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The impact of material and mesh size on the selectivity of deep-sea cod gillnets

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Abstract. This paper presents the results of investigations which were carried out in the Baltic Sea in 1994 - 1995. The results show that cod length in catch depends on mesh sizes rather than on the type of gillnet material. With mesh sizes of 45 mm (bar length) the average cod length in the catch was 41 cm, while with a mesh size of 65 mm, the average cod length was about 53 cm. The results of the investigation show that gillnets are characterized by very good selectivity; this is confirmed by the selectivity coefficients that range from 3.9- 4.5. The by-catch of undersized cod specimens was usually low for all analyzed gillnets. Most important, fishermen accept the present allowable mesh size of 105 mm (mesh opening) in the cod gillnets and this mesh size is sufficient to protect the cod of a total length of over 35 cm.

Key words: cod gillnets, cod selectivity, set gillnets, cod catches

INTRODUCTION

It must be emphasized that investigations of gillnet selectivity were initiated by Baranov (1948) at the beginning of the twentieth century, and extensive cod gillnet selectivity investigations were carried out in the Baltic during the last decade of that century. During this period, many papers were published on cod gillnet selectivity including those written by Mentjes and Panten (2000), Zaucha *et al.* (1993), Wileman *et al.* (1999) and Anon. (1999).

Seasonal coastal cod gillnet fishery in the shallow Polish coastal waters was common long before the twentieth century, but off-shore cod gillnet fisheries started in 1987 after several fishermen from the west and central coasts salvaged some gillnets. At first, the cutters were not equipped for this type of fishery in deeper waters, and in the beginning not more than a hundred gillnets were used. The fishermen formed an excellent opinion of the new system, and the first purchases of them were made in Bornholm the following year. In 1989, the first fullymechanized cod fishing gillnet line was purchased and installed on a 24 meter B-25s cutter. This equipment was the same as that used by Danish fishermen in Baltic cod fishery. Additionally, modern navigational equipment was also installed in the wheelhouse of the cutters. If one takes into consideration the fact that cutter modernization and the addition of the gillnet systems, in addition to the existing trawl capabilities, was carried out with financing from Danish banks, it is no wonder that Polish fishermen took to modern net fishing techniques very quickly and efficiently. The modernization efforts were made principally by fishermen from the west and some parts of the central coasts. Fishermen from the east coast remained far more traditional.

Cod catches with gillnets are made by all types of Polish fishing vessels, including motor boats up to a length of 15 m operating mainly in the coastal areas and side cutters operating in off-shore areas (excluding stern cutters). The amount of cod caught using the gillnet technique versus the total amount of cod caught has varied significantly in recent years and has ranged from 30 to 50%. These relations have depended mainly on the fishing ground catch rates of the period.

The spontaneous introduction of the gillnet technique to Polish Baltic fisheries was not accompanied by any research; thus, after a relatively short period in use, several key questions were raised. Firstly, there was a need to determine the impact of the type of material and mesh size on the length of fish caught and on net selectivity. Were the three to six (parallel, polyamide filaments in the gillnets) filaments in multimonofilaments polyamide gillnets or the use of 0.15 mm diameter monofilament really the best solutions? It must be kept in mind, that up until this time coastal fishermen had been using similar gear, but usually it had been made of multi-filament twine.

It is worth noting here that the size of the net meshes required in cod gillnets was the same for trawl codends, although the shape of meshes and the mechanism for retaining fish is completely different in each case. In 1994-1995, the mesh opening was 105 mm (Anon. 1995), i.e. the mesh bar length was 55 mm in the gillnets, but not less than 50 mm. The increase of the mesh opening in the standard cod codend to 120 mm produced the question of whether the maximum gillnet mesh size should automatically increase to 60 mm bar length.

The main aim the research was to determine the dependence between gillnet mesh sizes and the average length of cod caught with them. It was also decided to investigate the application of thinner and more flexible netting than that used in standard gillnets. Although multimonofilament material was used, the thickness of the netting used to make the nets was decreased by half. The resulting decrease in gillnet stiffness was so significant that these gillnets could not be used with the standard mechanized lines used in the catch process. One of the devices, the net stacking machine, did not work efficiently and the gillnets had to be stacked manually.

MATERIALS AND METHODS

Investigations of cod gillnet selectivity were carried out during the commercial operation of a 24-meter B-25s cutter. As both the captain and his crew were interested in obtaining the best catch results, they ensured that the experiments were carried out at various fishing grounds which were the most abundant at the time.

Three experiments were carried out; the first was in March1994, the second in December 1994 and the third in January and February 1995. Each experiment lasted for a period of about a month and was performed as follows:

- during the first experiment, gillnets made of thin materials with 45, 50 and 55 mm mesh sizes were tested and compared with the standard sets with 55 and 60 mm mesh sizes. The thin gillnets were composed of three sets; the net with 45 mm mesh size consisted of 48 gillnets

(4 segments consisting of 12 gillnets each) and the remaining gillnets (mesh sizes 50 and 55 mm) consisted of 60 gillnets (5 segments of 12 each). The standard gillnet set consisted of two net sets with 55 and 60 mm mesh sizes; each set consisted of 72 gillnets (6 segments of 12). Changes were made in the relative positioning of the individual sets during subsequent releases.

- during the second experiment, standard gillnet sets of 50, 55, 60 and 65 mm mesh sizes were compared. Only the gillnet sets with 50 and 55 mm mesh sizes were entirely new and were being exploited for the first time. The sets with 55, 60 and 65 mm mesh sizes had already been exploited in the previous season for about 6 weeks. During the investigations, it was possible to compare data relating to the new and previously exploited 55 mm mesh sizes. For each assortment of gillnets the number of gillnets with 50 and 55 mm meshes was 60 (5 segments). The number of gillnets sets exploited for at least one season was as follows: 55 mm mesh – 144; (12 segments) 60 mm mesh – 36 (3 segments); 65 mm mesh – 12 (1 segment).

- in the third experiment, new gillnets with 50, 55, 60 and 65 mm meshes were exploited alongside used gillnets of 55, 60 and 65 mm meshes. The set of new gillnets with 50 and 55 mm meshes consisted of 60 nets (5 segments each), the one with 60 mm meshes had 36 nets (3 segments) and the one with 65 mm mesh size had 84 nets (7 segments). The set of previously exploited gillnets consisted of 84 gillnets (7 segments) with 55 mm mesh, 36 gillnets (3 segment) with 60 mm mesh, and 12 gillnets (1 segments) with 65 mm mesh.

More detailed information regarding the analysis of these three cruises is presented in Table 1.

The data presented in Table 1 reveals that in the first experiment data was collected from four thin gillnet releases, in which 672 nets were used and only one standard gillnet exposure of 144 nets was used. During the experiment concerning the thin gillnets, about 6,000 cod specimens were measured out of over 5 tons of fish caught (live weight). These investigations were carried out on the western, southern and northern slopes of the Słupsk Furrow.

In the second experiment, 14 gillnet releases were carried out, during which 4,368 nets were used, and 23,829 cod specimens were measured from the approximately 30 tons of fish caught during the cruise. The experimental catches were carried out mainly on the southern slopes of the Słupsk Furrow.

In the third cruise, 29 gillnet releases of a total of 10,788 nets were made. Slightly more than 35 tons of cod (live weight) were caught using the experimental gillnet set, and measurements of 27,809 fish specimens were taken. The catches were initially made in the Słupsk Furrow (22 releases) and then (7 releases) on the eastern slopes of the Słupsk Furrow.

				Fishing	Fishing	Number sh	oots with:	Effect	ivity	Number
Cruise	Month Year	Net type	Number of shoots	grounds squares	depth [m]	segments	nets	boxes ^a numbers	live weight [kg]	of cod measured
Ι	March 1994	thin	4	J,K,L,M -7,8,11	30-50	56	672	177	5.310	5,838
	Dec		1	M-11	30-35	12	144	13	390	421
П	1994	standard	14	K,L,M-8,9	35-60	364	4,368	988	29.64	23,829
	Jan. Febr.	stanuaru	29	N,O-9	50-60	283	3,396	1,174	35.19	27,809
Ш	1995			P-12	65-85	899	10,788			

Table 1. Research cruise data

^aeach box contains 30 kg cod (live weight)

Two types of cod gillnets were used during the investigations:

- thin, multimonofilament gillnets made of polyamide netting with 0.08 mm thick filaments in three various mesh sizes. These gillnets had a standard mesh bar size of 45, 50 and 55 mm (bar length). They were purchased in Germany.

- standard multimonofilament gillnets made of netting in which the mesh bar consisted of four parallel polyamide filaments 0.15 mm thick; the standard mesh size in them was 50, 55, 60 and 65 mm.

Both the thin and standard gillnets investigated were made of netting produced with a double knot, which ensured the required knot stability. The basic mechanical gillnet factors are presented in Table 2.

Net type	Thickness of single twine [mm]	Change coefficient [%]	Mesh breaking resistance [daN]	Change coefficient [%]	Lengthening after mesh breaks [%]	Change coefficient [%]	Mesh bar thickness [mm]	Change coefficient [%]
Thin	0.08	1.62	2.48	6.45	7.18	6.0	0.21	1.55
Standard	0.15	1.37	10.35	5.31	5.99	4.93	0.43	1.83

Table 2. Basic mechanical properties of gill nets

Number of parallel twines = 4.

The data in Table 2 shows that the breaking resistance of the thin gillnets, whose filaments were two times thinner than those in the standard gillnets, was about four times lower than that of the standard nets. The thin gillnets were more flexible because the netting was thinner. Due to their mechanical features, mainly low resistance, these nets cannot be recommended for commercial cutter catches.

All of the types of cod gillnets imported from Germany or Denmark had actual mesh sizes in accordance with standard values that were within acceptable limits. The standard values were rarely exceeded and had little impact during exploitation. The mesh bar lengths for all the types of gillnets investigated, both new and those used in the investigations, are given in Table 3.

All the gillnet types, independent of mesh size, were mounted on an upper rope with a hanging factor of 0.5. Thus, with a constant number of meshes in the netting, 1,000 in each case, the length of the upper rope varied with different types of cod gillnets. The bottom line was a bit longer because the netting was mounted on it with a hanging factor of 0.54. The height of the gillnets was 25.5 meshes; the real height varied with netting mesh size.

The nets were equipped with expanded plastic floats on the upper rope and lower lead line which uniformly weighted down the bottom rope. In general, the materials applied and the construction of cod gillnets used in the investigations were similar to those used by Baltic fishermen.

The basic material for the investigations consisted of cod length samplings obtained during catches with different types of gillnets. In principal, all the fish from the gillnets were measured. The measurements were made using a measuring board and were rounded down to the nearest centimeter. The measurements of fish caught with particular gillnet types were added up in each experiment separately. The total length sets for cod were then processed by computer which yielded the following information:

- average, weighted fish length;
- graph of fish length distribution (%) in a selected set.

			45	mm			50	mm					55	mm			
			ne	w			ne	w	-		ne	w			us	ed	
ruise	et type	before investigations	change coefficient	after investigations	change coefficient												
Ū	Ž	mm	%	mm	%												
14	thin	45.6	0.88	46.1	1.24	51.5	0.87	52.0	1.28	56.4	1.26	56.5			•	•	
5/I														55.7	0.76	55.7	0.82
II/94	standard					50.1	0.64	50.9	0.74	55.2	0.65	55.7	0.91	55.8	1.02	56.2	1.12
III/95						50.2	0.54	51.1	0.87	55.2	0.77	55.9	0.99	56.0	0.96	56.4	1.09

Table 3. Variations of mesh bar lengths in various types of cod gill nets

			60 mm										65	mm			
			ne	ew			us	ed			ne	ew			us	ed	
ruise	et type	before investigations	change coefficient	after investigations	change coefficient												
Ü	Ž	mm	%	mm	%												
14	thin																
5/1						61.9	0.86	62.0	0.95								
II/94	standard					62.0	0.89	62,0	0.95					67.3	0.77	67.2	0.69
III/95		60.4	0.64	61.2	0.58	61.9	0.79	62.1	1.03	65.4	0.66	66.9	0.76	66.9	0.57	67.1	0.82

These data constituted material for the discussion on the impact of mesh size and material type on the length of cod caught. Using the data obtained for each type of gillnet, the following coefficients were determined:

- selectivity coefficient;
- the share of undersized fish retained, i.e. cod up to and including 34 cm.

The selectivity coefficient F_s was determined from a generally applied formula:

$$F_s = \frac{L}{2a}$$

where:

- L average, weighted length of cod caught in a selected type of gillnet,
- a average mesh bar size in a selected type of gillnet, determined while the net was wet at the end of the experiment.

The degree of undersized fish retained S_{z} in % was determined as follows:

$$S_z = \frac{b}{B} \ 100 \ [\%]$$

where:

b – number of cod (up to and including 34 cm),

B – total number of all cod in a selected set.

The investigations of material characteristics of the following basic mechanic properties of the analyzed gillnets were determined:

- breaking resistance of mesh,

- lengthening up to mesh bar breaks,

- thickness of the mesh bar and filaments,

- mesh size.

All the parameters were determined on wet gear, i.e. on gillnets that had been in the water for a period of at least 24 hours. The mesh size was determined aboard the ship, directly after the gillnet had been hauled in.

Breaking resistance and lengthening were determined in accordance with the Polish regulatory standard as described in Blady and Zaucha (1973). The thickness of the mesh bar and of particular filaments were established using methods and devices also described in detail in Blady and Zaucha (1973).

The gillnet mesh sizes were determined using a millimeter ruler. Several meshes (a maximum of four) were stretched manually along the ruler by applying slight force until they were straight. In practice, the result reflected the distance between the centers of two knots on either end of the mesh bar. This method provided fully repetitive results with the cod gillnets.

Each result was the average of at least 30 unit measurements, the distribution of which was characterized by the variability coefficient.

RESULTS AND DISCUSSION

During the three experiments, data were collected concerning five different types of gillnet meshes between 45 to 65 mm at 5 mm intervals. Three of these mesh sizes were made of thin materials, and four of them were made of standard materials. Therefore, it was possible to compare the fishing ability of gillnets made of various twine thicknesses, but of similar mesh sizes. Throughout the investigations, specimens representing 17 length distribution classes were obtained and the average lengths of fish caught were determined (Table 4). The percentage frequency of particular cod length classes for gillnets of various mesh sizes was also plotted. Due to the constraints of the current paper and with regards to the discussed relation of caught cod length and mesh size as well as the materials used in the gillnets, only nine of the most characteristic of these 17 classes are presented (Figs. 1-2).

Figure 1 presents the length distribution (%) of cod caught with thin gillnets with 45, 50 and 55 mm meshes (cruise I) and with standard gillnets with 60 and 65 mm meshes (cruise II). All the plots in Figure 1 are similar in character although their maximum peaks move towards the x axis as mesh size increases. However, for the same mesh sizes the maximum curve peaks

Continu	Month,	45 mm 50 mm		55	mm	60	mm	65 mm	
Cruise	Year	new	new	new	used	new	used	new	used
Ι	March 1994	40.99	44.76	46.56	46.29		48.28		
II	Dec. 1994		42.49	46.36	46.02		48.53		53.14
III	Jan/Feb.1995		43.48	44.59	45.34	48.85	48.30	52.28	52.18

Table 4. Average length of cod caught with various gill net mesh sizes

which belong to both thin gillnets and the standard gillnets are almost the same (Table 4). This means that, independent of twine thickness, gillnets with the same mesh size caught cod of the same sizes.

During cruise III, research material was collected with 55, 60 and 65 mm meshes, which were characteristic for the entirely new gillnets being used for the first time in catches and gillnets which had already been used at least once in the previous fishing season (Fig. 2). This figure presents four plots which were selected as the most characteristic for the investigated dependence. They reveal that after one exploitation season, the picture of the length distribution (%) of cod caught by a fixed mesh size was generally the same. It was, however, revealed that there is a certain, constant tendency for the exploited gillnets to capture a greater number of smaller cod specimens. This tendency was confirmed by other parameters which characterize the relation between mesh size and fish length in terms of the new and exploited gillnets. The clear decrease of the frequency which characterizes classes that form the peak for mesh sizes 65 mm versus 55 mm is also interesting.

This is probably concerned with the better fit of the 55 mm mesh to the actual cod length composition in the exploited fishing ground than that of the 65 mm mesh. For the latter, the number of length classes of relatively high frequency is higher than with the 55 mm mesh, for which the peak of the most numerous length classes was much higher than with the 65 mm mesh.



Fig. 1. Length distribution (%) of cod caught with new gillnets with mesh bar sizes of 45, 50, 55, 60 and 65 mm.



Fig. 2. Length distribution (%) of cod caught with new and exploited gillnets with mesh bar sizes of 55 and 65 mm.

The general character of these graphs was the same. They had one mode, and were characterized by a clear peak, which usually reached its maximum equal or close to the average length of cod specimens caught in a particular type of gillnet. Keeping in mind Wileman and other scientists' (Mentjes and Pantene 2000) considerations of the character and means of cod capture using gillnets, it must be emphasized that the means of capturing cod in the investigated gillnets was both qualitatively and quantitatively the same. This was confirmed by numerous observations made during the experiments. The fish were most often caught when they were encircled by the mesh at the point of their body's greatest girth. The fish were also caught when they became entangled in the gillnet, and, although this could be significant, its occurrence on a large scale was never observed. Therefore, the data sets collected were fully comparable with each another since in all the experiments the impact of the gear on the fish (and vice versa) was always the same. Thus, the average weighted cod length was used in calculations of the selectivity coefficient since it reflects the relation between mesh size and fish length as well.

The comparison of thin gillnets and standard gillnets with the same mesh size and within the range of average cod lengths (Table 4) leads to the conclusion that the differences determined were actually very small. Basically, both types of gillnets with the same mesh sizes catch cod of the same length. This is even more clearly illustrated by the selectivity coefficients (Table 6) that are similar for both types of gillnets. The only significant difference is that the thin gillnets capture almost three times more undersized cod specimens (Table 7). Still, in practice, this is a low figure.

In summary, it can be stated that the twine thickness used had a slight impact on gillnet exploitation behavior and the selection of cod specimens. Similar conclusions were reached by Wileman *et al.* [1999].



Fig. 3. Relation between fish length and mesh size in cod gillnets.

The cod gillnet mesh size had an decisive impact on the length of the fish it caught. This is well illustrated by the data in the Table 4. In order to present this relation even more distinctly, the plot in Figure 3 presents the dependence of the average length of cod specimens caught in gillnets of particular mesh sizes. These data reveal that during the experiments and depending on the mesh size used, the average cod length varied from 41 cm (in mesh size 45 mm) to 52-53 cm (in mesh size 65 mm).

