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Abundance, reproduction, and feeding of three species of British terrestrial planarians: Observations over 4 years

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Abstract
Over 4 years, daily counts recorded 830 *Microplana scharffi*, 2752 *M. terrestris*, and 108 of an unknown khaki *Microplana* species under wood, concrete, polythene, and a plank at a shaded site in a domestic garden. Numbers peaked in July and August. *Microplana scharffi* more often occurred under polythene, *M. terrestris* and the khaki species more often under wood. Cocoons peaked in June and July and hatchlings between July and September. Twelve *M. terrestris* cocoons yielded 50 hatchlings. Three *M. scharffi* cocoons yielded eight hatchlings. The time taken to hatch reduced from February to August. Earthworms accounted for 87% of *M. scharffi* prey. *Microplana terrestris* consumed earthworms, *Arion hortensis* and *Discus rotundatus*. Hatchling and unfed *M. scharffi* were yellow or cream. Fed individuals varied from pink to pale brown, depending on prey colour.

Keywords: *Feeding, populations, reproduction, terrestrial planarians, Tricladida*

Introduction

Microplana terrestris (Müller, 1774) and *M. scharffi* (Graff, 1896) are European terrestrial planarians with a widely scattered distribution in the British Isles (Jones 2005) and the rest of Europe. Terrestrial planarians are all scavengers or predators on various soil invertebrates (Ogren 1995), but both the above species can be considered to be "ecologically insignificant" (Jones and Boag 1996; Jones 2005), having little effect on prey populations. All terrestrial planarians require damp conditions so that activity patterns are affected by rainfall and soil moisture levels (Cumming 1995; Jones et al. 2001a; Boag et al. 2005). Normally, the occurrence of both of the above species is unpredictable and neither is very abundant where they do occur. There are few systematic observations on populations, predatory habits, or reproduction of either species. *Microplana terrestris* feeds mainly on molluscs but also on earthworms and arthropods (Jenyns 1846; Jennings 1959; Gunn 1992, Winsor et al. 2004) and is generally dark grey, almost black, in colour. *Microplana scharffi* feeds mainly on earthworms, but will also feed on molluscs and arthropods (Percival 1925; Gunn 1992; Winsor et al. 2004; Jones 2005). Feeding is known

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to affect the colour of *M. scharffi* which varies from "uniform milk-white" after a period of starvation to yellow, orange, pink, beige, or dirty grey (Percival 1925; Adam and Leloup 1944). Both species are hermaphrodite, lay cocoons and several juveniles hatch from each cocoon. Jennings (1959) noted that *M. terrestris* cocoons were produced from April to August and up to six juveniles hatched from each after 3 weeks. Percival (1925) noted only the dimensions of *M. scharffi* cocoons. Gislén (1944) collated records of *M. terrestris* from across Europe and showed that the highest number of records was in September and the lowest in February. However, these were mostly chance records, not systematically collected over a prolonged period, and many were from parts of Europe with severe winters so that winter records are likely to be few. Neither of these species has been the object of systematic and prolonged sampling.

In contrast, two introduced species, the New Zealand flatworm, *Arthurdendyus triangulatus* (Dendy, 1895), and the Australian flatworm, *Australoplana sanguinea* (Dendy, 1891), have been the subject of several organized studies in the British Isles, particularly the former. Both can be locally numerous, feed almost exclusively on earthworms and may have significant effects on earthworm populations (Blackshaw and Stewart 1992; Alford 1998; Jones et al. 1998; Boag et al. 1999; Cannon et al. 1999; Jones et al. 2001a, 2001b; Santoro and Jones 2001).

In 2000, one of the authors (J.M.) found several specimens of *M. terrestris* and *M. scharffi* in her domestic garden. The occurrence of both species in a convenient location prompted the suggestion that regular monitoring of both be undertaken over an extended period. The intention was to record adult occurrence, prey, cocoons, and juveniles of both species and also colour of *M. scharffi*. Additionally, experiments were carried out in small containers on feeding and reproduction. During the course of the observations, brown (khaki) specimens, similar in size and shape to *M. terrestris*, were seen and separately recorded. Their specific identity is not known and is the subject of further research, though sections show that it is a species of *Microplana* but not *M. terrestris*. They are hereafter referred to as the khaki *Microplana* species.

Materials and methods

Observations were made daily (with a few exceptions) over 4 years (March 2001 to February 2005) in a domestic garden near Thirsk, Yorkshire (Ordnance Survey grid reference: SE378848), about 20 m above sea level and 70 m from the River Wiske. The whole garden covers about 3600 m^2, and includes vegetable plots, flower beds, lawns, shrubs, and mature trees and is surrounded by large, mature trees. The soil is alluvial loam overlying glacial sands and gravel, in turn overlying Sherwood group sandstone. Organic gardening principles have been followed over the last 20 years, no herbicides or pesticides being applied. Soil pH of the kitchen site is 6.2. That of other sites ranges from 6.3 to 7.

The main study site (kitchen site) is north facing, immediately adjacent to, and permanently shaded by, the house (Figure 1). The site is about 2.6 m × 3.4 m and occupied by shrubs and ferns. Over the period of observations it was not disturbed by gardening activities, except occasional pulling of weeds, nor did the soil ever dry out. Maximum and minimum air temperatures, rainfall, and soil temperature were recorded. Four traps were placed on the soil surface. (1) A section of tree trunk 35 cm in diameter (962 cm^2) and 11 cm thick, ring side down. (2) A similar section of tree trunk encased in polythene (962 cm^2). (3) A concrete paving slab (about 609 cm^2), 4.7 cm thick. (4) A length of planking 170 cm × 10.5 cm (1785 cm^2), 2.5 cm thick. At around 09:00 h each day each trap

Figure 1. The kitchen site. (a) General view, with one of the authors (J.M.); (b) close-up of traps.

was lifted and the number of each species of flatworm, cocoons and any feeding behaviour and prey recorded. No baiting took place at this site. *Microplana scharffi* <1 cm and *M. terrestris* <0.5 cm were recorded as hatchlings. Where appropriate and for more valid comparisons, results are adjusted to 'per m^2' to take account of the areas of traps and to 'per day' to take account of the number of days (19–31) sampled in each calendar month. Maximum and minimum soil temperatures of 19 and 0°C, respectively, were recorded on several occasions, but at 0°C the site was always frozen under snow and was left undisturbed. The minimum temperature at which observations were made was 1.5°C.

Eight vegetable plots were also sampled (Figure 2). Plot perimeters varied from 9.39 m to 17.94 m and each was surrounded by lawn except for one 4 m section next to paving slabs and two mid-plot sites totalling 2.4 m. Total perimeter length was 108.23 m. Wooden planks (about 10 cm wide) were laid on the soil along all edges of each plot for the purpose of finding and removing slugs. During spring and summer, when the soil remained moist,

Figure 2. The vegetable plots. Planks are placed around the perimeter.

additional records were kept of any flatworms under the planks. The planks were left undisturbed during autumn and winter. A survey of the slugs beneath these planks was made in 2004 to assist in interpretation of the feeding results. The plots were gardened as usual over the study period.

Baiting (squashed slugs) was done at adjacent sites and at the study sites after the 4 years of sampling, but none at the study sites over the sampling period.

Video and photographic records were made where appropriate.

In order to judge to what extent there was repeat counting of flatworms on consecutive days, a length of plank totalling 3.43 m at one vegetable plot was set aside in spring 2002. Numbers of flatworms under this were counted each day for 28 days. For the following 48 days all flatworms were removed daily to another site. For the final 17 days flatworms were counted daily but not removed.

Captive flatworms and collected cocoons were retained in small glass jars which were kept under shrubs at the kitchen site. Flatworms were kept on moist leaf mould and cocoons on moist kitchen tissue. The lids were briefly removed each day to change the air. For each cocoon, the time to hatching and the number of hatchlings was recorded. Captive flatworms were fed on earthworms which had been removed from flatworms feeding beneath the vegetable plot boards, or on squashed slugs.

