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# On overwintering larvae of the Common Frog *Rana temporaria* LINNAEUS, 1758 (Anura: Ranidae)

## Überwinternde Larven des Grasfrosches, *Rana temporaria* LINNAEUS, 1758 (Anura: Ranidae)

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KURZFASSUNG

In einem von Quellwasser durchflossenen Tümpel im Wienerwald an der westlichen Stadtgrenze von Wien (Österreich) wurde von Jänner bis März 1998 die Überwinterung von 13 Larven von *Rana temporaria* LINNAEUS, 1758 verfolgt. Vier dieser Larven erreichten Entwicklungsstadium 40/41 (nach GOSNER 1960); zwei der vier beendeten offensichtlich die Metamorphose. Die restlichen 9 Larven überlebten den Winter mit großer Wahrscheinlichkeit nicht. Zwei von drei weiteren, dort gefangenen und im Labor aufgezogenen Larven starben nach der Metamorphose. Im März 2000 wurde an diesem Fundort erneut eine überwinternde Larve festgestellt. Ein verspäteter Laichzeitpunkt und die durch niedrige Temperatur bedingte Verzögerung der Metamorphose werden als die plausibelsten Gründe für dieses Phänomen gehalten.

ABSTRACT

From January to March, 1998, the fate of 13 overwintering larvae of *Rana temporaria* LINNAEUS, 1758, was tracked. The larvae were observed in a spring water-fed pond in the "Wienerwald" forest in the west of Vienna (Austria). Four out of 13 larvae observed in the pond reached larval stage 40/41 (according to GOSNER 1960) and two of them obviously completed metamorphosis. The remaining 9 larvae most probably did not survive the winter. Two out of three more larvae caught in this place and raised in the laboratory died after metamorphosis. In March 2000, another overwintering larva was found in the pond. Late spawning and the delay of metamorphosis under low temperature conditions are stressed to be the most plausible reasons of the phenomenon of overwintering.

KEY WORDS

Amphibia: Anura, Ranidae; *Rana temporaria*, tadpoles, overwintering larvae, delay of metamorphosis, late spawning, ecology, Vienna, Austria

## INTRODUCTION

Overwintering of Common Frog larvae (*Rana temporaria* LINNAEUS, 1758) is not unknown (BEDRIAGA 1891; CERNY 1979; SCHLÜPMANN & GÜNTHER 1996). However, other authors consider successful overwintering of Common Frog larvae either improbable (FISCHER-SIGWART 1897; AEBLI 1966; KOSKELA 1973), or a rare exception (GROSSENBACHER 1979).

In the first week of January 1998, E. CHRISTIAN (Institute of Zoology, University of Agricultural Sciences, Vienna) told me about the presence of tadpoles in a spring water-fed pond situated in the forested west of the city of Vienna (Austria). Since direct observation of overwintering larvae is a rare event, I documented the fate of these tadpoles over the course of the winter.

## MATERIALS AND METHODS

The pond was controlled 11 times between 12 January, 1998 and 26 March, 1998, in more or less regular weekly intervals. Air and water temperatures and electric conductivity of the water were determined in various places of the pond (table 1). Observations on the presence, whereabouts and developmental stage of the larvae in the pond are summarised in table 2. On four days (see table 2), tadpoles were captured for determination of their developmental stage (according to GOSNER 1960) and for measuring the total length (table 4). On all other days of observation,

