g (Bernotas, 2001), and according to our data their average body mass varied in the range of 73–89.1 g and did not actually differ. As to the growth of perches of the same age, it was faster and the average body mass varied from 116.6 to 126.9 g, whereas presently perch growth rates have slowed down and vary from 74.4 to 93.3 g. According to the groups of growth rates of Lithuanian fish, the

Table 5. **Fish stocks (kg) and commercial production (kg) per year in Lake Drūkšiai**

Species	Fish stocks per lake kg	Commercial production, kg/lake		
		Total	Amount of fish planned to be caught by amateur fishing gear	Amount of fish planned to be caught by commercial fishing gear
Perch	94860	9486	4743	4743
Roach	290860	29086	14543	14543
Pike	46800	4680	2340	2340
Bream	81740	8174	2452	5722
Tench	93850	9385	2815	6570
Vendace	11410	1141	0	1141
Other	52260	5226	2613	2613
Total	671780	67178	29506	37672

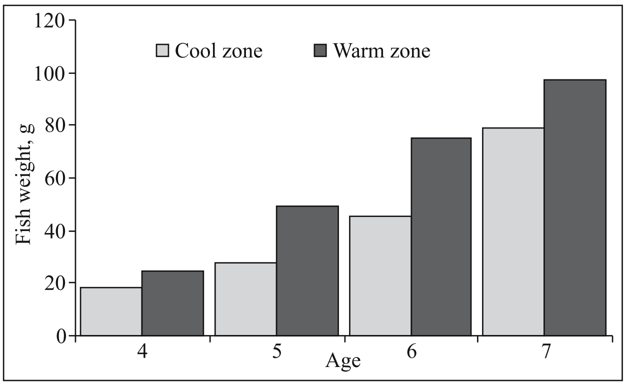

Fig. 5. Perch growth in Lake Drūkšiai zones of different thermal regime

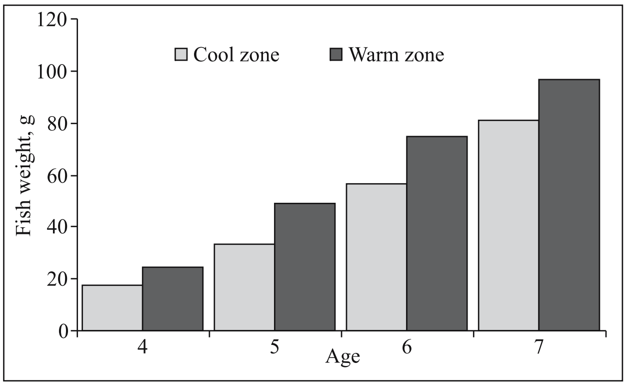

Fig. 6. Roach growth in Lake Drūkšiai zones of different thermal regime Perch

growth rates of the vendace, roach and pike in Drūkšiai are good, whereas those of the perch and bream are medium (Grigelis et al., 1975).

CONCLUSIONS

1. Investigations into the ichthyofauna of different aquatic areas of Lake Drūkšiai in 2005–2007 revealed significant changes in species diversity and community structure, caused by changes in the thermal regime and the impact of intensive anthropogenic eutrophication.

2. The species diversity in Lake Drūkšiai significantly decreased from 23–26 fish species (before launching the INPP) to the current list of 14 species. The lake is no longer home for the lake smelt, catfish and some introduced species such as the whitefish and pikeperch. The littoral of the lake does not hold river fish species such as the bullhead, dace, ide or gudgeon, a recent dweller of the littoral. The numbers and distribution of the tench and introduced warm-water species such as the German carp and common carp increased; catches of the grass carp and silver carp are also recorded.

3. As to the fish community structure, Lake Drūkšiai is undergoing a change of dominant species. The fish community is basically composed of three eurythermal species: silver bream (32.9%), perch (30.1%) and roach (21.7%). Recently the abundance of silver breams has particularly increased, whereas the numbers of the roach and bream decreased. The populations of stenothermal species decreased to the critical level: the lake smelt is not caught at all and the vendace accounts for merely ca. 3% of the total number of fish. By biomass, the lake is dominated by roach (38.7%), followed by several species with insignificant variations in biomass: perch (15.7%), bream (14.0%), tench (12.1%) and silver bream (9.5%).

4. As regards fishery, Lake Drūkšiai is a highly productive water body intensively used by anglers, but insufficiently exploited by commercial fishing devices. In 2007, fish stocks of the lake averaged ca. 671.78 t, and the commercial fish catching limit was ca. 67.180 t, or 18.5 kg/ha. Compared with fish stocks of 1994–1999 (ca. 737.59 t), the decrease constitutes ca. 9%.

5. Fish growth rates in Lake Drūkšiai changed after the INPP was launched. With the increase of the thermal load in the lake and the distribution of Dreissena, the growth rates of mesothermal and eurythermal fish species changed. Recent investigations into the growth rates of the roach and perch showed faster growth rates of most fish species in the "warm water" zone compared with the "cold water" zone.

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ŽUVŲ BENDRIJŲ KAITA IGNALINOS ATOMINĖS ELEKTRINĖS AUŠINTUVE

Santrauka
Darbe tyrinėjama Drūkšių ežero – Ignalinos atominės elektrinės aušintuvo – žuvų bendrijų ir populiacinių parametrų (gausumo, biomasės, žuvų augimo) kaita. Apibendrinti tyrimų rezultatai prieš pradedant eksploatuoti elektrinę ir jai dirbant įvairiais galingumais, kurie turi įtakos aušintuvo ekosistemos ekologiniams procesams, tarp jų ir biologiniam produktyvumui. Atlikus ichtiofaunos tyrimus įvairiose ežero akvatorijose 2005–2007 m. nustatyti gana ženklūs žuvų rūšinės įvairovės ir bendrijų struktūros pokyčiai, kuriuos sąlygoja terminis režimas ir intensyvi antropogeninė eutrofizacija. Nustatytos žuvų rūšinės įvairovės ir bendrijų struktūros kitimo tendencijos. Ištirtas žuvų augimas skirtingose ežero akvatorijose, kuojos ir ešerio populiacijų pavyzdžiu parodyta, kad augimo tempai išlieka spartesni šiltoje ežero zonoje negu šaltoje zonoje. Žuvininkystės požiūriu Drūkšių ežeras ir toliau išlieka didelio produktyvumo vandens telkinys, kuriame vykdoma intensyvi mėgėjiška ir nepakankama verslinė žvejyba. Žuvų ištekliai ežere 2007 m. siekė vidutiniškai 671,78 t, o verslinis žuvų sugavimo limitas yra apie 67,180 t, arba 18,5 kg/ha. Palyginus šiuos rezultatus su ankstesnio tyrimo duomenimis nustatyta, jog žuvų ištekliai sumažėjo 9%.

Raktažodžiai: Drūkšių ežeras – Ignalinos atominės elektrinės aušintuvas, žuvų bendrija, populiacijos parametrai ir jų kaita