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Ramp traps versus pitfall traps for collecting epigeal arthropods: a case study in a coniferous forest in Southwest Finland

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ABSTRACT

Pitfall traps are commonly used to sample epigeal arthropods, but they are not ideal in areas where soil disturbance is restricted or not possible. Ramp traps are a less well known alternative that does not require excavation. To compare the performance of the two trap types in capturing epigeal arthropods, both ramp (n = 12) and pitfall traps (n = 12) were set up in four paired transects in Korkiakallio forest (Turku, Finland), in summer 2022. The project team identified adult spiders to the species level, and other arthropods to the family level. Ramp traps captured significantly more individuals of ants (Hymenoptera: Formicidae), beetles (Coleoptera), true bugs (Hemiptera), and spiders of the species *Minyriolus pusillus* (Wider, 1834) (Araneae: Linyphiidae), while pitfall traps captured more myriapods (Myriapoda). Our findings provide additional evidence that ramp traps are not only a viable alternative to pitfall traps in challenging environments, but also complement (and should ideally be used alongside) pitfall traps.

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Arthropoda; spiders; beetles; ants; myriapods; true bugs

Introduction

The abundance and diversity of arthropods is an important indicator of the environmental conditions, general biodiversity, and ecological conditions of a terrestrial ecosystem (Danks 1992; Humphrey et al. 1999; Langor and Spence 2006; Solascasas, Azcarate, and Hevia 2022). Prior to the assessment of these factors for a particular habitat, it is desirable to have sufficient knowledge of the effectiveness, selectivity, and practical use of the available sampling methods of terrestrial arthropods. Efficient passive sampling of arthropods includes the use of traps that capture the target taxonomic groups within an area (Kent, Peele, and Sherry 2019). Thus, comparative studies of sampling methods offer useful information for ecological research that is based on sampling arthropods.

A common sampling method for epigeal arthropods is the pitfall trap, which has become the most popular choice due to its great performance, low price, and simplicity (Greenslade 1964; Siewers, Schirmel, and Buchholz 2014). It is possible to effectively assess the abundance and diversity of various epigeal invertebrates using pitfall traps (Hohbein and Conway 2018; Perner and Schueler 2004; Santos, Cabanas, and Pereira 2007). However, the pitfall trap is limited in its suitability for certain environments because it requires the excavation of a hole in the soil, which is to be occupied by the open container. This may not be possible or desirable in certain environments, e.g. caves, areas that are largely covered by bare rock, or sites where soil disturbance is prohibited. In such cases, alternative methods for sampling epigeal arthropods should be considered, such as mesovoid shallow substratum (MSS) traps (i.e. a vertically layered pitfall trap for sampling the mesovoid shallow substratum; López and Oromí 2010) or ramp traps.

Bostanian, Boivin, and Goulet (1983) developed the first ramp trap, targeted for collection of large beetles. Later, Bouchard, Wheeler, and Goulet (2000) developed more universal ramp trap designs that were also cheaper and less bulky than the original model. A standard ramp trap is a container that is placed on the ground, accompanied by one or more ramps leading up to it. Therefore, it does not require soil disturbance, which renders it preferable to a pitfall trap in places where excavation is not ideal. The ramp trap, like the pitfall trap, does not capture all the species in the ecosystem as trap catches are largely determined by the activity-density of epigeal arthropods, i.e. the density of individuals in the field and their locomotion (De Heij, Benaragama, and Willenborg 2022; Matevski et al. 2020). Nevertheless, ramp traps have been shown to be effective for sampling epigeal arthropods (Patrick and Hansen 2013; Pearce et al. 2005).

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Most previous studies have compared the performance of ramp and pitfall traps for capturing one or two arthropod groups, such as spiders or carabid beetles (Matevski et al. 2020; Patrick and Hansen 2013; Pearce et al. 2005). Here, we compare the numbers of individuals of various arthropod groups caught by these traps, with special emphasis on spiders at the species level. Based on previous research, we expect ramp traps to collect more individuals of spiders (Patrick and Hansen 2013; Pearce et al. 2005) and pitfall traps to collect more individuals of myriapods such as millipedes (Weary et al. 2019).

Material and methods

The study area, Korkiakallio (60.4792°N, 22.3196°E), is a 13.3 ha centrally elevated mature coniferous forest in the Oriketo region in Turku, southwest Finland (Figure 1). The primary vascular plant species in the study area are Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), common bilberry (*Vaccinium myrtillus*), and wavy hair-grass (*Deschampsia flexuosa*). The secondary vascular plant species in the forest are rowan (*Sorbus aucuparia*), lily of the valley (*Convallaria majalis*), eagle fern (*Pteridium aquilinum*), common juniper (*Juniperus communis*), and silver birch (*Betula pendula*). The ground is largely covered by the following mosses: ostrich-plume feathermoss (*Ptilium crista-castrensis*), glittering woodmoss (*Hylocomium splendens*), and red-stemmed feathermoss (*Pleurozium schreberi*).

