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Reproductive biology of burbot, *Lota lota lota*, in Lake Hańcza, Poland

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A b s t r a c t . Absolute fecundity (*Fa*) of burbot *Lota lota lota* females from Lake Hańcza was 47.3 - 439.8 × 10^3, the relative fecundity based on eviscerated weight (Fw_o) was 617.9 - 1572 × 10^3, and that based of total weight (*Fw*) was 44.8 - 1234.5 × 10^3. Regression equations were calculated, approximating the most significant relationships between fecundity and total body length of burbot ($Fa = 0.0138\ Sl^{2.5678}$, $Fa = 0,0099\ Tl^{2.8129}$) and weight ($Fa = 0.6481\ W^{1.0144}$). Mean gonadosomatic indexes (*GSI*) increased slightly with body length from 3.9 to 8.8% for females and from 3.7 to 20.6% for males.

Key words: fish, burbot, fecundity, condition, gonadosomatic index

Introduction

Burbot (*Lota lota lota* L.) is a popular fish in clean rivers, streams and lakes. It prefers well oxygenated, clean and cold water. In deep lake waters, if the conditions are suitable, burbot will feed throughout the year and attain considerable size (H e w s o n 1955, M ű l l e r 1960, 1970, K a i n z & G o l l m a n n 1996). River regulation and water pollution have decreased considerably the available habitats for this fish (C o p p 1990). In many waters burbot has been included into the "red list" of protected species (H e r z i g - S t r a s c h i l 1991, H a r s á n y i & A s c h e n b r e n n e r 1992, M a i t l a n d & L y l e 1996, K a i n z & G o l l m a n n 1996). The objective of our study was to broaden our knowledge on the reproduction of this still little known cold-water species in particulare that of the lake population in Lake Hańcza, the deepest lake of Poland.

Study Area, Material and Methods

Lake Hańcza is located in a nature reserve in Suwałki Landscape Park. Its maximal depth is 108.5 m, average depth 38.7 m, area 311.4 ha. It receives waters from the Czarna Hańcza River, three small streams, and from underground sources. Water visibility was 8–9 m. H i l l b r i c h t - I l k o w s k a (1995) classified this lake as mesotrophic based on the content of total phosphorus. Lake waters were well oxygenated to the bottom, with a characteristic peak of oxygen concentration in the metalimnion, at the depth of 10–15 m. Burbot were collected with trammel nets (mesh size 20–40 mm) set at the depth of 30 to 60 m in winter 1996 and summer 1997. Table 1 presents number and characteristic of the collected burbot. Catches carried out in winter 1996 had to yield mature gonads for fecundity studies and gonad development. Material collected in summer 1997 was used only to check gonad development. Gonads used to determine fish fecundity were wrapped in gauze and preserved in 4 % formaldehyde solution. Ovaries were then taken out, eggs separated from the ovary tissue, and diameter (*E*) of 50 eggs was measured up to 0.01 mm. Absolute fecundity (*Fa)* was calculated using gravimetric methods (B r y l i ń s k a & B r y l i ń s k i 1972). Relative fecundity (Fw_O) was determined by dividing the number of trophoplasmatic oocytes (viz. absolute fecundity) by the weight of eviscerated fish (*Wo*). Fish intestines were removed to avoid errors due to different filling of the digestive tracts with food. In some cases, however, total body weigh (*W*) was also used to compare the data of relative fecundity (named *Fw*) with these from the literature. For histological analysis, the material was preserved in Bonin-Holland solution, and then passed through different concentrations of alcohol, xylene, and immersed in paraffin. Sections were stained with Delafield's haematoxylin.

Table 1. Characteristics of burbot collected in Lake Hańcza (*Tl* – total length; *W* – body weight; *Wo* – eviscerated body weight; *T* – testis; *O* – ovary).

