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LIFE CYCLE OF THE EARTHWORM PREDATOR *ARTIOPOSTHIA TRIANGULATA* (DENDY) IN NORTHERN IRELAND

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Summary—The terrestrial planarian *Artioposthia triangulata* was sampled weekly for 4 y using shelter traps. Numbers of trapped and individual planarian weights were recorded. On each sampling occasion, planarians were allocated to one of four size categories on the basis of their weight. These data are presented and the life cycle in Northern Ireland is deduced. Planarian growth occurs during the autumn–spring period and coincides with earthworm (prey) availability. Weight loss in the early summer is associated with egg capsule production. These capsules take over 2 months to hatch, so that recruitment into the population occurs in late summer. © 1997 Elsevier Science Ltd

INTRODUCTION

Artioposthia triangulata (Dendy) is a terrestrial planarian from New Zealand that has successfully colonized some areas of north-west Europe, including Northern Ireland (Blackshaw and Stewart, 1992). It preys on earthworms and is capable of significantly reducing numbers (Blackshaw, 1990, 1991, 1995) and changing the species composition of earthworm communities (Blackshaw, 1995). This may have implications for soil fertility and crop growth (Lee, 1985) and for the conservation of those species of birds and small mammals that feed upon earthworms.

In common with most other planarians, *A. triangulata* is an hermaphrodite. Although cross-fertilization has not been proven for this species, it is the norm for the group (Froehlich, 1955). The eggs are released in a batch and enclosed within a capsule or cocoon. The numbers of young emerging from these capsules average about six (Blackshaw and Stewart, 1992). The capsules are large, black and easily seen, and may be found on the soil surface, in association with inactive flatworms under shelter, or in the soil itself (Willis and Edwards, 1977).

The capsules can occur from March to October (Willis and Edwards, 1977); a peak in production in early summer has been noted (Blackshaw and Stewart, 1992).

Development of eggs within capsules is highly temperature-dependent and it may be at least 1–2 months before hatching occurs (Blackshaw and Stewart, 1992). It is also likely that each individual will only produce relatively few capsules, because of the energy demands involved (Blackshaw and Stewart, 1992). Recruitment into the population is therefore likely to be slow.

Artioposthia triangulata can be trapped on the soil surface through the use of shelter traps (Blackshaw, 1990). These provide an easy, low-cost means of following changes in the size of individuals, although they cannot be relied upon to provide an estimate of the absolute population (Blackshaw, 1990). The planarian undergoes periods of both growth and degrowth (Blackshaw, 1992) and, consequently, individual ages cannot be determined by size. Conventional quantitative approaches to the study of its life cycle are therefore inappropriate.

Blackshaw (1995) reported seasonal changes in the average weight of trapped planarians. These changes provide a means of deducing growth patterns and the life cycle of *A. triangulata* under Northern Ireland conditions.

MATERIALS AND METHODS

The study site was an area of established grass (20 × 15 m) at Newforge lane, Belfast. Brassicas were grown adjacent to the sampling area from 1984 to 1987. The ground was then left fallow until it was ploughed in December 1990. Potatoes were grown in the cultivated area in 1991 and spring barley in 1992.

Ceramic tiles (15 × 15 cm) overlaying a thin sheet of polystyrene (Blackshaw, 1990) were arrayed in a

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regular pattern (4 × 5) at a spacing of 3 m on the soil surface in the grass area. Traps were examined weekly; individual planarians were weighed and then returned to the centre of the study area. Numbers of egg capsules were also recorded and removed.

Average weights were calculated for each week. Mean weights and numbers of *A. triangulata* were transposed to 6 wk running means to reduce the effects of interweek variations in activity.

For each week, each planarian was allocated to one of four size categories (< 200 mg, 200–400 mg, 400–800 mg, > 800 mg). These data were then expressed as the proportion of the weekly catch in each size category and transposed to 6 wk running means.

Sampling started in April 1988. Only data for the calender years 1989–1992 are presented here, but results for the last 5 wk of 1988 were incorporated so that the running means for the first 5 wk of 1989 are unbiased.