During the sampling periods, a total of 24 traps were used, including 12 ramp and 12 pitfall traps, that were placed in four sampling sites in the study area, each site near a corner to cover the area somewhat evenly (Figure 1). Each sampling site consisted of six traps that were divided into two parallel 6 m transects of each trap type. Each transect consisted of three traps of one type that were spaced 3 m apart, with a 10 m distance to the parallel transect of the other trap type. Similar sampling designs and sample sizes have previously been used successfully for comparing spider catches between ramp and pitfall traps (Patrick and Hansen 2013).

Sampling was performed with ramp and pitfall traps in three two-week sampling periods during the summer of 2022: 1–15 June, 24 June – 8 July, and 16–30 July. The length of the total sampling interval was set up to align with the time of highest adult arthropod densities, especially of spiders. Preservative liquid, 50% propylene glycol, was poured into both trap types at the start date, and was subsequently moved into glass jars along with collected samples at the end date of each sampling period. The contents of the glass jars were poured through a filtering membrane, from which the samples were moved with pincers to flasks containing 70% denatured alcohol for preservation.

Pitfall traps consisted of 200 mL cups (7.0 cm high, upper diameter 6.5 cm) and metallic rain covers (10 x 10 cm) that were placed so that the distance between the rain cover and the upper end of the cup was about

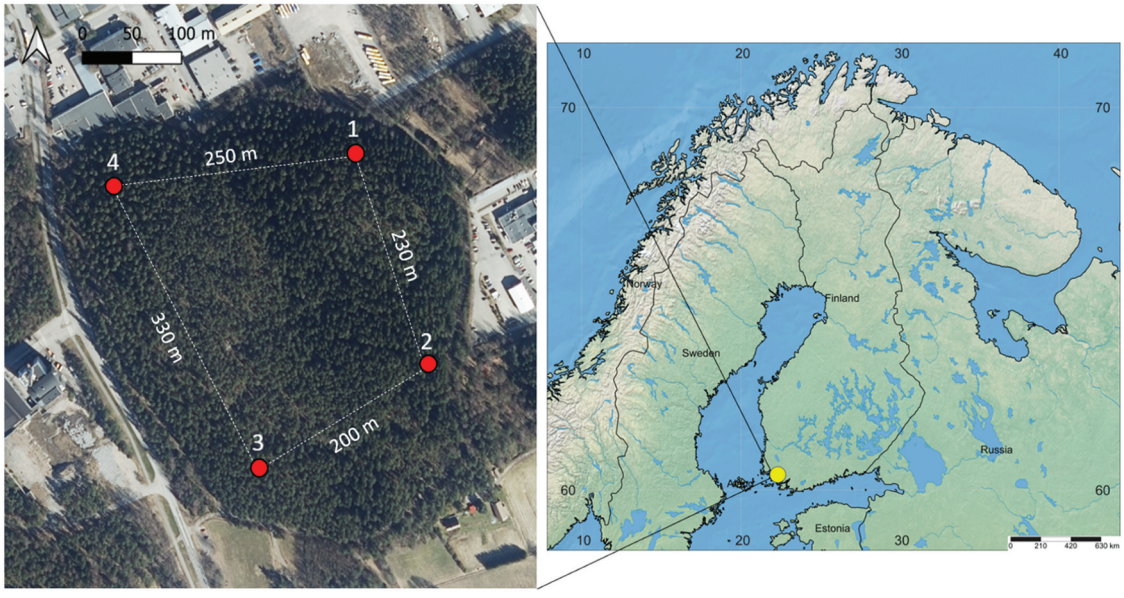

Figure 1. Map of Finland and its neighbouring countries (right), with the study area marked by a yellow circle, and aerial view of the Korkiakallio study area (left) in Turku, with sampling sites marked by red circles; each circle (1–4) represents a group of six traps, with approximate distances between sampling sites marked by dashed lines. The aerial photograph was derived from NLS orthophotos, National Land Survey of Finland (05.2020), license CCBY-4.0.

