Ann. appl. Biol. (1991), **118**, 689–694
Printed in Great Britain

Mortality of the earthworm *Eisenia fetida* (Savigny) presented to the terrestrial planarian *Artioposthia triangulata* (Dendy) (Tricladida: Terricola)

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(*Accepted 7 March 1991*)

Summary

Artioposthia triangulata is a terrestrial planarian that feeds on earthworms. Up to 76% of field collected *A. triangulata* fed on *Eisenia fetida* earthworms at 10 °C in the laboratory. In one experiment, the feeding rate declined from 63% of earthworms attacked to 36% and 34% in the first, second and third feeding opportunities over a week. The average number of *E. fetida* eaten was 1.4 per planarian per week. The gain in weight of individual *A. triangulata* was significantly related to the amount of earthworm tissue lost during the feeding process. Over a one week period, the amount of earthworm tissue lost was related to the total amount presented to the planarians but not to their size. Frequency of attack was, however, related to planarian size. The results are discussed in relation to an hypothetical population of earthworms in pasture. It is concluded that the results support the contention that *A. triangulata* could seriously deplete earthworm populations.

Key words: Flatworm, predation, food conversion

Introduction

The terrestrial planarian (or flatworm) *Artioposthia triangulata* (Dendy) originates from New Zealand (Dendy, 1894) and feeds on earthworms. It was first recorded outside New Zealand in Northern Ireland in 1963 (Willis & Edwards, 1977) and has been noted as a potential threat to the earthworm populations of Northern Ireland (Blackshaw, 1990).

Despite its association with a marked decline in earthworm numbers in an experimental site in Belfast over a relatively short time period (Blackshaw, 1989, 1990), there are no quantitative estimates of the planarian's feeding activities. Such estimates are central to informed judgements on the likely impact on the indigenous earthworm population.

This paper reports laboratory studies on aspects of *A. triangulata* feeding and is the first attempt to quantify the number of earthworms to be attacked and the consumption of earthworm tissue.

Materials and Methods

Experiment 1

Individual *A. triangulata* were recovered from under tile traps (Blackshaw, 1990) placed in two fields at Newforge Lane, Belfast during the autumn of 1989 and winter of 1990. They were brought into the laboratory and stored at 10 °C on damp filter paper in inverted plastic

Petri dishes. After 24 h each planarian was weighed and an *Eisenia fetida* (Savigny) earthworm, of known weight, placed with it in a clean dish. The dishes were then stored at 10 °C for a further 24 h. At the end of this period, the number of earthworms attacked was assessed, the planarians re-weighed and any earthworm remains weighed. A total of 120 *A. triangulata* were used.

For those that fed, the increase in planarian weight was calculated along with the amount of earthworm tissue lost (either the total earthworm weight or initial weight minus the weight of the remains) and examined in relation to *A. triangulata* and earthworm weights at the start of the experiment.

Experiment 2

A. triangulata were collected from the same sites as in Experiment 1 on nine occasions between November 1989 and March 1990 and subjected to the same procedure. At the end of the 24 h feeding period they were rested for a further 24 h before repeating the process. A third feeding period commenced 72 h after the second one finished so that each planarian had the opportunity to feed three times over a seven day period. A total of 99 *A. triangulata* were thus examined.

For each week of the study in Experiment 2, the number of earthworms attacked and the mean planarian weight, earthworm weight and total earthworm weight loss were recorded (Table 1).

The weights from the first 50 *A. triangulata* that fed during the first 24 h feeding period were abstracted and the data analyses undertaken in Experiment 1 repeated.

Results

Of the 120 *A. triangulata* in Experiment 1, 91 (75.8%) attacked earthworms. A smaller proportion (62.6%) of the 99 *A. triangulata* in Experiment 2 attacked earthworms during the first feeding period. The attack rate in Experiment 2 declined to 36.4% and 34.3% in the second and third feeding periods respectively.