This relationship is more precisely presented by the data in Table 5, where the differences in lengths of cod specimens caught are recalculated to the standard mesh size. These data reveal that every mesh size catches cod specimens of a specific length. The differences in the average lengths of cod specimens caught using a given mesh size were relatively small (about 2%) in the different experiments. These data also revealed a certain tendency towards changes of the length of fish caught as gillnets are used in subsequent seasons. The length of fish caught gradually decreased most often by about 1 cm after one fishing season. The data in Table 5 reveal one more significant relation; an increase of mesh size by 5 mm resulted in the increase of average cod length by about 2.5 cm when mesh size is increased from 45 and 50 mm, by 3.0 cm when increasing from 50 to 60 mm, and by 3.5 cm from 60 to 65 mm. This dependence is presented as follows:

 $y = c \cdot e^{d \cdot x}$ (correlation coefficient r = 0.9992)

where:

x – length of the mesh bar

y – average length of cod specimens.

This formula facilitates the determination of the average cod length for each mesh size in the investigated types of gillnets (same material characteristics and construction).

The measure of the quality of the selectivity of the various types of gillnet is the value of the selectivity coefficient presented in Table 6. The data in Table 6 reveal that gillnets are characterized by very good selectivity; this is confirmed by the selectivity coefficients that range from 3.9-4.4 (Baranov 1948). The highest value (almost 4.5) was obtained for the smallest mesh investigated. The selectivity coefficient was slightly lower with larger meshes, however, for all the gillnets investigated it remained at about 4.0. After the gillnets had been exploited for one season, either no decrease in the selectivity coefficient was observed or its value changed just slightly (by about 2.5%).

The evaluation of the selection quality of any type of gillnet is influenced by the number of undersized fish caught which should be fully able to escape from the fishing penetration zone of a given type of fishing gear. Therefore, the share of undersized fish in catches was estimated for each gillnet type (up to and including the length of 34 cm). The data are presented in Table 7.

These data reveal that the degree of capturing undersized cod specimens was usually low for all analyzed gillnets. However, it was significantly higher for thin gillnets than for standard gillnets. In the case of the former the figure was 3.18% and for the latter (standard nets in first use) it was 0.89%. Only gillnets with 65 mm meshes were different and their result was 0.52%. Since the data base for this mesh size was large and these gillnets were exploited in two different fishing grounds, the degree of undersized fish retention was determined for each fishing ground separately. For deeper fishing grounds, located on eastern slopes of the Słupsk Furrow, this figure was 0.77%, and, thus, it was consistent with the values determined for other types of gillnets. In the case of gillnets which had already been exploited in the previous season the average degree of undersized cod capture equaled 1.51%, or an increase of about two times in relation to the new gillnets.

Summarizing this research, it can be concluded that cod gillnets are among the most selective types of fishing gear. This results mainly from the mechanism of fish capture in gillnets, namely that in order to be captured, the fish's body must fit snugly in the mesh. Until other circumstances change this rule, the gillnets catch the average Baltic cod length which was obtained in the analyzed catches using different mesh sizes.

Unfortunately, this fishing gear is expensive and labor intensive. Therefore, when trawl catch rates increase, most cutter fishermen will stop gillnet fishery and return to trawls. Thus, when the CPUE decreases for both types of gear, it will only be possible to increase the effort in gillnet fishery by increasing the number of gillnets.

One very positive point is that fishermen accept the allowable mesh size (bar length) in gillnets, which is 55 mm or sometimes only 50 mm. Both these mesh sizes are good at protecting cod specimens up to 35 cm or even 38 cm in length, the IBSFC recommended length for Baltic cod. Therefore, gillnets are much better in comparison with trawls.

The only question which remains to be answered with regards to gillnet fisheries is the growing problem of the apparent by-catch of undersized fish (according to this source, it is approaching 15% or more). This issue may be the reason why certain groups of fishermen are opposed to giving gillnets proper grading with regards to the protection of juvenile specimens during gillnet catches.

	6 6		e						
Craviaa	Month year	45 mm	50 mm	55 mm		60	mm	65	mm
Cruise	Montin, year	new	new	new	used	new	used	new	used
Ι	March 1994	40.6	43.6	46.1	46.1		47.7		
П	Dec. 1994		42.4	46.2	45.7		47.7		51.1
III	Jan/Feb.1995		43.4	44.6	44.9	48.5	47.4	52.0	50.8
	Average	40.6	43.1	45.6	45.6	48.5	47.6	52.0	51.0

Table 5. Differences in caught cod length recalculated for the standard mesh bar length

Table 6. Selectivity coefficient for various cod gill net mesh sizes

Cruico	Nexthere a		50 mm	55	mm	60	mm	65 mm	
Cluise	Month, year	new	new	new	used	new	used	new	used
Ι	March 1994	4.45	4.30	4.12	4.16		3.89		
п	Dec. 1994		4.17	4.16	4.09		3.91		3.95
III	Jan/Feb.1995		4.25	3.99	4.02	3.99	3.89	3.91	3.89

Table 7. Percentage of undersized cod retained by various gillnet mesh sizes

Cruico	Month year	45 mm	50 mm	55	mm	60 mm		65 mm	
Cruise	Month, year	new	new	new	used	new	used	new	used
Ι	March 1994	2.34	2.95	4.24	1.34		4.06		
II	Dec. 1994		0.80	1.51	1.14		2.32		0.60
III	Jan/Feb.1995		0.50	0.60	0.85	1.04	1.20	2.52	0.60

REFERENCES

- Anon. 1995. Zarządzenie Porządkowe nr 1/95, Dyrektora Urzędu Morskiego w Słupsku z dnia 20 stycznia 1995 r [Regulation no. 1/95, Director of the Maritime Office in Słupsk from 20 January 1995].
- Anon. 1999. Size selectivity and relative fishery power of Baltic cod gillnets. EU report study contract no. 96/005.
- Anon. Fishery Rules of the International Baltic Sea Fishery Commission. Revised version following the 24th Session amendments.
- Baranov, F. J. 1948. Theory and assessment of fishing gear. [In:] Theory of fishing with gillnets. Chap. 7. Pishchepromizdat, Moscow. (translation from Russian by Ontario Dep. Of Lands, Marple, Ont.).
- Blady, W. and J. Zaucha 1973. Wyznaczanie podstawowych wskaźników metrologicznych materiałów sieciowych. Część I. Wskaźniki laboratoryjne [Determination of basic metrological indicators of netting. Part I. Laboratory indicators] Stud. Mater. Mor. Inst. Ryb., Gdynia, ser. C, nr 17: 116-118, 182-186.
- Mentjes, T. and K. Pantene 2000. Relative size and girth selectivity of cod gillnets in the western Baltic. ICES CM 2000/J: 12.
- Wileman, D., V. Tschernij, N. Madsen and R. Holst 1999. Size Selectivity and Relative Fishing Power of Baltic Cod Gillnets. [In:] Selectivity Research in Baltic Sea area, Sea Fish. Inst., Gdynia and Inst. Mar. Res., Lysekil, Gdynia, March 23-25, 1999: 110-148.
- Zaucha, J., W. Blady and W. Czajka 1993. Cod gillnets in the Polish cutter fishery. Bull. Sea Fish. Inst., Gdynia 3(130): 53-60.
- Zaucha, J., W. Blady, W. Czajka and W. Moderhak 1995. Studies of mesh size in cod gillnets with respect to protection requirements. Baltic Cod, Symposium, Gdynia, Poland March 21-22, 1995., IMR Report Lysekil, 327: 78-86.



The sexual maturation of mackerel icefish (*Champsocephalus gunnari* Lönnberg, 1905) from different regions of the Antarctic

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Abstract. The results of biological analyses of *Champsocephalus gunnari* Lönnberg, 1905 conducted aboard Polish vessels from 1975 to 1993 were used to investigate the maturation process, initial sexual maturity and spawning maturation cycle among the different stocks of this species in the Atlantic and Indian Antarctic sectors.

The diversity of the maturation process revealed in this paper confirms the separateness of stocks which were previously distinguished on the basis of other biological factors.

Key words: Antarctic, Champsocephalus gunnari, stock, sexual maturity

INTRODUCTION

The diversity of the water hydrology (Lutjeharms 1990) and sea bottom configuration of the Antarctic region impacts the distribution of ichthyofauna. These factors were used to divide the region into zoogeographical subareas and sub-provinces (Andriashev 1965, Eastman 1993), as well as into zones which differ in the degree of pack ice (Kock 1992). One of the few species which occurs on a mass scale in the Antarctic subarea is Champsocephalus gunnari Lönnberg, 1905 from the family Channichthyidae (Sosiński and Trella 2001). This endemic Antarctic species occurs around the islands in the Scotia Sea, in the northern part of the Antarctic Peninsula, and around the islands of Bouvet, Kerguelen and Heard (Iwami and Kock 1990). The wide range of occurrence of this species in diverse conditions caused the formation of local stocks that differ in certain biological characteristics. Kock (1981), Bengtson (1985) and Sosiński (1985) demonstrated the diversity of morphometric, meristic and biological characteristics. The diversity of the abundance of the 0- group was also demonstrated (North 1996), as was the degree of parasite infestation (Zdzitowiecki 1992, Kock and Möller 1977, Siegel 1980, Sosiński and Janusz 1986, 2000). The course of sexual maturation is one of the biological features which characterizes the stocks. Some data from investigations of C. gunnari sexual maturation that were conducted in different seasons and subareas were published by Kock (1981, 1990), Sosiński (1985), Kock et al. (1985) and Everson et al. (1996).

The aim of this paper is to supplement knowledge on the maturation of *Champsocephalus* gunnari Lönnberg, 1905 from separate stocks using the results of Polish investigations in six Antarctic subareas that were conducted over a period of 19 years.

MATERIALS AND METHODS

Atlantic Antarctic Sector

The material was sampled from the shelves of the Atlantic Antarctic sector surrounding the islands of the Scotia Ridge (in FAO-CCAMLR statistical subareas 48.1, 48.2, 48.3) and on the shelf of the Indian Ocean Antarctic sector surrounding the Kerguelen Islands in subarea 58.5.1 (Anon. 1990) (Fig. 1). The names of *C. gunnari* stocks were taken from the islands which they occur near:

Ι.



Fig. 1. Regions studied (Champsocephalus gunnari Lönnberg, 1905).

These islands are located to the south of the Antarctic convergence zone. Three of them, Shag Rocks, South Georgia in the Atlantic Antarctic sector and the Kerguelen Islands in the Indian Ocean Antarctic sector, are located in ice-free areas, while South Orkney Island, Elephant Island and South Shetland Island are located in the seasonal pack ice area (Kock 1992). The biological studies were carried out aboard the research ship R/v PROFESOR SIEDLECKI and on Polish fishing vessels. Fish were caught using bottom and pelagic trawls. A total of 14,768 specimens were subjected to ichthyological analyses in 1975-1993. The fish were measured to the nearest cm from the jaws to the end of the caudal fin (*longitudo totalis*), and maturity was determined macroscopically. Until the 1985-86 season, the gonad maturity stage was determined using the eight-degree Maier scale, while from 1986-87 to 1992-93, the five-degree Everson scale was used (1977). In this paper, the material was verified by assigning each fish a maturity degree from the five degree scale published by Kock and Kellermann (1991), which supplemented the Everson scale with a resting stage. The following presents the corresponding stages of gonad maturity of the Maier and Kock and Kellermann scales:

Maier Scale	Kock and Kellermann Scale (1991)
Ι	Ι
II	П
III	11
IV	Ш
V	111
VI	IV
VII	V
VIII	v v

Two concepts of maturity are used in the literature:

- sexual (gonad stage II-V)
- spawning (gonad stage III-V).

The length at which 50% of a given stock reaches maturity is the criterion that is applied and is denoted as follows:

- $-L_{50}$ for initial sexual maturity
- $-L_{m50}$ for initial spawning maturity (Kock 1989).

The lengths presented in this paper at which 5%, 50% and 95% (L_5 ; L_{50} and L_{95}) of the specimens reached sexual maturity (gonad maturity stages II-V) were determined from the following logistic curve equation:

$$p = \frac{1}{1 + \mathrm{e}^{-(\alpha + \beta L)}}$$

where p is the calculated proportion for fish in a given length class L, (L - longitudo totalis), while α and β are the equation coefficients (Everson *et al.* 1996). The degree to which the logistic curve fits the empirical data is described by the appropriate correlation coefficients (r).

In order to investigate the annual cycle of gonad maturation, juvenile specimens with gonads in stage I were excluded from the analyses and the remaining specimens with gonads in stages II-V were considered to be 100%.

RESULTS

Sexual maturation in fish consists of two stages; the first is achieving initial maturity, i.e. the juvenile stage, and the second is the periodic cycle of spawning maturation which usually lasts for one calendar year.

Juvenile (gonad stage I) and mature fish (gonad stages II-V) usually occurred together at the investigated fishing grounds.

The degree of gonad maturity and the percentage of the sexes in the studied population of *C. gunnari* are presented in Table 1. Although the percentage of the sexes in the samples varied, on average, males constituted 48.5% and females 51.5% of the studied population throughout the study period. Juvenile fish with gonads in stage I (immature) constituted from 0 to 85.9% of the studied sample at different times; the average for the entire study period was 16.2%. The magnitude of this group's contribution depended on fluctuations in generation abundance and time of year. The selectivity of the fishing gear was also significant. The largest number of specimens were in stage II (maturing virgin or resting), and included both those that were maturing virgins and resting after spawning. A significant portion of the study sample was comprised of maturing fish in gonad stage III (developing), while only a small contribution came from fish with gonads in stages IV (gravid) and V (spent).

Sexual maturity is reached by individuals at different lengths. This length is denoted as L_{50} for a population and it describes the length at which 50% of the population reaches sexual maturity (gonad stages II-V).

Figures 2-7 present plots of sexual maturity (a) and fish length distribution (b) that were used to calculate their parameters at the various fishing grounds. The parameters of these curves are presented in Table 2. Maturation, i.e. the transformation process of fish from the immature stage (gonad stage I) to sexually mature (gonad stages II-V), usually takes place within a narrow range of length classes. The section of the maturity curve between L_5 and L_{95} is steep, especially for females. At the fishing grounds studied, specimens began maturing at 11 cm and the process was complete by a length of 41 cm (Table 2).

The lowest values of L_{50} were observed for stocks from South Georgia in the Atlantic and the Kerguelen Islands in the Indian Ocean sectors of the Antarctic. Stocks which inhabit regions farther to the south in the Atlantic sector had a higher L_{50} . The L_{50} of the stock from Shag Rocks was slightly higher than that of the stock from South Georgia Island.

Females reached L_{50} at shorter lengths than males did in the majority of the stocks. Only in those from the Kerguelen Islands and South Shetland Island did females have a longer L_{50} value. The average length at which 50% of the specimens reached sexual maturity varied in different seasons. However, analyses of the stocks from the South Georgia, where the largest amount of material was collected over the longest period of time (1977-1993), indicate that L_{50} is maintained at a fixed level (Fig. 8).

A characteristic feature of various fish species, even of stocks of the same species, is the relation of L_{50} to the maximum specimen length which indicates the life cycle period when

Fishing	a	N d		Gonad r	naturity st	age		%	Ŋ
ground	Season	Month	Ι	П	Ш	IV	V	males : females	N
	1976/77	02	31.0	26.0	39.0	4.0		47.0:53.0	100
		03	40.0	26.0	33.0	1.0		45.0:55.0	100
Char	1978/79	01	4.0	70.0	26.0			43.0:57.0	100
Snag Rocks		03	19.0	26.0	53.0	2.0		27.0:73.0	100
ROCKS	1980/81	04		89.0	11.0			49.0:51.0	100
	1986/87	11	22.8	62.0	14.1	1.1		37.0:63.0	92
	1990/91	01	6.0	76.0	18.0			44.0:6.0	50
	1976/77	01	0.5	46.8	52.7			54.2:45.8	203
		02		12.0	88.0			61.0 : 39.0	100
		03	2.0	3.9	82.8	11.3		56.4 : 43.6	204
		05	19.6	42.3	12.4	17.5	8.2	50.5 : 49.5	97
	1977/78	09		99.0	1.0			73.0:27.0	100
		10		99.0	1.0			47.0 :53.0	100
		01	5.0	76.7	18.3			44.2 : 55.8	301
		02	1.0	49.0	50.0			48.0 : 52.0	100
		03	8.5	6.0	85.5			42.0:58.0	200
		04	5.3	9.7	81.3	3.7		21.7:78.3	300
	1978/79	11	1.0	99.0				47.0:53.0	100
		12	16.5	77.0	6.5			52.5 : 47.5	200
		01	1.0	85.0	13.0	1.0		49.0:51.0	100
		03	0.4	47.9	50.1	1.5		52.3:47.7	459
	1980/81	10	2.0	77.0	21.0			57.0:43.0	100
		11	2.3	81.7	16.0			49.0:51.0	300
		12	1.7	88.0	9.7	0.7		43.3 : 56.7	300
South		01		83.0	17.0			56.3 : 43.7	300
Georgia		02		63.0	36.5	0.5		58.5 : 41.5	200
e		04	70.0	30.0				32.0:68.0	50
	1981/82	11	7.0	84.0	8.0		1.0	47.0:53.0	100
		12	29.8	68.9	1.3			46.5 : 53.5	299
		01	6.0	80.0	14.0			44.0:56.0	100
		02	3.0	53.0	43.0		1.0	38.0:62.0	100
	1983/84	11	51.0	49.0	0.0			51.7:48.3	300
		12	10.1	89.2	0.8			53.7:46.3	397
	1004/05	01	9.0	91.0	5.0	0.5		58.0:42.0	100
	1984/85	11	1.6	92.7	5.2	0.5	0.5	35.4:64.6	192
	1985/86	11	15.9	81.1	2.5	0.0	0.5	48.8:51.2	201
		12	20.9	72.8	6.0	0.3		49.5:50.5	301
	1096/07	12	32.1 45.0	58.9	8.4	0.7		48.8:51.2	297 429
	1980/8/	12	45.0	40.9	15.5	0.7		33.9:40.1	438
	198//88	12	10.3	0/.8	15.4	0.4		43.2:50.8	227
	1000/00	01	49.5	45.9	4.5	1.2	0.0	47.0.52.1	111 657
	1988/89	12	32.3	54.9	10.8	1.2	0.8	41.9:52.1	100/
	1990/91	01	51.5 77	02.5	1.2		06	33.3 : 00.7 27 2 : 62 9	4ð 156
	1002/02	01	/./	90.4 17	2.1		6.2	31.2:02.8	100
	1992/93	04	0.0.7	4./	5.1		0.5	43.0:30.3	120