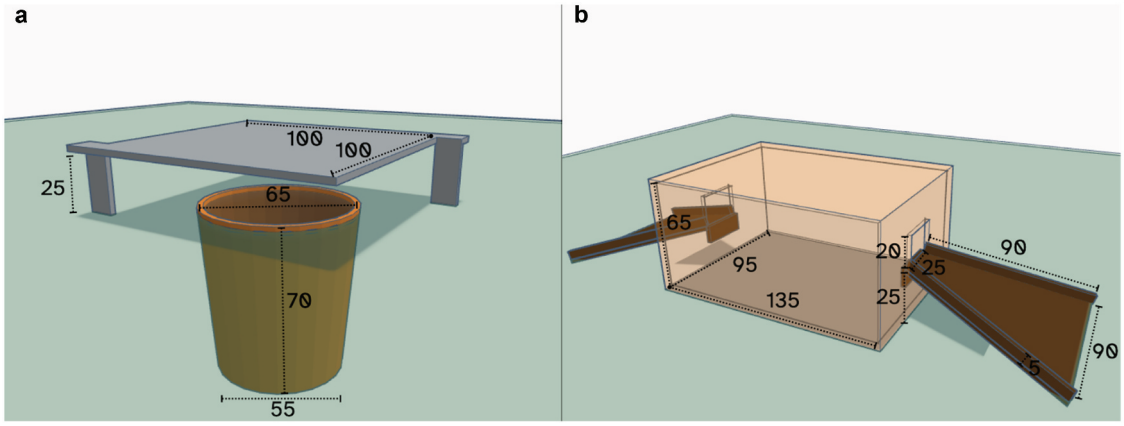

Figure 2. Schematics of traps used: **a**. pitfall trap with a rain cover; **b**. ramp trap.

2.5 cm (Figure 2a). Each pitfall trap was filled with 50 mL of 50% propylene glycol, reaching a height of about 2.8 cm.

The general design for the ramp traps (Figure 2b) was inspired by the models developed by Bouchard, Wheeler, and Goulet (2000). A plastic container of approximately 800 mL with a lid was used in the ramp traps, with the following measurements: 13.5 cm x 9.5 cm x 6.5 cm (length, width, height). Each container was filled with 75 mL of 50% propylene glycol, reaching a height of about 1.5 cm. The ramps were cut and bent out of steel sheets, and subsequently sprayed with brown paint that resembled the color of the forest soil. Fine sandpaper (P240) was gently rubbed against the painted surface to create a rougher texture that provided better grip. The lower edge of the ramp, that was in contact with the ground, was 9.0 cm wide, the vertical side edge was 0.5 cm high and 9.0 cm long, and the upper edge leading to the container was 2.5 cm wide with a 1.0 cm long downwardly bent projection that attached the ramp to the container. Two ramps were used for each trap, and each ramp was attached to a 2.5 cm x 2.0 cm (width, height) window that was cut out in the opposite narrow sides of a container at a height of 2.5 cm, setting the angle between the ramp and the ground to about 17°. Each ramp trap was also fastened to the substrate with a 20 cm long nylon strap with a 17 cm long steel stake that was struck through each end of the strap.

Collected arthropods, with selected groups excluded, were identified to the family level, and adult spiders were identified to the species level. Excluded arthropod groups include mites (Acari), springtails (Collembola), thrips (Thysanoptera), flies (Diptera), Psocodea, and winged Hymenoptera. These groups were omitted because of difficulties in identification – or, in the case of flies and winged Hymenoptera, they are not considered epigeal.

Online resources of the Finnish Biodiversity Information Facility (FinBIF 2022) were used in the identification of arthropod families, and the keys and illustrations of Nentwig et al. (2022) were used for the identification of adult spiders.

R version 421 (R Core Team 2022) was used to draw the bar plots, and the R package 'mvabund' (Wang et al. 2022) was used to test for differences between ramp and pitfall traps in the abundances of orders, families, and adult spider species. The package 'mvabund' is used for fitting generalized linear models to multivariate abundance data, and to test the variables for significance by resampling the data; we used it mainly for the latter, to test for differences between trap types (ramp and pitfall traps in our case). Differences in abundances between trap types were tested for significance by resampling residuals 999 times (Warton, Thibaut, and Wang 2017), after fitting an exponential function (i.e. log link) with negative binomial errors. The p values of individual taxa were adjusted for multiple testing. We classed any p values less than .05 as significant. The data and analyses are downloadable from https://doi.org/10.5281/zenodo.10262816.

Schematics of the traps were drawn in Tinkercad (https://www.tinkercad.com/).

Results

A total of 1898 specimens in 12 orders and 50 families were collected (Appendix Table A1). Of these, 822 specimens (11 orders, 38 families) were collected by pitfall traps, and 1076 specimens (10 orders, 44 families) were collected by ramp traps. Two orders (one doubleton) and six families (five singletons or doubletons) were only collected by pitfall traps, while one order (singleton) and 12 families (eight singletons or doubletons) were only collected by ramp traps (Table A1).

A total of 267 specimens were adult spiders (Appendix Table A2). These were identified to 45 species in 12 families. Pitfall traps collected 148 specimens of 28 species (including six species found only in this type of trap: three singletons or doubletons), and ramp traps collected 119 specimens of 39 species (including 17 species found only in this type of trap: 10 singletons or doubletons).

Five taxa were significantly more common in one of the trap types than the other. More individuals of ants (Hymenoptera: Formicidae; Figure 3), beetles (Coleoptera; Figure 4), true bugs (Hemiptera; Figure 5) and spiders of the species *Minyriolus pusillus* (Wider, 1834) (Araneae: Linyphiidae; Figure 6) were caught in ramp traps than pitfall traps. More individuals of myriapods (Myriapoda; Figure 7) were caught in pitfall traps than ramp traps. Many of the taxa also showed significant differences in abundance between sampling periods, and between sampling sites (https://doi.org/10.5281/zenodo.10262816). These latter differences are not treated further in this article.