The colour of each *M. scharffi* seen, and the colour before and after feeding, was noted with reference to ''Dulux Colour Collection'' paint charts. The Dulux colours were consolidated from the original 119 shades actually recorded to 23 colours and further into eight broad colours by an artist used to colour matching. They were further refined into two main categories ''Pale'' and ''Deep'' (or ''Vivid'').

Results were statistically analysed and graphed using SPSS version 14.

Results

Rainfall and temperature

Rainfall over the 4 years showed no regular pattern (Figure 3). Mean January to June rainfall was low over the 4 years. The mean wettest month was August, though the exceptionally high rainfall for August 2004 influenced the mean. The garden was twice flooded by the overflowing River Wiske (2 August 2002 and 8 January 2005) for about 11 h on each occasion. Soil temperature followed a predictable seasonal pattern (Figure 4).

Populations

In total, 3690 flatworms were recorded, 2628 at the kitchen site (Table I) and 1062 in the vegetable plots when conditions were suitable (Table II); 830 *M. scharffi*, 2752 *M. terrestris*, and 108 khaki species were seen. Table III shows the highest numbers of each species on any day. The highest number of flatworms on any day at the kitchen site was 22 (20 *M. terrestris* and two *M. scharffi*) on 18 July 2002. A further indication of population density was obtained after a flood in August 2002 when 23 *M. scharffi* were found drowned in a 6.5 m × 10 cm channel at the edge of a vegetable plot, the equivalent of 35 per m^2 (though some could have been washed into the channel).

At the kitchen site, *M. terrestris* and *M. scharffi* were recorded every month of the 4 years and in three of the years both were most abundant in July or August (Figures 5, 6).

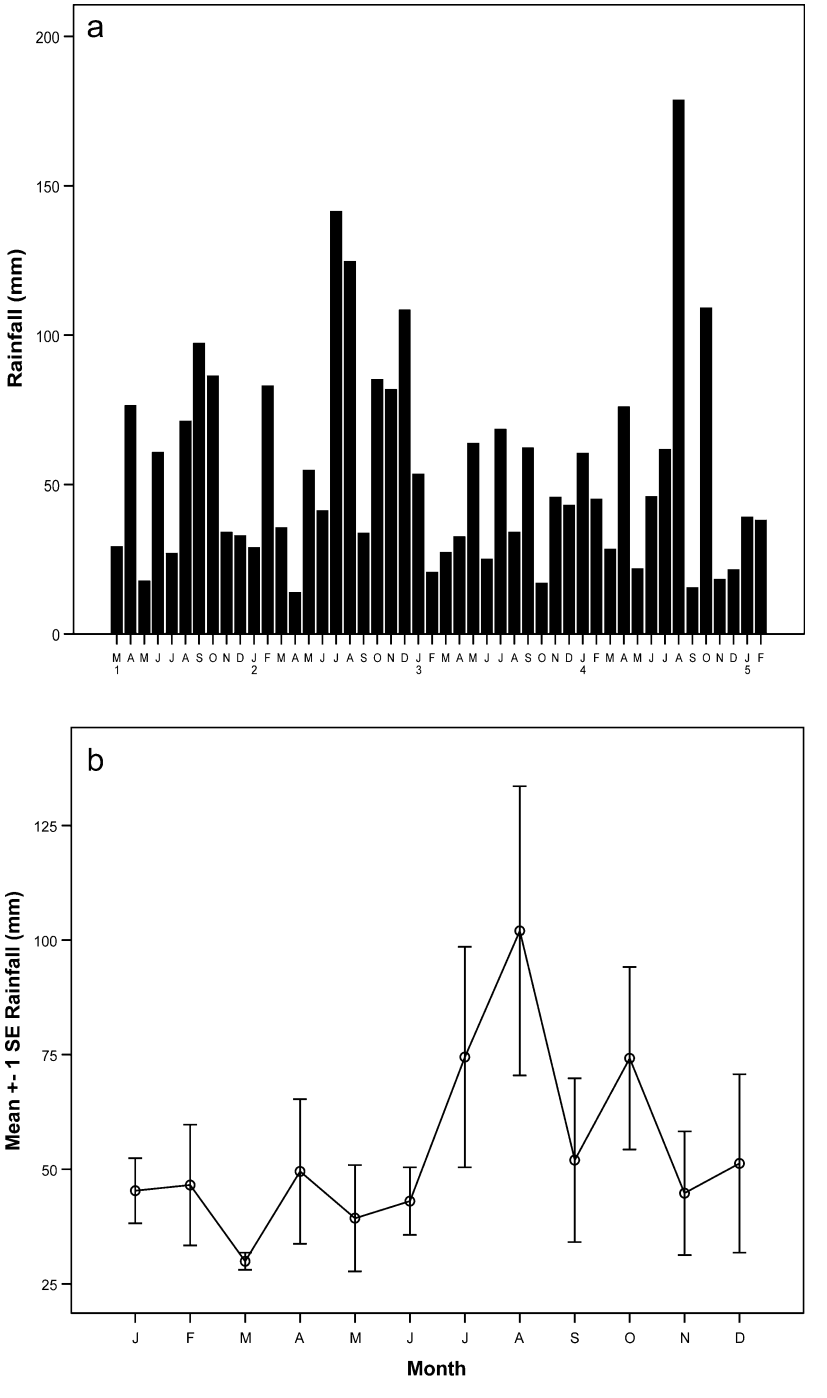

Figure 3. Rainfall (mm). (a) Monthly totals from March 2001 to February 2005: 1 to 5 on the *x*-axis are years 2001 to 2005; (b) mean $\pm$ SE monthly values from January (J) to December (D) over 4 years.