Table 1. Sexual maturity of C. gunnari from different fishing grounds in the Antarctic (%)

Fishing				Gonad 1	naturity st	age		%	
ground	Season	Month	Ι	II	III	IV	V	males : females	Ν
	1976/77	03	38.5	46.2	15.4			46.2:53.8	13
	1977/78	02	24.5	71.0	4.4			46.4 : 53.6	563
			22.2	68.1	9.7			52.6:47.4	702
South	1978/79	12	1.3	98.7				57.9:42.1	299
Orkney		02		99.5	0.5			59.2:40.8	201
		03		43.0	57.0			52.0:48.0	100
	1979/80	02		59.5	40.5			46.0:54.0	200
	1983/84	12		97.2	2.8			% males : females 46.2 : 53.8 46.4 : 53.6 52.6 : 47.4 57.9 : 42.1 59.2 : 40.8 52.0 : 48.0 46.0 : 54.0 52.3 : 47.7 48.5 : 51.5 56.5 : 43.5 67.5 : 32.5 54.5 : 45.5 57.5 : 42.5 58.3 : 41.7 48.3 : 51.7 50.0 : 50.0 55.6 : 44.4 52.1 : 47.9 52.0 : 48.0 53.4 : 46.6 51.5 : 48.5 58.0 : 42.0 63.9 : 36.1 38.1 : 61.9 55.3 : 44.7 23.3 : 76.7 29.1 : 70.9 50.8 : 49.2 45.2 : 54.8	109
	1978/79	11		98.7	0.7	0.3	0.3	48.5:51.5	301
		12		98.0		0.5	1.5	56.5 : 43.5	200
		01		99.8	0.3			67.5:32.5	400
		02	16.5	82.5	0.5	0.5		54.5 : 45.5	200
		03	3.0	89.0	8.0			57.5:42.5	200
Elephant	1983/84	12		99.0	1.0			58.3:41.7	96
	1986/87	10	58.3	36.7	2.8	2.2		48.3:51.7	180
		11	37.5	51.8	5.4		5.4	50.0 : 50.0	56
		02	78.8	7.1	14.1			55.6:44.4	99
	1987/88	02	34.9	63.7	1.4			52.1:47.9	146
	1988/89	01	70.0	26.0	3.0	1.0		52.0:48.0	200
	1978/79	01	16.5	83.5				53.4:46.6	103
Couth		02	1.0	73.2	25.4	0.3		51.5 : 48.5	299
South Shetland		03		55.0	45.0			58.0:42.0	100
Shetland	1979/80	02		34.4	65.6			63.9:36.1	61
	1986/87	02	4.8	71.4	23.8			38.1:61.9	21
	1974/75	04	16.5	39.7	43.8			55.3:44.7	655
Varaualar	1977/78	12	5.0	95.0				23.3:76.7	60
Islands		01	5.5	92.7	1.8			29.1:70.9	55
15141103		02		100.0				50.8:49.2	240
	1979/80	12	35.2	64.8				45.2:54.8	301

Table 1. continued

Table 2. Parameters of logistic curves for male and female C. gunnari in Antarctic fishing grounds

Fishing ground	$\begin{array}{c c c c c c c c c c c c c c c c c c c $		T	$L_{50}/L_{\rm max}$						
Fishing ground	Sex	α	β	L_5	L_{50}	L_{95}	n	r	$L_{\rm max}$	(%)
Shaa Daala	males	-5.15	0.20	11.3	26.3	41.4	267	0.69	40	65.8
Shag Kocks	females	-14.56	0.66	17.7	22.2	26.7	375	0.90	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	
South Coorgia	males	-17.24	0.73	19.5	23.5	27.6	3848	0.99	60	39.2
South Georgia	females	-17.68	0.86	17.2	20.6	24.0	4120	0.99	59	34.9
South Onlynov	males	-11.54	0.39	21.8	29.3	36.8	1129	0.98	49	59.8
South Orkney	females	-30.32	1.22	22.4	24.8	27.2	1058	0.95	46	53.9
Elanhant	males	-8.40	0.29	18.6	28.7	38.7	1159	0.95	52	55.2
Elephant	females	-11.39	0.42	19.9	26.9	33.9	919	0.98	50	53.8
South Shotland	males	-33.42	1.27	24.1	26.4	28.8	314	0.99	98 49 59.8 95 46 53.9 95 52 55.2 98 50 53.8 99 56 47.2	
South Shettahu	females	-44.25	1.54	26.8	28.7	30.6	270	0.99	53	54.2
Kargualan	males	-49.55	2.17	21.4	22.8	24.1	650	0.85	40	57.0
Kergueleli	females	-64.27	2.61	23.5	24.6	25.8	1.4 267 0.69 40 65.8 6.7 375 0.90 40 55.5 7.6 3848 0.99 60 39.2 4.0 4120 0.99 59 34.9 6.8 1129 0.98 49 59.8 7.2 1058 0.95 46 53.9 8.7 1159 0.95 52 55.2 3.9 919 0.98 50 53.8 8.8 314 0.99 56 47.2 0.6 270 0.99 53 54.2 4.1 650 0.85 40 57.0 5.8 661 0.87 39 63.2	63.2		

1,00

0,50

0,00



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N 4

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[%]

Fig. 8. L_{s0} length of the C. gunnari stock from South Georgia Island in subsequent seasons of the study.

maturation is achieved. $L_{\rm max}$ was accepted as the length of the largest specimens in a given stock (Table 2).

The L_{50} to L_{max} ratio for both for males and females (39.2 and 34.9, respectively) was the lowest in the fishing ground near South Georgia. It was higher in other stocks and varied from 47.2 to 65.8 (Table 2).

In order to analyze the annual spawning maturation cycle, mature specimens with gonads in stages II-V were selected and considered to be 100%. Then the percentages of fish in particular stages were compared. The results are presented in Table 3. Data for particular months at different fishing grounds are the averages from different seasons of the studies. The gonads of the specimens studied were most frequently in stage II. During the Antarctic summer and autumn (January-April), the percentage of fish with gonads in stage III increased. This is especially apparent in the stock from South Georgia, where the greatest number of studies over a relatively long period of time were conducted. A relatively small number of mature fish (gonad stage IV) and spent fish (gonad stage V) were observed.

Figure 9 presents the average degree of gonad maturity for sexually mature fish (gonad stages II-V) by month. In the majority of the stocks investigated, study material was collected only during a few months of the year.

As mentioned above, the most representative material was collected in the fishing grounds of South Georgia. Figure 9 presents the plot of the annual maturation cycle of the stock in this location, and it indicates that the average degree of maturity of both sexes increases in the Antarctic summer and fall.

The study material that was collected facilitated the analysis of the annual maturation cycle with respect to fish sex and size, with the assumption that specimens smaller than L_{95} (27.6 cm for males and 24.0 cm for females) are usually spawning for the first time while specimens larger than L_{95} are spawning for a subsequent time (Fig. 10).

						Males								H	Temales				
Fishing ground	Month	Ι	п	Π	п	VI		٧		N	Π	I	Π	I	N	7	Λ		N
		%	8	%	8	%	δ	%	δ	۸,	%	8	%	8	%	ð	%	δ	٨/
	11	94,4		5,6						18									53
	01	54,3	19,3	45,7	19,3					59									84
Shag Rocks	02	61,9		38,1						21	27,1		64,6		8,3				48
	03	43,6	12,4	49,3	13,3	7,1	0,9			41	34,6	13,1	65,4	13,1					100
	04	91,8		8,2						49	86,3		13,7						51
	60	98,6		1,4						73	100,								27
	10	87,7	12,3	12,3	12,3					104	90,5	7,6	9,5	7,6					94
	11	94,5	5,9	5,5	5,9					391	93,7	6,0	5,7	6,0	0,1	0,3	0,5	0,8	598
Couth	12	89,1	9,4	10,4	9,0	0,5	0,5			<i>611</i>	92,3	8,8	7,5	8,5	0,2	0,5			949
Georgia	01	80,9	14,5	18,9	14,6	0,2	0,7			669	86,8	20,1	13,0	20,2	0,1	0,3	0,1	0,3	758
UCUIĞIA	02	48,1	23,9	51,6	24,2	0,4	0,5			457	57,6	29,9	57,6	29,9	41,2	30,4	0,5	I, O	484
	03	17,7	18,7	75,1	16,8	7,2	8,2			430	21,7	21,8	77,6	21,3	0,8	I,I			410
	04	20,3	0,3	30,2	30,2	9,5	9,5	40,0	40,0	68	47,0	39,0	53,0	39,0					247
	05	68,6		11,4		8,6		11,4		35	39,5		18,6		32,6		9,3		43
	12	100,								226	97,1	2,9	2,9	2,9					178
South Orkney	02	76,8	36,9	23,2	36,9					353	89,3	13,3	10,7	13,3					430
	03	54,2	38,8	45,8	38,8					268	78,4	5,5	21,6	5,5					378
	10	50,0				50,0				8	92,4		7,6						66
	11	92,0	7,3	0,3	0,3			7,7	7,7	159	89,9	8,I	7,1	6,5	0,3	0,3	2,6	2,0	177
Flanhant	12	100,								167	97,6	0,1	1,3	I,3	0,6	0,6	0,6	0,6	127
Livpitatit	01	87,9	I2,I	8,6	8,6	3,4	3,4			275	97,9	I,3	2,1	I,3					160
	02	73,9	33,4	26,1	33,4					157	82,9	23,3	16,7	23,6	0,5	0,6			117
	03	86,4		13,6						110	98,8		1,2						83
	01	100,								41	100,								45
South Shetland	02	42,5	22,4	57,5	22,4					198	79,8	I5,I	19,9	I5,I	0,2	0,3			179
	03	37,9		62,1						58	78,6		21,4						42
Karmalan	12	100,								98	100,								124
Islande	01	100,								8	100,								15
commen	02	9,66		0,4						269	99,3		0,7						141
	04	41,1		58,9						299	55,2		44,8						248

Table 3. Average percentage of specimens with gonads in stages II-V among mature C. gunnari from different stocks

Fig. 9. Average degree of gonad maturity for sexually mature *C. gunnari* (gonad stage II-V) in subsequent months of the study.

Analyses of the data indicated that at a given time males usually reach a slightly higher level of maturity than females do, and that larger fish, which are repeating the annual maturation cycle, mature faster than smaller fish, which are usually spawning for the first time.

The relatively lower average in April as compared with March may result from the fact that mature fish migrated to spawn outside of the fishing grounds. At that time, the relatively high maturity index of males longer than L_{95} was caused by the large percentage of spent specimens (gonad stage V) (Table 4) which had returned from spawning.

DISCUSSION

This paper analyzes fish maturation according to criterion of achieving initial sexual maturity (L_{50}) (gonad stages II-V).

The lowest L_{50} in the Atlantic Antarctic sector was recorded for the stock from South Georgia. Stocks located more to the south had a relatively higher L_{50} . Similar observations have also been made by other researchers (Kock 1981, 1990, 1992, Kock *et al.* 2000, Everson *et al.* 1996, Olsen 1955) (Table 4). Despite the fact that the fishing grounds are located in closeproximity to each other, L_{50} is slightly higher in the Shag Rocks stock than in that from South Georgia. In the Indian Ocean sector, the L_{50} for the stock from the Kerguelen Islands is

Fig. 10. Average sexual maturity of male and female *C. gunnari* in the fishing ground of South Georgia in subsequent months of the study.

similar to that from South Georgia, which was confirmed by both the current results and those of other researchers (Kock 1992, de la Mare *et al.* 1998). Kock (1989) reports that the results obtained by Duhamel also indicate that L_{m50} is similar for both stocks. The habitats of these stocks are located closer to the Antarctic convergence zone, their environmental conditions are similar and they both differ from those in which the more southerly stocks live.

The length at which initial sexual maturity is achieved in relation to maximum length is the shortest for *C. gunnari* from South Georgia (males – 39.2%, females – 34.9%). The same figures are quoted by Kock (1981, 1992) and de la Mare *et al.* (1998). It is interesting that the L_{50} to L_{max} ratio for fish from Shag Rocks is closer to that of the population located more to the south than that of the of South Georgia, as was the case with L_{50} .

According to Kock (1981), the $L_{\rm m50}$ is higher for males than females in stocks from South Georgia and South Shetland Island. Also Kock *et al.* (2000) reported higher L_{50} and $L_{\rm m50}$ for males than females from South Orkney Island and Elephant Island. In the stock from South Shetland Island, the males have a higher L_{50} while $L_{\rm m50}$ is higher for the females. In the majority of cases, the authors also observed higher L_{50} for males, with the exception of stocks from the South Shetland and Kerguelen Islands.

The authors observed the tendency of the L_{50} value in South Georgia stock to stabilize over a longer period of time. Similar observations were made by Kock and Kellermann (1991) with regard to L_{m50} .

When mature, the majority of fish species spawn annually. However, it was confirmed that some mature *C. gunnari* do not spawn in a given year (Sosiński 1985, Kock 1989, 1990, 1992, Everson *et al.* 1996, Everson *et al.* 2000). This leads to the conclusion that maturation is

Frozen zones	Zoogeografic	Island shelves			Indic	ators			
according to	zones according to			<i>L</i> ₅₀ [cm]		1	L_{50}/L_{max} [%]		Sour
Kock	Andriasheva [1965]	51101 V 05	٩	0 + 9	Ŷ	σ	م + ۵	ç	
			22.8		24.6	57.0		63.2	Sosiński & Trella (
		¥7 1		25.8 ^{<i>a</i>, <i>b</i>)}					Do lo Morro et al
	Indian Ocean Province	islands		27.3 ^c					} De la Male <i>el al</i> .
	TIOVINCE	isiands		25.0					Kock et al. [1985]
				24.2			52.0		Kock & Kellerman
Ico free zone		Shag Dooks	26.3		22.2	65.8		55.5	Sosiński & Trella (
ice-mee zone		Shag Rocks		23.7					Everson et al. [199
	G 4 G .		23.5		20.6	39.2		34.9	Sosiński & Trella (
	Province		22.6		22.0	34.8		33.9	Kock [1989]
	TIOVINCE	South Georgia		24.0					Sosiński [1985]
				23.3					Everson et al. [199
				24.0			39.0		Kock & Kellerman
			29.3		24.8	59.8		53.9	Sosiński & Trella (
		South Onlynov		32.0					Sosiński [1985]
		South Orkney	33.8		29.5				Kock et al. [2000]
Seasonal pack				35.0			54.0		Kock & Kellerman
		Elephant	28.7		26.9	55.2		53.8	Sosiński & Trella (
	Western Antarctic			32.0					Sosiński [1985]
ice zone	Province		32.0		31.4				Kock et al. [2000]
			26.4		28.7	47.2		54.2	Sosiński & Trella
		a 1	22.8		22.5				Kock [1981]
		South		32.0					Sosiński [1985]
		Sileualiu	32.1		31.3				Kock et al. [2000]
				35.0			54.0		Kock & Kellerman

Table 4. Duration of achieving sexual maturity among C. gunnari from the Antarctic

^{a, b}Gunnari Ridge fishing grounds – 1993 ^cShel Bank fishing grounds – 1997 Gunnari Ridge fishing grounds – 1997 a two-year-long process (Kock and Kellermann 1991). Spawning occurs in a relatively short period of time, varies in different years and for different stocks and depends on the environmental and feeding conditions in which the stocks live (Everson *et al.* 2000).

Spawning was observed in the fishing grounds of South Georgia and Shag Rocks mainly in March-May (Kock and Kellermann 1991, Olsen 1955, Kock *et al.* 1985, Everson *et al.* 1996, Everson *et al.* 2000, Sosiński 1985), but spawning was also observed to begin in February and end in June (Kock 1990).

In more southerly areas, i.e. South Orkney Island, Elephant Island and South Shetland Island, spawning was observed in May-July (Kock 1990, Kock and Kellermann 1991, Kock 1989), and usually occurred two or three months later than in the area of South Georgia (Kock *et al.* 2000; Permitin 1973; Kock 1992).

Two spawning periods were confirmed in the Indian Ocean sector. Spawning takes place as follows: subarea 58.5.1., the Skif fishing ground and the Kerguelen – Heard ridge in April-June; near the Kerguelen Islands in August-September; subarea 58.5.2. near Heard Island in August-September; Shell Bank fishing ground in April (Kock and Kellermann 1991, de la Mare *et al.* 1998, Duhamel 1987, Gherasimchook *et al.* 1998).

The results of the studies described in this paper, i.e. the average percentage of fish of a given degree of gonad maturity (Table 3) and the average degree of gonad maturity (Fig. 9) in particular months, indicate that near South Georgia the percentage of fish with developed (III) and mature (IV) gonads began to increase in December and reached its maximum value in March and April. Spent specimens (V) were also very common in the stock in April and May.

This trend in maturing to spawning confirms the results obtained by Everson *et al.* (2000) that were obtained by analyzing the percentage of large, active fish (active, gonad stage III and above) versus that of resting fish (gonad stage II).

The relatively smaller percentage of active fish in the present study may indicate that mature fish were in spawning grounds located in fiords or closer to the island coasts which were inaccessible to Polish fishing vessels or that the duration of this stage is much shorter.

It is difficult to determine the annual spawning maturity cycle of *C. gunnari* from other stocks because of either the brief study period or the small numbers of specimens. The relatively low average level of maturity (Fig. 9) also resulted from the inaccessibility of fishing grounds. The results of the current study correspond with those obtained by Lisovenko and Silyanowa (1980) regarding the more highly developed gonads of larger fish ($>L_{95}$) (Fig. 10).

The stocks of *C. gunnari* that were studied occurred under diverse hydrological conditions. The Shag Rocks, South Georgia and Kerguelen Islands are located in the area of the West Winds Drift, while Elephant Island and South Shetland Island are in the East Winds Drift zone. South Orkney Island is located in the zone where water masses from the East Winds Drift and the Weddell Sea mix (Lutjeharms 1990, Chłapowski and Grelowski 1978).

The diverse water masses that are characterized by different hydrological parameters influences the creation of biological features, including the process of sexual maturation, which differ slightly in the separate stocks of *C. gunnari*.

