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Fish biology

FECUNDITY OF COD (*GADUS MORHUA CALLARIAS* L.) IN THE SOUTHERN BALTIC IN THE LATE 1990s

PŁODNOŚĆ DORSZA (*GADUS MORHUA CALLARIAS* L.) POŁUDNIOWEGO BAŁTYKU W DRUGIEJ POŁOWIE LAT DZIEWIĘĆDZIESIĄTYCH

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The fecundity of cod from the southern Baltic Sea in the late 1990s was estimated from 461 pairs of ovaries at the maturity stage IV (according to Maier's scale). Number of eggs per female was estimated for different length, weight, and age classes of fish obtained from the ICES subdivisions: 25 (Bornholm Deep) and 26 (Gdańsk Deep). Absolute fecundity in relation to body length and age, as well as relative fecundity, showed no differences between the two subdivisions, whereas absolute fecundity in relation to body weight was slightly higher in females from the Gdańsk Deep. Absolute fecundity in relation to age showed a high variability, particularly among age classes 5 and older. Absolute fecundity of cod in the southern Baltic has increased slightly over the past four decades. Length at first maturity, i.e. length at which 50% of females are mature, was estimated to be 40.2 cm for females from the Gdańsk Deep.

INTRODUCTION

The Atlantic cod (*Gadus callarias*, synonym *Gadus morhua*, L. 1759) is distributed in the continental shelf regions of the north Atlantic from the Bay of Biscay to Spitsbergen and Novaya Zemlya, off Iceland, Greenland and Newfoundland. In the Baltic Sea, it occurs in the entire region as a subspecies *Gadus morhua callarias* L. (cf. Ferens et al. 1962), but is most abundant in the Baltic proper. The cod attains maturity at various ages depending on area: in the North Sea at age 4–6 years, off Iceland and southern Greenland at age 5–6 years, in the Lofotens and off the northern coast of Norway at age 6–15 years (on average 10–12 years). The Baltic cod matures earliest—in the second or third year of its life.

According to Rutkowicz (1963), it is the most important biological feature indicating an adaptation of the species to its local environment.

Based on reports in the literature it appears that the stock of Baltic cod is not homogenous. According to Arö (1988) there are two cod stocks in the Baltic Sea. They differ in otolith structure (Berner 1960; Bagge and Steffensen 1980), hemoglobin type (Sick 1965; Jamieson and Otterlind 1971) and some morphometric and meristic characters (Schmidt 1931; Kandler 1944; Biriukov 1969; Berner and Vaske 1985), as well as, in frequency of loci in the allele coding certain enzymes (genetic markers) (Moth-Poulsen 1982). These results support the separation of the two stocks into two subspecies. The western Baltic stock of cod (*Gadus morhua morhua* L.) occurs west of Bornholm, in the Belt Sea and Sund (Subdivisions 22–24). It has contact with the stocks occurring in Kattegat and Skagerrak (Division IIIa) as well as in the southwestern Baltic. The eastern Baltic stock of cod (*Gadus morhua callarias* L., 'the Baltic cod') occurs east of Bornholm. In the region of the Arkona and Bornholm Basins there exists an intermediate stock which intermingles with the former two.

The biology of the Baltic cod has been thoroughly studied but there are relatively few studies of its reproduction. Botros (1959) estimated absolute fecundity of cod in the western Baltic (Kiel Bay, Subdivision 22) in the late 1950s. Strzyżewska (1962) estimated absolute fecundity of cod in the region of Gdańsk Deep (Subdivision 26) in the years 1959–1961. Subsequent studies were conducted in the western Baltic. Kraus et al. (1997; 1999) studied cod fecundity in the Bornholm Basin (Subdivision 25) in the years 1987–1996. Bleil and Oeberst (1996) reported on cod fecundity in the region of the Bornholm Basin (Subdivisions 22, 24 and 25) for the years 1992–1995.

The changes of hydrological conditions taking place in the Baltic Sea as well as the observed changes in relationships between pelagic and demersal fishes influenced the decision to start studies on fecundity in cod in the southern Baltic. The 1990s were a period when small intrusions of Atlantic water were observed (Matthaus and Carlberg 1990; Wojewódzki 1996) following a long ten-year period without such intrusions (Matthaus 1987). The changed conditions in the environment and the fact that the stocks of Baltic cod are considerably depleted owing to high fishing mortality with prevailing low (compared to that in the 1970s) recruitment may have changed the reproductive potential of cod in the Baltic Sea.

The aims of the present study were as follows: (1) to estimate the absolute and relative fecundities of cod from the Bornholm and Gdańsk Deeps in the late 1990s, (2) to estimate the length at first maturity for females from the Gdańsk Deep and (3) to compare all these estimates with those reported over the past four decades for an assessment of possible changes in cod fecundity.

MATERIAL AND METHODS

Specimens were collected in the years 1995, 1996, and 1999 from pre-spawning concentrations on the fishing grounds of the Bornholm and Gdańsk Deeps (Fig. 1). The examined fish came from the catches of fishing vessels and the research vessel, R/V *Baltica.* Females in maturity stage IV, exhibiting intense oocyte growth (according to Maier's scale) (Meisner 1948), were thoroughly examined. Total length of each female was measured to the nearest cm. Total body weight and gutted body weight (the latter only in 1999) were determined to the nearest 10 g. Otholits were removed for age determination.

