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Contents

Protective sieves as a method to reduce by-catch in fyke-net eel fishery of the Vistula Lagoon

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Abstract. Three species (eel, pike-perch and bream) support the Vistula Lagoon fishery. The most prized of these is eel, which is fished with fyke-nets. The allowable minimum mesh-size for the cod-end of the net is 16 mm (bar length). This mesh size does not permit young pike-perch and bream to pass through. Depending on the place and way in which the fyke-nets are anchored and the meshes in the cod-end stretched, a considerable number of young fish are retained by the meshes. Their survival depends on many factors, the two most important of which are the time that elapses between retention and release and how the fish are manipulated by the fishermen prior to release. To prevent the premature fishing mortality of these valuable fish, fishermen fit metal sieves into the fyke-net cod-ends that permit the young fish to escape. This paper presents the results of studies on how well young pike-perch and bream escape in relation to sieve hole diameter and fish size. The examined length frequency of pike-perch and bream retained in fyke-nets covered with 6 mm mesh size netting provided the materials for assessing the number of fish that entered the net and managed to escape from it through the sieves. This paper presents the analysis of results obtained with three sieves of various hole size (18×30, 22×36, 20×65 mm).

Key words: eel fyke-net fishery, protective sieves, by-catch.

INTRODUCTION

In fishery that uses the "bag" type of gear, the evaluation of the fit of net mesh size to the size of the fish that should be able to escape is based on, among other factors, the proportion of the quantity of fish passing through the meshes to that of fish in subsequent length classes that were caught in the net (Gulland 1983). It would be ideal if every single undersized fish passed through the net meshes, and if all the fish of legal size were retained. In this case, the gear would have knife-edge selection (Beverton and Holt 1957). The curve reflecting the proportion of retained fish to the length of fish that entered the net, from which the selection ogive could be derived, would be close to a vertical line. Although it is difficult to imagine a real situation in which this type of curve would reflect the impact of the fishing gear on a given fish population, it is often applied in works focused on the effect changes in the age at first capture have on the yield of an exploited population (Gayanilo *et al.* 1997). Most catches will contain fish that are not the target of the fishing regardless of net type, be it hauled, trap, or entangling. These fish are referred to as the by-catch. Generally, most of the by-catch is worthless to the fisherman for either economic or legal reasons (protective regulations). However, some of the by-catch can be of value to the fisherman and is retained for sale or for personal consumption; this is known as the incidental catch. The remainder of the by-catch is dumped back into the water and is known as the discards. According to Cook (2003), the by-catch is comprised of the discards and the incidental catch. The concept of by-catch has not been unequivocally defined, and experts from different countries might interpret this concept variously.

The increase in the global fishing effort has drawn the attention of the environmental protection lobby to the issue of the useless waste of large numbers of aquatic animals and juvenile fishes, especially in shrimp fishery. In order to limit the fishing mortality of these animals, trawls for shrimp were equipped with elements that size-segregate animals. This allowed the untargeted animals to escape (Broadhurst *et al.* 2003, Graham 2002). The magnitude of by-catch reduction depends on the construction of the device and on the species of animals that comprise the by-catch; this figure can reach 90% (Broadhurst and Kennelly 1996). Fishery losses caused by such devices do not exceed 12% (Revill and Holst 2004).

Much less focus has been placed on reducing the by-catch in fisheries that use trap gear. Some of the possible or believed reasons for this follow:

– animals caught in traps are in far less danger of mechanical damage and following selection by the fisherman will be released and stand a good chance of survival;
– although increasing mesh size in traps reduces the quantity of by-catch, this also dramatically reduces the quantity of the fish caught (Olsen *et al.* 1978).

Eel fishery with fyke-nets is the most profitable in the Vistula and Szczecin lagoons although these eels (*Anguilla anguilla*) are smaller compared with those caught in lakes (Borowski and Dąbrowski 1997, Świerzowski and Dębiński 1978). Thus, the problem of protecting juvenile pike-perch (*Sander lucioperca*) and bream (*Abramis brama*) is the opposite from that in shrimp fishery. The shape of the eel permits it to slip more easily than other fish through meshes. The current, legal minimum mesh size for fyke-net cod-ends is 16 mm. In order to maximize their income, fishermen try to minimize the mesh size in the fyke-nets used to catch eel. This increases the quantity of the by-catch of undersized fishes such as pike-perch, bream and perch (*Perca fluviatilis*) that have high commercial value as adults.

In the August to October period the fry of these fish enter fyke-nets in large numbers and are retained (some meshed) in the cod-ends. As the young fish are sensitive to higher temperature, low oxygen content, and manipulation during net lifting and cod-end emptying, a large portion of those caught in the cod-end die before being released by fishermen (Borowski and Dąbrowski, 1996). This leads to the increased mortality of this fish group and reduces the number of survivors recruited to the populations that will support the fishery in forthcoming years.

Eel fishermen in the Szczecin Lagoon began to reduce undesirable by-catch in 1983 by mounting perforated metallic or plastic sheets in the trap cod-end. The oval openings in the sheets should enable young fish to escape and reduce the work required to clear the gear of entangled young fish. Figure 1 illustrates the construction and operating principle of the sieves installed in the eel fyke-nets.

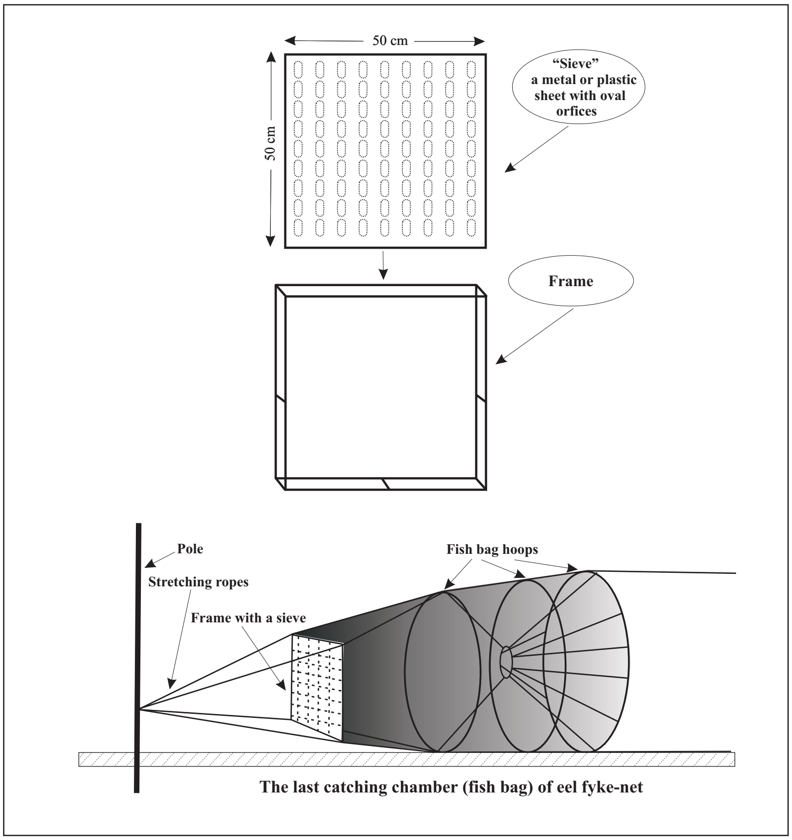

Fig. 1. Construction and operating principle of protective sieves mounted experimentally in fish bags in eel fyke-nets used in the Szczecin and Vistula lagoons.

Wysokiński and Garbacik-Wesołowska (1995) evaluated the effectivity of the sieves used in eel fyke-nets to reduce the by-catch of pike-perch fry in the Szczecin Lagoon. According to these authors, a sieve with 18×30 mm openings reduced the quantity of the pike-perch fry caught (fish smaller than 23 cm in length) to 1/10.

The aim of the current study was to evaluate the proportion of young pike-perch and bream that escape from fyke-nets fitted with protective sieves in the Vistula Lagoon. These devices should lead to a higher proportion of young pike-perch and bream escaping as compared with traditional fyke-nets. The impact on the eel fishery is discussed.

MATERIALS AND METHODS

Experiments with sieves mounted into fyke-net fish bags with a small mesh cover were carried out in the Vistula Lagoon in 1997 and 1999 from April to October. The last chamber of the fyke-nets fitted with protective sieves was covered with 6 mm netting material. This permitted the authors to assume that all the fish entering the net were retained. In total 46 measurements of samples of pike-perch and bream retained in fyke-nets with fitted sieves were analyzed. Three sieve types with various opening sizes were used: 18×30; 22×36; 20×65 mm (width×height). In total 5515 pike-perch ranging in length from 4 to 45 cm (minimum legal size) and 3185 bream ranging in length from 4 to 34 (minimum legal size) were measured. The longest length at which fish passed through the sieves and were retained in the "second" fish bag made of small mesh was designated as the upper fish length limit for evaluating the impact of the sieve on young fish retention.

Selectivity curves were determined using the following formulae:

$$S_l = \frac{1}{1+\exp(S_1 - S_2 \cdot L)}$$

$$L_{50\%} = S_1/S_2$$
$$S_1 = L_{50\%} \cdot \ln 3/(L_{75\%} - L_{50\%})$$
$$S_2 = \ln 3/(L_{75\%} - L_{50\%})$$

where:

S_i – probability of fish retention at length L;

$L_{50\%}$, $L_{75\%}$ is the fish length at which there is a 50% and 75% probability that they are retained (Paloheimo and Cadima 1964, Spare *et al.* 1989).

RESULTS

Pike-perch

The sieves had an impact on pike-perch measuring from 4 to 21 cm (the upper size limit of the fish that passed through the openings). The length of the fish considered ranged from 6 to 22 cm. The size of the fish varied over time. Sieve selectivity had no effect on fish that were over 20 cm. The proportion of fish measuring up to 20 cm that escaped from the fyke-nets with 22×36 and 18×30 mm sieve openings ranged from 73 to 62%, while that for the sieves with 20×65 mm openings increased to 90% in total. The latter sieve type substantially reduced fish retention up to a length of 18 cm (Fig. 2).

