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RESEARCH ARTICLE

Patterns of river lamprey size and sex ratio in the Baltic Sea basin

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Abstract. A comparative study of the size distribution of river lamprey, *Lampetra fluviatilis* (L.), was conducted in several rivers in the Baltic Sea basin. Total length and weight data were collected from 7503 lamprey individuals. Sex ratio distributions were also examined in some of the river lamprey populations. The length of lamprey varied from 20.0 to 51.0 cm. The smallest lamprey were in Finland, where mean length in different rivers ranged from 27.9 to 30.8 cm. Larger individuals were noted in Latvia, with mean lengths from 34.0 to 39.5 cm, and in Lithuania from 33.5 to 36.4 cm. The largest lamprey were in Poland, where mean length was from 38.3 to 42.9 cm. The heaviest lamprey were noted in Poland with mean body weights from 45 to 230 g, while slighter individuals were noted in Finland with mean body weights from 12 to 90 g. The body length and weight ranges indicate regional variation. The smallest lamprey individuals were noted in the populations in the rivers of the northern region of the Baltic Sea basin. The analysis of the sex ratio distribution indicated that in most rivers populations of river lamprey males slightly outnumbered females.

Keywords: Baltic Sea, endangered, *Lampetra fluviatilis*, migration, spring and autumn runs

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Introduction

Populations of anadromous lamprey have declined dramatically throughout Europe over the last 30 years mainly because of industrial and agricultural water pollution, stream regulation and damming, the construction of harbors, weirs and other artificial barriers in rivers, and land-management practices that lead to increased siltation on spawning gravels (Kelly and King 2001, Thiel et al. 2009). River

lamprey, *Lampetra fluviatilis* (L.), has become rare in the majority of its distribution area, and implementing conservation regulations is essential. This species is endangered in Europe, and European states are required by law to implement measures to ensure its protection (Witkowski 2010).

The river lamprey is distributed widely in Europe. It occurs in the coastal waters and rivers of the northwestern Mediterranean Sea, along the European Atlantic coast, the North Sea, and throughout the Baltic Sea. Freshwater resident populations are known in Loch Lomond (Scotland), Lake Mjosa (Norway), several Finnish lakes, and the basins of lakes Ladoga and Onega (Russia) (Hardisty 1986, Maitland 2003, Kottelat and Freyhof 2007). River lamprey occurs in the Baltic Sea and in many rivers flowing into this sea (Hardisty 1986). This species is present in numerous rivers of Sweden (Sjöberg 1980) and Finland (Kanua and Valtonen 1980, Tuunainen et al. 1980), in Russian rivers flowing into the Gulf of Finland (Berg 1948, Abakumov 1956, Iwanowa-Berg 1966), Estonia (Berg 1948), and in the rivers of Latvia (Abakumov 1956, Ryapolova 1972), Lithuania (Gaigalas and Matskevichus 1968), Poland (Jokiel 1983, Witkowski 1992, 2010, Bartel 1993), and Germany (Thiel et al. 2009).

The river lamprey is an important source of income for many fishermen in the southern Baltic Sea (Thiel et al. 2009, Kesminas and Švagždys 2010) and in Finland (Tuunainen et al. 1980, Ojutkangas et al. 1995). Historically, commercial river lamprey fisheries operated in British rivers (Giles 1994). Seasonal river lamprey catches in the southern Baltic Sea are at maximum values in autumn (Thiel et al. 2009).

Anadromic migrations (from the sea to rivers) take place in autumn and spring, and there are two strains of river lamprey – those that run in the autumn/winter and those that run in the spring (Berg 1948). The size of river lamprey varies, depending on the fishing site, but according to the findings of Gaigalas and Matskevichu (1968), which were based on their own data and those from the their bibliography, the size of river lamprey increases from the north towards the southwest.

An attempt was made to designate the size of river lamprey ascending Finnish, Latvian, Lithuanian, and Polish rivers to spawn, and to determine the differences in length and weight distributions of this species.