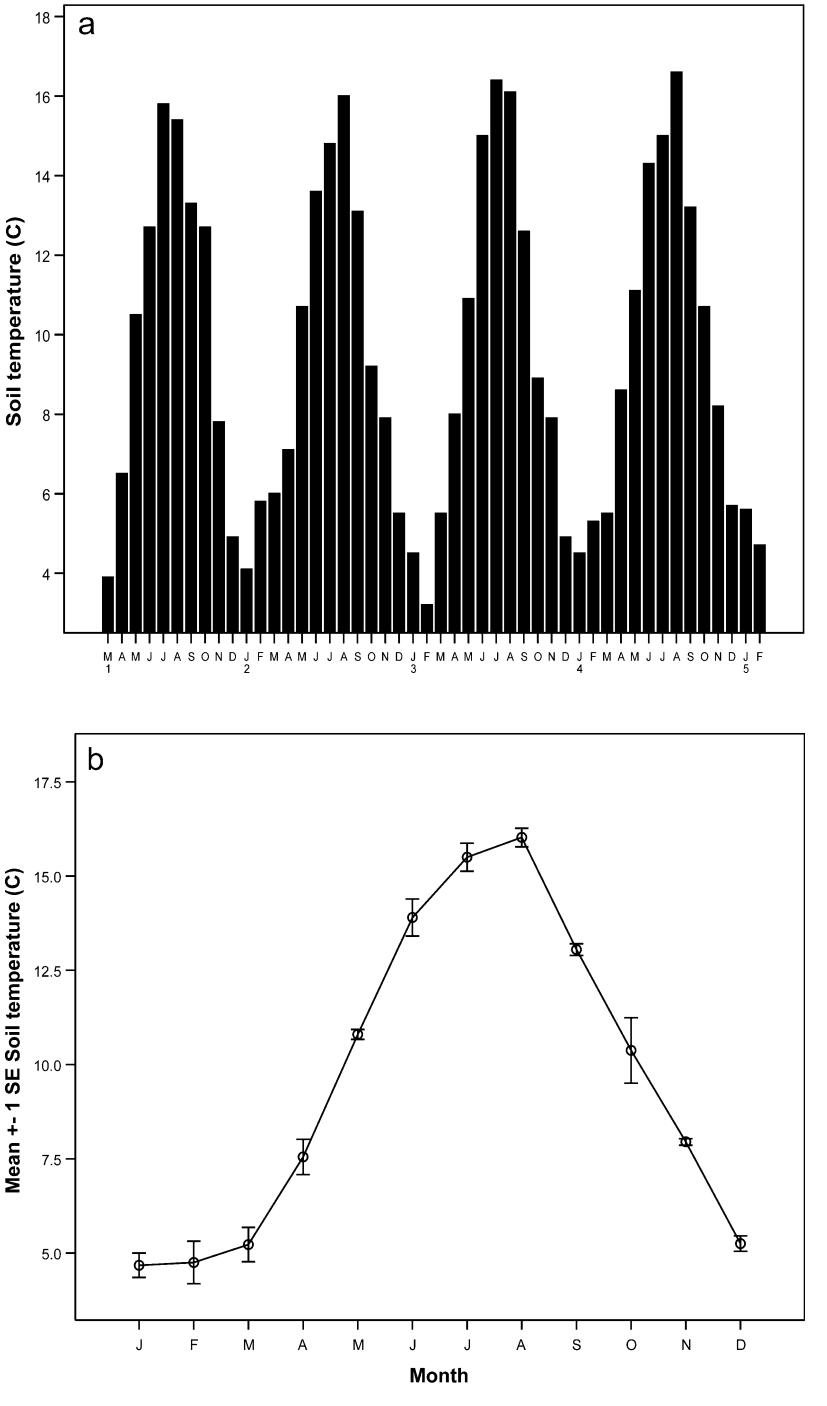

Figure 4. Soil temperature (°C) at the kitchen site. (a) Monthly average from March 2001 to February 2005: 1 to 5 on the *x*-axis are years 2001 to 2005; (b) mean ± SE values from January (J) to December (D) over 4 years.

Table I. Kitchen site: total sightings of each species of flatworm (each year runs from March to the following February).

	M. scharffi	*M. terrestris*	Khaki species	Total
2001–2	103	310	0	413
2002–3	93	712	14	819
2003–4	99	667	54	820
2004–5	194	343	39	576
Total	489	2032	107	2628

Table II. Vegetable plot planks: total numbers of each species seen between March and June each year (other months were not sampled).

	M. scharffi	*M. terrestris*	Khaki species	Total
2001	43	34	0	77
2002	229	442	0	671
2003	26	128	0	154
2004	43	116	1	160
Total	341	720	1	1062

Table III. Maximum number of flatworms recorded on any one day (date in parentheses).

	M. scharffi	*M. terrestris*	Khaki species
Kitchen site	7 (23 July 2004)	20 (18 July 2002)	3 (8 December 2004)
Vegetable plots	8 (8 June 2002)	12 (14 and 20 May 2002)	1 (27 April 2004)
Kitchen+vegetable plots	9 (8 June 2002)	22 (13 June 2002)	3 (8 December 2004)

The highest number of *M. scharffi* was in July 2004 when 53 specimens were found in 27 sampling days (1.96 per d). The highest number of *M. terrestris* was in July 2002 when 212 specimens were found in 29 days (7.31 per d). The khaki species was first recorded in August 2002, thus none were recorded for the first 17 months (Figure 7a). The highest number of the khaki species was in August 2003 when 15 specimens were found over 24 days (0.63 per d).

There is some correlation (Pearson, $P=0.014$) between rainfall (Figure 3) and numbers of *M. scharffi*, but not of the other two species ($P>0.05$). There is a significant correlation between soil temperature (Figure 4) and numbers of all three species ($P<0.01$).

All three species were seen at the maximum recorded soil temperature of 19°C.

Microplana scharffi and the khaki species were seen at a minimum of 1.5°C and *M. terrestris* at 3°C.

Habitat preference

Highest numbers of *M. scharffi* were found under the polythene trap, and lowest numbers under the plank (Table IV). Highest numbers of *M. terrestris* and of the khaki species were found under the wood and lowest under the plank (Table IV).

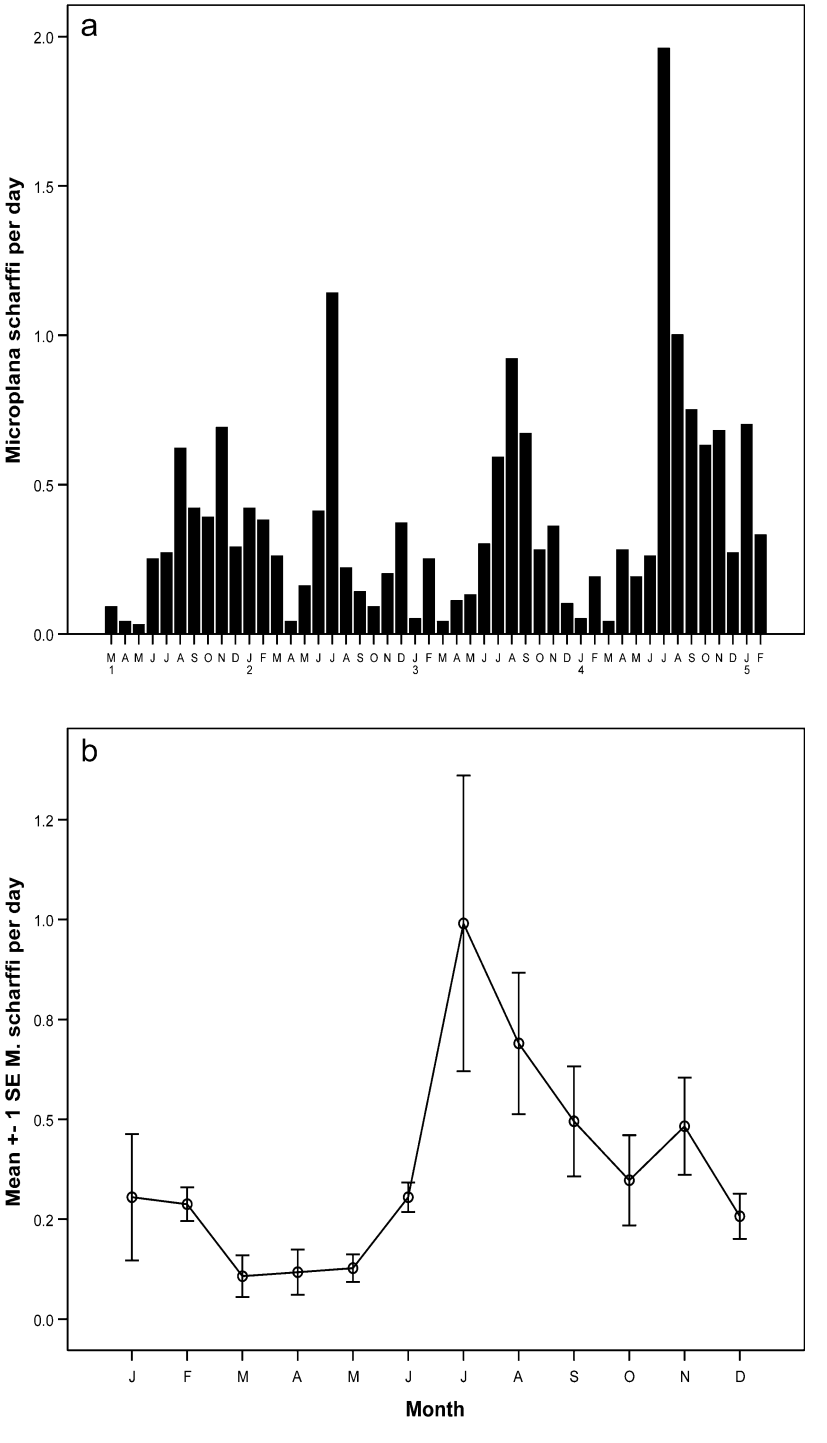

Figure 5. *Microplana scharffi*. (a) Monthly occurrence (corrected numbers) over 48 months from March 2001 to February 2005: 1 to 5 on the *x*-axis are years 2001 to 2005; (b) mean ± SE monthly numbers from January (J) to December (D) over 4 years.

