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The effect of low pH on perch, Perca fluviatilis L. I. Effects of low pH on the development of eggs of perch

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The pH tolerance of perch eggs from small lakes in southern Finland was tested under laboratory und field conditions. There was no egg mortality at control pH 6.4. At pH 5.0 the mortality was less than 10 %. The development time of the eggs was 11 % longer than at the control pH. At pH 4.0 the mortality was 59 % and development time 29 % longer than at the control pH. No eggs hatched at pH 3.5, but when transferred to pH 6.4 after 125 day degrees, 50 % of the transferred eggs hatched. The pH of water affected the volume of the eggs. At pH 3.5 and 4.0 the volume decreased at first, and was clearly lower than at pH 5.0 and 6.4.

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1. Introduction

The effects of acidification on fish were first reported from Norway by Dahl (1926). Dannevig (1959) recognized the relation between acid precipitation, acidity in surface waters, and the disappearance of fish. The altered water chemistry in lakes and rivers in Norway appears to have affected organisms at every trophic level in these ecosystems (Wright et al. 1975), but the most attention has been paid to fishes, in particular to salmonids because of the financial losses caused by acidification. Muniz et al. (1975, 1979) have reported fish deaths at low pH in southern Norwegian rivers. The reason for fish deaths is ionic imbalance in the fish as a result of the low pH (Leivestad & Muniz 1976). Acidification can affect reproduction (Carrick 1979), population structure (Almer 1972), growth (Beamish 1974), and food selection (Andersson 1972) of fishes. Developing eggs and fingerlings are most sensitive to low pH (Milbrink & Johansson 1975).

In Finland the acidification of lakes is not yet as extreme a problem as in Norway and Sweden and biological research into it is still in the early stages. The aim of this work was to study the effects of different pH values on the mortality, development time, and volume of fertilized perch eggs.

2. Material and methods

The work was carried out in the Evo region, Lammi, southern Finland, where there are many small forest lakes in an area of about 100 square kilometres. Three of these were chosen for the present study in order to take into account

Table 1. Properties of the water used in the pH tolerance experiments.

	Lake Valkea Mustajärvi	Lake Nimetön	Lake Karhujärvi	Evo Station
Surface area (ha)	13.9	0.4	0.8	
Maximum depth (m)	10	12	8	
Fish species	perch, pike, whitefish (introduced)	perch, pike	perch	
T°C (min-max)	13.0–19.1	12.4–18.3	12.0–20.4	9.7–15.4
pH	6.4	5.8	4.4	6.4
Alkalinity (meq/l)	0.06	0.04	-0.04	0.39
Colour (ppm Pt)	33	150	180	6
Conductivity (μS/cm 20°C)	23	35	39	63
Na (mg/l)	0.9	1.4	1.1	2.0
K (mg/l)	0.7	1.2	0.9	1.7
Ca (mg/l)	2.6	4.2	2.7	1.1
Mg (mg/l)	0.5	1.2	0.8	1.1
Fe (mg/l)	0.2	0.4	0.2	<0.1
Al (μg/l)	40	350	200	20

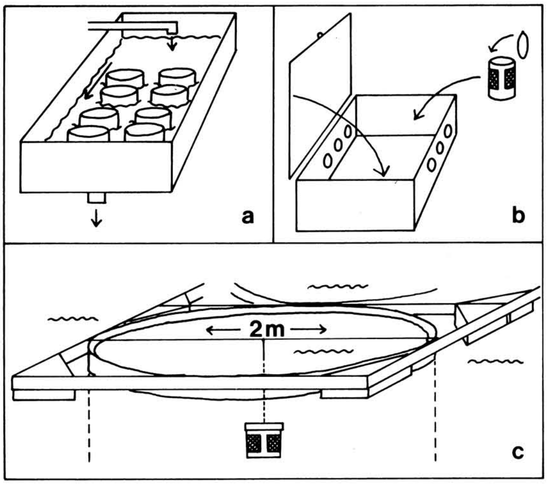

Fig. 1. Rearing systems (a) in the laboratory, (b) in the field, and (c) in Lake Nimetön.

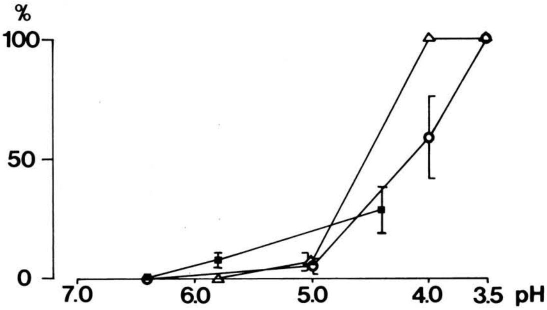

Fig. 2. The mortality of perch eggs at decreasing pH in the laboratory (circles), in the field (squares), and in Lake Nimetön (triangles). Vertical lines = standard error of the mean.

different pH values. Lake Valkea Mustajärvi, a 13-hectare lake with clear water and a pH of 6.4, Lake Nimetön, a small humic lake of 0.4 ha and pH 5,8, and Lake Karhujärvi, a humic lake of 0.8 ha and pH 4.4 (Table 1). The laboratory work was done at the Evo Inland Fisheries and Aquaculture Research Station.

