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Pikeperch (*Sander lucioperca* (L.)) abundance, exploitation, and management in the Vistula Lagoon

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Abstract. This work presents a characterization of the exploited pikeperch population of the Vistula Lagoon based on complicated results from the analyses of pikeperch samples collected from commercial catches performed in the Russian and Polish parts of the lagoon. The materials collected by the Sea Fisheries Institute (in Gdynia) and AtlantNIRO (in Kaliningrad) were used to describe the length and age structures of pikeperch and to evaluate the tendencies of changes in the biomass of the exploited pikeperch population in the 1975-2004 period. The results of the analysis of the frequency structure in 4 cm length classes of pikeperch caught in the 1951–2004 period indicated that catches were based on younger fish (of lesser length) until 1964 when the legal limit of 46 cm (total length – TL) was introduced and caused a reduction in the share of small-sized fish in both Polish and Russian catches.

The magnitude of pikeperch resources can be divided into two stages during the 1975-2003 period. The first stage is from 1975-1989 and is characterized by an average of 1,099,000 specimens at age group IV and older and a biomass of 1,340 tons. The second stage was in the 1990-2003 period when resources of the pikeperch population were lower at an average of 643,000 specimens and a biomass of 762 tons. The success of pikeperch fisheries in the waters of the Vistula Lagoon in the 1975-2004 period were dependent on abundance of fish from the V and VI age groups that were also under the greatest fisheries pressure. The results of investigations indicate that the legal limit size should be within the 42-46 cm range.

Key words: pikeperch, length and age structure, minimum landing length, fishery regulatory measures, exploited population biomass

INTRODUCTION

Pikeperch *(Sander lucioperca* [L.]), which originates from the Ponto-Caspian Basin, is the only representative of this genus in European waters (it does not occur in the waters of the Iberian Peninsula). The sensory qualities of its meat mean that it is one of the most highly valued freshwater fish species on the European market. Catches of pikeperch in the inland waters of Europe in the 1990-2001 period decreased from 14,500 to 6,400 tons. In the most recent year for which statistics are available (2003), catches had increased to 9,500 tons. During this period, catches in marine waters, with the exception of the Mediterranean Sea, ranged from 1,700 to 3,060 tons (average 2,400 tons). The last figure includes catches from the Baltic Sea lagoons.

Fifty-seven species of fish have been recorded in the waters of the Vistula Lagoon (Feodorov 2002). Of the 24 species occurring in the Vistula Lagoon that are classified as freshwater fish (Borowski 1996, Skóra 1993), pikeperch, as one of the most valuable, is of the most interest to those who manage the resources that support fisheries in the waters of the lagoon. Catch statistics from the lagoon attest to the fact that, beside eel and bream, pikeperch has had a decisive impact on the success of fisheries in this basin over that past century. In terms of value, pikeperch was second to eel, while in terms of annual landings it was second to bream; only in 1937-1938 did pikeperch catches (over 500 tons) exceed those of bream (Bartel *et al.* 1996).

After the Second World War, the Polish and Soviet administrations recognized the necessity of unifying the management of the exploitation of the fish resources in the Vistula Lagoon. The accord of 1952 included the exchange of information regarding the size of annual landings made by fishers working both sides of the lagoon and prognoses regarding the abundance of exploited stocks for the coming years. Beginning in 1958, for each calendar year a total allowable catch (TAC) was established for pikeperch and bream fished from the waters of the lagoon, and from 1961 negotiations were held to divide the TACs into national fishing quotas. This management strategy has been maintained throughout the political and economic transformations of these two countries.

Information regarding research of the exploited stocks of pikeperch and bream in the lagoon has been exchanged for many years, and this has resulted in the standardization of methods for determining age and the abundance of the currently exploited year-classes as well as those that will be recruited to the population in the coming two years. Quantitative estimations of the stocks of both of these fish species, catches of which are limited by annual quotas, are conducted independently at scientific institutions in both countries. These results are compiled and corrected at meetings of experts and are the foundation for co-ordination among the representatives of the fisheries administrations of both countries.

Co-operation has led to the standardization of fishery regulatory measures, including legal size limits – the minimum total length of fish permitted to be landed, minimum allowable mesh size deployed to catch a given species, closed seasons (periods during which no catches or landings of a given species are permitted).

Fisheries in the Vistula Lagoon should be considered as opportunistic (Łopuski and Żebrowski 1953), which means that several fish species of varied body size are fished simultaneously in one fishing ground. In some cases, the desirability of one fish species requires deploying nets with mesh sizes that are not selective with respect to other species. This means that the fisheries patterns used to exploit stocks of pikeperch and bream on the two sides of the Vistula Lagoon differ substantially. As a consequence, the age structure of the pikeperch and bream caught in the two countries differs significantly. This means that estimations of exploited stock resources based on the age structure of fish sampled from catches made by one country do not necessarily reflect the correct age composition of catches made by the other country. This has led to discrepancies in evaluating the actual number of fish removed from the stock, and has hampered the precision of estimations of quantitative changes occurring in the stocks.

The current paper represents the first attempt to evaluate the state of the exploited pikeperch population in Vistula Lagoon waters in the 1975-2004 period. The evaluation was performed based on compiled data collected independently from both sides of the lagoon and represents the age structure of the pikeperch landed by both Polish and Russian fishermen.

The aim of the paper was to identify quantitative changes in the segment of the pikeperch population in the lagoon that suffered fishing mortality in the past thirty years in the context of the size of annual fish catches from this population and the regulatory measures applied.

MATERIALS AND METHODS

The pikeperch stocks were estimated with data from Polish and Russian fisheries statistics on the mass of annual fish landings and biostatistical data. These results came from analyses of pikeperch samples caught in the 1951-2004 period and collected by the staffs of the Sea Fisheries Institute in Gdynia (Filuk 1955, 1962, 1967(a), 1968, 1972(a), 1972(b), 1973, 1978, 1982, 1985, 1987, 1989, Borowski 1999, 2000, Borowski and Dąbrowski 1996, 1997, 1998, Borowski et al. 1997, 1998, 1999) and AtlantNIRO in Kaliningrad. The biostatistical data included information on age structure, sexual maturity, sex ratio, and the average mass of individuals according to age category. The average mass of fish according to age groups was estimated based on samples taken from landings in both countries and from the average mass of fish recorded in experimental catches conducted with a bottom trawl in the Russian part of the lagoon each fall.

Cohort Analysis (Pope's version) and Separable Virtual Population Analysis (Darby and Flatman 1994) were the models applied to estimate the abundance and biomass of the studied population. The basis for performing the initial estimation of changes in pikeperch abundance in the catches of both countries in the 1951-2004 period was the data that describes the length structure of fish caught in subsequent years (sorted into 4 cm length classes). To evaluate the reaction of the studied population to changes in the intensity of catches, the size of fishing mortality coefficient *F* was determined using the classic Beverton and Holt (1957) model based on the data presented at the annual ICES session in 2002 (Draganik and Keyda 2002).

Tables 1 and 2 present the total Vistula Lagoon pikeperch landed during the studied period in both countries and the average individual mass of fish according to age group**.**

The value of the natural mortality parameter *M* was assumed to be 0.2. The average mass of fish from the population at the beginning of each calendar year, which is required for the SVPA model, came from fish samples collected with bottom trawls during monitoring catches performed in the Russian part of the lagoon (Table 3). Value *F* for fish from the oldest group used in the SVPA model were estimated based on the arithmetic averages of value F for fish assigned to the V-XII age groups derived from the cohort analysis model.

The results of the examination of the sexual maturity of the gonads of 3,678 pikeperch ranging in length from 11 to 94 cm sampled from the catches made in the Russian part of the lagoon provided the basis for using the iteration method (SOLVER, MICROSOFT® OFFICE 2003) to calculate the values of parameters a and b in the equation

$$P_L = \frac{1}{(1+e^{(a+b)L})}$$ (Rickey 1995) where:

P_L – percent of mature fish at length L;
L – fish length; a and b – parameters values calculated from empirical measurements.

Table 1. Number of pikeperch caught in the Vistula Lagoon by age group (in thousands)

Year of catch	Age group															Total
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
1975	0.02	7.75	73.70	114.37	62.99	29.35	13.44	4.44	1.21	0.51	0.02	0.02	0.02	0.02	0.02	307.90
1976	0.01	9.83	60.79	91.04	58.92	39.03	24.97	9.63	4.14	1.07	0.38	0.20	0.02	0.02	0.02	300.07
1977	0.01	3.20	18.56	45.37	51.40	44.49	24.22	10.73	4.77	1.91	0.45	0.02	0.02	0.02	0.02	205.20
1978	0.01	4.21	39.84	45.88	36.17	35.93	25.71	7.32	3.74	0.73	0.53	0.37	0.25	0.02	0.02	200.72
1979	0.22	6.60	70.20	87.25	44.55	34.35	20.57	9.84	3.22	0.57	0.02	0.02	0.11	0.02	0.02	277.57
1980	0.02	2.74	32.94	58.05	42.55	46.81	24.29	10.00	4.22	1.84	0.89	1.00	0.11	0.11	0.02	225.59
1981	0.56	5.17	37.21	43.27	26.54	38.50	22.68	13.29	9.54	2.84	0.02	0.77	0.14	0.14	0.02	200.69
1982	0.56	1.05	10.92	17.53	23.18	38.14	30.10	14.64	3.48	2.69	0.55	0.65	0.02	0.02	0.14	143.67
1983	0.56	1.16	13.10	28.31	30.74	22.25	17.17	8.43	1.69	0.78	0.23	0.02	0.02	0.02	0.22	124.70
1984	0.56	0.97	13.45	37.39	37.39	26.87	17.03	10.01	3.15	2.08	0.47	0.60	0.69	0.02	0.02	150.69
1985	0.65	0.19	9.03	28.96	34.13	32.51	18.25	10.62	4.54	2.88	1.88	0.69	0.40	0.30	0.02	145.04
1986	0.56	0.36	5.97	20.36	32.04	41.08	24.00	11.66	5.40	2.40	1.03	0.74	0.08	0.08	0.02	145.78
1987	0.56	9.62	30.35	45.64	36.54	35.30	22.38	9.81	5.58	4.00	0.46	0.52	0.27	0.10	0.02	201.15
1988	0.56	8.93	25.93	40.04	30.59	26.75	21.54	14.07	10.03	3.57	2.03	0.92	0.12	0.02	0.02	185.14
1989	0.56	10.57	30.92	43.06	30.86	29.28	24.66	19.21	13.96	3.77	2.10	2.06	1.33	1.00	0.02	213.38
1990	0.56	9.28	28.57	44.82	40.12	39.38	23.49	12.10	5.81	4.22	1.63	1.16	0.61	0.29	0.11	212.15
1991	0.41	11.46	30.19	43.53	43.26	38.92	20.77	10.14	4.27	2.69	0.99	0.83	0.50	0.23	0.13	208.33
1992	0.54	9.10	25.41	36.17	35.06	38.24	21.29	9.67	4.27	2.57	1.02	0.82	0.46	0.21	0.12	184.97
1993	0.93	3.00	9.45	21.89	24.44	20.02	9.07	4.60	1.92	0.99	0.28	0.49	0.26	0.02	0.04	97.39
1994	0.29	2.88	13.15	27.97	25.56	24.54	14.01	6.33	3.37	1.55	0.86	0.54	0.17	0.19	0.07	121.50
1995	0.13	5.70	12.10	18.07	14.22	13.79	9.25	4.32	2.19	0.81	0.77	0.47	0.39	0.02	0.09	82.32
1996	0.45	1.53	10.39	27.68	22.24	18.61	9.19	5.19	2.09	1.47	0.56	0.09	0.09	0.02	0.02	99.62
1997	0.05	1.20	9.31	24.54	23.62	26.90	15.84	6.81	4.67	2.59	0.84	0.56	0.05	0.08	0.04	117.09
1998	0.02	1.71	9.63	19.31	16.48	18.51	16.40	4.48	2.57	0.83	0.37	0.29	0.04	0.14	0.04	90.83
1999	0.12	6.23	32.99	56.28	36.55	24.51	12.63	6.01	1.68	0.52	0.27	0.20	0.12	0.02	0.02	178.15
2000	0.68	4.01	25.08	50.39	41.68	27.77	11.20	5.83	2.44	1.48	0.70	0.06	0.32	0.02	0.02	171.66
2001	6.96	64.13	104.95	106.40	50.71	29.39	14.32	4.39	2.77	1.01	0.47	0.47	0.25	0.02	0.02	386.26
2002	0.71	13.11	44.02	55.20	48.07	21.86	5.33	3.98	0.96	0.57	0.27	0.02	0.02	0.02	0.02	194.16
2003	1.98	21.12	48.53	51.46	34.24	10.48	3.54	0.94	0.70	0.20	0.10	0.02	0.02	0.02	0.02	173.38
2004	0.12	6.66	40.60	69.90	44.50	27.42	15.21	3.04	0.34	0.22	0.13	0.13	0.13	0.02	0.02	208.44

Table 2. Mean weight at age of pikeperch caught in the Vistula Lagoon (g)

Year of catch	Age group														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1975		825	1044	1498	1854	2220	2921	3212	4373			6035			
1976		750	903	1189	1608	2064	2297	2979	3383	3656	4835	6570			
1977		734	969	1298	1624	1953	2386	3250	3533	3680	3650				
1978		710	859	1193	1608	1860	2286	2854	2972	3800	3870	6000	4000		
1979	220	593	854	1194	1533	1776	2042	2553	3000	4320			8300		
1980		680	834	1091	1401	1630	2100	2611	2407	2649	2800	2951	3102	3253	
1981		435	1016	1212	1529	1900	2253	2334	2804	3256		5450	6200	7520	
1982		510	952	1323	1623	1937	2180	2393	2714	3593	3580	5500			8700
1983		835	1069	1405	1811	2079	2441	2739	2820	5065	6070				8000
1984		640	1020	1185	1740	2064	2254	2513	3014	3650	3125	4057	6657		
1985	370		895	1108	1477	1989	2357	2388	2436	2547	3393	2707	3110	4593	
1986		600	833	1059	1096	1571	2045	2211	2373	2801	3001	4890	4110	6050	
1987		675	821	1093	1333	2058	2336	2600	3031	3115	3225	5135	4700	7300	
1988		810	914	1224	1498	2061	2377	2702	3162	3520	3649	5025	5500		
1989		497	897	1133	1346	1665	2134	2510	2859	2971	3403	4217	5025	5600	
1990		760	911	1080	1580	2190	2550	2800	3250	3700	3890	3995	4260	4940	4741
1991		770	950	1090	1575	2123	2410	2793	3173	3573	3806	3990	4509	5383	5515
1992		790	960	1150	1600	2190	2410	2682	3120	3530	3655	3856	4270	5515	
1993			1175	1365	1931	2522	2429	2728	3448	3462	4025	5440	6700		
1994		647	848	1255	1908	2417	2652	2665	3024	3593	4288	4846	6083	7650	
1995		632	1104	1655	1864	2516	2814	3257	3518	3113	3423	5882	4270		
1996	379	501	847	1208	1810	2281	2736	3393	3710	3895	4105	3825	6200		
1997		617	808	1019	1572	2099	2376	2800	3659	3929	5392	5869	5600	8700	
1998		480	780	1163	1602	2226	2568	3233	3901	4378	5076	5553		6536	
1999		602	841	1154	1657	2079	2413	2707	3609	4354	5323	5178	5889		
2000	422	626	943	1175	1653	2158	2883	3078	3731	4620	5242	4207	6872		
2001	378	606	787	1280	1789	2070	2414	3227	3850	3482	5030	6036	6879		
2002	260	596	979	1370	1757	2340	2642	3268	4188	4285	4345				
2003	394	548	799	1560	2271	2642	3427	3676	3737	3926	4707				
2004	378	503	707	1139	2027	2592	3154	3846	3801	4144	5097	6300	7700	8000	

Table 3. Mean mass of pikeperch caught in experimental catches in the Russian part of the Vistula Lagoon (g)

Year of catch	Age group													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1958		166	301	450	879	1246	1790		5200			6650		
1971			465	873	1220			2560						
1972	34	200	412	602	975	1494	1633							
1973		162	305	559	900	1335	2000	2140	3050			7390		
1974		138	260	547	801	1267	1734	1813						
1975		189	352	586	940	1057	1616							
1988	29	70	265	551	712	1088	1311	1606		2470		4060		
1989	30	140	227	408	765	1049	1227	1562	1820	2135	2570			
1990		120	179	515	752	1074	1314	1617	1595	2250	2150			
1991			184	477	744	1090	1320	1568	2195	1700	3730			
1992	29		183	427	685	885	1461	1832	1560	2300				
1993	20	150	197	412	666	892	1135	1548	1783	2478	2680			
1994	47	54	253	521	711	960	1270	1799	1998	2223				
1995	22	42	160	270	457	746	942	1740	2307	1976				
1996			167	328	547	796	1123	1542	2797	3475		5080		4460
1997	57	116	190	435	704	1024	1309	1565		1905	5400			4730
1998	36	103	189	375	601	872	1246	1581	2580	2427	3020	4280		5820
1999			274	306	669	903	1146	1653	2054					
2000	20	90	249	456	702	948	1196	1420	2825	2815			4460	
2001	49	162	275	494	690	991	1250	1780	2140	2750				
2003	140	100	190	363	592	900	2333							
2004	74	31	289	403	528	746	1060							

The preceding logistic curve equation, commonly known as the ogive of sexual maturity, describes the dependence between fish length and the percentage of fish that have achieved sexual maturity in a given length category. The *a/b* ratio describes the length of fish at which 50% might reproduce. The values of *a* and *b*, which determine the shape of the ogive of the studied Vistula Lagoon pikeperch, were estimated with fish (a total of 1,422) whose gonads had achieved development stage IV or higher on a six-stage scale (Pravdin 1966).

Biological features of the pikeperch inhabiting the Vistula Lagoon related to its availability to fishery

The pikeperch of the Vistula Lagoon are an independent (self-sustaining) population that is distinct from those in the Curonian and Szczecin lagoons (Khlopnikov and Keida 1998, Golubkova 2003). Some specimens from this population undertake migrations to marine waters where the feeding conditions are better due to the occurrence of herring and sprat. At the end of fall, these fish return to the lagoon where there are more advantageous thermal conditions (water temperature is higher in comparison with that in the sea) (Shibaev *et al*. 2000, Lugovaya, E. S 1991). The thermal conditions of the water in October and November are decisive factors in the success of pikeperch catches; higher water temperatures delay and decrease the intensity of the return of the fish to the lagoon.

The biological potential of this species evaluated by the absolute fecundity of pikeperch females in the Baltic lagoons (Vistula, Szczecin, Curonian) is similar (123-623 eggs/g female mass) and is higher in comparison with pikeperch that occur in the lakes of northern Finland, where the fecundity index is lower (Kosior and Wandzel 2001).

Pikeperch fisheries in the Vistula Lagoon are regulated by the minimum fish size (total length) that is permitted to be landed (known as the legal limit), at which length theoretically the fish have an even chance of spawning or not. This size is determined based on the results of the analysis of the gonad maturity of a population of fish with a fairly wide range of lateral line values and refers to the length class in which 50% of the fish achieve maturity. The materials collected for the present paper (from the Russian part of the lagoon) served to estimate the fish maturity ogive equation parameters (Fig. 1) a and b which were 9.4635 and 0.2196, respectively, and, according to the criteria discussed here, the legal limit should be ~ 43 cm. If it were assumed that fish whose gonads achieve stage III maturity in spring will spawn, then the legal limit would be 40.2 cm.

Pikeperch spawning grounds are located in the coastal waters of the Polish part of the lagoon, one of which is located in the vicinity of the fairway that has been degraded significantly due to hydro-engineering projects.