RESULTS

A total of 103 egg capsules were recovered and 2472 observations were made on planarians from under the traps during this study. The numbers of planarians caught each year declined over the 4 y period from a maximum of 72 wk^{-1} in 1989 to only intermittent individuals in 1992.

The numbers of planarians trapped and their mean weekly weights showed marked seasonal fluctuations (Fig. 1). There were numerical peaks in the late spring/early summer of each year and these were preceded by the attainment of the peak mean weight for that year. There were also noticeable increases in numbers caught towards the end of 1989 and 1990. A similar pattern of autumnal increase in 1991 was truncated because of a collapse in numbers trapped from September onwards.

The distribution of trapped planarians into discrete size categories and the recovery of egg capsules are shown for each year in Fig. 2.

Capsule production occurred between weeks 11 and 28 (i.e. mid-March to mid-July) This was immediately preceded by a peak in the proportion of the population in excess of 800 mg each year and succeeded by an increase in that proportion weighing less than 200 mg.

Both the smallest and largest size categories showed a single peak cycle each year. By contrast, the two middle size categories (200–400 mg and 400–800 mg) showed two distinct peaks as a proportion of the trapped population for 1989, 1990 and 1991. The shortage of planarians under the traps towards the end of 1992 made interpretation of the data in the second half of that year problematic.

DISCUSSION

Data collected from shelter traps invariably depend upon both the size of a local population and the activity of individuals. This activity may be influenced by a changing environment or by behavioural characteristics. For terrestrial planarians, which are stenohygric hygrocoeles (Froehlich, 1955), a shortage of moisture in the summer months is likely to reduce activity, as indicated for *A. triangulata* in Fig. 1. In Northern Ireland, soils are wetter from autumn through to spring and

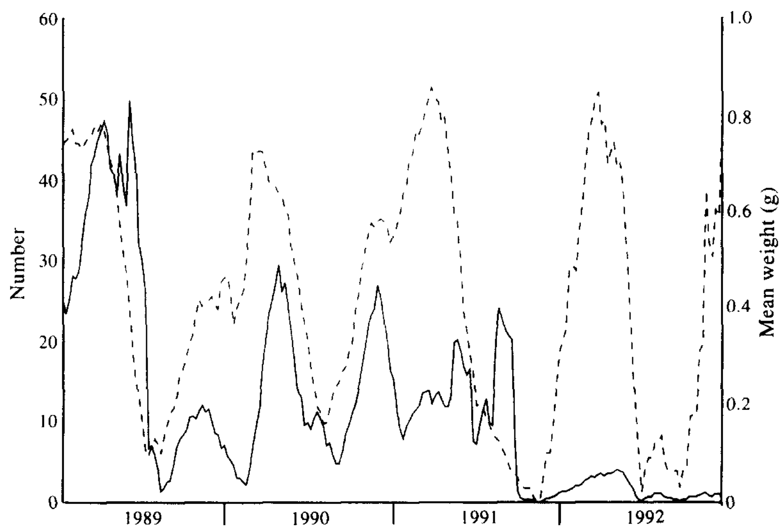

Fig. 1. Weekly counts of the numbers of *A. triangulata* trapped (solid line) and their mean individual weight (dotted line) for 1989–1992. Data are presented as 6 wk running means.

hence greater trap catches would be expected at these times.

Temperature will also play a role because *A. triangulata* has a relatively low upper lethal temperature of ca. 20°C (Blackshaw, 1992) and retreats into the soil when surface temperatures became uncomfortable. Individuals have been observed under debris on the soil surface during frosts (R. P. Blackshaw, unpubl. data) but, generally, cool temperatures may be expected to reduce overall activity and hence the frequency of planarians encountering a shelter trap. This is the probable reason for the marked declines in trap catches in the early part of the year during 1989–1991 (Fig. 1).

Neither of these factors affords a convincing explanation for the peak catches occurring in early summer each year. Since these peaks coincide with the production of egg capsules (Fig. 2), they may reflect behaviour-induced activity related to either mating or the search for suitable oviposition sites.