Three different pH tolerance experiments were performed: in the laboratory, in the field (three lakes), and in Lake Nimetön. In the laboratory, pH values 3.5, 4.0, 5.0, and a control were used. The water was tap-water (ground water of Evo Station) with a pH of 6.4; this was also used as control water. The experimental pH values were adjusted with H_2SO_4 (analytical grade). Temperature and pH were recorded daily and pH was adjusted with H_2SO_4 three times during the experiment. The eggs were reared in one-litre polyethene jars. Temperature was adjusted to fit the natural conditions according to the water in a nearby river (Fig. 1a).

In the field, the eggs were placed in Lake Valkea Mustajärvi, Lake Nimetön, and Lake Karhujärvi. They were reared in 100 ml polypropylene boxes, two sides of which were of nylon net with a mesh size of 1 mm. These were placed into a larger box (Fig. 1b). The box also shaded the eggs from direct sunlight. The rearing depth was 0.5 m.

In Lake Nimetön the experiment included a pH series of 3.5, 4.0, 5.0 and a control (5.8), using polyethene pools with a diameter of 2 m. These were filled with lake water and the pH values were adjusted with H_2SO_4. The eggs were reared at a depth of 0.5 m in polyethene boxes covered partly by nylon net (Fig. 1c). The cover of the box shaded the eggs from direct sunlight.

The roe of three females each from Lake Valkea Mustajärvi and Lake Nimetön, fertilized under natural conditions, was collected. The eggs were divided into batches (50–100 eggs per batch) so that eggs from the six females were tested in every pH tolerance experiment, except that in Lake Nimetön, where eggs from two females were used. During transport, the eggs and the transport water were always from the same lake. At the beginning of the experiment the eggs had developed about one day (15 day degrees). Dead eggs were counted daily, but not removed in order to avoid damaging the live ones. All counts were made with the eggs constantly under water. Observations of mortality during the experiment, development time, volume of the eggs, and transfer from low pH to control were made in the laboratory. When estimating the volume of the eggs, their shape was assumed to be spherical. The measurement was made daily and the mean of the volumes of 10 eggs per pH was calculated. The diameter was measured from the outer marigin of the chorion and the eggs used were from one female, from Lake Valkea Mustajärvi.

3. Results and discussion

3.1. Mortality of the eggs at different pH

At pH 5.0 and above the mortality of perch eggs was less than 10 % (n = 435 in the laboratory and 320 in the field). A hatchability of more than 90 % corresponds to that under natural conditions. At pH 4.0 the mortality of the eggs was 59 % in the laboratory ($n = 430$) and 100 % in Lake Nimetön ($n = 72$). At pH 3.5 no eggs hatched in either test ($n = 370$). In the field the mortalities were 0.3 % in Lake Valkea Mustajärvi ($n = 330$), 8 % in Lake Nimetön ($n = 320$), and 28 % in Lake Karhjujärvi ($n = 300$) (Fig. 2).

The time at which the mortality occurred was dependent on the experimental pH. At pH 5.0, death occurred at the beginning of the experiment, at pH 4.0 it increased towards the end, and at pH 3.5 it was highest during the first days of the experiment (Fig. 3).

The present results agree rather well with the pH range of 4.5-5.0 given by EIFAC (1969) for unaffected reproduction of perch, and the lower limit of pH 4.7 for succesful reproduction of perch given by Milbrink & Johansson (1975). However, it is very difficult to determine exact limits of pH tolerance for a fish species. Differences in tolerance between populations of a particular fish species have been reported (Gjedrem 1976) and the properties of the water, such as conductivity, are of importance (Leivestad et al. 1976). The latter may by the reason for different mortality at pH 4.0 in the laboratory and in Lake Nimetön. The conductivities were 63 μS (20 °C) in the laboratory and 35 μS (20 °C) in Lake Nimetön.

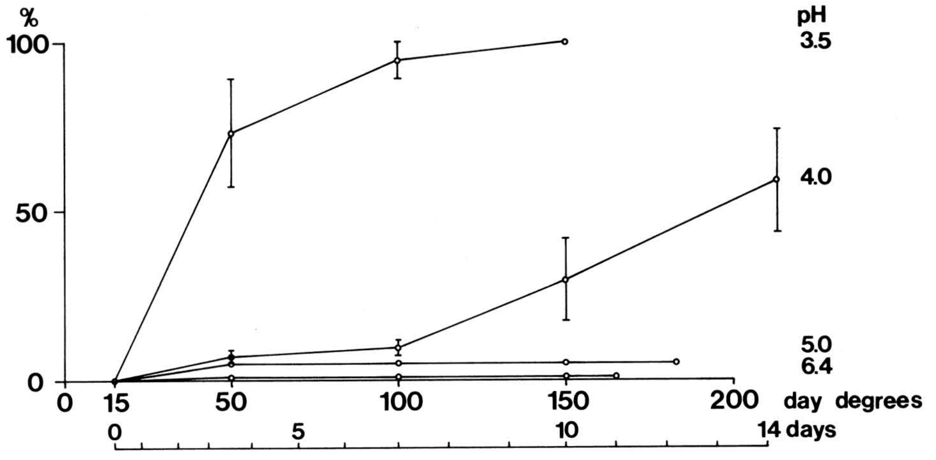

Fig. 3. The mortality of perch eggs during the experiment. Vertical lines = standard error of the mean.