Bream

The effectivity of the sieves with respect to bream was limited markedly by the opening size; the upper length limit was 14 cm for the sieves with 18×30 and 22×36 mm openings and 19 cm for sieves with 20×65 openings. In the first two sieve sizes with 18×30 and 22×36 mm openings fish up to 12 cm in length were able to escape, while sieves with 20×65 mm openings permitted 50% of the bream measuring 13 cm to escape (Fig. 3).

Selectivity curves

The respective selectivity curves for the protective sieves were fitted. For pike-perch they were knife shaped and demonstrated that an increase in opening size from 18×30 to

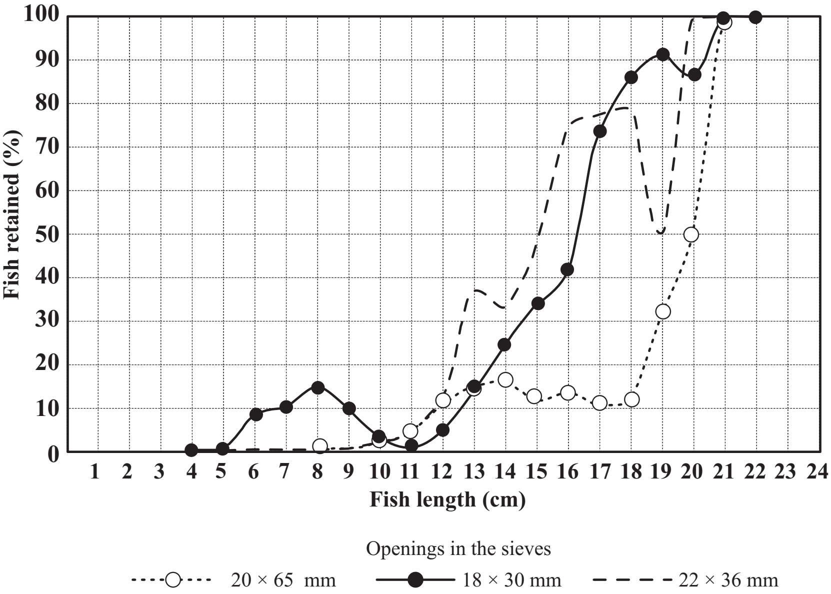

Fig. 2. Retention of pike-perch in fyke-nets in relation to sieve opening size.

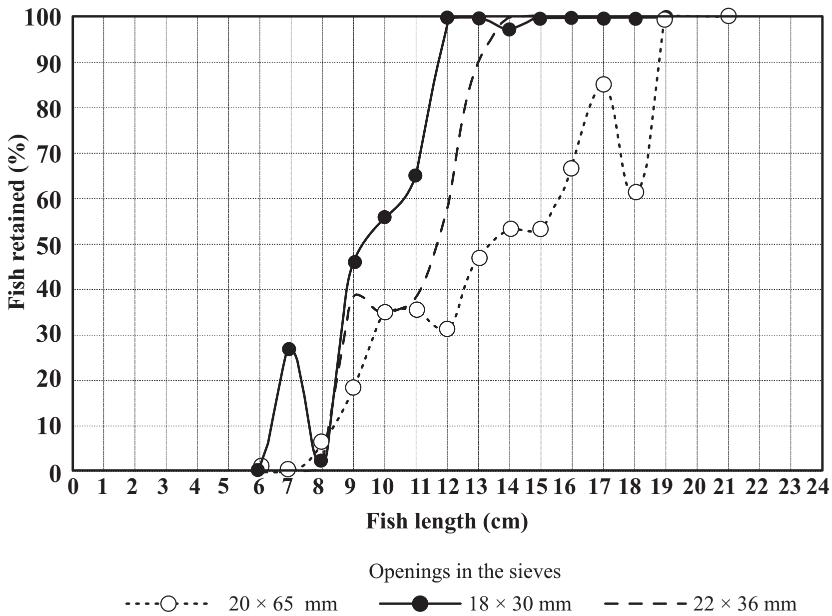

Fig. 3. Retention of bream in fyke-nets in relation to sieve opening size.

20×65 mm shifted the fish length from 16.5 to 20 cm at a probability of 50% being retained (Fig. 4). The respective curves for bream are flatter and indicate the advantage of increasing sieve openings to 20×65 mm (Fig. 5).

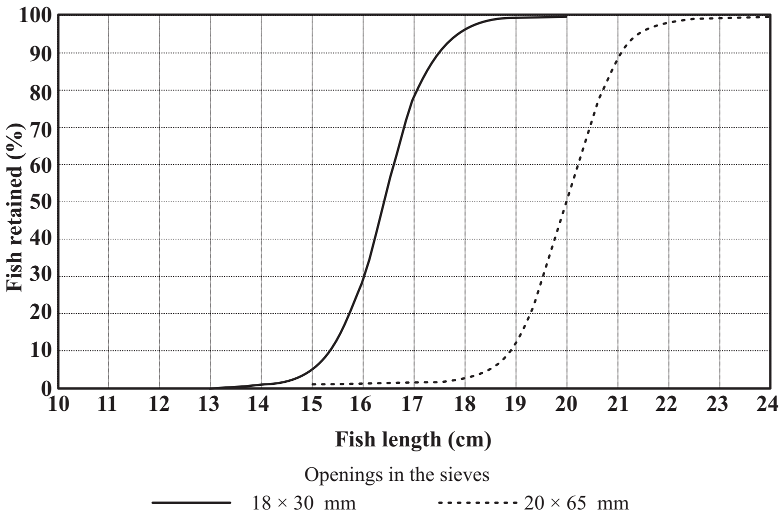

Fig. 4. Selectivity curves with respect to sieve opening size for young pike-perch.

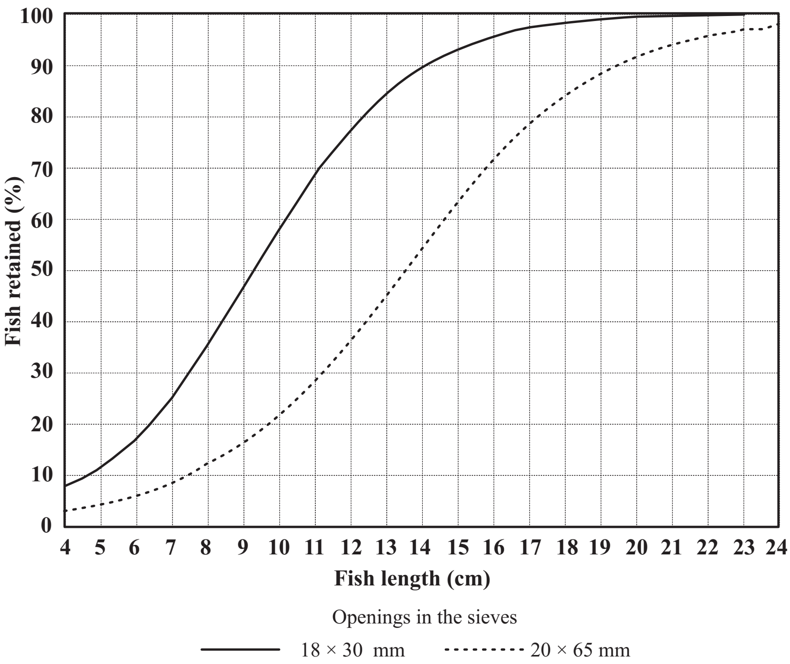

Fig. 5. Selectivity curves with respect to sieve opening size for young bream.

DISCUSSION

The results presented in the current paper suggest that there are limited possibilities of utilizing the separation method to protect undersized pike-perch and bream caught in fyke-net trap gear used in eel fishery. The only positive results were achieved with regard to the youngest fish that had not yet exceeded a total length of 20 cm. The results of analysis of the studied materials showed that sieves with 20×65 mm openings should be recommended as they could lead to partial success in protecting valuable undersized fish from mortality inflicted by fyke-net fishery.

The application of sieves like those presented in Figure 1 (20×65 mm openings) was stipulated by the Minister of Agriculture and Rural Development in 2003 and is mandatory in fyke-nets deployed in eel fishery in the Vistula Lagoon. This should be seen as a positive step in the management of this lagoon's resources. Sieves serve as a type of buffer for the steps taken by fishermen, who, facing declining stocks of eel (impact of overfishing and decreasing trend in recruitment), try to compensate for smaller catches by improving gear construction so as to minimize the possibility of legal-sized fish escaping. This is accompanied by a rise in the by-catch of undersized fish that are released back into the water; not much can be said regarding their chances of survival (Cook 2003).

According to the evaluations of Wysokiński and Garbacik-Wesołowska (1995), the application of sieves in eel fyke-nets deployed in the Polish part of the Szczecin Lagoon led to a reduction in the number of pike-perch retained in fyke-nets from 150 to 200 million to 12 million specimens.

As anticipated, the obligation of employing sieves was not greeted with great enthusiasm by the fishermen. Their skepticism stemmed from the belief that a portion of the eel entering the gear would escape through the sieve openings and that the gear fitted with the sieves would be more difficult to manipulate. The fishermen complained of several sieve defects after they had been in use for several months. The following are the most common:

– difficulties in manipulating the fyke-net while clearing caught fish;
– increased labor required to open and close the cod-end fitted with a sieve;
– increased risk of injury posed by metal sieves that corrode in brackish water;
– sieve construction opened while fastening the fyke-net.

The fishermen did not limit themselves to complaints; they suggested modifications to the construction and sizes of the sieve design currently stipulated by law. The sieve proposed by the fishermen is a square-shaped grate measuring 23.3×22.2 cm constructed of round metal rods 3 mm in diameter (Draganik 2004). The openings between them are 20×70 mm. Contrary to currently binding regulations, which stipulate placing the sieve in a vertical position in the end of the cod-end, the fishermen propose sewing it into the side of the fyke-net. According to preliminary observations, the quantity of 20 cm pike-perch retained in the sieve prototype was smaller than in the sieve model stipulated by current regulation or fyke-nets without sieves.