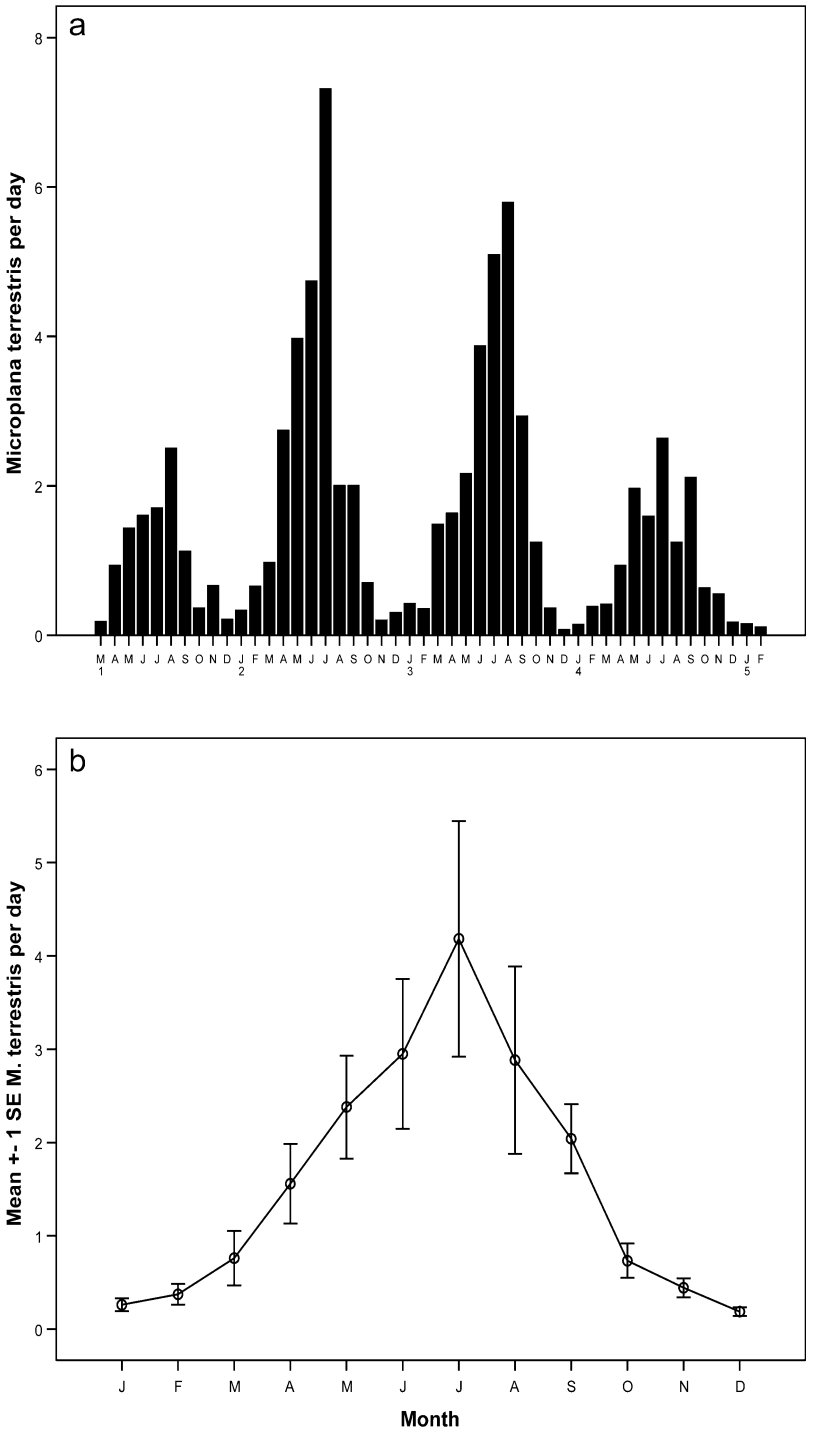

Figure 6. *Microplana terrestris*. (a) Monthly occurrence (corrected numbers) over 48 months from March 2001 to February 2005: 1 to 5 on the *x*-axis are years 2001 to 2005; (b) mean ± SE monthly numbers from January (J) to December (D) over 4 years.

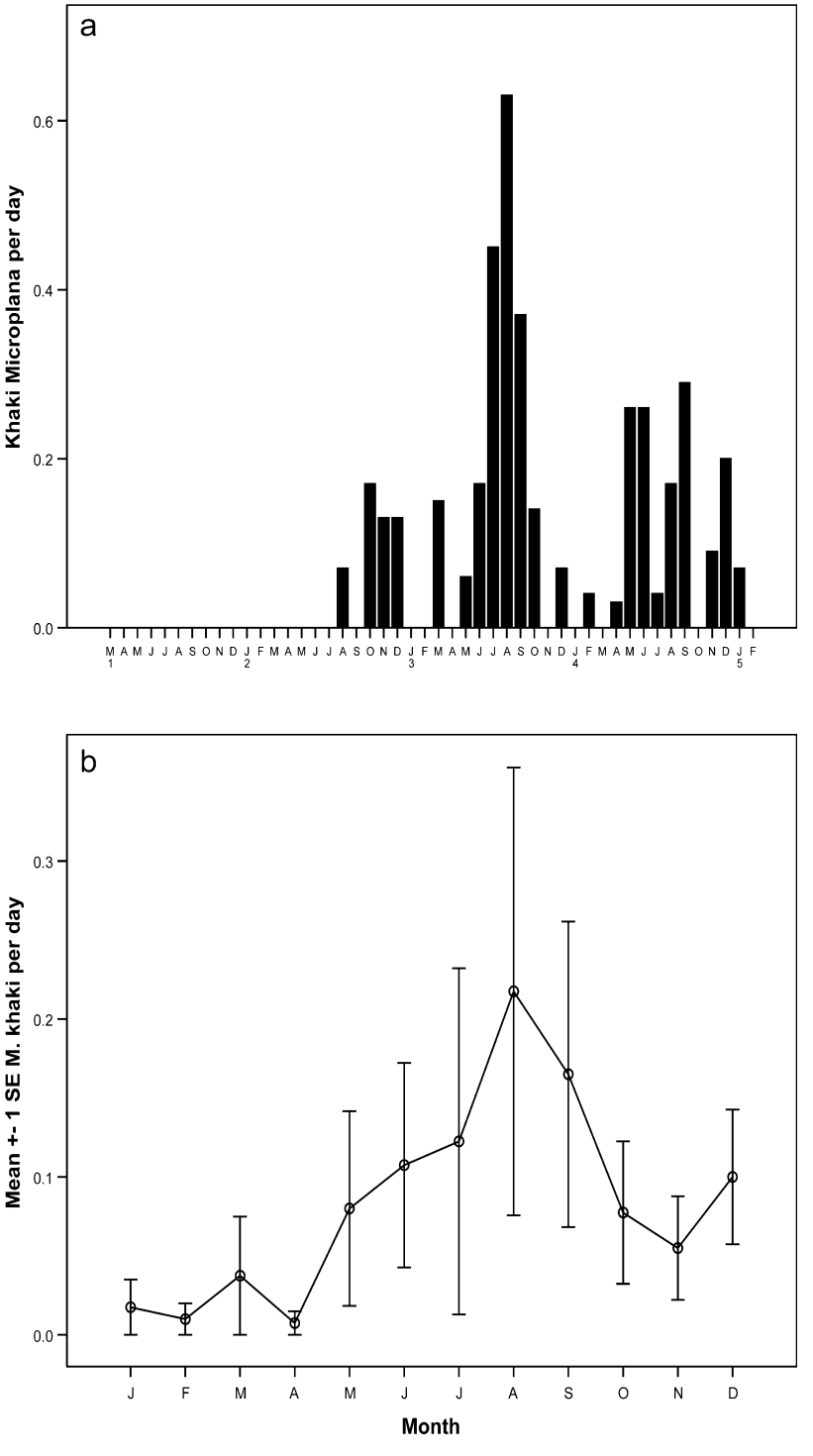

Figure 7. Khaki *Microplana* species. (a) Monthly occurrence (corrected numbers) over 48 months from March 2001 to February 2005: 1 to 5 on the *x*-axis are years 2001 to 2005; (b) mean $\pm$ SE monthly numbers from January (J) to December (D) over 4 years.