Date	(n)	Sex	Minima - maxima			
			Tl (cm)	*W* (g)	*Wo* (g)	*T* or *O* (g)
26-29.11.96	19	males	18.5 - 38.5	61.1 - 432	42.9 - 323	3.9 - 55.5
	31	females	18 - 46	61.3 - 570	45.9 - 470	2.4 - 29.1
29.07.97	7	males	27.0 - 34,5	150 - 335	99 - 265	0.83 - 5.68
	3	females	30.5 - 36	345 - 353	244 - 250	2.6 - 4.52

The least squares method was used to calculate the regression equations for the dependence between fecundity absolute and relative, and total (*Tl* in cm) and standard body length (*Sl* in cm) as well as total body (*W*) and eviscerated weight of fish (*Wo* in g), ovary weight (*O* in g), egg diameter (*E* in mm) and egg weight (*E* in g). The results were treated statistically. Significance of Pearson correlation coefficients was determined using the respective tables ($r_{tab.} \geq 0.4487$, P l a t t 1974) for n - 1 = 30 degrees of freedom, the accepted level of significance being P = 0.01. Analyses were performed to determine the best equation for the dependence between absolute fecundity (*Fa*) and the other parameters (*Tl*, *Sl*, W, *Wo*, *O*, *E*). In order to compare the condition of burbot males and females, data on body length and weight were analysed. Gonadosomatic indexes (*GSI*) calculated for males and females from the equation $GSI = O(T)/W * 100$ (in %).

Results

Absolute fecundity of burbot from Lake Hańcza ranged from 47.3 to 439.8 thousand eggs. The mean values minima and maxima are presented in Table 2. Absolute fecundity increased more rapidly than body length and weight increments; the respective regression line is polynomial (curvilinear). Absolute fecundity of burbot increased with increasing gonad weight (Table 3) in a similar way as with body weight. There were no significant correlations between absolute fecundity and egg diameter and egg weight (*E*). Absolute fecundity of burbot appeare to depend most of all on the fish size (Table 3), gonad weight (*O*) being more important than body length (*Sl*, *Tl*) and body weight (*W*).

Table 2. Mean ($\overline{x}$), minima and maxima (x_1 - x_n) of absolute (*Fa*) and relative fecundity (*Fw*, Fw_o), total body length (*Tl* in cm), body weight (*W* in g), body weight of gutted fish (*Wo* in g), ovary weight (*O* in g), egg diameter (E_n in mm) and weight (E_g in g) of burbot from Lake Hańcza (n = 30, in winter).

Tl		$Fa*10^3$		*O*	
$\overline{x}$	30.8	$\overline{x}$	189.4	$\overline{x}$	14.86
x_1-x_n	18.6-46.0	x_1-x_n	47.3-439.8	x_1-x_n	2.4-28
W		Fw_o*10^3		E_n	
$\overline{x}$	262.1	$\overline{x}$	895.9	$\overline{x}$	0.547
x_1-x_n	61.3-570	x_1-x_n	617.9-1572	x_1-x_n	0.477-0.651
Wo		$Fw*10^3$		E_g	
$\overline{x}$	205.4	$\overline{x}$	714.8	$\overline{x}$	0.080
x_1-x_n	45.9-470	x_1-x_n	444.8-1234.5	x_1-x_n	0.062-0.122

Table 3. Pearson coefficients of correlation (r) for curvilinear and linear regression functions between absolute fecundity ($Fa \times 10^3$) and relative fecundity ($Fw_o \times 10^3 / Wo$) and body length (*Tl*, *Sl* in cm) body weight (*W*, *Wo* in g) ovary weight (*O* in g) (n - 1 = 29).

y - x	r	y = ax^b	r	y = ax+b
Fa - Tl	0.895	$Fa=0.0099\ Tl^{2.8129}$	0.870	$Fa=15.279\ Tl-303.16$
Fa - Sl	0.902	$Fa=0.0138\ Sl^{2.7678}$	0.882	$Fa=15.948\ Sl-294.01$
Fa - W	0.895	$Fa=0.6481\ W^{1.0144}$	0.829	$Fa=0.7043\ W+4.9901$
Fa - Wo	0.868	$Fa=1.186\ Wo^{0.9476}$	0.775	$Fa=0.7955\ Wo+26.184$
Fa - O	0.907	$Fa=18.866\ O^{0.8482}$	0.863	$Fa=12.193\ O+8.3385$