Materials and Methods

Data on the length and weight characteristics of river lamprey were derived from published works (Bartel et al. 1993, Witkowski and Kuszewski 1995) or in some cases were completed through direct communication with the authors of the studies. The current study was based on material collected from spring and autumn catches in 17 rivers and at three brackish water sites

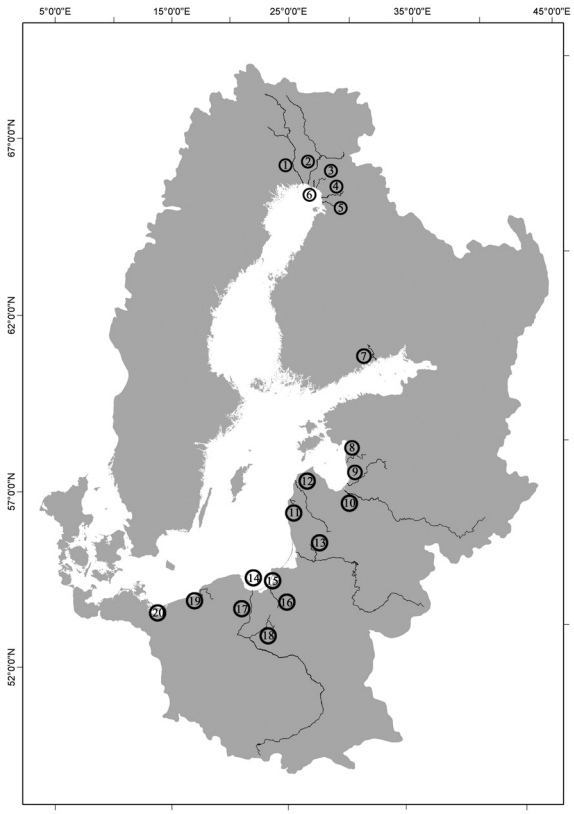

Figure 1. Locations of river lamprey collection sites in 1992-1993. 1 – Torne River, 2 – Kemijoki River, 3 – Simojoki River, 4 – Iijoki River, 5 – Kiiminkijoki River, 6 – Viantienjoki River, 7 – Kymijoki River, 8 – Salaca River, 9 – Gauja River, 10 – Daugava River, 11 – Saka River, 12 – Venta River, 13 – Jura River, 14 – Gdańsk Bay, 15 – Vistula Lagoon, 16 – Pasłęka River, 17 – Vistula River, 18 – Drwęca River, 19 – Grabowa River, 20 – Szczecin Lagoon.

Table 1
Summary statistics for total length, total weight, and sex ratio of river lamprey