Table IV. Kitchen site: total numbers of each species found under each type of trap over the 4 years (values in parentheses are number per m^2 to compensate for different trap areas with % equivalents for more valid comparison).

	M. scharffi	*M. terrestris*	Khaki species	Total
Polythene	266 (2764; 53%)	482 (5008; 25%)	27 (281; 25%)	775 (8053)
Wood	98 (1018; 19%)	673 (6993; 35%)	47 (488; 44%)	818 (8500)
Concrete	69 (1133; 22%)	309 (5074; 25%)	15 (246; 22%)	393 (6453)
Plank	56 (314; 6%)	568 (3185; 16%)	18 (101; 9%)	642 (3600)
Total	489 (5229)	2032 (20,260)	107 (1116)	2628

Removal experiment

Over the 28 days before the removal experiment, 17 *M. terrestris* (0.61 per d) and eight *M. scharffi* (0.29 per d) were recorded. Over the following 48 days 41 *M. terrestris* (0.85 per d) and six *M. scharffi* (0.125 per d) were removed. During the final 17 days, 13 *M. terrestris* (0.76 per d) and one *M. scharffi* (0.06 per d) were recorded.

Cocoons

A daily record of cocoons at the kitchen site was made throughout 2003 and 2004. Cocoons were not removed each day, therefore there was repeat counting. The parent species could not be determined. In total, 422 cocoons were recorded, 268 between 11 March and 16 October 2003 and 154 between 12 April and 7 September 2004. Numbers peak between May and August (Figure 8). The most seen on any one day was seven. The records show that 71% of cocoons were found beneath the wood trap (equivalent to

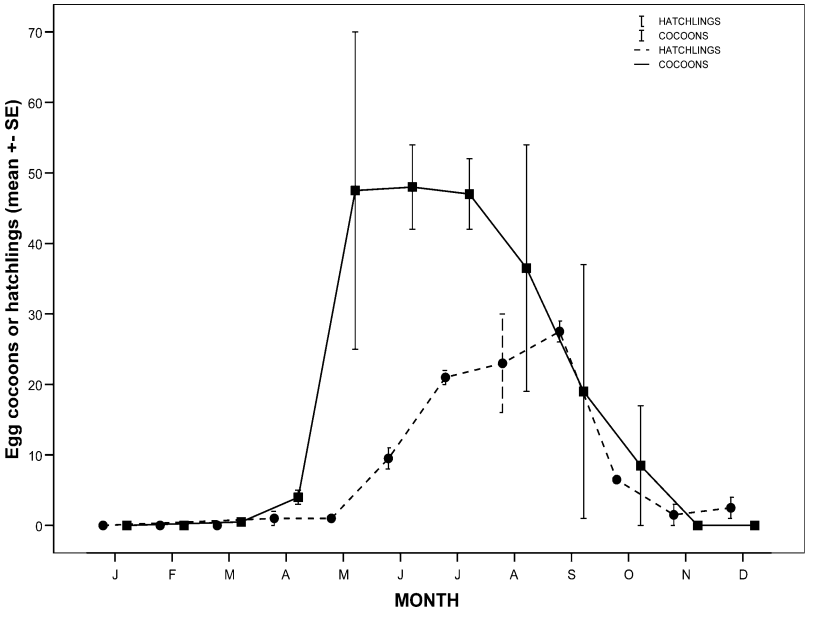

Figure 8. Kitchen site: cocoons (■ and solid line) and hatchlings (• and dashed line) in 2003 and 2004. Mean ± SE values for each month.

1550 per m^2), 28% were under the polythene trap (660 per m^2), and 1% under the plank (20 per m^2). None were found under the concrete.

Cocoons were also found in the lawn area of the garden under 7 cm depth of *Sphagnum* moss. One *M. scharffi* collected from a greenhouse (unheated) shed a cocoon on 5 February.

The longest time that a captive *M. scharffi* was in isolation before producing a viable cocoon was 84 days, 37 days after it had previously fed. Similarly, the longest time for an isolated *M. terrestris* to produce a viable cocoon was 43 days.

Specimens of *M. terrestris* were seen wrapped round each other on three occasions in the wild. In March 2002 three were entwined, and twice in June 2002, two were entwined. Specimens of *M. scharffi* were seen entwined twice, in May 2002 and June 2002. Whether any of these were copulating is uncertain. On one occasion one *M. terrestris* and one *M. scharffi* were entwined, so such behaviour could be incidental.

Cocoon colour and production

No specimen of *M. terrestris* was seen with a developing cocoon or shedding a cocoon, though one cocoon which hatched *M. terrestris* juveniles was collected in the wild whilst still brown and subsequently turned black. All other *M. terrestris* cocoons seen were black.

In *M. scharffi* the visible shedding process took less than 24 h. A cream/yellow swollen area appeared near the posterior which turned a russet/orange colour before being shed. The cocoon turned brown and then black within a few hours. Two *M. scharffi* shed cocoons prematurely while they were still cream coloured, due to disturbance. One burst immediately. The other turned russet then brown then black and appeared normal but disintegrated after 7 days.

Cocoon hatching

Twelve *M. terrestris* cocoons removed from the kitchen site and one shed by a captive specimen were kept until they hatched. Fifty juveniles hatched, 3.85 ± 1.07 SD per cocoon, the most common number being four (Figure 9). The cocoon shed (25 April 2002) from the captive specimen hatched after 49 days. One collected (25 July 2001) from the wild whilst still brown, therefore only a few hours old, hatched after 29 days. Incubation times of three *M. scharffi* cocoons successfully hatched were 89 days (shed 5 February 2002, five hatchlings), 63 days (shed 13 April 2002, one hatchling) and 51 days (shed 1 May 2002, two hatchlings). The number of days taken to hatch reduces from February to August (Figure 10). Cocoons released in August hatch in around 20 days.

Hatchlings

In total, 261 hatchling flatworms were seen at the kitchen site over the 4 years, 101 *M. scharffi*, 150 *M. terrestris*, and 10 khaki. A further 31 were seen at other places in the garden, 12 *M. scharffi* and 19 *M. terrestris*. Numbers of juveniles (all three species) were greatest between June and October (Figure 8). The peak in juvenile numbers is about 2 months later than the peak in number of cocoons (Figure 8).