Discussion

Although the ramp trap designs used here captured incoming arthropods from only two directions, they caught significantly more individuals of ants, beetles, true bugs and the spider *M. pusillus* than pitfall traps. Hymenoptera and Coleoptera were also the most abundantly sampled orders (Table A1), while the less abundantly sampled Hemiptera were only just significant (https://doi.org/10.5281/zenodo.10262816), which suggests that the sampling effort was too low for other groups as well as for families within Coleoptera. As for *M. pusillus*, being the smallest sampled spider species (Table A2) with a body length of 1.1–1.4 mm (Nentwig et al. 2022), its small size may be limiting its entry into pitfall traps. Namely, it has been shown that low mass in arthropods, which is associated with slow locomotion speed, generally decreases pitfall trap catch rates (Engel et al. 2017; Hancock and Legg 2011). The flat surface of the ramps likely increases the locomotion speed of especially small arthropods compared to locomotion on uneven soil surfaces, resulting in higher catch rates in ramp traps. Pitfall traps captured significantly more individuals of myriapods, especially lithobiids (Chilopoda: Lithobiomorpha), which is consistent with myriapods generally being soil-dwelling arthropods. This is in line with the research of Weary et al. (2019), in which pitfall traps captured more millipedes (Diplopoda) than ramp traps.

Ramp traps are more flexible than pitfall traps regarding their design options. More ramps may be added to capture arthropods from more than two directions, which should improve their catchability. One may

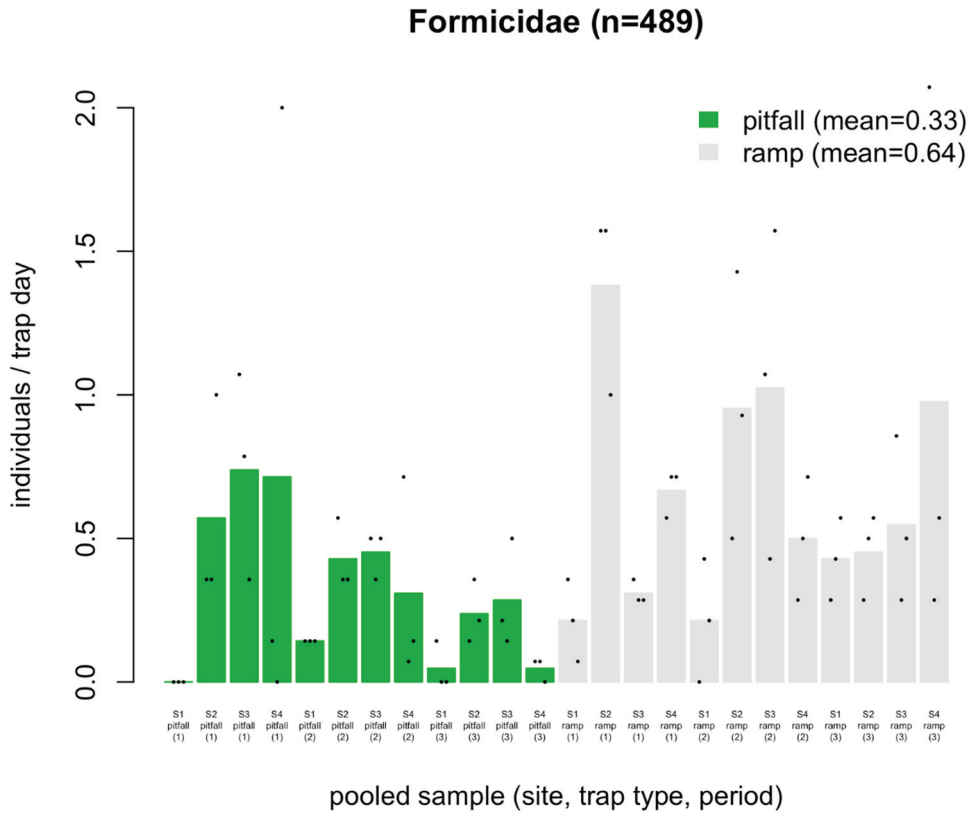

Figure 3. Average number of ants (Hymenoptera: Formicidae) caught per trap day in pitfall and ramp traps. Significantly more individuals were caught in ramp traps. Bars show the average for each group of three samples from the same sampling site (S1, S2, S3 or S4), trap type (pitfall or ramp) and sampling period (1, 2 or 3). Points show each sample.

