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FECUNDITY AND EGG SIZE IN SEA TROUT (*SALMO TRUTTA* M. *TRUTTA* L.) IN POND CONDITIONS

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ABSTRACT. During a five-year period, the fecundity and egg size of individual Vistula sea trout marked with PIT tags were studied. The dependencies between fish length, age and the number of times the fish had spawned and its fecundity and egg size were analyzed. Both fecundity and egg size increased as fish length increased. However, after taking into consideration fish growth, fecundity decreased slightly with age while egg size increased. These two traits were mutually inversely correlated. After taking into consideration differences in length, fish that were spawning for the first time were less fecund than their peers at a similar egg size.

Key words: SEA TROUT (*SALMO TRUTTA* M. *TRUTTA*), FECUNDITY, EGG SIZE

INTRODUCTION

The size and survival of salmonid larvae depends largely on the size of the eggs (Bagenal 1969b, Thorpe et al. 1984, Hutchings 1991, Ojanguren et al. 1996, Einum and Fleming 1999, Einum 2003). It has been demonstrated repeatedly, including in sea trout, *Salmo trutta* m. *trutta* L., that the size of the eggs increases with female size (Hardy 1967, Chełkowski et al. 1990, L'Abee-Lund and Hindar 1990, Bartel and Parlińska 1995, Lobon Cervia et al. 1997, Papała et al. 1998, Jonsson and Jonsson 1999); and also that female size increases fecundity (Hardy 1967, Taube 1976, L'Abee-Lund and Hindar 1990, Jonsson and Jonsson 1999, Einum and Fleming 2000b). Since females do have a limited amount of energy reserves for reproduction, the increase in egg size necessarily leads to a reduction in their number. There is, however, a trade-off between the number of eggs and their size (Smith and Fretwell 1974, Ojanguren et al. 1996, Lobon Cervia et al. 1997, Jonsson and Jonsson 1999, Einum and Fleming 2000a, 2004, Einum et al. 2003). The result of this lies in the

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environmental conditions (McFadden et al. 1965, Bagenal 1969a, Thorpe et al. 1984, Hutchings 1991, Lobon Cervia et al. 1997, Einum and Fleming 1999, Jonsson and Jonsson 1999, Olofsson and Mosegaard 1999, Einum et al. 2003), which often manifest themselves in differences among sea trout populations (L'Abee-Lund and Hindar 1990, Bartel and Parlińska 1995) or among fish with varied life histories (Thorpe et al. 1984, Jonsson and Jonsson 1999, Olofsson and Mosegaard 1999).

The aim of this work was to test under controlled conditions the dependency between the length of female sea trout, their age, and number of times they have spawned with fecundity and egg size.

MATERIAL AND METHODS

The studied fish were reared at the Department of Salmonid Research in Rutki of the Inland Fisheries Institute in Olsztyn. The eggs they were reared from were obtained from a brood stock of Vistula sea trout in 1995 and 1996. As 1+ juveniles, each fish was marked with a PIT tag. The data for the study were collected during spawning seasons during the 1998-2002 period. The females that spawned ranged in age from 2+ to 6+ (Table 1) and from the time of first maturity they spawned annually.

TABLE 1

Number and fork length of mature females according to age group

Age	No. of fish	Length (mm)		
		Mean	SD	Range
2+	42	321	39	257 - 464
3+	95	395	37	312 - 515
4+	47	440	35	383 - 515
5+	18	499	42	425 - 600
6+	5	534	17	520 - 560

They were fed at about 60% of the ration applied with rainbow trout, *Oncorhynchus mykiss* (Wal.), which corresponded to approximately 12 to 31 MJ of energy per kilogram of fish per year, depending on age. Immediately prior to spawning, the fish were weighed (± 1 g) and the fork length was measured (± 0.1 cm). Next, the total amount of eggs from the females was weighed as was a sample of approximately 200 eggs. This was the basis for calculating the individual fecundity. The measure of egg size was the volume of 30 eggs placed in a measurement cylinder filled with water and was expressed in cm^3. Prior to taking the measurements, the eggs were placed in water for at least three hours in order to let them swell. Multiple analysis of covariance (MANCOVA) and regression were applied to test dependence among variables, while nonparametric tests were used to compare average values. Statistical analyses were conducted with the STATISTICA program (StatSoft Inc. 2003).