Pikeperch are at the top of the trophic pyramid of the lagoon and have a significant impact on the ichthyofauna composition of the basin. This species feeds primarily on herring, roach, round goby, and cyprinids (Khlopnikov1992, Wilkońska and Żelepień 1998). The growth rate of the Vistula Lagoon pikeperch is faster in comparison with the analogous index in the Curonian Lagoon (Golubkova 2003) and slower than that of pikeperch from the Szczecin Lagoon (Neja and Turowska 1998, Draganik and Keyda 2002). The analysis of long-term data regarding pikeperch age and length indicates that the value of

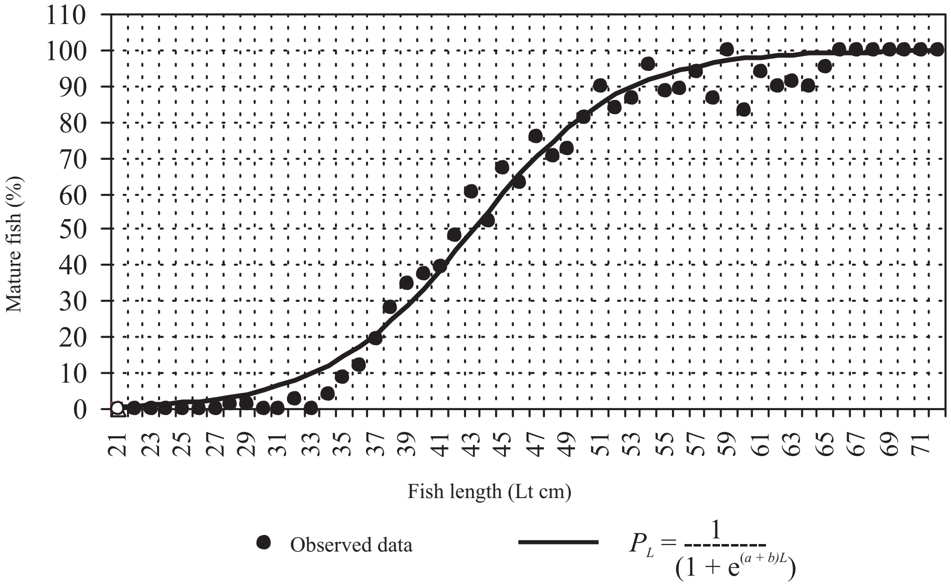


Fig. 1. Maturity ogive of pikeperch in the Vistula Lagoon.

L_∞ ranges from 81.2 cm to 104.6 cm, while K ranges from 0.182 to 0.087. For the purposes of the current investigations, the following values were assumed: L_∞ = 96.2 cm; K = 0.122; t_0 = –1.032 (Draganik and Keida 2002).

Commercial significance of pikeperch and the management of stocks in the Vistula Lagoon

Pikeperch catches in European marine coastal waters reach 2,400 tons annually, of this approximately 35% are made in the waters of the Baltic Sea lagoons (Szczecin, Vistula, Curonian) where annual landings reach 900 tons. In the 1920s, pikeperch catches from the waters of the Vistula Lagoon increased rapidly from 110 to 170 tons, and by the 1937-1938 season they exceeded 500 tons. During the 57 year period following World War II, the average size of annual pikeperch catches was 320 tons at a range of 172-513 tons (Table 4).

The pikeperch legal limit in both countries has been 46 cm (total length) since 1964. Maximum population productivity, regardless of exploitation intensity, can be ensured by this legal limit with the assumed growth and natural mortality indices if recruitment remains stable. The majority of the landed pikeperch mass comes from catches made with gillnets. The mesh size in this gear for targeted pikeperch catches cannot be smaller than 65 mm or 70 mm in Polish and Russian fisheries, respectively.

In catches of fish that attain smaller sizes, such as perch and roach, the minimum mesh size for entangling gear is 35 mm, which retains a significant quantity of undersized pikeperch. The desirability of eel means that lagoon fishermen target it with the highest

Table 4. Pikeperch catches in the Vistula Lagoon (tons)

Year	Poland	Russia	Total
1948	228.2	165	393.2
1949	308.0	75	383.0
1950	313.5	75	388.5
1951	231.1	124	355.1
1952	224.6	87	311.6
1953	253.8	125	378.8
1954	219.8	50	269.8
1955	177.7	210	387.7
1956	187.7	326	513.7
1957	158.7	275	433.7
1958	115.4	240	355.4
1959	163.6	250	413.6
1960	221.2	280	501.2
1961	128.8	185	313.8
1962	101.0	115	216.0
1963	88.6	150	238.6
1964	144.5	175	319.5
1965	149.9	77	226.9
1966	136.6	208	344.6
1967	128.4	235	363.4
1968	116.8	225	341.8
1969	113.2	150	263.2
1970	125.0	220	345.0
1971	146.6	215	361.6
1972	176.5	170	346.5
1973	181.7	142	323.7
1974	179.9	245	424.9
1975	185.9	320.8	506.7
1976	151.6	301.4	453.0
1977	106.0	260.9	366.9
1978	118.4	196.0	314.4
1979	214.1	169.0	383.1
1980	119.5	225.0	344.5
1981	93.4	236.0	329.4
1982	22.4	249.0	271.4
1983	30.2	200.0	230.2
1984	83.6	183.0	266.6
1985	85.5	177.0	262.5
1986	98.0	200.0	298.0
1987	106.9	200.0	306.9
1988	38.2	200.0	238.2
1989	88.9	238.0	326.9
1990	128.2	250.0	378.2
1991	95.4	237.0	332.4
1992	75.2	230.0	305.2
1993	49.5	127.5	177.0
1994	83.5	137.0	220.5
1995	61.9	108.7	170.6
1996	83.0	89.2	172.2
1997	106.2	138.8	245.0
1998	88.9	93.2	182.1
1999	122.5	131.9	254.4
2000	146.3	157.2	303.5
2001	128.5	139.6	268.1
2002	105.1	169.6	274.7
2003	95.3	140.0	235.3
2004	111.7	150.0	261.7

fishing effort using trap gear with a small mesh size (16 mm). The deployment of large trap nets to catch eel in the Polish part of the lagoon meant that large numbers of undersized pikeperch, especially those from the 0 and I age groups that had attained a size of 12 cm, were retained in the fall. In order to reduce mortality in this group of fish, a regulation was passed that required fitting fyke-net codends with metal or plastic sieves with holes that permit young bream and pikeperch fry to escape (Draganik *et al.* 2004).

The closed season which is in effect in April and May ensures that pikeperch catch mortality is limited when it forms dense spawning concentrations and also guarantees that the spawning population has suitable conditions to release as many eggs as possible.

The differences in the availability of pikeperch to fisheries resulted from seasonal concentrations in various locations in the Vistula Lagoon, migration, and variability in the gear deployed by the fishermen of both countries. This meant that the previously described pikeperch fishing regulatory measures did not guarantee that standardized exploitation would provide equal access to resources. In order to standardize access to and

Table 5. Annual catch quota and catch of the pikeperch in the Vistula Lagoon in 1961-2004*

Year	Catch quota (t)			Annual catch (t)
	Russia	Poland	Total	
1961	200	220	420	313.8
1962	200	220	420	216.0
1963	200	185	385	238.6
1964	200	185	385	319.5
1965	200	185	385	226.9
1966	200	185	385	344.6
1967	230	210	440	363.4
1968	230	210	440	341.8
1969	270	210	480	263.2
1970	300	210	510	345.0
1971	300	210	510	361.6
1972	300	210	510	346.5
1973	250	180	430	323.7
1974	250	180	430	424.9
1977	300	230	530	366.9
1978	300	230	530	314.4
1979	270	180	410	383.1
1980	230	180	410	344.5
1981	230	180	410	329.4
1983	200	150	350	230.2
1984	200	150	350	266.6
1989	250	180	430	326.9
1990	250	180	430	378.2
1993	230	160	390	177.0
1994	230	160	390	220.5
1995	250	150	400	170.6
1996	200	120	320	172.2
1997	200	120	320	245.0
1998	150	110	260	182.1
1999	200	130	330	254.4
2000	200	130	330	303.5
2001	200	130	330	268.1
2002	200	130	330	274.7
2003	180	118	298	235.3
2004	180	118	298	261.7
2005	180	118	298	

*No quotas were set in 1975, 1976, 1982, 1985, 1986, 1987, 1988, 1991, 1992

the exploitation of the productivity of the Vistula Lagoon pikeperch population, in 1961 catch limitations were introduced as annual catch quotas (the total allowable pikeperch mass each country is allowed to land in each calendar year). Table 5 presents the catch quotas that have been set over the years.

Length distribution

The length frequency distribution of the landed pikeperch is highly variable (Fig. 2). The minimum size (legal limit) which determined the shape of the frequency curve in the length classes of landed fish changed several times during the period studied. In the Russian part of the lagoon the minimum landing length (MLL) was 28 cm TL until 1953, while from 1953 to 1958 it was 40 cm TL and then 46 cm. In the Polish part it was 35 cm until 1953, and in the 1953-1963 period it was 40 cm, and since 1964 it has been 46 cm TL.

At the beginning of the 1950s, the length distribution curves reflecting the annual catches taken in the Polish part of the lagoon were strongly flattened. Not until the end of the decade did the distribution change to become more characteristic of selective fishing (bell curve). Changes in MLL meant that the length distribution curve of caught fish usually shifted to the right after a few years of tolerating by-catch of fish that were under the MLL. It took the fishermen an especially long time to become accustomed to the 46 cm TL size limit; not until the 1970s did the length distribution shift towards lengths longer than the MLL. There is also a series of years during which, despite the long period of MLL (46 cm TL) having been in force, there was high by-catch of undersized pikeperch. This can be seen in the measurements in the Polish part of the lagoon in the 1990s. The share of specimens under the MLL that were caught during this period reached as much as half of the quantity of all fish measured, and the distribution length differed substantially from that in the Russian part of the lagoon. In recent years (after 2000), these differences have become progressively smaller as the result of shifting the length frequency distribution curve of the Russian catch to the left, which means that by-catches of undersized pikeperch are increasing on both sides of the border.

Applying cohort and SVPA models to evaluate pikeperch stock size

Fish from age groups II to XII were recorded in catches. The selectivity of the applied fishing gear and the impact of varying environmental conditions on the localization of the occurrence of the youngest fish meant that the susceptibility of fish from age groups II and III to the deployed gear was lower in comparison to that of older fish. Consequently, calculations of the abundance and biomass of the exploited pikeperch population should only take into consideration fish belonging to age group IV and older.

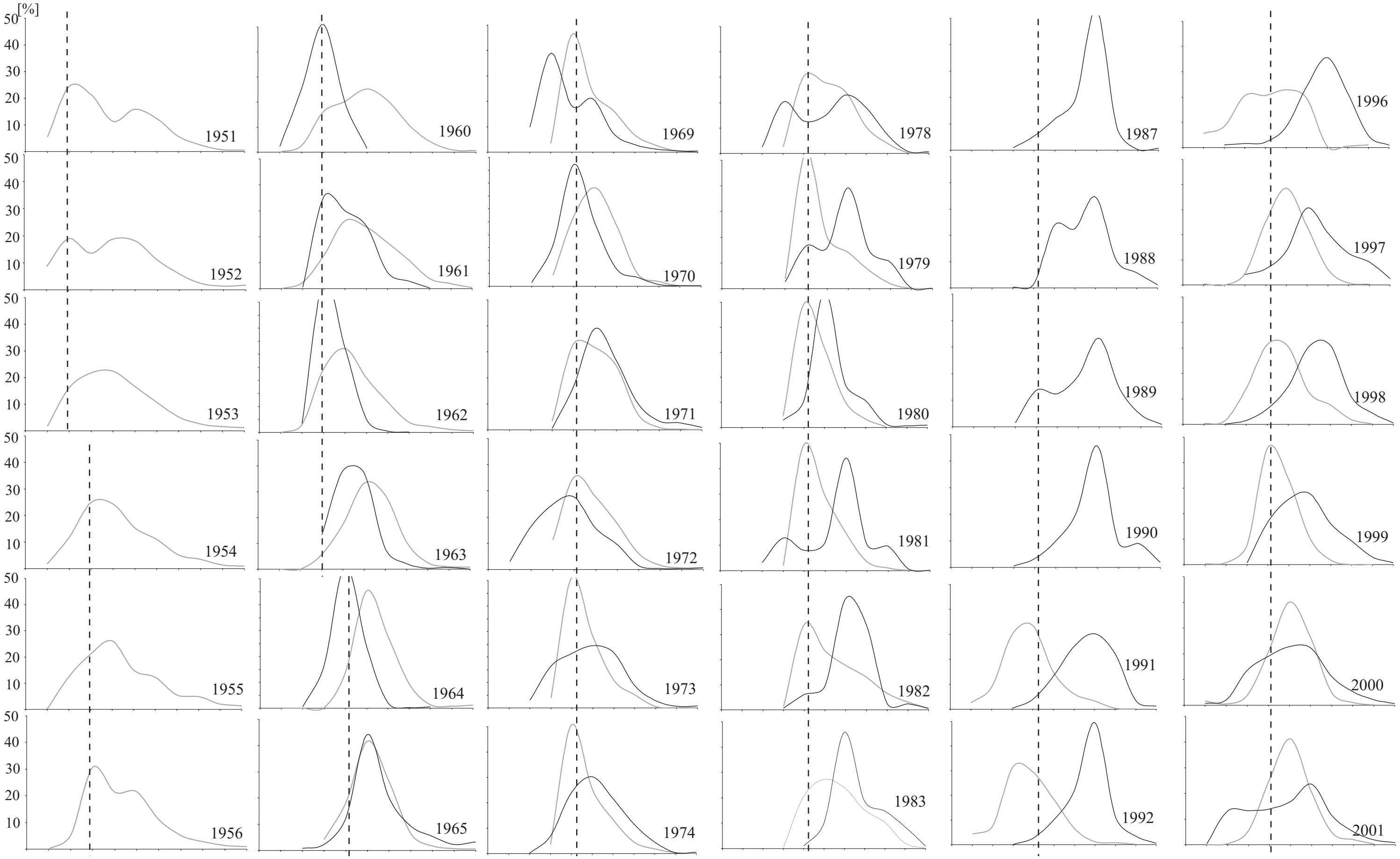
The value of fishing mortality *F* for fish belonging to age groups V and VI indicate that fisheries pressure on these groups has increased in recent years. While the average value of index F was 0.23 in the 1975-1989 period, the average value of this index in the 1990-2003 period was as high as 0.42.

The abundance of the exploited pikeperch population was evaluated based on cohort analysis and separable virtual population analysis. The results of pikeperch abundance and biomass estimations performed with these two methods are presented in Fig.3.

The analysis of the residuals of the observed abundance in the catches was compared with the abundance in catches calculated according to the models (Fig. 4); it was determined that better agreement is achieved with the SVPA model. These values will be used in the text of the current paper.

The analysis of the results permits identifying two distinct stages during the 1951-2004 period that differ with respect to the magnitude of pikeperch resources in the Vistula Lagoon. The first stage is from 1975-1989 when, despite the substantial fluctuation of indices, the level of resources was characterized by an average biomass of 1,340 tons and an average population abundance of 1,099,000 individuals. Since 1990, the trend has been for resources to decline and then stabilize at a level that is lower than previously. The average biomass for the 1990-2003 period was 762 tons and abundance was 643,000 pikeperch individuals.

These changes in the state of resources were reflected in the size of the estimated total allowable catches (TACs), which were the basis for determining the catch quotas for Polish and Russian fisheries. During the preparation of the results, the impact which the natural mortality value had on the estimated size of the resources of the studied population was evaluated. It was assumed that for fish in age groups VII to XII the value of M declined gradually from 0.2. Results of calculations indicated that these variations did not have a significant impact on the results of the evaluations of population abundance or biomass.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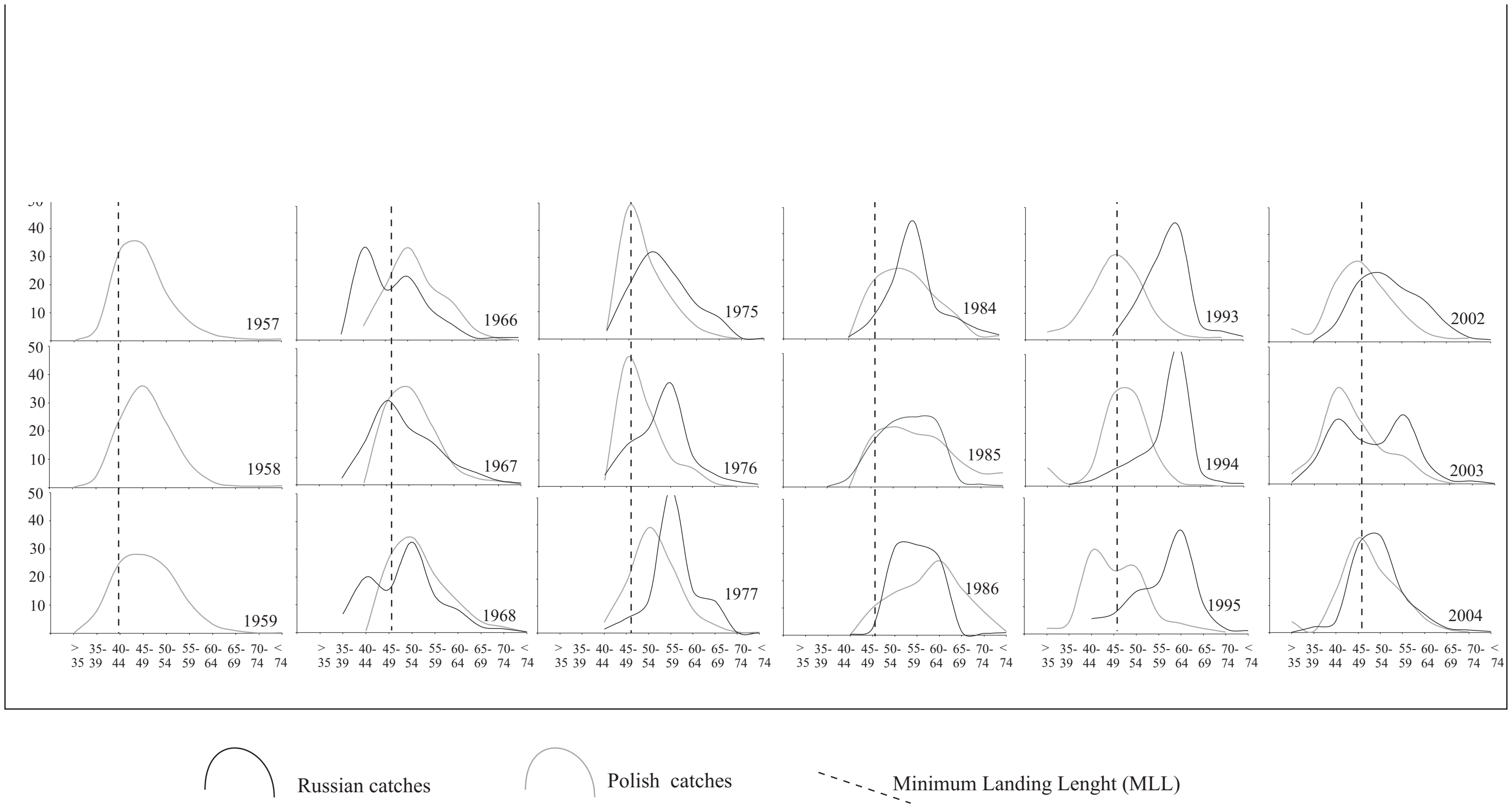

Fig. 2. Lenght of the pikeperch fished in the Vistula Lagoon

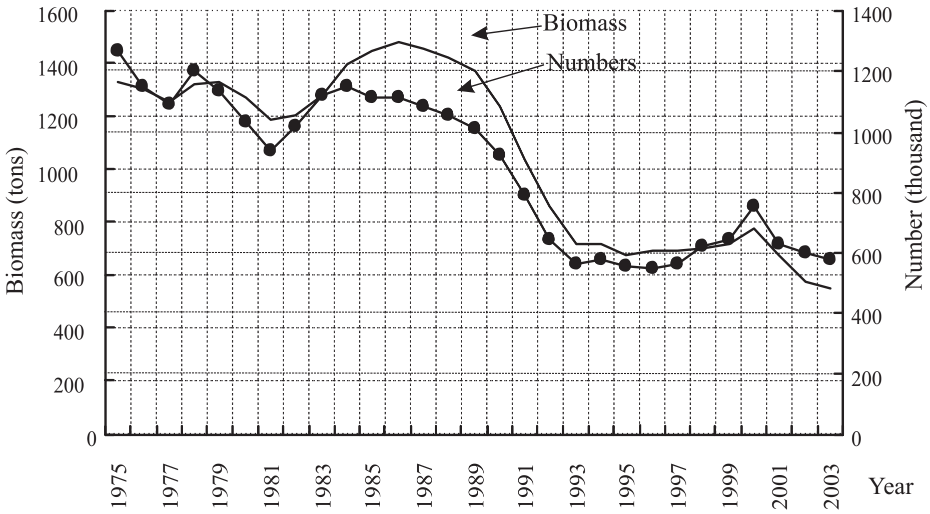

Fig. 3. Pikeperch abundance estimates (number and biomass of fish at age group III and older) in the Vistula Lagoon.