The diversity of *C. gunnari* stocks which occur throughout vast areas was also confirmed by the results of studies of other biological, morphometric and meristic features (Kock 1981, Bengtson 1985, Sosiński 1985). Stock diversity was also confirmed with regard to the magnitude of the 0-age group (North 1996), genetic parameters (Carvalho and Lloyd-Evans 1990) and the degree of parasite infestation (Zdzitowiecki 1992, Kock and Möller 1977, Siegel 1980, Sosiński and Janusz 1986, 2000).

REFERENCES

Andriashev, A. V. 1965. A general review of the Antarctic Fish fauna. Monogr. Biol. 15: 491-550. Anon. 1990. Stat. Bull. – CCAMLR, Vol. 1: 1-7.

- Bengtson, J. L. 1985. Review of Antarctic marine fauna. [In:] Selected Papers Presented to The Scientific Committee of CCAMLR 1982-1984 PART T, Hobart, S.C.-CCAMLR-II/B6/13. 1: 226.
- Carvalho, G. R. and D. P. Lloyd-Evans 1990. Pilot study of electrophoretic variation and stock structure in the mackerel icefish, *Champsocephalus gunnari*, South Georgia waters. CCAMLR, WG-FSA-90/10.
- Chłapowski, K. and A. Grelowski 1978. Hydrographic characteristic of krill ground Explored during the first Polish Antarctic Marine Research Expedition on r/v "Profesor Siedlecki". Pol. Arch. Hydrobiol. 25,3: 535-559.
- De la Mare, W.K., R. Williams and A. J. Constable 1998. An assessment of the mackerel icefish (*Champsocephalus gunnari*) off Heard Islands. CCAMLR Sci. 5 (1998): 79-101.
- Eastman, J. T. 1993. Antarctic fish biology. Evolution in unique environment. Academic Press Inc., San Diego.
- Everson, I. 1977. The living resources of the Southern Ocean. FAO Southern Ocean Fisheries Survey Program. Rome, GLO/50/77/1.
- Everson, I., K. H. Kock and G. Parkes 1996. Ovarian development associated with first maturity in three Antarctic channichthyid species. J. Fish. Biol. 49: 1019-1026.
- Everson, I., K. H. Kock and J. Ellison 2000. Inter-annual variation in the gonad cycle of the mackerel icefish. J. Fish. Biol. No 57: 103-111.
- Gherasimchook, V. V., V. N. Brodin, A. V. Kljausov, J. B. Rusello, P. V. Tishkov and N. B. Zaremba 1998. Brief Report of the Joint Soviet-Australian expedition of USSR FRV Profesor Mesyatsev to the Australian Fishing Zone around the Territory of Heard and McDonald Islands, May-August 1987. [In:] Selected Scientist Papers 1987. SC-CCAMLR-SSP/4, Hobart: 75-103.
- Iwami, T. and K.H. Kock. 1990. Channichthyidae. [In:] Fishes of the Southern Ocean. O. Gon & P.C. Heemstra (Eds.), I. L. B. Smith Institute of Ichthyology. Grahamston, South Africa.
- Kock, K. H. 1981. Fischereibiologische Untersuchungen an drei antarktischen Fischarten: *Champsocephalus gunnari* Lönnberg, 1905, *Chaenocephalus aceratus* (Lönnberg, 1906) und *Pseudochaenichthys georgianus*, Norman 1937 (Notothenidei, Channichthyidae). Mitt. Inst. Seefisch. Bundesforsch. Fisch.32: 1-226.
- Kock, K. H. 1989. Reproduction in fish around Elephant Island. Arch. Fish. Wiss. 39: 171-210.
- Kock, K. H. 1990. Reproduction of the mackerel icefish (*Champsocephalus gunnari*) and its implications for fisheries management in the Atlantic sector of the Southern Ocean. [In:] Selected Scientific Papers 1989. S.C.-CCAMLR-SSP/6. Hobart, Australia. S.C.-CCAMLR-VII/B6/16: 51-68.
- Kock, K. H. 1992. Antarctic fish and fisheries. Cambridge University Press. Cambridge, England.
- Kock, K. H. and H. Möller 1977. On the occurrence of the parasitic copepod *Eubrachiella antarctica* on some Antarctic fish. Arch. Fish. Wiss. 28: 149-156.
- Kock, K. H. and A. Kellermann 1991. Review of Reproduction in Antarctic notothenoid fish. Antarctic Sci., 3 (2): 125-150.
- Kock, K. H., C. D. Jones and S. Wilhelms 2000. Biological characteristics of Antarctic fish stocks in the Southern Scotia Arc region. CCAMLR Sci. 7 (2000): 1-41.
- Kock, K. H., G. Duhamel, J.C. Hureau 1985. Biology and status of exploited Antarctic fish stocks: a review. BIOMASS Scientic Series. No. 6. Cambridge, England: 1-143.
- Lisovenko, L. A. and Z. S. Silyanova 1980. The reproduction and fecundity of fish of the family Chaenichthyidae. [In:] An Ecological and Biological Description of Some Species of Antarctic Fishes. Moscow, VNIRO: 38-52 [in Russian].
- Lutjeharms, I. R. E. 1990. The oceanography and fish distribution of the Southern Ocean. [In:] Fishes of the Southern Ocean. I.L.B. Smith Institute of Ichthyology. O. Gon & P.C. Heemstra (Eds.), Grahamston, South Africa: 6-27.

- North, A.W. 1996. Population differentiation by size for 0-age-class *Champsocephalus gunnari* at Shag Rocks and South Georgia, CCAMLR subarea 48.3. Antarctic Sci. 8,1: 31-35.
- Olsen, S. 1955. A contribution to the systematics and biology of Chaenichthyidae fishes from South Georgia. Nytt Mag. Zool. 3: 79-93.
- Permitin, Y.Y. 1973. Fecundity and reproductive biology of icefish (fam. *Chaenichthyidae*) of the family *Mureanolepidae* and dragonfish (*Bathydraconidae*) of the Scotia Sea (Antarctica). Vopr. Ikthiol. 13 (2): 245-258 [in Russian].
- Siegel, V. 1980. Parasite tags for some Antarctic channichthyid fish. Arch. Fish. Wiss. 31: 31-35.
- Sosiński, J. 1985. Some data on taxonomy and biology of Antarctic icefish *Champsocephalus gunnari* Lönnberg, 1905. Acta Ichthyol. Piscat. 15, 2: 3-54.
- Sosiński, J. and J. Janusz 1986. The occurrence of the parasite *Eubrachiella gaini* Quidor, 1913 in the Antarctic fishes of the family Chaenichthyidae. Acta Ichthyol. Piscat. 16,1: 87-105.
- Sosiński, J. and J. Janusz 2000. Infection variability of the parasitic *copepod Eubrachiella antarctica* (Quidor, 1906) on fishes in the Atlantic sector of the Antarctic. Bull. Sea Fish Inst., Gdynia, 2(150): 25-41.
- Sosiński, J. and K. Trella 2001. Fish distribution on the shelves of the Atlantic Ocean Antarctic Area with respect to stock density. Bull. Sea Fish. Inst., Gdynia, 1(152): 45-76.
- Zdzitowiecki, K. 1992. Additional data on digenean infections of open sea fishes in South Georgia area. Acta Parasitol. 37 (4): 223-224.

The occurrence, food and size structure of smelt (*Osmerus eperlanus* L.) larvae in the Lithuanian part of the Curonian Lagoon

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Abstract. Smelt larvae were sampled twice a year either at the end of May or at the beginning of June and at the beginning of July from 1996 to 2000 in the Lithuanian part of the Curonian Lagoon. The share of smelt larvae in the ichthyoplankton of the Curonian Lagoon reached 18%, on average, at the end of May and at the beginning of June. Their density varied at different stations from 0 to 28.0 ind./m³. The highest smelt larva density was noted on June 3, 1997. At the end of May and the beginning of June, they mainly concentrated in the eastern part of the lagoon between Vente and Kintai (Fig. 1). At the beginning of July, smelt larvae were found only at several control stations, where their density did not exceed 0.2 ind./m³. A significant decrease in smelt larvae can be observed in the Curonian Lagoon during this month, as the majority of them have already migrated to the Baltic Sea. In 1998 the density of smelt larvae was lower at a depth of 0.5 m than at 1.5 m. Studies carried out repeatedly in 1999 did not confirm this tendency. Smelt larvae feed on zooplankton, mainly on copepods. However, correlation coefficients did not show a strong relationship between the density of smelt larvae and the biomass of zooplankton. At the end of May and at the beginning of June, the lengths of smelt larvae varied from 8.5 to 23.0 mm. At the beginning of July, the lengths of smelt larvae varied from 15.0 to 34.0 mm. The shortest mean length of smelt larvae was determined in 1996, while in 1998 it was the longest.

Key words: the Curonian Lagoon, smelt, larvae, density, distribution, length, zooplankton, food, spawning

INTRODUCTION

The Curonian Lagoon is the largest inland reservoir in Lithuania. It covers an area about 1610 km² (413 km² belong to Lithuania). The lagoon is connected with the Baltic Sea in the north by a narrow strait, and Lithuania's largest river, the Nemunas, flows into it from the south. Thus, the Curonian Lagoon is mainly a freshwater basin. The water salinity in the northern part of it can sometimes reach about 3 PSU but only when northerly and northwesterly winds prevail. The Curonian Lagoon is comparatively shallow water body; the deeper areas reach up to 5.8 m and the mean depth is 3.8 m (Kunskas 1978). Most of the pollution carried in by the Nemunas does not reach the Baltic Sea and stays in the Curonian Lagoon. Therefore, various ecological processes such as eutrophication, oxygen deficit formation, etc. are present in it.

The fish fauna in the Curonian Lagoon is composed of co-dominating freshwater and migratory fish species as well as marine fishes. In total, 36 fish species have been recorded in the Curonian Lagoon waters. From 15 to 20 fish species are usually found in commercial and experimental catches (Repečka *et al.* 1998). One of the main commercial fish species in the Curonian Lagoon is smelt.

The first reliable data regarding the fish resources and fishery in the Curonian Lagoon date from the end of the nineteenth century (Benecke 1881). Regular ichthyologic investigations in the lagoon have been carried out since 1949 (Maniukas 1959, Gaigalas *et al.* 1978, Gerulaitis *et al.* 1996, Repečka 1995, Gaigalas 2001). Precise knowledge of the larval period of fish, however, is still lacking. The international programme "Assessment and Monitoring of Costal Fish Resources" was begun in 1994 in the Curonian Lagoon to investigate ichthyoplankton (Repečka 1996, Repečka *et al.* 1996). In 1996, the first data about smelt larva density and distribution in the Lithuania part of the Curonian Lagoon were obtained (Žiliukiene 1998).

The aim of this article was to generalize the data from smelt larva studies in the Curonian Lagoon, to analyze in more detail smelt density dynamics, their horizontal and vertical distribution, size structure, relationship with zooplankton. Smelt resources were also evaluated based on of research data and commercial catches.

MATERIAL AND METHODS

Smelt larvae were sampled twice a year either at the end of May or at the beginning of June and at the beginning of July when weather conditions were favorable (sunny, average waves, southeastern wind) from 1996 to 2000 in the Lithuanian part of the Curonian Lagoon. Twenty-eight stations were selected for the studies (Fig. 1). The depth of the Curonian Lagoon at stations 4, 23 and 24 was about 4 m, at stations 3, 7 and 11 – about 3 m, at other stations – about 2 m. The studies were carried out every year at stations 13 and 16.

Gulf samplers are considered to be among the best for ichthyoplankton sampling (Aneer *et al.* 1992). The Gulf Olympia (Hildén and Urho 1988, Aneer *et al.* 1992) was used to catch smelt larvae. Two ichthyoplankton nets with 19 cm mouth opening diameter were attached at the same (0.5 m) or different (0.5 and 1.5 m) depths in front of the motorboat in order to prevent the effects of turbulent streams on the catches. The amount of water filtered through one ichthyoplankton net while towing at a speed of 0.55 m/s for 5 minutes was 4.5 m³. The Lithuanian part of the Curonian Lagoon is very shallow (1.5-2 m depths prevail), in places it is ranked with underwater vegetation and there are big stones on the bottom, therefore higher towing speeds at some investigated stations are dangerous. This towing speed was used for catching ichthyoplankton in the Curonian Lagoon in 1995 (Repečka 1996) and for catching fish larvae and juveniles in the Nemunas River (Stakenas and Svecevičius 1998).

The mesh size of ichthyoplankton nets varied from 90 to 500 μ (Aneer *et al.* 1992). It was attempted to catch fish larvae in the Curonian Lagoon with 300 μ mesh size nets. These ichthyoplankton nets appeared to be inefficient – large amounts of zooplankton were caught with it (Repečka 1996). Therefore 500 μ mesh size nets were used for catching smelt larvae.

Two samples were taken at every station. Samples from the same depth were joined together. In all, 84 samples were obtained. The extent of the annual investigations is presented in Table 1.

Fig. 1. Location of smelt larvae sampling stations in the Curonian Lagoon.

The material obtained was analyzed according to well-known and recognized biological methods (Kiselev 1969, Anon. 1974, Lange and Dmitrieva 1981).

The larva density is expressed as individuals per m³.

At the end of May and at the beginning of June of 1997-1999, simultaneously with the sampling of smelt larvae, samples of zooplankton were taken using an Apstein net. All the samples were collected in the upper 1-meter layer. The volume of filtered water was 31.4 liter. In all, 28 samples were obtained. Zooplankton was identified to the species level using standard references (Kutikova 1970, Manuilova 1964, Dussart 1967, 1969, Smirnov 1971). Biomass was assessed on the basis of body weight and length relationship (Balushkina and Winberg 1979).

Year	Date	Stations under investigations	Sampling depth [m]	Number of samples
1996	05.28; 07.03	6-10; 13-16; 29-30	0.5	18
1997	06.03; 07.05	1; 3-5; 7; 11; 13; 16; 29	0.5	16
1998	05.26; 07.08	12-13; 16-22; 29	0.5	18
1998	05.26	12-13; 17; 19; 21-22	1.5	6
1999	06.01	2; 12-13; 16-17; 23-28	0.5; 1.5	22
2000	06.02	12-13; 16-17	0.5	4

Table 1. The extent of investigations of smelt larvae in the Curonian Lagoon

Additionally, food contents in the alimentary canals of 25 smelt larvae collected in 1997-1999 were analyzed. The food organisms were identified to the genus level.

This paper also incorporates data on the water temperature in the Curonian Lagoon obtained from the Centre of Marine Investigations in 1996-1999 and commercial fish catches statistics compiled by the Department of Fish Resources of the Lithuania.

RESULTS AND DISCUSSION

At the end of May and at the beginning of June the share of smelt larvae in the ichthyoplankton of the Curonian Lagoon was 18%, on average. Their density varied at different stations from 0 to 28.0 ind./m³ (Table 2). The highest smelt larva density was noted on June 3, 1997. No smelt larvae were found in 2000.

Comparing the results obtained at the stationary stations 13 and 16 with the results obtained at other stations it has was revealed that at the end of May and at the beginning of June in 1996-2000 the largest accumulation of smelt larvae was in the eastern part of the Curonian Lagoon between Vente and Kintai.

At the beginning of July, smelt larvae were found only at several control stations, where their density did not exceed 0.2 ind./m³. A significant decrease in smelt larvae is observed in the Curonian Lagoon during this month, as the majority of them have already migrated to the Baltic Sea. The caches by beach-seine showed that in July the highest concentration of smelt is in the northern part of Lithuanian coastal zone of the Baltic Sea near Monciškes (Repečka *et al.* 1996).

According to Urho (1997) smelt larvae tend to occur more closely to the bottom especially during daytime. The vertical distribution of smelt larvae in different parts of the lagoon at the end of May 1998 and at the beginning of June 1999 is presented in Figure 2. In 1998, the smelt larva density was lower in the 0.5 m depth layer than at a depth of 1.5 m and constituted an average of 3.7 and 6.8 ind./m³, respectively. However, studies carried out repeatedly in 1999 did not confirm this tendency; of the 11 investigated stations, the smelt larva density was lower in the 0.5-m depth layer than in 1.5-m layer at only three stations. Their average density at the surface reached 2.2 ind./m³, while at the bottom it was 2.1 ind./m³. Since the meteoro-

1996.0	5.28	1997.	06.03	1998.	05.26	1999.	06.01	2000.	06.02
Station No	Density								
6	0	1	0.7	12	0.7	2	0	12	0
7	0	3	5.3	13	1.3	12	1.8	13	0
8	0	4	8.0	16	1.3	13	6.7	16	0
9	0	5	0	17	0.2	16	5.6	17	0
10	0	7	0.4	18	0.4	17	4.2		
13	2.3	11	1.7	19	0	23	0.7		
14	12.2	13	28.0	20	0	24	2.7		
15	3.7	16	25.2	21	0.2	25	0.9		
16	11.3			22		26	0.9		
						27	0.2		
						28	0.2		

Table 2. The density of smelt larvae (ind./m³) in the open part of the Curonian Lagoon at the end of May and at the beginning of June 1996-2000

Fig. 2. The density of smelt larvae in different depths layers of the investigated stations.

logical conditions were almost the same (sunny, average wavy motion, southeasterly prevailing winds) throughout the sampling period, more detailed investigations are needed in order to explain the different results obtained.


at different stations of the Curonian Lagoon.

The biomass of all zooplankton species in the Curonian Lagoon at the end of May and at the beginning of June in the 1997-1999 period varied at the different stations from 0.17 to 9.60 g/m³ (Fig. 3). The zooplankton community composition included Rotatoris species such as *Keratella quadrata, Asplanchna priodonta, Kellicottia longispina, Brachionus calyciflorus* and *Euchlanis dilatata*, Cladocera species such as *Daphnia longispina, D. cucullata, Bosmina longirostris, B. coregoni, Leptodora kindtii* and *Chydorus sphaericus* and Copepoda species

Station

such as *Mesocyclops leuckarti, Eudiaptomus graciloides* and *Cyclops strennus*. The structure of the zooplankton community in the Curonian Lagoon was predominated by Cladocera and Copepoda in both abundance (44 and 32%, respectively) and biomass (56 and 33%, respectively). In the Vistula Lagoon (southern Baltic Sea) from 17 June to 30 July 1998 rotifers constituted more than 85% of the total zooplankton abundance (Margonski 2000).