RESULTS

FECUNDITY

The number of eggs obtained from individual females ranged from 385 to 3778 eggs at an average of 1586 eggs (SD = 755).

Covariance analysis, with fish age as the independent variable and length as the accompanying variable, indicated that fecundity depended on length ($P < 0.001$) and was not the same in subsequent years ($P < 0.015$). Linear regression of logarithmically transformed length and fecundity explained more than 60% of fecundity variation and was highly significant (Fig. 1). After taking this dependence into consideration, *i.e.*,

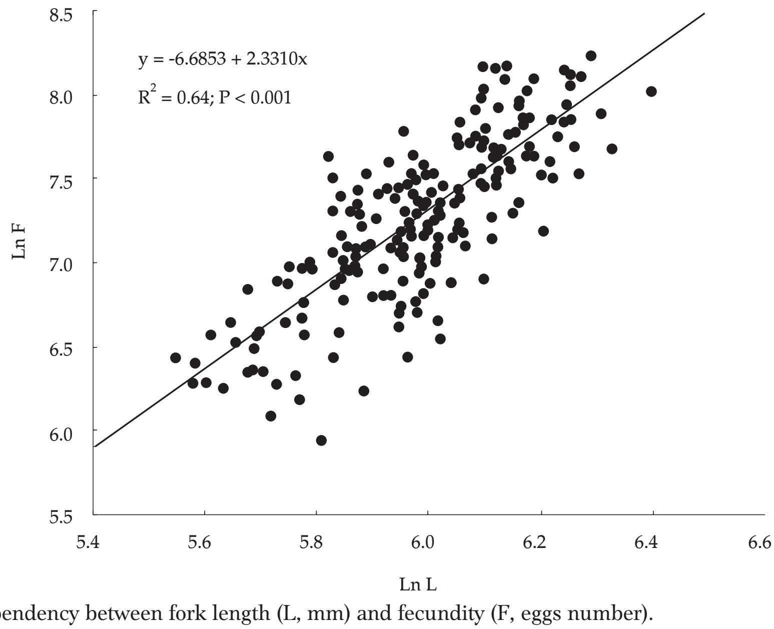

Fig. 1. Dependency between fork length (L, mm) and fecundity (F, eggs number).

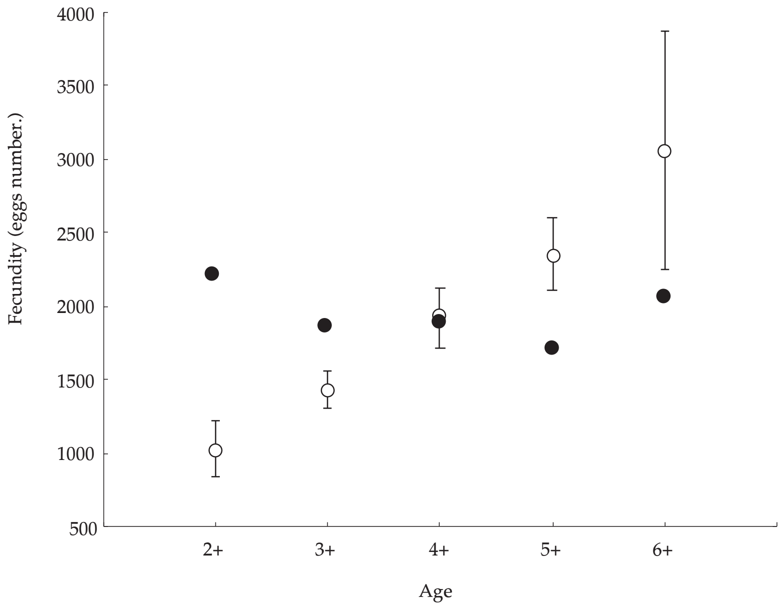

Fig. 2. Mean fecundity and confidence levels (circles) and mean fecundity adjusted for length (black bullets) in subsequent years.

after correcting the means, the most fecund fish were the youngest (Fig. 2). However, since the fish did grow, the mean actual fecundity increased in subsequent years.