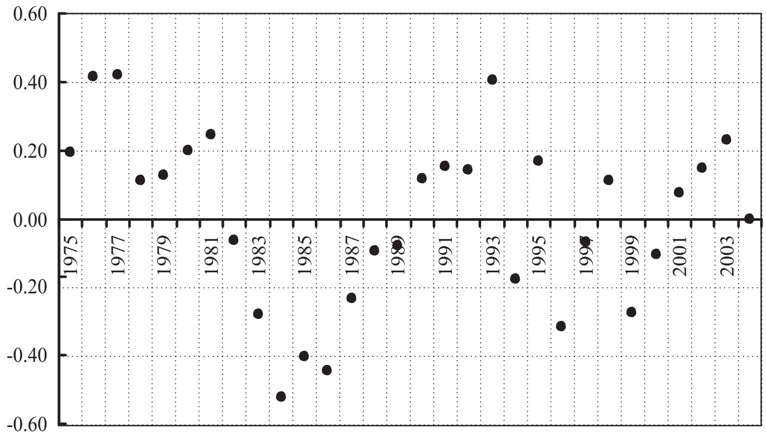

Fig. 4. Residuals of pikeperch catches in the Vistula Lagoon from the comparison of observed and calculated model values.

DISCUSSION

Estimations of pikeperch stock abundance were performed by experts from Polish and Russian scientific institutions separately with the data available at the respective institutions from fish samples caught in each country. The magnitude of the proposed TAC values was estimated annually at joint meetings of experts from both sides of the lagoon. This approach guarantees neither an objective nor precise evaluation of the current state of exploited population resources. The current work presents the results of estimations of pikeperch population mortality, abundance, and biomass obtained using the cohort analysis and separable virtual population analysis models. For the first time, the basis for calculations was the combined results of studies conducted in separate parts of the lagoon belonging to the two countries. The data used depict the impact of fisheries on the state of exploited population resources in the waters of the entire lagoon. The authors are aware that excluding the youngest age groups (II and III) limited the range of the estimated values describing the fish abundance in the studied population. However, changes in the availability of fish to the fisheries resulting from fishing gear selectivity and the impact of environmental conditions on the localization of targeted fish meant that the abundance of fish belonging to these two age groups in the catches did not reflect fairly the actual abundance in the environment, and including them in the calculations would only decrease the precision of the actual population abundance that supports the fisheries. The consequence of limiting estimations to the population of fish from age group IV and older was that the results were more representative for evaluating the trends (changes) in abundance and biomass than were the results of evaluation of the absolute values of these variables. The average size of the pikeperch population biomass estimated by Draganik and Keyda (2002) for the 1991-2000 period was 957 tons. It should be added that this value refers to the population of fish belonging to age group II and older and the results were calculated based on the assumption that the age structure of fish caught throughout the lagoon was analogous to that of the fish in the Polish part of the lagoon.

The results of estimations presented in the current paper indicate that there were substantial changes in pikeperch resources during the 1975-2003 period (results for 2004 were disregarded in the discussion as the size of the error resulting from the acceptance of the assumptions required by the construction of the model is unknown) as is indicated by significant changes in the resources of the exploited pikeperch population that can be divided into two periods. In the 1975-1989 period, the abundance and biomass of the studied population were substantially larger in comparison with the abundance and biomass estimated for the population sustaining catches in the 1990-2003 period with average values for these periods as follows: abundance$_{1975\text{-}1989}$ – 1,099,000; biomass$_{1975\text{-}1989}$ – 1,340 tons; abundance$_{1990\text{ - }2003}$ – 643,000; biomass$_{1990\text{ - }2003}$ – 762 tons.

In the second period, biomass was stable in comparison to variations in it during the 1975-1989 period. During the first period, average annual catches from the entire lagoon were 327 tons. In the second period, the average biomass level of 725 tons compared to the average fish biomass landed annually during this period (251 tons) indicates that fisheries pressure on the population was strong. This means that fisheries pressure was nearly twice as high in the 1990-2003 period in comparison with the previous period (average values of F were 0.42 and 0.23, respectively) on the fish belonging to the V and VI age group – those which determine the reproductive potential of a population (Kosior and Draganik 2003). Increased catches of smaller pikeperch as a result of an increasing share of entangling gear with smaller mesh sizes deployed to catch other, smaller fish species (Psuty-Lipska 2005) could have an impact on decreasing recruitment in the exploited pikeperch population in the Vistula Lagoon.

From the point of view of conservation and monitoring, compliance with binding catch regulatory measures and the MLL of landed fish, further referred to as the legal limit, appear to be the most effective due to their relative ease of application. Throughout the history of Vistula Lagoon pikeperch exploitation, the MLL has undergone several changes (increases) from 28 cm in 1916 (Ropelewski 1996) to 46 cm (total length), which has been in effect since 1964 in Poland and Russia. In light of studies conducted to date on the reaction of pikeperch populations to the intensity of catches, the 46 cm legal limit fulfills the criteria of the optimal exploitation of Vistula Lagoon pikeperch productivity.

If the management criteria for the legal limit is the length at which 50% of the fish specimens attain sexual maturity and are able to release spawn, this limit might be smaller. According to Kosior and Wandzel (2001), 50% of Vistula Lagoon pikeperch measuring 43.9 cm attain sexual maturity. According to the results from the analyzed materials collected for the current studies, this limit is 43.0 cm. In summation, it can be assumed that the legal limit should be within the range of 42 to 46 cm.

Obtaining representative estimation results of the state of pikeperch resources and their usefulness in making prognoses of changes in the state of resources in the context of the assumed exploitation model depends on the reliability of the fisheries statistics applied. While there is no basis for questioning the accuracy of current landing statistics, the quantity of undersized pikeperch that are caught and released and then subsequently die remains unknown. The long-term observations of the authors indicate that the quantity of undersized fish caught and registered in landings ranged very widely depending on year and the place in which observations were made. This is why the authors considered it appropriate to disregard fish from age groups II and III in the calculations.

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Mathematical model of dewatering preheated raw fish material during centrifugal sedimentation

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Abstract. This paper presents the results of analyses and research used to develop a mathematical model of dewatering preheated raw fish material during centrifugal sedimentation: $sm = 0.15\ (pt\ /\ \mathrm{h})^{0.06}\ kt^{\ 0.24}$. The model is based on dimensionless groups and describes the relationship between the basic parameters of the operation (maximum pressure generated during centrifuging, centrifuging time, and thickness of the centrifuged material layer) and the dry matter content in the centrifuged material.

Key words: fish, dewatering, centrifugation

INTRODUCTION

Using raw fish material that has not been refined into meal in the production of extruded vegetable-fish feed depends on the degree to which this material has been dewatered. Research conducted at the Sea Fisheries Institute in Gdynia indicated that the degree of dewatering during centrifuging (Dowgiałło 2003, 2004) allows this material to replace nearly 25% of the fish meal used in feed manufacture. The condition for increasing this share is more effective centrifuging to increase the dry matter content in the centrifuged raw material. Preheating raw material, which makes dewatering more effective, is one possibility.

Centrifugal sedimentation is applied to express fluid from biological materials (Schwartzberg 1997). There is a lack, however, of mathematical models to describe this process. Existing detailed models that describe expressing fluid from organic materials (Schwartzberg 1997) cannot be applied to describe this process since the models are strongly linked to the characteristics of the raw materials. In an effort to control the dewatering process, work was undertaken to develop such a model. This could have been achieved either by the modification and experimental verification of an existing general pressing operation model or by the development of a new model.

Mathematical model of dewatering during centrifugal sedimentation

Among the models found in the literature, which describe the pressing operation, the one developed by Sivik (1980), was chosen for further analyses:

$$U = 1 - \exp(-\frac{c}{w_0^2}\Theta^n p^m) \qquad [1]$$

where:
U – mass of extracted liquid/mass of liquid possible to extract;
w_0 – amount of dry matter per unit area in the press;
Θ – time;
p – applied pressure;
c – constant;
n, m – exponents.

Besides its simplicity, the advantage of this method, further referred to as method I, is that, as a modification of the Shirato *et al.* (1971) method, it is easy to recalculate parameter U into dry mass dm in the dewatered raw material. The disadvantage of it is its dimensional non-homogeneity, which means it has the traits of a statistical model. Additionally, it must be expanded by another operation parameter – namely the preheating temperature of the raw material.

Taking into consideration preheating temperature t and assuming that parameter w_0 of a given raw material is proportional to the height of the centrifuged material layer, equation [1] can be expressed as follows:

$$U = (1 - \exp(-\frac{c_1}{h^2}\Theta^n p^m)t^s \qquad [2]$$

where :
c_1 – constant;
t – preheating temperature;
s – exponent.

The second way of describing the dewatering of raw fish materials during centrifugal sedimentation is to create a new model that takes into consideration the basic parameters of the operation, as follows:

– maximal applied pressure p [MPa];
– centrifuging time τ [s];
– viscosity of expressed fluid μ [Pa · s];
– media resistance R [m^{-1}];
– sample height h [m];
– preheating temperature t [deg].

Since the effectiveness of dewatering, expressed as the dry matter content of the centrifuged raw material, increases along with pressure p, centrifuging time τ, and preheating temperature t, and decreases with the increasing viscosity μ of expressed fluid (mixture of water and dissolved protein), media resistance R of its flow and the height h of the centrifuged raw material layer that increases the resistance flow, the following can be written:

$$dm = f(p, \tau, \mu^{-1}, R^{-1}, h^{-1}, t) \qquad [3]$$

The parameters of equation [3] were regrouped with dimensional analysis into dimensionless groups $\frac{p\tau}{\mu R h}$ and $kt = \frac{t}{t_o}$, where t_o is equal to the ambient temperature (22ºC). Assuming that parameters μ and *R* are constant for a given raw material, and the increase in dry matter in the dewatered raw material is a hyperbolic process, which can be described with a power function, equation [3] was transformed into the form that will be referred to further as model II:

$$sm = c_1 \left(\frac{p\tau}{h}\right)^a kt^b \quad [4]$$

where $c_1 \left[\frac{\mathrm{m}}{\mathrm{Pa \cdot s}}\right]^a$ is the constant assuming the impact of parameters μ and *R*.

Determining the exponents of the model expressed with equations (2) and (4) and the outcome, which permits predicting precisely the dry matter of raw fish material dewatered during centrifugal sedimentation, can only be done based on the results of experimental research.

MATERIALS AND METHODS

The research material was comprised of frozen sprat with a dry matter of dm_{av} = 0.207 ±0.015. The ranges of the initial parameters of centrifuging and the technical conditions of the research station (sample container size, centrifuge revolutions) were as follows:

– sample mass *m*	$m \in$ [20 - 80] [g] corresponding to sample height $h \in$ [14 - 57] [mm];
– centrifuge drum revolutions *n*	$n \in$ [33 - 100] [r.p.s];
– centrifuging time τ	$\tau \in$ [60 - 180] [s];
– preheating temperature *t*	$t \in$ [40 - 90] [°C].

After thawing, the sprats were heated in a water bath to the desired temperature and then drained gravitationally. They were ground in a grinder with a mesh size of *Ø* = 4.5 mm. After grinding, they were centrifuged in a laboratory centrifuge (centrifugal flow chart is presented in Figure 1). Centrifuging was conducted for twenty-four initial parameter sequences corresponding to particular points of the Behnken-Box experiment design. As the initial parameter, the dry matter content (*dm*) was determined in the centrifuged samples.

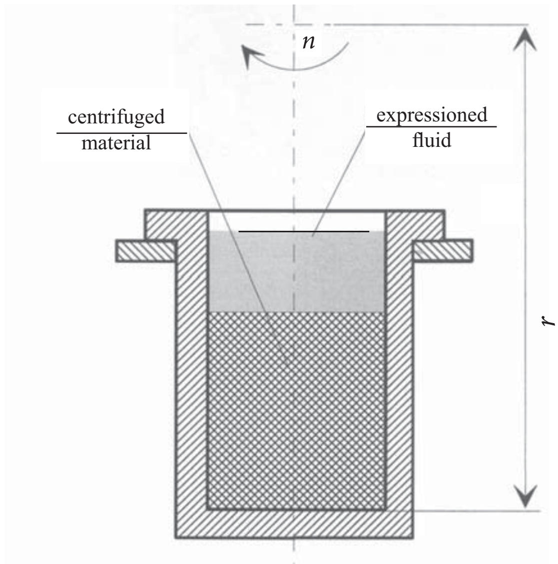

Fig. 1. Centrifugal sedimentation flow chart.

RESULTS AND DISCUSSION

Estimation of model I parameters

Knowing the average dry matter content of the raw material samples used (dm_{av} = 0.207), it was easy to demonstrate with the equation of equilibrium of the dry matter, that parameter U, the relationship of the expressed water (m_{we}) to the total mass of extracted water in the sample (m_{wt}) was equal to:

$$U = \frac{sm - 0.207}{0.793 sm} \qquad [5]$$

After calculating the value of parameter U for the particular sequences of the experiment plan, the results of the measurements were analyzed statistically in order to estimate the parameters of model I. It appeared that general model I does not agree with the measurement results. This was verified by replacing parameter h^2 with a parameter with an estimated exponent h^z. The revised statistical processing yielded the following:

$$U = (1 - \exp(-0.003\Theta^{0.206}\, p^{0.158}\, h^{-0.105})\, t^{0.337} \qquad (R^2 = 64.68\%) \qquad [6]$$

Figure 2 presents the plot of dry matter measured during the studies versus the values calculated using model I [6]. This indicates that the scatter of the measurement points

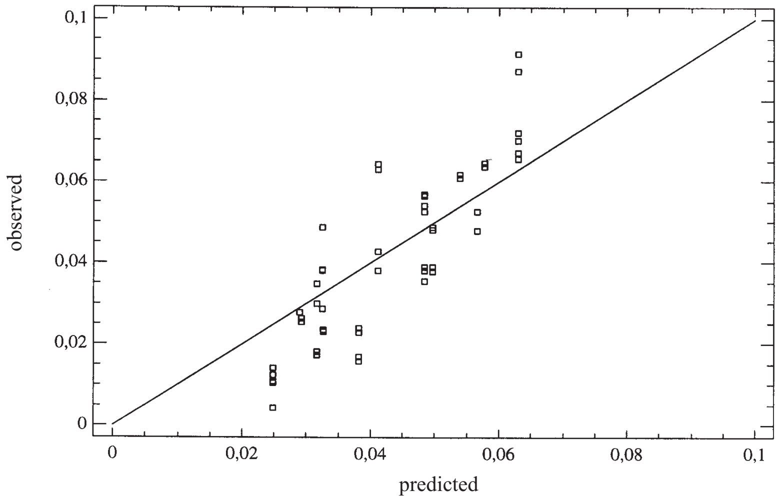

Fig. 2. Observed values of *dm* versus predicted values with model I (6).

around the theoretical data is too high for the practical application of model I to predict dewatering behavior in setting centrifuges.

Estimation of model II parameters

Since the available literature does not contain any discussion of the efficiency of fish raw material dewatering during centrifuging with the use of dimensionless groups, it was necessary to verify whether $\frac{p\tau}{\mu R h}$ behaves as a such group (Doeblin 1995). Thus, for different values of p, h, and τ (μ and R are constant), which constitute the same value $\frac{p\tau}{h}$ (Table 1), the dry matter content was measured by centrifuging the preheated raw material (90°C) four times. Their average values at a 95% confidence interval are presented in Figure 3.

The comparison made using the *t*-Student test showed there was no basis for rejecting the hypothesis that the mean values of dry matter obtained in the experiment are equal. Thus, group $\frac{pt}{h}$ made in dimensional analysis complies with the requirements of the number of the dimensionless group.

Table 1. Parameters of the control of dimensionless group values $\frac{pt}{h} = k$

k	*k1*	*k2*
p [MPa]	0.264	1.075
h [m]	0.014	0.050
τ [s]	180	157.9

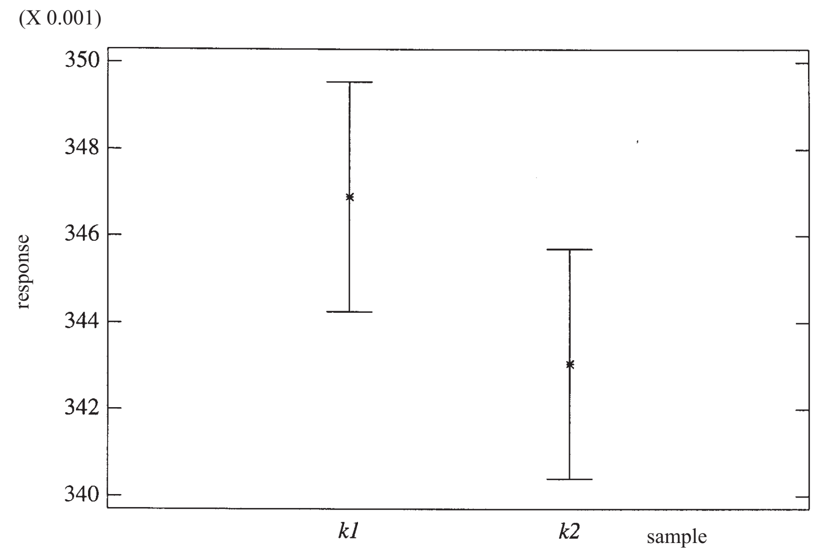

Fig. 3. Mean values at 95% confidence intervals of dry matter content in centrifuged samples with different parameters that create group *k* of the same value.

After transforming the measurement results to dimensionless groups, they were processed statistically which yielded the following:

$$sm = 0.15\left(\frac{pt}{h}\right)^{0.06} kt^{0.24} \qquad (R^2 = 85.27\%) \qquad [7]$$

The coefficient of multiple determination R^2 of model II (7) is higher by more than 20% and the measurement points are less scattered around the theoretical data than in the case of model I (Fig. 4).

In order to compare quantitatively the prediction accuracy of models regarding the dry matter content in dewatered raw material with the same parameters as in the experiment (dm_I and dm_{II}) and to calculate the mean values of the absolute relative error between measured and calculated values at 95% confidence intervals, the following was done:

$$\frac{|dm - dm_I|}{dm} = 0.2733 \pm 0.0284 \quad \text{and} \quad \frac{|dm - dm_I|}{dm} = 0.0419 \mp 0.0106$$

The comparison shows that the model II yields much higher accuracy regarding the prediction of dry matter content in dewatered raw fish material.

Figure 5 illustrates the impact of the values of particular dimensionless groups on the content of dry matter in the dewatered raw fish material.

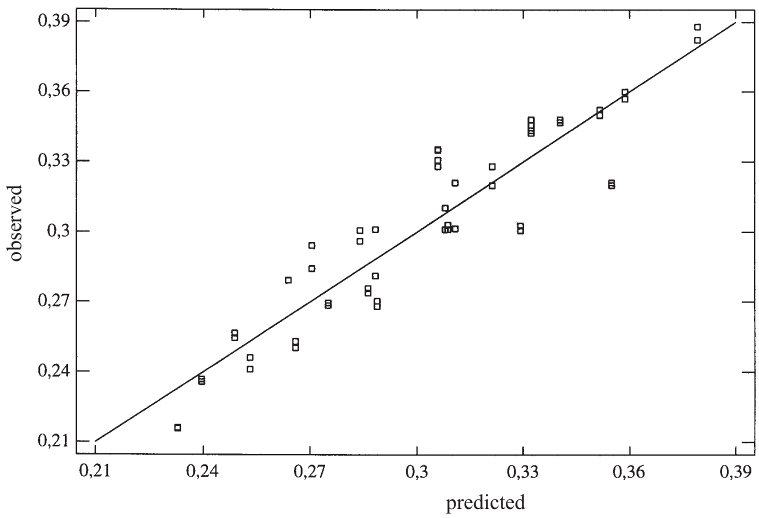

Fig. 4. Observed values of *dm* versus predicted values with model II (7).

