POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	58	1	191–196	2010

Short research contribution

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LIFE HISTORY STRATEGIES OF FISH: PATTERNS IN GROWTH AND LIFESPAN OF RUDD *SCARDINIUS ERYTHROPHTHALMUS* (L.) IN EUROPE

ABSTRACT: Variation in life history strategies of rudd *Scardinius erythrophthalmus* (L.) in Europe was evaluated based on published sources. The growth and lifespan were analysed as the main variables in life strategies of any fish. The results revealed that total length (TL) at age 1 year was correlated with latitude and faster growth during the first growing season leads to a shorter lifespan in Europe. Variation in length at age 1 year was more pronounced in southern (40–46°N: mean TL = 84.6 mm, SD = 27.2, n = 9) than in northern populations (49–61°N: mean TL = 46.4 mm, SD = 4.2, n = 10). Thus, rudd can show different life history strategies in southern populations whereas in northern populations these options are few.

KEY WORDS: rudd, back-calculated lengths, lifespan, latitude, meta-analysis

The growth of ectothermic fish varies widely between water bodies. These differences have been linked to both density-dependent and density-independent factors. The latter include environmental variables such as temperature and food resources (Vøllestad and L'Abée-Lund 1990, Wilde and Muoneke 2001), which probably are more important at the limits of the distribution range than near the centre (Myers 1988, Tarkan 2006). However, temperature and fish growth rate are generally linearly linked until the optimal temperature for growth is reached, but after that growth rapidly decreases and finally ceases (Magnuson *et al.* 1979, Mallet *et al.* 1999). Because mean monthly air temperature is correlated with latitude in Europe in low altitudes (New *et al.* 1999, Vázquez and Stevens 2004), some species can show almost linear relationships between growth and latitude (Heibo *et al.* 2005). On the other hand, some species can also show more curved patterns in growth with latitude suggesting that temperature may limit the growth also in south, not only in north (Wilde and Muoneke 2001, Lappalainen *et al.* 2008). This limitation in south may be due to temperature exceeding the optimal temperature for growth (Mallet *et al.* 1999). Therefore, the latitudinal patterns found may depend on the relative differences between the optimum temperature for growth and environmental temperature.

In this study, we examine latitudinal patterns of rudd *Scardinius erythrophthalmus* (L.) in length at age 1 (one year old) and maximum population age based on published sources. We also added one population of rudd in Lake Sapanca to latitudinal evaluations (Table 1). Rudd has a wide-spread dis-

Table 1. Back-calculated length of rudd at age 1 (mm TL) and maximum age in different sites (latitude in decimals). "–" = not mentioned.

Study site and country	Latitude (°N)	Length at age 1	Number of observations at age 1	Maximum age	Reference
Lake Kus, Turkey	40.18	72	169	4	Balık *et al.* (1997)
Lake Uluabat, Turkey	40.17	120	85	7	Emiroglu (2008)
Lake Kastoria, Greece	40.52	53	342	7	Papageorgiou and Neophytou (1982)
Lake Sapanca, Turkey	40.72	52	94	17	present study
Lake Ömerli, Turkey	41.05	105	297	8	Gürsoy (2008)
Lake Hamam, Turkey	41.82	119	74	3	Erdem *et al.* (1994)
Batak Reservoir, Bulgaria	42.00	60	149	6	Zivkov *et al.* (2003)
Ovcharitsa Reservoir, Bulgaria	42.27	100	225	6	Zivkov *et al.* (2003)
Dnieper River, Russia	46.00	80	–	5	Slastenenko (1956)
Elbe Region, Czech Republic	49.00	45	43	10	Frank (1962)
Klicava Reservoir, Czech Republic	50.12	40	–	10	Holcik (1967)
Lake Gołdopiwo, Poland	54.12	48	64	11	Zawisza and Żuromska (1961)
Lake Mamry Polnocne, Poland	54.17	46	24	16	Zawisza and Żuromska (1961)
Lake Węgielsztynskie, Poland	54.23	47	45	12	Zawisza and Żuromska (1961)
Lake Oświn, Poland	54.30	50	49	8	Zawisza and Żuromska (1961)
Vistula mouth, Poland	54.38	53	14	11	Frank (1962)
Lake Hiidenvesi, Finland	60.40	44	193	15	Nurminen *et al.* (2003)
Luza River, Russia	60.57	50	21	–	Boznak 2008
Lake Shchuch'e, Russia	61.41	41	26	–	Boznak 2008