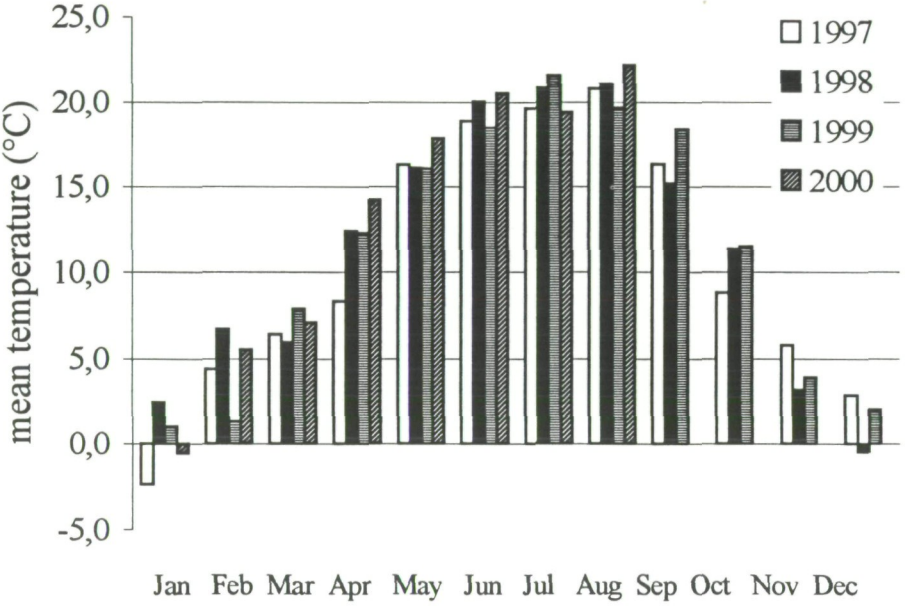


Fig. 1: Mean temperatures of the months in the period under study (winter 1997/98 - winter 1999/2000).
Abb. 1: Mittlere Monatstemperaturen im Untersuchungszeitraum (Winter 1997/98 - Winter 1999/2000).

the larvae were not handled and their developmental stage was estimated according to HERWIG & SCHNEIDER (1989). On 18 February, the entire water body was screened with a net, in order to establish the total number of larvae. As this operation produced no further information, it was not repeated. Weather conditions before and during the investigation period are described by data from Vienna Central Institute for Meteorology and Geodynamics and original notes. Further sporadic controls were run in the winter of 1998/99 and in the autumn and winter of 1999/2000.

## Weather conditions (fig. 1, table 3)

In 1997, the cold season began early with temperatures below 0°C occurring for the first time on 22 October, later on inducing heavy night time frost even in the valleys (coldest night of October/November at 29 October: -5,5°C). The number of frost days (minimum temperature below 0°C) per month is shown in table 3. November and December were comparatively mild with a short period of frost in the second third of December. January 1998 remained relatively mild until the last third of the month and showed little precipitation. After 25 January, hard winter conditions set in with extensive snowfall and heavy nighttime frost. The cold period passed on to the beginning of February and made room for a period of little precipitation which lasted until the middle of March. A short intermezzo with chill and heavy precipitation (partly snow) around the 16 March was not able to delay spring's arrival.

The cold season of 1998/99 began late and started with continuous frost days from 18 till 26 November. Severe frost occurred at the beginning of December, which went on dry and rather cold. January was dry, but not too cold, February brought deep temperatures and, at times, considerable snowfall. Spring closed in quickly in early March.

The cold season of 1999/2000 started early like in 1997/98 with frost arriving at 18 October (table 3) and was abundantly

Table 1: Temperature (°C) and electric conductivity (µS / cm) of the water body in which overwintering larvae of *Rana temporaria* were observed.
Tab. 1: Temperatur (°C) und elektrische Leitfähigkeit (µS / cm) des Gewässers mit überwinternden Larven von *Rana temporaria*.

