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SHORT COMMUNICATION

Suction samplers for grassland invertebrates: comparison of numbers caught using Vortis™ and G-vac devices

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Abstract. 1. The efficiency of Vortis™ and a modified garden leaf-blower/vacuum 'G-vac' sampler were compared by sampling invertebrates using standardised sample areas and suction times at three grassland sites. The G-vac caught more individuals of Araneae, Auchenorrhyncha, Thysanoptera and Hymenoptera than the Vortis. Numbers of Diptera did not differ between devices, but the Vortis™ captured greater numbers of Coleoptera.

2. Estimated air velocity within the collecting nozzle was greater for the G-vac and its mode of application resulted in greater disturbance of the grass sward than with the Vortis™. These differences may have contributed to the larger captures of certain taxa by the G-vac.

3. It is concluded that G-vacs can be applied with confidence as a credible alternative to the bespoke Vortis™, and particularly for taxa which are most frequently sampled using suction samplers.

Key words. Blo-Vac, D-vac, grassland insects, G-vac, vacuum sample, Vortis™.

Introduction

Various suction samplers based on the original D-vac model (Dietrick, 1961) have become popular for studies of invertebrates in grasslands (e.g. Samu & Sarospataki, 1995; Stewart & Wright, 1995; Dogramaci *et al*., 2011). Today, the most widely used models are those based on modification of garden leaf blowers/collectors (known as 'G-vacs') and the Vortis™ sampler (patented by Burkard Manufacturing Company Ltd, Rickmansworth, UK) (Southwood & Henderson, 2000; Stewart, 2002). G-vacs are relatively inexpensive, but a disadvantage is that suction can be impeded when the in-line net becomes clogged with vegetation (Stewart, 2002; Dogramaci *et al*., 2011). The Vortis™ is an order of magnitude more expensive, but avoids this problem by using centrifugal forces to spin invertebrates into a collecting cup mounted to the side of the air stream (Arnold, 1994). It is probably fair to say that over the last two decades the Vortis™ has become the standard suction sampler for use in academic research, particularly for Araneae and Hemiptera. There have been few comparisons, however, of material captured by alternative designs of suction samplers (Arnold, 1994; Macleod *et al*., 1994; Stewart & Wright, 1995). None have compared Vortis™ and G-vac samplers. A comparison is desirable to inform the design of field sampling protocols (and particularly where equipment budgets are limited). This study, therefore, compares numbers of invertebrates captured by a G-vac and a Vortis™ in a replicated study across three grassland sites using standardised sample areas and suction times.

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Methods

Suction sampling equipment

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 m^2. A nylon 1-mm mesh

bag was inserted into the nozzle and held in place by a rubber band. The Vortis™ was supplied by Burkard Manufacturing Company Ltd, UK. The Vortis™ collecting tube has an area of 0.02 m^2. Seated within the collecting tube, and raised 3 cm above the ground, is a narrower air intake pipe (with a cross section of 0.0085 m^2) fitted with vanes that create a vortex. The vortex spins material into an expansion chamber and invertebrates are collected in a vessel fitted to its side. Both devices were driven by a 25 cc two-stroke petrol motor. At the time of writing (April 2016), the G-vac and Vortis™ cost approximately £130 and £2200 respectively (including VAT).

Study sites

Three grassland sites in Shropshire, UK, were selected because of their flat terrain and internally homogenous vegetation. Sites 1 and 2 were at the Harper Adams University (altitude 60 m, Latitude 52°46′N, Longitude 2°25′W). Both were mesotrophic grassland type MG7a *Lolium perenne – Trifolium repens* ley within the National Vegetation Classification (NVC) (Rodwell, 1992). Site 3 was unimproved grass heath at Long Mynd (altitude 420 m, Latitude 52°31′N, Longitude 2°53′W) comprising NVC type U1 *Festuca ovina – Agrostis capillaris – Rumex acetosella* (Rodwell, 1992). At each site, a grid 12 m by 20 m was marked out and sub-divided into fifteen 4 m by 4 m squares using canes. Vegetation height was estimated using a single drop-plate measurement at the centre of each square (Cherrill & Rushton, 1993). Vegetation heights were: Site 1, mean = 12.3 cm, SD = 2.2 cm; Site 2, mean = 15.1 cm, SD = 3.4 cm; Site 3, mean = 3.7 cm, SD = 1.0 cm (n = 15 at each site).