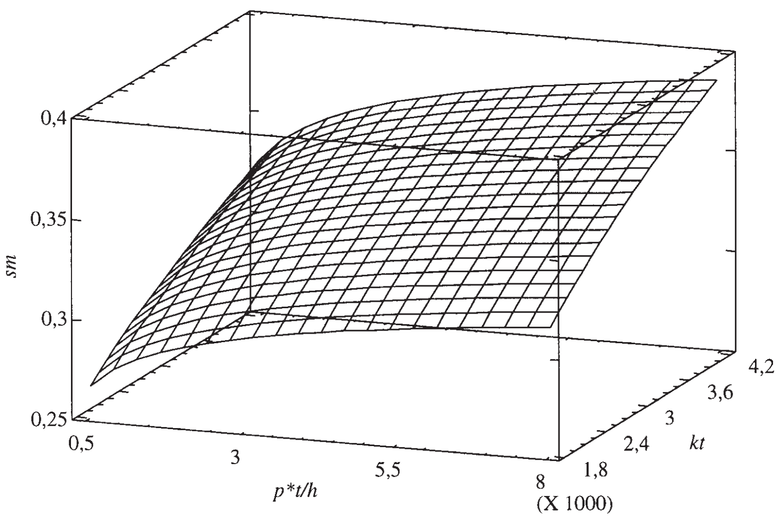

Fig. 5. Plot of the changes of dry matter contents in centrifuged raw fish material.

The test conducted during the research allowed the following conclusions to be drawn:

– the mathematical model developed for dewatered, preheated raw fish material facilitates highly accurate control of the dewatering operation during centrifugal sedimentation;

– preheating raw material increases the efficiency of dewatering during centrifugal sedimentation by about 25%, which can increase its contribution in extruded vegetable-fish feeds by as much as 30% of the equivalent of the fish meal contribution;

– the impact of the studied ranges of dimensionless group variability on increases in the dry matter content of dewatered material is comparable.

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Species composition and distribution of sharks in the central Atlantic from 1981 to 1989

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Abstract. The analysis of shark catches was made using records retrieved from survey data on large pelagic species caught with longlines from 1981 to 1989 in the area delineated by the coordinates 38º30´N – 8º30´S and 14º00´W – 38º30´W and referred to in this paper as the central Atlantic. Of the 4,677 sharks belonging to 16 shark species noted in the research catches, including rays and skates, blue sharks constituted 86% of the total number of sharks caught in the central Atlantic. The next most frequently caught shark species were whitetip and shortfin mako. The CPUE index values were calculated for them. The geographical distributions of blue sharks and shortfin mako sharks within 30´× 30´ geographical squares were analyzed. The proportion index between sharks and bony fish caught in unit areas was close to 1, with a maximum of 5.6, and in many areas was lower than 1. Sharks constituted 55% of all fish caught in the surveyed area.

Key words: blue shark, mako shark, longlines, central Atlantic, distribution, diversity index.

INTRODUCTION

Polish fishermen first encountered sharks (*Selachimorpha*) in the 1950s when they began to fish outside of the Baltic Sea. Trawls, the most common fishing gear in Polish fisheries of the period, were not very efficient in catching sharks, with the exception of spiny dogfish. The lack of access to material precluded Polish scientists from studying cartilaginous fish; this is why there were no publications on this topic. Publication by Sosiński (1978a, 1978b) on the length composition and growth rate of spiny dogfish, which are frequently caught with herring bottom trawls in the North Sea, were the only exceptions.

In the late 1970s, when it became evident that the renewable living resources of the oceans were on the verge of depletion, the Polish central authorities financed a research program aimed at increasing protein production entitled *Optimizing the production and consumption of protein*. This program also addressed the question of protein of marine origin, and this segment of it was conducted by the Sea Fisheries Institute in Gdynia. Those in charge were aware of the limits of the contemporary Polish fisheries industry. They acknowledged that in two decades the only available resources would be in the open ocean, specifically large pelagic fish at the top of the food chain. They also recognized that there were barriers posed by the difficulty of mastering techniques used to catch these fishes and the competition from the fleets of other countries (Japan, Spain, France, Korea, USA), which had been fishing for tuna successfully for years in open ocean waters using various fishing techniques. Due to this, one of the concepts of the research program was that in longline fishery sharks are an equally valuable source of protein as tuna. In consideration of this and the fact that, according to FAO statistics, worldwide shark catches in 1970-1975 were 450,000 tons, the Polish research program was an innovative one in a country with minimal knowledge of sharks.

In 1980-1981, the SFI's r/v Wieczno was adapted to the program's needs, and from 1981 to 1985 the vessel made four cruises to research the occurrence and catches of pelagic fish in the open waters of the Atlantic Ocean. The description of the traits of blue sharks caught during the first r/v Wieczno cruise in 1981 was published by Draganik and Pelczarski (1984). The successful cruise of r/v Wieczno prompted the managers of the Gryf Deep Sea Fishery Company in Szczecin to convert one of its stern trawlers, the m/t Koleń, into a longliner dedicated to fishing sharks and other large pelagic fish in open oceanic waters.

The aim of this paper is to present the geographical distribution and diversity index of sharks belonging to 16 species and to attempt to distinguish the fish assemblages within the surveyed area based on data collected during the 1981-1989 period.

MATERIALS AND METHODS

The materials for the paper came from the fish caught with longlines deployed from the r/v Wieczno and the m/t Koleń. Hooks manufactured by IZUI Iron Works (No. 7, 70-75 mm in length) were used. Table 1 presents the cruise calendar of these two vessels to Atlantic waters during which material was collected for the current paper.

The research region, described in the text as the central Atlantic, was delineated by the coordinates 38º30′N – 8º30′S and 14º00′W – 38º30′W (Fig. 1). In this region, the most hooks were set in the area delineated by the coordinates 2º-14ºN and 20º-38º30′W.

Regardless of the geographical position in the entire region where both vessels fished from 1981 to 1989, it was divided into 30′ by 30′ geographical squares. Despite the

Table 1. Calendar of the r/v Wieczno and m/t Koleń cruises during which materials analyzed in the paper were collected

Year	Month											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
m/t Wieczno												
1981			×	×	×	×						
1982				×	×	×	×					
1983		×	×				×	×	×	×	×	
1984												×
1985	×	×	×									
m/t Koleń												
1989	×	×	×									

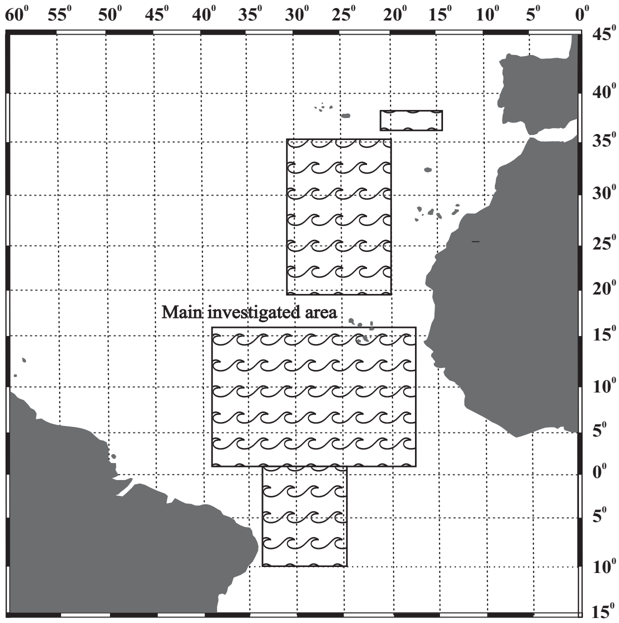


Fig. 1. Surveyed area.

geographical position of each square, it was considered to be a surface unit with equally distributed fish throughout its area. All of the fish caught in the central Atlantic were classified according to species and their total length (the distance from tip of the snout to the point on the horizontal axis intersected at a right angle by a perpendicular line extending downward from the tip of the upper caudal lobe), mass, sex, and stomach contents were recorded.

The total fishing effort during the research longline catches analyzed in this paper was 298,393 hooks deployed in 213 unit areas from 1981 to 1989 during four cruises of the r/v Wieczno in the central Atlantic and one of the m/t Koleń. During the research catches which yielded material for this paper, a total of 8,526 fish, including 4,677 sharks belonging to 16 shark species, 20 rays (not specified to the species) and 3,829 osseous fish belonging to 18 species were caught (Table 2). Acknowledging the impact of fishing gear selectivity on the composition of the fish species caught, the results concerning fish assemblages presented in the text refer to large pelagic fish species only.

Detailed data on 4,677 sharks caught are presented in Table 3. For the purpose of simplification, it was assumed that traits such as the number of fish species or their specimen size within geographical squares did not change in the 1981 to 1989 period.

The species diversity of fish in the geographical squares, including sharks, was described by the following index, often referred to as the Shannon-Wiener equation (Magurran 1989).

$$H = -\sum_{i=1}^{S} (p_i \cdot \ln p_i) \qquad [1]$$

where: p_i – the contribution of the i^{th} fish species in the sample, S – number of species.

Cluster analysis based on Bray-Curtis similarity measures and similarity percentage analysis (SIMPER) were performed on the data from research (Wieczno) and commercial (Koleń) catches using PRIMER 5 software. The assessment of species dominance in the groupings of fish caught with hooks by standard area units was only considered within the surveyed area delineated by the coordinates 38º30´W - 17º30´W and 16º30´N – 1º00´N.

Weight and length were related by a power relationship: [2]

$$W = a\,L_i^b$$

Table 2. List of the fish species recorded in the catches of m/t Wieczno and m/t Koleń in the central Atlantic

Code	Scientific and vernacular names		
	Scientific nameska	English name	Polish name
	Chondrichthyes	Cartilaginous fish	Ryby chrzęstnoszkieletowe
ALS	*Alopias supercilliosus*	Bigeye thresher	Kosogon wielkooki
ALV*	*Alopias vulpinus*	Thresher shark	Kosogon
ATS*	*Rhizoprionodon terraenovae*	Atlantic sharpnose shark	Rekin przybrzeżny
BSH	*Prionace glauca*	Blue shark	Żarłacz błękitny
DUS	*Carcharhinus obscurus*	Dusky shark	Żarłacz ciemnoskóry
GTH*	*Sphyrna tudes*	Smalleye hammerhead	Głowomłot olbrzymi
MAM	*Somniosus microcephalus*	Greenland shark	Rekin polarny
SMA	*Isurus oxyrinchus*	Shortfin mako	Ostronos
NGT*	*Carcharhinus signatus*	Night shark	Rekin nocny
OWS*	*Carcharhinus longimanus*	Whitetip shark	Żarłacz białopłetwy
PSK*	*Pseudocarcharias kamoharai*	Crocodile shark	Rekin krokodyli
REG*	*Apristurus sp.*	Cat sharks	
SCT	*Rhizoprionodon acutus*	Milk shark	
SRX	*Rajiformes*	Rays, skates	Płaszczki
SPL	*Sphyrna lewini*	Scalloped hammerhead	Rekin młot
SCZ*	*Sphyrna zygaena*	Smooth hammerhaed	Głowomłot pospolity
TGR*	*Galeocerdo cuvier*	Tiger shark	Rekin tygrysi
	Osteichthys	Bony fishes	Ryby kostnoszkieletowe
ALB	*Thunnus alalunga*	Albacore	Albakora
BET	*Thunnus obesus*	Bigeye tuna	Opastun
BUM	*Makaira nigricans*	Blue marlin	Marlin niebieski
DJX*	*Gempylus serpens*	Snake mackerel	Gempyl
DOL	*Coryphaena hippurus*	Dolphin fish	Koryfena
LCF*	*Alepisaurus ferox*	Lancetfish	Żaglon
LEF*	*Lepidocybium flavobrunneum*	Escolar	Eskolar
MOX*	*Mola mola*	Sunfish	Samogłów
OIL	*Ruvettus pretiosus*	Oil fish	Kostropak
POA	*Brama brama*	Atlantic pomfret	Brama
SFA	*Istiophorus platypterus*	Sailfish	Żaglica
SKJ	*Katsuwonus pelamis*	Skipjack tuna	Bonito
SWO	*Xiphias gladius*	Swordfish	Włócznik
TAL*	*Teractichthys longipinnis*	Bigscale pomfret	Pomfret
WAH	*Acanthocybium solandri*	Wahoo	Wacha
SPF*	*Tetrapturus pflügeri*	Longbill spearfish	Marlin smukły
WHM	*Tetrapturus albidus*	White marlin	Marlin biały
YFT	*Thunnus albacares*	Yellowfin tuna	Tuńczyk żółtopłetwy

* codes used in the paper only

(Pitcher 1982), where: length (L) was regarded as a independent variable, W_i – fish weight at length $L_{i,}$ a and b – constant factors calculated from empirical data.

The indices presenting the variability of the investigated shark species characteristics in the Atlantic region were derived with the IDRISI 32. program (1999).

Table 3. List of data on shark species fished in the central Atlantic

Code	Species	English vernacular names	Central Atlantic			
			No of fish	Average length (cm)	Length range (cm)	Sex ratio (F/M)
ALS	*Alopias supercilliosus*	Bigeye thresher	60	274	105 – 394	1.2
ALV	*Alopias vulpinus*	Thresher shark	68	280	160 – 420	1.25
ATS	*Rhizoprionodon terraenovae*	Atlantic sharpnose shark	2	92	90 – 94	1.0
BSH	*Prionace glauca*	Blue shark	4051	242	80 – 350	0.3
DUS	*Carcharhinus obscurus*	Dusky shark	125	140	52 – 285	1.3
GTH	*Sphyrna tudes*	Smalleye hammerhead	1	125		M
MAM	*Somniosus microcephalus*	Greenland shark	1	337		
NGT	*Carcharhinus signatus*	Night shark	1			
OWS	*Carcharhinus longimanus*	Whitetip shark	189	169	85 – 253	0.8
PSK	*Pseudocarcharias kamoharai*	Crocodile shark	7	84	65 – 102	0.5
REG	*Apristurus sp.*		9	101	90 – 105	0.1
SCT	*Rhizoprionodon acutus.*	Milk shark	2	171	170 - 172	
SCZ	*Sphyrna zygaena*	Smooth hammerhaed	26	252	192 – 294	0.3
SMA	*Isurus oxyrinchus*	Shortfin mako	130	182	102 – 330	0.9
SPL	*Sphyrna lewini*	Scalloped hammerhead	4	234	170 – 265	0.3
TGR	*Galeocerdo cuvier*	Tiger shark	1	234		
Sharks total			4,677			
All fish caught			8,516			
Hooks set			298,295			

RESULTS

Catch distribution of sharks caught in the surveyed area

The number of hooks deployed in one set and in a unit area varied significantly. An average of 1,401 hooks was deployed per unit area. However, the spatial fishing effort was uniform. In 140 standard unit areas (65% of the total number of the area units surveyed), the number of hooks deployed per unit area ranged from 500 to 1,200. The allocation of fishing effort according to geographical distribution is presented in Fig. 2. The blue shark constituted 86% of all the sharks caught and recorded within the limits of the entire area surveyed. The index of catch per unit effort (CPUE) measured as the number of fish caught per 1,000 hooks was used to assess blue shark distribution and density within the surveyed area (Fig. 3). The whitetip shark, the second most common shark species in the central Atlantic, constituted only 4% of all the sharks caught in the surveyed area.

Fig. 2. Fishing effort distribution in the surveyed area from 1981 to 1989 (hooks per 30′ × 30′ geographical squares).

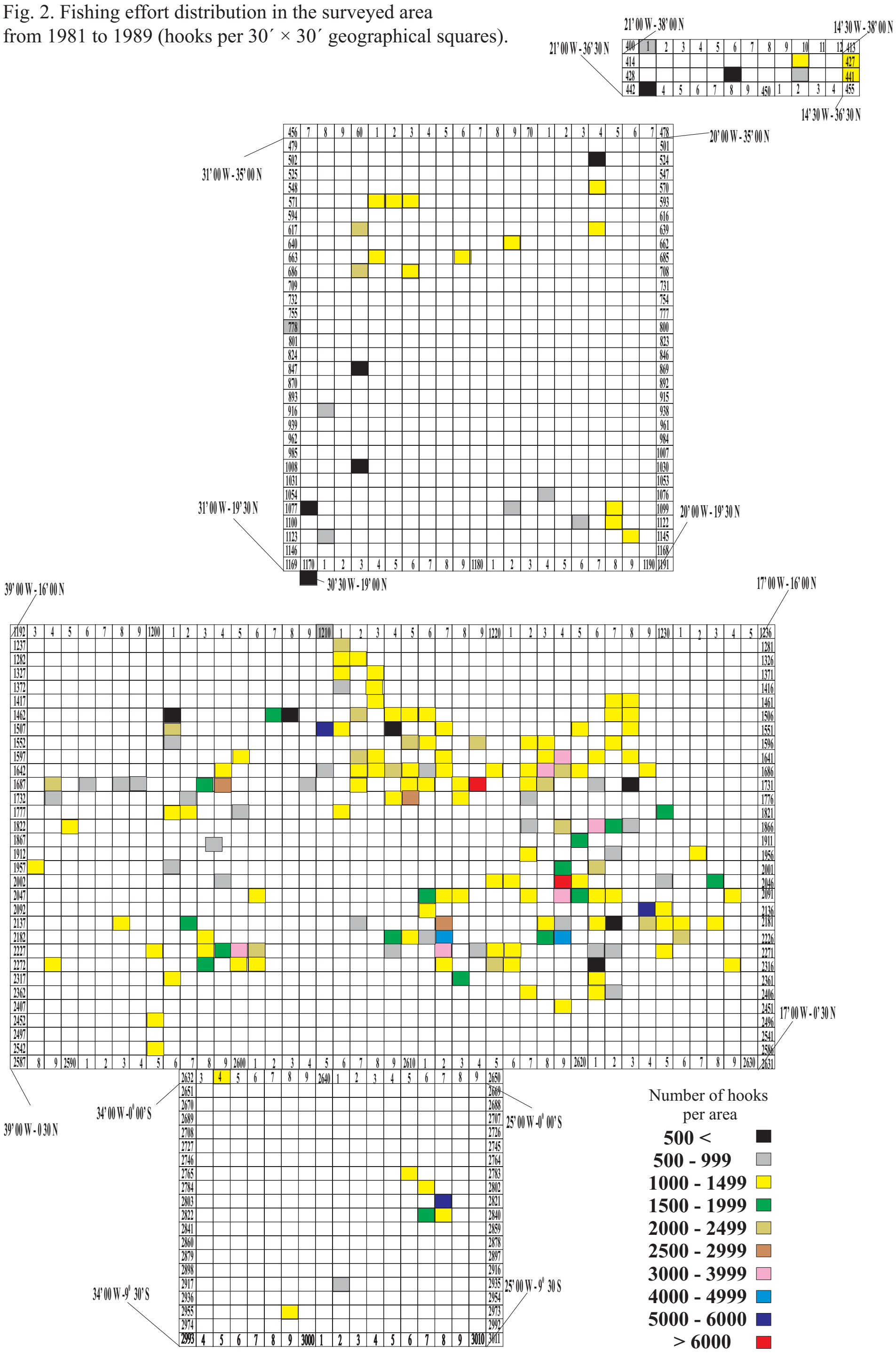
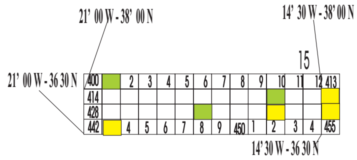


Fig. 3. Blue shark abundance index (number of fish caught per 1000 hooks within the standard unit area) in the surveyed central Atlantic in the 1981-1989 period.



