Proc. Estonian Acad. Sci. Ecol., 1993, 3, 4, 181—186
https://doi.org/10.3176/ecol.1993.4.03

DISTRIBUTION OF FISH SPECIES IN ESTONIAN LAKES

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Presented by E. Ojaveer

Received May 14, 1993; accepted May, 21, 1993

Abstract. According to the available data, perch and pike are the most widely distributed fishes in our lakes (they are lacking only in 8% of the lakes studied), while roach falls slightly behind them. Next come crucian carp, tench, bream, rudd, ruff, and other fishes. Almost all the fish species studied (except crucian carp) prefer larger and deeper lakes with a tendency toward eutrophy. Lakes rich in organic substances and poor in fish are not favoured; forest and bog closed lakes are usually avoided. Most fishes are quite sensitive to winter anoxia. In some cases perch, pike, and crucian carp are able to live and spawn in such forest and bog lakes where other fish species do not occur.

Key words: lakes, fish species, distribution, ecological requirements.

INTRODUCTION

Since 1951 the Institute of Zoology and Botany of the Estonian Academy of Sciences has carried out hydrobiological and ichthyological complex investigations on more than 500 Estonian lakes (Eesti järved, 1968; Mäemets, 1977; Mikelsaar, 1984). Most of them have been studied repeatedly. This paper gives a short survey of the occurrence frequency of fish species in our lakes with the area of 2 ha and more, and tries to compare the lakes where a certain fish species occurs with the lakes where it is lacking.

MATERIAL AND METHODS

The total number of lakes with an area of 2 ha or more in Estonia is 769 (Kask, 1964). The largest of them are L. Peipus (Peipsi) (3560 km²) and the Narva Reservoir (*c.* 200 km²) on the Russian border in the east and L. Võrtsjärv (270 km²) in the south-east. The rest of the lakes are comparatively small, up to 985 ha (L. Ülemiste in the vicinity of Tallinn). The occurrence frequency of fish species has been more or less ascertained for 368 lakes (47.8% of the total number of lakes). The composition of the fish fauna in a certain lake was established on the ground of experimental and commercial catches as well as sport fishing; in addition, information obtained from local inhabitants was used.

The lakes under study were classified according to the ecological typology worked out by Aare Mäemets (Mäemets, 1977; Мяэметс & Мяэметс, 1991). In the present paper eight lake types are distinguished: eutrophicated oligotrophic lakes, where the accumulation of all substances

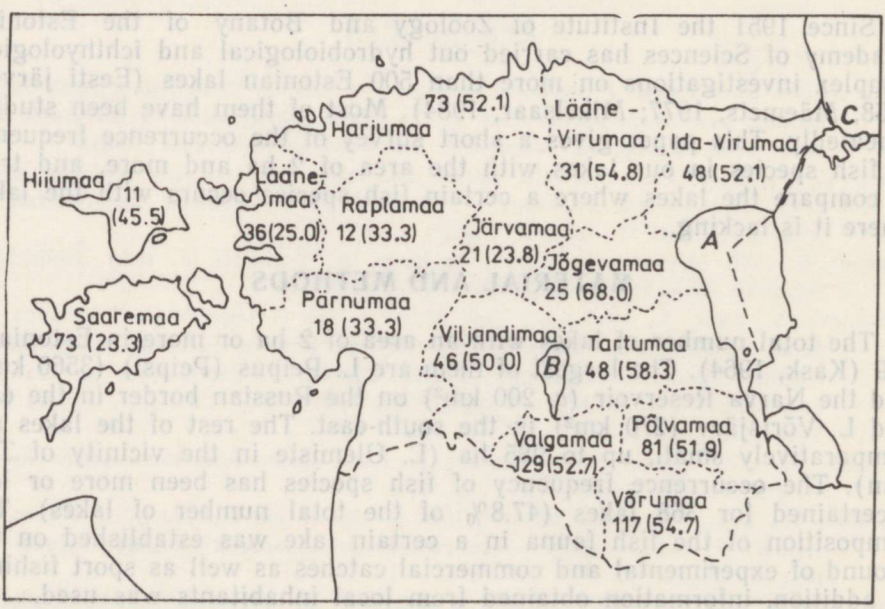
is rather weak (entirely oligotrophic lakes have almost disappeared in Estonia); semidystrophic lakes — moderate dominance of the accumulation of humic substances; dystrophic lakes — strong dominance of the accumulation of humic substances; dyseutrophic lakes — simultaneous accumulation of both humic substances and nutrients (the final stage of lake development in our climatic zone); eutrophic lakes — dominance of the accumulation of nutrients; hypertrophic lakes — strong accumulation of nutrients (total P>100 mg·m^{-3}, total N>1200 mg·m^{-3}); halotrophic lakes — rich in chlorine; alkalitrophic lakes — dominance of calcareous substances.