tribution range in the northern hemisphere (36°N–62°N, 10°W–70°E) (FishBase, http://www.fishbase.org/) and it shows different life history traits between water bodies (e.g. Zawisza and Żuromska 1961). Here we focus on data collected in Europe, even though rudd is also found in the United States (Blackwell *et al.* 2009), and even in New Zealand (Lake *et al.* 2002).

All lengths (standard and fork length) were transformed to total lengths according to Gaygusuz *et al.* (2006). As an estimate of the maximum age, we used the oldest rudd found in each population. The relationships between latitude and lengths and between lengths and maximum age were studied with Spearman correlation. The data for rudd population in Lake Sapanca (40°45'N, 30°18'E) was collected between 1999 and 2001. In the laboratory, rudd were measured for total length (TL in mm). A sample of scales for ageing was taken from a standard area between the lateral line and dorsal fin of the fish. Age was determined as described by Steinmetz and Müller (1991). Linear and non-linear models were fitted to determine what equations best describe the relationship between body length and scale radius. The body-scale relationship was best described by a power function. Hence, the lengths were back-calculated with the equation $L_i = (S_i/S_c)^b \times L_c$, where L_i is the total length of fish at age i, L_c the total length of fish at capture, S_i the radius of scale at age i and S_c the radius of scale at capture (Bagenal and Tesch 1978).

The results showed that the overall variation in length at age 1 was more pronounced in southern (40–46°N: mean TL = 84.6, SD

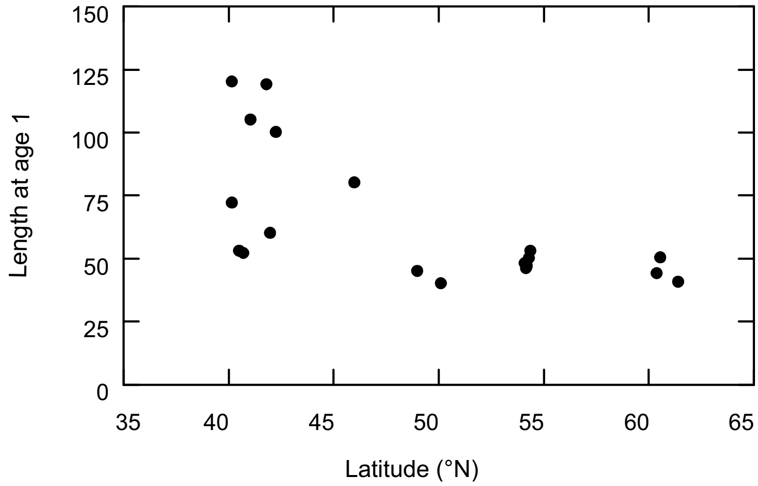

Fig. 1. Relationship between back-calculated length at age 1 and latitude.

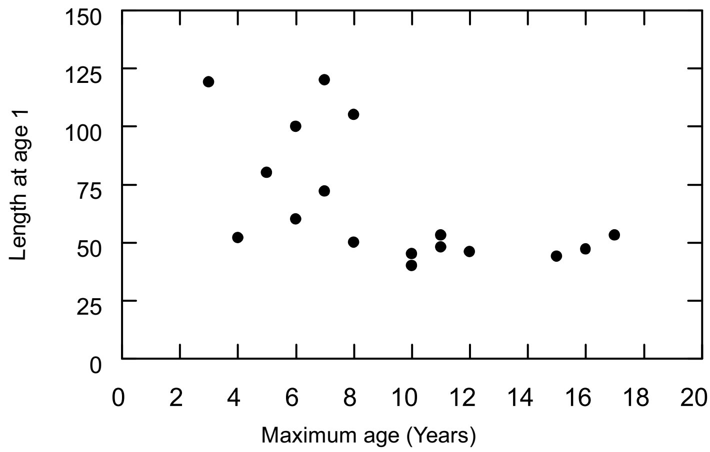

Fig. 2. Relationship between back-calculated length at age 1 and the maximum age in each population.

