

Suction duration and numbers of Araneae and Auchenorrhyncha collected in grassland when using an open-ended cylinder to define the sample area

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Suction samplers are typically used with touch-down samples, where the nozzle is held stationary on the ground, or within an open-ended cylinder, where the nozzle is moved through the enclosed vegetation. With touch-down sampling, published estimates suggest that virtually all individuals and species of grassland invertebrate are captured within 3 s. Effects of suction duration on catch when sampling within a cylinder have rarely been investigated. Here, it was found that extrapolation from studies of touch-down sampling, based on the relative areas of the G-vac nozzle and the cylinder, can be used to guide minimum sampling durations for Auchenorrhyncha (leafhoppers and planthoppers) when using a G-vac. Additional time, however, may be necessary when sampling Araneae (spiders), probably because movement of the G-vac nozzle within the cylinder results in disturbance of the vegetation such that more specimens are made available to be captured than with touch-down sampling.

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1. Introduction

Modified garden blow-vacs, commonly referred to as G-vacs, are used widely to sample grassland invertebrates and particularly Araneae (spiders) and Auchenorrhyncha (leafhoppers and planthoppers of the Hemipteran suborders Cicado-

morpha and Fulgoromorpha) (Southwood & Henderson 2000, Hill *et al.* 2005). G-vacs are popular because they are relatively inexpensive, and because they capture grassland invertebrates which live close to the ground. Such species are often under-represented in sweep-net samples (Samu & Sarospataki 1995, Stewart & Wright

1995, Stewart 2002). G-vacs can also be used to obtain crude density estimates where sampling is conducted within an enclosed area – typically defined by an open-ended cylinder many times wider than the G-vac nozzle (Samu *et al.* 1997, Hill *et al.* 2005). The time required to capture all, or most invertebrates, when using a suction device within an open-ended sampling cylinder has, however, been investigated rarely (Henderson & Whitaker 1977, Törmälä 1982).

In contrast, Brook *et al.* (2008) estimated that 90% of Coleoptera, Araneae and Auchenorrhyncha species are captured in the first 3 s of suction when the nozzle of a Vortis device is held stationary on the ground at a single unenclosed point (commonly known as a “touch-down” sample). Moreover, Bell *et al.* (2000) found no increase in numbers of Araneae captured beyond the first 1 s suction of a touch-down sample when using a G-vac.

When using a cylinder, the time needed to capture a representative sample of invertebrates will be at least the minimum time required for a single touch-down sample multiplied by the ratio of the area of the cylinder to that of the nozzle. Longer may be required, however, because movement of the nozzle within the cylinder may enhance capture of specimens that would otherwise be hidden beneath the vegetation. The present study addresses this problem by investigating the numbers of individuals and species of Araneae and Auchenorrhyncha captured with increasing sample duration when using a G-vac within an open-ended cylinder at each of three grasslands. In this study, the G-vac nozzle had an area of 0.01 m², while the area of the cylinder was 0.18 m².

If it is assumed that a period of 3 s is appropriate for a touch-down sample, then most specimens would be expected to have been captured from the cylinder in just under 60 s (i.e. 18 multiplied by 3 s to give an equivalent sampling intensity in terms of seconds per m²). To test this hypothesis three successive samples of 30 s were taken from within the cylinder such that the accumulation of specimens and species could be investigated after 30 s, 60 s and 90 s sampling.

2. Methods

2.1. Study sites

Three grassland sites with flat terrain and internally homogenous vegetation were selected to include a range of agricultural management regimes. Site 1 was an ungrazed grassland, mown at intervals from mid-July onwards (altitude 60 m, latitude 52°46' N, longitude 2°25' W). Site 2 was an unmown pasture grazed by dairy cattle and situated within 500 m of Site 1. Site 3 was unimproved sheep-grazed grassy heath (altitude 420 m, latitude 52°31' N, longitude 2°53' W). Vegetation at Sites 1 and 2 was dominated by sown grasses and was representative of mesotrophic grassland type MG7a *Lolium perenne* – *Trifolium repens* ley within the National Vegetation Classification (NVC) (Rodwell 1992). Site 3 was dominated by semi-natural vegetation characteristic of poor acidic soils and was most similar to NVC type U1 *Festuca ovina* – *Agrostis capillaris* – *Rumex acetosella*.