The characteristics of different lake groups were compared by Student's *t*-test. The difference was regarded to be significant when $P<0.05$.

RESULTS

Table 1 and the Figure show that the number and qualities of lakes are quite heterogeneous in different parts of Estonia. Almost half of the investigated lakes (174) are located in three counties of South-East Estonia (Võrumaa, Valgamaa, and Põlvamaa) in a hilly moraine landscape, while our watershed regions (Järvamaa, Raplamaa) as well as relatively plain regions of West Estonia (except Saaremaa) are rather poor in lakes. Two fifths of the lakes studied are eutrophic; they are more abundant in South-East, East, and Central Estonia. A quarter of the lakes are dyseutrophic; they have reached their final stage of development. These lakes are particularly frequent in West Estonia. One third of the lakes under study belong to the remaining six lake types. Among them eutrophicated oligotrophic lakes are especially abundant in North-East Estonia (Kurtna lake group), halotrophic coastal lakes are the most frequent on Saaremaa Island.

As regards the character of the surroundings of a lake, its water exchange, winter anoxia, pollution, and lowering of the water level, the



The total number of lakes with the area of 2 ha or more, and the percentage of ichthyologically investigated lakes (in brackets) in the counties of Estonia. *A* — L. Peipus, *B* — L. Võrtsjärv, *C* — Narva Reservoir.

following should be mentioned. Forest and bog closed and through-flowing lakes are more common in North and North-East Estonia, as well as in Lääne and Rapla counties, while coastal lakes occur mostly on our large islands Hiiumaa and Saaremaa. A quarter of the lakes (especially shallow coastal lakes) suffer from winter anoxia. Intensive flax retting has deteriorated the living conditions of fishes in many lakes of South-East Estonia (an important flax-raising area). Agricultural non-point pollution has strongly damaged numerous lakes (or has quickened their eutrophication), first of all, in intensively cultivated counties of East Estonia — Jõgeva and Tartu. Many lakes have been spoilt as a result of land reclamation, which has brought about the lowering of the water level. In North-East Estonia large oil-shale mines, which use great quantities of groundwater, are responsible for the lowering of the water level.

Table 2 gives a survey of the occurrence frequency of fish species in the lakes of Estonia and some neighbouring areas. According to the available data, perch and pike are the most widely distributed fishes in our lakes, occurring both in 92.1% of the lakes studied. Roach comes third. The next three places are occupied by crucian carp, tench, and bream. The occurrence frequency of the rest of fish species may be underestimated due to insufficient reliable data, except in the case of vendace, lake (dwarf) smelt, and pike-perch.

Among the fish species mentioned in Table 2, peled (northern whitefish) and carp are pond fishes in Estonia; however, they have been introduced in numerous lakes too, where they almost never spawn. Nevertheless, some exceptions have been reported. Peled has sometimes spawned in L. Kuremaa (Jõgevamaa) and carp in L. Lohja (Harjumaa). Giebel (German) carp was not found in Estonia till 1948, then it was brought into L. Maardu (near Tallinn), where it spawned successfully to be released further in many lakes. Up to now it has naturalized and survived in nine Estonian lakes.

Table 3 presents the main numerical characteristics of the lakes studied. The lakes are arranged in groups according to the occurrence or absence of certain fish species. These groups were compared by means of Student's *t*-test. Besides, the lake groups whose ichthyofauna consisted of only one species (either pike, perch, or crucian carp) were compared with the lakes where this species co-occurred with other fish species.

Table 4 deals with the same characteristics as Table 1 but the lakes are grouped as in Table 3.