The mean fecundity of fish aged 2+ was 1026 eggs. It was higher in fish one year older ($P < 0.001$) at 1445 eggs. Fish aged 3+ that were maturing for the first time had a similar fecundity to those that were maturing for the second time, although, after taking into consideration the differences in length, *i.e.*, after correcting the means, it occurred that the fecundity of fish spawning for the first time was significantly lower (1303 vs. 1537 eggs; $P < 0.027$). At age 4+, mean fecundity was 1920 eggs and was higher than in females that were a year younger ($P < 0.001$). The fecundity of fish maturing for a second or third time did not differ, but the fecundity of a few fish maturing for the first time, after taking into consideration large and significant ($P < 0.029$) differences in length, *i.e.*, after correcting the means, was decidedly and highly significantly lower than that of the remaining fish (1188 vs. 2200 eggs; $P < 0.001$). The mean fecundity of the fish aged 5+ was 2356 eggs and was higher than the fecundity of fish that were a year younger ($P < 0.016$) and lower than the fecundity of the fish aged 6+ at 3059 eggs ($P < 0.025$).

EGG SIZE

Egg size (volume of 30 eggs) ranged from 1.45 to 4.40 cm^3 and the average for all the fish was 2.54 cm^3 (SD = 0.52). Covariance analysis, with fish age as the independent variable and length and fecundity as accompanying variables, indicated that the size of eggs increases with fish length ($P < 0.001$), decreases with increased fecundity ($P < 0.001$) and, independently of these dependencies, it is not the same in different age groups ($P < 0.001$). Taking into consideration the impact of the accompanying variables, adjusted mean size – as the actual mean egg size is presented according to year in Fig. 3. Since egg size increased significantly with age (with the exception of a small group of 6+ specimens that were excluded from the analyses) a multiple regression equation was formulated with egg size (V) and fish fork length (L), fecundity (F) and age (number of growth seasons, A):

$$V = 0.0089\,L + 0.1626\,A - 0.0005\,F - 0.9531; \quad (R^2=0.78,\ P < 0.001).$$

Fish length had the greatest impact on egg size (coefficient $\beta = 1.05$), lower fecundity ($\beta = -0.74$), and the least age ($\beta = 0.26$).

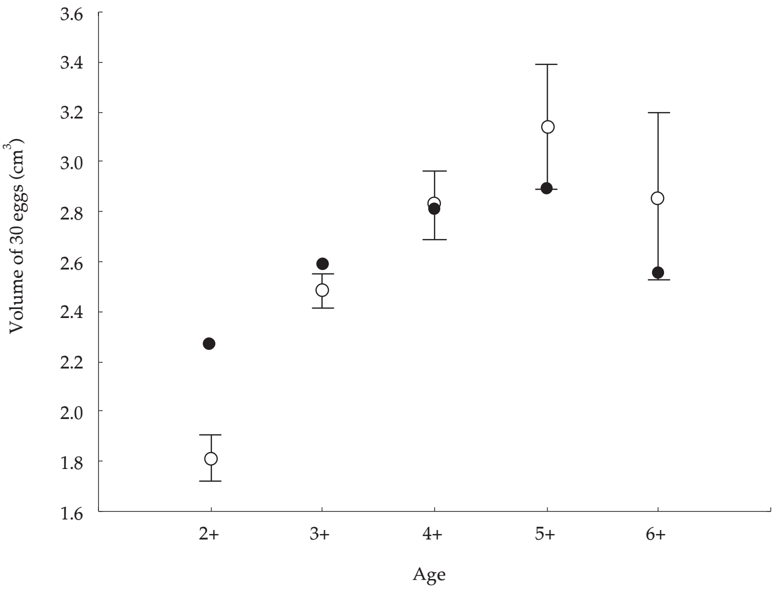

Fig. 3. Mean egg size and confidence levels (circles) and mean egg size adjusted for length (black bullets) in subsequent years.