								Length (cm)				Weight (g)				
Country	Region	Place	Latitude	Longitude	Year	Time of year	N	Mean	Min	Max	SD	Mean	Min	Max	SD	Sex ratio
Finland	Bothnian Bay	Torne	65.50	24.09	1992	autumn	105	29.2	23.7	33.9	2.089	39.4	19	70	9.68	
		Kemijoki	65.46	24.27	1992	autumn	103	28.8	23.1	33.7	2.013	45.1	21	87	10.70	
		Simojoki	65.37	25.02	1992	autumn	114	28.3	23.0	33.8	1.988	42.3	20	78	9.87	
		Iijoki	65.19	25.21	1992	autumn	101	27.9	20.1	35.0	2.499	36.5	13	75	11.29	
		Kiiminkijoki	65.11	25.18	1992	autumn	103	28.4	20.0	35.9	2.786	37.5	12	87	13.29	
		Viantienjoki	65.39	24.53	1992	autumn	105	27.9	22.8	33.4	2.118	35.3	18	75	10.05	
	Gulf of Finland	Kymijoki	60.31	26.52	1992	autumn	304	30.8	20.6	39.6	2.475	55.6	24	90	12.42	
Latvia	Riga Bay	Salaca	57.45	24.21	1990	autumn	772	34.0				82.0				1.04:1
		Salaca	57.45	24.21	1991	autumn	700	34.9				88.4				0.72:1
		Guaja	57.09	24.15	1990	autumn	550	36.2				90.0				1.12:1
		Guaja	57.09	24.15	1991	autumn	710	36.1				87.0				1.07:1
		Daugava	57.03	24.01	1990	autumn	176	37.0				93.0				1:1
		Daugava	57.03	24.01	1991	autumn	60	36.9				95.5				1.28:1
	Baltic Sea	Saka	56.53	21.10	1990	autumn	200	38.0				108.7				1.38:1
		Saka	56.53	21.10	1991	autumn	300	38.0				107.6				1.17:1
		Venta	57.23	21.32	1990	autumn	150	38.1				112.0				1.17:1
		Venta	57.23	21.32	1991	autumn	200	39.5				116.8				1.33:1
Lithuania	Curonian Lagoon	Jura	55.02	22.08	1992	spring	30	33.5	31	40	2.01	90.4	68	120	17.65	2.33:1
		Jura	55.02	22.08	1993	autumn	28	36.4	32	41	2.22	94.9	50	135	19.68	3.13:1
Poland	Gdańsk Bay	Gdańsk Bay	54.29	18.59	1992	autumn	63	40.4	34	47	2.77	149.6	82	206	27.55	1.10:1
		Vistula	54.21	18.57	1992	autumn	116	40.8	34	46	2.72	126.2				1.47:1
		Vistula	54.21	18.57	1993	spring	44	38.3	32	45	2.99	115.2				1.31:1
		Drwęca	52.59	18.41	1992	spring	126	39.4	34	47	2.49	112.0	68	191	22.70	1.06:1
		Drwęca	52.59	18.41	1992	spring	38	39.8	35	44	2.03					
		Drwęca	52.59	18.41	1992	autumn	37	42.0	36	46	2.15	139.8	110	194	21.11	1.65:1
		Drwęca	52.59	18.41	1992	autumn	89	40.7	35	48	2.22	117.4				1.34:1
	Vistula Lagoon	Vistula Lagoon	54.23	19.38	1992	autumn	1657	40.3	30	48	2.49	130.4	60	210	25.91	0.99:1
		Pasłęka	54.25	19.45	1992	autumn	439	36.9	30	47	2.69	103.2	60	210	22.31	1.53:1
	Baltic Sea	Grabowa	54.26	16.23	1992	autumn	95	39.2	30	47	2.84	115.3	45	230	27.14	1.16:1
		Grabowa	54.26	16.23	1992	autumn	389	40.2	29	49	2.30	109.2				1.36:1
		Szczecin Lagoon	53.47	14.26	1992	autumn	309	42.9	35	51	2.72	133.5				0.56:1

(Fig. 1). Lamprey sampling sites were located in the southern, eastern, and northern regions of the Baltic Sea basin. The geographic location of the sampling sites lay between 52.59 and 65.50°N and 14.26 and 26.52°E (Table 1). The lamprey were caught during spawning migrations, and the selectivity of the fishing gear probably did not impact the size of the fish in the samples analyzed. The length of all the river lamprey was measured to the nearest cm, while a portion of the samples were weighed to the nearest g, and the mean weight of the rest of the sample was determined based on the weight of the whole sample.

Pattern recognition was performed with agglomerative hierarchical cluster analysis using the Statistica 9 (StatSoft Inc., Tulsa, OK, USA) procedure with the Ward's method of distance calculation. Euclidean distance was used as the measure of distance, which permitted categorizing the rivers based on lamprey length into sensible structures known as guilds. For cluster analysis, three variables measured at 15 sites (mean, minimum, maximum length) were analyzed. Spring and autumn data were analyzed separately. Spearman's rank correlation was used to detect relationships between mean total length and sampling site locations.