According to tables 3 and 4 pike is lacking in 29 lakes. These are rather small lakes with a tendency either toward dystrophy or hypertrophy. Water transparency (WT) is low, dichromate oxygen consumption (DOC; i.e. the content of organic substances) is quite high, but fish productivity (FP; i.e. the prospective catch of fish, $kg \cdot ha^{-1} \cdot yr^{-1}$) is rather low. Forest and bog lakes are dominating here. Many of them suffer from winter anoxia (WA), flax retting, and agricultural pollution.

Pike is the single fish species in three lakes. They are not small but they are shallow and their WT and pH are quite low, DOC very high, FP very low. All these lakes are dystrophic. Two of them are located in a bog (L. Ohepalu and L. Tudu in Lääne-Virumaa), one in a forest (Nohipalu Mustjärv in Põlvamaa). All the three lakes suffer from the lowering of the water level. L. Ohepalu suffers from WA, L. Nohipalu Mustjärv is harmed by flax retting.

Perch as well as pike is lacking in 29 lakes, the majority of which (17) coincide. Therefore these lake groups are quite similar.

Perch is the single fish species in four lakes (L. Kurtna Ahnejärv in Ida-Virumaa, L. Koolma in Põlvamaa, L. Kungjärv in Võrumaa, L. Märdi in Valgamaa). Three of them (except L. Kurtna Ahnejärv) are dystrophic, two are closed forest lakes (L. Kurtna Ahnejärv, L. Koolma), and two bog lakes. In these lakes pH is low, DOC very high, FP rather low.

Roach is lacking in 63 lakes. They are comparatively small, not very deep, their WT is quite low, water is slightly acid, DOC rather high, FP relatively low. These lakes are inclined to dystrophy. The overwhelming majority of them are located in forests and bogs. There are many closed lakes among them, which suffer from WA. Many of them are used for flax retting.

Crucian carp is lacking in 122 lakes. They are not very small. Their depth, WT, pH, DOC, and FP are close to the mean values. These lakes have also revealed a tendency toward dystrophy. However, only a few of them are harmed by WA.

Crucian carp is the single fish species in nine lakes. They are comparatively small and shallow, their WT and FP are low. The overwhelming majority of them are forest and bog lakes damaged by WA. These lakes are located mainly in North and North-East Estonia (L. Purgatsi, L. Järvi Pikkjärv, and L. Turvaste Mustjärv in Harjumaa; L. Kantküla Mustjärv, L. Savalduma, and L. Udujärv in Lääne-Virumaa; L. Jõuga Liivjärv and L. Pesujärv in Ida-Virumaa), only one such lake lies in South-East Estonia (L. Kauru in Valgamaa).

Tench is lacking in 149 lakes. They are relatively small and shallow, their WT, pH, and FP are slightly below the mean values, but DOC is rather high. Among them there are many senile (dyseutrophic) and dystrophic forest and bog lakes, many of them suffer from WA.

Bream prefers quite large, not very deep eutrophic and hypertrophic lakes with moderate WT, pH, DOC, and FP. This fish is lacking in 195 lakes, which have a trend to dyseutrophy and dystrophy. These lakes are quite small and shallow, their DOC exceeds the mean value, but FP is rather low. Most of them are located in forests and bogs, many have experienced water level lowering and are harmed by WA.

Pike-perch as a fastidious fish inhabits our best eutrophic and hypertrophic lakes. They are relatively large and deep, their pH and FP are rather high. As these lakes are located mostly in cultivated areas, they are exposed to agricultural pollution. Pike-perch avoids closed lakes as well as shallow coastal lakes. It is quite sensitive to WA and flax retting.

Vendace and lake smelt are permanent inhabitants of our large lakes (L. Peipus and L. Võrtsjärv). From time to time they come down from L. Peipus to the Narva Reservoir, but they probably do not spawn there. Besides, these fishes occur in some of our medium-sized lakes: vendace lives and spawns in L. Ülemiste (985 ha, in the outskirts of Tallinn) and L. Saadjärv (708 ha, Jõgevamaa); lake smelt was lately successfully introduced into L. Vagula (519 ha, Võrumaa).

As it was mentioned above, the occurrence frequency of the rest of our lake fishes is probably bigger than the insufficient reliable data indicate; therefore, it is not reasonable to discuss their presence or absence in our lakes now.