At each site, a grid 12 m by 20 m was marked out and sub-divided into fifteen 4 m by 4 m grid-squares. Vegetation height was quantified using a single drop-plate measurement (Cherrill & Rush-ton 1993) at the centre of each grid-square ($\bar{x} \pm SD$: Site 1, 12.3 \pm 2.2 cm; Site 2, 15.1 \pm 3.4 cm; Site 3, 3.7 \pm 1.0 cm) ($n = 15$ at each site).

2.2. Suction sampling

The G-vac suction sampler was a modified McCulloch GBV 345 garden blower/vacuum (Stewart & Wright 1995, Stewart 2002). The end of the collecting pipe was sawn off perpendicular to its length to give a nozzle with a cross sectional area of 0.01 m². A nylon 1 mm mesh bag was held in place at the end of the pipe by a rubber band. Estimated air velocity within the nozzle was 20.3 ms⁻¹ (Zentane *et al.* 2016).

Suction samples at each site were taken on a single day only (15th, 17th and 21st July 2014 for Sites 1, 2 and 3 respectively). Minimum air temperatures during sampling, measured in shade at 1 m above ground using a dry bulb mercury thermometer, at the three sites were 30 °C, 26 °C and 24 °C respectively. Vegetation and leaf litter was dry to the touch.

Table 1. Total numbers of individuals and species of Araneae collected after 90 s suction sampling.

	Site 1	Site 2	Site 3
Theridiidae			
<i>Enoplognatha latimana</i> Hippa & Oksala, 1982	4	0	0
Linyphiidae			
<i>Dicymbium nigrum</i> (Blackwall, 1834)	1	1	0
<i>Entelecara flavipes</i> (Blackwall, 1834)	0	0	1
<i>Dismodicus bifrons</i> (Blackwall, 1841)	0	0	0
<i>Oedothorax fuscus</i> (Blackwall, 1834)	7	6	4
<i>Oedothorax retusus</i> (Westring, 1851)	12	2	0
<i>Gongylidiellum vivum</i> (O.P.-Cambridge, 1875)	2	0	0
<i>Micrargus herbigradus</i> (Blackwall, 1854)	0	0	1
<i>Micrargus subaequalis</i> (Westring, 1851)	1	0	0
<i>Savignia frontata</i> Blackwall, 1833	5	6	1
<i>Milleriana inerrans</i> (O.P.-Cambridge, 1885)	1	0	0
<i>Erigone dentipalpis</i> (Wider, 1834)	2	17	3
<i>Erigone atra</i> Blackwall, 1833	9	44	3
<i>Agyneta decora</i> (O.P.-Cambridge, 1871)	2	0	0
<i>Meioneta rurestris</i> (C.L. Koch, 1836)	0	2	0
<i>Bathyphantes gracilis</i> (Blackwall, 1841)	18	53	0
<i>Tenuiphantes tenuis</i> (Blackwall, 1852)	13	42	0
<i>Microlinyphia pusilla</i> (Sundevall, 1830)	3	0	0
Thomisidae			
<i>Xysticus cristatus</i> (Clerck, 1757)	1	0	0
Immatures			
Unidentified families	162	182	7
Linyphiidae	100	193	7
Tetragnathidae	6	0	0
Lycosidae	29	0	0
Thomisidae	1	0	1
Total number of individuals	379	548	28
Number of species	15	9	6

G-vac samples were taken within an opened plastic cylinder with a cross-sectional area of 0.18 m², height of 60 cm in height and weight of 5 kg (sufficient to form a seal with the ground surface). The cylinder was placed at the centre of a grid-square. The G-vac was then used to take three successive 30 s sub-samples before the cylinder was moved to the next grid-square. The motor was run on full-throttle whilst the nozzle was within the cylinder, but was idled whilst the mesh bag was replaced between 30 s sub-samples. Within each 30 s sub-sample, the G-vac nozzle was swept over the surface of the vegetation for 5 s before the nozzle was repeatedly lowered and raised from the ground surface in a series of overlapping “touch-downs” covering the enclosed area for the remaining 25 s. Changing the mesh bag between sub-samples took approximately 15

s and, although not quantified, it is possible that a small number of active fliers may have escaped from the cylinder while this was being done.