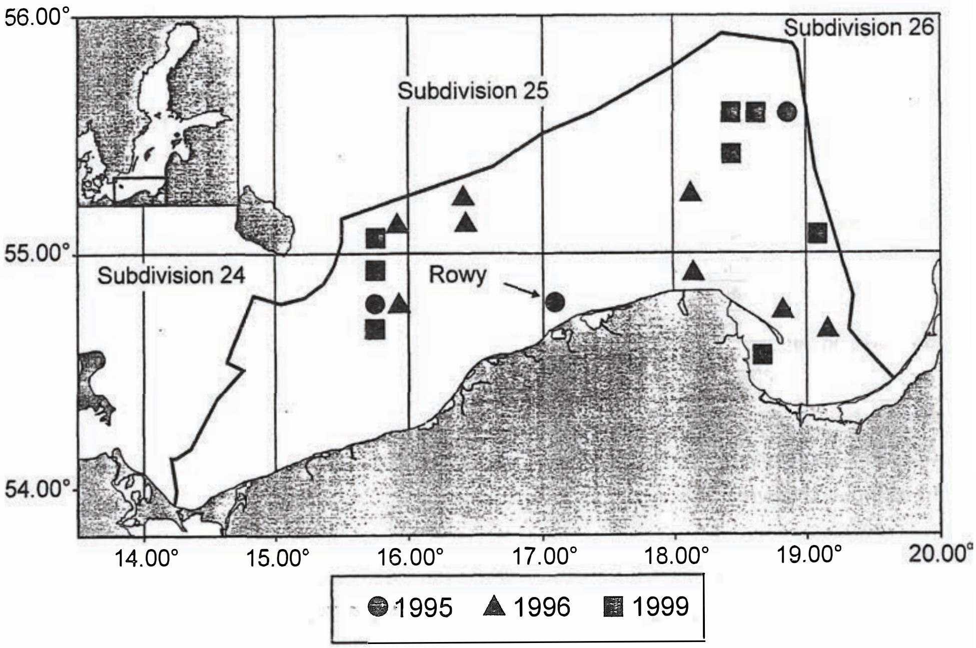

Fig. 1. Map of the southern Baltic—sampling sites in the successive years

In 1995 and 1996, the eggs were preserved in Gilson's fluid. Number of eggs in the ovaries collected in 1999 was determined using a new method of preservation and fragmentation of ovaries (Bleil and Oeberst 1993). In this method, the gonads are frozen (at –20°C), and then defrosted in 80% alcohol, thus avoiding contact with highly toxic reagents such as Gilson's fluid.

Individual absolute fecundity of a cod female was estimated by multiplying the number of eggs in a subsample with the ratio of ovary weight to subsample weight. The dry gonads were weighed to the nearest mg and the subsamples (in three replicates) to the nearest 0.1 mg. Relative fecundity was calculated as a number of eggs per gram of gutted body weight.

Fecundity of cod females in the southern Baltic was estimated separately for the two ICES subdivisions: Subdivision 25, Bornholm Deep and Subdivision 26, Gdańsk Deep. It should be noted that during data collection in 1995 one collection was taken on an inshore fishing ground (longitude 17.00° east). The authors agreed that this sample of 50 pairs of gonads could not be included in the materials from either the Bornholm Deep or the Gdańsk Deep. Therefore, this sample was analyzed separately as the "Rowy" fishing ground (Fig. 1). The females collected in 1999 from commercial catches in the Gdańsk Deep were used for determination of size of maturing fish (Table 1).

Table 1

Summary of the collected material

Location	Year	Month	Number of females	Total length range (cm)	Total weight range (g)	Age range (years)
Subdivision 25	1995	April	64			
	1996	March, April	28			
	1999	May	108			
	Total		200	36–101	460–14 000	3–7
Subdivision 26	1995	April, May	66			
	1996	April	40			
	1999	April–June	105			
	Total		211	30–98	390–10 970	3–10
Rowy	1995	April	50	38–68	810–3 910	3–6
Subdivision 26*	1999	April–June	1109			

* Fish from commercial catches for determination of size of maturing fish.

In total, 461 pairs of ovaries were collected and preserved. Fish were grouped in 1-cm length, 100-g weight and 1-year age classes, and mean fecundity was estimated for each class.

Absolute fecundity was expressed as a power function of total length, total weight or age:

$$F_a = aX^b$$

where: F_a = absolute fecundity; X = total length, total weight or age; a, b = parameters. This relationship was linearized by a logarithmic transformation and the parameters a and b were estimated using least-squares linear regression. In the case of the relationship between total weight and absolute fecundity, the null hypothesis was tested whether the exponent in the power relationship (or regression coefficient in the linear one) in the population is equal to unity. If this hypothesis is retained, it may be concluded that in the population, absolute fecundity is proportional to body total weight.

Relative fecundity, given by number of eggs per unit of gutted body weight, was expressed as a linear function of total length, total weight or age:

$$F_w = a + bX$$

where: F_w = relative fecundity; X = total length, total weight or age; a, b = parameters. The parameters a and b were estimated using least-squares linear regression. The significance of the regression was tested. If the null hypothesis that the population slope equals zero is retained, it may be concluded that relative fecundity in the population does not vary with length, body weight or age.

The data from Subdivisions 25 and 26 collected in the years 1995–1999 were compared with regard to six relationships: between length, weight and age as independent variables and absolute or relative fecundities as dependent variables. In the case of absolute fecundity, a hypothesis about equality of the two population regression coefficients was tested. If the null hypothesis was retained, the two lines were assumed to be parallel and another hypothesis was tested whether the two population regressions have the same intercept (Zar 1984). In the case of relative fecundity, the two samples were compared by applying a simple factor ANOVA, if relative fecundity was found unrelated to length, body weight or age. Additionally, the data for Subdivision 26 collected in the years 1995–1999 were compared with those collected by Strzyżewska (1962) in the period of 1959–1961. In this case two relationships were analyzed: between length and weight as independent variables and absolute fecundity as a dependent variable.