Suction sampling

Suction samples were taken at sites 1, 2 and 3, on 15th, 17th and 21st July 2014 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, 26 and 24 °C respectively. Vegetation and leaf litter was dry to the touch at all three sites.

A G-vac and Vortis™ sample was taken from within each 4 m by 4 m grid-square, giving 15 samples for each of the three sites. Samples using the G-vac and Vortis™ were taken concurrently starting in squares at opposite ends of a grid. Sampling was completed within 90 min at each site. G-vac and Vortis™ samples within each grid-square were matched in terms of the total sample time (90 seconds) and the area (0.174 m^2 for G-vac, 0.180 m^2 for Vortis™) using the following procedures.

Operation of the Vortis™

A single Vortis™ sample comprised nine sub-samples. The area of each sub-sample was defined by the cross-section of the integral collecting tube (0.02 m^2). Each sub-sample was taken by holding the Vortis™ flat on the ground surface with the motor on full-throttle for 10 seconds. The nine sub-samples were taken at intervals of several paces around the centre of the grid-square. The motor was allowed to idle while the Vortis™ was lowered and raised between sub-samples. After all nine sub-samples had been taken, the collecting cup was emptied into a labelled bag giving a pooled sample based on a total time of 90 seconds and area of 0.180 m^2. Pooling of a series of 10 seconds sub-samples to derive a single Vortis™ sample is a widely used approach (e.g. Barham & Stewart, 2005; Hollier *et al*., 2005; Maczey *et al*., 2005; Woodcock *et al*., 2009). This protocol was followed within each of the 15 grid squares at each site.

Operation of the G-vac

The area of a single G-vac sample was defined by the internal diameter of an open-ended cylinder (0.174 m^2) placed in the centre of a grid square. The cylinder delimited a sample area larger than the G-vac collecting nozzle and prevented inadvertent capture of invertebrates from adjacent vegetation (Cherrill, 2015). The cylinder was 60 cm in height and weighed 5 kg (sufficient in weight to form a seal around its base with the ground surface). The G-vac was used to take three sub-samples, each of 30 seconds, within the cylinder. The total suction time of 90 seconds is comparable to that used in earlier studies (e.g. Stewart & Wright, 1995; Samu *et al*., 1997; Littlewood *et al*., 2006, 2009; Sanders & Entling, 2011). The net was emptied and replaced between sub-samples to prevent clogging. Each sub-sample was taken by first sweeping the nozzle over the surface of the vegetation for 5 seconds before the nozzle was repeatedly lowered and raised from the ground surface for the remaining 25 seconds (while ensuring the nozzle was still below the rim of the cylinder). The motor was run on full-throttle when the nozzle was within the cylinder, but was allowed to idle while the net was emptied. This protocol was followed within each of the 15 grid squares at each site.

Treatment of samples

Samples were placed in a cool box for transport to the laboratory and frozen prior to sorting. Numbers of individuals were counted for Araneae, Hemiptera (suborders Cicadomorpha and Fulgoromorpha combined) (henceforth Auchenorrhyncha), Thysanoptera, Diptera, Hymenoptera (suborder Apocrita only, excluding bees and ants) and Coleoptera. In the hemimetabolus orders (Araneae and Hemiptera), numbers of immature and adult specimens were combined, while in the holometabolus orders (Thysanoptera, Diptera, Hymenoptera and Coleoptera), only adults were counted.

Statistical analysis

The effects of sampling method (treatment) on the abundance of invertebrates caught for each taxonomic group were investigated with generalised linear mixed models (GLMMs), using the function *glmer( )*. A model with Poisson error structure was fitted with sampling method (treatment) as the fixed term and site as a random factor. This allowed more general conclusions to be drawn about the two suction sampling methods, while taking into account potential anomalies between sites; thereby, increasing the degrees of freedom, and thus the statistical power of the analysis. All statistical analyses were conducted in R 3.02 with the package *lme4* installed (R Core Team, 2013).