= 27.2, CV = 0.32, n = 9) than in northern populations (49–61°N: mean TL = 46.4, SD = 4.2, CV = 0.09, n = 10). Length at age 1 was negatively correlated with latitude (r_s = –0.689, *P* = 0.0011, n = 19) (Fig. 1). On the other hand, faster growth during the first growing season led to a shorter lifespan seen as negative correlation between maximum age and length at age 1 (r_s = –0.715, *P* = 0.001, n = 17) (Fig. 2).

Our analyses demonstrated marked differences in growth of rudd among populations situated over a large latitudinal gradient. A high degree of variation in growth is common in freshwater fish species, as have been noted also for rudd (Zawisza and Żuromska 1961, Zivkov *et al.* 2003). This variation is often attributed to the influence of environmental conditions of which most important are temperature and food availability (Mann 1991). Adaptation to ambient temperature can reduce latitudinal differences in growth rate. Certain species can show improved growth rates at high latitudes relative to low latitudes in similar temperatures (e.g. Conover and Present 1990, Jonassen *et al.* 2000), while some others do not show any thermal adaptation (Larsson *et al.* 2005). However, there are no studies of thermal adaptation of rudd.

Other environmental factors besides temperature are known to affect growth. Growth of cyprinids is generally depressed in eutrophic lakes as the abundance of large zooplankton is frequently reduced (Schindler and Scheuerell 2002, Moustaka-Gouni *et al.* 2006). Jeppesen *et al.* (2000) showed that the body weight of cyprinids declined significantly with increasing phosphorus concentration. In contrast, lakes situated in southern latitudes where rudd had relatively fast growth, were not eutrophic ones but these may still provide higher amount of food, or the longer duration of growing season may otherwise be beneficial (Hamam, Kuş, Uluabat, Bracciano lakes, Batak and Ovcharitsa reservoirs) (Erdem *et al.* 1994, Balık *et al.* 1997, Ferrara *et al.* 2002, Zivkov *et al.* 2003, Emiroğlu 2008). However, our results suggest that in the southern latitudes rudd can show distinctly different life history strategies between populations. In some lakes, rapid growth leads to shorter lifespan, whereas in other ones growth is steadier and lifespan is longer. In northern latitudes these strategies seems to be more or less the same.

Our findings of faster growth of rudd and subsequent reduction in lifespan are consistent with some other freshwater fish species in England (Britton 2007). Britton (2007) showed that there was a linear relationship between growth coefficient K and instantaneous mortality of roach (*Rutilus rutilus* (L.)), perch (*Perca fluviatilis* L.), chub (*Leuciscus cephalus* (L.)) and dace (*Leuciscus leuciscus* (L.)). Similarly, Metcalfe and Monaghan (2003) reported that growth rate and lifespan of fish were negatively correlated.

The present study shows that length at age 1 of rudd are negatively correlated with latitude, and that faster growth rate during the first growing season leads to shorter lifespan. However, despite of these patterns, large variations in length at age 1 were obvious in southern populations (40–46°N). Fonseca and Cabral (2007) showed that species, which had higher larvae and juvenile growth, selected either opportunistic or periodic life history strategies, whereas species that had slower growth selected equilibrium strategy. Thus, our results seem to suggest that even a single species may have more options in life history strategies in southern that in northern populations.

ACKNOWLEDGEMENTS: We thank Adnan Sümer and Özcan Gaygusuz for their assistance in collecting rudd specimens from Lake Sapanca.

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Received after revision June 2009