Length at first maturity for cod females from the Gdańsk Deep collected in 1999 was determined, taking the total length at which 50% of females had gonads at maturity stage III (according to Maier's scale) and more advanced. On the basis of empirical data, percentages of mature females in successive length classes, a relationship between the two variables was determined and the corresponding curve plotted showing the frequency of spawning females. A logistic curve was applied of the form:

$$P_L = \frac{1}{1 + e^{(a+bL)}}$$

where: P_L = per cent mature females at length L; a and b = parameters (Rickey 1995). Length $L_{50\%}$ at which 50% of females reach maturity was estimated using the formula:

$$L_{50\%} = -\frac{a}{b}$$

RESULTS

The samples used for estimation of cod fecundity in the southern Baltic were quantitatively similar for the Bornholm Deep and the Gdańsk Deep. Absolute fecundity of cod showed considerable variability in relation to total length (Table 2), total weight and age.

Table 2

Absolute fecundity of cod females (in thousands eggs per female) in successive length classes

Length class (cm)	Subdivision 25			Subdivision 26			Rowy		
	n	Range	Mean	*n*	Range	Mean	*n*	Range	Mean
30				1		145.3			
...									
33				1		699.6			
...									
36	1		455.9	4	367.5–542.8	434.6			
37	3	419.0–716.8	536.7	1		514.9			
38	2	358.1–490.4	424.2	3	247.3–711.0	416.3	1		526.5
39	1		563.2	4	379.5–575.0	510.2			
40	3	416.0–759.6	607.4	4	357.5–668.0	529.2			
41	3	425.6–757.1	595.9	5	420.8–717.3	584.6			
42	6	370.1–1039.0	700.8	5	384.4–816.3	609.9			
43	6	391.3–1012.5	632.1	5	550.9–809.0	655.3	2	628.6–715.0	671.8
44	10	470.0–952.3	696.8	4	815.5–1038.4	933.6			
45	11	265.6–1449.5	819.5	11	617.0–1224.2	832.6	5	579.2–957.3	732.1
46	16	409.8–1304.7	825.8	8	572.9–930.0	784.3	3	536.4–962.8	784.8
47	15	558.8–1269.5	824.8	11	526.4–1546.7	941.3	3	755.2–943.4	832.5
48	14	728.3–1376.2	1031.4	9	596.6–1413.6	882.3	7	710.9–1214.0	838.4
49	13	660.4–1499.8	980.8	11	702.1–1487.3	1009.1	1		845.3
50	16	490.8–1695.2	1079.8	9	724.4–1199.8	909.8	3	794.4–1358.9	1050.6
51	7	920.6–1380.8	1202.2	12	620.7–1903.6	1165.4	2	936.4–1059.1	997.8
52	12	671.5–1832.7	1247.7	10	767.8–1465.0	1174.4	4	309.9–1359.6	1002.7
53	10	1088.0–2511.3	1420.2	10	757.1–1516.8	997.2	2	1142.7–1242.3	1192.5
54	10	793.8–1466.8	1168.2	12	666.4–1997.0	1134.4	3	860.6–1304.9	1029.8
55	9	1012.5–2167.7	1493.3	13	643.5–2424.4	1413.7	2	1104.8–1606.0	1355.4
56	5	757.6–2245.9	1334.2	11	808.8–2154.3	1418.0	2	1113.5–1565.4	1339.4
57	5	1107.2–1755.3	1360.5	3	991.1–1567.7	1191.1	1		1116.7
58				5	1361.8–2022.7	1663.6	1		924.7
59	3	1227.3–1771.8	1414.2	2	1869.7–1901.7	1885.7	2	1095.5–1110.2	1102.9
60							2	904.5–1421.3	1162.9
61	4	1754.6–2331.2	1911.0	6	1366.2–3405.4	2247.4			
62	1		3371.6	6	1503.4–3188.1	2144.3	1		1157.9
63	3	579.7–1768.2	1321.6	2	1439.1–1636.1	1537.6			
64	3	1313.1–1990.6	1599.2						
65				3	1688.7–1791.6	1757.0	1		1887.5
66				1		2029.2			

Table 2 (cont.)

Length class (cm)	Subdivision 25			Subdivision 26			Rowy		
	n	Range	Mean	*n*	Range	Mean	*n*	Range	Mean
67				1		3700.1	1		1478.8
68	2	1039.2–3223.4	2131.3	1		2079.6	1		1560.1
69				3	1900.4–2874.5	2522.2			
70	1		3411.9	2	564.4–1870.7	1217.5			
71				1		4130.4			
72				1		3926.4			
73	1		1714.1	1		4788.8			
74				2	2258.3–2392.6	2325.5			
75	1		3704.8	1		3417.0			
...									
77	1		4090.9						
78				1		6067.1			
...									
81	1		4297.0						
...									
83				1		3923.4			
...									
87				1		2580.2			
...									
90				1		3406.0			
...									
97				1		5392.4			
98				1		6095.7			
...									
101	1		6123.4						
Total	200			211			50		

In the material collected from the Bornholm Deep there were 200 females from 36 to 101 cm in length, belonging to 34, 1-cm length classes (Table 2). Individual absolute fecundity in the examined females ranged from 265.6 thousand eggs in a 45 cm female to 6123.4 thousand eggs in the biggest female, 101 cm in length. Absolute fecundity was analyzed in relation to weight after grouping individuals in 34, 100-g weight classes within the range 400–14 000 g. Mean absolute fecundity increased from 419.0 thousand eggs in the first class to 6123.4 thousand eggs in the last one (each of these extreme classes being represented by a single fish). Females belonging to only five age groups, 3 to 7 years old were present in the sample. Mean absolute fecundity ranged among age groups from 880.2 thousand eggs in the youngest group to 3976.6 thousand eggs in the oldest one. Individual absolute fecundity in the two most common age groups, 4 and 5 years old, varied from 358.1 thousand to 1 449.5 thousand and from 265.6 thousand to 4090.9 thousand eggs, respectively.