The advantages of the sieve proposed by the fishermen are acknowledged, but it remains to be seen how the size and placement of the device impacts the proportion of retained pike-perch < 20 cm in comparison with fyke-nets with the currently required sieves. Although fitting the fyke-nets with sieves that have a mesh size of 16 mm in the cod-end is undeniably advantageous for the protection of pike-perch and bream in their pre-recruitment phase of life, several issues should be considered. The first question to answer refers to the real effect of the application of protective sieves. Namely, what is the fate of young pike-perch and bream that pass through protective sieves or of those released by fishermen from the cod-ends? The authors observed that aquatic birds prey upon a portion of them.

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Lipid oxidation and lysine availability in smoked Atlantic mackerel fillets and Baltic sprats

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Abstract. Fatty fish are a valuable dietary source of proteins and of polyenoic fatty acids from the n-3 family. Smoking may affect the state of lipids and proteins due to heating and the reactivity of smoke components, predominantly phenols. The aim of this work was to investigate the effect of smoking in mild conditions on lipid oxidation and lysine availability in Atlantic mackerel fillets and sprats. There was large variability in the results regarding the state of the lipids and proteins in individual defrosted raw mackerel fillets taken from the same batch. No correlation was found between the degree of lipid oxidation and the contents of lipids in the thawed fillets. The ranges of the peroxide value and anisidine value were considerably high. Hot and cold smoking did not affect the peroxide value of mackerel fillets, while in smoked sprats it was much lower than in the thawed fish. Smoking did not cause any decrease in lysine availability, although the anisidine value increased about twofold in smoked mackerel and fourfold in smoked sprats. The contents of phenols were similar in the skins of the analyzed samples of all assortments of smoked fish and ranged from 19 to 24 mg/100 g. The phenol content in the meat of the smoked sprats was only 20% lower than that in the skin.

Key words: mackerel fillets, sprats, smoked fish, lipid oxidation, lysine availability, wood smoke phenols

INTRODUCTION

Generally, smoked fish is produced by dressing fresh or thawed raw material, brining, predrying, and treating with wood smoke or smoke preparations. The fish can be smoked in the round, like Bűckling, as gutted fish, or as fillets. The processing parameters differ mainly with regard to the temperature and density of the smoke and the duration of the process, which can last from a few hours in most hot smoking procedures to even several days in cold smoking (Miler and Sikorski 1990). In modern automatic smokehouses the parameters are adjusted to the properties of the raw material and are strictly controlled. Temperature and some smoke components can adversely affect fish lipids and proteins if the smoking lasts very long and the temperature is high. On the other hand, smoke phenols are known for their antioxidant activity. Changes in lipids in smoked fish have been treated by Kołakowska *et al*. (2002), while the effect of smoking on fish lipids and proteins has recently been reviewed and investigated by Kołodziejska *et al.* (2004). Lysine availability in raw, broiled, and smoked rainbow trout was determined by El and Kavas (2003).

STUDY OBJECTIVES

There is scarce information in the literature regarding the effect that mild hot or cold smoking of fish in modern industrial smokehouses under controlled conditions has on the nutritional value of the products (Kołodziejska *et al*. 2004). Thus, the aim of this work was to investigate lysine availability and the lipid oxidation degree as measured by the contents of peroxides and secondary oxidation products in smoked mackerel and sprats in order to evaluate the extent of the loss, if any, of the nutritional value of the fish due to smoking.

MATERIALS AND METHODS

Preparation and smoking of mackerel fillets and sprats

The mackerel (*Scomber scombrus*) frozen on board in 20 kg blocks, packed in polyethylene film and cardboard boxes, imported from Norway, was stored at –30°C for 1-3 months at the PRORYB processing plant in Rumia, Poland. After thawing in a water/steam mixture at 21°C, the fish were gutted and filleted on a processing line. For the experiments one of the fillets of each pair was left raw for analysis. The other one was smoked, *i.e.*, brined in a 20% salt solution, 1:1, for 3 min at 7°C, and hot or cold smoked in an automatic kiln supplied with smoke from a mixture of oak and beech shavings smoldering in an external generator (Fig. 1). In cold smoking the fillets were predried at 28ºC for 3-3.5 h and smoked at 26ºC for 1-1.5 h.

Baltic sprats (*Sprattus sprattus*), caught in March 2003, were frozen in 20 kg glazed blocks and stored for 8-9 months at –30ºC. After defrosting and washing with water, they were brined in a 20% salt solution, 1:1, for 5 min at 7ºC, spitted, surface dried at 15ºC for 60 min, heated in a smokehouse at 53ºC for 20 min, and smoked at 51ºC for 50 min. The products were analyzed after one day of storage in closed cardboard boxes at 2°C.

For chemical analysis skinless fillets of each mackerel or about 60-70 sprats were minced in a grinder using a plate with an orifice diameter of 2 mm and mixed thoroughly to prepare a representative average sample for the determination of chemical indices in at least triplicate.

Chemical assays

NaCl was determined by $AgNO_3$ titration according to PN-74/A-86739 (1974), the dry weight and total Kjeldahl nitrogen according to AOAC procedures (1990), lipids by extraction according to Bligh and Dyer (1959) and drying at 80ºC to a constant weight, peroxide value by the thiocyanate method according to BN-74/8020-07 (1974), and anisidine

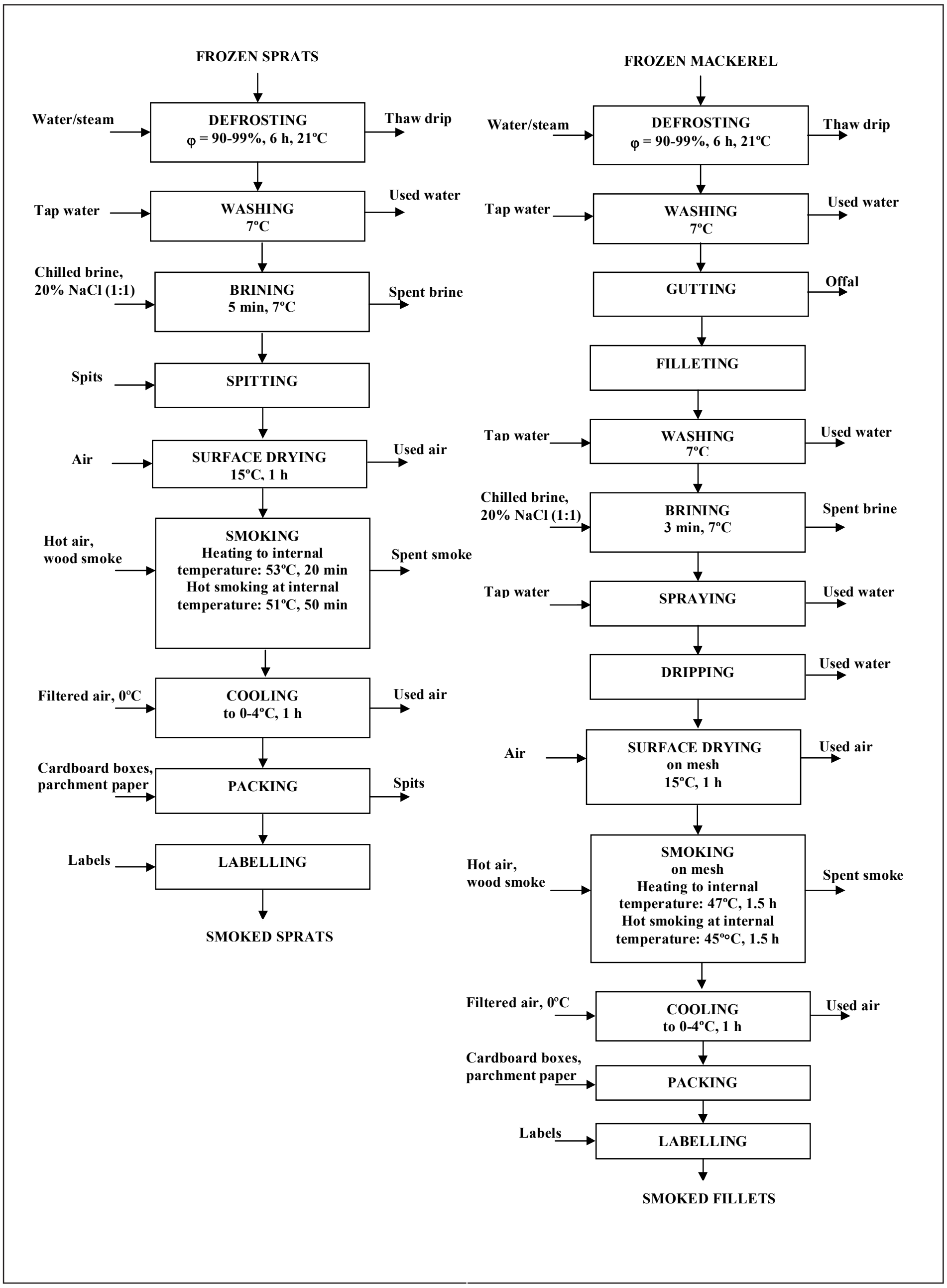

Fig. 1. Flow sheet of the hot smoking procedure of mackerel and sprats in mild conditions.

value in the extracts according to PN-93/A- 86926 (1993). Available lysine was assayed using the Carpenter method (Rao *et al*. 1963), phenols by bromometric titration according to PN-72/C- 04602.04 (1972), and pH with a microcomputer CP-315M pH meter (Elmetron). The concentration of phenols is presented in mg of phenol/100 g wet weight.

RESULTS AND DISCUSSION

In earlier experiments variability was noted in the gross chemical composition, available lysine content, and lipid oxidation indices of average samples prepared from the meat of three mackerel chosen at random from three batches of fish (Kołodziejska *et al.* 2004). This suggested that the large range of results was caused by the variability of the size and composition of the individual fish, although the raw material had been graded before freezing. Therefore, in the present experiments pairs of fillets, one of which was defrosted and the other hot smoked, from nine fish from the same batch were analyzed. The results (Table 1) indicate, that they are indeed significantly affected by the variability of the raw material. The average contents of water, crude protein, and extractable lipids in the fresh and corresponding smoked fillets from one batch were similar to those obtained from three different batches of raw material.

No correlation was found between the degree of lipid oxidation (Table 2) and the contents of lipids (Table 1) in the thawed fish taken from the same batch. The ranges of the peroxide value and anisidine value were considerably high at 4.0-12.3 and 2.7-6.5, respectively. On the other hand, in the experiments by Kołakowska *et al.* (1998) lipid oxidation appeared to be higher in mackerel that contained less fat.