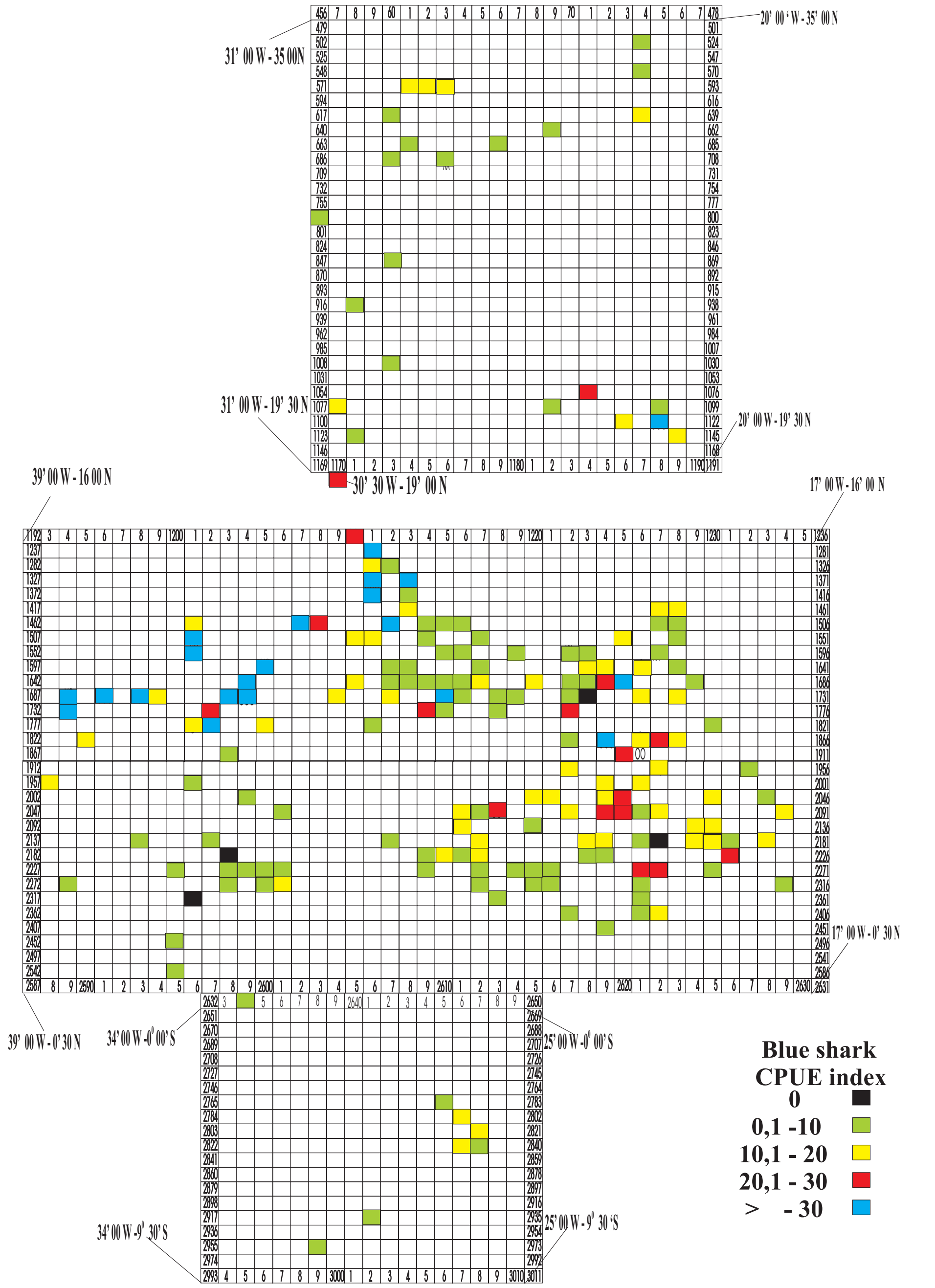


Table 4. Index of catch per unit effort observed in the survey catches (central Atlantic)

Year	Catch per 1000 hooks		
	BSH	OWS	SMA
1981	12.1	0.2	0.3
1982	12.6	1.1	0.5
1983	10.2	0.8	0.3
1984	19.9	0.9	0.6
1989	15.4	0.1	0.6
Average	13.6	0.6	0.4

BSH – (*Prionace glauca)* Blue shark
OWS – (*Carcharhinus longimanus)* Whitetip shark
SMA – (*Isurus oxyrinchus)* Shortfin mako

The recorded catch rates (CPUE index) for three species (blue, whitetip, and shortfin mako) varied considerably within the surveyed period (Table 4).

The highest index of shark species diversity (1.02) was observed in the unit area located south of 6º N. In the area north of the equator, blue shark was common throughout the surveyed area and only in the region between 23º and 28ºW was it less common. The greatest number of sharks were caught in the area between 16º30´N and 1º00´N. This area was considered in the analysis of differences in the localities of fish assemblages. The index of the number of fish caught per unit effort (1000 hooks) was used for cluster analysis in selected areas and four fish assemblages were identified that can be caught with longline fishing gear (Table 5).

The fish assemblage that can be caught with longlines in the northwest and the east of the studied area is dominated by blue shark. The occurrence of blue shark in the eastern part is scattered, but this species is separated from other fish by a much smaller distance (with regard to the density of occurrence index). This justifies describing the large pelagic fish that occur there as a multispecies assemblage. The assemblage described as yellowfin tuna occurred in the southwestern part of the area. The assemblage with the most scattered occurrence was that of swordfish (Fig. 4).

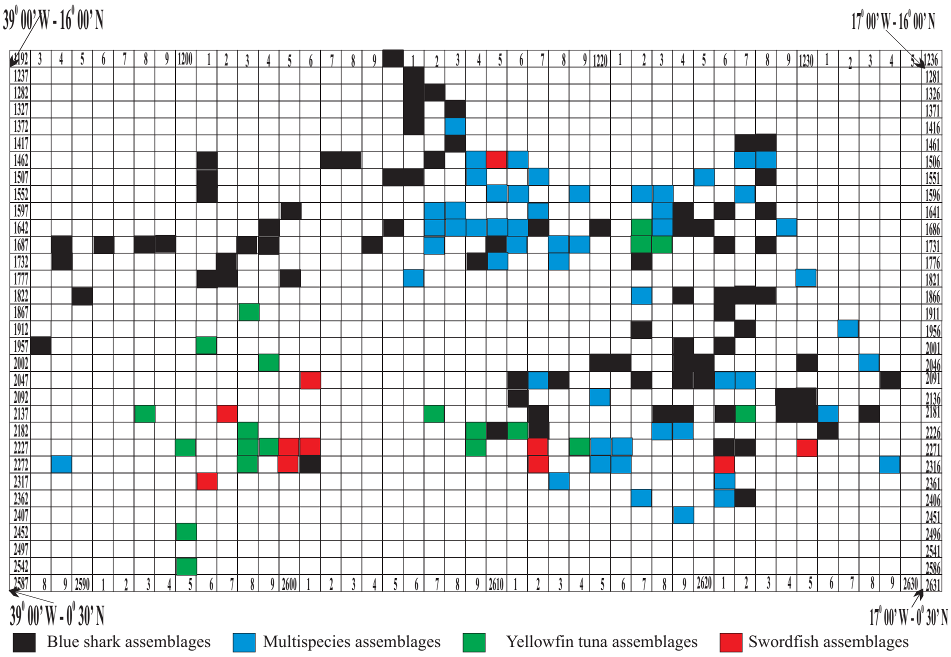


Fig. 4. Distribution of assemblages of large pelagic fish identified in the surveyed area.

Table. 5 Assemblages of large pelagic fish distinguished by average abundance index (number of fish caught per 1000 hooks) with average similarity of samples within and average dissimilarity between cluster groups

	Average abundance	Average similarity	Similarity/SD	Contribution %	Cumulative Contribution %	Average similarity %	Average Dissimilarity %			
							Blue shark f.a	Multispecies fish assemblages	Yellowtile fish f.a	Swordfish f.a
Blue shark fish assemblages						58.03	x	58.54	73.11	66.51
Blue shark	23.63	44.59	3.90	76.83	76.83					
Sword fish	3.13	4.02	0.74	6.92	83.75					
Yellowtile fish	2.78	3.93	0.92	6.76	90.52					
Multispecies fish assemblages						53.14	58.54	x	63.99	59.92
Blue shark	7.03	29.25	3.25	55.05	55.05					
Yellowtile fish	3.55	9.29	1.25	17.48	72.53					
Swordfish	1.20	2.58	0.69	4.85	77.38					
Other fish	0.95	2.26	0.87	4.24	81.62					
LCF	1.46	2.20	0.56	4.13	85.76					
BET	0.98	2.15	0.72	4.05	89.81					
OWSst	0.92	1.77	0.59	3.33	93.14					
Yellowfin tuna fish assemblages						46.41	73.11	63.99	x	66.38
Yellowtile fish	10.39	23.78	1.91	51.24	51.24					
Blue shark	2.59	5.23	1.06	11.28	62.52					
Other fish	2.35	5.21	1.54	11.22	73.74					
BET	1.59	3.27	0.85	7.05	80.79					
DJX	3.09	2.61	0.36	5.63	86.42					
WAH	1.35	1.80	0.67	3.88	90.29					
Swordfish fish assemblages						48.31	66.51	59.92	66.38	x
Swordfish	7.04	17.41	1.49	36.03	36.03					
Blue shark	3.54	9.16	1.53	18.96	55.00					
BET	2.61	7.54	1.55	15.61	70.61					
Yellowtile fish	2.86	6.58	1.07	13.61	84.22					
Other fish	1.16	3.63	1.51	7.52	91.74					

Although it occurred in small quantities, the shortfin mako shark was common and evenly distributed throughout the area, unlike the blue shark.

Sharks constituted 55% of all the fish caught in this area. The proportion index between sharks and bony fish caught in the standard unit areas in the central Atlantic was close to 1, with a maximum of 5.6.

Length and weight of the sharks fished in the central Atlantic

The average lengths of sharks caught are presented in Table 6. The length structure of sharks fished in the central Atlantic was analyzed for blue sharks and shortfin makos. The length range of blue shark males varied from 80 to 350 cm and of females from 120 to 320 cm. The female to male proportion index for specimens longer than 150 cm (99.65% of the investigated population), which were classified by length at 10 cm intervals, was under 1 (0.31 for the total fish measured). The greatest contribution of females (index 0.55) was observed among fish ranging in length from 171 to 200 cm. Only in two length classes, 111-120 and 121-130 cm, did females dominate with a proportion index of 3:1.

It was confirmed that large specimens occurred more often in the northern part of the region, while in the south, the distribution of blue sharks was sporadic and smaller specimens dominated in the majority of the region.

The length of shortfin mako sharks caught ranged from 110 to 255 cm for males and from 110 to 330 cm for females. The proportion index of females to males was 0.87. The geographical distribution of large and small makos was opposite to that of blue sharks. The smallest specimens, in comparison with the average length of fish caught in the standard area unit, occurred most frequently in waters north of 5ºN.

Table 6. Length – weight relationship data for sharks fished in the central Atlantic
($W = aL^b$; W in kg, L in cm)

Species		Both sexes pooled		Females		Males	
		a	*b*	*a*	*b*	*a*	*b*
Bigeye thresher	Length range	105 – 372					
	n	40					
	a b values	0.00009	2.3932				
	r	0.96					
Thresher shark	Length range	190 – 420					
	n	38					
	a b values	0.00006	2.4499				
	r	0.93					
Blue shark	Length range			112 – 312		80 – 310	
	n			685		2260	
	a b values			0.0006	2.1056	0.0008	2.0426
	r			0.82		0.82	
Dusky shark	Length range			58 – 267		80 – 247	
	n			26		29	
	a b values			0.00002	2.7538	0.000001	3.269
	r			0.95		0.98	
Mako	Length range			110 – 330		111 – 255	
	n			60		67	
	a b values			0.000008	3.015	0.000003	3.2163
	r			0.93		0.90	
Whitetip shark	Length range			86 – 240		85 – 253	
	n			30		48	
	a b values			0.0001	2.4638	0.00006	2.5662
	r			0.93		0.89	

Thresher sharks and bigeye thresher sharks followed by blue sharks had the lowest body mass growth rate in relation to length. This is understandable when taking into consideration the size of the tail fin in the first two species and the slimness of the third. In contrast, the mako had the highest body mass growth rate in relation to length. With the exception of whitetip sharks, the females were in better “condition” and their body mass growth rate in relation to total length was faster and more regular. The results of comparison of coefficients which relate linear measurement to body mass for five shark species are presented in Table 5. The ratio of males to females varied from 1.3 to 0.1. Of the six species caught in the central Atlantic, including thresher shark, bigeye thresher shark, blue shark, dusky shark, whitetip shark, and shortfin mako shark, the numbers of females caught were higher only in the case of thresher shark, bigeye thresher shark, and dusky shark.

DISCUSSION

The geographical distribution of sharks exhibited considerable variation within the surveyed area. Blue sharks, sandbark sharks, whitetip sharks, and shortfin makos were most common in the surveyed area of the Atlantic. The grouping pattern of all the fish caught with hooks by standard unit areas according to species prevalence was scattered rather than separated by large areas of evident species domination. Dusky shark and whitetip shark, species which, according to Hurley (1998), are rarely noted as by-catch in Canadian waters, were common in the catches in the central Atlantic. Atlantic sharpnose shark was very common in the coastal waters of the Gulf of Mexico (Marquez-Farias and Castillo-Geniz 1998), but not so in the central Atlantic. The shark species distribution in the research catches followed that described by Compagno (1984a, b). In the region referred to in this paper as the central Atlantic, shark occurrence falls within the limits of the Atlantic warm-temperate waters extending from 15º to 50º W on the eastern side of the Atlantic. Blue shark is considered to be a typical inhabitant of the area (Briggs 1974) and comprised 86% of the total number of sharks fished in the central Atlantic.

The maximum length recorded for the blue shark caught in the central Atlantic in the 1981-1989 period (male – 350 cm) was similar to that recorded in the North Atlantic by Skomal and Natanson (2003) and slightly smaller than that of fish caught off Nova Scotia, Canada by McCord and Campana (2003), after converting fork length to total length. Considering the parameter values of the von Bertalanffy Growth Function (VBGF) compiled from the literature by Nakano and Seki (2003), the largest blue shark fished in the Central Atlantic was aged 15-16 years.

Although blue shark is one of the most common and numerous oceanic shark species in the Atlantic Ocean, its abundance has declined by an estimated 60% during the past eight to 15 years (Baum *et al*. 2003). On the other hand, the values of the CPUE index observed in the area near the coast of north Africa at the beginning the last decade (Buencuerpo *et al*. 1998) were similar as those observed in the surveyed area (central Atlantic) in the 1980s.

As regards sharks that attain a large body size, the values of the K parameter (which determines the rate at which growth slows) are among the lowest of any fish species

(Hoening and Gruber, 1990). According to Tanaka *et al.* (1990), values of K for blue shark range from 0.1 to 0.25. This might be interpreted as evidence of the susceptibility of shark populations to fishing. The low natural mortality and high longevity of these fish mean that there are many old specimens in the population producing a small number of offspring. This contrasts with teleost fish, in which there is a close dependence of recruitment on the parental stock. This indicates that there are limited possibilities for shark populations to support fishery (Pratt and Casey 1990). Reports that blue shark is the most frequent by-catch shark species in directed billfish and tuna longline fisheries elsewhere in the northern and central Atlantic, with the exception of the Gulf of Mexico (Toniuchi 1990, Hoey and Scott 1998, Cramer *et al.* 1998, Matsunaga and Nakano 1998, Natale 1998) indicate that careful management is essential. Blue shark is rarely caught in the Gulf of Mexico where Atlantic sharpnose shark of the genus *Apristurus sp.* comprises the bulk of shark catches (Bonfil *et al.* 1990, Witzell 1985, Marquez-Farias and Castillo-Geniz 1998). Although common, the blue shark is not the most frequently fished shark in the billfish fisheries conducted in the western central Atlantic where shortfin mako shark, blacktip shark, and dusky shark are more abundant (Goodyear 1998). In comparison with other shark species, blue shark is also less frequently caught in purseine (Stretta *et al.* 1998) or gillnet (Buencuerpo *et al.* 1998) fisheries of large pelagic fish.

The CPUE index derived from research catch data for the central Atlantic was close to that observed in north African coastal waters, but it was considerably lower than that recorded for Iberian Peninsula waters (Buencuerpo *et al.* 1990).

According to the blue shark female maturity pattern in Pratt (1979), the surveyed central Atlantic waters can be considered as the habitat of the mature blue shark population. Only a few specimens of blue shark measuring less than 130 cm were caught, all of which were found in the southern part of the area. The vertical blue shark distribution pattern was the same as described by Draganik and Pelczarski (1984) with the majority of fish caught at depths ranging from 18 to 40 m. The most successful catches were made in areas where the surface temperature did not exceed 25ºC. When comparing geographical shark catch distribution in the central Atlantic with temperatures at a depth of 50 m, it can be concluded that the 25ºC isotherm might be considered as the border separating temperate shark-abundant waters from warmer areas poorer in fish.

The impact of water temperature on shark catches in the central Pacific was emphasized by Porras *et al.* (1993), who reported that sharks occurred in longline catches made in areas where the surface temperature was below 28ºC. This paper also presents a map showing the highest CPUE index values for sharks in areas where temperatures in the isotherm at depths of 50 m were less than 25ºC.

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Ichthyofauna of the Pomeranian lobelia-lake Lake Dołgie Wielkie

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Abstract. Nine fish species belonging to four families occurred in experimental catches. *Cyprinidae* were the most numerous and the most commonly occurring group. The ichthyofauna of Lake Dołgie Wielkie was dominated by fish that feed on zooplankton and macroinvertebrates. Due to the spawning grounds available in this basin, the fish groups occurring here were categorized as either obligatory or facultative phytophils.

Key words: fish assemblages, *Lobelia dortmanna*, coastal lake, species richness

INTRODUCTION

The aquatic ecosystem of the Słowiński National Park (SPN) has an area of approximately 21400 ha; 46% of this is comprised of inland waters while the remaining waters are marine. Of the lakes located within the park, only Lake Dołgie Wielkie is classified as a lobelia-lake. Most of the basins of this type are located in western Pomerania, the Kaszubian Lake District, and on the Charzykowska Plain. With their typical post-glacial flora, lobelia-lakes are unique aquatic basins and are rare occurrences in Poland (Kraska et al. 1996). Lake Dołgie Wielkie is classified as a coastal lake due to its location. However, the lack of a connection with the sea and its particular hydrochemical conditions mean that this lake is characterized by a different water chemical composition than other seaside basins. (Cieśliński 2004).

Lake Dołgie Wielkie (54º42'N, 17º11'E) is a small (156 ha area), shallow (maximum depth 2.9 m, average depth 1.6 m) basin located in the immediate vicinity of the Baltic Sea between lakes Gardno and Łebsko (Fig. 1). The basin of Lake Dołgie Wielkie stretches from west to east and is separated from the sea by a length of sand dunes which are overgrown by a crowberry forest. The basin is supplied with water from precipitation and by periodic inflows from its eastern side. The lake is permanently connected to the Gardno-Łebsko canal. The typical forest drainage basin provides a natural barrier for the lake ecosystem. The basin is inhabited by plant species that are typical of lobelia-lakes, namely *Myriophyllum alterniflorum* DC., *Isoëtes lacustris* L., *Litorella uniflora* (L.) and the sporadically occurring *Lobelia dortmanna* L. (Kraska 1997). Oxygen deficits and fish mortalities were noted in the lake in the summer of 2002.

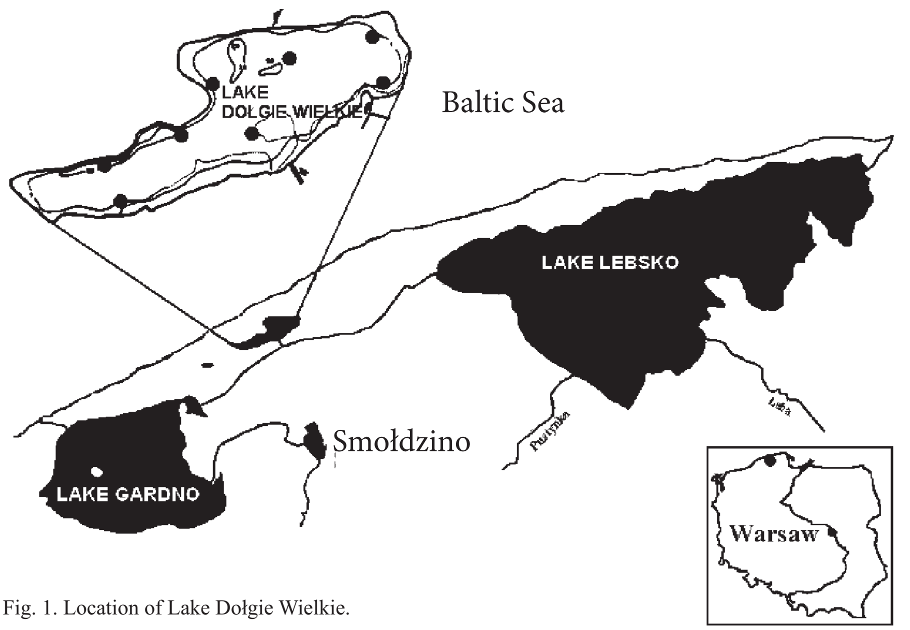

Fig. 1. Location of Lake Dołgie Wielkie.

Due to the lack of anthropogenic pressure, Lake Dołgie Wielkie may have retained its original character, which means that it may be a valuable subject of investigation.

The aim of this research was to determine the ichthyofauna diversity and to analyze the structure of the fish assemblage.

MATERIALS

A total of 14,378 fish were caught with fry nets at monthly intervals in the April to September periods of 2001 and 2002. The catches were conducted in the shore zone in a manner that assured that the area covered in each catch was uniform and that the small drag net extended throughout the water column from the surface to the bottom. The groundrope was weighted so that the net skimmed the bottom. In order to avoid the impact of diel fluctuations in fish activity, fishing was conducted on sunny days between 09:30 and 14:30. The catches were sorted according to species based on anatomical and morphometric traits (Mooij 1989, Brylińska 2000, Pinder 2001).