Results

Size distribution

Finland

All the individuals examined were caught in autumn. The size of river lamprey in seven Finish rivers ranged from 20.0 to 39.6 cm, while weight varied from 12 to 90 g (Table 1). The largest individuals were caught in the Kymijoki River, which flows into the Gulf of Finland. The smallest values of mean length, from 27.9 to 28.4 cm, and weight, from 35.3 to 37.5 g, were observed in the Iijoki River, the Viantienjoki River, and the Kiiminkijoki River. The latter individuals were 2.4 and 2.9 cm, thus 7.8 and 9.4%, shorter than individuals of mean length from the Kymijoki River (Fig. 2). The differences in weight values were from 18.1 to 20.3 g (Fig. 3). The mean weights of river lamprey from the latter three rivers

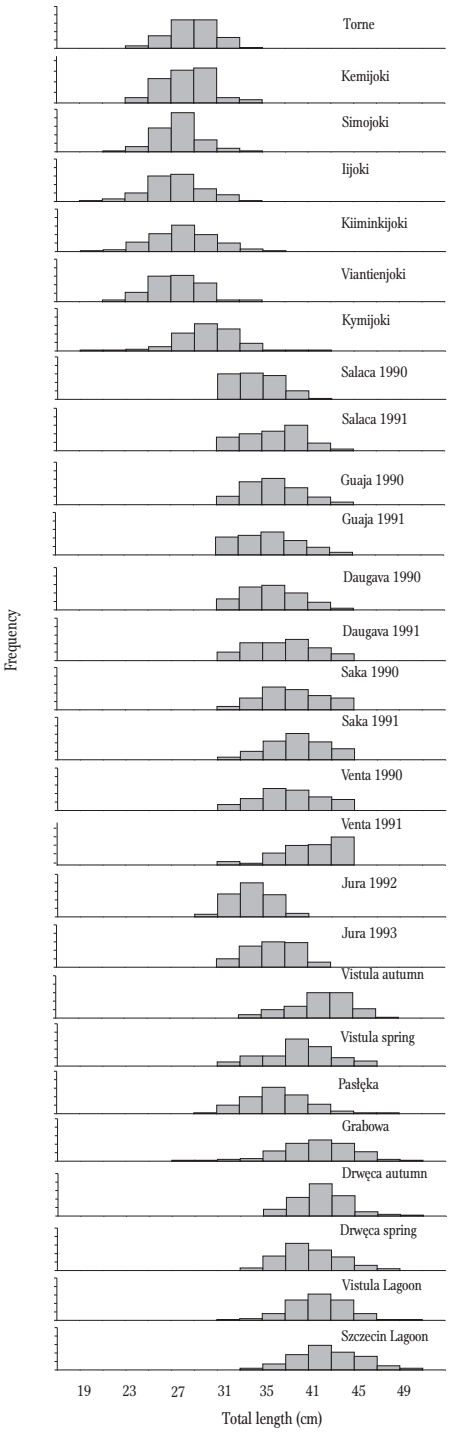

Figure 2. Length frequency distribution of river lamprey in 1990-1993 in investigated rivers.