Alimentary canal analysis revealed that in the Curoniain Lagoon at the end of May and at the beginning of June smelt larvae, the length of which was 15.5-23.0 mm, fed on zooplankton, mainly on *Daphnia* sp.,*Cyclops* sp. Copepods amounted from 72 to 100% of zooplankton organisms in the alimentary canals. In the Vistula Lagoon in June and July 1998 rotifers constituted up to 70% of prey organisms eaten by smelt (Margonski 2000).

The smelt larvae density dynamics and the biomass of all zooplankton species at various stations in the Curonian Lagoon are presented in Figure 3. According to some sources in the literature, the more abundant the zooplankton is, the more abundant fish larvae are in that area (Noskova 1972, Stakenas and Svecevičius 1998, Stakenas 1999). However, an inverse relationship also exists there (Pavlov *et al.* 1988, Griniene 1999). If some larvae have found an enormous patch of food, there are few larvae and a lot of food. However, when many larvae sometime gather at a similar patch and consume all the food, then there are many larvae and no food. The relationship of larvae and zooplankton may be dependent on how long the larvae have stayed there. The factor of food selectivity also affected most fish species (Werner and Hall 1974, O'Brien *et al.* 1976, Brooks 1968, Strauss 1979, Žiliukiene 1994, 1995). Therefore, the correlation coefficients did not show a significant relation between the density of larvae and the biomass of zooplankton in the investigated stations of the Curoniian Lagoon (1997 – r = 0.62, p = 0.10; 1998 – r = 0.50, p = 0.17; 1999 – r = 0.18, p = 0.58).

At the end of May and at the beginning of June, the length of smelt larvae varied from 8.5 to 23.0 mm (Fig. 4). The shortest mean length of smelt larvae was recorded in 1996 (14.3 mm), while in 1998 it was the longest (18.5 mm). In 1997 and 1999, their average length was 16.3 and 17.3 mm, respectively.

It is known that smelt spawn at a temperature of 4-6°C (Virbickas 1986). This temperature was registered at the end of March or at the beginning of April 1997-1999 (Fig. 5). In 1996, the water did not reach this temperature until the end of April. According to some sources in the literature, the abundance peak of spawning smelt occurred much later, on April 17 (Švagždys 1998). In addition, the smelt larvae caught in 1996 were smaller. Thus, on the basis of these data, it is possible to conclude that smelt spawning in 1996 occurred later than usual.

The size structure of smelt larvae caught in the Curonian Lagoon at the end of May and at the beginning of June of different years is shown in Figure 4. In 1998, five length classes were distinguished in 1996 and 1999 there were six length classes and in 1997 eight length classes. This suggests that the spawning of smelt in 1997 was prolonged. Water temperature is one of the most important abiotic factors that determine the course of spawning. In 1997, low water temperature (3.8-5.3°C) was prevalent throughout April (Fig.5), and the spawning of smelt extended for a very long period of time.

At the beginning of July, the length of smelt larvae varied from 15.0 to 34.0 mm. In 1996, 1997 and 1998, their average length was 30.8, 19.7 and 23.0 mm, respectively.

Figure 6 shows that the density of smelt larvae at the end of May and at the beginning of June was much higher in 1997 than in 1996 and 1998-2000.

It is established that no matter how abundant smelt reproducers, they may produce an abundant, average or weak generation (Švagždys 1998). However, in the last 25 years, large "parent stock" of smelt produced abundant year-classes twice more than low spawning popula-



Fig. 4. Length distribution of smelt larvae of the Curonian Lagoon and their length dispersion in different years.



Fig. 5. Water temperature of the Curonian Lagoon in March and April of different years.



Fig. 6. Average density of smelt larvae at stations 13 and 16 of the Curonian Lagoon at the end of May and at the beginning of June and the Lithuanian commercial catches of smelt in different years.

tion (Švagždys 1998). According to the literature, 4-year-old smelt are the largest part of the biomass of commercial catches (Švagždys 1998). Although the catches of smelt in 1998 and 2000 were larger than in 1996-1997, we can expect that in 2002 and 2004 the stock size of this species will be deficient since the density of smelt larvae in the Curonian Lagoon in those years was the lowest (Fig. 6). The density of smelt larvae and the commercial catches of this fish in 1999 show that their resources in 2003 will be average.

REFERENCES

- Anner, G., M. Blomqvist, H. Hallbäck, J. Mattila, S. Nellbring, K. Skóra and L. Urho. 1992. Methods for sampling and obsevation of shallow water fish. The Baltic marine biologists publication No. 13.
- Anon. 1974. Methodical manual on the research of fish nutrition and their nutritional relationships in natural conditions. Moscow [in Russian].
- Balushkina, E.V. and G.G. Winberg 1979. Relation between plankton animals body length and weight. General principles of aquatic ecosystems research. G. G. Winberg, Leningrad: 169-172 [in Russian].
- Benecke, B. 1881. Fische, Fischerei und Fischucht in Ost und Westpreussen. Havtungche Verlagsdruckerei, Königsberg.
- Brooks, J. L. 1968. The effects of prey selection by lake planktivores. Syst. Zool. 17 (3): 273-291.
- Dussart, B. 1967. Les Copepodes des eaux continentals d'Europe occidentale. 1. Calanoides et Harpacticoides. Ed. N. Boubee Cie, Paris.
- Dussart, B. 1969. Les Copepodes des eaux continentals d'Europe occidentale. 2. Cyclopoides et biologie. Ed. N. Boubee Cie, Paris.
- Gaigalas, K., A. Gerulaitis, R. Krotas, and J. Maniukas. 1978. Fish species and fishery Nemunas. Vilnius, 2: 91-150 [in Lithuanian].
- Gaigalas, K. 2001. Fish in the Curonian Bay basin, their resources and fishery. Egle, Klaipeda. [in Lithuanian].
- Gerulaitis, A., K. Gaigalas, R. Repečka, V. Valušiene, G. Rudzianskiene, T. Overkaite and D. Skripkaite 1996. The investigations of fish stocks and catch prognoses in the Kursiu lagoon and Nemunas delta. Fishery in Lithuania. Vilnius, II: 165-182 [in Lithuanian].
- Griniene, E. 1999. The influence of macrophytes on the spatial distribution of zooplankton in the littoral zone of the Curonian Lagoon. Animal ecology. Petro ofsetas, Vilnius: 4-5 [in Lithuanian].
- Hildén, M. and L. Urho. 1988. Sampling of larval European smelt: a factorial experiment. Am. Fish. Soc. Symp. 5: 123-145.
- Kiselev, L.V. 1969. Plankton in the sea and inland waters. Nauka, Leningrad [in Russian].
- Kunskas, R. 1978. Physico-geographical description of the Curonian Lagoon. Curonian Lagoon. Part. 1. Mokslas, Vilnius: 11-50 [in Lithuanian].
- Kutikova, L.A. 1970. Rotatoria of USSR fauna. Nauka, Leningrad: 744 [in Russian].
- Lange, N.O. and E.N. Dmitrieva. 1981. Methods of ecologicalmorphological research of the development of young fish. The studies of reproduction and development of fish. Nauka, Moscow: 67-88 [in Russian].
- Maniukas, J. 1959. Ichthyofauna, state of fish resources and fishery in the Curonian Lagoon. Pergale, Vilnius: 293-403 [in Lithuanian].
- Manuilova, E. F. 1964. Cladocera of USSR fauna. Nauka, Moskow: 327 [in Russian].
- Margonski, P. 2000. Impact of hydrological and meteorological conditions on the spatial distribution of larval and juvenile smelt (*Osmerus eperlanus*) in the Vistula Lagoon (southern Baltic Sea). Bull. Sea Fish. Inst., Gdynia, 3 (151): 119-133.
- Noskova, E.D. 1972. Causes determining the dynamics of abundance of smelt in the Curonian Lagoon. Works of the International Research Institute of Fish Industry and Oceanography. 83: 286-300 [in Russian].
- O'Brien, W.J., N.A. Slade and G. D. Vinyard 1976. Apparent size as the determinant of prey selection by bluegill sunfish (*Lepomis macrochirus*). Ecology. 57 (6): 1304-1310.
- Pavlov, D.S., V.N. Mikheev., M.V. Vasilev and L.Z. Pekhlivanov 1988. Nutrition, distribution and migration of fish from the water reservoir "Aleksandr Stambolijski". Nauka, Moscow [in Russian].
- Repečka, R. 1995. Investigations of the fish fauna in the Lithuanian part of the Curonian Lagoon. Coastal Conservation and Management in the Baltic Region. Petro-ofsetas, Vilnius: 117-123.
- Repečka, R. 1996. Assessment and monitoring of coastal fish resources. Lithuania. Assessment and monitoring of coastal fish resources in Estonia, Latvia, and Lithuania. Sweedmark Consultancy Report: 1-23.

- Repečka R., Žhiliukas V., Stankus S. 1996. The abundance of the fish larvae and fry in the coastal zone of the Baltic Sea and Kurshiu marios. Fishery in Lithuania II: 95-108 [in Lithuanian].
- Repečka R., G. Rudzianskiene, K. Gaigalas, L. Ložhys, S. Stankus and T. Overkaite 1998. The monitoring of commercial fish population structure and abundance in the Curonian Lagoon and the delta of the River Nemunas. Fishery in Lithuania III (I): 153-174 [in Lithuanian].
- Smirnov, N.N. 1971. Chydoridae of world fauna. Fauna of USSR. Crustacea, 1 (2): 531 [in Russian].
- Stakenas, S. 1999. Ecological characteristics of 0+ fish communities in the shore-zones of the middle Nemunas and the Neris rivers. Acta Zool. Lituanica 9 (I): 155-163.
- Stakenas, S. and G. Svecevičius. 1998. Ecological characteristics of fish larvae and juvenile communities in the middle Nemunas. Fishery in Lithuania III (2): 23-33 [in Lithuanian].
- Strauss, R.E. 1979. Reliability estimates for Ivlev's electivity index, the forage retio, and a proposed linear index of food selection. Trans. Amer. Fish. Soc. 108.
- Švagždys, A. 1998. The dependence of smelt abundance changes upon the effect of natural factors. Fishery in Lithuania III (I): 189-199 [in Lithuanian].
- Urho, L. 1997. Controlling bias in larval fish sampling. Arch. Hydrobiol. Spec. Issues Advanc. Limnol. 49: 125-135.
- Virbickas, J. 1986. Fish of Lithuania. Mokslas, Vilnius [in Lithuanian].
- Werner, E.E. and D.J. Hall 1974. Optimal foraging and the size selection of prey by the bluegill sunfish (*Lepomis macrochirus*). Ecology, 55 (5): 1042-1052.
- Žiliukiene, V. 1994. Peculiarities of feeding of pike and bream juveniles rearing in illuminated cages. Ecology, 3: 23-28 [In Russian].
- Žiliukiene, V. 1995. Zooplankton as one of the factors limiting growth and development of bream juveniles. Proceedings of the 32ND - 33RD sitting of the international working group. Lietuvos informacijos institutas, Vilnius: 35-40.
- Žiliukiene, V. 1998. Ichthyoplankton of Kursiu lagoon. Fishery in Lithuania III (I): 215-225 [in Lithuanian].



Morphomechanic changes during the embryogenesis of spring herring (*Clupea harengus* L.) in the Puck Bay

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Abstract. The study on enbryogenesis in the Baltic herring (*Clupea harengus membras* L.) shows the embryonic development to take, on average, 188 h (the duration measured in thermal units is to 2450 h°). Herring eggs are very small; when activated they absorb a relatively large volume of water, about twice the cell volume when laid. The hydrated eggs are highly diverse in size. The volume of eggs produced by a female may range from 0.97 to 1.95 mm³. The biological importance of the differences observed is discussed.

Key words: *Clupea harengus membras* L., reproduction, eggs, embryonic development, larvae, Baltic Sea, Puck Bay

INTRODUCTION

The Baltic herring (*Clupea harengus membras* L.) is a very interesting species for many reasons. Thanks to its high level of biological flexibility, this fish has found it possible to exist and reproduce in aquatic environments which are very diverse in terms of ecological factors, mainly salinity.

The herring reproduces with equal success in highly hypertonic oceanic waters, in much less saline semi-enclosed seas fed by extensive freshwater catchments and in estuaries (Nikolski 1970, Załachowski 1997).

Differences in the salinity of waters which herring inhabit have very little impact on their internal structure (Svetovidov 1949, Kryzhanovski 1956a, Nikolski 1970, Dushkina 1988). Independently of the diversity of environmental conditions, these fish retain a similar cross-section and shape and morphology of both external and internal structural elements. Their behaviour does not vary significantly either, nor do their feeding habits or food preferences, i.e. the principle features which describe the biology of the species are similar. The only relatively clear difference which can be detected is life-span and size and mass growth rates. These differences are greater among populations or breeds which inhabit saline waters and much smaller among those which inhabit brackish basins (Nikolski 1970, Załachowski 1997).

The literature on herring is rich and investigations date back over hundred years (Brook 1885; Blaxter 1960; Holliday and Blaxter 1960; Galkina 1968; Kosior and Strzyżewska 1979; Wawrzyniak 1987); this is principally due to the fact that these fish are commercially important and they are very palatable and nutritional. However, there are few reports dedicated to the early stages of their embryonic development. Mainly, variations in oxygen demand during embryonic development are addressed (Volodin 1956). Later, detailed studies of Atlantic herring include a detailed description of the embryogenesis of this species whose habitation conditions and, more importantly, reproduction conditions, namely increased water salinity, are different from those of Baltic herring. This may have an impact on the differences of egg size and the rate of developmental processes (Ojaveer 1981, Griffin *at al.* 1998, Hill and Johnston 1997).

As shown by the literature, the spring herring in the temperate zone begins spawning in warm seasons, predominantly in late May/early June, at ambient temperatures of 5–14°C. Herring lay significant numbers of eggs, up to 65,000, covered by an adhesive, gelatinous substance which helps the spawn to stick to solid elements such as rocks, rubble or underwater plants (Kupfer 1878, Kryzhanovski 1956a, Kosior and Strzyżewska 1979, Wawrzyniak 1987).

The eggs that are laid are unfertilized, small ($\phi = 0.86$ -1.01 mm – Volodin 1956, 1.2-1.5 mm – Kryzhanovski 1956a) and of a regular spherical shape. Their size increases by 40-50% from the moment of activation as it absorbs water (Kryzhanovski 1956a, Volodin 1956). Kryzhanovski (1956b) reported that Baltic herring eggs that were activated in waters with a five-fold higher salinity increase their volume identically to spawn incubated at 5‰. It is known that the hatching larvae are well developed, relatively large versus egg size and mobile due to the small-sized, longitudinal yolk sac.

The external features of morphogenesis are roughly known and do not differ from other teleost fish; however, the internal features which characterize the structure of the egg, the spatial distribution of the internal structures and the dynamics of morphological changes which comprise the whole of embryogenesis have not been very well recognized.

In this context, the findings reported by Hill and Johnston (1997) on microstructural changes during Pacific herring embryonic development, by Griffin *et al.* (1998) on the embryogenesis of the Baltic herring at different salinities and by Ojaveer (1981) on the temperature and salinity effects on Baltic herring embryonic development are all particularly elucidating. These findings allowed the relatively adequate identification and interpretation of a series of phenomena that take place during embryogenesis, such as, e.g., microscale structural processes, although these are not wholly indicative of causal relationships between the habitat and morphomechanics of embryogenesis in the full dynamics of the latter.

Earlier, long-term, studies of over a dozen species of freshwater teleost fish have shown that there were differences in both the spatial structure of eggs and the structural variations of embryonic development. These differences were revealed during the analyses of the transformations and morphomechanic phenomena during embryonic development, despite the abovementioned characteristic identity of different species. These differences are usually more significant and noticeable among distantly related taxa, however, they also occur among closely related species (Winnicki and Korzelecka 1997, Winnicki *et al.* 1998, Bonisławska *et al.* 1999, Tański *et al.* 2000). Therefore, it was of interest to follow the embryogenesis of herring, which is a marine fish, and to compare its development with observations of the development of freshwater fish. The principal aim was to try to find an explanation for the reasons for the morphophysiological differences which may occur, with a special focus on one ecological factor that differed from those of the freshwater fish, i.e. water salinity.

MATERIALS AND METHODS

The investigations were carried out in May and June 2000 in the field laboratory in Jastarnia on the Hel Peninsula.

Materials for studies consisted of reproductive material obtained from mature herring specimens caught in the Puck Bay where water salinity was approximately 5‰. The obtained spawn was fertilized using the dry method, placed in petri dishes and then incubated in sea water, which allowed for chemical and physical conditions which were close to those in nature. Maintaining a constant reproduction temperature that was appropriate for spawn development was achieved by placing the material in a temperature-controlled room. Embryo development took place at a temperature of $13\pm1^{\circ}$ C. Regular water exchange in the dishes assured the optimum oxygen conditions for the developing embryos.

Observations of the morphomechanics of embryonic development *in vivo* were carried out using two sets of apparatuses. Each of them included a microscope (Nikon objective $2\times$) coupled with a high resolution digital camera, a monitor, a video recorder and a computer. One set was used to get a picture of the egg from above, while the second set was employed to view the developing embryo from the side. This permitted detailed observations of the variations in the spatial distribution of various structures of the developing embryo (Winnicki and Korzelecka 1997, Korzelecka *et al.* 1998).

The measurements of eggs, egg cells (yolk sphere)^{*} and larvae were made using the above described tools. The picture obtained under the microscope (magnification×100) was registered on video tape and saved in a computer. Then, using Multiscan software, detailed measurements of the two diameters (the longer and shorter) of the eggs and egg cells were taken and averaged in order to derive the volumes ($V = 4/3 \cdot \pi r^3$). The use of two diameters in measurements was introduced by Bartel (1971) and it is sufficiently precise in calculations of the sizes of eggs and the internal egg cell. The measurements were taken from eggs in a sample of 100 eggs from one female.

The same method was used to measure the freshly hatched herring larvae (30 specimens), then their total length was measured (*longitudo totalis* – 1.t.), and the length (*l*) and height (*h*) of the yolk sac were measured. The volume of the yolk sac was determined from the formula for the volume of a prolate spheroid (Blaxter and Hemple 1963, Bermudes and Ritar 1999, Gisbert *et al.* 2000).

$$V = \pi/6 \cdot l \cdot h^2 \,(\mathrm{mm}^3)$$

where: l – yolk sac length (mm), h – yolk sac height (mm)

The duration of embryonic development was determined in hours; in addition, the duration of the entire embryogenesis was converted into thermal units, i.e., degree-hours (h°).