3.2. Development time of the eggs

The development time of the eggs increased with decreasing pH. At pH 5.0 the number of day degrees (183) from fertilization to hatching was 11 % more and at pH 4.0 29 % more (213 day degrees) than in control water, where it was 165 (Fig. 4). The time from hatching of the first eggs to hatching of the last in a batch of roe also increased with decreasing pH. It was 27 day degrees at pH 6.4, 40 at pH 5.0 and 51 at pH 4.0. These observations are in good agreement with the results of pH tolerance of brook trout, *Salvelinus fontinalis* Mitchill (Swarts et al. 1978). The increased development time of eggs can affect the reproductive success of perch because it makes the eggs more sensitive to predators and microbial infections. The energy contents of the yolk sac may be lower after a longer development time, which can affect the survival of the fry.

The reason for the longer development time may be inhibition of the hatching enzyme (chorionase) due to low pH. The pH optimum of the hatching enzyme of rainbow trout, *Salmo gairdneri* Richardson, is near 8.5 (Hagenmaier 1974), with activity being reduced rapidly with decreasing pH. In addition, lower activity of the alevins at low pH may result in failure to rupture the chorion, and low pH may induce some change in the structure of the chorion, making it more difficult to break (Peterson et al. 1980).

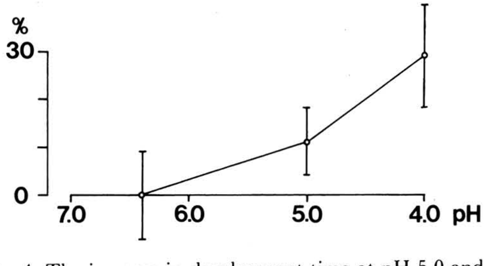

Fig. 4. The increase in development time at pH 5.0 and 4.0 (% of day degrees at hatching in pH 6.4). Vertical lines = standard deviation.

3.3. Volume of the eggs

Differences in the volume of the eggs due to experimental pH were observed from the beginning of the experiment. At pH 3.5 and 4.0 egg volume first decreased and then increased, the original volume being exceeded after five days at pH 4.0 and six days at pH 3.5 (Fig. 5). After rearing for 125 day degrees, 20 eggs from one female from Lake Nimetön were transferred from pH 3.5 to control water, and the following observations were made: half of the eggs hatched after three days (42 day degrees, total 167), whereas no eggs hatched at pH 3.5. The volume of the eggs increased rapidly, from 5.6 mm^3 on transfer to 20.1 mm^3 in one hour and to 29.0 mm^3 before hatching. Another 20 eggs were transferred from pH 4.0 to control water and 18 of these hatched after three days. The volume of the eggs increased from 7.2 to 20.1 mm^3 in one hour and to 33.5 mm^3 before hatching. A further 26 eggs were transferred from pH 5.0 and they all hatched after two days. The increase in volume was from 20.1 mm^3 to 24.4 during the first hour and to 33.5 mm^3 before hatching. The reason for the differences in the volumes of the eggs at different pH values

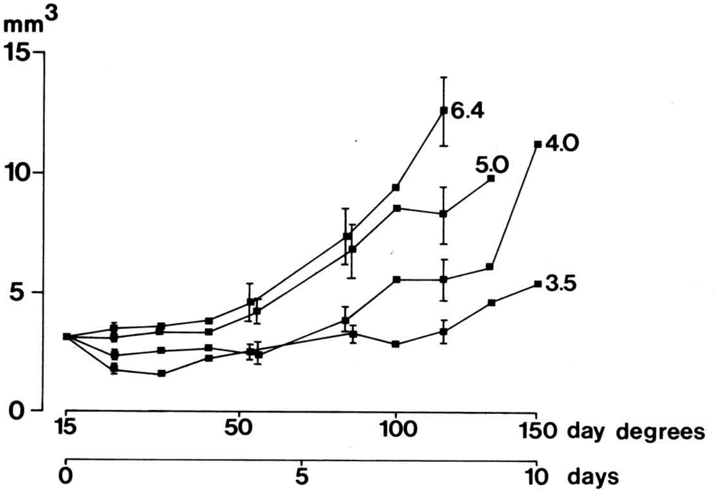

Fig. 5. The variation in egg volume at different pH. Vertical lines = standard deviation.

might be a structural change in the chorion at low pH, as suggested by Runn et al. (1977).

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