The peroxide value in the thawed and mildly hot smoked mackerel fillets was similar (Table 2), while in smoked, gutted mackerel it was significantly lower than in the thawed

Table 1. The gross chemical composition of the meat from corresponding thawed and mildly hot smoked Atlantic mackerel fillets

No. of fish	Water [%]		Lipids [%]		Crude protein [%]	
	thawed	smoked	thawed	smoked	thawed	smoked
1	56.1	52.6	22.6	28.9	18.1	18.3
2	55.2	51.7	25.6	27.6	17.4	18.4
3	57.0	53.5	22.5	22.9	16.4	17.5
4	60.6	54.5	18.5	21.9	17.8	18.7
5	58.3	54.2	22.3	24.3	18.6	18.4
6	58.0	55.0	21.4	25.8	14.6	16.6
7	51.0	52.0	27.1	27.1	19.8	19.0
8	52.0	55.0	23.8	27.1	21.1	21.3
9	54.0	54.0	19.9	21.1	21.5	24.5
All samples[1]	55.8 ± 3.1	53.6 ± 1.3	22.6 ± 2.7	24.6 ± 2.9	18.4 ± 2.2	19.2 ± 2.4

[1] Mean value ± standard deviation; no statistically significant differences ($p > 0.05$) were found between results characterizing thawed and smoked fish.

fish (Kołodziejska *et al.* 2004). It is known, however, that above a certain level the peroxide value does not reflect the degree of lipid oxidation when the rate of decomposition and further reactions of the primary oxidation products is higher that that of their generation. The rate of the decomposition of the lipid hydroperoxides is affected by the initial degree of oxidation of the lipids in the raw fish (Kołakowska *et al.* 1998). These authors showed that in mackerel lower in lipids but more oxidized initially, hot smoking caused a decomposition of the peroxides, while the peroxide value increased in mackerel that were richer in lipids but less oxidized. However, in both of our experiments the peroxide value in the thawed raw material was similar while it differed in the smoked products.

The average value of available lysine in hot smoked mackerel fillets was similar to that in the thawed fillets (Table 2). This confirms the results obtained by Kołodziejska *et al.* (2004) in the experiments with smoked, gutted mackerel. Apparently, the mild conditions of hot smoking are not severe enough to cause significant losses of lysine due to heating and chemical interactions with the smoke components.

In the experiments regarding cold smoked mackerel there was also considerably large variability in the gross chemical composition of the individual thawed fillets from the same batch (Table 3). However, the variability was much larger in the smoked product. This may have been caused not only by the differences in composition of the raw material, but also by the superimposed effect of the smoking conditions. Cold smoking, just like hot smoking, did not affect the peroxide value of lipids extracted from the product (Table 4).

The chemical composition of sprats, including the content of lipids, among the different batches of raw material and smoked fish was similar (Table 5). The lipids extracted from thawed sprats contained significantly more peroxides and secondary oxidation products than did mackerel lipids (Table 2, 4, and 5). This may have been cased by the longer storage time of the frozen sprats than that of mackerel.

In all experiments the anisidine value increased due to hot or cold smoking in all the fish assortments, but the lysine availability did not change under these conditions (Table 2, 4 and 5).

Table 2. Peroxide value, anisidine value, and available lysine in the meat from corresponding thawed and mildly hot smoked Atlantic mackerel fillets

No. of fish	Peroxide value [mg O/100 g lipids]		Anisidine value		Available lysine [g/100 g protein]	
	thawed	smoked	thawed	smoked	thawed	smoked
1	4.0	5.7	5.1	7.1	6.7	6.1
2	9.3	8.8	5.7	7.3	7.3	6.6
3	12.3	10.4	6.5	8.3	6.0	6.8
4	4.8	7.6	6.4	9.0	5.3	5.2
5	5.9	6.9	4.1	6.9	6.0	6.6
6	8.6	11.6	2.9	7.2	8.5	7.9
7	7.9	9.2	2.7	7.4	7.0	7.1
8	9.7	9.3	3.5	7.5	7.4	7.9
9	11.6	11.8	4.3	8.6	7.2	7.1
All samples[1]	8.2[a]	9.0[a]	4.6[a]	7.7[b]	6.8[a]	6.8[a]

[1] The values characterizing thawed and smoked fish followed by different letters differ significantly ($p < 0.05$)

Table 3. The gross chemical composition of the meat from corresponding thawed and cold smoked Atlantic mackerel fillets

No. of fish	Water [%]		Lipids [%]		Crude protein [%]	
	thawed	smoked	thawed	smoked	thawed	smoked
1	60.9	52.4	21.0	24.9	18.5	16.3
2	59.5	44.5	27.1	33.1	18.5	16.5
3	59.6	43.1	21.8	35.1	17.6	18.3
4	53.8	43.8	28.5	30.0	16.7	19.9
5	57.9	42.5	24.4	30.2	16.0	20.1
6	58.6	39.1	21.3	38.4	17.5	17.7
7	57.1	38.9	26.7	30.9	16.3	21.3
8	57.2	38.5	22.4	33.5	18.0	18.9
9	58.5	33.3	27.0	39.6	18.8	22.3
All samples[1]	58.1[a]	41.8[b]	24.5[a]	32.9[b]	17.5[a]	19.0[a]

[1] The values characterizing thawed and smoked fish followed by different letters differ significantly ($p < 0.05$)

Table 4. Peroxide value, anisidine value and available lysine in the meat from corresponding thawed and cold smoked Atlantic mackerel fillets

No. of fish	Peroxide value [mg O/100 g lipids]		Anisidine value		Available lysine [g/100 g protein]	
	thawed	smoked	thawed	smoked	thawed	smoked
1	7.3	2.3	4.3	11.7	-	-
2	4.9	2.6	2.5	8.3	-	-
3	5.3	3.3	3.2	7.0	6.3	5.3
4	4.2	2.9	2.5	7.4	6.2	5.6
5	4.2	5.0	2.6	6.8	8.1	8.0
6	4.3	3.5	5.1	6.1	7.6	8.2
7	3.8	4.2	1.7	6.1	6.5	6.1
8	6.8	8.0	2.9	7.4	6.8	7.9
9	3.7	6.0	2.2	7.2	6.7	6.9
All samples[1]	4.9[a]	4.2[a]	3.0[a]	7.6[b]	6.9[a]	6.8[a]

[1] The values characterizing thawed and smoked fish followed by different letters differ significantly ($p < 0.05$)

The contents of phenols were similar in the skin of the analyzed samples of all the smoked fish assortments and ranged from 19 to 24 mg/100 g, regardless the differences in the smoking conditions (Table 6). The phenol content in the meat of smoked sprats was only 20% lower than in the skin. This small difference can be explained by the small size of the fish and their very thin skin. The contents of phenols in the meat of smoked gutted mackerel and in cold and hot smoked fillets corresponded to the different conditions of smoking and the area of skinless tissue exposed to the action of the smoke (Table 6).

Table 5. The gross chemical composition, peroxide value, anisidine value and available lysine in the meat of thawed and mildly hot smoked Baltic sprats[a]

	Thawed sprats	Smoked sprats
Water [%]	74.2 ÷ 77.7 75.7 ± 1.8	67.1 ÷ 70.2 66.9 ± 1.6
Lipids [%]	7.8 ÷ 8.2 8.0 ± 0.2	7.9 ÷ 8.6 8.3 ± 0.3
Crude protein [%]	16.6 ÷ 16.7 16.7 ± 0.0	19.5 ÷ 22.3 21.0 ± 1.4
Peroxide value [mg O/100 g lipids]	25.3 ÷ 33.9 29.2 ± 4.4	8.0 ÷ 14.0 10.3 ± 3.2
Anisidine value	5.7 ÷ 9.1 7.7 ± 1.8	34.7 ÷ 35.9 35.3 ± 0.6
Available lysine [g/100 g protein]	8.2 ÷ 8.7 8.5 ± 0.3	9.1 ÷ 9.5 9.3 ± 0.2
pH	6.58 ÷ 6.70 6.65 ± 0.06	6.16 ÷ 6.26 6.20 ± 0.05

[a] Range of variability and mean value ± standard deviation characterizing samples from three batches of fish

Table 6. The contents of phenols and NaCl in the meat and skin of smoked Atlantic mackerel and Baltic sprats[a]

Fish	Phenols		NaCl
	[mg/100 g meat]	[mg/100 g skin]	[g/100 g meat]
Mildly hot smoked mackerel[2]	6.6 ± 1.5	20.2 ± 7.6	1.89 ± 0.21
Mildly hot smoked mackerel fillets	9.5 ± 1.8	24.1 ± 9.1	2.23 ± 0.05
Cold smoked mackerel fillets	15.2 ± 1.0	22.6 ± 6.5	3.47 ± 0.06
Mildly hot smoked sprats	15.4 ± 1.1	18.7 ± 2.5	1.59 ± 0.02

[a] The mean value ± standard deviation of four determinations from the same batches of fish
[b] The parameters of smoking are presented in Kołodziejska *et al.* (2004).

CONCLUDING REMARKS

The mild conditions of smoking can be applied without inducing any health hazards to consumers only in those processing plants that use high quality raw material and meet all current requirements for processing hygiene and quality assurance (Kołodziejska *et al.* 2002). Smoking Atlantic mackerel fillets and Baltic sprats in an automatic industrial smokehouse in mild conditions does not cause any significant loss in available lysine or important changes in the content of the primary oxidation products in lipids extracted from smoked fish. The increase in the anisidine value in mackerel fillets and sprats due to smoking indicates that the low concentrations of smoke phenols that accumulated in the tissues do not arrest the decomposition of the primary products of lipid oxidation.

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Fecundity of asp *Aspius aspius* (L., 1758) from Międzyodrze waters

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Abstract. The mature section of the asp population in the Międzyodrze waters is comprised primarily of individuals ranging in age from five to seven years. The proportion of mature males to mature females is nearly 1:1. The absolute fecundity of asp ranges from 63 044 to 324 833 eggs. The dependence of absolute fecundity on female length and weight was nearly linear. Absolute fecundity also increased with the age of the fish, although this correlation was much weaker. Relative fecundity was in the range of 35.11-107.94 eggs per g of female body (without viscera). No significant correlation was confirmed between relative fecundity and the length, weight or age of the investigated asp.