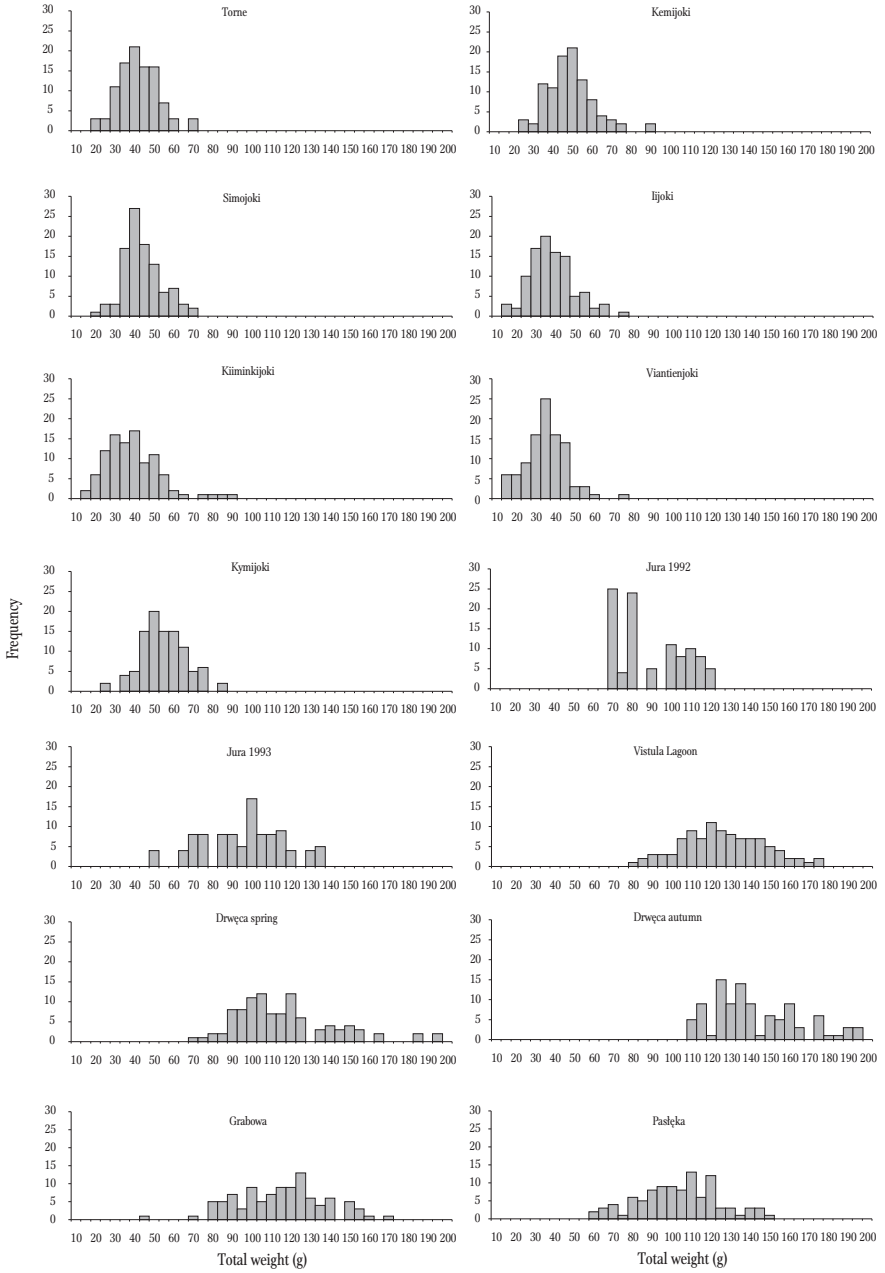

Figure 3. Weight frequency distribution of river lamprey in 1990-1993 in investigated rivers.

were from 63.5 to 67.4% of the mean weight of this species caught in the Kymijoki River.

Individuals from the Simojoki, Kemijoki, and Torne rivers were larger (Fig. 2), with mean lengths that ranged from 28.3 to 29.2 cm and mean weights from 39.4 to 45.1 g (Table 1). Thus, they were 1.6 to 2.5 cm shorter and 10.5 to 16.2 g slighter than the mean-sized fish from the Kymijoki River. The mean length values of river lamprey from the Kymijoki River were higher than those of this species from six rivers flowing into the Bothnian Bay.

Latvia

The mean length of river lamprey from Latvian rivers flowing into Riga Bay ranged from 34.0 to 37.0 cm (Table 1). Of the three populations

investigated, the smallest individuals were observed in the Salaca River, and their mean values were 34.0 to 34.9 cm and 82 to 88.4 g (Table 1); however they were longer by 3.2 to 4.1 cm and heavier by 26.4 to 32.8 g than individuals from the Kymijoki River. When expressed in percentages, these fish were 110.4 to 113.3% of the length and 147.5 to 159% of the weight of the river lamprey from the Kymijoki River.

The river lamprey populations from the Gauja and Daugava rivers were larger than those from the Salaca River. Their mean length was from 36.1 to 37.0 cm, and mean weight was from 87.0 to 95.5 g (Table 1). The mean length of river lamprey from the Gauja and Daugava rivers was greater than that of individuals from the Salaca River. The differences in weights were not as distinct (Table 1). Even greater mean lengths were observed in the river lamprey from the Saka and Venta rivers that flow into the main basin of the Baltic Sea. Some differences in mean weights and lengths were observed among these populations (Table 1), and the mean lengths and mean weights of river lamprey caught in particular rivers in 1990 and 1991 fluctuated insignificantly.