According to the available data, there are three small karst lakes in Estonia without any fish species altogether (L. Lemküla, L. Piisupi, and L. Võhmetu in Lääne-Virumaa; 4—10 ha). Sometimes they disappear totally, and then appear again. The fish fauna is most likely lacking in many of our insufficiently studied bog pools, too.

Table 1

Distribution of lakes according to their ecological typology and unfavourable characteristics in the counties of Estonia, % of the total number of lakes studied

Lakes, counties	Number of lakes	Lake types								Unfavourable qualities				Unfavourable phenomena			
										Closed lakes		Through-flowing lakes			Pollution		
		Eutrophicated oligotrophic	Semidystrophic	Dystrophic	Dyseutrophic	Eutrophic	Hypertrophic	Halotrophic	Alkalitrophic	Forest and bog lakes	Others	Forest and bog lakes	Coastal lakes	Winter anoxia	Flax retting	Other	Lowering of the water level
All the lakes	368	6	5	7	24	42	12	3	1	13	10	27	4	28	10	12	11
Harjumaa	38	11	5	8	29	42	5			37	3	29		26		13	8
Hiiumaa	5				80			20				40	60	60			
Ida-Virumaa	25	32	12		32	20			4	24		56		16			28
Jõgevamaa	17					65	35			6		47		35	6	41	18
Järvamaa	5				20	60	20			20		20		20			20
Läänemaa	9		11		78			11		33		33	11	33			11
Lääne-Virumaa	17	6		23	12	29	12		18	41	12	29	6	29	6	12	18
Põlvamaa	42	5	5	26	12	43	9			14	19	29		29	24	5	7
Pärnumaa	6			16	50	17		17				33	17	83		17	33
Raplamaa	4			75	25							100		25			
Saaremaa	17			6	35	6		53		6	18	29	59	53			18
Tartumaa	28				14	47	39			7	11	29		32	7	32	7
Valgamaa	68	3		3	25	59	10			3	12	21		31	18	4	6
Viljandimaa	23				22	61	17				9	13		17	13	17	13
Võrumaa	64	8	16	3	20	42	11			9	15	13		16	15	16	9

Table 2

Occurrence frequency of fish species in the lakes of Estonia and neighbouring territories (the number of lakes in brackets)

Fish species	Estonia (368)		Russia: Pskov pr.[1] (668)	Russia: Leningrad pr.[2] (469)	Russia: Karelia[3] (800)	Russia: Vologda pr.[4] (275)	Latvia[5] (549)	Lithuania[6] (750)	Finland[7] (252)	Sweden[8] (102)
Coregonus albula	1.36	(5)	5.7	5.9	41.5	3.6	4.5	2.5	11.5	30.4
Coregonus peled	2.17	(8)	1.3			1.8				
Coregonus lavaretus	2.17	(8)	0.6	2.3	36.6	8.4	2.2		10.7	
Osmerus e.e. m. *spirinchus*	1.09	(4)	1.2	7.0	8.2	4.7	3.2	1.3	1.2	1.0
Esox lucius	92.12	(339)	91.5	97.5	94.5	86.5	95.8	97.1	65.9	70.6
Anguilla anguilla	20.11	(74)	4.3	7.8		0.7	35.3		5.9	57.8
Rutilus rutilus	82.88	(305)	91.0	85.7	87.2	81.1	92.4	96.4	48.8	65.7
Leuciscus leuciscus	4.62	(17)	0.9	2.1	8.5	5.1			0.4	
Leuciscus cephalus	4.62	(17)	1.5	1.9		2.9				
Leuciscus idus	9.51	(35)	31.4	22.5	33.4	48.4	36.3		11.5	
Phoxinus phoxinus	1.90	(7)							3.6	31.4
Scardinius erythrophthalmus	45.65	(168)	31.9	19.2		13.5	50.0	60—70	5.6	
Aspius aspius	2.45	(9)	0.3	2.3		4.7				2.9
Leucaspius delineatus	15.76	(58)	0.1							
Tinca tinca	59.51	(219)	47.8	12.3		13.8	84.7	91.5	5.6	
Gobio gobio	5.98	(22)	3.0			1.1	2.0			
Alburnus alburnus	20.11	(74)	30.5	21.8	16.5	16.0	43.1	57.5	15.9	8.8
Blicca bjoerkna	18.48	(68)	30.7	12.3		13.8	54.2	45—50	11.5	
Abramis brama	47.01	(173)	43.7	43.3	35.6	52.4	63.4	70.0	19.0	7.8
Carassius carassius	66.85	(246)	54.3	24.5	1.8	46.2	85.0	45—55	18.7	
Carassius auratus gibelio	2.45	(9)	0.6							
Cyprinus carpio	3.26	(12)	2.1							
Cobitis taenia	8.42	(31)	0.1							
Nemacheilus barbatulus	1.09	(4)							8.3	
Misgurnus fossilis	13.32	(49)	2.5			0.7				
Lota lota	31.52	(116)	35.2	53.8	74.8	61.5	61.2	30—40	36.1	66.7
Gasterosteus aculeatus	2.17	(8)								
Pungitius pungitius	10.87	(40)							2.8	
Perca fluviatilis	92.12	(339)	94.5	98.1	96.2	90.5	94.7	97.7	95.2	95.1
Stizostedion lucioperca	11.14	(41)	7.0	8.5	1.5	8.4	4.9	6.7	8.3	
Gymnocephalus cernua	41.03	(151)	75.1	63.6	60.7	65.4	64.7	60.3	48.0	2.9
Cottus gobio	4.35	(16)	0.4						2.8	