Relative fecundity (Fw_o) ranged from 617.9 to 1572 thousand eggs, its mean value being 898.9 thousand eggs (Table 2). Relative fecundity (Fw_o) did not increase with body length, but remained at an almost unchanged level. Coefficients (r) for the relationship between relative fecundity and the parameters under study (*Tl*, *Sl*, W, *Wo*, *O*, *E*) were all insignificant, showing that no relationship can be found between these variables (r = 0.055 - 0.272).

Body weight was related significantly to total length with females ($W = 0.256\ Tl^{2.642}$, r = 0.953) showing slightly better condition than males ($W = 0.0312\ Tl^{2.5752}$, r = 0.937), as body weight of females was slightly higher than of males of the same length.

Mean *GSI* increased slightly with body length (Table 4), from 3.9 to 8.8 % for females, and from 3.7 to 20.6 % for males. Mean male *GSI* was 12.5 %, being noticeably higher than the respective value calculated for females (5.6 %). The relationship between gonad and body weight (Fig. 1) was significant in females ($O = 0.0262\ W^{1.1349}$; r = 0.936) and in males ($T = 0.2201\ W^{0.8721}$; r = 0.803) revealing that males had proportionally greater gonads weight than females of the same size. Mean *GSI* for females and males after spawning (on 29 July 1997) was the same – 1 %.

Many protoplasmatic oocytes can be seen (O.p.), in the female gonads (Figs 2, 3) with a characteristically large number of nucleoli in the oocyte nuclei (Cj) and a dark cytoplasm (haematoxylin staining). In addition to this, single resorbed oocytes can also be seen (o.t.); these are the eggs, that had not been spawned during the last reproduction. The single resorbed oocytes in burbot ovary are good be seen in the end of July, this is probably 4 to 7 month after spawned time. Gonads of a few females (Fig. 3a) had a single row of vacuole in the oocyte cytoplasm, suggesting that these oocytes have already commenced the

Table 4. Gonadosomatic index (*GSI*) of females and males of burbot in total body length classes (*Tl* in cm).

Date	Sex	Parameter	*Tl*					
			17-22	23-28	29-34	35-40	41-46	Σ
26.11.96	Females	*GSI*	3.9	5.1	5.8	5.7	5.5	5.6
		X_1-X_n	3.9	4.1-7.3	4-8.8	4.6-6.8	4.3-6.8	3.9-8.8
		n	1	4	16	5	2	28
	Males	*GSI*	11.8	16.1	11.2	11.8	-	12.5
		X_1-X_n	4.9-20.5	13.6-20.6	9.4-13.1	3.7-15.5	-	3.7-20.6
		n	5	4	5	5	-	19
29.07.97	Females	*GSI*	-	-	1.3	0.9	-	1
		X_1-X_n	-	-	1.3	0.7-1.1	-	0.7-1.3
		n	-	-	1	2	-	3
	Males	*GSI*	-	0.6	1.1	-	-	1
		X_1-X_n	-	0.5-0.8	0.6-2.7	-	-	0.5-2.7
		n	-	2	5	-	-	7

trophoplasmatic growth stage (o.t.). Male testes (Fig. 3b) contain sprematocytes, which can be seen close to the canals (with empty light). All female and male gonads collected in 1996 and 1997 were fertile as they contained reproductive cells in different stages of development, corresponding to the annual cycle of sexual development.