| Date Datum | Water Temperature Wassertemperatur | | | | Air Temperature Lufttemperatur | Electric Conductivity Elektrische Leitfähigkeit | | |
|---|---|---|---|---|---|---|---|---|
| | 2 cm below surface 2 cm unter der Wasseroberfläche | 30 cm below surface 30 cm unter der Wasseroberfläche | Inflow Zufluß | Outflow Abfluß | Beside pond neben dem Tümpel | Pond Tümpel | Inflow Zufluß | Outflow Abfluß |
| 12.I.98 | 11.8 | 9.5 | 9.9 | 10.7 | 6.3 | 888 | 893 | 890 |
| 15.I.98 | 12.1 | 9.8 | 10.2 | 11.8 | 6.7 | 890 | 912 | 898 |
| 21.I.98 | 8.1 | 6.4 | 9.1 | 8.0 | 0.8 | 870 | 877 | 869 |
| 23.I.98 | 7.8 | 6.4 | 8.1 | 7.6 | -2.8 | - | - | - |
| 30.I.98 | 7.4 | 5.9 | 7.9 | 6.8 | -3.3 | 875 | 882 | 880 |
| 03.II.98 | 8.8 | 8.1 | 9.0 | 8.5 | 0.0 | 861 | 873 | 867 |
| 18.II.98 | 9.0 | 9.2 | 8.8 | 9.1 | 4.0 | 866 | 870 | 868 |
| 28.II.98 | 10.2 | 10.0 | 9.1 | 9.9 | 19.8 | 864 | 872 | 866 |
| 04.III.98 | 9.9 | 9.7 | 9.6 | 10.0 | 16.5 | 871 | 877 | 873 |
| 17.III.98 | 9.1 | 8.9 | 8.9 | 8.9 | 5.8 | 868 | 865 | 866 |
| 26.III.98 | 9.0 | 8.8 | 8.1 | 8.6 | -0.8 | 864 | 869 | 862 |
| Mean / Mittel | 9.3 | 8.3 | 8.9 | 9.0 | 4.8 | 871.7 | 879.0 | 873.9 |

provided with snow. The temperatures were rather above the long-standing average, with exception of a short onset of cold at the end of January (fig. 1). February temperatures were similar to 1998. Spring, however, set on reluctantly.

## The pond

The spring water-fed pond in the catchment area of the Mauerbach stream (48°13'11''N / 16°13'06'' E, 260 m a.s.l.) is located on a meadow ("Salzwiese") with scattered reed covering and individual bushes. The artificially enlarged pond, roughly 5 m in diameter, is located approximately 6 m from the edge of low shrubs. It is barely possible to measure the slight flow in the water body caused by the spring; it appears, however, constant over the year. A space free of vegetation in the area of the outflow allows a view to the sandy bottom. The edge of the pond is partly encircled with reeds and partly with hummocks of rushes and sedges.

In 1998, two thirds of the water body (depth approximately 50 cm) were covered with *Chara* sp. which was found in the area of the mouth of the spring's stream. Rushes and sedges occurred in limited numbers. The aquatic vegetation changed during the following two years: the growth of algae gradually replaced larger areas of *Chara* sp. For data on temperature and electric conductivity of the pond water see table 1.

# RESULTS

Because of lack of continuous information from the winters of 1998/99 and 1999/2000, the results will primarily refer to the overwintering of the larvae in the winter of 1997/98. The most important observations are compiled in table 2.

Three out of 16 larvae detected on 12 January 1998 were raised in the laboratory at an average water temperature of 17°C and completed metamorphosis. Two of them developed abnormally dilated trunks and died eventually on 6 February. The third animal developed normally, metamorphosed on 2 February and was released near the pond on 4 March.

Four of the 13 larvae in the pond developed at least to stage 40/41 according to GOSNER (1960). In all likelihood, two of them were able to complete the metamorphosis - one specimen was observed having 4 legs and a developed oral fissure; the other one was observed for the last time in good condition on 17 March, at the beginning of tail reduction.

Table 2: Observations on overwintering larvae of *Rana temporaria* in 1998 and remarks on their development. A - larval stage according to HERTWIG & SCHNEIDER 1989; B - larval stage according to GOSNER 1960.

Tab. 2: Beobachtungen an überwinternden Larven von *Rana temporaria* im Jahr 1998 und Angaben zur Entwicklung. A - Larvenstadien nach HERTWIG & SCHNEIDER 1989; B - Larvenstadien nach GOSNER 1960.