2.3. Treatment of invertebrate samples

Material from the three 30 s sub-samples in each grid-square were counted separately. Adult Araneae and Auchenorrhyncha were identified to species, while immature specimens were identified to family. Nomenclature follows Merrett *et al.* (2014) and Wilson *et al.* (2015).

2.4. Statistical analysis

Repeated measures Generalised Linear Model with negative binomial error distribution was used within IBM SPSS ver 24 to test for an effect

Table 2. Total numbers of individuals and species of Auchenorrhyncha collected after 90 s suction sampling.

	Site 1	Site 2	Site 3
Cicadellidae			
<i>Aphrodes bicinctus</i> (Schrank, 1776)	3	0	0
<i>Anoscopus albifrons</i> (Linnaeus, 1758)	2	0	0
<i>Anoscopus serratulae</i> (Fabricius, 1775)	3	0	0
<i>Anoscopus</i> unidentified females	2	0	0
<i>Deltocephalus pulicaris</i> (Fallen, 1806)	0	0	19
<i>Arocephalus punctum</i> (Flor, 1861)	0	0	2
<i>Arthaldeus pascuellus</i> (Fallen, 1826)	60	2	0
<i>Psammotettix nodosus</i> (Ribaut, 1925)	0	0	2
<i>Euscelis incisus</i> (Kirshbaum, 1858)	37	0	0
<i>Cicadula persimilis</i> (Edwards, 1920)	1	0	0
<i>Zyginidia scutellaris</i> (Herrich-Schaeffer, 1838)	22	0	0
Delphacidae			
<i>Javesella obscurella</i> (Boheman, 1847)	0	4	0
<i>Javesella pellucida</i> (Boheman, 1847)	202	30	0
<i>Javesella</i> unidentified females	0	23	0
Immatures			
Cicadellidae	116	3	3
Delphacidae	292	23	0
Total number of individuals	740	85	26
Number of species	8	3	3

of the independent variable “sample duration” (30, 60 and 90 s) on the dependent variable which was the accumulated number of individuals (or species). The analysis was conducted for Araneae and Auchenorrhyncha within each site separately. In each analysis, the between-subject factor was grid-square and the within-subject factor was sample duration. Detection of a significant effect of sample duration, based on Walds Chi-square Test (with critical P of 0.05), was followed by Bonferroni-corrected pairwise comparisons between accumulated numbers captured after 30, 60 and 90 s.

At Sites 1 and 2, all means (and Standard Errors, SE) are based on data from 15 grid-squares, while at Site 3 some samples were mislaid leaving data for 10 grid-squares only.

3. Results

In total 955 specimens of Araneae and 851 Auchenorrhyncha were captured across the three sites. Nineteen species of Araneae and twelve species of Auchenorrhyncha were found (Tables 1 and 2).

3.1. Numbers of individuals

Sample duration had a significant effect on the cumulative number of Araneae captured at Site 1 ($\chi^2 = 14.56$, $d.f. = 2$, $P = 0.01$) and Site 2 ($\chi^2 = 70.54$, $d.f. = 2$, $P = <0.001$), but not Site 3 ($\chi^2 = 3.21$, $d.f. = 2$, $P = 0.20$). At both Sites 1 and 2, numbers increased with each additional 30 s sub-sample. In contrast, at Site 3 very few additional Araneae were captured in the second and third 30 s sub-samples (Fig. 1a).