Discussion

Burbot commence spawning in winter, from December to March (Siergieyev 1959, Sorokin 1968,1971, Volodin 1964), a little later in lakes – from January onwards

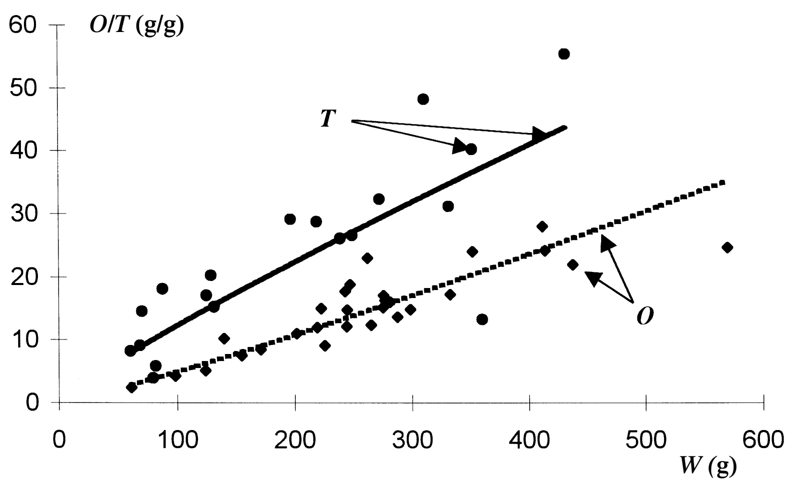

Fig. 1. Relationship between ovary weight (*O* in g), testis weight (*T* in g) and body weight (*W* in g) of burbot in winter. Equations given in the text.

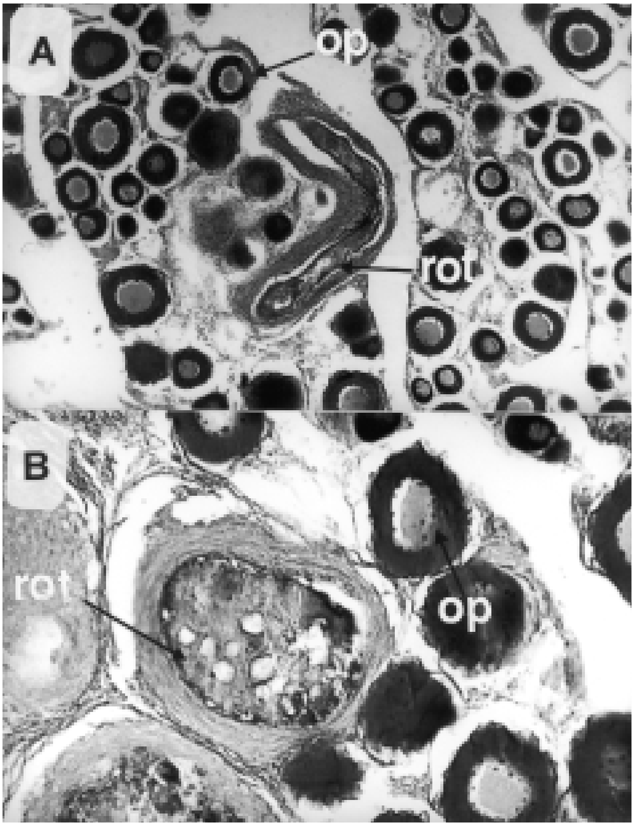

Fig. 2. Ovary of a burbot (July 1997). A – female no 9, *Tl* = 35 cm; B – female no 12, *Tl* = 36 cm; o.p. – oocyte of protoplasmatic stage; r.o.t. – resorbed oocyte of trophoplasmatic growth stage non spawned during the last reproduction.

(Kainz & Gollmann 1996). Water temperature in this period is from 0 to 4 °C (Hewson 1955, Struganov 1962, Sorokin 1971, Gerster & Guthruf 1987 after Kainz & Gollmann 1994), or even up to 5.7 °C (Farkas 1993 after Kainz & Gollmann 1994). Spawning period is characterised by low temperatures and is extended in time.

Elsewhere, the diameter of trophoplasmatic oocytes immediately prior to spawning is from 0.80 to 1.00–1.12 mm (Munth & Smith 1974, Volodin & Raspopova 1994). Gerster & Guthruf (1987) after Patzner & Reihl (1992) stated that burbot eggs diameter ranged from 0.5 to 1.70 mm (mean 1.00 mm). Patzner & Reihl (1992) described burbot eggs are transparent, yellowish, with micropyle close to animal pole, with a canal diameter 2.5 to 3.0 µm, having one lipid droplet some 0.4 µm in diameter. Oocyte diameter in burbot ovaries from Lake Hańcza were collected the end of November ranged from 0.477 to 0.651 mm, being a little smaller than that observed in a comparable period by Munth & Smith (1974).