Lithuania

The individuals examined were caught in spring in the Jura River during spawning. The mean length of individuals caught in 1992 and 1993 was 33.5 and 36.4 cm. Lamprey in the length range of 35-39 cm were caught most frequently (Fig. 2), and the mean body weights were 90.4 and 94.9 g, respectively (Table 1).

Poland

The length of river lamprey caught from Polish populations ranged from 29 to 51 cm and the weight values fluctuated from 45 to 230 g. The length of individuals caught at depths from 20 to 70 m in Gdańsk Bay near Krynica Morska were from 34 to 47 cm, at a mean length of 40.4 cm, and the weights of these fish ranged from 82 to 206 g, at a mean of 149.6 g (Table 1). Individuals from the 38-41 cm length range (Fig. 2) and the 146-150 g weight range (Fig. 3) dominated the material examined. The river lamprey caught in the Vistula Lagoon were of a similar size. The mean sizes of this species caught in autumn in the Pasłęka River were distinctly smaller than those of individuals caught in the Vistula Lagoon and were the lowest noted among the material collected in Poland in 1992 and 1993. Although the length and weight ranges were similar (Table 1), the river lamprey from the Pasłęka River were dominated by individuals from smaller length and weight classes than the fish from the Vistula Lagoon (Fig. 3). The largest individuals were noted in the Szczecin Lagoon in the length range of 35-51 cm at a mean length of 42.9 cm. However, at a mean weight of 133.5 g, these individuals were somewhat slighter than the fish caught in Gdańsk Bay (Table 1).

The river lamprey caught in the Vistula and Drwęca rivers in autumn 1992 were longer and heavier than the individuals caught in spring at the same sites. The mean length of 40.8 cm in autumn 1992 was 2.5 cm, or 6.1%, less in spring 1993. The minimum and maximum sizes of the fish were also lower in spring 1993 (Table 1).

Rivers comparison

The river lamprey examined exhibited significant size trends with latitude and longitude, and the mean size of these fish decreased significantly with latitude ($r = -0.914$, $P < 0.001$, $N = 23$) (Fig. 4). The results indicate that mean total length is also negatively

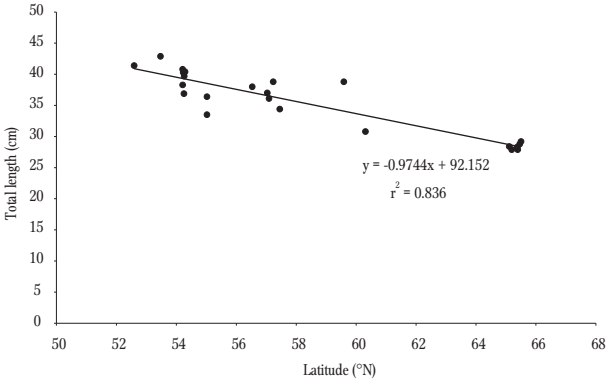

Figure 4. Relationship between mean total length and latitude.

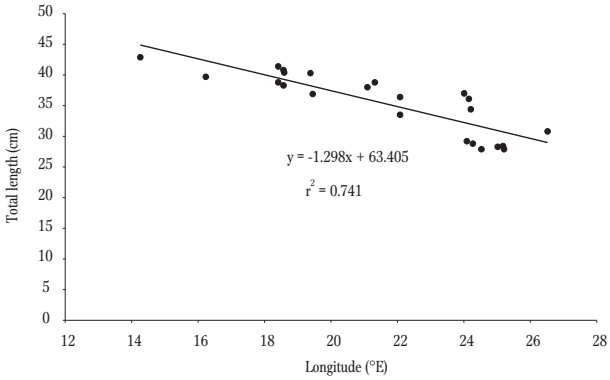

Figure 5. Relationship between mean total length and longitude.