Sample duration had a significant effect on the cumulative number of Auchenorrhyncha at Site 1 ($\chi^2 = 21.15$, $d.f. = 2$, $P = <0.001$). The number of individual Auchenorrhyncha increased in the second 30 s sub-sample only, with few added in the third 30 s (Fig. 1c). Sample duration had no significant effect on cumulative numbers captured at Site 2 ($\chi^2 = 2.07$, $d.f. = 1$, $P = 0.15$) or Site 3 ($\chi^2 = 2.05$, $d.f. = 1$, $P = 0.11$). At these sites, very few additional specimens were captured in the second 30 s sub-sample, and none were captured in the third 30 s (with the consequence that the third sub-sample was omitted from these analyses) (Fig. 1c).

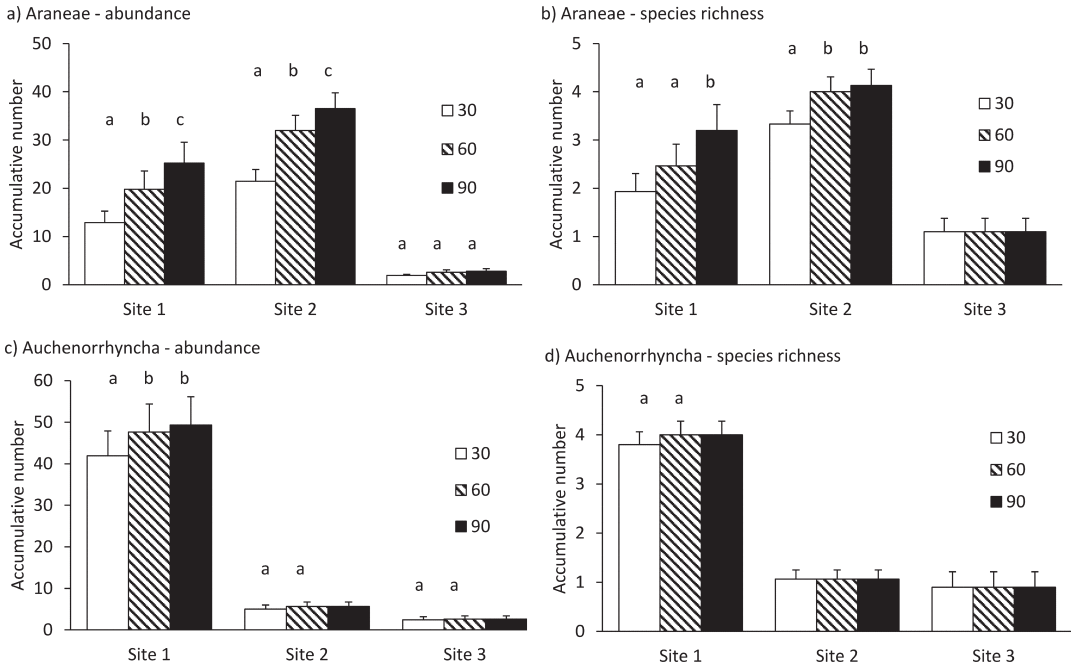


Fig. 1. Mean (\pm SE) for accumulative numbers of individuals and species of Araneae and Auchenorrhyncha captured after 30 s, 60 s and 90 s. Columns within a site, and bearing the same letter, were subject to statistical analysis and were found to be not significantly different (at $P = 0.05$). Columns without a letter have identical mean and SE to the adjacent column(s). Means are based on $n = 15$ at Sites 1 and 2, and $n = 10$ at Site 3.

3.2. Numbers of species

Sample duration had a significant effect on the cumulative number of species of Araneae captured at Site 1 ($\chi^2 = 11.82, df = 2, P < 0.01$) and Site 2 ($\chi^2 = 27.48, df = 2, P < 0.001$). The mean number of Araneae species increased in the third 30 s sub-sample at Site 1, and in the second 30 s sub-sample at Site 2 (Fig. 1b). At Site 3, no additional species were found in the second or third 30 s sub-samples and hence these data were not subject to statistical analysis (Fig. 1b).