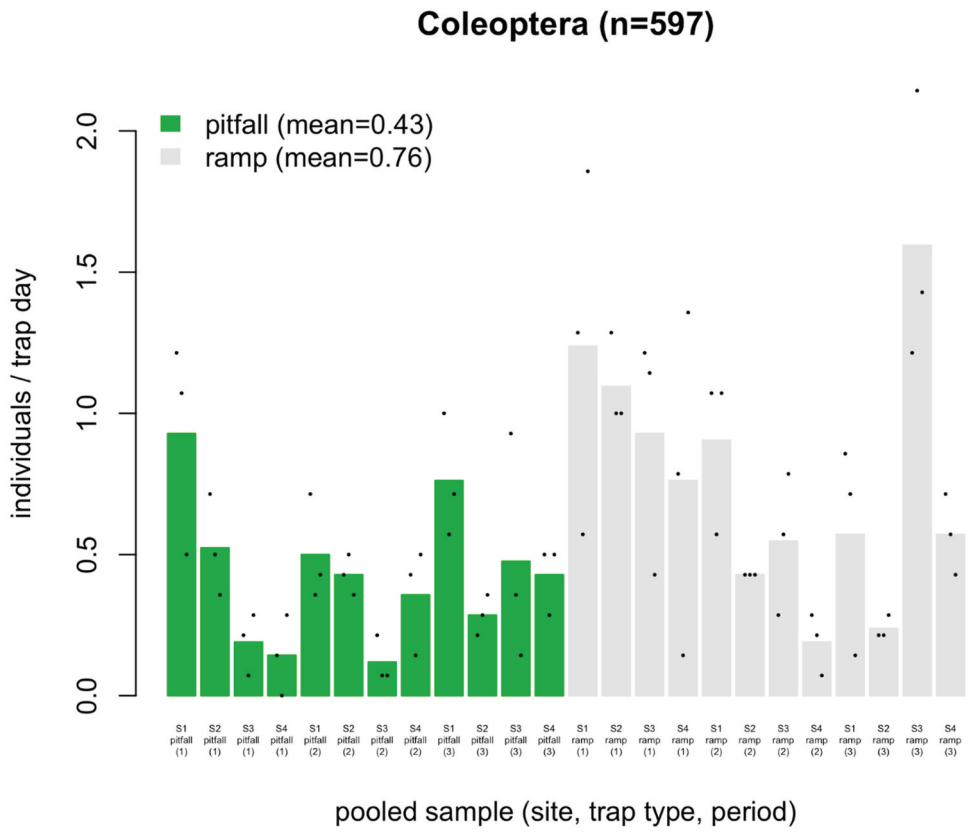

Figure 4. Average number of beetles (Coleoptera) caught per trap day in pitfall and ramp traps. Significantly more individuals were caught in ramp traps. Bars show the average for each group of three samples from the same sampling site (S1, S2, S3 or S4), trap type (pitfall or ramp) and sampling period (1, 2 or 3). Points show each sample.

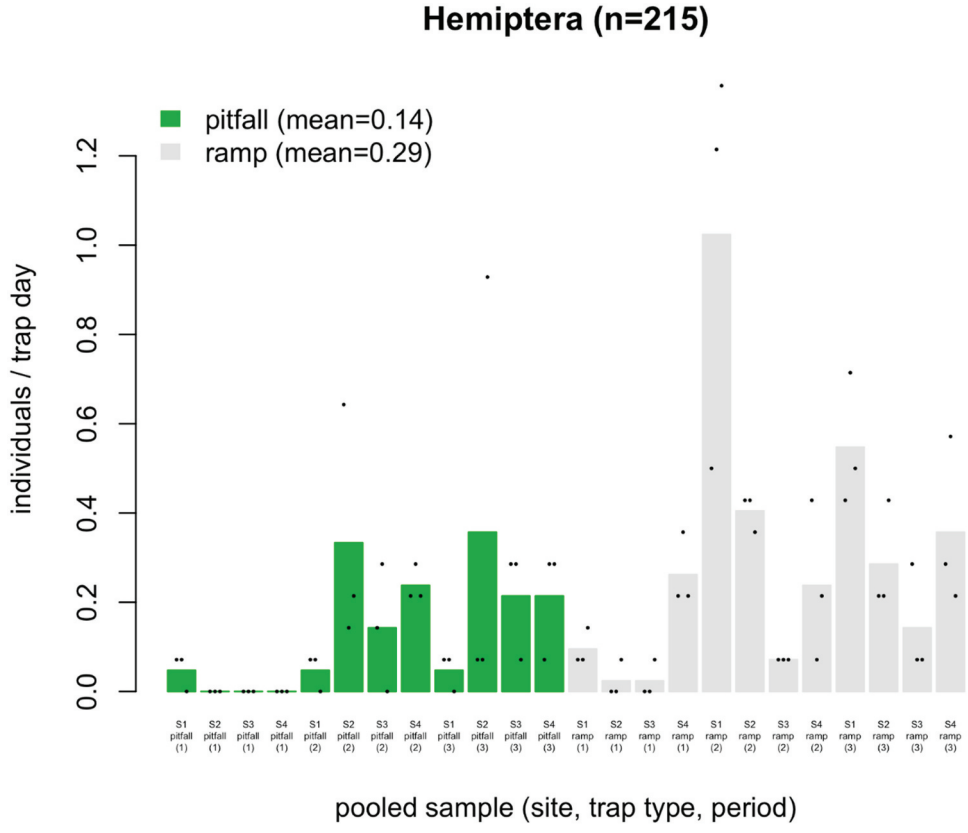

Figure 5. Average number of true bugs (Hemiptera) caught per trap day in pitfall and ramp traps. Significantly more individuals were caught in ramp traps. Bars show the average for each group of three samples from the same sampling site (S1, S2, S3 or S4), trap type (pitfall or ramp) and sampling period (1, 2 or 3). Points show each sample.