Results and Discussion

A total of 7379 invertebrate specimens were collected across the three sites (Site 1: 2730, Site 2: 4106, Site 3: 543). Compared with the Vortis™, the G-vac captured greater numbers of Araneae ($z_{87} = 13.59$, $P < 0.001$), Auchenorrhyncha ($z_{87} = 7.68$, $P < 0.001$), Thysanoptera ($z_{87} = 11.70$, $P < 0.001$) and Hymenoptera ($z_{87} = 5.89$, $P < 0.001$) (Fig. 1). For these four taxa, greater numbers

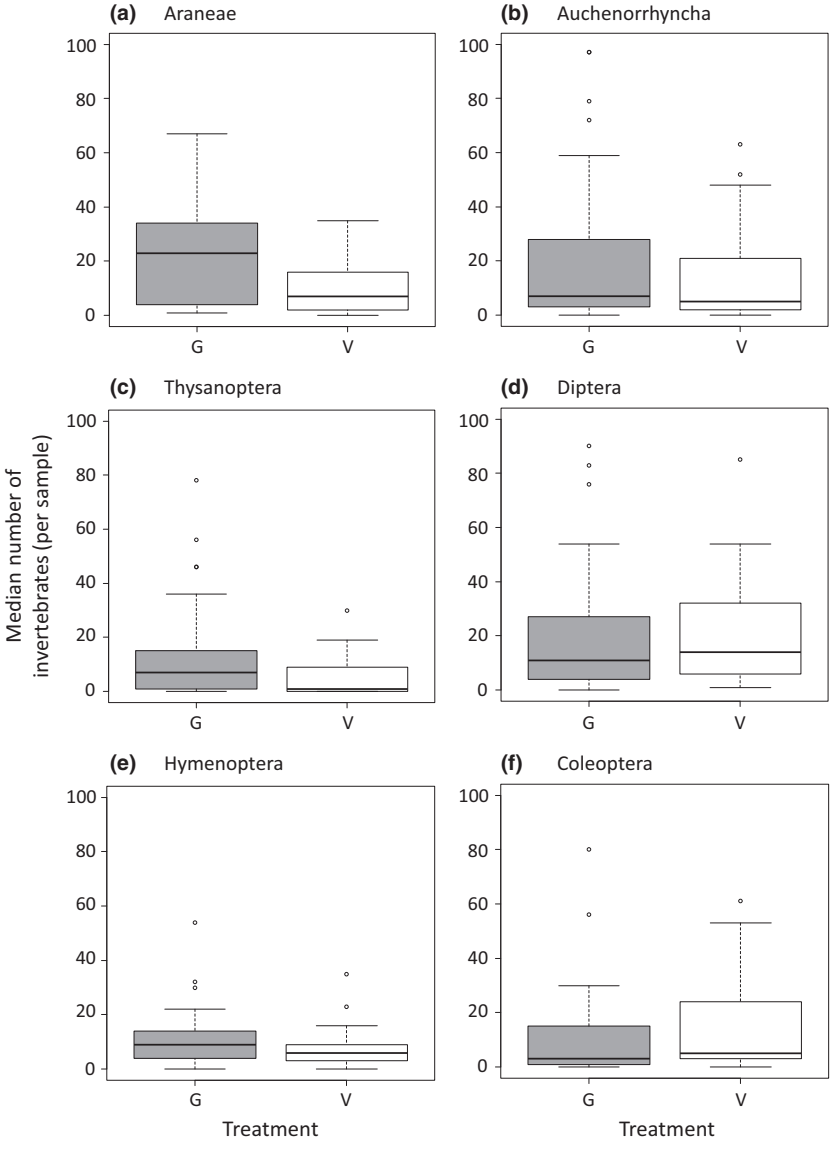

Fig. 1. Boxplot showing numbers of specimens of each of six taxa caught using G-Vac (G) and Vortis™ (V) suction samplers (n = 45 in each case). The bold horizontal line indicates the median, the top and bottom of the boxes the 75th and 25th percentile respectively; and the dashed whiskers the maximum and minimum values (except where outliers are present, where the whiskers represent 1.5 times the interquartile range of the data).