| Date<br>Datum | Number of specimens<br>Anzahl Exemplare | Observations<br>Beobachtungen | Larval stage / Number of specimens<br>Larvenstadium / Anzahl Exemplare | |
|---|---|---|---|---|
| | | | A | B |
| 12.I.98 | 16 | 4 specimens in the area without vegetation; rest in *Chara* sp.; 3 specimens gathered for keeping in laboratory.<br>4 Exemplare im vegetationslosen Bereich, die übrigen zwischen *Chara* sp.; 3 Exemplare zur Laboraufzucht gefangen | 19 / 16 | |
| 15.I.98 | 12 | 3 specimens in the area without vegetation, 9 in *Chara* sp.<br>3 Exemplare im vegetationslosen Bereich, 9 in *Chara* sp. | | 37 / 3; 38 / 9 |
| 21.I.98 | 9 | One specimen in the area without vegetation, 3 specimens at the edge of *Chara* sp., rest among *Chara* sp.<br>Ein Exemplar im vegetationslosen Bereich, 3 Exemplare am Rand von *Chara* sp., die übrigen zwischen *Chara* sp. | 19 / 3; 20 / 6 | |
| 23.I.98 | 3 | One larva in the area without vegetation; rest at the edge of *Chara* sp.<br>Eine Larve im vegetationslosen Bereich, die übrigen am Rand von *Chara* sp.. | | 38 / 1; 39 / 2 |
| 30.I.98 | 4 | 2 specimens at the edge of *Chara* sp.; rest among *Chara* sp.; *Chara* sp. investigated only at the edge.<br>2 Exemplare am Rand von *Chara* sp., die übrigen zwischen *Chara* sp.; *Chara* sp. Bestände nur am Rand untersucht. | 20 / 4 | |
| 03.II.98 | 4 | One specimen in the area without vegetation; one specimen at the edge of *Chara* sp.; rest among *Chara* sp.<br>Ein Exemplar im vegetationslosen Bereich, ein Exemplar am Rand von *Chara* sp., die übrigen zwischen *Chara* sp. | 20 / 4 | |
| 18.II.98 | 4 | Intensive investigation with net; 2 specimens at the edge of *Chara* sp., 2 specimens among *Chara* sp.<br>Intensive Untersuchung mittels Netz; 2 Exemplare am Rand von *Chara* sp., 2 Exemplare zwischen *Chara* sp. | | 40 / 3; 41 / 1 |
| 28.II.98 | 1 | One specimen in the area without vegetation, feeding on a bread crumb; no investigation of *Chara* sp;<br>Ein Exemplar im vegetationslosen Bereich, an einer Brotkrume fressend; *Chara* sp. Bestände nicht untersucht. | 21 / 1 | |
| 04.III.98 | 2 | One specimen in the area without vegetation, one larva among *Chara* sp.<br>Ein Exemplar im vegetationslosen Bereich, eine Larve zwischen *Chara* sp. | 21 / 2 | |
| 17.III.98 | 2 | Specimens at the edge of *Chara* sp; one larva with reduced tail.<br>Exemplare am Rand von *Chara* sp.; eine Larve mit reduziertem Schwanz. | 21 / 1; 22 / 1 | 43 / 2 |
| 26.III.98 | 0 | In spite of intensive investigation with a net no more specimens were found.<br>Trotz intensiver Suche mittels Netz wurden keine Exemplare mehr gefunden. | | |

Table 3: Number of frost days (minimum temperature below 0°C) in the cold seasons of the period studied.

Tab. 3: Anzahl der Frosttage (Temperaturminimum unter 0°C) der kalten Perioden im Untersuchungszeitraum.

| Cold season /<br>kalte Jahreszeit | Number of frost days / Anzahl der Frosttage | | | | | | |
|---|---|---|---|---|---|---|---|
| | October | November | December | January | February | March | April |
| 1996/1997 | 0 | 5 | 7 | 29 | 15 | 5 | 4 |
| 1997/1998 | 6 | 6 | 8 | 17 | 9 | 11 | 0 |
| 1998/1999 | 0 | 14 | 25 | 21 | 15 | 6 | 0 |
| 1999/2000 | 2 | 10 | 15 | 26 | 6 | 3 | 0 |

Table 4: Total length of overwintering larvae of *Rana temporaria*. * - Beginning of tail reduction.
Tab. 4: Gesamtlängen von überwinternden Larven von *Rana temporaria*. * - Beginn der Schwanzreduktion.

| Date / Datum | 15. Jan. 1998 | 23. Jan. 1998 | 18. Feb. 1998 | 17. Mar. 1998 |
|---|---|---|---|---|
| Total Length (mm) / Gesamtlänge (mm) | 35 | 36 | 36 | 38 |
| | 35 | 37 | 38 | 21* |
| | 35 | 37.5 | 37 | |
| | 35.5 | | 36.5 | |
| | 34 | | | |
| | 35 | | | |
| | 35.5 | | | |
| | 34 | | | |
| | 35 | | | |
| | 35 | | | |
| | 35.5 | | | |
| | 35 | | | |
| Mean / Mittel | 35.0 | 36.8 | 36.9 | - |

In January, several animals were identified on the ground under the clear water or were still visible along the border to the vegetation. The greater part of the larvae, however, remained in the border area of *Chara* sp. and the only way to direct them into the open water was to carefully poke in the vegetation with a stalk.