Fish that spawned for the first time had larger eggs than did the other fish. In fish aged 3+, egg size was, respectively, 2.54 and 2.35 cm^3 ($P < 0.015$), and in fish aged 4+, these figures were 3.53 and 2.76 cm^3 ($P < 0.001$). These differences, however, stem from the fact that fish which were maturing for the first time were significantly larger than their peers at an average of 401 vs. 379 mm ($P < 0.007$) for fish aged 3+ and 477 vs. 418 mm ($P < 0.029$) for fish aged 4+. After taking into consideration these length differences, *i.e.*, adjusting the means, the size differences in the eggs became insignificant.

DISCUSSION

Most researchers agree that when salmonid fish have better feeding conditions they produce relatively more, but smaller, eggs than they do when conditions are poor (Bagenal 1969a, Hutchings 1991, Jonsson et al. 1996, Einum and Fleming 1999). This phenomenon is evident when fish from different rivers (L'Abee-Lund and Hindar 1990) or when those from different segments of the same river are compared (Lobon Cervia et al. 1997). This is explained as follows: the larvae from larger eggs with greater stores of energy have a better chance of survival when there are food deficits in the environment and that this loses significance when food is plentiful (Einum et al. 2003). Different results regarding the trade off between egg size and number were also observed in fish with varied life histories (Thorpe et al. 1984, L'Abee-Lund and Hindar 1990, Jonsson and Jonsson 1999, Olofsson and Mosegaard 1999). In the current experiment, the fish came from one brood stock and were raised together under the same conditions. Even so, the differences observed in fecundity and egg size were significant, and both of these traits increased with fish size. Jonsson and Jonsson (1999) contend that with the plentiful food available under hatchery conditions the dependence of egg size on sea trout length disappears. There are, however, opposing opinions on this. In the study by Bagenal (1969a) better-fed sea trout produced more but smaller eggs, and in Jonsson et al. (1996) the eggs of intensively-fed Atlantic salmon, *Salmo salar* L., were smaller. In principle, the fish in the current study were fed in excess, but conditions in hatchery tanks are not always advantageous and growth is often halted. Evidence of this might be that the growth of the fish in the current study was considerably slower than that of Vistula sea trout in the sea (Bartel 1988). It appears that one can agree with the conclusion of Jonsson and Jonsson (1999) that there is no universal dependence between the amount of food and the number and size of eggs.

Except for and independently of fish size, both of the studied characteristics varied with age. Fecundity decreased slightly and the difference was really only evident in the youngest fish, while egg size clearly increased throughout the life of the fish. Additionally, the impact of age on the results of the trade off differed from that of the influence of fish size – it shifted in the direction of egg size.

Jonsson and Jonsson (1999) observed that the eggs of fish that were not spawning for the first time were larger than those of fish of the same size that had attained first maturity; the authors believe that this is the expression of an general tendency of investing more in the production of eggs. This tendency is especially evident in hatcheries (Jonsson and Jonsson 1999). No such differences in egg size were confirmed in the current study; however, fish that had spawned previously produced many more eggs. Consequently, they also invested more in reproduction. Conversely to the studies by Jonsson and Jonsson (1999), they did so in the quantity of the eggs produced and not in the size of individual eggs.

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STRESZCZENIE

PŁODNOŚĆ I WIELKOŚĆ IKRY TROCI (*SALMO TRUTTA* M. *TRUTTA* L.) W WARUNKACH STAWOWYCH

Przez pięć lat badano płodność oraz wielkość ikry samic troci wiślanej, poznakowanych indywidualnie znaczkami PIT (tab. 1). Następnie przeanalizowano zależności pomiędzy długością ryb, ich wiekiem i liczbą odbytych tareł a płodnością i wielkością ikry. Płodność rosła wraz z długością ryb (rys. 1). Jednak po uwzględnieniu różnic w długościach, wynikających ze wzrostu ryb, ich płodność nieznacznie malała wraz z wiekiem (rys. 2). Ryby rozradzające się po raz pierwszy miały, relatywnie do długości, płodność niższą od ryb powtarzających tarło. Wielkość ikry rosła wraz z długością i wiekiem ryb, a malała wraz ze wzrostem płodności (rys. 3). Równanie regresji opisujące te zależności wyjaśniało 78% zmienności wielkości ikry. Większa ikra u ryb dojrzewających po raz pierwszy była wynikiem ich większej długości.