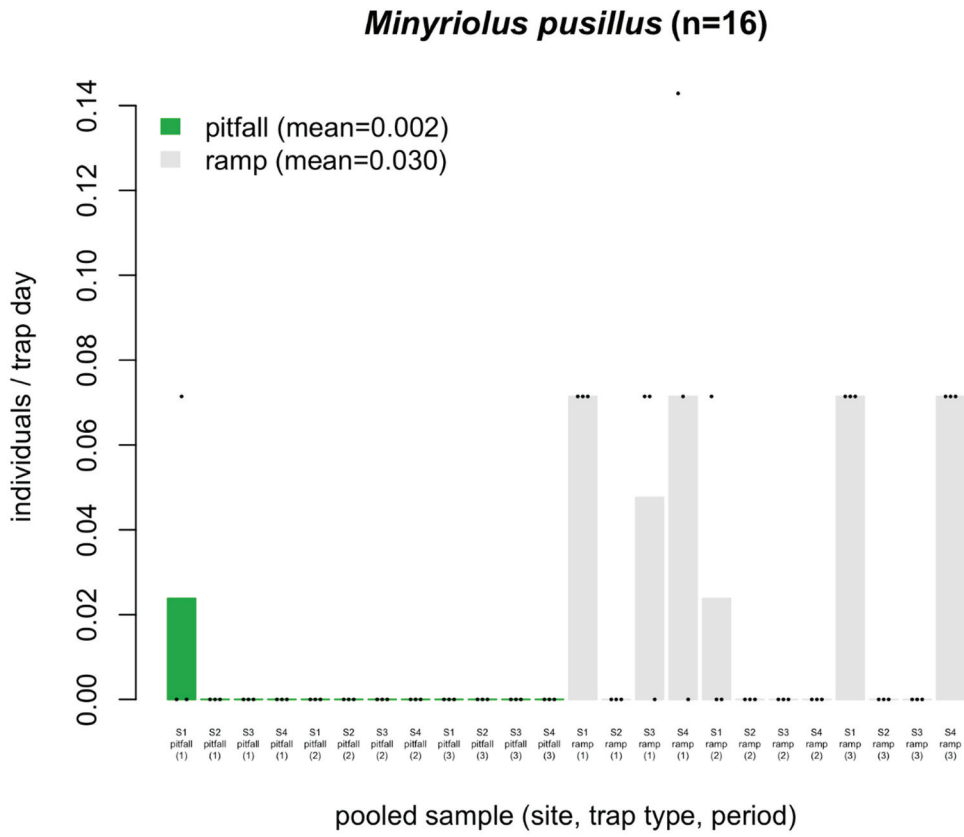

Figure 6. Average number of spiders of the species *Minyriolus pusillus* (Araneae: Linyphiidae) caught per trap day in pitfall and ramp traps. Significantly more individuals were caught in ramp traps. Bars show the average for each group of three samples from the same sampling site (S1, S2, S3 or S4), trap type (pitfall or ramp) and sampling period (1, 2 or 3). Points show each sample.

also use larger or wider ramps; however, Bouchard, Wheeler, and Goulet (2000) do not recommend major modifications to the ramp design for highest capture rates.

When comparing ramp and pitfall trap types, it is important to ensure that they are in the same size class. Here both trap types, in terms of the size of the ramps and the circumference of the pitfall cup, might be classified as small. Matevski et al. (2020) used ramp traps with one Styrofoam ramp whereas Patrick and Hansen (2013) used designs with two metallic ramps that were covered with textured spray paint. Patrick and Hansen (2013) discovered that ramp traps captured more spiders than pitfall traps, whereas Matevski et al. (2020) obtained the opposite result. Here we did not find a significant difference between trap types for overall spider captures, which is likely due to a smaller sampling effort. The numerous designs of ramp traps that have been compared to pitfall traps, with differing results, do not allow for a unanimous result. However, it seems that ramp traps with two ramps are more efficient designs.

Our work provides an additional data point on the relative performance of ramp and pitfall traps, for a single site in boreal forest. This complements existing data from other habitats (e.g. for Californian Oak Woodland and Chaparral: Weary et al. 2019). However, much more data would be needed from a variety of habitats, including from multiple boreal forest sites with varying understory vegetation. It is also unclear how the relative performance of the traps is affected by seasonality: our data is from three time periods during summer, with the early arthropod season (April–May) not covered.

