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Ruffe (*Gymnocephalus cernuus* L.), newly introduced into Lake Constance: preliminary data on population biology and possible effects on whitefish (*Coregonus lavaretus* L.)

Roland Rösch & Wolfgang Schmid

Rösch, R. & Schmid, W., Fischereiforschungsstelle des Landes Baden-Württemberg, Mühlesch 13, D-88085 Langenargen, Germany

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In 1987, ruffe (*Gymnocephalus cernuus* L.) was recorded for the first time in Lake Constance, Germany. Since then its population has increased dramatically. This species is now (1995) found in high numbers throughout the lake from inshore areas to depths up to 100 m. In autumn 1994, the ruffe population consisted of fish of an age of 0+ to 3+. Maximum body length was 16 cm. At the end of the first year ruffe attained an average body length of 7.6 ± 0.9 cm (mean ± *S.D.*), at the end of the second year 10.4 ± 1.1 cm. During the growing season ruffe were bottom feeders, preying mainly on chironomids and detritus. However, during the spawning season of whitefish (*Coregonus lavaretus* L.) in December ruffe switched to whitefish eggs as a main prey. In December 1993, high numbers of eggs were found in the stomachs of all ruffe investigated with a maximum of 322 eggs in a ruffe of 16 cm body length and 60.1 g body wet weight. In December 1994, ruffe started predation on whitefish eggs at the end of the spawning period, but the percentage of ruffe preying on whitefish eggs did not exceed 60%. Due to this egg predation, negative impacts on the natural reproduction of nearshore spawning whitefish are to be expected. There is also a possibility of interactions during the growing season with the commercially important perch (*Perca fluviatilis* L.) population.

1. Introduction

In recent years, the ruffe (*Gymnocephalus cernuus* L.) has been detected in many lakes and rivers outside its natural occurrence, for example in Lake Superior in North America (Moyle 1991, Simon & Vondruska 1991, Pratt *et al.* 1992) and in Scottish, Welsh, and English Lake District lakes in Great Britain (Maitland *et al.* 1983, Adams & Tippett 1991, Winfield 1992). In Lake Constance, on the border between Germany and Switzerland, this species was recorded for the first time in 1987 (Berg *et al.* 1989). By 1990, ruffe were found everywhere in the western part of the lake (Fischer 1994), and by 1991 also in the eastern

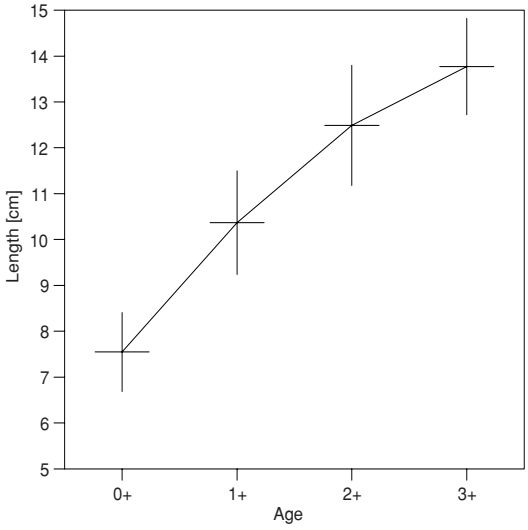

Fig. 1. Average body length (mean ± standard deviation, n = 230) of ruffe at the end of 1994.

part (Hartmann 1993). The ruffe is now the most abundant fish species in the inshore areas of Lake Constance (Rösch, unpublished data).

These findings and reports of intensive predation on whitefish (*Coregonus lavaretus* L.) eggs by ruffe (Adams & Tippett 1991) were the reason for beginning an intensive study on the biology and population dynamics of ruffe in Lake Constance. Preliminary results of this study are presented.

2. Material and methods

Lake Constance, situated between Germany and Switzerland, is a lake of 540 km^2 surface area with a maximum depth of 254 m. It is actually undergoing intensive oligotrophication with a maximum of phosphorus of 90 µg/l in the beginning of the 1980s and a value of 24 µg/l in spring 1995 (IGKB 1995). The fish population is intensively exploited with whitefish and perch as the economically most important species. Average annual yield is 800 tonnes.

In 1993 and 1994 bottom gill nets of a mesh size of 22 mm (35 m length, 2 m height, yarn strength 0.15 mm) were set in Lake Constance monthly near Langenargen on the north shore of the lake. Nets were set in the late afternoon at depths of 5 to 35 m and lifted in the next morning.

The whole catch per net was sorted by species, counted, and a sample of 20 ruffe was taken for further analysis. For each fish, total body length was determined to the lower 0.5 cm, before weighing to the nearest 0.1 g. For age determination scales were taken from the left side of the body. The stomach of each fish was preserved separately in 5% formalin solution.