In the material collected from the Gdańsk Deep there were 211 females from 30 to 98 cm in length, belonging to 46, 1-cm length classes (Table 2). Individual absolute fecundity ranged from 145.3 thousand eggs in the smallest female, 30 cm in length, to 6095.7 thousand eggs in the biggest female, 98 cm in length. In relation to weight, absolute fecundity was analyzed for 40, 100-g weight classes within the range 300–11 000 g. Mean absolute fecundity ranged among the weight classes from 145.3 thousand eggs (in a single fish from the first one) to 6095.7 thousand eggs (in a single fish from the last one). The females from this region belonged to eight age groups, from 3 to 10 years old. Mean absolute fecundity in these groups ranged from 825.3 thousand eggs in the youngest group to 5744.1 thousand eggs in the oldest one. Similarly as in the Bornholm Deep, the most represented age groups in the Gdańsk Deep were 4 and 5 years old. Individual absolute fecundity in these two groups varied from 290.6 thousand to 2392.6 thousand and from 526.4 thousand to 3405.4 thousand eggs, respectively.

The females collected on the Rowy fishing ground belonged to 22, 1-cm length classes within the range from 38 to 68 cm (Table 2). Individual absolute fecundity ranged from 309.9 thousand eggs in a 52 cm female to 1887.5 thousand eggs in a 65 cm female. Mean absolute fecundity, estimated separately for 21, 100-g weight classes within the range 800–4000 g, ranged from 620.8 thousand to 1560.1 thousand eggs (the latter class contained a single fish). Four age groups were present in this sample, from 3 to 6 years old. Mean absolute fecundity ranged among these age groups from 745.0 thousand eggs in the youngest group to 1185.6 thousand eggs in the oldest one. Individual absolute fecundity in the two most represented age groups, 4 and 5 years old, varied from 309.9 thousand to 1565.4 thousand and from 579.2 thousand to 1606.0 thousand eggs, respectively. The results for the Rowy fishing ground given here, but excluded from statistical analysis in the present study, can potentially be used in other studies for estimation of cod fecundity in the southern Baltic.

Relative fecundity, given by number of eggs per unit of gutted fish weight, estimated for Subdivisions 25 and 26 examined in 1999, is given in Table 3. Individual relative fecundity varied widely from 358.1 eggs per gram in a 81 cm female to 1685.8 eggs per gram in a 62 cm female in Subdivision 25 and from 252.0 eggs per gram in a 70 cm female to 1565.6 eggs per gram in a 49 cm female in Subdivision 26.

Absolute fecundity increased with body size. The relationship between absolute fecundity and total length estimated for Subdivisions 25 and 26 was curvilinear (Figs. 2A, C, respectively). Absolute fecundity within a single length class was highly variable, particularly in females above 50 cm. It increased unevenly in females above 65 cm, probably owing to the low number of larger females.

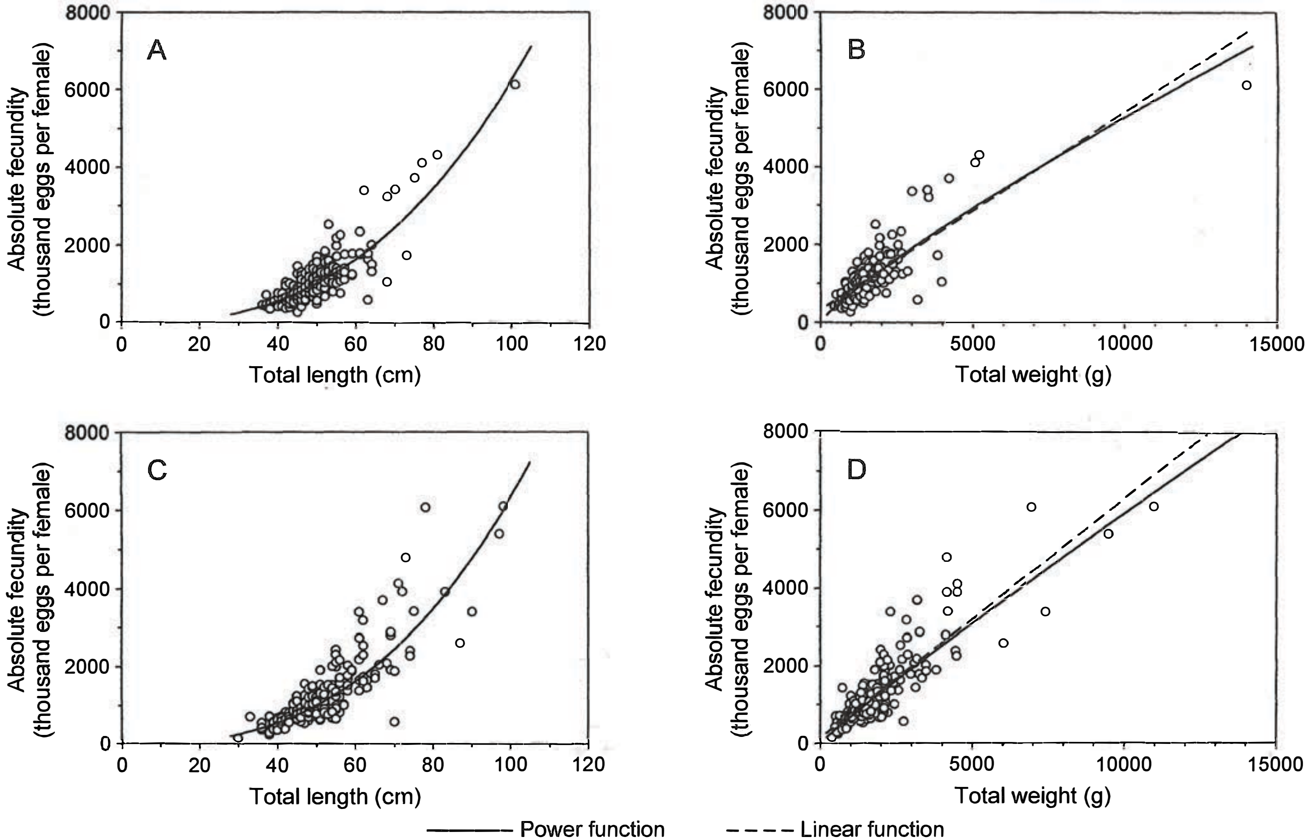

Fig. 2. Absolute fecundity of cod females (empirical data) in relation to total length (A) and total weight (B) in Subdivision 25 and in relation to total length (C) and total weight (D) in Subdivision 26