More research is needed on the performance of different ramp trap designs (e.g. the number of ramps per trap and their measurements, material, and treatment, for capturing various arthropod groups) and their performance in relation to other traps in different environments and temporal scales. This may lead to more efficient ramp trap designs and better understanding of their usage for capturing various or target-specific arthropod groups.

The installation of ramp traps in the field is faster and easier than pitfall traps because there is no need to excavate soil, which makes ramp traps optimal for

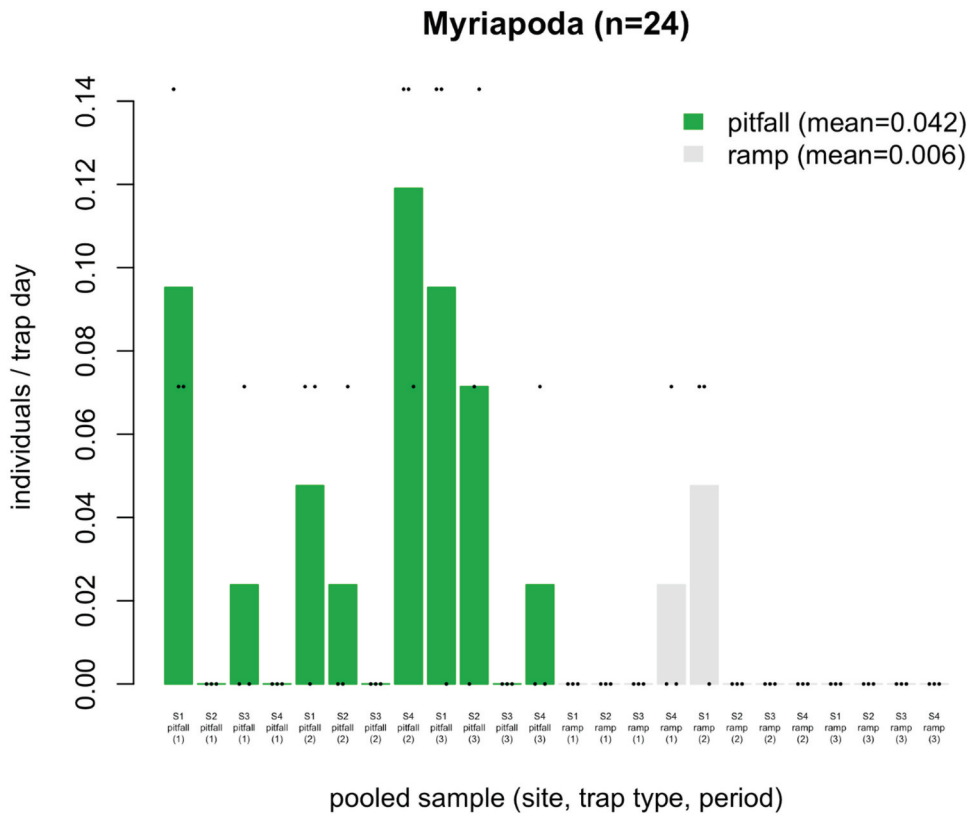

Figure 7. Average number of myriapods caught per trap day in pitfall and ramp traps. Significantly more individuals were caught in pitfall traps. Bars show the average for each group of three samples from the same sampling site (S1, S2, S3 or S4), trap type (pitfall or ramp) and sampling period (1, 2 or 3). Points show each sample.

avoiding unwanted soil disturbance. Since ramp traps are placed on the ground, they are also protected from disturbances such as flooding. In areas of bare rock, the ramp traps may be held in position by placing a weight in the container. Pitfall traps are, however, easier to transport due to their simplicity in consisting of fewer parts. The complicated construction and challenges in maintenance of ramp traps in removing preservative liquid are reasons to favour pitfall traps. All in all, ramp traps function as an alternative to pitfall traps and, in the case of some groups, a more efficient sampling method.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix

Table A1. Total number of individuals of each captured arthropod order (bolded) and family in pitfall and ramp traps at the Korkiakallio study area in Turku, southwest Finland. Acari, Collembola, Thysanoptera, Psocodea, Diptera, and winged Hymenoptera are excluded.