The analysis of the material was based on determining the dominance of each species. The domination classes were taken from Terlecki (1993). In addition to determining the fish assemblage of Lake Dołgie Wielkie, a list is presented of the species occurring in the lake according to ecological spawning groups (Balon 1990). Assigning species to one of the four trophic groups was done using data regarding the food items of adult fish (Brylińska 2000). The fish assemblages and the share of dominant species in the two years of the study were compared with the Chi^2 test (Stanisz 1998).

RESULTS

The investigated fish belong to nine species (Table 1). The selectivity of the gear limited the occurrence of large fish, which is why most of the considerations refer to juvenile fish stages. Fry (0+) comprised 80-90% of the fish caught. Five species of fish belonged to the family *Cyprynidae*, two to *Percidae*, and one each to *Esocidae* and *Cobitidae*. The most numerous group of fish in the catches belonged to the cyprinid family, among which sunbleak and roach were dominants comprising almost 95% (Fig. 2). Perch and gudgeon were fairly numerous species and were classified as recedents. The share of the remaining species did not exceed 1%. A statistically significant difference was noted between the domination structure of the fish species that occurred in both years of the study (Chi^2 test, $p<0.0001$). In 2001, sunbleak occurred most numerously and was classified as a eudominant, while roach was a subdominant species (Fig. 2). However, in the following year

Table 1. Species composition of the ichthyofauna of Lake Dołgie Wielkie in the 2001-2002 period according to relative abundance, permanence of attendance, and age group.
Dominance indicator values: E – eudominant (>50.0%), D – dominant (10.1-50.0%), S – subdominant (5.1-10.0%), R – recedent (1.1-5.0%), P – subrecedent (<1.0%).

Species	Domination	Attendance	Age
Leucaspius delineatus (Heck.)	E	91.7	0-4
Rutilus rutilus (L.)	D	45.8	0-4
Perca fluviatilis L.	R	66.7	0-5
Gobio gobio (L.)	R	40.3	0-3
Scardinius erythrophthalmus (L.)	P	37.5	0-6
Gymnocephalus cernuus (L.)	P	31.9	0-3
Abramis brama (L.)	P	11.1	0-2
Esox lucius L.	P	8.3	0-6
Cobitis taenia L.	P	1.4	-

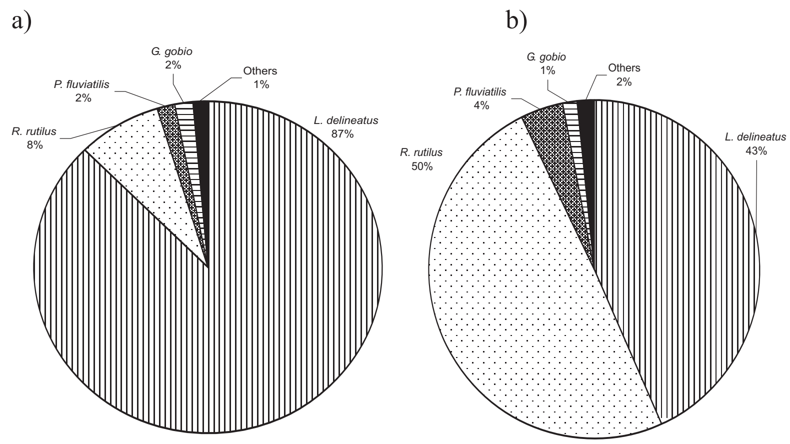

Fig. 2. Domination structure of the fish in Lake Dołgie Wielkie in the 2001 (a) and 2002 (b) periods.

Table 2. List of fish species occurring in Lake Dołgie Wielkie according to spawning group

Non-guarding and open substratum egg scattering (A.1)		
Phytolithophils (A.1.4)	Roach	*Rutilus rutilus* (L.)
	Bream	*Abramis brama* (L.)
	Perch	*Perca fluviatilis* L.
	Ruffe	*Gymnocephalus cernuus* (L.)
Phytophils (A.1.5)	Rudd	*Scardinius erythrophthalmus* (L.)
	Pike	*Esox lucius* L.
	Spined loach	*Cobitis taenia* L.
Psammophil (A.1.6)	Gudgeon	*Gobio gobio* (L.)
Guarding and clutch tending (B.1)		
Phytophil (B.1.4)	Sunbleak	*Leucaspius delineatus* (Heck.)

the share of these two species within the structure of the fish assemblage in Lake Dołgie Wielkie was comparable (Chi^2 test, $p = 0.3764$), and both of these species were classified as dominants.

There was little ecological differentiation in the ichthyofauna of the lake. All of the fish caught belonged to the same spawning group which deposit eggs in aquatic vegetation, while some also used bottom substrates (phytolithophils) (Table 2). The majority of the fish species occurring here were batch spawners.

The fish assemblage of Lake Dołgie Wielkie was dominated by fish that were either planktivorous (57.6%) or benthophagous (38.4%). The share of predatory fish was small. Herbivorous fish were represented by rudd, which was the least numerous species. Predatory and planktivorous fish comprised the largest share of catch weight at 55.9 and 27.0%, respectively, while that of the fish classified in the other groups did not exceed 10%.

DISCUSSION

Lobelia-lakes are valuable aquatic ecosystems because of the occurrence in them of particular types of flora and the high density of species threatened with extinction. At the same time, they are very susceptible to degradation and require special protection (Kraska *et al.* 1996). The nine species of fish occurring in Lake Dołgie were dominated by *Cyprinidae*. The ichthyofauna species diversity here was much higher in comparison with the small lobelia lakes in western Pomerania and similar to that in the large basins (100-500 ha) of this region (Heese 2000). The species diversity of the ichthyofauna of Lake Dołgie Wielkie might be the result of the existence of a large number of different microhabitats. This is connected to the substantial surface area of this lake and its chemical diversity (Trojanowska *et al.* 1993). The aquatic vegetation also increases the habitat structure and has an impact on the diversity and abundance of fish assemblages. In habitats where macrophytes occur, the abundance and diversity of fish assemblages are higher than in those devoid of vegetation (Weaver *et al.* 1997, Xie *et al.* 2000).

The ichthyofauna of the studied lake was substantially poorer than that of the neighboring coastal lakes of Gardno and Łebsko, in which 40 species occur either permanently or periodically (Sobocki 2001). These lakes have permanent connections to the sea, a constant inflow of riverine water, and provide advantageous habitat conditions for many fish species that are typically lacustrine, rheophilous, anadromous, and even marine.

Lobelia-lakes, due to their endemic flora of Boreal Atlantic origin and esthetic qualities, are unique and highly values basins that are often under special protection. As is the case with most lobelia-lakes (Heese 2000), Lake Dołgie Wielkie is not a site with especially valuable ichthyofauna. The environmental conditions prevailing in these lakes limit their inhabitation by eurytopic species. The domination of the fish assemblage of batch spawning fishes is one of the behavioral adaptations that permits reproductive success in some environmental conditions (*e.g.*, periodic conditions of oxygen depletion).

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Retained and discarded catches from eel fyke-net fishery in the Vistula Lagoon

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Abstract. Observations aboard commercial fishing vessels indicate that the most frequently discarded specimens are those for which there is no commercial demand or those which are too small, including, ruffe, round goby, flounder, roach under 18 cm TL, pikeperch under 35 cm TL, and common bream under 35 cm TL. The primary criterion applied by fishermen aboard vessels regarding catch retention is the anticipated demand and market for fish while the minimum landing length is less significant.

Key-words: fyke-net fishery, discard, pikeperch, minimum landing length (MLL), market forces

INTRODUCTION

Discarding is the practice of returning to the water fish which have been caught during fishing. Catch is usually discarded due to legal or economic reasons. Many multispecies fisheries, particularly those conducted with trawls, but also with gillnets and fyke-nets, are characterized by high discard rates of unwanted fish or juvenile and undersized commercial species. Much recent research has shown that discarding can have an impact on community structure, species composition, and abundance, and the functioning of the food-web (Alverson *et al.* 1994, Dayton *et al.* 1995, Garthe *et al.* 1996, Hall 1999). Reducing discard levels is expected to lower the environmental impact of fishing and lead to improved profitability.

It is difficult to conduct empirical studies of the mortality of fish retained in fishing gear, subjected to manipulation outside of the aquatic environment, and then released. For the sake of simplification, it is frequently assumed that this mortality is insignificant and, as such, it is omitted from estimations of total mortality. In fact, the chances of these specimens surviving are not good (Cook 2003).

Due to the intensive mixing of saline sea water with the freshwater discharges from rivers, the Vistula Lagoon provides favorable conditions for primary production and the development of consumer assemblages in the trophic pyramid. The specificity of the Vistula Lagoon water, mainly the effect of changes in salinity ranging from 0.1 to 1.6 PSU in the western part and from 2.9 to 4.7 PSU in the eastern part (Majewski 1975), means that spawning grounds of 'typically marine' species, like herring, as well as various freshwater species are located here.

Fyke-net fishery in the Vistula Lagoon is a traditional and substantial source of income for the fishermen operating in the Polish part of the basin. This fishery is characterized by a high proportion of discarded to retained catch due to the construction of the gear, which is designed to catch the basin's most valuable but not abundant species – eel.

Fyke-nets are deployed throughout the fishing season from March to October. Except for pikeperch and common bream, which are mainly caught using gill-nets, the other species observed in these catches are only caught in fyke-nets. The average annual catch effort is estimated at 150,000 fyke-net days. (Borowski 2000).

Eel fishermen in the Vistula Lagoon began to reduce undesirable bycatch in 2003 by outfitting their gear with bycatch reduction devices (BRD), which are perforated metal or aluminum sheets with 20x65 mm oval openings in the cod-ends (Psuty-Lipska and Draganik, 2005). The oval openings in the sheets should enable young fish to escape while simultaneously reducing the work required to clear the gear of retained juvenile fish. Sieves serve as a type of buffer for the steps taken by fishermen, who, facing declining eel stocks from overfishing and decreasing recruitment trends, try to compensate for smaller catches by improving gear construction to minimize the possibility of legal-sized fish escaping. This is accompanied by a rise in the bycatch of undersized fish that are released back into the water.

The aim of current study was to use an observer-based survey of commercial fyke-nets with BRD in the Vistula Lagoon to assess the composition, magnitude, and variation of retained and discarded catches in different regions. This information was used to assess the volume of discards from eel fyke-net fishery during one fishing season.

MATERIALS AND METHOD

Sampling catches

Commercial fyke-nets catches were sampled in four regions representative of the Vistula Lagoon: border zone (BOR), Tolkmicko region (TOL), Suchacz region (SUH) and Kąty Rybackie region (KAT) (Figure 1, Table 1). Scientists accompanied commercial fishermen during cruises as observers. The fishermen checked from two to six fyke-nets during each cruise. The uninterrupted deployment of the gear ranged from two to four days. The process of hauling in the last chamber of the gear, removing the caught fish, and redeployment lasted from six to fifteen minutes when winds were unfavorable. The fishermen then sorted the fish throwing discards into separate containers. The fish not destined for the market but retained for the fishermen's personal consumption were classified as retained catch. The observer identified and measured the length of all the retained and discarded species or representative sub-samples.

Since the observations were conducted at the end of the closed seasons for pikeperch and common bream (April 20 to June 10), permission to retain these species as commercial catch was obtained from the Fisheries Inspectorate in order to maintain standard fisheries practices.

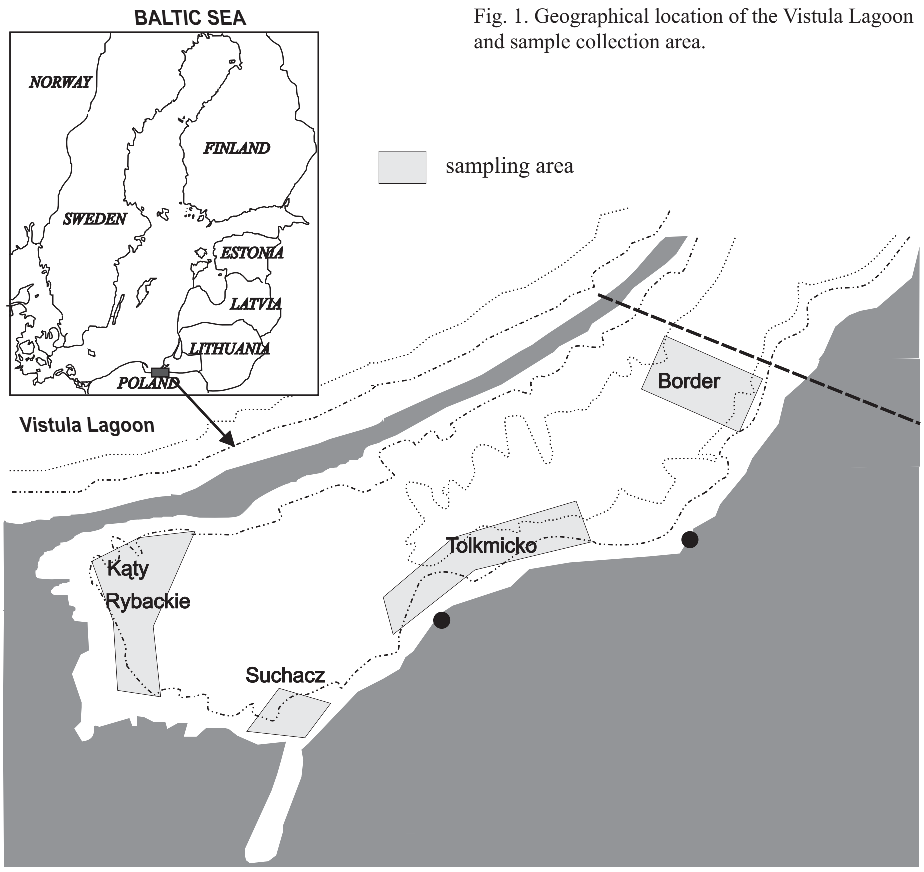


Fig. 1. Geographical location of the Vistula Lagoon and sample collection area.

Table 1. The number of fyke nets sampled and fish measured

Region	May 2004		October 2004		May 2005	
	samples	No. fish [range between samples]	samples	No. fish [range between samples	samples	No. fish [range between samples
Border	3	106 [28-47]	3	422 [51-196]	7	1451 [69-405]
Tolkmicko	3	348 [88-141]	2	932 [376-556]	11	3043 [103-335]
Kąty Rybackie	–	–	–	–	9	703 [11-198]
Suchacz	6	828 [46-228]	4	174 [28-56]	–	–

Data analysis

The mean observed retained and discarded catch rates per fisherman-day were calculated for each region. One-way analysis of variance ANOVA on log-transformed data was used to test for differences among regions in the mean number of individuals of both segments of the catch. The Student-Newman-Keuls (SNK) test was used to identify significant differences among means.

Estimates of retained and discarded catches from all fyke-nets in each region throughout the three-month study (May, June, October) were derived by multiplying the observed mean catch rates per fisherman-day (CPU) by the observed number of fyke-nets in each region in 2004 and the number of days. The fyke-nets were counted monthly by local fisheries inspectors. In calculations performed for months during which the seasons for pikeperch and common bream were closed, all of the specimens of these species that were caught were regarded as discards.

RESULTS

Catch composition

A total of 24 fish species were registered in the studied catches (Table 2), of these ruffe, bream, sichel, roach, and round goby were present in almost all samples. Lamprey, burbot, ide, twaite shad, and rainbow trout were only observed in catches one time each. Ruffe

Table 2. Species observed in the samples showing the total number caught, their contribution to the total catch, the proportion discarded and the contribution of discards of each species to the numbers of total discards

Common name	Latin name	No. caught	Total catch [%]	Discarded [%]	Total discards [%]
Ruffe	*Gymnocephalus cernuus,* (L.)	3370	42.09	100.00	55.54
Bream	*Abramis brama,* (L.)	1519	18.97	78.34	19.61
Sichel	*Pelecus cultratus,* L.	1038	12.96	2.22	0.38
Roach	*Rutilus rutilus,* (L.)	555	6.93	58.92	5.39
Round goby	*Neogobius melanostomus,* Pallas	519	6.48	82.66	7.07
Pikeperch	*Sander lucioperca,* (L.)	407	5.08	73.71	4.94
Perch	*Perca fluviatilis,* L.	207	2.59	19.81	0.68
Flounder	*Platichthys flesus,* (L.)	145	1.81	96.55	2.31
Crucian carp	*Carassius carassius,* (L.)	112	1.40	50.00	0.92
Eel	*Anguilla anguilla*, (L.)	31	0.39	6.45	0.03
Herring	*Clupea harengus,* L.	22	0.27	40.91	0.15
White bream	*Abramis bjoerkna*, (L.)	18	0.22	100.00	0.30
Smelt	*Osmerus eperlanus,* (L.)	15	0.19	100.00	0.25
Tench	*Tinca tinca*, (L.)	14	0.17	100.00	0.23
Vimba bream	*Vimba vimba*, (L.)	11	0.14	100.00	0.18
Rudd	*Scardinius erythrophthalmus*, (L.)	7	0.09	14.29	0.02
Bleak	*Alburnus alburnus,* (L.)	6	0.07	100.00	0.10
Stickleback	*Gasterosteus aculeatus*, L.	3	0.04	100.00	0.05
Bitterling	*Rhodeus amarus*, Bloch	2	0.02	100.00	0.03
Lamprey	*Lampetra fluviatilis*, (L.)	2	0.02	100.00	0.03
Burbot	*Lota lota,* (L.)	1	0.01	100.00	0.02
Ide	*Leuciscus idus,* (L.)	1	0.01	100.00	0.02
Twaite shad	*Alosa fallax*, Lacepede	1	0.01	100.00	0.02
Rainbow trout	*Onchorhynchus mykiss*, Richardson	1	0.01	100.00	0.02
		8007	100.00		

was the most common species in the material collected. Due to its lack of commercial significance, this species comprised more than half of the abundance of discarded fish. The least frequently discarded fish species were sichel, eel, and perch. The round goby was only retained in the vicinity of Kąty Rybackie (KAT). There is wholesaler demand for these fish at the fishery bases located on the Vistula Spit, while on the opposite side of the spit there is no demand. A high proportion of discards was registered for common bream and pikeperch (78 and 73%, respectively), which are both pillars of the Vistula Lagoon fishery. The percentage of eel, which is the most valuable fish species for fishermen working the lagoon, in the total catches is characteristically low at less than 1%.

Size composition

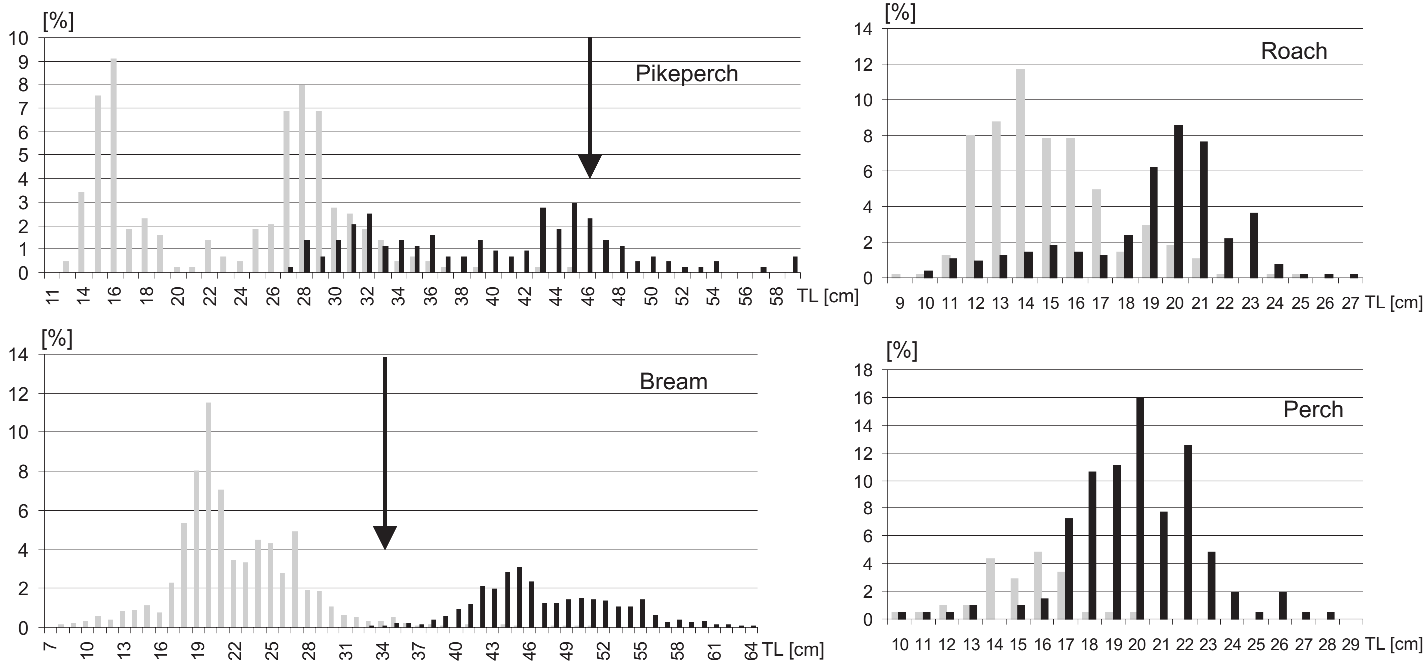
Only for the two most common species – pikeperch and bream, have minimum landing lengths been set for the Vistula Lagoon (MLL 35 and 46 cm TL, respectively). The results presented in Figure 2 of the length frequency distribution of retained and discarded catches indicate that in the case of bream the MLL includes commercial sizes. Caught fish under 35 cm TL were noted aboard the vessels infrequently. The situation as regards pikeperch was different. The majority of the retained fish were under the MLL, which, according to fishing regulations, is illegal. Market demand, however, is for fish that are under the MLL, and during the years observations were conducted most fishermen were willing to risk retaining fish under the MLL despite the monitoring system and the enforcement of penalties. Throughout the observations no significant differences were noted in the behavior of the fishermen from various fishing bases in the Vistula Lagoon with regard to these two species.