Key words: *Aspius aspius*, asp, fecundity, gonadosomatic index (GSI), Międzyodrze

INTRODUCTION

Asp, which occurs in Polish waters, is regarded as the only true piscivore among the European cyprinids (Papadopol and Banarescu 1977).

The fairly rich literature dedicated to this species in Polish waters addresses age and growth rate, food and feeding, morphologic characters, artificial hatching and rearing in ponds, and its parasite fauna. Backiel (1964, 1970, 1971) studied the growth rate, mortality, food consumption and the biological production of the asp from the Vistula River. Trzebiatowski and Leszczewicz (1976) concentrated their work on the growth rate and feeding of asp from the Szczecin Lagoon. The work of Heese (1992) and Martyniak and Heese (1994) as well as Kompowski and Neja (2003) focus on the growth rate of asp from the Pierzchały Reservoir on the Pasłęka and the Międzyodrze. Horoszewicz (1964) studied the food and feeding of asp from the Vistula River. Fleituch (1986) and Terlecki *et al.* (1990) studied the food composition of asp from the Rożnów Reservoir on the Dunajec River and the Zegrzyński Reservoir on the Narwia River, respectively. Studies were conducted on the morphological characters of asp from the Vistula River near Włocławek (Kopiejewska 1980), Biebrza River (Witkowski 1984), and the Międzyodrze region (Kompowski and Neja 2002a, b). The parasites of asp from the Oder River mouth were studied by Łukowski (1977), and in Lake Dąbie by Hryczyńska and Piasecki (2001). A relatively large number of papers by Polish authors address the artificial reproduction, embryonic development and pond propagation of asp (Wolnicki and Górny 1993, Śliwiński *et al.* 1995, Kujawa *et al.* 1997a, b, 1998a, b, Ostaszewska and Węgiel 2002). This literature review indicates that, to date, there has been a lack of studies on the natural spawning and fecundity of asp in Polish waters. Additionally, publications on this topic are few and focus primarily on asp in distant eastern European and central Asian waters.

The aim of this work was to study the fecundity of asp in the water of the Międzyodrze delta-estuary region located in the lower reaches of the Oder River above Lake Dąbie.

MATERIALS AND METHODS

The study material was comprised of 267 asp taken from commercial catches conducted in Międzyodrze waters in the Oder River delta to the south of Lake Dąbie (northwestern Poland) in 2002-2003. The length (*SL*) of the fish was measured to the nearest mm. Weight was determined to the nearest g. The sex of the specimens was determined, as was the gonad maturity stage according to the eight-degree Maier scale (Meisner 1948). The viscera were removed and the specimens were immediately weighed again to the nearest 0.1g in order to determine the gonadosomatic index (GSI). Fish age was determined from scales sampled from the first or second row above the lateral line and then from the base of the first ray of the dorsal fin

Fecundity was determined based on 53 ovaries from females in the standard length (*SL*) range of 43.3-64.3 cm; they were in maturity stage IV or V. The ovaries were preserved in a 4% formalin solution. Absolute fecundity was determined by weighing the rinsed and dried gonads to the nearest 0.01g. Three samples, weighed to the nearest 0.0001 g, were taken from each pair of gonads. The weight of the samples was within the range of 0.2-0.5 g. Next, the number of eggs contained in each sample was counted under a stereoscopic microscope. The number of eggs in the ovaries was calculated according to the proportion of the sample weight to that of the whole gonad. The relative fecundity was calculated for 1 g of body weight without the viscera.

The dependence between fecundity and length, body weight, and age was studied with linear regression, as follows:

$$y = ax + b;$$

where:
y = absolute or relative fecundity;
x = standard length (*SL*) in cm, weight in g, or age in years;
a and b = parameters calculated with the method of the least squares.

In order to describe the strength of the relation among the variables above, Pearson's correlation coefficient r was calculated. Additionally, these dependencies were studied using several different types of nonlinear regression (power, exponential, polynomial at varied degrees).

The GSI coefficient was calculated individually for each individual with the following formula:

$$GSI = g\ 100/w;$$

where:
g = fresh gonad weight;
w = total fish weight.

RESULTS

Age structure, length distribution and sex ratio of the studied asp

A total of 267 fish ranging in length from 16.9 to 64.3 cm (Table 1) were studied. Their age range was from 2 to 10 years. There were 53 immature specimens. Of the 214 specimens in mature stages, there were 104 males and 110 females. The sex ratio was 48.6% males to 51.4% females, which is nearly 1:1. The age of the males ranged from three (one specimen) to eight years, with the five, six, and seven year age groups dominating. The age of the females ranged from four to ten years, and the same age groups dominated as with the males. The average length of females (49.94 cm) was slightly longer than that of males (47.01 cm).

Gonadosomatic index

The highest average values of this index among females (12.07) occurred at the end of March (Table 2). This is also when the maximum individual value of this index was observed

Table 1. Age structure of studied asp

Age group	Immature specimens		Males		Females	
	n	average length *SL* [cm]	*n*	average length *SL* [cm]	*n*	average length *SL* [cm]
2	3	20.47	–	–	–	–
3	11	28.97	1	41.60	–	–
4	11	35.22	6	39.20	6	37.32
5	16	42.04	26	45.09	25	45.47
6	8	44.20	42	47.32	31	49.04
7	2	47.55	21	50.13	27	53.22
8	–	–	5	53.96	15	55.91
9	–	–	–	–	2	56.75
10	–	–	–	–	3	59.93
Undetermined	2	44.15	3	43.30	1	43.00
Total	53	37.30	104	47.01	110	49.94

Table 2. Gonadosomatic index (GSI) of male and female asp from Międzyodrze

Month (date)	Females				Males			
	n	average	range	*SD*	*n*	average	range	*SD*
March (21 and 27.03)	18	12.07	0.22-20.73	6.75	18	0.96	0.02-1.72	0.49
April (14 and 16.04)	24	1.77	0.61-8.44	1.47	35	0.79	0.11-2.02	0.46
May (27 and 29.05)	8	1.04	0.27-1.61	0.43	9	0.53	0.10-1.13	0.36
June (8.06)	1	0.31	0.31-0.31	–	–	–	–	–
August (17.08)	–	–	–	–	3	0.09	0.06-0.14	0.04
September (24.09)	12	4.11	0.22-11.51	4.63	12	0.48	0.31-0.76	0.13
October (15 and 30.10)	34	9.34	0.05-14.64	4.61	18	0.97	0.42-1.30	0.26
November (28.11)	6	11.54	1.39-14.88	5.11	2	0.98	0.74-1.23	0.35
December (19.12)	5	3.29	0.24-14.32	6.17	5	1.08	0.76-1.53	0.33

(20.73). In April the average female GSI fell to 1.77, which indicates that the majority of the studied fish had already spawned. In May the female GSI value was even lower at 1.04. During the fall from September to November, the average GSI value rose sharply to a level close to that seen in the pre-spawning period. The GSI variations observed in males were not as distinct. The testicles comprised a much lower portion of total body mass than did the ovaries; the maximum individual GSI value observed among males in mid April, immediately before spawning, was 2.02.

Fecundity

The absolute fecundity of asp from the Międzyodrze ranges from 63 044 eggs in females 43.3 cm in length and with a total weight of 1311 g to 324 833 eggs in females 64.3 cm in length and with a total weight of 4 903 g. The average fecundity in the studied population was 158 526 ± 56 659 eggs. The absolute fecundity increased with the length of the studied females. It was possible to describe the dependence of asp female fecundity on length fairly precisely (r = 0.822) with the simple equation of the following parameters: a = 10019; b = –369370.

The dependence of absolute fecundity on total asp weight was also very close to a linear dependency and it was possible to express it quite precisely (r = 0.888) with the equation with the following parameters: a = 65.043; b = –14217.

The dependency of absolute fecundity on body weight without viscera was slightly weaker (r = 0.847) and could be expressed with an equation with the following parameters: a = 74.485; b = –7835.

Absolute fecundity, understandably, increased with the age of the fish (Table 3). However, this dependency was significantly weaker than that of absolute fecundity on length or weight.

The relative fecundity of the studied population of asp was in the range of 35.11 to 107.94 eggs per g of female body without viscera. The average fecundity of the studied population was 70.53 ± 13.20 eggs. No significant correlation between relative fecundity and length, weight or age of the studied asp was determined (Table 3).

Table 3. Dependence of the fecundity of female asp from Międzyodrze on age

Age group	Absolute fecundity			Relative fecundity	
	n	average	range	average	range
5	10	100 551.0	63 044-161 772	59.85	49.7-84.8
6	16	148 740.7	85 986-248 545	74.08	57.9-88.8
7	15	191 074.5	94 839-324 833	73.74	50.2-107.9
8	8	177 833.9	111 918-211 496	72.13	49.6-87.8
9	2	205 600.4	199 444-211 757	83.07	79.2-86.9
10	2	158 268.2	107 579-208 958	47.24	35.1-59.4
Total	53	158 526.2	63 044-324 833	70.53	35.1-107.9

DISCUSSION

The studies indicate that asp spawning occurs in the Polish part of the Międzyodrze in the first half of April. Of the cyprinids inhabiting the Międzyodrze waters, only the zope (*Abramis ballerus*) spawns in a comparably early period (Karabanowicz and Kompowski 1994, Kompowski and Błaszczyk 1997). According to Woltera *et al.* (1999), asp begin spawning in the German part of the Międzyodrze on the flooded polders as early as March. Some of the other asp populations that have a similar spawning period to those in the Międzyodrze include those from the following rivers: Kuban (Troitskiy 1957); Tereku (Shikhshabekov 1979); Syr Darya (Babaev 1977); Elbe (Fredrich 2002); Želivka (Czech Republic) (Křižek and Vostradovský 2002). Asp from the Kuibyshev Reservoir on the Volga River spawn at the end of April (Kuznetsov 1971), while those from the lower Volga and its delta spawn in late April and early May (Atalla Mukheisin Ali 1974).