Table 3

Relative fecundity of cod females (in eggs per gram gutted body weight) in successive length classes

Length class (cm)	Subdivision 25			Subdivision 26		
	n	Range	Mean	*n*	Range	Mean
30				1		675.8
...						
36	1		1266.4	3	742.5–1068.0	882.7
37	1		1021.9			
38	1		1021.7	2	660.5–1146.7	903.6
39	1		1126.5	4	637.8–1042.9	891.3
40	3	729.8–1406.6	1097.1	3	567.5–984.6	781.1
41				4	824.2–1258.4	1008.4
42	4	919.9–1484.3	1070.9	3	530.3–946.2	773.9
43	2	731.4–1020.5	876.0	4	675.9–854.3	765.8
44	9	734.4–1360.4	983.7	2	1029.2–1448.3	1238.8
45	7	688.1–1611.3	1098.2	7	719.1–1374.7	932.9
46	10	455.3–1553.2	915.8	6	749.0–1062.9	913.7
47	9	657.4–1511.3	1051.7	6	821.5–1473.0	1074.4
48	8	772.1–1529.1	1112.6	6	608.4–1296.9	922.8
49	8	735.2–1428.4	1032.3	6	778.8–1565.6	1112.5
50	9	834.6–1165.1	1043.8	5	649.6–1153.6	883.0
51	4	987.7–1244.6	1074.2	4	964.6–1299.4	1141.9
52	5	609.8–1267.1	1023.7	4	593.1–1013.8	807.3
53	4	894.3–1236.1	1067.7	2	584.6–1157.8	871.2
54	4	838.3–1087.7	958.8	3	788.9–1426.4	1056.5
55	4	860.9–1526.5	1073.7	4	710.5–1493.3	1145.2
56	2	753.4–1321.1	1037.3	3	906.8–1241.6	1082.5
...						
58				1		1057.0
59	2	615.6–957.7	786.6	1		980.3
...						
61	1		987.3	4	859.6–1821.0	1212.3
62	1		1685.8	4	880.2–1439.3	1124.9
63	1		769.9			
64	1		1020.8			
65				1		610.7
...						
67				1		1462.5
...						
69				1		1120.7
70	1		1364.8	2	252.0–715.4	483.7
71				1		1332.4
72				1		1232.8
73				1		1484.9
...						
75	1		1139.9			
81	1		358.1			
...						

Table 3 (cont.)

Length class (cm)	Subdivision 25			Subdivision 26		
	n	Range	Mean	*n*	Range	Mean
83				1		1095.9
...						
97				1		806.0
98				1		709.6
...						
101	1		612.3			
Total	106			104		

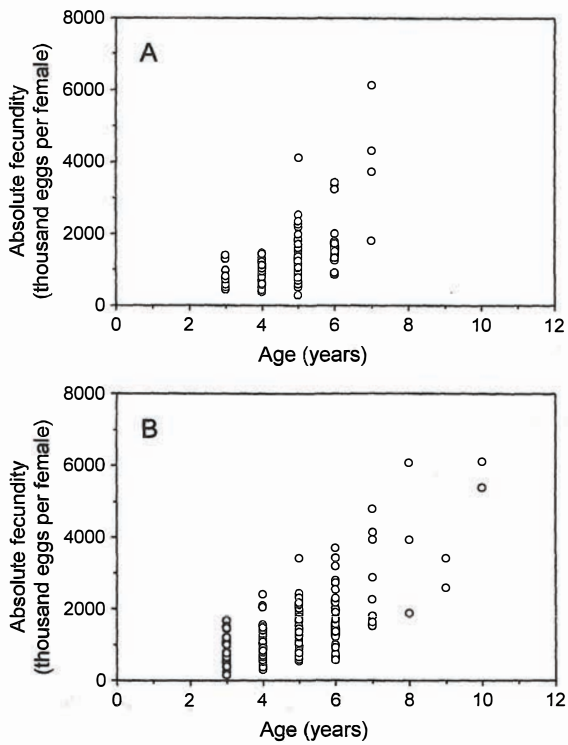

Fig. 3. Absolute fecundity of cod females in relation to age (empirical data) in Subdivisions 25 (A) and 26 (B) in the years 1995–1999

The relationship between absolute fecundity and total weight estimated for Subdivisions 25 and 26 was nearly linear (Figs. 2B, D, respectively). High variation can be observed within a single weight class in females above 2000 g.

An increase of absolute fecundity with age can be explained by a simultaneous increase in weight. Fig. 3 shows a high variation in absolute fecundity within age groups, particularly in fish at the age of 6 years and older. This may be due to errors in age estimation, which involves a subjective interpretation of circuli on the otolith.

As shown by the estimated regression lines, absolute fecundity in cod females in relation to body length was nearly identical in the two subdivisions (Fig. 4A). Absolute fecundity in relation to total weight was, on the other hand, somewhat higher in females from the Gdańsk Deep (Fig. 4B).