Excel and Statistica 5.1 software were used to statistically process the results of the studies.

[&]quot;The very idea of 'egg' needs to be clarified, as the term usually refers to the whole egg, i.e. the membrane, the perivitelline fluid and the egg cell (further referred to as the yolk sphere), irrespective of whether the last element is always smaller than the whole egg and it comprises only one part of the live egg.

RESULTS

Water absorption and the creation of the perivitelline space lasted for about two hours at a temperature of 12.8°C (Fig. 1; Fig. 2 a-c) and it was completed at the moment the first cell division occurred (Fig. 2e). At this moment, the perivitelline space constituted almost 70% of the volume of the swollen, hydrated egg.

The egg cells (yolk sphere) which were observed from the side retained their regular spherical shapes, and the diameters of eggs obtained from the same female were 0.78 \pm 0.024 mm ($\bar{x}\pm$ SD), with a volume of 0.25 \pm 0.022 mm³ ($\bar{x}\pm$ SD).

Herring eggs with their thin, transparent membranes, are covered by a adhesive, gelatinous substance which ensures that the eggs stick firmly to the substrate and that they cling together in an aggregation (Fig. 3). The shape of the eggs that comprise the aggregations are usually irregularly angular, while individual eggs retain their regular spherical shape.

The diameter of the swollen eggs of the Baltic herring was small at 1.31 ± 0.025 mm ($\bar{x}\pm$ SD) and the volume was 1.17 ± 0.067 mm³ ($\bar{x}\pm$ SD). However, there are significant, individual differences. The diameter of the smallest eggs from the same female was 1.23 mm, while that of the largest was 1.37 mm. The volume varied from 0.97 mm³ to 1.35 mm³, respectively; thus, the difference in the volume of the large and small eggs was almost 1.4-fold.

It was characteristic that size diversity, including egg size, was not reflected in the size of the egg cells (yolk sphere), covered by a thin layer of ectoplasma at the moment they are laid, and which are uniform in eggs of different sizes.

The reception mount is formed after about 1h 10 min. (15 h^o) from the moment of activation (Fig. 2d). The ectoplasma usually collects at the side in the equatorial zone of the egg. This side position in the egg is maintained throughout embryogenesis (Fig. 2e-i).

The course of embryogenic development, or the sequence of major structural changes from the activation of the egg cell until hatching, are presented in the photographs in figures 2a-l.

Embryonic locomotion follows a specific pattern, clearly visible on the videotapes made *in vivo*, which recorded the characteristic regularity of the primal plasmatic movements which occur directly after activation and lead to the creation of the germinal disk, to the first, very slow, range-limited somatic movements in the trunk portion of the body of the embryo, the frequency of which decreases as hatching draws nearer, up to the pulsation of the budding heart (63 h – 820 °h) and then the formed heart at approximately 83 h (1080 h°) (Fig. 4);

Larval sizes. The length of newly hatched larvae was diverse and varied from 4.86 to 6.32 mm, with an average of 5.59±0.52 ($\bar{x}\pm$ SD), while the average volume of the yolk sac, which decreased as larval length increased, was $v = 0.096 \pm 0.03 \text{ mm}^3$ ($\bar{x}\pm$ SD).

In addition to the important results above, the figures also present the following:

 unlike other teleost fish, herring egg cells (yolk spheres) are similar in size at the moment of activation and there is no correlation between their size and that of the egg, which is highly diverse;

- the lack of structural fat in the egg cell and also in the yolk allows the germinal disk to assume a side position which is the origin of the future structures of the specimen;

- the lack of red blood dye - hemoglobin - in the morphotic elements of the blood during embryogenesis;

the change in the yolk sac shape from a regular sphere until hatching to longitudinal, slightly flattened oval (Fig. 4) which resorbs very slowly (6-7 days, temp. 13.1°C);



- the relatively long hatching period of larvae from eggs of the same batch, lasted 47 h (614 h°);

- the larvae which are relatively long when they hatch are basically ready for active, independent life in the water (Fig. 2m).





Fig. 2. Embryonic development in herring:

a, b, c – formation of the perivitelline space; d – reception mount is formed – 1 h 10 min (15 h°); e – egg swelling process ends, the first cleavages appear (two blastomeres) – side view – 2 h (25 h°); f – beginning of the second cleavage – 2 h 30 min (33 h°); g – eight blastomere stage – 3 h 20 min (43 h°); h – fine cell morula – 6 h (80 h°); i – large cell morula – 10 h 30 min (130 h°); j – gastrula 2/3-3/4 - 14 h (180 h°); k – head is formed – 31 h (406 h°); l – clear metamerism of the embryo's body, lens visible in eye – 46 h 30 min (600 h°); m – herring larvae directly after hatching – 165 h (2150 h°).



Fig. 3. Gelatinous substance covering the egg membrane which allows the eggs to attach to the substrate and to each other to form aggregations.



Fig. 4. Somatic and cardiac movements of herring *Clupea harengus membras* L. larvae during embryonic development.

DISCUSSION

The results obtained provided a fairly complete picture of the morphomechanical changes which take place during the embryogenesis of spring-spawning Baltic herring; some of them, however, require additional discussion.

The first important issue is the size and shape of the perivitelline space, which is created after activation and which determines the egg size. The sizes of eggs differ significantly and, unlike other salmonids, the difference in the size of the entire egg does not depend on the size of the egg cell (yolk sphere) which is the same in every egg from a given batch.

The idea introduced by Zotin (1954) can be helpful in order to explain the mechanism which limits the size of the perivitelline space (amount of water absorbed by eggs). Zotin maintains that this mechanism involves only the increase of membrane resistance, which, following egg activation and hydration, also limits membrane plasticity. This explanation is acceptable since even small variations in the normal amounts of membrane-hardening enzyme released into the perivitelline space (Zotin 1961, Fisher 1963, Winnicki 1967b) may temporally shift the membrane hardening, while variations in the amounts of hydrophilous colloids responsible for water absorption (Bogucki 1930) can change the rate of water absorption. This may result in egg size variations. The above described mechanisms do not play a very important role in the egg development of other fish such as salmonids, for which the relative size and volume of the perivitelline space is relatively small and basically uniform, while the membranes themselves are structurally solid and far less flexible (Winnicki and Domurat 1964). The phenomenon of the egg size diversity should be connected with the primary structure and size of the membrane surface created during oogenesis, which, at the moment of laying, is clearly corrugated and stretches during the egg hydration period (Winnicki 1968).

This idea is supported by the unusually spacious perivitelline space of the herring egg (Fig. 2e). In other fish, this area constitutes less than approximately 20% of the hydrated egg,

especially among species which lay larger-sized eggs and whose egg cells (yolk spheres) just before and shortly after fertilization are also very diverse in terms of size and volume, which is reflected in the greater volume of the entire egg (Privolniev 1953, Kaj and Lewicka 1962, Steffens 1963, Bartel 1971, Wallace and Aasjord 1984, Bonisławska *et al.* 2000).

Attention should be drawn to the fact that the investigated eggs had a relatively low turgor value (Winnicki 1967a). This may indicate that the egg membrane is transparent enough to allow the egg to absorb saline water into the perivitelline space; this is indicated by egg buoyancy that is either close to zero or is even zero and the lack of deformations in the spherical shape of the egg cell (yolk sphere) when observed from the side (Fig. 2e, i). It also seems that uniform osmotic pressure on both sides of the membrane, the lack of turgor and the significant elasticity and flexibility of the membrane (Winnicki 1967b) may be factors which contribute to permanent deformations of the surfaces of eggs which are in larger aggregations (Fig. 3). In these aggregations, even the low adhesiveness of the gelatinous sheath causes the irregular angularity of the eggs – something that had already been observed by Kupfer (1878) over a century ago. Perch differs in that (Retzius 1912, Korzelecka *et al.* 1998) only the thick gelatinous layer which surrounds the egg changes shape while the egg itself retains a regular spherical shape.

The germinal disk assumes a side position from the beginning, or rather from the moment the reception mount is formed, as does the embryo itself later. This results from the distortion of the statics of the yolk sphere by the developing protrusions on its surface of live structures filled with protoplasma which is heavier than the yolk. The biological reason behind this phenomenon lies in the necessity of securing for the future embryo, which is significantly long by the end of incubation, the possibility of easily enveloping the spherical and ever smaller yolk sac (Winnicki and Korzelecka 1997, Korzelecka and Winnicki 1998, Griffin *et al.* 1998).

The diversity of larval size seems to be connected with the irregular development rate of eggs in the irregularly angular aggregations in which poorer oxygen conditions in the lower layers influence the rate of embryonic development. It can be assumed that larvae hatched from eggs which are incubated in better oxygen conditions will be longer; thus, their reserves in the form of the yolk sac will be smaller.

Non-uniform larvae hatching observed during the experiments seems to result from different values of the S/V (surface /volume) of the eggs. This ratio describes the efficiency of O_2 transition whose value is higher, and thus better, for small eggs, and lower for large eggs (Bonisławska and Winnicki 2000).

The biological reason for this morphophysiological phenomenon may be to lengthen the hatching process in order to decrease hatch mortality when environmental conditions fluctuate, or to counteract the threat from other organisms for which the hatched larvae could become easy prey (Dushkina 1988).

The duration of the embryonic development in its entirety and that of individual stages of embryogenesis in the spring herring (*Clupea harengus membras* L.) in the Puck Bay is comparable with that of the Pacific herring (*Clupea pallasi*) (Griffin *et al.* 1998), although the spring herring eggs were incubated at $13\pm1^{\circ}$ C and at salinity of about 6‰, while the Pacific herring eggs were incubated at 12° C and at salinity that was twice as high (14‰). The slightly slower development observed in the Pacific herring seemed to have resulted from intraspecific differences and different conditions of egg incubation.

Also interesting are the elements of embryonic motor features that are basically limited to the near total lack of quasiperistaltic contractions (Korzelecka 1999), and to the significant

outpacing of the contractions of the embryo's soma by the heart. This could be connected with securing the necessary oxygen for the developing embryonic structures to allow energetic processes which are dependent on the mixing and transfer of body fluids (Fig. 4). This process involves both the heart for pumping blood and the somatic muscles whose contractions are conducive to lymph activity and thus activate blood circulation especially when heart contractions are still slow, irregular and inefficient. This conclusion is supported by the significant slow down in the contractions of the embryo's somatic muscles during the later development stages, i.e. when heart contractions become rhythmic their frequency is high which results in much more efficient fluid transfer.

REFERENCES

- Bartel, R. 1971. Pomiary średnicy jaj pstrąga tęczowego (Salmo gairdneri Rich.) [Measurements of the diameter of rainbow trout (Salmo gairdneri Rich.) eggs]. Rocz. Nauk. Rol. 93-H-3: 7-17.
- Bermudes, M. and A.J. Ritar 1999. Effects of temperature on the embryonic development of the striped trumpeter (*Latris lineata* Bloch and Schneider, 1801). Aquacult. 176, 3-4: 245-255.
- Blaxter, J.H.S. 1960. The effect of extremes of temperature on herring larvae. J. Mar. Biol. Ass. UK, 39: 605-608.
- Blaxter, J.H.S. and G. Hemple 1963. The influence of egg size on herring larvae (*Clupea harengus*). J. Cons. Int. Explor. Mer. 28: 211-240.
- Bogucki, M. 1930. Recherches sur la perméabilité des membranes et sur la pression osmotiquedes oeufs salmonides. Protoplasma, 9: 334-369.
- Bonisławska, M., A. Korzelecka and A. Winnicki 1999. Morpho-mechanical aspects of the embryonic development of sun bleak (*Leucaspius delineatus* Heck.). Folia Univ. Agric. Stetin. 192, ser. Piscaria (25): 13-23.
- Bonisławska, M., K. Formicki and A. Winnicki 2000. Size of eggs and duration of embryogenesis in fish. Acta Ichthyol. Piscat. 30, 1: 61-71.
- Bonisławska, M. and A Winnicki 2000. Duration of embryonic development and S/V (surface/volume) coefficient in fish eggs. Arch. Ryb. Pol. 8, 2: 161-169.
- Brook, G. 1885. On the development the herring. Rap. Fish. Bd Scotland, Edinburg.
- Dushkina, L.A. 1988. The biology of early ontogenesis of sea herring. Izd. Nauka, Moskva [in Russian].
- Fisher, K.C. 1963. The formation and properties of the external membrane of the trout egg. Royal Soc. Canada, 1: 323-332.
- Galkina, L.A. 1968. The survival of herring eggs and larvae at spawning grounds in the White Sea and their high abundance period. Vopr. Ichtiol. 8, 4 (51): 679-688 [in Russian].
- Gisbert, E., P. Williot and F. Castello-Orvay 2000. Influence of egg size on growth and survival of early stages of Siberian sturgeon (*Acipenser baeri*) under small scale hatchery conditions. Aquacult. 183, 1-2: 83-94.
- Griffin, F.J., M.C. Pillai, C.A.Vines, J. Kääriä, T. Hibbard-Robbins, R. Yanagimachi and G.N. Cherr 1998. Effects of salinity on sperm motility, fertilization, and development in the Pacific Herring, *Clupea pallasi*. Biol. Bull. 194: 25-35.
- Hill, J. and I.A. Johnston 1997. Photomicrographic atlas of Atlantic herring embryonic development. J. Fish Biol. 51: 960-977.
- Holliday, F.G.T. and J.H.S. Blaxter 1960. The effects of salinity on the developing eggs and larvae of the herring. J. Mar. Biol. Ass. UK, 39: 591-603.

- Kaj, J. and K. Lewicka 1962. Wpływ wielkości ikry w jajnikach troci (Salmo trutta L.) na rozwój embrionalny i postembrionalny [The influence of the size of spawn in sea trout (Salmo trutta L.) ovaries on embryonic and postembryonic development]. Rocz. WSR w Poznaniu, 12: 55-68.
- Korzelecka, A. 1999. Motoryka embrionalna u ryb kostnoszkieletowych [Embryonic motion in teleost fish]. Ph.D. thesis, Agricultural University of Szczecin.
- Korzelecka, A. and A. Winnicki 1998. Peculiarities of embryogenesis in *Scardinius erythrophthalmus* L. Electronic Journal of Polish Agricultural Universities; http://www.ejpau.media.pl/series/volume1/fisheries/art.-01.html.
- Korzelecka, A., M. Bonisławska and A. Winnicki 1998. Structure, size and spatial distribution of perch (*Perca fluviatilis* L.) egg components during incubation. Electronic Journal of Polish Agricultural Universities, Annual I, vol. 1, http://www.ejpau.media.pl/Journal/english/series/1998/fisheries/art.
- Kosior, M. and K. Strzyżewska 1979. Płodność dorszy i śledzi bałtyckich [Fecundity of Baltic cod and herring]. Stud. Mater. Mor. Inst. Ryb., Gdynia, ser. B, 44: 5-32 [in Polish].
- Kryzhanovski, S.G. 1956a: Materials on the development of clupeids. Tr. In-ta Morf. Zhiv. im. A. N. Severcova, AN SSSR, 17, 254 [in Russian].
- Kryzhanowski, S.G. 1956b. Herring development in waters with elevated salinity levels. Vopr. Ichtiol. 6: 100-105 [in Russian].
- Kupfer, C. 1878. Die Etwicklung des Herings im Ei. Jahresber. Comm. Wissenschaftl. Untersuch. Dtsch. Meere in Kiel: 177-224.
- Nikolski, G. W. 1970. Ichtiologia szczegółowa [Detailed ichthyology]. PWRiL, Warszawa.
- Ojaveer, E. 1981. Influence of temperature, salinity, and reproductive mixing of Baltic herring groups on its embryonal development. Rapp. P.–V. Reun. Cons. Int. Explor. Mer. 178:409–415.
- Privolniev, T.I. 1953. Changes in salmon egg weight during embryonic development. Izw. VNIORCH, 33: 4-9 [in Russian].
- Retzius, M.G. 1912. Zur Kenntnis der Hüllen und besonders des Follikelepithels an den Eiern der Wirbeltire. I Bei den Fischen. Biol. Untersuch. (n.s.) 17: 5-29.
- Steffens, W. 1963. Eingrößen und Eizahlen der Regenbogenforelle (Salmo gairdneri). Deuts. Fisch. Ztg. 10: 253-262.
- Svetovidov, A.H. 1949. On the geographic distribution of clupeids in connection with certain problems of the zoological geography of the Atlantic and Pacific oceans. Tr. 2-go Vsesojuz. geogr. sjezda M., t. 31: 59-64 [In Russian].
- Tański, A., A. Korzelecka, M. Bonisławska, A. Winnicki and K. Formicki 2000. New data on morphomechanical changes during embryogenesis of pike (*Esox lucius* L.). Univ. Agric. Stetin. 214, ser. Piscaria (27): 207-213.
- Wallace, J.C. and D. Aasjord 1984. An investigation of the consequences of egg size for the culture of Arctic char, *Salvelinus alpinus* (L.). J. Fish Biol. 24: 427-435.
- Wawrzyniak, W. 1987. An attempt on the artificial spawning and eggs incubation of herring (*Clupea harengus* L.) of Puck Bay origin. Acta. Ichthyol. Piscat. 17, 2: 3-10.
- Winnicki, A. 1967a. The turgor of the salmonid eggs during hatching. Bull. Acad. Pol. Sci., Cl. II, ser. sci. biol. 15, 12: 785-787.
- Winnicki, A. 1967b. Plasticity and hardening of the rainbow trout egg membranes. Bull. Acad. Pol. Sci., Cl. II, ser. sci. biol., 15, 12: 779-783.
- Winnicki, A. 1968. Rola i właściwości osłonek jajowych ryb łososiowatych [The role and properties of egg membranes in salmonids]. Wyd. WSR, Olsztyn, PhD thesis.
- Winnicki, A.and J. Domurat 1964. Wytrzymałość osłonek jajowych niektórych ryb rozwijających się w różnych środowiskach [Durability of egg membranes of selected fish developing in various environments]. Zesz. Nauk. WSR, Olsztyn, 18: 315-324.
- Winnicki, A. and A. Korzelecka 1997. Morphomechanical aspects of the development of the bleak (*Alburnus alburnus* L.). Acta Ichthyol. Piscat. 27, 2: 17–27.
- Winnicki, A., A. Korzelecka and A. Tański 1998. New data on breeding and early ontoganesis of threespined stickleback (*Gasterosteus aculeatus* L.). Arch. Ryb. Pol. 6, 1: 115-122.