Significant relationships were found between the increase in planarian weight as a result of feeding (= Gain) and the weight of earthworm tissue not recovered after feeding (= Loss).

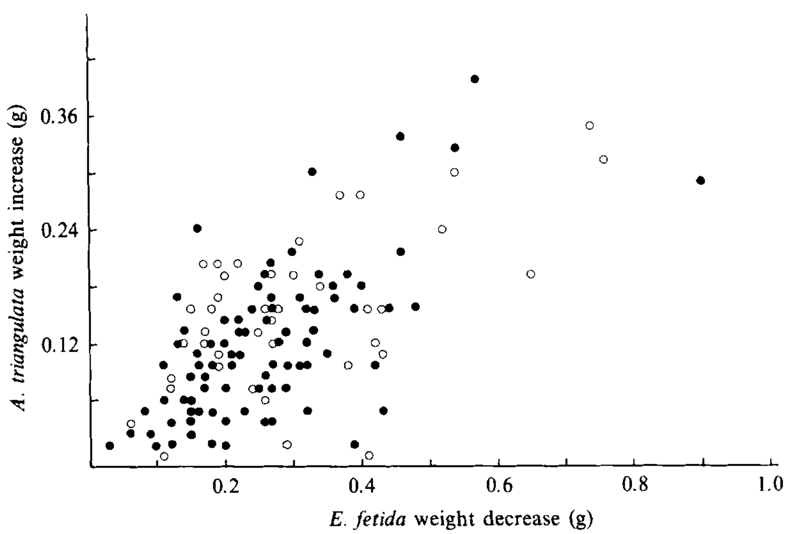

Fig. 1. Weight changes for *A. triangulata* feeding on *E. fetida* in Experiment 1 (●) and Experiment 2 (○). Coincident points are not shown.

Table 1. *Numbers and weights of* A. triangulata *and earthworms in Experiment 2*

Date collected	Number of planarians	Worms attacked	Mean weights (g) Planarian†	Worm	Consumed*
28.11.89	11	12	0.270	0.467	0.408
5.12.89	4	5	0.460	0.316	0.412
9.1.90	13	17	0.607	0.303	0.282
16.1.90	14	22	0.837	0.329	0.411
23.1.90	7	10	0.472	0.291	0.359
13.2.90	10	12	0.700	0.257	0.310
20.2.90	12	13	0.861	0.194	0.198
27.2.90	10	11	0.944	0.212	0.216
20.3.90	18	37	0.776	0.205	0.324

* Sum of all earthworm tissue not recovered from three feeding opportunities.
† Weight at the beginning of the one week feeding period.

Table 2. *Frequency of attacks on earthworms in one week by different sizes of* A. triangulata

Size (g)	Number of attacks per week n	0	1	2	3	Mean
<0.2	7	3	4	0	0	0.57
0.2–0.4	17	2	11	3	1	1.18
0.4–0.8	35	6	17	8	4	1.29
>0.8	40	4	11	16	9	1.75

The two data sets (Fig. 1) were tested for coincidence and it was found that a single regression line could adequately describe them:

$$\text{Gain} = \underset{(\pm 0.037)}{0.359}\,(\text{Loss}) + \underset{(\pm 0.011)}{0.032}\ (r = 0.639;\ P < 0.001) \qquad (1)$$

Within these data were 20 instances of partial consumption of earthworms by *A. triangulata*. The comparable relationship was:

$$\text{Gain} = \underset{(\pm 0.052)}{0.507}\,(\text{Loss}) - \underset{(\pm 0.020)}{0.030}\ (r = 0.917;\ P < 0.001) \qquad (2)$$

However, if these 20 data units were omitted from the total data set the regression between planarian weight increase and earthworm weight loss became:

$$\text{Gain} = \underset{(\pm 0.046)}{0.278}\,(\text{Loss}) + \underset{(\pm 0.013)}{0.055}\ (r = 0.481;\ P < 0.001) \qquad (3)$$

and this was not parallel to Equation 2.