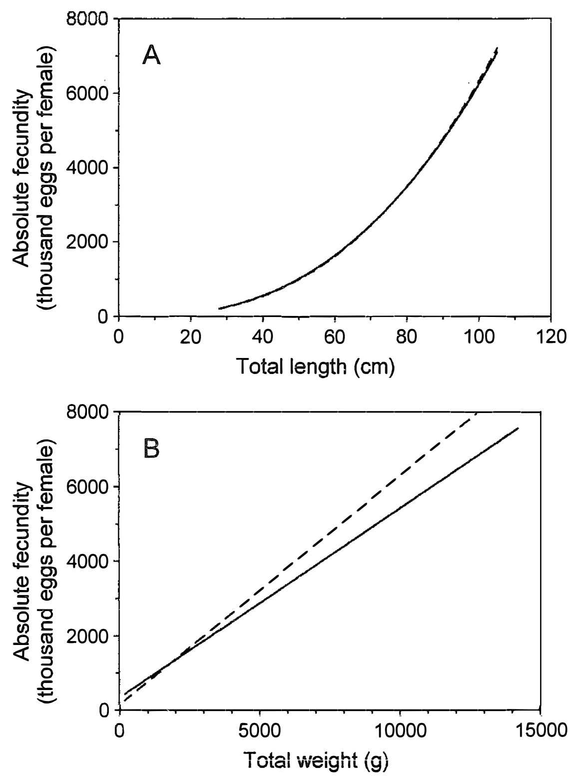

Fig. 4. Absolute fecundity of cod females in the years 1995-1999 in relation to total length (A) and total weight (B) in Subdivisions 25 and 26

Statistical analysis showed that absolute fecundity was correlated with total length, total weight, and age. The correlation with age was lowest. The relationships of absolute fecundity against total length and age were both distinct power functions with the exponents 2.6–2.8 and 1.4–1.6, respectively (Table 4). In the relationship of absolute fecundity to total weight, the exponent did not depart significantly from unity for fish caught in Subdivision 26 (in the periods of 1995–1999 and 1959–1961; samples B and C, respectively). It was, however, less than unity in Subdivision 25 (sample A), which indicates that absolute fecundity in this subdivision increases slower than total weight.

A comparison of the relationships of absolute fecundity against total length and age for fish caught in the years 1995–1999 in Subdivisions 25 and 26 (Table 4, Samples A and B), showed no significant difference between the two subdivisions. Absolute fecundity in relation to length was in Subdivision 26 higher in the period of 1995–1999 than in the period of 1959–1961 (Table 4, Samples B and C).

Table 4

Statistical analysis of cod absolute fecundity (F_a, thousands eggs per female) in a power relationship against total length (L, cm), total weight (W, g) and age (τ, years) and in a linear relationship against total weight for three samples: data collected in the years 1995–1999 in the Bornholm Deep (Sample A) and the Gdańsk Deep (Sample B) and data collected in the years 1959–61 (Strzyżewska, 1962) in the Gdańsk Deep (Sample C)

Relationship	Samples	Parameter *a*	Parameter *b*	*n*	R^2	Test	Probability
	A	0.036	2.62	200	0.62		
	B	0.029	2.67	211	0.72		
	C	0.016	2.76	116	0.67		
$L-F_a$	A and B					H_0: equal slopes	$P > 0.5$
						H_0: equal intercepts	$P > 0.5$
	B and C					H_0: equal slopes	$P > 0.5$
						H_0: equal intercepts	$P < 0.0001$
	A	2.16	0.85	200	0.61	H_0: slope = 1	$P < 0.0025$
	B	1.12	0.93	211	0.72	H_0: slope = 1	$P > 0.05$
	C	0.92	0.94	116	0.69	H_0: slope = 1	$P > 0.25$
$W-F_a$	A and B					H_0: equal slopes	$P > 0.1$
						H_0: equal intercepts	$P > 0.1$
	B and C					H_0: equal slopes	$P > 0.5$
						H_0: equal intercepts	$P < 0.00025$
	A	89.5	1.59	200	0.32		
$\tau-F_a$	B	123.8	1.42	211	0.38		
	A and B					H_0: equal slopes	$P > 0.25$
						H_0: equal intercepts	$P > 0.05$
	A	334	0.509	200	0.69		
	B	141	0.615	211	0.75		
	C	99	0.548	116	0.68		
$W-F_a$ (linear)	A and B					H_0: equal slopes	$P < 0.005$
	B and C					H_0: equal slopes	$P > 0.1$
						H_0: equal intercepts	$P < 0.01$

When the relationship of absolute fecundity against total weight was expressed as a power function, no significant difference was found between Subdivisions 25 and 26. When a linear function was used, absolute fecundity was found to increase with total weight faster (which corresponds to a greater regression coefficient) in Subdivision 26 than in Subdivision 25. Absolute fecundity in relation to total weight for fish from Subdivision 26 was higher in the period of 1995–1999 than in the period of 1959–1961, irrespective of the relationship used (Table 4).

Relative fecundity decreased slightly in Subdivision 25 and increased slightly in Subdivision 26 with total length, total weight and age. However, these changes in relative fecundity were non-significant (Table 5), showing no effect of body size or age on relative fecundity. The ANOVA test showed no significant difference in relative fecundity between the two subdivisions (Table 5).

Table 5

Statistical analysis of cod relative fecundity (F_w, number of eggs per gram gutted body weight) in a linear relationship against total length (L, cm), total weight (W, g), and age (τ, years) and ANOVA of cod relative fecundity for two samples: data collected in the years 1995–1999 in the Bornholm Deep (Sample A) and the Gdańsk Deep (Sample B)

Relationship	Samples	Parameter		n	R^2	Test	Probability
		a	b				
$L-F_w$	A	1255	–4.59	106	0.024	H_0: slope = 0	$P > 0.1$
	B	776	4.02	104	0.031	H_0: slope = 0	$P > 0.05$
$W-F_w$	A	1075	–0.031	106	0.030	H_0: slope = 0	$P > 0.05$
	B	945	0.021	104	0.015	H_0: slope = 0	$P > 0.1$
$\tau-F_w$	A	1131	–22.7	106	0.005	H_0: slope = 0	$P > 0.25$
	B	816	35.8	104	0.035	H_0: slope = 0	$P > 0.05$
	A and B					H_0: equal relative fecundities	$P > 0.1$

In the analysis of length at first maturity for cod females from the Gdańsk Deep, it was found that 50% of females which attained a length of 40.2 cm were mature (Fig. 5, Table 6). The smallest female from the Bornholm Deep observed to have gonads at the maturity stage IV was 36 cm in length, and that from the Gdańsk Deep was 30 cm (Tables 2, 6).