[1]Лесненко, Абросов, 1973; [2]Покровский & Сорокин, 1980; [3]Озера Карелии, 1959; [4]Жаков, 1989; [5]Котов et al., 1958; [6]Вирбицкас, 1988; [7]Sumari, 1971; Pärjälä, 1985; Rask & Tuunainen, 1990; Tonn et al., 1990 (almost all small lakes and ponds); [8]Alm, 1960 (Kälarne lake group — comparatively small lakes, up to 875 ha).

Table 3

Basic numerical characteristics of the lakes studied

Occurrence of fish species	Number of lakes		Area, ha*	Maximum depth, m	Water transparency in summer, m**	pH of the surface water in summer	Dichromate oxygen consumption, mg $O \cdot l^{-1}$	Prospective catch of fish, $kg \cdot ha^{-1} \cdot yr^{-1}$
All the lakes	368	mean	48.05	7.58	1.84	7.65	37.36	15.77
		min.	2.00	0.50	0.30	4.00	7.00	3.00
		max.	985.00	38.00	6.00	10.40	157.00	30.00
Pike occurs	339		50.94	7.68	1.88	7.67	36.55	16.32
is the single fish	3		38.30	4.97	1.30	5.43	60.00	4.33
is lacking	29		14.56	6.42	1.42	7.40	47.27	9.62
Perch occurs	339		51.05	7.81	1.90	7.67	36.64	16.27
is the single fish	4		10.97	6.50	2.32	5.53	61.00	8.75
is lacking	29		13.24	4.88	1.17	7.65	46.23	9.86
Roach occurs	305		53.63	7.97	1.92	7.87	34.90	17.00
is lacking	63		21.27	5.69	1.50	6.60	49.20	9.81
Crucian carp occurs	246		58.38	7.11	1.78	7.85	37.43	16.07
is the single fish	9		15.20	4.88	1.22	7.29	41.44	10.67
is lacking	122		27.47	8.56	1.98	7.23	37.23	15.16
Tench occurs	219		65.03	7.90	1.92	7.97	33.97	17.60
is lacking	149		23.43	7.09	1.73	7.18	42.35	13.07
Bream occurs	173		68.76	9.56	1.89	7.95	33.06	18.67
is lacking	195		29.39	5.77	1.80	7.45	41.31	13.19
Pike-perch occurs	41		91.99	9.44	1.59	8.08	33.00	20.61
is lacking	327		42.94	7.34	1.88	7.61	37.95	15.16

···· $P<0.05$; −−− $P<0.01$; —— $P<0.001$

* Without our large lakes (L. Peipus, L. Võrtsjärv, Narva Reservoir).