Microplana scharffi hatchlings were seen in all months except November and peaked in July (Figure 11a). *Microplana terrestris* hatchlings were seen between April and November, peaking in September (Figure 11b). Khaki hatchlings appeared between June and

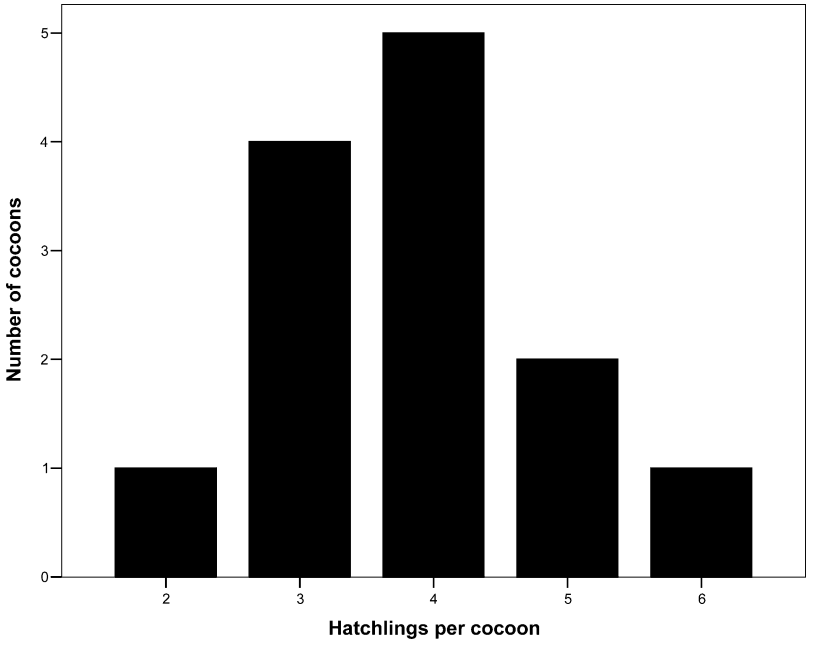

Figure 9. *Microplana terrestris*. The number of hatchlings emerging from 13 viable cocoons.

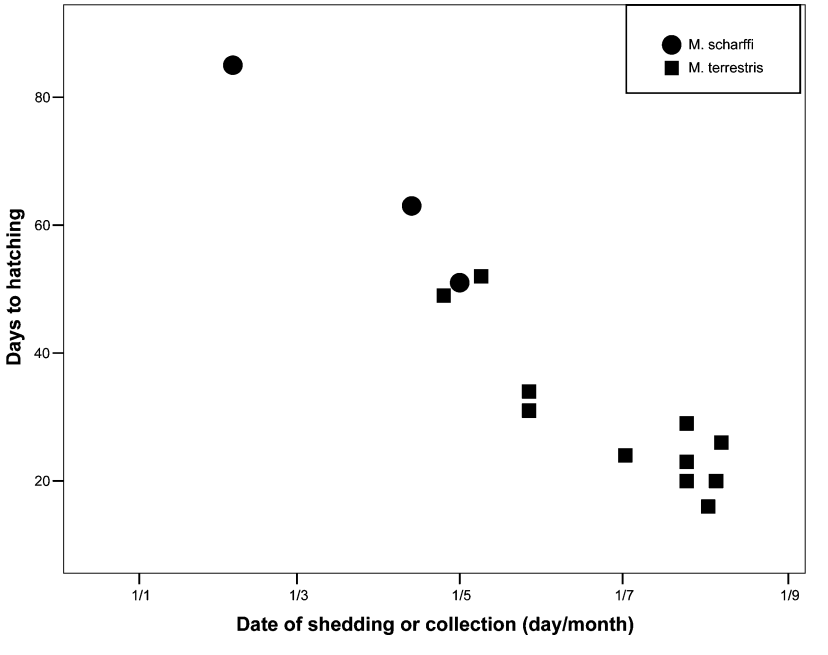

Figure 10. *Microplana terrestris* and *M. scharffi*. The time taken for cocoons to hatch after shedding or collection at different dates. Collected cocoons were within 1 day of being shed so that the maximum error in the time taken to hatch is 1 day.

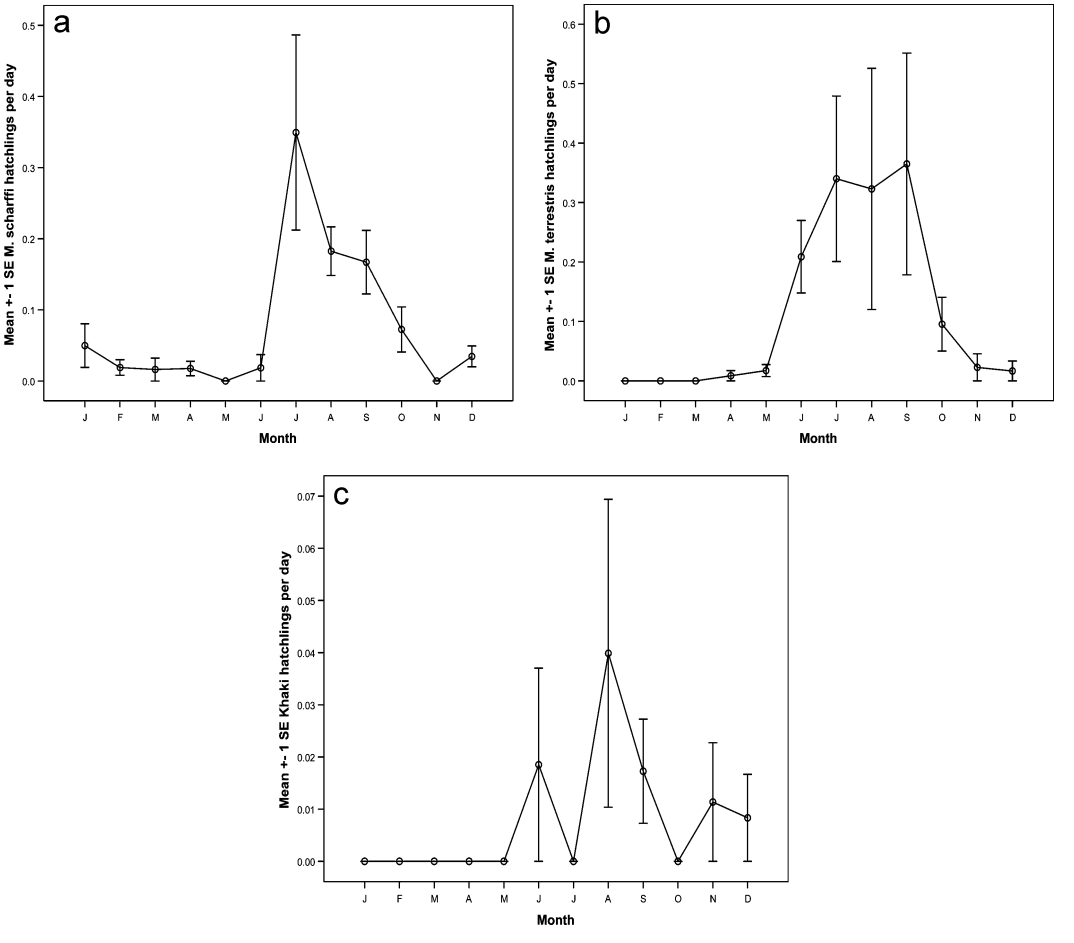

Figure 11. Kitchen site: numbers of hatchlings seen each month for 2003 and 2004. (a) *Microplana scharffi*; (b) *Microplana terrestris*; (c) khaki *Microplana* species.

December, peaking in August (Figure 11c). The records show that 57% of *M. scharffi* hatchlings were found under the polythene, 19% under each of the wood and the concrete, and 5% under the plank. No similar data were collected for the other two species.

Feeding and feeding preferences

In the garden as a whole (all sites) 105 *M. scharffi* were seen feeding, during all months of the year; 266 *M. terrestris* were seen feeding in all months except January; and six khaki species were seen feeding (22 November 2002, 18 October 2003, 7 December 2004, 8 December 2004—three specimens). At the kitchen site, 46 *M. scharffi* (19 in one month, March 2002) and 126 *M. terrestris* were seen feeding. Highest numbers of feeding *M. terrestris* occurred between February and July (Figure 12). Numbers of the other two species were too small for analysis.