Volodin, V. M. 1956. The embryonic development of fall herring and oxygen requirements during this period. Vopr. Ichtiol. 7: 123-133 [in Russian].

Załachowski, W. 1997. Ryby [Fish]. PWN, Warszawa.

- Zotin, A. I. 1954. The mechanism which forms the perivitaline space in the eggs of salmonids. Dokl. AN SSSR, 96: 421-424 [in Russian].
- Zotin, A. I. 1961. The physiology of water exchange in fish and cyclostomes. Izd. AN SSSR, Moskva [in Russian].



Variability of sprat peak spawning and larvae appearance timing in the southeastern Baltic Sea during the past six decades

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Abstract. Based on the analysis of historical (Mankowski 1950a, 1950b, 1951, 1955, 1959, Grauman 1969, 1970, 1972, 1980a, 1980b) and recent (STORE EU-project FAIR CT-98 3959) ichthyoplankton data, the seasonal dynamics of the Baltic sprat egg and larval abundance in the Gdansk Deep were considered for different time periods: late 1940s – early 1950s; late 1960s – mid 1970s; late 1990s. The percentage ratio of larvae to egg abundance was also estimated for these periods.

Significant differences between these periods were revealed in larva peak timings and larva/egg ratio values. The latter declined drastically towards the late 1990s. The possible influences of factors such as increases in surface water temperature, oxygen depletion in the Baltic Sea, age structure changes and increases in the larva dispersion rate are discussed.

Key words: sprat, peak spawning timing, spawning activity shift, larva/egg ratio

INTRODUCTION

Equally with the Bornholm and Gotland basins, the Gdansk Deep is one of three most important sprat reproduction areas in the Baltic Sea (Biriukov 1980, Elwertowski 1982, Koester *et al*, 2000). Ichthyoplankton sampling in several decadal periods was first conducted in this area by scientists from Poland (Sea Fisheries Institute, Gdynia) and the former Soviet Union (AtlantNIRO, Kaliningrad and BaltNIRH, Riga). Since 1992, the research has been continued by scientists from Russia (AtlantNIRO). Currently, the Institute of Marine Sciences in Kiel, Germany is performing these ichthyoplankton investigations within the framework of the Baltic STORE Project. These data may be used to analyse spawning-related sprat population responses as well as other reactions caused by inter-annual hydrographic changes in the sea. The main aim of this article is to demonstrate that historical ichthyoplankton data set, which includes a very important Polish contribution, can reveal the inter-annual variability of sprat egg and larva peak abundance timing as well as the larva/egg ratio by comparing different time periods.

METHODS

The long-term ichthyoplankton data collected by AtlantNIRO and cited in the publications of Mankowski (1950a, 1950b, 1951, 1955, 1959), Biriukov (1980) and Grauman (1969, 1970, 1972, 1980a, 1980b) were analysed. The results of the surveys carried out in 1990s under the Baltic STORE Project (FAIR 97 3959) by the German R/V ALKOR and ships chartered by AtlantNIRO, Russia were also incorporated into the research materials.

Hensen's nets and IKS-80 nets with mouth opening 0.42 and 0,50 sq. m, respectively were used in the surveys. According to Oeberst *et al.* (1981) these nets have a similar catchability for Baltic sprat early develoment stages. Samples were collected by vertical hauls from the bottom to the water surface. The data on sprat egg and larva abundance per m² were averaged for three time periods: 1947-1955; 1968-1977; 1996-1999. During the spring-summer seasons (March-August) in 1947-1949 and 1951-1955, 135 ichthyoplankton samples were collected inside the 70-m isobath in the Gdansk Deep as described in Mankowski's publications mentioned above. In the 1996-1999 spring-summer seasons (March-August), 365 samples were collected in the same area. No complete published information regarding the number of samples collected for 1968-1977 is available.

The seasonal abundance of sprat eggs and larvae were disaggregated for March – August (Fig. 1-4), whereas the mean seasonal values were estimated for April – July (Fig. 6). Percentage ratios of larva and egg abundance were estimated for the different months of the spawning period in order to roughly evaluate spawning success. AtlantNIRO archival data were used to analyze the hydrographic regime of the southern Baltic waters, and data obtained under the STORE Project and from Glowinska (1949, 1963) and Filarski (1955) were also considered.

RESULTS

The time periods under consideration were characterized by large differences in sprat egg abundance levels in the Gdansk Deep with the maximum level occurring in the late 1990s. It must be mentioned that sprat egg abundance in the late 1940s and early 1950s was not the lowest in the twentieth century. It was higher than in the late 1930s and higher than in the late 1950s.

Some seasonal variability can be seen with the comparison of sprat early stage abundance in different months (Fig. 1-4).

The averaged data for the 1947-1955 period revealed a sprat egg abundance peak in June and a rather poor larva peak in July. Relatively high egg abundance was observed during some years, namely in April 1952, 1955, May 1949, 1953, June 1951, 1954, 1955 and July 1947, 1948. A high larva abundance was observed in April 1955, May 1949, 1953 and in July 1948, 1951, 1952, 1954. The peak egg abundance exceeded the mean value for the season by 1.26 times, i.e. 123 sp/m² in June versus an average of 98 sp/m² for April-July. The peak larva abundance exceeded the mean value by 1.38 times, i.e. 27.3 sp/m² in July versus an average of 19.8 sp/m² in April-July.

In the 1968-1977 period, high egg abundance was, on average, rather low in April and high from May to July with a weak peak in June (Figs. 1 and 2). Throughout this period, the highest egg abundance was observed in July 1969, June-July 1971, 1972 and May-June 1973-



Fig. 1. Seasonal variability of sprat egg abundance (sp./m²) for different time periods.



Fig. 2. Seasonal variability of relative sprat egg abundance (%) for different time periods.

1975. The maximum larva density was in June 1968-1971 and May 1973-1975. The peak egg abundance exceeded the mean value for the season by 1.29 times, i.e. 228 sp/m^2 in June and 177 sp/m^2 for April – July; the peak larva abundance exceeded the mean value by 1.72 times, i.e. 42.2 sp/m^2 in June and 29.4 sp/m^2 for April – May (Figs. 3 and 4).

In the 1997-1999 period, the highest abundance of sprat eggs was recorded in May-June with a peak in May, while in 1996 it occurred in July. The seasonal variability of sprat larva abundance differed sharply from that of egg abundance and was characterized by a peak in April (due to high values in 1998) and the lowest level in July (Figs. 3 and 4). In 1998 – 1999,



Fig. 3. Seasonal variability of sprat larva abundance (sp/m2) for different time periods.



Fig. 4. Seasonal variability of relative sprat larva abundance (%)) for different time periods.

the peak egg abundance in May was 1.3 times as high in comparison with the mean value for April – July, 620 and 470 sp/m², respectively. The peak larva abundance in April was 2.26 times as high in comparison with the mean for April – July, 66.9 and 29.4 sp/m², respectively.

Thus, more significant inter-decadal differences were revealed in larva peak timings than in those of eggs. While larva peak abundance was recorded in July in the late 1940s and early 1950s and in June in the late 1960s and mid 1970s, it was observed in April-May in the late 1990s (Figs. 3 and 4).

In some cases, peak spawning timing could be linked with thermal regime features.



Fig. 5. Seasonal variability of sprat egg abundance (sp/m²) in warm and cold years.

Although all of the periods considered were relatively warm (Glowinska 1949, Glowinska 1963, Grauman 1980b, Zezera 2001), some years were rather cool. As a result, the spawning peak shifted to July during these years due to the influence of low water temperature (Fig. 5).



Fig. 6. Mean abundances (sp/m²) of sprat egg (a) larva (b) and larva/sprat ratio (c) in the Gdansk Deep for different time periods.

Such shifts were recorded in 1947 and 1996 when the impact of cool winter-origin water inflows into the Gdansk Deep in late May resulted in a bottom temperature drop to 2.5°C. During relatively warm years (1973-1975), the sprat spawning peak was observed in May – June, while it shifted to July during cooler years (1968-1971). In the warm years considered, the egg abundance in May exceeded that in cold years by 6.5 times in 1949 as compared with 1947, by 2.1 times in 1973-1975 as compared with 1968-1971 and by 6.8 times in 1998 as compared with 1996.

The comparison of sprat early stage abundance over the three indicated periods revealed a pronounced trend towards egg abundance increase, a weak trend towards larva abundance increase and a general trend towards the decrease of the larva/egg ratio (Fig. 6).

Additionally, some features of seasonal variability in different periods are illustrated in Figs. 7-9. While there were only small differences between sprat egg abundance in May and July of 1947-1955 and 1968-1977, the egg abundance in May of 1996-1999 exceeded that in July. The seasonal variability of larva abundance and the larva/egg ratio was characterized by an increase from May to July in the 1940-1950s and, conversely, by a reduction from May to July in the late 1960s.



Fig. 7. Sprat egg abundance in May and July for different time periods.



Fig. 8. Sprat larva abundance in May and July for different time periods.



Fig. 9. Ratio (%) of sprat larva and egg abundance in the Gdansk Deep in May and July for different time periods.



Fig. 10. Some environmental parameters in the Gdansk Deep in May for different time periods.

The southern Baltic hydrographic regimes for the time periods considered, i.e. 1947 - 1955, 1968 - 1977, 1998 - 1999, were relatively warm as compared to that of the late 1950s - mid 1960s and late 1970s - mid 1980s. Nevertheless, the surface temperature during the 1990s was $1-2^{\circ}C$ higher in May in comparison to that in the late 1940s - early 1950s. The main interdecadal differences in the environmental parameters of the Gdansk Deep were as follows: the surface temperature was the highest in the late 1990s; the bottom temperature was insignificantly higher in the late 1940s - early 1950s; the bottom oxygen content was also higher in the late 1940s - early 1950s (Fig. 10).

DISCUSSION

Baltic sprat is a rather thermophillous species with multibatch spawning (Alheit 1986, Alekseeva et al. 1997, Kraus and Koester 2001) that reproduces successfully at temperatures above 4°C (Grauman 1980). In spring the Baltic sea sprat spawn in the upper part of the halocline (Makarchouk, Hinrichsen, 1998, STORE, 2000) when the temperature of this water layer in the Gdansk Deep is 4 to 6°C. The width and minimum temperature of the intermediate cold layer (the last one could drop below 1°C in May) can vary significantly in some years and thus influence the spawning intensity and spawning timing of sprat (Karasiova and Zezera 2000). All of time periods considered were relatively warm and were characterized by North Sea water penetration in the process of advection. However, the frequency and intensity of this event during these periods decreased from the early 1950s to the mid 1990s (CORE 1998). As a whole, the enormous sprat stock increase towards the end of the last century seems to be linked with the rise of surface temperature as well as with eutrophication processes (Nehring et al. 1989) It appears that the earlier sprat larvae peak timing in the late 1990s can be connected with the temperature increase to some extent (Zezera 2001). Since sprat larvae begin to rise to the water surface after consuming the yolk sack (Makarchouk and Hinrichsen 1998), the surface temperature influence can be important.

The fall in the larva/egg ratio in late 1990s can be explained by a decline in survival or more rapid larva drift from the spawning grounds to the shallow coastal areas.

In comparison with previous periods, the late 1990s were characterized by earlier spring heating, a higher surface temperature in May and both lower bottom salinity and oxygen content. In the late 1990s the bottom temperature increase coincided with the sea surface temperature rise which seems to have resulted in faster oxygen depletion not only in the near-bottom layer, but also at depths of 90 m.

The volume of seawater with sufficient oxygen saturation decreases during the spawning season due to increased oxygen consumption. Small sprat eggs have poor buoyancy and may sink to depths where the low oxygen content negatively influences their development and survival (STORE 2000). Since older individuals with relatively large-sized eggs reproduce earlier in the spawning season (Polivaiko 1980), the egg survival and hence the larva/egg ratio can be higher at the beginning of spawning. Besides, the last egg batches can produce less viable larvae than the first batches (STORE 2000).

Thus, the influence of the stock age structure, female condition and egg batch number could be important (STORE 2000) especially in the 1990s due to the large stock size. Perhaps

the fraction of the sprat from the old age groups which spawn earlier was lower in the late 1990s than that of the previous period; therefore, sprat egg abundance in March is currently very low.

Another explanation could be connected with the deterioration of nutrition conditions of sprat larvae in summer due to possible changes in phytoplankton and zooplankton composition and abundance. Some changes in the mezoplankton in the central Baltic have been reported by Moellmann *et al.* (2000).

Finally, differences in larvae dispersion and migration rates could take place under the impact of wind mixing and turbulence. The strengthening or the weakening of storm activity during ichthyoplankton sampling seems to be significantly important for the retention of larvae in deep-water areas or their shift out of them, thus affecting evaluations of their abundance.

These aspects require further investigations. The combined effects of all of these factors seem to result in the inter-annual variability of peak abundance timing of sprat early developmental stages.

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REFERENCES

- Alekseeva, E.I., M.M. Baranova, M.A. Dmitrieva and E.F. Ryazantseva 1997. Ovaries maturation, batch eggs forming, batch fecundity and distribution during sex cycle of Baltic sprat Sprattus sprattus balticus. ICES CM 1997/U: 02.
- Alheit, J. 1986. Reproductive biology of sprat, Sprattus sprattus: factors determining annual egg production. ICES. CM 1986/H:58.
- Biriukov, N.P. 1980. The Baltic Sprat. Leningrad: 1-142 [in Russian].
- CORE. 1998 Mechanisms influencing long term trend in reproductive success and recruitment of Baltic cod: Implications for fisheries management. Final Report to the EU Commission, AIR 94 1226.
- Elwertowski, J. 1982. Baltic commercial fishes resources. Structure, dynamics, biomass, production. Stud. Mater. Mor. Inst. Ryb., Gdynia, ser. B, 50: 5-114 [in Polish].
- Filarski, J. 1955. Hydrological observations in the Southern Baltic Region in 1953-1955. Pr. Mor. Inst. Ryb., Gdynia, vol 10/A: 35-52 [in Polish].
- Glowinska, A. 1949. Hydrographic observations off the Polish Coast in 1947 and 1948. Ann. Biol., 1948, vol 5: 131-133.
- Glowinska, A. 1963. Hydrologic conditions in the southern Baltic in the years 1951-1960. Pr. Mor. Inst. Ryb., Gdynia, vol 12/A: 23-35 [in Polish].
- Grauman, G. B. 1969. Some data on reproduction of sprat in the southern Baltic. AtlantNIRO Proc. 21: 140-150 [in Russian].
- Grauman, G. B. 1970. Studies of sprat spawning in the Baltic Sea in 1970. Ann. Biol. 27: 168-169.
- Grauman, G. B. 1972. Spawning of Baltic sprat in 1971 and 1972. Ann. Biol. 29: 154-155.
- Grauman, G. B. 1980a. Ecological peculiarities of main pelagophillous fishes reproduction in the Baltic Sea. Fisch. -Forsch. 18, 2: 77-81 [in Russian].
- Grauman, G. B. 1980b. Interannual variability of sprat eggs and larvae abundance in the Baltic. [In:] Fishery investigations in the Baltic. Riga, vol 15: 138-154 [in Russian].

- Karasiova, E. 1999. On the possible relation of the cod peak spawning timing with the environmental conditions in the Gdansk Deep of the Baltic Sea. ICES CM 1999/ Y: 29.
- Karasiova, E. M. and A. S. Zezera 2000. On influence of long-term variability of temperature regime in the Gdansk Deep of the Baltic Sea on the sprat reproduction and the offspring survival. ICES CM 2000/ L: 06.
- Koester, F.M., H.-H. Hinrichsen, D. Schnack, M.A. St. John, B.R. MacKenzie, J. Tomkiewicz, C. Moellmann, M. Plikshs and A. Makarchouk 2000. Recruitment of Baltic cod and sprat stocks: Identification of critical life stages and incorporation of environmental variability and spatial heterogeneity into stock recruitment relationships. ICES CM 2000/ N: 16.
- Kraus, G. and F. Koester 2001. Duration. Frequency and timing of sprat spawning in the Central Baltic: An analysis based on gonad maturity. ICES CM 2001/J: 25.
- Mankowski, W. 1950a. Macroplankton of the Gulf of Gdansk in 1947. Biul. Mor. Inst. Ryb., Gdynia, 5: 45-62 [in Polish].
- Mankowski, W. 1950b. Plankton investigations in the Southern Baltic in 1948. Biul. Mor. Inst. Ryb., Gdynia, 5: 71-101 [in Polish].
- Mankowski, W. 1951. Macroplankton of the Southern Baltic in 1949. Pr. Mor. Inst. Ryb., Gdynia, 7: 63-73 [in Polish].
- Mankowski, W. 1955. Plankton investigations in the Southern Baltic in 1951. Pr. Mor. Inst. Ryb., Gdynia, 8: 197-233 [in Polish].
- Mankowski, W. 1959. Macroplankton investigations of the Southern Baltic in the period 1952-1955. Pr. Mor. Inst. Ryb., Gdynia, 10A: 69-123 [in Polish].
- Makarchouk, A. and H.-H. Hinrichsen 1998. The vetrtical distribution of ichthyoplankton in relation to the hydrographic conditions in the Eastern Baltic. ICES CM 1998 / R: 11.
- Moellmann, C., G. Kornilovs and L. Sidrevics 2000. Long-term dynamics of main mesoplankton species in the Central Baltic Sea. J. Plankton Res. 22(11): 2015-2038.
- Nehring, D., S. Schulz and O. Rechlin 1989. Eutrophication and fishery resources in the Baltic. Rapp. P.v. Reun. Cons. int. Explor. Mer. 190: 198-205.
- Oeberst, R., K. Krenkel, R. Hinrichs and G.B.Grauman 1981. Vergleich der Fangigkeit der Ichthyoplankton netze IKS-80, Hensensches Eirnetz und WP 2. Fisch.-Forsch. 19, 2: 53-57.
- Polivaiko, A.G. 1980. Some data on ripening, spawning and fecundity of Baltic sprat. 1980. Fisch.-Forsch., 18, 2: 69-72.
- STORE 2000. Environmental and fisheries influences on fish stock recruitment in the Baltic Sea. EU Project Fair CT 98 3959, Consolidated Progress Report, part 1 – 336.
- Zezera, A.S. 2001. Main features of the South-eastern Baltic Sea Hydrological regime in 2000 and the latest retrospectives. ICES CM / W: 21.