The summarised results from Experiment 2 (Table 1) showed that the average number of earthworms attacked each week was 1.40 (standard deviation = 0.91) per planarian. A total of 15 individuals did not attack any earthworms. Weighted regression analysis indicated that the average amount of earthworm tissue lost as a result of *A. triangulata* feeding was related to the mean weight of tissue presented to the planarians over one week:

$$\text{Loss} = \underset{(\pm 0.245)}{0.663}\,(\text{worm weight}) + \underset{(\pm 0.071)}{0.134}\ (r = 0.715;\ P < 0.05) \qquad (4)$$

though not to the mean weight of the planarians ($r = -0.319$; $P > 0.10$).

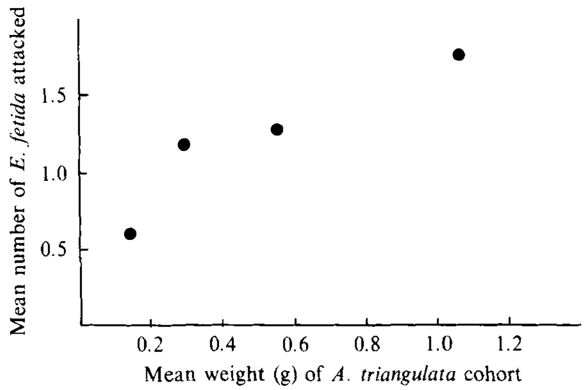

Fig. 2. Relationship between average numbers of *E. fetida* attacked and average weight of four cohorts of *A. triangulata*.

The planarians were divided into discrete weight groups and the frequency of attacks and average number of attacks tabulated (Table 2). The average number of attacks per week was then plotted against the average weight of planarians in each group (Fig. 2).

Discussion

The relatively high number of attacks observed in Experiment 1 (75.8%) and the first feeding opportunity in Experiment 2 (62.6%) compared with the second (36.4%) and third (34.3%) feeding opportunities in Experiment 2 may be indicative of a state of hunger existing in field populations. Nevertheless, individual *A. triangulata* were recovered that would not feed when presented with earthworms over a one week period.

The feeding mechanism of *A. triangulata* consists of enveloping the earthworm prey and secreting digestive juices that dissolve the prey tissue; the resulting liquid is taken in through the pharynx (Willis & Edwards, 1977). Even casual observation shows that there are residues left in experimental dishes. This may consist of discoloured filter paper or a partially eaten earthworm. It is likely, therefore, that there were substantial errors involved in the estimation of earthworm weight loss in these studies. These will contribute to reduced correlation coefficients and associated significance levels.

The number of earthworms attacked was related to the size of the planarian (Table 2). Logically a planarian of zero weight can make no attacks, so the shape of this relationship (Fig. 2) is probably curvilinear – suggesting a maximum average attack rate of less than two worms per week under these experimental conditions. Extrapolation to the field is difficult but greater predatory pressure may be expected in the late spring and early summer when *A. triangulata* appears to reach maximum size prior to reproduction (R. P. Blackshaw, unpublished data).

In contrast, the amount of earthworm tissue lost as a result of feeding for a week was not dependent on *A. triangulata* size even though it was related to the mean weight of worm presented to the planarians (Equation 4). There is an apparent anomaly between this conclusion and Fig. 2, where the number of attacks increased with the size of planarian. At present, there is no adequate explanation for this.

The gain in planarian weight was shown to be related to the weight of earthworm tissue lost in Fig. 1. Although there was also a significant relationship between the mean weight of earthworm tissue lost and the mean weight of earthworms presented each week, this was derived from a relatively narrow earthworm size range and may not hold true for larger individuals or other prey species. The difference in efficiency of conversion between partially and fully consumed earthworms (Equations 2 and 3 respectively) may be caused by excessive production of the digestive juices for the latter, so that digestion of the earthworm tissue continued after feeding had ceased. This phenomonum has previously been observed and can manifest itself as pools of dissolved earthworm tissue in a Petri dish (R. P. Blackshaw, unpublished data).