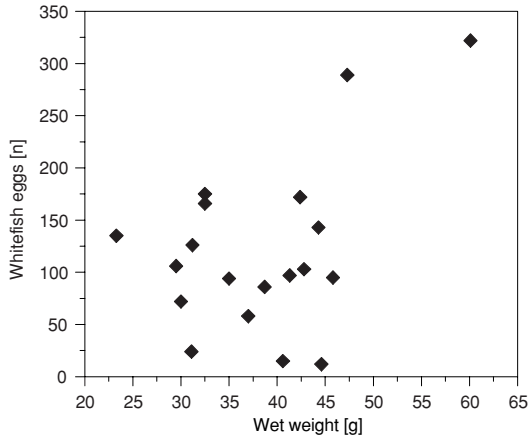

Fig. 2. Number of whitefish eggs found in ruffe stomachs on 30 November1993 plotted against fish body wet weight.

Stomach contents were analysed using a stereo-microscope (8–50× magn.) and sorted into whitefish eggs, detritus, zooplankton, chironomids, and others, before being counted. Stomach contents of perch, burbot and whitefish were examined immediately after catching.

Before and during the whitefish spawning periods of 1993 and 1994, the percentages of unripe, ripe and spent females were determined by daily fisheries using bottom gill nets of 38, 42, and 44 mm mesh size. This fishing is routinely done by the Fischereiforschungsstelle, in order to determine the spawning period of whitefish in the lake.

In November/December 1994 during the spawning period of nearshore spawning whitefish, bottom gill nets of 8, 10, 12, 15, 17, 20, and 25 mm mesh size (2 m high, 10–30 m length, yarn strength 0.15 mm) were set at depths of 15–35 m. The nets were set in the early morning for 1.5–3 h at whitefish spawning places. Lengths of ruffe were again determined to the lower 0.5 cm and body wet weight to the nearest 0.1 g. For age determination, scales were taken from three males, three females and three juveniles per 0.5 cm length class independent of the mesh size used. For stomach content analysis, a random sample of 20 to 30 ruffe from the whole daily catch was taken and preserved in 5% formalin. Analysis of stomach content was performed as described above.

3. Results

3.1. Age and growth

In November/December 1994 the ruffe population in Lake Constance consisted of fish of an age of 0+ to 3+. Older fish were not found. In their first year, ruffe reached an average body length of 7.6 cm and within 4 years attained a length of 13.8 cm (Fig. 1). Differences between males and females were not

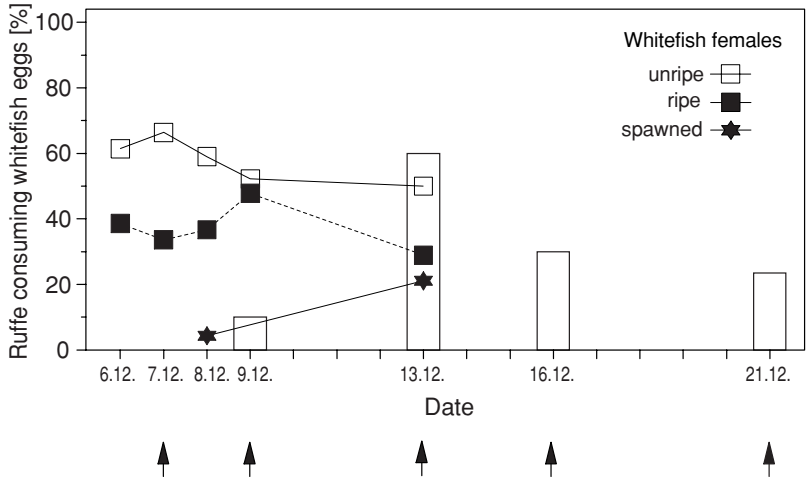

Fig. 3. Percentage of ruffe (bars) preying on whitefish eggs in 1994. The arrows indicate sampling of ruffe. The percentage of ripe, unripe and already spawned whitefish females is also given.

significant. Sexual maturity was reached for both males and females at an age of 1 or 2 years.

The highest numbers of ruffe were caught in nets of 15 and 17 mm mesh size, whereas in mesh sizes 8, 10, and 12 mm relatively few specimens were caught. This does not indicate a low number of 0+ fish, only that the 8 to 12 mm mesh size proved to be inappropriate mesh sizes for 0+ ruffe in December 1994 in Lake Constance. In nets of 20 mm mesh size comparatively few specimens were caught, and in nets of 25 mm almost no ruffe were found.

