LIFE CYCLE OF AN *ENALLAGMA BOREALE* SELYS POPULATION FROM THE BOREAL FOREST OF ALBERTA, CANADA (ZYGOPTERA: COENAGRIONIDAE)

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In a boreal forest pond, most larvae of *E. boreale* were semivoltine but some may have been univoltine. Low temperatures during egg development may account for small size and slow growth of some cohorts.

INTRODUCTION

WALKER (1953) reports that *Enallagma boreale* is the "most widely distributed species of *Enallagma* in Canada and is the commonest species in the far north." The larvae inhabit a variety of freshwater habitats and even some saline waters. Although the species is very common and widely distributed, little work has been done on *E. boreale*'s life cycle. The only field study of its life cycle was done by PEARLSTONE (1971) who studied a population in Marion Lake, a small coastal lake in south-western British Columbia. LEBEUF & PILON (1977) studied the life cycle under laboratory conditions.

The purpose of our paper is to report on the life cycle of a population of *E. boreale* larvae from a pond in the boreal forest of Alberta and to comment on the possible role of temperature in affecting size and growth of cohorts.

STUDY AREA AND ECOLOGICAL PARAMETERS

The study pond is in the boreal forest of Alberta, approximately 2 km North of the Bigoray River (53°31′N, 115°26′W); see CLIFFORD (1978) for a description of the area. The pond was a borrow

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pit, probably dug when Highway 753 was built, and is 7 m from the road. The pit is rectangular in shape, approximately 85 m long and 12 m wide. The pond is approximately 1 m deep at the deepest point. *Carex* sp. was abundant in the shallow water at the N end of the pond, where the bank slopes gently. *Potamogeton* sp. and *Myriophyllum* sp. were also concentrated in the N end of the pond but occurred in slightly deeper water. *Potamogeton* was also found along the steep E, W, and S banks but was not abundant there. Much of the pond's substratum was devoid of vegetation, but some *Sparganium* sp. occurred in the deepest water at the centre of the pond.

Water temperature was measured with a thermograph. In spring of both years, the thermograph was placed 1 m in from the steep western bank at a spot where the *Carex* bed abutted the *Potamogeton-Myriophyllum* bed. Position of the thermograph was marked with an aluminum stake that remained in place throughout the study. During ice free periods of 1978, this station was in at least 30 cm of water; however during 1979, the water level dropped more than during 1978 and we moved the thermograph deeper into the *Potamogeton* bed to ensure it was in at least 30 cm of water. Mean weekly water temperature (Fig. 1) was calculated by averaging the high and low temperature for each day and averaging these means over a week's time.

After ice-breakup in late April 1978, water temperature rose slowly during May and June. The shallow pond was susceptible to changes in air temperature, and water temperature dropped during periods of cool, cloudy weather. Average daily water temperature remained fairly constant from late June to mid-August, at which time the water started cooling. Water temperatures continued to drop until freeze-up, which occurred in late October or early Novem-

Fig. 1. Mean weekly water temperature.

ber. The higher water temperature in both spring and autumn 1979 reflected the hot, dry weather during spring and summer of that year.

Dissolved oxygen concentrations and pH were measured at the site of the thermograph on every sampling trip, approximately every 2 weeks. Dissolved oxygen values ranged from 5.0 to 14.4 mg/l (62 to 149% saturation). Although the DO content fluctuated widely between sampling dates, there was a tendency for higher values in late summer and early autumn. The pH ranged from 6.9 to 7.6 with no discernable seasonal pattern.
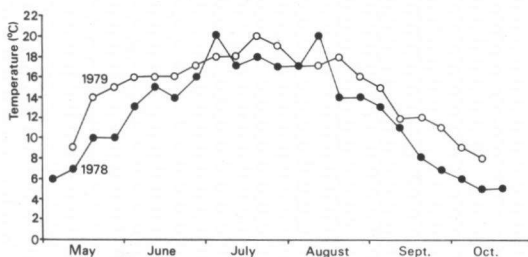
SAMPLING METHODS