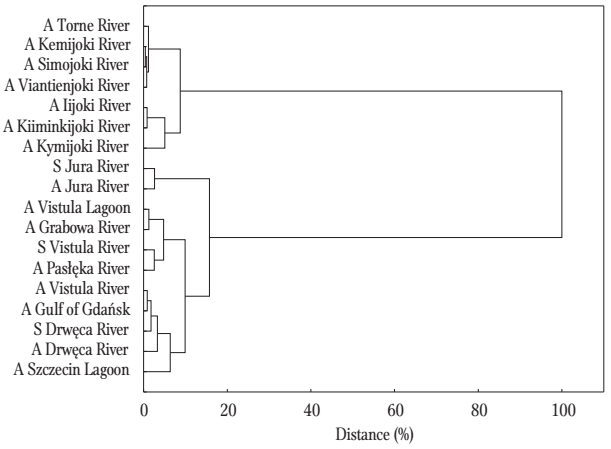

Figure 6. Cluster diagram of Euclidean distances based on river lamprey length. S – spring, A – autumn.

correlated with longitude ($r = -0.861$, $P < 0.001$, $N = 23$) (Fig. 5). The rivers analyzed were divided into two clusters (Fig. 6). The first cluster can be described as consisting of northern rivers in which lamprey mean body lengths were lower. This cluster includes seven Finnish rivers in which lamprey length is significantly lower; six of them flow into the northern part of the Bothnian Bay and one flows into the Gulf of Finland. Generally, cluster 2 includes the southern Baltic Sea lamprey populations which had a higher mean body length. Spring and autumn data from the Jura River were divided into separate branches of this cluster.

Sex ratio

The sex ratio in all the analyzed rivers ranged from 0.56:1 to 3.13:1 (Table 1). The populations in five Latvian rivers were dominated slightly by males, while the share of females ranged from 42 to 58%. Males dominated the Jura River populations in both years, with the share of females ranging from 25 to 30% (3.13:1 and 2.31:1, respectively). The females were slightly larger than the males. The mean length and mean weight values of the females were 34.7 and 36.9 cm and 89 and 103.6 g, while those of the males were 34.5 and 36.1 cm and and 91.8 g in 1992 and 1993, respectively. The share of males in the populations examined in Poland was slightly higher, with the exception of the Vistula Lagoon where the sex ratio was 1:1. The Szczecin Lagoon was exceptional in that females dominated. The share of females in the material from the populations at the remaining sites ranged from 39.6 to 48.6%. The females were larger than the males in all the populations examined in both spring and autumn. The mean weight of the females fluctuated from 111.4 to 151.9 g and the mean length from 37.4 to 42 cm in the Pasłęka and Drwęca rivers, respectively. The mean length of the males ranged from 36.5 cm in the Pasłęka River to 40.5 cm in the Drwęca River and the mean weight ranged from from 97.8 to 132.5 g in these rivers, respectively. Differences in length and weight between males and females ranged from 0.9 to 2.9 cm and from 15.5 to 25.6 g, respectively.

Discussion

There are few characterizations of the size, weight, and population parameters of river lamprey inhabiting the Baltic Sea, and little attention has been focused on body weight and length variations linked to geographic distribution. River lamprey vary substantially in size, both within neighboring river systems and among different regions of a given area (Hardisty 1986). The dimensions of lamprey body size increased with increasing salinity gradients, which extend southwesterly in the Baltic Sea (Gaigalas and Matskevichus 1968). The river lamprey from the rivers sampled exhibited considerable size differentiation ranging from 200 to 500 mm, which was larger

than that reported by Hardisty and Potter (1971) (from 250 to 500 mm).

River lamprey from the northern part of the Bothnian Bay are the smallest ones in the Baltic Sea catchment basin and differ considerably in length and weight from individuals from other Baltic populations. Their length range is similar to that of river lamprey from Ladoga Lake (Berg 1948). River lamprey from the Kymijoki River that ranged in length from 206 to 396 mm were similar in size to those from the Neva River (Ivanowa-Berg 1966).