3.2. Diet

During the spawning period in Nov. 1993 all ruffe switched to whitefish eggs as a main prey. Some fish had eaten also chironomids and detritus. The number of whitefish eggs ingested increased with the body wet weight of the fish (Fig. 2). The maximum was 322 eggs for a ruffe of a body length of 16 cm and a body wet weight of 60.1 g. Five days after the end of whitefish spawning the number of eggs found in ruffe stomachs was clearly reduced. 4 weeks later no whitefish eggs were found in ruffe stomachs. Stomachs of whitefish and perch (10 of each species were investigated) caught in the same nets as ruffe were empty. Burbot (n = 8) preyed mainly on small (0+) cyprinids, but a few whitefish eggs were found in their stomachs.

During the whitefish spawning season of 1994, ruffe started preying on whitefish eggs as soon as spawned whitefish females were found (Fig. 3). On

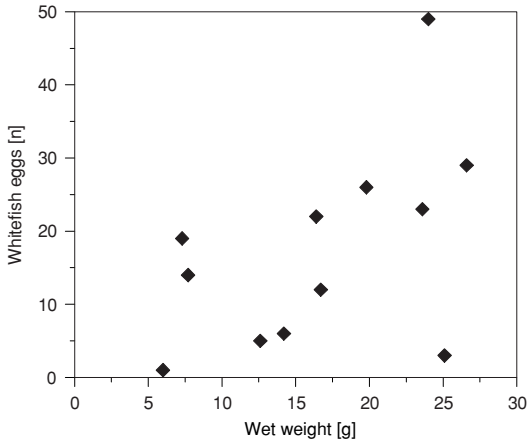

Fig. 4. Number of whitefish eggs found in stomachs of ruffe on Dec. 13th, 1994.

Dec. 13th, near the end of whitefish spawning, 60% of the ruffe investigated had consumed eggs. This proportion had reduced to 30% after 3 days and to 23% after another 5 days.

For Dec. 13th, the number of whitefish eggs found per stomach is plotted versus fish weight (Fig. 4).

4. Discussion

In 1987, the ruffe was recorded for the first time in Lake Constance (Berg *et al*. 1989). The way this species was introduced into the lake is unknown, as natural immigration from lower regions of the Rhine

river is impossible due to the waterfall in Schaffhausen which in former times prevented even Atlantic salmon (*Salmo salar*) from migrating into the lake (Klunzinger 1892).

Within its natural occurrence, the ruffe is known as a predator of *Coregonus* eggs and larvae (Huusko & Sutela, 1992). However, in many lakes ruffe and whitefish coexist and so it is assumed that ruffe egg predation is taken into account in life history strategies of whitefish. However, this is not applicable to lakes, where the ruffe is newly introduced.

The growth of ruffe in Lake Constance is within the range exhibited by this species in european inland waters and rivers (Willemsen 1977, Hölker & Hammer 1994). However, the maximum length of ruffe caught in Lake Constance was 16 cm, which is relatively low compared to ruffe populations in its area of natural occurrence. Whether this length is an effect of a high population density or of a still young and increasing population is unknown. An indication of the second assumption possibility is that only ruffe younger than 4 years were caught during the present study. In 1991, Fischer (1994) caught mainly fish of an age of 0+ to 1+ with only a few older specimens, which means that in 1991 the ruffe population in Lake Constance was even younger than in 1994.

Whitefish egg predation by ruffe in Lake Constance is high compared to predation by burbot, which in the present investigation was very low. Furthermore, ruffe is the most abundant fish species in the inshore areas of Lake Constance (Rösch, unpublished data), and numbers of whitefish eggs in ruffe stomachs as high as in the present investigation have not been reported elsewhere. However, an estimation of the total whitefish egg predation by the ruffe population is impossible at the present because the population size (number, biomass) and daily ration of ruffe are unknown.

In December 1993, perch and whitefish had empty stomachs, whereas those of ruffe were filled. Bergman (1987) showed that feeding activity of ruffe remains high over a wide temperature range, whereas for perch feeding activity decreases with decreasing temperature. This is also true for whitefish (Rösch 1987).

Huusko and Sutela (1992) reported eyed whitefish ova in a stomach of ruffe. For Lake Constance data on ruffe feeding in early spring are not available so far.

The present results of whitefish egg predation by ruffe indicate that the possibility of an influence on the natural recruitment of nearshore spawning whitefish of Lake Constance cannot be excluded. As the efficiency of whitefish stocking in Lake Constance is unknown (Hartmann 1986, Eckmann *et al*. 1988), predictions on the influence on whitefish year class strength are impossible at present.

Lake Constance is a lake undergoing intensive oligotrophication (IGKB 1995). The diet of the commercially very important perch in eutrophic lakes consists of zooplankton (Hartmann & Nümann 1977), but in oligotrophic lakes its main prey is benthos. Assuming a further oligotrophication of Lake Constance, a return of perch to benthos fauna is possible. In this case, competition between ruffe and perch is also to be expected.

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