We sampled the pond approximately every 2 weeks during the ice-free periods of 1978 and 1979. Samples were taken with a dip net having a mesh of square holes that were 210 um along each side. One sample was taken from the *Carex* bed and one from the *Potamogeton-Myriophyllum* bed on each trip if the plants were present. In 1978, the mud bottom (in areas devoid of vegetation) was also sampled but no larvae were collected in this area. During 1979, we also took samples from the *Sparganium* bed (*Sparganium* was very sparse in 1978), but few zygopterans were found in this area until late autumn, at which time the *Carex* bed and much of the *Potamogeton-Myriophyllum* beds were dry. Samples were preserved in the field with Kahle's fluid (formalin 11%; 95%-ethanol 28%; glacial acetic acid 2%; water, added in the field, 59%).

OBSERVATIONS ON LIFE CYCLES

We attempted to determine size ranges for the different instars by constructing a histogram of head widths of all *E. boreale* larvae collected during the study (Fig. 2). However, larvae were rare and only the final three instars could be determined. Larvae in the final instar could be distinguished from larvae in the penultimate instar by their long wing pads. Larvae in instars smaller than F-2 were combined into four size classes based on head width (1.8-2.0, 2.0-2.2, 2.2-2.4, 2.4-2.6 mm). Larvae with head widths smaller than 1.8 mm were excluded from the analysis because we were concerned about confusing small *Coenagrion resolutum* larvae, which were also present in the pond, with small larvae of *E. boreale*. The two species were distinguished by the presence of small dark dots on the postocular areas of *C. resolutum* (BAKER & CLIFFORD, 1980). Larvae with head widths of 1.8-2.0 mm had probably gone through five or six instars. We originally intended to compare the life cycle of *E. boreale* larvae from the different vegetation zones; but, because larvae were rare, we combined all samples to obtain large enough sample sizes.
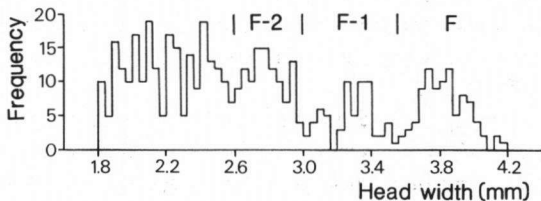

Fig. 2. Frequency of head widths of *Enallagma boreale* larvae with probable instars indicated.

Although we sampled the pond in late May 1978, we collected no specimens of *E. boreale*. Starting in June 1978, we took larger samples and were more successful in capturing *E. boreale* larvae. In early June all larvae collected were in instars F-2 to F (Fig. 3). During June and early July, larvae with swollen wing pads disappeared from the population and this corresponds with the flight period, 1 June to 5 July; in late June and early July, the population was made up mostly of medium-size larvae. These larvae must have been present during the previous year, as they were too large to be the offspring of those animals that emerged in June 1978. RIVARD et al. (1975) have shown that the development time of *E. boreale* eggs is approximately 60 days at 17.5°C. Zygopteran eggs were found only in *Potamogeton;* and, since the thermograph near the *Potamogeton* bed indicated a temperature of approximately 14-15°C during June, it seems unlikely that eggs laid in early June could hatch, and the larvae in 1 month be half grown. These larvae continued to grow during summer and by September 1978 the majority of larvae were in the final instar. Many had swollen wing pads during late May and June of the next year, and they disappeared from the population by 10 July. The flight period was 8 June to 25 July.

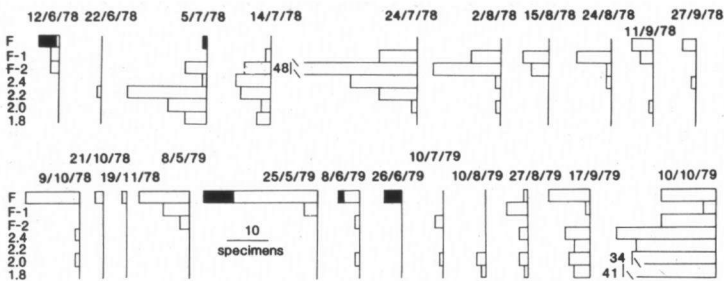We collected fewer animals in the mid-size range in July 1979 than in July 1978;

Fig. 3. Instar-frequency distribution of *Enallagma boreale* larvae in instars F to F-2, and size frequency distribution for smaller larvae with head widths of 1.8-2.6 mm. Black areas represent frequency of final instars with swollen wing pads. Scale represents ten specimens.

this made it more difficult to determine the life cycle of the 1978 cohort. A few animals were present however during July and early August, and the F-1 and F instar larvae present in late August-early September 1979 probably represent the 1978 cohort.