Data presented in the literature suggest that absolute fecundity of burbot females weighing from 44.5 to 3164 g was from 32.2 to 1453 × 10^3 eggs, this range (Table 5, Fig. 4) being broader than in the population from Lake Hańcza, which had high absolute fecundity. Also upper values of relative fecundity (*Fw*) in Lake Hańcza burbot (448.8 - 1234.5 × 10^3) suggests that were higher then in other populations (Table 5). Higher relative fecundity (*Fw*) was characteristic of

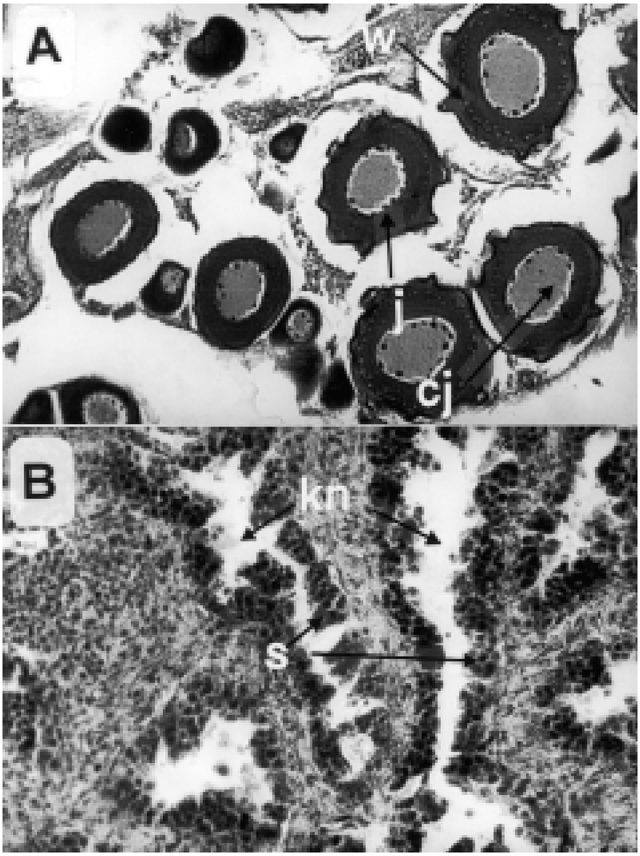

Fig. 3. Ovary (A) and testes (B) of burbot (July 1997). A – female no 9, *Tl* = 35 cm, w – single row of vacuoli, j – nucleoli, cj – nuclei of oocytes; B – male no 10, *Tl* = 32.5 cm, kn – canals with empty leight, s – spermatocytes.

the smallest and often the largest females in relation to those of medium body weight, although variability within particular groups was quite high. The same has been observed elsewhere (Volodin & Raspopova 1994, Kainz & Gollmann 1996).

Gonadosomatic index (*GSI*) increased from July to November respectively from 0.5–1.3 to 3.9–8.8 % and from 0.5–2.7 to 4.9–20 % of body weight (*W*). Vostradovská (1963) found that females *GSI* in burbot from Lipno Reservoir in November ranged from 4.37 to 16.90, whereas it in males ranged from 8.06 to 25.8 % of body weight. These data suggest also that *GSI* in burbot is higher for the testes than the ovaries. According to Volodin (1994), in Rybin'ski Reservoir female *GSI* for burbot weighing from 311 to 530 g reached in January from 16.2 (± 0.7) to 20.0 % of body weight.