The observations made during the current study indicate that the proportion of males to females in the studied asp population is close to 1:1. These observations, however, include the entire vegetative period and late fall. Some researchers have reported that during spawning the number of males is two or even threefold higher than the number of females (Troitskiy 1965, Bashunova 1980, Křižek and Vostradovský 2002). This appears to be so because males occur in the spawning grounds throughout the spawning period, while females arrive later and leave as soon as they have deposited their spawn (Bashunova 1980, Křižek and Vostradovský 2002).

The average length of females in the Międzyodrze was slightly longer than that of males. This concurs with the observations of Troitskiy (1957) of the asp from the Kuban River as well as those of Babaeva (1977) who studied the asp from Syr Darya.

Table 4 presents the results of the absolute fecundity of asp from various basins. Only the extreme values are taken into consideration and the average values are omitted. This is because the latter are not characteristic features of various populations but depend on the fluctuating annual age-length distribution. The range of absolute fecundity variability in the asp from the Międzyodrze is quite wide and is similar in this way to the range observed in the asp from the Kuban River. It is interesting to compare the fecundity of asp of the same length from different basins. Such a comparison (Table 5) of the absolute fecundity of asp from the 47-60 cm length class from Międzyodrze, the lower reaches and the delta of the Volga, and of Syr Darya indicates that the fecundity of the fish from the first

Table 4. Absolute fecundity of asp from various basins

Basin	Absolute fecundity [thou. eggs]	Standard length *SL* [cm]	Source
Ili	19-269	35.8-51.2	Bashunova 1980
Lower Wolga and delta	48.3-121.9	42-56	Atalla Mukheisin Ali 1974
Terek and other rivers in Dagestan	52.2-212.8	48-58	Shikhshabekov 1979
Syr-Darja	67.6-189.0	44-66	Babaev 1977
Kubań	73.5-366.5	40-65	Troitskiy 1956
Międzyodrze	63-324.8	43.3-64.3	Kompowski and Neja Current work

Table 5. Absolute fecundity of asp of the same length from various basins (thou. eggs)

Length *SL* [cm]	Basin (author)		
	Międzyodrze (Kompowski and Neja, Current work) [a]	Lower Wolga and its delta (Atalla Mukheisin Ali 1974) [b]	Syr-Darja (Babaev 1977) [c]
45	81.5	102	–
46	91.5	110.1	79.9
47	101.5	118.2	99.3
48	111.5	126.3	107.9
49	121.6	134.3	100.8
50	131.6	142.4	119.2
51	141.6	150.5	121.8
52	151.6	158.6	130.3
53	161.6	166.7	140.7
54	171.7	174.7	141.0
55	181.7	182.8	150.8
56	191.7	190.9	174.5
57	201.7	199.0	143.1
58	211.7	207.1	196.0
59	221.8	215.1	186.7
60	231.8	223.2	191.0

[a] Calculated with: $F = 10019\ SL - 369370$ (current work).
[b] Calculated with: $y = 8.08x - 261.58$; where:
y = absolute fecundity [thou. eggs].
x = standard length [cm] (Atalla Mukheisin Ali 1974).
[c] Weighted average from the 1968-1970 period.

two basins is similar while that of fish from the latter is significantly lower. Asp from the Lake Aral catchment area is classified as the sub-species *Aspius aspius iblioides* (Kessler), and this is possibly the basis for this difference. Significant individual variability should also be taken into consideration when comparing fecundity. For example, the absolute fecundity of asp in the 52 cm length class from Syr Darya ranges from 81.2-213.3 thousand eggs (Babaev 1977).

Asp absolute fecundity is fairly well-correlated with female length and weight, and as is also confirmed by the work of other authors (Atalla Mukheisin Ali 1974, Babaev 1977), both of these dependencies are closest to linear dependencies.

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Oxygen consumption and ammonia excretion in the mysid shrimp *Neomysis integer* and early developmental stages of the smelt *Osmerus eperlanus* from the Vistula Lagoon

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Abstract. Oxygen consumption, ammonia excretion, and the O:N ratio was measured in two animal species living in the Vistula Lagoon pelagic community early developmental stages of the smelt *O. eperlanus* and the mysid shrimp *N. integer*. The O:N ratios and literature data on the daily food ration in both species indicate that *O. eperlanus* catches more food that is richer in protein in comparison with the shrimp. This indicates that the smelt probably beats *N. integer* in food competition.

Key words: *Neomysis integer, Osmerus eperlanus*, oxygen consumption, nitrogen excretion, O:N ratio, Vistula Lagoon, food competition.

INTRODUCTION

In studies of zooplankton ecology, difficulties in extrapolating laboratory data obtained on feeding and daily food rations to field populations are very common. This is because the metabolism of animals collected from the field change greatly under laboratory conditions (*e.g.*, Ikeda 1970, 1974).

Conover and Corner (1968) and Ikeda (1970) proposed applying the O:N ratio calculated from respiration and ammonia excretion rates as an indicator of metabolic substrate utilization in animals. These authors demonstrated that a highly carbohydrate-oriented metabolism causes high O:N ratio values (exceeding 24), while low O:N ratios (6-8) are characteristic of protein-oriented metabolism. Thus, the O:N ratio among herbivorous species, in which carbohydrates are utilized in large amounts as metabolite, is rather high (12-100), and that of carnivores is consistently low (2-20) (Myzaud 1973, Ikeda 1977, Martin 1968). The carbohydrate content of marine zooplankton is known to be low (only a few percent of the dry weight) and is insignificant as a metabolic substrate. This means that the O:N ratio is used specifically to identify the relative importance of protein in the metabolic substrate of zooplankton.

In the case of "global" competition, where each species competes with all others in the exploitation of shared food resources, a single act of competition can be represented by higher daily food ration and/or the better quality of the food eaten (Drost *et al*. 1988, Schiemer *et al.* 1989, Svedaeng 1991; see Kamler 1992 for a review of this problem).

Two animal species from the Vistula Lagoon were the subject of the current study: mysid shrimp and early developmental stages of smelt.

Mysid shrimp, *N. integer* (Leach, 1814), is a boreal species that occurs in coastal waters from the Baltic to the North Sea and is a typical estuarine, brackish-water species. It can form swarms and is very common in the Gulf of Gdansk and the Vistula Lagoon (Demel 1935, Wiktor *et al*. 1980, Jażdżewski and Konopacka 1995).

The smelt *O. eperlanus* (Linnaeus, 1758) is chiefly a cold-water fish that occurs in the northern hemisphere from Scandinavia to the Baltic Sea and European Atlantic shelf waters. It is a migratory species that feeds on zooplankton (Karjalainen *et al.*1997).

The mysid shrimp *N. integer* is very common in the near-bottom zooplankton community of the Vistula Lagoon. In the early summer (May-June) it probably competes for food with other plankton such as early life stages of fishes living in the lagoon including Baltic herring, smelt, perch, and pikeperch (see Pusty-Lipska and Borowski 2003 for further information on the fish species inhabiting the Vistula Lagoon).

According to Maciejewska *et al*. (2001), Maciejewska and Opaliński (2002) and Maciejewska (2004), the daily food consumption rate of the mysid shrimp and the early developmental stages of smelt are very similar. Information on the O:N ratio can provide insight regarding the quality of the food consumed by each species.

The aim of this study was to determine the O:N ratio in the mysid shrimp *N. integer* and early developmental stages of the smelt *O. eperlanus* from the Vistula Lagoon. Information on O:N ratio and daily food consumption rate in mysid shrimp and smelt can elucidate the problem of food competition between these two species.

METHODS

The *N. integer* and *O. eperlanus* individuals used in the study were caught in the Vistula Lagoon in July 2003 in the 1.5 m surface water layer using a Neuston plankton net. The water temperature was 18°C.

Oxygen consumption was measured with the "closed vessel" method. Individual animals were placed in chambers with a volume of 100 cm^3. Unfiltered sea water with natural plankton as food for the animals was used. Four chambers without animals were prepared concurrently as controls for each of the measurement series.

After two hours the oxygen concentration in the chambers was measured with an OXI 3000 oxygen-meter. Ammonia concentration was determined with the indo-phenol method (Solorzano 1969). Following this, the animals were weighed (*Ww* – wet weight) and dried for 24 hours at a temperature of 60°C to a constant weight (*Dw* – dry weight).

Animal oxygen consumption was expressed as the quantity of oxygen per hour per individual (Respiration, mm^3 ind^{-1} h^{-1} and µmol ind^{-1} h^{-1}), or per mg of wet or dry animal weight (Metabolic Rate, mm^3 mg^{-1} h^{-1}).

Animal ammonia excretion was expressed as the quantity of ammonia per hour per individual (Excretion *U,* μmol ind^{-1} h^{-1}), or per mg of wet or dry animal weight (Excretion Rate, *U/w* – μmol mg^{-1} h^{-1}). Since the animals can swim and eat in the chambers, the measured metabolism can be defined as the routine rate *sensu* Fry (1947).

Sixty pairs of measurements (60 each of oxygen consumption and ammonia excretion) were made for *N. interger* and 31 pairs for *O. eperlanus*.

The O:N ratio was calculated by determining the gram molecules (by atoms) of consumed oxygen and excreted ammonia-nitrogen.

RESULTS

The average respiration of *N. integer* measuring 15.3 mm in length and with a wet weight of 22.6 mg was 23.68 mm^3 (or 1.05 μmol) of oxygen per individual per hour (Table 1, Fig. 1) and the average ammonia excretion was 0.071 μmol per individual per hour (Table 1, Fig. 2).

The average O:N ratio calculated by atoms was 18 (Table 1).

The average respiration of *O. eperlanus* measuring 40.2 mm in length and with a wet weight of 331.7 mg was 91.53 mm^3 (or 4.05 μmol) of oxygen per individual per hour (Table 1, Fig. 3), and the average ammonia excretion was 0.481 μmol per individual per hour (Table 1, Fig. 4).

The average O:N ratio calculated by atoms was 10 (Table 1).

Table 1. Body length (*SL*), body wet (*Ww*) and dry (*Dw*) weights, oxygen consumption (*R*), ammonia excretion (*U*) and O: N ratio in *Neomysis integer* and *Osmerus eperlanus*. Mean values± Standard Error. *n* – number of replications. Vistula Lagoon, July 2, 2003.