On the biology of *Lepidonotothen macrophthalma* (Norman, 1937) from the Scotia Ridge, Southern Ocean

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Abstract. Large concentrations of *Lepidonotothen macrophthalma* (Norman, 1937) were confirmed in the shallow areas of the Scotia Ridge east of Burdwood Bank in November 1984 and October 1986. To date, with the exception of *Patagonotothen ramsayi* (Regan, 1913), the mass occurrence of other species of Nototheniidae has not been observed in areas outside the Antarctic. This paper includes ranges of length and age, gonad maturity stage, and degree of stomach fullness and the total length of individuals when they reach first maturity.

Key words: Southern Ocean, Nototheniidae, Lepidonotothen macrophthalma, biology

INTRODUCTION

The family of Nototheniidae fish has a vast range of occurrence that stretches from 35°S near South America to about 82°S near the Ross Ice Shelf. Thirty-four (68%) of the 49 species in this family are Antarctic species (De Witt *et al.*1990, Eastman 1993, Eastman and Eakin 2000), and of the 15 species which occur outside Antarctica (to the north of the Antarctic Convergence line), only *Patagonotothen ramsayi* (Regan, 1913) has been described to date as one which occurs in larger concentrations (Hart 1946, Ekau 1982). Relatively large concentrations of a second species, *Lepidonotothen macrophtalma* (Norman, 1937), which had not previously been observed on the underwater slopes of the Scotia Ridge to the east of Burdwood Bank, were located by the Polish ships m/t TAURUS in November 1984 and the R/V PROFESOR SIEDLECKI in October 1986. Samples for biological analyses were collected from these concentrations. The taxonomic description of this species as *Notothenia macrophthalma* (Norman 1937). As a result of further studies of the family Nototheniidae, the genus Lepidonotothen was designated and the described species *Lepinotothen macrophthalma* (Norman 1937) was assigned to it (De Witt *et al.* 1990, Koch 1992, Eastman and Eakin, 2000). With the exception of taxonomic traits, no other biological data regarding this species is available.

The aim of this study was to inform the scientific public that a large stock of *Lepidonotothen macrophthalma* (Norman, 1937) had been found and to present the biological traits of this stock which were determined from the individuals examined.

MATERIALS AND METHODS

The fish studied were caught on the underwater slopes of the northern part of the Scotia Ridge which are located to the east of the Burdwood Bank (Fig. 1). The northern border of Antarctica, the mid Antarctic Convergence line, is located approximately 60 nm to the south of the slopes.

The fish were caught with a P32/36 bottom trawl with an average horizontal opening of 20 m and a 90 mm mesh size codend. The size of the samples and the corresponding catch data are presented in Table 1. Biological analyses were conducted aboard the vessel after the fish had been caught.

The fish were measured (*longitudo totalis*) to the nearest cm below and weighed to the nearest g. The relation between the weight and total length of the fish was determined with the formula $W = k \cdot l^n$, the parameters of which were calculated using the least squares method. The five-degree Everson scale (1977), which is applicable to Antarctic fish, was used to determine gonad maturity. The criterion for achieving sexual maturity was the length of fish at which the gonads of 50% of them were in stages II to V (L_{50}), and was derived using the following formula:

$$p = \frac{1}{1 + \mathrm{e}^{-(\alpha + \beta L)}}$$

where: *p* is the calculated proportion of fish in a given length class *L*, and α and β are the equation coefficients (Everson *et al.* 1996).



Fig. 1. Study area for *Lepidonotothen macrophthalma* in the Scotia Ridge region. 1– m/t TAURUS – November 26, 1984, 2– R/V PROFESOR SIEDLECKI – October 21, 1986

		Time of Vessel			Analysis (spec.)							
Coordinates	Depth [m]	trawling [min]	speed [knots]	Catch [kg]	length [cm]	mass [g]	sex and maturity	feeding	meristic features	otoliths		
M/T TAURUS – 26.11.1984												
53° 46' S 051° 39' W	325	120	2.5	4 500	270	0	100	100	12	100		
53° 46' S 051° 50' W	420	120	3.5	4,500	270	Ū	100	100	15	100		
R/v PROFESOR SIEDLECKI – 21.10.1986												
53° 27'S 050° 01' W	516	40	2.0	15*	100	100	100	100	0	100		
53° 27' N 050° 05' W	620	40	40	40	3.0	15*	100	100	100	100	U	100

Table 1. Catch data and numbers of studied specimens of Lepidonotothen macrophthalma (Norman, 1937)

*Catch magnitude not representative due malfunction of trawling gear

Feeding intensity was described as the degree of stomach fullness on a scale of 0 to 4, where 0 is an empty stomach and 4 is a full stomach. Fish age was read using otoliths which, prior to marking, were soaked in water for 10 minutes to ensure better results. The otoliths (sagittae) used to read fish age have a rounded rear edge (postrostrum) with shallow ridges. The ventral edge is almost linear and leads to the rostrum. The parallel dorsal edge is much shorter and leads to the antirostrum. A cut, the excisura, is located between the rostrum and antirostrum. The angle between the rostrum and antirostrum is approximately 90° or less (Fig. 2).



17 cm - age group VII

30 cm - age group XVI

Fig. 2. Otoliths of Lepidonotothen macrophthalma from the Scotia Ridge region.

The structure of the annual rings is most clearly seen between the nucleus and the postrostrum, although sometimes the otolith was more clearly readable in the rostrum. Due to the representative ness of the material, age composition and length distribution are presented only for the population from 1984.

The parameters of the von Bertalanffy growth formula, obtained from the classical methods of Ford-Walford and Beverton and Holt, yielded a lowered L_{inf} value than the maximum L_{max} observed in the investigated population. Therefore, an alternative method, namely that of Taylor-Pauly (see Ekau 1988) which is based on the assumption that $L_{max} = 0.95\% L_{inf}$, was also applied.

RESULTS

The number of rays on the various fins of 13 specimens were counted and on the basis of these figures the following formula was developed:

$D_1 V_{-}$	VI			$D_2 = 3$	31	32	33	34	35
4	9			2 -	1	1	6	4	1
P 23	24	25		A 3	1	32			
1	5	7		10)	3			

The length of the studied specimens ranged from 15 to 34 cm. The population which was studied in 1984 was characterized by a double peak distribution curve, with the peaks in the 18 cm and 25 cm classes (Fig. 3). The age read from otoliths varied from 6 to 20 years. Specimens from the VII (26.2%) and XII (17.2%) age groups dominated among the fish caught in 1984.

The average lengths in age groups were calculated using the combined material from 1984 and 1986 (Table 2). These data were then used to calculate the parameters of the theoretical growth curve using the von Bertalanffy equation (Fig. 4). The curve fits the empirical data well within the range of fish ages and is confirmed by the correlation coefficient r = 0.973. The alternative Taylor-Pauly method which was used assumes that $L_{max} = 0.95\% L_{inf}$ yielded the following parameters:

 $L_{inf} = 35.79; k = 0.07744; t_0 = 2.752; r = 0.970$

No differences in length growth rate between the sexes were determined. Growth parameters from the von Bertalanffy equation were as follows for the two sexes:

males $L_{inf} - 28.36$	females $L_{inf} - 28.50$
K - 0.2807	K - 0.2946
$t_{0} - 3.348$	$t_{0} - 3.316$

Young fish were in the immature stage, while the gonads of the older ones after spawning were in either the spent or resting stages (Table 3). The maturity stage analysis indicated that on average *L. macrophthalma* achieved first sexual maturity at a length of $L_{50} = 20.94$ cm and that females matured at shorter lengths than did the males (Fig. 5).



Fig. 3. Population composition of *Lepidonothen macrophthalma* in October 1984 by length (A) and age (B).



Fig. 4. Average age and the von Bertalanffy growth curve for *Lepidonotothen macrophthalma* from the Scotia Ridge region.

Length	Age groups						Ag	e grou	ps					Total		
[cm]	VI	VII	VIII	IX	Х	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	Total
15	3	4														7
16	2	10														12
17		15														15
18		16					1									17
19		14	1	1	2				1							19
20		4	2	3	10	3	1		1							24
21		7		4	8	6	4	3								32
22		2	6	6	4	4	2	1								25
23			1	4	1	4	13	1	2	1						27
24				8	20		5	5	5							43
25				4	5	4	20	5	9	1						48
26					3	6	3	11	12	3	1					39
27						5	9	1	1		8					24
28						4	4	5	4		1				1	19
29							1	2		2				2		7
30								1	2		1					4
31																0
32																0
33																0
34							1									1
Total	5	72	10	30	53	36	64	35	37	7	11	0	0	2	1	363
Average	15.4	18.1	21.4	22.6	22.6	24.1	24.7	25.5	25.4	26.3	27.3			29.0	28.0	
±σ	0.54	1.73	1.26	1.68	2.03	2.68	2.43	2.22	2.14							

Table 2. Average lengths in age groups of Lepidonotothen macrophthalma studied in 1984 and 1986

Table 3. Percentage of L. macrophthalma specimens with gonads in various maturity stages

Sample	Data	Sar						
number	Date	Sex	1	2	3	4	5	n
		males	9	44	0	0	0	53
1	26.11.1984	females	9	38	0	0	0	47
		total	18	82	0	0	0	100
		males	23	2	0	0	0	25
2	21.10.1986	females	35	16	0	0	24	75
		total	58	18	0	0	24	100

Table 4. Degree of stomach filling in the studied specimens of L. macrophthalma

Sample	Date		Degree of stomach filling							
number		0	1	2	3	4				
1	26.11.1984	14	58	24	4	0	100			
2	21.10.1986	28	28	29	10	5	100			



Fig. 5. Maturity ogive curves of Lepidonotothen macrophthalma from the Scotia Ridge region.

At the moment they were caught, most of the fish were not feeding (stages 0 and 1). In 1984, 4% of the specimens were feeding, and in 1986 this figure was 15% (Tab. 4).

The weight of the fish varied from 60 g for 17 cm specimens to 200 g for 28 cm specimens. The curve of weight dependence on fish length and its parameters are presented in Figure 6.

The weight-length dependency was almost identical in the two sexes, as is illustrated by the following equation:

males $y = 0.0169 x^{2.8373}$	$R^2 = 0.9657$
females $y = 0.0182 x^{2.8101}$	$R^2 = 0.97867$


Fig. 6. Length-weight dependence for *Lepidonotothen macrophthalma* from the Scotia Ridge region.

DISCUSSION

The specimen described by Norman (1937) was caught at a station located south of the Falkland Islands near Burdwood Bank. Permitin and Sazanov (1974) reported that their seven specimens had been caught on the shelf of the Falkland Islands and Burdwood Bank, and the key by De Witt *et al.* (1990) reported *L. macrophthalma* in the same location. The fish described in this work were caught on the slopes of the shallow areas located east of Burdwood Bank.

These data indicate that this species occurs between the Antarctic Convergence zone and the Falkland Islands. In October 1986 the *L. macrophthalma* concentration was located close to the Antarctic Convergence zone (within approximately 60 nm). However, this species did not occur south of the Antarctic Convergence zone.

Species	Design	Age groups								
	Region	Ι	II	Ш	IV	V	VI	VII	VIII	
L. macrophthalma	East of Burdwood Bk.						15.4	18.1	21.4	
L. nudifrons	Antarctic Pen.	4.5	6.2	7.9	9.6	11.3	13.0	14.7	16.4	
L. larseni	South Georgia	5.3	9.9	13.6	16.5	18.7	20.5	21.7	22.4	
L. larseni	Len Bank	6.8	9.9	12.2	14.0	15.4	16.4	17.2	17.8	
L. squamifrons	South Georgia	9.7	15.6	21.4	25.9	29.3	32.4	34.8	37.3	
L. squamifrons	Len Bank			9.3	13.5	16.9	18.0	20.0	23.9	

Table 5. Comparison of the growth rate of *Lepidonotothen macrophthalma* with that of other fish of the genus Lepidonotothen (*l.t.* in cm)

The specimens described by Norman and Permitin and Sazanov were caught at depths of 368-463 m and 280-360 m, respectively. The catches from the m/t TAURUS were made at depths of 325-420 m and from R/V PROFESOR SIEDLECKI at depths of 516-620 m. These data confirmed that *L. macrophthalma* inhabited the benthic areas of the deeper waters primarily in depths ranging from 380 to 600 meters.

The November 1984 haul fished by the m/t TAURUS contained a high concentration of this species, and the results of the catch were comparable with those of exploited species in Antarctic fishing grounds (Sosiński 1999). It is probable that such concentrations occur only sporadically.

The results of analyses of biological characteristics presented in this work which characterize the studied populations from 1984 and 1986, excluding meristic characteristics and fish length, are the first of their kind published for this species. The number of fin rays is identical with figures found in Norman (1937), Permitin and Sazanow (1974), FAO – CCAMLR (Fisher and Hureau 1985) and by De Witt *et al.* (1990).

The specimens which were studied by Norman and by Permitin and Sazanow were between 15 and 20 cm long but their samples consistet of only eight specimens in total. The stock which was analyzed in the present study also included longer specimens of up to 34 cm.

The otoliths used to read the age of *L. macrophthalma* did not differ from the structure of the otoliths of other fish species (Blacker 1974, Hecht 1987, Burchett 1984, North 1988) including Nototheniidae. Thus, it can be assumed that the set comprised of opaque and hyaline zones represents an annual increase and that the number of growth zones represents the age of fish in years. The age readings of the fish caught in 1984 and 1986 permitted the length growth rate of *Lepidonotothen macrophthalma* to be determined, and the age composition was also determined in 1984 when length measurements were included.

The age composition of the exploited population, which consists of numerous age groups, is typical for weakly exploited stocks. The significant number of fish in age group VII may be evidence of the good recruitment of this generation. The lack of young fish in the sample may have resulted from the selective properties of the fishing gear. The age composition of the population from 1984, presented in Figure 2, indicates the longevity of *L. macrophthalma*.

The very slow growth rate of this species is comparable with that of the related species *Lepidonotothen nudifrons* (Lönnberg, 1905) (Radtke and Hourigan 1990). However, *L. nudifrons* is an Antarctic species, while *L. macrophthalma* is subantarctic (De Witt *et al.* 1990; Eastman and Eakin 2000). Among other Lepidonotothen representatives, *L. larseni* (Lönnberg, 1905) and *L. squamifrons* (Günther, 1880) exhibit rapid growth rates (Table 5).

Age groups							Source	
IX	Х	XI	XII	XIII	XIV	XV	Source	
22.6	22.6	24.1	24.7	25.5	25.4	26.3	current work	
18.0	21.1	22.8					Radtke and Hourigan 1990 *	
23.0							Shust and Pinskaya 1978	
							Shandikov 1986	
40.2	43.3	46.1	48.2	49.3	50.0		Shust and Pinskaya 1978	
24.0	28.9	30.0	32.0	35.0	35.0	40	Duhamel and Ozauf-Costaz 1985	

REFERENCES

- Blacker, R. W 1974. Recent advances in otolith studies. [In]: Harden-Jones F. R (ed.). Sea Fish. Res., London: 67-90.
- Burchett, M. S. 1984 . Age determination of *Notothenia rossii* from South Georgia (Antarctica) using scales and otoliths. Cybium, 8.2: 19-28.
- De Witt, H. H., P. C. Heemstra and 0. Gon 1990. Nototheniidae [In:] Fishes of Southern Ocean. J. L. B. Smith Inst. lchthyol., Grahamstown: 279-331.
- Duhamel, G. and C. Ozauf-Costaz 1985. Age, growth and reproductive biology of *Notothenia squamifrons* Günther, 1880 from the Indian sector of the Southern Ocean. Polar Biol. 4: 143-153.
- Eastman, J. T. 1993. Antarctic fish biology. Evolution in a unique environment. Academic Press Inc., San Diego.
- Eastman, J. T. and R. R. Eakin 2000. An updated species list of notothenoid fish (Perciformes, Notothenioidei) with comments on Antarctic species. Arch. Fish. Mar. Res. 48(1): 11-20.
- Ekau, W. 1982. Biological investigation on *Notothenia ramsayi* Regan 1913 (Pisces, Notothenioidei, Nototheniidae). Arch. Fish. Wiss. 33, 1-2: 43-68.
- Ekau, W. 1988. Ökomorphologie nototheniidaer Fische aus dem Weddellmeer, Antarktis. Ber. Polarforsch. 51: 1-140.
- Everson, I. 1977. The living resources of the Southern Ocean. FAO Southern Ocean Fisheries Survey Program. Rome, GLO/50177/1.
- Everson, J., K. H. Kock, G. and Parkers 1996. Ovarian development associated with first maturity in three Antarctic channichthyid species. J. Fish. Biol. 49:1019-1026.
- Fisher, W and J. C. Hureau 1985. FAO species identification sheets for fishery purposes. Southern Ocean. Vol. 2. Rome. CCAMLR-FAO:.233-470.
- Hart, T. J. 1946. Report on trawling surveys on the Patagonian shelf. Discov. Rep. 23: 223-408.
- Hecht, T., 1987. A guide to the otoliths of Southern Ocean Fishes. S. Afr. J. Antarct. Res. 17,1: 1-87.
- Kock, K. H. 1992. Antarctic fish and fisheries. Cambridge Univ. Press. Cambridge.
- Norman, I. R. 1937. Coast Fishes Part II. The Patagonian Region. Discov. Rep. 16: 1-150.
- Norman, I. R. 1938. Coast Fishes Part III. The Antarctic Zone. Discov. Rep. 18: 1-105.
- North, A.W. 1988. Age of antarctic fish: validation of the timing of annuli formation in otoliths and scales. Cybium. 12, 2: 107-114.
- Permitin, Y.Y. and Y.I. Sazanov 1974. Taxonomic position of *Notothenia squamifrons* Günther and related species. Vopr. Ikhtiol. 14, 4(87): 589-601.
- Radtke, R. L. and T. F. Hourigan 1990. Age and growth of the antarctic fish Nototheniops nudifrons. US Fish. Bull. 88: 557-571.
- Shandikov, G.A. 1986. Biological characteristics of *Nototheniops tchieh* (Balushkin) (Nototheniidae) from the Ob. and Lena seamounts, Indian sector of the Southern Ocean. Tr. Zooł. Inst. AN SSSR, 153: 91-109 [In Russian].
- Shust, K.V. and J. A. Pinskaya 1978. Age and growth of six species of Nototheniid fish (Family Nototheniidae). Vopr. Ikhtiol. 18,2 :837-843 [In Russian].
- Sosiński, J. 1999. The ichthyofauna of the King George Island (Antarctica) shelf waters and its value to commercial fishing. Bull. Sea Fish. Inst., Gdynia, 3(148):41-55.

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