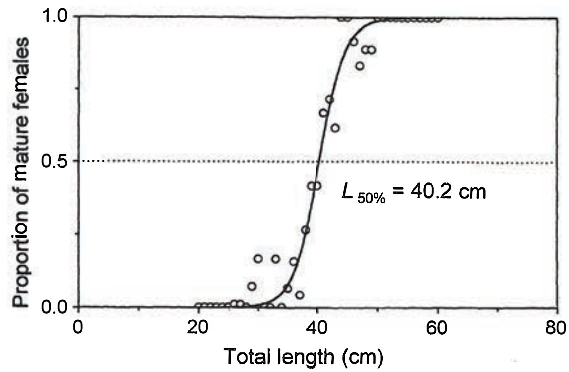

Fig. 5. Frequency of females attaining maturity in relation to total length

Table 6

Summary of results on length (in cm) at which cod females reach maturity

Authors	Length standard	Year of catch	Subdivisions			
			22	24	25	26
Thurow (1970)	Minimum length at first maturity	1958–1969 1970–1977	27 28			
Berner (1981)	Minimum length at first maturity Length at which 50% of females are mature		28 45.1	28 45.9	22 37.3	
Kosior and Skólski (1992)	Minimum length at first maturity	1965–1975 1977–1983 1985–1990				36.1 37.9 41.0
Present study	Minimum length at first maturity Length at which 50% of females are mature	1995–1999			36	30 40.2

DISCUSSION

According to Harwood (1990), absolute fecundity in fishes shows a high plasticity. Observations of changes in fecundity may be useful in the assessment of changes occurring in the environment and as a basis for the assessment of changes in the population itself throughout a longer period.

The authors compared the results of their own studies dealing with fecundity in cod in the late nineties with the results of earlier studies:

- for Subdivision 26 with the results from the years 1959–1961 reported by Strzyżewska (1962),
- for Subdivision 25 with the results from the years 1988 and 1999 reported by Kraus et al. (1999),
- for Subdivision 25 with the results reported by Botros (1959) for the Kiel Bay (Subdivision 22).

Absolute fecundity in relation to length and weight for cod caught in the region of the Gdańsk Deep (Subdivision 26) has increased over the past four decades (Fig. 6).

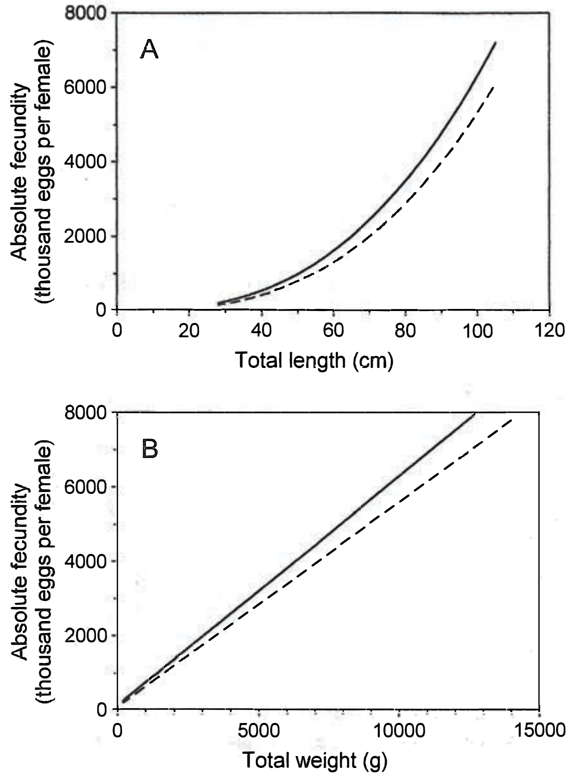

Fig. 6. Absolute fecundity of cod females in relation to total length (A) and total weight (B) in Subdivision 26 in the years 1995–1999 (present study) and 1959–1961 (Strzyżewska 1962)

As shown by the regression lines, absolute fecundity in relation to weight estimated in the present study for cod from the Bornholm Deep (Subdivision 25) was similar in smaller fish to those reported for the years 1988 and 1990 by Kraus et al. (1999), but it increased more slowly with fish weight in the present study than in the earlier studies (Fig. 7).

A graphical comparison of the present results for Subdivision 25 with those reported by Botros (1959) for cod from the Kiel Bay showed that absolute fecundity in relation to total length above 70 cm and that in relation to total weight was higher in the latter subdivision (Fig. 8).

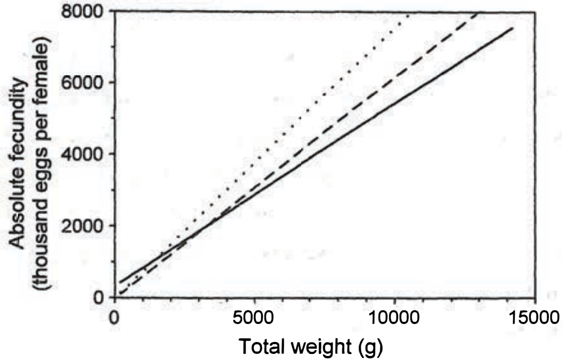

Fig. 7. Absolute fecundity of cod females in relation to total weight in Subdivision 25 in the years 1995–1999 (present study) and 1988 and 1999 (Kraus et al. 1999)