Studies on gonad maturation in different burbot populations (Pulliainen et al. 1992, Pulliainen & Korhonen 1993, 1994) from the northern coast of the Bothnian Bay (23–93 %), Lake Kemijaervi in northern Finland (44 %), Kemi River (24 %), Kitanien River (86 %), and Tonio River (98 %) revealed high percentage of non spawning ("sterile") individuals. The proportion of non spawning burbot was a little lower in big fish (over 39 cm in length, *Tl*), ranging from 21 to 51 %. The high proportion of non spawning burbot was said to be related to environmentally toxic chemicals (PCB, PCDD, Al, Cr, Pb

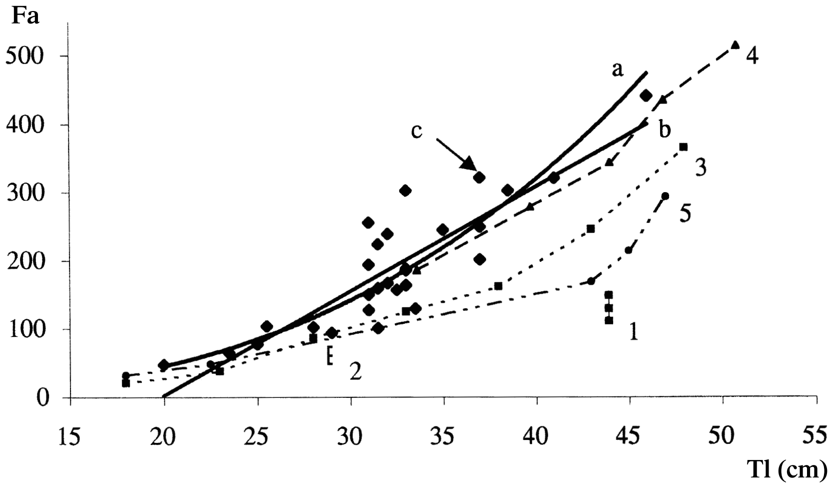

Fig. 4. Relationship between absolute fecundity (*Fa*) and total body length (*Tl*) of several populations of burbot. a, b, c – absolute fecundity of burbot in Lake Hańcza (a, $Fa = 0.0099\ Tl^{2.812}$, b, $Fa = 15.279\ Tl - 303.16$, c – one female). 1. Variation in fecundity (brooks near Tachov); 2. River Vltava (K o u ř i l et al. 1985); 3. Absolute fecundity (Upper Tuloma Reservoir, N e l i c h i k 1975); 4. Absolute fecundity (Rybinskoe Reservoir, V o l o d i n 1994); 5. Lake Traum and Stream Stimnitz (K a i n z & G o l l m a n n 1996)

Table 5. Minima and maxima for absolute (*Fa*) and relative (*Fw*) fecundity of burbot from different populations.

W (g) / *Tl* (cm) min	max	$Fa \times 10^3$ min	max	$Fw \times 10^3$ min	max	Authors
148	840	96.1	605.7	516.4	720.9	P o d u b s k ý & Š t ě d r o n s k ý (1967)
158	900	49.7	180.4	157.0	581.9	K o u ř i l et al. (1985)
29.0	58.0					
80	420	8.7	239.1	108.4	824.3	
22.8	38.7					
44.5	352.5	32.2	174.2	494.2	723.6	K a i n z & G o l l m a n n (1996)
528.0	1120	161.9	500.0	394.9	450.4	
2475	3164	1497.0	1453.1	459.9	645.4	
17.0	70.0	8.1	1110.0	151.0	976.0	N e l i c h i k (1975)
380	605	142.8	571.5	475.0	519 (±22)	V o l o d i n (1994)
577	1635	153.0	1131.0	328 (±21)	515 (±71)	
61.3 / 18.5	570.0 / 46.0	47.3	439.8	448.8	1234.5	present study

and Hg), which accumulated in the liver and coincided with irregular growth of otoliths and bone respiation (P u l l i a i n e n et al. 1992). Biological effects such as morphological and reproductive deformation incited by organic pollutants such as PCBs has be reported for the Baltic Sea (Baltic Sea Environment Proceedings 1990). Studies on gonad maturation in burbot from Lake Hańcza did not reveal any sterile fish amongst the sexually mature individuals, but water of this lake is exceptionally clean.

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