Taxon	Pitfall	Ramp
Araneae	**166**	**134**
Clubionidae	0	1
Cybaeidae	1	1
Dictynidae	0	1
Gnaphosidae	0	5
Hahniidae	3	2
Linyphiidae	127	87
Liocranidae	0	1
Lycosidae	18	13
Mimetidae	1	0
Miturgidae	1	8
Salticidae	2	0
Tetragnathidae	0	2
Theridiidae	7	3
Thomisidae	6	10
Blattodea	**5**	**6**
Ectobiidae	5	6
Coleoptera	**224**	**381**
Apionidae	0	1
Cantharidae	1	0
Carabidae	24	46
Chrysomelidae	0	3
Cryptophagidae	17	9
Curculionidae	25	35
Elateridae	3	19
Geotrupidae	40	71
Lampyridae	2	13
Latridiidae	11	9
Leiodidae	36	53
Mordellidae	0	5
Nitidulidae	1	1
Ptiliidae	0	2
Silphidae	7	5
Staphylinidae	57	105
Throscidae	0	4
Dermaptera	**2**	**0**
Forficulidae	2	0
Hemiptera	**69**	**146**
Aphididae	9	18
Aphrophoridae	0	1
Cicadellidae	7	24
Delphacidae	14	5
Microphysidae	4	1
Miridae	17	76
Nabidae	1	0
Rhyparochromidae	14	18
Tingidae	3	3
Hymenoptera	**167**	**322**
Formicidae	167	322
Julida	**3**	**1**
Julidae	3	1
Lithobiomorpha	**9**	**0**
Lithobiidae	9	0
Opiliones	**168**	**83**
Nemastomatidae	10	1
Phalangiidae	158	82
Polydesmida	**7**	**1**
Polydesmidae	7	1
Polyzoniida	**2**	**1**
Polyzoniidae	2	1
Siphonaptera	**0**	**1**
Ceratophyllidae	0	1
Specimens	822	1076
Families	38	44
Orders	11	10

Table A2. Total number of adult individuals of each spider family (bolded) and species captured in pitfall and ramp traps at the Korkiakallio study area in Turku, Finland.

Taxon	Pitfall	Ramp
Clubionidae	**0**	**1**
Clubiona comta C. L. Koch, 1839	0	1
Cybaeidae	**1**	**1**
Cryphoeca silvicola (C. L. Koch, 1834)	1	1
Dictynidae	**0**	**1**
Lathys heterophthalma Kulczyński, 1891	0	1
Gnaphosidae	**0**	**6**
Haplodrassus signifer (C. L. Koch, 1839)	0	2
Haplodrassus soerenseni (Strand, 1900)	0	4
Hahniidae	**3**	**2**
Hahnia pusilla C. L. Koch, 1841	3	2
Linyphiidae	**119**	**83**
Abacoproeces saltuum (L. Koch, 1872)	0	1
Agyneta cauta (O. Pickard-Cambridge, 1903)	6	1
Agyneta conigera (O. Pickard-Cambridge, 1863)	11	8
Agyneta ramosa Jackson, 1912	11	9
Agyneta subtilis (O. Pickard-Cambridge, 1863)	3	2
Bathyphantes parvulus (Westring, 1851)	0	1
Centromerus arcanus (O. Pickard-Cambridge, 1873)	10	0
Dicymbium tibiale (Blackwall, 1836)	0	1
Diplocentria bidentata (Emerton, 1882)	1	1
Diplocephalus latifrons (O. Pickard-Cambridge, 1863)	1	2
Diplostyla concolor (Wider, 1834)	16	3
Erigonella hiemalis (Blackwall, 1841)	0	1
Macragus rufus (Wider, 1834)	2	2
Maso sundevalli (Westring, 1851)	0	1
Micrargus apertus (O. Pickard-Cambridge, 1871)	1	2
Microneta viaria (Blackwall, 1841)	2	1
Minyriolus pusillus (Wider, 1834)	1	15
Nusoncus nasutus (Schenkel, 1925)	0	1
Pocadicnemis pumila (Blackwall, 1841)	1	3
Porrhomma pallidum Jackson, 1913	0	1
Tapinocyba pallens (O. Pickard-Cambridge, 1873)	8	3
Tenuiphantes tenebricola (Wider, 1834)	37	21
Troxochrota scabra Kulczyński, 1894	0	1
Walckenaeria alticeps (Denis, 1952)/*W. antica* (Wider, 1834)	2	0
Walckenaeria cucullata (C. L. Koch, 1836)	6	0
Walckenaeria dysderoides (Wider, 1834)	0	2
Lycosidae	**12**	**8**
Alopecosa aculeata (Clerck, 1757)	6	6
Pardosa lugubris (Walckenaer, 1802)	3	1
Trochosa terricola Thorell, 1856	3	1
Miturgidae	**0**	**4**
Zora nemoralis (Blackwall, 1861)	0	3
Zora spinimana (Sundevall, 1833)	0	1
Salticidae	**2**	**0**
Neon reticulatus (Blackwall, 1853)	2	0
Tetragnathidae	**0**	**1**
Pachygnatha listeri Sundevall, 1830	0	1
Theridiidae	**5**	**2**
Euryopis flavomaculata (C. L. Koch, 1836)	4	1
Neottiura bimaculata (Linnaeus, 1767)	0	1
Robertus lividus (Blackwall, 1836)	1	0
Thomisidae	**6**	**10**
Ozyptila praticola (C. L. Koch, 1837)	1	5
Ozyptila trux (Blackwall, 1846)	1	5
Xysticus luctuosus (Blackwall, 1836)	4	0
Specimens	148	119
Species	28	39