Most feeding *M. scharffi* were feeding on earthworms, though some were feeding on slugs (Table V). *Microplana terrestris* was recorded feeding on a variety of prey (Table V). Of the small slug prey items, 86 of 92 (93.5%) were *Arion hortensis* Férussac, the remainder being

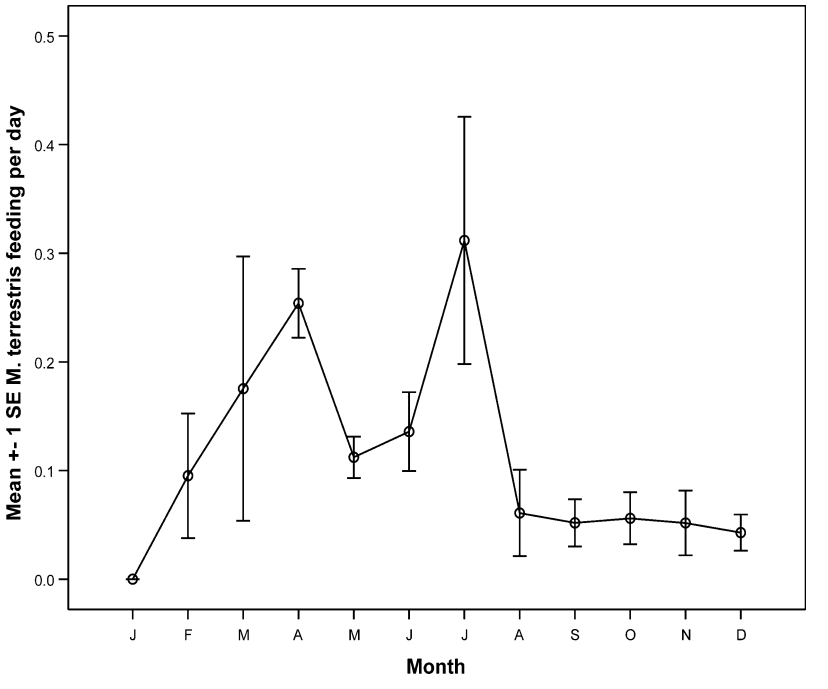

Figure 12. *Microplana terrestris*. Kitchen site. The mean ± SE number of flatworms seen feeding per day per calendar month over 4 years.

Deroceras reticulatum (Müller). A survey of the slugs present around the vegetable plots found 760 slugs, 518 (68%) of which were *A. hortensis*. This suggests that of the slugs present, *M. terrestris* has a clear preference for *A. hortensis*. The small snails consumed were all *Discus rotundatus* (Müller), even though there were considerable numbers of *Oxychilus* sp. present. Khaki species were found feeding on earthworms (four specimens) and *D. rotundatus* (two specimens). Captive *M. scharffi* and *M. terrestris* did not feed on live prey, either earthworms or slugs, despite being left together for 14 days, damaged prey had to be provided. Centipedes were seen to damage earthworms in captivity, though not slugs, and such damage may provide opportunity for scavenging in the wild.

Five *M. scharffi* were kept in captivity between January and August 2002, primarily to observe colour changes when starved (see below). Two were fed on earthworms but given no further food and died after 63 and 139 days. Two which were pink when collected (and presumed to have fed recently) died after 114 and 127 days. One which was pink was fed after 75 days. All of these flatworms shed a cocoon during their period without food and were reduced in size.

Table V. The number of individuals seen feeding on each type of prey at all sites in the garden (percentage of the total in parentheses).

	Earthworm	Slug	Small snail	Woodlouse	Millipede	Beetle
M. scharffi	92 (88%)	12 (11%)	0	0	0	0
M. terrestris	99 (37%)	92 (35%)	55 (21%)	13 (5%)	5 (2%)	1
Khaki species	4 (67%)	0	2 (33%)	0	0	0

Feeding and colour of M. scharffi

The five captive specimens of *Microplana scharffi* had all turned to yellow after about a month without food. Three were successfully fed on earthworms and they all consequently became dark pinkish brown or greyish brown in colour. This faded through paler browns, pinks and oranges to yellow. Newly hatched *M. scharffi* are yellow. Attempts to feed hatchlings were unsuccessful, therefore colour changes after feeding are unknown. In the wild, two *M. scharffi* were seen which displayed three colours at the same time because they were in the process of feeding. The area immediately over the pharynx was reddish brown, the anterior was darker orange/cream and the posterior was pale yellow.

On some occasions *M. terrestris* appeared very slightly lighter after feeding, with a more pink or more brown hue, but not marked.

Colour of M. scharffi

The colour of 822 specimens (709 adults, 113 hatchlings) from all sites in the garden were colour matched. A further eight were discounted but included in the total: two which were multicoloured (in the act of feeding); four which crawled away before matching; two which were unmatchable. Originally 119 different shades were recognized, but these were subsequently grouped into 23 (Figure 13a) and then into eight (Figure 13b) colour ranges. Yellows and creams were the most abundant colours recorded—67% of the total, 63% of the adults and 93% of the hatchlings; 59% were considered ''pale'' (46% adults, 13% hatchlings) and 41% ''vivid'' (40% adult, 1% hatchlings).

Discussion

The results show that these species of terrestrial planarian may be quite numerous in favourable circumstances and that the numbers recorded show regular seasonal variation. It must be stressed that the kitchen site is particularly suitable for these organisms and that in other habitats planarians are far from as numerous. It is clear that, at the kitchen site, highest numbers of all three species are found in the summer months, July for *M. scharffi* and *M. terrestris*, August for the khaki *Microplana* sp. (Figures 5–7). The high summer numbers appear to be associated with both higher rainfall and temperature (Figures 3, 4). They may also be the result of environmental conditions at the kitchen site which is north-facing. Elsewhere in the garden, the soil, at least at the surface, dried out over the summer, whereas the kitchen site remained damp and it is possible that there was some consequent aggregation taking place in this favourable area. Conversely, the kitchen site is surrounded on two sides by walls of the house, and on the other two sides by several metres of concrete or tarmac paving and any migrating flatworms would have to cross this. Peak cocoon production is in June and July (Figure 8), preceding the summer high numbers, so that it is unlikely that summer high numbers are associated with any reproductive aggregation.

The summer high numbers compare with records of *M. terrestris* from across Europe compiled by Gislén (1944). The highest number was in September (29 records, the next highest record being 14 in both August and October) with none in February, but it is unlikely that there was even sampling effort over the year.

Similar surveys of other terrestrial planarian species in the UK show different trends. A long-term study of populations of the Australian flatworm, *Australoplana sanguinea*, in a domestic garden showed peak numbers in November of most years and very low numbers in June, July, and August (Jones et al. 1998, 2001a), and surface soil at that site did dry out