Species	*n*	*SL* [mm]	*Ww* [mg]	*Dw* [m]g	*R* [mm^3 ind^{-1} h^{-1}]	*R/Ww* [mm^3 mg^{-1} h^{-1}]
Neomysis integer	60	15.3±0.2	22.6±0.8	4.1±0.2	23.68±0.68	1.069±0.021
Osmerus eperlanus	31	40.2±0.9	331.7±23.1	36.3±2.9	91.53±4.87	0.293±0.012

Species	*R/Dw* [mm^3 mg^{-1} h^{-1}]	*U* [μmol ind^{-1} h^{-1}]	*U/Ww* [μmol mg^{-1} h^{-1}]	*U/Dw* [μmol mg^{-1} h^{-1}]	O:N by atoms
Neomysis integer	5.859±0.128	0.071±0.002	0.0033±0.0001	0.018±0.001	18
Osmerus eperlanus	3.813±0.955	0.481±0.031	0.0015±0.0001	0.019±0.005	10

DISCUSSION

Observations indicate that the main food types consumed by mysid shrimp is zooplankton (Rotatoria, Cladocera, Ostracoda, Copepoda, Amphipoda) and small quantity of phytoplankton (Maciejewska 1992). The daily food ration of this species is 0.125 cal per mg of wet weight or 0.56 mg of dry weight of zooplankton per mg of animal body wet weight per day (Maciejewska, Opaliński 2002); the O:N ratio is 18 (“mixed food type”).

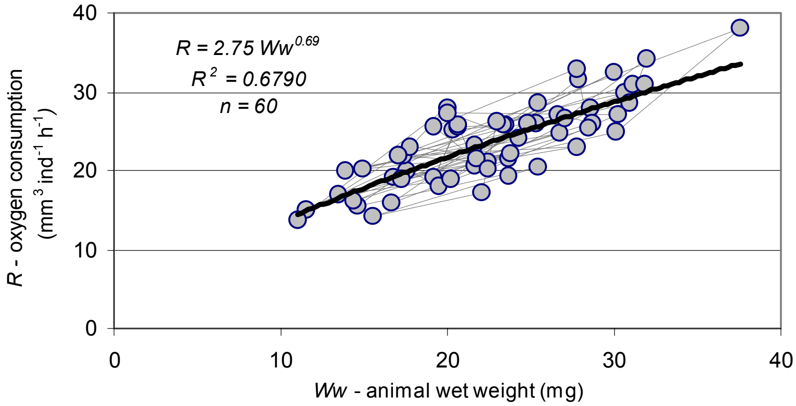

Fig. 1. The dependence between oxygen consumption (*R*) and animal body wet weight (*Ww*) in the mysid shrimp *Neomysis integer*. *n* – number of replications. Vistula Lagoon, July 2, 2003.

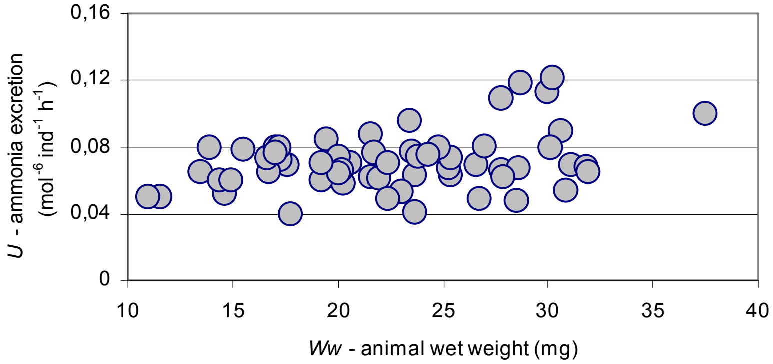

Fig. 2. The dependence between ammonia excretion (*U*) and animal body wet weight (*Ww*) in the mysid shrimp *Neomysis integer*. *n* – number of replications. Vistula Lagoon, July 2, 2003.

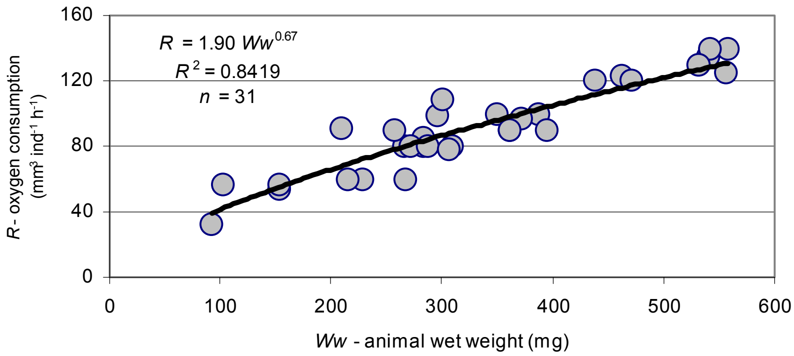

Fig. 3. The dependence between oxygen consumption (*R*) and animal body wet weight (*Ww*) in the early developmental stages of the smelt *Osmerus eperlanus*. *n* – number of replications. Vistula Lagoon, July 2, 2003.

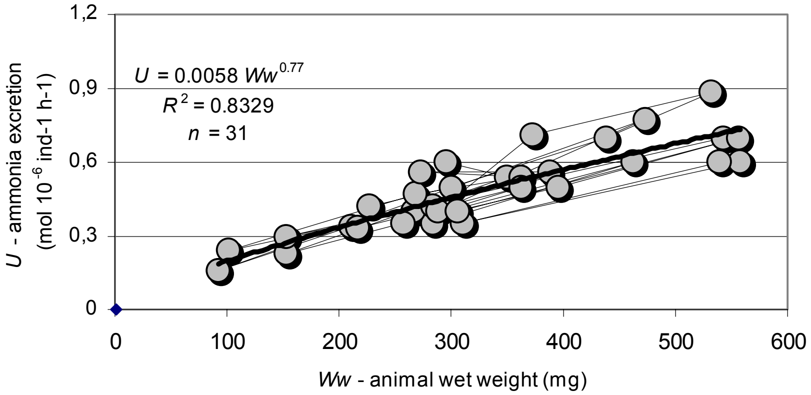

Fig. 4. The dependence between ammonia excretion (*U*) and animal body wet weight (*Ww*) in the early developmental stages of the smelt *Osmerus eperlanus* . *n* – number of replications. Vistula Lagoon, July 2, 2003.

Table 2. Atomic ratios of oxygen uptake to nitrogen excretion (O:N) in pelagic animals

Species	O:N	Authors and remarks
	Carnivorous animals	
Arrow worm *Sagitta setosa*	1.8	Mayzaud (1973)
Amphipod *Phronima sedentaria*	4.3	Mayzaud (1973)
Arrow worm *Sagitta hispida*	6.8	Reeve *et al.* (1970)
Copepod *Temora stylifera*	7-15	Nival *et al.* (1974)
Baltic Sea red shrimp *Palaemon adspersus*	8	Present paper
Smelt *Osmerus eperlanus* (fry)	10	Present paper
Grass carp *Ctenopharyngodon idella* (fry) fed on animal food	12	Recalculated from Urban (1983, 1984)
Pteropod *Limacina antarctica*	12	Ikeda, Mitchell (1982)
	Omnivorous animals (mixed food eaters)	
Grass carp *Ctenopharyngodon idella* (fry) fed on mixed food	14	Recalculated from Urban (1983, 1984)
Antarctic krill *Euphausia superba*	15-18	Ikeda, Mitchell (1982)
Mysid shrimp *Neomysis integer*	18	Present paper
Antarctic krill *Euphausia superba*	26	Opaliński *et al.* (1991)
Antarctic krill *Euphausia superba*	28	El-Sayed *et al.* (1978)
	Herbivorous animals	
Copepod *Calanus pulchrus*	20	Ikeda (1977, from Fig. 6)
Copepod *Paracalanus parvus*	30	Ikeda (1977, from Fig. 6)
Euphausid *Euphausia pacifica*	40	Ikeda (1977, from Fig. 6)
Grass carp *Ctenopharyngodon idella* (fry) fed on algae	41	Recalculated from Urban (1983, 1984)

Data on the oxygen consumption of this species measured with the same method can be found in Maciejewska and Opaliński (2002).

The main food type of the smelt from this region is zooplankton without phytoplankton (Alina Krajewska, Sea Fisheries Institute in Gdynia, personal information). The daily food ration of this species is 0.198 cal per mg of wet weight. This equals 0.84 mg of zooplankton dry weight per mg of animal body wet weight per day (Maciejewska et al. 2001); the O:N ratio is 10 ("animal food type"). Data on the oxygen consumption of this species measured with the same method can be found in Maciejewska *et al*. (2001), Maciejewska (2004), and Opaliński *et al*. (2004).

According to Conover and Corner (1968), Ikeda (1977), and Ikeda and Mitchell (1982), both of the investigated species are protein-oriented in their metabolism. However, of the two species smelt is the more carnivorous because its O:N ratio is lower (10), and it is more protein and lipid oriented in its metabolism, *i.e.*, the food it consumes is dominated by zooplankton.

The same can be seen in Table 2, which presents literature data on the O:N ratio in plankton animals of various feeding types. It is significant that the O:N values increase from carnivorous animals (or animals fed with animal food under experimental conditions) to herbivorous animals (or animals fed with algal food). On the carnivore-herbivore continuum *O. eperlanus* belongs to the first category, while *N. integer* rather belongs to the carnivore-omnivore category.

It seems that smelt loses the food competition to the mysid shrimp. Its daily food rate (0.84 mg dry weight of zooplankton per mg wet weight of animal) is one-third higher than in the shrimp (0.56 mg dry weight of zooplankton per mg wet weight of animal). Smelt juvenile stages can also catch food particles that are richer in proteins, and their O:N ratio is lower in comparison with that of the shrimp. According to the criteria of "winning", the smelt beats the mysid shrimp in inter-specific food competition.