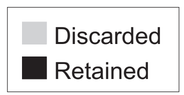
There is no MLL in force for roach or perch in the Vistula Lagoon, and the decision to retain or discard fish is based solely on market length. The greatest market demand is for roach of 18 cm TL and perch of 17 cm TL. Slight variation in the behavior of the individual fishermen was observed – some retained all of the perch and roach caught regardless of their lengths.

The most common length distribution of ruffe noted in the catches was from 10 to 19 cm TL, which was nearly the same as for the round goby (11-19 cm TL) (Fig 3). As noted earlier in this paper, all ruffe were discarded, while the round goby discards depended on the base the fisherman was working from. Observations were made of the incidental retention of longer fish (above 16 cm TL) of non-commercial species for the personal consumption of the fishermen.

Among the species occurring in the Vistula Lagoon and observed during the investigations, MLLs have also been set for eel (50 cm TL), crucian carp (20 cm TL), tench (28 cm TL), and vimba bream (30 cm TL). Only two eel specimens had not achieved the minimum length and were discarded, as regards the remaining species the fish caught clearly exceeded the minimum length. Catches of tench and vimba bream were incidental and the fish caught were too small even for personal consumption. Observations indicated that the fishermen were nearly uniform regarding the retained length of crucian carp; compliance with the MLL and market acceptance were probably both reasons for this. Crucian carp under 18 cm TL were normally discarded.

There is no MLL for sichel in the Vistula Lagoon, and nearly all specimens in all length categories (from 15 cm to 41 cm TL) were retained.





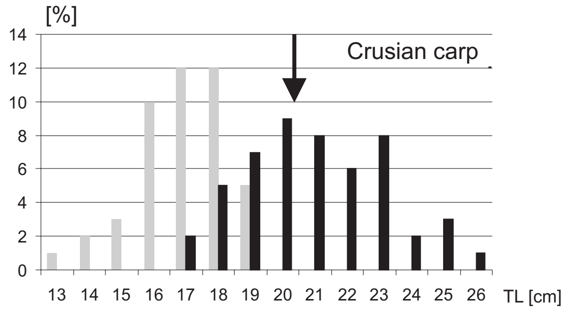


Fig. 2. Length frequency distributions of retained and discarded catches of main commercial species. The arrows denote the MLL of the species.

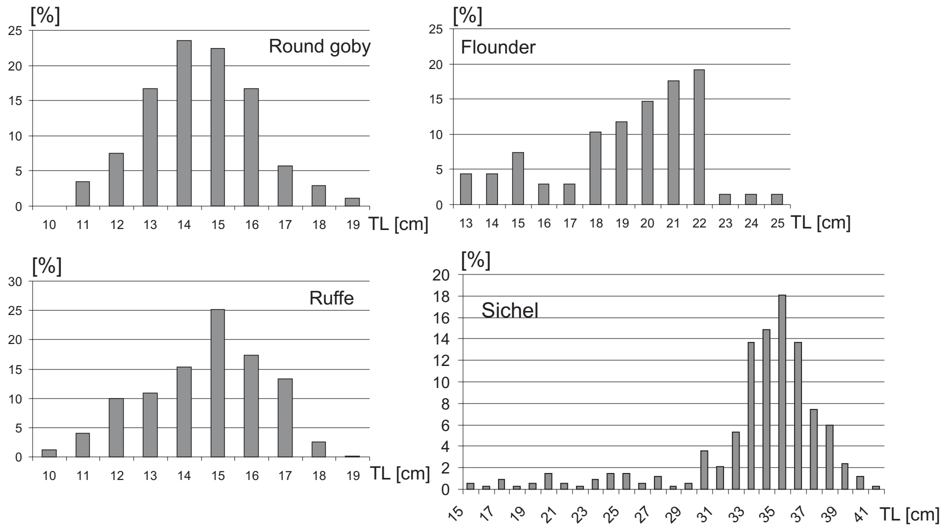


Fig. 3. Length frequency distributions of common species.

Mean daily catch rates

The average daily abundance of the most numerously occurring species divided into retained and discarded catches varied by fishing region (Figure 4 and 5, Table 3). Cyprinids (bream and roach) were fished in greater quantities in the western regions of the lagoon

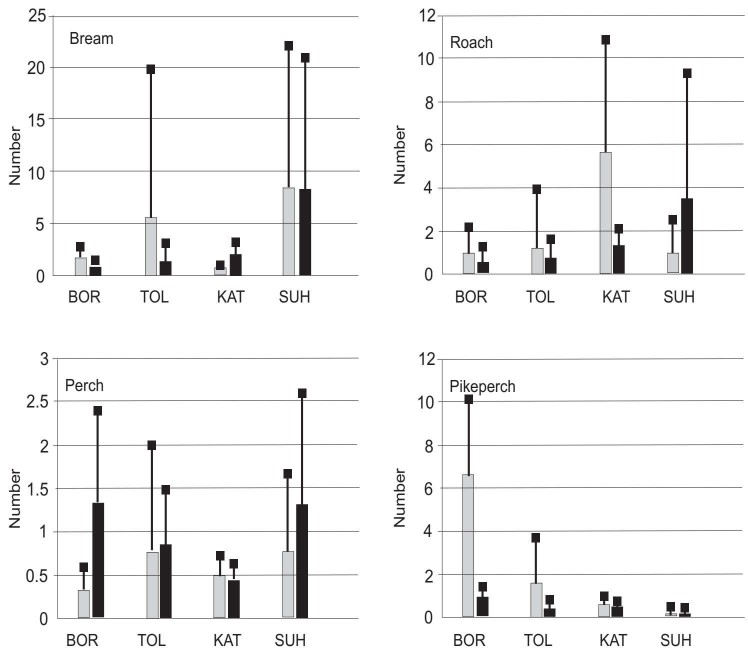


Fig 4. Mean daily (± 1 S.E.) number of retained and discarded catches of major species in each study area. Shading as per Fig 2.

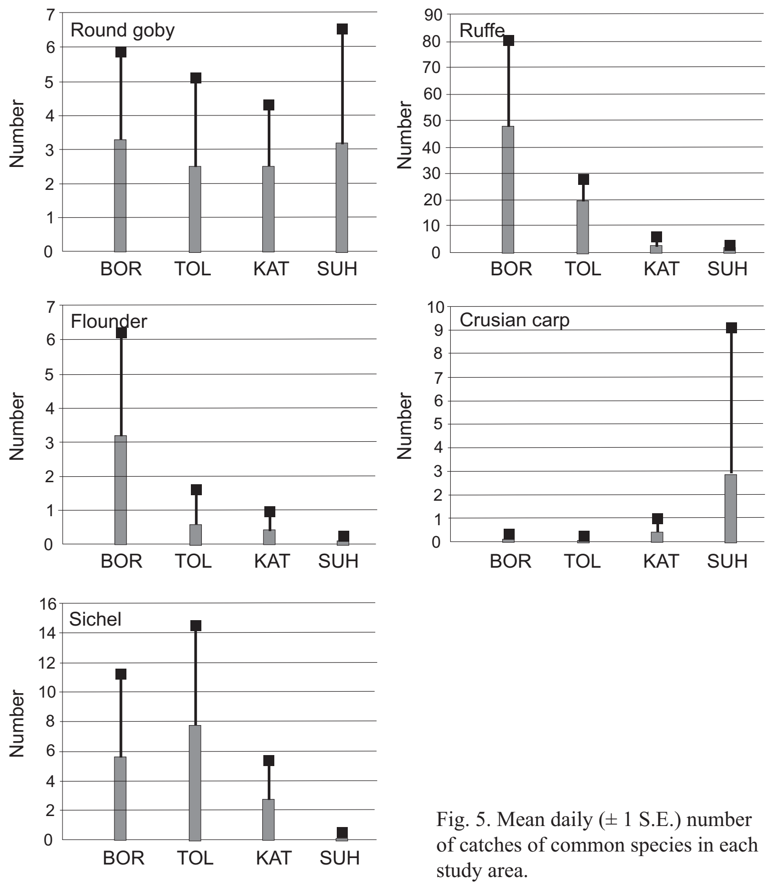


Fig. 5. Mean daily (± 1 S.E.) number of catches of common species in each study area.

(KAT, SUH) while the average daily abundance of pikeperch was caught in the fyke-nets deployed in the eastern region (BOR). The average daily catches of perch of both retained and discarded fish was similar in all of the investigated regions. The situation was similar with respect to round goby; however, average catches of this species were threefold higher than those of perch. The most differentiation in average daily catches was observed among ruffe (KAT and SUH) from trace amounts of it increasing eastwardly to the maximum (in the border regions). The differentiation of the average abundance of flounder was similar, while that of crucian carp was the opposite.

The results of ANOVA analysis indicated that in the portion of retained catches the model indicated a significant difference among the various fishing regions with the exception of retained eel. The SUH and KAT fishing grounds, which are in relative close proximity, varied most frequently; only the difference between the average abundance of retained sichel was insignificant in this instance. With regard to the average abundance of retained fish, the fishing grounds of the central and eastern lagoon (BOR and TOL) were the most similar as no statistically significant differences were noted for any of the species. Of the discarded catches, the model did not indicate any statistically significance with regard to two species – sichel and perch. The greatest differences between fishing

Table 3. Summaries of results of one-way ANOVA and SNK tests of retained and discarded catches of common species

	Region MS (df = 3)	Residual MS (df = 47)	*F*-ratio	*p* - value	SNK results – significant differences between ranked means are shown by shadowing					
Retained					BOR/ TOL	BOR/ SUH	BOR/ KAT	TOL/ SUH	TOL/ KAT	SUH/ KAT
Round goby	0.706	0.013	53.992	**0.000**			■		■	■
Sichel	1.961	0.121	16.154	**0.000**		■		■	■	
Crusian carp	0.288	0.064	4.512	**0.007**		■		■		■
Bream	1.129	0.188	6.005	**0.001**		■		■		■
Perch	0.333	0.099	3.374	**0.026**						■
Roach	0.550	0.155	3.552	**0.021**		■		■		■
Pikeperch	0.076	0.012	6.300	**0.001**		■		■		■
Eel	0.003	0.011	0.269	0.848						
Discarded										
Round goby	1.331	0.112	11.927	**0.000**			■		■	■
Sichel	0.023	0.022	1.009	0.397						
Ruffe	5.923	0.129	45.996	**0.000**		■	■	■	■	
Crusian carp	0.227	0.054	4.194	**0.010**		■		■		■
Bream	1.751	0.236	7.432	**0.000**		■		■		■
Perch	0.094	0.058	1.631	0.195						
Roach	0.684	0.122	5.601	**0.002**	■	■	■	■	■	
Flounder	1.455	0.097	14.930	**0.000**	■	■	■			

regions were registered for the average abundances of roach and ruffe, while the most similar locations in terms of this were the central and eastern regions (TOL and BOR).

Estimates of total retained and discarded catches

The average weight of discarded fish specimens of the most common species throughout the fishing season were calculated as follows: round goby – 56 g; ruffe – 46g; perch – 64g; roach – 59g; flounder – 96g; pikeperch 154g; bream – 479g. In number, ruffe was the most commonly discarded fish throughout the Vistula Lagoon, while in weight it was bream (Table 4). The region with the highest number and greatest weight of discards was

Table 4. Estimated total discarded catches for the major species in the each study region between May and October 2004. Number of individuals in thousends, weight in tons

	BOR		TOL		KAT		SUH		Vistula Lagoon
	number	weight	number	weight	number	weight	number	weight	total weight
Pikeperch	291.4	44.880	26.3	4.054	20.1	3.102	1.9	0.290	52.326
Bream	78.7	37.681	92.0	44.077	32.5	15.560	92.7	44.418	141.736
Round goby	158.4	8.869	84.7	4.745	1.6	0.091	270.3	15.139	28.844
Ruffe	2 138.3	98.359	584.4	26.882	86.3	3.970	4.5	0.208	129.419
Roach	30.6	1.713	53.4	2.991	168.3	9.426	12.7	0.709	14.839
Flounder	136.8	13.132	25.5	2.449	12.3	1.181	15.4	1.475	18.237

the border region (BOR), while those of the lowest number and least weight were in the northwestern region (KAT).

DISCUSSION

An important step in understanding the effects of bycatch and related management considerations is the collection of information on quantities, sources, and destinations. Discarding patterns are initially affected by fish assemblages, which, in turn, are determined by environmental factors. The various regions of the Vistula Lagoon differ with regard to optimum conditions for fish that have different ecological requirements. The habitat in the southwestern region (KAT and SUH) of the basin is better for freshwater fish, primarily from the cyprinid family, while that in the eastern region (BOR) is preferred by fish that require higher salinity (Psuty-Lipska and Borowski 2003). During the observations, perch and round goby were the most equally distributed species in the Vistula Lagoon. The latter is relatively new to the ichthyofauna of the lagoon; the first individuals of this species were noted in 1999 (Borowski, pers. comm.). Since this time, this new arrival from the Ponto-Caspian region has expanded intensively, which concurs with the scenario described for other basins (Vanderploeg *et al.* 2002). Over the course of five years, the round goby has attained, along with ruffe, the position of the most numerously caught species, although it is not commercially exploited. It is probable that within the next five years the round goby will become an attractive, although substitute, fisheries target in the Vistula Lagoon, just like perch and roach are at the moment. This has also occurred with respect to sichel. This fish species, which was common in coastal waters in the nineteenth century (Bartel *et al.* 1996), was not noted in catches from the beginning of the twentieth century until 1982, and in the space of fifteen years levels of sichel catches have reached 30 tons. This is the result of two coincidences. Firstly, due to its shape, the average consumer associates sichel with herring, which is very popular in Poland, and sales of it are brisk. Secondly, the biomass of this species has increased due to its rich feeding base and decreased pressure from pikeperch (Keida, unpublished). As a consequence, sichel, which has to date been a non-targeted species, has become the most numerously landed fish.

During the investigation, there was a serious problem regarding compliance with MLL regulations for the most valuable species for the fishermen – the pikeperch. Although eel are a more lucrative catch, due to its low biomass resulting from low natural recruitment and the cessation of stocking programs in 1994 (Borowski *et al.* 1998) as well as the widespread implementation of BRD that prevent undersized fish retention, the problem of complying with eel MLL is practically non-existent. As regards pikeperch, the behavior of the fishermen indicates that the significantly smaller sizes acceptable at market mean that they consciously transgress regulations and take the risk of landing undersized fish. The pikeperch that are most often discarded are those for which there is no consumer. This raises the question of how effective setting an MLL is.

The next issue that requires further investigation is the mortality of discarded fish in the fyke-net fishery. The survival of discards following capture is generally regarded as highly variable and depends on a range of factors, including species, length when retained in the gear, fish size, water temperature, and light and sea conditions (Chopin and Arimoto 1995, Davis and Ryer 2003). Observations onboard the vessels in the Vistula Lagoon indicate that discard mortality among pikeperch is high and even reaches 100%.

Reports of the weight of discards in comparison with those of caught pikeperch and bream in the official catch statistics provide an idea of the scale of the discard problem in the fyke-net fishery. In 2004 in the Polish section of the Vistula Lagoon, 212.5 tons of bream and 111.7 tons of pikeperch were caught while 141.7 tons and 52.3 tons, respectively, were discarded. The average weight of fish landed was 1398 g for bream and 1465 g for pikeperch. Total catches of freshwater and diadromous fish were at 709.1 tons, which, in comparison with the estimated magnitude of the discarded catch of the most common species (excluding flounder as a marine fish) at 367.2 tons, gives some idea of the scale of the problem.

Overall, discard practices in the fyke-net fishery of the Vistula Lagoon are not influenced primarily by legal regulations; market forces have great sway here. It has been established that when compliance with regulations leads to the discard of marketable fish, fisherman may ignore the regulations on the basis that they find them morally wrong (Catchpole *et al.* 2005 after Nielsen and Mathiesen 2000). Technical regulations that increase the selectivity of gear might reduce this phenomenon, but not eliminate it. Thus, for scientists as well as fishery managers knowledge of market mechanisms and the socio-economic conditions affecting the fishermen become indispensable. Only an interdisciplinary approach can result in the successive decrease in the significance of the discard problem in some types of fishery.

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A survey of the data on swordfish (*Xiphias gladius* Linnaeus 1758) in the southern and southeastern part of the Baltic Sea

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Abstract. There were twenty-eight reliable records of swordfish (*Xiphias gladius* L.) catches or the discovery of their remains from 1822 to 2002. The majority of the noted fish individuals were adults and two were juveniles. The swordfish caught at Smiltynė on August 31, 2002 was a female with gonads in the second stage of maturity. The fish had stopped feeding and was infected with parasites from Atlantic fish, namely the nematode *Anisakis simplex* larvae L2 (2 specimens/1 fish) and cestodes *Fistulicola plicatus* (3 specimens/1 fish). Swordfish is a paratenic host for these helminths. The swordfish caught in the southern or southeastern Baltic Sea are supposed to have inhabited the mesohaline-oligohaline waters of the medium latitudes incidentally during their feeding or pre-spawning migrations. Thus, they became cut off from the main fish population in the Atlantic ocean and, as a result, were eliminated from the reproductive cycle of this species.

Key words: swordfish, *Xiphias gladius,* biological characterization, *Anisakis simplex*, *Fistulicola plicatus*, Baltic Sea

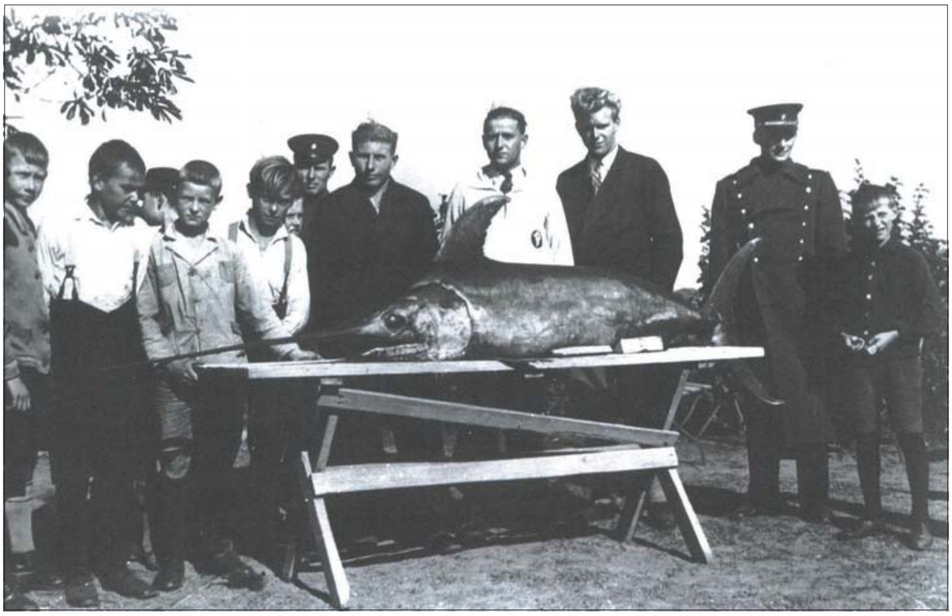

Fig 1. Swordfish (no. 14) caught on September 24, 1931 near Smiltynė, Klaipėda.
Body length – 2.60 m, weight – 2 centners. The photograph belongs to Assistant Professor Bukelskis of the Department of Zoology, Faculty of Natural Sciences, Vilnius University.