During none of the controls any physical impairment was observed in the animals. For unknown reasons, however, 9 of the 13 larvae could not be found after 23 January. On 18 February, the water body and the aquatic vegetation were screened with a net in order to discover the missing larvae. As this operation failed, no such attempt was repeated.

Overwintering could not be observed in the winter of 1998/99. In the autumn of 1999, larvae at stages without hind limbs were detected again. There were 15 specimens on 26 August, 10 on 3 September, and still 7 in October (H. GROSS pers. comm.). During a control on 12 December 1999, and on 6 January 2000 no animals were found. On 2 March 2000 one larva (with hind limbs; stage 34 according to GOSNER 1960) was captured, it was, however, in bad condition. The attempt to bring it to metamorphosis in the laboratory failed. The larva died on 9 March 2000.

## DISCUSSION

The reasons for overwintering in Common Frog larvae can only be surmised. For larvae of the Fire Salamander *Salamandra salamandra* (LINNAEUS, 1758), THIESMEIER (1992) believes the cause of overwintering to be late birth, lack of food, and low temperatures. When discussing about larvae of *Rana* kl. *esculenta* LINNAEUS, 1758, which have not completed metamorphosis before the onset of winter due to a disturbed hormonal balance, BORKIN et al. (1982) and GÜNTHER (1996) consider overwintering as a rare phenomenon. Gigantism in *R. temporaria* tadpoles was described by LUTHER (1917) and GISLÉN & KAURI (1959); they make, however, no reference to overwintering. In the present case, hormonal imbalance appears rather improbable. Outdoors, as well as in the laboratory, the larvae exhibited a thoroughly normal development (considering the low temperature) without gigantism (table 4).

Although there is no temperature-derived indication of delayed spawning (fig. 1), retarded development of late hatched larvae seems to be the most plausible explanation for the overwintering in the present case corroborated by the sporadic occurrence of larvae in the autumn of 1999. A possible reason for the delayed development in 1997/98 and 1999/2000 could be in fact the early onset of the cold season with first frost in October. (In winter 1998/99 when overwintering larvae were lacking, frost occurred not before middle of November; table 3.) In addition, the con-

stantly low temperature of the water inflow in autumn would have delayed metamorphosis too.

On the other hand, spring water inflow prevented the pond from freezing in the frost period in winter and therefore enabled metamorphosis for at least two animals. Neighbouring ponds lacking a spring stream were totally frozen at that time!

According to KOSKELA (1973), low temperatures in two ponds in North Finland delayed development of Common Frog larvae. He found about 1000 larvae still there in September. In his latest observation on 9 December 1971, he documented 5 larvae swimming under the ice. The animals died during the winter, however.

The present results suggest, that relatively constant and not too low water temperatures (e. g., caused by the spring stream) as well as certain climatic conditions (the early onset of winter, mild winter conditions) enable successful overwintering of late hatched Common Frog larvae.

The percentage of the larvae which survived the winter of 1997/98 in the field is not clear. At least four out of 13 animals arrived at stage 40/41 according to GOSNER (1960), two of them almost certainly completed metamorphosis. In all probability, the other 9 larvae which were no longer identified after 23 January did not survive the winter. It can be ruled out that they had left the water after successful metamorphosis, since the larvae in the laboratory (kept under clearly warmer temperature conditions and supplied with sufficient food) completed their metamorphosis about one week later (2 specimens on 30 January, 1 on 2 February). Similarly, only one out of 15 larvae identified in autumn 1999 survived the winter in the pond until beginning of March, but later died in the lab before metamorphosis.

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