At Site 1, the number of Auchenorrhyncha species showed a small non-significant increase in the second 30 s sub-sample ($\chi^2 = 3.16, df = 1, P = 0.08$), but no additional species were captured in the final 30 s (Fig. 1d). Moreover, no additional species were captured after the first 30 s sub-sample at either Site 2 or 3 and hence these data were not subject to statistical analysis (Fig. 1d).

4. Discussion

Several studies have investigated how numbers of species and specimens increase with suction time using touch-down samples (Macleod *et al.* 1994, Bell *et al.* 2000, Brook *et al.* 2008). Macleod *et al.* (1994) used a G-vac to repeatedly sample the same unenclosed point with consecutive touch-downs up to a total duration of 160 s. Cumulative numbers of Coleoptera and Araneae increased from the first 5 s sub-sample to 30 s but not thereafter. The time after which no further benefit accrued may have been overestimated because specimens were probably drawn in from surrounding vegetation as the G-vac was repeatedly raised and lowered (Samu *et al.* 1997, Cherrill 2015). This problem was overcome by Bell *et al.* (2000) and Brook *et al.* (2008) who sampled independent points for different durations. These authors suggest that most Araneae and Auchenorrhyncha are captured within the first few seconds of a touch-down sample. Bell *et al.* (2000) found no increase in numbers or species of spiders between 1 s and 10 s suction with a

G-vac. Brook *et al.* (2008) estimated that 90% of individuals and species of Coleoptera, Araneae and Auchenorrhyncha are captured within 3 s using a similar Vortis suction device. In a direct comparison of the two devices, Zentane *et al.* (2016) found the Vortis to be less efficient than a G-vac, hence these estimates can be viewed as being broadly comparable.

In the present study, the G-vac nozzle was used to sweep the upper layers of the vegetation before being applied in a series of overlapping touch-downs within a cylinder of area 0.18 m². A 30 s sub-sample therefore approximates to a sampling intensity of approximately 1.7 s per 0.01 m² (i.e. 30 s divided by 18). Based on Bell *et al.* (2000) and Brook *et al.* (2008), touch-down sampling within the cylinder for 60 s (i.e. equivalent to approximately 3.4 s per 0.01 m² touch-down) would be predicted to have captured nearly all specimens and species therein. Although the approach to sampling within these studies was not identical, the prediction agrees with the results reported here for Auchenorrhyncha. Numbers of individuals and species did not increase after 60 s at any of the three sites (Figs. 1c and 1d).

In contrast, numbers of individuals and species of Araneae accumulated beyond 60 s sampling, except at Site 3 where Araneae were relatively scarce (Figs. 1a and 1b). Overall, the results suggest that sampling within the cylinder for 60 s (crudely equivalent to a series of twenty 3 s touch-downs) was sufficient for Auchenorrhyncha. Longer may be needed, however, to reach the point where further sampling captures no additional Araneae. The efficiency of sampling may be related to the structural complexity of the vegetation, because at the site with the shortest grass (Site 3) no additional Araneae were caught after the first 30 s (Figs. 1a and 1b). Suction sampling is generally more efficient in short vegetation (Henderson & Whitaker 1997, Hossain *et al.* 1999, Brook *et al.* 2008, but see Sanders & Entling 2011) and it is also known that less structurally complex grasslands tend to support fewer invertebrates (Langellotto *et al.* 2004, Horvath *et al.* 2009).

The present study provides partial support for the hypothesis that when using a G-vac within an open-ended cylinder, the minimum necessary

suction duration can be extrapolated from studies using the alternative touch-down approach. A sampling intensity equivalent to 3 s per unit area (where unit area is defined by the cross-sectional area of the nozzle) is sufficient to capture all species and nearly all individuals of Auchenorrhyncha, but longer may be needed for Araneae, and particularly in taller grass. This is probably because movement of the nozzle within a cylinder results in disturbance of the vegetation such that more Araneae are made available to be captured than with touch-down sampling.

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