INTRODUCTION

The swordfish (*Xiphias gladius* Linnaeus 1758) as a cosmopolitan marine fish of tropical and subtropical open waters, and its main distribution ranges and spawning grounds are in the central Atlantic Ocean and the Mediterranean Sea. Due to its nutritional value, the fish is fished both for sport and commercially. A pelagic life strategy and periodic distant pre-spawning and feeding migrations are characteristic of it. Swordfish are observed to stray into the waters of medium latitudes extremely rarely. In the Atlantic Ocean these fish were caught farthermost from its spawning grounds near Iceland and off of the southern part of the western coastline of the Scandinavian peninsula (Müller 1987). The occurrence of single swordfish individuals in the North and Baltic seas has always been reported via the media or in the scientific and popular science literature, and, to date there has been no detailed scientific summary report of the biological characters of this fish or its occurrence in the Baltic Sea.

The first reports of swordfish catches in the Baltic Sea date to the eighteenth and nineteenth centuries. Information on swordfish catches near Germany was publicized by Bloch (1785) and Möbius and Heinke (1884). Reports of swordfish sightings in the Baltic Sea near the Kingdom of Prussia (present-day Poland and the Kaliningrad Region), in the coastal zones of Lithuania, and adjacent Baltic states were published by the following authors: in Lithuania – Lühe 1910; Anonymous 1928; Grosse and Transehe 1929; Ivanauskas 1934, 1935; Anonymous 1931a; Anonymous 1931b; Anonymous 1936a; Anonymous 1936b; Anonymous 1937; Elisonas 1940; Bacevičius 2002a; in Latvia and Estonia – Grosse and Transehe 1929; Plikšs and Aleksejevs 1998; Reuters 1998 (quoted in *Lietuvos rytas*, 8 August 1998); in Poland – Demel 1925; Demel 1933 (quoted in Skora 1996); Jakuczun 1971; Rembiszewski and Rolik 1975; Skora 1996. The fish caught in the coastal zone of the Eastern Kingdom of Prussia were kept in the museum of the Zoological Institute of the Konigsburgh University (Benecke 1881; Mühling 1898), but precise museum descriptions and exhibits were destroyed during World War II. There are no documented facts about swordfish occurrence in the economic zone of Russia in the Baltic Sea in the coastal area of the Kaliningrad region (Khlopnikov *et al*. 1998).

The aim of this article is to systematize all reliable reports of swordfish individuals caught or discovered in the southern and southeastern Baltic (ICES subdivisions 24, 25, 26, and 28, coastal area of Poland, the former Prussia, the Kaliningrad Region, Lithuania, Latvia, and Estonia) and to compile data from investigations into swordfish biological characters, diet, and parasites. In undertaking this study, the authors also attempted to register data from exhibits in the natural history museums of this region as well as from extant descriptions, written records, and photographs.

MATERIAL AND METHODS

The investigation material for this article was collected under the auspices of the History of Marine Animal Populations (HMAP) program that is part of the Census of Marine Life (CoML) investigative initiative. Conducted from 1997 to 2002, HMAP was coordinated by the Center for Marine and Regional Studies, University of Southern Denmark, in Esbjerg.

Until recently, all swordfish specimens had been caught or discovered by fishermen. As a rule, scientists were provided only with information regarding catch location, time, body length (cm) and weight (kg and centner, 1 centner = 50 kg). When the remains of decaying fish that had been cast ashore were discovered (for instance swordfish juvenile no. 27 in Table 1) the weight was estimated and marked with a question mark. Detailed biological and parasitological analyses of the fish caught in the Baltic Sea have not been performed to date. No information on the vitality of swordfish at the time of catch has survived. Fishermen from the Lithuanian coastal zone interviewed by the authors were not always able to identify swordfish precisely. It is presumed that stranded garfish (*Belone belone* L.) could have been mistaken for swordfish juveniles by the fishermen. All questionable reports or incomplete data on swordfish noted in the southern and southeastern Baltic were omitted from the table. Data on the maturity stages of the gonads of the caught fish have not survived.

On August 31, 2002, following a short wester at the end of an exceptionally hot summer, a swordfish got caught in a net near Klaipėda at Smiltynė. The nets (55 mm mesh size) had been deployed in the coastal zone at depths of 3-7 m. Standard fish body length (L.c.) and rostrum (sword) measurements (cm) were taken, and weight was recorded (kg). The gonads were examined separately. After making a lengthwise incision in the abdomen, the intestine was rinsed and the diet composition, species diversity, and abundance of parasitic helminths were determined.

RESULTS

Data on swordfish sightings

In total, twenty-eight reliable records of swordfish catches or discovered remains exist from the southern and southeastern Baltic Sea (ICES subdivisions 24, 25, 26, and 28). This fish species was netted four times; fish no. 26 was caught with a spinning rod (according to the fisherman) and in all other cases the swordfish were retrieved dead and in a state of decay (no. 27). Body length, weight, and other characters of the caught or found swordfish are presented in Table 1. The fish are presented in successive numerical order according to when they were noted. More reports on swordfish occurrence are available in scientific publications, but they do not include the precise information indispensable for this study. For instance, Plikšs and Aleksejevs (1998) present data on nine swordfish caught in the pre-war period in Poland and also report that swordfish were caught near Estonia in 1952 and 1953 and near Latvia in 1964 and 1965. However, this source does not present any precise data. Hence, these data are not included in the table, and they need revising.

Several generalizations were made from the information available. It was concluded that the greatest number of swordfish were noted from August to October of exceptionally hot years (1931, 1936, 1993, 2002), after stormy spells (1936, 1958, 1980, 1998), or in periods dominated by abrupt shifts of atmospheric fronts (1936, 2002). Water temperature was not lower than 15°C (1998, 2002). The most northerly location in the Baltic Sea

Table 1. Summary of data on swordfish recorded in ICES subdivisions 24, 25, 26, and 28 in the Baltic Sea

No	Date caught	Locality country	Number of individuals	Length in cm (L.c.)	Weight in kg/ cnt	Matuurity stage, sex	Source
1	2	3	4	5	6	7	8
1	1822	Libou* / Liepaja, Latvia	1	240	-	adult	Grosse & Transehe, 1929
2	August 1824	Palongen* / Palanga, Lithuania	1	-	-	-	Grosse & Transehe, 1929
3	1848	Papenseschen Strande* / Papė, Latvia	1	-	-	-	Grosse & Transehe, 1929
4	1851	Papenseschen Strande* / Papė, Latvia	1	-	-	-	Grosse & Transehe, 1929
5	1852	Papenseschen Strande* / Pape, Latvia	1	-	-	-	Grosse & Transehe, 1929
6	1881-1887	Livlandia* /Latvia	4	-	-	-	Grosse & Transehe, 1929
7	1887 fall	Libou* / Liepaja, Latvia	1	232	-	adult	Grosse & Transehe, 1929
8	24 October 1894	Arensburg* / Kuressaare (Saaremaa), Estonia	1	-	-	-	Grosse & Transehe, 1929
9	1891	Freschhaff* / Zalev Vislany / Vyslinkij zlyv, Poland-Russia	1	-	-	-	Cited in Mühling, 1898
10	1895	Karki */ Karklininkai, Lithuania	1	-	-	-	Grosse & Transehe, 1929
11	1910	Krantz* / Zelionograd, Russia	1	-	-	-	Lühe, 1910
12	1925	Poland	1	-	-	-	Demel, 1925
13	14 August 1928	Papenseschen Strande* / Pape, Latvia	1	225	80	adult	Anonymous, 1928 Grosse &Transehe 1929
14	24 September 1931	Smiltynė, Klaipeda, Lithuania	1	260	2 cnt /100 kg	adult	Anonymous, 1931a; 1931b Ivanauskas, 1934; 1935; Photograph, taxidermic swordfish in the Tadas Ivanauskas Zoology Museum in Kaunas; Elisonas, 1940
15	1933	Poland	1	-	-	-	Demel 1933, cited in Skora, 1996

1	2	3	4	5	6	7	8
16	August 1936	Karklininkai, Lithuania	1	230?	60	adult	Anonymous, 1936a; Photograph Anonymous, 1936b; Photograph
17	1957	Saaremaa–Hiiumaa, Estonia	1	-	-	-	Plikšs & Aleksejevs, 1998
18	1958	Miedzyzdrojow, Poland	1	-	-	-	Jakuczun, 1971
19	6-7 September 1970	Wolyn, Poland	1	215	2 cnt /100 kg	adult	Jakuczun 1971, Photograph
20-21	1980	Juodkrantė, Lithuania	2	200	-	adult	Anonymous; Photograph, unpublished data
22	1993	Ventspilis, Latvia	1	-	-	-	Plikšs & Aleksejevs, 1998
23	1993 09 15	Puck Bay, Poland	1	180	35	-	Skora, 1996; Stuffed swordfish
24	August 1995	Gulf of Gdansk near Piaski,Poland	1	<120	-	juvenile	Skora 1996; Photograph
25	23 October 1995	Gulf of Gdansk, Kanty Rybackie, Poland	1	232	66	adult	Skora, 1996; stuffed swordfish
26	8 August 1998	Isle of Saaremaa, Estonia	1	246	81	adult	Reuters Agency, photograph (*Lietuvos rytas* 8 August 1998)
27	11 October 1998	Nemirseta, Lithuania	1	150	10 ?	juvenile	Umbrasienė 1998, Unpublished data, photograph
28	31 August 2002	Smiltynė, Klaipėda, Lithuania	1	234.5	50	adult female II	E. Bacevičius, 2002b, S. Karalius; Unpublished data, photograph, taxidermic swordfish head.

* Former names of localities

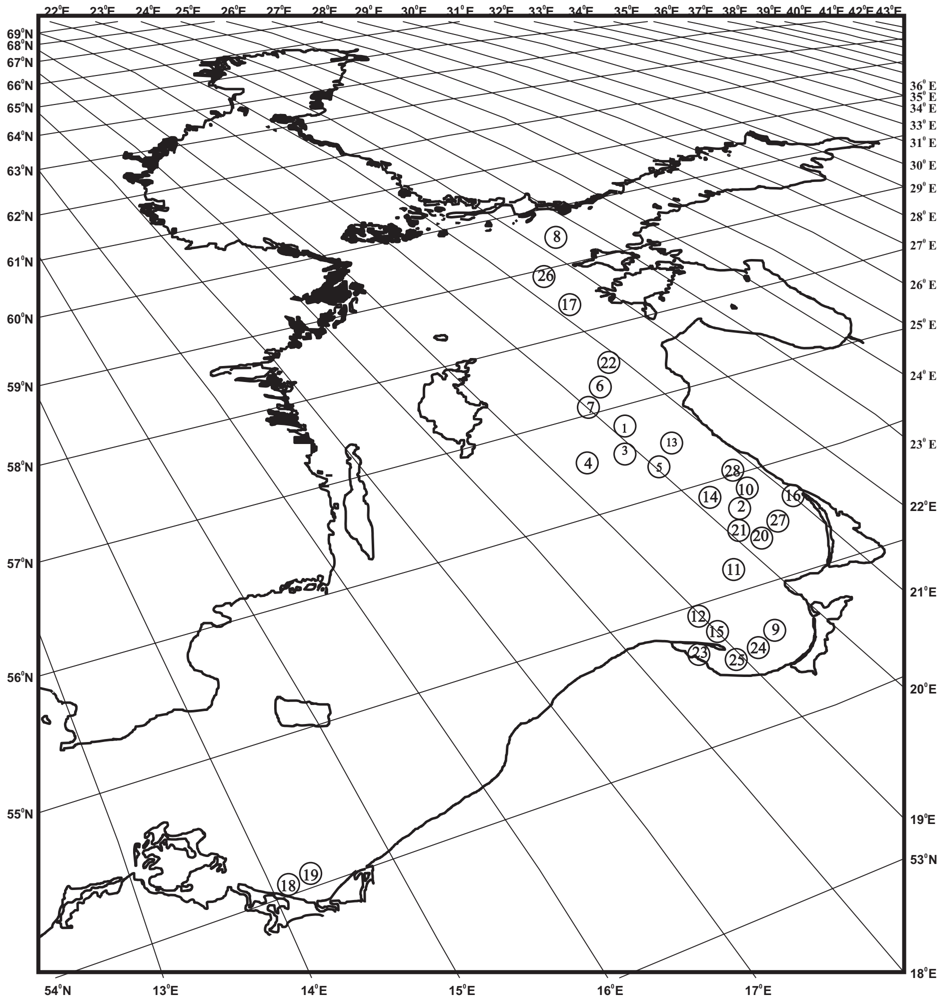

Fig. 2. Map of swordfish discoveries in ICES subdivisions 24, 25, 26, and 28 from the coastal zone of the Baltic Sea. The numbers in white circles indicate the number of swordfish from Table 1. The fish were numbered by the year in witch they were caught.

where swordfish were caught was near the Saaremaa and Hiiumaa islands in Estonia (no. 26). Usually, not more than one swordfish individual per year was sighted; two individuals were sighted very rarely (in 1980 – nos. 20 and 21; 1993 – nos. 22 and 23; 1998 - nos. 26 and 27). The age of the caught specimens was not established. Fish body lengths fluctuated between 120 cm (no. 24) and 260 cm (no. 14). Weight varied from approximately 10 kg (no. 27) to 100 kg (nos. 14 and 19; Table 1).

Eight swordfish individuals have been caught or noted at different times in the coastal zone of Lithuania (nos. 2, 10, 14, 16, 20–21, 27, 28), and there are photographs of six of them (nos. 14, 16, 20–21, 27, 28). The swordfish (no. 14) caught near Smiltynė on September 24, 1931 was preserved by taxidermy and is kept at the Tadas Ivanauskas Zoology Museum in Kaunas. The photograph of this fish is stored at the Zoology Department of Vilnius University. Fish no. 28 netted near Smiltynė on August 31, 2002 was a female with gonads in the second stage of sexual maturity. Its length (L.c.) was 234.5 cm, and it weighed 50 kg. Its head was preserved by taxidermy and is kept by the owner. Photographs of it were published in the press and scientific publications (Bacevičius 2002 a, b).

Information on swordfish feeding habits

After rinsing the digestive tract of the fish caught near Smiltynė (no. 28), no food remains were detected in either the stomach or the intestines.

Parasitological analysis of swordfish

The results of the parasitological analysis of the swordfish (no. 28) netted near Smiltynė on August 31, 2002 indicated that there were two parasite species in the intestine that are characteristic of Atlantic Ocean fish: non-encapsulated larvae L2 (2 specimens/1 fish) of the nematode *Anisakis simplex* Rudolphi 1809 and three cestodes *Fistulicola plicatus* Rudolphi, 1819 embedded deep in the wall of the rectal intestine (Bacevičius 2002b, 2003).

DISCUSSION

Twenty-eight reliable reports of swordfish catches or remains in the southeastern Baltic Sea were recorded in the records available from the 1822–2003 period. Some of the information on swordfish specimens in the Baltic Sea (four cases) is incomplete, therefore it has not been included in the survey. It is presumed that not all swordfish specimens that have strayed into the Baltic Sea have been described (Winkler *et al.* 2000). Only the fish observed near fishermen's settlements or resorts were recorded, and data regarding them was passed on to ichthyologists. To date, data on swordfish in the territorial waters of Denmark, Sweden, and Germany in the southern and southwestern Baltic Sea (ICES subdivisions 23 and 24) have not been systematized.

No more than one to two swordfish specimens were stranded or caught in nets annually during the period examined. The majority of the specimens were adults (fish length was not indicated in some of the nineteenth century reports), and two specimens were juveniles. The Baltic Sea is a mesohaline-oligohaline basin with fluctuating salinity at medium latitudes on the eastern coast of the northern Atlantic ocean; thus, the swordfish noted in the southeastern region of it must have strayed there during feeding or prespawning migrations. As Table 1 indicates, swordfish were caught or noted during the hydrological summer period in the sea (usually from August to September, and more rarely until the end of October), when, presumably, some fish migrated with the warm waters of the Gulf Stream to the northern part of the European continent reaching the southern part of the western coastal zone of the Scandinavian peninsula. Some fish enter the North Sea or migrate even further to the Baltic Sea.

There is still insufficient data to establish a correlation between the periodicity of swordfish occurrence and the prevailing meteorogical conditions over Europe in the warm season of the year. It is possible that some cases of swordfish detection in the Baltic Sea coincide with the extraordinary meteorological phenomena which were observed in the eastern coastal area of the North Atlantic or over the central part of Europe at that time. For instance, two fish individuals were caught in 1993 and one in 2002 at the end of an extremely hot summer. However, swordfish were also caught in the cool and very stormy summer and fall months of 1936 and 1998. These issues require further comparative studies.

In the Atlantic Ocean swordfish feed in the pelagic zone preying actively on medium-sized fish such as scomber, sardines, anchovies, etc. They are typical pelagic oportunistic predators and rely heavily on their vision to catch prey. There are no reports of them feeding in the Baltic Sea (Torin 1971; Müller 1987). The digetive tract of the only swordfish specimen (no. 28) caught to date at Smiltynė was rinsed but nothing was detected in the stomach or intestines. Presumably swordfish suffer osmotic shock in the south-eastern part of the Baltic Sea due to low salinity and, as a result, they stop feeding and eventually become exhausted. Subsequently, they are cast ashore or are netted prostrate (Gibson 1996). Since there are no extant data on swordfish noted in the nineteenth and early twentieth centuries, it is impossible to estimate statistically in what state swordfish were usually found - cast ashore dead or netted. There are no definitive data regarding swordfish vitality (changes in gills, muscle rigidity, or other symptoms of vitality) at the time of their discovery.

To date, no information has been collected on the endoparasites or ectoparasites of swordfish caught in the Baltic Sea. Two species of intestinal parasitic helminth (*i.e.*, larvae L2 [2 specimens/1 fish] of the nematode *Anisakis simplex* Rudolphi, 1809 and cestodes *Fistulicola plicatus* Rudolphi, 1819 [3 specimens/1 fish]), were detected in the swordfish (no. 28) netted near Smiltynė on August 31, 2002. Planktophagous and ichthyophagous fish of the Atlantic Ocean are the intermediate hosts of these parasites. Up to nineteen species of metasoic parasites have been recorded in swordfish caught in the European coastal zone of the Atlantic Ocean and adjacent areas (Hogons *et al*. 1983; Wierzbicka and Sobecka 2003). Neither ectoparasites characteristic of Atlantic Ocean swordfish or parasitic helminths typical of the fish of Baltic Sea saline waters were recorded. It is possible to conclude that swordfish did not feed in Baltc Sea waters. The parasites detected are from the Atlantic Ocean life stage and are testimony to the peculiarities of previous feeding habits.

In the Atlantic Ocean, swordfish are a paratenic host for the nematode *A*. *simplex* and a definitive host for the cestode *Fistulicola plicatus*. A probable hypothesis seems to be that stage L2 *A*. *simplex* larvae infect the intestines of Baltic Sea fish such as Baltic herring or cod and then Grey seals (*Halichoerus grypus* Fabricius, 1791). Nematodes could reach sexual maturity and even produce eggs in warm-blooded marine mammals. Their further reproduction is impossible because, according to available data, the crustacean *Euphausia superba*, the specific marine intermediate host of this nematode, and which is indispensable for further helminth development, does not inhabit the Baltic Sea (Grabda 1974, 1976; Fagerholm 1982; Bacevičius 2003). It is hypothesized that the development of these helminths ceases in the Baltic Sea as they are eliminated from the parasite development cycle in the Atlantic Ocean. Due to this, swordfish in the Baltic Sea should be regarded not as a definitive or intermediate host of this parasite species, but as a paratenic host. All live swordfish in the Baltic Sea are biologically cut off from the main fish population in the Atlantic Ocean. According to available data, they do not return to the tropical waters of the Atlantic Ocean. They stop feeding, eventually become exhausted, and die or become entangled in fishing gear and eliminated from the reproductive cycle of this species. Marine parasitic crustaceans as well as intestinal and muscle helminths that survive from the period of life in the Atlantic Ocean are eliminated in a similar way.

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