The probable food competition between these two species only lasts for a short time. After a few weeks the smelt grow to an approximate length of 50 mm when they catch bigger food particles such as younger shrimp specimens (Karjalainen *et al.* 1997)

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Leeches of the littoral part of Lake Wigry, Northeastern Poland

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Abstract. The species composition of leeches and their density and biomass were studied in the Wigry Lake littoral zone (northeast Poland). Thirteen species were recorded including two species described recently, *i.e.*, *Piscicola pojmanskae* and *P. pomorskii*. The most abundant species was *Helobdella stagnalis* (51% and 16% of the abundance and biomass of *Hirudinea*, respectively).

Key words: Hirudinea, Wigry Lake, *Helobdella stagnalis*, *Piscicola pojmanskae*, *Piscicola pomorskii*

INTRODUCTION

Leeches constitute a typical component of fauna in most water bodies in our climatic zone. According to Bennike (ex Serafińska 1958), the most appropriate biotopes for leeches are lakes that offer a great variety of living conditions. This influences the kind and number of leeches (Wolnomiejski and Wolnomiejska 1967).

The characteristic habitat for Hirudinea is the coastal zones of water reservoirs. They are only accidental components of profundal fauna and occur singly in deeper parts of reservoirs.

The first mention of Lake Wigry leeches was in a publication by Demel (1923) in which he described the occurrence of seven common species in the lake littoral. Further information concerning taxonomic composition and the range of occurrence of leeches was found in Rzóska (1935) and Pawłowski (1936). The present authors did not find any later references to Hirudinea in Lake Wigry. The taxonomic composition and range of occurrence of the leeches in Lake Wigry, known in Polish hydrobiology as the "cradle", has not been the subject of studies for seventy years.

STUDY AREA AND METHODS

Lake Wigry is situated in northeastern Poland in the Suwalskie Lake District (Fig. 1). It is the largest (area of 2118.3 ha) and the deepest (max. depth 73 m, mean depth 15.8 m) of the

Fig. 1. Location of the sampling sites in Lake Wigry, water flow indicated with arrows.

lakes in Wigry National Park. Until 1992, when the sewage treatment plant became operational, the only significant source of nutrients was the municipal sewage from the city of Suwałki that flowed into the northern part of the lake with the waters of the Czarna Hańcza River. The inflow of nutrients into Lake Wigry has also been limited in recent years by the direct protection of the basin, and thanks to this borders between the mesotrophic and eutrophic states.

The coastline development index is considered to be high at a value of 4.43. A large number of deep bays, peninsulas, and islands characterize the diversity of the coastline. The largest bays are the Hańczańska, Eastern, Northern, and Wigierska, and the hydrological, limnological, and ecological status of them vary.

About 90% of the shoreline to a depth of 1.5 m is covered by emergent macrophytes (dominated by *Phragmites australis* (Cav.), *Typha angustifolia* L., *Schoenoplectus lacustris* (L.) Palla, *Carex sp*.). Submerged plants cover about 13% of the lake bottom to a depth of 4.5 m (dominated by *Ceratophyllum demersum* L., *Potamogeton* spp., *Batrachium circinatum* (Sibth.) Spach, *Fontinalis antypyretica* Hedw., *Chara* spp.) (Kamiński 1999).

The material for biological analysis was collected in 1997-1998 at monthly intervals except in winter (December-March). Samples were taken (five times at each site) using a

Kajak core sampler with a total surface area of 40.7 cm^2. The quantitative method, which is not typical in the study of Hirudinea, was applied because the investigations concerned all the benthic fauna of the lake.

DESCRIPTION OF THE STUDY SITES

Location of sampling sites presented in Figure 1.

Site no.	Location	Depth	Sediments	Aquatic vegetation
1	Northern Basin, Hańczańska Bay	2 m	organic	*Cerathophylum demersum* *Potamogeton* spp.
2	Northern Basin, Hańczańska Bay	3 m	organic, gravel	
3	Northern Basin, Hańczańska Bay	6 m	organic, gravel	
4	Northern Basin	2 m	calcerous gyttja	*Cerathophylum demersum* *Phragmites australis* *Potamogeton* spp.
5	Neck	1 m	sand, gravel	*Cerathophylum demersum*
6	Neck	2 m	sand, gravel, calcerous gyttja	*Cerathophylum demersum* *Phragmites australis* *Potamogeton spp.*
7	South-Western Basin	1.5 m	gravel	*Cerathophylum demersum* *Potamogeton* spp.

RESULTS

The total number of Hirudinea individuals collected was 94. Thirteen species belonging to the families Glossiphonidae, Piscicolidae, Hirudinidae, and Erpobdellidae were observed (Table 1). Leeches were present at five out of seven sites. The frequency of Hirudinea varied considerably and ranged from 0 (site 2 and 3) to 60% (site 5 and 6).

The average density of Hirudinea at the sampling sites was 104 ind. m^{-2}. The highest average density was observed in sites at the Neck (for the topography of the lake, see Fig. 1) (424 ind. m^{-2} and 215 ind. m^{-2} at site 5 and 6, respectively) (Table 1).

The average biomass of the leeches was 1.4 g m^{-2}. As was the case with density, the highest average biomass was observed at sites in the Neck (6.8 g m^{-2} and 2.4 g m^{-2} at site 5 and 6, respectively) (Table 1). Species richness was the highest at site 5, where 8 of 13 leeches species noted in the lake were found. The poorest species richness, abundance, and biomass were recorded at site 1, where only specimens from *Helobdella stagnalis* were found. No leeches were found at the sites in Hańczańska Bay (site 2 and 3).

Among all the specimens collected, *Helobdella stagnalis* **(**51%) dominated in Lake Wigry. It was present at five sites.

Piscicola pojmanskae and *Piscicola pomorskii*, species that have not been widely described to date, occurred at site 7 in the basin.

Table 1. Numbers of individuals at sampling sites in littoral of Wigry Lake in 1997-1998. Frequency and summary of average densities (ind. ·m^{-2}) and biomass (g ·m^{-2})

Taxa	Sampling sites							N
	1	2	3	4	5	6	7	
Glossiphonidae								
Alboglosssiphonia hyalina (O. F. Muller)					1			1
Alboglossiphonia heteroclita (Lukin)					1			1
Helobdella stagnalis (L.)	2			2	31	9	4	48
Hemiclepsis marginata (O. F. Muller)					1			1
Glossiphonia concolor (Apathyi)						2		2
Glossiphonia nebulosa Kalbe						1		1
Piscicolidae								
Piscicola pojmanskae Bielecki							2	2
Piscicola pomorskii Bielecki							1	1
Hirudinidae								
Haemopis sanguisuga (L.)					2			2
Erpobdellidae								
Erpobdella monostriata (Lindenfeld et Pietruszyński)						2		2
Erpobdella nigricollis (Brandes)					6	4		10
Erpobdella octoculata (L.)					10	8		18
Erpobdella testacea (Savigny)				1	3	1		5
In sum	2	0	0	3	55	27	7	94
Average density (ind. · m^{-2})	17	0	0	25	424	215	45	
Average biomass (g · m^{-2})	0.10	0	0	0.34	6.76	2.43	0.17	
Frequence (%)	10	0	0	10	60	60	40	

DISCUSSION

Ninety-four specimens of Hirudinea belonging to 13 species were found in Lake Wigry. Specimens of all species were found at depths of up to 2 m. This is confirmation of the tendency of leech occurrence described by Rzóska (1935) and Pawłowski (1936). According to these authors, the most favorable leech habitat conditions are found in the littoral zone. The most numerous Hirudinea were selected from sites located in the Neck. All of the species found in the lake in 1997 occurred at this site. The littoral in this part of the lake is stony, which is the perfect substratum type for leeches. This region is inhabited richly by other groups of benthic invertebrates (authors data, unpubl.). This relationship confirms that bottom character has a significant impact on leech distribution as well as the correlation between the occurrence of Hirudinea in the reservoir and the abundance of organisms that are their food resource.

The widely distributed *Helobdella stagnalis* has the best developmental conditions in the lake. Specimens of this species are the dominant form in Lake Wigry. According to Lukin (1962a, b), of all the leech species *Helobdella stagnalis* is the most resistant to water contamination. The current studies confirmed that there is a dependence between the quantity of *Helobdella stagnalis* occurrence and the type of littoral that is managed and contaminated by man (Wolnomiejski 1965, Wolnomiejski and Wolnomiejska 1967, Jabłońska-

Barna and Bielecki 2002). Specimens of this species were recorded at stations that are not directly impacted by anthropogenic pressure, although there is organic pollution. The region of the lake at station 1, where only *Helobdella stagnalis* was recorded, is exposed directly to the influence of the Czarna Hańcza River. The river carries waters from the Suwałki sewage treatment plant. Analyses based on other groups of macrozoobenthos indicated a lack of taxa in this part of the lake (Jabłońska and Koszałka 2000). In coastal waters where sites 4, 5, 6, and 7 were located, the influence of anthropogenic pollution from localities situated along the shoreline is significant.

The majority of the Hirudinea described in Lake Wigry are freeliving predators. Only three of them – *Hemiclepsis marginata, Piscicola pojmanskae* and *Piscicola pomorskii*, are fish parasites. The distribution of this species does not reflect the character of the littoral, and the presence of them in particular parts of the lake depended on the presence of hosts. The occurrence of *P. pojmanskae* and *P. pomorskii* in the lake is significant, as to date these species have been described only rarely (*e.g.*, Bielecki 1997, Jueg and Bielecki in press.). The identification of the species of genus *Piscicola*, which are morphologically very similar, is difficult. It is possible mainly on the basis of the structure of the reproductive system. Descriptions and identification keys to the species of this genus can be found in Bielecki (1997).

Piscicola pojmanskae have been found to date in fish ponds and dams reservoirs (Bielecki 1997). Only one publication described the presence of specimens of this species on the bodies of fish caught in lakes Ukiel and Wulpińskie (Bielecki and Dzika 2000). Jabłońska-Barna and Bielecki (2002) recorded specimens of this species in the brackish Lake Gardno.

Piscicola pomorskii was described by Bielecki in 1997. To date, only two specimens of this species have been recorded, both on the fins of brown trout (*Salmo trutta fario* L.) collected in the Wołczennica River which has a direct connection with the Baltic sea (Bielecki 1997).

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