The seasonal changes in numbers of *A. triangulata* trapped are shadowed by changes in the weights of the planarians (Fig. 1). Since this species appears to be an opportunist feeder (Blackshaw and Stewart, 1992), it is reasonable to assume that greater trap catches reflect higher activity, with more opportunities for predation and, hence, growth. The fact that the times when there is more planarian activity follow a similar pattern to that of earthworm activity (Satchell, 1967) only serves to reinforce this hypothesis.

Blackshaw (1991) calculated an average weight gain of 116 mg wk^{-1} for *A. triangulata* feeding on *Eisenia fetida* (Savigny) in the laboratory. During this study, the fastest rate of growth was achieved in the winter of 1991–1992, when the weekly average weight increased from 53 to 836 mg over a 16 wk period, equating to a rate of growth of 49 mg wk^{-1}. Thus, the maximum observed rate of growth in the field is much less than that found in

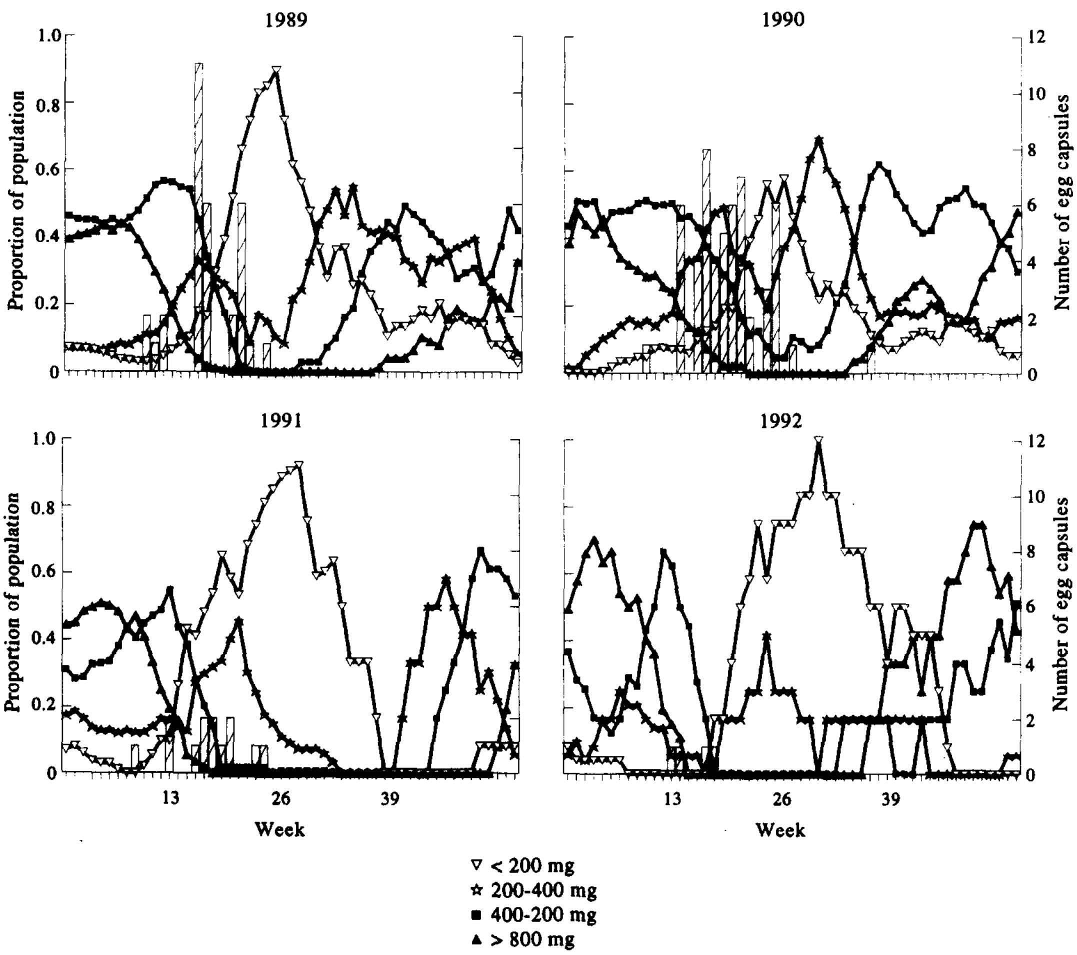

Fig. 2. Numbers of *A. triangulata* egg capsules found (histogram) and the proportion (6 wk running means) of trapped planarians weighing 200 mg (shaded triangles), 200–400 mg (stars), 400–800 mg (squares) and 800 mg (solid triangles) from 1989 to 1992.

the laboratory, as had been postulated by Blackshaw (1991).