During late September and October 1979, the large number of larvae in the mid-size instars represent the 1979 cohort, which, in contrast to the 1977 and 1978 cohorts, developed quickly during their first summer. Possibly some larvae in the 1979 cohort grew fast enough to emerge the following spring.

DISCUSSION

Results suggest that most *E. boreale* larvae in our study were semivoltine. Larvae in the 1977 cohort overwintered the first time (1977-1978) in early instars (head width less than 1.8 mm) and the second time (1978-1979) in instars F to F-2. However, the life cycle was variable in terms of both rate of development and size of cohorts. For example, the 1979 cohort overwintered the first time (1979-1980) in mid-size instars and some may have emerged the next spring.

RIVARD et al. (1975) suggested that, at their study site near Montreal, Quebec (46° N, 74° W), local water temperatures were similar to the optimal temperature range for development of *E. boreale* eggs. They showed that the percent mortality of eggs held at constant temperatures of 15.0, 17.5, 20.0, 22.5, 25.0°C was 100.0 75.4, 75.0, 0.0, 0.0% respectively. Water temperatures in our study were much lower than the optimal range found for egg development by Rivard et al., and this may, in part, explain the variability in life cycle. During June 1978 (when most adults emerged and presumably most eggs were laid) water temperature was approximately 15°C and even in July water temperature was only 18°C. Possibly the low temperature resulted in large mortality of eggs, causing the small size of the 1978 cohort. Water temperature during spring and fall 1979 was higher than during the same seasons in 1978; and it is possible that more eggs hatched and

larvae developed faster than in 1978, resulting in the large number of half-grown larvae in autumn 1979. Thus, our study suggests that temperature may markedly influence both the development rate of larvae and size of cohorts in areas such as the boreal forest of Alberta.

There are few studies with which to compare our results. PEARLSTONE (1971) suggested *E. boreale* was univoltine in southwestern British Columbia, and there may have been "two. overlapping generations." His results can also be interpreted as a mixture of univoltine and semivoltine animals. INGRAM & JENNER (1976) found *Enallagma hageni* was univoltine in North Carolina but, at the same location, some larvae of *E. aspersum* were univoltine while others were bivoltine. KORMONDY & GOWER (1965) found *E. ebrium* was univoltine in Pennsylvania. JOHANNSSON (1978) suggested *E. cyathigerum,* which is closely related to *E. boreale* (CANNINGS & STUART, 1977), was univoltine in a pond in the Norfolk Broads of England. MACAN (1964) studied the life cycle of *E. cyathigerum* in an English moorland fishpond. He suggested that, in at least some years, some eggs hatched early enough for the larvae to grow quickly during their first summer and emerge the following summer. However he notes that most eggs hatch later and that larvae from these eggs are too small to emerge the following summer and will take 2 or 3 years to develop to maturity.

It is instructive to compare the life cycle of *Enallagma boreale* with that of *Coenagrion resolutum* from the same pond (BAKER & CLIFFORD, 1981). During summer of both 1978 and 1979, *C. resolutum* larvae grew fast enough from eggs hatched that summer to be in instars F-6 - F-4 by early August. Thus the lower temperatures in 1978 did not appear to affect the life cycle as we have suggested for *E. boreale.* The difference is probably related to the effect of temperature on eggs. RIVARD et al. (1975) suggested *E. boreale* eggs take 60 days to hatch at 17.5°C and 75% of the eggs will perish before hatching; at 15°C, 100% perish before hatching. However, SAWCHYN & GILLOT (1975) have recorded eggs of *C. resolutum* taking only 29 days to develop at 16°C; they give no results on mortality. Hence, it appears that *C. resolutum* larvae are adapted for developing at lower temperatures than *E. boreale,* and this difference may account for differences in life histories under the same environmental conditions.

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