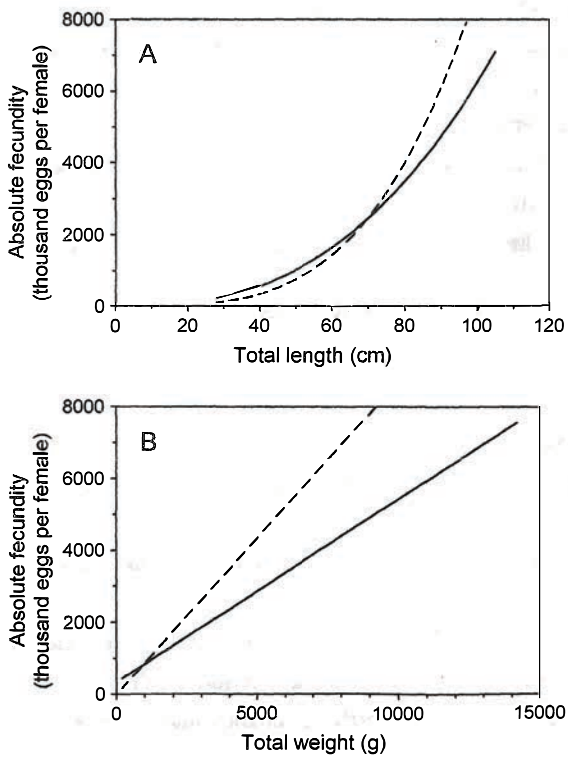

Fig. 8. Absolute fecundity of cod females in relation to total length (A) and total weight (B) for Subdivision 25 in the years 1995–1999 (present study) and reported for Subdivision 22 in the 1950s by Botros (1959)

Demonstrating the occurrence of two stocks of the Baltic cod, Arö (1988) maintains that the western Baltic stock occurs in Subdivisions 22–24. The present results show that the cod from the Bornholm Deep may have lower fecundity than that from the Kiel Bay.

A review of the results reported by different authors shows that both minimum size at first maturity and size at which 50% of females attain maturity depend upon the region and period of collection of the materials. Giving no values, Kandler (1944) reported in the 1940s that minimum sizes of females in Subdivision 25 had been almost unchanged for 20–30 years. According to Thurow (1970), the minimum sizes at first maturity in the Kiel Bay (Subdivision 22) observed in the years 1958–1969 were comparable to those from the period 1970–1977 in the Mecklemburger Bay, and were 27 and 28 cm, respectively. According to Berner (1981), the minimum size at first maturity of females from Mecklemburger Bay and the Arkona Deep is 28 cm, while females from the Bornholm Deep are 22 cm in length at first maturity. The sizes at which 50% of females are mature are different depending on the subdivision; in the Mecklemburger Bay it was 45.1 cm, in the Arkona Deep 45.9 cm and in the Bornholm Deep 37.3 cm. Kosior and Skólski (1992) reported that since 1965, an increase in the length at which 50% of females are mature had been observed. In the period 1965–1975 this length was 36.1 cm, it was 37.9 cm in the period 1977–1983 and 41 cm in the period 1985–1990. According to these authors, this change might have resulted from a shift in spawning time to the spring months and also from an increase in growth rate due to the decrease in cod abundance observed in the late eighties.

CONCLUSIONS

1. In the late 1990s, absolute fecundity of cod females in relation to body length showed no difference between Subdivisions 25 and 26, while in relation to total body weight, it was slightly higher in Subdivision 26.
2. Absolute fecundity in relation to age is highly variable, particularly among age classes 5 and older.
3. Absolute fecundity of cod females in the southern Baltic has increased slightly over the past four decades.
4. Relative fecundity of cod females in Subdivisions 25 and 26 varies widely (maximum differences of the order of 5–6 times) among individual fish.
5. In the region of the Gdańsk Deep, 50% of females that attain a length of 40.2 cm are mature.

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PŁODNOŚĆ DORSZA (*GADUS MORHUA CALLARIAS* L.) POŁUDNIOWEGO BAŁTYKU W DRUGIEJ POŁOWIE LAT DZIEWIĘĆDZIESIĄTYCH

STRESZCZENIE

Oszacowano płodność dorszy w południowym Bałtyku w drugiej połowie lat dziewięćdziesiątych. Materiały do badań zbierano w okresie skupień przed tarłowych na łowiskach Głębi Bornholmskiej (Podobszar ICES 25), Głębi Gdańskiej (Podobszar ICES 26) oraz dla łowiska Rowy. Badań dokonano na podstawie 461 par jajników w IV stadium dojrzałości (wg skali Maiera). Liczbę jaj przypadającą na samicę zestawiono według klas długości, masy ciała i wieku ryb.

Płodność względna (liczba jaj na gram masy ciała bez wnętrzności) wahała się w szerokich granicach: od 358,1 do 1685,8 w rejonie Głębi Bornholmskiej oraz od 252,0 do 1565,6 w rejonie Głębi Gdańskiej. Płodność absolutna w zależności od długości ciała i wieku, jak również płodność względna nie wykazały różnic między oboma podobszarami. Natomiast płodność absolutna w zależności od masy ciała była nieco wyższa u samic z rejonu Głębi Gdańskiej. Płodność absolutna w zależności od wieku charakteryzowała się dużą zmiennością w poszczególnych grupach wieku, szczególnie od piątej grupy wieku wzwyż. Na podstawie porównania z materiałami Strzyżewskiej (1962) stwierdzono, że płodność absolutna dorsza w południowym Bałtyku wzrosła na przestrzeni czterech dekad. Natomiast płodność oszacowana dla Głębi Bornholmskiej wykazywała powolniejszy wzrost ze wzrostem masy ciała w porównaniu z wynikami Krausa et al. (1999) dla tego samego podobszaru; była także niższa w odniesieniu do masy ciała od płodności absolutnej oszacowanej przez Botrosa (1959) dla Zatoki Kilońskiej (Podobszaru ICES 22).

Długość pierwszej dojrzałości płciowej, przy której 50% samic dorszy jest dojrzałych, oszacowano na 40,2 cm dla samic z Głębi Gdańskiej. Najmniejsza samica w IV stadium dojrzałości w rejonie Głębi Bornholmskiej mierzyła 36 cm, a w rejonie Głębi Gdańskiej – 30 cm.

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