The river lamprey from the rivers flowing into Riga Bay were distinctly larger than individuals from the Gulf of Finland and smaller in length and weight than those from the Saka and Venta rivers. In the subsequent year of the study no significant differences in the mean length or weight of this species were noted. Similarly, no significant differences in the mean length or weight were observed in river lamprey from the Daugava River in previous study (Ryapolova 1972). However, the mean length and weight reported in the latter publication were distinctly lower than those observed in the Daugava River in 1990-1991. Similarly, the mean length (36.2 cm and 36.1 cm) and weight (90.0 g and 87.0 g) were considerably higher than those obtained earlier for females (mean length 31.8 cm, mean weight 58.0 g) and males (mean length 30.7 cm, mean weight 52.0 g) (Eglite 1962 after Gaigalas and Matskevichus 1968). The current size data for river lamprey from the Jura River, a tributary of the Neman River, were obtained from individuals caught in Lithuanian rivers, and the values were lower than those for river lamprey from the Neman River reported in an earlier study (Gaigalas and Mitskevichus 1968).

The largest river lampreys were observed in Polish rivers, and the largest among them were noted in the Szczecin Lagoon. The size of river lamprey was larger in the rivers of the southern region of the Baltic Sea. This finding is similar to an earlier report by Gaigalas and Matskevichus (1968). River lampreys were caught in the spring and autumn in the Vistula and Drwęca rivers. The individuals caught in autumn were larger than those caught in spring, and the difference in mean length of fish caught in the Vistula River in autumn was 2.5 cm, or 6.1%. Berg (1948) reported a similar phenomenon of size decrease in spring in comparison with that in autumn in the Neva River, where individuals caught in spring were 10% shorter those caught in autumn. Even more distinct size decreases in spring of 18% for males and 24% for females were reported by Ivanova-Berg (after Gaigalas and Matskevichus 1968). The study by Gaigalas and Mitskevichus in the Esya River, a tributary of the Neman River, led to a similar conclusion; size decreased by 18.8% in the months of April and May. These size decreases are probably because of weight loss that occurs when the fish overwinter in the lower courses of rivers and in the sea (Sjöberg 1980). However, the different phase of sexual development that the fish are in during this period might also account for these differences (Witkowski and Kuszewski 1995).

There are some indications that different populations exhibit slight differences in sex ratio. Males outnumber females in the majority of rivers. The lowest sex ratio was 0.56:1 in the Szczecin Lagoon, and the highest was in the Curonian Lagoon at 3.13:1. Average sex ratios in Latvia and Poland were1.13:1 and 1.23:1, respectively. The sex ratios from Latvian and Polish rivers were quite similar to those noted by Potter (1979) from the Teme River 1.20:1, but Potter (1979) noted ratios of 1.06:1 and 1.6:1 in other rivers. The average share of males to females was 2.73:1 in Lithuanian waters; it is likely that imprecise sex recognition contributed to this ratio. On the other hand, many authors suggest that the share of males increases during the later periods of spawning runs in spring.

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Streszczenie

Wzorce rozmiarów ciała i proporcji płci u minoga rzecznego w zlewni Morza Bałtyckiego

Celem pracy było poznanie wzorca rozkładu wielkości minogów rzecznych *Lampetra fluviatilis* (L.) w kontekście z ich rozmieszczeniem w basenie Morza Bałtyckiego. Zebrano dane o długości całkowitej oraz masie 7503 osobników. Dodatkowo oszacowano stosunek płci u minogów rzecznych z wiosennego ciągu tarłowego. Długość oraz masa ciała minogów analizowanych populacji wykazywały regionalne zróżnicowanie. Najkrótsze osobniki tego gatunku występowały w Finlandii, średnia długość z różnych rzek zawierał się w granicach od 20,0 do 39,6 cm. Większe osobniki poławiano na Łotwie (średnia długość 34,0-39,5 cm) oraz na Litwie (średnia długość 33,5-36,4 cm). W Polsce występowały największe minogi, o średniej długości od 38,3 do 42,9 cm. Minogi rzeczne o największej średniej masie ciała od 45 do 230 g występował w Polsce natomiast najlżejsze osobniki o średniej masie od 12 do 90 g były notowane w Finlandii. Generalnie osobniki populacji z północnej części Bałtyku były mniejsze od przedstawicieli z południowego Bałtyku. Analiza rozkładu stosunku płci minogów rzecznych w większości przypadków ukazała dominację w populacji samców nad samicami.