** The depth of the disappearance of the Secchi disk.

Table 4

Occurrence of fish species in different lakes, % of the total number of lakes studied

Occurrence of fish species	Number of lakes	Lake types								Unfavourable qualities				Unfavourable phenomena			
										Closed lakes		Through-flowing lakes			Pollution		
		Eutrophicated oligotrophic	Semidystrophic	Dystrophic	Dyseutrophic	Eutrophic	Hypertrophic	Halotrophic	Alkalitrophic	Forest and bog lakes	Others	Forest and bog lakes	Coastal lakes	Winter anoxia	Flax retting	Other	Lowering of the water level
All the lakes	368	6	5	7	24	42	12	3	1	13	10	27	4	28	10	12	11
Pike occurs	339	6	5	6	24	43	11	4	1	12	9	28	4	27	9	11	11
is the single fish	3			100						33		67		33	33		100
is lacking	29	10		21	21	24	21		3	35	17	28	3	45	21	17	
Perch occurs	339	6	5	6	23	45	11	3	1	12	9	28	4	26	9	12	11
is the single fish	4	25		75						50		50		25			25
is lacking	29	10		17	28	17	25	3		35	24	21	7	52	21	14	7
Roach occurs	305	5	5	2	23	48	13	3	1	15	10	25	4	27	10	13	12
is lacking	63	13	5	33	27	11	6	5		37	10	37	5	35	13	3	6
Crucian carp occurs	246	5	5	3	26	44	13	3	1	13	12	25	5	36	11	14	10
is the single fish	9	23		11	33	22	11			56	11	22		67	11	11	11
is lacking	122	7	6	16	19	37	10	3	2	15	5	31	3	11	8	7	13
Tench occurs	219	5	5	1	19	51	14	4	1	10	11	20	4	26	10	15	11
is lacking	149	8	5	17	30	26	9	3	2	19	8	38	5	31	11	7	11
Bream occurs	173	4	4	2	14	57	18	1		4	5	14		16	12	15	8
is lacking	195	8	6	12	31	28	7	6	2	22	14	38	8	39	10	9	14
Pike-perch occurs	41				5	66	29				2	5		7	7	22	10
is lacking	327	7	5	8	26	39	10	4	1	15	11	30	5	31	11	10	11

DISCUSSION AND CONCLUSIONS

Table 2 shows that perch, pike, and roach are the most common fishes in the lakes of Estonia as well as North-West Russia, Latvia, Lithuania, Finland, and the Kälarne lake group of Sweden (550—600 km north-west of Estonia). These fish species are unpretentious and resistant to several unfavourable living conditions, particularly to poor oxygen content (Алабастер & Ллойд, 1984). Perch and pike are also very tolerant to low pH (Rask, 1983; Rask & Tuunainen, 1990; Toivonen, 1991) and to high content of organic matter. Besides, in comparison with other fish species, perch has an important advantage: it can spawn in muddy forest or bog lakes where normal spawning grounds are lacking.

The next triplet of fish species in the lakes of Estonia and Lithuania consists of very common and well-known cyprinids, first of all essential food fishes bream and tench. In the neighbouring areas they are partially substituted for by ruff and burbot. The pretentious cold-water fishes, whitefish and vendace, occur quite rarely in the Baltic countries and the adjacent provinces of Russia; as expected they are more frequent further in the north (Karelia, Finland, and Sweden).

Thanks to numerous attempts at transplantation, pike-perch is distributed more widely in Estonia than in neighbouring regions.

Almost all the fish species under study prefer larger and deeper lakes, where they can choose suitable biotopes, food, and spawning grounds more easily. These lakes have a tendency toward eutrophication, their DOC is comparatively low, and FP quite high. Among them there are relatively few forest or bog closed lakes as well as lakes suffering from WA. Crucian carp is an exception in many respects: it prefers shallower lakes and is rather indifferent to DOC and WA. Therefore it does not avoid forest or bog closed lakes. As we know, crucian carp is well adapted for surviving WA (Алабастер & Ллойд, 1984; Holopainen & Hyvärinen, 1985).

Besides crucian carp, pike and perch are quite unpretentious fishes, too. In our conditions they are able, by way of exception, to live and spawn successfully as a single fish species in such forest and bog lakes where other fishes are lacking.

ACKNOWLEDGEMENTS

I thank my colleagues, especially Aare Mäemets, Toomas Saat, and Evald Ojaveer for valuable comments on the manuscript. The English text was kindly checked by Ester Jaigma.

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