were caught with the G-vac within each of the three sites (Appendix 1). There was no difference between the G-Vac and Vortis™ when sampling for Diptera ($z_{87} = 0.75$, $P = 0.455$). The Vortis™ caught more Coleoptera than the G-Vac ($z_{87} = 4.91$, $P < 0.001$), although this was not seen consistently within all sites (Appendix 1). The contrasting modes of application of the two devices are likely to have contributed to the observed differences. The disturbance caused by the repeated movement of the G-vac nozzle through the vegetation within the sampling cylinder is likely to have dislodged invertebrates and exposed them to the updraft.

Air velocity in the collecting nozzle is a key factor in efficiency of suction samplers. Stewart and Wright (1995) summarised information on air velocity for a range of devices including D-vacs (with estimates in the range 5–11 ms^{-1}) and G-vacs (range 16–46 ms^{-1}). Technical specifications provided by the manufacturers give air throughput estimates of 12.16 and 10.5 $m^3 min^{-1}$, respectively, for the G-vac and Vortis™ used in this study (McCulloch, 2015; Burkard Manufacturing Company Ltd, 2001). Based on a nozzle cross section of 0.01 m^2, this gives an air velocity of 20.3 ms^{-1} for the G-vac. For the Vortis™, calculated air velocity in the inner vortex pipe (0.0085 m^2) is very close to that estimated for the G-vac at 20.6 ms^{-1}, while air intake averaged across the area of the outer collecting cylinder (0.02 m^2) is 8.75 ms^{-1}. The greater average air velocity generated by the G-vac may therefore also have contributed to the greater captures by the G-vac. It should be borne in mind, however, that some specimens may have been sucked into the samples from beyond the immediate sampling areas. Such peripheral suction effects can inflate numbers when air is drawn through gaps between the ground and the enclosure used to delimit the sample area (Cherrill, 2015). This may also occur when a suction sampler is raised and lowered from the ground. In this study, however, it is unlikely that peripheral suction effects contributed to differences between devices, because the potential effect was greater for the Vortis™. G-vac samples were taken from within a cylinder (with a perimeter of 1.48 m) while each Vortis™ sample comprised nine sub-samples (with a total perimeter of 4.51 m), yet catches were typically smaller for the Vortis™.

The readily available and affordable G-vac sampler used in this study was similar in design to others reported in the literature (having a 25 cc engine and nozzle area of 0.01 m^2) (Stewart, 2002). The Vortis™ may have an advantage of capturing smaller quantities of unwanted plant material, reducing sorting times (Stewart, 2002), but this advantage is at a cost of smaller catches for some taxa. This study suggests that G-vacs can be applied with confidence as an alternative to the Vortis™, and particularly for those taxonomic groups for which the use of suction samplers is most widespread, most notably the Araneae and Auchenorrhyncha.

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Appendix 1. Median and inter-quartile range (IQR) for numbers of specimens of each of six taxa caught using Vortis™ (V) and G-Vac (G) suction samplers at three sites (n = 15 in each case). All values are integers.

		Site 1		Site 2		Site 3	
Taxon	Method	Median	IQR	Median	IQR	Median	IQR
Araneae	V	7	4–13	16	15–25	1	0–3
	G	24	11–36	34	29–43	3	1–4
Auchenorrhyncha	V	28	21–39	5	3–7	2	0–4
	G	43	28–72	6	2–8	3	1–6
Thysanoptera	V	1	0–3	12	9–18	0	0–0
	G	8	3–14	25	11–36	0	0–2
Diptera	V	14	10–17	35	32–54	4	3–6
	G	11	4–17	30	17–54	4	1–5
Hymenoptera	V	4	2–6	10	8–13	4	1–7
	G	6	2–11	15	9–22	5	2–10
Coleoptera	V	3	1–5	35	24–43	3	2–6
	G	3	1–8	18	14–25	1	0–2