It is unlikely that biomass loss to the earthworm population can be predicted from *A. triangulata* size and/or growth at this point.

The choice of *E. fetida* as an experimental prey organism was largely determined by its ready availability from stock cultures. This species is generally not considered to be representative of soil dwelling earthworms and may be more or less palatable to *A. triangulata* than other species. The decline in feeding rate from 63% to 36% for first and second feeds in Experiment 2 could be equally due to prey unpalatability, rather than a state of hunger in the planarian field populations. (Under this scenario, the feeding rate of 1.4 earthworms planarian^{-1} week^{-1} would be an underestimate). Furthermore, this study was carried out at a single temperature, 10 °C. Care must therefore be exercised in extrapolating from these data. Nevertheless, the results do provide the first opportunity to estimate the quantitative impact of *A. triangulata* feeding on earthworm populations.

Edwards & Lofty (1977) tabulated the numbers and weights of earthworms reported from different studies, and included three populations listed from UK pasture. Earthworm populations of 389 – 470 m^{-2} weighed 52 – 110 g (Svendson, 1957), 390 m^{-2} weighed 56 g (Reynoldson, O'Connor & Kelly, 1955) and 481 – 524 m^{-2} weighed 112 – 120 g (Reynoldson, 1955). The average weight of earthworms in these studies is within the range of weights recorded in Table 1.

If it is assumed that an earthworm population of 475 m^{-2} with a biomass of 110 g is typical of UK grassland soils and that the average number of worms taken by *A. triangulata* is 1.4 per week, then a planarian population of 6.52 m^{-2} could remove this population in a year. If the relationship from Equation 1 also held true, an earthworm population of this size could contribute an additional 39.5 g of planarian tissue.

Blackshaw (1990) recovered *A. triangulata* populations at densities in excess of 6.5 m^{-2} from 22 out of 160 quadrats in eight sites so populations at this level may exist. He also found that planarian numbers were positively correlated with earthworm numbers across the eight fields, suggesting that *A. triangulata* populations may adjust to the level of food available to them. Implicit in this hypothesis is that earthworm biomass is the most important regulator of planarian numbers. The projected contribution of 39.5 g of planarian tissue from an earthworm biomass of 110 g m^{-2} does not take account of metabolic losses and mucus secretion between feeds. Nevertheless, the weight of tissue would only equate to the production of six progeny, growing to a weight of 1 g, from each *A. triangulata* in a population of 6.5 m^{-2}.

However, the planarians may not be able to maintain a feeding rate of 1.4 earthworms per week, especially if the hypothesis of hunger existing in field collected specimens is true. In addition, the above projections do not consider earthworm reproduction. Rather than elimination over one year therefore, what is more likely to happen is a gradual shift in the predator-prey balance so that the depredations of the population of *A. triangulata* eventually exceeds the capacity of the earthworm population to replace lost individuals and a rapid decline ensues. Under this scenario, planarian population densities would generally be less than 6.5 m^{-2}. This hypothesis is consistent with what has been observed in field surveys of the planarian (R. P. Blackshaw, unpublished data) and the pattern of reported disappearance of earthworms in a field where *A. triangulata* activity had been known for some time (Blackshaw, 1990). In order for this hypothesis to be sustained the planarian needs a strategy to cope *with* food shortages when earthworm populations have been brought to a low density; planarian death would enable the earthworm numbers to recover. There is no evidence of an alternative food source for *A. triangulata* but it does appear to be able to survive prolonged periods without feeding (R. P. Blackshaw, unpublished data).

The results support the contention of Blackshaw (1990) that *A. triangulata* may be capable of eliminating an earthworm population locally and emphasise the potential importance of this planarian.

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(Received 30 October 1990)