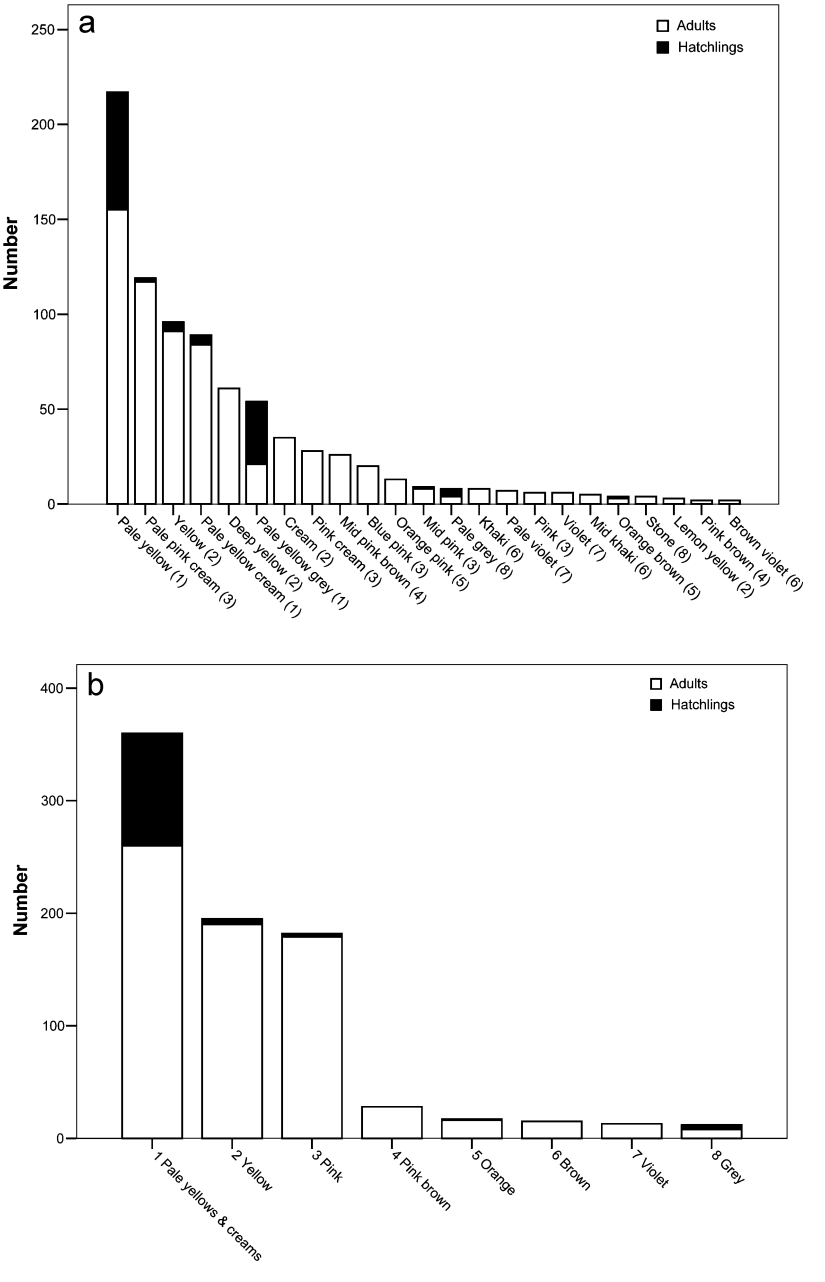

Figure 13. *Microplana scharffi*. The numbers of specimens of each colour category. (a) Using 23 colour categories: figure in parentheses indicates the eight-colour category that the colour is assigned to; (b) using eight colour categories (1–8). Data are ranked from highest to lowest totals.

during the summer months. Blackshaw (1997) found that the New Zealand flatworm was more numerous in late spring and early summer in Northern Ireland, with low numbers in summer and early autumn. In Scotland, numbers of New Zealand flatworms were fairly even over the year though reduced from June to October, with lowest numbers in August

and highest in November (SEERAD [date unknown]). These different trends undoubtedly are the result of reduction in soil surface moisture in summer and autumn, which to some extent emphasizes the slightly unusual conditions at the kitchen site. In the rest of the garden, flatworms were found under the plank traps when conditions were moist and warm, but disappeared in cold or dry conditions. Presumably flatworms migrate to deeper levels in the soil. The high numbers found drowned beside the vegetable plots after the flood in August 2002 support this.

It is almost certain that at the kitchen site there was repeat counting of flatworms since they were not removed each day, nor could they be individually marked. However, the removal experiment strongly suggests that this may not have been a major problem. Also flatworms were rarely if ever seen in the same spot on consecutive days probably because they move each night and also as a result of disturbance of the trap each day.

Whilst appreciable numbers of the three species could be found under the four different types of trap (Table IV), more *M. scharffi* were found under polythene than under the other types, and more of the other two species were found under the wood. The lower numbers of all species were found under the plank, probably due to it being thin and narrow with consequent poor thermal insulation and water-retention properties.

The observations on feeding activity, cocoon production, and hatchling abundance confirm each other. Increased feeding activity of *M. terrestris* in the spring and summer months up to July (Figure 12) is followed by cocoon production which peaks in June and July (Figure 8), in turn followed by hatchling numbers which peak from August to October (Figure 8). Jennings (1959) noted that *M. terrestris* in captivity produced cocoons between April and August, similar to the period reported here (Figure 8). He also noted decreased protein reserves in summer coinciding with cocoon production. In Northern Ireland, cocoons of the New Zealand flatworm appeared mostly between March and June (Blackshaw 1997), but in Scotland highest numbers of cocoons were found in August with highest numbers of hatchlings in September (SEERAD [date unknown]).

Microplana scharffi feeds mainly on earthworms which were 88% of the prey items recorded (Table V), slugs forming the remainder. Jennings (1959) reported that *M. terrestris* "feeds mainly upon slugs (*Arion* sp.) and small earthworms" but will consume other soil organisms if they are injured. Unfortunately he did not quantify his results. Our observations showed that earthworms were consumed as often as slugs, and *Discus rotundatus* was also eaten, together with other occasional prey items. This suggests that *M. terrestris* is fairly unselective in its prey, feeding on whatever it can. Presumably this depends on availability, mobility, and defensive behaviour of potential prey individuals. The experiments on captive specimens suggest that wounded or damaged prey has to be provided, thus they are scavengers rather than predators. However, Jennings (1959) noted that *M. terrestris* did take live slugs but showed no awareness of potential prey until making direct contact. The association between *M. terrestris* and *D. rotundatus* was noted by Cuppen and van der Velde (1981), though they did not record any feeding by the former on the latter.

It has long been known that flatworms can survive for long periods without food. One captive individual of *M. scharffi* survived for 139 days, even laying a cocoon during this time. *Arthurdendyus triangulatus* can survive for up to 15 months without food (Christensen and Mather 1995), starting to lose weight after about 20 days of starvation (Christensen and Mather 2001), though that is a much larger species which may permit longer survival. During degrowth, the reproductive structures are progressively resorbed (Baird et al. 2005).

The observations on cocoon development, hatching time, and juvenile occurrence of *M. scharffi*, though based on small numbers, are the first on that species. Percival (1925) merely noted the deposition of cocoons and their dimensions, 3 mm × 2 mm or 2.5 mm across if spherical. Development time seems to be similar to that of *M. terrestris*, and decreases in both as soil temperature increases (Figure 8). The number of juveniles emerging from each cocoon is similar in both species. Jennings (1959) recorded a hatching time of 3 weeks for *M. terrestris* cocoons kept in (unspecified) laboratory conditions, similar to the shortest time reported here, and up to six juveniles hatching from each cocoon, again similar to the numbers found here.

Microplana scharffi was recorded showing a wide range of colours and in this respect is unique amongst the European species of terrestrial flatworms. Percival (1925) notes the colour of *M. scharffi* as ''sulphur-yellow, while others were salmon-pink or dirty grey. After a period of starvation the colour goes, and the whole (dorsal) surface, except the (anterior) pigmented area, is of a uniform milk white.'' The records show that 64% of adult *M. scharffi* and 93% of hatchlings recorded were yellows and creams (Figure 13), the colours of unfed specimens. This suggests that the remaining 36% of specimens had recently fed. Colour changes are obviously due to ingestion of pigments from prey, haemoglobin from earthworms causing pink coloration, and dark pigments from slugs causing the grey coloration. The majority of pale colours recorded could be partly a consequence of fed individuals moving away from the surface after feeding, thus not being recorded under the traps, and partly because unfed individuals seek prey at or near the surface thus being more likely to be recorded under the traps.

The identity of the khaki species is unknown and will be reported elsewhere when established, though it is a *Microplana* but not *M. terrestris*. The appearance of the khaki species at the kitchen site after 17 months of observations suggests that it could have been introduced to the garden shortly before August 2002, though no plants were moved to the kitchen site over the period of observations. Only one specimen was found elsewhere in the garden, under one of the vegetable plot planks. Specimens of this species had previously been collected (October 1992) from a garden near Southport, the site of the work in Jones et al. (1998) and Jones et al. (2001a) but not then recognized, so that it may be more widespread.

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