Of equal interest is the rate of weight loss coinciding with the production of egg capsules. The capsules are large structures and weigh from 100 to 180 mg (Blackshaw and Stewart, 1992). Their deposition represents a substantial loss of body tissue to an individual planarian.

Considering 1989 as an example (Fig. 1), the rate of weight loss from the spring peak weight (783 mg) to the summer minimum (94 mg) was 46 mg wk^{-1}. This indicates that the maximum body tissue available for reproduction was 689 mg over 15 wk. The capsule weight range of 100–180 mg suggests that production may therefore be limited to 3.8–6.9 capsules $individual^{-1}$ over this period. In Northern Ireland, an average six juveniles hatch from each capsule (R. P. Blackshaw, unpubl. data, quoted in Blackshaw and Stewart, 1992). The potential reproductive rate in the field is likely to be less than 40 offspring $planarian^{-1}$ y^{-1}.

The prevalence of small *A. triangulata* (< 200 mg) following capsule production is indicative of hatch and recruitment (Fig. 2). The time between peak capsule deposition in 1989 and 1990 and the peak proportion of individuals < 200 mg was 9 wk. This is in line with the results presented by Blackshaw and Stewart (1992). In 1991 and 1992, the capsule peak was not clear. Despite this, the data suggested an egg development phase of at least the same duration as the previous 2 y.

Tabulation of the week in which peaks of the planarian size classes occurred for 1989–1991 (Table 1) indicates a pattern of degrowth that starts when the population consists mainly of larger individuals (> 800 mg) at the beginning of the year. These reduce in size so that the 400–800 mg category peaks first, and then the 200–400 mg category. This is linked to the production of capsules and is followed by a period when the smallest individuals dominate the population in the summer. The process is mirrored by a period of growth in the latter half of the year.

It is not known if *A. triangulata* adults die after reproduction. [Indeed, the term "adult" is dubious since a planarian short of food will utilise its reproductive organs as a reserve (Bowen *et al.*, 1976)!].The rise in the proportion of the population weighing 200–400 mg, as larger-sized groups declined, and their presence throughout the period of capsule production and recruitment into the population imply that some of the reproductively active planarians may at least survive for a period after capsule production. It is therefore possible that individuals can live for more than 1 y, and this may explain the occasional very large (> 3 g) *A. triangulata* that have been seen (R. P. Blackshaw, unpubl. data). This must, however, remain as speculation until a means of determining the age of individuals is discovered.

Table 1. The timing of peak proportions in different size categories of the *A. triangulata* population (in weeks since the start of the year)

	Year		
Size (mg)	1989	1990	1991
< 200	25	27	30
200–400	16, 34	20, 31	23, 47
400–800	12, 40	11, 38	15, 51
> 800	7	3	7

Although there is still a need to work out much of the detail, this study has established the outline of the life cycle of *A. triangulata*, in Northern Ireland at least. The growth of individuals takes place over the winter and spring when conditions are suitable and earthworms are more readily available. Reproduction occurs mainly in early summer and causes considerable weight loss to individuals. Most of the resultant capsules hatch by late summer.

The timing of this life cycle was not fixed in this study, and size class peaks occurred at different times each year (Table 1). Food is the major factor limiting *A. triangulata* population growth in Northern Ireland (Blackshaw, 1995). It may also be a driving force behind the life cycle, with capsule production not starting until sufficient food reserves have been laid down. Since earthworm availability depends upon both population size and (climate-driven) activity, deviations from the pattern found in this study can be expected in other regions colonized by *A. triangulata*.

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